the Mineralogical Record

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March–April 1999
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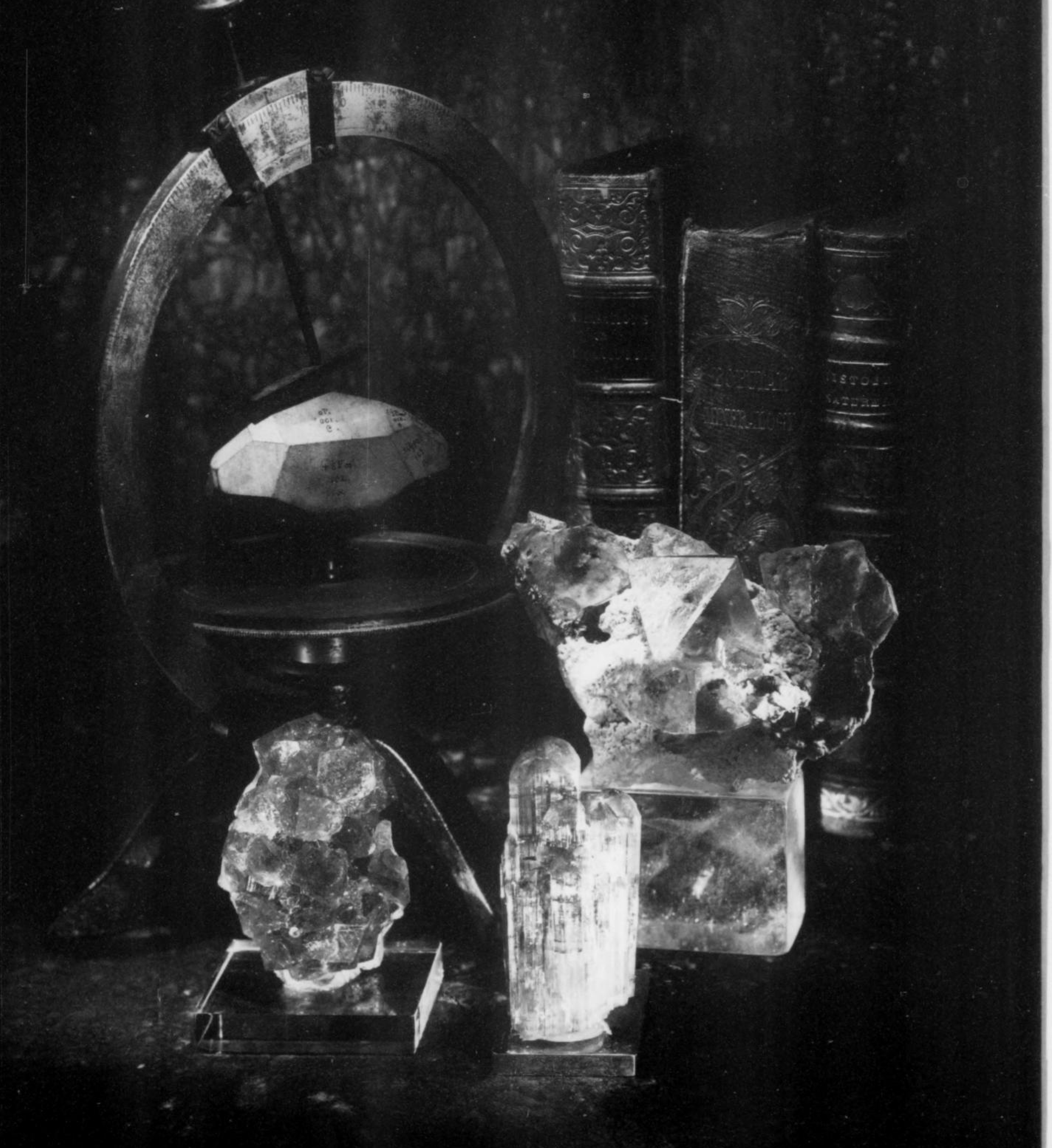

THE
MINERALOGICAL
RECORD

March–April 1999 Volume Thirty, Number Two

Articles

Columns

What's new in minerals

COVER: CHALCOCITE, colored blue by a micro-thin coating of bornite, 5.7 cm, from the Flambeau mine, Ladysmith, Wisconsin. William Larson collection; Jeff Scovil photo.

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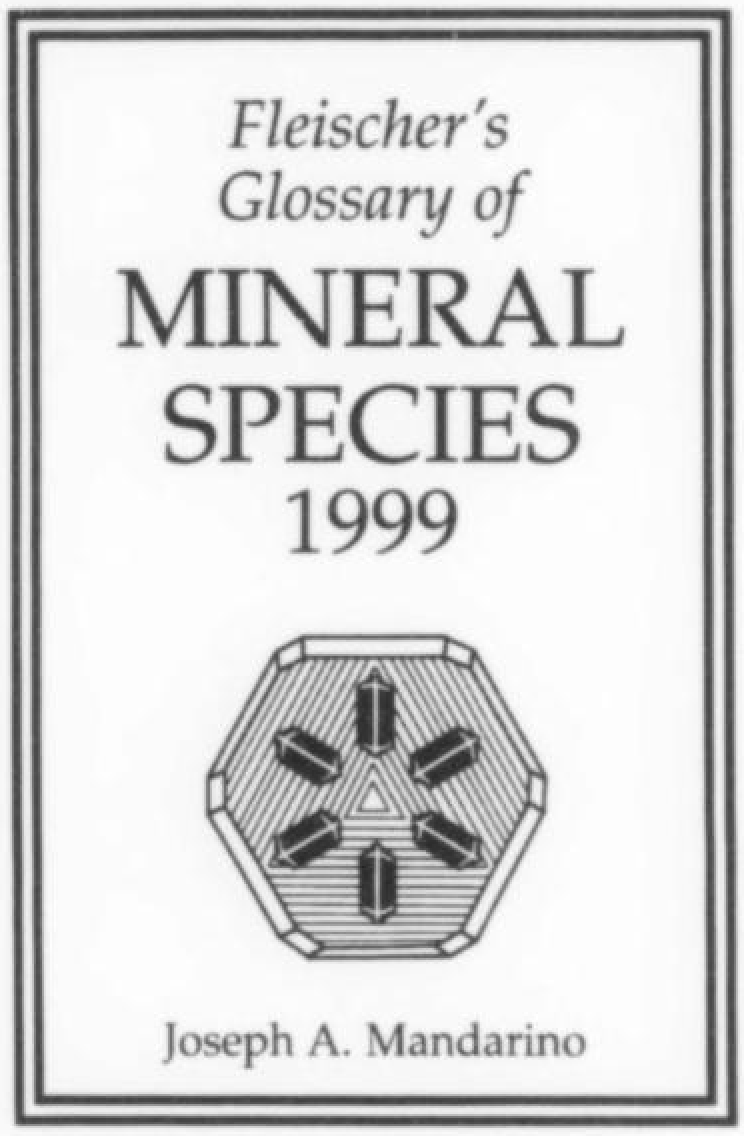
*Continued on p. 159

notes from the EDITOR



Fleischer's
Glossary of
MINERAL
SPECIES
1999

Joseph A. Mandarino

1999 GLOSSARY!

I am pleased to announce that the eighth edition of the famous glossary, now renamed as *Fleischer's Glossary of Mineral Species 1999*, in honor of its originator, is now available. Since the first slim edition in 1971, this work has chronicled the growing list of accepted mineral species, giving basic data and references. Due to failing health, author Michael Fleischer invited Dr. Joseph A. Mandarino to join him as co-author of the sixth (1991) and seventh (1995) editions. With Mike's passing on September 5, 1998, Joe has carried on the work alone, and is the sole author of this latest edition.

I am also pleased to announce that, although approximately 200 species have been added since the previous edition, a little fine-tuning of the typography (and deletion of the section giving composition in words) has kept the page total under control. We are therefore able to offer this new edition at the **same price** as the previous edition: $18 plus $2 postage.

A great many small corrections and changes have also been made to this mineral database, including the recommendations of various I.M.A. committees on specific mineral groups. Therefore, this new *Glossary* is the most up-to-date reference in the literature, and will be kept up-to-date between editions by Dr. Mandarino's meticulous *Abstracts of New Mineral Descriptions*, which appear regularly in the *Mineralogical Record*.

You can order your copy today by **e-mail** (minrec@aol.com), by **fax** (520-544-0815), or by regular mail or telephone to the Circulation Manager. Be sure to include your *Visa* or *Mastercard* number and mailing address if ordering by e-mail or fax. The books are already packaged and ready to ship as soon as your order is received.

TUCSON SHOW INSIDER'S VIDEO

Reader feedback needed! We have been experimenting with the idea of producing a collector's-eye video of the Tucson Show each year, shot and narrated by the editor. The focus would be primarily on actual minerals in dealer booths and on exhibit, with a minimum of "talking heads" telling you how great the show was. This would be down-and-dirty home-video *cinéma vérité*, snooping into flats under tables, visiting motel rooms, and touring the show. No fancy music or artistic titles, and all background conversations included unedited.

The test videos we shot last year were really quite interesting to view later, whether or not you attended the show. People who had not seen the show were particularly excited about it, and often watched the video several times. So the concept has received rave reviews from our tiny test audience.

Now we need to get a better idea of how many people would actually purchase such a video if we made it available next year. And obviously we need to make a profit on this product, which will go directly into magazine expenses to help keep your favorite journal looking sharp. Probably $25 would be a reasonable price . . . the cost of a decent book or a couple of good back issues.

Let me know by letter, by fax to the editorial office (520-299-5702) or by e-mail (minrec@aol.com) if you would *definitely* be interested in this video for the 2000 show. New millennium; new fun! Comments on what precisely you would like to see on such a video would also be welcome. If you want to pre-order by putting your Visa or Mastercard number on file with us, we will ship the video to you right after the show (presuming the response justifies the product), and charge your account then and only then. If we can build up a list of regular customers we'll do the video every year, and what a great record it will become over time!

I.C. VIDEO

Speaking of shopping for minerals, I recently received Isaias Casanova's "Minerals on Video" volume 14, and was very impressed. Isaias demonstrates that a good eye for aesthetics can turn up many really fine specimens in the $100 to $500 range . . . so many, in fact, that I feel like arguing when people complain that good minerals today are priced out of sight. As long as you stick to the "classics" and the more common species that have been around a while, bargains are abundant. Highlights of his video (for me) included a superb, sharp, pink Tsumeb smithsonite thumbnail for $95, a Kaokoveld dioptase thumbnail for $135, a really fine, gemmy orange grossular thumbnail from Asbestos, Quebec, for $475, a couple of exquisite green apophyllite miniatures from India for $95 each, a Weardale fluorite miniature for $140, a beautiful 79 mine aurichalcite (2.75 inches) for $140, a Zambian libethenite miniature (unobtainable at the source for many years) for $120, and a perfect creedite miniature from Santa Eulalia for $125. These are exceptionally reasonable prices if compared to inflation-corrected prices existing for similar specimens 10 to 20 years ago. Get on Isaias's mailing list by sending $10 for the next video to I.C. Minerals, P.O. Box 1376, Goldenrod, FL 32733 (Tel & Fax: 407-679-0905; e-mail icm@aol.com).

20TH ANNUAL FM-TGMS-MSA MINERALOGICAL SYMPOSIUM

MINERALS OF MEXICO

INTRODUCTION

The 20th Annual Tucson Mineralogical Symposium, sponsored by the Friends of Mineralogy, the Tucson Gem and Mineral Society, and the Mineralogical Society of America, was held in conjunction with the 45th Tucson Gem and Mineral Show on Saturday, February 13, 1999. Minerals of Mexico were the feature of the 1999 Tucson Show and the subject of the 1999 Mineral Symposium.

Mexico has a mining specimen collecting history dating back nearly 500 years. Collecting, or discussing, Mexican minerals is roughly akin to narrowing one's focus to the western half of the U.S., most of Europe, or half of Russia. The size, the broad range of geologic environments present, the multitude of major mining districts, and the high level of specimen exploitation mean virtually anything short of diamonds, platinum, and other ultramafic-associated species can be and is present. Because of this, we were pleased to lead off with a talk by one of the preeminent geologic researchers of Mexico, that set the geologic stage for Mexico and provided a framework for the deposit-specific papers that followed. Talks then focussed on a few deposit types that account for the vast majority of the species and the volume of mineral specimens from Mexico: vein-epithermal deposits, and carbonate replacement-skarn deposits. We finished with a historic overview of mineral studies in Mexico by one of Mexico's foremost geological/mineralogical historians.

Several of the talks were designed to tie directly to exhibits on the floor of the Show, so that participants were able to see a broad spectrum of the materials discussed in the talks.

Peter Megaw and **Jim McGlasson**

The Tectonic Evolution of Mexico

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Mexico is a geologically complex land with excellent examples of most of the tectonic styles of crustal evolution. The country is made up of a variety of basement terranes of different ages and lithologies, with a history that includes Proterozoic and Phanerozoic orogens. During the Proterozoic and Paleozoic, Mexico's geologic evolution was closely related to circum-Atlantic tectonics and was controlled by collisions between Gondwana and Laurentia. After the latest of these collisions, large parts of Colombia were left behind in what is now Mexico. These blocks form all of southern and north-central Mexico.

A major shift in the tectonic evolution of Mexico occurred during Permo-Triassic times when subduction began in the western edge of Mexico and the tectonic evolution of the country shifted from one of major continental collisions related to circum-Atlantic tectonics to one of subduction and accretionary tectonics related to the evolution of the circum-Pacific area. During Mesozoic times accretionary tectonics accounted for an addition of about 40% of land area to Mexico. Consolidation of these terranes and magmatism account for the most recent history. The majority of Mexico's specimen-producing ore deposits were emplaced during these later times.

Chris Tredwell's Collection of Minerals from Guanajuato: Preservation Through Purchase

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Department of Geosciences
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Christopher Tredwell and **Peter K. M. Megaw**
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The mining district surrounding the city of Guanajuato, capital of the Mexican state of Guanajuato, which has been producing silver since the 1550's, is famous for its specimen-quality minerals. The major ore minerals include silver, acanthite and the sulfosalts polybasite, pearceite and pyrargyrite. It is also the type locality for aguilarite, Ag_4SeS. Calcite and amethyst are its signature gangue minerals. Less common are adularia ("valencianite"), datolite, fluorite, hydroxyapophyllite, milarite and stilbite.

Chris Tredwell formed a collection of mostly contemporary Guanajuato specimens that is important for its quality, diversity and locality documentation. It consists of about 285 specimens. About 20 are silver minerals and the rest are euhedral gangue minerals. Specialization, proximity and persistence are the factors accounting for this notable collecting success. Living in Leon, Tredwell was able to visit Guanajuato frequently and acquire specimens directly from local sources. This permitted Tredwell to carefully document the localities by mine and sometimes by level. It also afforded him superior selection. Tredwell developed the collection over a ten-year period and his collecting would have continued indefinitely had not his domestic situation changed.

Appreciating particularly the documentary value of the collection, Peter Megaw sought to market it as a whole rather than disperse it to collectors. He approached both the University of Arizona and Harvard University, and both were interested for different reasons. The University of Arizona having recently acquired the premier private collection of Mexican minerals formed by Miguel Romero Sanchez (1925–1997) is now committed to systematically collecting Mexican minerals. The Tredwell collection would significantly supplement existing holdings with unusually well-documented specimens. For Harvard University, acquisition of the Tredwell collection would create another "focus" collection analogous to its fine suites from Bisbee, Arizona, and Cave-in-Rock, Illinois.

Rather than compete, they agreed to cooperate, and the four parties involved formed a consortium to study the mineralogy and paragenesis of the Guanajuato silver veins. The Tredwell collection will be a valuable resource supporting both the research and educational goals of the consortium. The collection has been fully catalogued and photographed. Tredwell specimens illustrate an educational exhibit on the mineralogy of the principal vein systems at Guanajuato, created for the 45th Tucson Gem and Mineral Show.

Silver Mineralogy of Guanajuato Mining District, Guanajuato, Mexico

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The mines of the Guanajuato district in Mexico are well known to collectors for producing fabulous specimens of silver sulfides and sulfosalts, calcite and amethyst. The district has been in nearly continuous production since its discovery in 1548, and has had a total silver production in excess of 40,000 metric tons. The district is dominated by three major northwest-trending vein systems: the La Luz (the western side of the district), the Veta Grande (home to the Rayas, Valenciana and Cata mines) and the Veta Sierra (the eastern extent of the district, and home to the Peregrina and Santa Catarina mines). Mining occurs within three geologic units. The oldest, the Mesozoic Esperanza Formation, is a series of micritic limestones and mudstones which is unconformably overlain by the main ore horizon, the Guanajuato Formation of Eocene age. The Guanajuato Formation is a red conglomerate with a total thickness of about 1300 m. It is overlain by a thick package of Tertiary volcanics. The ore is in quartz/calcite veins controlled by northwest-trending faults, and in large stockworks.

The veins are rich in a suite of sulfides that include pyrite, sphalerite, tetrahedrite, arsenopyrite and cinnabar in addition to the silver mineralization. The relative ratios of the various sulfides and the presence of certain elements correlate well with the location within the ore horizon where mineral specimens occur. For example, the principal silver ore minerals at Guanajuato are members of the acanthite-naumannite system (Ag_2S – Ag_2Se). Petruk and Owens (1974) noted that the ratio of selenium to sulfur increases toward the top of the ore horizon. In recent years several fine aguilarites (the intermediate member of the acanthite-naumannite system, Ag_4SeS) have been found, providing the opportunity to reexamine the relationship. We performed microprobe analyses on 31 specimens with reputed "well documented" locality information. The Se/S ratio is indeed diagnostic for determining the proximity to the Tertiary volcanic unit. The only specimen of naumannite investigated was from the uppermost level of the San Carlos mine, while the large, lustrous Rayas mine acanthites (with nearly zero selenium) are from the deepest levels of that mine.

Polybasite, pearceite, stephanite, pyrargyrite and miargyrite also occur in abundance in Guanajuato in addition to the acanthite-naumannite series. Examination of approximately 50 specimens shows that the assemblages of the various silver minerals also correlate with depth in the ore horizon. Polybasite and stephanite almost always occur with some acanthite; however, the amount of acanthite decreases with depth in the district. Miargyrite is present as intergrowths on many specimens but, in general, shows an increase in abundance from east to west in the district.

Developing a topographic mapping of element ratios and mineral distributions in the Guanajuato district will be a very important tool for understanding the paragensis of the deposit. It can also be a valuable tool for assigning locality information to the large number of specimens that have the simple, but unfortunately unspecific, label "Guanajuato, Mexico."

PETRUK, W., and OWENS, D. (1974) Some mineralogical characteristics of the silver deposits in the Guanajuato mining district, Mexico. *Economic Geology*, **69**, 1078–1085.

Mineralogy of the Silicate Orebodies of the West Camp, Santa Eulalia Mining District, Chihuahua, Mexico

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Santa Eulalia is the largest carbonate-replacement deposit in Mexico. The Potosi, Inglaterra and Buena Tierra mines in the West Camp of the district contain several distinctive calcium-iron-silicate skarn bodies referred to as "silicate ores" to distinguish them from the typical calc-silicate skarns of the East Camp. The silicate bodies occur as both mantos and chimneys within, adjoining, and separate from the principal normal sulfide orebodies. All lie at least 350 meters above the nearest ore-related intrusive rocks.

There are at least seven silicate orebodies, but the Main (or 10th Level), Inglaterra (including La Piñata), and El Tunel are the largest and have been the most prolific specimen producers. These bodies are composed of a fine-grained anhydrous assemblage dominated by manganoan hedenbergite and manganoan fayalite, which was replaced by a hydrous silicate assemblage dominated by ilvaite and chlorite, accompanied by rhodochrosite and quartz. Pyrrhotite, galena and sphalerite occur between bands in the hydrous assemblage and replace both the anhydrous and hydrous silicates. Pyrite, arsenopyrite, realgar, silver sulfosalts and a suite of over 80 well-crystallized silicate, oxide and gangue minerals also occur in the abundant vugs developed between hydrous mineral bands. The most important/plentiful/attractive collector species include: rhodochrosite, pyrrhotite, creedite, natanite-jeanbandyite-wickmanite, helvite, gypsum, fluorite, ilvaite, jacobsite, hübnerite and quartz (often with exotic inclusions). Although there is currently no formal mining of these ores, specimens continue to trickle out and numerous older pieces can be found in dealer stocks everywhere.

Giant Jarosite Crystals from the Peña Blanca Uranium District, Chihuahua, Mexico

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Jarosite is a potassium-iron hydroxy-sulfate that commonly occurs in the oxidized portion of pyrite-bearing deposits, where it is often confused with "limonite." The discovery of more than just pulverulent material, and the recognition of a primary acid-sulfate mineralization stage in epithermal mineral deposits, has led to the recognition that jarosite may also be a primary hydrothermal mineral. We describe what are probably the largest and finest jarosite crystals in the world, produced from such a primary geologic environment.

The jarosite crystals found at the Peña Blanca uranium mine were discovered in what are now mined-out parts of the open pit. The crystals are beer-bottle brown in color and translucent. The largest are more than 4 cm in length, 2 cm high, and 1 cm thick. Rosettes of crystals up to 2 cm in diameter have also been found. This study will report on the crystal forms, physical and optical properties, X-ray powder diffractometry, electron microprobe geochemical studies, Ar/Ar age dating studies, fluid inclusion thermometric studies, and data on occurrence, associations, and genesis.

The entire Peña Blanca uranium mine area has become a national nuclear waste repository; guards and locked gates assure visitors that they are not welcome.

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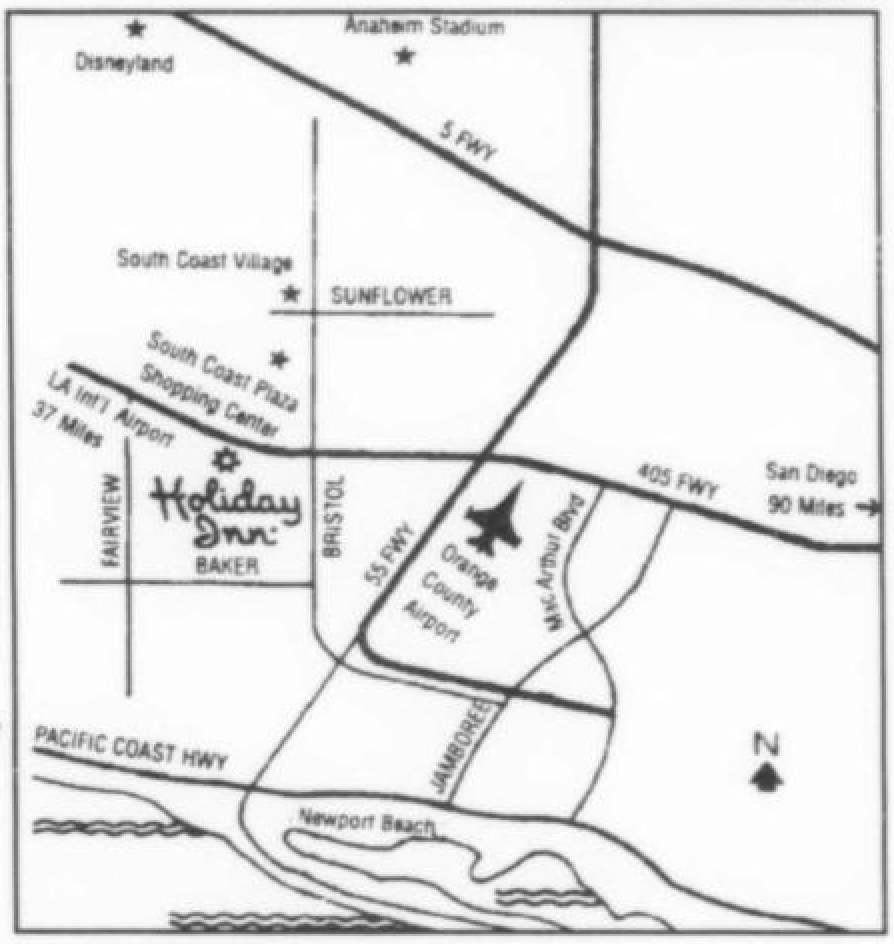

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THE PEABODY MUSEUM COLLECTION

YALE UNIVERSITY

Thomas Moore
15 Lakeview Drive
Niantic, Connecticut 06357

Yale University has had a museum containing objects of natural history at least as far back as the American Revolution. When Benjamin Silliman took over the mineral collection in 1802, however, it was all being stored in a single candlebox. Within a few decades it grew to become the most important mineral collection in the country. Sadly, despite its early glory, it has fallen on hard times in the 20th century.

INTRODUCTION

The low, dignified Gothic form of the Peabody Museum of Natural History is situated at the corner of Whitney Avenue and Sachem Street in New Haven, Connecticut, a few blocks north of the central quadrangle of Yale University. In the early 1920's the architect, Charles Z. Klauder, designed the building as a remembrance of the medieval Chateau Coucy. This old structure had slept peacefully on a hilltop in Picardy until, in March 1917, it was deliberately destroyed by order of General Erich von Ludendorff, in reprisal for recent French Army advances along the Arras-Cambrai-Laon front. Six centuries earlier, the Chateau had been the stronghold of Enguerrand de Coucy III, Sire of Coucy, whose life and times Barbara Tuchman describes and interprets vividly in her book *A Distant Mirror: the Calamitous 14th Century* (1978). Out of our own calamitous century, and indeed like a mirror lifted out of the Great War's rubble, Klauder's building reflects Coucy's in, among other things, the great rotunda inside the front entrance, whose vaulted ceiling ribs arc gracefully to converge on a central "eye," exactly as in the Chateau's donjon. From this eye a Foucault pendulum once hung, back in the Museum's cutting-edge days, when it was also this country's first public museum to feature a diorama display on organic evolution, from amoeba to man.

As an institution, the Peabody Museum predates the present building by half a century, and many of its holdings, including much of the mineralogical collection, go back many decades further still, to well before George Peabody's founding gift in the 1860's. A Museum flyer describing the present mineral collection suggests the long, complex, sometimes glorious march of its history:

> The Mineralogy Division oversees a large and historically important research and reference collection of approximately 35,000 specimens. Most . . . are catalogued into the systematic

Figure 1. **The Peabody Museum of Natural History on the campus of Yale University, New Haven, Connecticut. Built in the 1920's, it was designed after the medieval Chateau Coucy in France. Ellen Faller photo.**

collection created by a combination of the original Peabody Museum holdings and the G. J. Brush Mineral Collection.

The collection was developed through the investigations and publications of James Dwight Dana and Edward Salisbury Dana, which formed the basis of *The System of Mineralogy . . .* The collection contains many unique and irreplaceable specimens from localities worldwide. There are 36 documented type specimens, and others that are presumed type specimens requiring further documentation. Many 19th-century mineralogists sent material that they had studied to the Danas for inclusion in the *System.* In addition to the many referenced specimens, the collection contains suites of material from localities that no longer exist, early prospecting material, a collection of gemstones, and a collection of Connecticut minerals.

BENJAMIN SILLIMAN

The founding father of this great assemblage, however, predates even the Danas. He was Benjamin Silliman (1779–1864), who, without prior formal training in science, almost single-handedly took Yale into pre-eminence in early American education in chemistry, geology and mineralogy. The story is a likable one, its early stages showing how much the culture of academia in America differed two centuries ago (for a fascinating historical review see Greene and Burke, 1978).

In 1798 the President of Yale, Timothy Dwight the Elder, persuaded the Yale Corporation to approve a new professorship in "chemistry and natural history," and in 1801 he offered the post to 22-year-old Benjamin Silliman. The choice was politically correct, as Silliman's family were respectable folk with established Yale connections and proper religious and political (anti-Jeffersonian) views. But in another way the conservative President Dwight was taking an uncharacteristic gamble, as Silliman at this time was studying law, and knew almost nothing about the natural sciences. Nevertheless the young man bravely accepted the professorship, was prudent enough to finish his course of law studies, and then set out to educate himself in his new field(s). For two winters he took courses at the Medical College of the University of Pennsylvania in Philadelphia, where "in his spare time he and chemist Robert Hare performed chemical experiments in a laboratory they set up in a cellar kitchen of their boarding house" (Narendra, 1979); so much for the chemistry part of the professorship. But as "natural history" was considered to cover geology, mineralogy, botany and zoology, Silliman must sometimes have despaired, since instruction in these subjects, especially in the first two, was hard to come by in Philadelphia or, indeed, anywhere else in the country.

Consequently Silliman went abroad. On the occasion (excuse?) of facilitating a major purchase by Yale of books and scientific equipment in England, he went for a year (May 1805 to May 1806) to study science there and in Scotland. During that year, with typical energy, intelligence, and providential canniness, he made abundant professional and social contacts with eminent scientists; he attended lectures propounding the contending views of geological "Neptunists" of the school of Werner (all rocks are ultimately sedimentary) and "Vulcanists" of the school of Hutton (all rocks are ultimately igneous); and he gathered rock and mineral specimens in the field, visiting active mines in Cornwall and Derbyshire, once nearly being killed in a rockslide while investigating the lava sills of Salisbury Crag, above Edinburgh.

Figure 2. **Arsenopyrite crystal group, 16 cm, from Freiberg, Obersachsen, Germany. Peabody Museum collection and photo.**

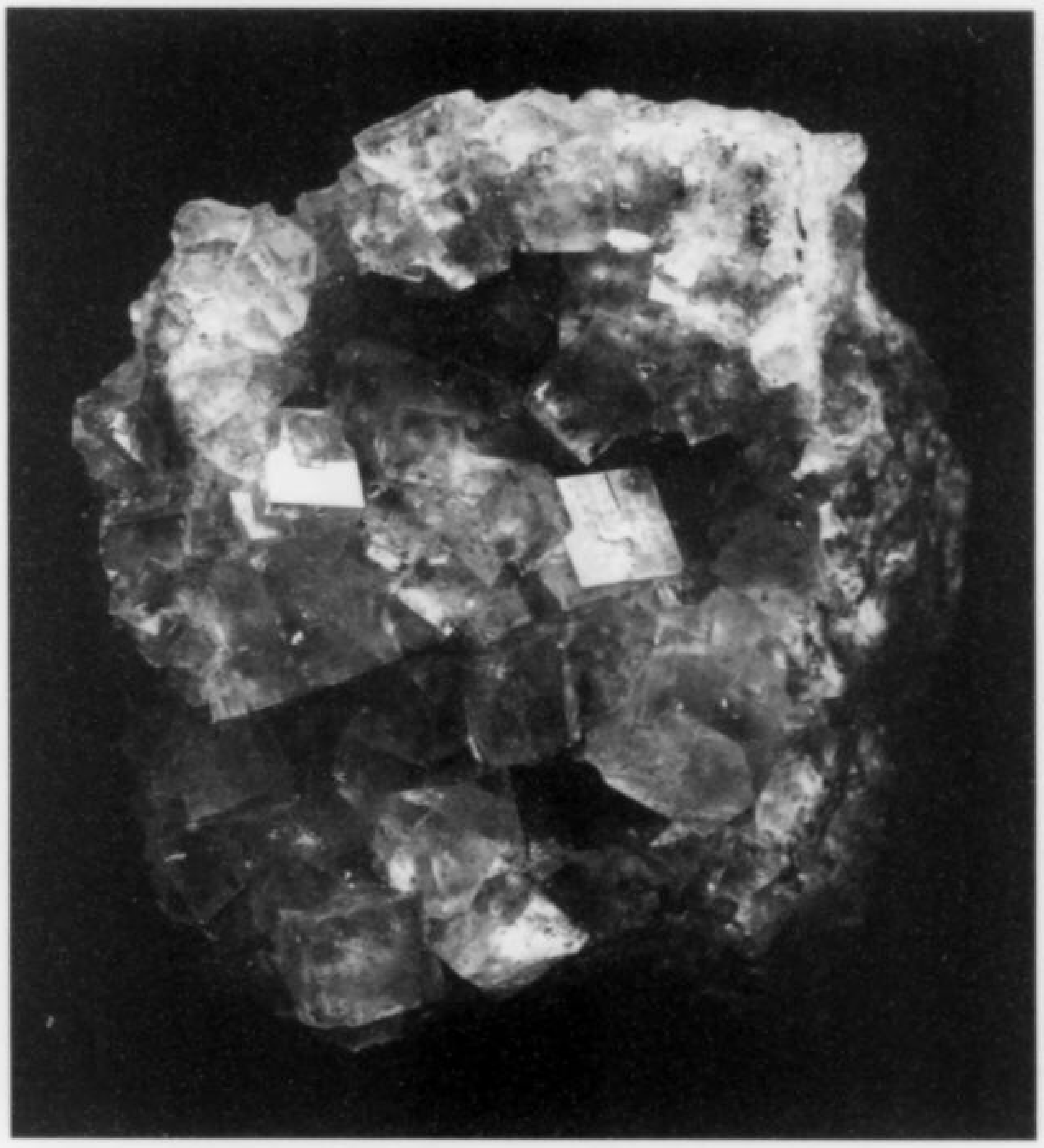


Figure 3. **Fluorite crystal group, 7 cm, from Grube Kurprinz, Gross-Schirma bei Freiberg, Obersachsen, Germany (label dated 1854). Peabody Museum collection and photo.**

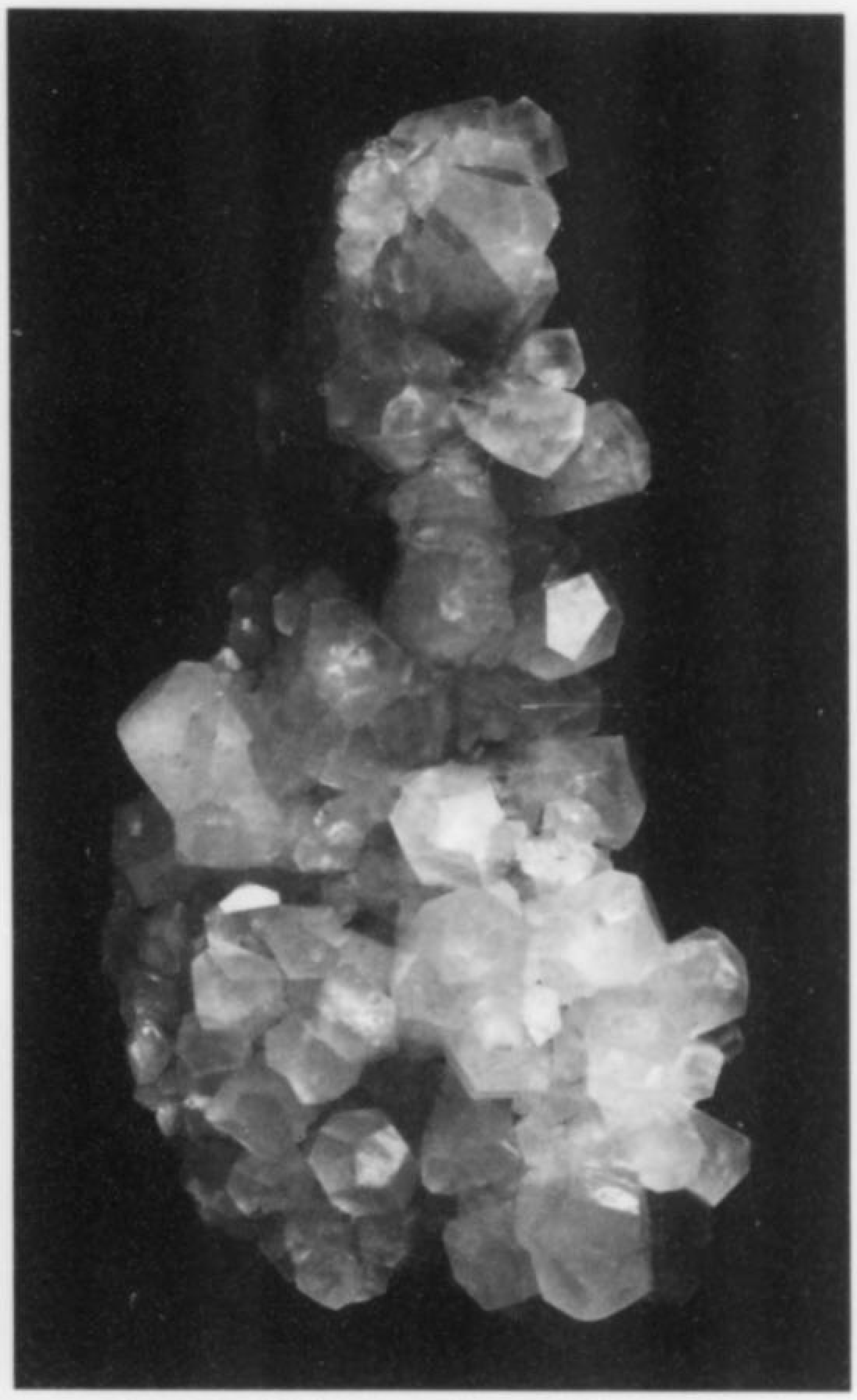


Figure 4. **Calcite crystal group, 10 cm, from Andreasberg, Harz Mountains, Germany. Peabody Museum collection and photo.**

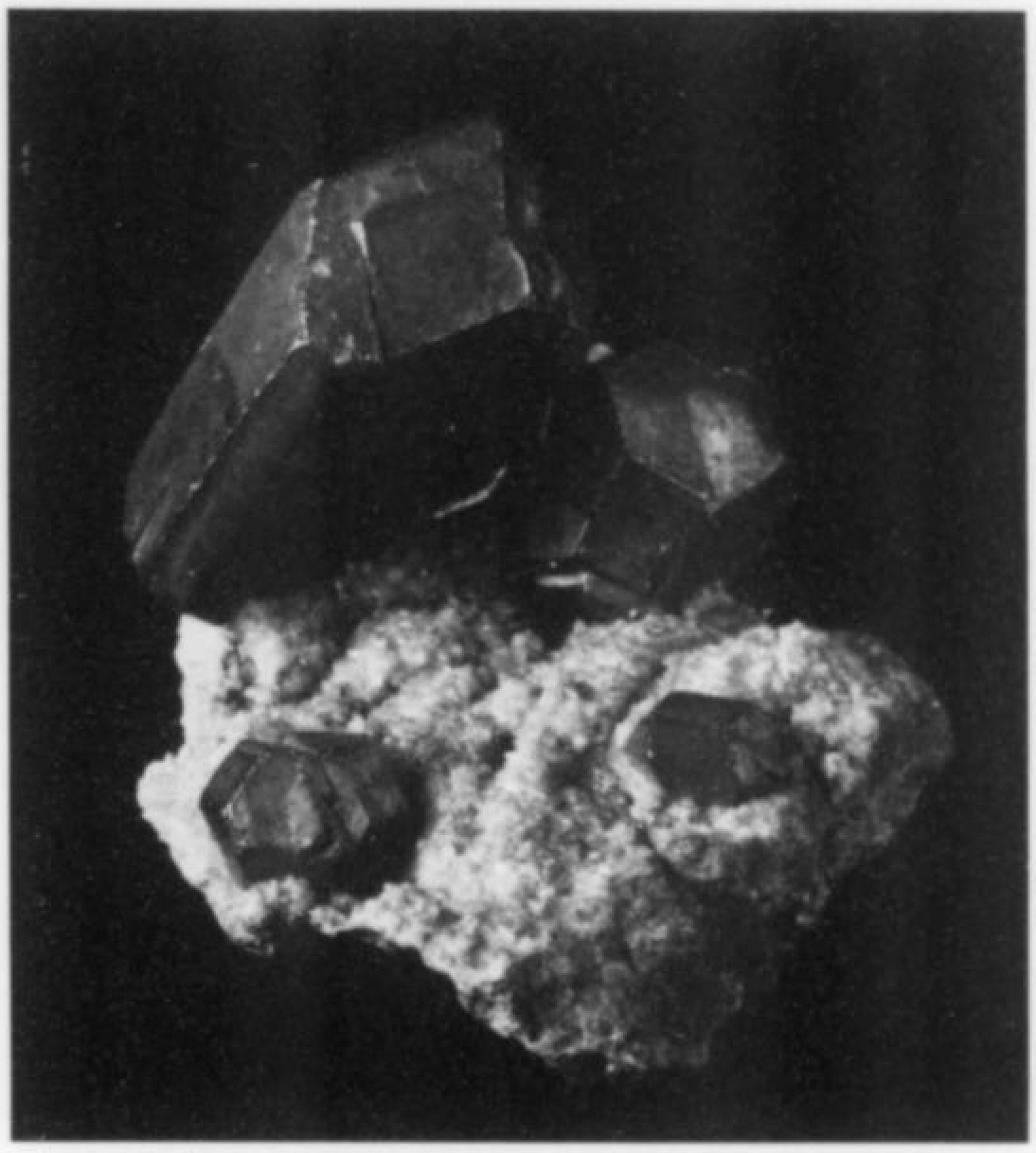


Figure 5. **Galena crystals on matrix, 3.5 cm, from Andreasberg, Harz Mountains, Germany. Peabody Museum collection and photo.**

Late in 1806, back in New Haven, Silliman delivered his first geological paper to the Connecticut Academy of Arts and Sciences. He later noted the progress in general geological edification that had been made since four years before the paper, when "it was a matter of extreme difficulty to obtain, among ourselves, even the names of the most common stones and minerals; and one might inquire earnestly, and long, before he could find any one to identify even quartz, feldspar, or hornblende, among the simple minerals;

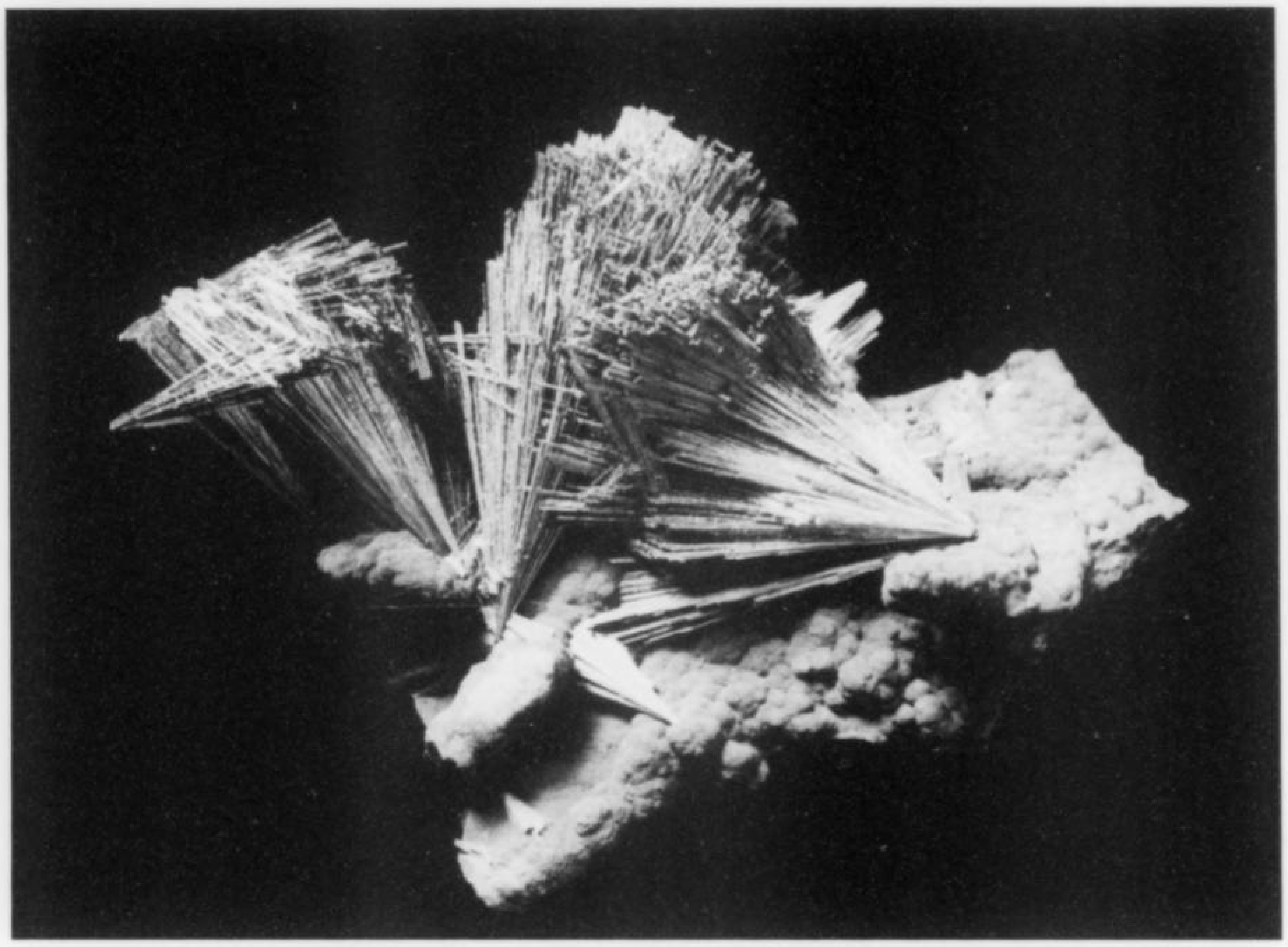


Figure 6. **Pyrolusite crystal sprays on matrix, 8 cm, from near Bonn, Nordrhein-Westfalen, Germany. Peabody Museum collection and photo.**

or granite, porphyry, or trap, among the rocks" (Silliman, 1818).

The specimens which Silliman brought back to New Haven joined a motley assemblage of others, whose tenure at Yale reached back to pre-Revolutionary times. These earliest "natural history" collections included "a bottle of water from the Ganges River, moose antlers weighing 50 pounds, the skin of a 17-foot anaconda, feathered headdresses from the South Sea Islands, a chain nine feet long made by a blind man from a single stick of wood, [and] a two-headed calf killed in Hamden." Somewhere around the time of Silliman's appointment to his professorship, most of the items in this collection were lent to someone; they were never returned, and were in due course forgotten about, but some 200 specimens of minerals, rocks and fossils seem somehow to have remained behind.

THE PERKINS COLLECTION

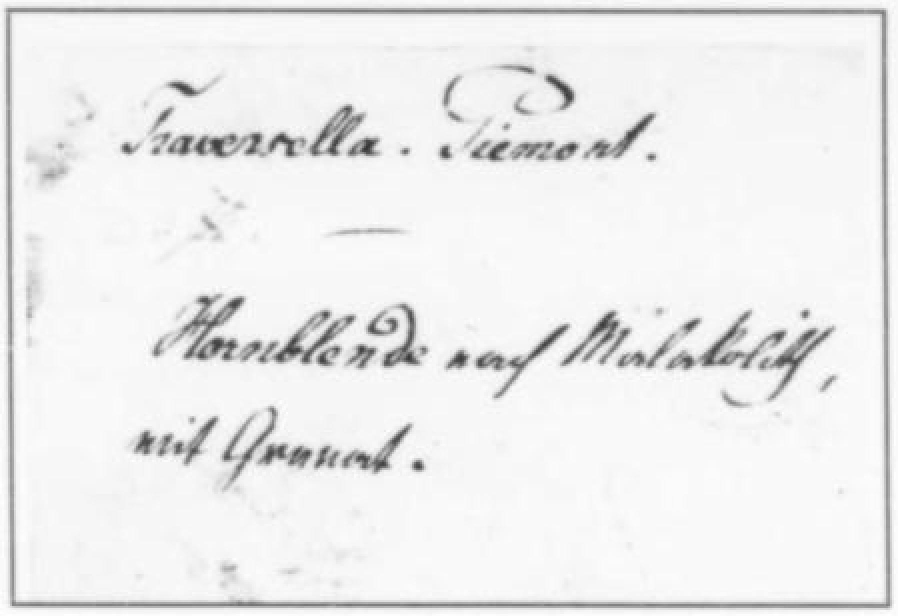
The year 1807 saw Silliman's first major purchase of a coherent mineral collection for Yale. For the controversially immense sum of $1,000 he bought the 2,000 English and European specimens which constituted the mineral cabinet of Benjamin Douglas Perkins (Yale B.A., 1794)—at that time "one of the two or three best in this country" (Narendra, 1979). Everyone, from eager first-year Yale students to Governor Jonathan Trumbull, visited Silliman's rooms in the old Lyceum, which were both his living quarters and the locale of his series of private mineralogy lectures (official courses in mineralogy were not added to the regular Yale curriculum until 1813), and all marveled at the beautiful things in the Perkins cabinet. They seem to have marveled, too, at Silliman's skill as a teacher and/or showman, his conviviality, and his erudition.

THE GIBBS COLLECTION

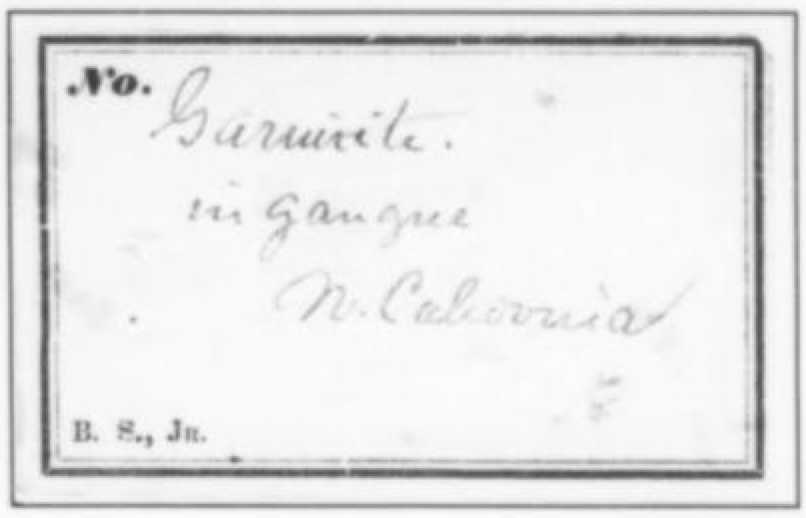
An even greater coup than the acquisition of the Perkins collection was by then already in the works. In the summer of 1806, Silliman, home barely a couple of months from England, had gone with his mother to visit his brother in Newport, Rhode Island, and there had obtained an introduction to Miss Ruth Gibbs, sister of Colonel George Gibbs. This wealthy businessman/traveler had himself recently returned from Europe and had quickly gone off again thence, having left behind, in a Newport warehouse, a large part of his outstanding mineral collection. Wilson (1994) summarizes the story of how Gibbs, while living in Switzerland, developed an interest in minerals, finally buying the great collections of the Russian Count Grigorii Kyrillovitch Razumovskii and of the French nobleman Gigot D'Orcy (executed in 1793, during the Reign of Terror). Gibbs also acquired smaller numbers of specimens from Jacques Louis, Comte de Bournon, another giant of European collecting, and from a few other sources (see Wilson (1994) for detailed accounts of these major collections as they probably were when Gibbs bought them up).

On subsequent visits to Newport by Silliman (from New Haven) and Gibbs (from Europe), the two men became friends, and in the winter of 1809/1810 Gibbs revealed to Silliman his intention to have the collection in its entirety set up for public display at Yale. By the summer of 1812, some 10,000 Gibbs specimens were on view in Connecticut Hall. Next, in 1820—Silliman having, hardly for the first time, prevailed upon Yale officialdom to raise considerable monies—the Gibbs collection, joined by the Perkins collection, was set up as a splendid display in the Cabinet Building.

By 1825 George Gibbs had gone through his inheritance and fallen into heavy debt; he wrote to Silliman that the collection was for sale for $20,000, and that Yale could have first refusal. Silliman was, of course, the perfect man for coordinating the massive fund-raising effort that followed. After fervent appeals to "the loyalty of our alumni and the liberality of friends of Science," a public meeting was held for all citizens of New Haven, followed immediately by house-to-house canvassing for donations. Altogether some


Traversella. Piemont.

Hornblende auf Malakolith, mit Granat.


No. Garnierite.
in gangue
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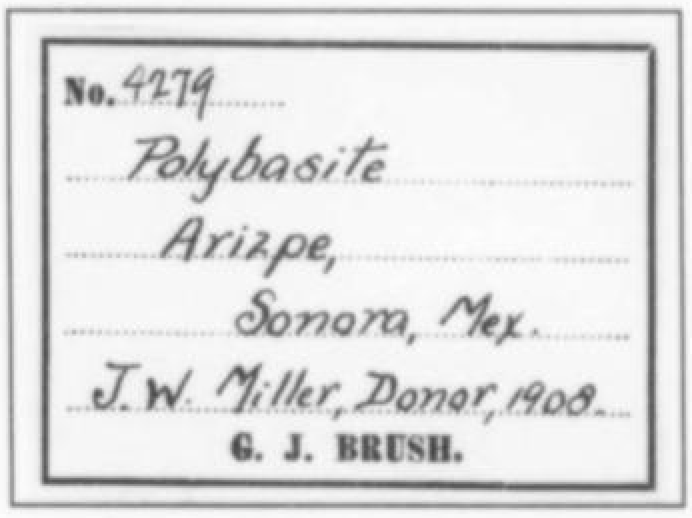
B. S., Jr.


No. 4279
Polybasite
Arizpe,
Sonora, Mex.
J.W. Miller, Donor, 1908.
G. J. BRUSH.

