the Mineralogical Record

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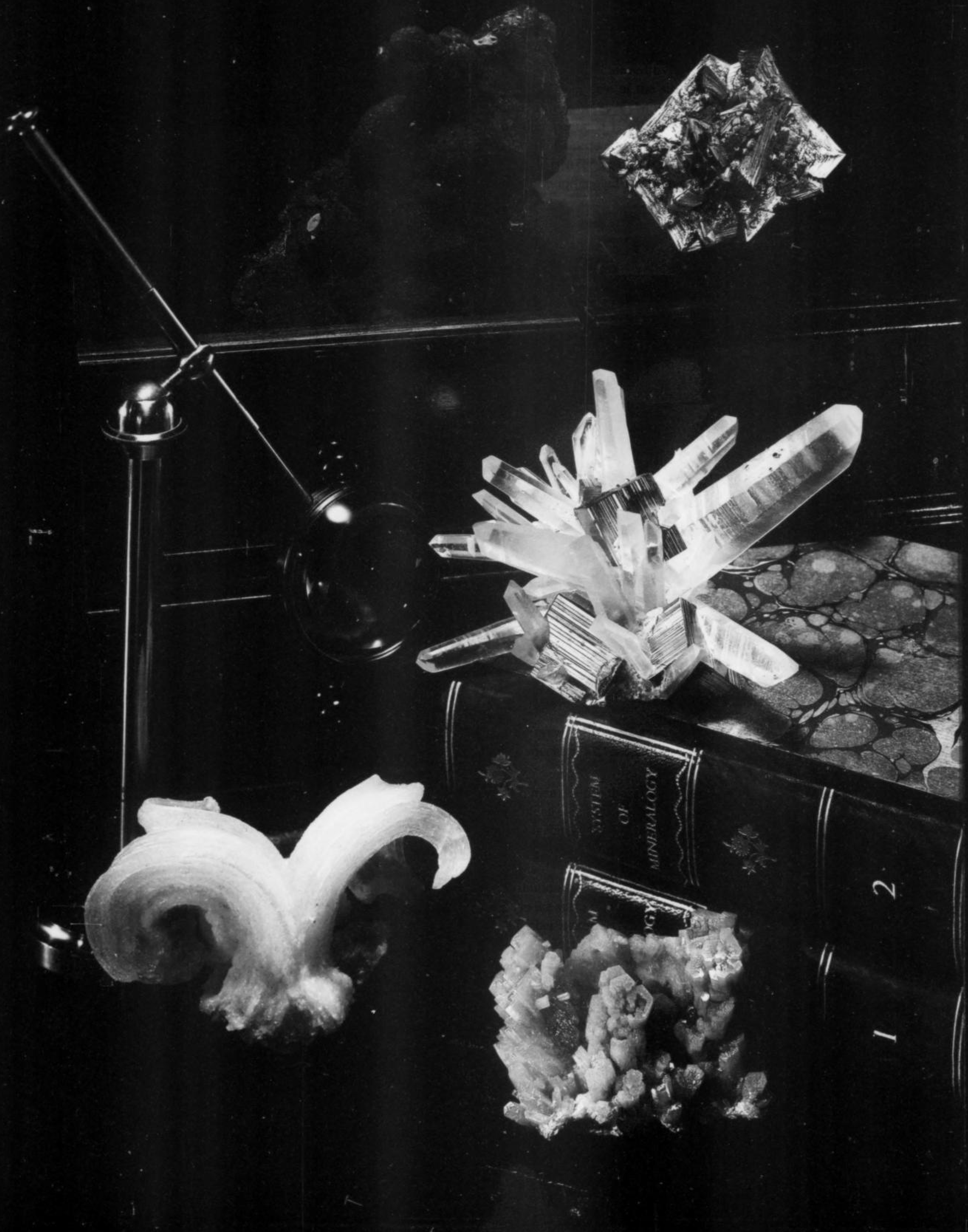
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the Mineralogical Record

May–June 1991
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Articles

Columns

COVER: TITANITE crystal, 3.5 cm, from Felbertal, Pinzgau, Austria. From the collection of A. Steiner; photo by Rainer Bode.

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notes from the EDITOR

NEW GROUP AD

The various group ads in the *Mineralogical Record* provide a convenient and inexpensive place for mineral dealers to list their contact information. It occurred to us that dealers are not alone in needing such a service. Consequently we are initiating in this issue a new type of group advertisement called "The Museum Directory," where mining and mineral museums can list their contact information, museum hours and collection specialties. In the past, this information has often been difficult to find when needed; we hope it will facilitate not only museum visits but also specimen acquisitions for museums, and general interaction between museums and the collector community. We would welcome listings for additional museums, both public and private; the fee is modest. Interested curators are invited to contact the editor.

FIRST MEXICAN CONGRESS

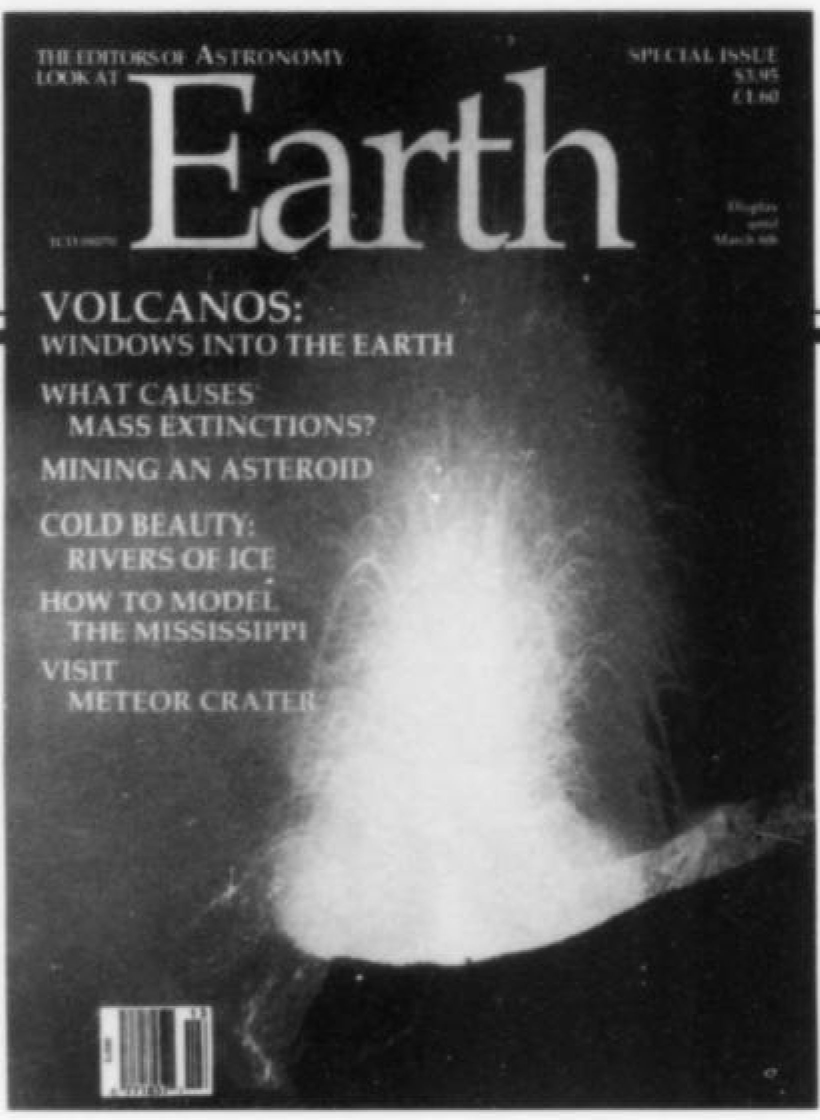
Notes from the Editor generally does not give symposia announcements unless it's a "call for papers," but I must make an exception for *Primero Congreso Mexicano de Mineralogía* . . . "The First Mexican Congress of Mineralogy." This event, sponsored jointly by the Geological Institute of the University of Mexico, the Earth Science Institute of the University of Hidalgo, and the Mexican Mineralogical Society, will be held June 23-28, 1991, in Pachuca, Hidalgo, Mexico. Some presentations will be in English. June 27-28 will be reserved for geological-mineralogical field trips. For information and a schedule of speakers contact Diego A. Córdoba, Instituto de Geología, Apartado Postal 70-296, Ciudad Universitaria, Delegación Coyoacán, 04510 México, D.F.

NEW MAGAZINE

A new, "popular" or mass-market magazine devoted to geology is being launched by Kalmbach Publishing Company (P.O. Box 1612, Waukesha, WI 53187; Tel: 800-446-5489). In case readers of the *Mineralogical Record* have seen the ads for this new publication, and might be wondering whether it holds anything of interest for them, here are some details.

The magazine is called *Earth,* or, including the small print on the cover, *The Editors of Astronomy Look at Earth*. Already we are curious . . . what are astronomy editors doing in a geology publication, and why would geology enthusiasts want to read about geology through the eyes of astronomers?

The first issue contains six feature articles, *three* of which are on meteorite impacts, so right away we see astronomy interfacing, as it were, with geology. One of those three articles deals with Arizona's Meteor Crater, and gives a good, layman's-language review of the geomorphological aspects. Unfortunately, if it weren't for a passing mention in the lead (under the article title) we would not even learn that the meteorite which was responsible consisted of nickel-iron. Anything having to do with the meteorite specimens, what they contain and what they tell us about the parent body is omitted. The article on the Sudbury Basin (an astrobleme/ore deposit accounting by itself for 20% of all Canada's mineral wealth) fares about the same, although a few lines are devoted to the metals present, and the fact that the Noril'sk deposit in Siberia has identical mineralogy. It's interesting, but it holds little if anything for the amateur mineralogist. The third meteorite article deals with the great mass extinctions, one cause of which may have been asteroid impacts. It presents, briefly, the asteroid impact theory and then goes on to discuss the problems and unanswered questions associated with it.



The other three articles deal with features of the earth that have instructive parallels on other planets: volcanoes (Hawaii), glaciers as photographed from orbit, and stream channel patterns (that can be duplicated in miniature with a home-made plywood stream table).

The editor, in his introduction to the issue, clearly reveals the peculiar bias toward astronomy-related geology (and he implies that the articles are essentially rejected submissions to *Astronomy* magazine), but then goes on to discuss the magazine's concept as if he doesn't consciously see the slant. He does, however, make the point that vol. 1, no. 1, is a "trial issue," and that readers are therefore encouraged to write in with their suggestions. The magazine is in its formative stages, and editors are particularly receptive to suggestions at such a time. Perhaps the response will encourage him to look at some small-scale specimens of the kind we enjoy learning about.

A one-year bimonthly subscription is $14.95 ($19.95 foreign).

BACK ISSUES

In this issue (pages 226–229) is an annotated listing of *all* back issues of the *Mineralogical Record* currently in stock. If you are working on building a complete set, if you're looking for articles on particular specialties, or if you just need more good mineralogical reading in your life, spend some time perusing it. We also have available one **complete mint set** of all issues from vol. 1 to vol. 20, including those not otherwise in stock, priced at $1500 plus shipping (call the editor at 602-299-5274).

Readers often wish we were a monthly rather than a bimonthly publication, so that they could receive an issue once a month. I sometimes envy the relatively recent subscribers because they can, in effect, have that merely by purchasing a back issue every other month. So here's a **special offer.** When you renew your subscription, renew at the 2-year rate and receive instead a 1-year renewal plus any six *consecutive* issues as listed on pages 226–229. You'll have what amounts to a one-year, 12-issue subscription at a considerable savings on the list price.

THE OUTLAW MINE, NYE COUNTY, NEVADA

Gail E. Dunning
773 Durshire Way
Sunnyvale, California 94087

Gary E. Moss
118 Springfield Drive
San Francisco California 94132

Joseph F. Cooper, Jr.
482 Green Valley Road
Watsonville, California 95076

The Outlaw mine has long been known as an occurrence of rare and complex Pb-Bi-Ag-Cu sulfosalts including benjaminite, for which it is the type locality. The mine has been idle for more than 60 years, and because of its remoteness near the bottom of Mariposa Canyon, few collectors have visited the site. More than 30 minerals have been identified from the mine and studies continue on the sulfosalt mineralogy.

INTRODUCTION

Our interest in the Outlaw mine, the type locality for benjaminite, began in the early 1960's after reading of Nuffield's 1953 re-examination of the mineral, a rare Ag-Cu-Bi-Pb sulfosalt. Although benjaminite has received considerable analytical attention since 1953, the mine's precise location remained a mystery to us. Only a few study samples of the ore have been obtained from the mine since the original material was collected by H. G. Clinton and subsequently reported on by Shannon in 1925 (D. R. Shawe, personal communication, 1987). After several years of unsuccessful searching, we finally located the site in 1977 after doing a literature search on the area.

This rather small and obscure mine contains a very interesting assemblage of sulfides and sulfosalts which formed in a high to low-temperature hydrothermal environment over time. In addition, several uncommon secondary minerals derived from oxidation of the sulfides and sulfosalts occur in the vein quartz.

The mine is located in an unsurveyed area of the southern Toquima Range near the head of Mariposa Canyon, about 8 km east of Round Mountain, Nye County, Nevada. It can be reached by trail from the mouth of Mariposa Canyon or by a poorly graded bulldozer trail descending from the Red Bird Toquima mine via Round Mountain and the Shoshone Canyon road.

HISTORY

Early Mining History

Records on file at the Nye County Recorders Office, Tonapah, Nevada, state that the Outlaw mine was first located in 1917 by Charles Lohman of Round Mountain, Nevada. In addition to the Outlaw mine, seven other unnamed claims in the general area of Mariposa Canyon were also recorded under his name. A Notice of Intent was filed on the Outlaw mine on December 10, 1919, and a Proof of Labor on September 24, 1921. Contrary to the statement made by H. G. Clinton that the Aikinite Mining Company had actively worked the mine (Shannon, 1925), no record was found of this company or its association with the Outlaw mine between 1916 and 1930.

In addition, no information was found regarding how much ore had been mined or its silver value except for Mr. Clinton's assay results of 300 ounces of silver per ton. From the available description of the ore, workings and remaining samples at the site, it would appear that no more than a few tons of ore were ever produced. The ore that was mined was probably hand-sorted and carried down the canyon by pack animal and then by truck to one of the local smelters. Working these small, silver-bearing deposits was made economical only by relatively high silver prices which existed for a short time during the 1920's.

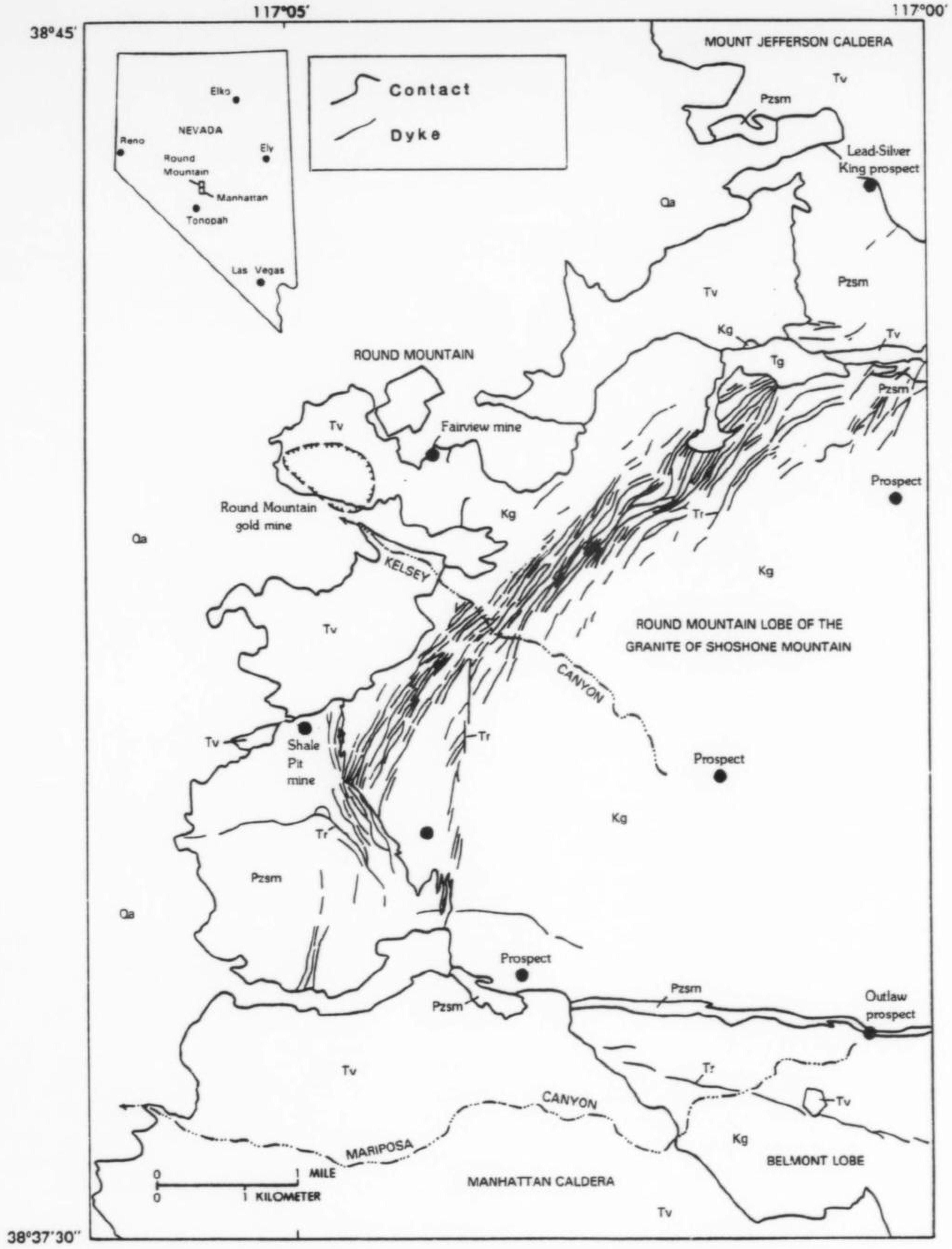


Figure 1. **Geologic map of the Round Table quadrangle (from Shawe, 1977).**

Since Shannon's 1925 description of the mine, there were no additional references to the mine or its minerals until 1977 when D. R. Shawe briefly described the locality during a geological study of the southern Toquima Range. Neither Kral (1951) nor Kleinhample and Ziony (1984) made mention of the Outlaw mine.

The mine workings consists of a single adit, 1.2 meters wide and 1.8 meters high, which follows a quartz vein for about 60 meters (Shannon, 1925). At the time of our visit, the adit was found caved at the portal and the dump mostly overgrown with brush and grass. There was no evidence that any mining or mineral collecting activity had occurred at the site since mining ceased in the early 1920's although Shawe (1977) obtained several specimens in 1973 during the mapping of the Round Mountain quadrangle.

The remains of a 3-meter square stone foundation was found in tall grass and brush about 25 meters north of the portal. A number of unbroken bottles, probably dating from the mining days, were found locally around the stone foundation.

The small ledge described by Clinton as exhibiting several colors

Figure 2. **Base camp near the mouth of Mariposa Canyon. G. Dunning photo.**

leaching from the rock, was found just north of the portal and measures about 1.5 meters high, 2 meters wide and 2 meters deep. The exposed rock consists of fractured quartz covered with several secondary minerals, mostly green and yellow in color. This small exploratory excavation was probably made to determine the tenor of the ore exposed.

Our Search for the Mine

It was while exploring the mines of the Manhattan and Belmont districts in the early 1960's that authors Dunning and Cooper first became interested in the Outlaw mine. Our first reference to the Outlaw mine and the rare mineral benjaminite was found in *Dana's Textbook of Mineralogy* (Ford, 1932), where it states that benjaminite "occurs with chalcopyrite, pyrite, covellite, muscovite, molybdenite and fluorite in quartz at the Outlaw mine, 12 miles north of Manhattan, Nye County, Nevada." With this limited locality information, we made several attempts to locate the mine by following various old roads leading north from both Manhattan and Belmont. However, without more specific information, the exact locality of the Outlaw mine remained unknown to us during this period.

During the following years, benjaminite became the object of several investigations questioning its validity as a mineral species. These studies were based solely on the material collected by H. G. Clinton and described by Shannon (1925). Finally in 1975, Harris and Chen presented evidence which confirmed benjaminite as a valid mineral. Because the new data renewed our interest in both benjaminite and the Outlaw mine, we began a determined search for the locality, despite the lack of specific locality information, which culminated in an October 1976 trip to the area.

Our two days of exploring the area began at Round Mountain and we slowly worked southeast along the western flank of the Toquima Range approximately 20 km (12 miles) north of Manhattan. Along the flank several small prospects were found that contained copper sulfides. In exploring Kelsey Canyon (Lohman Canyon on older maps), we found a small prospect containing some tetrahedrite and secondary copper minerals. In addition, we also found a small silver-bismuth claim (which yielded only a few small specimens of metallic minerals) as well as an old mercury retort and workings among some trees. After finding no ore at the retort, and with time running out, as well as heat and fatigue taking their toll, we decided to return another time to look again. In reviewing our 7½-minute quadrangle map and the local geology, we concluded that Kelsey Canyon was not the right area and that our future trip should start by looking at Mariposa Canyon about 8 km to the southeast.

During the winter of 1976–77, we obtained a copy of Shannon's article from a seldom-visited upper story corner of Stanford Library. Although no map was included in the paper, it was stated that the Outlaw mine was located near the head of Mariposa Canyon, just as we had suspected. To add to our knowledge of the area, we also acquired a copy of a 1977 Miscellaneous Field Studies Map which had just been released by the U.S. Geological Survey, prepared by D. R. Shawe. Much to our surprise, the Outlaw mine was located on the map near the head of Mariposa Canyon, about 1.6 km further up the canyon from the end of the road where we stopped looking.

Armed with this additional research, we left the Bay Area on another exploring trip early in the morning of April 16, 1977. We arrived in Austin, Nevada, about 4:30 p.m., refueled the Jeep, had an early dinner and decided to push on to Mariposa Canyon. About two hours later, we arrived at the end of the road near the old mercury retort, set up camp and settled in for the night. The ominous height of the canyon walls with its large rocks and thick brush promised to make the next day a long one.

In looking for a trail up the canyon on April 17th, we found that the natural waterway was obviously not the most expedient approach to the upper canyon area. After some searching near the mercury retort, the remains of an old trail were discovered which led up the hill to the right of the waterway. We followed it for about 300 meters before losing it among the trees and rocks. After more looking, we picked up the trail again on the second small ridge higher on the hill behind the old retort where it switchbacked up the sidehill for about 100 meters. Once on the trail, we made good time and in less than an hour we had reached the crest of the ridge blocking the canyon.

Figure 3. **The view up the narrow and rocky canyon waterway 100 meters from base camp. G. Dunning photo.**

Figure 4. **View of the head of Mariposa Canyon and the workings of the Red Bird Toquima mine on the distant ridge, center of view. G. Dunning photo.**

From this vantage point, we could see up Mariposa Canyon. High on the ridge ahead of us, probably 2 km away, we saw what appeared to be the workings of a mine. Orienting the map to the topographical features of the canyon, we concluded that the mine on the ridge was the Red Bird Toquima. This mercury mine was an important find since our research said the Outlaw mine was 1 km south of the Red Bird Toquima.

After taking several pictures, we followed the old trail down to the canyon floor, which was less than 10 meters wide in places. From this point, the walk up the canyon was relatively easy and in about an hour we rounded a sharp bend in the canyon and saw a small mine dump along the north side about 20 meters above the canyon floor. As we approached the site, abundant quartz was found scattered about the area. Some of its contained muscovite and fluorite with a few flakes of molybdenite. In comparing the site and the rock samples with the description given by Shannon (1925), we were convinced that we had at last found the abandoned site of the Outlaw mine.

Unpacking our tools, we began to break some of the loose quartz rocks near the top of the dump. Seams of a bright metallic mineral were soon discovered which resembled aikinite. Some very fine samples were recovered from several quartz rocks which were partially buried in the loose dirt near the portal. As the day proceeded, almost all of the minerals described by Shannon were found in the rocks of the dump. Much to our delight, we were able to collect over 100 samples which contained seams and pods of aikinite and (we hoped) benjaminite.

The adit, which was reported to be about 60 meters long, was found to be caved near the portal. However, just north of the portal, we found the ledge described by H. G. Clinton (Shannon, 1925) and collected several samples of the material which had leached from the fractured quartz. We filled our packs, took some site photographs and began the slow trip back down the canyon.

Historical Review of Benjaminite

Benjaminite was described as a new mineral by Earl V. Shannon from specimens supplied from the property of the Aikinite Mining Company near Round Mountain, Nye County, Nevada. The following account by Shannon (1925) describes the history of the first samples examined and how they were brought to his attention:

> The first specimens from the Outlaw mine studied were sent to the U.S. Geological Survey in the early 1920's, where they were incorporated in a series of bismuth ores by Frank L. Hess and forwarded to the National Museum. At that time, it was not known who sent them in, and the only information regarding them was contained on a label which read "Aikinite Mining Company, Round Mountain, Nevada." It was concluded from the name of the mining company that the mineral had been identified as aikinite and that it was a characteristic mineral of the deposit. Indeed, it not only greatly resembled aikinite physically, but also gave the quantitative tests and polished section reactions for that mineral.
>
> Nothing further could be learned about the mineral or the mine until an inquiry was sent to Mr. H. G. Clinton of Manhattan, Nevada. [It is not known what relationship Mr. Clinton had with the National Museum.] Fortunately, it was learned that Mr. Clinton was familiar with the mine, its geology, history and mineralogy. Also, he was able to visit the locality and supply an additional very fine specimen of the material since the original small lot had been almost entirely used up in the several analyses. It was also learned from this correspondence that the material originally received at the Geological Survey had also come from Mr. Clinton. The following is quoted from his letter:
>
> *The Aikinite Mining Company has been out of existence for years but they were operating the Outlaw mine some 12 miles [20 km] north of here [Manhattan] at the head of Mariposa Canyon.The mineral [benjaminite] occurs in large and small bunches and blotches in a dense white quartz, near the southern contact of a rock locally called pegmatite, but described by*

Figure 5. Approaching the dump of the Outlaw mine, located about 1.6 km up the canyon on the north side. G. Dunning photo.

> *J. M. Hill as a soda-granite, and an intrusive rhyolite. I have had assays of 300 ounces in silver from the mineral. I have also noted large flakes of molybdenite associated with it, but all that was ever mined has been carried away.*
>
> *I note that you have only a few fragments of the mineral left so I am sending my specimen, which is the finest I have yet seen. I hope to get more. I am sending also all the other minerals associated with it, including three or four colors of material that leach out of the ledge, also a small piece of the soda granite. Close to this Outlaw tunnel is a deposit of cinnabar with values in free gold. Three miles east on the same contact is another bismuth-silver deposit, the bismuth here being in the form of carbonate. Three miles west is a deposit of the molybdenite like the sample sent.*

Upon learning of the high silver content reported by Mr. Clinton, Shannon conducted chemical tests and soon confirmed the presence of silver in his samples. He deduced the formula $Pb_2(Ag,Cu)_2Bi_4S_9$ from two partial and two complete chemical analyses and proposed the name benjaminite for the mineral in honor of Dr. Marcus Benjamin of the U.S. National Museum.

Since Shannon's description in 1925, no further tests were made on benjaminite until 1939, when Dr. Clifford Frondel of Harvard University examined a sample of the original material and obtained the specific gravity and an X-ray powder photograph which he found to be similar to that of cosalite (Palache *et al.*, 1944). In 1953, E. W. Nuffield of the University of Toronto examined Shannon's type material (U.S. National Museum 95058 and Harvard University HMM 85749) and found it to be a mixture of aikinite and a possible silver-bearing mineral with distinct X-ray crystallographic data. The name benjaminite was retained by Nuffield, though the chemical composition remained, at that time, undefined.

Ten years later in 1963, Shadlun *et al.* presented microprobe and X-ray diffraction data on a sulfobismuthide of copper and silver from the Dzhida deposit, USSR. They determined the composition to be $(Cu,Ag)_2Bi_{5.1}S_{12.7}$ and compared it to the data of Nuffield (1954) on

Figure 6. Gail Dunning examining the walls of the small ledge described by Mr. Clinton (Shannon, 1925) containing coatings of secondary minerals. G. Moss photo.

***Figure 7a*. Sketch of polished surface of benjaminite showing relation of benjaminite to quartz and chalcopyrite and replacement of chalcopyrite and benjaminite by covellite (from Shannon, 1925). Q = Quartz; B = Benjaminite; C = Chalcopyrite; M = Molybdenite; Cv = Covellite.**

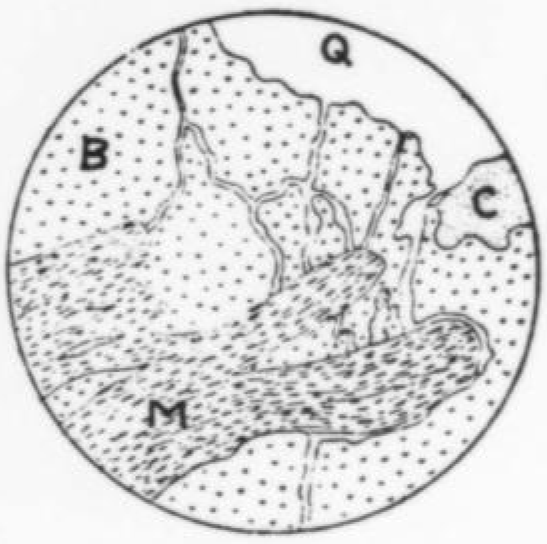


***Figure 7b*. Sketch of polished surface showing relations of benjaminite, molybdenite, chalcopyrite and quartz (from Shannon, 1925).**

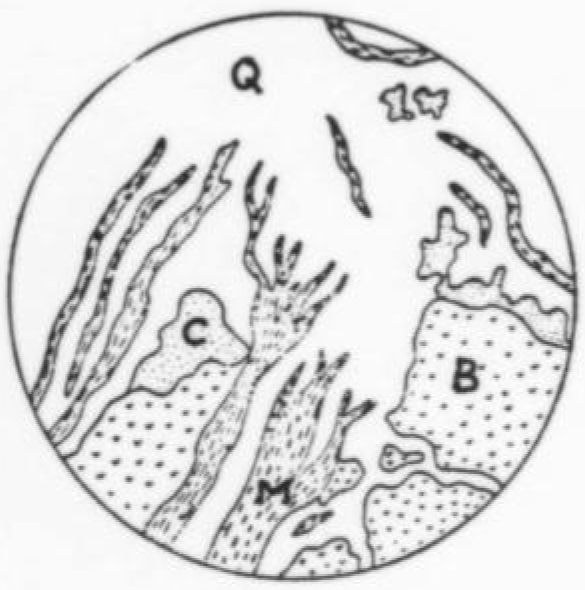


***Figure 7c*. Sketch of polished surface showing relations of benjaminite, molybdenite, chalcopyrite and quartz (from Shannon, 1925).**

pavonite from Bolivia. While in close agreement, it was not as close to the type benjaminite of Nuffield (1953) from Nevada and was only reasonably close to the synthesized compounds $AgBi_3S_5$ and $(Cu,Ag)_2Bi_4S_7$.

Mintser (1967), in a study of material from the Adrasman deposit, Central Asia, assigned the name benjaminite to a mineral with the composition $Pb_2(Cu,Ag)_2Bi_4S_9$, even though its X-ray powder pattern was not identical to Nuffield's 1953 data, and despite the fact that the composition $Pb_2(Cu,Ag)_2Bi_4S_9$ for benjaminite had been discredited by Nuffield (1953).

In 1971, Lur'ye *et al.* described a lead-silver-copper sulfobismuthide from the benjaminite-pavonite group in the Kaptarkhan ore deposit, East Karamazar, Central Asia. Microprobe analysis of the mineral gave the composition $Pb(Cu,Ag)_{2.2}Bi_{4.6}S_{7.7}$ with Cu:Ag 1:2. The X-ray powder data agreed reasonably well with Nuffield's 1953 data on benjaminite from Nye County, Nevada.

Fleischer (1968, 1972), making a comparison of published data, concluded that the specimens of Shadlun *et al.* (1963) and Mintser (1967) cannot be definitely linked to benjaminite because both benjaminite and pavonite cannot be unambiguously identified solely on the basis of X-ray powder data. Single crystal X-ray data would be required to define the above specimens in addition to the type benjaminite.

On re-examining Mintser's material, Borodayev and Mozgova (1971) found that the grains considered homogeneous by Mintser were intergrowths of berryite, matildite, and lindströmite. Further, they concluded that the "benjaminite of Shannon (1925) and Mintser (1967) must once again be discredited," and that "the powder pattern obtained by Nuffield (1953) should not be identified with the material which was chemically analyzed by Shannon." It was on this basis that the Commission on New Minerals and Mineral Names (IMA) voted in 1973 to discredit the name "benjaminite," regardless of the fact that the name had been assigned by Nuffield (1953) to the distinct species of unknown composition in Shannon's type material. Borodayev and Mozgova (1971) concluded that there were insufficient grounds for distinguishing individual mineral species among low-Pb (such as $(Ag,Cu,Pb)_3Bi_7S_{12}$) and Pb-free ($AgCu_4Bi_7S_{13}$) phases, and suggested that all be considered as a single series of benjaminite with discontinuous, isomorphous miscibility of a general formula $(Ag,Cu,Pb)_3Bi_7S_{12}$.

Nuffield (1975), on re-examination of the type specimen from Nye County, Nevada (U.S. National Museum 95058), found that the phase previously identified as benjaminite by him actually consisted of two finely intergrown silver-bearing phases, one of which, a low-Pb phase, $(Ag_{2.66}Cu_{0.52})_{3.18}(Bi_{7.09}Pb_{0.40})_{7.49}S_{11.64}$, was predominant and contributed most of his original X-ray data. Harris and Chen (1975) also found this low-Pb phase in identical material from Nye County, Nevada, as well as in material from both Camsell River, Northwest Territories, and Cobalt, Ontario, Canada.

Because of the misunderstanding about the identification and the subsequent discrediting of benjaminite by the IMA Commission, and in view of more recent studies by Nuffield (1975) and Harris and Chen (1975), a proposal was submitted by them jointly to reinstate the name benjaminite to represent the low-Pb phase. This proposal was approved by the IMA Commission and benjaminite was reinstated as a valid mineral with a definite chemical composition.

The crystal structure of benjaminite has recently been solved by Makovicky and Mumme (1979) on material chemically and crystallographically studied by Karup-Møller and Makovicky (1979) from specimens in the collections of the Royal Ontario Museum (M13805) labeled "benjaminite, Manhattan, Nevada." Associated minerals include berryite, hammarite, matildite and chalcopyrite. The structure of benjaminite was seen to follow closely the idealized pattern for the seventh member of the pavonite homologous series ($^{N}P,Me^{oct}_{N+1}Bi_2S_{N+5}$) established by Makovicky *et al.* (1977).

***Figure 8*. Typical vein quartz sample, 5 x 8 cm, containing metallic seams and pods of aikinite/ benjaminite. G. Dunning sample and photo.**

Data on metal substitution and stability of benjaminite has been recently presented by Herbert and Mumme (1981) based on material from the AW mine, New South Wales. Benjaminite from this locality contains no copper, resulting in the formula $Ag_{2.82}Bi_{6.62}Pb_{0.06}S_{12}$. Their results on this copper-free benjaminite make it possible for the Pb-substitution site in the structure to be more precisely defined. The Ag/Bi(Pb) disorder was established between the two metal sites *Me4* and

Me6 within the thicker octahedral layers in the structure. This is believed to have a greater effect on the limited thermal stability of benjaminite than has the Cu and Pb substitution (Herbert and Mumme, 1981).

Paar and Chen (1982) have identified another benjaminite occurrence in the Au-Cu deposit at Waschgang, Upper Carinthia, Austria, associated with chalcopyrite, gold, tetradymite, hessite, matildite, gladite, krupkaite, pekoite, pavonite, cupropavonite and siegenite.

GEOLOGY

The geological features of the Round Mountain quadrangle, which covers part of the southern Toquima Range, have been studied by a number of authors including Ferguson (1921), Shawe (1977, 1986), Shawe *et al.* (1986) and Kleinhample and Ziony (1984, 1985).

The rock units comprising the quadrangle geology consist of Cambrian and Ordovician marine sediments (phyllitic shale, subordinate limestone, chert and quartzite) which were intruded in Cretaceous time by a large pluton of granite. This intrusion was followed during middle Tertiary time by a swarm of rhyolite dikes. A small diorite stock apparently intruded both the granite and rhyolite sometime later. During late Tertiary time, all of these rocks were eroded and covered with latitic ash-fall and ash-flow volcanic rocks.

The Toquima Range was uplifted in late Cenozoic time by block faulting followed by extensive erosion resulting in a variety of alluvial deposits just west of the Toquima Range. Most of these alluvial deposits are Quaternary in age, although some of the older high-level gravels may be late Tertiary.

Hydrothermally altered rocks are widespread in the quadrangle. Several episodes of mineralization have been recognized in them including the formation of tungsten-bearing quartz, tourmalinization along granite contacts, gold deposits in volcanic rocks, and several small but interesting base metal replacement deposits.

The Outlaw mine is located near the head of Mariposa Canyon along a mineralized quartz vein at a contact between Cretaceous porphyritic granite and an Ordovician (?) schist which was formed from metamorphosed Paleozoic sedimentary rocks. Locally the quartz vein, which follows an irregular contact between the granite and schist, is 1–2 meters wide, strikes northeast and dips steeply northwest.

The vein quartz is milky white and locally vuggy. Shearing is common and shows thin lenses of granite or schist sheared into the vein margins. Muscovite forms thin coatings on the vein walls, as well as irregular lenses and blebs within the quartz. Small tourmaline crystals line shears in the quartz near the tourmaline schist wallrock. Fluorite, pyrite and rare rutile occur intergrown with irregular masses of muscovite within the quartz, and as isolated crystals in quartz. Much of the pyrite is granular to porous, showing the appearance of having been corroded and leached. In addition, sphalerite, galena, molybdenite and several Pb-Bi-Ag-Cu sulfosalts occur filling vuggy quartz and as euhedral crystals and irregular masses in the sheared vein quartz.

Fracturing of the pyrite, sphalerite, galena and molybdenite is common and these fractures have been filled with sulfosalts. Following the sulfosalt formation (primarily aikinite) a late stage generation of Hg-bearing Pb-Bi-Ag-Cu sulfosalts occurred.

Weathering of the sulfides and sulfosalts has resulted in a series of secondary minerals locally lining the vuggy quartz and replacing in part the sulfosalts in the quartz.

MINERALOGY

Sulfides and Sulfosalts

Aikinite $PbCuBiS_3$

Aikinite is the most abundant of the sulfosalts in the deposit and occurs as small crystals and irregular masses up to 5 cm in size. Individual crystals occur either embedded in the massive quartz or more rarely as free-standing crystals in the vuggy quartz. The prism faces are well striated and usually bent or kinked at various angles. Its color varies from medium gray on fresh fractures to a coppery red or dull lead-gray on exposed surfaces.

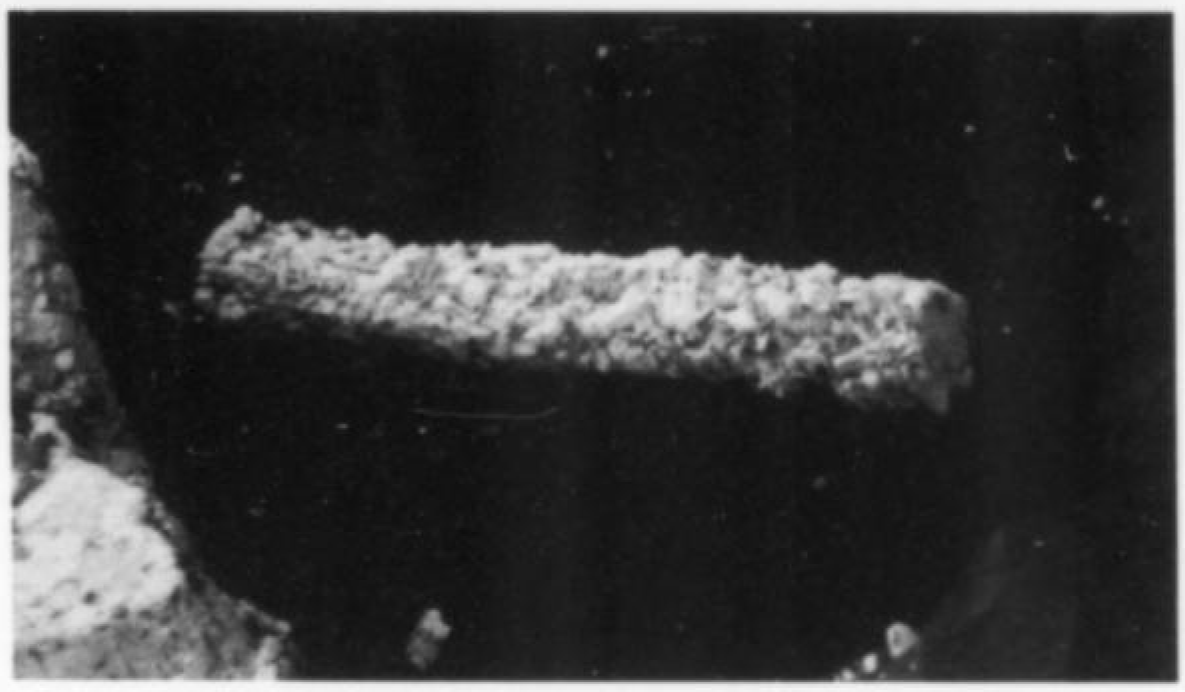


***Figure 9.* Single aikinite crystal on quartz coated (or replaced?) by anglesite, bismoclite, and quartz crystals. Crystal is 0.2 mm wide by 1.2 mm long. G. Dunning specimen and SEM photo.**

Although aikinite as a species contains no essential silver in its formula, impure aikinite was the principal ore sulfosalt mined at the Outlaw mine. Clinton's 300-ounce silver assay would be equivalent to aikinite containing about 8% benjaminite, assuming that the other silver-bearing minerals (berryite, gustavite and matildite) did not contribute significantly to the total silver content.

Foord *et al.* (1988) list the results of microprobe analyses on several aikinite samples collected by D. R. Shawe in 1973 and 1979 from the Outlaw mine which show only aikinite, friedrichite (?) (which may be nonstoichiometric aikinite) and hammarite to be present as representative of the aikinite-bismuthinite series. Emission spectrographic analyses (Foord *et al.*, 1988) show variable levels of As, Sb, Se, Hg, Te, Tl, Ag, Cr, Ni, Mo and Ba in these aikinite samples.

Aikinite masses and crystals from the oxidized zone have been either wholly or partially replaced by several secondary minerals. Energy dispersive analyses of these pale cream-colored pseudomorphs have indicated that they are composed of a thin veneer of glassy anglesite surrounding a porous core of anglesite and a member of the bismoclite-daubreeite series, but containing no silver and only a trace of copper. This suggests that the silver and copper were removed by the oxidizing solutions. Several free-standing aikinite (?) crystals were observed by SEM completely coated (or replaced?) by a mixture of minute anglesite and bismoclite-daubreeite crystals.

Benjaminite $(Ag,Cu)_3(Bi,Pb)_7S_{12}$

Shannon (1925) was the first to note the presence of a silver-bearing mineral in samples that were submitted by Mr. Clinton from the Outlaw mine. Considerable confusion has existed over the years concerning benjaminite and its place in sulfosalt mineralogy. So far, benjaminite has been observed only in samples collected during the 1920's and retained in museum collections (Nuffield, 1953, 1975; Harris and Chen, 1975; Karup-Møller, 1972; Makovicky and Mumme, 1979; and Karup-Møller and Makovicky, 1979). Foord *et al.* (1988) did not observe any benjaminite in their samples which were collected by D. R. Shawe in 1973 and 1979.

Polished samples of aikinite from our material when examined on the SEM using EDS gave several small peaks for silver but no distinction could be made between the area containing the silver and the area containing the aikinite.

Benjaminite can only be distinguished from the host aikinite and other sulfosalts in polished section using microprobe and single crystal X-ray analyses, and then with difficulty. Its identification is further complicated by oriented intergrowths of gustavite or a gustavite-like growth on a unit cell scale and by the presence of another lead-rich phase, as yet undescribed (Nuffield, 1976).

Berryite $Pb_3(Ag,Cu)_5Bi_7S_{16}$

Berryite has been identified in samples from the Outlaw mine collected during the 1920's (Royal Ontario Museum M13805) by Nuffield (1953), Harris and Chen (1976), Karup-Møller (1972), and also by Karup-Møller and Makovicky (1979).

Bismuthinite Bi_2S_3

Nuffield (1975) noted small amounts of bismuthinite in polished sections of aikinite from the Outlaw mine.

Chalcocite Cu_2S

Chalcocite was observed by Shannon (1925) and also by Harris and Chen (1975) in a few rare and very minute areas replacing covellite.

Chalcopyrite $CuFeS_2$

Chalcopyrite was noted by Shannon (1925) as microscopic, isolated grains which formed along the late quartz filling fine cracks in aikinite. He also observed cases where the chalcopyrite had grown on aikinite, or apparently, in other cases, replaced aikinite. Chalcopyrite was observed in our study as well as by Foord *et al.* (1988) and by several other authors (see under benjaminite).

Coloradoite HgTe

A few rounded inclusions of coloradoite up to 100 microns in size were observed by SEM using backscatter electron imaging (BSE) and EDS from six polished sections prepared from our material collected during 1977. Foord *et al.* (1988) also observed the mineral as inclusions within unnamed sulfosalt 2 using microprobe analysis.

Covellite CuS

Shannon (1925) observed minute amounts of covellite replacing both chalcopyrite and aikinite. It was also noted by Harris and Chen (1976) and in our polished sections.

Galena PbS

Galena is reported for the first time by Foord *et al.* (1988) from the Outlaw mine. Microprobe analyses of an elongated galena intergrowth in the unnamed sulfosalt 2 appears to illustrate a Hg(Ag) + Bi ↔ 2Pb coupled substitution. A structural formula based on one sulfur atom, using the average of two analyses is: $(Pb_{0.88}Bi_{0.05}Hg_{0.04}Ag_{0.01})S$ (Foord *et al.*, 1988).

Gustavite $PbAgBi_3S_6$ (?)

Gustavite has been observed as oriented exsolution lamellae in benjaminite from the Outlaw mine using single-crystal X-ray photographs (Nuffield, 1975; Karup-Møller, 1977; Makovicky and Mumme, 1979; and Karup-Møller and Makovicky, 1979).

Hammarite $Pb_2Cu_2Bi_4S_9$

Minute grains identified as krupkaite by Karup-Møller (1977), Makovicky and Mumme (1979), and also by Karup-Møller and Makovicky (1979) in a sample from the Royal Ontario Museum (M13805) have been shown by Foord *et al.* (1988) to be nearly identical to that reported by Harris and Chen (1976) as hammarite. Microprobe analysis of a sample collected by D. R. Shawe in 1973 from the Outlaw mine gave a composition very close to that of hammarite (Foord *et al.*, 1988).

Lindströmite $Pb_3Cu_3Bi_7S_{15}$

Lindströmite has been reported in a sample of the Royal Ontario Museum (M13805) by Nuffield (1953) and by Karup-Møller and Makovicky (1979).

Matildite $AgBiS_2$

Matildite has been reported in a sample of the Royal Ontario Museum (M13805) by Nuffield (1953), and Karup-Møller (1977).

Molybdenite MoS_2

Foliated scales and small rosettes of molybdenite and interleaved muscovite occur in the quartz vein and are associated with fluorite. Some of the rosettes were reported by Shannon (1925) to reach a diameter of 5 cm with a sharp hexagonal outline. These molybdenite crystals are composed of six triangular sectors with a twinning line down the center and striations on either side like the A structure of mica. As observed by Shannon (1925), the molybdenite in polished sections is older than the aikinite and its folia have been contorted, separated and bent by later fractures, although the cracks do not cross the folia, but pass around the ends.

Pyrite FeS_2

Pyrite occurs as cubic crystals up to 3 cm and is usually found in the quartz and within the aikinite veins and pods.

Sphalerite ZnS

Small masses of fine-grained sphalerite were observed by SEM in our samples collected in 1977 and associated with sulfur. Foord *et al.* (1988) also noted some sphalerite in samples collected by D. R. Shawe in 1973 and 1979. Shannon (1925) did not report sphalerite from the samples he studied.