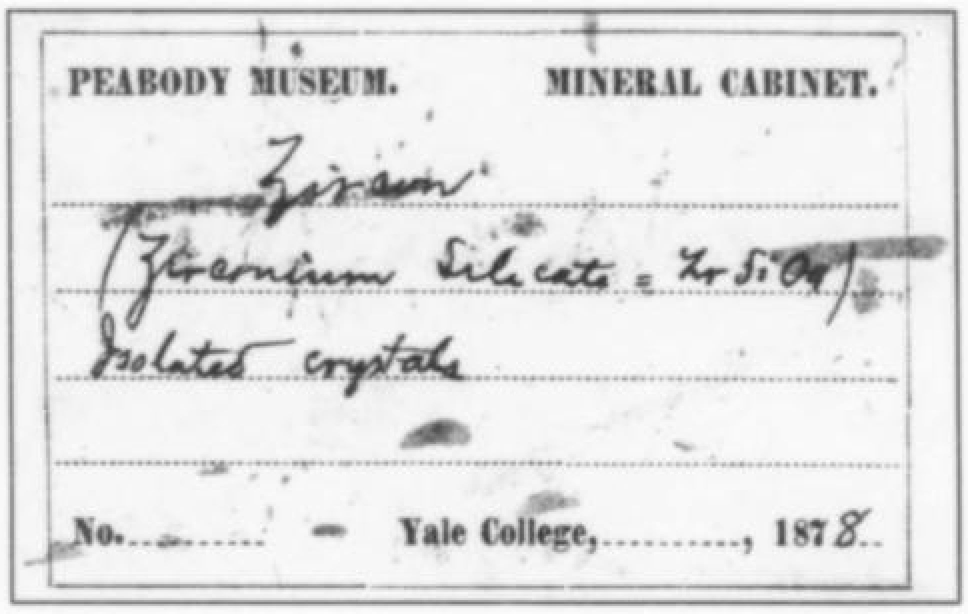
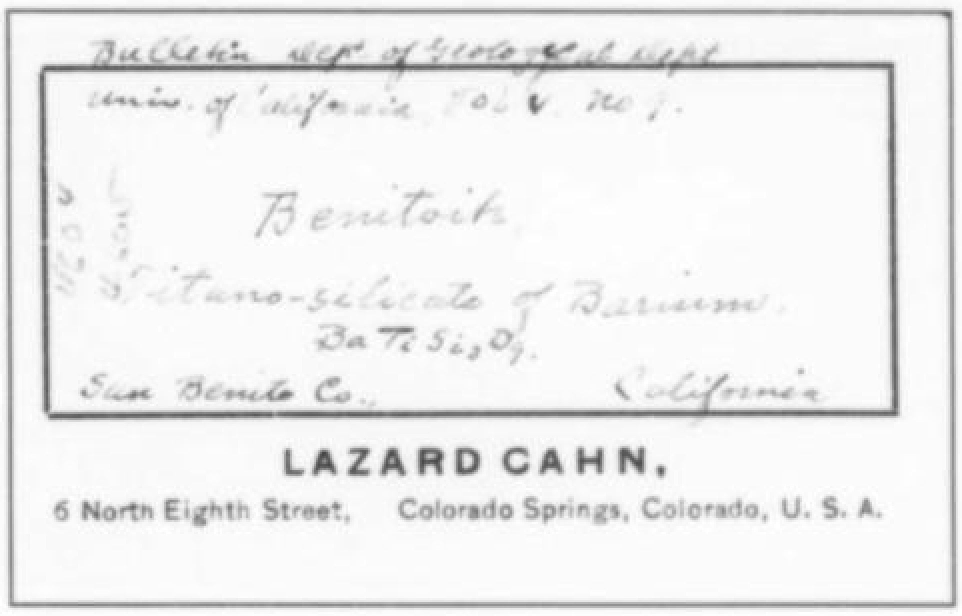

PEABODY MUSEUM. MINERAL CABINET.
Zircon
(Zirconium Silicate = $ZrSiO_4$)
Isolated crystals
No. — Yale College, ..., 1878.

Figure 7. **Specimen labels from the collections of Benjamin Silliman Jr. (above), George Brush (right), Lazard Cahn (below), the Peabody Museum in the 1870's (left) and Reinhard Blum (above left).**


Bulletin dept. of Geological dept.
Univ. of California, Vol. V. No. 1.
Benitoit
Titano-silicate of Barium.
$BaTiSi_3O_9$.
San Benito Co. California
LAZARD CAHN,
6 North Eighth Street, Colorado Springs, Colorado, U. S. A.

$15,000 were procured by these means, leaving the University to pay the rest, which it duly did within only a few more years.

THE LEDERER COLLECTION

Unfortunately, the Gibbs collection contained almost no minerals from American localities. In 1843 there was presented to Yale and Silliman a fine chance to remedy that deficiency, when the collection of Baron Alois J. X. Lederer went up for sale. For more than 25 years Lederer had been Imperial Austrian Consul-General to the United States, and had accumulated some 3,000 excellent specimens, exclusively of American minerals, many of these being duplicates of a collection which he had assembled at the same time for the Vienna Museum of Natural History. And so another fund-raising drive commenced, this time under the captaincy of Benjamin Silliman Jr., his father's assistant. This time there was stiffer resistance from alumni, many of whom had just recently given much for the new Yale library, if not also, 17 years earlier, for the Gibbs collection. But again the purchase was made, and again the University had to put up a major sum of its own. Narendra (1979) suggests that the argument of the Sillimans, father and son, which carried the day with donors was the one summarized by Wilmarth Lewis (1946), friend of the Peabody Museum, as follows:

> Fine collections attract great scholars, great scholars attract brilliant disciples, the quality of the institution's teaching is improved, and the students are the gainers thereby. Everyone is benefited by collections, whether they know it or not.

GEORGE PEABODY

In 1853, Benjamin Silliman Sr. retired, and the later curatorial history of Yale's collection commenced: Silliman's first successor was his old student, and by now his son-in-law, James Dwight Dana. But during these last few years of his long life, the elder Silliman got one more chance to use his skills of persuasion to bring wealth to Yale. In 1857 the wealthy international banker George Peabody stopped in New Haven to visit his nephew O. C. Marsh, then a Yale freshman. The young Marsh might more naturally have gone to Harvard, like other members of the Peabody family of Massachusetts, but he was an avid mineral collector, and had chosen Yale because of the renown of Benjamin Silliman Sr. In 1863, after much talk and correspondence among Peabody, Marsh, and the two Sillimans, the banker announced his bequest to Yale of $100,000. In 1866, two years after Silliman Sr.'s death, this was changed to an outright gift of $150,000, and the Peabody Museum was founded. The minerals were, naturally, included in the new museum's holdings, and George Jarvis Brush was appointed the first official curator of the Peabody Museum mineral collection. When Brush moved over, in 1872, to become the director of the Sheffield Scientific School, Edward S. Dana, son of James Dwight Dana, succeeded to the curatorship.

JAMES DOUGLAS

During the second half of the 19th century, even while the work of the Danas at Yale was generating the *System of Mineralogy*, Benjamin Silliman Jr. seems to have kept a hand in the development of the collection, especially in its "display" aspects. The browser today may be surprised to notice that the collection, while in general overwhelmingly skewed toward old localities in Europe and the eastern United States, possesses also great strength in classic Bisbee, Arizona, material: generous numbers of very fine azurite, pseudomorphous malachite, cuprite and calcite specimens, and what is surely one of the world's best two or three miniatures

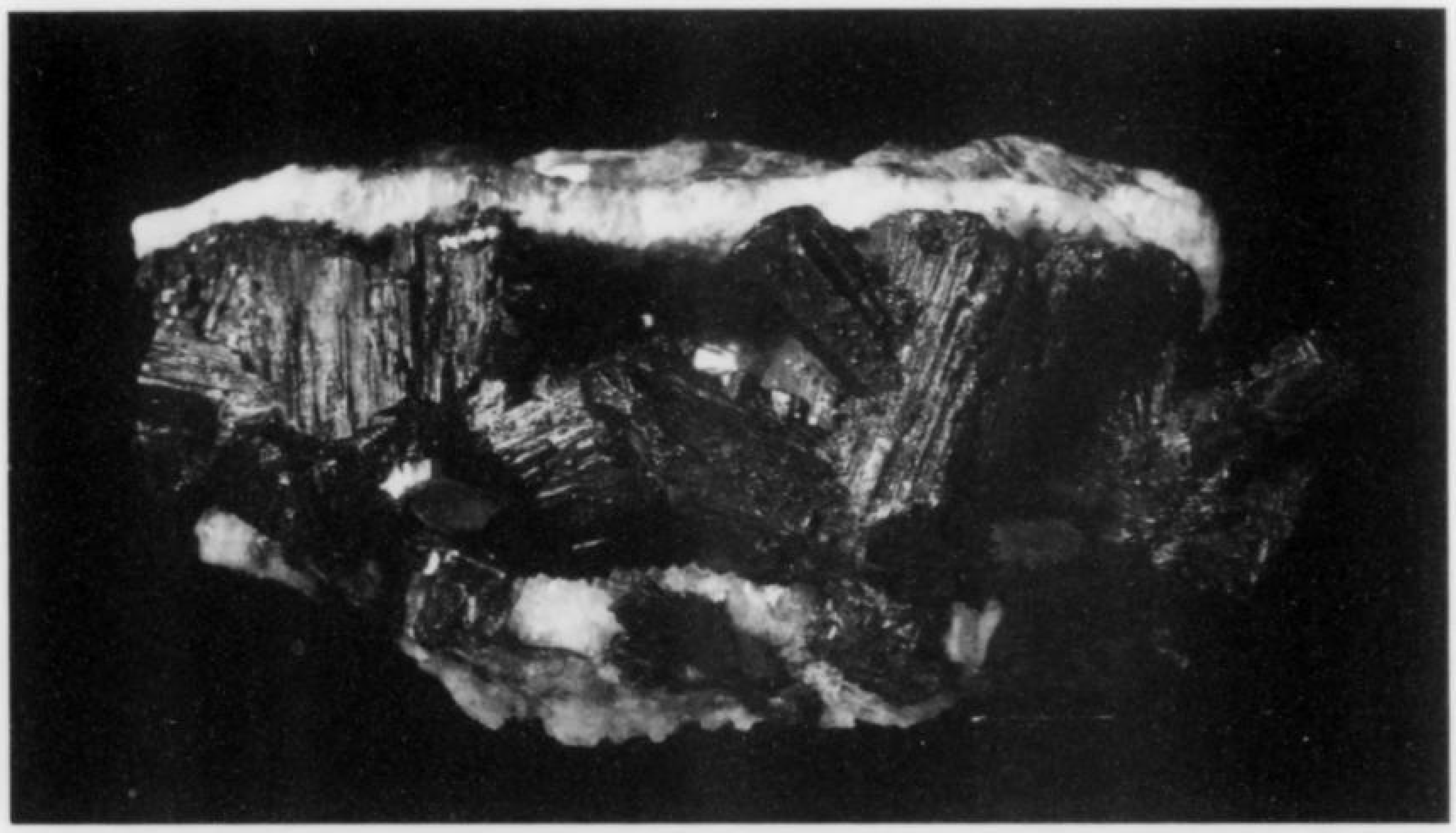
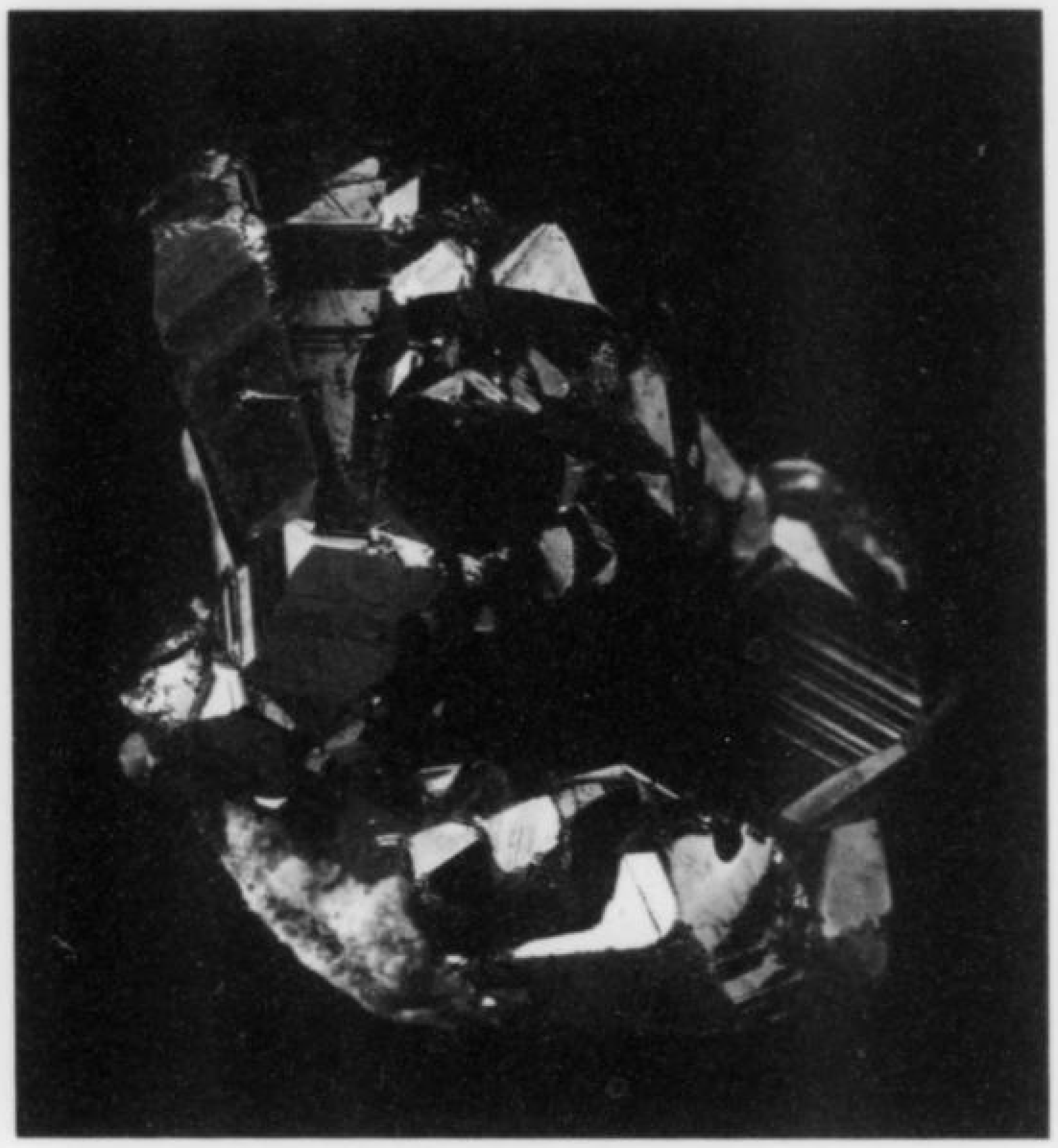


Figure 8. Dyscrasite crystal group, 5 cm, from Andreasberg, Harz Mountains, Germany. Peabody Museum collection and photo.

Figure 9. Kermesite crystal sprays on matrix, 9 cm, from Grube Neue Hoffnung Gottes, Bräunsdorf bei Freiberg, Obersachsen, Germany. Peabody Museum collection and photo.



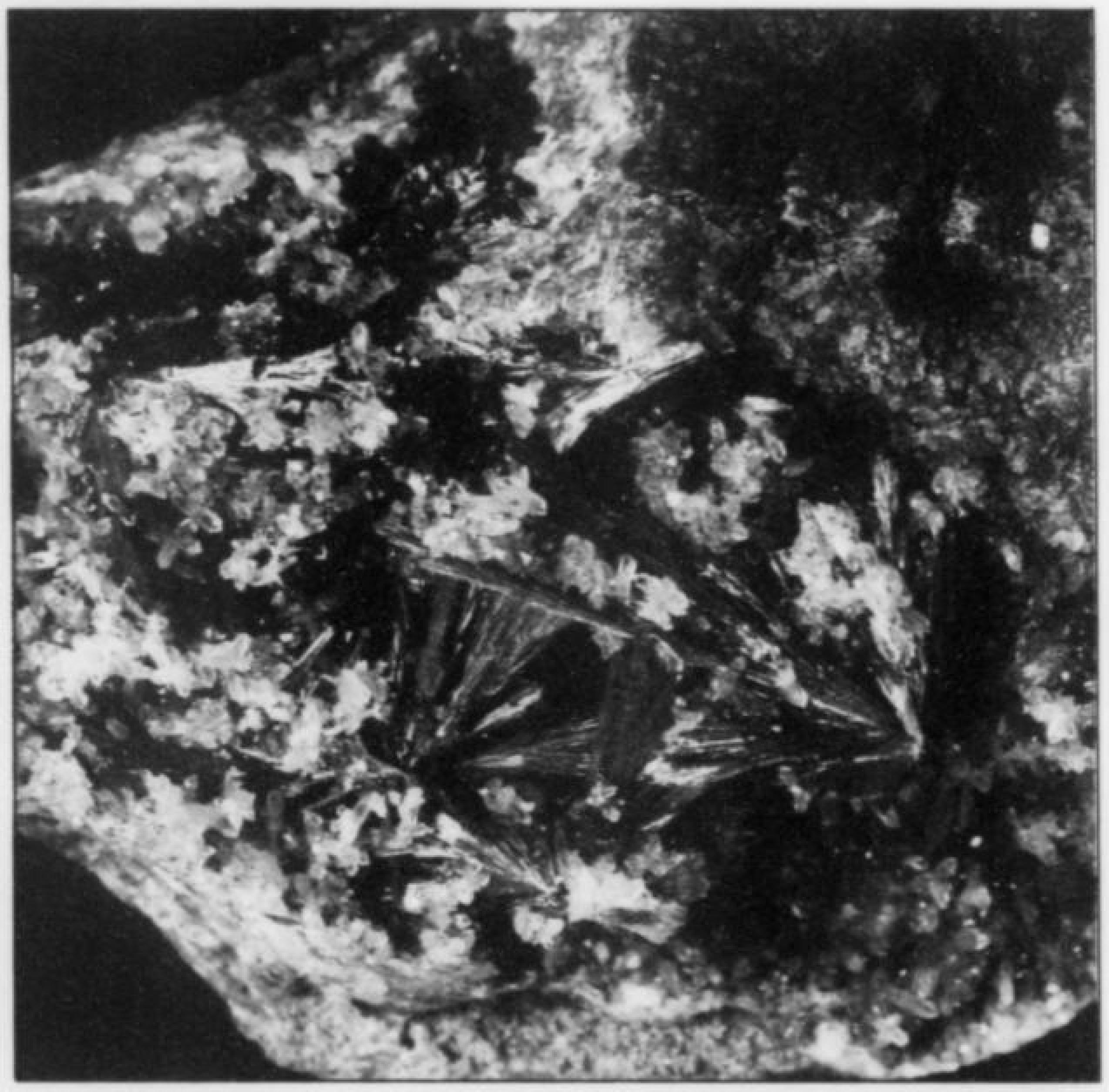


Figure 10. Pyrargyrite crystal group, 2.5 cm, from Andreasberg, Harz Mountains, Germany. Peabody Museum collection and photo.

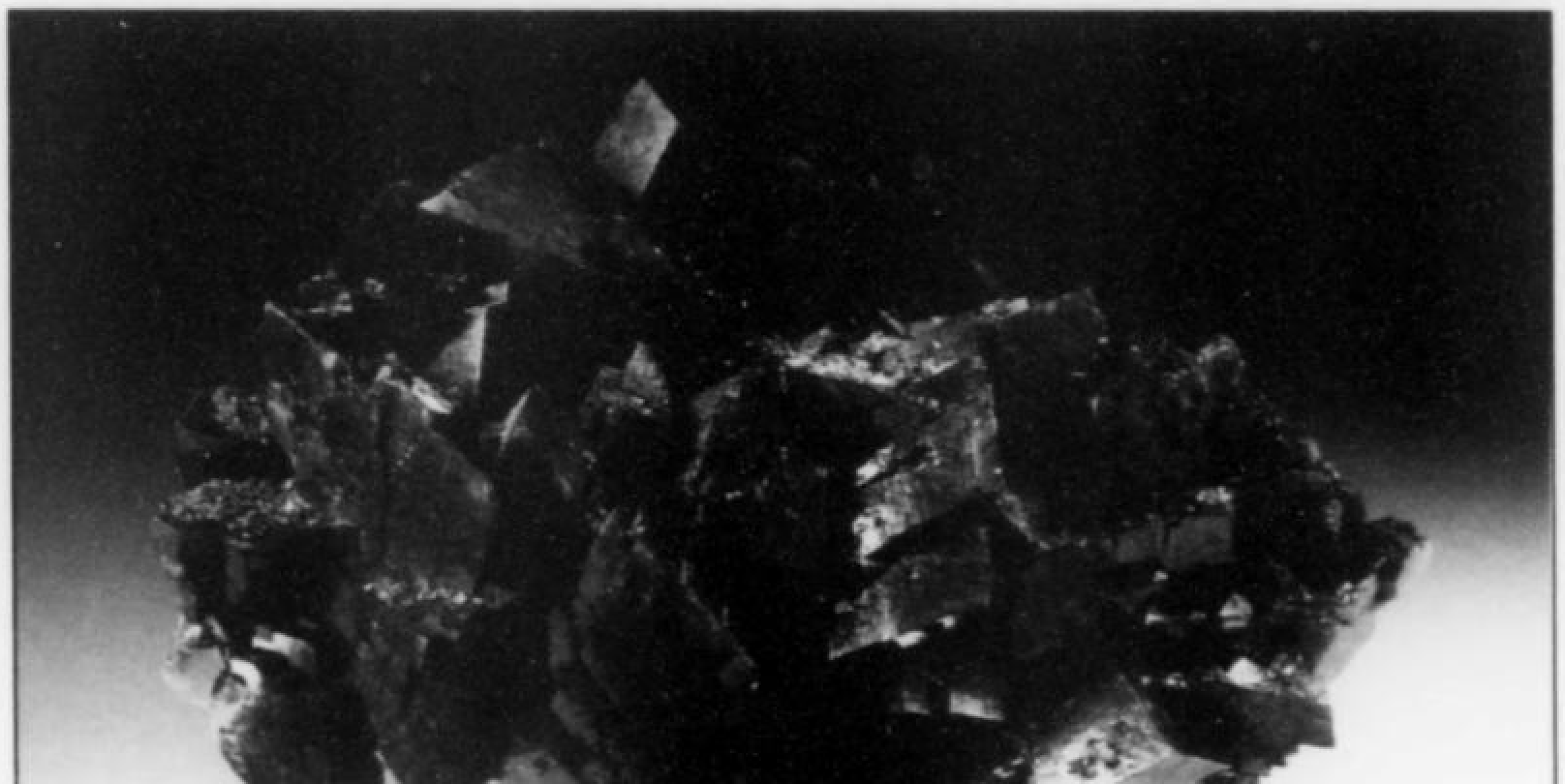


Figure 11. Siderite crystal group, 7 cm, from Neudorf, Harz Mountains, Germany. Peabody Museum collection; Wendell Wilson photo.

Figure 12. Pyromorphite on matrix, 11 cm, from Hofsgründ bei Freiburg, Baden-Württemberg, Germany (George Gibbs collection). Peabody Museum collection and photo.

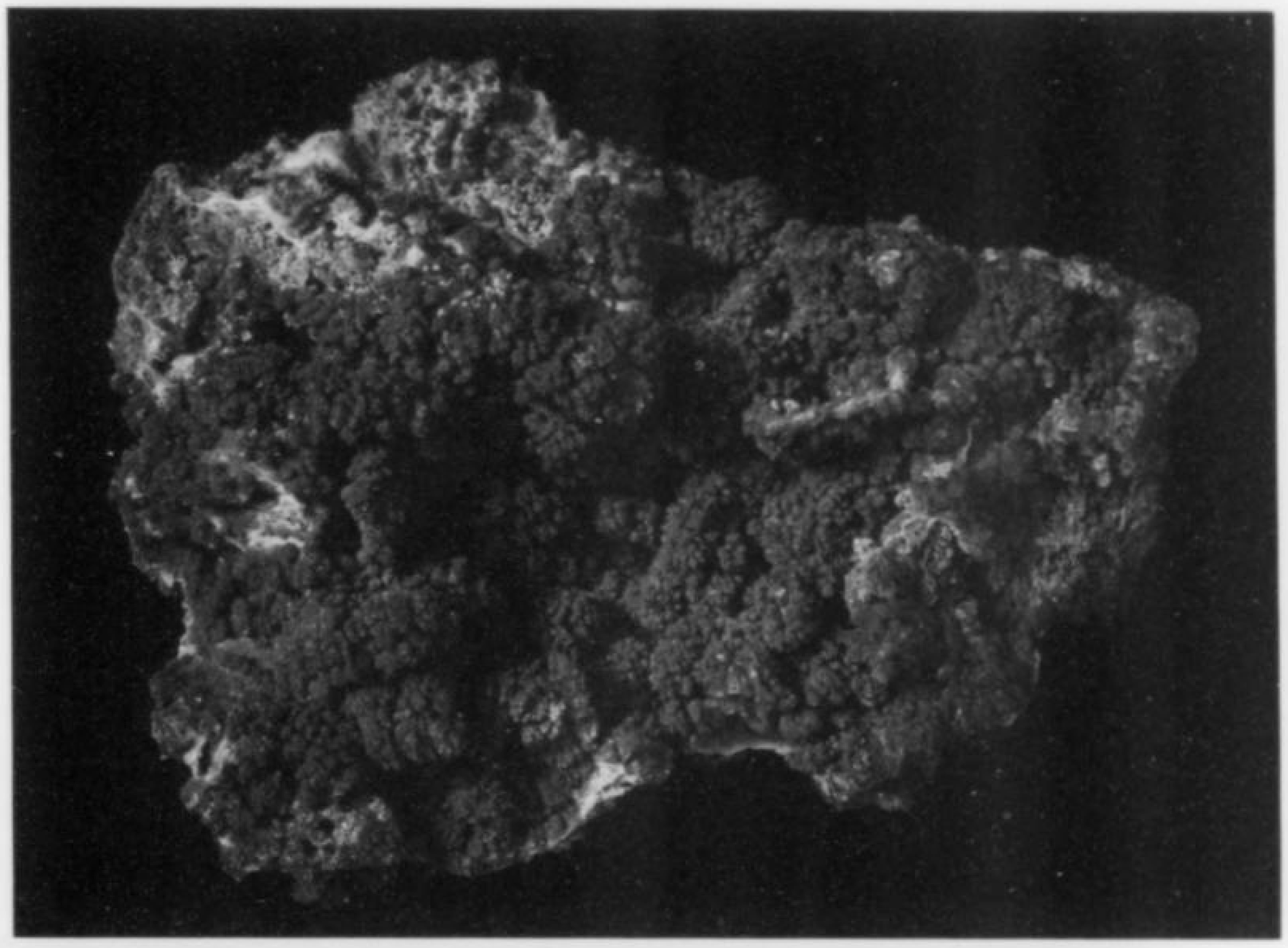
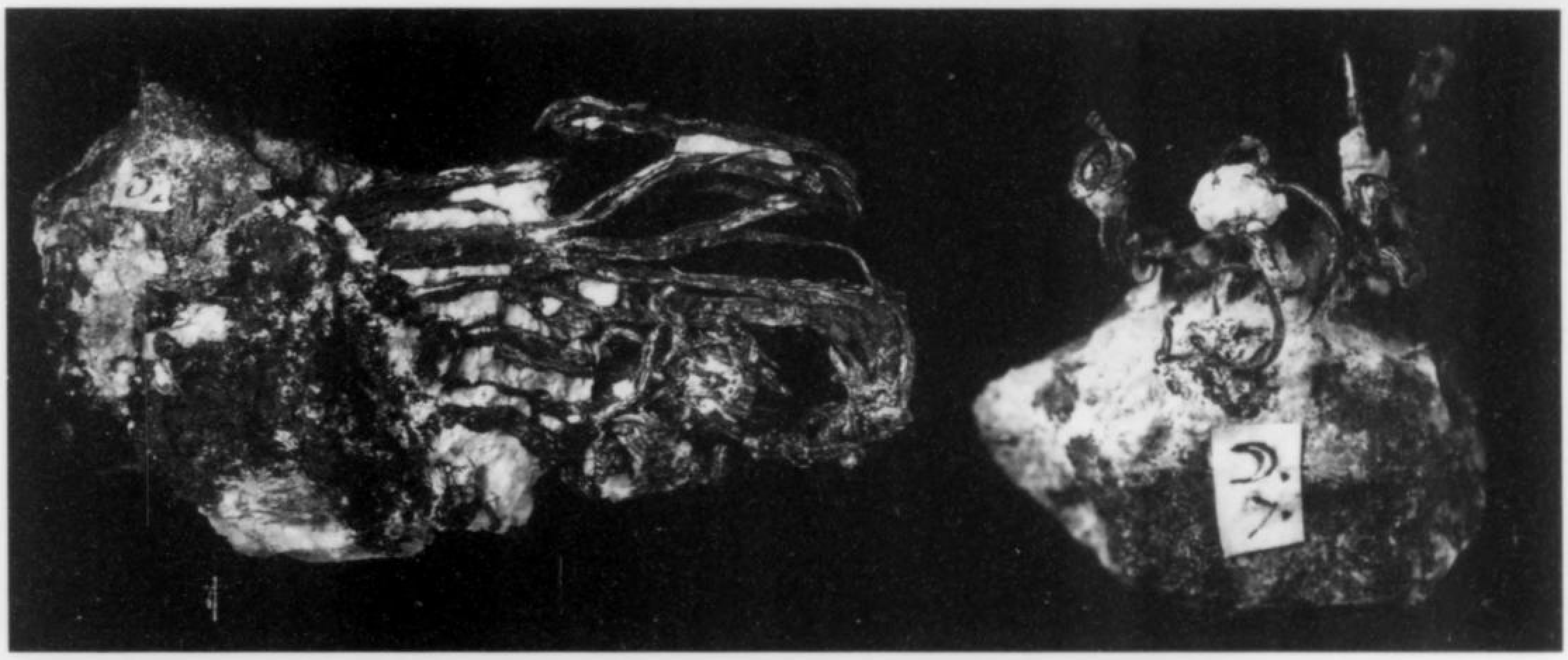


Figure 13. Native silvers, 9 cm and 4 cm, from Grube Himmelsfürst, Freiberg, Obersachsen, Germany (George Gibbs collection, from the Gigot d'Orcy collection). Peabody Museum collection and photo.



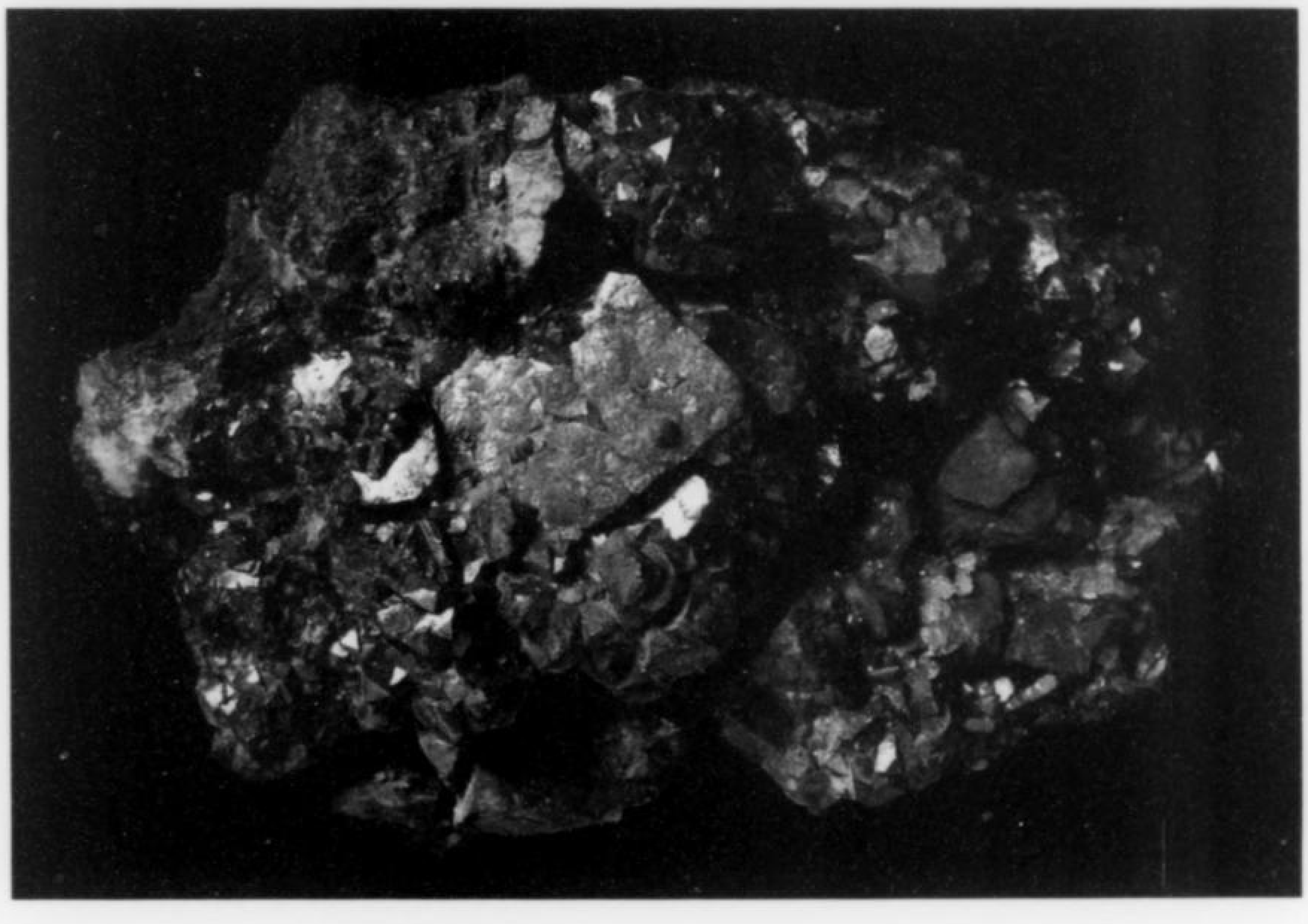


Figure 14. Skutterudite crystal group, 9 cm, from Schneeberg, Erzgebirge, Obersachsen, Germany. Peabody Museum collection and photo.

of spangolite. Apparently this Bisbee plethora is a result of an early connection between Benjamin Silliman Jr. and James Douglas, metallurgist, who came from his early work at the lead/zinc mines at Phoenixville, Pennsylvania, to Bisbee in 1881. Douglas and Silliman had worked together on engineering problems at Phoenixville, and Silliman had sent Douglas west to investigate Bisbee's Copper Queen mine, a property which Silliman had recently optioned from its majority owners. Douglas eventually recommended that Silliman find a buyer to pay $500,000 for 51% of the Copper Queen, but Silliman couldn't, and his option terminated. But it was probably during the 1880's, when these machinations were going on, that Yale acquired through Douglas its fine Bisbee suite.

THE BRUSH COLLECTION

In 1904, George Jarvis Brush, who had briefly curated the Peabody Museum collection 32 years before, donated to it his own collection of some 15,000 specimens. This was scientifically the most important single collection ever acquired by Yale. During all his professional life as a metallurgist and mineralogist, and as head of the Sheffield School after 1872, Brush had been the most thoughtful kind of what we would now call a "species collector," gathering minerals not from aesthetic impetus, but specifically for research and reference. This, then, is the collection which gives the present Yale assemblage its general "reference" character: rich in rare species (and, thanks to the work of the Danas, in type specimens), but fairly low in the showy display pieces. More of this later.

The Brush collection was curated, just after its acquisition, by Samuel Penfield, and then, after 1906, by William E. Ford. With E. S. Dana's retirement in 1922, the curatorship of the Peabody Museum collection was combined with that of the Brush collection; to this day the two are folded together according (naturally) to Dana, with only the catalog numbers (either "PM" or "B") to distinguish specimens which had belonged to Brush from those held by the Museum before 1904. Since 1922 a number of curators have presided over the combined collection, most notably Horace Winchell, who was named curator in 1951 and was Curator Emeritus until his death in 1993. Karl K. Turekian has served as Acting Curator since 1985.

THE BLUM AND CAHN COLLECTIONS

Two distinct and distinctive subcollections, both cataloged separately from the main one, should be mentioned. One is the Blum collection of pseudomorphs, acquired in 1871: over 1,700 specimens gathered by Professor Reinhard J. Blum of the University of Heidelberg; see my note (vol. 28, no. 1) on Yale's case at the 1996 Denver Show, in which a few pieces from this collection were shown. And the Lazard Cahn collection of micromounts, acquired in 1958 and curated before and after that date by Neil Yedlin, consists of 5,000 specimens mounted in micromount boxes, filling an inconspicuous few drawers near the end of the systematic Brush/Peabody array.

THE MINERAL DISPLAY TODAY

It must be said that today's mineral-minded visitor to the Museum may at first feel some disappointment: he knows that Yale has a venerable and extensive collection, but finds that the only minerals on view in the Peabody's publicly accessible galleries are in a single small display room which clearly has known better-maintained days. Yet a couple of wallcases of New England minerals here are excellently presented, and contain some things (e.g. a sharp, fist-sized, loose yellow amblygonite crystal from Maine) which fairly yank the dusty museum air right back out of one's lungs. An inquiry at the Museum's front desk reveals that in order to see a few more minerals the visitor must go outside the building again, circle around it, and find, just inside the entrance to the adjoining Kline Geology Laboratory building, a double row of glass display cases containing about 100 specimens. Most of these are very good and some are outstanding, especially the big Cornwall bournonite, the miniature of green muscovite from North Carolina, the matrix analcime from the Phoenix mine, Michigan, and a German pyrolusite and German whewellite.

But where, one still wonders, are the *rest* of the mineralogical holdings? They are "in storage," filling more than a thousand deep wooden drawers and (for the largest specimens) eight rows of ceiling-high, glass-fronted wooden cases, in a small room just off one of the hallways of the geology building. This room is not for the browsing public—more than three visitors at a time would cause terminal congestion along the narrow aisles between the big cases. An interested party must pre-arrange a visit, and then be guided expertly and affably around the room by longtime Collection Manager Ellen Warren Faller.

First impressions are strongly encouraging: to the immediate right as one enters the room there's a flat glass case with some large and superlative old Bristol, Connecticut, chalcocite and bornite specimens, and a sharp 3-cm crystal, in matrix, of wolframite pseudomorphous after scheelite, from Trumbull, Connecticut. In the first of the high wooden cases, facing the entranceway, there are several Japanese stibnite clusters averaging 2 feet high and/or wide.

My own experience with this fine old collection began with just such a visit to the storage room, after which I arranged to do some volunteer work—duly done through most of the summer of 1996 and in January 1997. It was a brutal enough commute for me each day on ferocious Route 95, but great and good were the foreglows and afterglows of each daylong session of looking into so many old, deep drawers full of treasure. I worked at applying (and gratifying) my personal interest in German minerals and old German localities by doing what I could to get locality information for German specimens in better focus, and then make new, separate labels showing (if possible) where these antique items were *really* from in Germany.

Sometimes this was a matter simply of adding the contemporary names of States (*Bundeslände*); sometimes of adding these to the old regional terms which were never political ones (e.g., "Siegerland"), or to obsolete ("Prussia") or vaguely generalized ("Saxony") names of old political units. Often enough, when the word "Germany" did not appear on the master printout, but some such term as "Schlesien" or "Elsass" did, the specimen had to shed its German affinities altogether—Schlesien, or Silesia, being now in Poland, and Elsass (Alsace) in France. And one "German" specimen proved to be from Russia, and yet another from Mexico. Little, unfortunately, could be done to refine names of towns, without accompanying mine names, at centers of mining districts—saying "Andreasberg" or "Freiberg" alone is about like saying "Leadville" or "Joplin" or even "Poona." But it was, on the other hand, most satisfying to be able to supply with certainty a name of a mine, quarry, prospect, or even outcrop, which was *not* given originally on the old label or in the catalog. Here I must acknowledge my great indebtedness to (i.e., complete dependence upon) the two richly detailed books by Bode and Wittern (1989) and Haake *et al.* (1994) entitled *Mineralien und Fundstellen; Bundesrepublik Deutschland*, the former authors covering the former West Germany, the latter the former East. To apply such reference guides to such a collection as Yale's could only have been—and was!—an extremely fine-tuned education in an arcane field I'd *thought* I'd had a fair knowledge of.

Education can sometimes come in such pretty packagings, too. Who would have guessed that such lovely groups of pale green 1-cm prehnite crystals came, long ago, from a handful of little quarries in Radautal near Bad Harzburg, east of Goslar in the Harz; who has knowingly appreciated the beautiful "ruby jack" sphalerite of the Grube Gute Hoffnung near St. Goar, on the bank of the Rhine (where tour boats ply, bound for the Lorelei Rock, every day); who knows of the fine, bright, embedded spherules of yellow-green wavellite, not from Arkansas or even Devonshire, but from quarries on Wachtelberg Hill near the village of Langenstriegis, west of Freiberg?

Of course the collection also contains some top-quality specimens of more predictable German things (Freiberg silver and argentite and stephanite, Andreasberg pyrargyrite and calcite, Ems pyromorphite, Stassfurt anhydrite, Hagendorf phosphates, etc.), as the photos here suggest. And yet the German representation, like that of other countries, is spotty, full of odd absences: there are no fine display pieces here of Siegerland rhodochrosite, Erzgebirge proustite or erythrite, Neudorf bournonite or tetrahedrite, or even of my favorite of all pseudomorphs: galena after pyromorphite from the Grube Kautenbach, Bernkastel/Mosel.

Some specimens, German and otherwise, are heartbreakingly deteriorated and crumbling; some labels are hardly legible. Too many specimens throughout the collection are more or less seriously bashed for having been packed too tightly with others, or jammed into cardboard or plastic boxes too small for them. But there are positive surprises, too: there's something very endearing about the many small specimens lovingly mounted, perhaps by students, with beeswax on little round wooden pedestals. Or these may instead be specimens which Col. Gibbs had acquired from the Comte de Bournon, who was known for mounting what we would call "thumbnail" specimens in this way (see Wilson, 1994), protecting tiny single crystals or delicate thumbnails from neglect and loss. Then come more eccentricities: tiny crumbs of rare species lost amid yellowing layers and more layers of cotton nesting; odd-looking powders and flakes and sands and aciculae in assortments of vials and pipettes and miniature paper boxes; labels proposing straight-faced such species and/or varietal names as might have bemused Agricola.

But then, sometimes, a major and majestic thrill is afforded by one of the rare specimens whose ancient adhering paperslip bears black-inked alchemical signs and symbols. This clue identifies the piece as having once belonged to Gigot D'Orcy, who, before the French Revolution cost him his head, liked to tag his minerals this way.

In short, to go through the 1000+ drawers of this collection, from native gold to "pyropissite" (an organic material, yes) is to get to know a lovably eccentric oldster, as variegated in rich experience and in wisdom as in liver spots and faintly foul odors: absent-minded, dreamy, full of surprises of much different orders than those we encounter at (say) mineral shows in our own more self-aware, streamlined time.

All specimens pictured here are German, for the quite arbitrary reason that that's what I worked on; actually the collection's main strengths among older localities are elsewhere. There is an exceptional richness in English minerals, most of these presumably from the Perkins collection acquired so long ago by Silliman. As noted, there are myriad fine things from Bisbee; as also from France (generally), the Mte. Somma (Vesuvius) lavas in Italy, and the Swiss and Austrian Alpine vugs.

In the classic occurrences of the eastern United States the collection is extremely strong, continually serendipitous for the browser. To mention some major examples, there are great numbers of old upstate New York specimens (including Russell danburites and Rossie galenas and pyrites, in choice crystallizations by the dozens); choice Tilly Foster mine, New York, clinochlore, chondrodite and brucite specimens; *three drawers* entirely filled with crystallized pale green brucite from Wood's Chrome mine, Lancaster County, Pennsylvania; many fine French Creek mine, Pennsylvania, pyrite and chalcopyrite specimens; abundant Phoenixville, Pennsylvania, specimens of pyromorphite, wulfenite, cerussite and anglesite, these probably also courtesy of the Silliman/Douglas connection; excellent phosphates from the Maine pegmatites; zeolites from Paterson/Prospect Park, New Jersey; and plenty of old Franklin/Sterling Hill specimens, including three drawersfull of sometimes amazingly fine franklinite.

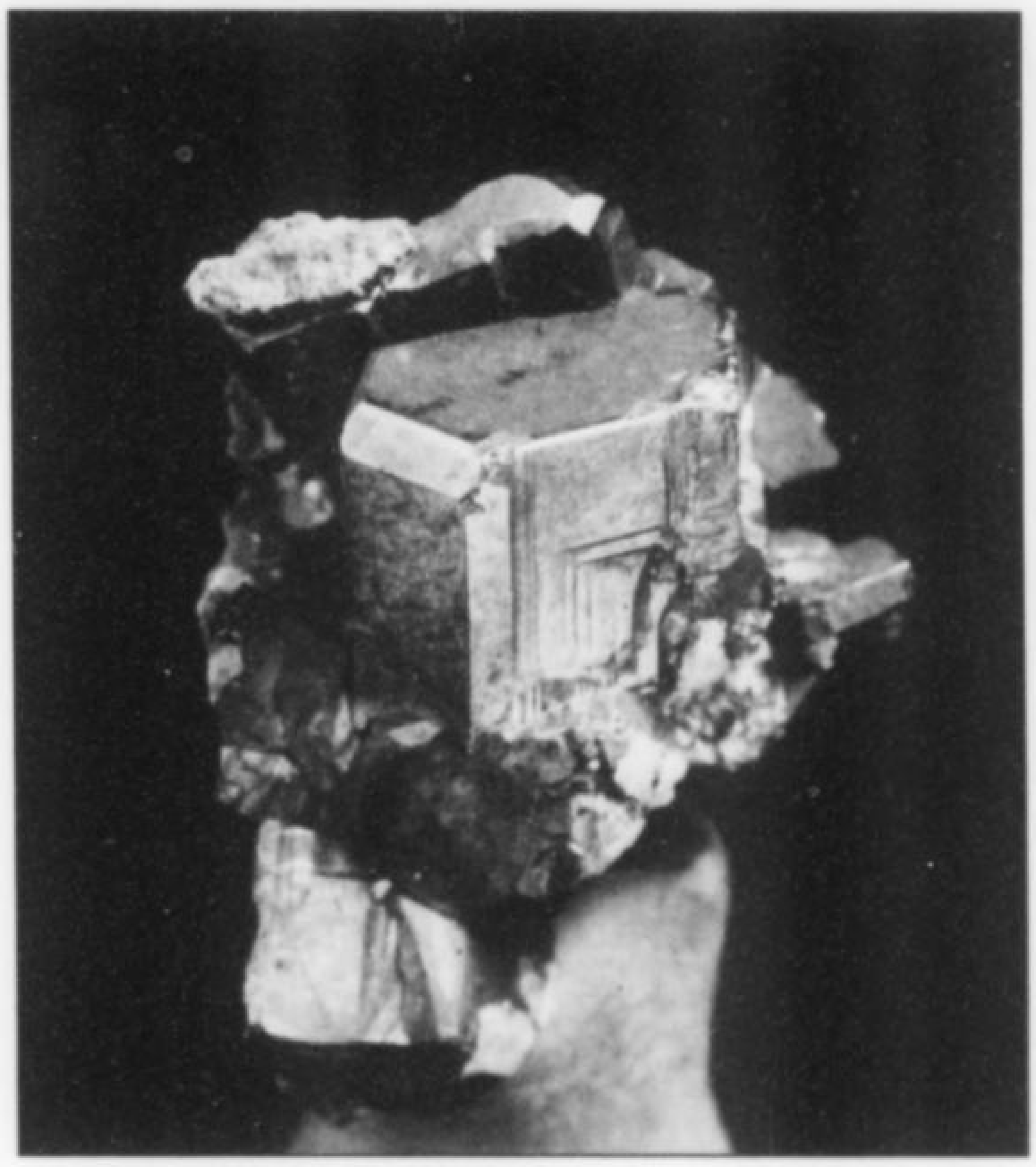


Figure 15. **Stephanite crystal group, 2 cm, mounted on wax, from Annaberg, Erzgebirge, Obersachsen, Germany. Peabody Museum collection and photo.**

The Connecticut representation, while perhaps not the best in *any* collection, is, as one might expect, the most "complete" among the subcollections. Come here to experience reality if you have taken it merely on faith from old reference works that this small state has produced first-rate crystals of ilmenite, columbite, epidote, datolite, many zeolite and garnet species, and many others, *besides* the green gem elbaite, yellow gem beryl, and purple apatite from the pegmatite swarms around Portland and Middletown. Most dramatic of all, perhaps, is the downright decadent two drawersfull of chalcocite and bornite specimens of all sizes from Bristol—nearly all the chalcocites in aesthetically effective clusters of steely gray cyclic twins, individually to 3 cm across. There are about 50 fine chalcocite specimens and a dozen fine bornites here, and in other drawers there repose instructive arrays of "ore" specimens from the Bristol mine, including pyrite, chalcopyrite, covellite, tetrahedrite and native copper.

But, sadly . . . the hard fact is that the Yale collection in general has been moribund for quite a few decades now. While as a historical repository of type specimens, as a still-active research collection, and as a support for Yale mineralogy courses, its worth of course is great, the collection is *just* rich enough in fine display specimens to remind one of how poor it is in these also, and how

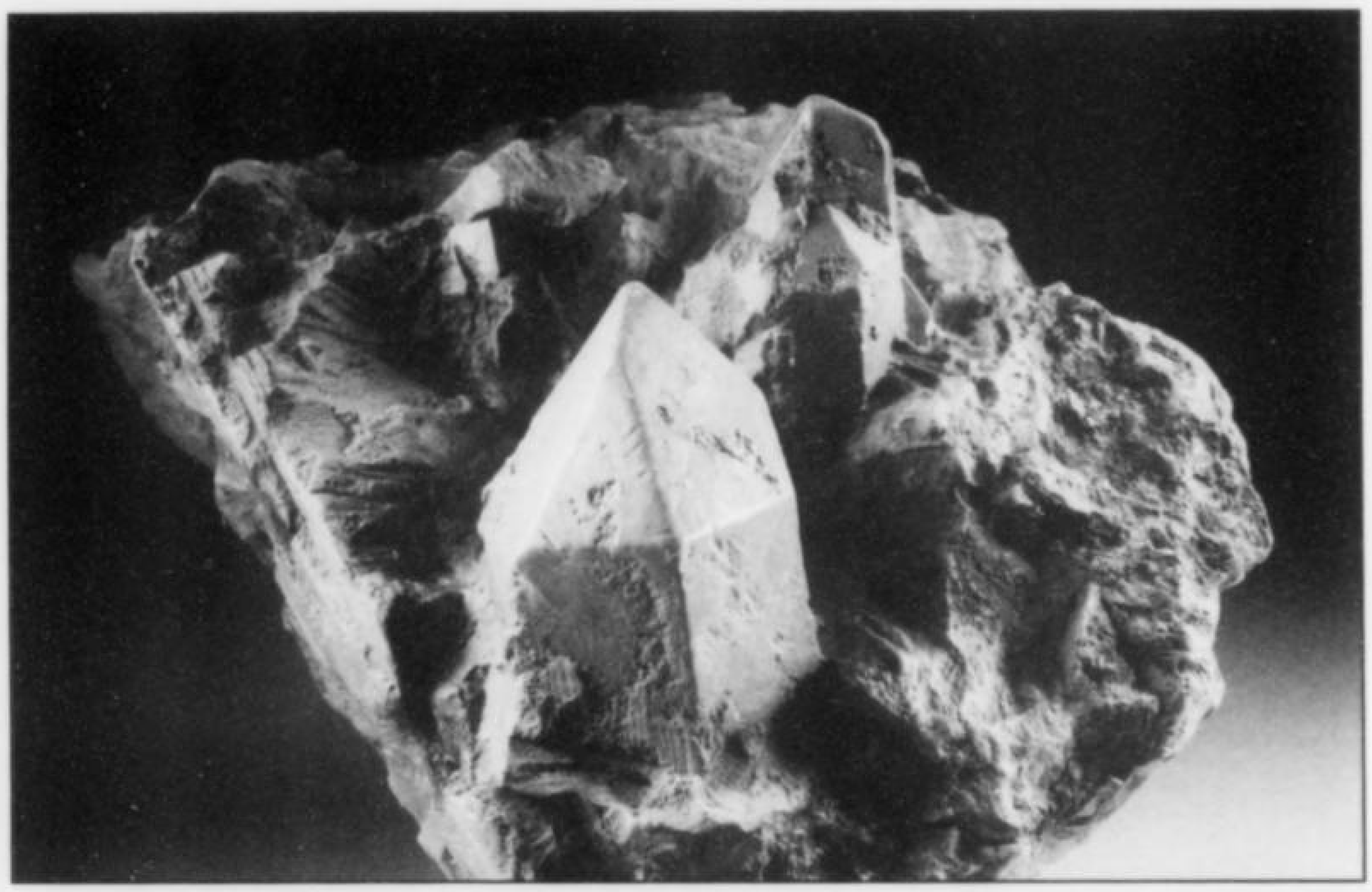


Figure 16. **Talc pseudomorph after quartz, 7 cm, from Johannezeche, Göpfersgrün, Fichtelgebirge, Bayern, Germany. Peabody Museum collection; Wendell Wilson photo.**

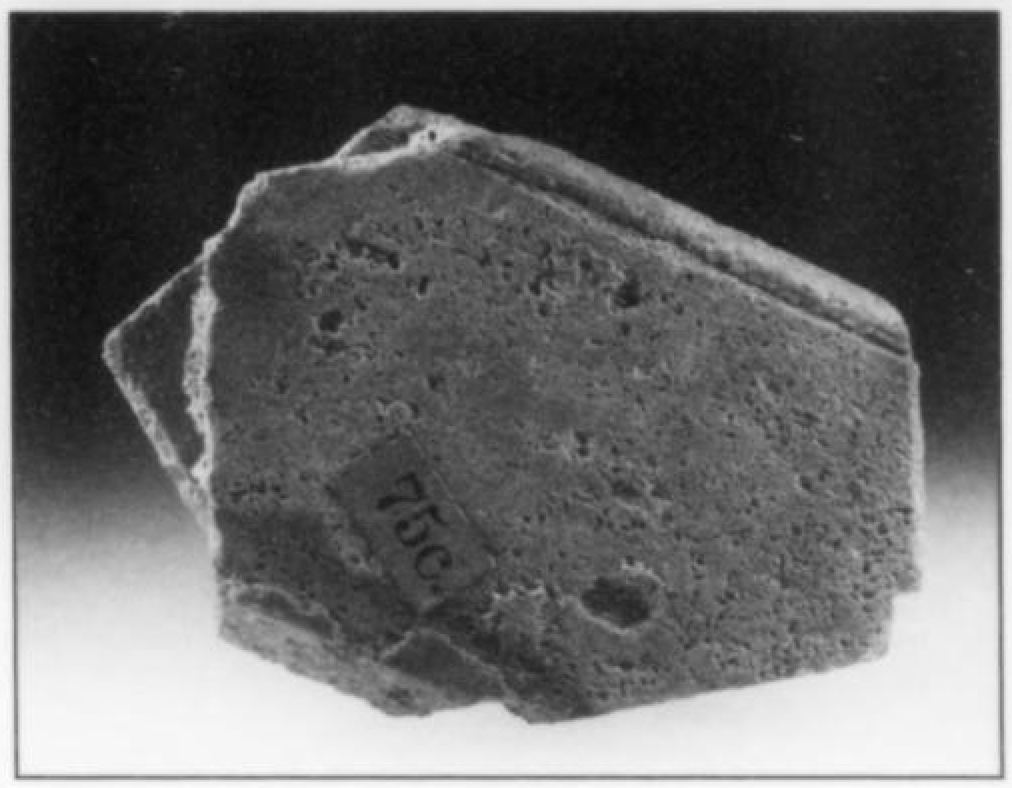


Figure 17. **Topaz pseudomorph after orthoclase, 4.5 cm, from Saubach, Vogtland, Obersachsen, Germany. Peabody Museum collection; Wendell Wilson photo.**

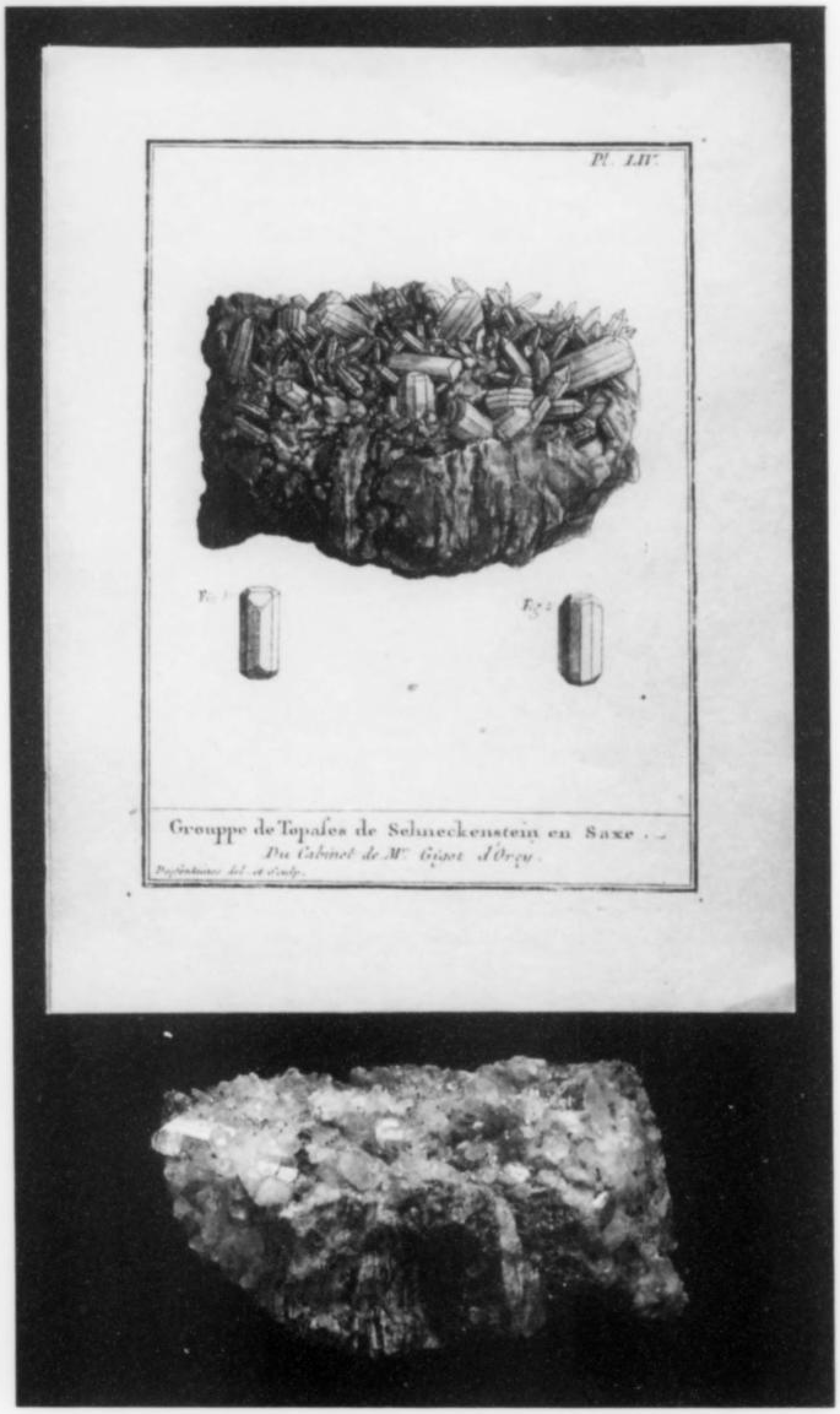


Figure 18. **Topaz crystals on matrix, 14 cm, from Schneckenstein, Vogtland, Obersachsen, Germany (George Gibbs collection, from the Gigot d'Orcy collection). The plate illustrating the specimen approximately natural size is from Fabien Gautier d'Agoty's *Histoire Naturelle Règne Minéral* (1781); a close inspection shows that the specimen has lost many small topaz crystals since 1781, only the broken crystal bases remaining. Peabody Museum collection and photo.**

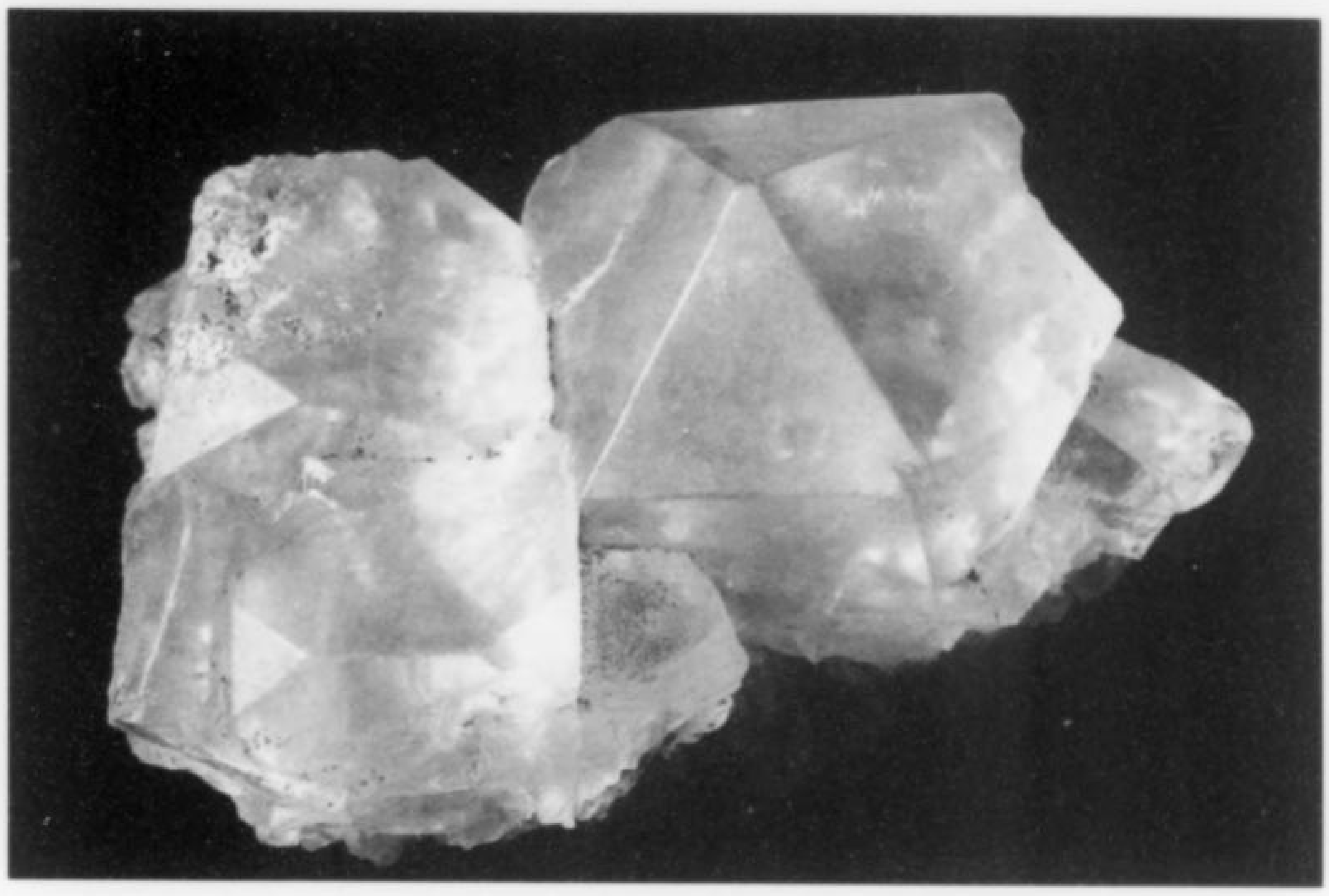


Figure 19. **Sylvite crystal group, 7 cm, from Stassfurt, Sachsen-Anhalt, Germany. Peabody Museum collection and photo.**

out of date. Save for stray donations from recent times, there is very little from anywhere in Brazil, Mexico or Quebec; there are only occasional nice-looking pieces from Tsumeb, Bolivia, and much of the western United States; the Indian zeolites are mediocre by current standards; there is virtually nothing from Morocco, Peru or South Africa, nor, of course, anything representing the post–Cold War outpourings of Russia, Kazakhstan, China and the Pakistan/Afghanistan border regions.

Granted, this never was imagined or shaped as a "display" collection—not, at least, since the heady Silliman/Gibbs days of 175 years ago. Probably it is too late to attempt any really thorough general updating without a budget for purchases that would rival NASA's; however, much could be done through intelligent trading from the rich stores of heavily redundant old classics. The most regrettable lack, as matters stand now, would seem to be a good display facility. Certainly I know nothing of the relevant budgetary or political considerations. So take it merely as a volunteer/browser's comment, or lament, that it is a very great shame that these hundreds and hundreds of wonderful specimens of old, seldom-seen classics should go largely *un*seen by modern mineral connoisseurs. There are the very modest permanent displays in the Museum and in the lobby of the Kline Geology Lab; Ellen Faller sometimes puts a case in at a mineral show; but the collection budget now stands at just $1,000/year. That's not enough to do anything. So it looks as if you will have to arrange your visit to the storage room, if you plan to be in the area. Contact Ellen Faller, Collection Manager, Phone: 203-432-3141, E-mail: ewf@george.peabody.yale.edu.

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The Friends of Mineralogy

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Vol 1, No 1, Mineralogical Record, Spring 1970

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* Compiling and publishing information on mineral localities, and important mineral collections.

* Encouraging improved educational use of mineral specimens, collections, and localities.

* Support a semi-professional journal of high excellence and interest designed to appeal to mineral amateurs and professionals, through which *FM* activities may be circulated.

* Operating informally in behalf of minerals, mineral collecting, and descriptive mineralogy, with voluntary support by members.

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THE SILVERMINES DISTRICT

COUNTY TIPPERARY, IRELAND

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The Silvermines deposits in the Republic of Ireland have been exploited for centuries, but did not become famous as a source of fine specimens until the discovery of a giant vug lined with magnificent crystals of galena, sphalerite, pyrite, bournonite and other minerals in the Mogul mine in 1978. Neighboring mines were also well-endowed with fine specimens, but sadly, few were preserved.

INTRODUCTION

The giant base metal and barite deposits of Silvermines, County Tipperary, Republic of Ireland, have received considerable attention from geologists in recent years. Detailed study has resulted in an extensive scientific literature and has contributed enormously to our understanding of this class of deposits, sedimentary-exhalative, to which some of the larger orebodies belong. However, in spite of this copious technical literature, there is no recent, detailed descriptive mineralogy of interest to specimen mineralogists and collectors. This may be partly because the deposits did not acquire a reputation as a prolific source of fine specimens until the astonishing discovery of a huge vug in 1978 in the large zinc-lead mine operated by Mogul of Ireland Ltd.: Mogul mine. This was in spite of a history of intermittent mining since the Middle Ages, and the development of extensive oxidized zones in some of the early workings.

The village of Silvermines is located 9 km south-southeast of the town of Nenagh and 36 km north of Tipperary town, County Tipperary, Republic of Ireland. The mine workings extend for approximately 4 km from west to east, the eastern-most workings (Ballygown South) being immediately south of the village. They lie at the northern foot of the Silvermines Mountains, which rise in the south to about 500 meters. To the north of the mines is flat agricultural land.

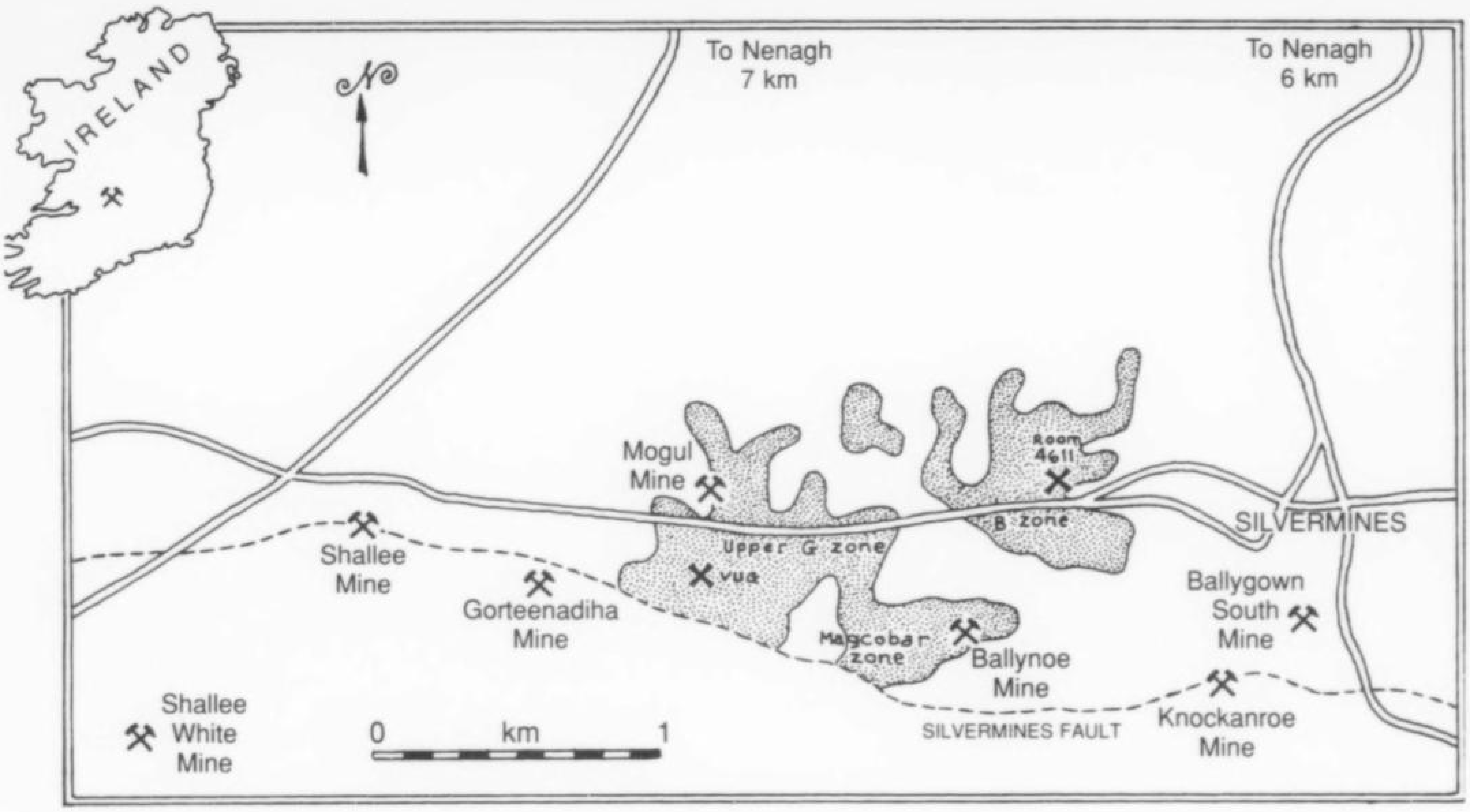

Figure 1. **Map of the Silvermines area, Tipperary, Ireland, showing the main mines and occurrences. (Data from Andrew, 1986; Ordnance Survey of Ireland 1:10560 sheet "Tipperary 26.")**

HISTORY

Russell (1990) and Cowman (1988 and 1992) have described the history of Silvermines in detail and the following account is derived from these sources. The earliest record of mining in the district is from 1289, when a group of Italian miners began digging, presumably for argentiferous galena. The locals were hostile toward the foreigners, and the miners suffered assaults and intimidation. This culminated in a brawl in 1303 in which, according to an account quoted by Russell (1990), a priest "was beaten and got his head broken." The indignant clergyman retaliated by excommunicating the miners, who then refused to go underground for fear of perdition.

Activity resumed early in the 17th century. By 1640, after considerable investment, the mines were employing over 500 men and, apparently, were prospering. The lead and silver found ready local markets and, in 1640, the King received £800 as his share of the profits. This prosperity was cut cruelly short in 1642 by a massacre in which 14 people, mainly women and children, perished when one of the local landowning families attacked the mine. Outraged by this, John Kennedy, the elder brother of the culprit, ordered the arrest of his errant sibling who subsequently escaped justice by committing suicide.

The following years were turbulent and bloody. When peace eventually broke out, litigation caused further delays. Thus it was not until the 18th century that operations could recommence, at first for lead and silver, and later also for copper. These seem to have met with mixed success and by 1800 the mines were idle again.

Early 19th-century attempts to reopen the mines failed and, in 1850, the General Mining Company of Ireland took over the property. In spite of financial problems, scandals and litigation, this company managed to raise some thousands of tons of lead, zinc and copper and was helped by the high silver content (up to 80 ounces/ton) of the ores. A large vein of pyrite was exploited for sulphuric acid manufacture at the Knockanroe mine, and nearby a bed of "calamine" (hemimorphite and smithsonite) was discovered and worked for a while at the Ballygown South mine. Difficulties in processing the calamine ore, together with competition from abroad, forced the closure of the mines in 1874.

There were several reinvestigations of the old workings in the first half of the 20th century but there was no significant revival of activity until 1948, when a group of entrepreneurs and prospectors set up the Irish Exploration Company Ltd. In 1949 this became the Silvermines Lead and Zinc Company Ltd., with a capital of £350,000. They began by exploiting the calamine deposit and by reprocessing old dumps. From the beginning they were beset by technical difficulties, followed by a collapse in metal prices. The company struggled from crisis to crisis, sinking ever deeper into debt, and was soon facing bankruptcy. Then it discovered one of the biggest barite deposits in the world.

Lacking the resources to develop the enormous Ballynoe barite deposit it had found, the company struck a deal with the Magnet Cove Barium Corporation (subsequently Dresser Industries), and as a result Magcobar (Ireland) Ltd. was born. Opencast mining began in April 1963, and by 1988 had produced some 5.5 million tonnes of barite. Underground production continued until 1995.

In 1962, the board of the Silvermines Lead and Zinc Company Ltd. came to an agreement with two Canadian companies—Draper Dobie & Company Ltd. and Consolidated Mogul Mines Ltd.—who were given over 2 million shares in options in the company, the exercise of which cleared the company's debts. Mogul embarked on an exploration program and soon discovered 10 million tonnes of ore grading at about 11% lead and zinc.

Mogul of Ireland Ltd. was set up in 1964 and mining, at what became known as Mogul mine, commenced in 1968. Until its

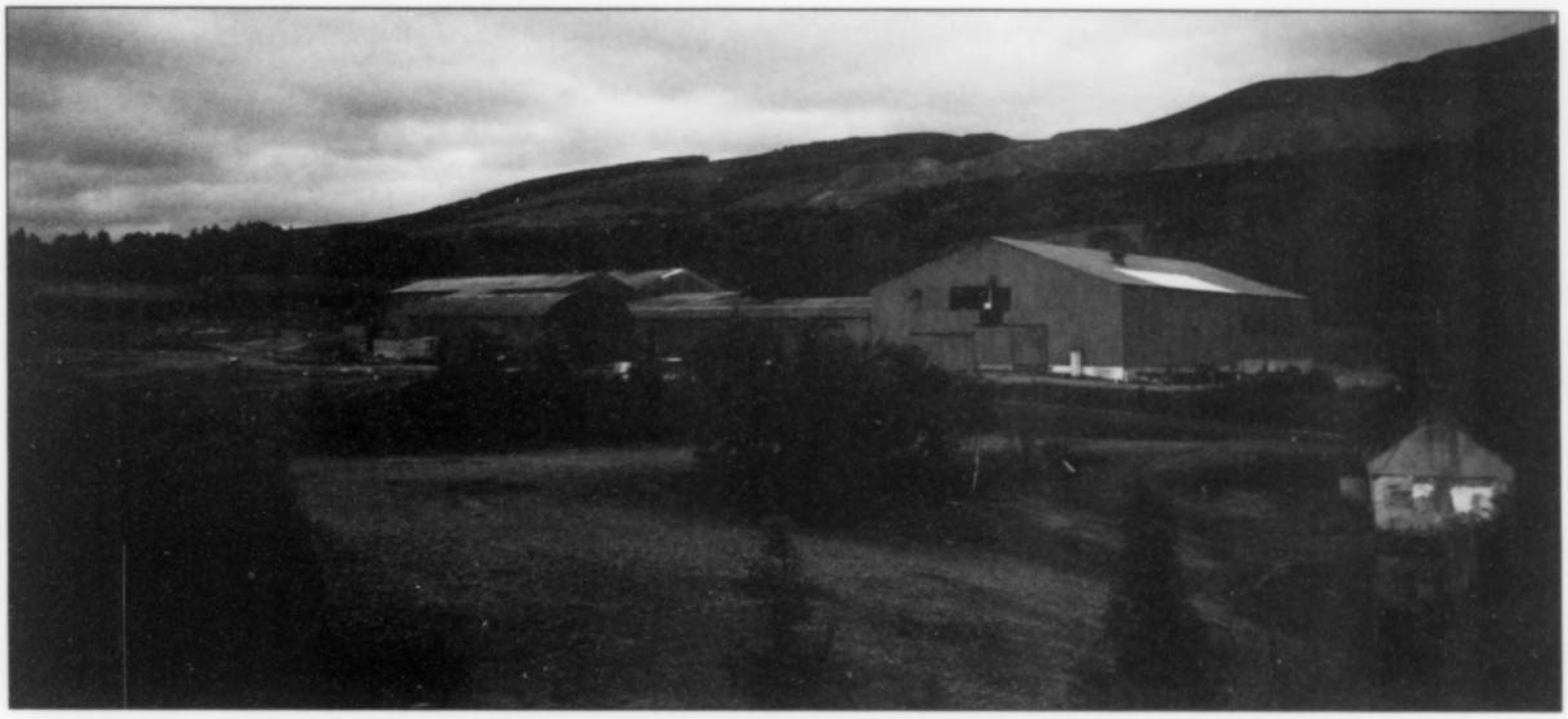

Figure 2. **The Mogul mine site (foreground) and dumps from Magcobar's Ballynoe barite mine on the hillside behind. Stephen Moreton photo.**

closure in July 1982, the mine produced 1.75 million tonnes of lead and zinc concentrates from about 12 million tonnes of ore. Following closure the property was acquired by Ennex International. Extensive drilling by Ennex has so far failed to locate additional economic orebodies, and it is unlikely that there will be a resumption of mining in the foreseeable future. The property has recently been sold for use as a waste disposal site.

The Silvermines Lead and Zinc Company Ltd. is now known as Silvermines Group plc., and is a successful investment company with diverse interests in property, engineering, electronics and other areas but no longer in the mining district from which it took its name.

GEOLOGY

For a comprehensive and detailed technical description of the geology and ore mineralogy of the deposits the reader is referred to Andrew (1986) and the references therein. The dominant geological feature of the district is the roughly east-west Silvermines Fault Zone. To the south of this lie Silurian graywackes and Devonian sandstones; to the north are Lower Carboniferous dolomite and limestones, often muddy and with shales and cherty horizons.

The mineralization is partly epigenetic, and partly sedimentary-exhalative. The epigenetic mineralization comprises simple veins and breccia zones on both sides of the Silvermines Fault Zone, and cavity and fracture-fill zones north of the fault. The large sedimentary-exhalative deposits are divided into three main zones north of the fault: *B* and *Upper G* zones, worked for zinc, lead and silver by the Mogul mine, and the barite or *Magcobar* zone, which formed the Ballynoe barite deposit worked by Magcobar (Ireland) Ltd. Beneath the southern part of the Upper G zone lies one of the larger, steeply-dipping, epigenetic Zn/Pb deposits—the *Lower G* zone—also worked by the Mogul mine.

The deposits are related to a system of west-northwest-trending faults, components of the large Silvermines Fault Zone. These acted as conduits for ascending metalliferous brines (at *ca.* 220°C) which formed the epigenetic deposits as they rose. In places the solutions debouched onto the sea floor and, being of greater density than the surrounding seawater, accumulated in hollows and depressions where sulfides and barite were precipitated to form the large sedimentary-exhalative orebodies. The epigenetic deposits may therefore be seen as the feeder zones for the stratigraphically higher, bedded deposits, some of which have been lost by erosion, leaving the three surviving examples described here.

The remains of several of the vents, where the fluids spilled onto the seafloor, have been identified and the positions of others inferred. These have attracted intense study, in view of their similarity to present-day examples of deep ocean hydrothermal vents or "black smokers." A particularly well-preserved example was found in the southeast corner of the Magcobar opencast (Boyce *et al.*, 1983).

The large sedimentary-exhalative deposits lay beneath the water table and largely escaped supergene oxidation. Some of the epigenetic deposits, on the other hand, have undergone extensive, near-surface alteration generating residual deposits containing barite, sulfide-bearing muds, "calamine" and gossan (Boland *et al.*, 1992). The calamine deposit at Ballygown South is the best known example.

MINERALOGY

The large sedimentary-exhalative deposits have furnished most of the ore, and also most of the mineral specimens, in the modern mines. The Magcobar barite zone consisted of up to 15 meters of massive barite (averaging 85% $BaSO_4$), underlain by hematitic and jasperoid bands and overlain by pyritic, dolomite breccias with minor galena and sphalerite (Taylor and Andrew, 1978). Its uppermost meter or so was recrystallized and contained much pyrite/marcasite (Andrew, 1986). The B and Upper G zones, worked at the Mogul mine, consisted of massive pyrite/marcasite up to 30 meters thick with varying amounts of sphalerite, galena and gangue (Taylor and Andrew, 1978; Andrew, 1986).

Numerous rarer sulfides and sulfosalts have been identified, mostly as microscopic intergrowths and inclusions in polished sections. (See Table 1.) The gangue minerals were dolomite, barite, calcite, quartz, clays and chert, the barite being concentrated toward the southern parts of the B zone, near to the Magcobar zone. The host rocks contain much siderite, dolomite and barite.

An unusual discovery was made in the 4611 room of the B zone. Here a deposit of rich silver mineralization was found. It occupied a lens of coarse buff or grayish white, massive barite within which the silver ores were concentrated in a northwest-trending zone described as 4 to 8 feet (1.2 to 2.5 meters) thick, 22 feet (6.8 meters) wide and 35 feet (10.8 meters) long (Taylor, 1984). The mineralization consisted of patches, grains and intergrowths of argentite/acanthite, proustite, xanthoconite, smithite, miargyrite, argyrodite, unidentified bismuth sulfosalts (Gasparrini, 1978), jordanite, pyrargyrite and gersdorffite (Taylor, 1984). This is the only known example of this style of mineralization in Ireland, and is thought to be related to a nearby small feeder (Taylor, 1984).

The Lower G zone, also exploited at the Mogul mine, was a steeply dipping epigenetic deposit in which sphalerite and galena were the dominant sulfides with increasing pyrite and marcasite toward the upper parts. Chalcopyrite, arsenopyrite and numerous Pb, Cu and Ag sulfosalts occurred in minor amounts with dolomite, calcite, quartz and barite as gangue (Andrew, 1986).

The relatively compact nature of the vein material, together with the fact that much of the mining of the oxidized zones took place in the 17th and 18th centuries, before the advent of mineral collecting in Ireland, may explain why Silvermines acquired only a modest reputation as a source of fine specimens prior to the modern discoveries. Geology and mineralogy began to blossom in Ireland in the 19th century, but fine Silvermines specimens from this period are few and far between. This is disappointing, as acicular cerussite is said to have been "particularly abundant" (Weaver, 1819) and, following the discovery of the calamine deposit at Ballygown South, well-crystallized hemimorphite must also have been common.

It was not until the modern phase of mining that the district achieved recognition, and this was due largely to a single, but spectacular, discovery in Mogul mine in 1978. In October of that year, during pillar recovery in the Upper G zone (the 3-W-2 pillar), an enormous vug was encountered. According to the mine geologist, it measured "approx. 3 meters long, 1 meter high and 2 meters wide with the long axis orientated down dip (approx. 25°). The vug occurred in pyritic (10–20%) dolomitized debris flow breccias in the immediate hangingwall of the (at this point) 18-meter-thick massive pyrite of the Upper G orebody" (Andrew, 1988). Smaller vugs (<20 cm) occurred nearby, and crystalline material had also been found in the epigenetic Lower G zone (and also in the northern reaches of the B zone: Taylor and Andrew, 1978) but none of these occurrences was as remarkable as the 3-W-2 vug.

Many fabulous pieces of galena, honey-yellow sphalerite, pyrite and bournonite were recovered from this vug, most of it being acquired by the late Cornish mineral dealer Richard Barstow, although the exact circumstances are obscure. These magnificent pieces now grace museums and collections all over the world.

Magcobar's barite mine, in spite of its size, had a poor reputation for specimen-quality material. This reputation was undeserved and probably deterred many collectors (including, to his great regret, the author) from visiting the site until it was too late. Mining at the bottom of the opencast in the early 1990's encountered a vuggy zone containing magnificent, lustrous pyrite crystals. Sadly there was no Richard Barstow on hand to rescue this treasure, and the miners simply disregarded the find and carried on mining (Jack Hicky, personal communication).

Four substantial deposits of partly oxidized, residual material are known to occur in the district. These have been prospected by

***Table 1.* Minerals identified from the Silvermines district (from Taylor and Andrew, 1978; Andrew, 1986; Gasparrini, 1978; Taylor, 1984; Weaver, 1819; Boland *et al.*, 1992; Ryback and Moreton, 1993; Kinahan, 1886; Giesecke, 1832; Russell, 1907; Rhoden, 1959a and 1959b; Zakrzewski, 1989).**

Primary Sulfides	
Acanthite/Argentite	Ag_2S
Chalcopyrite	$CuFeS_2$
Galena	PbS
Marcasite	FeS_2
Pyrite	FeS_2
Pyrrhotite	$Fe_{1-x}S$
Sphalerite	$(Zn,Fe)S$
Primary Sulfosalts	
Argentotennantite	$(Ag,Cu)_{10}(Zn,Fe)_2(As,Sb)_4S_{13}$
Argyrodite	Ag_8GeS_6
Arsenopyrite	$FeAsS$
Boulangerite	$Pb_5Sb_4S_{11}$
Bournonite	$PbCuSbS_3$
Freibergite	$(Ag,Cu,Fe)_{12}(Sb,As)_4S_{13}$
Gersdorffite	$NiAsS$
Gudmundite	$FeSbS$
Jordanite	$Pb_{14}(As,Sb)_6S_{23}$
Löllingite	$FeAs_2$
Miargyrite	$AgSbS_2$
Proustite	Ag_3AsS_3
Pyrargyrite	Ag_3SbS_3
Smithite	$AgAsS_2$
Tennantite	$(Cu,Ag,Fe,Zn)_{12}As_4S_{13}$
Tetrahedrite	$(Cu,Fe,Ag,Zn)_{12}Sb_4S_{13}$
Xanthoconite	Ag_3AsS_3
Secondary Metalliferous Minerals	
Anglesite	$PbSO_4$
Azurite	$Cu_3^{2+}(CO_3)_2(OH)_2$
Cerussite	$PbCO_3$
Chalcocite	Cu_2S
Coronadite	$Pb(Mn^{4+},Mn^{2+})_8O_{16}$
Covellite	CuS
Erythrite	$Co_3(AsO_4)_2\cdot 8H_2O$
Goethite	$Fe^{3+}O(OH)$
Hematite	Fe_2O_3
Hemimorphite	$Zn_4Si_2O_7(OH)_2\cdot H_2O$
Hydrohetaerolite	$Zn_2Mn_4^{3+}O_8\cdot H_2O$
Linarite	$PbCu^{2+}(SO_4)(OH)_2$
Malachite	$Cu_2^{2+}(CO_3)(OH)_2$
Pyromorphite	$Pb_5(PO_4)_3Cl$
Silver	Ag
Smithsonite	$ZnCO_3$
Gangue Minerals	
Ankerite	$Ca(Fe^{2+},Mg,Mn)(CO_3)$
Barite	$BaSO_4$
Calcite	$CaCO_3$
Chlorite Group	$A_{4-6}Z_4O_{10}(OH,O)_8$
Dolomite	$CaMg(CO_3)_2$
Illite	$(K,H_3O)(Al,Mg,Fe)_2$- $(Si,Al)_4O_{10}[(OH)_2,H_2O]$
Muscovite (sericitic)	$KAl_2(Si_3Al)O_{10}(OH,F)_2$
Quartz	SiO_2
Siderite	$FeCO_3$

Ennex International (Boland *et al.*, 1992) and found to consist of troughs overlying epigenetic sulfide zones and filled with black sulfide-bearing (pyrite, galena, sphalerite) muds, residual barite, ochreous "calamine" (mostly hemimorphite) muds and gossan. The best known and most extensively mined of these is the Ballygown South deposit. Iron oxides, hemimorphite, smithsonite, cerussite and anglesite are the principal secondary minerals (in descending order of abundance). Recently, very minor hydrohetaerolite and coronadite have also been identified (Ryback and Moreton, 1993).

Grains of secondary silver minerals have been detected in this oxidized residuum but specific silver minerals have not been identified (Boland *et al.*, 1992). Native silver has not been reported in recent years but was noted by Kinahan (1886) in some of the old mines and also by Giesecke (1832), although no details are given. In view of the highly argentiferous nature of the ores, the presence of native silver in the oxidized deposits is not unlikely.

All the mineral species known to date from the district are listed in the accompanying table. Earlier, less complete lists were given by Russell (1907) and Rhoden (1959a and 1959b). Giesecke (1832) reported, without further details, "brittle silver-ore" (syn. stephanite) and "grey cobalt ore." However, without the benefit of modern techniques, the former could easily have been a mistaken identification of many of the silver sulfosalts known from recent work to occur (and which do not include stephanite), and the latter is an ambiguous term which could apply to a variety of minerals. Accordingly they have been omitted from the list. "Quicksilver," said to have been found in the 17th century (Wynne, 1860), and a report of orpiment (Gages, 1860) have never been substantiated and have long been regarded as doubtful. A report of geocronite, as grains up to 200 microns (Zakrzewski, 1989), gives analyses with As>Sb so the mineral should actually be jordanite and is listed as such in the table. Andrew (1986) mentions guitermanite but, as this is not a recognized species, it is omitted from the list.

Most of the rarer sulfides and sulfosalts are known only as microscopic grains, inclusions and intergrowths. The mineral-by-mineral description that follow therefore concentrates on those species that have been found in specimens of interest to collectors.

Barite $BaSO_4$

Barite in massive form is abundant. Tabular crystals to 3 cm across were reported from the Magcobar mine (Boyce *et al.*, 1983) and radiating and stalactitic masses and aggregations of wedge-shaped crystals are known from the Ballygown South mine (Russell, 1907). Many sulfide specimens from the Mogul mine are accompanied by white to translucent tabular crystals up to about 2 cm across.

Boulangerite $Pb_5Sb_4S_{11}$

Boulangerite was concentrated around some of the feeders of the B and Upper G zones, including the silver-rich lens of room 4611. Close to the main B zone northwest feeder it was found as fine hairs in numerous small vugs (Taylor, 1984).

Bournonite $PbCuSbS_3$

Some of Barstow's specimens from the great vug include well-formed tabular to blocky bournonite crystals up to about 2 x 1 cm. They are sharp but have relatively low luster and appear to have suffered some dissolution.

Cerussite $PbCO_3$

At one time cerussite was abundant as masses of acicular white crystals, sometimes copper-stained, particularly at Gorteenadiha or Gortnadyne mine (Russell, 1907).

Galena PbS

Many magnificent crystals of galena were recovered from the great vug by Richard Barstow. The dominant habit is cuboctahedral, and crystals up to 2.5 cm across were found, often as intergrown groups but occasionally singly. They are commonly a little distorted so that the cube faces are rectangular. Both cube and octahedron faces tend to be somewhat uneven, sometimes distinctly convex. But their luster is often exceptional and mirror-bright.

Hemimorphite $Zn_4Si_2O_7(OH)_2\cdot H_2O$

Hemimorphite is the principal secondary zinc ore in the "calamine" deposits. (Smithsonite is the next most common but is impure, limonitic and not of collector quality.) Only at the Ballygown South mine has it been worked in quantity. The colorless to white crystals were described as small (up to 2 mm) but "wonderfully brilliant and sharp," lining cavities in gossan (Russell, 1907). Larger, blockier white crystals up to 4.5 mm across also occur. Although largely unaffected by supergene processes, some Barstow specimens from the Mogul mine exhibit clusters of 0.5-mm, transparent pale yellowish hemimorphite crystals on sphalerite.

Pyrite FeS_2

Massive pyrite, often colloform and frequently brecciated, was the principal sulfide in the B and Upper G zones and occasionally formed "chimneys" where the fluids emerged from vents on the ancient sea floor. Cubes up to 4 cm across were found associated with the fossil hydrothermal vent in the Magcobar mine (Boyce *et al.*, 1983). Little is known of the more recent Magcobar occurrence, as few specimens were preserved. Specimens recovered by Barstow from the great vug in the Mogul mine often have pyritohedra up to 2 mm underlying the galena and sphalerite. These are sometimes beautifully iridescent.

Quartz SiO_2

Slender, colorless and often flattened prisms up to 3 cm long are sometimes present on specimens from the Mogul and Magcobar mines.

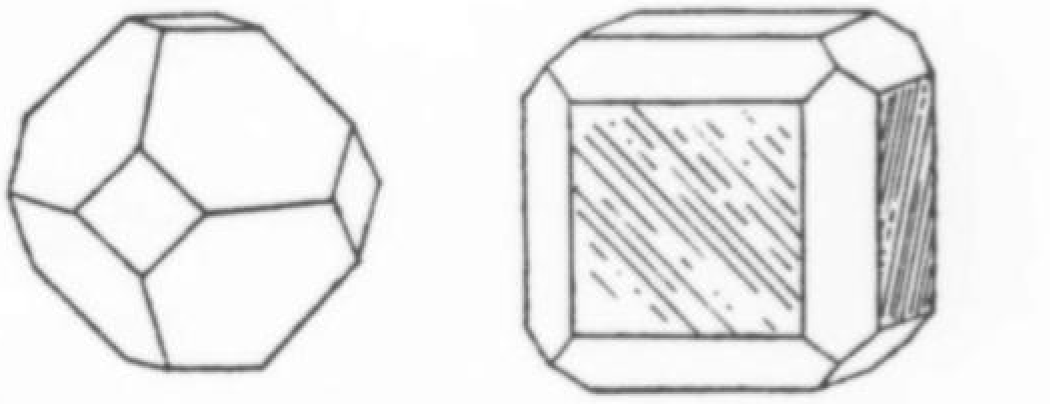

Figure 3. **Crystal drawings showing the habits of galena (left; cube + octahedron) and sphalerite (right; cube + dodecahedron) from the Mogul mine.**

Sphalerite ZnS_2

Pale cream, yellow and brown sphalerite is the major ore mineral of the district, the color varying according to the iron content. Good, crystallized specimens have so far been restricted to the Mogul mine, where they occurred lining cavities in pyrite in the northern part of the B zone, in cavities in the Lower G zone and, of course, in the great vug in the Upper G zone. The Mogul specimens consist of rich masses and crusts of lustrous, gemmy crystals up to 1.4 cm across, accompanying galena and pyrite, sometimes also with platy barite crystals, creamy dolomite and occasionally quartz. The color is usually amber to honey-brown, occasionally

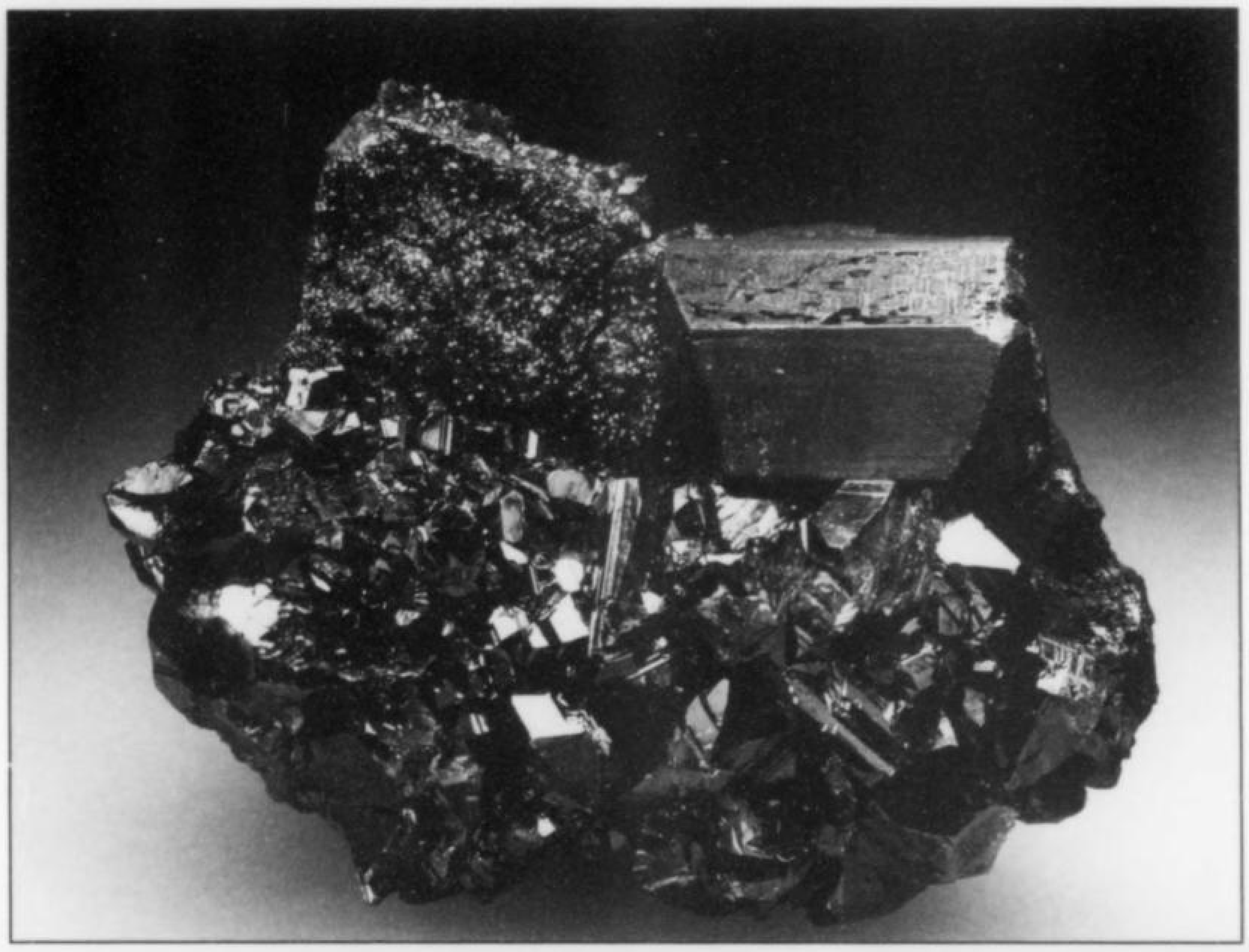

Figure 4. Bournonite crystal, 2.1 cm, with pyrite on sphalerite crystals, from the Mogul mine. Ben DeWit collection; Wendell E. Wilson photo.

Figure 6. Galena in parallel growth, probably a result of spinel-law twinning on (111), on drusy sphalerite, from the Mogul mine. Ben DeWit collection; Wendell E. Wilson photo.

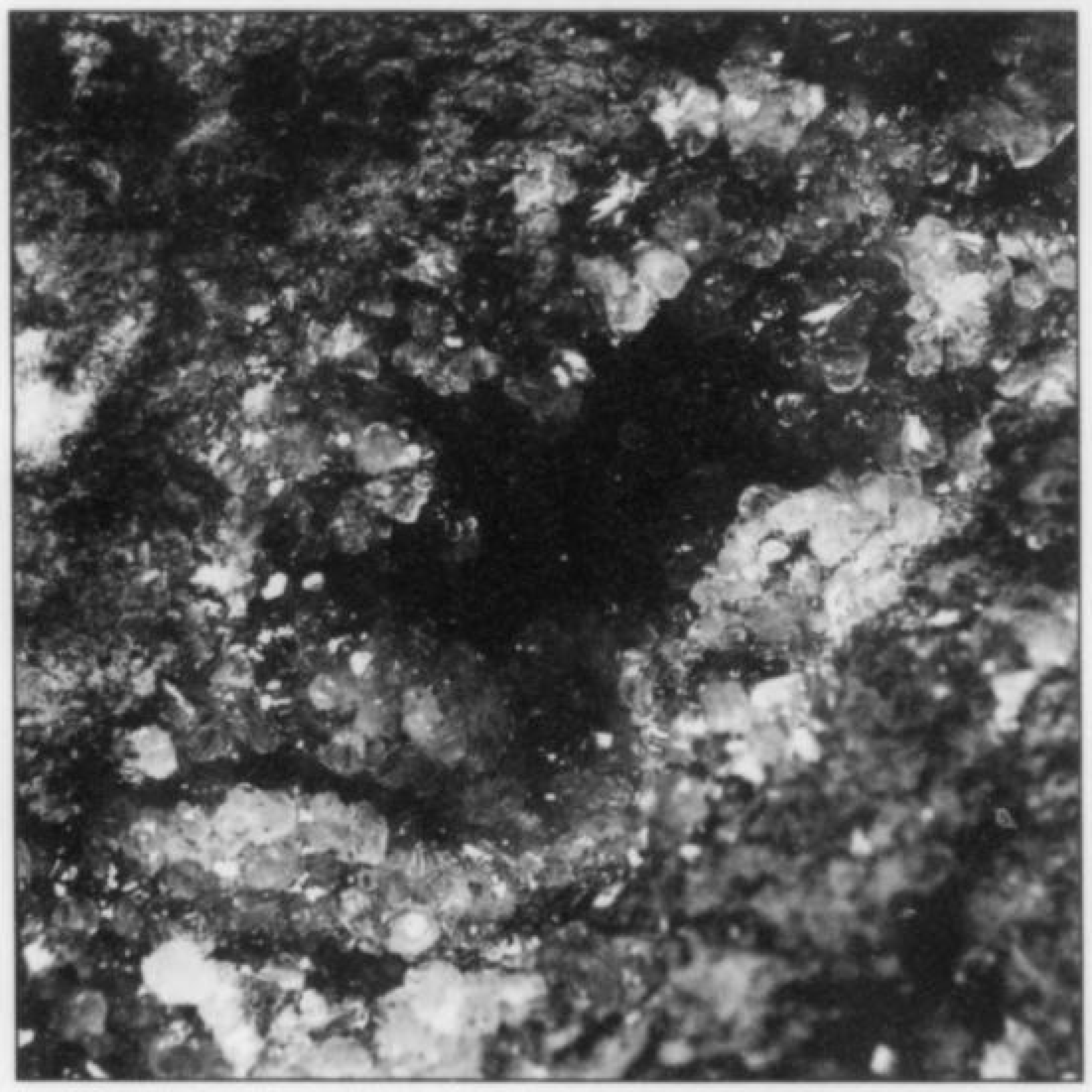

Figure 5. Hemimorphite crystals to 2 mm, from the Ballynoe South mine. Stephen Moreton specimen and photo.

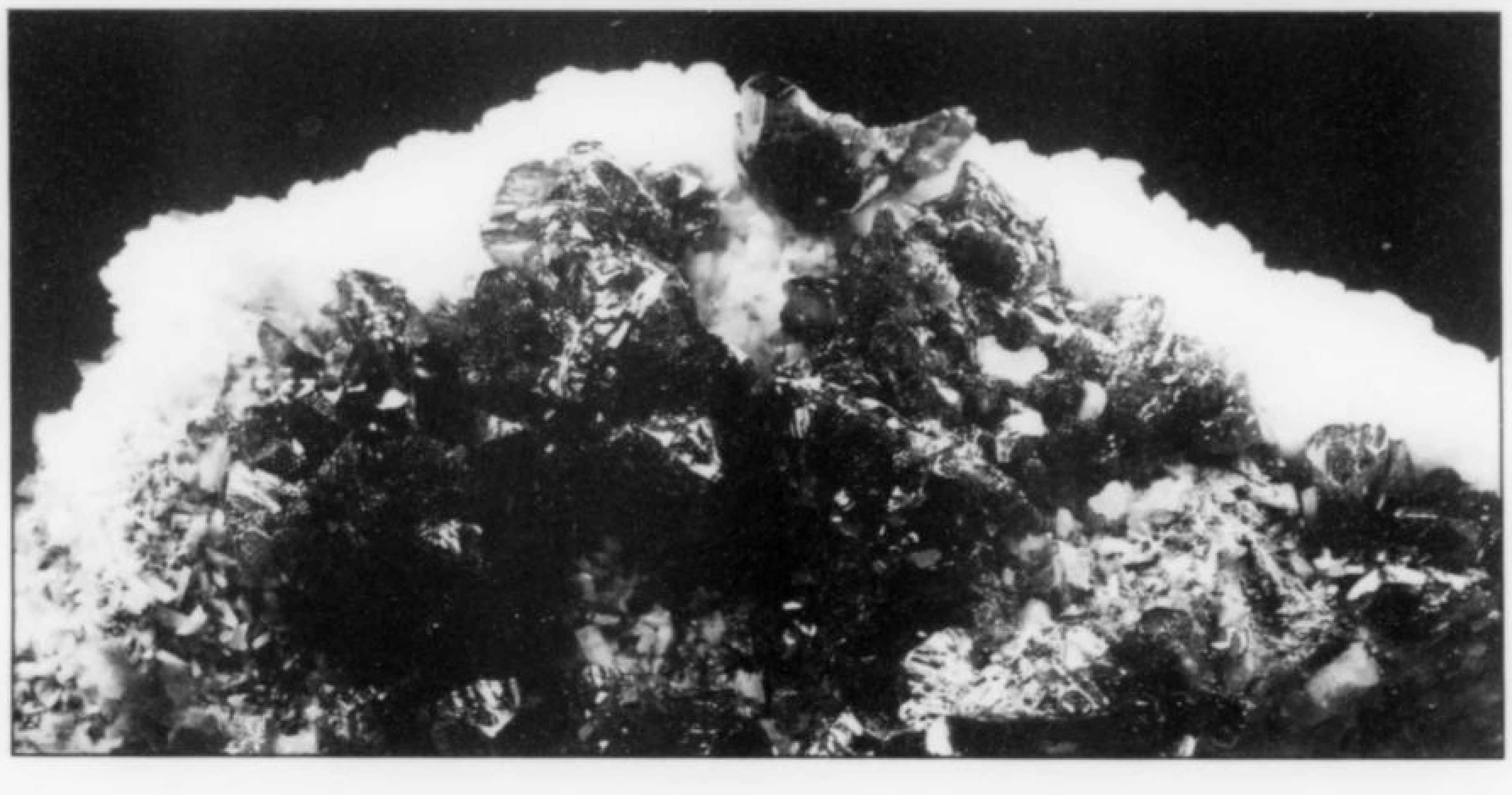

Figure 7. Complex sphalerite crystals with white barite microcrystals, 8.5 cm across, from the Mogul mine. Ben DeWit collection; Wendell E. Wilson photo.

Figure 8. Cuboctahedral galena crystal cluster, 5.3 cm, from the Mogul mine. Kent England collection; Wendell E. Wilson photo.

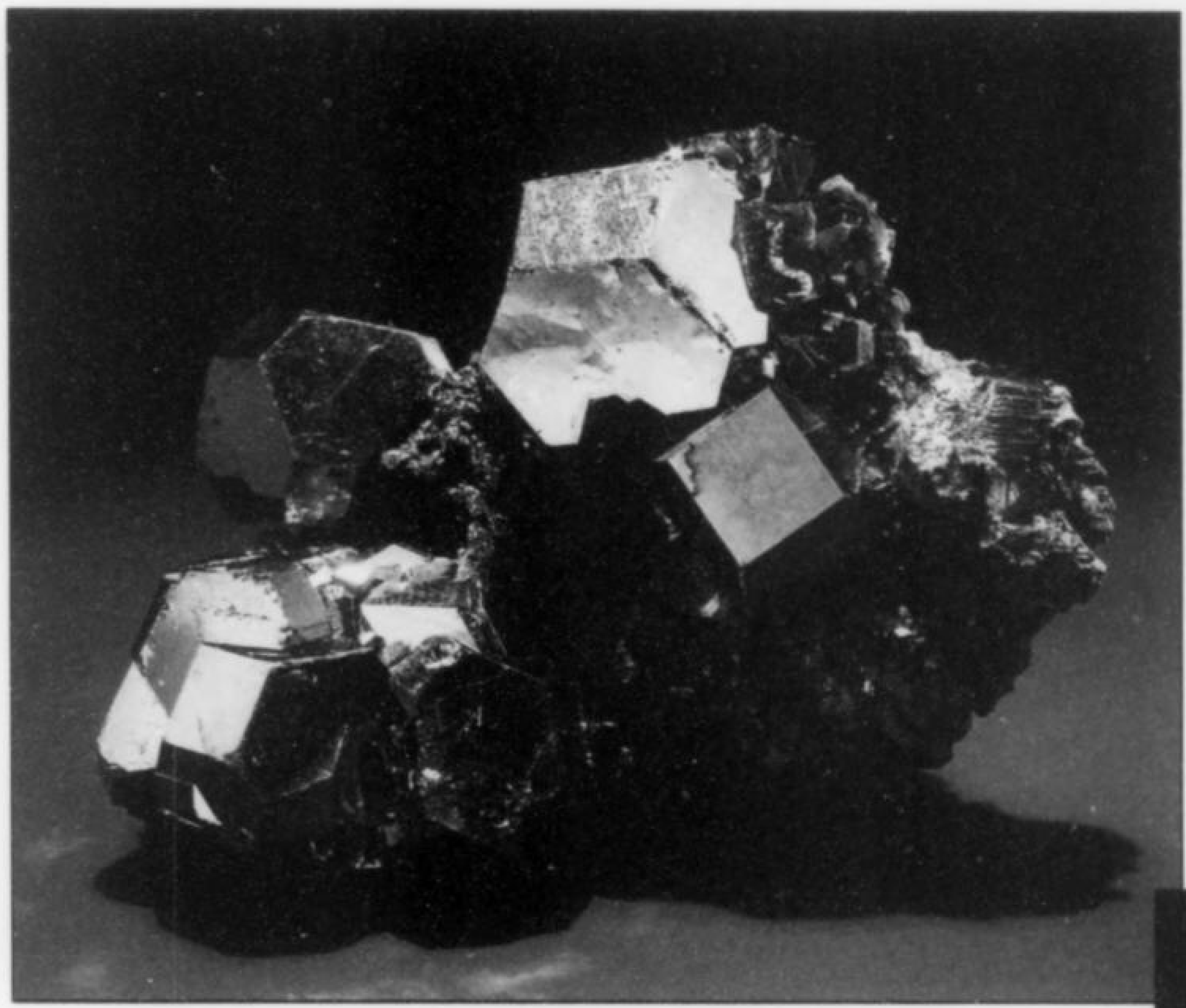

Figure 9. Cuboctahedral galena crystals to 2.5 cm, with sphalerite on pyrite, from the Mogul mine. Smithsonian Institution specimen #147196; photo by Dane Penland.