Unnamed Bi-Pb-Hg-Ag-Cu sulfosalt 1 (Phase X)

This unnamed sulfosalt is reported by Foord *et al.* (1988) from three of eight polished sections of aikinite from the Outlaw mine. It has been observed only as veinlets cutting nonstoichiometric aikinite, which it had replaced. Single-crystal studies of the material will be necessary to determine if it is a mercury-substituted heyrovskyite, a mercury-substituted eskimoite, a new member of the lillianite homologous series, or a new species.

Unnamed Bi-Pb-Hg-Ag-Cu sulfosalt 2 (Phase Y)

This unnamed sulfosalt is reported by Foord *et al.* (1988) from a single polished section and forms the bulk of one area about 200 x 200 microns. It contains lath-like intergrowths of the previous unnamed sulfosalt, exsolved blebs and irregular masses of galena and coloradoite. They state that this material may possibly be a mercury and copper-substituted ourayite. Single-crystal X-ray studies will be necessary to completely characterize this mineral.

Secondary Minerals

Anglesite $PbSO_4$

Minute, glassy crystals of anglesite occur as coatings on individual free-standing aikinite crystals noted in several small quartz cavities. Embedded aikinite crystals usually have an outer veneer of clear anglesite when oxidized. Anglesite crystals are also abundant as coatings in quartz cavities where oxidizing solutions have concentrated. Associated minerals usually include sulfur, corkite, a member of the bismoclite-daubreeite series and koechlinite. The anglesite was identified by its EDS spectrum and crystal habit. Foord *et al.* (1988) also noted anglesite as a part of the alteration crust of aikinite.

Bismoclite-Daubreeite BiOCl—BiO(OH,Cl)

An SEM examination of the alteration products of aikinite using EDS showed abundant, thin, square tetragonal plates with a very flat vicinal pyramidal habit. These square crystals gave positive peaks for both bismuth and chloride after peak-stripping the interfering low-energy bismuth peaks masking the Cl. Comparison of the EDS data was made with known bismoclite from Goldfield, Nevada, and daubreeite from the Constancia mine, Tazna, Bolivia, and it shows a closer match for the bismoclite end-member than that for daubreeite. Foord *et al.* (1988) also noted this material and considered it as a member of the bismoclite-daubreeite series.

Figure 10. **Higher magnification view of Figure 9 showing the complex crystal aggregation of anglesite, bismoclite and quartz. Field of view 0.21 mm x 0.30 mm. G. Dunning specimen and SEM photo.**

Figure 12. **Higher magnification view of Figure 9 showing the individual habits of anglesite, bismoclite and quartz. All of the crystals are transparent and glassy. Field of view is 0.08 x 0.1 mm. G. Dunning specimen and SEM photo.**

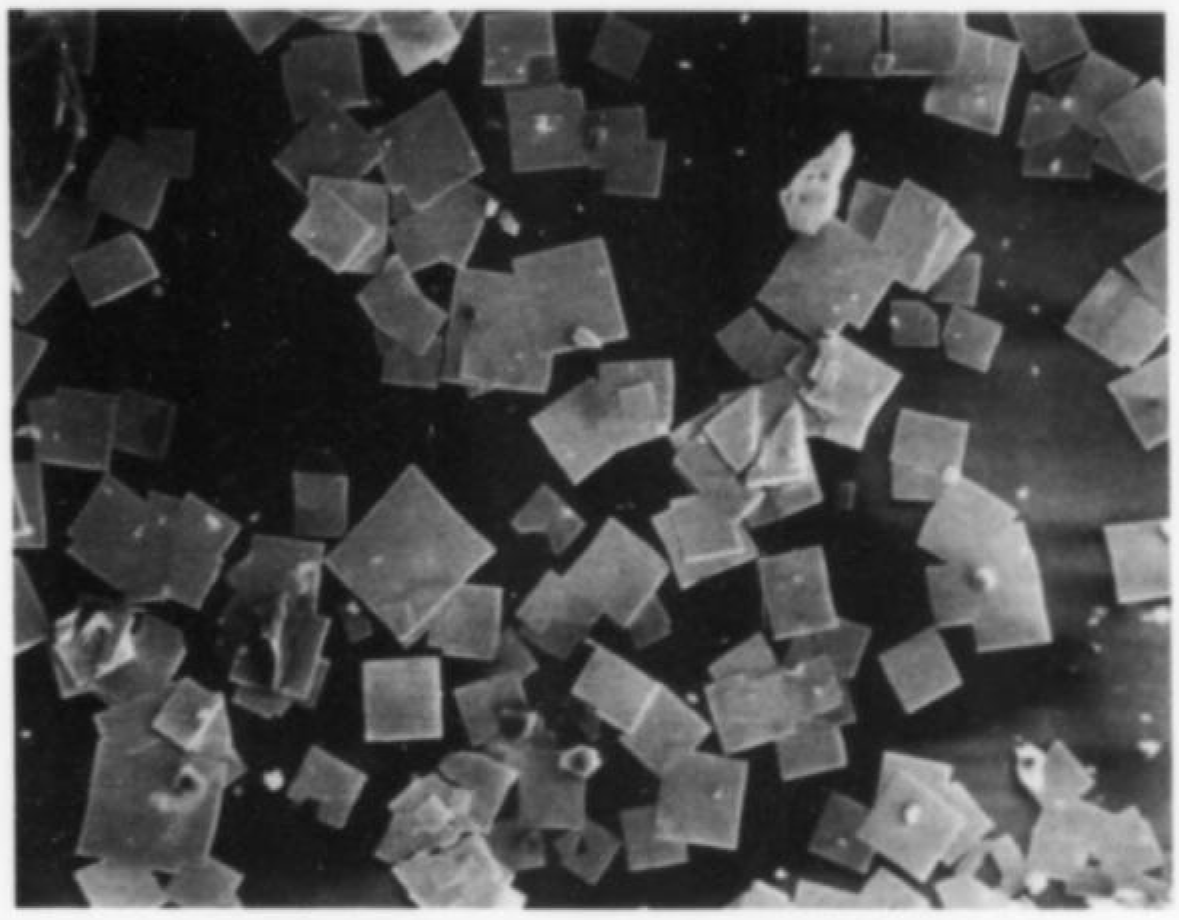


Figure 11. **Coating of tetragonal bismoclite crystals on quartz recovered from the small ledge area. The crystals range in size from 0.01 to 0.03 mm. G. Dunning specimen and SEM photo.**

Figure 13. **Complex aggregation of bismoclite crystals found lining quartz cavities where the sulfosalts have been oxidized. Field of view is 0.06 x 0.08 mm. F. Cooper specimen and G. Dunning SEM photo.**

Bismutite $Bi_2(CO_3)O_2$

A few yellowish white crusts of bismutite were observed coating quartz fractures near altered aikinite. It was identified by a positive bismuth test (EDS) and evolution of carbon dioxide when placed in 1:1 nitric acid.

Cerussite $PbCO_3$

A few colorless crystals of cerussite, commonly elongated [001] and flattened {010}, occur coating quartz fractures near altered aikinite.

Chalcanthite $CuSO_4 \cdot 5H_2O$

Fine-grained coatings of light blue to green chalcanthite appear on quartz samples recovered from the small cave near the Outlaw tunnel. It was identified by its EDS spectrum and optical properties.

Corkite $PbFe_3^{+3}(PO_4)(SO_4)(OH)_6$

Minute pseudocubic crystals of corkite, commonly showing complex intergrowths, were noted by SEM along quartz fractures in the oxidized zone. It was identified by its EDS spectrum and crystal habit.

Figure 14. **Minute complexly intergrown pseudocubic crystals of corkite, to 0.01 mm, lining quartz cavities in the oxidized zone. Identification was by EDS and crystal habit. G. Dunning specimen and SEM photo.**

Ferrimolybdite $Fe_2^{+3}(MoO_4)_3 \cdot 8H_2O$ (?)

Rare coatings of ferrimolybdite were observed near oxidized molybdenite flakes in quartz. It was identified by its color, EDS spectrum, and close association to the molybdenite.

Goethite (?) α-$Fe^{+3}O(OH)$

A few minute, acicular crystals of goethite (?) were observed in a single quartz cavity. EDS analysis showed only iron.

Jarosite $KFe_3^{+3}(SO_4)(OH)_6$

Both massive and crystallized dark brown jarosite are common along quartz fractures in the oxidized zone. It was identified by its EDS spectrum and crystal habit.

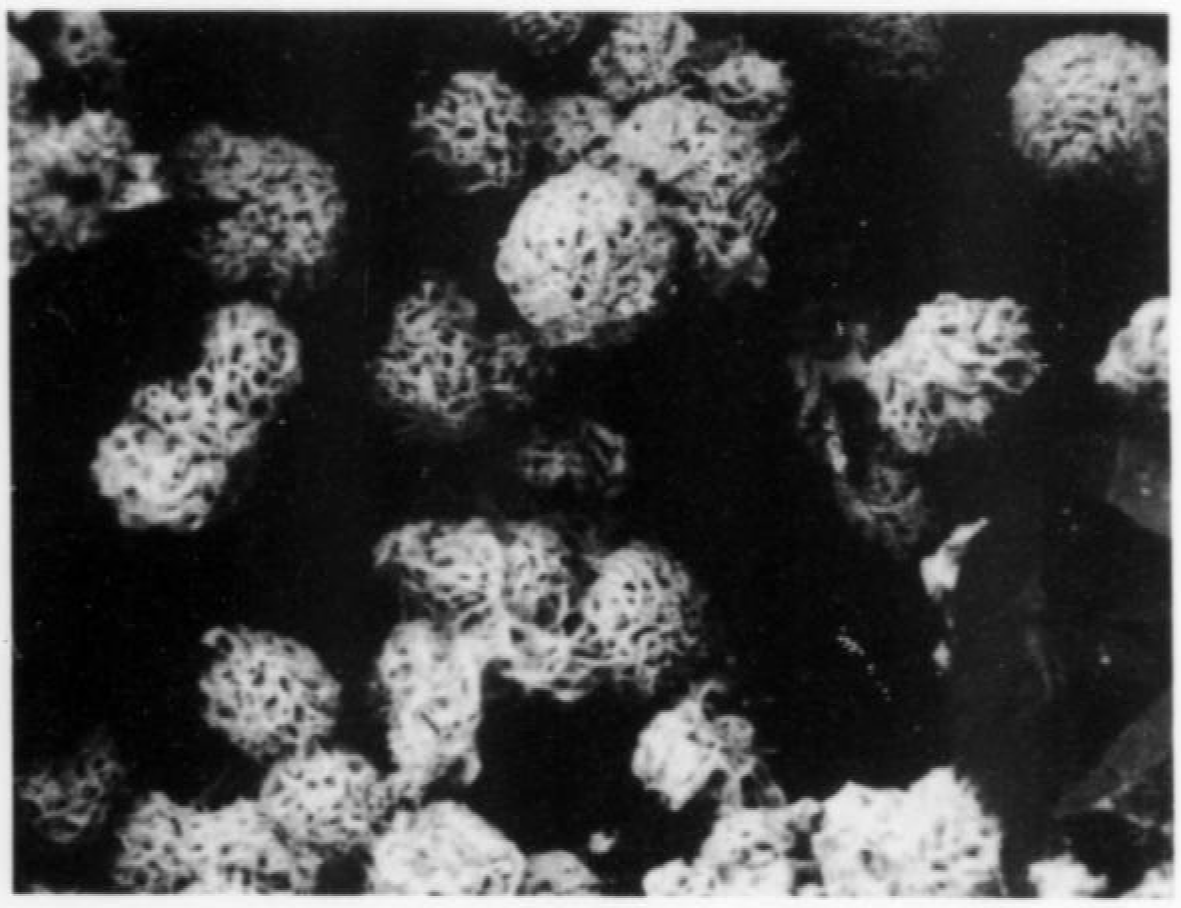


Figure 15. **Spheres to 0.04 mm composed of yellowish-white laths of koechlinite found along quartz fractures in the oxidized zone. Some partially oxidized molybdenite was found in the quartz. G. Dunning specimen and SEM photo.**

Koechlinite Bi_2MoO_6

White to light gray spheroids of koechlinite, composed of flattened, subhedral crystals, occur rarely filling fractures in quartz in the oxidized zone. Its identification was based on EDS and compared to an X-ray verified sample of koechlinite from Plumas County, California.

Sulfur S

Massive, dark orange to brown sulfur was found filling quartz cavities associated with anglesite and bismoclite-daubreeite.

Gangue Minerals

Fluorite CaF_2

Isolated fluorite crystals up to 4 cm in size occur in granular masses of muscovite. These crystals vary in color from deep purple to purplish red, yellow and colorless. Shannon (1925) described samples at his disposal as forming a skeletal cube, apparently developed by metasomatic replacement of quartz.

Muscovite $KAl_2(Si_3Al)O_{10}(OH,F)_2$

Muscovite is common in the quartz veins as scales and aggregates of scales with a pearly luster. Individual crystals range up to 1 cm and are in part hexagonal in outline. The color varies from pale green to white and pale brown.

Quartz SiO_2

White vein quartz forms the gangue of the minerals found at the Outlaw mine and is coarsely crystalline. Thin-section observations of the vein quartz by Shannon (1925) show it forming broad, interlocking crystals which contain numerous fluid inclusions. Some of the largest of these inclusions contain bubbles while the smaller ones are generally aligned into strings. A later introduction of quartz was observed filling numerous fine fractures in the older quartz, and especially the sulfosalts. Polished sections of the sulfosalts show these later quartz veins, which are quite conspicuous.

DISCUSSION

The microscopic examinations of Shannon (1925), together with additional information on vein mineralogy from our studies, as well as those of Foord *et al.* (1988), suggest that the paragenetic sequence of mineral formation for the Outlaw quartz vein can be divided into at least three periods.

Shannon (1925) stated that the original vein quartz, muscovite, molybdenite, pyrite and fluorite had formed first at relatively high temperatures. This he concluded from the fact that mica, molybdenite and fluorite are commonly associated with high-temperature pegmatitic or hydrothermal veins.

Next in the sequence, he placed benjaminite (actually a mixture of aikinite, benjaminite and other bismuth sulfosalts), quartz, chalcopyrite, covellite and chalcocite, with a considerable but unknown time gap between the two sequences. He considered both covellite and chalcocite to be products of downward secondary enrichment, and that the vein mineralogy most probably belongs to a single genetic event.

From their study of coexisting galenas and sulfosalts in the Round Mountain and Manhattan areas, Foord *et al.* (1988) have suggested a general sequence of deposition of sulfides and sulfosalts. An early high-temperature event related to the Cretaceous granite plutons involved deposition of simple sulfides in tactites and quartz veins. At a later time, a high-temperature bismuth-rich and silver-rich hydrothermal activity locally modified these deposits. During Tertiary time several events occurred which introduced additional mineralization into the veins. Specifically, the formation of the mercury-bearing Bi-Pb-Ag-Cu sulfosalts, coloradoite and the mercurian galena in a Cretaceous quartz vein as described by Bailey and Phoenix (1944) is believed to have occurred during this episode of mineralization (Foord *et al.*, 1988). The presence of mercury in the Outlaw mine primary

Table 1. **Minerals identified at the Outlaw mine, Nye County, Nevada.**

Sulfides and Sulfosalts	
Aikinite	$\mathrm{PbCuBiS_3}$
Benjaminite	$\mathrm{(Ag,Cu)_3(Bi,Pb)_7S_{12}}$
Berryite	$\mathrm{Pb_3(Ag,Cu)_5Bi_7S_{16}}$
Bismuthinite	$\mathrm{Bi_2S_3}$
Chalcocite	$\mathrm{Cu_2S}$
Chalcopyrite	$\mathrm{CuFeS_2}$
Coloradoite	HgTe
Covellite	CuS
Galena	PbS
Gustavite	$\mathrm{PbAgBi_3S_6}$ (?)
Hammarite	$\mathrm{Pb_2Cu_2Bi_4S_9}$
Lindströmite	$\mathrm{Pb_3Bu_3Bi_7S_{15}}$
Matildite	$\mathrm{AgBiS_2}$
Molybdenite	$\mathrm{MoS_2}$
Pyrite	$\mathrm{FeS_2}$
Sphalerite	ZnS
Unnamed Bi-Pb-Hg-Ag-Cu sulfosalt 1	
Unnamed Bi-Pb-Hg-Ag-Cu sulfosalt 2	
Secondary Minerals	
Anglesite	$\mathrm{PbSO_4}$
Bismoclite	BiOCl
Daubreeite	BiO(OH,Cl)
Bismutite	$\mathrm{Bi_2(CO_3)O_2}$
Cerussite	$\mathrm{PbCO_3}$
Chalcanthite	$\mathrm{CuSO_4\cdot 5H_2O}$
Corkite	$\mathrm{PbFe^{+3}_3(PO_4)(SO_4)(OH)_6}$
Ferrimolybdite	$\mathrm{Fe^{+3}_3(MoO_4)_3\cdot 8H_2O}$ (?)
Goethite (?)	$\alpha\text{-}\mathrm{Fe^{+3}O(OH)}$
Jarosite	$\mathrm{KFe^{+3}_3(SO_4)_2(OH)_6}$
Koechlinite	$\mathrm{Bi_2MoO_6}$
Sulfur	S
Gangue Minerals	
Fluorite	$\mathrm{CaF_2}$
Muscovite	$\mathrm{KAl_2(Si_3Al)O_{10}(OH,F)_2}$
Quartz	$\mathrm{SiO_2}$
Rutile	$\mathrm{TiO_2}$
Tourmaline	complex borosilicate

mineral assemblage postdates the high to moderate sulfide and sulfosalt mineralization (Foord *et al.*, 1988) and is related to the formation of several mercury deposits in the area described by Bailey and Phoenix (1944).

A third general period of mineral formation consisted of alteration of the sulfides and sulfosalts by low-temperature oxidizing solutions. Our study of the secondary mineral assemblage has shown the replacement of the aikinite veins and crystals, in a limited way, by anglesite, cerussite, bismoclite-daubreeite, corkite, koechlinite and other minerals. The embedded aikinite crystals in the oxidation zone consistently show a pseudomorphic replacement by anglesite and bismoclite.

CONCLUSIONS

The Outlaw mine is one example of a small mineralized vein system which has yielded a number of unusual sulfides, sulfosalts and secondary minerals. Further studies of this deposit will surely reveal additional sulfosalts but their small size will preclude easy identification. Much additional vein quartz still remains at the mine but extensive work will be required to extract it. The area is accessible only by steep trails either up Mariposa Canyon or down from the Red Bird Toquima mine. All of the common minerals are easily recognized in hand sample but the sulfosalts must be identified in polished section using microprobe analysis and possibly single-crystal X-ray techniques.

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STRONTIAN CRANDALLITE FROM THE ALTO BENEDITO PEGMATITE, PARAIBA, BRAZIL

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INTRODUCTION

Minerals of the crandallite group are fairly common in Brazil, but visible crystals are almost never found in pegmatites. An exception is the Alto Benedito pegmatite, where microcrystals of strontian crandallite and barian goyazite have been found in association with a number of other species.

The Alto Benedito pegmatite is located 15 kilometers northwest of Picuí and 4 km east of Frei Martinho on the Borborema high plain, in the state of Paraiba, north-northwest of the coastal town of Recife. The site is on the 1972 Cerro Corá 1:100,000 map (SB-24-Z-B-111), at coordinates x = 786 E and y = 9292 N. Access from Picuí is by paved highway BR 104, to the Frei Martinho municipal road, then 8.5 km to where the road forks, marked by a road sign ("Escola Fazenda Cenecista E. G. Ferreira"), and from there 6.7 km to a farmhouse near a small dam. The pegmatite is then reached in about 15 minutes by a narrow footpath leading eastward.

HISTORY

Formerly known as Alto Questão, the Alto Benedito pegmatite was intensively mined for beryl and tantalite during World War II, and has been reworked sporadically on a small scale since then. The mine workings consist of a deep open cut along the outcrop, and several tortuous adits and small stopes to the northwest.

During 1979–1980 a vug yielding barian goyazite was encountered (reported by White (1981), who referred to the locality as "Alto Bernardino").

In 1987–1988 a vug containing quartz and strontian crandallite was found, the subject of this article.

As of 1989, many of the workings had caved in or become flooded, and are no longer accessible.

THE PEGMATITE

The occurrence is a zoned granitic pegmatite with giant crystals, striking N45°E and dipping 25–30°NW. Its maximum thickness is 10–15 meters. The pegmatite crops out over a length of about 100 meters, becoming thinner toward the north. The wallrock is a biotite schist.

In the middle portion of the pegmatite, between the wallrock and the quartz core, it is still possible to observe a sequence consisting of (a) biotite schist, (b) a 1-meter-thick granitic zone bordered on the wallrock side by a thin rim of tourmaline, (c) a medium-grained pegmatitic zone, (d) a coarse-grained zone containing giant crystals, muscovite lenses and scattered, vuggy substitution bodies, and (e) a milky quartz core over 1.5 meters, thick, standing about 5 meters inward from the wallrock. Elongated biotite laths occur locally near the wallrock. Iron and manganese phosphates occur disseminated through the northern portion of the pegmatite body, which is crossed by a thin basalt dike.

Along the quartz core, vugs of variable size and shape has been found lined with milky quartz crystals and, in many cases, filled with a pale brown clay. The most recently discovered vug was 1.5 meters long and about 50 cm high; many attached quartz groups and floaters were found coated with strontian crandallite crystals plus a few apatite and hydroxylherderite crystals.

CRANDALLITE

Crandallite occurs as crystals scattered or densely distributed on the faces of quartz crystals; it is nearly identical in appearance to the earlier-found barian goyazite. The crandallite generally forms small rhombohedrons, singly and in intergrown groups. Proportions vary from equant (looking like deformed cubes) to rare tabular habits. Some crystals show cavities resulting from irregular growth. The crystal forms *c*{0001}, *r*$\{10\bar{1}2\}$, *n*$\{20\bar{2}1\}$ and *f*$\{01\bar{1}1\}$ have been identified; habits involving the combinations *c-r-f*, *c-r-n-f* and *n-r-f* have been reported from a nearby vug by Silva and Villaroel (1986). The {0001} cleavage is perfect.

Crystals are white to pale brown with a porcelaineous luster, in some places waxy due to incipient alteration. Some crystals are stained by oxides of iron and/or manganese. Most crystals are no larger than a few tenths of a millimeter, but exceptional examples reach 1 mm. The crystals are opaque to slightly translucent. Density (measured) = 3.04 ± 0.02 g/cm^3; calculated = 3.06 g/cm^3. Mohs hardness is

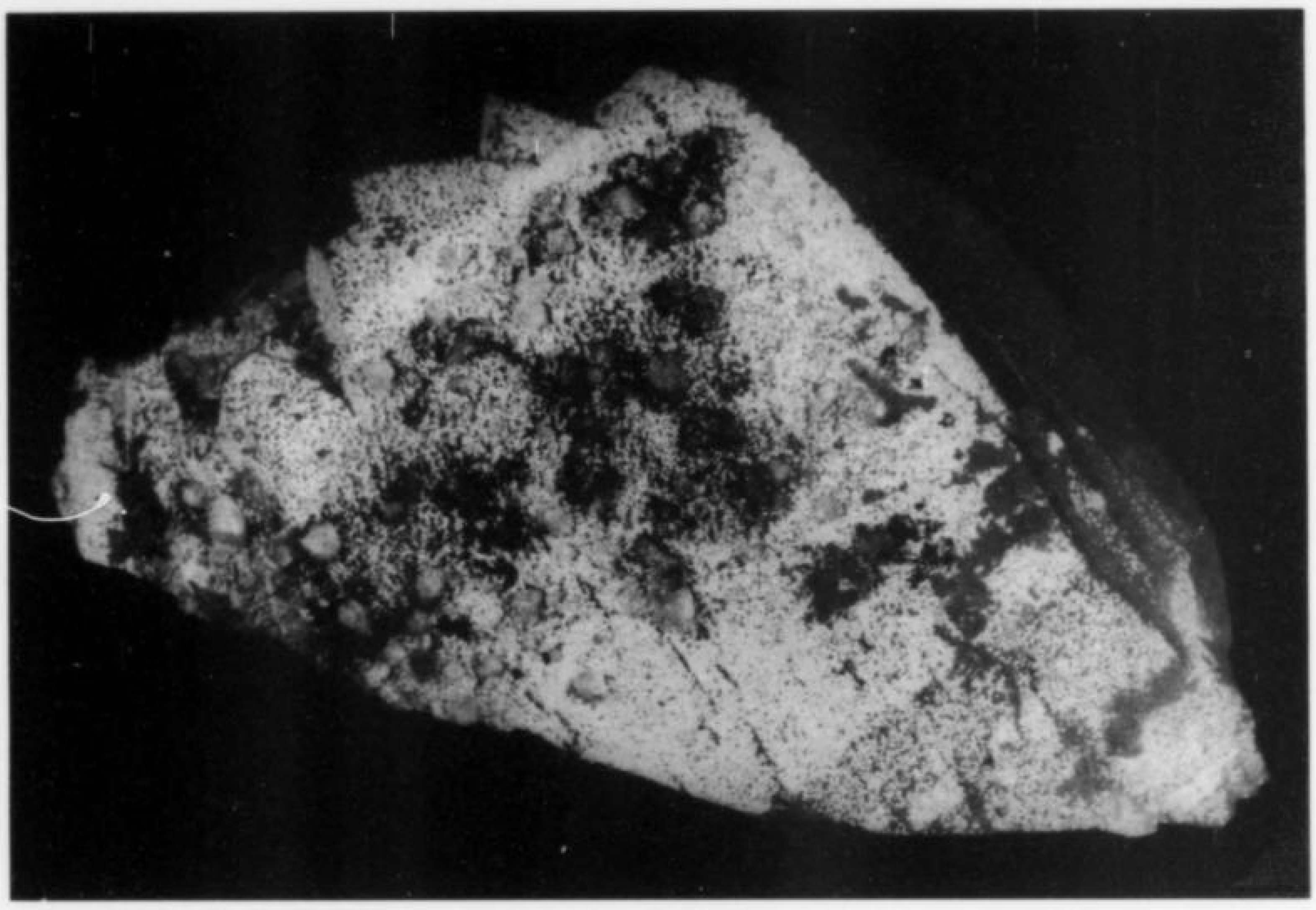

Figure 1. **Small crandallite crystals and larger hydroxylherderite crystals coating a 9-cm quartz specimen.**

Figure 2. **Crandallite crystals (white) to nearly 1 mm and translucent hydroxylherderite crystals.**

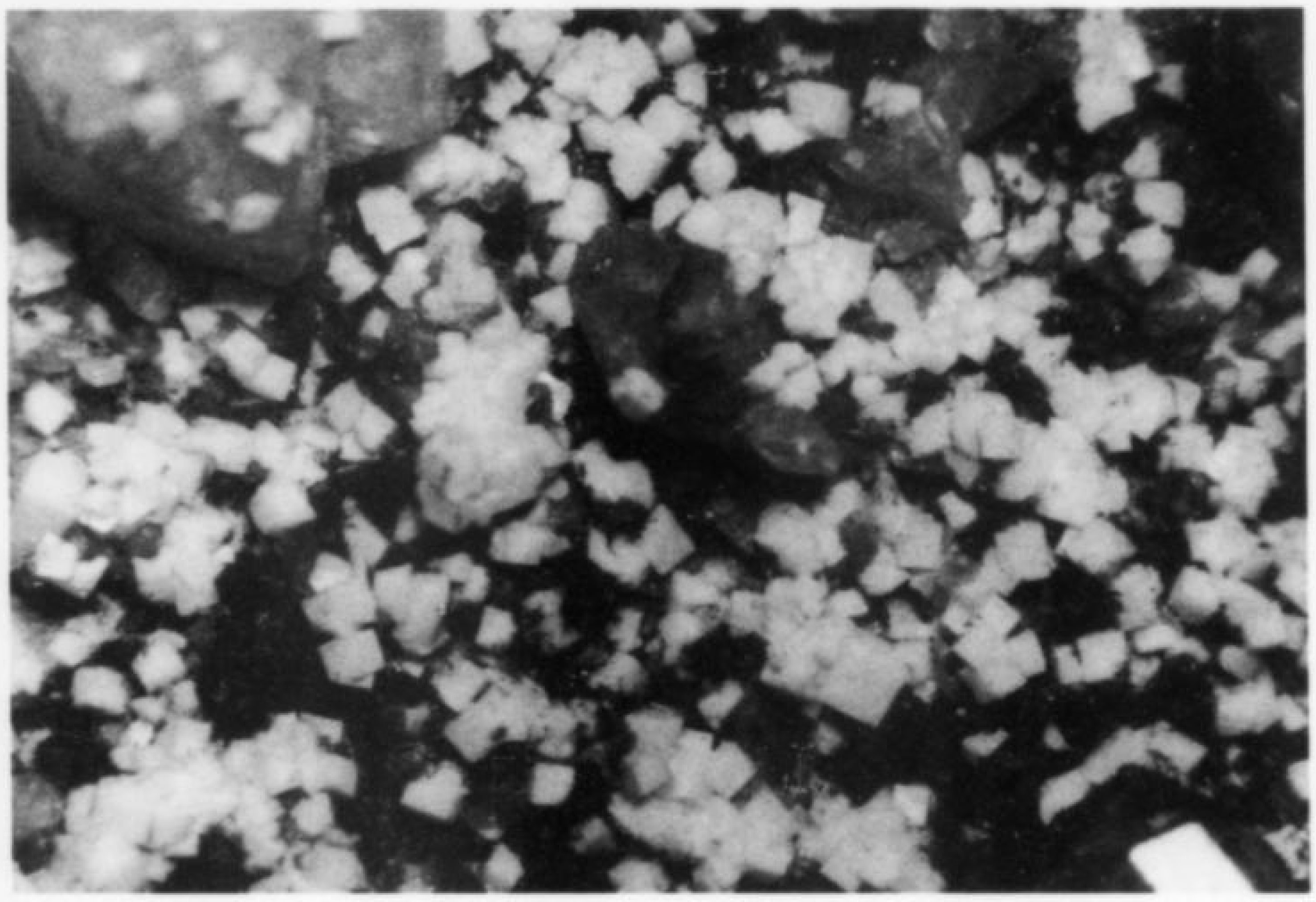

Figure 3. **A large hydroxylherderite crystal, 9 cm in length, with partial coating of small, white crandallite crystals.**

about 5. The refractive indices are 1.638 and 1.642, with birefringence of 0.004. The mineral does not fluoresce under ultraviolet radiation. Principal X-ray diffraction lines and their relative intensities are: 5.79 (58), 3.524 (44), 2.976 (100), 2.215 (41) and 1.9012 (25). Measurements of the hexagonal cell are: a = 7.003 Å and c = 16.667 Å, ± 0.005 Å.

A wet chemical analysis gave the following results: Al_2O_3 = 35.15%, CaO = 7.19%, SrO = 10.53%, P_2O_5 = 32.64%, H_2O (total) = 14.48%: total = 99.99 weight %. This indicates the following formula: $(Ca_{0.56}Sr_{0.44})Al_3(PO_4)_2(OH)_5\cdot H_2O$. Spectrochemical analysis revealed only traces of Ba, K, Na and Ti. Alto Benedito crystals are therefore a strontian crandallite, nearly intermediate in composition between crandallite and its strontium analog, goyazite.

Table 1. **Minerals of the Alto Benedito pegmatite.**

Albite	$NaAlSi_3O_8$	Platy aggregates, patches and small plates in vugs.
Amblygonite	$(Li,Na)Al(PO_4)(F,OH)$	Coarsely crystalline, white to pale brown masses in feldspar.
Autunite	$Ca(UO_2)_2(PO_4)_2\cdot 10–12H_2O$	Fluorescent coatings with opal on feldspar and mica.
Beryl	$Be_3Al_2Si_6O_{18}$	Large industrial-grade crystals and needles; white, gray or green; always opaque and cracked.
Crandallite	$(Ca,Sr)Al_3(PO_4)_2(OH)_5\cdot 2H_2O$	Small patches scattered in heterosite.
Cyrilovite	$NaFe_3^{+3}(PO_4)_2(OH)_4\cdot 2H_2O$	Small patches scattered in heterosite.
Ferrisicklerite	$Li(Fe^{+3},Mn^{+2})PO_4$	Coarsely crystalline replacements of heterosite.

Fluorapatite	$Ca_5(PO_4)_3F$	Whitish prisms to 3 mm with crandallite.
Frondelite	$Mn^{+2}Fe_4^{+3}(PO_4)_3(OH)_5$	Rare; associated with heterosite.
Garnet		Scarce, weathered aggregates; pale brown
Goyazite	$SrAl_3(PO_4)_2(OH)_5 \cdot H_2O$	Small (0.25–1.0 mm), white rhombohedrons on quartz crystals; barium-containing (5.1% BaO).
Heterosite	$Fe^{+3}PO_4$	Anhedral to subhedral crystals to 10 cm.
Hureaulite	$Mn_5(PO_4)_2[PO_3(OH)]_2 4H_2O$	Porous, orange to pink aggregates of small crystals; also pale brown, waxy, coarse patches in heterosite.
Hydroxyl-herderite	$CaBe(PO_4)(OH)$	Pale brown, translucent to opaque platy crystals to 9 cm; also stout, colorless to pale gray, transparent to translucent crystals to 1 mm; with crandallite.
Lepidolite	$K(Li,Al)_3(Si,Al)_4O_{10}(F,OH)_2$	Rare; small, pink flakes.
Magnetite	$Fe^{+2}Fe_2^{+3}O_4$	Very rare; rounded octahedrons to 1 cm.
Microcline	$KAlSi_3O_8$	Large crystals.
Microlite	$(Ca,Na)_2Pa_2O_6(O,OH,F)$	Small crystals in greenish muscovite.
Mitridatite	$Ca_3Fe_4^{+3}(PO_4)_4(OH)_6 \cdot 3H_2O$	Small spots in weathered hureaulite.
Muscovite	$KAl_2(Si_3Al)O_{10}(OH,F)_2$	Broad flakes and books with schorl; yellowish, isosceles-triangular crystals and coarse greenish patches; lithium-free.
Phospho-siderite	$Fe^{+3}PO_4 \cdot 2H_2O$	Thin coatings on earthy spots in and on heterosite.
Pyrite	FeS_2	Small crystals with sulfur in weathered schorl.
Quartz	SiO_2	Milky, anhedral to prismatic crystals to 15 cm lining vugs; rare black quartz; gray.
Schorl	$NaFe_3^{+2}Al_6(BO_3)_3Si_6O_{18}(OH)_4$	Well-formed needles near wallrock; crystals to 30 cm and anhedral blocks in feldspar.
Sulfur	S	Associated with pyrite and schorl.
Tantalite	$(Fe^{+2},Mn)Ta_2O_6$	Small, flattened crystals in feldspar and mica; flakes in pinkish microcline.
Triphylite	$LiFe^{+2}PO_4$	Scarce; weathered small cores in heterosite.
Uraninite	UO_2	Very small grains in microcline.
Wad and Limonite	Mn and Fe oxides	Coatings and dendrites.

Associated minerals in the most recently found vug include fluorapatite and hydroxylherderite. The fluorapatite occurs as whitish, transparent to translucent hexagonal prisms to 3 mm, standing or lying, in groups and as singles, irregularly scattered among the crandallite crystals. Some occur on or enveloped by crandallite crystals. A wet chemical analysis of the fluorapatite gave the following results: $CaO = 53.55\%$, $MnO = 0.69\%$, $P_2O_5 = 40.90\%$, $F = 2.68\%$, $Cl = 1.87$: total $= 99.69\%$. This indicates the following formula, setting $P = 3$: $(Ca_{0.99}Mn_{0.01})_5(PO_4)_3(F_{0.735}Cl_{0.265})$.

The hydroxylherderite occurs as pale brown, platy, translucent to opaque crystals up to 9 cm in size, and as stout, transparent to translucent, colorless to pale gray crystals to 1 mm. Hydroxylherderite formed before crandallite and fluorapatite.

All of the minerals found at the Alto Benedito pegmatite are listed on Table 1.

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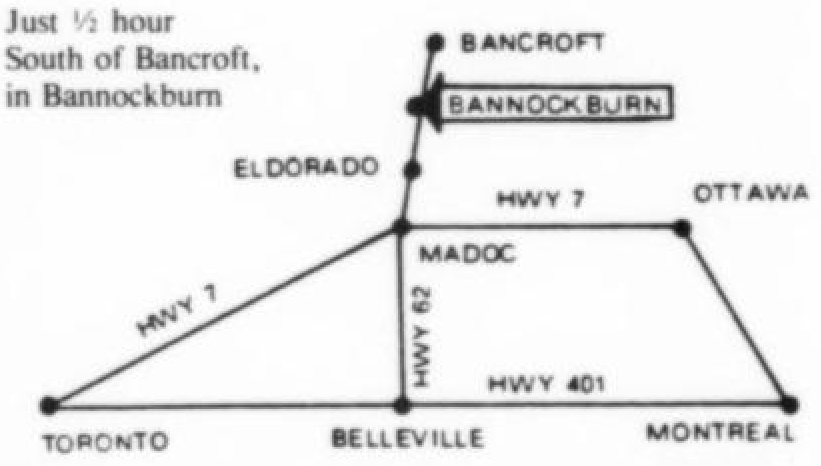

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THE MESSINA MINING DISTRICT, SOUTH AFRICA

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The copper mining district of Messina in the northern Transvaal Province of South Africa has produced a profusion of quartz specimens over the years. In 1985 a single pocket of quartz with inclusions of ajoite yielded spectacular specimens rivalling or even eclipsing older material, which incorporates other copper silicates such as shattuckite and papagoite.

INTRODUCTION

The town of Messina is the most northerly settlement in the Republic of South Africa. It is situated approximately 8 km south of the Limpopo River, which forms the boundary between South Africa and Zimbabwe. The climate of the region is essentially subtropical with summer temperatures reaching up to 40° C. The winter months (June to August) are more congenial, with slightly cooler weather prevailing. Malaria is endemic in the region and, until 1914, it considerably handicapped the copper mining industry (Söhnge, 1946); precautions should be taken if a visit is planned.

Access to the town and surrounding mines is relatively easy; the main national road passes through Messina and up to Beit Bridge, the border crossing to Zimbabwe. The Messina District consists currently of five mines: the Artonvilla, Harper, Messina, Spence and Western Campbell mines. Permission to visit the mines or dumps for collecting must be obtained from the holding company, Messina (Transvaal) Development, which has head offices in Johannesburg. Provided correct channels are followed, permission is generally granted. But the exposure of good quartz specimens showing attractive inclusions is a rare occurrence at the mines, and visitors are liable to be disappointed in what can be collected on an average day.

HISTORY

According to Söhnge (1946) (one of the earliest and most comprehensive reports on the Messina copper mines), the copper deposits in the Limpopo river area were known to ancient indigenous African tribes for centuries. The word "Messina" is a corruption of the word "Musina," which was the name of one of the tribes which moved into the area from the eastern Transvaal (Van Warmelo, 1940). The Musina people had emigrated to escape attacks by Sotho raiders from the south, most likely during the upheavals that accompanied the rise of the Zulu nation in Natal during the early 19th century (Bahnemann, 1986). Prior to the arrival of these migratory tribes, the earlier inhabitants may have had tentative links with the people of the present-day Zimbabwe ruins in southern Zimbabwe. Ancient mine excavations have yielded stone hammers, soapstone artifacts and iron tools and wedges (Rogers and Weber, 1935). "Musina" is believed to mean "Spoiler," because the small amounts of copper tended to spoil or down-grade the iron produced by the early miners. Ancient smelters are still known today along the high ridges and hills within 20 km of the town of Messina, and particularly at the summit of Singelele Kop (hill).

It was the tales of the ancient copper miners that led Lt. Colonel J. P. Grenfell to send a prospecting team to investigate the region, following the South African Anglo-Boer war. The Digby, Harper and Campbell shafts are named after members of this exploration party. The outcome of the expedition was the registration of the Messina (Transvaal) Development Company in 1905. This had an initial capital of £110,000 and £50,000 in debentures. Söhnge (1946), quoting Emery (1930), provides some details on the Grenfell expedition:

> To the courage and foresight of Colonel J. P. Grenfell, the Messina mines owe their existence. The ancient workings at Messina, which were some 80 feet deep (water level) and some 30 feet wide and which contained . . . rich copper sulphides, were investigated by Colonel Grenfell in 1906.
>
> The diary of the first effort to make a profitable venture out of Messina copper was mostly a record of Colonel Grenfell's struggles against lions, malaria and the elements of tropical Africa. The mines produced from 1906 to 1914 a small tonnage of high-grade sorted ore and concentrates which, in the early

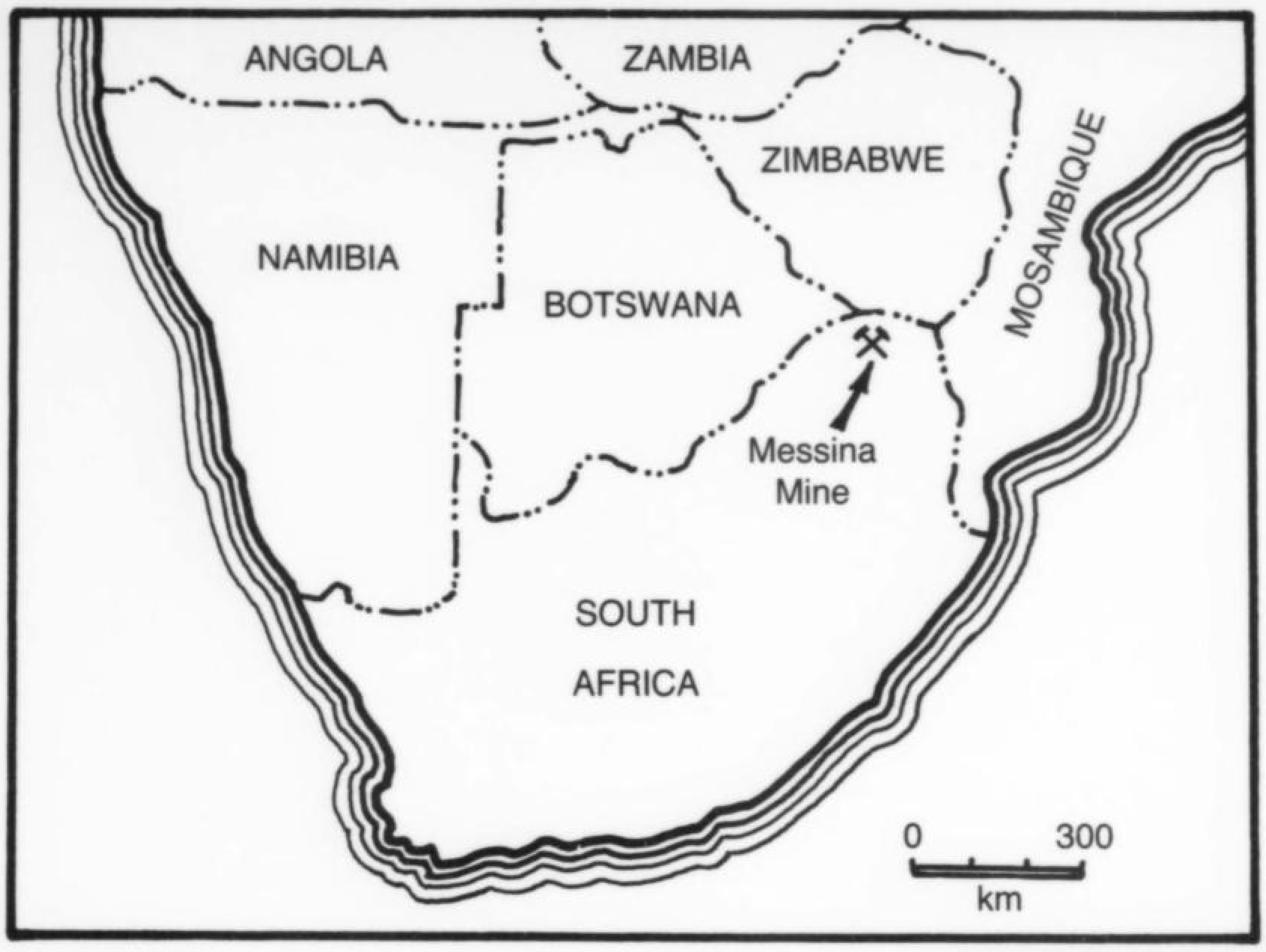


Figure 1. **Location of the Messina mining district in the Republic of South Africa.**

days, were transported by wagon 170 miles to the railhead at Pietersburg.

In 1914 a new reduction works was put into commission, and a small Welsh reverberating furnace turned low-grade concentrates into high-grade matte, which, together with the high-grade concentrations, was shipped overseas to Welsh refineries. In 1920, the Messina mines were closed down pending the erection of the new addition to the concentration plant, and the erection of the new smelting works.

Mining operations were resumed in 1922. Production statistics show that during 1938, 1939 and 1940, the Messina plant was producing 10,000 tons of copper annually. Ore reserves in 1939 were estimated at 2,811,605 tons at a grade of 2.09% Cu (Söhnge, 1946). Since the initial establishment of the Messina (Transvaal) Development Company, 40 million tons of ore have been mined, yielding approximately 700,000 tons of copper (Bahnemann, 1986). It is interesting to note that all of the modern shafts have been sunk on or next to ancient workings.

The discovery of specimen-grade minerals at the mines has been sporadic. All of the specimens are collected either by miners or by other mine personnel, and only appear infrequently on the local market. All specimens are usually labeled "Messina mine," with little or no accurate labeling of material coming out of the adjacent mines. (This seems to be a common local problem similar to the labeling of minerals from the manganese field in the northern Cape Province where individual mines seldom get a mention over and above the N'Chwaning mine). It appears, however, that many of the quartz and papagoite specimens are over 20 years old. The author recently helped unwrap some specimens donated to the Witwatersrand University's Geology Department museum. These represented a donation from a local retired physics professor. Within the trunk was an exceptional group of quartz crystals with inclusions of blue papagoite, shattuckite and brilliant specular hematite crystals. The interesting feature of the specimen was that it was wrapped and sealed in an aged yellow page of a 1955 issues of the S.A. Mining and Engineering magazine, long since out of print, suggesting the specimen was collected well over 30 years ago. The quartz specimens with fine ajoite inclusions are often more recent, many dating from discoveries made in 1985.

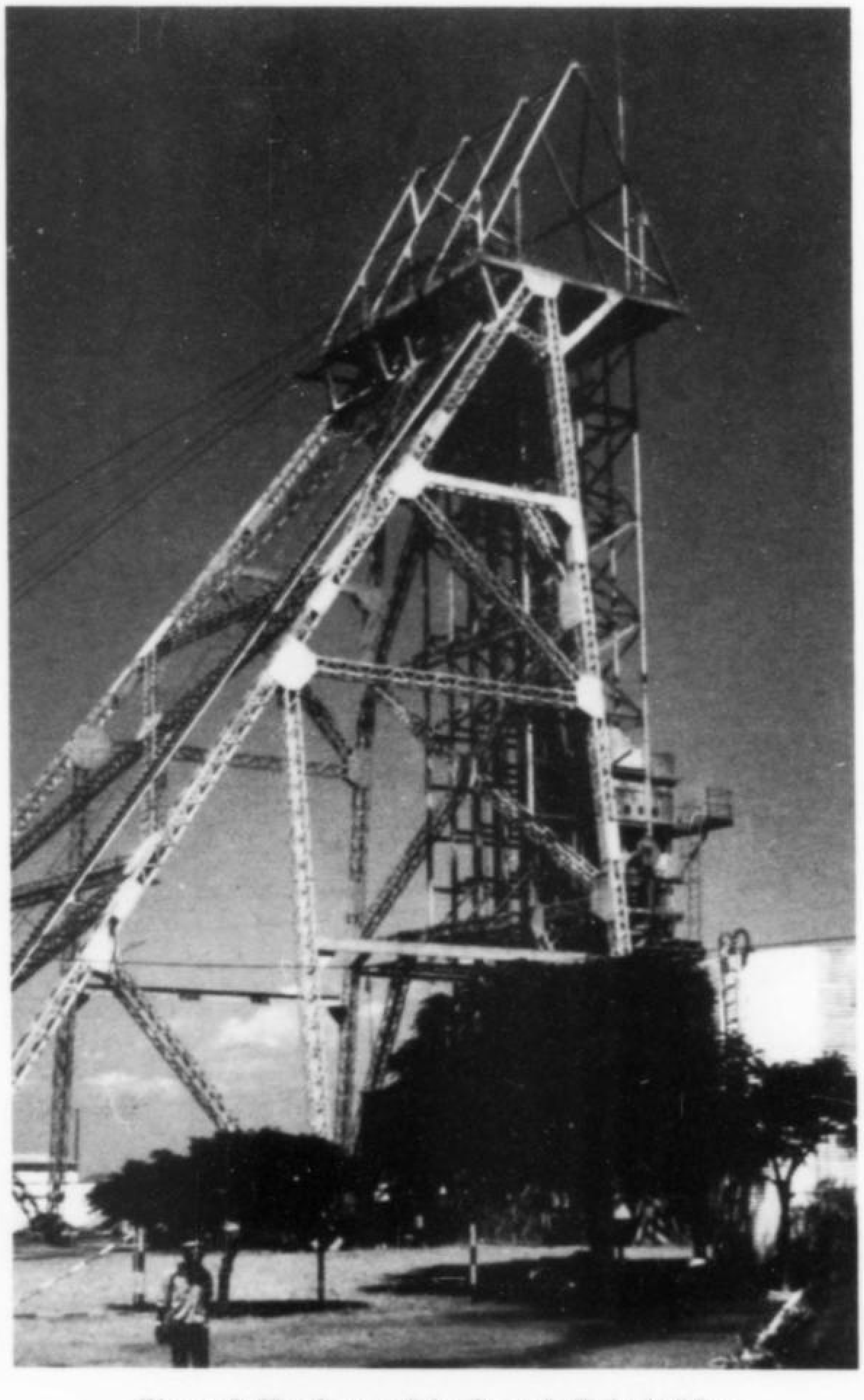


Figure 2. **Headgear of the Campbell shaft, Messina mining district. Photo by Terence S. McCarthy.**

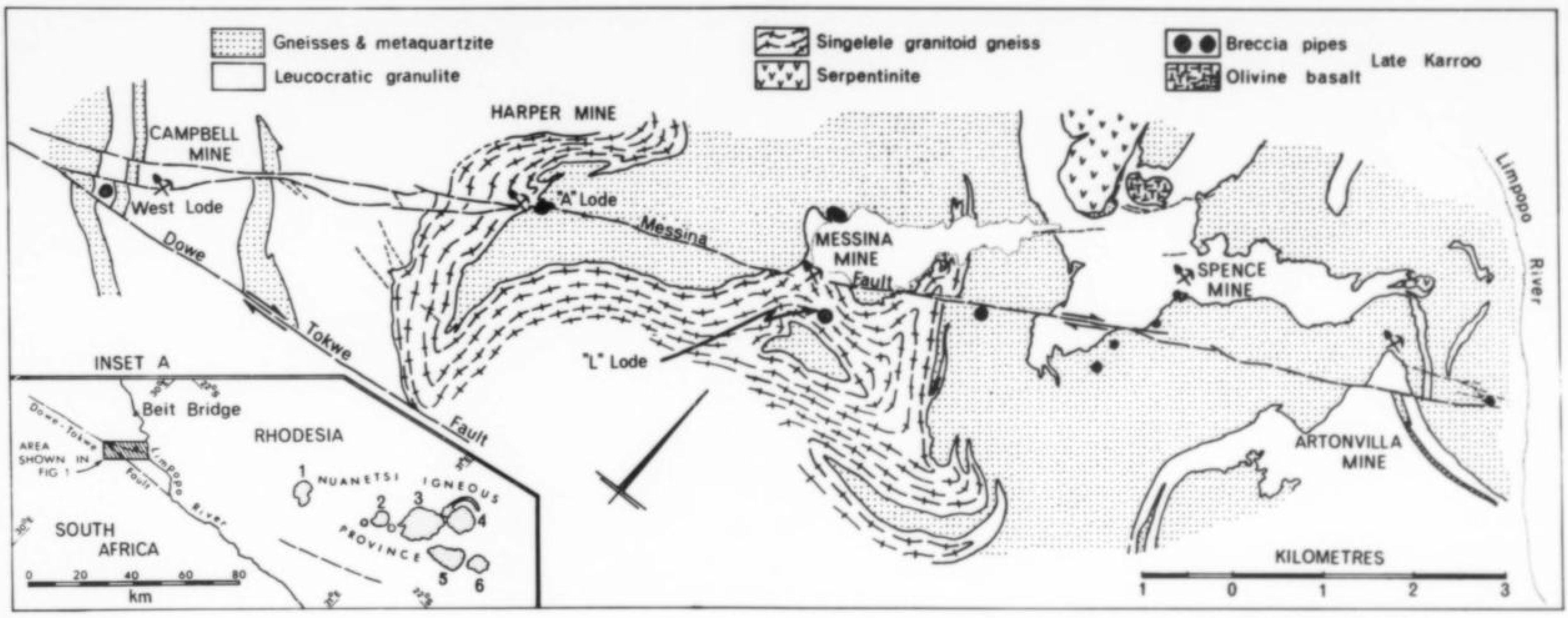


Figure 3. **Location of the various mines in the Messina district, and the regional geology (from Jacobsen *et al.*, 1976).**

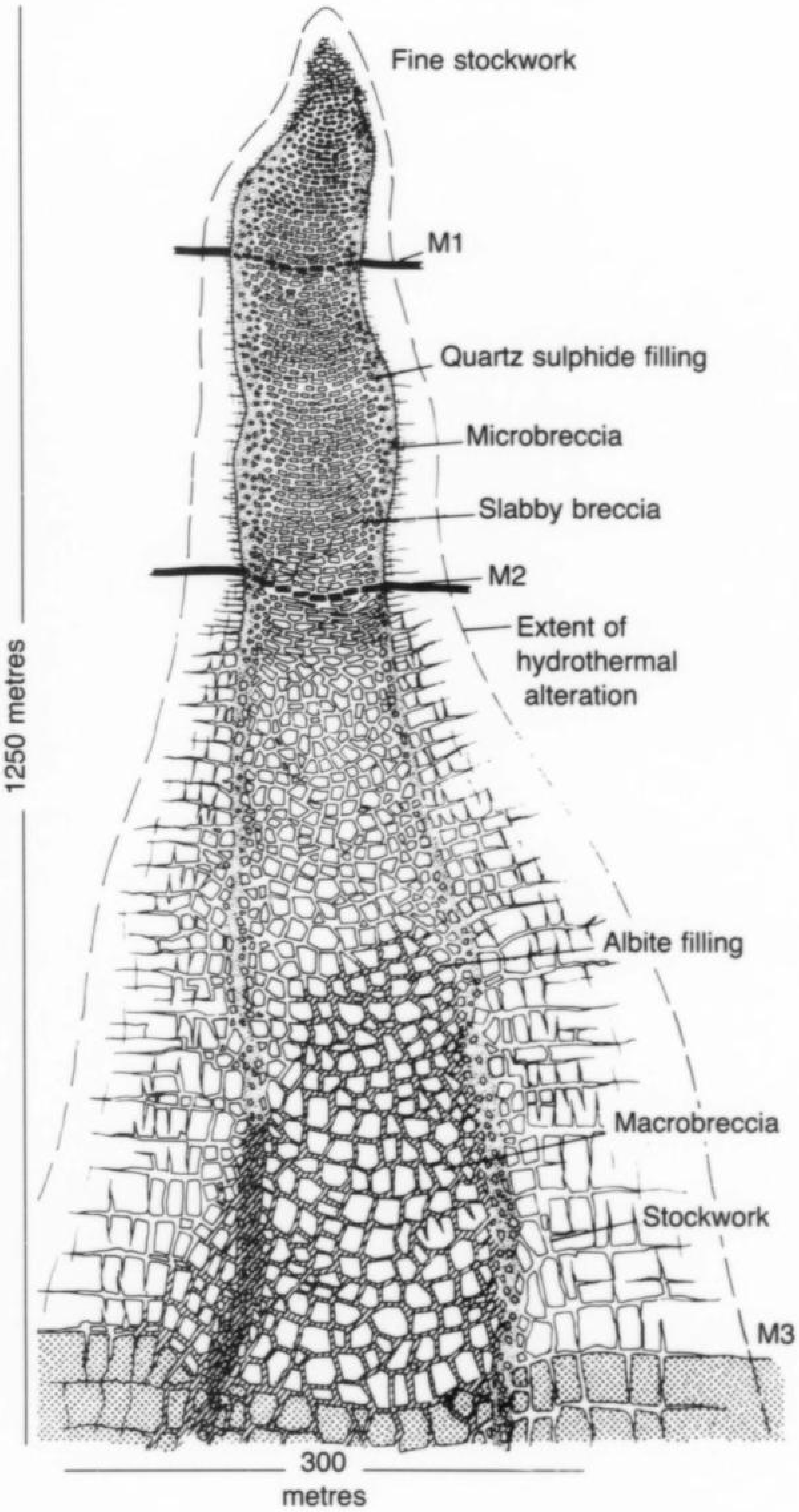


Figure 4. **Graphic representation of the Messina breccia pipes. M1, M2 and M3 are marker zones cut at various levels by the breccia column (from Jacobsen *et al.*, 1976).**

GEOLOGY

The copper mines are hosted by gneisses of varying composition (Bahnemann, 1986), forming a structurally complex suite of lithologies resulting from multiple folding and metamorphic recrystallization (Watkeys, 1979).

The basement rocks consist of pyroxene tonalites, overlain by complexly folded metasediments (Bahnemann, 1972). The rocks close to the mines have been metamorphosed to granulite and upper amphibolite facies (Bahnemann, 1972). In contrast, lower-grade metamorphism associated with mineralization resulted in propylitic hydrothermal alteration (Jacobsen and McCarthy, 1976). A number of intrusives of late Karoo age (Triassic/Jurassic) occur close to and within the mine area. These have been called the Nuanetsi Igneous Complex (Cox *et al.*, 1965), thought by some workers to be the intrusive event which introduced the copper mineralization (e.g., Jacobsen, 1967; Jacobsen and McCarthy, 1975 and 1976). Bahnemann (1986), however, has reservations about this theory. He states that the deposition of the Messina copper deposits may pre-date the late Karoo event and that they may be of Waterberg age (1800 million years). The regional tectonic setting of the deposits explains, to a large degree, their structural complexity; the mines are located in the Limpopo Mobile Belt, which delineates the boundary between the Archean Kaapvaal and Rhodesian cratons (Hunter and Pretorius, 1981). The ore deposits occur in part of the Central Zone of the Limpopo Mobile Belt (Cox *et al.*, 1965).

The Messina copper deposits are interpreted as hydrothermal replacement ores (Bahnemann, 1986) forming pipe-like breccia bodies exhibiting collapse features and associated mineralized fractures and fissures. The ore deposition has been primarily structurally controlled (Jacobsen, 1974), frequently by wrench fault systems. The shapes of the individual orebodies are influenced by the fold structure, fracturing and the nature of the lithologies.

Copper is the only economic metal won from the orebodies. It occurs in the primary sulfide minerals chalcopyrite, bornite and chalcocite. Chalcopyrite is present along the peripheries of orebodies and is gradually replaced by bornite, chalcocite and native copper towards

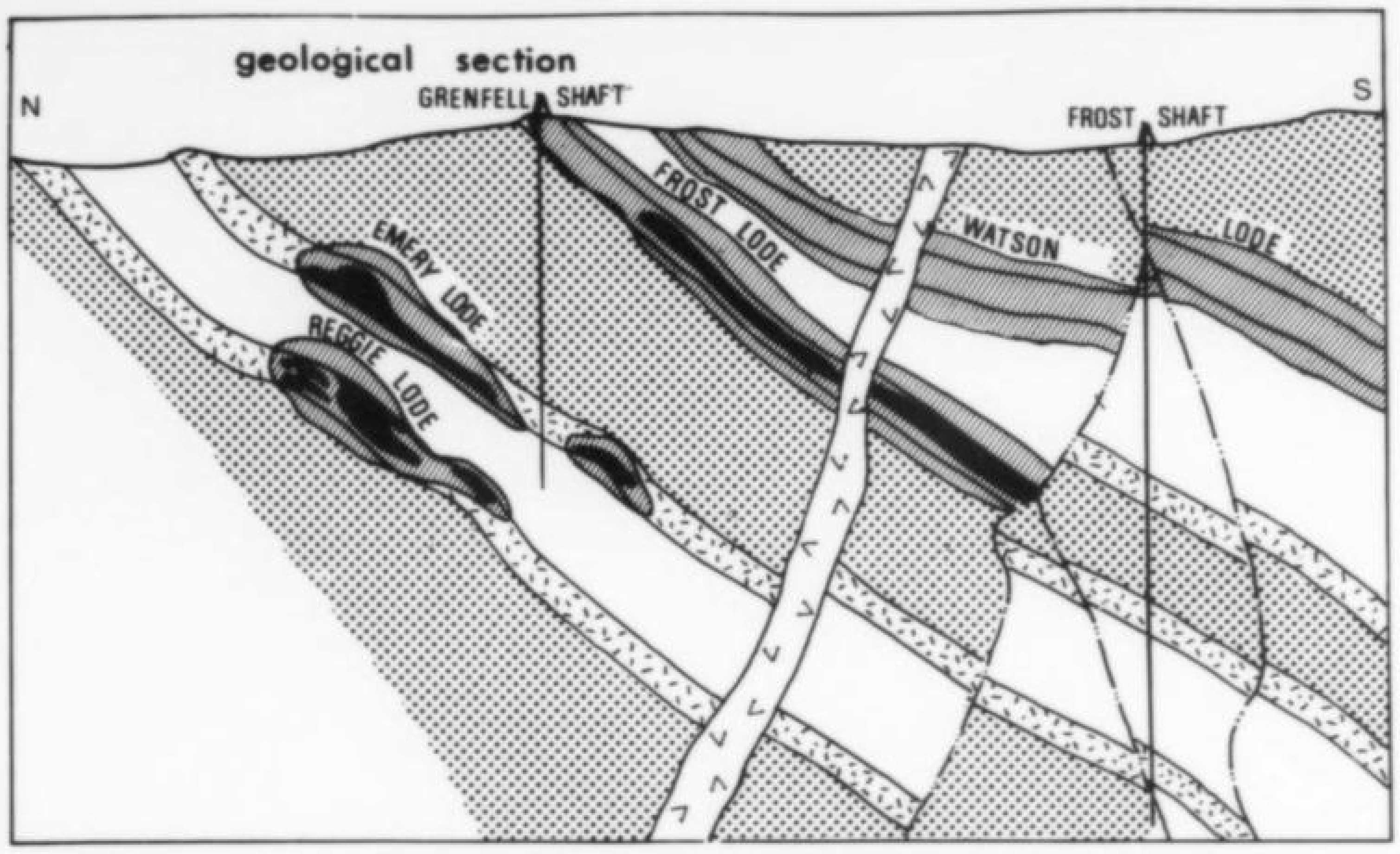
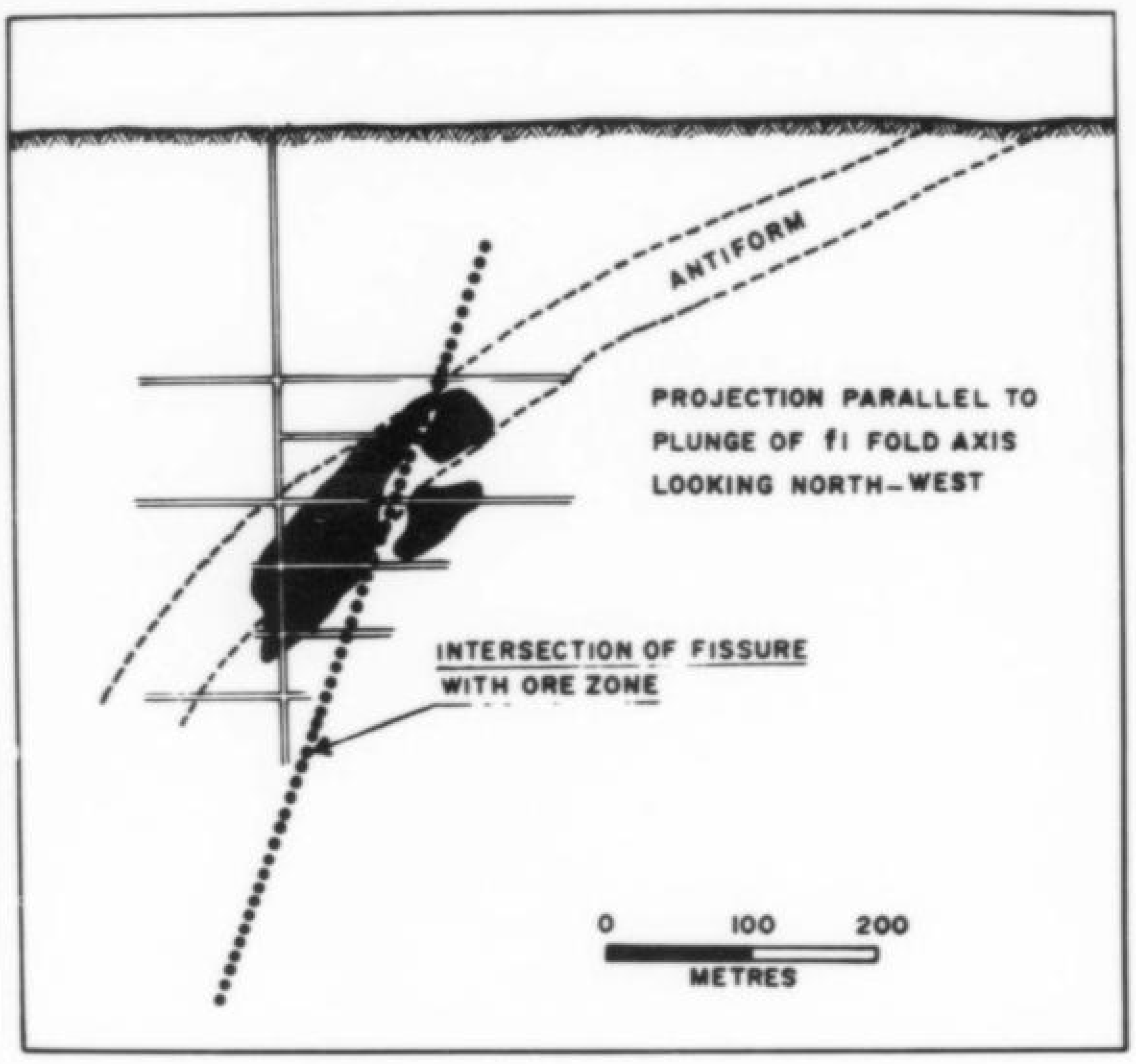


Figure 5. **Geological cross-section through the Frost and Grenfell shafts at Artonvilla mines (from Jacobsen and McCarthy, 1976).**

Figure 6. **Longitudinal section through the orebody at the Spence shaft (from Bahnemann, 1986).**



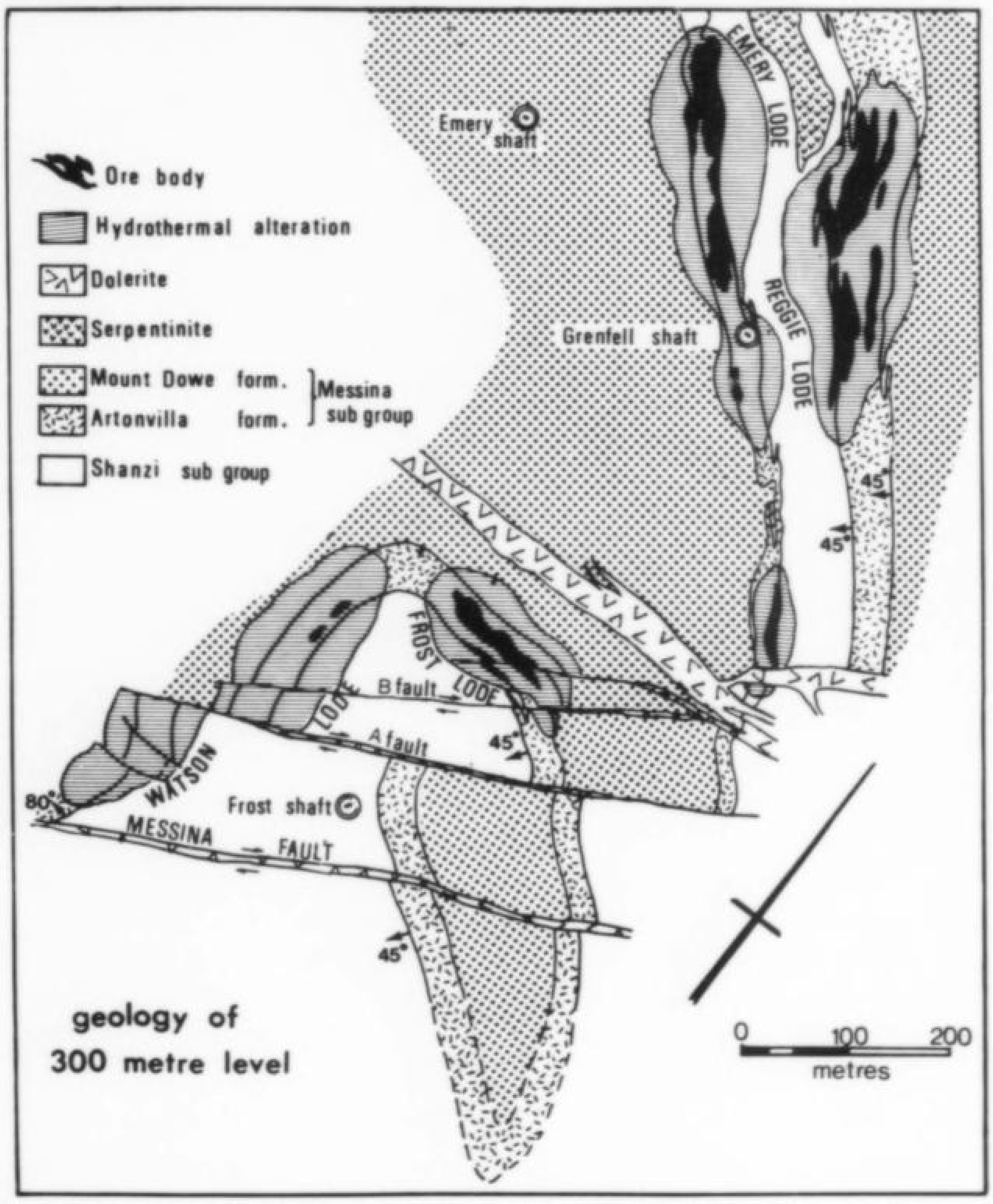


Figure 7. **Distribution of the orebodies on the 300-meter level at the Artonvilla mine (from Jacobsen and McCarthy, 1976).**

the center and downwards. Bahnemann (1986) states that host rock alteration follows the zonation of the sulfides by a general increase in hydration of silicate minerals, leaching of quartz and the development of albite, zoisite and epidote, leading to complete destruction of the host rock.

Jacobsen and McCarthy (1976), in a detailed study of the Artonvilla mine, have observed that disseminated replacement bodies are best developed at this particular mine. Four separate lodes occur where mineralization is accompanied by intense hydrothermal alteration. These disseminated orebodies, such as the Emery lode, show concentric zoning with respect to both the sulfides and the hydrothermal minerals; an outer zone of sericitization is followed inward by zones of albitization, chloritization and epidotization. Concomitant with these stages are sulfide changes which display a zonation from an outer pyrite zone, through chalcopyrite and bornite, to chalcocite and occasional native copper zones in the core (Jacobsen and McCarthy, 1976). These authors conclude that a single hydrothermal fluid was introduced into the Archean host rocks. This fluid entered the structural traps at temperatures in excess of 650° C and passed through the rocks down a temperature gradient which reached about 400° C at the outer extremity, resulting in well-developed mineral zonation. The central parts of the orebody indicate mineral associations equilibrated at temperatures ranging from 140° C to 280° C.

Although the copper mineralization is similar in all five mining areas, certain aspects of the geology differ significantly (Hammerbeck and Schoeman, 1976). Bahnemann (1986) also considered that levels of erosion are thought to have varied, with the deepest levels in the east (Artonvilla) and shallowest in the west (Campbell mine). Each mine is briefly described below, together with the minerals present.

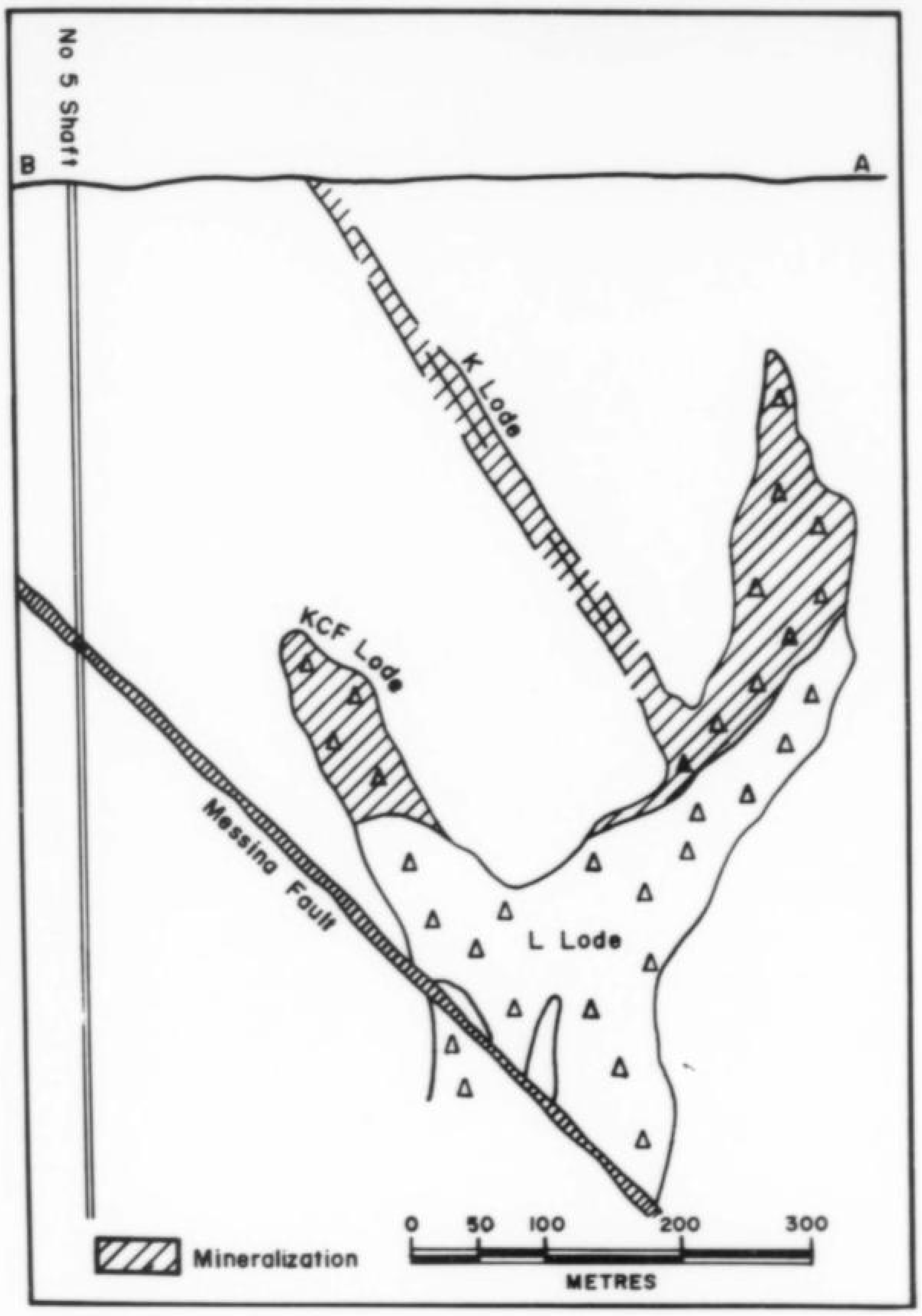


Figure 8. **Cross-section through the L Lode breccia pipe at the Messina mine (from Bahnemann, 1986).**

Artonvilla and Spence mines

The orebodies at Artonvilla are located in bands of biotite-garnet-cordierite gneiss enclosed by leucocratic granite gneiss and metaquartzite (Hammerbeck and Schoeman, 1976). The orebodies known as the Watson, Frost, Emery and Reggie lodes occur on fold limbs representing three-fold repetition of the gneiss by multiple isoclinal folding.

The Artonvilla and Spence deposits were not yet discovered when Söhnge wrote his memoir in 1946. As a result, the information available on collectible minerals there is limited to the more recent literature.

Bahnemann (1986) described the mineral zoning associated with the hydrothermal alteration at the Artonvilla mine, and concluded it was similar to that observed in the mines to the west. The outer alteration zone of the cordierite-biotite-garnet gneiss consists of "sericite" resulting from the alteration of plagioclase, sillimanite, cordierite, biotite and quartz accompanied by pyrite. Farther inwards, chloritization has occurred and chalcopyrite has replaced pyrite and, in turn, is replaced by bornite. This accounts for the successive coatings of these sulfides on some specimens. Hematite and epidote appear for the first time, together with bornite, and all original feldspar is replaced by albite. In the central zone of alteration, where the host rock is largely replaced by grey-green masses of clay, chalcocite, native copper and goethite occur. In their most altered state, the rocks have been changed completely to an assemblage of epidote, chlorite, goethite, bornite, chalcopyrite, native copper and euhedral quartz crystals (Bahnemann, 1986), and consists of "a vuggy albitite in which minor amounts of prehnite, calcite, epidote and analcite occur. Late quartz crystals line some of the vugs. Most of the albite reveals a fine dusting of iron oxide which may in part account for the red coloration of the altered rock" (Jacobsen and McCarthy, 1976).

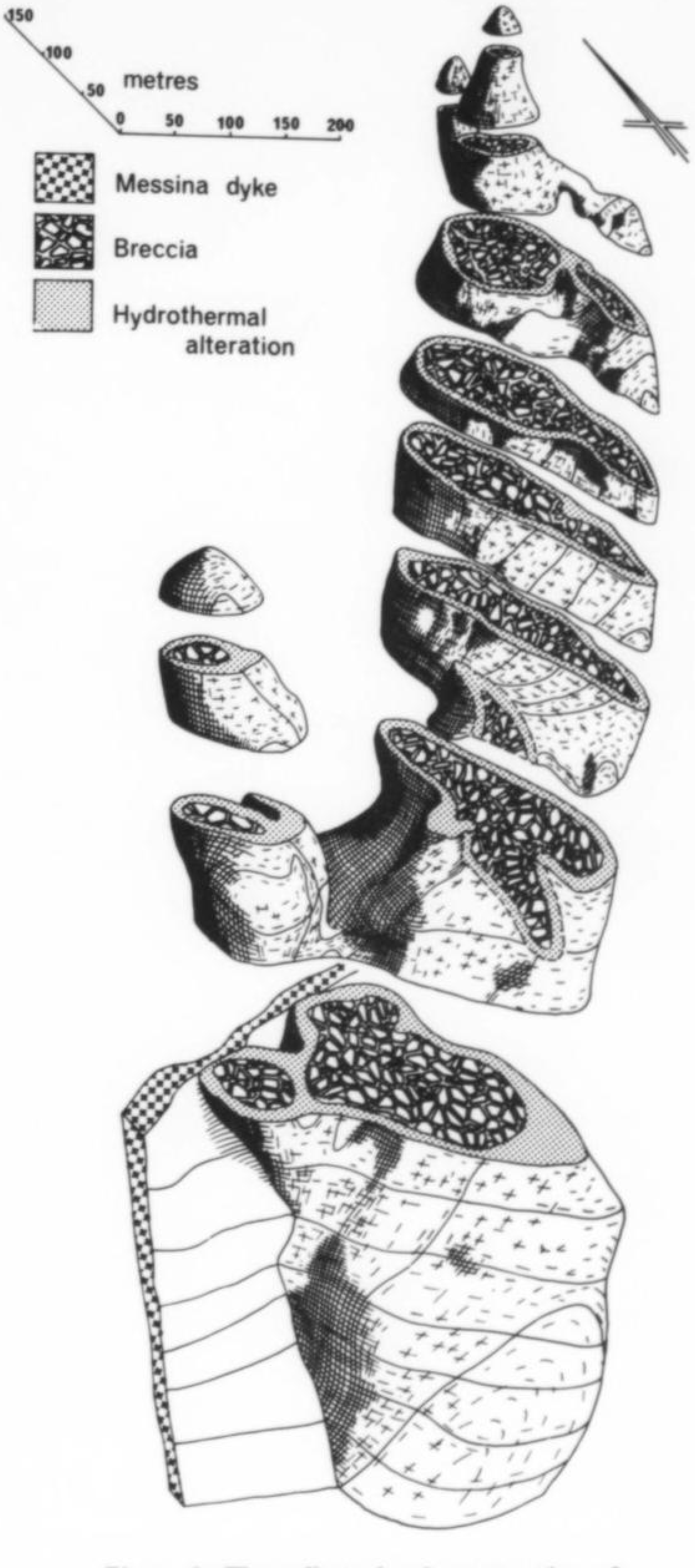


Figure 9. **Three-dimensional construction of the L Lode breccia pipe at the Messina mine (from Jacobsen *et al.*, 1976).**

Messina mine

The Messina mine (or "Five Shaft" area) forms the nucleus around which the town of Messina developed. The local term "Five Shaft" has been used to distinguish this particular mine from the Messina mining district as a whole. Some confusion has resulted when specimens are labeled "Messina," because this term alone could be taken to mean "Messina mine" or "Messina district."

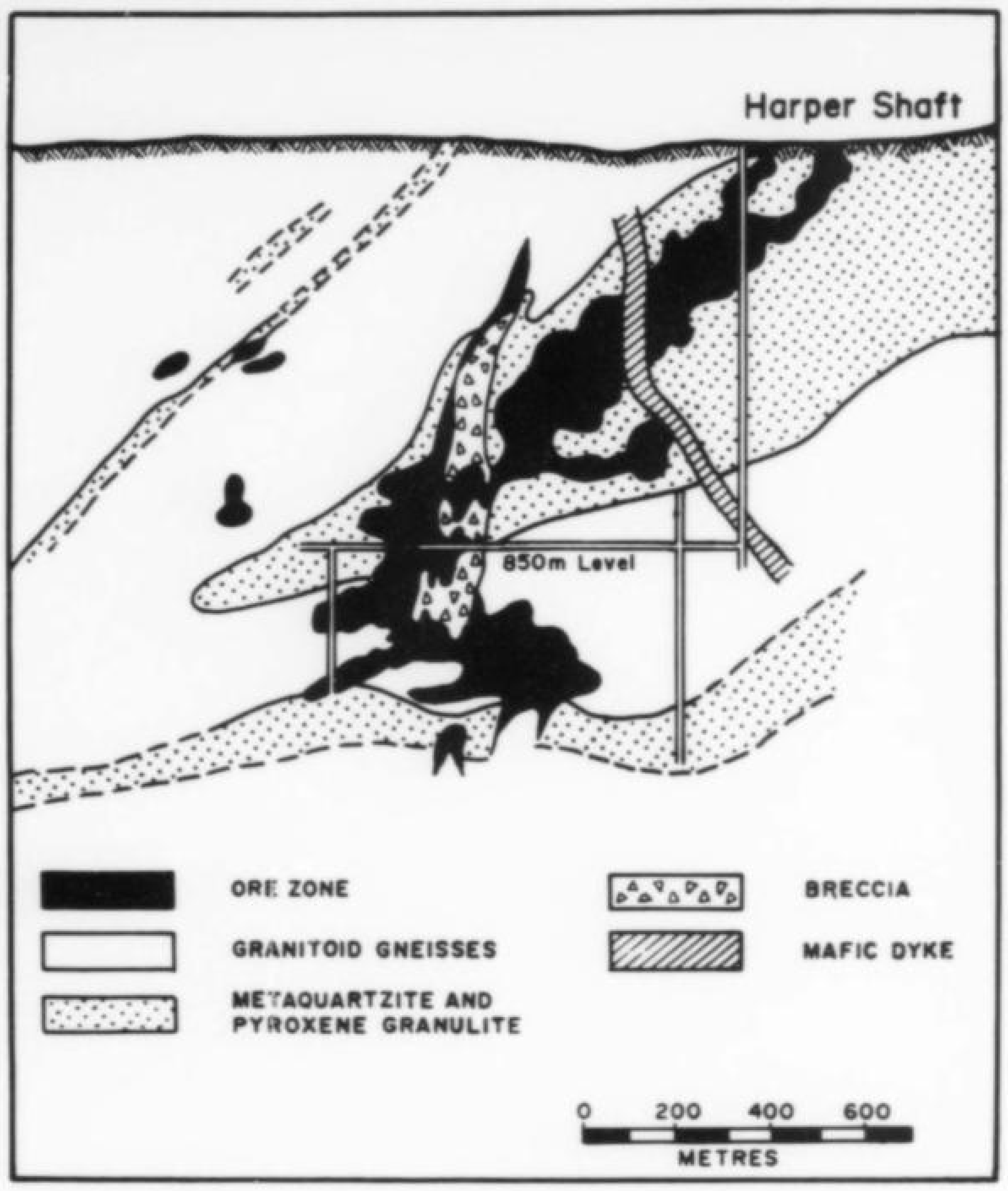


***Figure 10*. Geological cross-section looking northwest at the Harper mine. The section is parallel to the Messina Fault (from Bahnemann, 1986).**

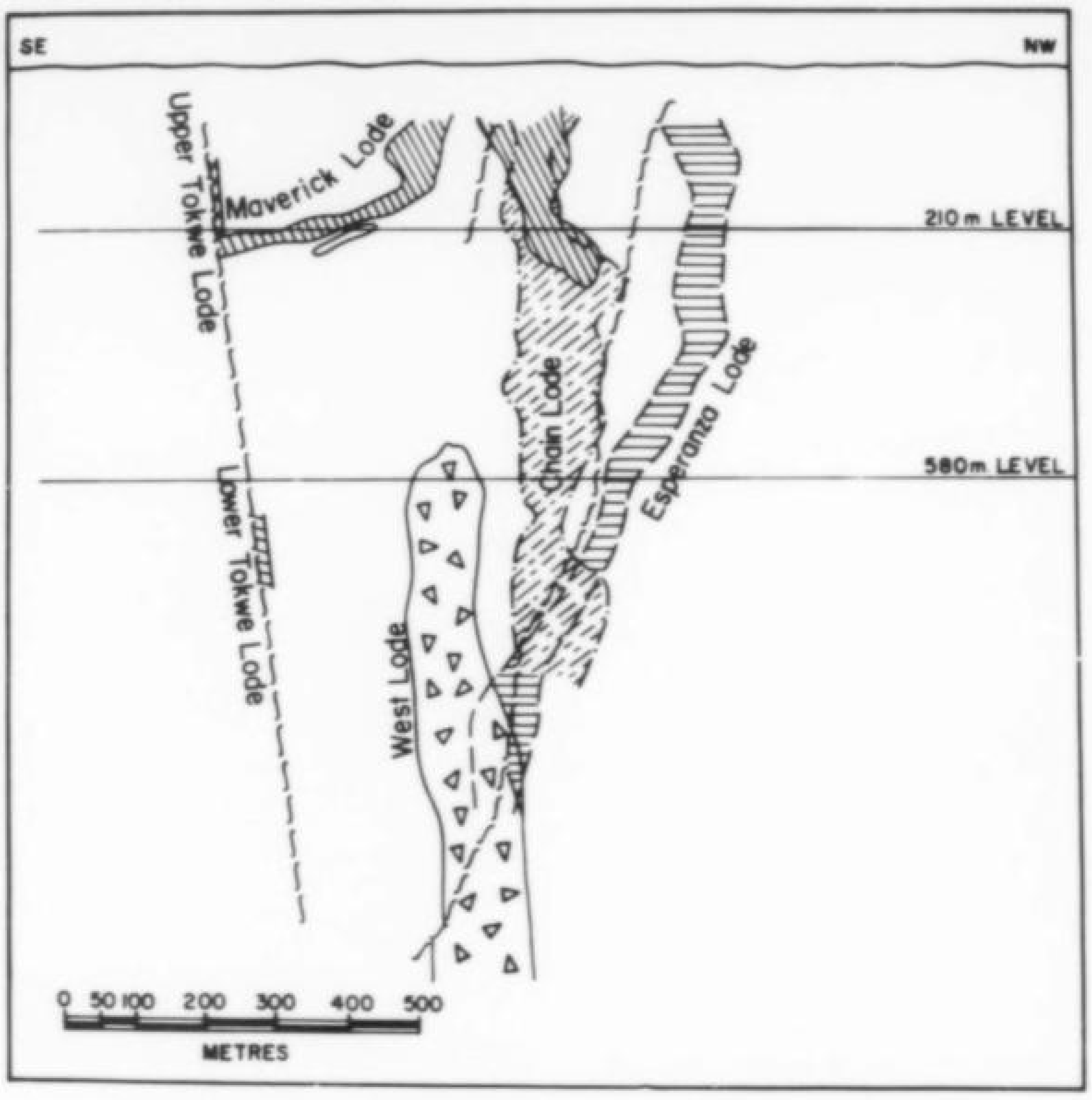


***Figure 11*. Cross-section of the Campbell mine transverse to the Messina fault; view towards the southwest (from Bahnemann, 1986).**

In contrast to the Artonvilla and Spence mines, the Messina mine orebodies occur in granite gneiss of the older basement rocks (Hammerbeck and Schoeman, 1976). The various ore lodes have, in the past, been given a variety of names so numerous that eventually an alphabetical categorization of the orebodies became necessary. The Messina mine contains the KCF lode, K lode and L lode. These are breccia pipes with mineral zonation similar to that described previously for the Artonvilla and Spence mines. Söhnge (1946) observed that the K and L lodes consist of brecciated zoisite rock that is host to quartz-copper veins. Epidote, piemontite, talc and sericite are common accessories. Quartz crystals enclosing and coated by specular hematite are widespread and common as fillings in vugs and open fissures. The brecciation in the pipes is spectacular, with variations in sizes from microbrecciated material infilling between larger slabs up to 20 meters in size. The size of the fragments tends to increase downwards and inwards, and at deeper levels and pipes tend to grade into a stockwork of breccia and quartz veins dissecting the country rock (Bahnemann, 1986).

It is these breccia zones, particularly at the Messina mine, that have produced the great variety of quartz crystals. Bahnemann (1986) states that:

> Altered fragments of country rock are cemented by an interlocking mass of quartz crystals which have grown inwards into the voids between the fragments. In still-open vugs, these quartz crystals may reach spectacular sizes. Native copper is present as inclusions in quartz crystals.

Bahnemann (1986) makes a further observation with regard to the presence of prehnite at the Messina mine:

> Porcelaneous white prehnite is a conspicuous mineral, giving the wall rock a distinctly "bleached" appearance. It forms scallopy white rims around quartz and chlorite, and it lines fissures and vugs. The distribution of prehnite . . . appears to be tied to the areas where basement rocks host the mineralization. It is absent at Artonvilla and is found only sporadically at the Harper and Campbell mining areas in or close to basement rocks.

Harper mine

The orebodies of the Harper mine show combined characteristics of the stratiform ore sheets of Artonvilla and the breccia pipe of the Messina mine. The clear zonation of sulfides and associated alteration of the host rocks is absent at the Harper mine, and quartz is scarcer at the Harper mine than at the Messina mine (Söhnge, 1946). Another feature of the orebody is the predominance of bornite and chalcocite, particularly in the central core zones of the pipe.

Campbell mine

Several isolated orebodies occur in the Campbell mine area, and these have been given names such as the Line Lode, Snake Lode, Esperanza Lode, Tokwe Lode (situated on the Dowe Tokwe fault) and the West Lode. The Esperanza Lode is richly mineralized and has been termed an enlarged branch fissure by Van Graan (1964). The fissure consists of fractured and altered host rock dissected by vein quartz but with little breccia. Reddish albite, mustard-colored epidote and zoisite, together with white quartz and the copper sulfides, chalcopyrite, chalcocite and bornite, give the ore an attractive, colorful appearance different from ore in the breccia pipes. The structure, lithology and mineralization of the West Lode are similar to those of the L Lode at the Messina mine.

MINERALS

By far the most abundant and attractive mineral, from a collector's standpoint, is quartz. The habits and varieties of sizes and groups, together with several colorful secondary mineral inclusions, make the Messina mines quartz specimens interesting items. Minerals that occur associated with the orebodies and breccia zones are listed in Table 1.

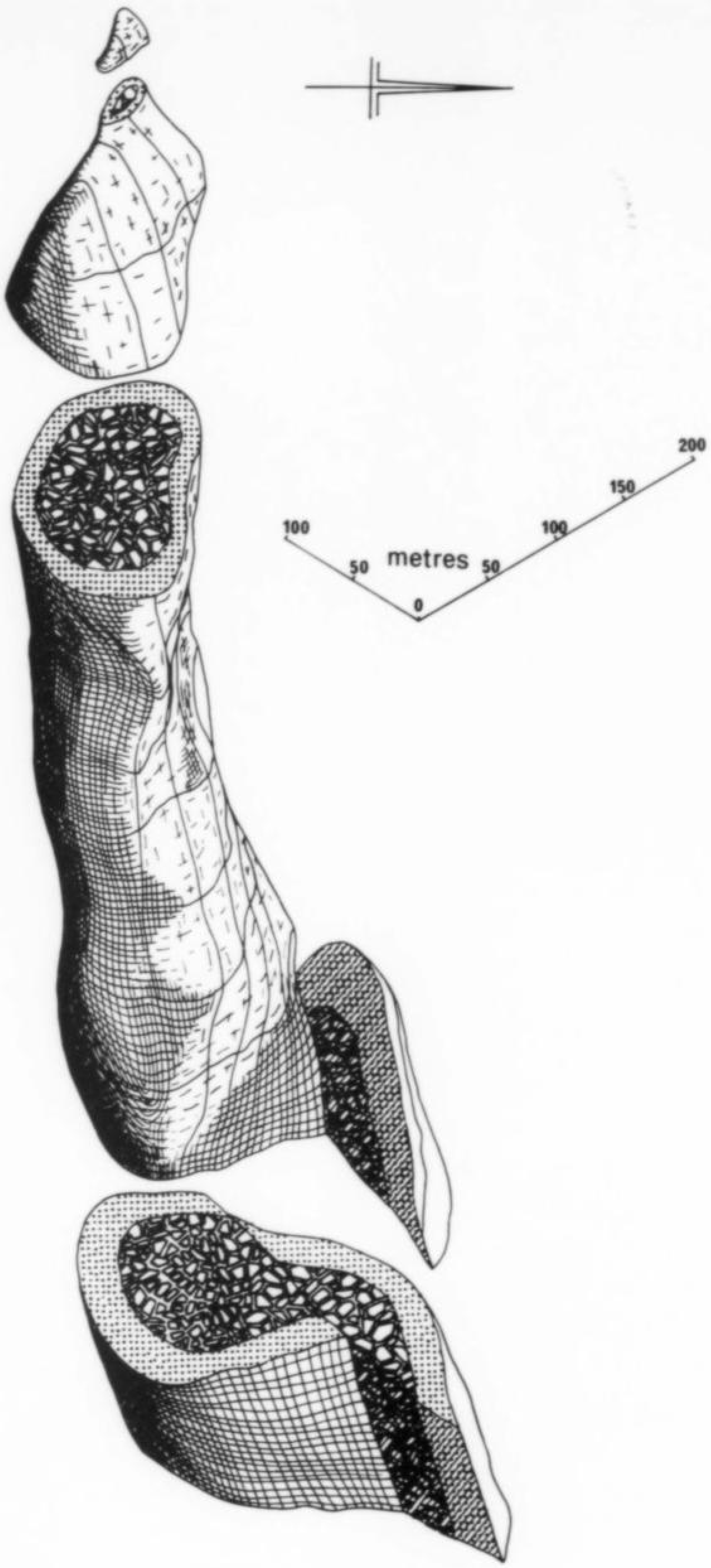


Figure 12. **Three-dimensional diagram of the West Lode at the Campbell mine (from Jacobsen *et al.*, 1976).**

Ajoite $(K,Na)Cu_7^{+2}AlSi_9O_{24}(OH)_6 \cdot 3H_2O$

In July of 1985 a pocket of several dozen quartz crystals was discovered in the Messina mine. These have inclusions of chrysocolla-colored (blue-green) material which commonly delineates phantom faces at or near the terminations of the quartz. This blue material was analyzed by X-ray diffraction (Rob Smith, personal communication) and found to be ajoite (Schaller and Vlisidis, 1958; Chao, 1981). The majority of specimens are individual loose crystals in thumbnail to miniature sizes. Some larger groups were also found; the largest and finest single crystal specimen consists of an undamaged quartz crystal 25 cm long, rimmed at the base by smaller quartz crystals also containing ajoite. In this particular specimen, the ajoite inclusions are present in the central parts of the specimen rather than at the terminations.

Several thin sections were cut perpendicular to the *c*-axis of a smaller thumbnail specimen, and the distribution of the ajoite within the crystal examined in detail. At and near the termination, the ajoite completely fills and extends across the internal portion of host crystal. Further down towards the point of attachment, the central core regions of the host crystal no longer contain ajoite. Instead, the included material forms an outer rim which parallels the external hexagonal form of the quartz.