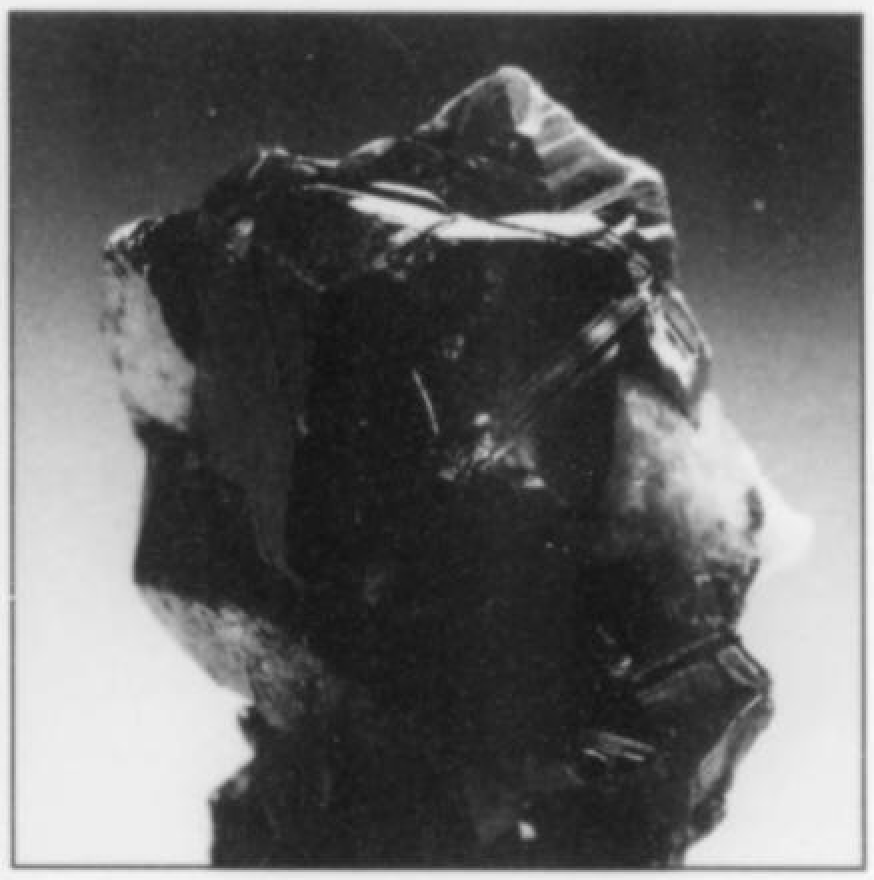

Figure 10. Sphalerite crystal, 1.4 cm, showing the very rare cubo-dodecahedral habit, from the Mogul mine. Ben DeWit collection; Wendell E. Wilson photo.

Figure 11. Gemmy sphalerite crystals to 1 cm on bournonite, from the Mogul mine. Ben DeWit collection; Wendell E. Wilson photo.

sulfur-yellow, rarely almost colorless. At least one rare specimen shows a predominantly cubic habit, modified by the dodecahedron.

PRESENT SITUATION

The Mogul and Magcobar mines are now both closed and flooded. The huge dumps of the latter are disappointingly barren. There is scant dump material associated with the former, and what there is contains little more than rotting pyrite. The ochreous dumps of the Ballygown South mine are small in quantity and poor in quality. Much digging is required to find anything other than micromount specimens of hemimorphite. Similarly, the 18th and 19th-century dumps to the west are almost devoid of worthwhile specimens.

For good specimens, the collector is now almost entirely reliant on those recovered by Barstow. Some additional material was given away at the mine office to passers-by at the time the Mogul mine closed and, for a while, some locals adorned their mantlepieces with magnificent specimens of honey sphalerite and lustrous galena. The area has now been well trawled by dealers from all over the world, but fine specimens may still remain tucked away, unappreciated, in attics and sheds (and, in one case the author heard about, in a garden rockery in Clonakilty, County Cork). Barstow is reputed to have saved an enormous quantity of material, but this is now widely dispersed and when pieces do resurface they are often overpriced.

Finally, the preponderance of Mogul specimens in the photos accompanying this article reflects the fact that a collector and dealer—Richard Barstow—happened to be on hand at the right time. Had he not been there, it is probable that only a fraction of the material would have been rescued, for the benefit of just one or two institutions and a handful of lucky individuals. The fate of the acicular cerussite mined before the advent of collecting, and the recent find of pyrite crystals in the Magcobar mine, left where they lay because no one cared, highlight the importance of the role of collectors and dealers in the preservation of our mineralogical heritage.

ACKNOWLEDGMENTS

The author is indebted to the following, without whom this article would not have been possible: the late Richard Barstow for saving and distributing much of the Mogul mine material, and Dr. Wendell Wilson for providing much of the photography. An important contribution to the detailed mineral descriptions, information on the great vug and other helpful suggestions came from Dr. George Ryback of Kent, England. Thanks are also due to Prof. Mike Russell and Dr. Allan Hall of the University of Glasgow, Scotland, and Des Cowman of the Mining Heritage Society of Ireland for help while researching the article; Dr. Dave Green of the Manchester Museum, England, for checking the manuscript; Jack Hicky, miner at Silvermines, for information about the Magcobar pyrite crystals; John Ashton, geologist at Tara Mines Ltd., Ireland, for information about the great vug; and Mrs. Helen Sheehan of Hillview, Silvermines, for her hospitality and excellent accommodation close to the mine.

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THE FLAMBEAU MINE
LADYSMITH, WISCONSIN

L

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The Flambeau copper mine, owned by Kennecott Minerals Company, was in operation for less than five years, from 1993 to 1997. But during that time it yielded hundreds of pounds of crystallized chalcocite specimens, some of which are among the largest and most beautiful in the world.

INTRODUCTION

The Flambeau mine site is located in Rusk County, Wisconsin, about 1 mile southwest of the town of Ladysmith. The terrain in the area is generally flat, with forests, lakes and wetlands interspersed among dairy farms and small communities. The Flambeau River (from which the mine takes its name) passed within 140 feet of the southwestern end of the open pit, before the pit was completely backfilled.

The Flambeau deposit was a high-grade copper orebody which, over the 4.5-year life of the mine, yielded about 1.8 million tons of ore averaging 10% copper and 0.18 ounce of gold per ton. About 330,000 ounces of gold and 3 million ounces of silver were produced. Mine construction began in early 1992; the operation is the first and only sulfide metal mine to open under Wisconsin's new mining regulations. Ore production began in May of 1993, maximum pit depth of 220 feet was reached in March of 1997, and mining of the orebody was completed in July 1997. The pit, which reached a maximum size of 2,500 by 500 feet, has since been totally filled, and the site reclaimed and revegetated.

During the course of mining some extraordinary specimens of chalcocite began to show up; contract specimen recovery by two of the authors (CJ and JKJ) began in June 1994 and continued until the closing of the mine in 1997. From the 1.8 million tons of ore mined, around 1,000 pounds of crystallized chalcocite specimens were ultimately recovered, including many large, extremely well-formed and (surprisingly) beautifully colored specimens.

When news of the Flambeau chalcocites first began to circulate, many people were surprised by the location, considering that Wisconsin is generally not thought of as a mining state today. However, in the previous century its lead and zinc resources were well-known and helped the territory to attain statehood. Wisconsin's nickname of the "Badger State" is a reference to early lead miners who lived in abandoned mine tunnels and hillside burrows. The Wisconsin State Seal depicts a miner and his tools, a badger, and a stack of lead ingots. Consequently, in addition to its instant fame among mineral collectors as a new "classic locality" for chalcocite, the Flambeau mine has stimulated renewed interest in the mining history of the state. The Flambeau Mining Company, Kennecott Minerals, and the various individuals who helped to facilitate

Figure 1. **The Flambeau mine complex, 1997. Photo © Terry Bowe, Courtesy Flambeau Mining Company.**

specimen recovery are owed a debt of gratitude for working to preserve and share the unique mineralogical aspects of the site with the scientific and collecting communities. This applies especially to mine manager Greg Fauquier, who made the decision in favor of specimen recovery and never waivered in his support. He is the person most responsible for the preservation of the Flambeau specimens.

HISTORY

Like many mining stories, the history of the Flambeau orebody discovery and subsequent mining project is colorful and begins long before ground was broken. Early in 1915 George W. O. Hotchkiss, working for the Wisconsin Geological and Natural History Survey, was prospecting and mapping much of north-central Wisconsin. His notes and rock samples were eventually stored at the offices of the Wisconsin Geological Survey in Madison. Amazingly, his original specimen of volcanoclastic rock with chalcopyrite and malachite mineralization is still on file in Madison (May and Dinkowitz, 1996).

Many years elapsed between this early work and Kennecott's interest in the Lake Superior region starting in the 1950's. This interest was based in part on the supposition that mineralization in the Canadian Precambrian Shield (which to the north in Manitoba and Ontario includes many massive sulfide deposits) might continue south into Minnesota, Michigan and Wisconsin. In 1954,

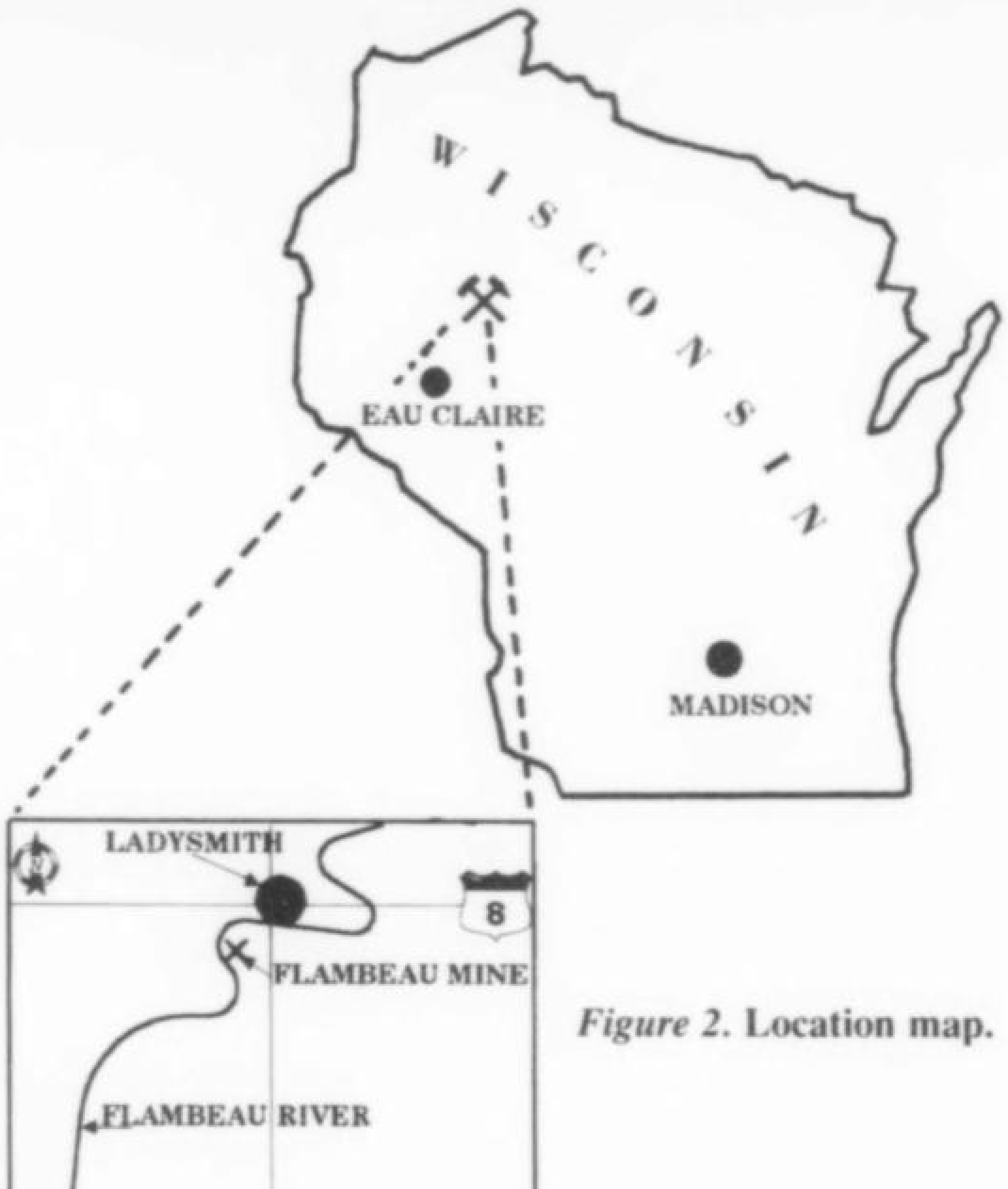

Figure 2. **Location map.**

Figure 3. **View of the Flambeau open pit looking eastward along the strike of the orebodies.**

George Moerlien began prospecting in Wisconsin and Michigan for Kennecott's wholly owned subsidiary, Bear Creek Mining. While in Madison that same year, Moerlien was shown Hotchkiss's rock specimens and information. One specimen was particularly exciting in that it assayed 0.7% copper. The report by Hotchkiss on this specimen stated that it came from a well dug near an old schoolhouse south of Ladysmith.

Moerlien traveled to the schoolhouse and searched the area; although no outcrop was visible, azurite and malachite-stained fragments of volcanic rock from the digging of the old well were found. It was decided that, since airborne electromagnetic (AEM) surveys were being flown over parts of Minnesota and Wisconsin anyway, some smaller targets should also be flown. The schoolhouse prospect was selected as one of these. No anomalies were detected by the airborne survey, but enthusiasm persisted about the possibility of deep massive sulfide mineralization.

W. F. Read and Russell C. Babcock of Lawrence University continued geological mapping through the late 1950's, generating data on which the next stages of exploration were based. The period between 1960 and 1965 was quiet while Kennecott went west looking for copper porphyry deposits.

Kennecott re-entered Wisconsin in the mid-1960's, at about the same time that Carl E. Dutton of the United States Geological Survey began conducting a library research program whereby all of the notes, rocks and mineral specimens collected since 1915 were re-examined and compiled. Dutton and Reta Bradley eventually organized all of this early data into a comprehensive geological map of Wisconsin, published in 1970.[1]

Great Lakes Exploration, a wholly owned Kennecott subsidiary, with Jack Phillips as exploration geologist, came to Wisconsin in 1965 to continue the massive sulfide exploration program. This new interest was due in part to developments in airborne electromagnetic survey technology allowing deeper penetration. Jack Phillips spotted the same sample Moerlien had seen, sitting on Dutton's desk. Based on this sample, plus other weakly mineralized outcrops found in western Rusk County, and a review of the extensive data generated by Read and Babcock in the 1950's, Phillips convinced Great Lakes Exploration to fly an airborne survey over a large area of the county. This area included the schoolhouse site, the Flambeau River, and the Blue Hills. E. H. Eisenbrey supervised the AEM program. This time a strong anomaly was discovered on the east bank of the Flambeau River, just south of Ladysmith. In 1967, Eisenbrey authorized two additional short AEM lines to be flown from the river east to highway 27, a distance of 1 mile. This survey confirmed the anomaly.

In the spring of 1968, an extensive exploratory core-drilling program began in Rusk County and on November 6th of that year the Flambeau deposit was discovered. Core pulled from that hole showed 48 feet of massive supergene enriched chalcocite ore

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[1] The source for much of this history is Ed May, who over a long period of time guided the development of the Flambeau mine and held various positions from chief geologist to project manager to consultant at various periods of the project. Mr. May now lives in Littleton, Colorado. Other information is selected from M. G. Mudry, Jr. *et al.* (1991), and Babcock (1991).

averaging 9.25% Cu. Environmental studies, public hearings and drilling to define the deposit continued through 1976.

From 1977 to 1985 the project was dormant, but in 1986 Kennecott reopened the Flambeau project when copper metal price forecasts turned optimistic. Progress toward actual construction and mining involved numerous public hearings, reviews, and permit applications from 1987 to 1991. Permits were finally granted in June of 1991. Ground was broken on the first sulfide metal mine to operate under Wisconsin's new mining laws in 1992 and on June 28, 1993, the first crushed copper ore was shipped via rail for processing.

From 1993 until its closure in 1997, the mine successfully operated without any violations, citations or complaints. This is a truly outstanding accomplishment considering that the mine is within 150 feet of the Flambeau River, 500 feet of Highway 27, within 1000 feet of private residences, and 2500 feet from a liberal arts college, the Rusk County hospital, and a nursing home. Ore shipments during the four years of operation totaled 1,896,000 tons averaging about 10% copper (including 266,000 tons of especially rich ore averaging 17% copper!), 0.18 ounce of gold per ton, and also some silver. Although comparatively small, the Flambeau orebody was one of the richest copper deposits ever mined, so rich that no beneficiation of the ore was required at the mine site! The copper ore was shipped 800 miles by rail to the smelter in Timmins, Ontario, and the gold-rich gossan was shipped about 1,000 miles to the smelter at Rouyn, Quebec.

By July of 1998 the pit had been completely backfilled (in the reverse order of initial rock and soil removal) and the surface revegetated. Plans are being made for construction of a series of hiking trails and other recreational facilities on the site.

GEOLOGY

The Flambeau mine is located in a broad belt of Precambrian volcanic and associated sedimentary rocks known as the Wisconsin magmatic terranes, which lies on the southern margin of the Canadian Shield. These rocks are the remnants of an extensive volcanic island arc that collided with the margin of an ancient continent in the Lake Superior region about 1,860 million years ago. The collision zone is shown on modern geologic maps (Fig. 4) as the Niagara Fault Zone (Sims, 1992). The collision resulted in intense deformation of the volcanic and sedimentary rocks and produced a mountain range known as the Penokean Mountains. This once-lofty mountain range eroded to a landscape of low rolling hills, the only remnants of which are found in northern Wisconsin. The original extent of the Penokean Mountains is not known because the eroded roots of the mountains have been buried beneath younger sedimentary rocks from the Michigan border eastward, and westward from Ladysmith, Wisconsin.

The orebody at the Flambeau mine is a volcanogenic massive sulfide deposit, one of ten similar sulfide bodies found along the length of the volcanic belt in northern Wisconsin in recent years (DeMatties, 1996). Several of the sulfide bodies were evidently deposited on the flanks of rhyolitic volcanic islands where hot hydrothermal brines containing iron, copper, zinc and lesser amounts of lead, silver and gold issued forth onto the ocean floor. At Ladysmith these metal-rich brines produced a broad, thin layer about 50 feet thick composed of sulfide mud with some admixed volcanic materials covering perhaps a square mile. The Flambeau sulfide deposit is underlain by a thick sequence of felsic volcanic lava flows and tuffs, with lesser amounts of volcanogenic sediments. A thick pile of basaltic volcanic rocks, some of which are pillowed, as well as some felsic volcanic rocks, overlie the ore horizon (May and Dinkowitz, 1996).

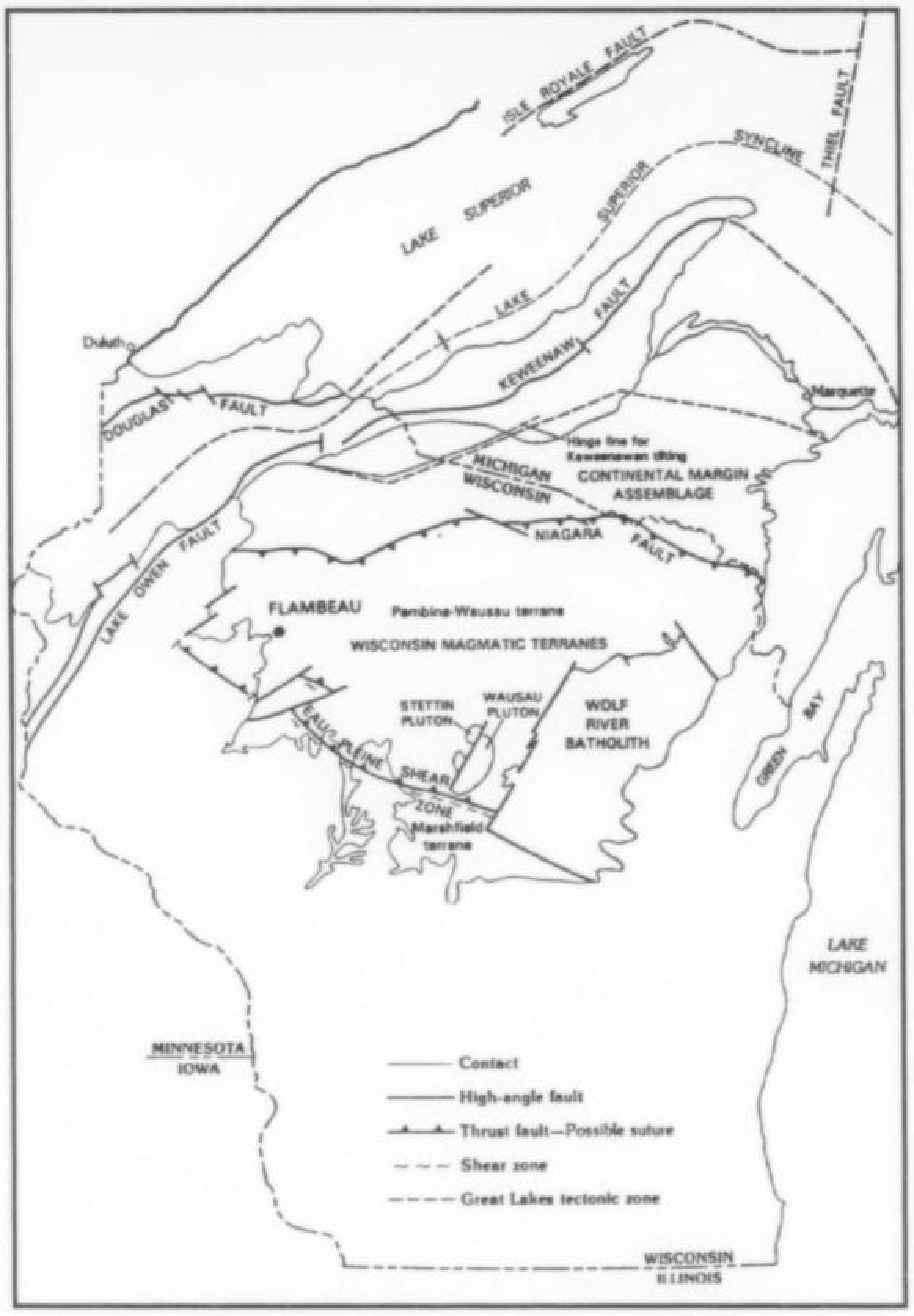


Figure 4. **Tectonic map of the southern part of the Lake Superior region, Wisconsin and northern Michigan (from Sims, 1992).**

The primary ore consisted of vaguely layered, fine-grained pyrite, chalcopyrite, sphalerite, pyrrhotite and minor galena (which probably contained some silver) (May and Dinkowitz, 1996). Minor gold was disseminated in the sulfide-rich lens. Abundant cherty horizons within the sulfide ore indicate that the hot springs also carried considerable silica. A possible siliceous mound, or "chimney," was encountered during mining operations. The sulfide orebody had a chert-rich "cap" approximately 5 feet thick, which was overlain by a 10-foot-thick cherty quartz-sericite schist containing substantial amounts of very fine-grained gold (May and Dinkowitz, 1996).

The felsic volcanic rocks underlying the orebody were extensively altered to sericite and kaolinite over a broad zone by the hydrothermal solutions that deposited the ore. Unlike some volcanogenic massive sulfide orebodies, the altered rocks beneath the ore zone at the Flambeau mine contain copper mineralization. In fact, no well-defined alteration pipe has been identified beneath the Flambeau orebody (May and Dinkowitz, 1996).

Folding and faulting associated with the formation of the Penokean Mountains about 1,850 million years ago tilted the volcanic rocks in the Ladysmith area more than 90°, so that the originally horizontal layers are now nearly vertical (Fig. 5). Metamorphism resulted in recrystallization of the sulfide minerals to a coarser grain size (about the size of coarse sand), and converted the felsic volcanic rocks to quartz-sericite schists and the basaltic rocks to actinolite-rich schists (May and Dinkowitz, 1996). Widespread andalusite and spessartine garnet developed in the aluminum-rich alteration zone beneath the orebody.

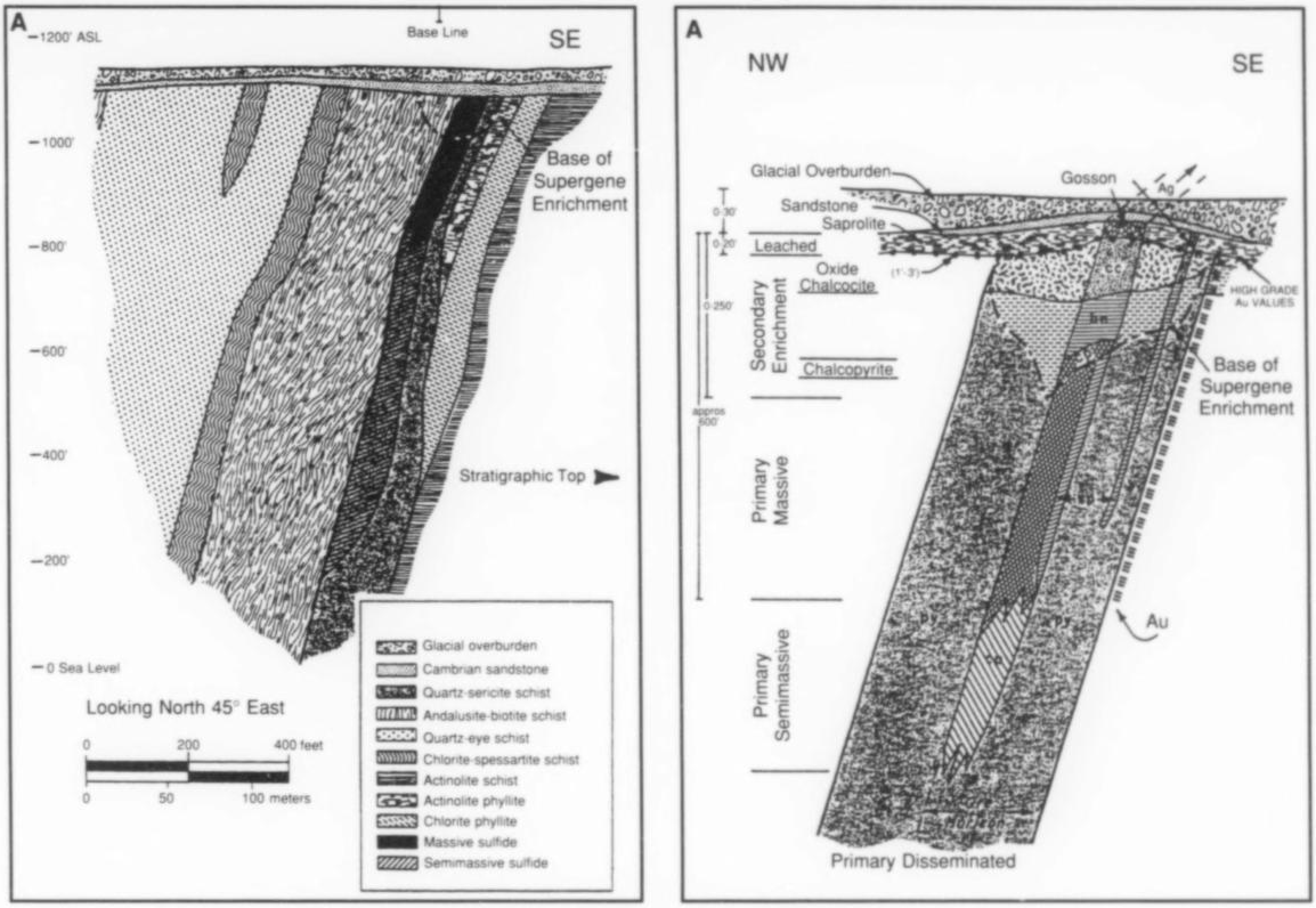


Figure 5. **Cross-sections through the Flambeau deposit showing (left) geology and (right) zonation of the orebodies (after May, 1977).**

The Penokean Mountains were then subjected to a long period of weathering and erosion. The mountain range was reduced to low rolling hills by about 1,200 million years ago—perhaps much earlier. The Barron Quartzite, exposed about 12 miles west of the Flambeau mine, and the Flambeau Quartzite exposed about 15 miles in the south, were deposited on the eroded edges of volcanic rocks that formed the Penokean Mountains. The age of these quartzite units is not well established. They may be as young as about 1,200 million years (LaBerge, 1994), or as old as about 1,700 million years (Dott, 1983). (As discussed later, the age of the quartzite may be significant with regard to the timing of the enrichment of the ores.) Regardless of its age, the quartzite was heavily eroded during later Precambrian time, leaving only widely scattered remnants in northern Wisconsin.

The Upper Cambrian sea which covered Wisconsin some 520 million years ago, deposited a layer of sandstone over most of Wisconsin, including the Flambeau deposit. The sandstone was, in turn, mostly eroded from the area; but, fortuitously, a small remnant (an outlier) directly above the Flambeau orebody persisted. Finally, continental glaciers moved across northern Wisconsin about 20,000 years ago and removed most of the weathered rock that had accumulated over the eons of weathering. The small outlier of Cambrian sandstone protected the Flambeau orebody from glacial erosion, and from erosion by streams following the retreat of the glaciers.

Supergene Enrichment

The Flambeau mine is basically like many other volcanogenic massive sulfide deposits in the Canadian shield. Indeed its origin is similar to at least ten other sulfide deposits in northern Wisconsin (DeMatties, 1996). However, it differs fundamentally from other massive sulfide deposits in its mineralogy (mainly chalcocite) and in the high grade of the ore. This major difference at the Flambeau mine is the result of the orebody having been extensively altered and enriched by chemical weathering. In oxygen-rich ground waters the sulfide minerals became unstable. Above the water table the sulfur in the sulfides was oxidized to sulfate $(SO_4)^{-2}$ which produced sulfuric acid. The iron in the original pyrite (FeS_2), pyrrhotite ($Fe_{1-x}S$) and chalcopyrite ($CuFeS_2$) was oxidized to goethite ($FeO(OH)$) or hematite (Fe_2O_3). These iron minerals remained at the surface due to their extreme insolubility, and formed an iron-rich cap (*gossan*) on the deposit. Gold was also concentrated in the surface environment, with the result that the gossan was also rich in gold. Near the surface the acid-rich groundwater dissolved nearly all of the copper, zinc and silver and carried them downward to the water table. Below the water table, where oxygen was much less abundant, the copper which had been dissolved in the groundwater replaced iron in the sulfide minerals. Primary pyrite and pyrrhotite were converted to chalcopyrite, and primary chalcopyrite was subsequently converted to bornite (Cu_5FeS_4), with the iron going off in solution. Continued percolation of copper-bearing water, and replacement of the remaining iron in these copper minerals, eventually converted the chalcopyrite and bornite to chalcocite (Cu_2S); this greatly enriched the original ore in copper in a zone just below the water table. This enrichment process resulted in a crude three-fold zonation of the deposit with an upper zone rich in chalcocite, underlain by a zone rich in secondary bornite and a lower zone rich in secondary

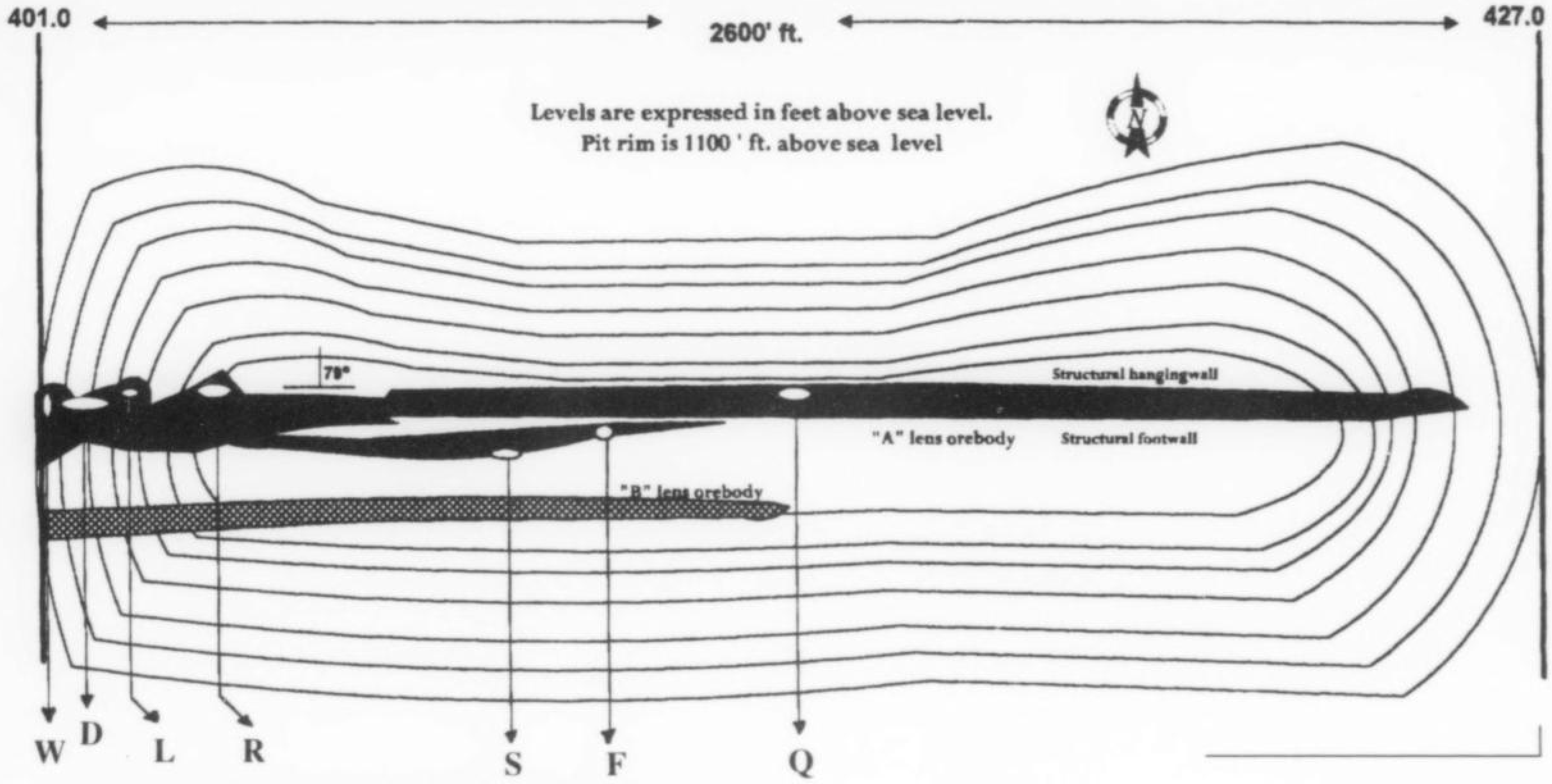


Figure 6. **Diagram of the Flambeau open pit and benches, showing locations of the orebodies (A and B) and the major chalcocite pockets: (W) First Pocket and Watercourse Pocket, (D) Drill Pocket, (L) Lucky Friday Pocket, (R) Rocket Pocket, (S) Sunrise Pocket, (F) Fog Pocket and (Q) Quick Pocket.**

chalcopyrite. The boundaries between these zones are highly irregular. Because zinc is much more soluble than copper, it does not form an enriched zone below the water table. The zone of copper enrichment at the Flambeau mine was approximately 200 feet thick. Below the enriched zone the primary ore minerals occupy the ore horizon.

As shown in Figure 7, many weathered deposits contain a variety of secondary minerals in the leached zone above the water table. Azurite, malachite, chrysocolla, cuprite, native copper and native silver were present at the Flambeau mine, but they occurred in very subordinate quantities. Grade and tonnage calculations (May and Dinkowitz, 1996) indicate that a volume of primary ore approximately six times the volume that was mined had to be concentrated by supergene enrichment to produce the rich copper ore. The relatively thin covering of gossan and leached ore above the rich chalcocite zone suggests that most of the leached zone was removed by erosion during or after the sulfide enrichment.

A vast majority of the chalcocite at the Flambeau mine consisted of massive to granular material; this constituted most of the rich ore. Grain size and texture of the ore suggest that the chalcocite was produced as a result of copper replacement of iron in the earlier recrystallized pyrite. Relatively open cavities were developed in about ten sites within the enriched ore zone. Three large cavities ("pockets") with dimensions of several feet in size (discussed later), were encountered during mining operations. These pockets were evidently formed where the groundwater flow was channeled along confined pathways. Most of the collectible crystals occurred in these three large pockets.

A consistent and distinctive pattern of crystal development occurred in the major pockets. The massive to granular chalcocite

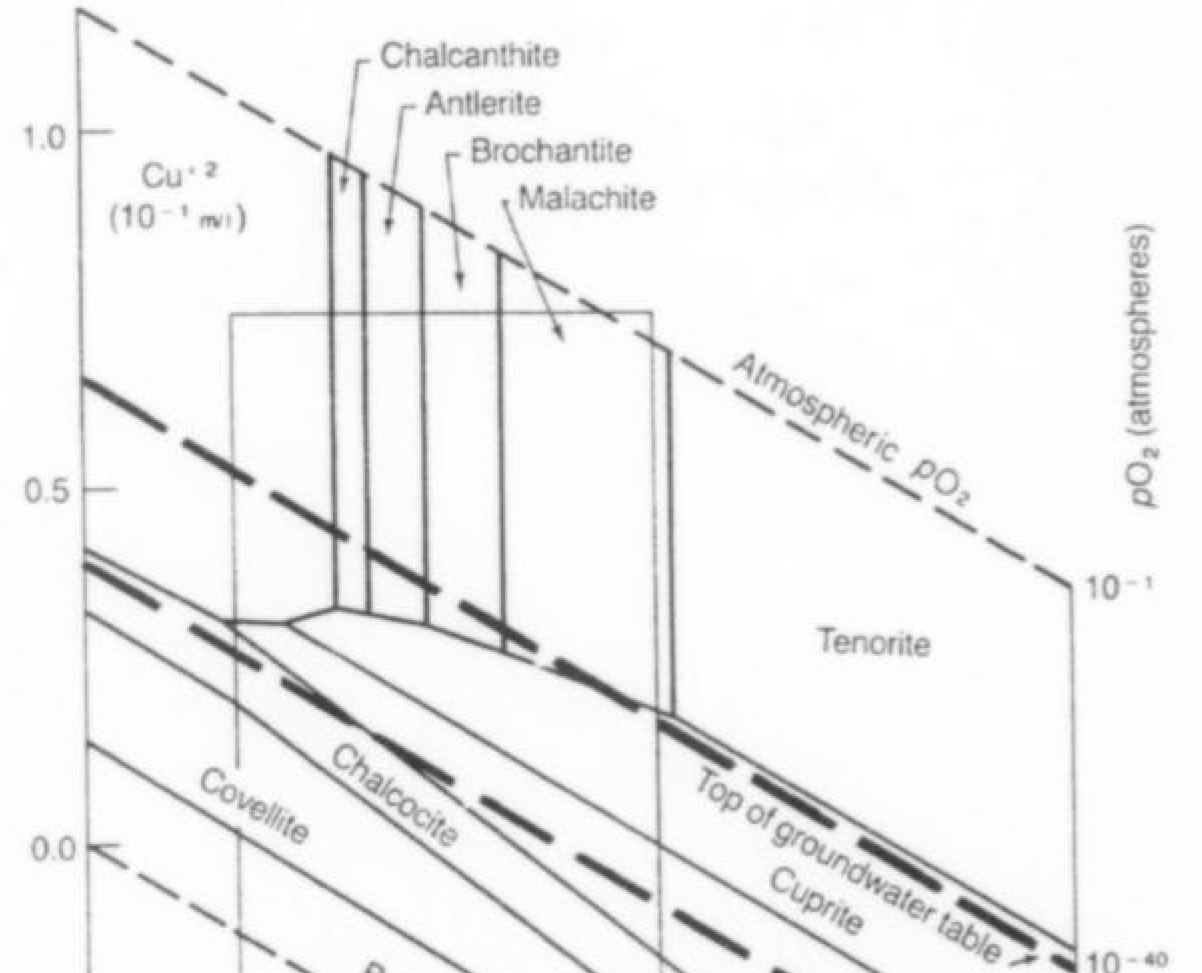


Figure 7. **Stability diagram for copper minerals; the zone indicated encompasses the species typical of the Flambeau assemblage (from Guilbert and Park, 1986).**

on the pocket walls was coated with a meshwork of chalcocite with a distinctive cellular or ropy texture (Fig. 6). The cellular chalcocite is succeeded inward by peculiar curved or twisted chalcocite crystals up to at least 5 cm long (Fig. 7). Euhedral crystals and crystal groups usually developed only in a limited portion of a pocket. The crystals typically show orthorhombic morphology, indicating that they grew originally as chalcocite, and thus, they are not replacements of earlier bornite or some other crystal phase. Like other orthorhombic minerals, they exhibit a wide variety of crystal habits. Additionally, X-ray studies show that the crystals are essentially pure chalcocite, not a combination of several mineral phases. Therefore, both the field relations and the crystal morphology suggest that the chalcocite crystals at the Flambeau mine developed late in the enrichment process. Curiously, and perhaps significantly, there was almost no development of euhedral crystals of bornite or chalcopyrite associated with the enrichment. However, botryoidal masses of chalcopyrite did develop, which were partially to completely replaced by bornite, and this, in turn, was replaced by chalcocite.

Perhaps the most distinctive feature of Flambeau mine chalcocite is the attractive brassy yellow, bronze, purple or blue patina on the crystals. Nearly all of the crystals recovered have a patina of one or more colors. Lead-gray crystals, of the kind typical of most deposits, are decidedly uncommon at the Flambeau mine. EDAX analyses performed by Lance Kearns first determined that the coating is not chalcocite. Microprobe studies by Joseph Mandarino and Malcolm Back show that the various colors are produced by a very thin coating of bornite.

Various lines of evidence indicate that the chalcocite crystals at the Flambeau mine are very old. First, the observed geology and the grade and tonnage calculations (May and Dinkowitz, 1996) demonstrate convincingly that the supergene enrichment occurred before the invasion of the Cambrian sea which deposited a layer of sandstone almost directly on the enriched ore some 520 million years ago. Thus, the enrichment must have been older than Cambrian in age. The volcanic rocks that host the deposit were deformed about 1,860 million years ago (Sims and others, 1989) during the Penokean Orogeny. Therefore, the enrichment might have occurred at any time between 1,860 million and 520 million years ago.

Other lines of evidence suggest that the enrichment may have occurred well back in Precambrian time. During mining operations several blocks of quartzite were encountered in the gossan and altered volcanic rocks beneath the Cambrian sandstone cover on the deposit. These quartzite blocks may be remnants of the Barron or Flambeau Quartzite, which may, at one time, have covered the orebody. If so, their presence may indicate that the enrichment occurred during erosion of the Penokean Mountains which occurred prior to deposition of the Barron and Flambeau Quartzites. As stated earlier, the age of these quartzite bodies is not well established.

Mineralogical evidence also suggests that enrichment probably occurred well before the invasion of the Cambrian sea. Fresh, tin-white arsenopyrite and vein quartz (Fig. 8) cut the enriched chalcocite and bornite ore at several locations in the mine. It seems highly unlikely that the arsenopyrite would have survived unaltered through the entire enrichment process. It is far more likely that arsenopyrite-quartz veins were emplaced after the enrichment was completed. The question, then, is to identify a potential hydrothermal event that might have added the arsenopyrite. LaBerge (1997) suggests that the arsenopyrite may have been emplaced during igneous activity associated with the 1,100-million-year-old Keweenawan mid-continent rift system. Arsenic is locally abundant in the copper deposits of northern Michigan as domeykite (Cu_3As) (Nicholson *et al.*, 1992). Basaltic dikes of Keweenawan age are widespread throughout northern Wisconsin, including the Ladysmith area. These observations suggest that the enrichment, and therefore the chalcocite crystals may have formed more than 1,100 million years ago.

During the period of Earth history when the enrichment of the Flambeau mine occurred, the area destined to become Wisconsin (and most of North America) was located near the earth's equator. In fact, many geology textbooks show that the Great Lakes region straddled the equator during the latter part of the Precambrian and much of the Paleozoic era. During much of this time, the climate may have been similar to that in present day Australia, where the water table is a hundred meters or more below the surface. Since enrichment at the Flambeau mine extends down over 60 meters below the present-day surface, the water table must have been from 60 meters to as much as 360 meters below the surface.

When plate movements carried North America into more temperate climate zones the water table would have moved closer to the surface. (The present water table in the vicinity of the mine is less than 6 meters below the surface.) As the water table rose closer to the surface the chalcocite crystals, which had formed near the former deep water table, were subjected to groundwater that presumably contained significant amounts of dissolved iron from weathering of sulfide minerals. The chemical environment of the alteration system may be seen on the Eh/pH diagram in Figure 5. A very thin layer of bornite was precipitated on the chalcocite crystals from the iron-rich groundwater. However, with the exception of a few scattered bornite replacements of small chalcocite crystals, no large-scale formation of bornite related to a higher water table has been recognized at the Flambeau mine.

MINERALS

Locations within the open pit are specified according to the two parameters used by the mining company: (1) *the horizontal hundred-foot markers*, beginning on the extreme western edge of the pit with marker 400 and counting off due eastward 2,600 feet to marker 426 at the eastern margin of the pit, and (2) *the vertical levels*, in feet above sea level, ranging from the 1100 level at the top rim of the pit down to level 970 at the floor of the pit.

Important pockets have been given names for easy reference; these are, from west to east: the ***First Pocket*** (marker 401.2, 1030 level, found June 30, 1994), the ***Watercourse Pocket*** (marker 401.2, 1030 level, found June 30, 1994), the ***Drill Pocket*** (marker 401.5, 1010 level, found January 31, 1995), the ***Lucky Friday Pocket*** (marker 402.0, 1000 level, found October 13, 1995), the ***Rocket Pocket*** (marker 402.3, 970 level, found August 15, 1996), the ***Sunrise Pocket*** (marker 406.2, 1010 level, found October 10, 1994), the ***Fog Pocket*** (marker 409.6, 1000 level, found March 30, 1995), and the ***Quick Pocket*** (marker 415.2, 980 level, found May 20, 1996). All are in the "A" (northern) orebody (see Fig. 6). During the three years of specimen recovery only these eight significant pockets were found, several of which were quite small. The vast majority of specimens collected came from the Drill, Lucky Friday and Rocket Pockets.

Table 1 lists all of the species thus far identified at the Flambeau mine, including sulfates found as a result of ore studies conducted by Kennecott.

Ankerite $Ca(Fe,Mg)(CO_3)_2$

Small crystals of ankerite up to 1 cm were encountered on the east end of the orebody in an area confined within markers 420.0 and 422.5 on levels 1020, 1010, 1000, and 990. The ankerite was found lining small pockets and vugs in massive chalcocite. Microcrystals of chalcocite, chalcopyrite, marcasite, pyrite and siderite occur on the ankerite. Ankerite on the outer edges of these small vugs fluoresces a pale green under shortwave ultraviolet light. The identification as ankerite (instead of ferroan dolomite) is tentative; EDS analysis reveals considerable variation in Ca, Fe and Mg, even within single crystals.

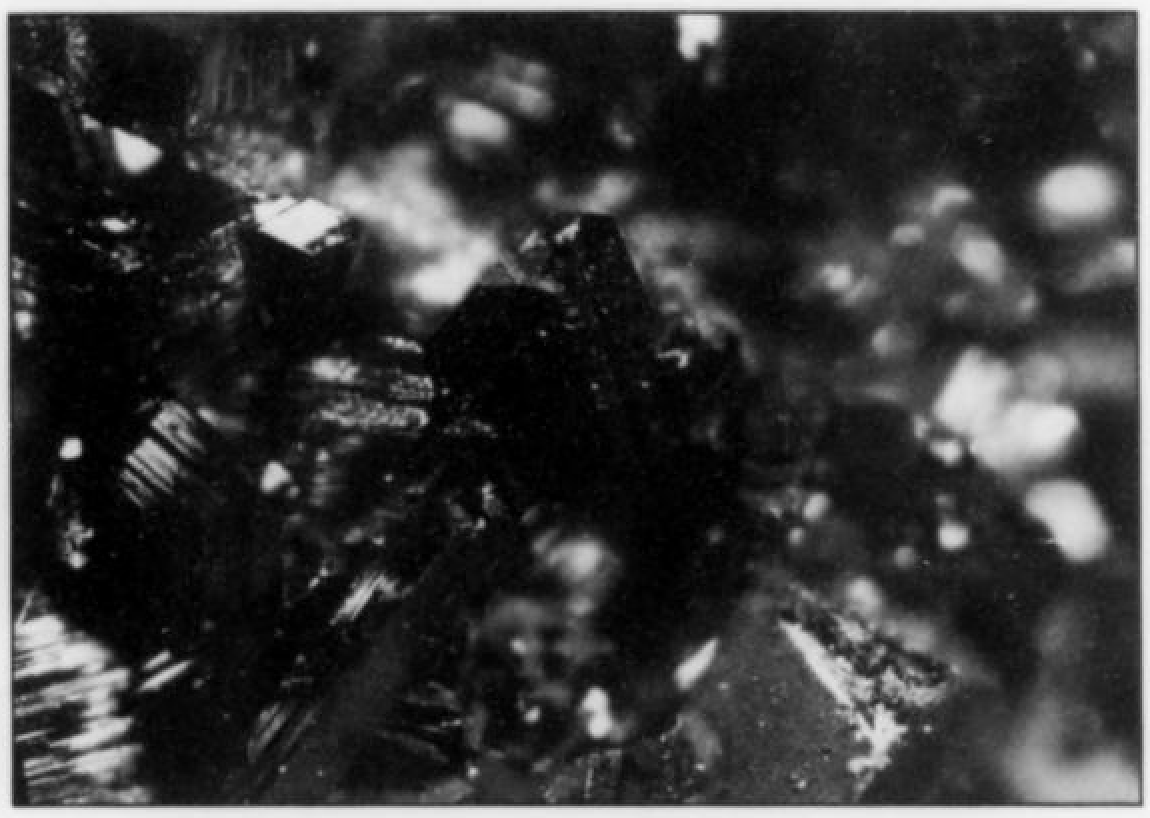


Figure 8. **Arsenopyrite crystals to 1.1 mm, from the Flambeau mine. Dan Behnke specimen and photo.**

Arsenopyrite FeAsS

Arsenopyrite occurred as microcrystals through the deposit, but was more common on the eastern end of the orebody, at markers 419.0 to 423.0, on the 1020 level. Several specimens with crystals up to 2 cm were recovered at marker 406.2, 1010 level, in a massive quartz pod within enclosing massive bornite. One crystal, however, was found in a pocket in massive secondary bornite.

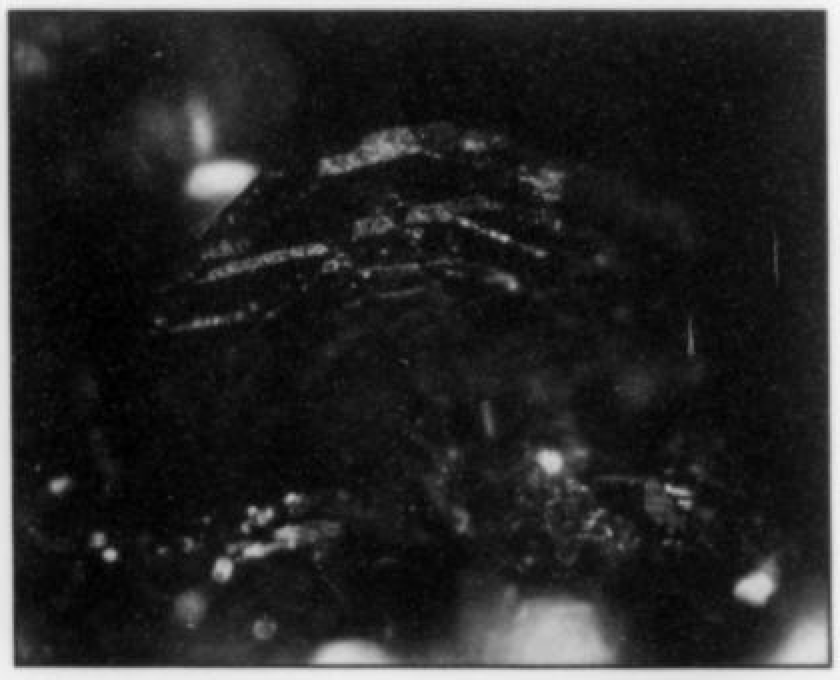


Figure 9. **Azurite crystal, 0.5 mm, from the Flambeau mine. Dan Behnke specimen and photo.**

Figure 10. **Azurite rosette, 1 mm, from the Flambeau mine. Dan Behnke specimen and photo.**

Azurite $Cu_3(CO_3)_2(OH)_2$

Crystallized and massive azurite was encountered in the oxide zone beneath the gossan cap, particularly in the fault zones at markers 406.9 and 413.0. Crystals do not exceed 4 mm. Only a few specimens were recovered because most of the material was shipped as ore in 1994 before specimen recovery efforts began. Specimens saved include deep blue druses of microcrystals lining vugs in digenite, malachite and limonite gossan.

Bornite Cu_5FeS_4

Massive bornite was quite common along the strike of the orebody. Most bornite formed by copper enrichment of the earlier chalcopyrite, which in turn had formed by enrichment of primary pyrite. No macroscopic crystals of bornite have been observed or recovered.