The amount of ajoite present within the quartz varies. Some specimens may be almost completely included with the blue material while others have only faint veils scattered in the specimen. No ajoite has been reported as occurring in free-growing crystals not included in quartz. Since the find in 1985, no other similar specimens have been found.

Albite $NaAlSi_3O_8$

Albite is a common constituent of the alteration zones in the orebodies, particularly at the Artonvilla mine (Jacobsen, 1967). The Messina and Harper mines have a higher degree of prehnitization and zoisitization than seen at the Artonvilla mine.

Albite occurs as rust-red to mustard-brown to white crystals. The red coloration of the albite has been attributed by Poldervaart and Gilkey (1954) to the addition of ferrous ions to the structure after the albite had formed. The red albite was identified using X-ray diffraction (Jacobsen, 1967). This mineral often occurs as small crystals up to 4 mm, studding the surfaces of the abundant secondary quartz crystals. In addition, both red and white varieties of albite are common in the host rock alteration zones.

Almandine $Fe^{+2}Al_2(SiO_4)_3$

Almandine constitutes up to 70% of the garnet crystals occurring in the host rock and amphibolite. Pyrope comprises 20% and the remaining 10% consists of grossularite (Jacobsen, 1967). These volumetric percentages differ in the biotite-garnet-quartz granulites where almandine constitutes 55%, pyrope 30% and grossularite 15%.

Analcime $NaAlSi_2O_6 \cdot H_2O$

This species of the zeolite group occurs as a pink to white, soft, almost clay-like material occurring in veinlets, veins and irregular masses in the more highly feldspathic rocks (Jacobsen, 1967). At Artonvilla, analcime occurs exclusively in the higher altered albitic rocks, suggesting that it represents the decomposition product of earlier hydrothermal albite. Analcime is frequently associated with calcite, chalcocite, chlorite, native copper and epidote.

Azurite $Cu_3^{+2}(CO_3)_2(OH)_2$

Azurite is a widespread oxidation product of the copper deposits and commonly occurs with malachite. No large crystals have been reported to date. The azurite occurs as encrustations of microcrystals along joint planes and partings in outcrops of the country rock.

Barite $BaSO_4$

Barite occurs sporadically as flattened, orthorhombic crystals of a habit resembling wulfenite crystals. The color of the barite is light beige to tan. Crystals may occur as floater groups. In some cases, spear-shape terminations of larger (>1 cm) crystals may be rimmed with an overgrowth of barite microcrystals of similar habit and color. The barite is a late-stage mineral commonly found to exist on top of the secondary quartz crystals.

Biotite $K(Mg,Fe^{+2})_3(Al,Fe^{+3})Si_3O_{10}(OH,F)_2$

Biotite occurs in the host rocks, particularly the granulites. Hydrobiotite may also be present within the ore zones as hydrobiotite (Jacobsen, 1967) where it occurs in association with sericite.

Figure 13. Ajoite inclusions in quartz crystals to 3.5 cm in diameter, from the Messina mine. Rob Smith collection.

Figure 14. Ajoite inclusions in a quartz crystal, 20 cm, from the Messina mine. Rob Smith specimen.

Figure 15. Hematite inclusions in a quartz crystal, 4.4 cm, from the Messina mine. Don Olson specimen.

Figure 16. Ajoite inclusions in quartz crystals to 5 cm, from the Messina mine. Rob Smith specimens.

Figure 17. Ajoite, papagoite and epidote inclusions in quartz group 11 cm tall, from the Messina mine. Rob Smith collection.

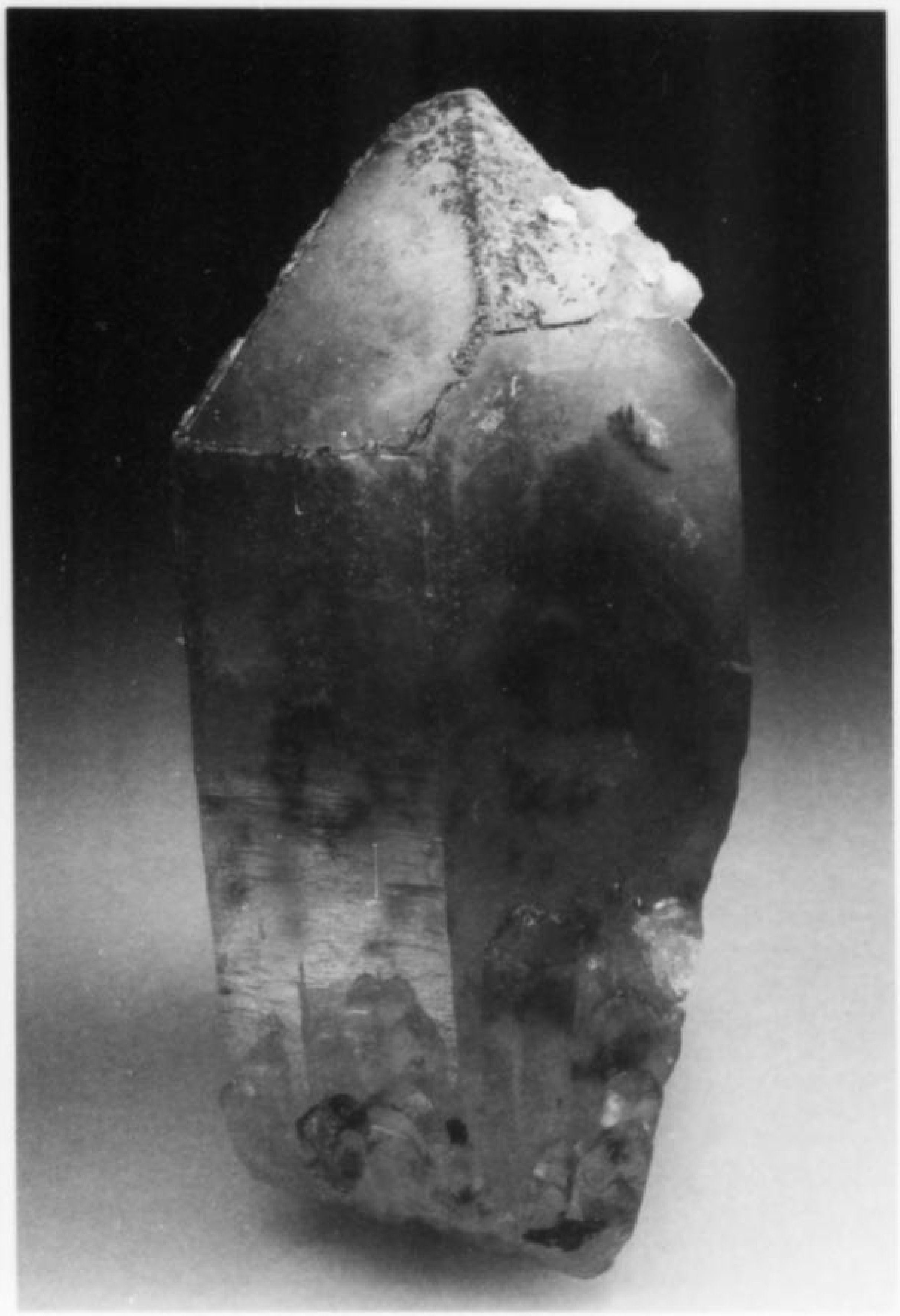


Figure 18. Cuprite and papagoite inclusions in a quartz crystal, 10.4 cm, from the Messina mine (old specimen). Cal and Kerith Graeber specimen.

Figure 19. Ajoite inclusions in quartz crystals to 3 cm, from the Messina mine. Cal and Kerith Graeber specimens.

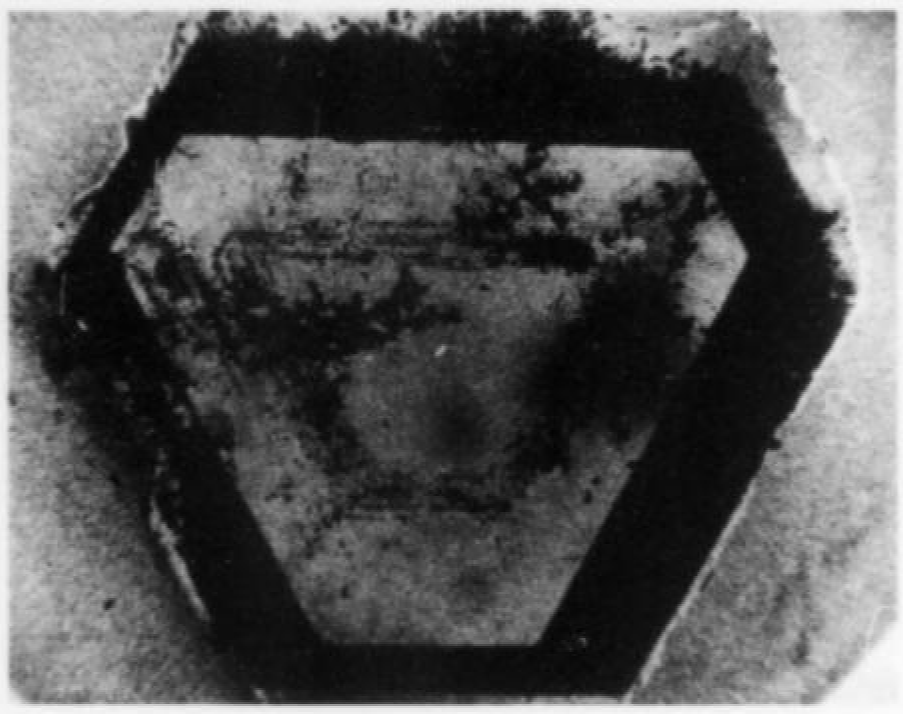


Figure 20. **Thin section of ajoite-bearing quartz. The section is perpendicular to the *c*-axis. The ajoite appears as a black band parallel to the hexagonal crystal form. Diameter of crystal is 9 mm. Author's collection; photo by Mark Hudson.**

Bornite Cu_5FeS_4

Bornite is the most common copper sulfide and is frequently associated with chalcocite. It occurs predominantly as massive peacock-colored ore infilling breccia cavities, and only very rarely forms crystals.

Calcite $CaCO_3$

White to colorless calcite is common as fillings in the breccia voids and is one of the few carbonates present in the orebodies—the others being disseminated malachite and azurite. At Artonvilla, calcite occurs in association with late-stage minerals such as chalcocite, native copper, chlorite and epidote. Jacobsen (1967) suggests that the calcite originated from alteration of the original calcic plagioclase. In thin section, native copper is seen to occur along the intergranular borders between chalcocite and calcite.

Calcite occurs as well-formed crystals, which are usually scalenohedral and in some cases doubly terminated, in all of the mine workings (Söhnge, 1946). Rhombs and scalenohedrons are commonly perched on ore and incorporate quartz, epidote, specularite, chlorite, sericite and the sulfides. Rosettes of calcite 3 to 5 cm in diameter (Söhnge, 1946) are locally present. The light brown color of some calcite is most likely due to limonite staining.

Chalcocite Cu_2S

Chalcocite is one of the primary copper minerals in the Messina district orebodies, and occasionally forms euhedral crystals. Chalcocite is generally closely associated with bornite, with maximum concentrations present in the central cores of the lodes. It occurs as discrete, disseminated grains as well as larger, irregular masses and veins parallel to the banding of the host rock (Jacobsen, 1967).

Euhedral and subhedral chalcocite crystals have been found in vugs in some of the underground workings, but mostly in Messina mine (Söhnge, 1946). In one such cavity, a zoned quartz crystal from the Messina mine was found to contain perfect pseudohexagonal crystals of chalcocite, each 1 mm in diameter and closely resembling thick, stubby crystals of biotite. Euhedral chalcocite crystals have also been found perched on chalcopyrite crystals (Söhnge, 1946).

Chalcopyrite $CuFeS_2$

Chalcopyrite was one of the earliest copper sulfides to form in the ores, and it is associated with almost the entire paragenetic range. Chalcopyrite is most commonly associated with bornite, pyrite, pyrrhotite, magnetite and specularite. Euhedral crystals of chalcopyrite are found attached to quartz crystals, and are commonly coated by a dusting of calcite microcrystals.

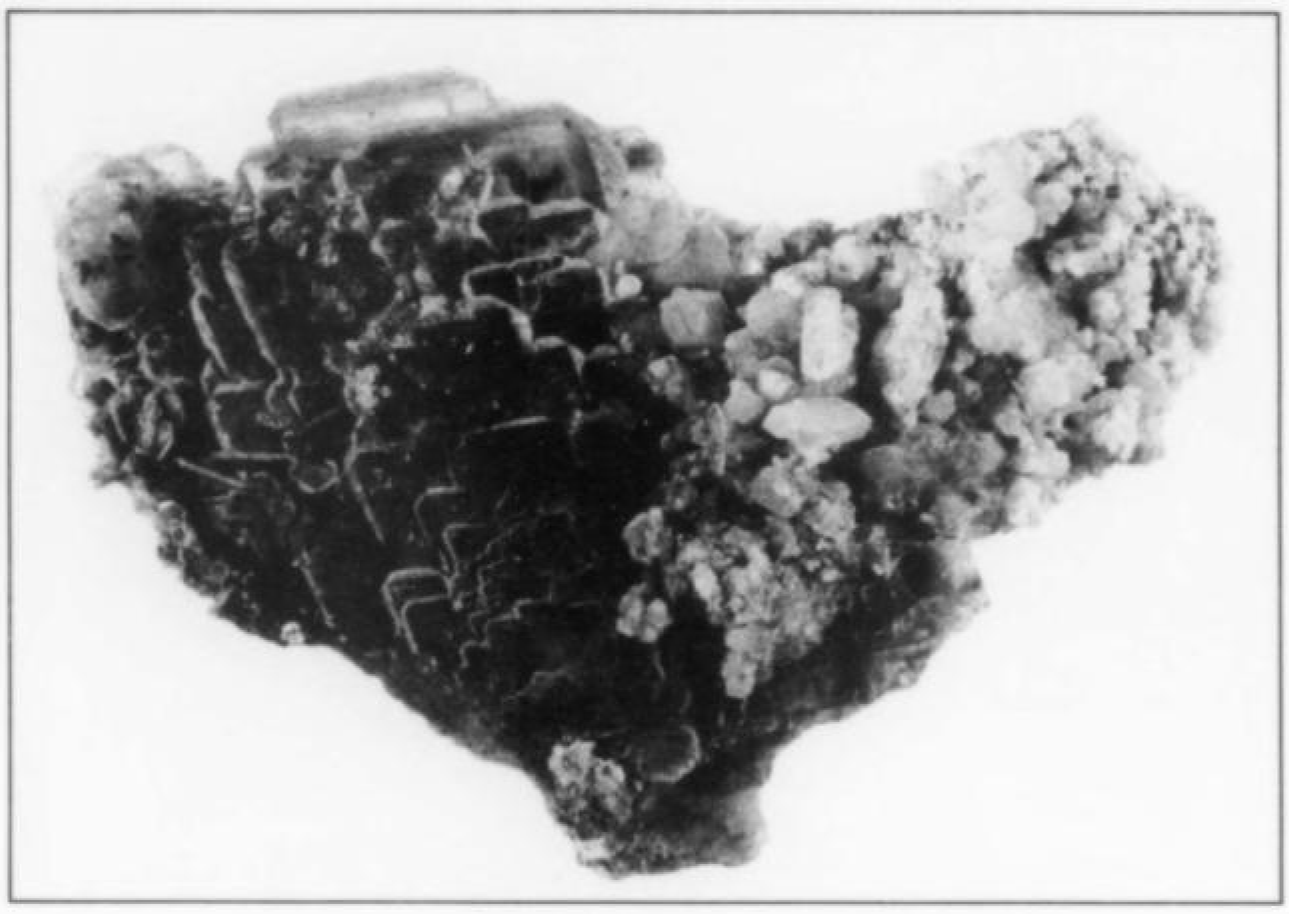


Figure 21. **Group of light brown, parallel barite plates. Small, doubly terminated quartz crystals are attached on the right side of the specimen, which is 10.5 cm long. Messina mine. Rob Smith collection; photo by Mark Hudson.**

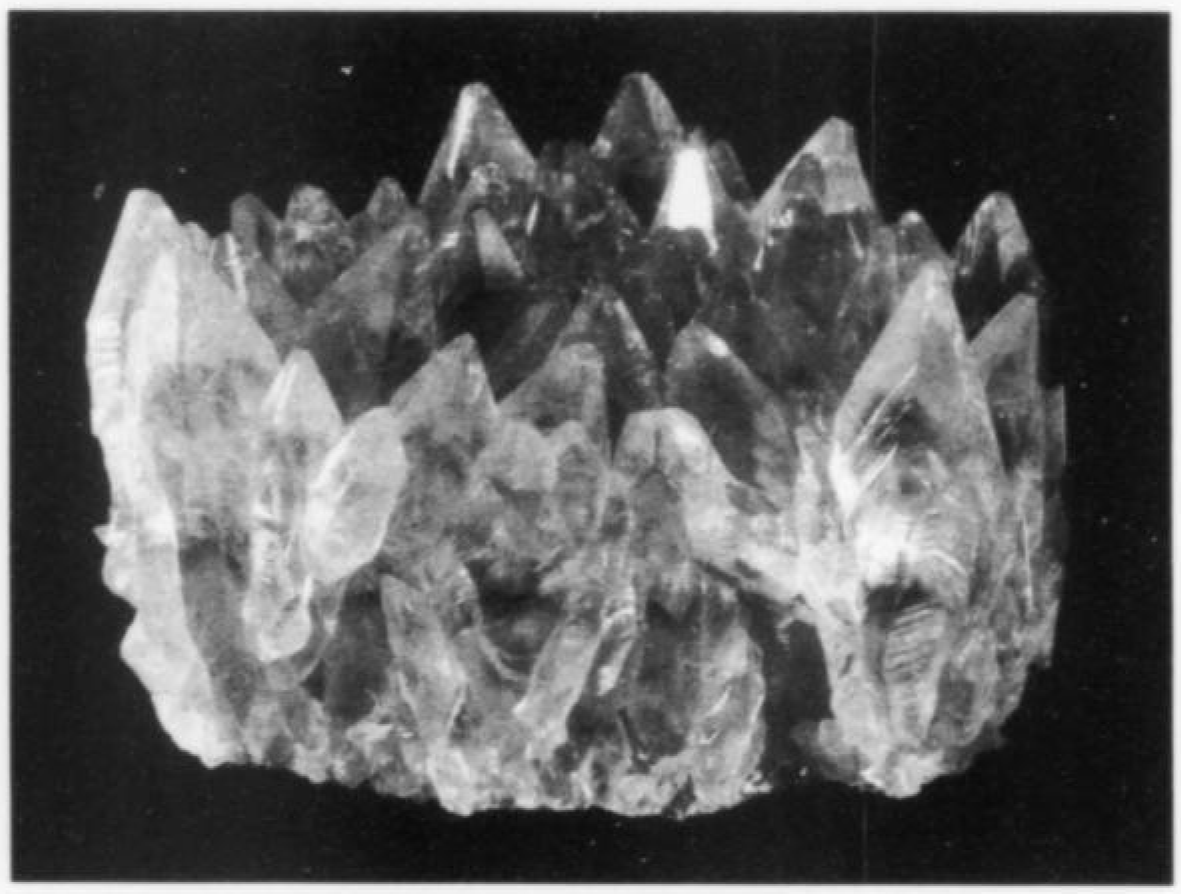


Figure 22. **A group of colorless calcite crystals from the Messina mine. The specimen is 7 cm across. Rob Smith collection.**

Beautiful crystal clusters have been recovered from many vugs (Söhnge, 1946). Supergene chalcopyrite stalactites up to 1 cm long and 2 mm across came from a small stope on the 6th level in the Messina mine; the hollow cores are filled with chalcocite and bornite.

Chlorite Group

Chlorite is a prominent alteration mineral commonly associated with epidote and secondary quartz (Laing, 1973). Detailed analytical work in all of the species of chlorite found in the ore lodes has not been conducted, although Jacobsen (1967) lists clinochlore $(Mg,Fe^{+2})_5Al(Si_3Al)O_{10}(OH)_8$ and pennantite $Mn_5^{+2}Al(Si_3Al)O_{10}(OH)_8$ as the most common species.

Chlorite occurs abundantly in the lodes and imparts a gray-green color to many of the quartz specimens, either as external coatings or as inclusions. Laing (1973) states that the pale green color of specimens can be attributed to a mixture of chlorite and sericite.

Clausthalite PbSe

Clausthalite, which forms a series with galena, has been described by Jacobsen (1967) from the Artonvilla mine as "a very minor constituent of the ore." It is found in close association with bornite, chalcocite, specularite and digenite.

Copper Cu

Native copper is relatively common in the Messina deposits, particularly in the central chalcocite zones. Native copper often occurs as inclusions in quartz crystals, generally as flattened copper platelets up to 5 mm in diameter and less than 1 mm thick. Alternatively, the native copper forms extremely fine wires or threads dispersed within the quartz crystals, imparting a very pale, cloudy, copper color to the quartz. Only under high-power magnification can the wire-like habit of the native copper be identified. Native copper also occurs independently as irregular masses and occasionally as aesthetic wires and dendrites.

Söhnge (1946) described elongate, multiple hopper crystals of native copper on chalcocite, quartz, calcite and other silicates. In some cases, the copper projects through scalenohedra of later-formed calcite. Arborescent copper in the form of distorted, polysynthetic octahedral growths, botryoidal clusters and long wires, occurs in cavities between quartz and epidote crystals.

Cordierite $Mg_2Al_4Si_5O_{18}$

Cordierite occurs in most of the garnet-biotite-quartz rocks as anhedral grains containing numerous biotite inclusions. In hand specimens, cordierite is gray-blue in color, but in areas where hydrothermal alteration has occurred, the mineral becomes distinctly greenish.

Covellite CuS

Jacobsen (1967) states that covellite is very rare, and is restricted to zones of late hydrothermal activity at Messina. Covellite and goethite are commonly developed in supergene replacement ores.

Cuprite Cu_2O

Bright red inclusions with native copper in quartz have been qualitatively identified by electron microprobe analysis as "copper oxide," presumably cuprite (Tod Solberg, personal communication).

Digenite Cu_9S_5

Digenite is found only as exsolution lamellae in association with chalcocite and clausthalite.

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

Epidote is a common hydrothermal mineral in the ore lodes, where it occurs as emerald-green to yellow-green crystals (Laing, 1973). These can partially coat quartz crystals or may be present as isolated lath-like inclusions. Jacobsen (1967) observes that a light-colored apple-green variety associated with chlorite, calcite and albite is common in the Emery Lode. A second occurrence in the lower portions of the lode consists of bright lime-green to yellow-green crystals. These have a slightly lower refractive index than the apple-green variety, but both have been identified by X-ray analyses.

The size of epidote crystals which either fill vugs or adhere to quartz crystals is generally less than 1 cm in length. Individual crystals can however reach dimensions in excess of 5 cm.

Fluorapatite $Ca_5(PO_4)_3F$

Fluorapatite is referred to by Jacobsen (1967) as being rare and found only in the lower levels of the Emery Lode at Artonvilla. Pyrite and chalcopyrite are the only associated sulfides.

Goethite $Fe^{+3}O(OH)$

Jacobsen (1967) states that goethite is the most common iron mineral in the more central portions of the orebodies, where it is characterized by a reddish coloration in hand specimens.

Hematite Fe_2O_3

Hematite forms as an alteration product of hornblende (Laing, 1973) and, to a lesser degree, biotite (Jacobsen, 1967). The early hematite occurs as a fine dust and replacement mineral whereas the later hematite (specularite) frequently replaces magnetite.

The hematite in the Messina district ore lodes imparts a red coloration to many of the minerals, particularly as inclusions in quartz crystals. Specular hematite is commonly associated with quartz as masses of fine platelets either coating the crystal faces or as inclusions. The specular hematite also forms rosettes ("eisenrosen") which, when grouped on specimens, can be very aesthetic. These may also be present as individual rosette-like balls included in quartz crystals.

Hematite is common in the bornite-chalcocite zones of some orebodies. The Harper and Messina mines commonly carry specularite, whereas iron oxide is scarce at the Campbell mine (Söhnge, 1946). In some lodes of the Campbell mine, tabular specular hematite crystals 3 cm in diameter have been found. Similar crystals 3 cm in diameter and 8 mm thick came from a vug in the 21-760 stope in the Messina mine. Locally aggregates of flaky specularite fill vugs up to 2 meters in length at the same mine.

Kaolinite $Al_2Si_2O_5(OH)_4$

Many underground fissures are lined with gray kaolinite, minute flakes of which also coat pyrite and other sulfides. Zoned quartz crystals contain hollow spheroidal aggregates of gray-white kaolinite, attesting to the formation of the quartz during and following kaolinite generation. Cloudy white phantoms in other quartz crystals are defined by thin kaolinite crystals. Söhnge (1946) remarked that beidellite, a member of the smectite group, may also be present but has not been confirmed.

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

Magnetite is one of the primary constituents of the country rock and is usually not associated with the ore zones. In the envelope surrounding the orebodies, magnetite is partially replaced by early iron and copper sulfides.

Malachite $Cu_2^{+2}(CO_3)(OH)_2$

Malachite is a ubiquitous oxidation mineral of the copper sulfides; surface stains and veinlets are found in all of the ancient workings (Söhnge, 1946). Radial clusters of malachite needles up to 2 cm long have been found in crevices in chalcocite ore. Under magnification, the slender prisms show twinning. Malachite crystals grouped in parallel arrangements of prismatic crystals are also found attached to quartz crystals. In thin section, malachite has been seen to form pseudomorphs after prehnite (Söhnge, 1946). In these cases, the malachite assumes an olive-green color rather than the more common bright green.

Molybdenite MoS_2

Söhnge (1946) states that he was told of molybdenite in the K Lode at the Messina mine. Laing (1973) states that "in the foyer of the mine offices a molybdenite sample is indicated as coming from the 19th level of the West Lode, Campbell mine."

Muscovite $KAl_2(Si_3Al)(O_{10}(OH,F)_2$

Two varieties of muscovite occur in the Messina district. Sericite is a common coating on quartz and epidote crystals. Scales and clustered aggregates of sericite deposited on earlier hydrothermal minerals are invariably a glistening white, whereas the sericite derived from wall-rock alteration is, in general, a pale green color. Chromian muscovite occurs as bright green micaceous crystals in all of the host rock meta-quartzites.

Papagoite $CaCu^{+2}AlSi_2O_6(OH)_3$

Papagoite has been observed as cloudy, pale blue inclusions in quartz crystals, and also occurs as massive, isolated lumps. Some samples recently analyzed (R. Turner, personal communication) appear to be plancheite. Although ajoite may have a more blue-green coloration than papagoite, determinative chemical techniques would be needed to confirm the identification.

Figure 23. **Piemontite crystals to 2.4 mm, on quartz from the Messina mine. Don Olson specimen; photo by Dan Behnke.**

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

The manganese-bearing member of the epidote group, piemontite (referred to as *withamite* by Söhnge), is also present. The crystals range from distinctive, transparent wine-red to opaque rust-red varieties. Some quartz crystals contain inclusions of isolated piemontite crystals up to 5 mm in length.

Prehnite $Ca_2Al_2Si_3O_{10}(OH)_2$

Söhnge (1946) remarks that prehnite may be regarded as a diagnostic accessory of many copper prospects in the fault zones of the district. Distinct crystals of prehnite have not been found.

Pyrite FeS_2

At the Campbell mine, pyrite is restricted to the upper parts of the breccia pipe (Laing, 1973). In thin section, pyrite is seen to have replaced the alteration minerals chlorite, sericite, epidote and secondary quartz. Pyrite can itself be replaced by younger pyrrhotite. Söhnge (1946) notes that pyrite is common in the upper portions of the L Lode at the Messina mine. Apart from these two occurrences, pyrite is comparatively rare in the Messina district lodes.

Pyrrhotite $Fe_{1-x}S$

Pyrrhotite is an uncommon constituent of the ores and generally occurs in the chalcopyrite-rich zones.

Quartz SiO_2

The Messina district is best known for the abundance of quartz crystals that have been produced over the decades. Due to the brecciation of the orebodies, a multitude of cavities, vugs and fissures provided the space for growth of crystals up to almost 1 meter long. Many researchers have remarked on the abundance and diversity of quartz crystals; for example, Laing (1973) observed that:

> a notable feature . . . throughout the breccia pipe (Campbell mine) . . . is the development of vugs which are often lined with well-formed crystals of quartz and calcite.

He later added:

> The early stage of open space filling is dominated by the deposition of quartz which grows from the breccia fragment surfaces outwards, encrusting succeeding layers of quartz forming a typical "cockade" (phantom) texture. In some cases, well-formed prismatic crystals are formed . . . where permeability of the breccia fragments was low and (sulfide) mineralization scarce, open spaces . . . contain well-terminated prismatic crystals.

Table 1. **Minerals reported from the Messina mining district.**

Ajoite	$(K,Na)Cu_7^{+2}AlSi_9O_{24}(OH)_6\cdot 3H_2O$
Albite	$NaAlSi_3O_8$
Almandine	$Fe_3^{+2}Al_2(SiO_4)_3$
Analcime	$NaAlSi_2O_6\cdot H_2O$
Azurite	$Cu_3^{+2}(CO_3)_2(OH)_2$
Barite	$BaSO_4$
Biotite	$K(Mg,Fe^{+2})_3(Al,Fe^{+3})Si_3O_{10}(OH,F)_2$
Bornite	Cu_5FeS_4
Calcite	$CaCO_3$
Chalcocite	Cu_2S
Chalcopyrite	$CuFeS_2$
Clausthalite	$PbSe$
Clinochlore	$(Mg,Fe^{+2})_5Al(Si_3Al)O_{10}(OH)_8$
Clinozoisite	$Ca_2Al_3(SiO_4)_3(OH)$
Copper	Cu
Cordierite	$Mg_2Al_4Si_5O_{18}$
Covellite	CuS
Cuprite	Cu_2O
Digenite	Cu_9S_5
Epidote	$Ca_2(Fe^{+3},Al)_3(SiO_4)_3(OH)$
Ferrohornblende	$Ca_2(Fe^{+2},Mg)_4Al(Si_7Al)O_{22}(OH,F)_2$
Fluorapatite	$Ca_5(PO_4)_3F$
Goethite	$Fe^{+3}O(OH)$
Hematite	Fe_2O_3
Kaolinite	$Al_2Si_2O_5(OH)_4$
Magnetite	$Fe^{+2}Fe_2^{+3}O_4$
Malachite	$Cu_2^{+2}(CO_3)(OH)_2$
Molybdenite	MoS_2
Muscovite	$KAl_2(Si_3Al)O_{10}(OH,F)_2$
Papagoite	$CaCu^{+2}AlSi_2O_6(OH)_3$
Pennantite	$Mn_5{}^{+2}Al(Si_3Al)O_{10}(OH)_8$
Piemontite	$Ca_2(Al,Mn^{+3},Fe^{+3})_3(SiO_4)_3(OH)$
Prehnite	$Ca_2Al_2Si_3O_{10}(OH)_2$
Pyrite	FeS_2
Pyrrhotite	$Fe_{1-x}S$
Quartz	SiO_2
Shattuckite	$Cu_5^{+2}(SiO_3)_4OH_2$
Sphalerite	$(Zn,Fe)S$
Zoisite	$Ca_2Al_3(SiO_4)_3(OH)$

Table 2. **Minerals observed as inclusions in quartz from the Messina district.**

Ajoite
Azurite (rare)
Bornite
Calcite
Chalcocite
Chalcopyrite
Chlorite
Clinozoisite
Copper
Cuprite
Epidote
Hematite
Kaolinite
Malachite
Muscovite
Papagoite
Pyrite
Shattuckite
Zoisite

Söhnge (1946) remarked that the Messina mine is noted for its wealth of beautiful quartz crystals ranging from microscopic size to individual crystals half a meter long. He further noted that doubly terminated crystals up to 10 cm in length have been found in many vugs. The larger crystals are, almost without exception, zoned internally with over a dozen phantom layers occurring in some crystals. Söhnge (1946) observed that the zones can consist of minute inclusions of specular hematite, epidote and chlorite. It is common to find an outer euhedral layer of clear quartz that has grown on the zoned core after the latter has been coated by hematite, epidote, talc, sericite, chlorite, zeolites, malachite or azurite. The presence of flaky specular hematite imparts a striking sheen to well-formed clear crystals. Söhnge (1946) also stated that hollow kaolinitic spherules are sometimes incorporated in the core of quartz crystals from some localities.

The growth habit of the quartz has produced specimens of unusual shapes. Tabular crystals have been formed by the excessive growth of two parallel prism faces or predominant development of three rhombohedral faces at each end of the short prism, producing disc-shaped crystals.

A feature of the quartz crystals is that many are doubly terminated, even individuals in subparallel groups. Another attractive aspect of some quartz specimens is the circling of the base of a large crystal by a peripheral halo of smaller crystals. This often gives an appearance of the larger crystal rising out from a nest of smaller basal crystals.

The included minerals in the quartz specimens cover a wide diversity of species. These have all been described in detail under the individual species subdivisions, but are also listed for reference in Table 2.

Shattuckite $Cu_5^{+2}(SiO_3)_4(OH)_2$

Shattuckite occurs as royal-blue to dark navy-blue inclusions in quartz crystals. The habit may be formless aggregates or may occur as small (<1 cm) circular haloes defined by the parallel arrangement of minute crystals. Shattuckite is usually distinguishable from papagoite and ajoite by its darker blue color.

Sphalerite (Zn,Fe)S

Jacobsen (1967) stated that sphalerite is a rare constituent at the Artonvilla mine while Söhnge (1946) affirmed that sphalerite is a rare accessory found at the Campbell mine. At both of these localities, the sphalerite was only visible in thin section.

Zoisite and **Clinozoisite** $Ca_2Al_3(SiO_4)_3(OH)$

Zoisite and clinozoisite are present in the orebodies although in variable amounts. They are far less abundant at the Artonvilla mine than in the westerly orebodies, and at the Messina mine in particular, where zoisitization is the dominant alteration. Laing (1973) states that zoisite and clinozoisite are usually present as columnar aggregates of pale brown to gray-brown crystals. At the Messina mine, zoisite is white to very pale gray in color and cleaves with a splintery to flaky fracture (Söhnge, 1946).

ACKNOWLEDGMENTS

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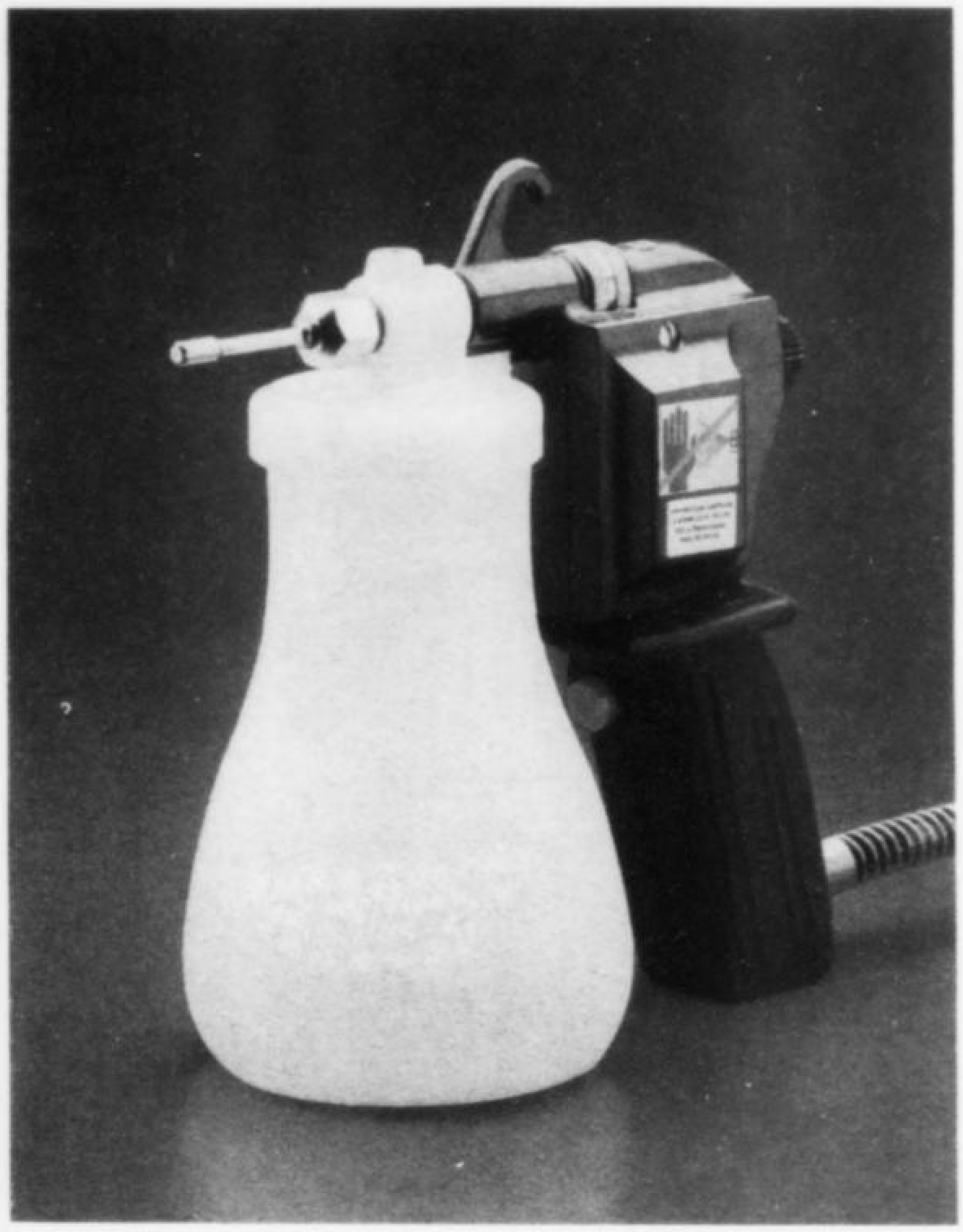


DISPLAY
STANDS
THE LARGEST AND
FINEST DISPLAY STAND
LINE AVAILABLE
ANYWHERE

Famous Mineral Localities

THE IDRIA MINES
SLOVENIA, YUGOSLAVIA

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Idria is among the world's most famous mercury deposits. During five centuries of operational history the Idria orefield has produced 147,000 metric tons of mercury, about 13% of the world's total output. It has also yielded superb specimens of crystallized cinnabar, and is the type of locality for idrialite.

INTRODUCTION

Idria (Idrija) is located at the southeastern edge of the Alps in northwestern Slovenia, Yugoslavia, about 30 km east of the Italian border and 38 km west of Ljubljana. Access is by way of Kalce, where a road branches off the main highway connecting Ljubljana and Triest and proceeds about 20 km to the town of Idria. The name is of probable Celtic origin; although spelled "Idrija" by the local inhabitants, "Idria" is the more common spelling in foreign publications and is also considered correct.

More than 450 historical reports, surveys, monographs, and papers have appeared in the profession and popular literature regarding Idria. It is the second most important mercury deposit in Europe (after Almaden, Spain; see Crawford, 1988), and is the historical namesake of California's famous New Idria mercury district. The year 1990 marked the 500th anniversary of mercury mining at Idria, celebrated by scientific organizations and the media throughout Yugoslavia.

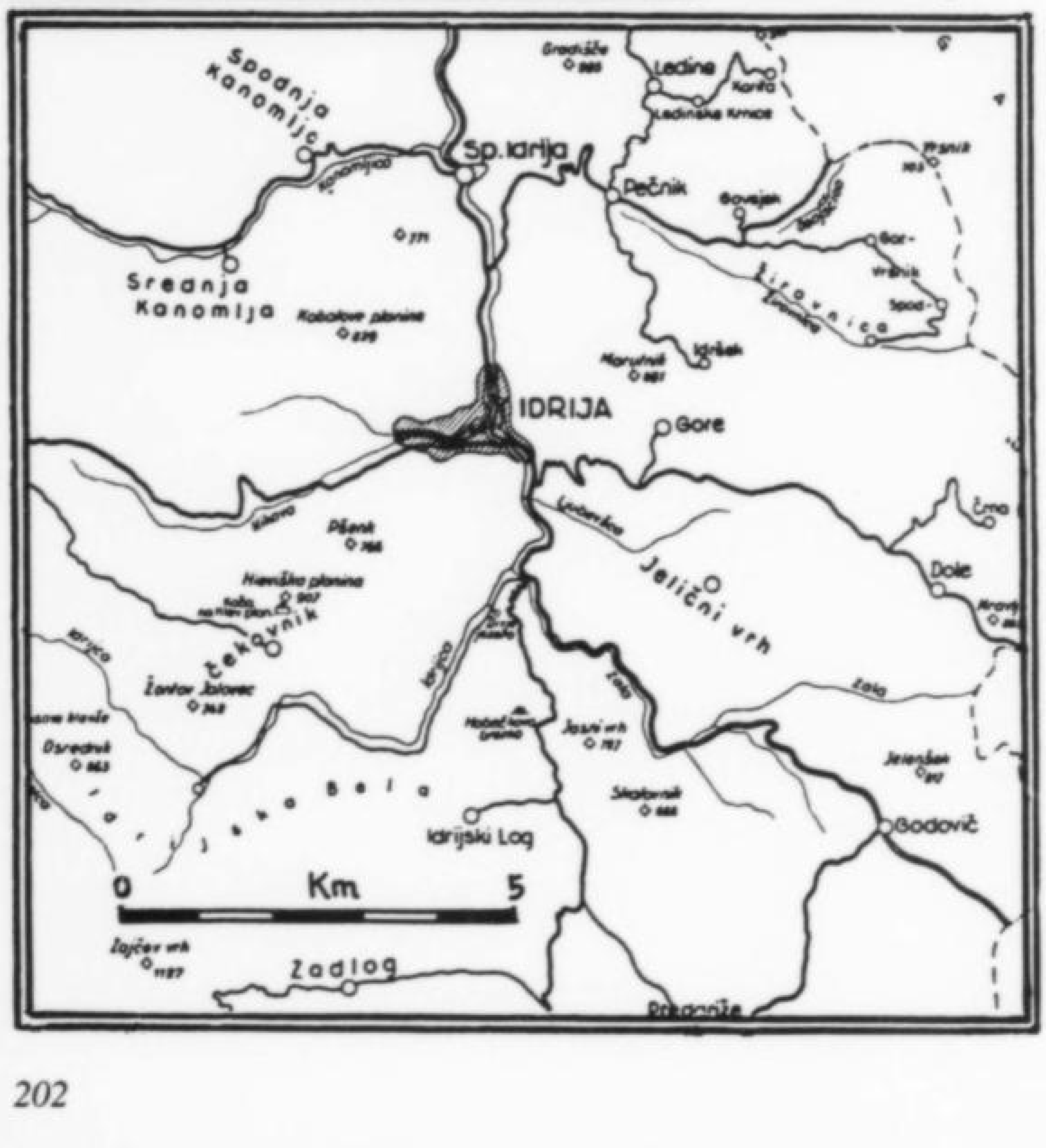
HISTORY

The Idria mercury deposits were discovered in 1490. According to legend, the first person to notice the metallic mercury seeping out of the ground was a cooper; washing his newly made tubs and barrels in a local stream, he noticed one morning that bits of a silvery liquid had collected in a tub. He took a sample to a goldsmith in Škofja Loka who correctly identified it as mercury. The story is credible because even today liquid mercury can be found in schists which crop out in the same area.

Mercury mining developed slowly during the first years following the discovery, in part because the outcropping schist ore contained an average of only 0.3–1.5% mercury. This ore was mined until 1500, when workers shifted their efforts to the new Anthony tunnel ("Antonijev rov") where mining has continued up to the present day. On June 22, 1508, a rich orebody was found at a depth of 42 meters in the center of town. Known as St. Ahac's day ("sv. Ahac" in Slovene), the occasion has been celebrated annually ever since.

Figure 1. **Yugoslavian postage stamps commemorating the 500th anniversary of mercury mining at Idria.**

Figure 2. **Location map.**



Despite an abundance of rich ore, primitive mining techniques constrained production. A myriad of small mines operated independently, each with its own buildings, mills and furnaces; few owners shared facilities or cooperated with neighboring mines.

In 1573 a group of 43 Idria mine owners signed a joint management agreement with the Austrian government (Idria was at that time a part of Austria), resulting in a complete consolidation and renovation of the mines. Individual mines were connected underground, a new main shaft was constructed, adequate timber supplies were provided, and dams were installed to power the hoists.

By the end of the 1500's, the Idria workings had reached a depth of 170 meters, qualifying as one of the deepest and best equipped mines in Europe. High-grade cinnabar ores were found in abundance, and it was no longer necessary to mine the low-grade, poorly paying schists. The bright red color of the cinnabar made ore recognition easy, and hand-sorting operated at high efficiency. The cinnabar was roasted in earthenware vessels placed over hot charcoal, reducing it to the pure metal as illustrated in Georgius Agricola's famous mining treatise, *De Re Metallica* (1556).

The fame of the Idria mines attracted scholars from all over Europe. Hand-colored illustrations and a description of the mine and its facilities were published first by Sigmund Sisserus and Gualterus Poppe in 1665, and later by Edward Brown in 1669, and by Johann Valvasor in 1689.

In spite of continued efforts to scientifically control mercury vapor at the mines and ovens, the number of miners and laborers stricken with mercury poisoning reached epidemic proportions under the careless management of Sigmund Kienpach. Sick employees, crippled by the chronic lethargy and mental deterioration associated with mercury poisoning, became known as *kimpahs,* a pejorative term still used today by Idria miners for inept and lazy people. Kienpach was dismissed in 1695, and Johan Stampfer took his place as the new mine director. Determined to improve conditions, Stampfer saw to the construction of new furnaces which emitted less (and recovered more)

Figure 3. **The main shaft at Idria, 1989. Photo by P. Bancroft.**

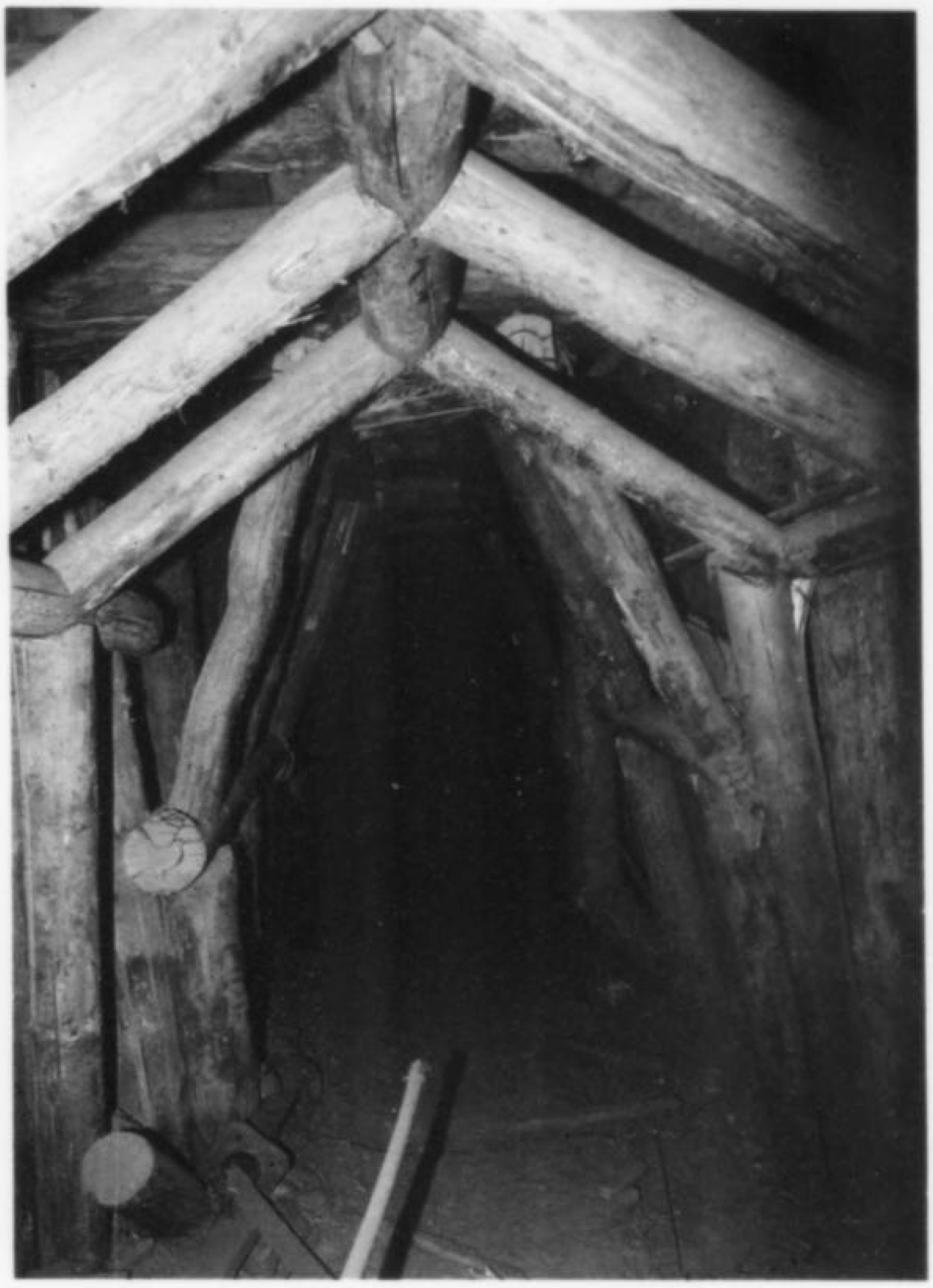


Figure 5. **Timbered section of a 300-year-old tunnel in the upper levels of the Idria mine. Photo by P. Bancroft.**

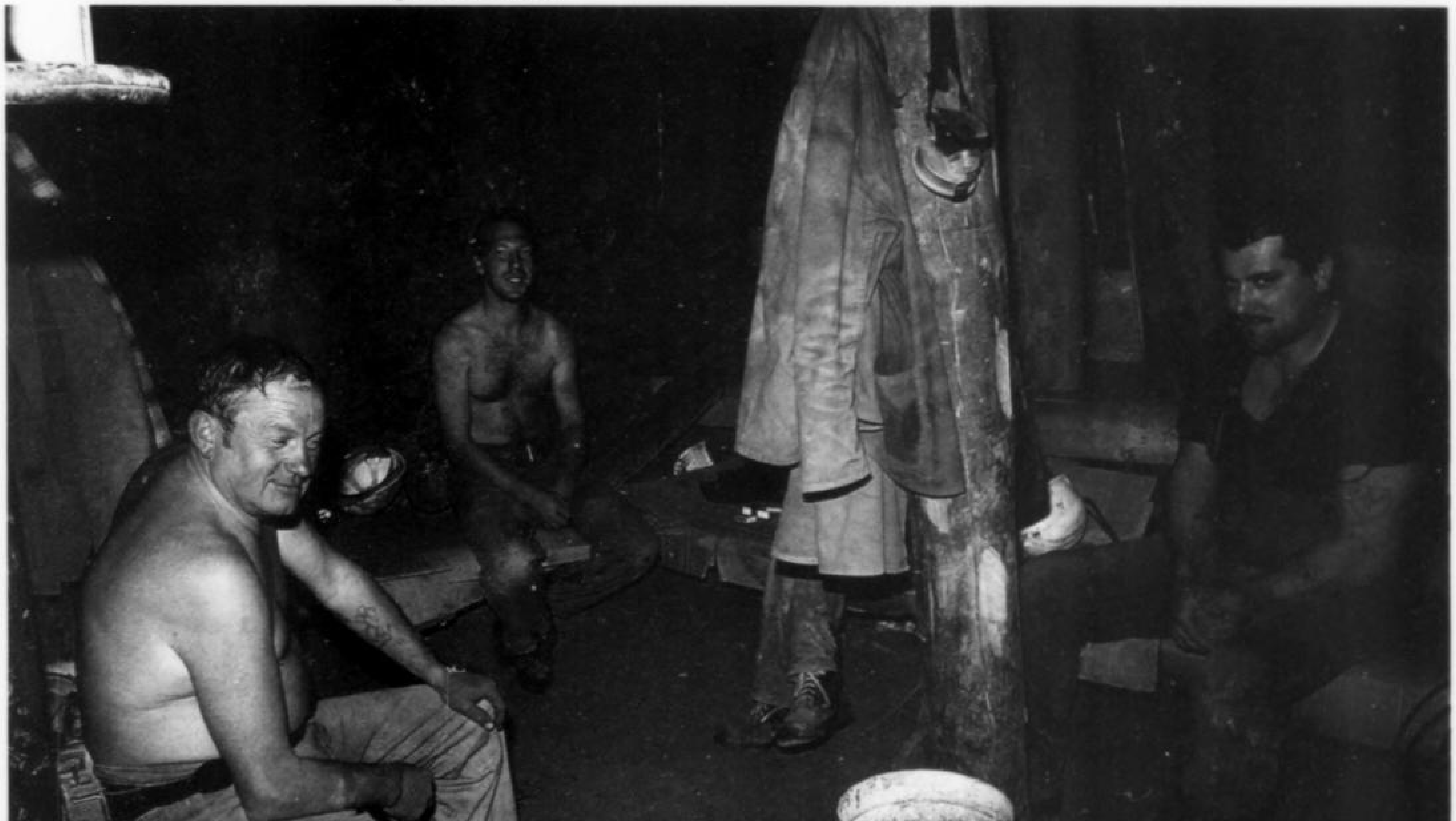


Figure 4. **Mercury miners taking a break in an underground rest area of the Idria mine. Photo by P. Bancroft.**

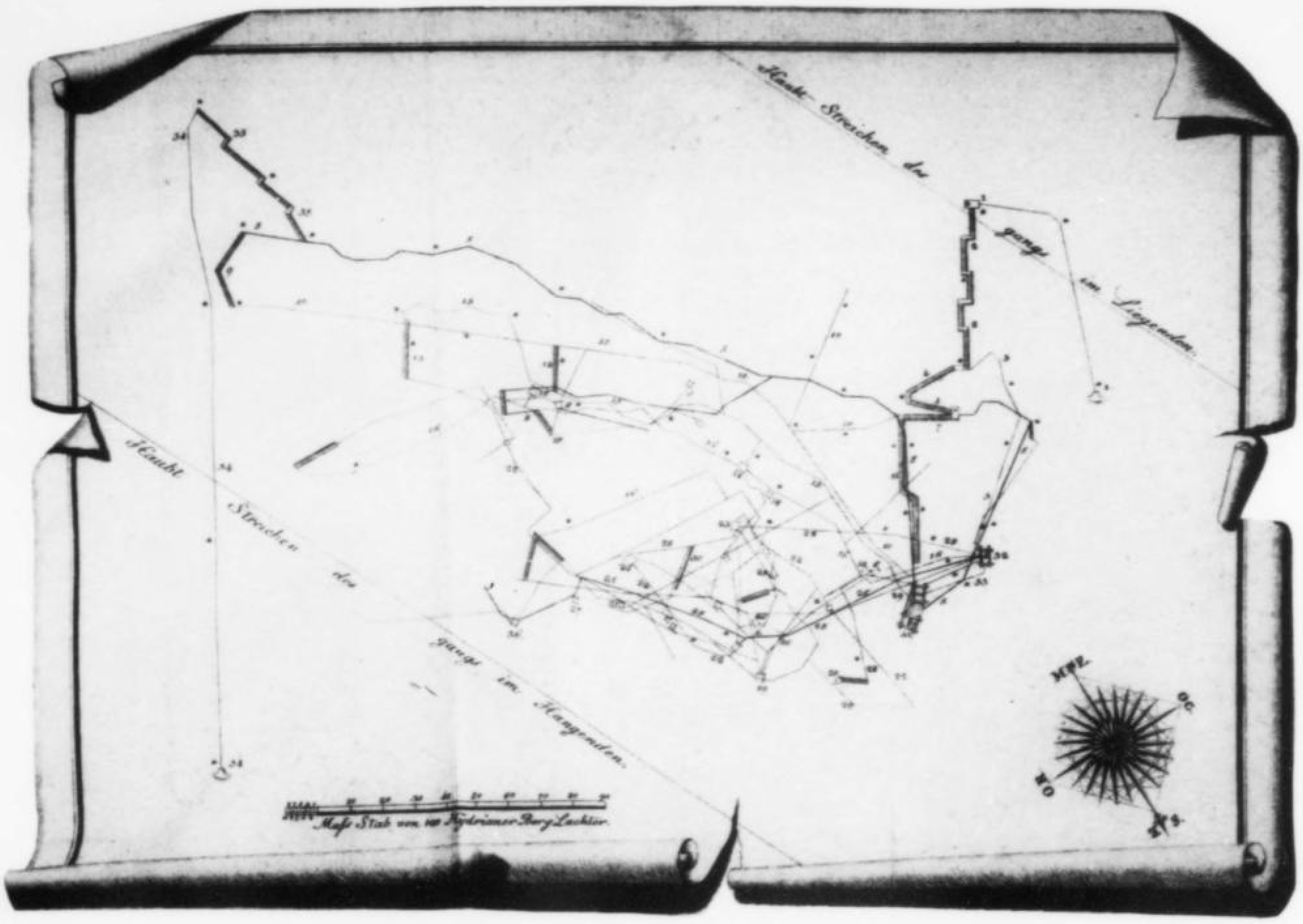


***Figure 6.* Map of the underground workings as they were in 1781 (Hacquet, 1781).**

mercury. Unfortunately, the Vienna Court went into debt when mercury prices declined, and Stampfer was dismissed.

Idria's next director was Anthon Steinberg, who persuaded the government to authorize some important improvements. A new shaft (the Theresia shaft) was opened in 1738, the mine was deepened, new levels leading to rich new orebodies were opened, and the surface facilities were renovated.

In 1750 A. Haubtmann took over as director. He had a new Spanish furnace installed, and had new dams built on the Idria and Belca Rivers. The manmade lakes created by the dams were used as reservoirs and as waterways for the transportation of logs to the lumber mills which cut timbers for the mines. The huge "klavze" dams remain in place today, and are known colloquially as the "Slovenian pyramids."

Concerned about the high frequency of illness among the mercury miners, Empress Maria Theresia's personal physician dispatched Dr. Johannes Antonius Scopoli to the mines. Scopoli, who was also a professor of mineralogy, was the first trained physician ever assigned to treat the miners. In 1766 he was joined by a famous surgeon and researcher, Balthasar Hacquet; together they served the Idria miners for many years and became greatly admired throughout the mining world.

During the 1780's the Idria district once again suffered hardship when Spain's famous Almaden mine began flooding the international market with its mercury. The price of mercury fell so disastrously that Idria was forced to shut down, laying off miners, greatly reducing pensions, and precipitating poverty throughout the region.

Within a few years, however, the price of mercury rose again and mining in the district flourished once more. In 1785 the Spanish government contracted with the Vienna Court for large quantities of Idria mercury, a contract which was renewed through 1798. Production rose from between 30 and 140 tons per year to 600 tons annually. The production of 1794 peaked at 672 tons, one of the highest annual yields in the mine's history, but unfortunately achieved at the cost of "robbing the pillars" and selectively removing the highest grade lodes. Low-grade ore was discarded in pits or used underground for backfill. During this time the mine was again deepened, and by 1792 two more shafts had been completed: the Jožef (now known as the Delo) shaft and the Frančišek (now the Borba) shaft.

Another development during this time was made necessary by a heavy flow of underground water which had overwhelmed the pumps and flooded the lower levels. A new, high-capacity pumping apparatus called a *kamšt* (derived from the German *Wasserkunst*) was installed, drawing worldwide attention in mining circles. The pump's main waterwheel, 13.5 meters (44 feet) in diameter, provided power to draw water up from a depth of 285 meters. The Idria *kamšt* operated faithfully for 160 years, and is now preserved as a mining antique, near its original site.

Between 1785 and 1790 the Idria workforce grew from 5900 to 1,350 men, attracting miners from nearby Austrian mines and from as far away as Bohemia and the Tyrol. But mercury poisoning remained a serious hazard, and hundreds of miners suffered premature death as a result of exposure to the toxic vapor.

During the next 50 years production reports describe a serious decline in ore grade. From an average of 10% in 1816, mercury content in the ore being mined fell to 2% by 1850. In order to compensate and remain profitable, ore production had to be increased accordingly. An additional shaft was built, the mine was deepened and new levels were added. But in 1803 a fire roared through the lower workings, leaving one dead, and in 1846 another disastrous fire underground claimed 16 lives. Both fires had to be extinguished using the only procedure known at the time: flooding the entire mine.

In 1837 the flow of ground water in the mines finally exceeded the capacity of the giant *kamšt,* and additional steam-powered pumps were installed.

By the year 1880, Idria has grown to be one of the world's largest underground mining operations. Workings extended under an area 600 meters wide and 1.5 km long. Six shafts from the surface and 27

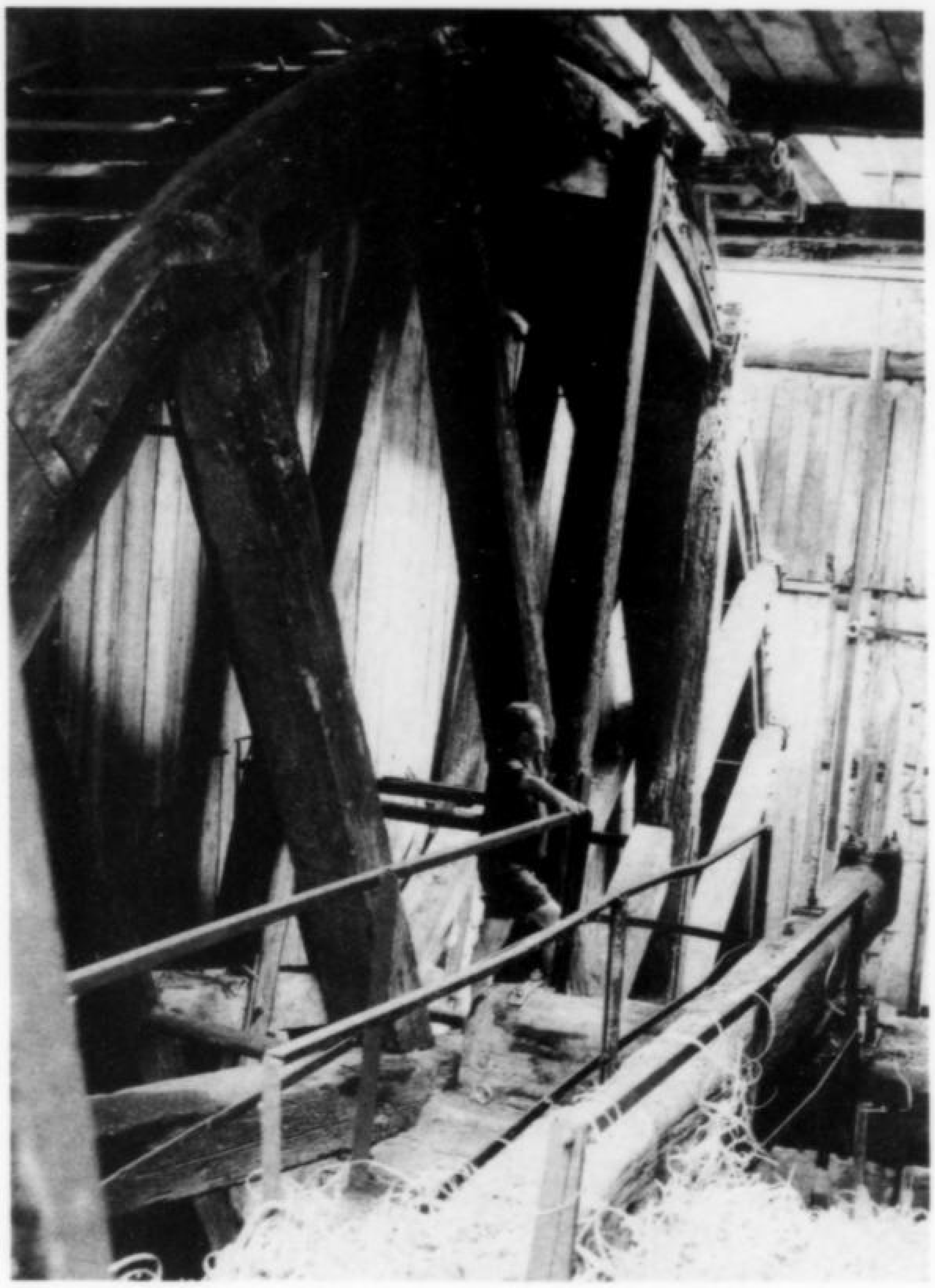


Figure 7. **The giant water wheel installed in 1790 to drive the *kamšt* pump. It pumped 2,000 gallons per minute from a depth of 283 meters until being taken out of service in 1948 (photo courtesy of the Idria mine staff).**

interior raises were in constant use. Mechanized drilling was introduced in 1874, and by 1900 the workings had been electrified. An all-time production record of 820 tons of mercury was achieved in 1913.

As ore production increased, major changes in the old roasting ovens became necessary. Twenty-one giant Čermak-Špirek furnaces were installed, creating a facility so impressive for its days that mining engineers from as far away as Almaden, Spain, came to marvel at it. These furnaces functioned for many years, until finally being replaced by modern rotary ovens, but one has been preserved as an historical exhibit.

During World War I the Italians took possession of the Idria mines and operated them until 1943, when the Germans took control. During these years ore grade and production began a final decline. Idria was now a very old mine, and no amount of exploration or improved technology could restore its prosperity.

Following World War II, Yugoslavia acquired the territory and nationalized the Idria mines. Facilities were modernized and all known ore reserves were carefully exploited, including the long-ignored mercury-laced schists. In recent decades world mercury production has increased, putting further economic pressure on Idria. Exhausted of its ore and no longer able to compete on the world market, Idria is now scheduled to shut down permanently in the year 2006. Large sections of the mine are currently settling and caving, resulting in a subsidence rate at the surface of about 2.5 cm per year. Miners today are primarily occupied with backfilling in an effort to prevent future subsidence from swallowing the town.

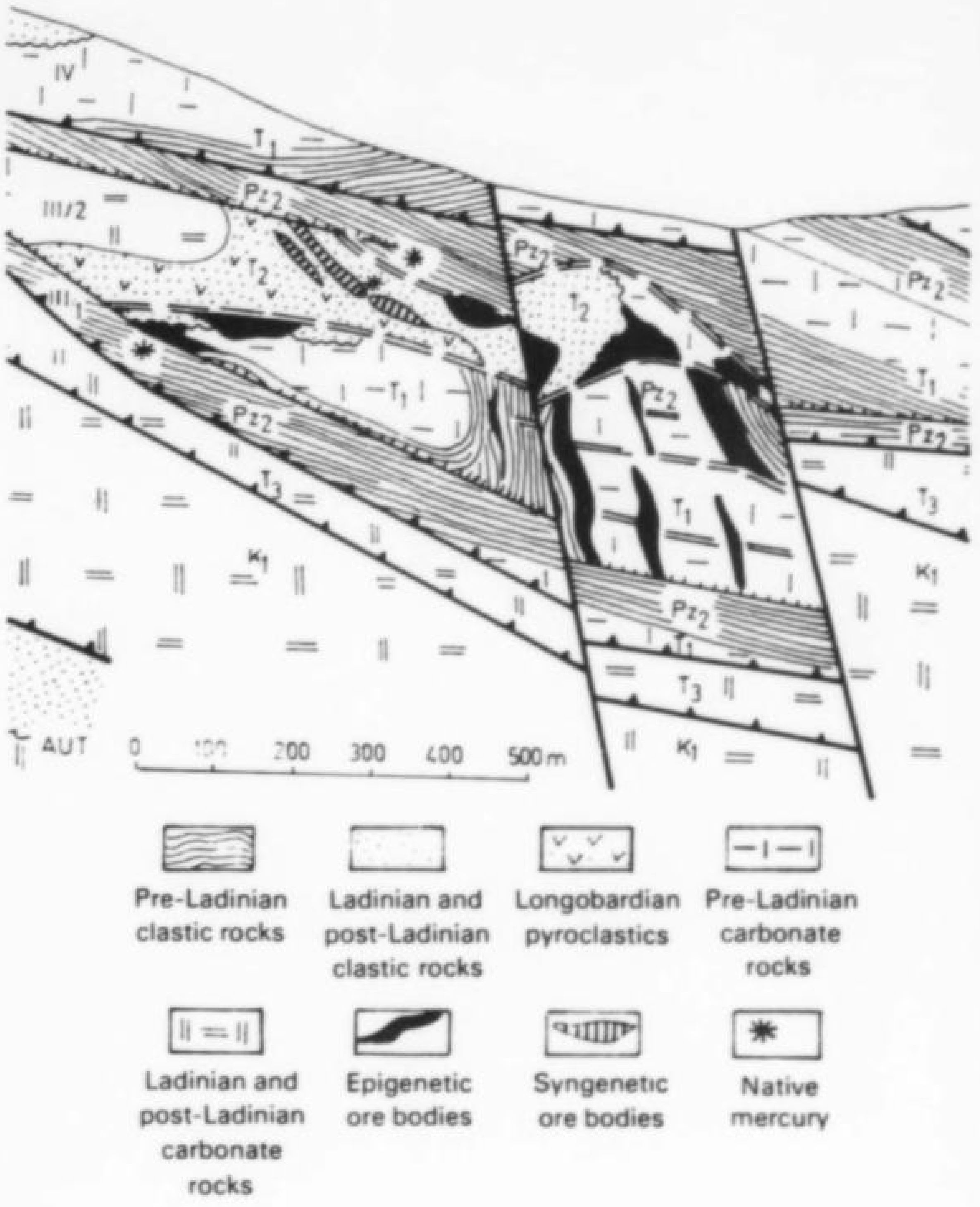


Figure 8. **A cross-section through the Idria deposit showing the complex structure surrounding the orebodies (from Mlakar and Drovenik, 1971).**

GEOLOGY

The Idria ore field has been the subject of repeated geological studies over the years (the most recent being Mlakar and Drovenik, 1971). It is situated in the Dinaric metallogenic province, which stretches the length of Yugoslavia, paralleling the Adriatic coast. The Triassic metallogeny of the province includes many occurrences and deposits of mercury which appear to fall within several discontinuous mercury-bearing zones, some of which are several hundred kilometers long. Idria is by far the greatest of these deposits, and the only one presently in commercial operation.

Geologically the Idria area is very complex, consisting of Paleozoic, Triassic, Cretaceous and Eocene rocks which have been subjected to folding, overthrusting and faulting. The mineralized horizons (Carboniferous schist; Permian sandstone and dolomite; Triassic shales, sandstones and dolomites; Eocene sediments) cover an area 1.5 km long, 600 meters wide and 450 meters deep. There are 156 known mercury lodes and orebodies, of varying size and grade, distributed irregularly in the enclosing rocks; disseminated ore was volumetrically the dominant type.

There were two phases of mineralization: the first consisted of epigenetic hydrothermal solutions which deposited cinnabar in fissures and as replacements, and the second of syngenetic mineralization which ultimately reached the marsh bottom as thermal springs. The mineralization is Middle Triassic in age and appears to be genetically related to a spilito-keratophyre-porphyrite magmatic complex. But the ultimate source of the mercury may well be the upper mantle.

Mined from an elevation of 330 meters above sea level to 120 meters below sea level, the Idria mine is currently accessible only down to the –32 meter level. This includes 15 levels at 15–30 meter intervals. The main entrance is the Antonijev rov, and there are four vertical shafts.

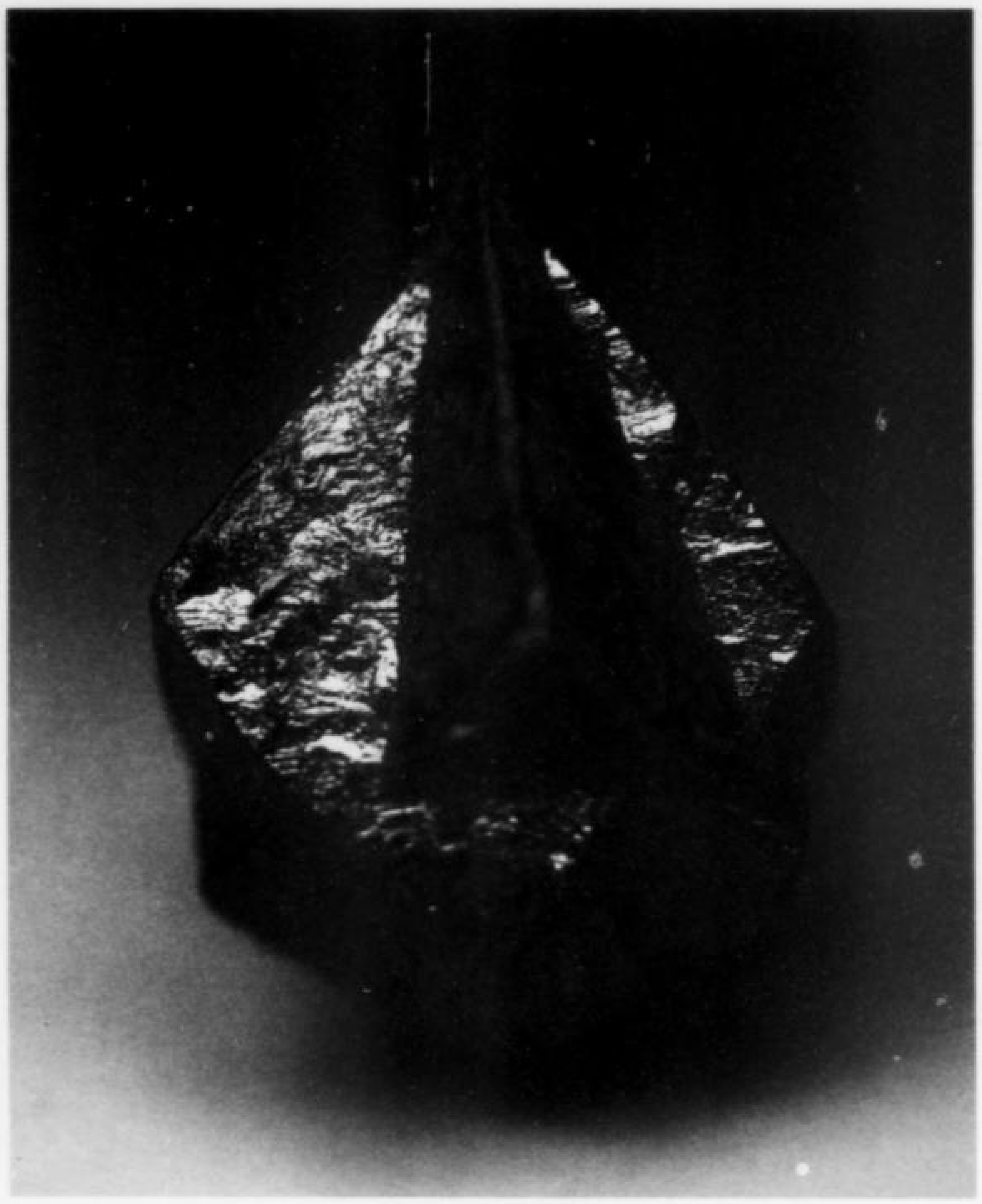


Figure 9. A perfectly formed, 1.5-cm penetration twin of cinnabar from the Idria mine. Collection and photo: P. Bancroft.

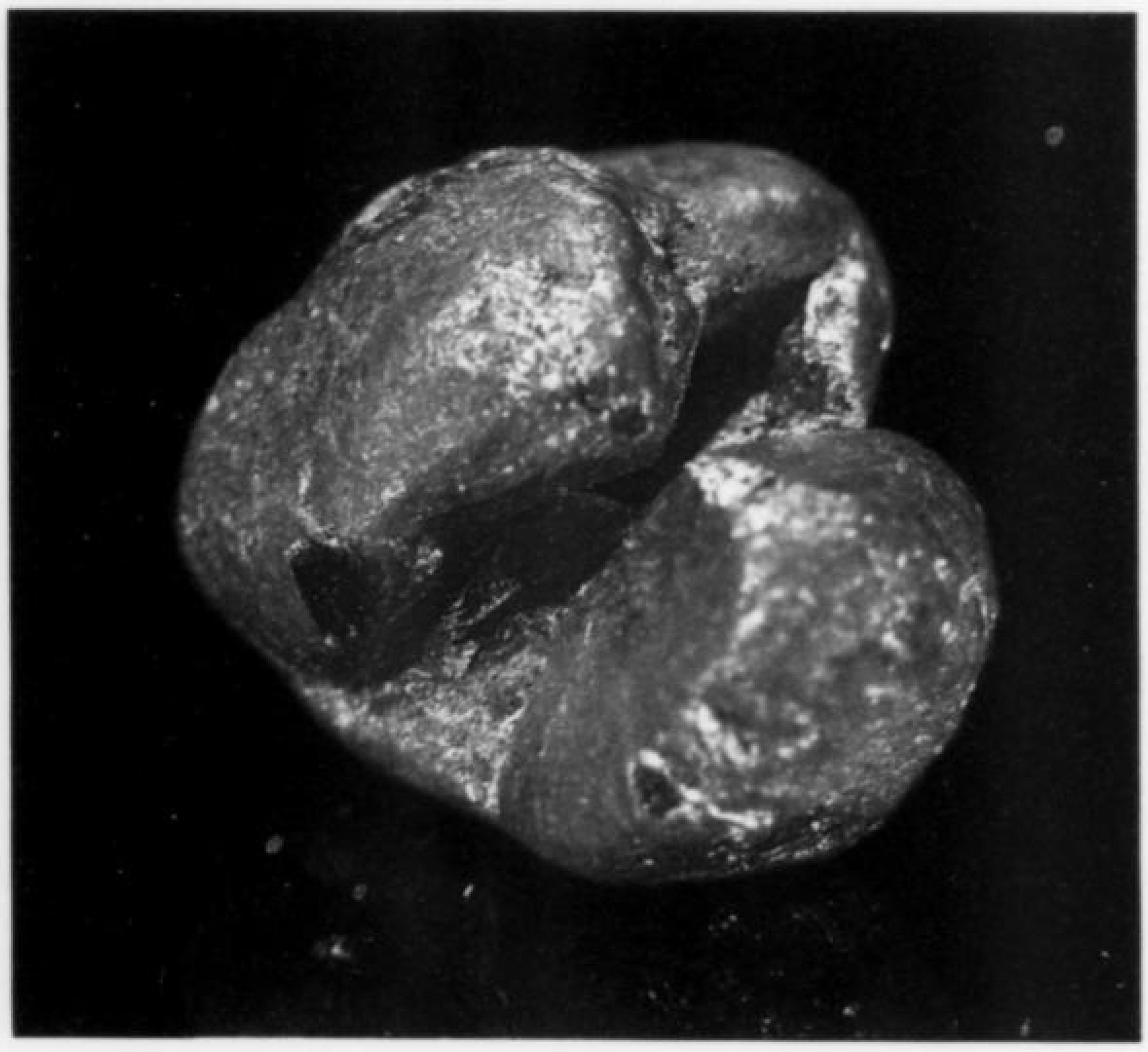


Figure 10. A 1.5-cm cinnabar twin, water-rounded within a pocket by groundwater flow. Collection of the Idria mine; photo by M. Žorž.

Figure 11. Cinnabar crystal specimen, 1.5 cm, from Idria. Canadian Museum of Nature specimen #32238; photo by George Robinson.

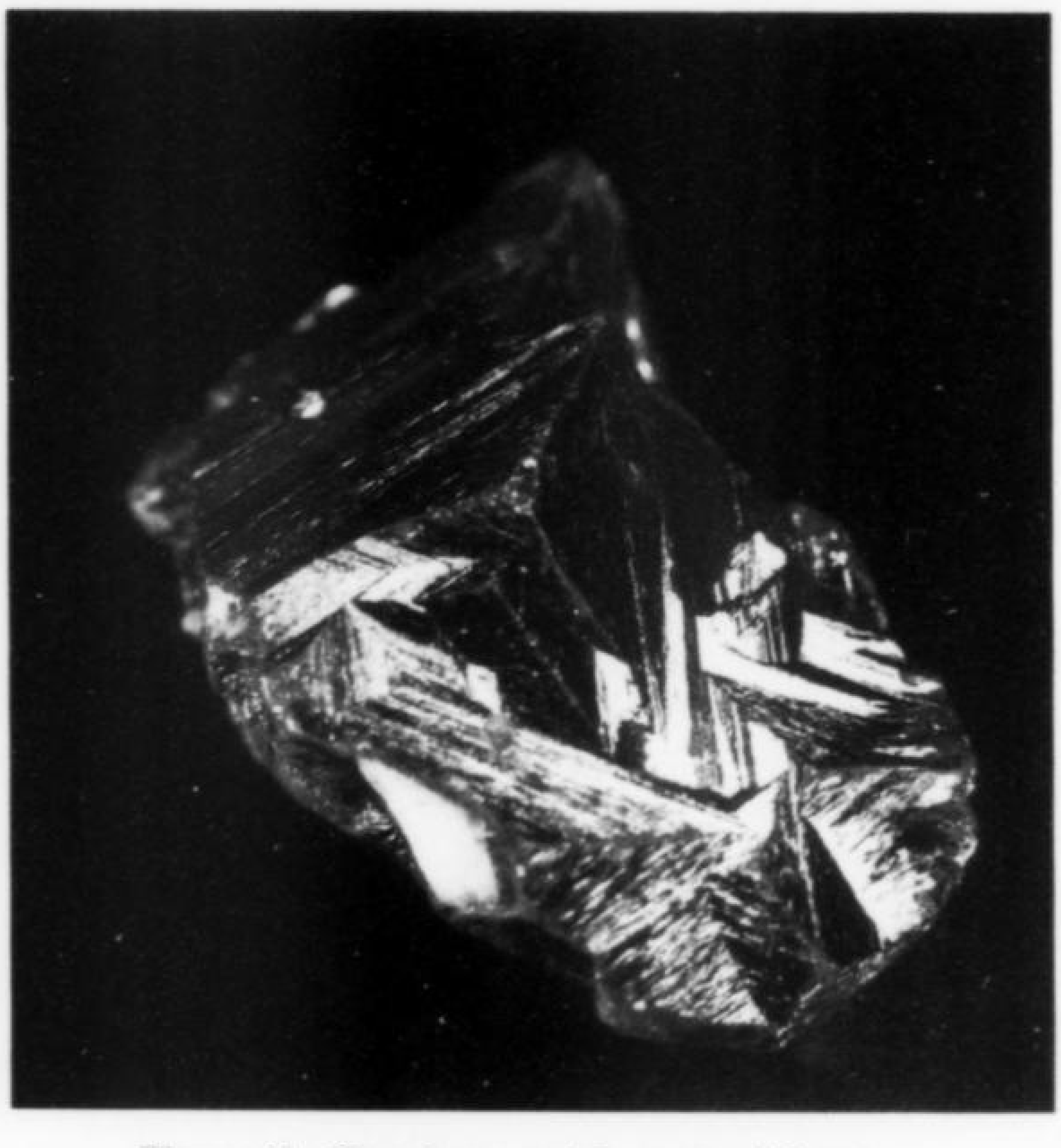


Figure 12. Cinnabar crystal group, 2.6 cm, from Idria. Collection of the Idria mine; photo by M. Žorž.

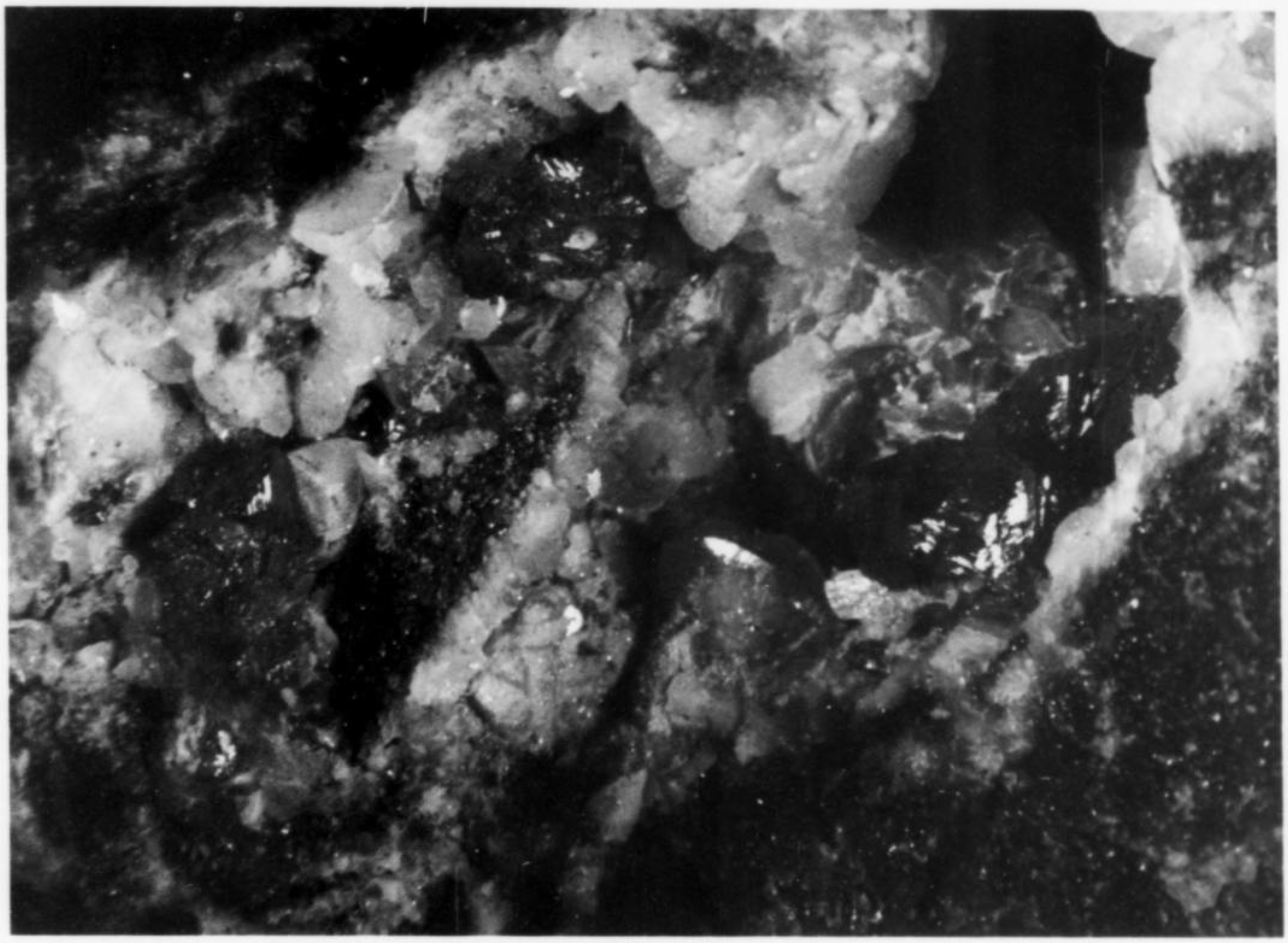


Figure 13. **Bright red cinnabar crystals on calcite matrix, 8 cm long. Collection of the Idria mine; photo by M. Žorž.**

MINERALOGY

Cinnabar HgS

The principal ore mineral has always been cinnabar, although native mercury also occurs in a few orebodies. Specimen collecting was unfortunately not popular during much of the operational history of the mine, therefore relatively few good specimens are known in museums and private collections today. Some of the miners kept fine specimens as memorabilia of their careers, but these are not readily accessible to the public.

Bright red, well-formed rhombohedral crystals to 2 cm, some on a matrix of dolomite, calcite and cinnabar are preserved in the mine's collection. Penetration twins are uncommon, but closely resemble the well-known cinnabar twins found in China. Luster is bright on the best specimens. Some fracture surfaces in limestone are coated by a layer of small, tightly packed gemmy crystals in parallel orientation.

Metacinnabar HgS

Metacinnabar, the isometric polymorph of cinnabar (and hypercinnabar) occurs sporadically as small crystals to a few millimeters in size.

Idrialite $C_{22}H_{14}$

Idrialite is a hydrocarbon mineral first identified at Idria by Dumas (1832) as part of a mixture including cinnabar, clay, pyrite, gypsum, and a combustible, brownish black mercury-containing material referred to as *inflammable cinnabar* or *Quecksilberbranderz*. Debate persisted for decades about the precise carbon-hydrogen ratio. Goldschmidt (1880) investigated a purer sample which he described as a pistachio-green resin occurring as nodules and incrustations at Idria. (See the sixth edition of Dana's *System of Mineralogy* (1892), page 1013, for these and other 19th century references.)

Strunz and Contag (1965) examined impure idrialite from the type locality and arrived at the now-accepted formula ($C_{22}H_{14}$), the equivalent of a compound known in organic chemistry as picene. They also observed that it fluoresces blue-white under ultraviolet light, and they determined the orthorhombic unit cell constants. The mineral is soluble in sulfuric acid, producing an intense blue-green color.

Glebovskaya (1968) conducted a molecular spectroscopy study which identified the organic equivalent as demethylbenzphenanthrene (same formula), a conclusion supported by Fleischer (1987). However, Blumer (1975) determined by chromatographic separations followed by ultraviolet and mass spectrometry that idrialite is a complex mixture of polycyclic aromatic hydrocarbons including naphthenopicene, tribenzofluorene, benzopicene, naphthenobenzopicene, pentabenzothiophane and others.

Our own studies (by M.Z.) have confirmed the formula, color and fluorescence. Associations include quartz and cinnabar. Idrialite is a rare mineral at Idria, found primarily in the Lower Triassic horizons.

Other Minerals

Mercury is present everywhere, but especially in schist, as globular exudates around pyrite nodules. Pyrite has been found in poorly formed cubes to 2 cm. Marcasite, sphalerite and orpiment have also been reported, but none in collector-quality specimens. The chief gangue minerals are dolomite, calcite and quartz (some of it chalcedonic). Epsomite and melanterite are widespread as post-mining minerals forming stalactites, crystals and extensive coatings on old timbering. Kaolinite has been found in sedimentary layers up to 15 cm thick. A black, glossy, globular material has recently been found on dolomite matrix, and has yet to be identified or characterized.

Idria coat of arms.

Figure 14. The process of roasting cinnabar to produce metallic mercury (from Agricola, 1556).

CONCLUSION

Fine Indria specimens will always be rare, despite the long and distinguished history of the locality. With the final closing of the mine scheduled for a few years from now, and with no high-grade ore left to mine, it seems unlikely that any more fine specimens will be recovered. All that can be realistically hoped, from the collector's standpoint, is that miners will gradually sell off their personal souvenir specimens in future years, providing a trickle of collectible pieces.

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SILVER MINERALS OF THE TŘEBSKO DEPOSIT, PŘÍBRAM ORE FIELD, CZECHOSLOVAKIA

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INTRODUCTION

The Příbram ore field is situated about 60 km southwest of Prague. The historic portions of the ore field are the Březové Hory and the Bohutín districts. Mining has been under way at this famous locality since the 13th century, reaching a peak at the beginning of the 16th century. The Příbram ore field has long been the subject of study by mineralogists and geologists. Although the last mine in the town of Příbram closed in 1978, collecting of minerals in the Příbram ore field still continues. In the past, attention was paid primarily to veins prominent in the original Březové Hory district, but also to some smaller, economically less important ore deposits. Stobbe (1981) reviewed Příbram ore field mineralogy, as it has been determined for the Klement vein, the Frantisek vein, and the Březové Hory district.

One of the economically less important occurrences is the uranium deposit at Třebsko, about 10 km south-southwest of Příbram. Recently attention has been concentrated on the polymetallic ore mineralization, especially the silver mineralization in the reopened first level. The characteristics and modes of occurrence of these minerals are the subject of this paper.

HISTORY

The first relatively intensive work at the Třebsko deposit was undertaken in the 16th century; at that time the Gabe Gottes Fundgrube shaft was sunk (Valta, 1936). In the vicinity of this shaft another exploration shaft was sunk in 1887 (Hofmann, 1895), which permitted the study of eight veins. According to Hofmann (1895) the vein fillings contain predominantly siderite, calcite, galena and sphalerite, while stibarsen, native arsenic, argentite, pyrargyrite and Ni-Co arsenides with "pitchblende" occur sporadically.

In 1950 a new shaft was sunk from which two levels were driven; the maximum depth was 100 meters. In 1959 this shaft was closed and flooded.

GEOLOGY

Shaft No. 7 is situated at the contact between the Central Bohemian Pluton and the marginal part of the southeastern limb of the Barrandien Formation in the vicinity of the southwestern closure of the Příbram anticline. On the first level the vein systems intersect gray to black Proterozoic pelites. The thickness of individual veins varies from 2 to 3 cm to several tens of centimeters. One of these, the T-1 vein, is among the most important vein system of the Třebsko deposit. Because the second level has been flooded the T-1 vein could be sampled on the first level only for this study. Its strike is the same as that of the main vein in the original Březové Hory district, and the dip is vertical.

In the neighborhood of the deposit there are rocks of the Proterozoic post-spilite series discordantly overlying Lower Cambrian sediments to the northwest. In the southeast and southwest are rocks of the Central Bohemian Pluton. Proterozoic rocks, represented mostly by dark gray pelites, are only slightly metamorphosed and folded into the Příbram anticline. The vicinity is intersected by disjunctive faults, including a first-order fault called the Dědov Fault. These faults are filled by dike rocks (diabases, diorite porphyrites, lamprophyres and aplites) with admixed crushed material from surrounding rocks. There may be hydrothermal filling as well. Hydrothermal veins have developed first of all in the southeast limb of the Příbram anticline, between the Dědov Fault and Central Bohemian Pluton.

PARAGENESIS OF THE T-1 VEIN

The T-1 vein has a lenticular shape and a variable mineralogy. At about 15 meters south of shaft No. 7 polymetallic ore mineralization occurs with the prevalence of galena, native silver, Ni-Co arsenides and pyrargyrite. There is a prominent vertical zoning characteristically visible in this galena orebody. At the bottom of the carbonate gangue arsenide minerals prevail, whereas galena occurs only sporadically. The thickest part of the vein (width about 50 cm) contains galena with wires of native silver, and relatively rare pyrite and sphalerite. The uppermost part of the orebody is composed of abundant calcite with native silver, and rare galena and pyrargyrite.

The stibarsen orebody reaches a thickness of 40 cm; here a maximum

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*Ed. note: Author Petr Slavicek was unfortunately killed in a collecting accident shortly after this article was completed. As he was descending a shaft, the rope became tangled around his neck and he died before his companions could reach him. He was 22 years old.