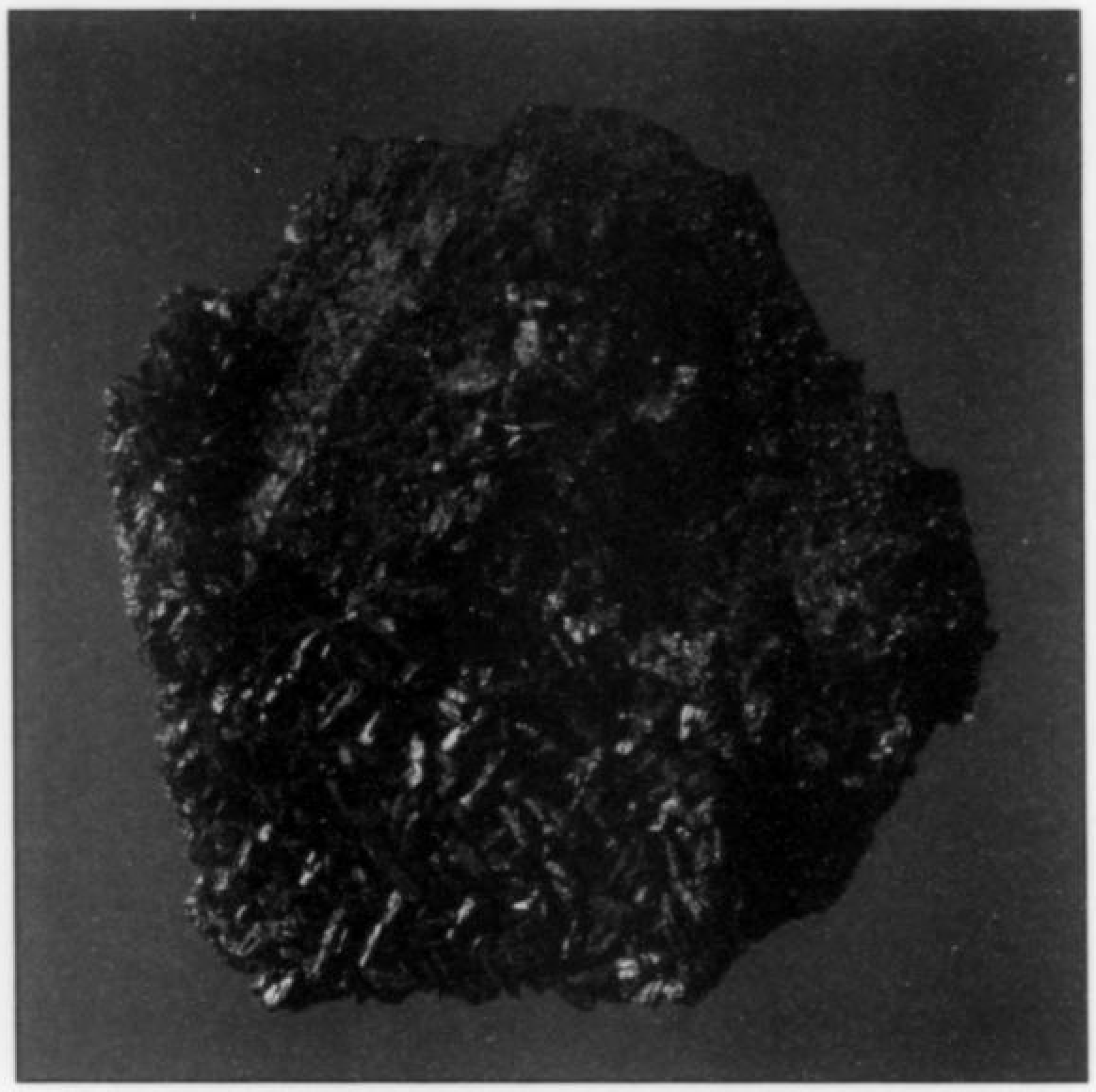


Figure 11. **Bornite after chalcocite, 3 cm, showing blue patina, from the Flambeau mine. F. John Barlow collection; Munroe Studios photo.**

The Sunrise Pocket, at marker 406.2, 1010 level, on the footwall contact contained several fine specimens of bornite after chalcocite with crystals up to 3.5 cm. Some of these were found as floaters in a bornite sand and others were found attached to chalcocite crystals. At marker 415.0, 990 level, on top of a blast pile, half a dozen more pseudomorphs of bornite after chalcocite were discovered. The largest of these is a group with one crystal of bornite-after-chalcocite measuring 5.5 cm by 3.8 cm. Bornite is also present as a blue, purple, brown or reddish iridescent coating on chalcocite crystals.

Calcite $CaCO_3$

An area on the footwall side of the orebody at marker 418.0 produced about 100 specimens of translucent white calcite crystals. This occurrence is in the country rock, 12 meters from the orebody.

Chalcanthite $Cu^{2+}SO_4 \cdot 5H_2O$

George Robinson (personal communication) has identified chalcanthite (by EDS) from the Flambeau mine, as post-mining coatings on sericite schist.

Chalcocite Cu_2S

The mineral that has made this locality a world-class specimen producer is chalcocite. It was the dominant ore mineral at the Flambeau mine, occurring as massive and granular material as well

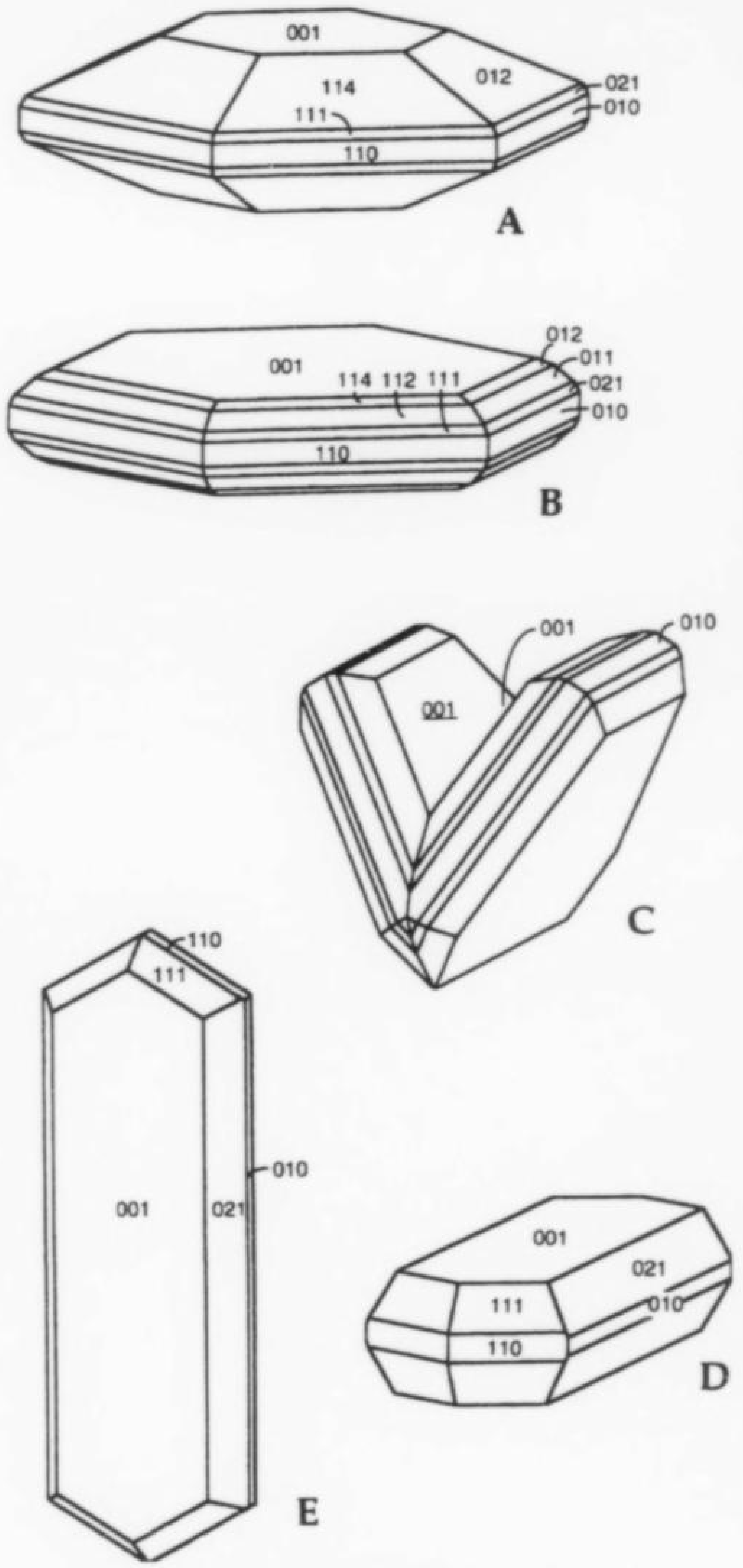


Figure 12. **Representative chalcocite crystal habits from the Flambeau mine, including (A, B) pseudohexagonal tablets, (C) a twin, (D, E) elongated crystals showing the true orthorhombic symmetry. Drawings by R. Peter Richards from Rosemeyer (1995).**

as fine crystals. The crystals were found on fracture surfaces and within cavities and pockets, primarily near the contact of the orebody with the quartz-sericite schist, on both the hanging and the footwall. The identity of the chalcocite has been confirmed by X-ray diffraction (Lance Kearns, pers. comm.).

The multi-colored patina or coating present on a vast majority of the chalcocite crystals from the Flambeau mine has been confirmed to be bornite (J. A. Mandarino and Malcolm Back, Royal Ontario Museum, pers. comm.). These bornite coatings are typical of the species in that almost every color of the rainbow is present, and the specimens are notably iridescent.

The best of the Flambeau mine chalcocite specimens are stunning and set the standard for contemporary occurrences of this

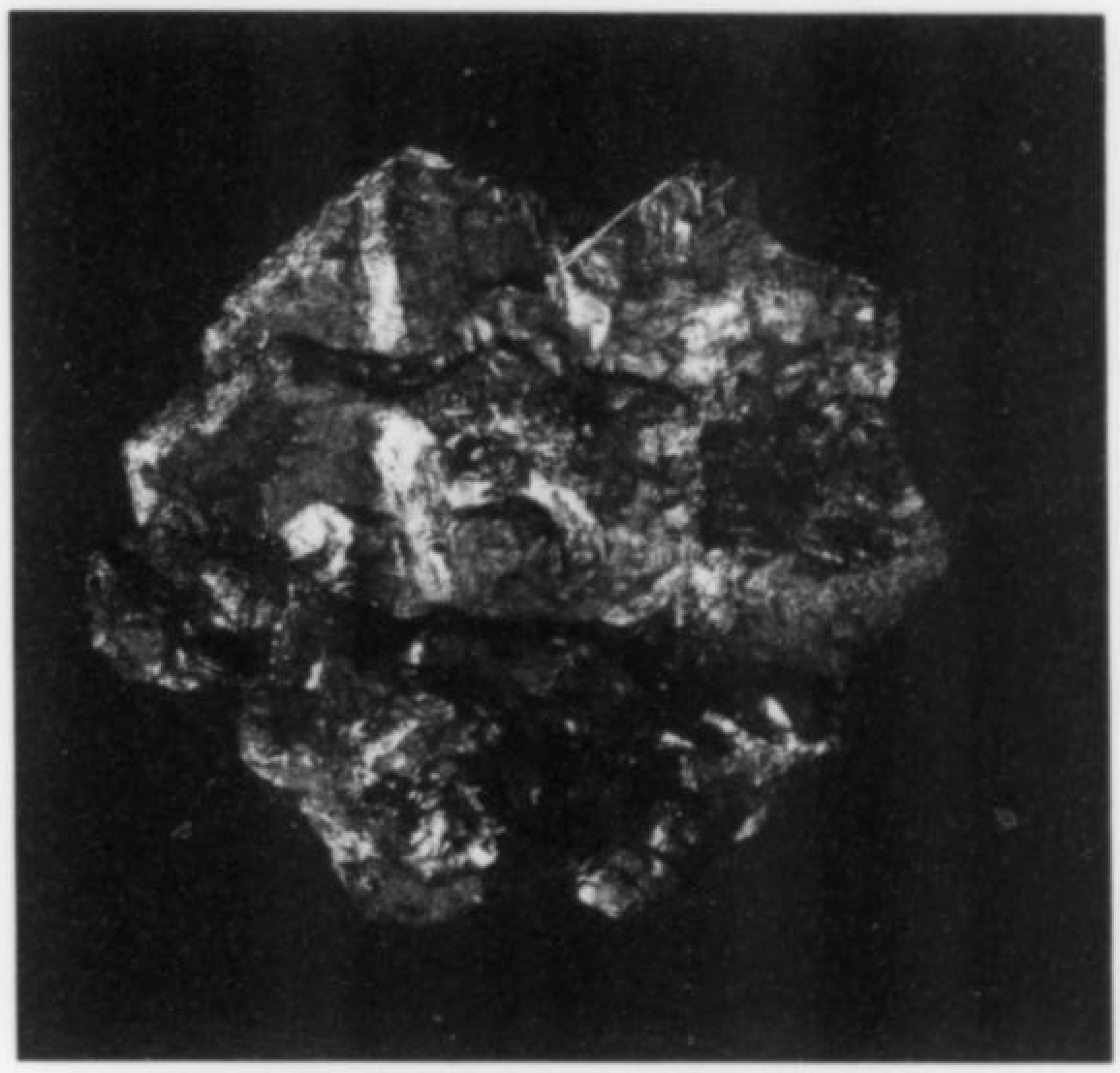


Figure 13. **Chalcocite crystal group, 3.5 cm, lacking colored patina, from the Flambeau mine. F. John Barlow collection; Munroe Studios photo.**

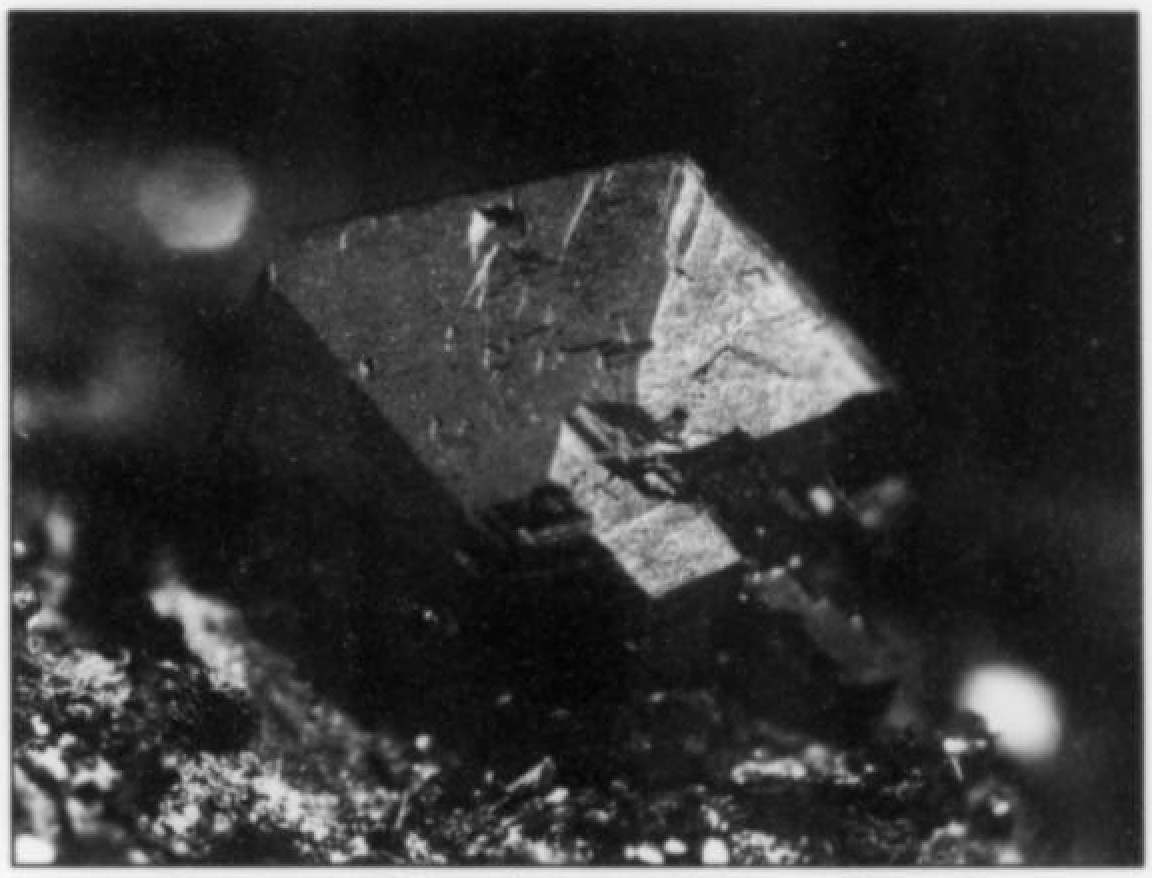


Figure 14. **Chalcocite crystal, 3 mm, from the Flambeau mine. Dan Behnke specimen and photo.**

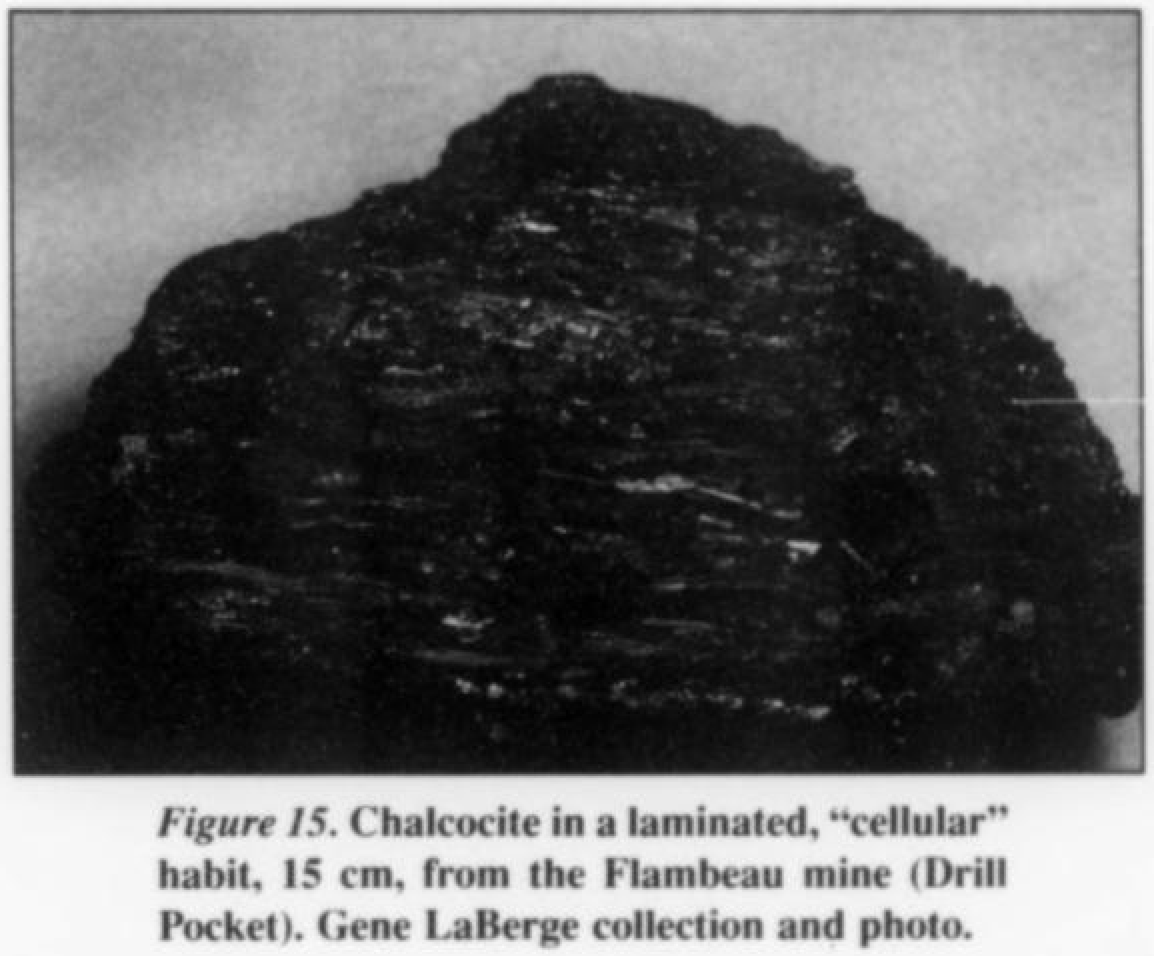


Figure 15. **Chalcocite in a laminated, "cellular" habit, 15 cm, from the Flambeau mine (Drill Pocket). Gene LaBerge collection and photo.**

Figure 16. **Chalcocite microcrystals (lacking patina) on botryoidal chalcocite showing purple and blue patina, from the Flambeau mine. Jane and Casey Jones collection; Jeff Scovil photo.**

Figure 17. **Large chalcocite crystal group, 13 cm, showing pale blue patina, from the Flambeau mine. F. John Barlow collection; Munroe Studios photo.**

Figure 18. Chalcocite crystal group, 3.2 cm, showing pale purple and gold-colored patina, from the Flambeau mine. F. John Barlow collection; Munroe Studios photo.

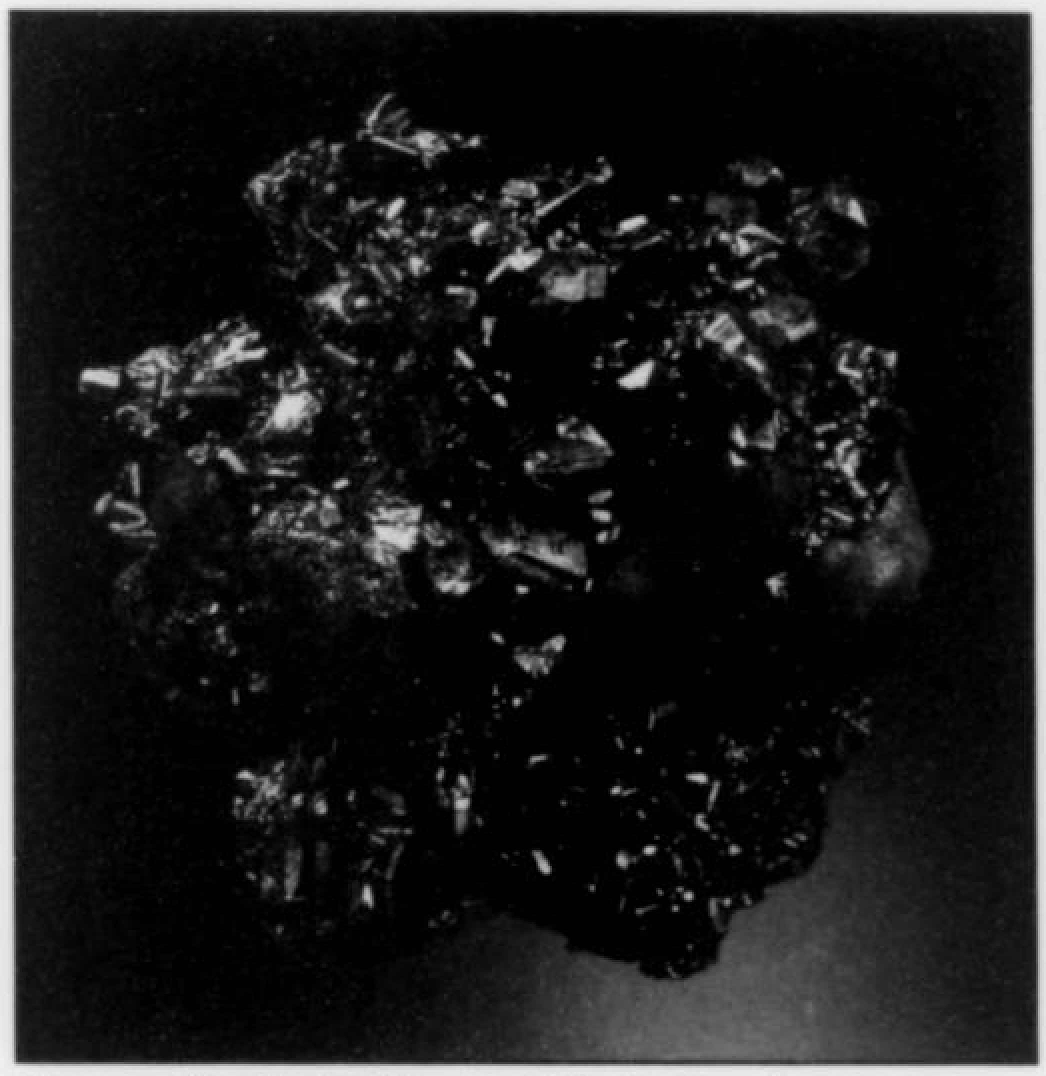


Figure 19. Chalcocite crystal cluster, 4 cm, showing blue, purple and gold-colored patina, from the Flambeau mine (Rocket Pocket). Jane and Casey Jones collection; Jeff Scovil photo.

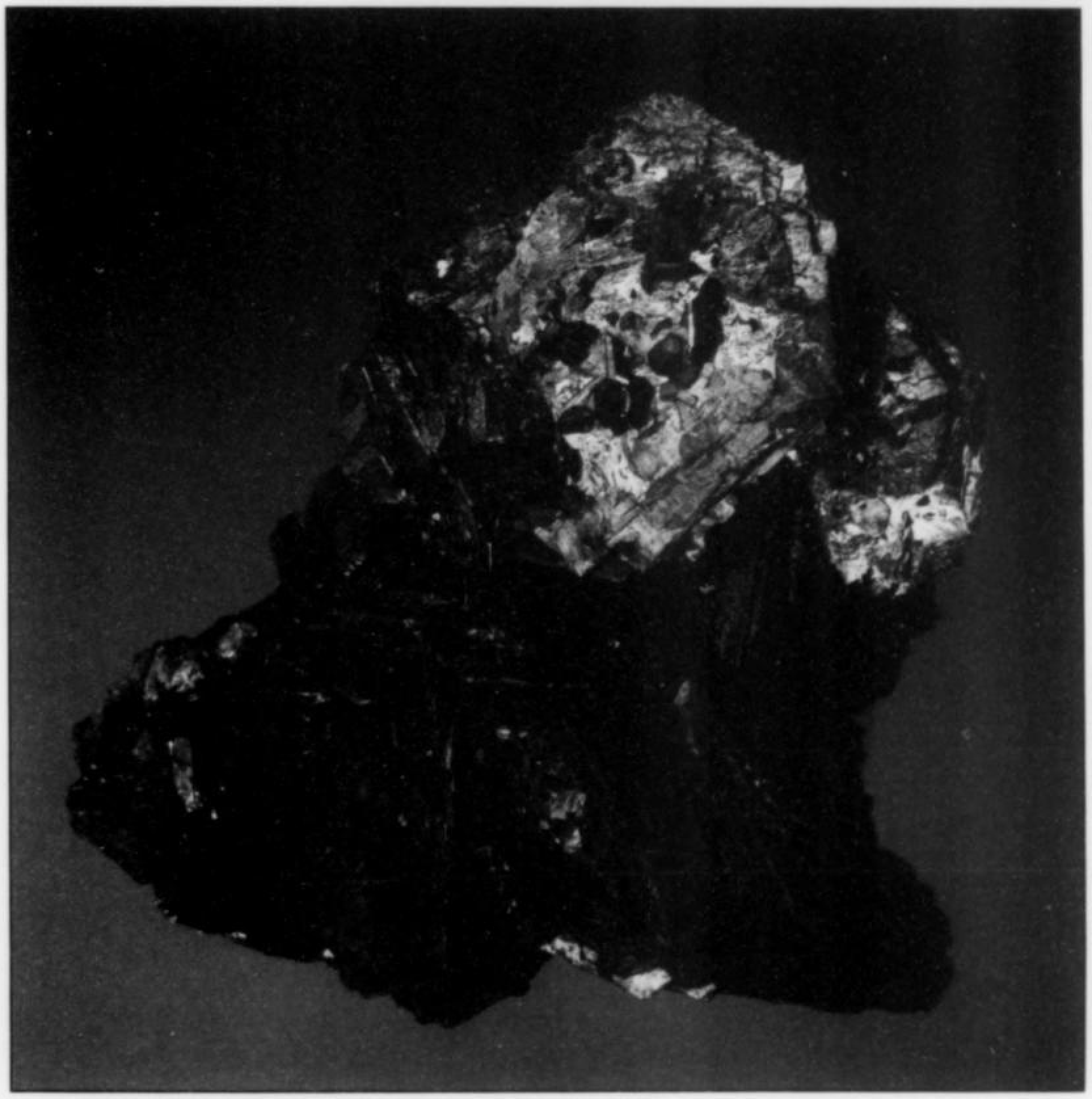


Figure 20. Chalcocite crystal group, 7.5 cm, showing pale purple and gold-colored patina, from the Flambeau mine. F. John Barlow collection; Munroe Studios photo.

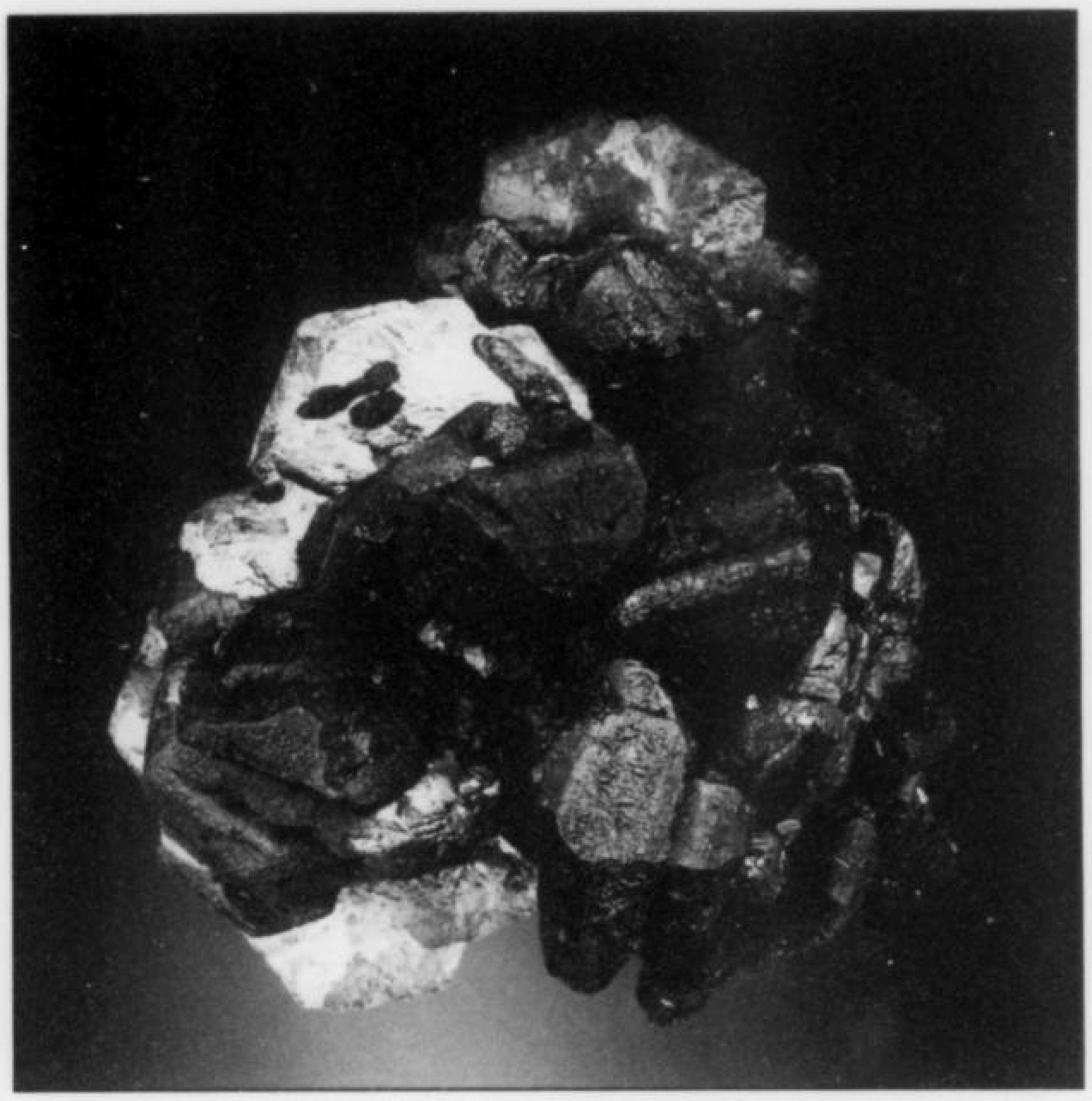


Figure 21. Chalcocite crystal cluster, 7.7 cm, showing purple and gold-colored patina, from the Flambeau mine (Lucky Friday Pocket). Casey Jones collection; Jeff Scovil photo.

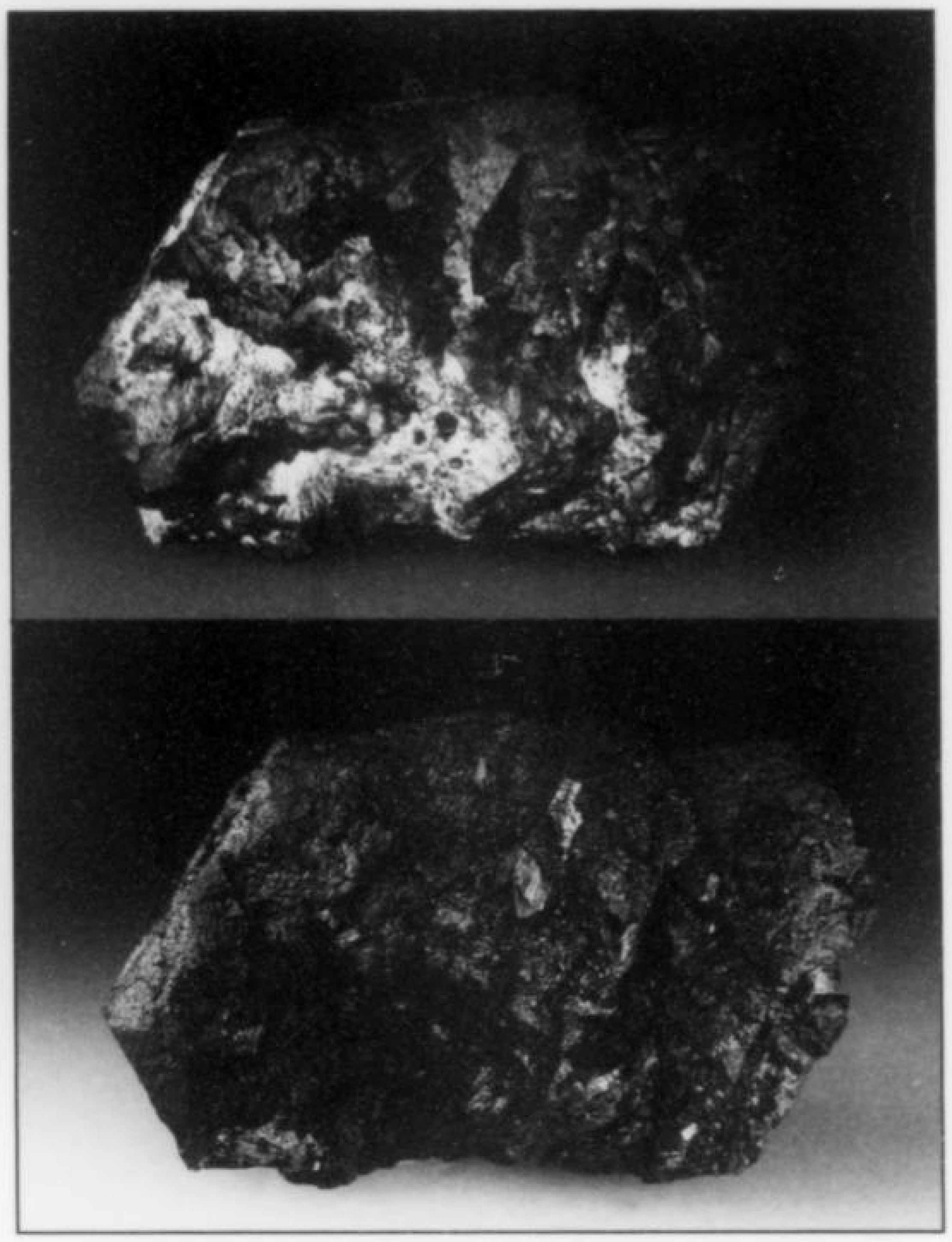


Figure 22. Chalcocite crystal (above) with gold-colored patina, 4.2 cm, from the Flambeau mine. Jane and Casey Jones collection; Wendell E. Wilson photo. (Below) The same crystal, with lighting from a different angle, showing a magenta-pink patina.

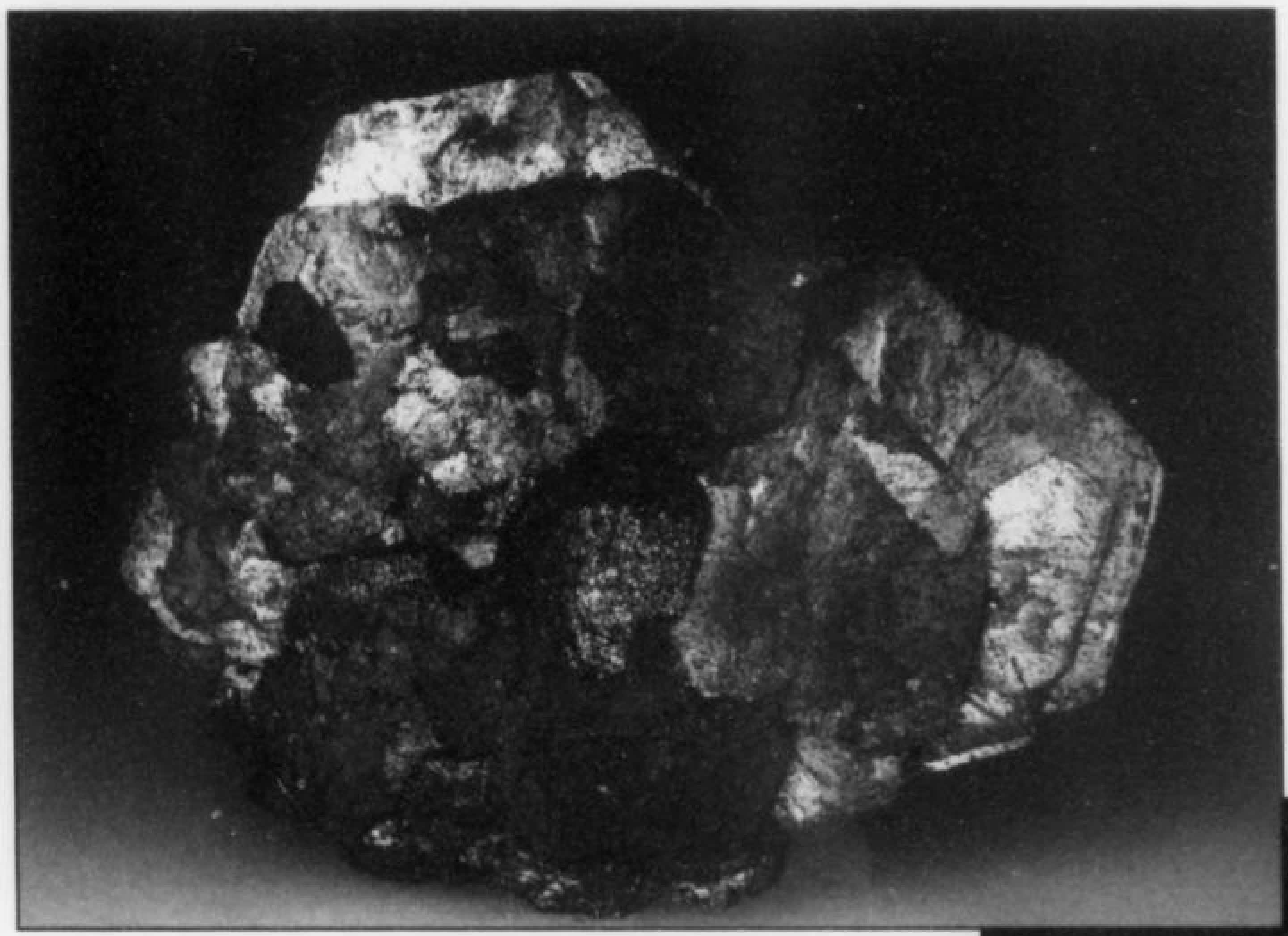
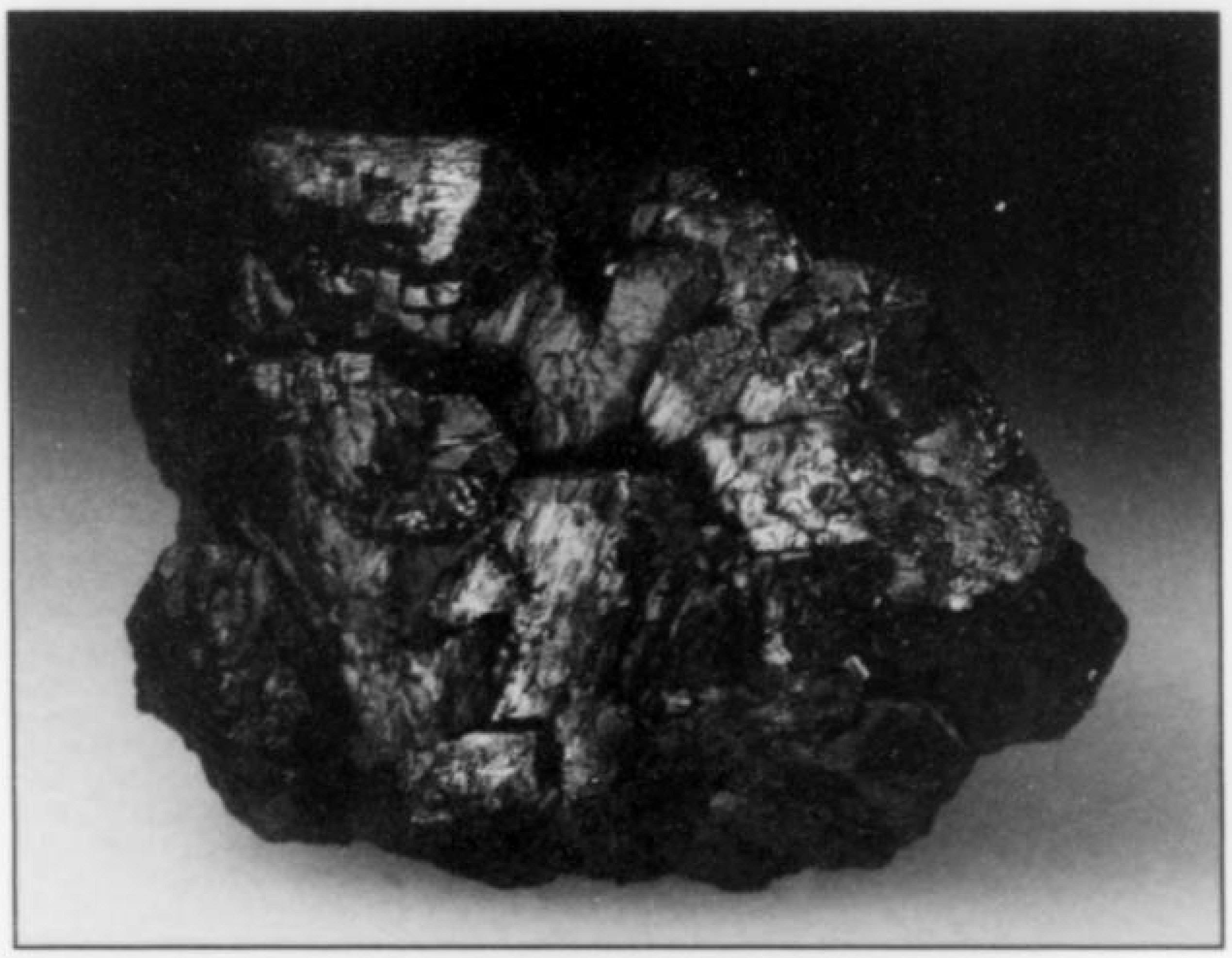


Figure 23. Chalcocite crystal, 5.5 cm, showing gold-colored patina with magenta-pink patina, from the Flambeau mine. Jane and Casey Jones collection; Wendell E. Wilson photo.

Figure 24. Chalcocite crystal group, 4.5 cm, showing purple and gold-colored patina, from the Flambeau mine. Jane and Casey Jones collection; Wendell E. Wilson photo.

Figure 25. Large chalcocite crystal group, 18 cm, showing purple patina, from the Flambeau mine. F. John Barlow collection; Munroe Studios photo.



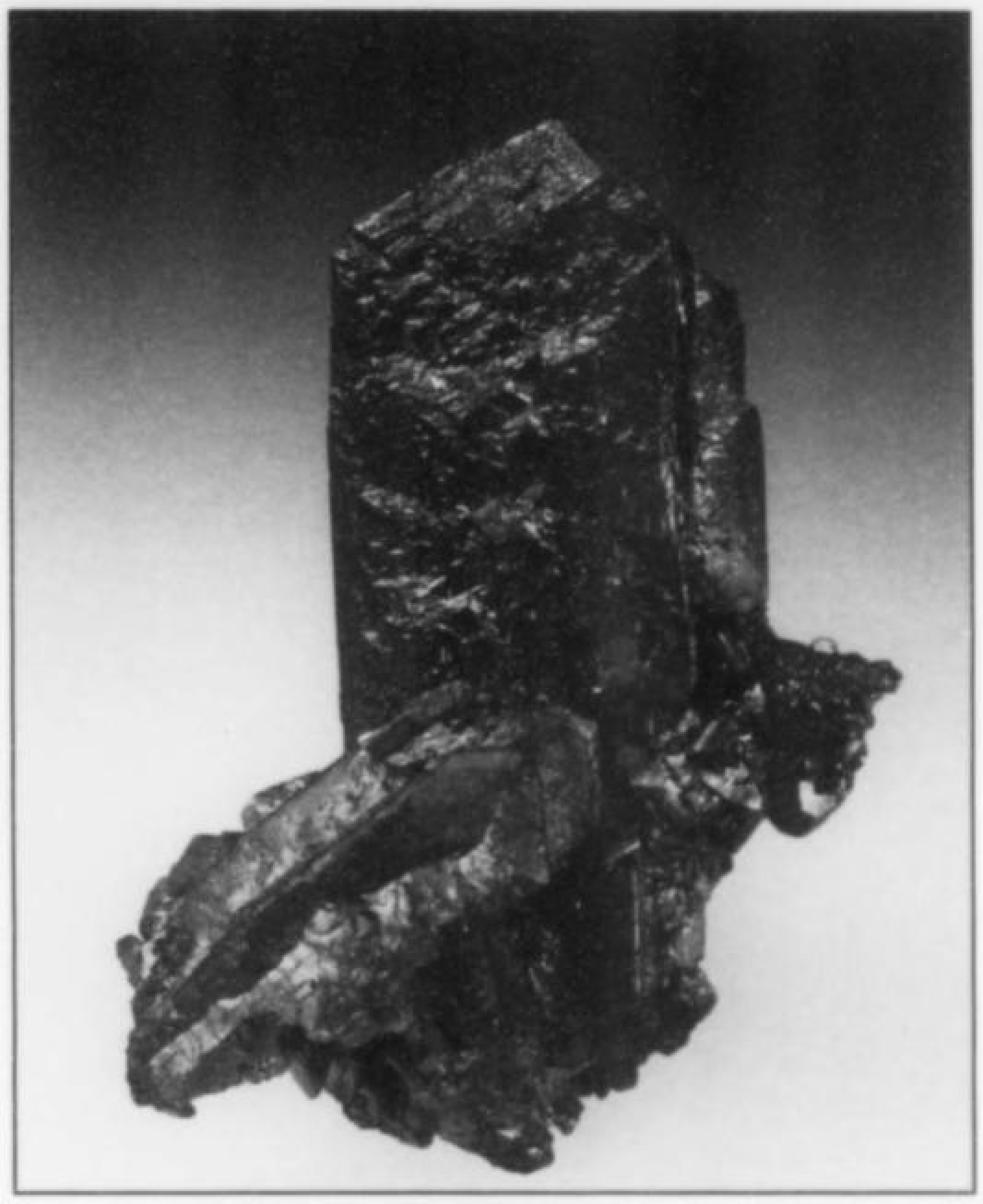


Figure 26. Chalcocite crystal group, 2.6 cm, showing purple and gold-colored patina, from the Flambeau mine (First Pocket). Jane and Casey Jones collection; Jeff Scovil photo.

Figure 27. (middle left) Chalcocite crystal cluster, 3.8 cm, showing purple and gold-colored patina, from the Flambeau mine. Jane and Casey Jones collection; Wendell E. Wilson photo.

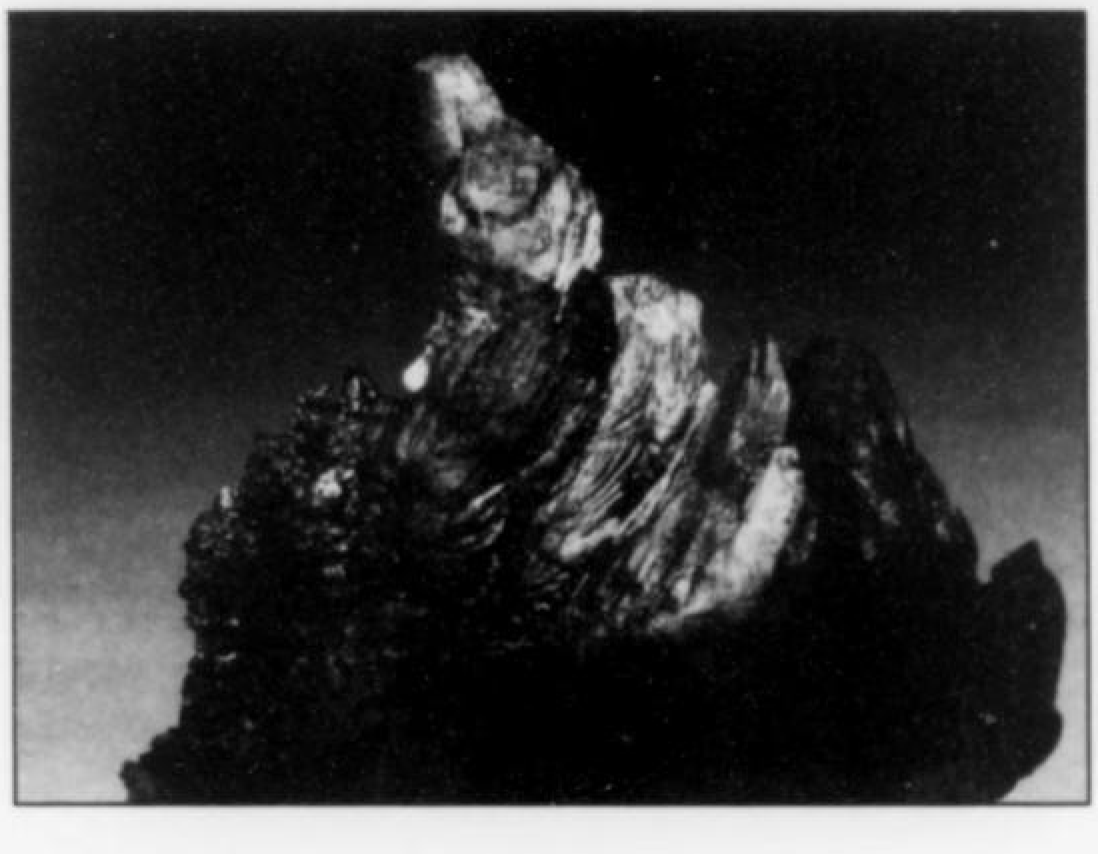


Figure 28. Chalcocite specimen, .5 cm, showing a peculiar flame-like habit, with purple and gold-colored patina, from the Flambeau mine. Gene LaBerge specimen and photo.

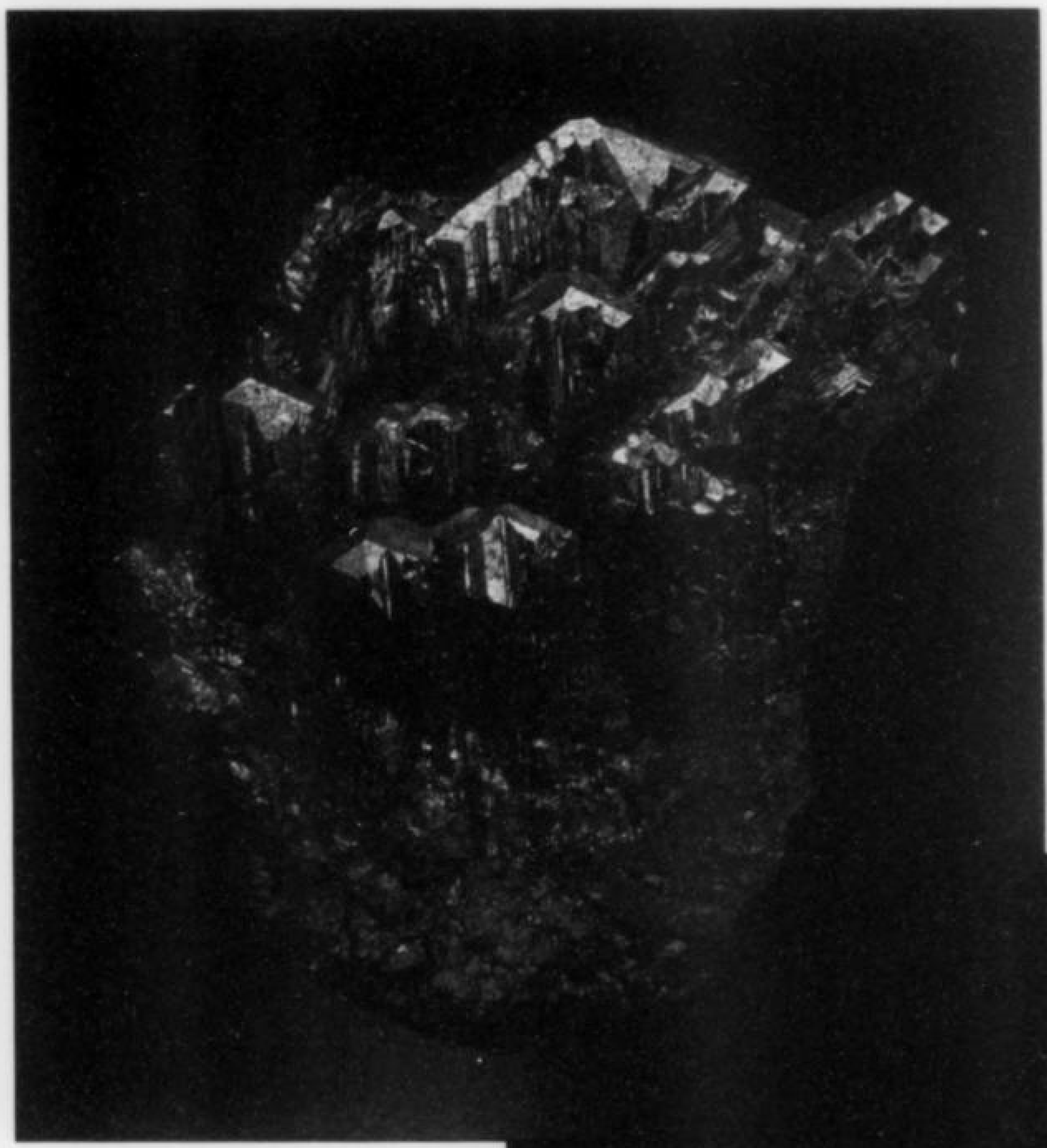


Figure 29. **Chalcocite in a parallel crystal cluster, 4.5 cm, showing blue and purple patina, from the Flambeau mine (Rocket Pocket). Gene LaBerge collection; Jeff Scovil photo.**

Figure 30. **Chalcocite crystal group, 6 cm, showing purple patina, from the Flambeau mine (1010 level). F. John Barlow collection; Munroe Studios photo.**

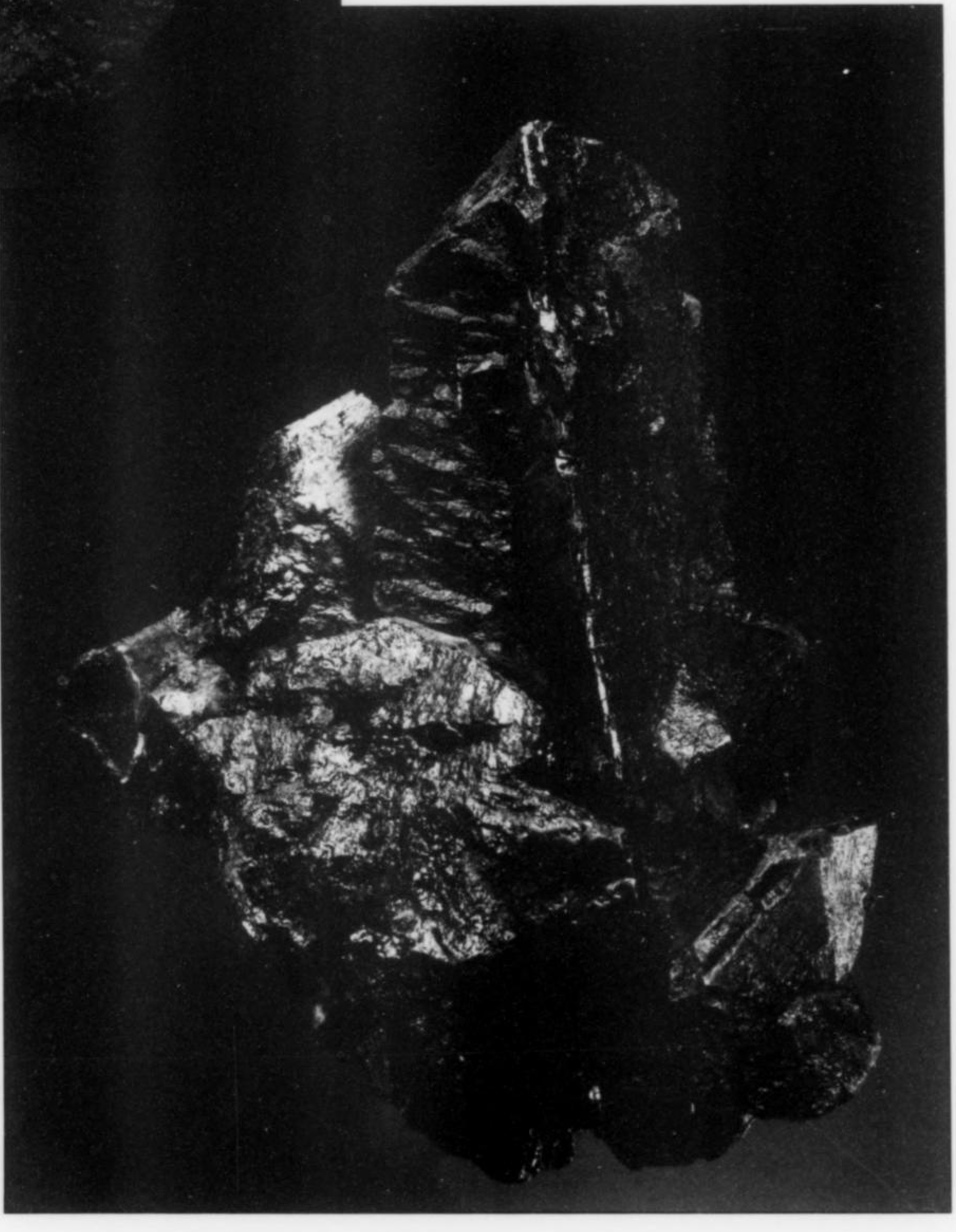


Figure 31. **Chalcocite crystals to 3.6 cm, showing a blue patina, from the Flambeau mine. Jane and Casey Jones collection; Wendell E. Wilson photo.**

Figure 32. **Chalcocite crystal group, 4.7 cm, showing blue patina, from the Flambeau mine. Jane and Casey Jones collection; Wendell E. Wilson photo.**

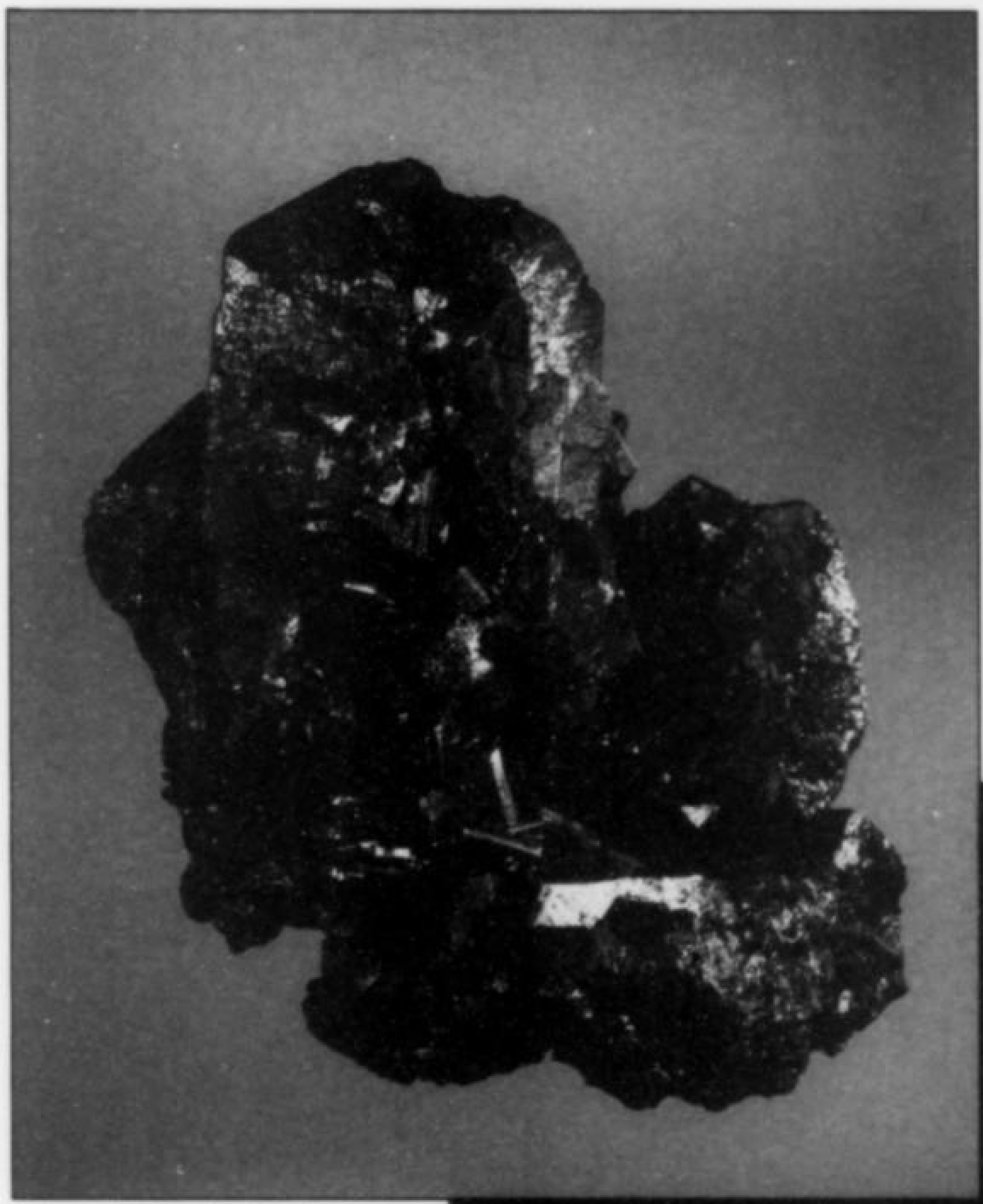


Figure 33. **Chalcocite crystal group, 6.5 cm, showing blue and purple patina, from the Flambeau mine (Drill Pocket). F. John Barlow collection; Munroe Studios photo.**

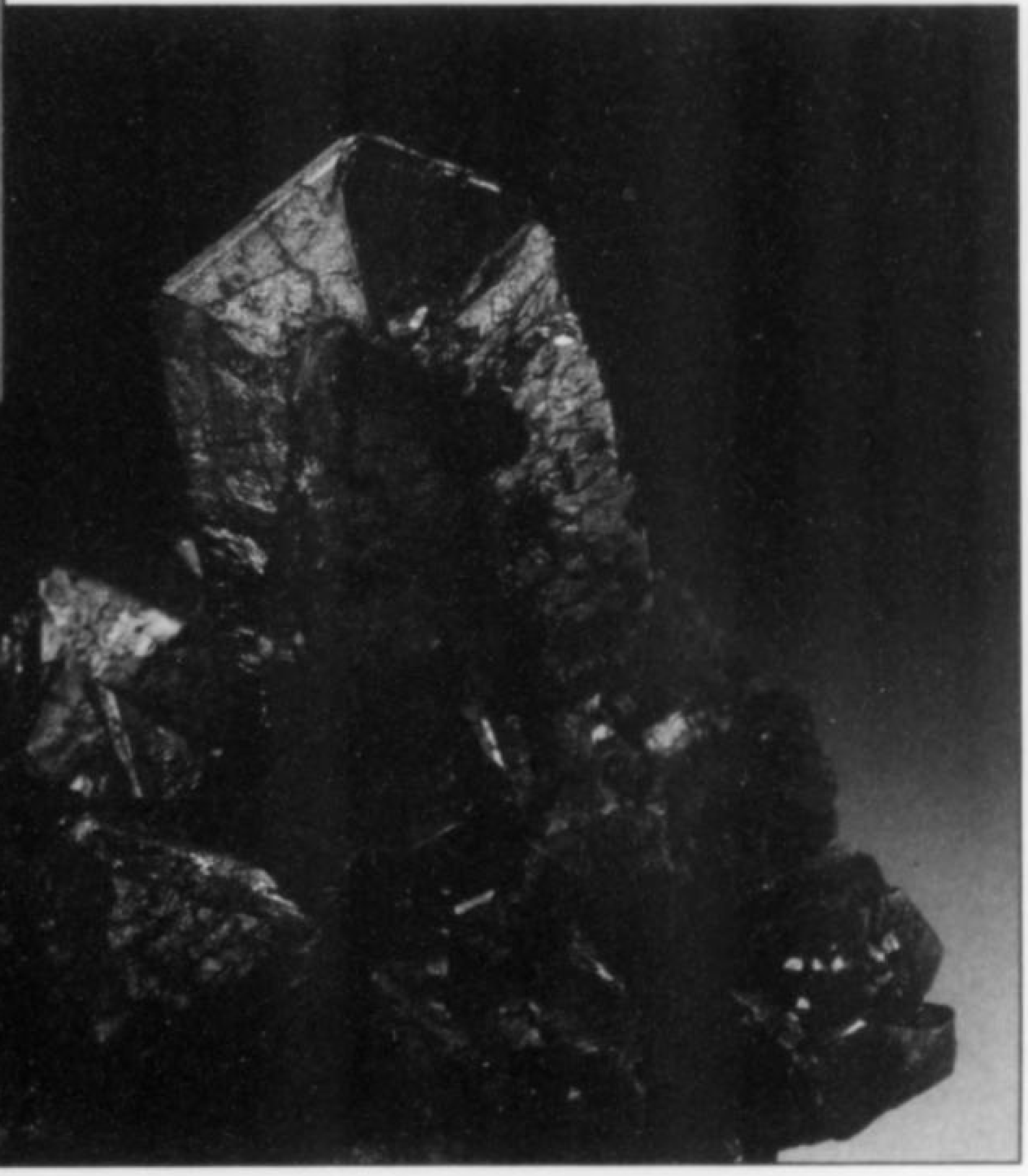


Figure 34. **Chalcocite crystal group, 5.7 cm, showing blue patina, from the Flambeau mine. William Larson collection; Wendell E. Wilson photo.**

species. The habits vary from poorly developed "ropy" reniform groupings to sharp cyclic and penetration-twin crystals. Classic pseudohexagonal twin crystals to over 5 cm have been found. One amazing penetration twin, an "X-twin" crystal, is just over 7 cm in size.

Botryoidal chalcocite is decidedly rare, occurring at only two locations in the orebody (at marker 423 and marker 408 at the footwall contact). About a dozen high-quality pieces were recovered. Some poorly crystallized specimens have a habit resembling ropy lava or *pahoehoe*, with well-developed crystals extruding out along the ridges of the "flow."

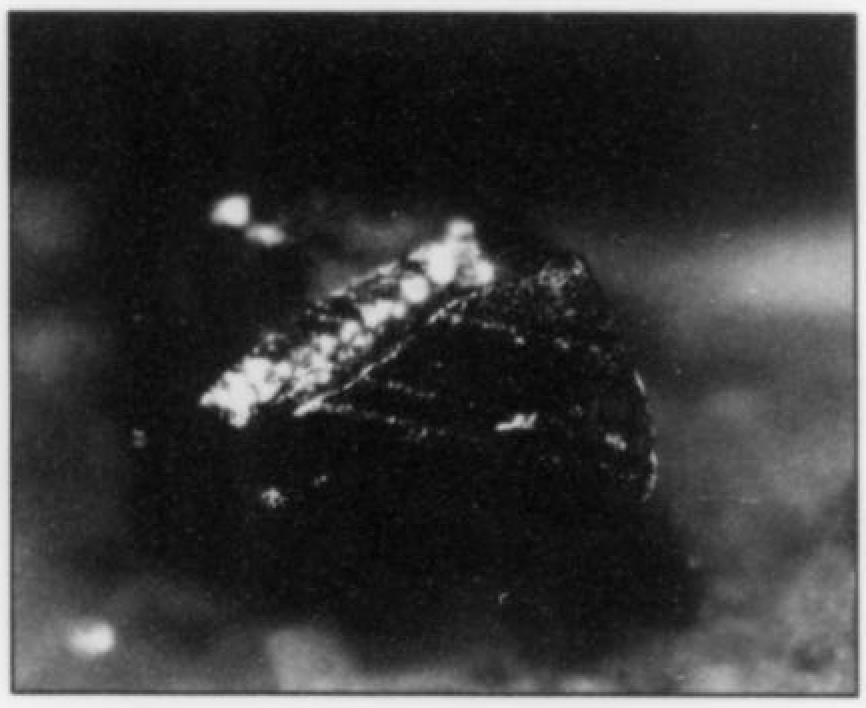


Figure 35. **Chalcopyrite microcrystals to 0.3 mm, from the Flambeau mine. Dan Behnke specimen and photo.**

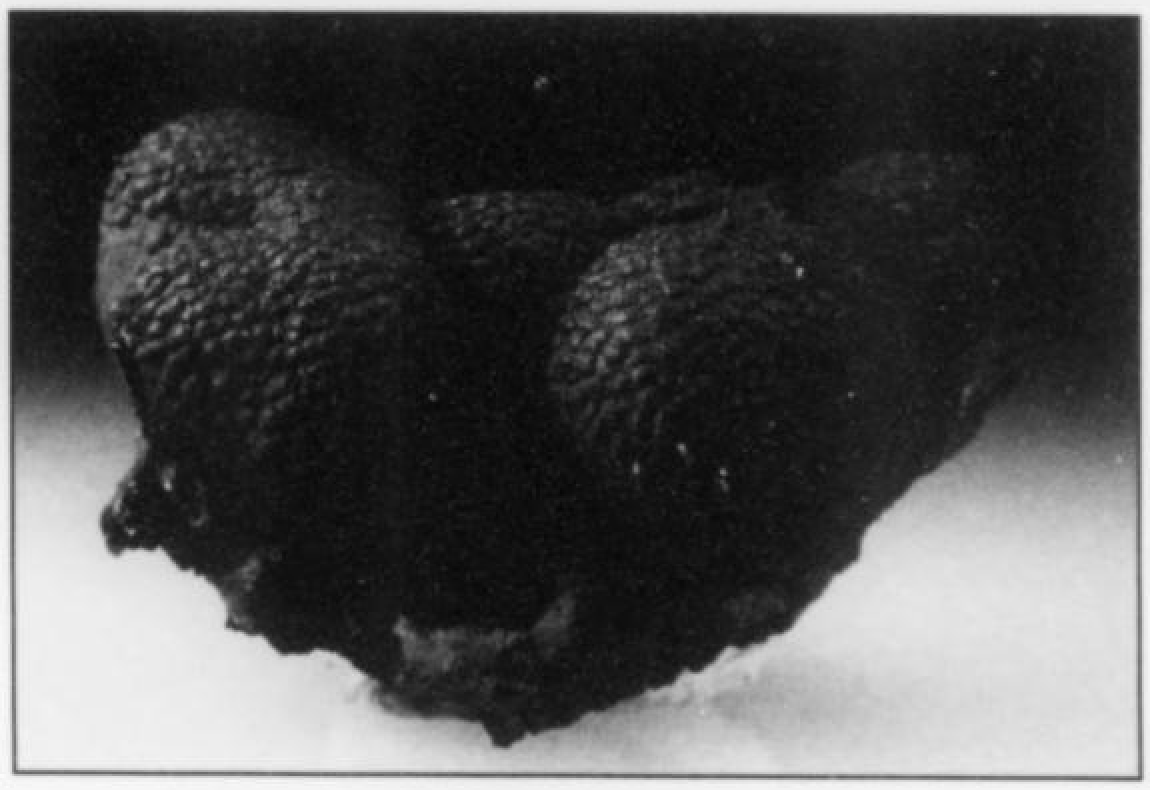


Figure 36. **Botryoidal chalcopyrite with multi-colored patina, 4 cm, from the Flambeau mine. Jane and Casey Jones collection; Wendell E. Wilson photo.**

Chalcopyrite CuFeS

Massive chalcopyrite was less common than either bornite or chalcocite at the Flambeau mine. Microcrystals up to 3 mm (even less common) were present throughout the deposit. A few very fine, iridescent, botryoidal specimens were collected at the footwall contact at marker 407.5.

Chrysocolla $(Cu^{2+},Al)_2H_2Si_2O_5(OH)_4\cdot nH_2O$

Chrysocolla was seen only rarely, as crusts and films coating rock. It is present in a range of colors, from pale to bright blue, green and brownish green, in intimate association with azurite in the gossan and the oxide zone.

Figure 37. **Copper microcrystals, 2.2 mm across, from the Flambeau mine. Dan Behnke specimen and photo.**

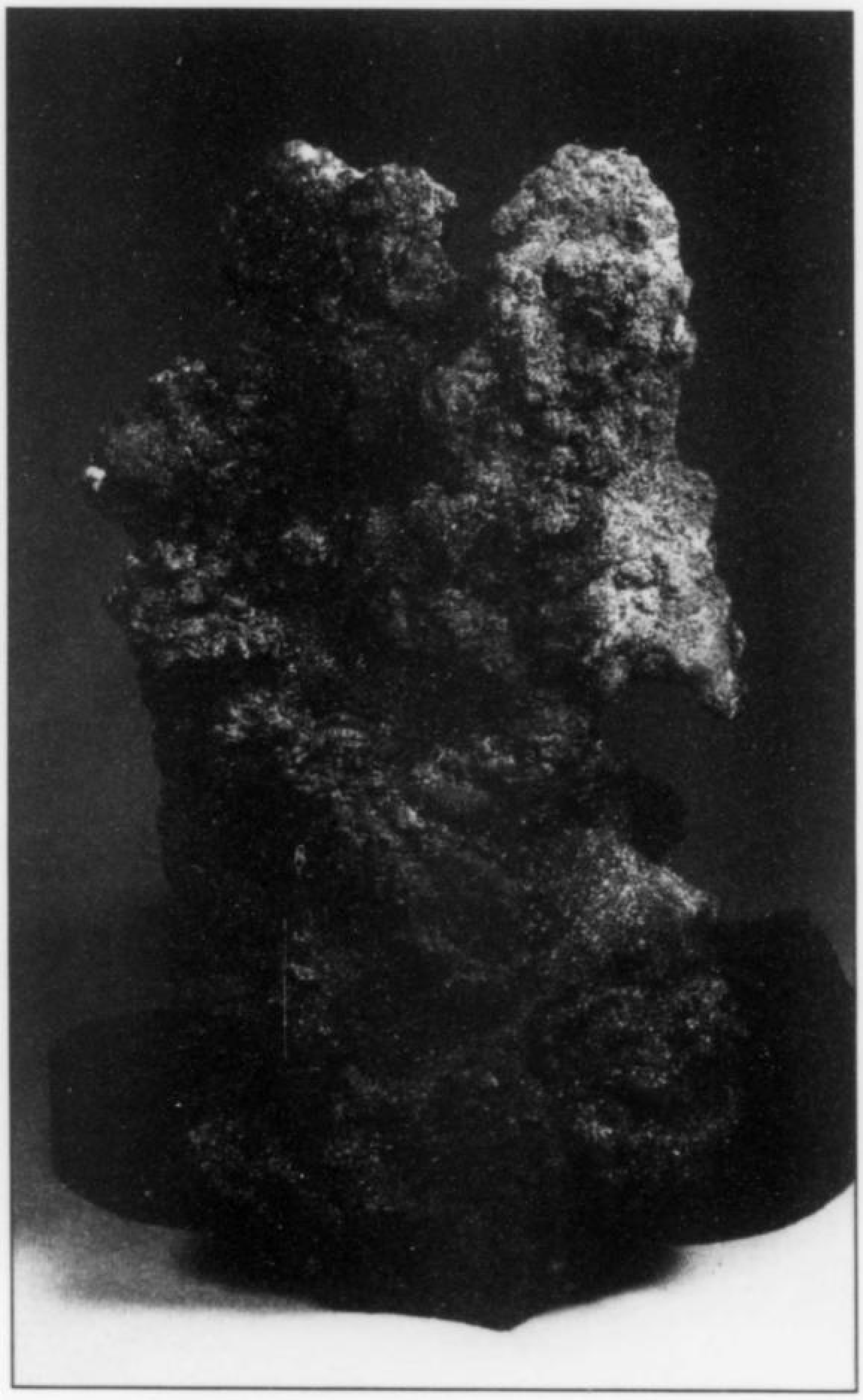
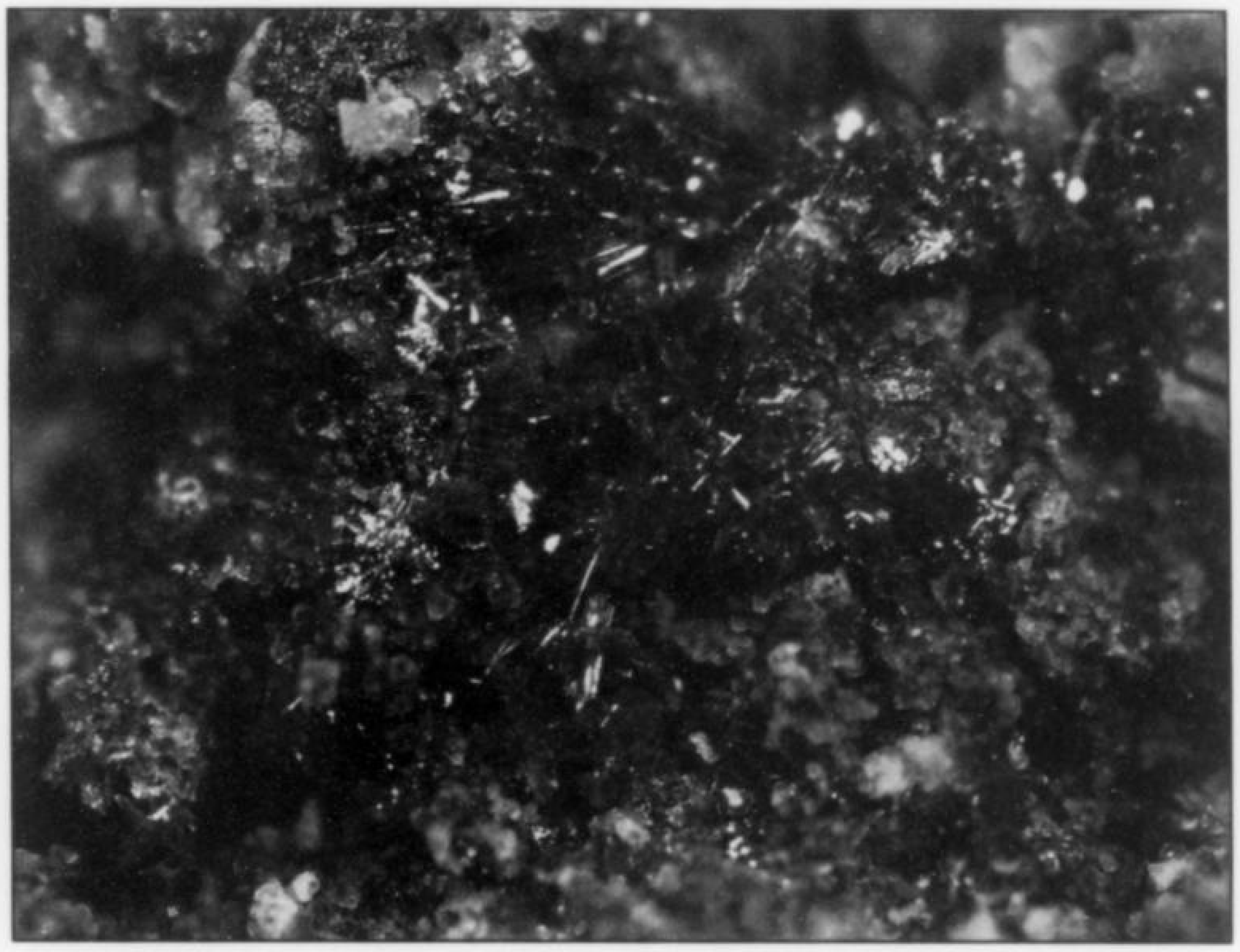


Figure 38. **Large native copper mass, 20 cm, from the Flambeau mine. Gene LaBerge collection and photo.**

Copper Cu

Native copper occurred primarily as fracture-filling sheets and foil. These occurrences were within the ore horizon, as far as 15 to 18 meters from the footwall. One notable location was in the maker 402.5 to 403.5 area on the hanging wall side. Another was at marker 418.0, 1010 level, on the footwall side of the deposit. One other location, marker 423.00, 1000 level, produced four specimens of crystallized native copper. Flambeau copper is chemically unusual in that it is high in mercury (0.11 weight %) and low in arsenic and selenium, unlike the Lake Superior copper deposits (Motti *et al.*, 1998).



Cuprite Cu$_2^{1+}$O

Microcrystals of cuprite were found with other copper minerals. Acicular cuprite occurred entirely as microcrystalline material with varying thickness and coverage, not exceeding 3 mm in thickness and 2 x 2 cm in area of coverage.

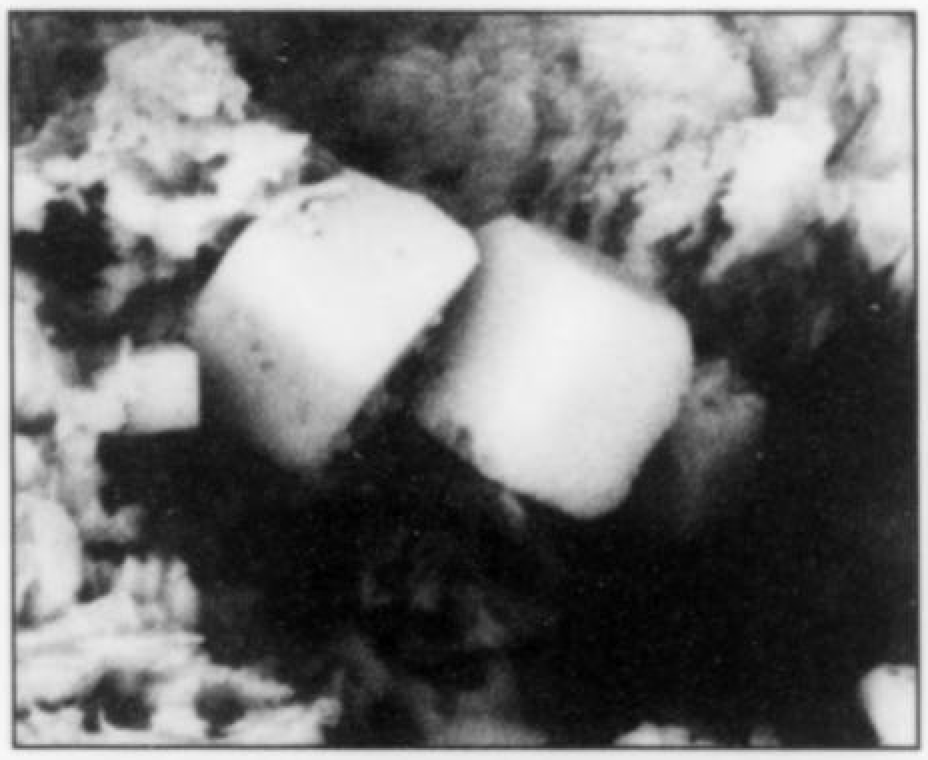


***Figure 41.* Dzhalindite crystals, 5 microns, from the Flambeau mine. Robert Housley collection and SEM photo.**

Dzhalindite In(OH)$_3$

Dzhalindite, a rare indium hydroxide, was found at the far northeastern end of the orebody, at marker 422.0, 1000 level. The Flambeau mine appears to be the fourth known world occurrence. It was discovered while identifying other material, (Robert M. Housley, pers. comm.). Originally described from the type locality as pale yellow and semi-transparent, the mineral at Flambeau is only visible at 500X, with an Autoscan scanning electron microscope; crystals are 400 micrometers is size. Associations include chalcocite, spheroidal siderite and hessite.

Gahnite ZnAl$_2$O$_4$

Subhedral green grains and blebs of gahnite in granular sulfides have been identified by EDS and optical analysis (George Robinson, pers. comm.).

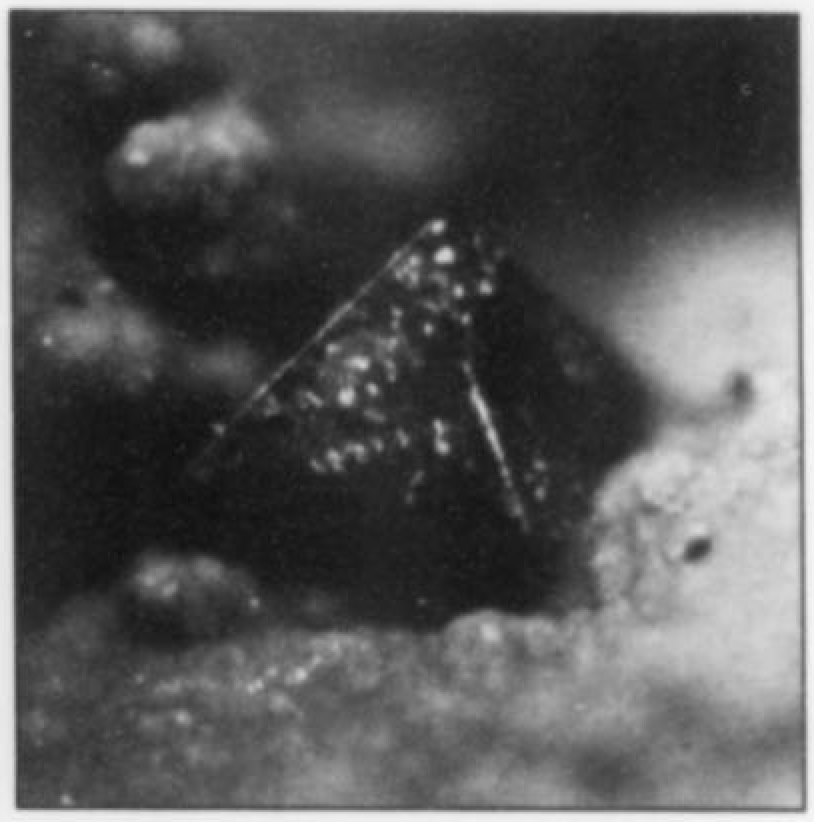


***Figure 39.* Octahedral cuprite crystal, .005 mm, from the Flambeau mine. Dan Behnke collection and photo.**

***Figure 40.* Cuprite microcrystals, view 3 mm across, from the Flambeau mine. Dan Behnke collection and photo.**

Galena PbS

Galena is very rare at the Flambeau mine; only four specimens have been collected, at marker 423.5, 980 level.

Glaucodot (Co,Fe)AsS

Glaucodot was identified by Excalibur Mineral Company (on behalf of Dan Behnke) during routine analytical work. It was collected from an undocumented location during the gathering of educational ore samples intended for distribution to schools.

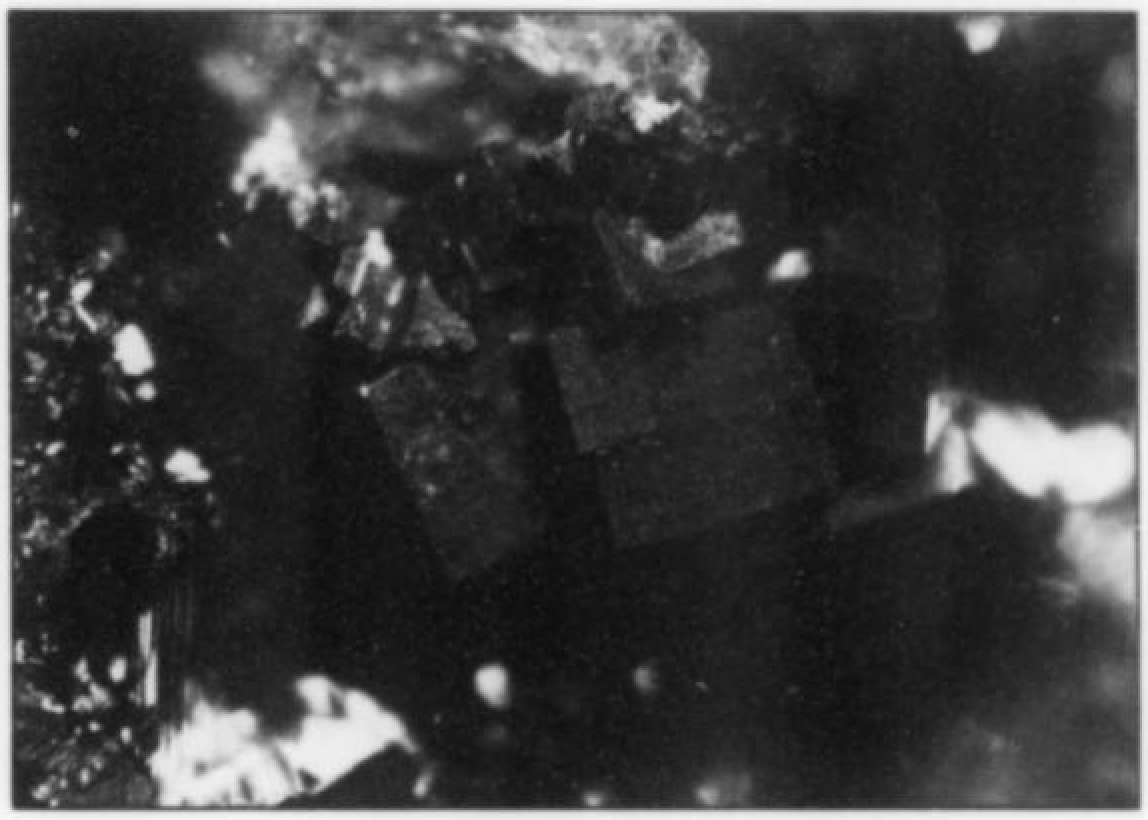


***Figure 42.* Glaucodot crystal group, 1.3 mm, from the Flambeau mine. Dan Behnke collection and photo.**

Gold Au

All native gold collected at the Flambeau mine came from one occurrence at marker 402.0, 1000 level, in vein quartz, shattered by blasting, between the orebody and the surrounding quartz-sericite

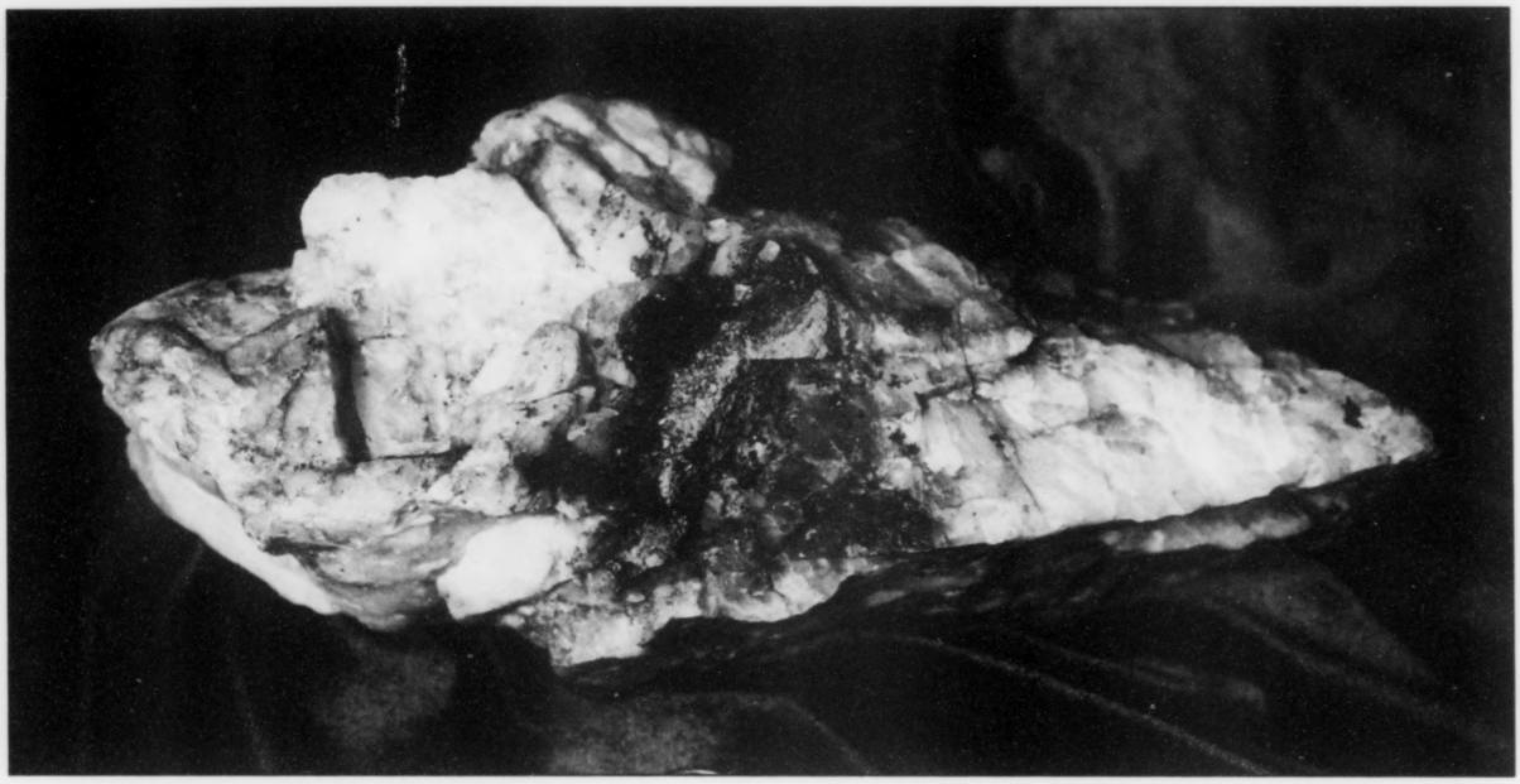


Figure 43. **Gold in quartz, 17 cm, from the Flambeau mine. Photo by Bruce Whitehead, courtesy of Kennecott Minerals.**

schist. The gold occurred as microcrystalline sponge-like masses and coatings, intimately associated with veinlets of bornite and chalcocite running through the shattered quartz. One specimen, in which the gold area measures about 1.2 x 7.6 cm on quartz, is probably the largest mass of gold ever found in Wisconsin; it is currently preserved in the Kennecott Minerals collection.

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

Goethite forms a significant proportion of the gossan at the Flambeau mine.

Gypsum $CaSO_4 \cdot 2H_2O$

Microcrystals of gypsum have been reported (Dan Behnke, pers. comm.). Some take on the shape of flames, especially those with the bright violet-red bornite patina. These occurred most notably in the Drill Pocket, the Rocket Pocket and the Lucky Friday Pocket.

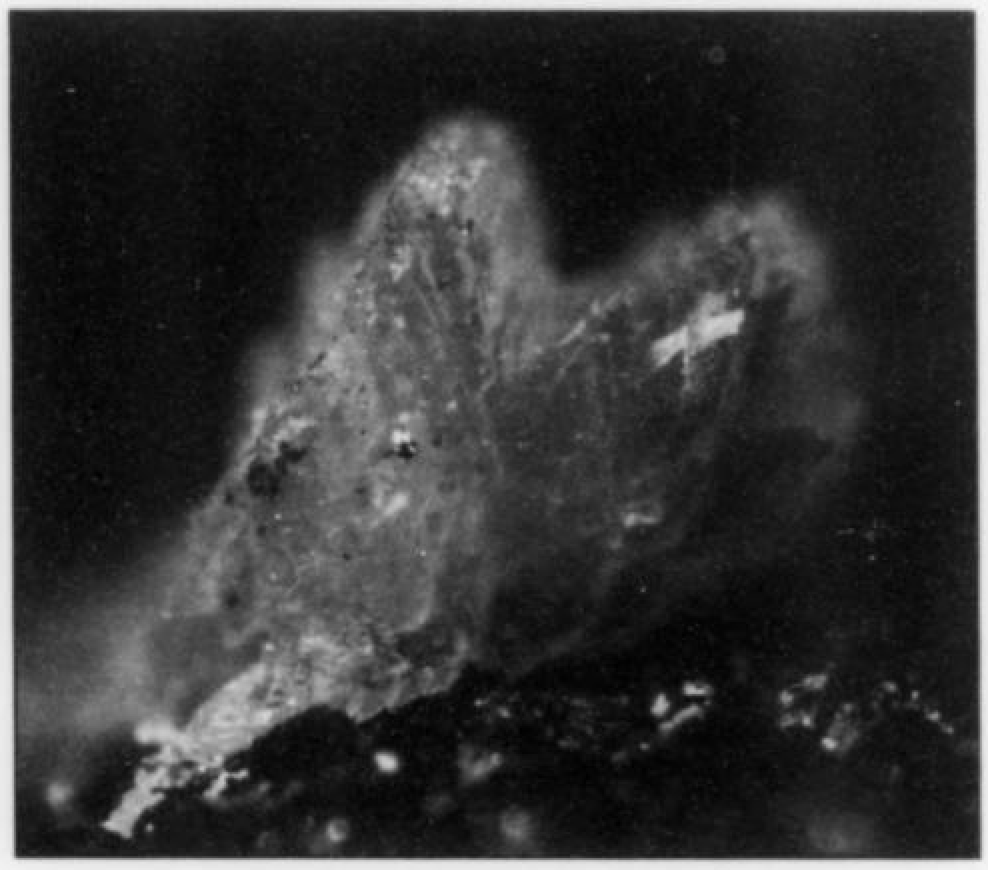


Figure 44. **Kolbeckite crystal cluster, 1.1 mm, from the Flambeau mine. Jane and Casey Jones collection; Dan Behnke photo.**

Kolbeckite $ScPO_4 \cdot 2H_2O$

Another rare mineral discovered quite by chance at the Flambeau mine is kolbeckite. Had it not been a sunny day, the reflection off the tiny crystal might have gone unnoticed. Only a dozen specimens have been recovered thus far. They were collected at the hanging-wall contact in the quartz-sericite schist near marker 412.0, 1010 level. The largest crystal, 1 mm in size and a vivid lemon-lime green, is associated with chalcopyrite. The identification was verified by Robert M. Housley (pers. comm.).

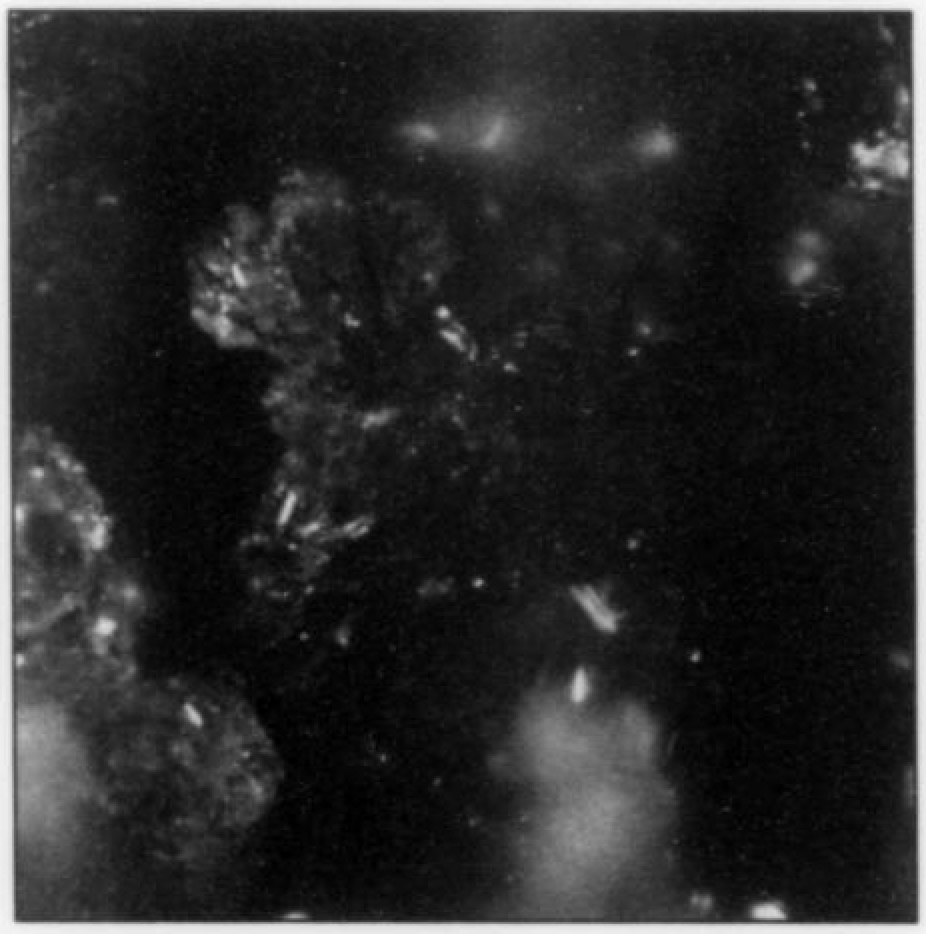


Figure 45. **Leucophosphite crystal cluster, 0.7 mm, from the Flambeau mine. Tom Buchholz collection; Dan Behnke photo.**

Leucophosphite $KFe_2^{3+}(PO_4)_2(OH) \cdot 2H_2O$

Leucophosphite has been identified from the Flambeau mine as minute clusters and bundles of glassy, transparent, pale brown crystals less than 1 mm in size (Dan Behnke and Tom Buchholz, pers. comm.).

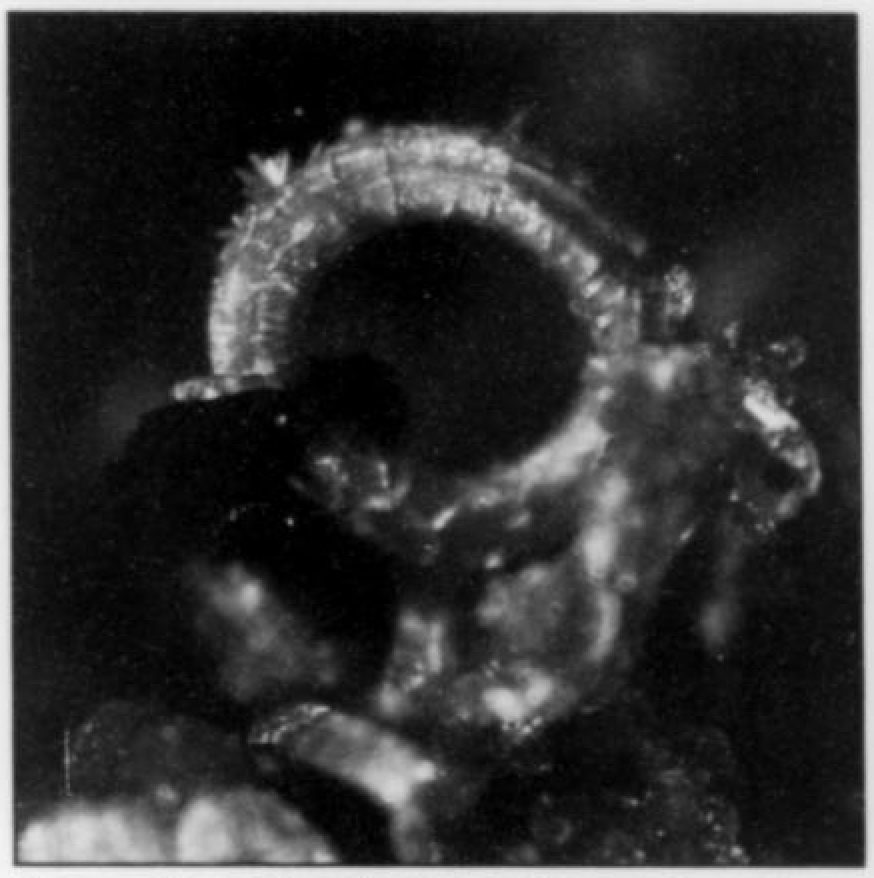


Figure 46. **Malachite ring with azurite microcrystal, 0.8 mm, from the Flambeau mine. Dan Behnke collection and photo.**

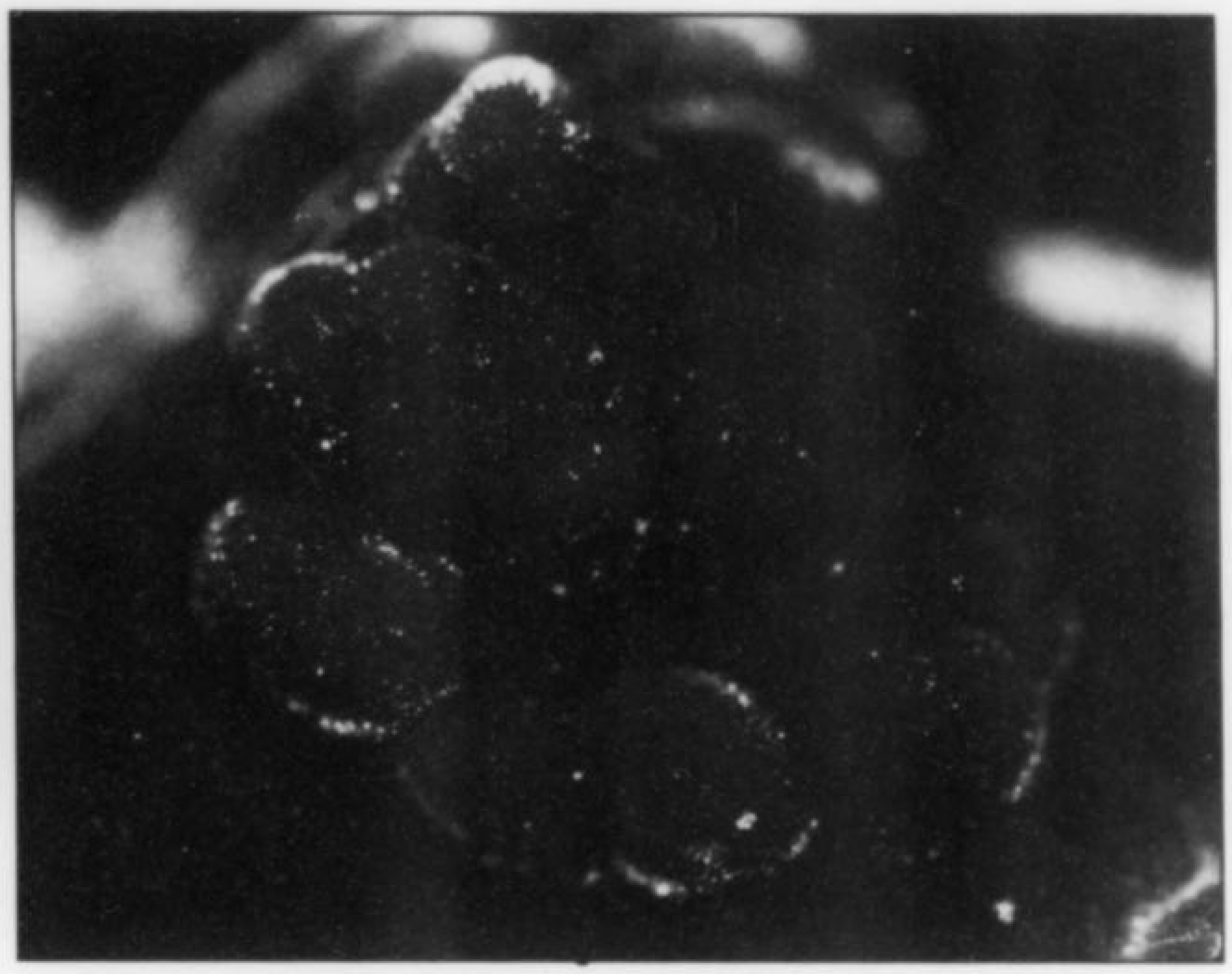


Figure 47. **Botryoidal malachite, 3.5 mm across, from the Flambeau mine. Dan Behnke specimen and photo.**

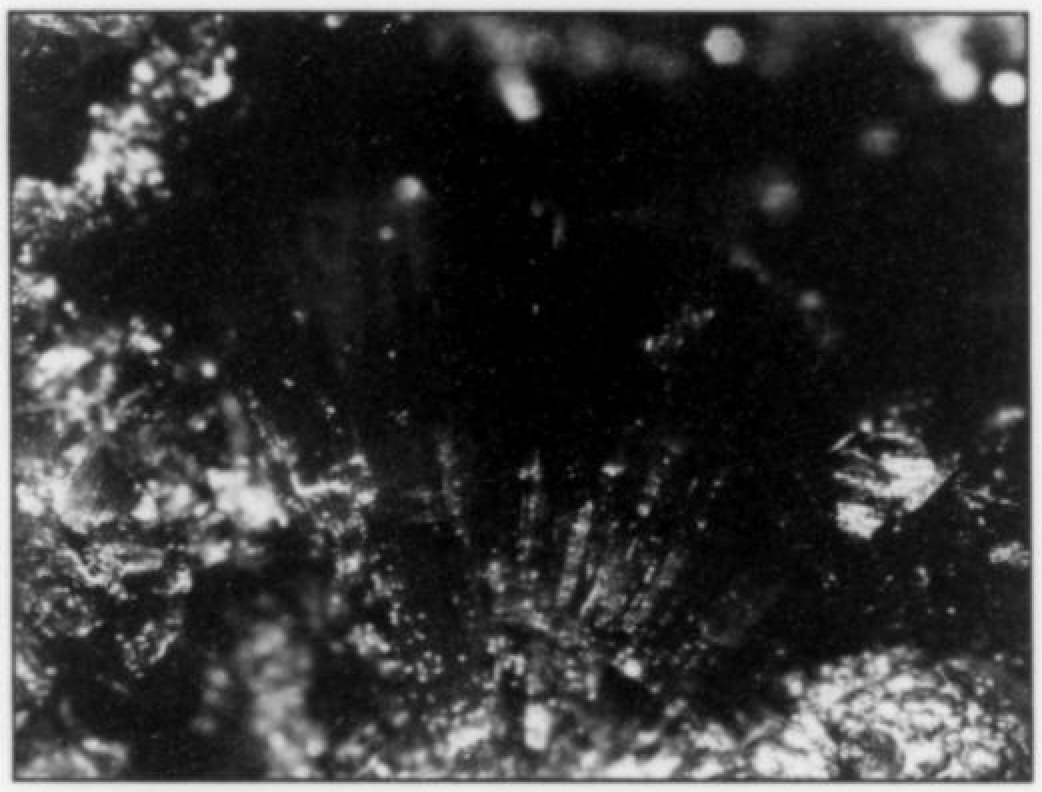


Figure 48. **Malachite crystal spray, 1.5 mm, from the Flambeau mine. Dan Behnke collection and photo.**

Figure 49. **Malachite spirals, 1.3 mm, from the Flambeau mine. Dan Behnke collection and photo.**

Malachite $Cu(CO_3)(OH)_2$

Interesting habits of malachite were found throughout the orebody in the upper levels, the 1080 level through the 1010 level, and particularly at markers 402.0, 406.0 and 413.0. One of the more unusual forms consist of filaments or hairs of malchite. Masses of these fine filaments were sometimes exposed when breaking open host rock known to contain malachite. Some of these filaments are associated with azurite microcrystals. Analyses by George Robinson (pers. comm.) have revealed many of these filaments to be poorly crystallized chrysocolla, perhaps altered from malachite.