Figure 1. **Silver in calcite from the Třebsko deposit, about 2 cm across. Tomáš Řídkošil specimens; photos by Dušan Slivka.**

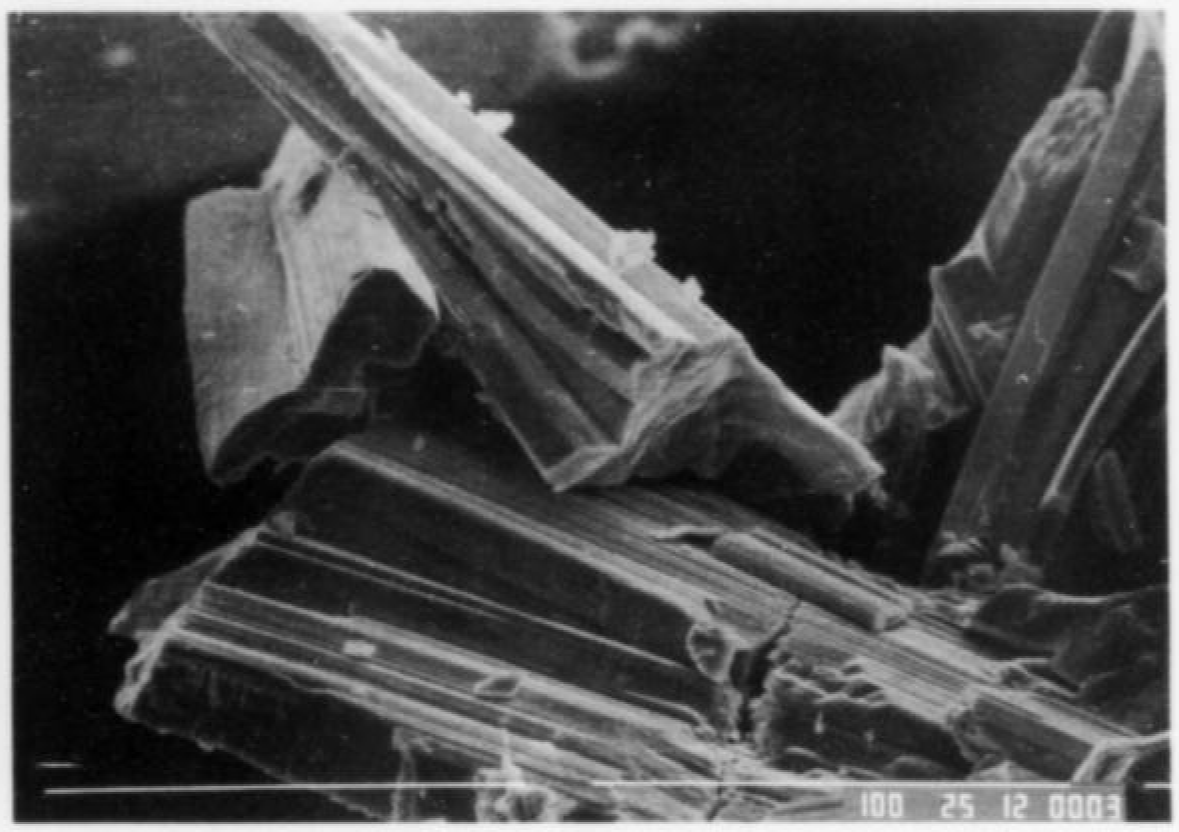

Figure 2. **SEM photomicrograph of andorite-fizelyite phases at 25x. Tomáš Řídkošil specimens.**

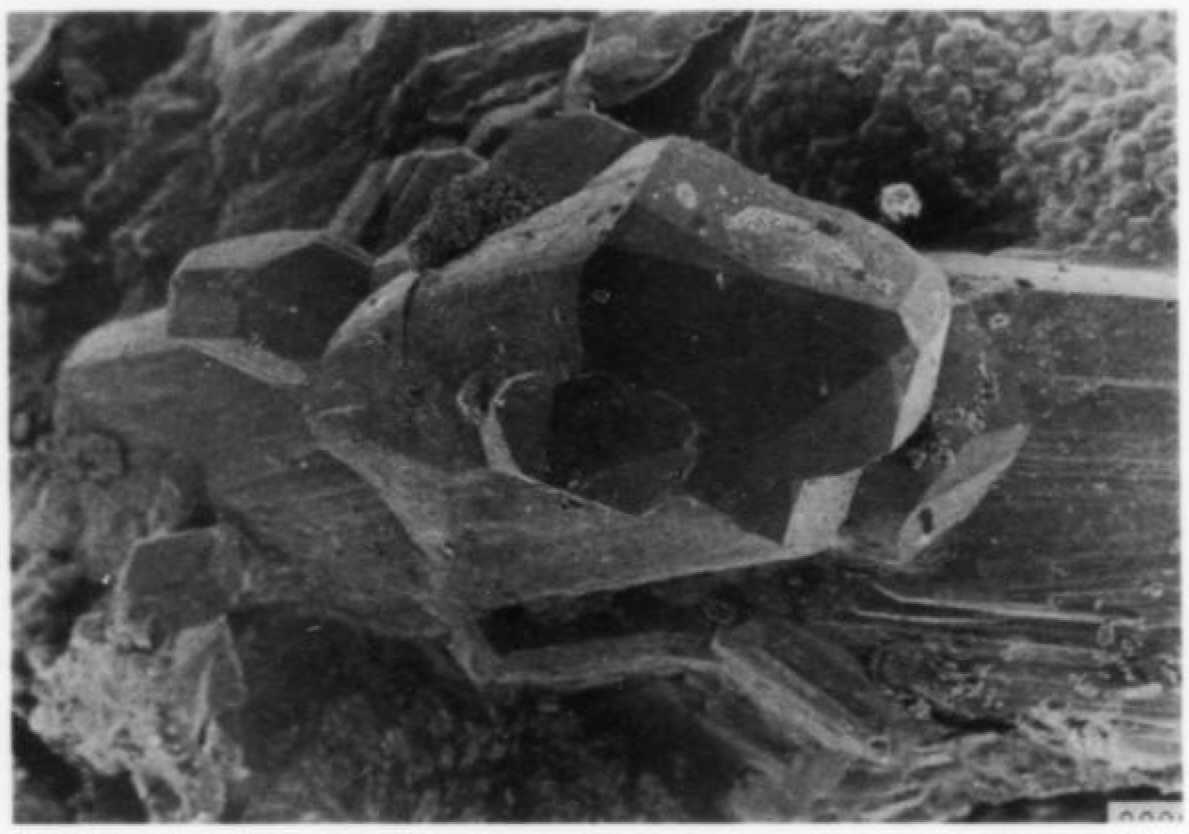

Figure 3. **Miargyrite interpenetration twins, 4 x 5 mm; SEM photomicrograph. Tomáš Řídkošil specimens.**

concentration of silver minerals was recorded. Thus there are evidently two principal lenticular orebodies in which prominent mineralization is developed (the galena and stibarsen orebodies). Table 1 lists the ore, gangue and supergene minerals identified in the galena and stibarsen orebodies. A total of 21 ore minerals, four gangue minerals and five supergene minerals have thus far been identified, some of them in several generations. The data are based on a large suite of samples studied by ore microscopy, X-ray diffraction and electron microprobe.

Differences in paragenetic development of both lenticular orebodies are seen, especially in the contents of siderite and calcite in the gangue. The gangue in the galena lenticular body is characterized by a high content of calcite (3 generations) and a markedly low content of siderite. Only siderite occurs with stibarsen; calcite gangue minerals are lacking. The following five stages of development are identified in the succession of the galena orebody: (1) siderite-sulfide, (2) sulfantimonide, (3) calcite-sulfide, (4) arsenide and (5) supergene. In the stibarsen orebody there are three stages: (1) siderite-sulfide, (2) sulfantimonide and (3) supergene.

SILVER MINERALS of the T-1 VEIN

Acanthite Ag_2S

Acanthite has been found in quartz as microscopic, irregular, black inclusions up to 0.3 mm in size. Chemical composition is: Ag = 85.80, Cu = 0.40, S = 12.60, total = 98.80 (weight %). Empirical formula is: $(Ag_{2.024}Cu_{0.016})_{\Sigma = 2.04}S_{1.00}$.

Andorite $AgPbSb_3S_6$ and **Fizelyite** $Ag_2Pb_5Sb_8S_{18}$

Andorite and fizelyite are among the youngest minerals in the stibarsen orebody. They occur as wire-like aggregates to 1 mm in quartz cavities. Crystals are gray-black. They display no cleavage, and only a conchoidal fracture. A detailed study (Kašpar *et al.*, 1983) showed that aggregates consist of andorite and fizelyite associated with miargyrite.

The chemical composition of andorite determined by electron microprobe is: Ag = 11.63, Cu = 0.32, Pb = 23.60, Sb = 41.93, S = 22.02, total = 99.50 (weight %). The equivalent empirical formula is: $(Ag_{0.942}Cu_{0.044})_{\Sigma = 0.986}Pb_{0.995}Sb_{3.009}S_{6.000}$.

Figure 4. **Pyrostilpnite crystals, 2 mm in size, with stibarsen in cavity. Tomáš Řídkošil specimens; photos by Dušan Slivka.**

Figure 5. **Radially concentric stibarsenic aggregate, about 1.5 cm. Tomáš Řídkošil specimens; photos by Dušan Slivka.**

Figure 6. **Pyrargyrite crystals, SEM photomicrograph at 30x. Tomáš Řídkošil specimens; photos by Dušan Slivka.**

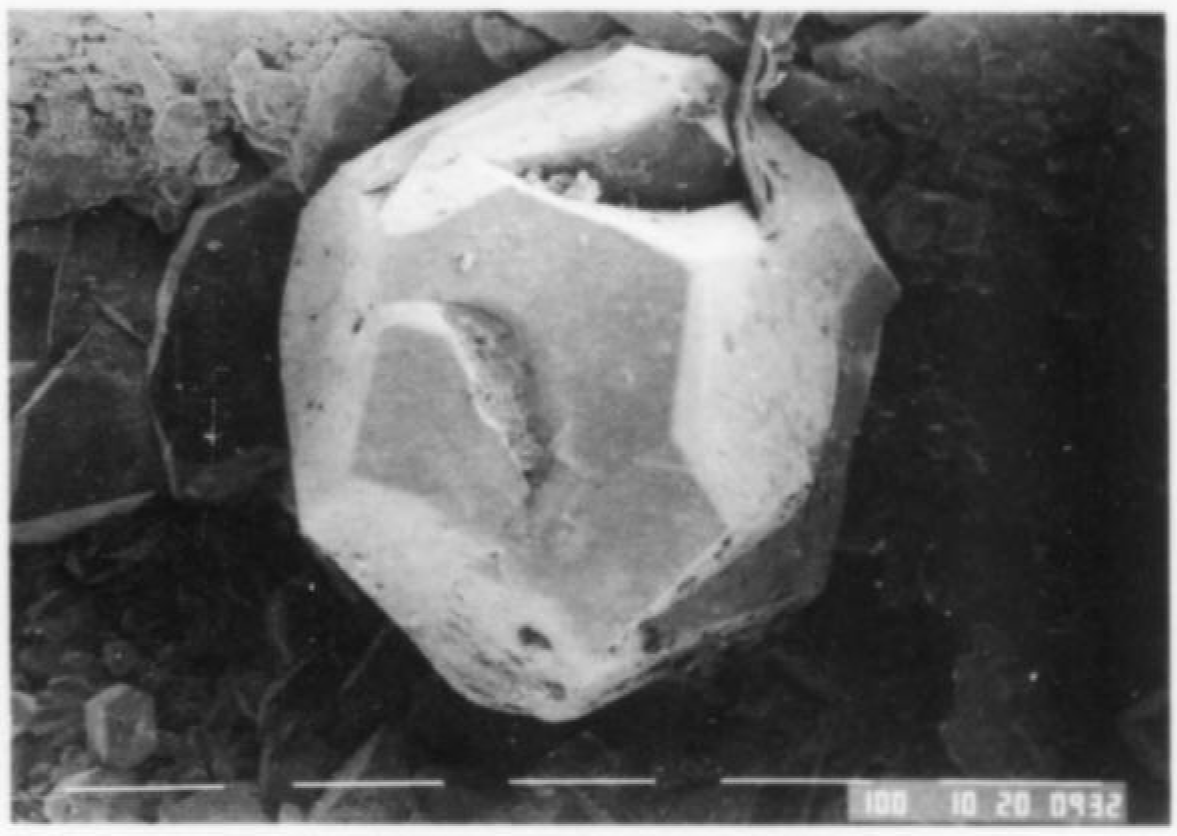

Figure 7. **Sphalerite in 1-mm quartz cavity, SEM photomicrograph at 25x. Tomáš Řídkošil specimens.**

The chemical composition of fizelyite is: Ag = 8.00, Cu = 0.33, Fe = 0.43, Pb = 35.59, Sb = 33.32, S = 21.69, total = 99.36 (weight %); the empirical formula: $(Ag_{1.973}Cu_{0.138})_{\Sigma = 2.111}Pb_{4.571}(Sb_{7.282}Fe_{0.205})_{\Sigma = 7.487}S_{18.000}$.

Miargyrite $AgSbS_2$

Miargyrite is present in the stibarsen orebody as granular aggregates (average grain size 1.5 cm) and rarely as prismatic crystals. The crystals of miargyrite are thick tabular on {001} or {100}, less commonly on $\{10\bar{1}\}$; cleavage {010} is imperfect; color is red-black, and thin splinters are translucent with a deep red color. Miargyrite also forms rectangular lamellae in andorite and fizelyite (Kašpar *et al.*, 1983). It is less abundant than pyrargyrite, and is one of the main silver minerals in the stibarsen orebody. The composition of miargyrite is: Ag = 36.35, As = 0.23, Bi = 0.21, Pb = 0.22, Sb = 42.56, S = 22.08, total = 101.64 (weight %); empirical formula: $(Ag_{0.979}Pb_{0.003})_{\Sigma = 0.982}(Sb_{1.015}As_{0.009}Bi_{0.003})_{\Sigma = 1.027}S_{2.000}$.

Pyrargyrite Ag_3SbS_3

Pyrargyrite is the most common silver sulfantimonide in both lenticular orebodies. Pyrargyrite-containing portions of the stibarsen orebody consist predominantly of stibarsen accompanied by native arsenic, miargyrite, pyrostilpnite, xanthoconite, andorite and fizelyite. Pyrargyrite occurs in aggregates up to several centimeters in size and very rarely as crystals up to 1 cm in length. The crystals have ditrigonal pyramids, a columnar habit, and the typical carmine-red color. The composition of the pyrargyrite is: Ag = 59.44, Cu = 0.03, Fe = 0.01, Sb = 22.91, S = 17.75, total = 100.14 (weight %), which is equivalent to $(Ag_{2.986}Fe_{0.001}Cu_{0.003})_{\Sigma = 2.990}Sb_{1.019}S_{3.000}$.

Pyrostilpnite Ag_3SbS_3

Pyrostilpnite forms radiating aggregates of fiery red color and adamantine luster, which occur intergrown in pyrargyrite and miargyrite, or separately in stibarsen cavities. Crystals resemble the habit of gypsum, reaching about 1 mm in size. In polished section pyrostilpnite is often associated with, and post-dates, pyrargyrite and miargyrite. The chemical composition of pyrostilpnite is: Ag = 60.53, As = 0.34, Bi = 0.37, Fe = 0.13, Sb = 21.93, S = 16.99, total = 100.29 (weight %). The corresponding empirical formula is: $(Ag_{3.177}Fe_{0.013})_{\Sigma = 3.190}(Sb_{1.019}As_{0.025}Bi_{0.010})_{\Sigma = 1.054}S_{3.000}$.

Silver Ag

Native silver is interpreted as the youngest ore mineral. It occurs frequently in the middle part of the galena orebody as irregularly formed wire-like aggregates, and very rarely as lamellae in calcite and galena. The maximum observed length of individual silver-white or yellow-brown to black-tarnished wires is 3 cm. Native silver often occurs as dendritic or skeletal inclusions in safflorite, rammelsbergite and skutterudite.

Table 1. **Minerals of the T-1 vein, Třebsko deposit.**

Acanthite	(S)	Niccolite	(G)
Andorite	(S)	Pyrargyrite	(G,S)
Ankerite	(G,S)	Pyrite	(G)
Annabergite	(G)	Pyrostilpnite	(S)
Arsenic	(S)	Quartz	(G,S)
Arsenolite	(S)	Rammelsbergite	(G)
Bournonite	(S)	Siderite	(G,S)
Calcite	(G)	Silver	(G)
Chalcopyrite	(G)	Skutterudite	(G)
Erythrite	(G)	Sphalerite	(G,S)
Fizelyite	(S)	Stephanite	(G)
Galena	(G)	Stibarsen	(S)
Gypsum	(G,S)	Stibnite	(S)
Hoernesite	(S)	Symplesite	(S)
Marcasite	(G)	Xanthoconite	(S)
Miargyrite	(S)		

G = Galena lenticular orebody
S = Stibarsen lenticular orebody

Stephanite Ag_5SbS_4

Stephanite occurs sporadically in zones enriched in silver, and is present in the galena orebody. It is associated with galena, sphalerite and pyrargyrite, in some places, with native silver, pyrargyrite and pyrite in others. Stephanite occurs as tabular crystals of lead-gray color and metallic luster, up to 1 cm in size. Electron microprobe analyses give the composition: Ag = 67.83, As = 0.38, Cu = 0.03, Fe = 0.02, Sb = 14.75, S = 16.16, total = 99.17 (weight %) equivalent to: $(Ag_{4.990}Cu_{0.004}Fe_{0.001})_{\Sigma = 4.995}(Sb_{0.962}As_{0.039})_{\Sigma = 1.001}S_{4.000}$.

Xanthoconite Ag_3AsS_3

Xanthoconite forms powdery orange coatings on stibarsen; it was identified by X-ray powder diffraction.

OTHER MINERALS

Ankerite $Ca,Fe(CO_3)_2$

Ankerite occurs in both orebodies as yellowish aggregates or rhombohedra up to 3 mm in size. It is less common than siderite.

Calcite $CaCO_3$

Calcite occurs only in the galena orebody, in three generations.

Galena PbS

Galena is a dominant vein-filling mineral of the galena orebody. It generally occurs together with siderite, sphalerite, ankerite, calcite, silver minerals and arsenides.

Quartz SiO_2

Quartz gangue is considerably less common than carbonate gangue; it is found in both orebodies. Quartz (I) is blue or gray and, together with siderite and sphalerite, is among the oldest minerals. Quart (II), smoky in color, fill drusy cavities.

Siderite $FeCO_3$

Siderite (I) is one of the oldest vein minerals. It cements breccias and forms veins and stringers of yellowish brown aggregates in both orebodies. Siderite (II) from the stibarsen orebody forms druses of rhombohedra up to 1 cm in size.

Sphalerite ZnS

Sphalerite occurs in two generations in the galena orebody whereas in the stibarsen orebody three generations were found. Sphalerite occurs as yellow-brown to red-brown grains with a strong adamantine luster. Sphalerite (II) from the stibarsen orebody forms rare, orange, pseudo-hexoctahedral crystals to 1 cm in size.

Stibarsen AsSb and Arsenic As

Both of these phases occur as typical botryoidal and dish-shaped, black to gray-colored aggregates. Their thickness reaches several tens of centimeters. The aggregates are penetrated by numerous veinlets with fine crystals of ankerite, miargyrite, pyrargyrite, pyrostilpnite and quartz. Native arsenic forms dense, layered aggregates inside stibarsen.

Supergene Minerals

Disjunctive tectonics as well as other favorable conditions have resulted in the formation of abundant supergene minerals: pink erythrite, green annabergite, and gypsum which accompany arsenides in the galena orebody.

In cavities in aggregates of stibarsen and native arsenic transparent cubic crystals of arsenolite up to 2 mm in size occur.

The drusy cavities in siderite (II) in the stibarsen orebody also contain symplesite. It forms radiating aggregates up to 5 mm in size. The color is pale green with a silky luster. In some cases hoernesite accretions on symplesite aggregates can be seen as white coatings.

CONCLUSIONS

The mineral filling of the T-1 vein on the 1st level of shaft No. 7 at Třebsko is rather variable in the horizontal direction. Tectonic processes have divided the ore mineralization into two lenticular orebodies. Along a relatively short horizontal stretch the two orebodies differ from each other in their mineral content, types of macrostructure and individual crystallization sequences. Siderite-sulfide and sulfantimonide periods in both bodies can be correlated. Along the short vertical interval available for study a conspicuous vertical zoning is seen in the galena orebody. In the lower part of the body Ni-Co arsenides prevail, whereas galena and abundant native silver predominate in the thickest part of the body. The upper part of the galena orebody consists predominantly of calcite and native silver. Vein T-1 is rich in silver minerals, including acanthite, andorite, fizelyite, miargyrite, native silver, pyrargyrite, pyrostilpnite and xanthoconite. Thus, the newly identified silver minerals at Třebsko not only increase the number of minerals known from the Příbram region, but also enrich our knowledge of the evolution and the mineral composition of ore veins in the upper parts of the Příbram ore deposits.

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What's New in Minerals?

TUCSON SHOW 1991

War in the Middle East and a recessional economy in the U.S. had their effect on attendance and sales this year, but not as badly as some had feared. Dealers began arriving and opening their motel room doors earlier than ever, and one dealer in Chinese minerals (*Tradewell*) was entirely sold out by the time he was originally scheduled to open! From the first openings to the final tear-down at the Convention Center, the event took just about three weeks, and most dealers reported good sales approaching what they had taken in last year. Paid attendance at the Tucson Convention Center was about 27,000, down 23% from last year.

Although there were many different motel shows operating more or less simultaneously, mineral collectors this year were able to find many (if not most) of their favorite dealers at one location: the Executive Inn on Drachman. It was the first year for this new show, organized by Marty Zinn, and by nearly all accounts it was a success; 80% of his dealers reported being very satisfied with sales, and, of these, 20% actually exceeded their sales of the previous year (wherever they were then). Certainly there were still good mineral dealers to be found at other motels; Carlos Barbosa, for example, was still at the Desert Inn (although he will be at the Executive Inn in 1992), and a number of dealers worth seeing were at the La Quinta, Travelodge and elsewhere. But in general it appears that the main focus for mineral collectors in the future will be the Executive Inn. This concentration is a welcome development, especially for collectors who can't visit Tucson long enough to tour all of the various shows.

As usual there were a great many excellent specimens available, mostly from continuing sources that have been mentioned here before and need not be repeated. A number of collections were also for sale,

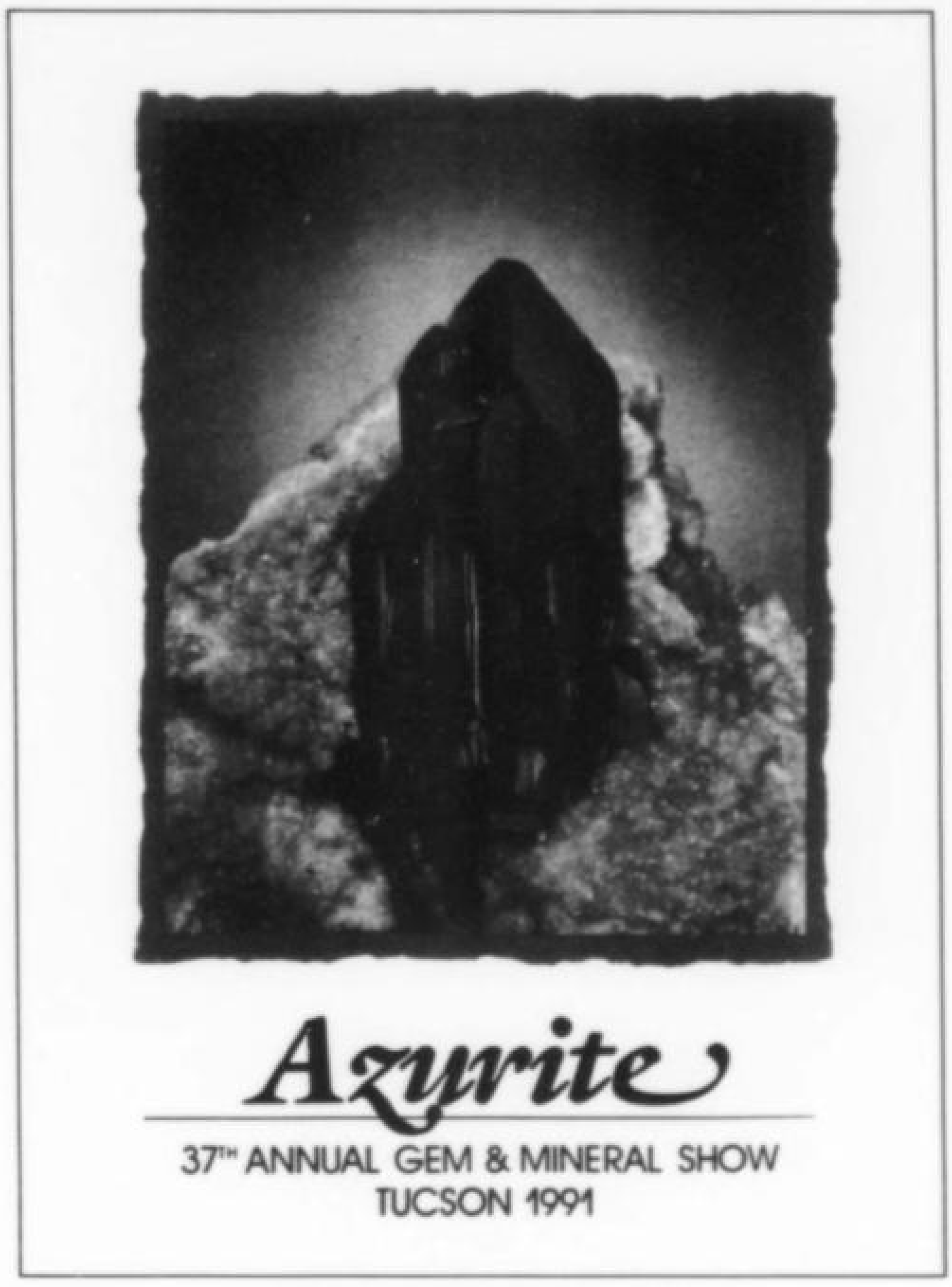

Figure 1. **Show Poster.**

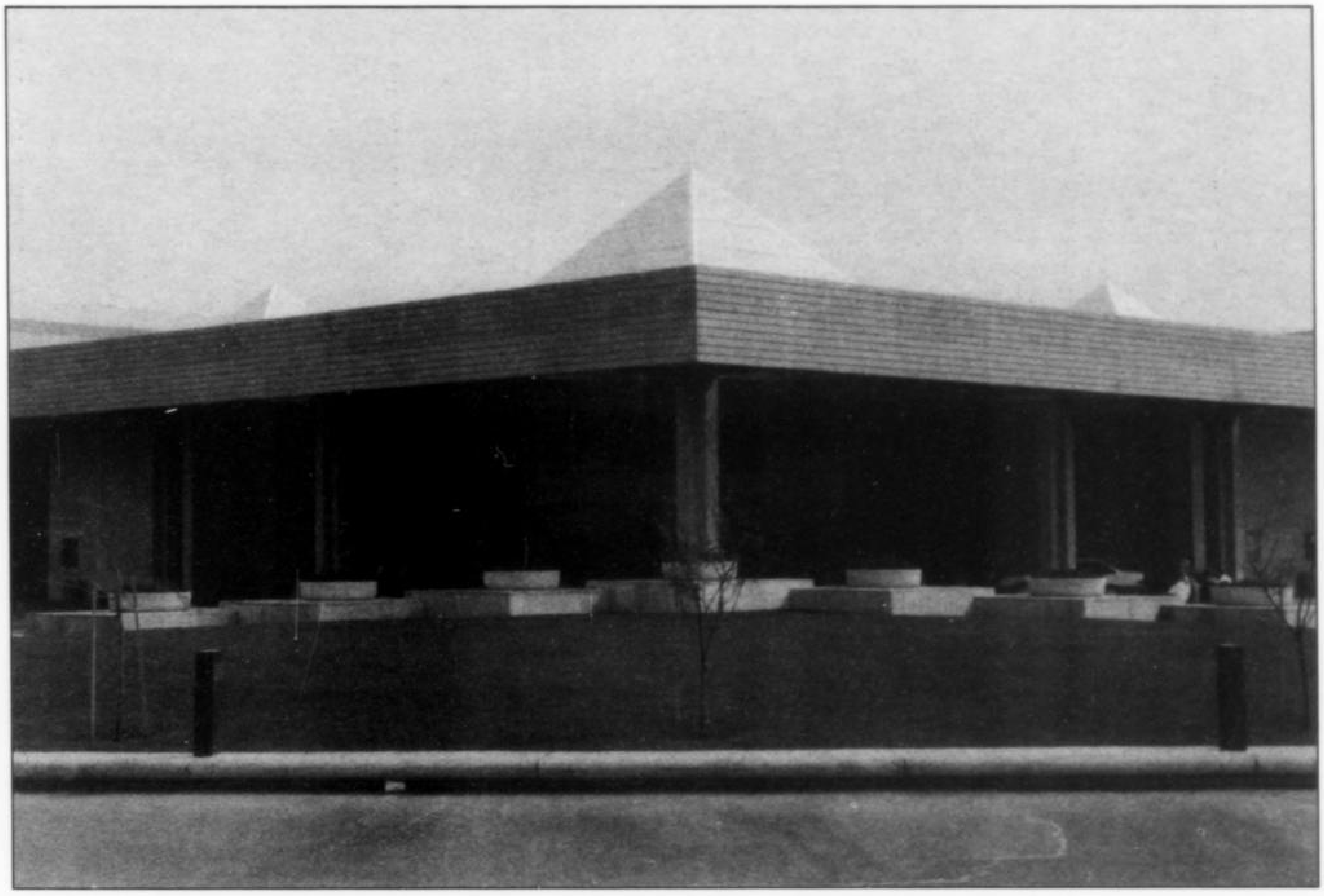

Figure 2. **Tucson Convention Center.**

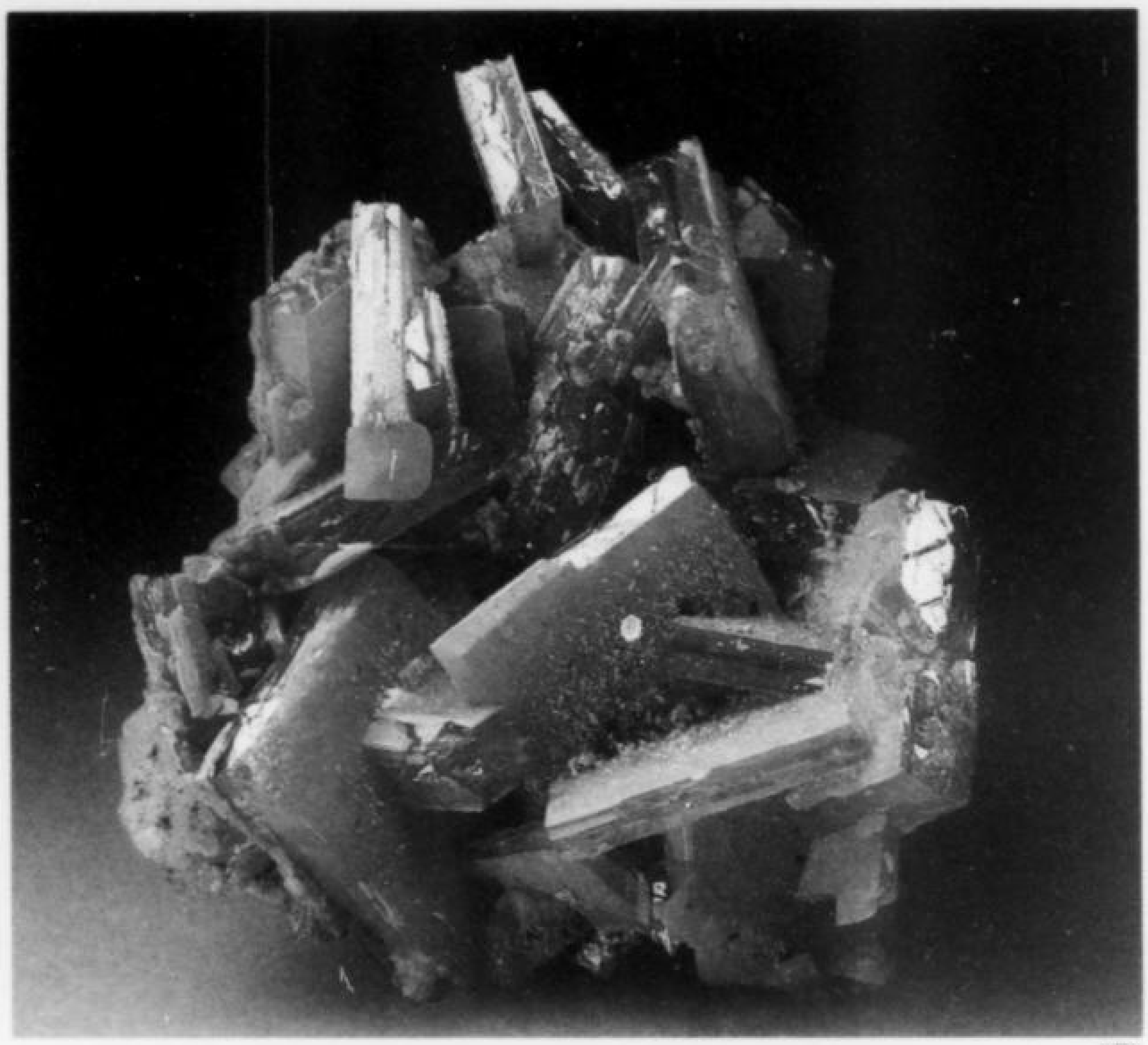

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Figure 3. **Stolzite group, 5 cm, from Sainte-Léger de Peyre, France. Jérôme Adani specimen.**

WEW

Figure 4. **Pyrrhotite crystal, 3.8 cm, on matrix, from the Nicolai shaft, Tetjhe, Primorskij Kraj, USSR. Bryan Lees specimen.**

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Figure 5. **Pink apatite crystal, 2.6 cm, on muscovite from Nagar, Pakistan. François Leitard specimen.**

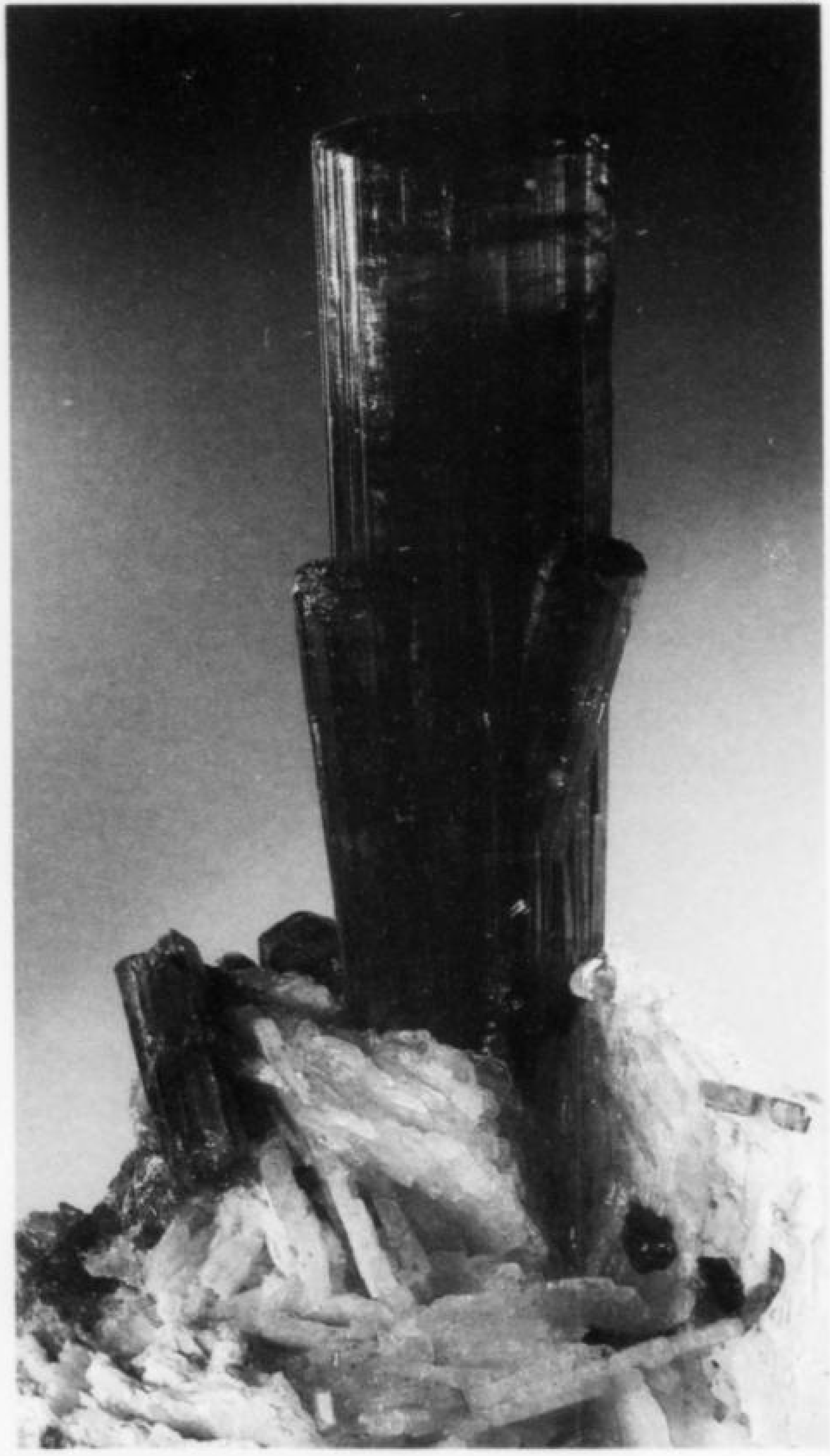

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Figure 6. **Elbaite crystal, 10 cm, on elbaite from the Cruzeiro district, Minas Gerais, Brazil. Helmut Brückner specimen.**

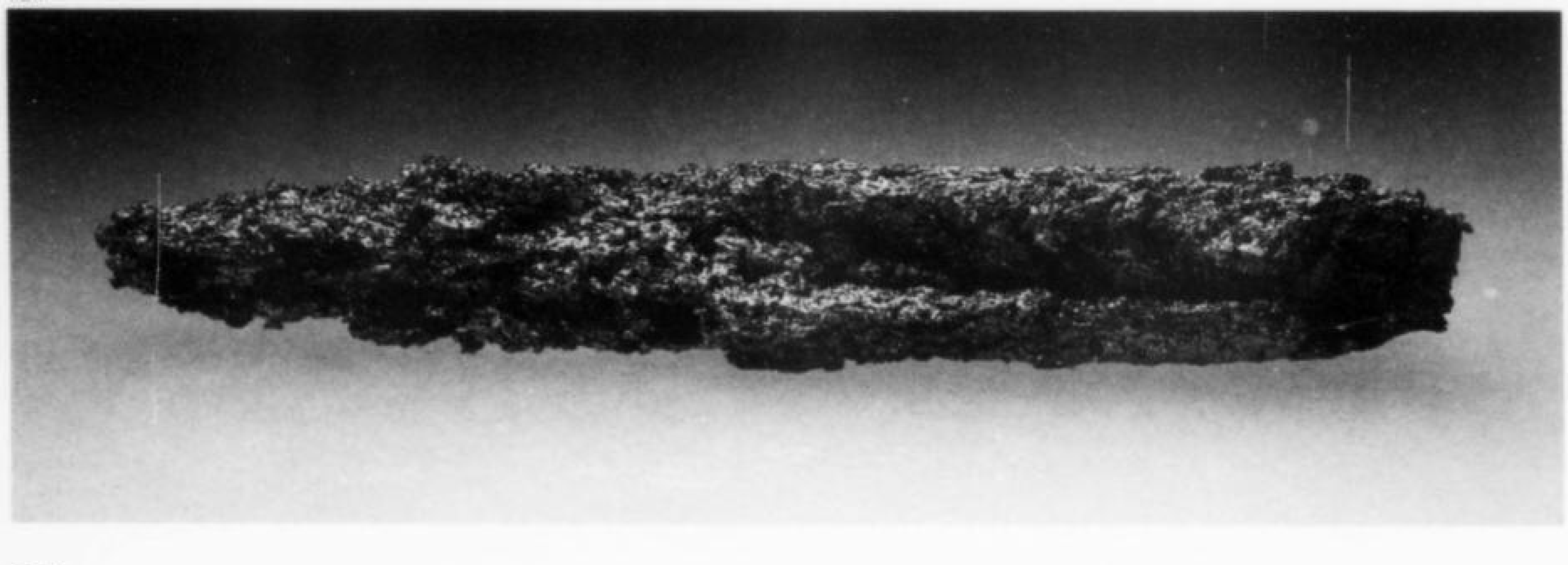

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Figure 7. **Palladian gold, 5.8 cm, from Itabira, Minas Gerais, Brazil. Carlos Barbosa specimen, now in the collection of the Natural History Museum of Los Angeles County.**

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Figure 8. **Aquamarine beryl crystals to 9.3 cm tall, from the Jaquetô mine, Bahia, Brazil. Alvaro Lucio specimens.**

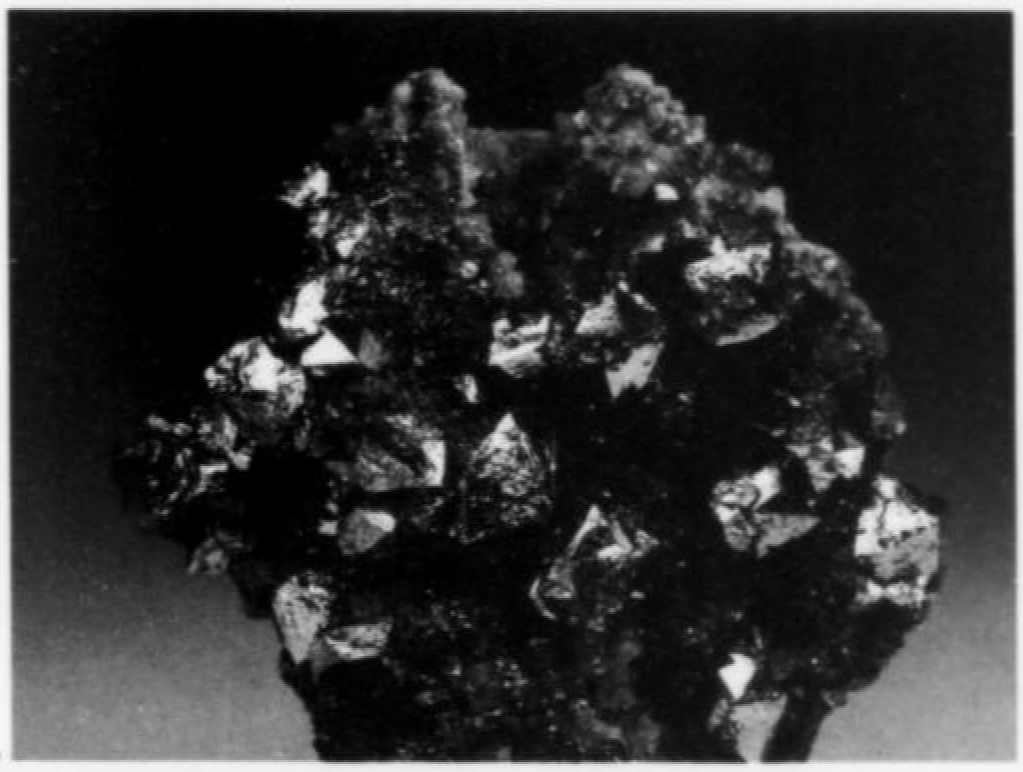

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Figure 9. **Siegenite crystals to 4 mm, from the Buick mine, Bixby, Missouri. Raging Mole Minerals specimen.**

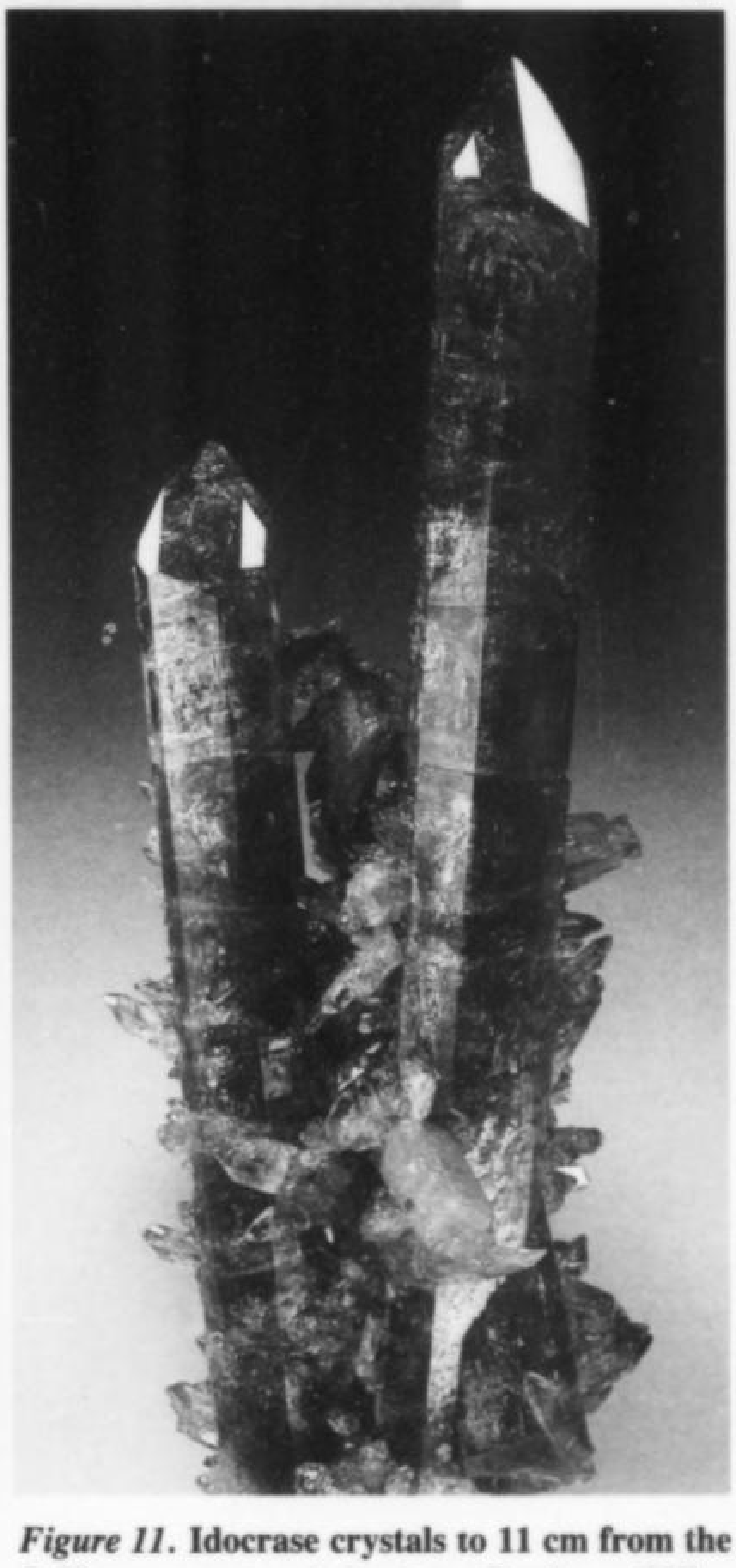

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Figure 11. **Idocrase crystals to 11 cm from the Jeffrey quarry, Asbestos, Quebec. Gilles Haineault specimen.**

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Figure 10. **Catapleiite crystal, 1.5 cm, from Mont Saint-Hilaire, Quebec. Jean-Pierre Cand specimen.**

and these contained some extraordinary specimens not often seen on the market these days. Sharon Cisneros (*Mineralogical Research*) had a portion of the Jack L. Parnau collection; Cal Graeber had several top-quality collections including those of Richard Olsen (of New Orleans), Gene Shier (of Austin), and a New York collection whose ownership was confidential; Wayne and Dona Leicht had more of the Robert Dietrich collection. And there were others.

Beginning with the motel dealers (because they opened first):

Jérôme Adani (Chemin de Fontenay, 12100 Millau, France) had nearly a hundred specimens of **stolzite** from the St. Lucie mine, Sainte-Léger de Peyre, Lozére, France. Stolzite, $PbWO_4$, is visually indistinguishable from its molybdate analog, wulfenite; lest anyone doubt the identification, Adani posted an EDAX scan above the specimens, clearly showing the tungsten peak. Small crystals and fragments from this occurrence have appeared on the market over the last year or two, but Adani's specimens are far and away superior, ranking as some of the world's finest examples of the species. The square, tabular crystals, many of them 3 to 4 cm across, have a peculiar pinkish beige color. A second generation of (paler) growth is visible around the rims.

Bill Schaub and David Kerry Jones (*Raging Mole Minerals*, 215 N. Madison Ave., Middletown, KY 40243) had a sizeable new batch (400–500 specimens) of **siegenite,** $(Ni,Co)_3S_4$, from the Buick mine, Bixby, Missouri. Very little of this material had been collected since the 1984 find (see vol. 15, p. 37–39), so the recent discovery was a pleasant surprise. The crystals, as before, show sharp edges and a bright metallic luster; many are spinel-law twins. Crystal size is generally around 4 mm, and the crystals occur liberally scattered on a dark, contrasting matrix.

Jay and Chris Buscio (*Dry Creek Minerals*, 9900 El Chorlito Drive, Rancho Cordova, CA 95670) had roughly 100 specimens of **aegirine** crystals in groups from Mt. Malosa, Zomba district, Malawi.* The crystals are black, prismatic and highly lustrous, resembling neptunite. Crystal size ranges from 1 to 8 cm in length. Terminations are of two types: steeply pointed and rather flat. Associations commonly include white to grayish white microcline crystals to 2 or 3 cm, and smoky quartz crystals to 4 or 5 cm. Beryl and pinkish microcrystals of a mildly radioactive unknown have also been found there.

Alvaro Lucio (Caixa Postal 1286, 30000 Belo Horizonte, Minas Gerais, Brazil) had some attractive **aquamarine beryl** crystals from a new find at the Jaquetô mine, Medieros Netos County, Bahia, Brazil. Forty crystals of significant quality comprised the lot, in sizes of 3 to 12 cm. The crystals are highly etched floaters (no matrix or points of attachment), commonly barrel-shaped but also more elongated, with a myriad of tiny, sparkling etch faces along the prism zone and many-pointed terminations. The color is a very pleasant, medium sky-blue, although probably not dark enough to show well in faceted stones.

Alvaro also had some large (to more than 20 cm) and interesting groups of **lepidolite** from the well-known tourmaline locality at Barra de Salinas, Minas Gerais. The irregular crystals have straw-like prism sides and flat terminations to 3 or 4 cm across. These pale lavender crystals occur growing on and surrounding much larger, darker purple lepidolite crystals.