Marcasite FeS_2

Marcasite microcrystals have been found rarely at the deposit.

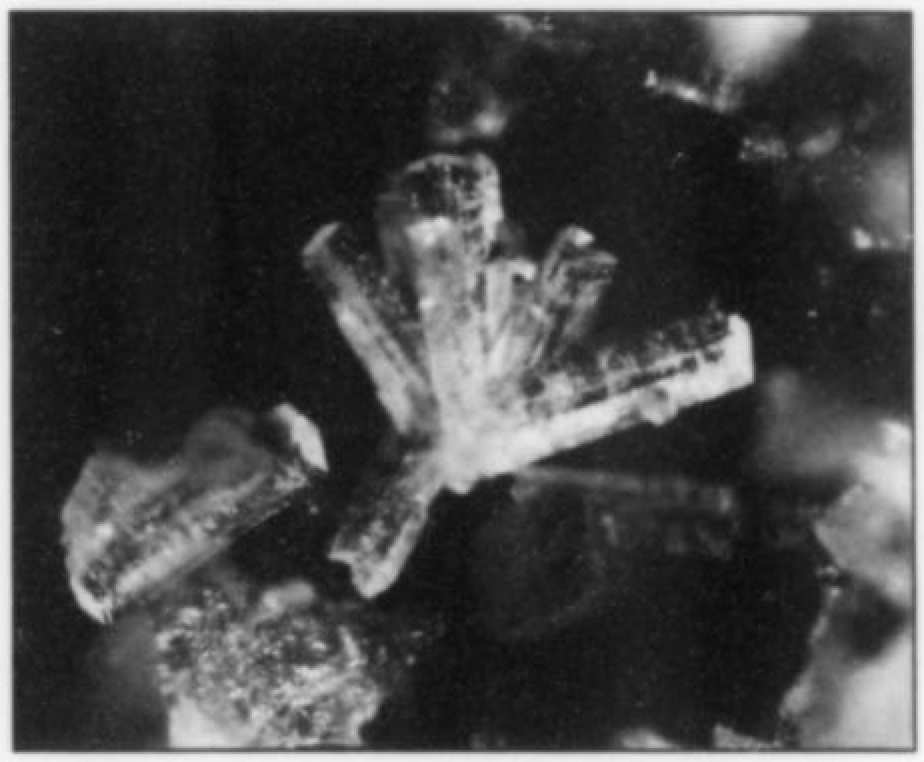


Figure 50. **Orthoclase crystal cluster, 0.5 mm, with siderite, from the Flambeau mine. Dan Behnke collection and photo.**

Orthoclase $KAlSi_3O_8$

Minute, gemmy, colorless prisms of orthoclase have been identified from the Flambeau mine, in association with rounded yellow crystals of siderite (Dan Behnke, pers. comm.).

Pyrite FeS_2

Pyrite is almost exclusively massive at the Flambeau mine. Only a few well-formed pyrite crystals are known, and most of those are microcrystals. Pyritohedral crystals from marker 422.5, 990 level, however, reach 1.5 cm; some are coated with sooty chalcocite.

Pyrrhotite $Fe_{1-x}S$

Motti *et al.* (1998) report pyrrhotite as an accessory mineral in the pyrite/chalcopyrite ore.

Rutile TiO_2

Dark red, prismatic microcrystals of rutile have been identified by EDS (George Robinson, pers. comm.).

Siderite $Fe^{2+}CO_3$

Microcrystals of siderite form coatings on ankerite and bornite from the marker 422.0 area, level 1010 to the 980 level.

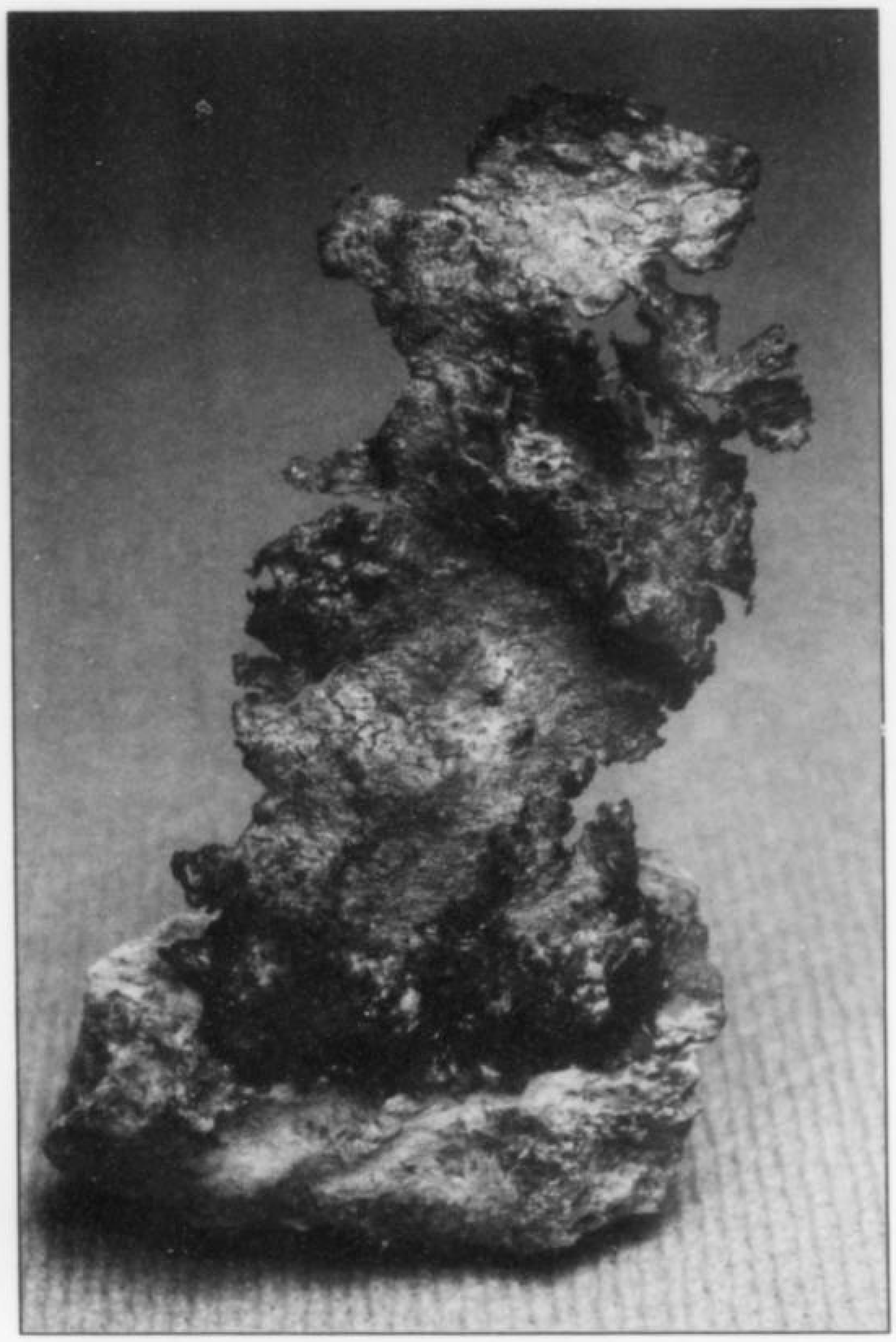


Figure 52. **Silver sheet, 5 cm, from the Flambeau mine. Gene LaBerge specimen and photo.**

Silver Ag

Silver has been found very rarely at the Flambeau mine as halfbreeds with native copper, occurring as fracture-filling sheets and foil with native copper, and as distorted crystals. Flambeau silver carries an unusually high mercury content of 1.13 weight % (Motti *et al.*, 1998).

Sphalerite ZnS

Sphalerite has been found as medium-grained massive ore restricted to a small zone at the far east end of the pit, at marker 424.5 on the 980 level. Microcrystals are also present sparingly throughout the orebody.

Tennantite $(Cu,Ag,Fe,Zn)_{12}AS_4S_{13}$

Steely black tetrahedral microcrystals of tennantite have been identified by EDS, some of which have a thin coating of chalcopyrite (George Robinson, pers. comm.).

Vivianite (or Metavivianite) $Fe_3^{2+}(PO_4)_2 \cdot 8H_2O$

Yellow-green, bladed microcrystals of vivianite or metavivianite have been identified by EDS (George Robinson, pers. comm.).

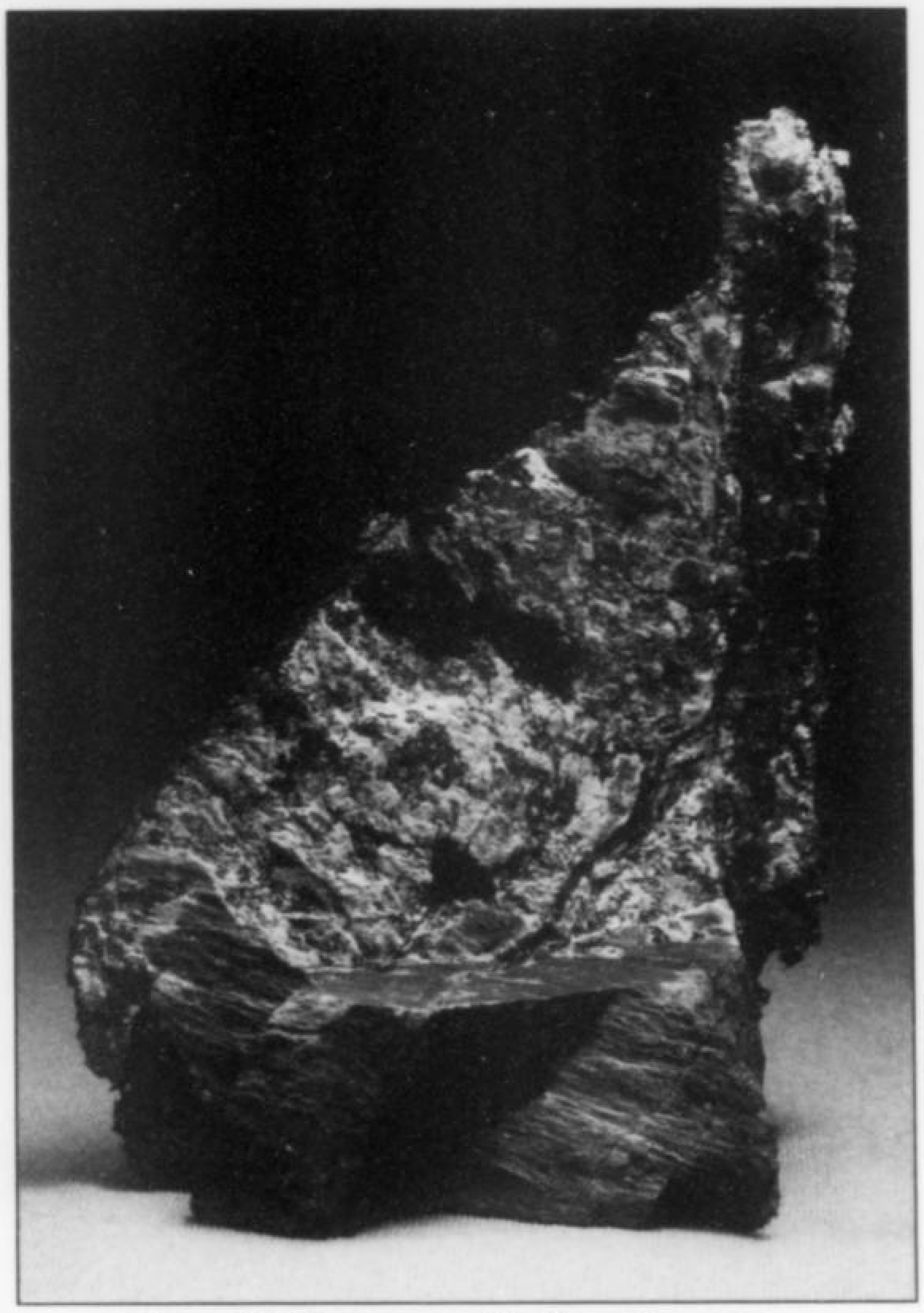


Figure 51. **Silver-copper "halfbreed" specimen, 16 cm, which has been named "the Sailboat"—the "mast" is silver and the "sail" is copper—from the Flambeau mine. Gene LaBerge specimen and photo.**

Figure 53. **Lustrous tennantite microcrystals to 0.5 mm, from the Flambeau mine. Dan Behnke specimen and photo.**

Figure 54. **Vivianite crystals, perhaps including metavivianite, to 1 mm, from the Flambeau mine. Tom Buchholz collection; Dan Behnke photo.**

***Figure 55.* The Sunrise Pocket, 1994. Casey Jones photo.**

COLLECTING HISTORY

As with so many operating mines in the past, collecting at the Flambeau mine began with geologists and miners on site picking up a pretty rock. The mine visitors' center needed specimens from the pit to put on display for the interested public, so mine geologists collected specimens of azurite, malachite, native copper and chalcocite. Seeing these specimens encouraged the authors (CJ and JKJ) to seek a specimen recovery contract with the Flambeau Mining Company in June of 1994. By that time most of the azurite-malachite-containing oxide zone had been mined out and shipped as ore. Evidently some fine specimens of azurite and malachite were found during the first year of mining, but only a few have been preserved, in administration offices and in the Visitors' Center.

Our first day of collecting at the Flambeau mine (in June 1994) was very much different from the underground environments we had been accustomed to. We went to work immediately in an area where the orebody contacted the siliceous chert, and were quickly rewarded with a few reniform to sub-euhedral crystallized chalcocite specimens. All of these first few pieces were of the typical black to steely-gray color so characteristic of chalcocite at other localities.

First Pocket and Watercourse Pocket

Two days of sporadic finds of poorly formed gray chalcocite only served to whet our appetite. The much better specimens we had seen at the visitors' center and administrative offices convinced us that the good ones were just inches away. On June 30, 1994, our intuition proved right. A small pocket located beneath a ledge had been opened when a large block of chalcocite ore was removed; it contained five chalcocite specimens that rivaled anything we could have realistically imagined. The excitement of the discovery of what are surely the finest chalcocites ever found in the Western Hemisphere encouraged us to continue working.

This led us to name this void the *First Pocket*, located at marker 401.2, 1030 level. Thankfully, this pocket led us later that day to the *Watercourse Pocket*, which was a few inches into the face of the work area where the First Pocket was located. The *Watercourse Pocket*, as the name implies, had water running through it. The chalcocite from this void all had a gold-colored patina when fresh; some remained gold-colored, whereas other specimens tarnished to a violet or purple color over time. The crystallization was not quite up to the quality of the crystals of the First Pocket, but this confirmation that good crystallization was present bolstered our confidence.

Sunrise Pocket

The next pocket was found on our return to Ladysmith in October of 1994; we named it the Sunrise Pocket. It had been a long interval between this discovery and the previous success earlier in July. This was due in part to heavy rains in September, which caused local flooding of such severity as to be expected only once every 500 years.

On October 10, Joe Celski, the excavator operator, cut into a pocket area. He was able to remove muck from our promising zone without impeding production elsewhere by taking a couple of cleanup swipes with his excavator shovel on his way to another mucking spot. Of course, starting time for collecting is as soon as there is just enough light to see. Joe expertly maneuvered the shovel of the excavator to get as much of the muck away from the corner that looked the most promising. Still, we had to hand-muck approximately three or four cubic yards of sulfide ore. Just as the sun was peeking over the rim of the pit, the outline of an *in situ* pocket was revealing itself in a corner formed by the 1010 level bench and the footwall rocks.

Slowly brushing away the loose, damp bornite sand revealed gleaming bright, metallic golden chalcocite crystals. They were tightly packed with just enough space between specimens to allow

Figure 56. **The Lucky Friday Pocket (triangular zone at center), 1995. Casey Jones photo.**

removal one by one. Laying on my stomach, I slowly worked the pieces out using the sand as a cushion for the crystal specimens when needed. Small broken shards of quartz-sericite schist and small chalcopyrite casts after calcite (looking like hundreds of tiny ice-cream cones) made up the pocket debris. The chalcocites that came from this pocket are unusual in that they are associated with pseudomorphs of bornite after chalcocite. These specimens are spectacular in size, generally from 1.2 to 3 cm. One crystal group, which we named the "Flambeau Chief," has a prominent crystal almost 4 cm across.

Drill Pocket

It was a long, cold winter between the Sunrise Pocket and the next significant pocket to be discovered. While we were attending the Tucson Show in February, 1995, the drill rig operator, Randy Ralston, broke into what could be considered a small chamber measuring approximately 2 meters long by 1 meter wide and extending to an unknown depth. The location was documented as marker 401.5, 1000 level, on the hanging-wall contact. We named it the *Drill Pocket*, because the drill rig had punched into the top of the void. The Drill Pocket contained what we still believe were the finest chalcocites in the world. Unfortunately, because we were not there to collect the specimens and mining needed to proceed, the area was blasted away and many of these specimens were either heavily damaged or lost forever. Fortunately, mine personnel were able to salvage and sack specimens while mucking proceeded. But we still dream of what this void could have yielded if we had been there to collect it properly.

Typically the Drill Pocket specimens have a deep blue patina which appears to be very stable. The choicest specimens are tabular, 6 to 10-cm crystals in distinctive X-shaped twins. These came only from the Drill Pocket. Clusters and matrix pieces were also recovered in some abundance. A number of plates of tabular, deep blue chalcocite crystals were presumably removed from the pocket wall. The Drill Pocket also yielded cyclic twins and untwinned chalcocite; some of the cyclic twins have a brilliant yellow patina which tends to turn purple or brown with time.

Fog Pocket

The next significant pocket was the *Fog Pocket*, at marker 409.6, 1000 level, found on March 30, 1995. This small pocket was encountered one cold morning while scouting the exposed 1000-level bench on the footwall contact. While probing for loose ground a small avalanche of rock and ore debris fell away at chest level. Quickly recovering my balance and homing in on the new muck pile at my feet, I (CJ) saw beautiful, delicate, small, perfectly shaped six-sided crystals of golden/violet chalcocite scattered atop the broken muck. The two dozen or so thumbnail-size specimens were quickly wrapped.

Tracing the route of the rock-fall upward revealed a small opening densely packed with crystallized chalcocite, trending up to the crest of the bench, just overhead. Due to the cold weather, recovery was particularly difficult, wearing fingerless gloves and using only small screwdrivers and bare fingers to extract the beauties. I was crouching as much for warmth as for access to the pocket opening, and my breathing was creating a transient but none-the-less annoying fog bank, thus the *Fog Pocket*. This pocket produced a dozen outstanding specimens. The sharp edges and delicate habit of these crystals surpassed those of any other pocket.

Lucky Friday Pocket

Next came the *Lucky Friday Pocket*, found on Friday, October

13, 1995. This pocket was also a bitter-sweet experience. By this time we were living full time in Ladysmith and were on site every day watching every load of ore and waste rock lifted out of the broken and shattered blast pile. We were also checking almost all of the drill holes that were being drilled by Randy Ralston and crew. On this day there was guarded optimism.

The day before, while drilling the blast pattern for this shot, one hole penetrated a good size void at 7.5 feet. This hole was left unloaded with explosives, and we stuffed as many burlap bags as we could down the drill hole for cushioning. Credit must be given here to the blasting crew for their expertise, and in particular to Ames Construction project manager, Bob Donaldson, for the creative blasting techniques used to help minimize destruction of specimens while still "pulling the round." Late that day (the 12th), scouting this blasted zone, we found broken loose crystals. We had Joe Celski position the excavator so he could direct the trucks in such a way as to be able to dig perpendicular to the strike of the ore-body, taking small slices from the area where we expected to find the burlap bags. With heavy clouds threatening snow, the bucket swept past where the hanging-wall contact was exposed, and big crystals started sliding out and down the soft pocket muck. The feeling was one of elation yet concern that nothing would survive. No burlap was yet visible. There were 3 meters of heavy broken ore on top of this exposure. Joe expertly worked the cap off the area and the burlap bags became visible. With just an hour of light left, expedient removal of the best specimens was of the utmost concern. Incredibly many specimens survived the harsh treatment of blasting, mucking and rushed recovery.

Once again the nature of these chalcocites is completely different from any we had previously seen. The crystals range from thick, disc-like, subparallel stacks to rarer heavy, thick, penetration X-twins and the classic, perfect, sixling twins. The predominant color was golden, darkening to iridescent brass, violet, purple, blue and gray, depending on the angle of light and viewing. There are a very few specimens that have a non-iridescent druse of matte-blue bornite coating the chalcocite.

The Lucky Friday pocket produced many excellent crystal specimens ranging from thumbnail to large cabinet size. Some are sharp bronze-colored singles and groups; others are matrix pieces with thick discoidal crystals to 4 cm perched on massive chalcocite. The largest specimens are spectacular, three-dimensional clusters 17 to 20 cm in diameter and up to 15 cm tall, with numerous thick discoidal, bronze-colored, pseudohexagonal, 1 to 3-cm crystals radiating from a central core. These appear to be "floaters," having no obvious points of attachment, which grew in black granular chalcocite.

Quick Pocket

The Quick Pocket needs to be mentioned because of its unusual location. It was found on the hanging-wall contact but far from the more productive west end. This pocket was encountered on May 20, 1996. Digging while drilling was taking place just above the pocket area necessitated especially vigilant monitoring of loose ground. The drilled pattern was to be shot regardless of mineral specimen concerns, because the main ramp into the pit was at stake. Therefore, quick recovery methods had to be used (thus, the name "Quick Pocket"). The chalcocite from here is generally less well developed and tends to be more or less replaced by bornite. However, a few specimens of chalcocite with well-developed crystals were recovered; many have a violet to reddish plum-colored patina. Crystals range up to 6 cm.

Rocket Pocket

The Rocket Pocket was found at marker 402.3, 970 level, in August of 1996. This was to be the last significant pocket encountered. It did not come quickly, but rather was drawn out over almost a week. The process began with the drilling of the pre-split holes on the 970 level at marker 402.3, on the far west end of the pit. These holes were drilled for the 6-foot step outs which were planned for every 30 feet (or three levels). Consequently these holes were drilled to a depth of 30 feet, versus the normal blast hole of 10 feet. Starting on Friday, August 9, drilling progressed smoothly beginning on the far south footwall side of the pit. But trouble began when the first drill hole closest to the hanging-wall contact zone collapsed, and the drill steel became hopelessly stuck. A new hole was begun near this bad hole, and at a depth of about 2 feet the drill steel dropped through 4 feet of void before biting into hard ground again. Whenever drill-steel dropped, our hopes soared!

The decision was made to pull out of this hole before the steel became stuck, because the condition of this hole was rapidly deteriorating. After pulling the steel from this hole it was evident that it could not be used to set explosives. A 3-foot section of 2-inch PVC pipe was pounded as far as possible into the broken and collapsing hole. The next hole to the north was barely competent enough to load. The rest of the holes to the north held up well and were not a problem. This drilling had taken Friday, Monday and Tuesday. That was one long weekend. The regular blast pattern was drilled out and loaded with explosives along with the pre-split holes on Wednesday. Just as the words "fire in the hole" finished leaving Bob's mouth, the ground erupted in the familiar staccato of timed charges going off. The PVC pipe had become airborne, shooting almost straight up and trailing smoke and dust like a rocket. There was an easy name for a pocket. We were on site and ready to go at first light, tools at hand; this had to be a good one. A void was there, it was up against hard face, and we were *due*. Again, Joe set up to mine away the hanging-wall contact area in the most productive and merciful (to the specimens) way.

At about 10:00 am the outline of a large cavity was exposed at the hard face of the far west end of the pit, right below where the pipe had taken flight. Recovery began as soon as the excavator's bucket was out of reach of possible contact with body parts. The pocket was full of blasted ore so crystals could not easily be seen. Careful probing and removal of this waste material began to show more and more specimens. The crystals once again were completely different in habit from any of the other chalcocites we had found. We believe that as much as 20% of this pocket was completely destroyed by the blast. Among what remained were the largest specimens recovered, four weighing over 20 pounds, with up to 90% crystal coverage. Habits include sharp single crystals, single sixling twins, stacked sixling twins and unusual feather-like or flame-like crystals. All the specimens have a distinctive multi-colored iridescent sheen. It took a total of 16 hours to remove all of the specimen material from this pocket. The void was big enough to sit in with room to spare, approximately 3 feet wide by 4 feet high by 3.5 feet deep. Although we continued to monitor mining during the days that followed, the Rocket Pocket was to be the last crystal pocket encountered at the Flambeau mine.

CONCLUSION

The beautiful, uniquely colored chalcocite specimens will remain as a tangible reminder of this small, short-lived mine which now qualifies as a new "classic" locality for the species. But the discovery of the Flambeau orebody has yielded other benefits as well. Geological study helped to define distinctions and anomalies within the Canadian Shield which may lead to the discovery of new orebodies in the area. As a case study of industry and community relationships, the Flambeau operation set benchmarks for mineral

Table 1. **Minerals identified from the Flambeau mine.**

Elements	
Copper	Cu
Gold	Au
Silver	Ag
Sulfides, Sulfosalts	
Arsenopyrite	$FeAsS$
Bornite	Cu_5FeS_4
Chalcocite	Cu_2S
Chalcopyrite	$CuFeS_2$
Galena	PbS
Glaucodot	$(Co,Fe)AsS$
Hessite	Ag_2Te
Marcasite	FeS_2
Petzite	Ag_3AuTe
Pyrite	FeS_2
Pyrrhotite	$Fe_{1-x}S$
Tennantite	$(Cu,Ag,Fe,Zn)_{12}As_4S_{13}$
Oxides, Hydroxides	
Cuprite	Cu_2O
Dzhalindite	$In(OH)_3$
Ghanite	$ZnAl_2O_4$
Goethite	$Fe^{3+}O(OH)$
Rutile	TiO_2
Carbonates	
Ankerite	$Ca(Fe,Mg)(Co_3)_2$
Azurite	$Cu_3(CU_3)_2(OH)_2$
Calcite	$CaCO_3$
Malachite	$Cu_2(CO_3)(OH)_2$
Siderite	$FeCO_3$
Silicates	
Chrysocolla	$(Cu^{2+},Al)_2H_2Si_2O_5(OH)_4\cdot nH2O$
Quartz	SiO_2
Orthoclase	$KAlSi_3O_8$
Phosphates	
Kolbeckite	$ScPO_4\cdot 2H_2O$
Leucophosphite	$Kfe^{3+}{}_2(PO_4)_2(OH)\cdot 2H_2O$
Sulfates	
Beaverite	$Pb(Cu^{2+},Fe^{3+},Al)_6(SO_4)_4(OH)_{12}$
Chalcanthite	$Cu^{2+}SO_4\cdot 5H_2O$
Crandallite	$CaAl_3(PO_4)_2(OH)_5\cdot H_2O$
Gypsum	$CaSO_4\cdot 2H_2O$
Hidalgoite	$PbAl_3(AsO_4)(SO_4)(OH)_6$
Kemmlitzite	$(Sr,Ce)Al_3(AsO_4)(SO_4)(OH)_6$
Osarizawaite	$Pb_2Cu_2Al_4(SO_4)_4(OH)_{32}$
Plumbogummite	$PbAl_3(PO_4)_2(OH)_5\cdot H_2O$

and resource partnerships built on mutual respect, unlike the often paternalistic mining company relationships of the past. The Flambeau Mining Company, Kennecott, and Kennecott's parent company, Rio Tinto, believed that as many parts of the community should be involved as possible, including local businesses, educators, museums and mineral collectors. As a business venture, the small size and high grade of the ore allowed extraction of a substantial amount of copper in a short period of time, benefiting company, community and consumer. From an ecological and community standpoint, Flambeau exemplified the goals and standards of organizations such as the United Nations World Commission on Environment and Development, which revolve around a long-term view of sustainable development. How we manage and acquire resources today affects future generations in the long term, and community relations in the short term. Mine management was willing to accept the idea that the collectible specimens had more social and scientific value as specimens than as ore, an enlightened viewpoint for which we can all be grateful.

ACKNOWLEDGMENTS

We would like to express our appreciation to the following people who helped this project succeed. Special thanks to Greg Fauquier, who believes that the mineral industry has nothing to fear from challenge, new ideas, and even criticism, and much to gain from new opportunity; to Edward and Maryann May whose support and commitment to this project went far beyond geology; to John Barlow for his ear, his advice and support, and his intense love of minerals which probably willed there to be world-class specimens in Wisconsin; and to George Burnham, for his inspiration as an explorer and recoverer of new mineral localities. There are many more whose help on the project and this article we deeply appreciate: Tom Baker, John Barnes, Dan Behnke, Tom Bucholz, Laura Childs, Jack Christman, David Cline, Bill Cordua, Stephen Dinkowitz, Stanley Dyl, Jeff Earnshaw, Bob Housley, Jane Huckstorff, Anthony R. Kampf, Sally LaBerge, Mark and Lynn Langenfeld, Jana Murphy, Tom Myatt, Neil Prenn, George Robinson, Tom Rosemyer, Karl Smith, Holly Wiesman, Wendell Wilson, Ron Vick, and Marty Zinn. The mineral collectors from the Rusk County area and elsewhere around Wisconsin were generous with their help and information. We wish to thank especially Russ Babcock and David Litvin of Kennecott Minerals, who provided insightful comments and corrections to the manuscript. We hope that all of the personnel of Kennecott Minerals, the Flambeau Mining Company and the Ames Construction Company know the gratitude we feel toward them for each and every individual act beyond their job requirements, which helped these beautiful specimens survive.

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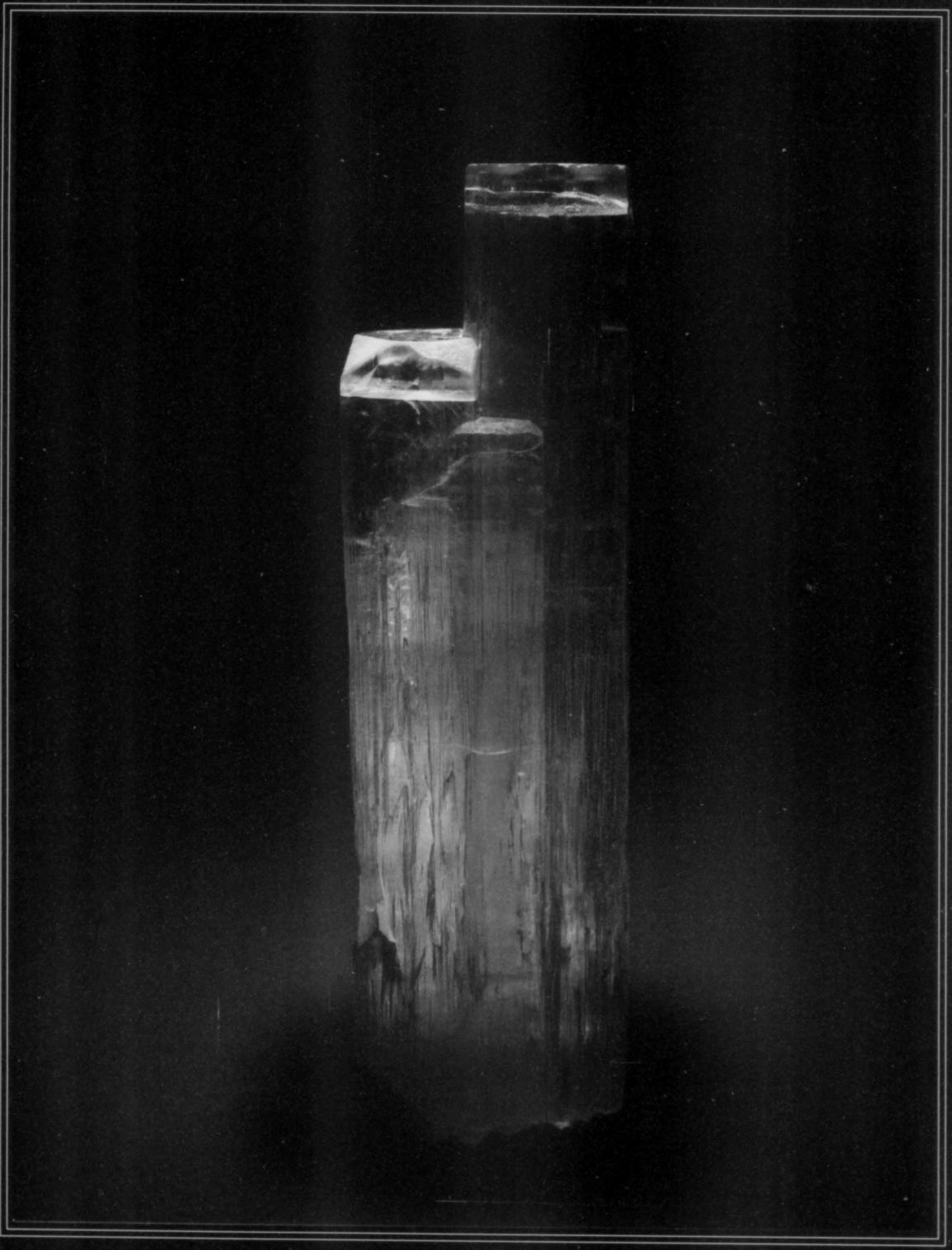

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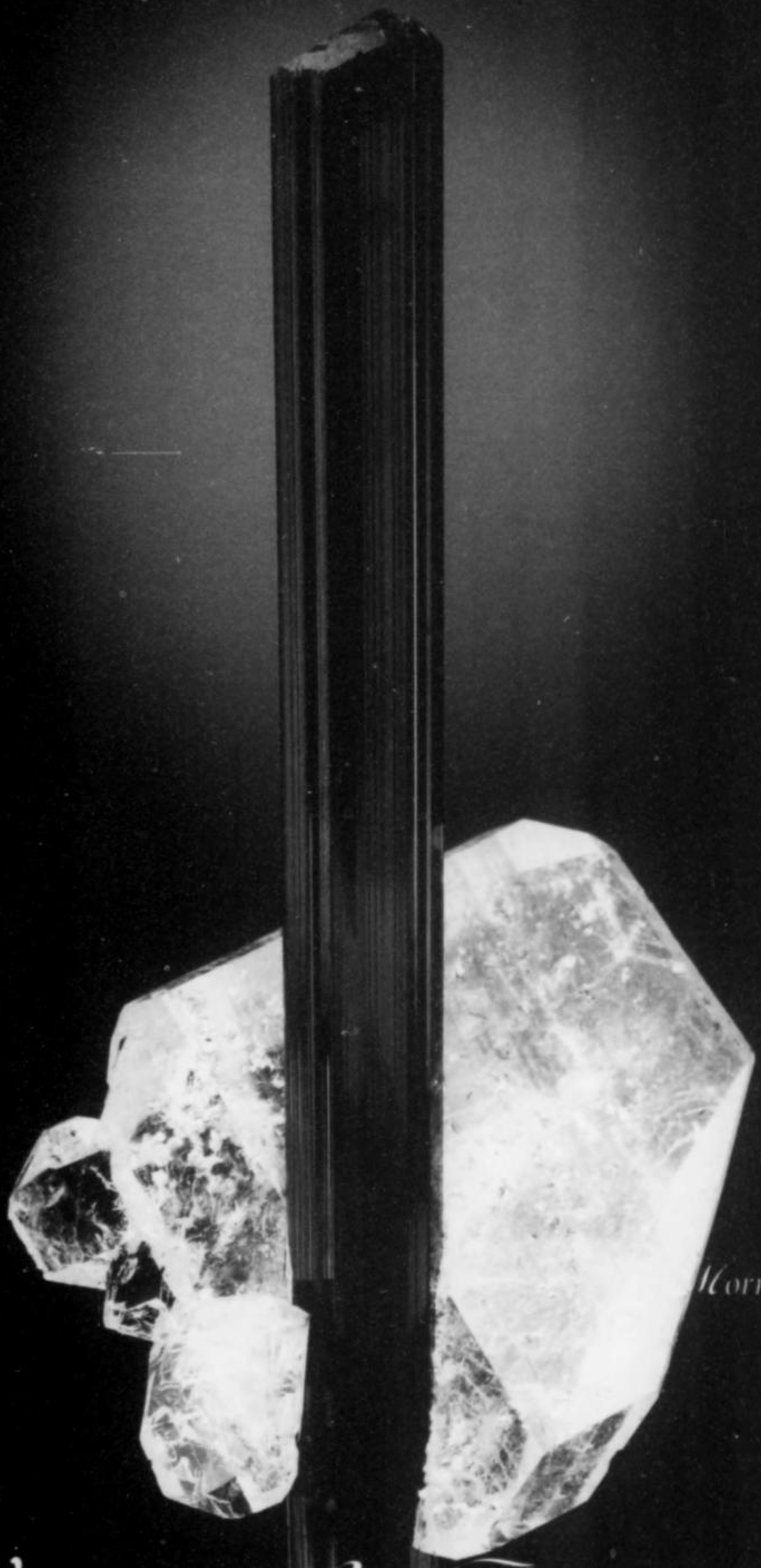

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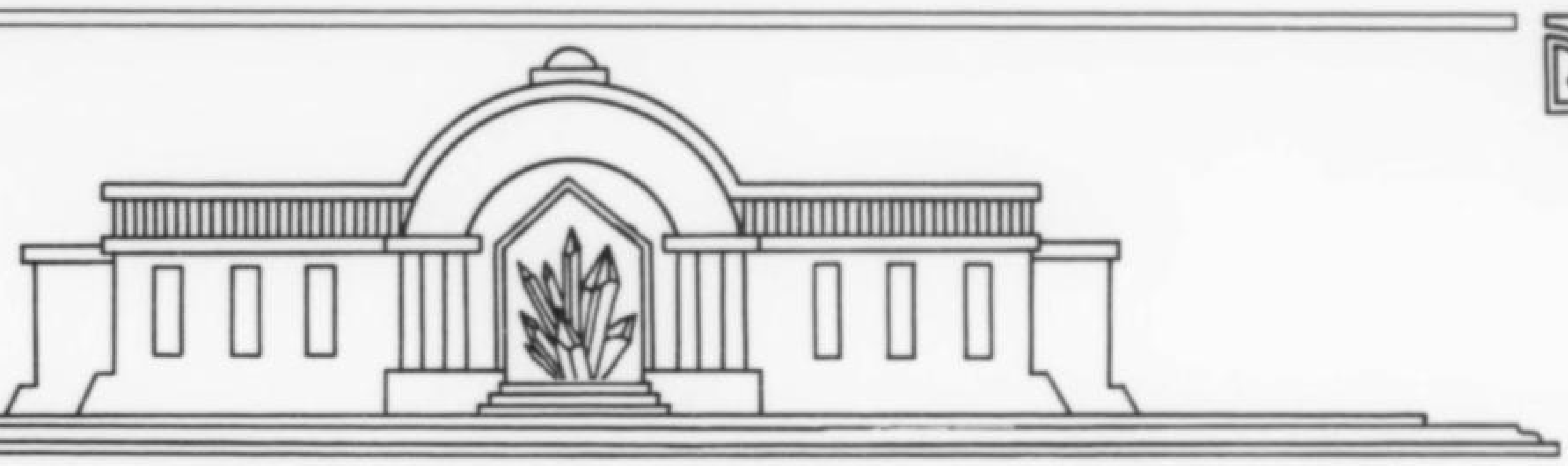

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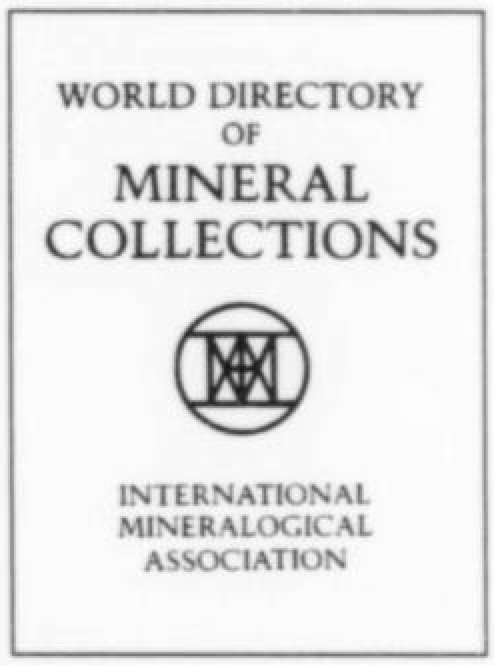

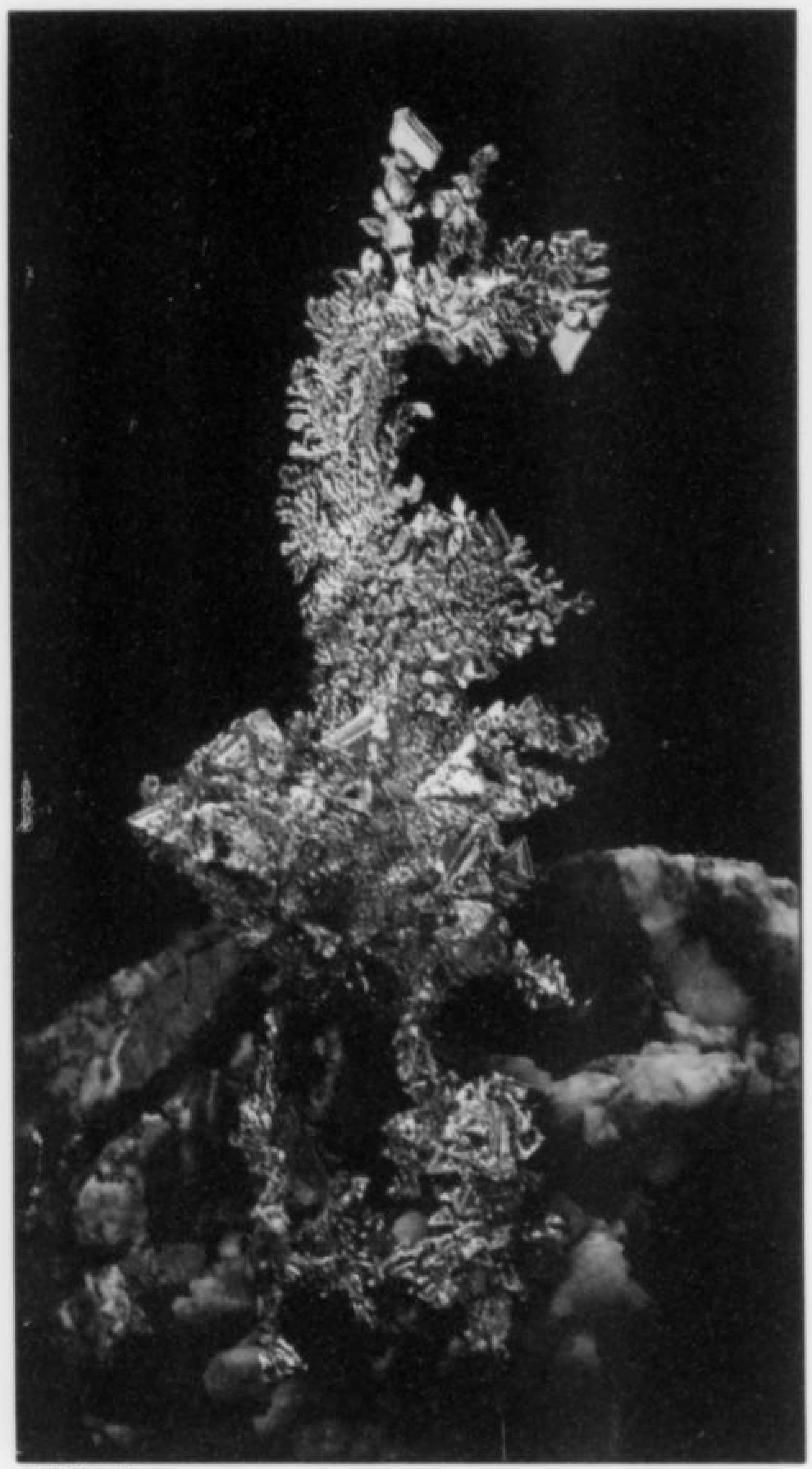

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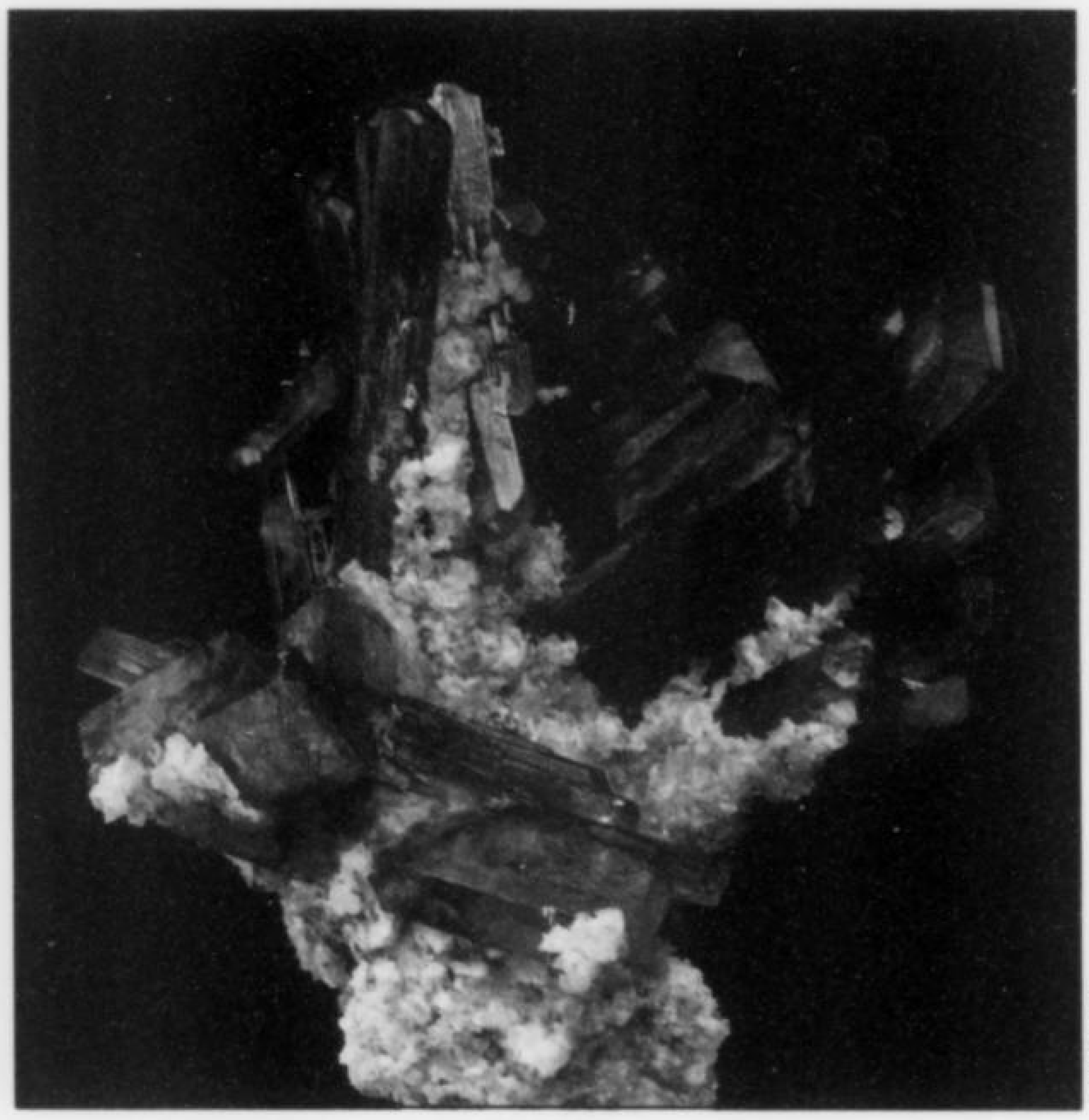

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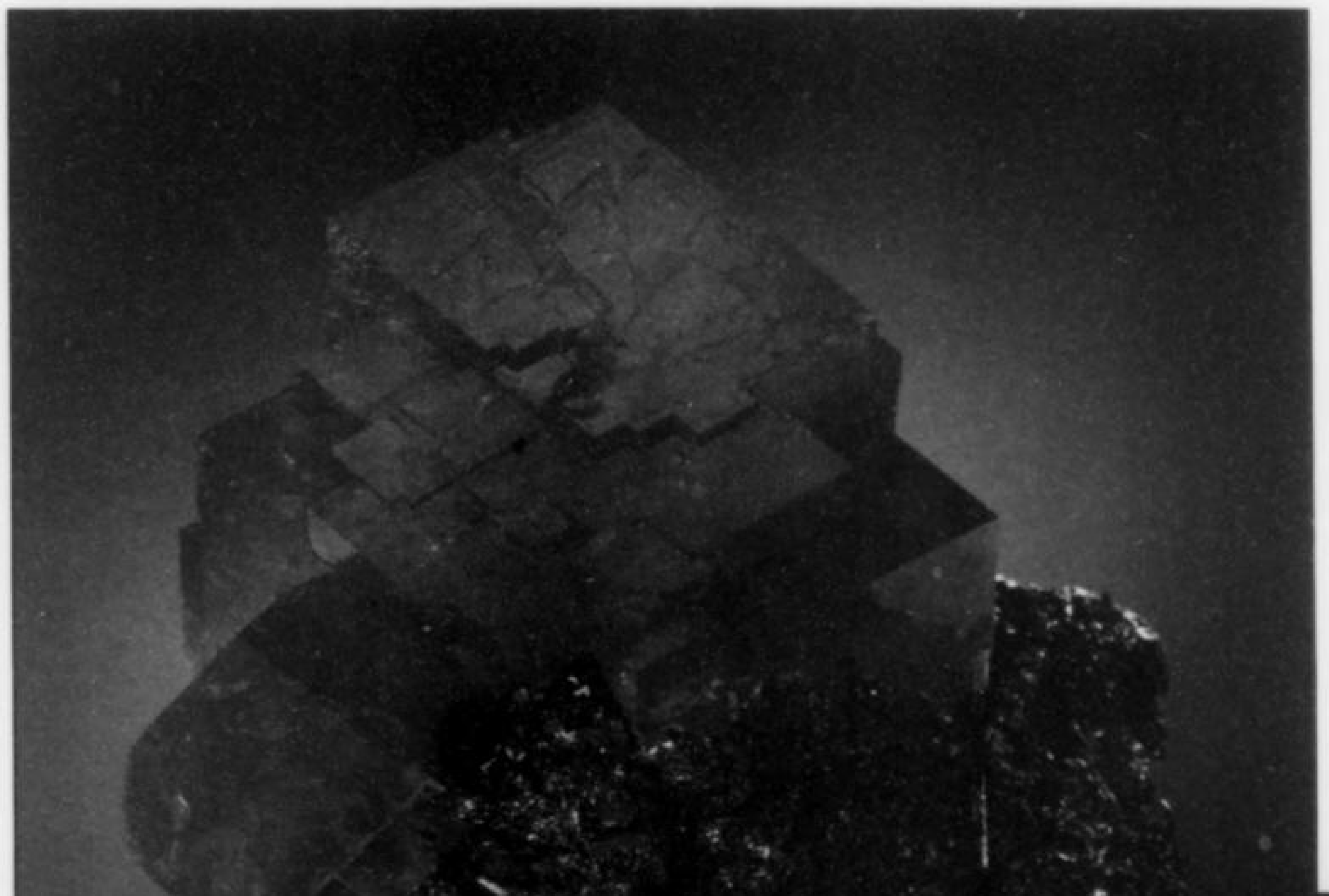