Alvaro and also *Vasconcelos* (Governador Valadares, Minas Gerais, Brazil) had some attractive new **tourmaline** crystals and groups from a mine in the Cruzeiro district, Minas Gerais. These crystals are finger-size to more than 10 cm in length and show bright pink cores surrounded and topped by greenish blue tourmaline, sometimes with platy white albite matrix. The *Rocksmiths* (at the Convention Center) also had specimens from what is apparently the same locality although these crystals (up to 10 x 15 cm) consist primarily of rubellite, with bright, lustrous, dark red terminations and mottled pink prisms.

Henry Schmidt (*Mineral Miner*) had several hundred Roman-sword **celestite** crystals from the White Rock quarry, Clay Center, Ohio. The crystals are white to palest blue, and range up to 30 cm long and 3 cm wide; some have thick cross-sections to 2 x 6 cm, but most are rather thin, and lack matrix. A few are doubly terminated, and the majority show chevron phantoms along their length.

François Lietard (*Minerive*) had some of the highest quality specimens at the Executive Inn, mostly pegmatite minerals from Afghanistan and Pakistan. Included in his stock were deep pink **apatite** crystals to 2.6 cm, on muscovite matrix, from Nagar, Pakistan; gemmy, deep green **diopside** crystals to 4 or 5 cm from Kaflu (?), Pakistan; classic **lazulite** crystals to 3 cm from Sar E Sang, Nuristan, Afghanistan; and white **beryllonite** crystals, equant and deeply striated, to 4 cm across, from Pakistan.

Rod and Helen Tyson (*Tyson's Minerals*) had some remarkable crystals of native **antimony** from the Lake George antimony mine, New Brunswick. Twenty-two of the specimens, with frosty, 1-cm rhombs of antimony, were collected in 1989. An article on the occurrence has been written and will appear shortly.

Rod and Helen also had some new **idocrase** groups collected last year at the Jeffrey quarry, Asbestos, Quebec. These consist of prismatic, yellowish green crystals with steep terminations and glassy luster. Fine groups of 2–3 cm crystals were available, including a museum-size group about 20 cm tall, but the showpiece of the pocket is a stunning pair of crystals to 11 cm, held together in their lower half by many smaller crystals (owned by Gilles Haineault).

Carlos Barbosa had specimens of silver-colored **palladian gold** (about 6% Pd) from Itabira, Minas Gerais, Brazil. They occur as elongated growths with irregular surfaces typical of arborescent metals.

Bryan Lees (*Collector's Edge*) is developing into a primary source for top quality specimens from the Soviet Union. Among his stock I noted fine miniatures of wire **silver** from Shaft 46, Dzezkazgan, in central Kazachstan; sharp, lustrous **pyrrhotite** crystals to 4 cm from the Nicolai shaft, Tetjhe, Primorskij Kraj; and arborescent **gold** specimens (thumbnails mostly) from the Lena River district. In fact, Bryan's entire stock of worldwide specimens sparkled with a *consistent* level of high quality that most dealers can only aspire to.

Dalton and Consie Prince (*Collector's Choice*) had many specimens of the excellent new **hemimorphite** discovered last year at Santa Eulalia, Mexico. The crystals are large, many reaching over 6 or 7 cm, white to water-clear and rather thick (distinguishing them from the famous Ojuela mine specimens known for so many years). I have seen fine specimens of this material available from many different dealers including Chris Wright, Gene Schlepp and others.

Dalton and Consie also had cabinet specimens of a recent find of pale green **datolite** crystals from Charcas, San Luis Potosi, Mexico. These resemble the groups from Dalnegorsk, Siberia, although the individual crystals are not as large (perhaps 2 or 3 cm).

Chinese **cinnabar** was widely available again this year, from a number of sources, and I would not mention it again but for the appearance of a spectacular specimen which Tom Palmer (*Crystal Cavern Minerals*, El Paso) sold to the Los Angeles County Museum of Natural History. This penetration twin, without matrix, measures 3.7 cm and is said to have come from Duyun, Guizhou Province. If it's not the best such twin in the world, it certainly has few rivals. Tom has been working in recent years to build up his contacts in China, and this year he offered a large array of high-quality Chinese specimens accumulated from many trips over a two-year period. Doug Parsons, Peter Wu (*Tradewell*), John Li (*Wydar Company*), Horst Burkard and several other dealers have all been working to open up Chinese sources to the Western market.

Doug Parsons, in addition to his usual stock of display-quality Chinese minerals, is one of the few dealers (if not the *only* one) concentrating significantly on the rarer and less spectacular but mineralogically interesting species from that country. One of the most

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*Formerly Nyasaland, a small republic in southeastern Africa, situated between Mozambique, Zambia and Tanzania.

interesting curiosities this time is transparent quartz crystals with inclusions of metallic **cosalite** crystals to a few millimeters long, from Chenzhou prefecture, Hunan.

At the TGMS show at the Convention Center, Cal Graeber had several fine specimens of **dioptase** from a new locality at 'Mbumba near Sanda in the Congo Republic. Actually the mine has been operating for about ten years, but Giuseppe Agozzino (a Milanese dealer who has been going there) held back his specimens for several years in the hope that production would increase. (It didn't.) The specimens Cal had were brought out by Giuseppe in 1983 and were only now being released. The crystal habit is similar to other Congo occurrences in being somewhat elongated relative to the typical Tsumeb habit, but not as attenuated as the smaller crystals from Kaokoveld, Namibia. The 'Mbumba crystals are quite large, up to 3.4 cm (1.33 inches), and occur in solid groups lacking much matrix. These beautiful specimens are certainly sufficient to place 'Mbumba on the short list of the world's most notable dioptase occurrences.

Cal also had some excellent, deep red, partially gemmy, scalenohedral **rhodochrosite** crystals to about 3 cm from the Peruvian locality at Uchuchaqua (an example is on the cover of the January 1991 issue of *Lapis*). Mike Bergmann (*Galena Rock Shop*, 713 S. Bench St., Galena, IL 61036) had a fine specimen of wire **silver** from this same locality. Also in Cal's stock were some cabinet-size groups of pink rhombohedral **rhodochrosite** resembling Colorado specimens from the Grizzley Bear mine or the American Tunnel, except that these were from the Santa Rita mine, Casapalca, Peru.

Dagmar Müller (Schillerstr. 15, D-7015 Korntal, Germany) had some large and attractive cabinet specimens of blue-gray platy **barite** from Cavnic, Romania. The groups, 10 to 15 cm across, are dense, sharp and lustrous.

Frank and Wendy Melanson (*Hawthorneden*) also had Cavnic specimens, primarily **tetrahedrite** crystals on a matrix of very pale pink, botryoidal rhodochrosite (or perhaps manganoan calcite). The tetrahedrites are sharp and lustrous, in simple tetrahedral habit, and range in size from approximately 1 to 3 cm on edge. Cavnic specimens have been relatively abundant on the European market for the last few years, and a person could build quite a nice suite from this old classic locality.

Frank and Wendy also had 100 to 200 specimens of palest green **beryl** in highly etched fragments from Mina Chia near Linopolis. The specimens, mostly miniatures and thumbnails, are brightly lustrous and, due to the intense etching (which must have dissolved a significant proportion of the original crystals), are beginning to take on free-form shapes impossible to orient. These show hundreds of distorted and curved "faces" intersecting each other to produce a beautiful diamond-like effect.

Also in Frank and Wendy's booth was a surprising array of very fine, old **descloizite** specimens from Berg Aukas, Namibia. These had been in storage for 13 or 14 years and only now brought out. (What *else* is in your garage, Frank?) Berg Aukas is certainly the world's premier locality for the species, and Frank's specimens (mostly miniatures) were of the highest quality, lustrous, aesthetic and free of damage.

Gene Schlepp (*Western Minerals*) had a dazzling specimen of recently collected **pyrargyrite** from Fresnillo, Zacatecas. It consists of a 5-cm crystal, about 2.7 cm thick, with a couple of smaller crystals around the base. The prism sides are complex, and the termination is a very low-angle rhomb or pyramid. The extraordinary thing about this lustrous, damage-free crystal is that the interior is totally transparent and a deep blood-red. This is surely one of the finest pyrargyrites in existence.

Gilbert Gauthier brought some recently found, dark golden **calcite** crystals from the Mashamba-West mine, Shaba, Zaire. The crystals are lustrous, very gemmy, and prismatic, up to 1 x 3 cm or so, with three-faced rhomb terminations. Dark green malachite balls make a nicely contrasting association. Like the pink cobaltoan calcites from the same mine, these little jewels will be important acquisitions for calcite collectors.

Les Presmyk (*De Natura*) had several very fine **hematite** crystals and groups collected recently at the Veta Grande claim, La Paz County, Arizona (see vol. 11, p. 227). These are Arizona classics, with their large, mirror-smooth faces and associated quartz crystals.

Bruno Higgins (*Bellavista Minerals Ltd.*, Grossackerstr. 100, CH-8041 Zurich, Switzerland) had several octahedral, pink-red **spinel** crystals 1 to 2.5 cm on edge, from Tanzania. In addition, he had some very beautiful, water-clear, mirror-faced, purple cubic **fluorites** to about 2.3 cm on edge, from Durango (La Nora mine?), Mexico. Eight specimens including at least two fine cabinet pieces with matrix were recovered in December 1990.

Brian Cook (*Nature's Geometry*, P.O. Box 662, Draton, CA 95444) did not have a booth at the Convention Center, but he did have a small exhibit there, showing some thumbnail crystals of **cuprian elbaite.** Discovered by Heitor Barbosa in 1987, this material caused a sensation on the gem market because of its extraordinary blue colors; crystal fragments and cut stones commonly sell for around $1,000/carat, and sometimes up to $5,000/carat. This high gem value, combined with the fact that crystals are typically found shattered, broken and embedded, has resulted in the extreme rarity of crystal specimens. The occurrence is a series of pegmatite veins known as the Batalha mine, located northwest of Salgadinho and very near the village of São José da Batalha, Paraíba, Brazil. The most attractive color is a very bright, clean turquoise-blue, grading into colors described variously as sapphire-blue, tanzanite-blue, "electric"-blue, benitoite-blue, blue-green, sea-green, lettuce-green, emerald-green, and purple. Crystals are strongly pleochroic, changing from turquoise-blue to sapphire-blue as they are turned in the light. According to a recent article in *Gems & Gemology* (vol. 26, no. 3), the turquoise-blue color is the result of Cu^{+2}, in amounts up to 2.38 weight % CuO. This is the only known instance of copper acting as a coloring agent in tourmaline. (Mn^{+3} causes the purple coloration, but can be neutralized to Mn^{+2} by heating. Cu^{+2} is unaffected by heat treatment.) Several kilograms of cuprian elbaite were recovered from the "big pocket" found in 1989, but the mine was inactive in 1990. The surviving crystals are small, prismatic, in some cases deeply striated and etched, with complex rhombohedral terminations. Shattered crystals up to 30 cm were seen in place but could not be removed intact. Associations include quartz (colorless, milky, smoky, citrine and amethyst); muscovite in white, pale green and pink books to 6 cm; and pale to dark purple lepidolite. All original feldspar at the deposit has been altered to kaolinite.

Other highlights which come to mind include: more French **axinites** (Michel Jouty); a superb thumbnail of Mont Saint-Hilaire **catapleiite** (Jean-Pierre Cand); cabinet specimens of newly collected **franklinite** etched out of enclosing calcite by Dick Hauck; fine Rowley mine (Arizona) **wulfenites** from a large pocket mined recently by George Godas; superb green **apophyllites** from Aurangabad, India (Ken Roberts; *Zeolites India*); huge **siderite** rhombs to 8 or 9 cm from Pedreira Atalaia, Brazil (*Valadares Minerals*); dozens of fine Pakistan **aquamarines** (Wayne Thompson and others); French **bournonites** (Ernesto Ossola); superb Chinese **realgar** miniatures (Ken Roberts); and many others.

EXHIBITS

Azurite was the featured mineral this year, and some (many!) of the world's best and most famous specimens were on exhibit at the Convention Center. These are too numerous to mention, so I will instead note briefly *some* of the *non*-azurite displays that were impressive: Jim Blees's thumbnail collection; Ralph Clark's thumbnails; Joe Kielbaso's antique set of Krantz glass crystal models; Keith Proctor's famous "Rose of Itatiaia" tourmaline (Keith really deserves credit

Figure 12. Cinnabar penetration twin (two views), 3.7 cm, from Duyun, Guizhou province, China. Tom Palmer specimen, now in the collection of the Natural History Museum of Los Angeles County.

Figure 13. Diopside crystals to 4 cm from Kaflu (?), Pakistan. François Leitard specimen.

Figure 14. Dioptase crystal, 3.4 cm, from 'Mbumba, Congo Republic. Cal Graeber specimen.

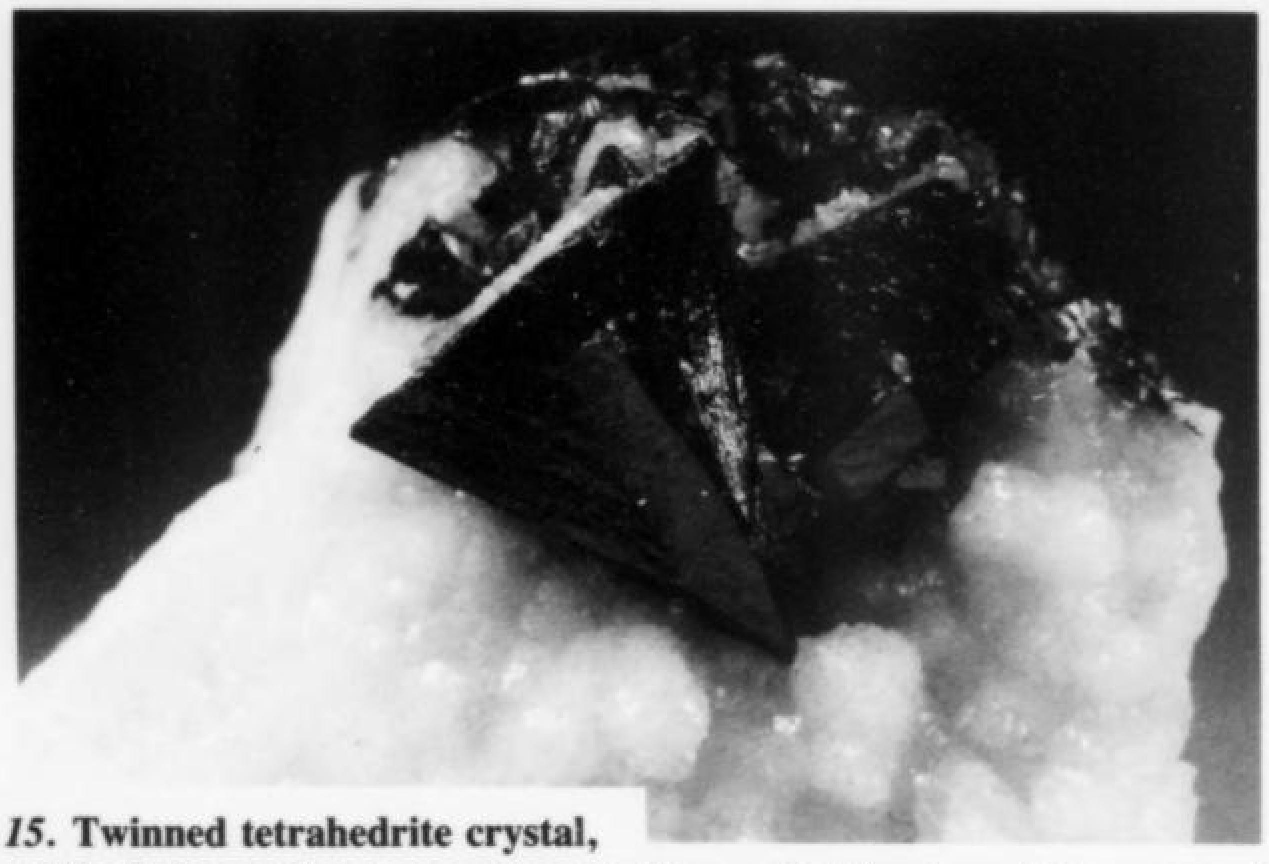

Figure 15. Twinned tetrahedrite crystal, 1.2 cm, with chalcopyrite on manganoan calcite, from Cavnic, Romania. Frank Melanson specimen.

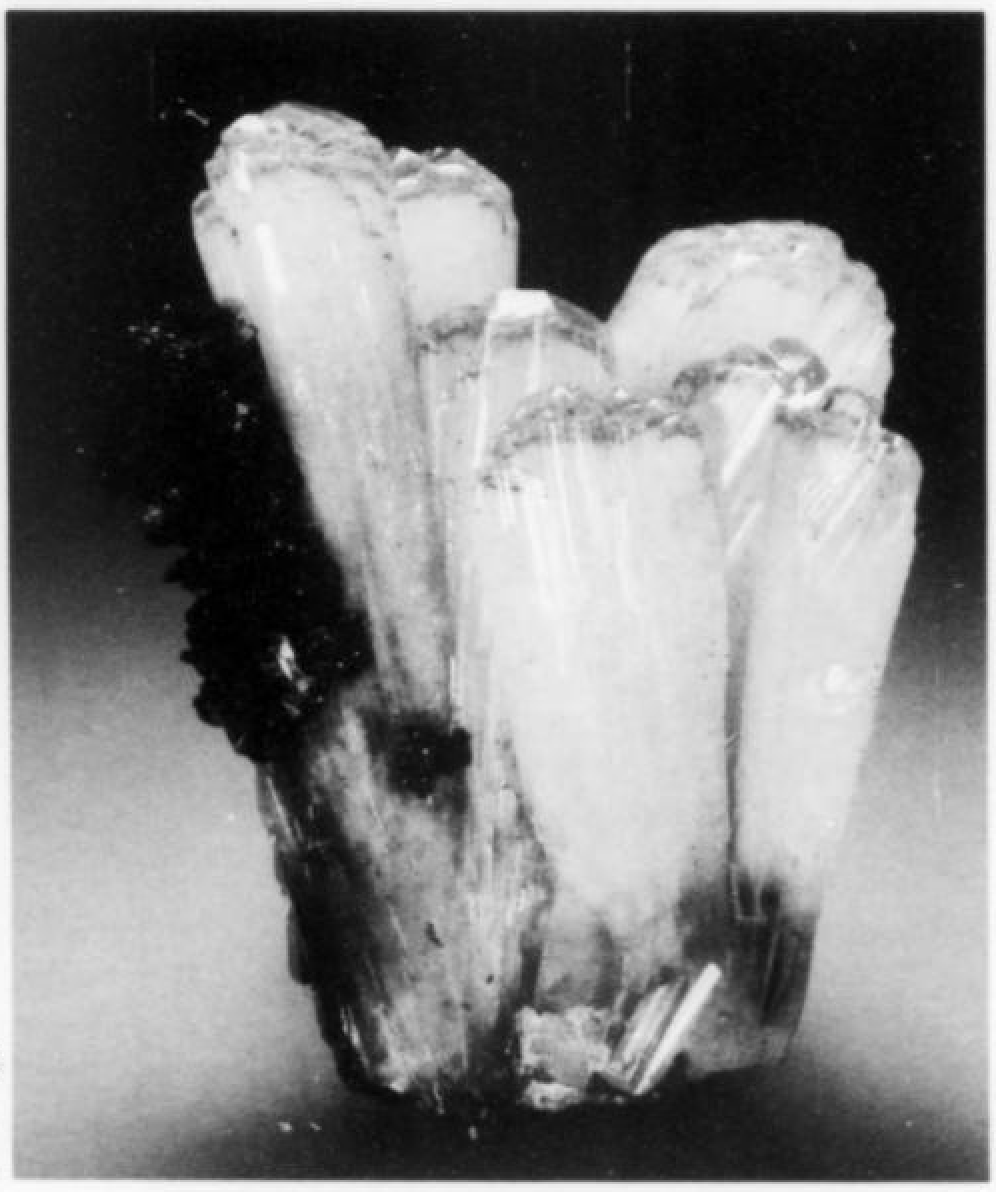

Figure 16. Hemimorphite group, 7.6 cm, from Santa Eulalia, Mexico. Dalton and Consie Prince specimen.

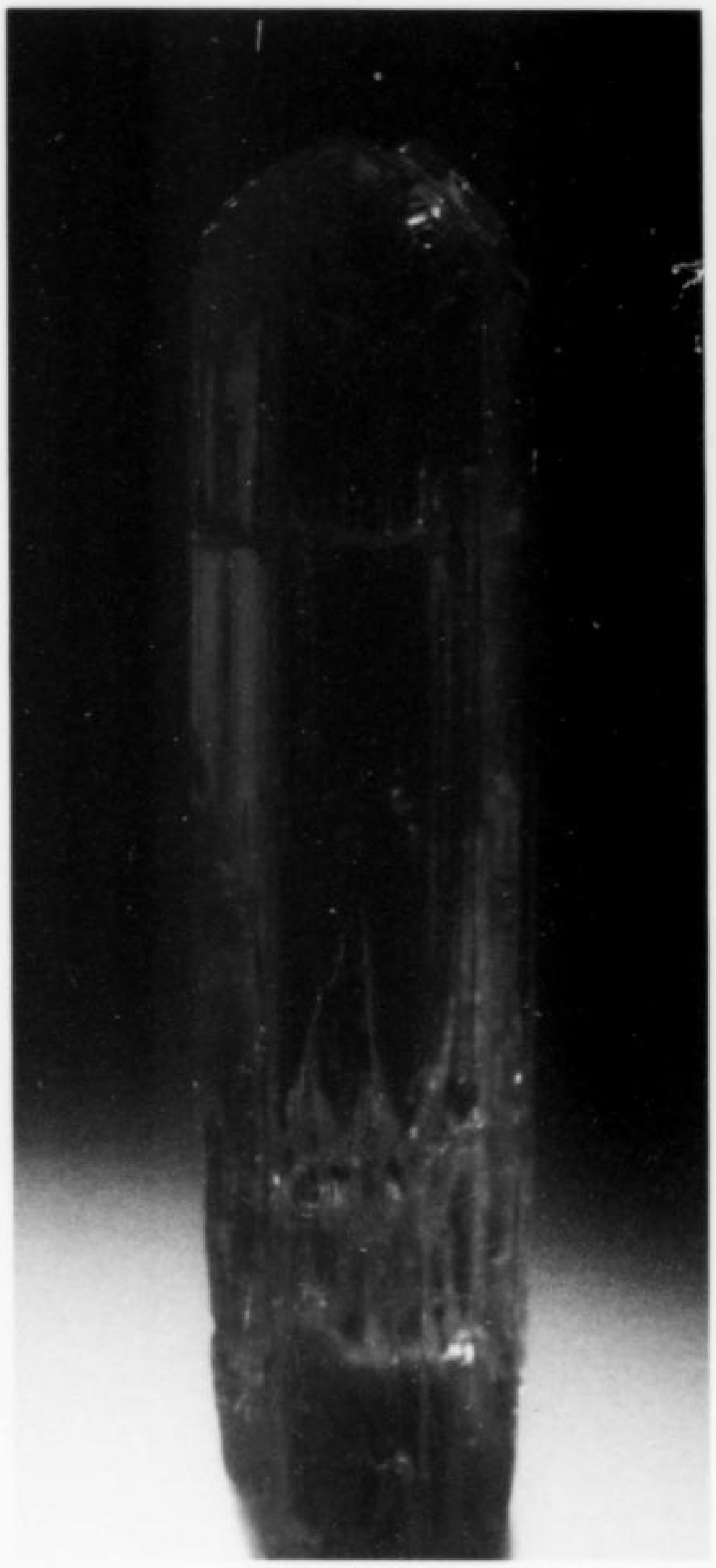

Figure 17. Cuprian elbaite crystal, 2.2 cm, from the Batalha mine, Paraiba, Brazil. Brian Cook specimen.

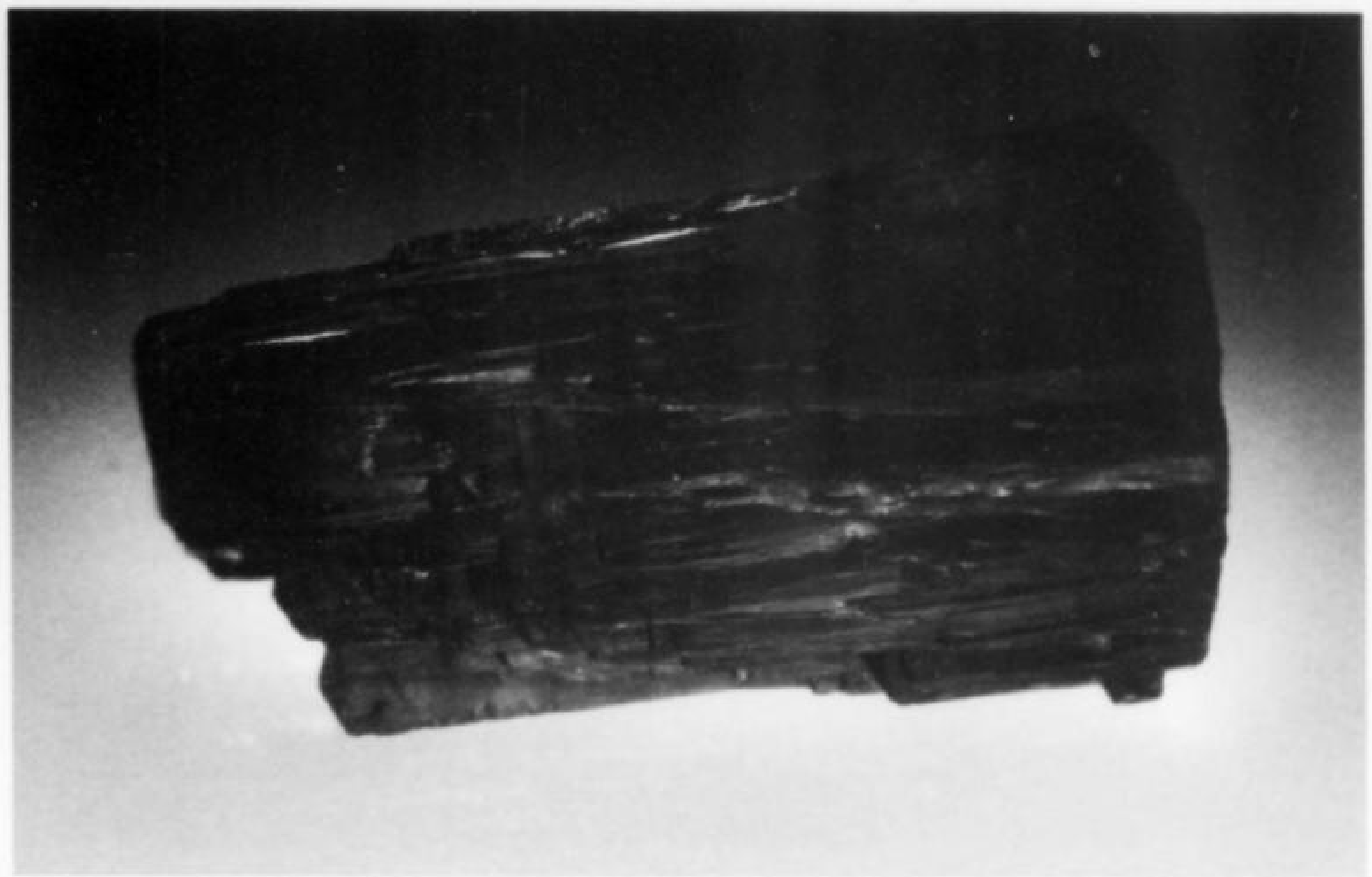

Figure 18. Cuprian elbaite crystal, 1.6 cm, from the Batalha mine, Paraiba, Brazil. Brian Cook specimen.

Figure 19. Cuprian elbaite crystal, 3.3 cm, from the Batalha mine, Paraiba, Brazil. Brian Cook specimen.

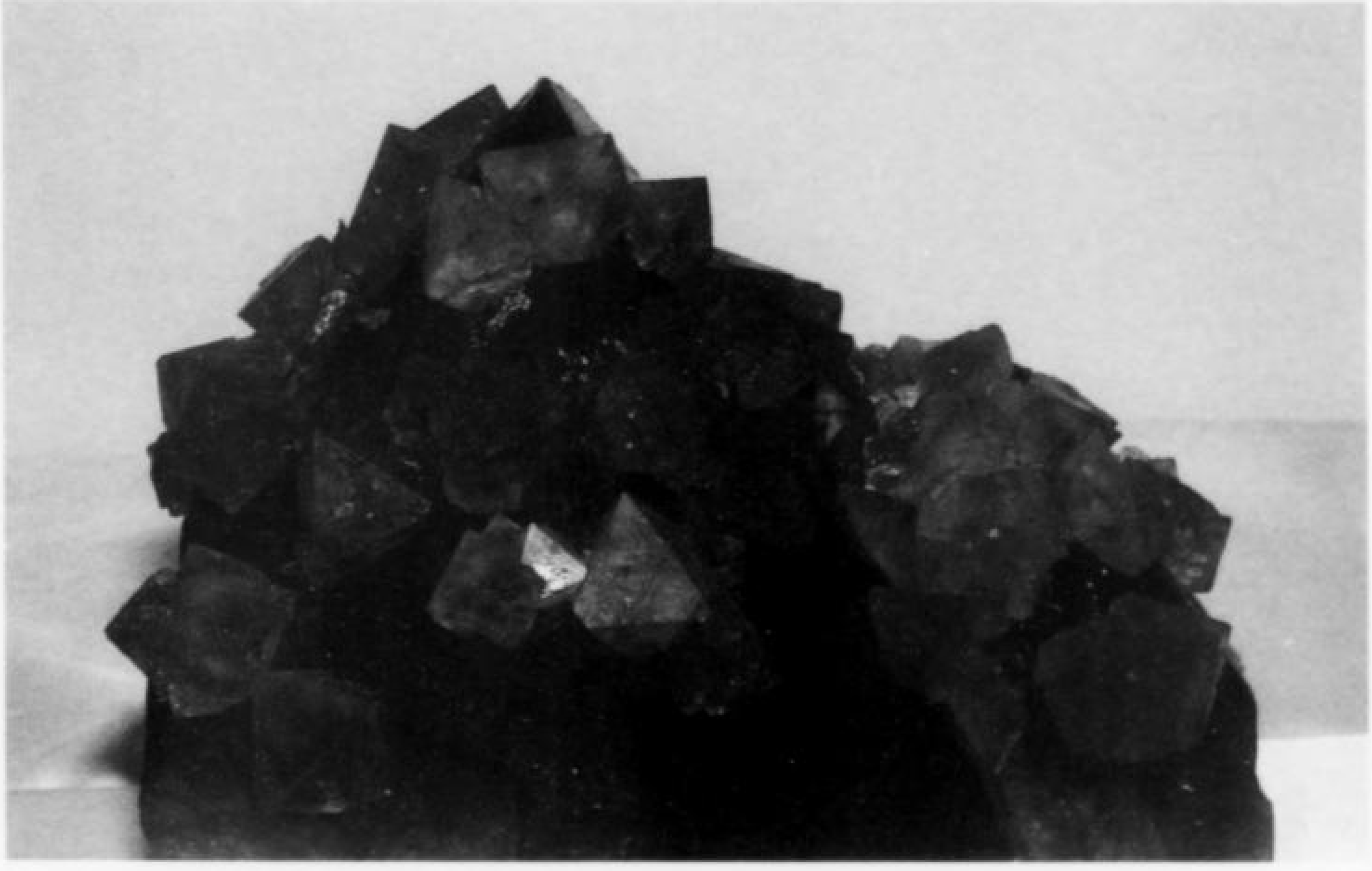

Figure 20. Pink fluorite on quartz, 18 cm across, from Chamonix, France. Wayne Thompson/Gene Meieren/Ed Swoboda specimen.

Figure 21. Pyrargyrite crystal, 5 cm, from Fresnillo, Zacatecas, Mexico. Although backlit only at the top in this photo, the crystal is equally gemmy throughout. Gene Schlepp specimen.

Figure 22. **The four winners of the Carnegie Mineralogical Award: (left) John Sinkankas, 1988; (in back) Peter Megaw representing the Tucson Gem and Mineral Society, 1987; (center) Frederick Pough, 1989; and (right) Paul Desautels, 1990. Photo by Carolyn Wilson.**

for transporting this very heavy and fantastically superb specimen to shows for collectors to see); the three cabinet specimens (owned jointly by Wayne Thompson, Gene Meieren and Ed Swoboda), a huge quartz crystal from Chamonix, France, covered with 2-cm pink fluorite octahedrons, an aquamarine with pink apatite and an aquamarine with cuboctahedral fluorite, both from Nagar, Pakistan; Andreas Weerth's beautiful, brown Pakistan topaz on white matrix; Bill Smith's historical case based on the Lechner collection; the Kongsberg Mining Museum's case of spectacular silvers; Panasqueira minerals in the Portuguese National Museum of Natural History case; and the A. E. Seaman Museum's case of classic Michigan Copper Country minerals (including specimens from the Wayne State University and Cranbrook Institute collections).

Surely there is no other event of any kind, anywhere in the world, capable of drawing together in one place such a fabulous abundance of mineral exhibits. The Tucson Show is unique in this respect. I urge everyone, particularly those who have never attended before, to make plans to visit the 1992 Tucson Show. Pyromorphite will be the featured mineral. Show dates will be February 13–16 (back to four days) at the Convention Center, and the motel dealers will probably begin opening their doors around the 5th or 6th.

HONORS

This year Paul E. Desautels, former curator of minerals for the Smithsonian Institution and for the Perkins Sams collection at the Houston Museum of Natural Science, was awarded the fourth annual Carnegie Mineralogical Award in honor of his lifetime of achievements. In his acceptance speech he briefly reviewed how far the hobby has come since he began mineral collecting in the early 1930's; back then there were no mineral shows, practically no mineral dealers, and no full-color mineral magazines. We can all be grateful for the highly developed nature of the *mineralculture* today, and for the significant role Paul played in that development.

As a result of the death of Al McGuinness, the McDole trophy was regretfully retired this year. There will be no more swigging from Ed's original rum bottle, and no more collectors officially joining with Ed in the ranks of the "Old Bounders." However, such a vacuum could not be allowed to remain. An award, ranking as the top mineral collecting honor in the world, was still needed. Consequently the Tucson Gem and Mineral Society established a new award in place of the McDole trophy this year: the Paul Desautels Award. The first recipient was Gene Meieren. Collectors interested in competing for this honor at the 1992 show should contact the TGMS for details.

Annual List of Volunteers

Our thanks to the following people who donated their time to helping the Mineralogical Record during the previous year, as subscription agents, at show tables, and selling raffle tickets.

Pat Barker
Bill Basbagill
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Bob Chavez
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David Crawford
Grace Dyck
Mel Dyck
Piers Foa
Harvey Gordon
Cal Graeber
Kerith Graeber
Tom Gressman
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Terry Huizing
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Horst Windisch
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Miriam Zweibel

Annual List of Donors

Our thanks to the following people, whose generosity contributed very substantially to the quality of the *Mineralogical Record*, and to the Mineralogical Record Library (the list does not include purchasers of the Antiquarian Reprint Series books and the Tucson Show raffle tickets).

Anonymous (Canada)
Anonymous (Georgia)
Peter Bancroft
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Lawrence H. Conklin
Ralph Dames
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Tom Gressman
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Gary Hansen
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Fred Steinar Nordrum
Norm and Roz Pellman
Arthur Roe
Miguel Romero
Randolph S. Rothschild
Ann Vossbrinck

Notes from Europe

by **Thomas Moore**

MUNICH SHOW 1990

This year's show took longer to arrive than usual: rather than mid-October, the show didn't happen until mid-November. But when I finally arrived at the Munich Fairgrounds to help open the place for the Friday "insiders' " day, I found an unprecedented *four* halls (1, 2, 3 and 5) occupied by dealers and other bustling enthusiasts, and more special features than ever before. The show this year, for the first time, went American to the extent of providing space for non-competitive displays from private collections. These filled two ranks of cases, one small case per collection sampling, down the middle of *Halle 5*. The displays ranged from an excellent Tsumeb suite put in by S. Schweisfurth of Siegen, to a handful of first-rate fluorites from Herb Obodda, through a group of modest quartz specimens self-collected by an eastern (formerly East) German hobbyist, among others. It's nice to finally see this concept adopted at Munich.

Along one wall of *Halle 1* was an array of original oil paintings of mineral specimens by Giuse Frank-Patania of Zürich, all of them quite beautiful. For the very young, a huge plastic basin full of turbid brown water and gold-dust-seeded gravel offered a rare opportunity for indoor gold-panning practice and bare-ankled sloshing, while parents perchance were browsing in the related alcove devoted to the show's secondary theme, "Gold in Bayern." This area contained displays of specimens, maps, documents and mining paraphernalia from the old Bavarian mining town of Goldkronach, historically Germany's only locality for native gold *in situ*.

The primary show theme, however, was *Calcite,* and such was the grandiosity and dazzlement of *this* display area that I must dilate on it for an extra paragraph or two—with a side-commendation herewith for the 200-page show booklet on calcite. It contained an especially appetizing 30-page locality survey piece, "Beautiful calcite crystals worldwide," which was liberally illustrated with beautiful photos to show exactly what calcite collectors' dreams are made on.

The outer perimeter of the calcite *Sonderschau* area was approached through a maze of flat-lying slabs of fossiliferous travertine and other calcareous rocks. One came finally to a ring of green-felt-covered upright dividers, inside which was a circle of vertical glass cases with fine calcites arranged by localities, plus two flat cases of beautiful faceted calcites exhibited by Arthur Grant. Then came a majestic inner ring of tall, upright slabs of limestone and marble from famous localities (e.g. Carrara, Naxos), and, inside these, more cases of fine calcites, arranged according to collectors and institutions. In the shrinelike dead center of everything came at last three hexagonal glass cases full of Cumbria, England, calcites from the Sir Arthur Russell collection of the British Museum (Natural History). The Stonehenge effect of these concentric rings of upright rock slabs worked well, if one did not dwell too much on the possibility of one of those great white slabs (which must have weighed well over 1000 lbs. each) toppling over on an innocent gaggle of gawkers.

Calcite's range of forms, colors, habits and associations is a well enough known wonder. Illustrating it here was a range of museums and private collections which had lent specimens for display. There was Iceland spar from the Geological Museum of Copenhagen; huge calcite-amethyst-goethite geodes from the Idar-Oberstein area, shown by Rudolf Dröschel; offbeat Belgian pieces owned by Dieter Heimann; and fine worldwide calcites from the Vienna Natural History Museum, including a Fontainebleau, France, sand calcite 45 cm across, and an almost equally large, delicate, pale green, coralloidal piece from Laurium, Greece. Humboldt University of Berlin showed a marvelous, clear, 2-cm crystal on a wire silver curl from Kongsberg. The Mineralogical Museum of Baie Mare, Romania, showed fine Romanian calcites, and the Fersman Museum of Moscow exhibited fine Soviet ones. There was a case for fluorescent Franklin, New Jersey, calcite, a case with four enormous St. Andreasberg, Harz, crystal groups (ca. 1883), and a fine convocation of worldwide calcites from Victor Yount . . . among many others.

The ultimate stars of the show, inevitably, were the English calcites in the three innermost cases, accompanied by fine specimens of associated species from the Cumbria mines—fluorite, barite, kidney-ore hematite, etc. The display also featured chatty old labels, and placards with information (in English!) on Sir Arthur Russell (1878–1964) and on *his* source for many of the best pieces: the 19th-century collector/dealer John Graves of Frizington. Among the noble Cumbrian crystal groups my two favorites, both from the Pallaflat mine, were an enormous pellucid cluster with clean scalenohedrons to 10 cm long, and another group just as fine but with 10-cm butterfly twins showing both open and closed re-entrant angles. Both these groups are on hematite matrix, and surely must be two of the most dramatic mineral specimens of any kind.

Many of the high hopes for this Munich Show centered on fantasies of a post–Cold War outpouring of brand new riches from the former East Bloc. About 75% of the dealer stands in Halle 5, plus many scattered elsewhere, were manned by Soviet, Czech, Polish, eastern German etc. mineral folk, some of them debuting in the west this year. So, I confess, I was mildly disappointed to find that there were no unveilings of Eastern materials both *really* new and *really* dramatic. But how spoiled of me: it's hardly time yet to get jaded with such fine things as the Crimean **vivianite** and **anapaite,** Polish **hauerite,** Ukrainian gem **heliodor,** and Siberian **sperrylite** which have come trickling through the crumbling dam in the past few years, and which were still widely available this year in Munich. And although a decade ago it would have been quite amazing to see representatives of the Fersman Museum of Moscow selling off specimens at a humble show stand, that stand is now a Munich fixture.

Of the *most* recent Soviet things mentioned in the U.S.S.R. paragraph of Robinson and King's latest worldwide roundup (see "What's New in Minerals," vol. 21, no. 5), the one which most impressed me at Munich was the **sal ammoniac** reported as coming from "Kadamdzhaj, in middle Asia," and attributed by a Soviet dealer in Munich to the Pozar mine in the Tadjik S.S.R. in (yes) middle Asia. [Ed. note: an article in the December 1990 issue of *Lapis* gives the locality as Rabat, Tadzhikistan.] The crystals come in mostly thumbnail-sized groups without matrix, have a grayish white, translucent, vitreous appearance, and form attractive arborescent shapes, like branching frost on your window but in three dimensions. My specimen so far shows no sign of hydrophilic dissolution even though in the Rhineland here we've had rain or snow almost every day since the show . . . two months ago as of this writing.

Not mentioned by Robinson and King is a new Soviet occurrence for **axinite** in excellent, deep brown, fanlike aggregates of glassy crystals, somewhat resembling specimens from the old Obira mine, Japan. These new ones are from Dal'negorsk, Primorskij Kraj, in the Soviet Far East. Manfred Baumstark (see his listing on the German Dealers ad) was offering very handsome miniatures of these for around $400 apiece. The same dealer also had some exciting (if you know the rarity of the stuff), loose, single and twin crystals of glassy white **whewellite** to 3 cm from the old locality of Zwickau, Upper Saxony, eastern Germany—these for only about $50. Elsewhere at the show, at several stands, whewellites of a different type—big bladed singles and V-twins colored dark gray by organic (?) inclusions—were also to be had at surprisingly low prices.

(continued on p. 225)

Congratulations to

Paul E. Desautels

1990 Recipient

Carnegie Mineralogical Award

The Carnegie Mineralogical Award was established in 1987 to recognize outstanding contributions which promote mineralogical preservation, conservation and education, ideals embodied in the Carnegie Museum's **Hillman Hall of Minerals & Gems.** The award is open to individuals, groups, organizations and institutions. Private mineral enthusiasts, collectors, educators, curators, and mineral clubs and societies, as well as museums and universities, are all eligible. The award, consisting of a certificate of recognition, a cast bronze medallion, and a $1500 cash prize, is presented each February during the Tucson Gem and Mineral Show.

The Mineral Museums Advisory Council administers the award and oversees the selection process. Nominations for the **1991 Carnegie Mineralogical Award** may be submitted, until December 31, to either of the following addresses.

Richard A. Souza
Section of Minerals, The Carnegie Museum, 4400 Forbes Ave., Pittsburgh, PA 15213

Ronald E. Bentley
MMAC Representative, 6 Claremont Street, Enfield, CT 06082

Letters

OLD SWEDISH COLLECTION

Here is a story that might interest your readers. I am a retired chemical engineer. The company I worked for had a joint venture with the old Swedish Match Company, and I was a director of that venture. In late 1985 we received an invitation from the King of Sweden to hunt deer on his Royal Preserve a little south of Stockholm, and we made the trip in January of 1986. We were well taken care of by the Master of the Royal Hunt and his wife and staff. It was bitter cold, and the ground had six inches of snow cover, but that only made the experience more invigorating; we had a good hunt.

The last evening we were there, the conversation came around to the fact that I was a mineral collector. The Huntmaster's wife mentioned that there were some "rocks" over in the old unused hunting lodge. After trying to describe for me what was there, she finally agreed to take me to see for myself. The temperature was 5° F, there was no electricity or heat in the building, and it was pitch dark. We took flashlights and set off to have a look.

When I got there and had caught my breath we went inside. I couldn't believe what I was seeing! Row after row of head-high antique cabinets *filled* with all types of mineral specimens, each piece carefully labeled as to species, locality and date acquired. There must have been over 10,000 specimens there, as best I could determine in the darkness. I walked up and down the dusty aisles, just staring. The specimens were well sealed in their cabinets, and appeared clean.

As I recall, it was the wife's side of the family that had been hereditary Gamekeepers and Huntmasters for the King, and the collection had been built by her deceased grandfather. Since his death it had stood undisturbed for many years, and no one else had shown the slightest interest in it for as long as she could remember. To her they were just "rocks," and the old building was not even insured.

I tried to explain to her the potential significance of the collection, but I don't think I made any headway. I never had the opportunity to return there, and I don't even remember the woman's name anymore. But I hope the collection has been (or will be) saved; it would be well worth the effort. Maybe one of your readers, a dealer or perhaps a museum curator, will be able to research the situation and make contact with the family for the purpose of rescuing this historic collection.

Bill Oppold
Chapel Hill, NC

DE KALB DATOLITE

George Robinson's interesting article on the De Kalb diopside locality (vol. 21, no. 6, p. 535) mentions that the occurrence of datolite there has not been confirmed. Perhaps I can shed some light on this matter.

In 1974 I was contacted by Dorothea Weller, a granddaughter of Calvin Mitchell (owner of the property on which the occurrence is located). She asked if I would be interested in faceting some diopside for her, which she showed me. I was also allowed to see and copy some early correspondence between Mitchell and the mineralogists of his day. Attached here is a copy of a letter to Mitchell from Samuel L. Penfield [Ed. note: see vol. 20, no. 3, p. 181] regarding the identification of datolite from the Calvin Mitchell farm.

While going through a box of several hundred diopside crystals for potential cutting rough, I found two small datolite crystals myself. They are colorless, quite flattened in habit and doubly terminated, measuring approximately 9 x 13 x 19 mm. I believe Mrs. Weller still has them in her possession.

Richard M. Stenberg
Springfield, MA

Following is the letter to Calvin Mitchell from Samuel L. Penfield, dated June 24, 1888:

My dear sir,

Enclosed you will please find the little crystal which you entrusted to me last summer. It proves to be datholite [sic], an unusual mineral for your part of the country but quite common around here. Your crystal is, however, quite unlike any that I have seen from other parts of the world as regards its shape. I have always seen it in crystals attached to the rock and not in perfect free crystals. I proved that it was datholite by taking its specific gravity and by measuring the angles of its faces.

I am in hopes that you will be willing to part with the crystal, as I would like to deposit it along with some of my other St. Lawrence County minerals in the National Museum at Washington. There is danger of losing such small crystals, but if carefully put away in a large scientific museum it will be preserved and valued. I am in hopes that you will present the crystal to the National Museum, where it will be preserved and labeled with your name as donor.

Very truly yours,
Samuel L. Penfield
Sheffield Scientific School
of Yale University

According to John S. White, Curator-in-Charge of the Mineral Sciences Department of the U.S. National Museum (Smithsonian Institution), the crystal was never donated by Calvin Mitchell, nor does the National Museum possess any other such crystals. The two still retained by Dorothea Weller may be the original (and only) crystals of De Kalb datolite. Ed.

GLOSSARY

The "Glossary of Mineral Species" *is* an "indispensable reference," and has been for me since the first edition. A copy will sit on my desk at Bryn Mawr College, handy for my work curating the fine old collections. Another copy will be at home, where I'm revising my recently published update of the List of Pennsylvania Mineral Species.

Juliet C. Reed
Associate Curator
Bryn Mawr College

ALL ABOARD PLEASE

According to Tom Heard of Columbia, South Carolina, "Being a mineral collector without the *Mineralogical Record* is like being in the middle of the ocean without a boat." I quite agree.

Daniel A. Steckel
Charlotte, NC

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Two German dealers who have especially excelled at bringing Eastern minerals to market are Erich and Erika Schmidt (Friedhofstr. 3, D-8591 Tröstau). The Schmidts, for example, are the "king and queen" of the tremendous new **dyscrasites** from Příbram, Czechoslovakia; more of these giant, metallic gray crystal clusters (on the order of the one pictured in the recent *Record* supplement on the Carnegie Museum collection) were again to be had from the Schmidts in Munich, and it's still possible to obtain a fine thumbnail for as little as about $60. Here also were single loose prisms of **danburite,** partially colorless and transparent, partially light brown from included clay, with sharp terminations, averaging 6 cm long, from Dal'negorsk. And it was from the Schmidts, too, that I learned for the first time that the Pöhla mine in the Erzgebirge, recently a source of magnificent orange **barites,** also produces outstanding wire **silvers**: a 6 x 7-cm curling mass of bright wires was available for about $3700.

French people, places and minerals also seemed to be especially salient in Munich this year. The by now well publicized new **bastnaesites** from the Tremorius mine near Luzenac, Aríege Department, Pyrenees, France, were available from several dealers—the best of them from Christian Agthe (Breubergweg 15, D-1000 Berlin 20). The bastnaesite is a beautiful, translucent, golden brown, in stacks of thin hexagonal plates averaging 5 to 10 mm across, usually lying flat but occasionally perched at angles in vugs in a glistening white matrix mixture of limestone and talc. Agthe had many good thumbnails and miniatures of this material, plus a few cabinet-sized matrixes with bastnaesite plates to 2 cm across. Less well known, and less abundant at the mine, are fine **allanite** crystals; the best I saw was a shiny, sharp, blackish brown, terminated prism 2 cm long on a 2.75-cm matrix for $85.

Another new French locality which is beginning to get the press it deserves is the **stolzite** occurrence at the St. Lucie mine near St.-Léger de Peyre, Lozére. A nice self-collected handful of these specimens was being shown at Munich by Laurent Gautron and Yves Merchadier (76 Rue Botzaris, F-75019 Paris). The St. Lucie is an old lead mine worked between 1879 and 1914. Diggings begun on the old dumps in 1988 uncovered the stolzite crystals, which are grayish orange-brown flat tablets, coated when first found with (fortunately removable) iron oxides, the crystals stacked or offset in nice jumbled groups. In other words, the material looks a lot like second-rate wulfenite, although in fact it is among the world's better stolzite. The very best pieces now repose, properly, in the French National Museum collection, but Gautron and Merchadier were offering some fine thumbnails and small miniature groups at high though not unspeakable prices. Stay tuned: they hope to be able to bring out more in the future.

Of the regular French dealers, one of the most consistently rewarding to visit is Gilbert Gauthier (7 Avenue Alexandre III, F-78600 Maisons-Laffitte), a specialist in Zaire minerals who *still* has the finest Mashamba mine **cuprites** around, as well as some new, vibrant pink, cabinet-sized crystal groups of Mashamba mine cobaltoan **calcite** fully up to the high standards of a few years ago. Gauthier also had four amazingly good crystal groups of **chalcocite** from the Messina copper mine, Transvaal, South Africa. These are somewhat dulled by oxidation, but the best of the four is a smashing 4-cm miniature with 1.5-cm, striated, very sharp untwinned crystals. Via the Fersman Museum, Gauthier also had what may be the best thumbnail I'll never be able to afford of **plumbomicrolite** from Keyvy, Kola Peninsula, U.S.S.R.: two intergrown, rough, earthy brown, 2-cm octahedrons in a classy little matrix-free group.

Himalayan minerals continue to be plentiful, and the best assortments of them regularly to be seen on this continent continue to come in the company of Andreas and Rebecca Weerth (see the German Dealers ad). Most dramatic this time were some beautiful, large, black **schorls** on albite matrix with gemmy **topaz**; incandescent orange-brown **spessartines** from Gilgit, Pakistan; matrix **rubies** from Jegdalek, Afghanistan; and a single show-stopper "watermelon" **elbaite** 8 cm long on a 10 x 12-cm albite matrix, with only a slight suspicious fogginess about its color tones to hint that it was not from California but rather from Pakistan. This is also the place to say that the classic **lazurite** crystals in white marble matrix from Badakhshan, Afghanistan, continue to pour onto the market, and to get bigger and better in their crystal development (and, best of all, to fall in price).

Among other recent material of which I saw reassuringly steady supplies in Munich are the **apatite/muscovite** groups from the Zé Pinto prospect, Minas Gerais, Brazil (see vol. 21, no. 5); the **hematite/rutile** girder groups from Ibitiara (vol. 21, no. 1); Chinese **realgar**; Indian **cavansite**; and even a dim, dispersed afterglow of the strike of French **axinite** which I reported from Lyon (vol. 21, no. 3). The partnership of Jakob and Klein (Bräuhausstr. 10, D-8000 München 2) was able to fill several good-sized showcases with fair-to-excellent thumbnails and miniatures of Tsumeb minerals, most strikingly some very good grayish brown **wulfenites** and many **malachite** pseudomorphs after azurite. The fine, sharp, part-gemmy, **diopside** crystals in white calcite from Sørøya Island, Norway, which I met for the first time on my Scandinavian tour last June also showed up at a few stands at Munich, but prices, whether for loose crystals or for matrix specimens, were an order of magnitude or so higher than at the Kopparberg, Sweden show. Although "better deals nearer the source" is not *always* a valid rule of thumb it seems to be true in this case.

A separate paragraph is in order to do justice to the final item in this "contemporary classic" survey—so very spectacular were the **azurites** from Touissit, Morocco, being offered by Horst Burkhart's "Marokkomineralien" dealership (Dornheckenstr. 20, D-5300 Bonn 3). Here, $1000 could buy a mind-blowing 6 x 8-cm cluster of flat bladed crystals with individuals to 4 cm long, of the highest luster. World-class azurite miniatures and thumbnails too were available, some with minor limonite matrix whose earthy brownness only enhanced the aesthetics. Some crystals have small green malachite-alteration spots but mostly this is just very brilliant and razor-sharp deep blue azurite, the finest I've seen from Touissit since the beginning of its specimen production—Burkhart had about 30 of these in all.

What *else* is new? Let's see . . . there was one small spread of marble chunks from Carrara, Tuscany, Italy, with open vugs showing truly "classical" little **quartz** crystals. Here and there I saw sprinklings of an appealing new **libethenite** from Estremoz, Portugal: solid encrustations of sparkly dark green microcrystals over simple hexagonal pyramids of milky quartz with red hematite interveinings. And finally, for dessert, how about some "chocolate **apophyllite**" from Maharastra, India, served up by the firm of *Krystallos* (see, once again, the German Dealers ad)? Of this there were only four specimens and these possibly (the man said) the only ones there will ever be. If they were ice-green they'd qualify as routine-looking, though very fine, Pashan Hills **apophyllite,** each one a cluster of 2 to 4-cm high typical bipyramids with prisms. But, instead, they're a deep, glassy, opaque brown, with odd, lighter brown freckles inside: "chocolate apophyllite," I regret to concede, says it all. At the same stand, too, there were a few specimens of some *clear* **apophyllite** spectacular enough to get one past the inevitable jadedness brought on by Indian zeolite spreads: these are clusters of brilliant, absolutely colorless and transparent, pristine large crystals with nice flesh-colored **stilbite** blades at many interstices, three dramatic groups 10 x 20 cm or so for around $700 apiece, and, I guess, the most beautiful apophyllite I have ever seen.

As a parting word I'll just mention a nifty new brand of skin cream, each jar of which comes with a tiny quartz crystal inside, in the customer's choice of three mystic persuasions: amethyst, smoky or clear. The accompanying pamphlet affirms that "crystal energy adds a new dimension to skincare."

Thomas Moore
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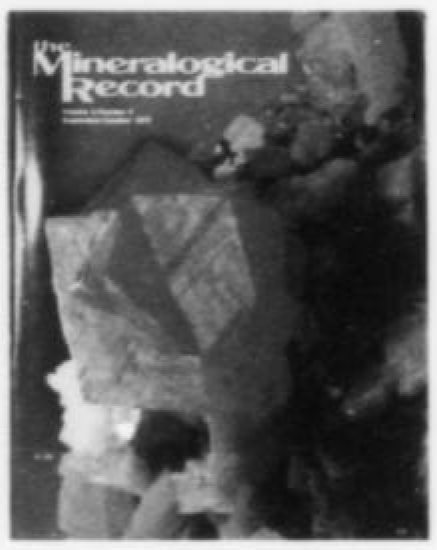

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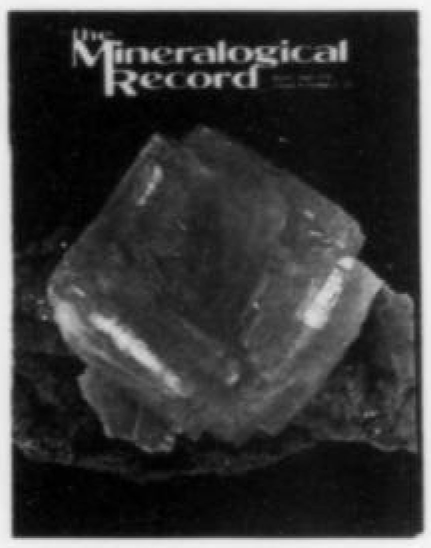

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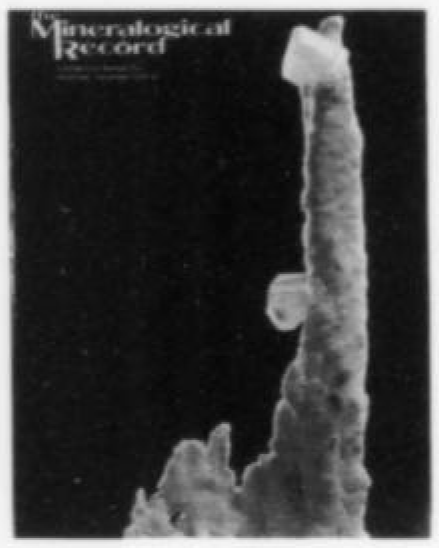

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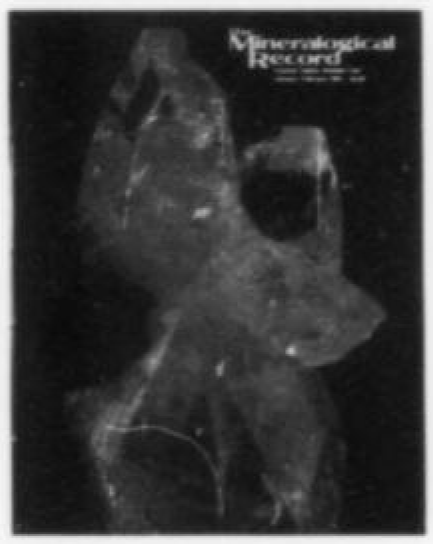

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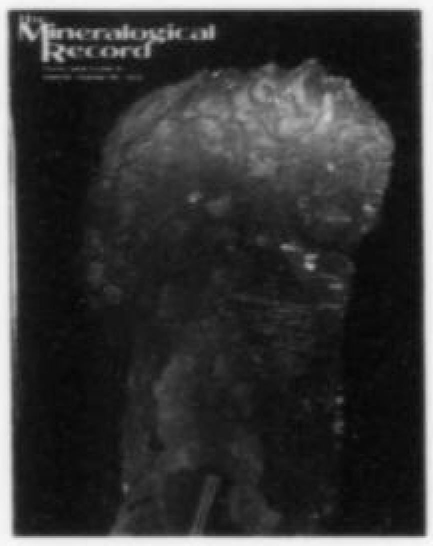

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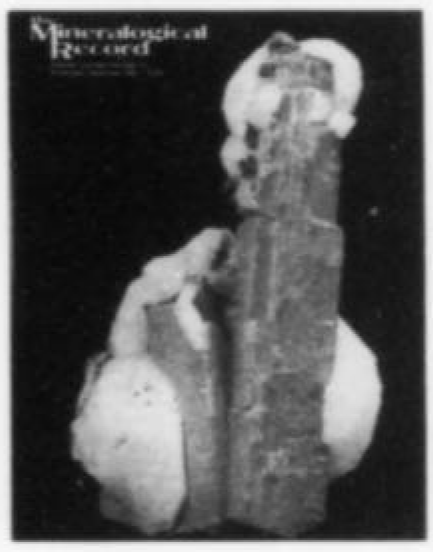

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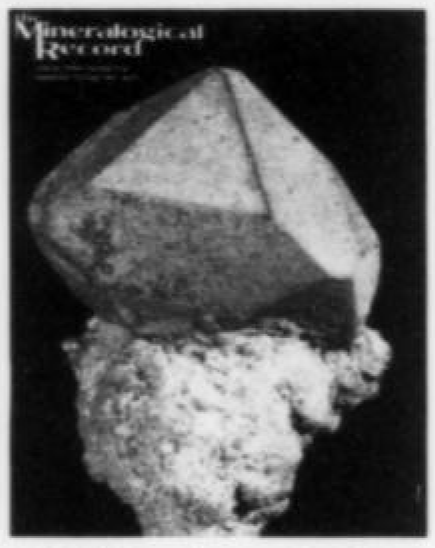

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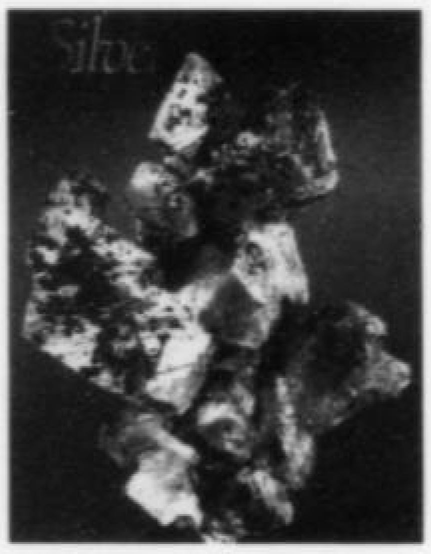

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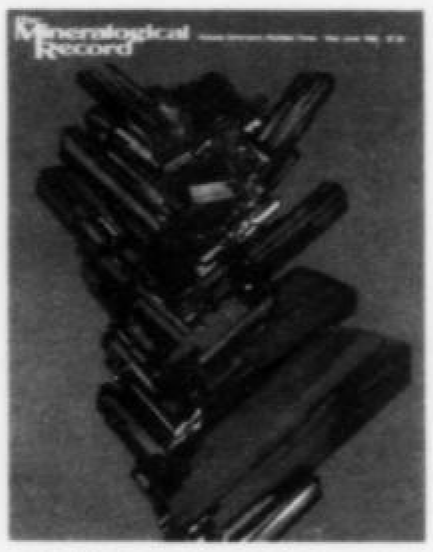

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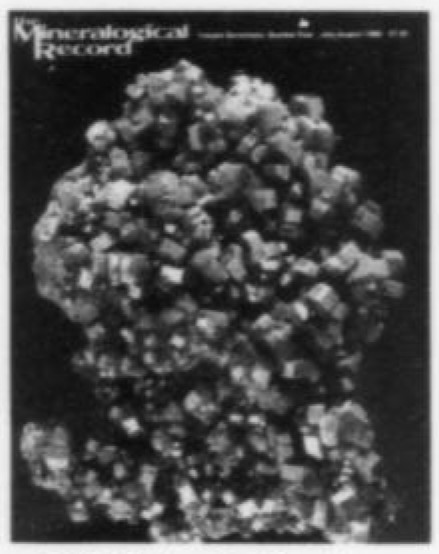

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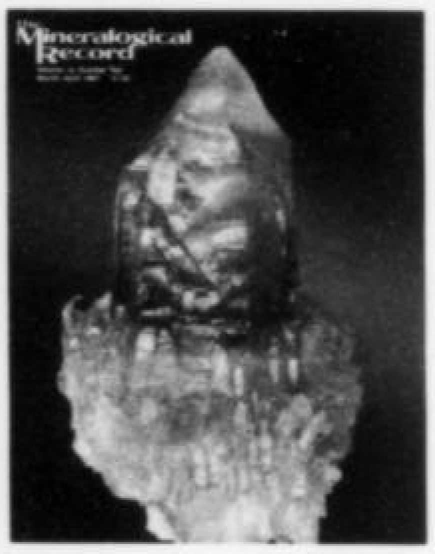

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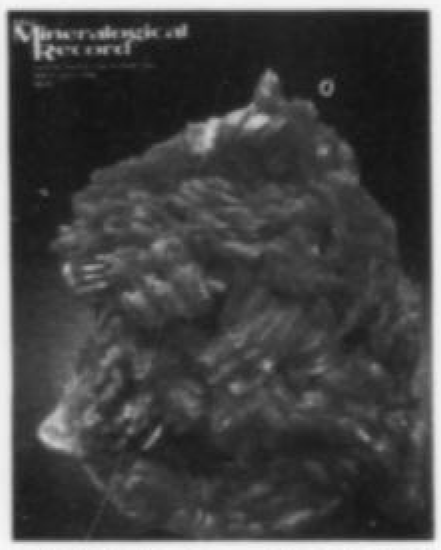

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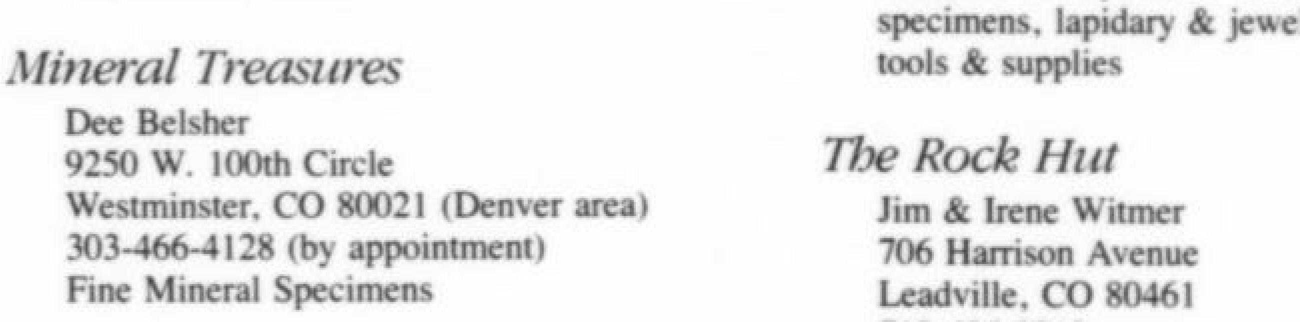

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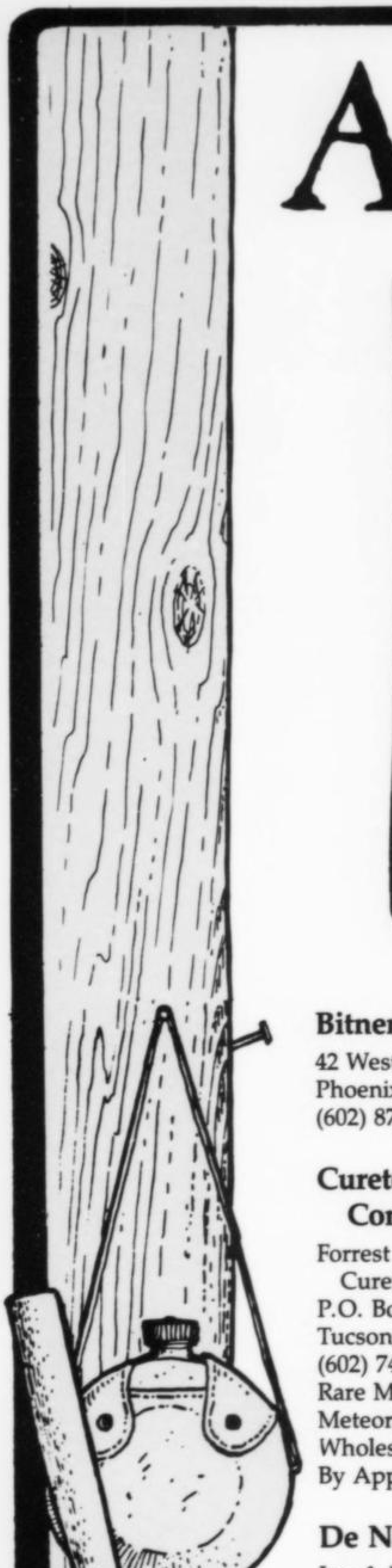

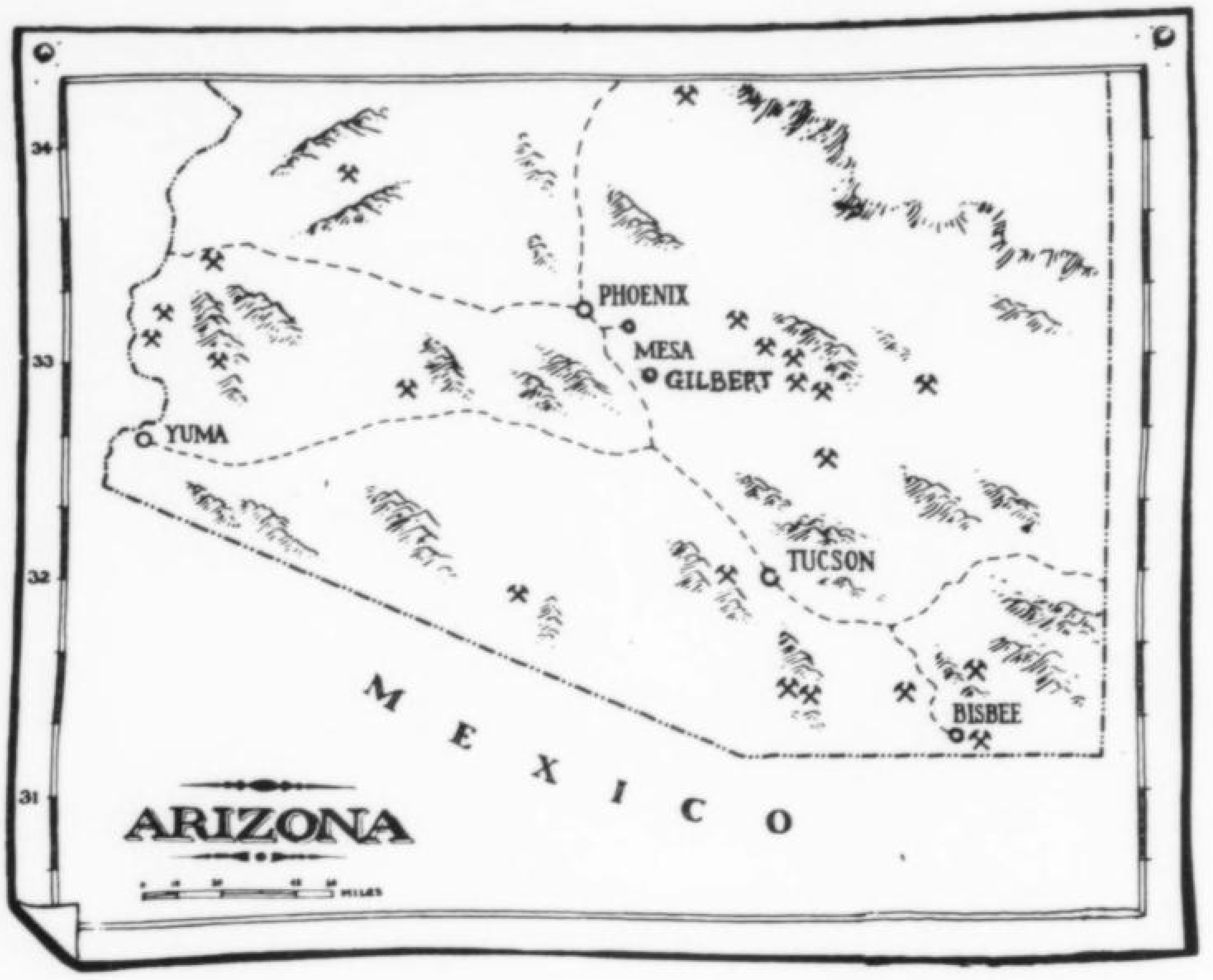

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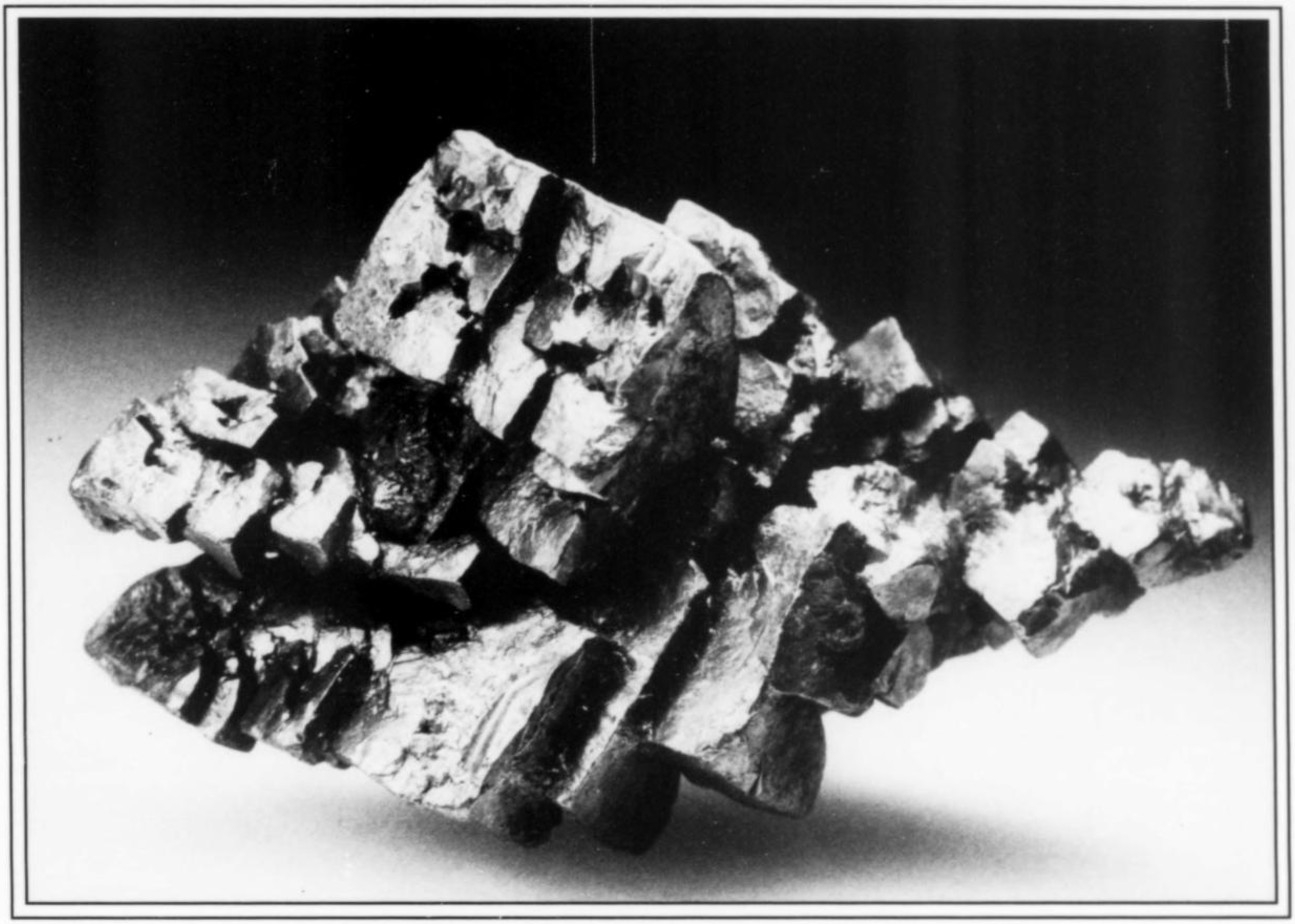

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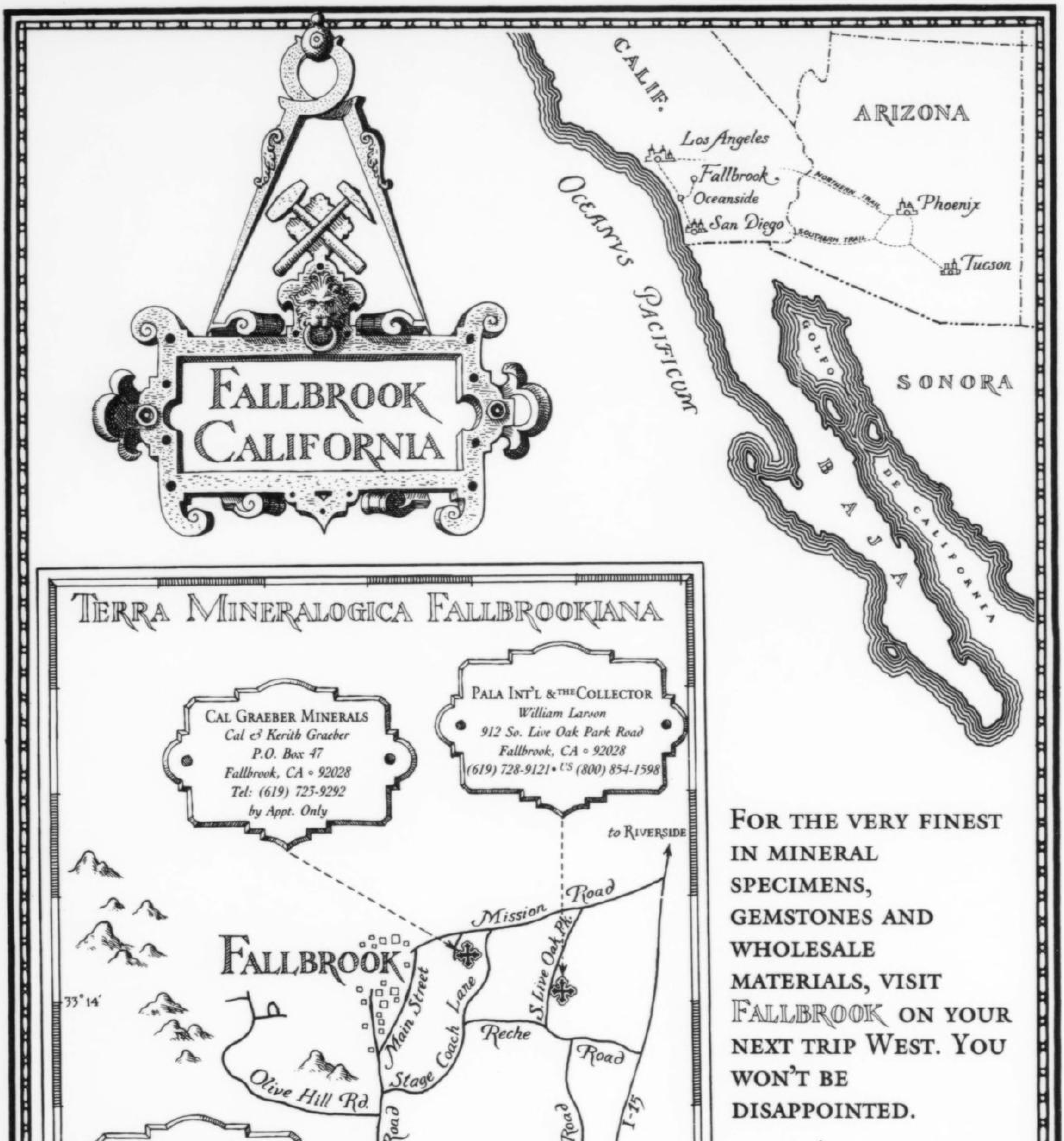

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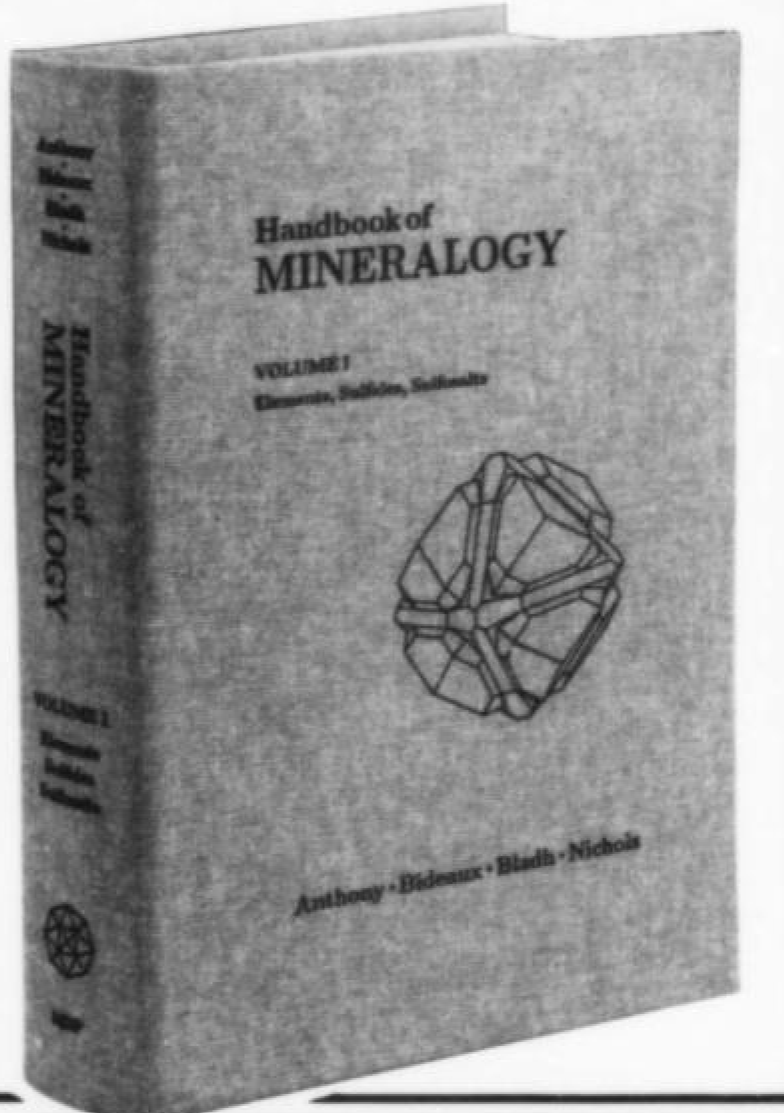

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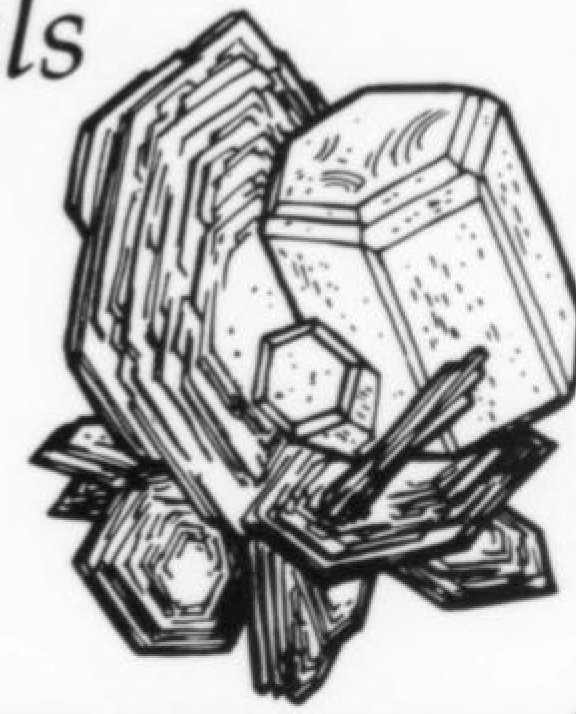

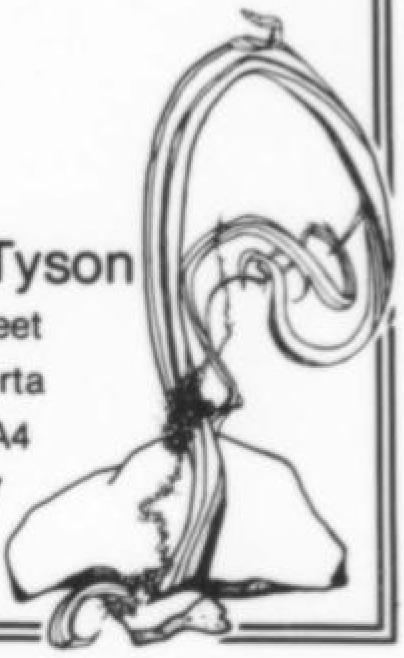


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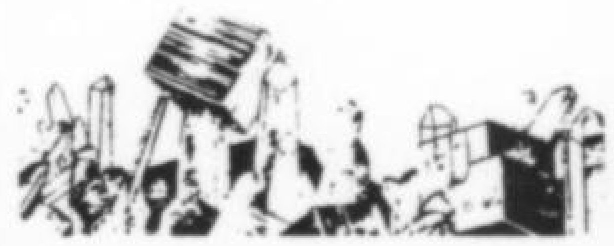

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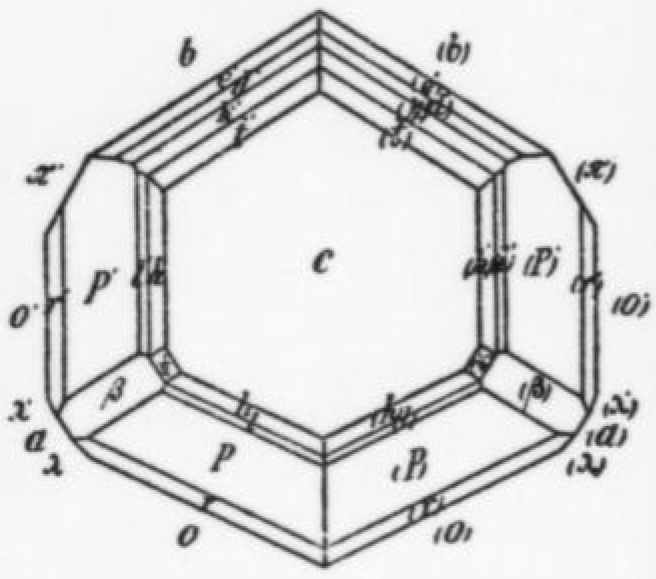
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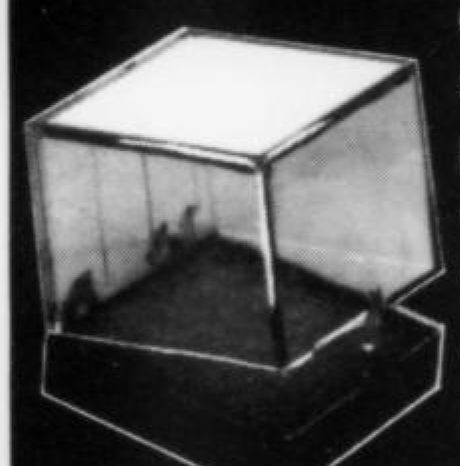

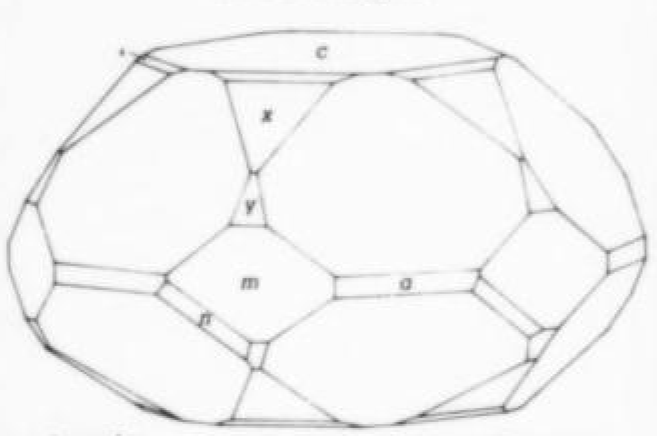
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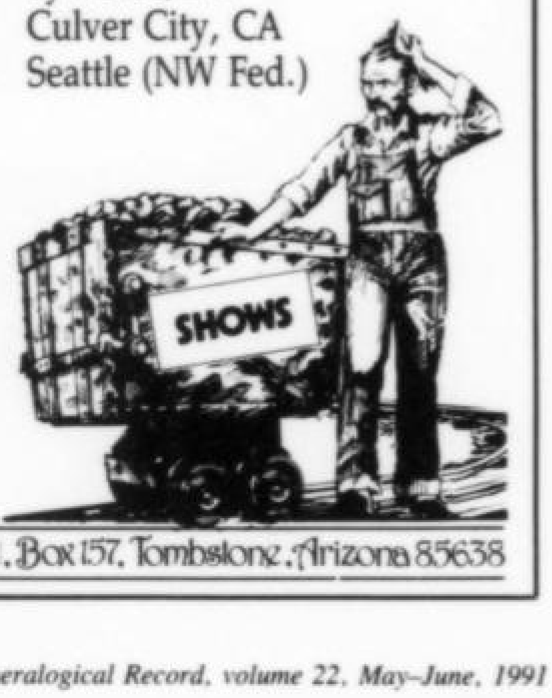
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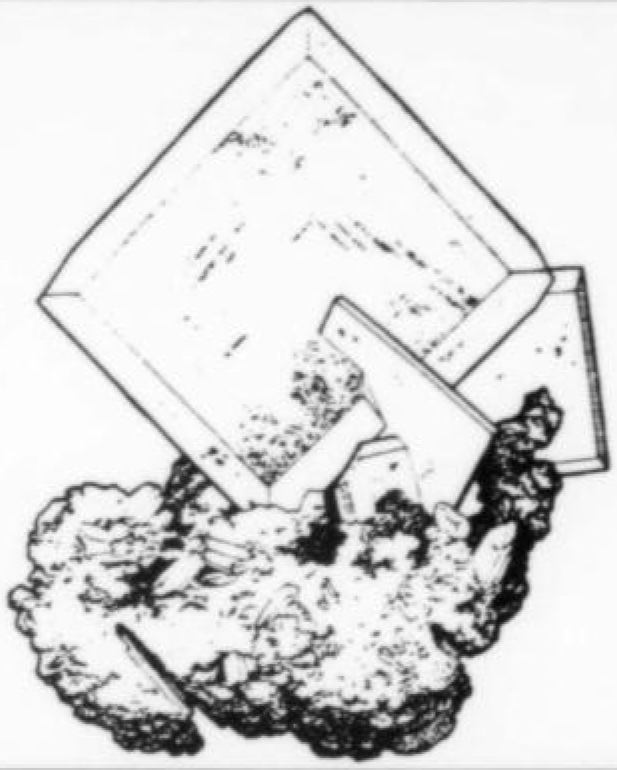

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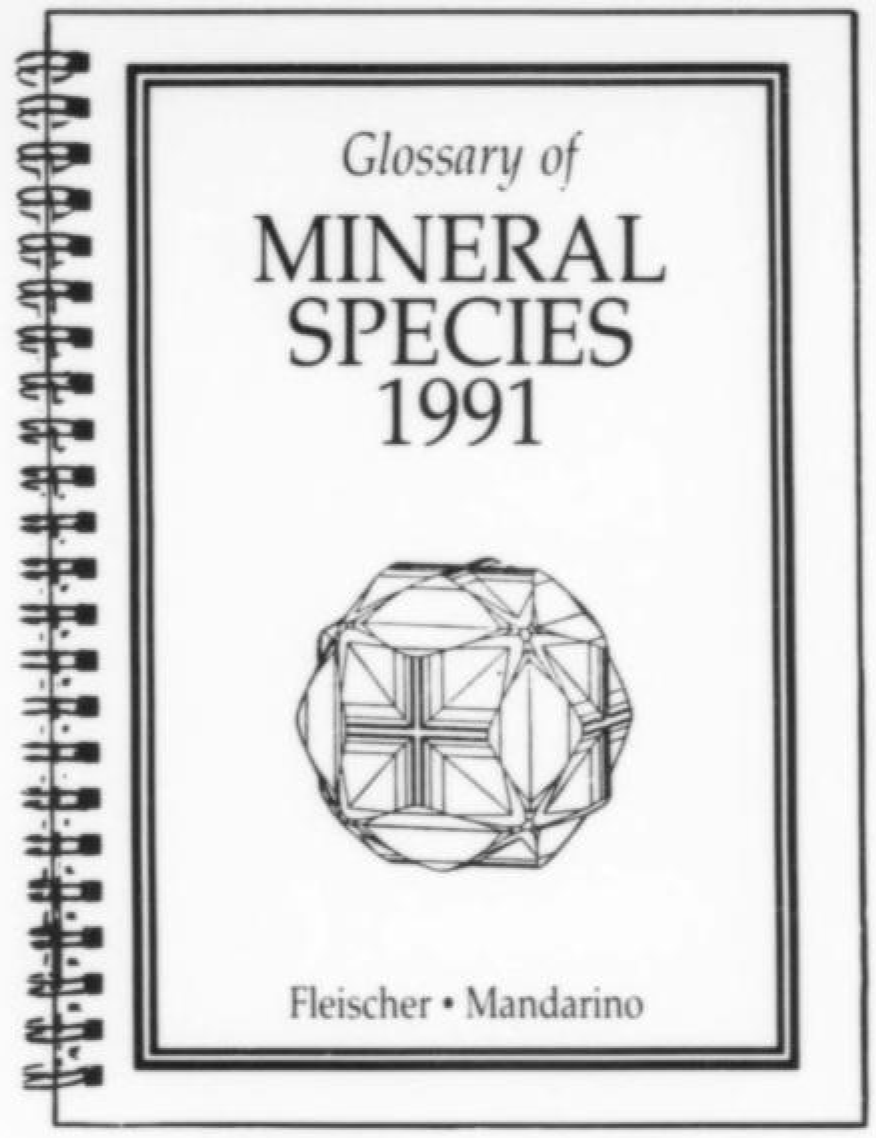

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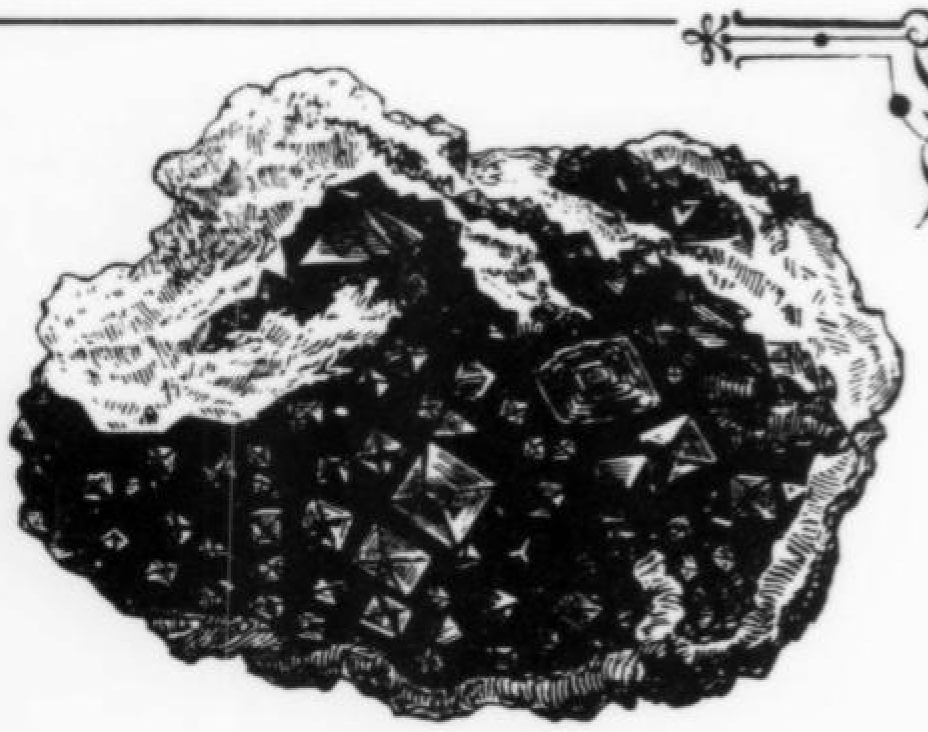

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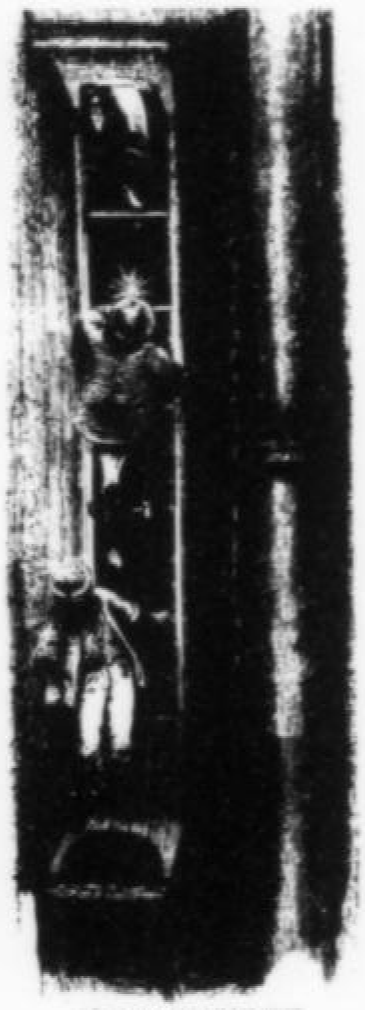

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