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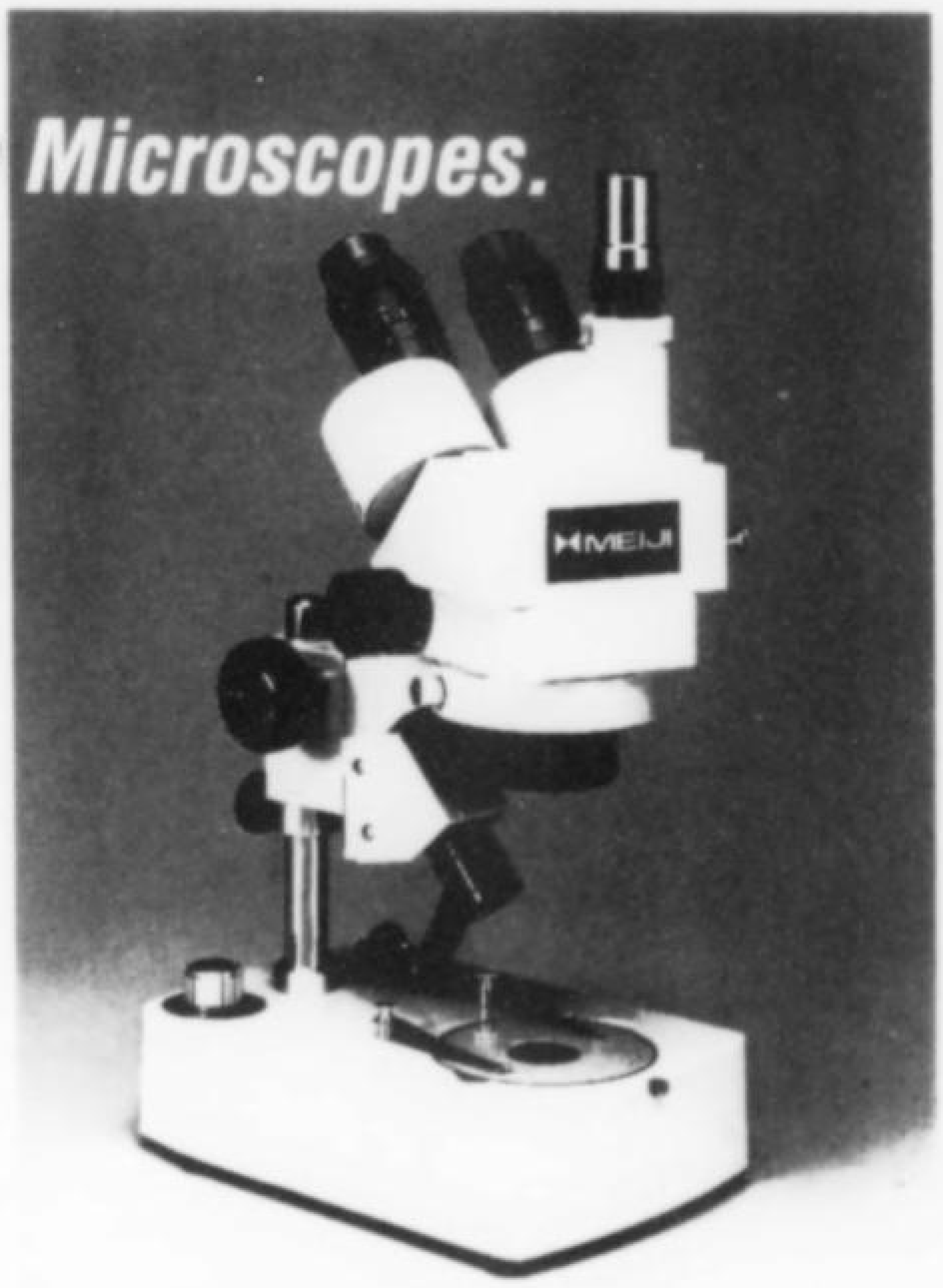

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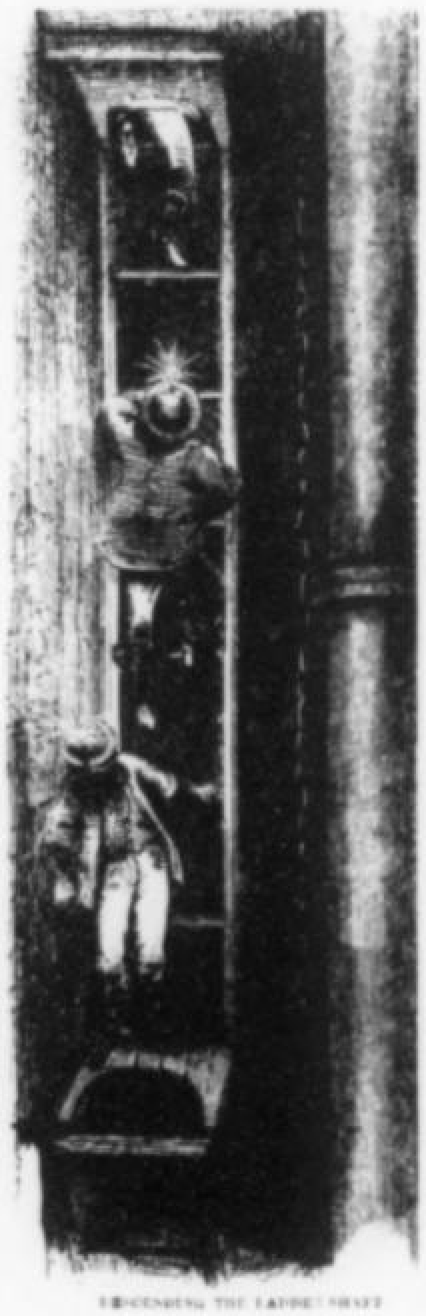

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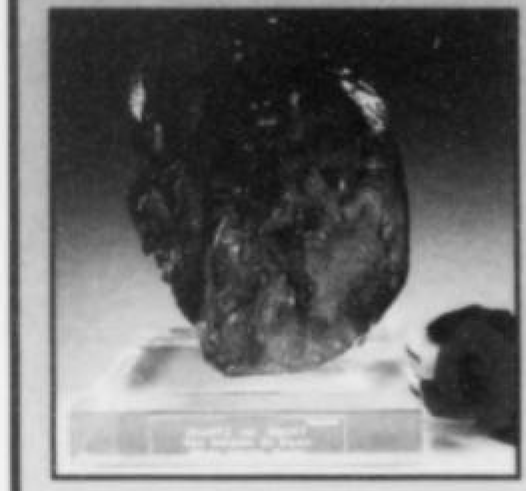

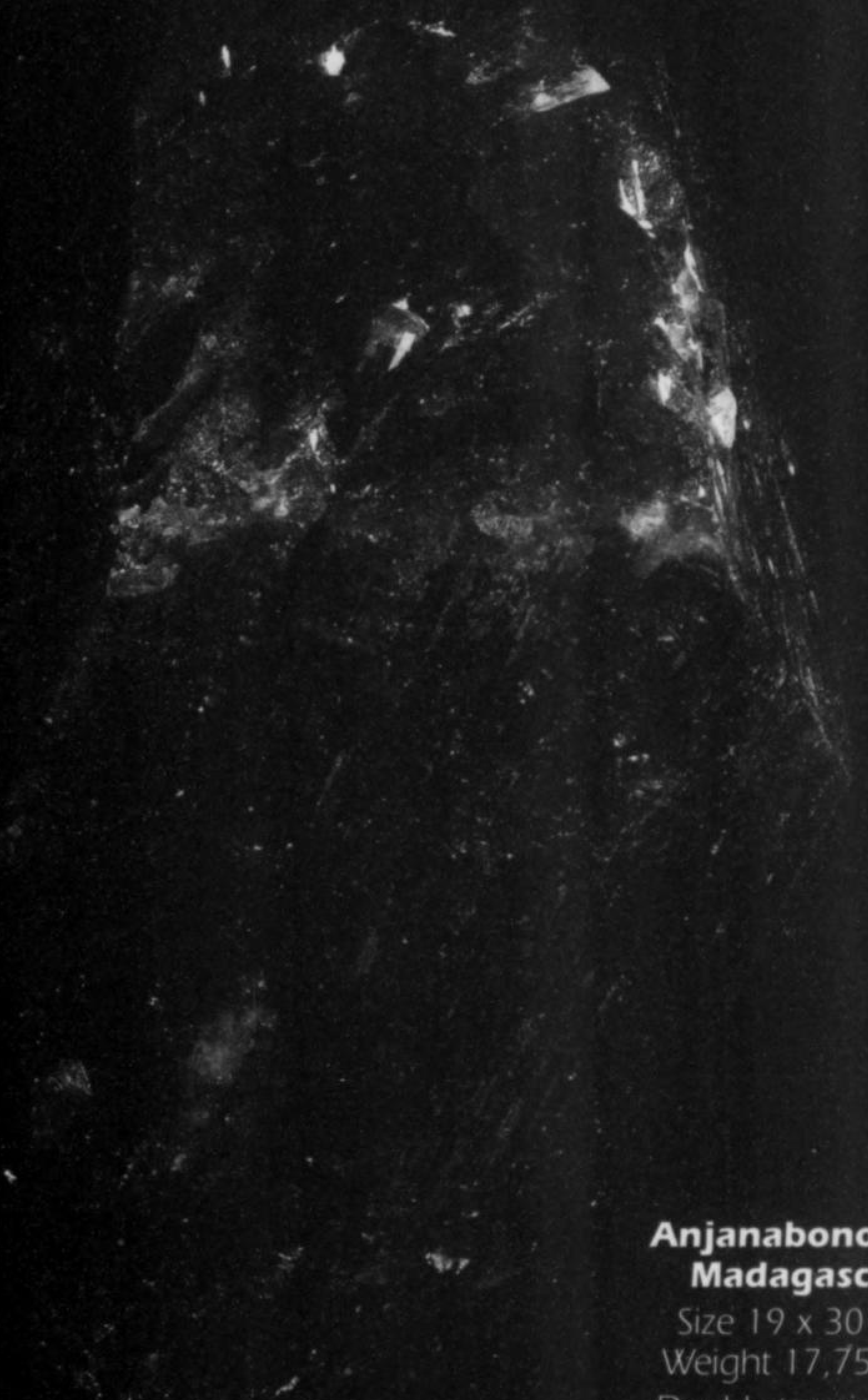

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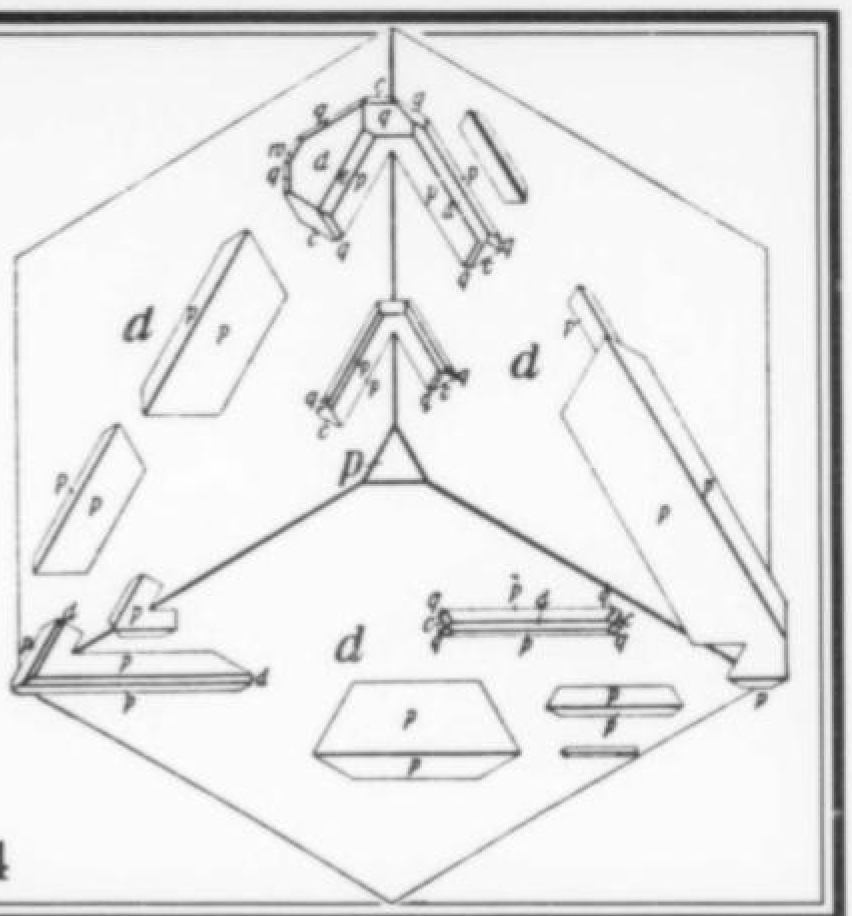

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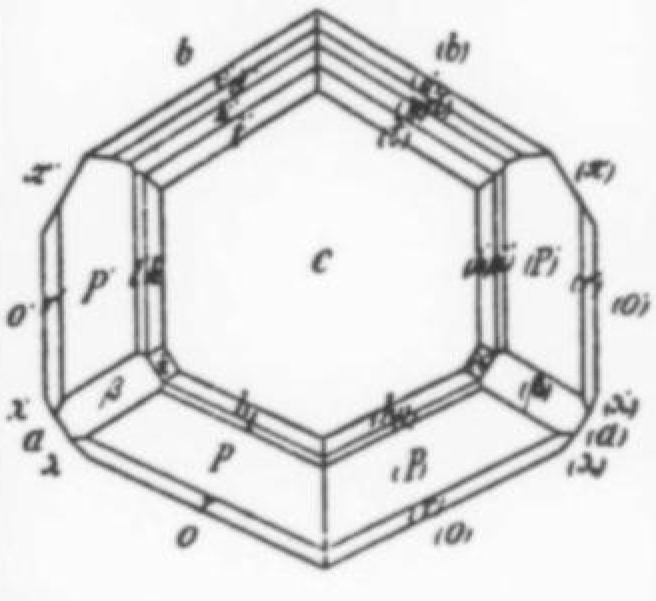
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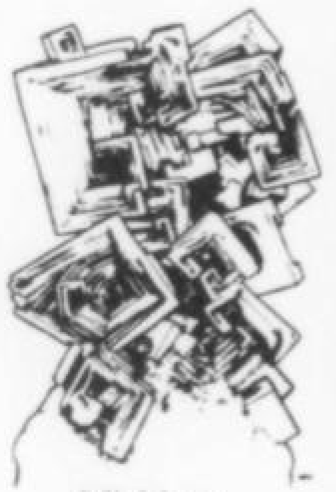

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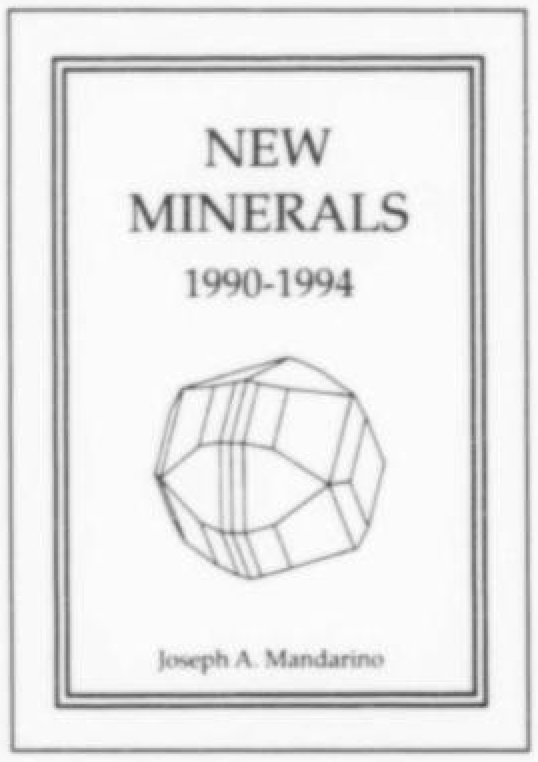

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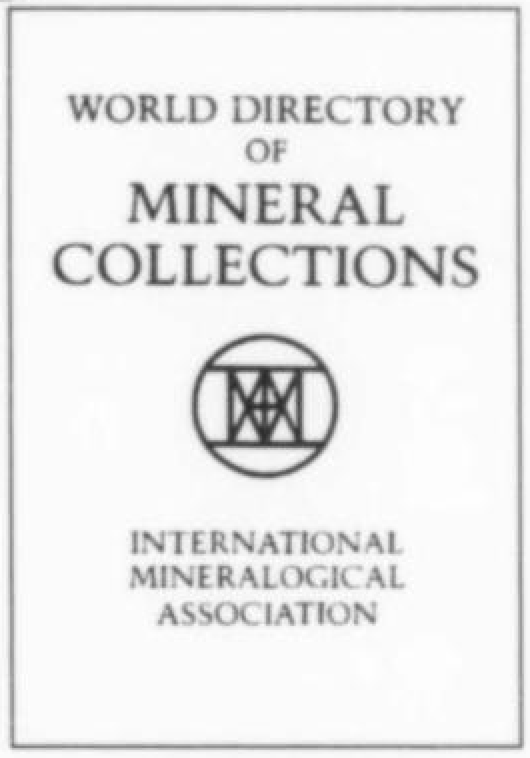

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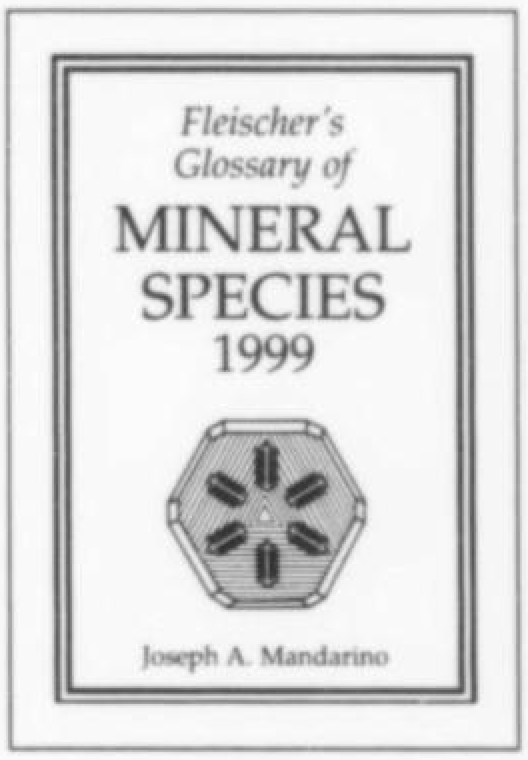

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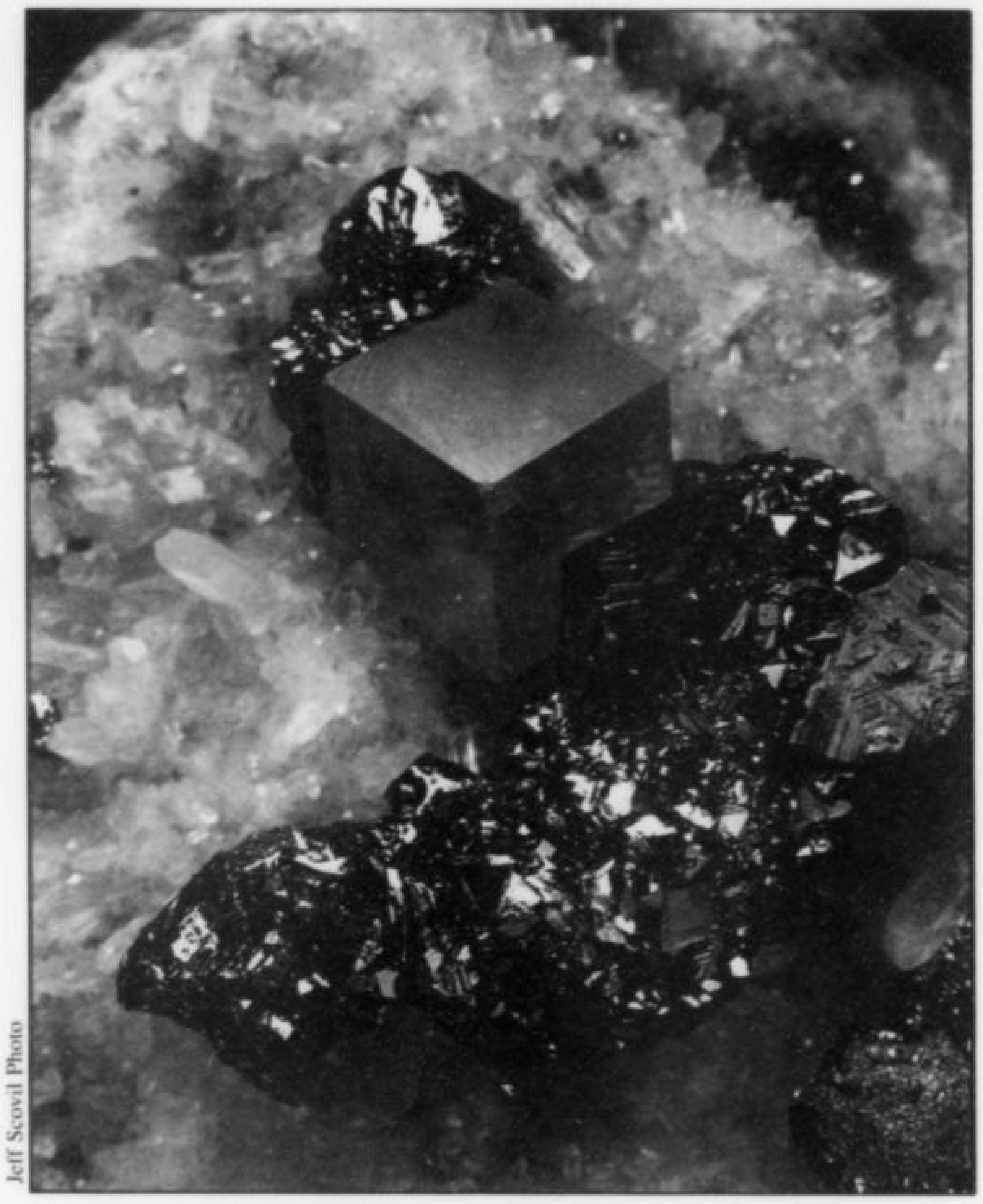

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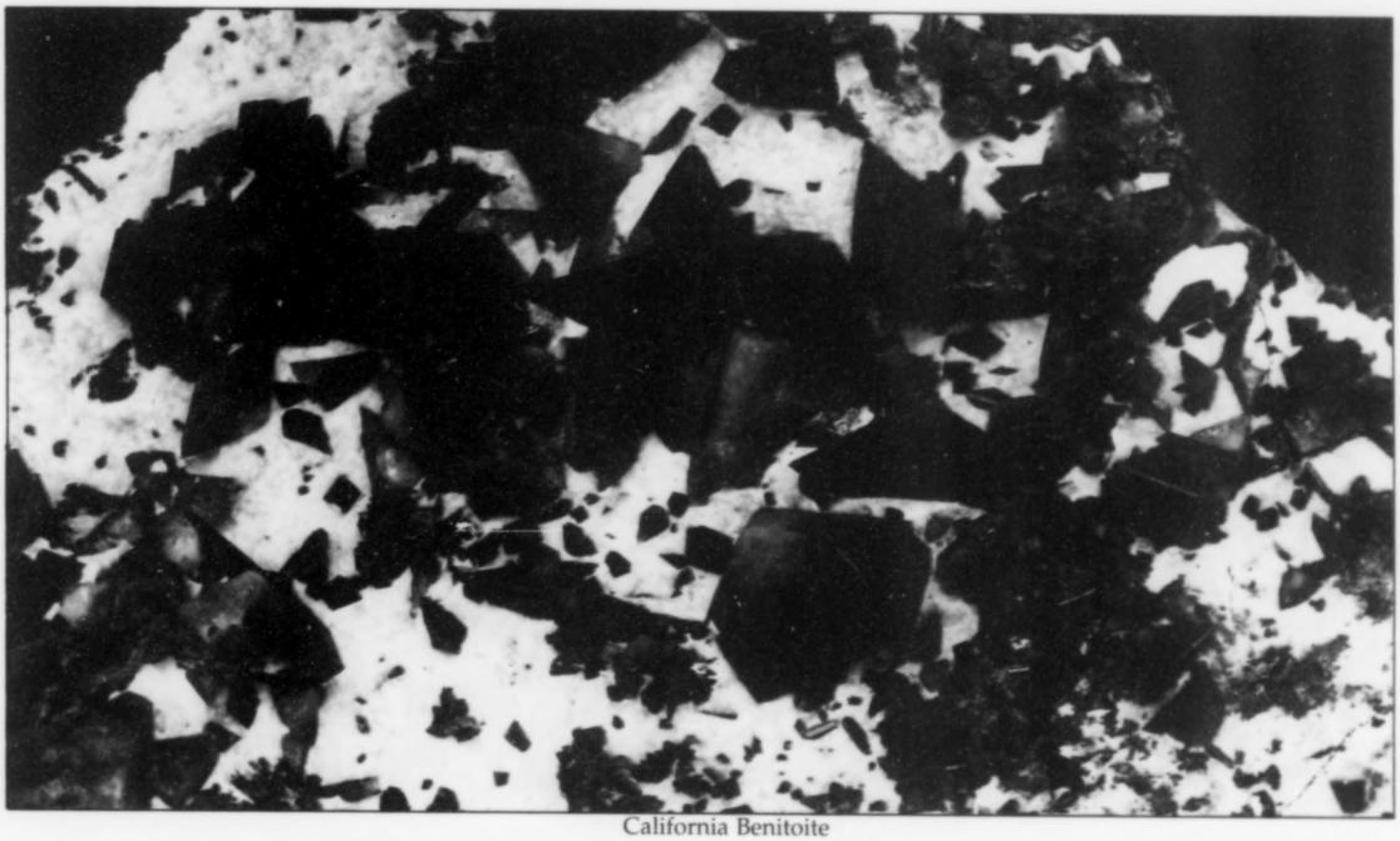

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Jeffrey Wheeler Photo—Collector's Edge specimen

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What's New in Minerals

Munich Show 1998

by Jeff Scovil

The big question on everyone's mind this year was, "How will the new location work out?" After many years at the familiar old Messegelände in downtown Munich, the show moved this year to the new Messe located at the old airport. The airport is to the east of town, a ways from all the familiar and convenient restaurants and hotels. Not wanting to lose too much business, most of the hotels were running shuttles to and from the show.

The new Messe buildings are quite spacious and unlike the old location; and there is plenty of parking. The show has been consolidated from six halls at the old location to three at the new facility. Everyone seemed happy with the new arrangement, which made for less "social stratification." At the old location, the showiest and most expensive dealers were generally in halls 1 and 2, closest to the entrance. As you got farther from the door, the booths became less and less expensive. By the time you got to the farthest hall you felt you were in a third-world enclave. (This was not necessarily a bad thing, because that is where many of the sleepers could be found.)

Johannes Keilmann, who runs the show, has always been bold and innovative. This year nostalgia was the order of the day, and he recreated an eight-room block of the old Desert Inn Motel from Tucson! The lobby featured a bar, which was always busy, as well as numerous photos of Desert Inn denizens and visitors from years past. The latter provided a lot of amusement for those who used to frequent the now-infamous motel. There was a cactus garden in front of the DI, and Keilmann had even salvaged the original Desert Inn sign from above the main entrance. On opening night he actually managed to produce a real mariachi band to play while the crowd downed champagne!

The theme of the show had everyone seeing **red**, as that *was* the theme. Exhibits from private collectors, museums and dealers from around the world were truly amazing. There were proustites and pyrargyrites beyond compare from both Chile and Germany. One case was devoted to just crocoite and another to the finest kammererites (= chromian clinochlore) I have ever seen. Of course, what would the show be without rhodochrosites from South Africa, Peru, Argentina, Germany and Colorado? Bryan Lees of *Collector's Edge* brought several cases of superb material from the Sweet Home mine, as well as photographs of collecting underground. Fossil collectors were not left out in the cold, having impressive (though not red) exhibits of dinosaur skeletons, fish and many other fossils to peruse.

There were many fine minerals to buy in all price ranges. Truly new things were a little scarce, as always, but they could be found. Peter Korbel of *Eastern Minerals* has been working closely with a source in Madagascar for new material. During the show he received a new shipment of fine, large **titanite** crystals coming out of Vohemar. These have been out for a while, but what is interesting is their association with **fluorapatite**. These latter are pale yellow prisms to 5.6 cm with pyramidal modifications. Crystals often show a roughly parallel orientation with the foliation of the gneissic matrix. The latest find was made in July.

Superb Minerals India had the **fluorite** collectors excited with a new find of hemispherical fluorite from Nasik, India. The yellow, gumdrop-like hemispheres to 2.5 cm occur on drusy quartz.

Marcus Grossmann always has interesting material, this time including **parisite** crystals from Mt. Malosa, Malawi. The rough, tan-colored crystals to 2.4 cm occur on microcline with aegerine (for which the locality is already famous). The classic locality of Virgem de Lapa, Minas Gerais, Brazil, may once again be producing **hydroxylherderite**. Marcus had several of the purplish crystals up to 7.5 cm long. (But perhaps they are actually from the recent find near the Morro Redondo mine, Coronel Murta.)

I am glad that several people keep their eyes open and bring me things that I would otherwise miss. John White found some loose **schorl** crystals with uncommonly steep pyramidal terminations. They are from the Shigar Valley in northern Pakistan; the larger of the two crystals is 2.7 cm long. John had also found a dealer who had recently collected a number of fine **barites** from the old Clara mine, Oberwolfach, Schwarzwald, Germany. This mine is best known for its phosphate mineral suite. The crystals are brownish and wedge-shaped, up to 9.6 cm long.

A new locality for **okenite** has been found on the Vanidindari Road, Maharashtra, India. The white puff balls are atypical in that they look as if they had become matted during washing. The spheres, up to 2 cm across, are attractively perched on amethyst and were sold by *Krystal Ocean Exports*.

Ian Bruce of *Crystal Classics* had quite a rarity in **cannizzarite** ($Pb_4Bi_5S_{11}$). It is a volcanic sublimate mineral from Vulcano Island, in the Eolie Islands, Sicily, Italy, occurring as gray/black microcrystals on matrix.

Although not truly new, the beautiful **hematite** of the Cavradi, Switzerland, region is hard to resist. *Teodozi Venzin* is the premier *Strahler* of the area, and had a very impressive display from his private collection, as well as superb material for sale (such as an 8.3-cm hematite crystal on matrix with the usual epitaxial rutile).

An impressive find from Chamachu, Baltistan, Pakistan, are **diopsides** to 9.1 cm in length and quite gemmy. *François Lietard* was selling them, as well as the new faden **quartz** from Waziristan, Pakistan, that he had at the Sainte Marie Show. These quartz crystals have now found their way into several dealers' booths.

A surprising new find from Dal'Negorsk, Russia, is **zinkenite**. Unlike the well known crystals from France, which are more stout, the Russian material is very finely acicular, flexible and delicate. The specimens (the largest of which was 8.8 cm across the spray) were being sold by *Jordi Fabre*.

One of the truly impressive new finds were the amazing **anatase** crystals from Valdres, Norway. Instead of being on quartz crystals

Figure 1. **Reconstructed Desert Inn at the Munich Show (Jeff Scovil photo).**

like the old material, the new crystals are on a brecciated matrix coated with adularia microcrystals. Individual crystals are up to 2.5 cm long, incredibly sharp and truncated by the pinacoid. Collecting has been going on since at least summer of 1996, with the best material being sold by *Budil & Risse*.

That is the end of this show report. I am sure I missed some material, and can't be all-knowing and everywhere at once; but I try. Until next time, glück auf!

Pomona Show 1998

by Jeff Scovil

Normally, when I go to the Munich Show, I stay for about a week afterwards to do some vacationing. This time I had to get my R & R *before* the show, because immediately upon my return to the States I had to take off for the "Pomona" show on the seventh and eighth of November. It had been moved up a couple of weeks because of a scheduling conflict at the Pomona County Fairgrounds, where it is held.

There were a couple of other changes as well. We were in a slightly smaller building, which worked out fine because the wholesale section was dropped. The show was also reduced from three to two days.

One of the new finds at the show was the **spessartine** garnets on quartz crystals from Mengna, Hunan, China, first seen at the Munich Show. Most of them had been bought up by *Seibel Minerals*. Luckily, by Pomona time they were available for sale again. The small orange garnets coat the lower parts of pale smoky quartz crystals that are 14 cm or more in length.

Late in the summer, a quantity of very good **azurite** roses were found at Morenci, Arizona. The luster is not quite what one would expect from Bisbee, but they are quite handsome and well formed. Several were for sale at the booth of *Em's Gems*, the largest being 10.4 cm across!

Nevada's Barrick Meikle mine [full article coming shortly. Ed.] continues to produce **barites** that are modern classics, along with some interesting **calcites**. In September, a calcite vug about 60 x 30 x 30 cm was encountered that, in addition to the typical calcites, produced twelve fine twins. They are all pale yellow, with a well-defined re-entrant angle on fairly complex morphology. These crystals were being sold by *Geoprime*.

The most exciting things at the show, in my opinion, were the **stibnites** *Geoprime* had from a new locality in Nevada: the Murray mine, Elko County. The single crystal I saw is 29.2 cm long and rather reminiscent of the Chinese material. Associated species are blocky white barite coated with drusy quartz.

Phoenix Show 1998

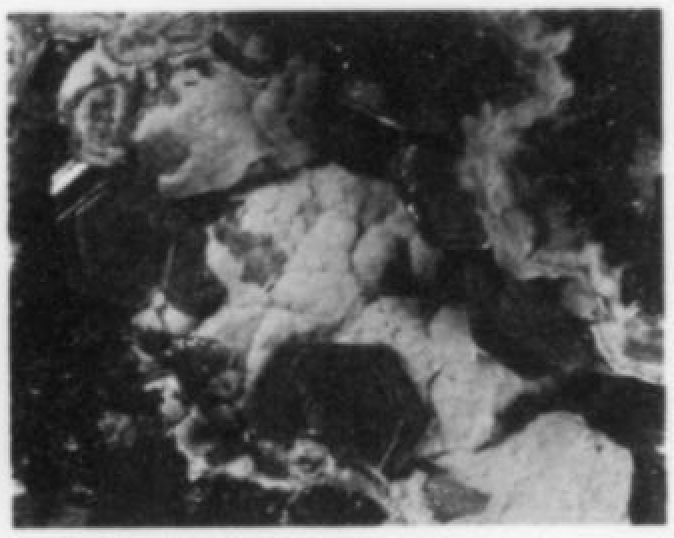
by Jeff Scovil

The Mineralogical Society of Arizona has been putting on an annual show for many years. In 1996 the Society teamed up with *GeoExpositions* in a joint effort to produce a new show they call the "Phoenix Treasure Market." The show moved to the much nicer facilities of the Civic Plaza downtown. There were 50 dealers at the show in 1998, as well as many fine displays by dealers, collectors and museums. The latter included the Arizona-Sonora Desert Museum and the Arizona Mining and Mineral Museum.

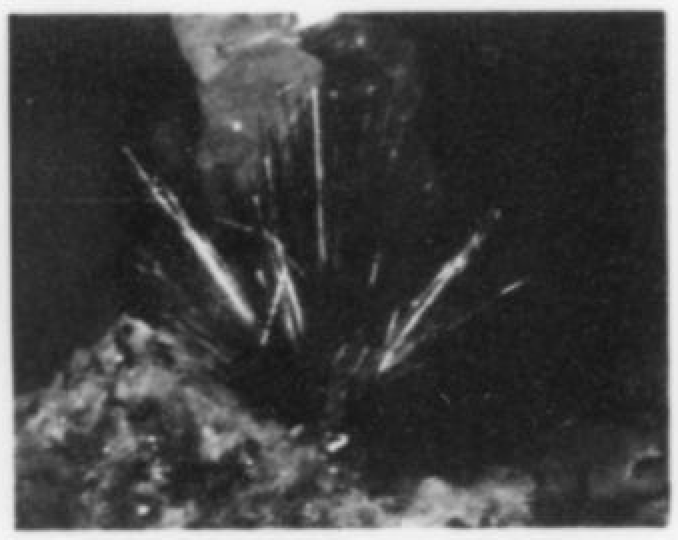
The only new item of note to appear at the show was some

(continued on page 153)

MINERALS & SUPPLIES



Chalcophyllite - Rancagua, Chile



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crystals brought in by *Jack Lowell.* Jack said they had been identified as **parisite** from a new, and as yet undisclosed locality in northern Pakistan. The crystals are brownish red, tabular and hexagonal, up to 3.5 cm across. It seems that there is some disagreement over the identification, as another dealer familiar with the material thinks that they are **bastnaesite**. Time will tell.

One last note is about something I first saw in Munich as a single crystal—an elbaite from Kaffi, Nigeria. In early November I was asked to photograph some of this material by Barker & Co. This firm had bought a quantity of the new tourmalines in partnership with Bill Larson of *The Collector.* The material first appeared on the market in Europe in July of 1998, and is being marketed solely as gem rough. This is not such a great tragedy, as the crystals are alluvial and all are abraded to a greater or lesser degree. Terminations are rare and, when encountered, are often incomplete. The crystals are primarily red, but some nice bi-colors have been found with green to blue-green as the second color. Over 300 kilograms of the material is reported to have been recovered.

Bilbao and Barcelona Shows 1998

by Miguel Calvo

The Spanish mineral specimen market was highlighted in 1998 by a world-class discovery of **pyromorphite** from the San Andres mine. Pyromorphite from this locality is well known, and fine specimens (in limited quantity) reached the mineral shows about 10–15 years ago. However, after the official closure of the mine in 1990, many areas of the mine caved, and no new specimens reached the market. In the fall of 1997, two Andalusian collectors worked a small tunnel in the collapsed area, using a telescoping tube made of sheet steel. After some months of work, they reached the mineralized area, and obtained more than a thousand fine pyromorphite specimens, from thumbnail to cabinet size.

Pyromorphite crystals to 1 cm fully cover matrix, or in small specimens form floater groups of crystals. The matrix is in most cases earthy limonite. The color of the pyromorphite from the San Andres mine is a spectacular bright apple-green, very attractive and lustrous. Only in a few specimens is barite or rarely cerrusite found in association.

Immediately after the discovery, the Spanish dealer *Jordi Fabre* secured the better specimens of the lot, mainly those obtained from a particular pocket (named "geoda La Victoria" by the finders) found around the last day of work. In this pocket, the pyromorphite crystals are associated with barite. The largest specimens from this pocket caused a great stir at the 1998 Tucson Show, and sold immediately. (See vol. 29, no. 3, p. 214–216.) At the Bilbao and Barcelona shows, Jordi Fabre, Luis Miguel Fernandez, from Zaragoza and Juan Peña, from Sevilla had more fine pyromorphite specimens from San Andres mine.

And a note about the locality. The nearest town to the mine is Villaviciosa de Cordoba, but the mine is actually in Espiel. The specimens may be precisely labeled as follows.

Mina San Andres	San Andres mine
Grupo minero Cíclope	Ciclope mining district
Cerro del Búfalo	Buffalo Hill
Espiel (Córdoba) España	Espiel, Cordova province, Spain

Another interesting find from Spain is the native **silver** from the Balcoll mine, Falset, Tarragona province. The mine is also a "classic" locality, like the San Andres mine, but much older, dating from the beginning of the century. The silver specimens were found by Joan Abella, while searching some calcite-dolomite blocks in the dumps of the mine. The blocks had been dumped there about 1905. Most specimens are composed by silver filaments, but some have oriented growths of very elongated skeletal crystals up to 7 mm, forming the typical "herringbone" habit. These are the finest silver specimens found in Spain in many years.

The silver was found inside masses of crystalline carbonates that were dissolved with acid. In some specimens silver is partially altered to **acanthite**. Other specimens include millimeter-size acanthite crystals, cubes with octahedral modifications, but not directly associated with the silver. *Jordi Fabre* had specimens at the Bilbao and Barcelona shows, and *Joan Abella,* the finder, also at the Barcelona show, in the booth of the Grup Mineralogic Catala.

Juan Peña also had other interesting Spanish minerals. Among them were colorful (but unfortunately unstable) iron sulfates such as voltaite, coquimbite, botryogen and others from the abandoned subterranean workings in the area of the Alfred pit, Riotinto mine, Riotinto, Huelva. From the same locality Juan Peña also had specimens of crude microcrystals of **covellite** covering the surface of massive pyrite.

Goethite is a very common mineral, but crystals are rare. At the Bilbao show *Zona Minera,* from Madrid had some small calcite geodes from Tordelrábano, Guadalajara province, with laminar goethite crystals up to 7 mm long. Small **anatase** crystals on quartz crystals are still appearing from a roadcut near the old tin mine in Penouta, Viana do Bollo, Orense province. There are also **cassiterite** specimens from the Penouta mine, found as relatively crude twinned crystals, up to 5 cm. The primary source of these specimens is *José Fernández,* from Villamartín de Valdeorras, Orense province. *José Vincente Casado,* from León, and other dealers, had specimens at the Bilbao and Barcelona shows.

The fluorite mines in Asturias province have contributed this year with some novelties. In the Moscona mine, yellow transparent **barite** crystals have been found, up to 3 cm, associated with the well-known yellow **fluorite** and with **calcite** crystals. (These specimens were obtained in a relatively small quantity.) In the Jaimina mine, located near the classical Berbes locality, pale blue and violet cubic crystals, up to 10 cm have been found. The crystals have an irregular distribution of the color, not the usual zonation parallel to the faces of cube.

The La Unión-Cartagena area is usually a prolific producer of specimens, but this year no substantial novelties appeared. Dealers from the area have the usual blue **barites** and the specimens of acicular **gypsum** crystals from San Timoteo mine. Gypsum has also been found in the "El Paraiso de Klein" mine, near Pulpi, but actually located in the municipio of Pilar de Jaravía, Valencia province. Transparent crystals up to 10 cm have been found. Associated with them are **celestite** needles, in some specimens as inclusion in the gypsum crystals.

The Eugui quarry is well known for its magnificent **dolomite** specimens. However, **magnesite** is rarely found as crystals. This year, Pedro Echevarría, from Pamplona, obtained a reasonable suite of specimens, with lenticular magnesite crystals protruding from massive magnesite. And speaking of Eugui, in the Barcelona show *Jordi Fabre* had a large, fine dolomite specimen with crystals up to 7 cm scattered in matrix; these crystals have the rhombohedron heavily modified by other faces.

From outside of Spain, the most eyecatching specimens seen lately are the large **amethyst** druses, up to half a meter, from Mina Ayoreita, Rincón del Tigre, Santa Cruz province, Bolivia. In the Barcelona show, *Intan S.L.,* owners of the mine, had a large selection of druses and loose crystals. Individual crystals are up to 10 cm, but the color is usually pale and irregularly distributed, and the crystal faces are lusterless.

Also interesting are the "faden" **quartz** from Dara Ismael Khan district, Waziristan, Pakistan. *Miró,* a French dealer, had specimens with crystals up to 10 cm. *Luis Miguel Fernandez* had green **fluorites** from Melchor Muzquiz, Coahuila, Mexico.

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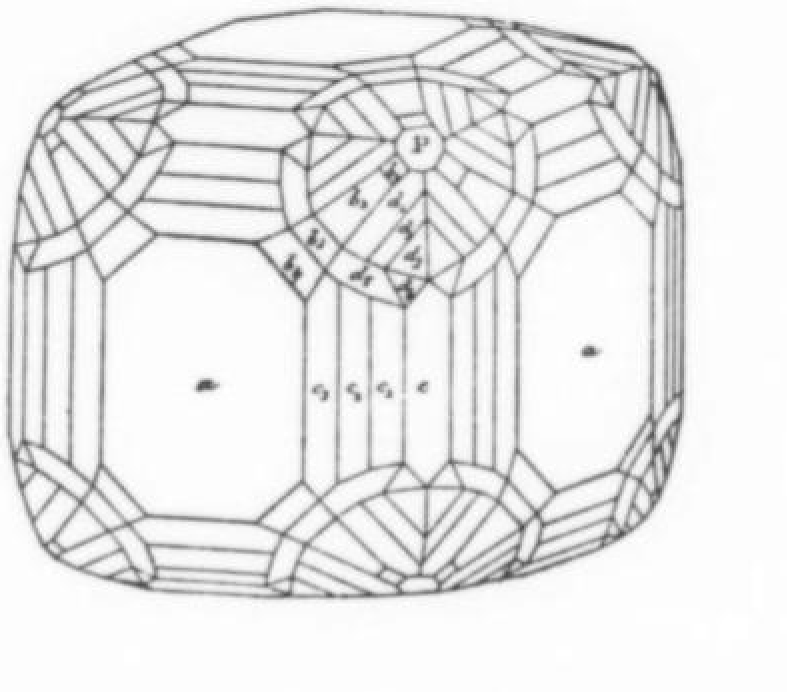

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Bamfordite Triclinic

$Fe^{3+}Mo_2O_6(OH)_3 \cdot H_2O$

Locality: Bamford Hill, 85 km WSW of Cairns, northern Queensland, Australia (Lat. 17°19′ S, Long. 144°56′ E).

Occurrence: In tungsten-molybdenum-bismuth deposits. Associated minerals are: quartz and muscovite.

General appearance: Microcrystalline aggregates of tabular crystals 0.005 to 0.05 mm long.

Physical, chemical and crystallographic properties: *Luster:* earthy in aggregates and vitreous in crystals (indices of refraction indicate adamantine). *Diaphaneity:* transparent. *Color:* strong apple-green with a slight yellowish tinge. *Streak:* greenish yellow. *Luminescence:* not mentioned. *Hardness:* between 2 and 3. *Tenacity:* not mentioned. *Cleavage:* {100}, perfection not stated. *Fracture:* not mentioned. *Density:* 3.620 g/cm^3 (meas.), 3.68 g/cm^3 (calc.) (see comments). ***Crystallography:*** Triclinic, P1 or P$\bar{1}$, a 5.889, b 7.545, c 9.419 Å, α 71.46°, β 83.42°, γ 72.78°, V 378.9 Å^3, Z 2, a:b:c = 0.7805:1:1.2484. Morphology: forms, {001}, {100}, {010}, {110}, and {1$\bar{1}$0}. Twinning: none observed. ***X-ray powder diffraction data:*** 5.620 (70), 4.711 (50), 4.095 (70), 3.319 (100), 3.232 (90), 2.614 (50), 1.956 (50). ***Optical data:*** Biaxial (–), α 1.91, β 2.03, γ 2.11, 2V(meas.) about 90°, 2V(calc.) 74°; dispersion not given; nonpleochroic; Y = a, Z′ ∧ c = 7°. ***Chemical analytical data:*** Means of six sets of electron microprobe data: Fe_2O_3 18.93, P_2O_5 0.39, MoO_3 68.93, WO_3 1.90, H_2O 9.90, Total 100.05 wt.%. Water by CHN analyzer. Empirical formula: $Fe^{3+}_{1.00}Mo_{2.01}W_{0.03}P_{0.02}O_{6.00}(OH)_{3.34} \cdot 0.64H_2O$; the simplified formula is based on the crystal structure analysis. ***Relationship to other species:*** None apparent.

Name: For the locality. ***Comments:*** IMA No. 96-059. The calculated density given in the paper (3.616 g/cm^3) is for the ideal composition; the value given above is for the empirical formula. Although the mineral is referred to as a hydrated iron molybdate in the paper, it is called a "hydrated iron molybdenum oxyhydroxide" in the paper's title. The mineral was mentioned first in 1915 and referred to as "molybdoferrite" in 1920.

BIRCH, W. D., PRING, A., McBRIAR, E. M., GATEHOUSE, B. M., and McCAMMON, C. A. (1998) Bamfordite, $Fe^{3+}Mo_2O_6$-$(OH)_3 \cdot H_2O$, a new hydrated iron molybdenum oxyhydroxide from Queensland, Australia: Description and crystal chemistry. *American Mineralogist* **83**, 172–177.

Boralsilite Monoclinic

$Al_{16}B_6Si_2O_{37}$

Locality: (1) Stornes Peninsula, Larsemann Hills, Prydz Bay, east Antarctica (Lat. 69°24′ S, Long. 76°07′ E) (the type locality) and (2) Almgjotheii in the aureole of the Rogaland intrusive complex, southwestern Norway (Lat. 58°33′ N, Long. 6°31′ E).

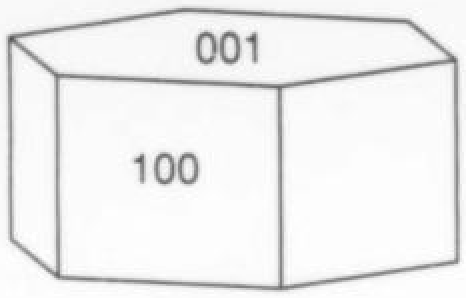
Occurrence: Associated minerals are: (1) quartz, potassium feldspar, and schorl/dravite; (2) quartz, potassium feldspar, "tourmaline," grandidierite, dumortierite, and werdingite.

General appearance: (1) fibrous aggregates (up to 1 cm) of fine prisms (0.05 to 0.3 mm wide and up to 2 mm long). (2) prisms 0.05 to 0.2 mm wide.

Physical, chemical and crystallographic properties: *Luster:* vitreous. *Diaphaneity:* transparent in thin section. *Color:* colorless. *Streak:* white. *Luminescence:* not mentioned. *Hardness:* could not be determined. *Tenacity:* not mentioned. *Cleavage:* "prismatic" fair, but the indices of the prism are not given. *Fracture:* not mentioned. *Density:* could not be determined, 3.07 g/cm^3 (calc.). ***Crystallography:*** Monoclinic, C2/m, a 14.767, b 5.574, c 15.079 Å, β 91.96°, V 1240.4 Å^3, Z 2, a:b:c = 2.6493:1:2.7052. Morphology: no forms were mentioned, but "prisms" are elongated parallel to [010] (see Comments). Twinning: fine on {100}. ***X-ray powder diffraction data:*** 5.41 (70), 5.19 (100), 4.95 (60), 4.31 (70), 3.378 (60), 2.162 (40). ***Optical data:*** Biaxial (+), α 1.629, β 1.640, γ 1.654, 2V(meas.) 81.8°, 2V(calc.) 84°; dispersion r > v, extremely weak; nonpleochroic; Z = b. ***Chemical analytical data:*** Several sets of electron microprobe and secondary ion mass spectrometry (SIMS) data are given. A representative set of data for the Antarctica mineral is: FeO 0.48, B_2O_3 18.53, Al_2O_3 71.23, SiO_2 10.05, Total 100.29 wt.%. Empirical formula: $Fe_{0.08}Al_{15.98}B_{6.09}Si_{1.91}O_{37.00}$. ***Relationship to other species:*** Structurally related to sillimanite.

Name: For the chemical composition, *bo*ron, *al*uminum, and *sil*icon. ***Comments:*** IMA No. 96-029. The "prisms" referred to under Morphology must be made up of pinacoid faces.

GREW, E. S., McGEE, J. J., YATES, M. G., PEACOR, D. R., ROUSE, R. C., HUIJSMANS, J. P. P., SHEARER, C. K., WIEDENBECK, M., THOST, D., E., and SUN, S.-C. (1998) Boralsilite ($Al_{16}B_6Si_2O_{37}$): A new mineral related to sillimanite from pegmatites in granulite-facies rocks. *American Mineralogist* **83**, 638–651.



Caresite

Caresite — Hexagonal (trigonal)

$Fe^{2+}_4Al_2(OH)_{12}CO_3{\cdot}3H_2O$

Locality: (1) Poudrette Quarry, Mont Saint-Hilaire, Rouville County, Quebec, Canada; (2) the Corporation Quarry, Mont Royal, Montreal, Quebec, Canada.

Occurrence: (1) In miarolitic cavities and in pegmatite bodies within nepheline syenite; (2) In small cavities in a nepheline syenite dike. Associated minerals are: (1) microcline, analcime, natrolite, calcite, a vermiculite- or smectite-group mineral, chamosite, and aegirine; (2) analcime, microcline, natrolite, tetranatrolite, aegirine, siderite, biotite, anatase, hematite, nordstrandite, dawsonite, berthierine, lovozerite, zircon, fluorite, and pyrite.

General appearance: Tabular crystals on {001} and pyramidal crystals (up to 0.5 mm).

Physical, chemical and crystallographic properties: *Luster:* vitreous. *Diaphaneity:* transparent. *Color:* yellow to orange-brown, sometimes with a green-black coating. *Streak:* white. *Luminescence:* non-fluorescent. *Hardness:* about 2. *Tenacity:* brittle. *Cleavage:* {001} perfect. *Fracture:* uneven. *Density:* 2.59 g/cm^3 (meas.), 2.57 g/cm^3 (calc.). ***Crystallography:*** Hexagonal (trigonal), $P3_112$ or $P3_212$, a 10.805, c 22.48 Å, V 2273 Å^3, Z 6, c:a = 2.0719. Morphology: forms, {001} and {100}; also an apparent hexagonal pyramid (inconsistent with the symmetry) which may be caused by a combination of an {h01} trigonal bipyramid and an {hhl} rhombohedron or by a diminishing pinacoid during crystal growth. Twinning: none observed. ***X-ray powder diffraction data:*** 7.49 (100), 3.746 (50), 2.625 (40), 2.314 (50), 1.948 (40), 1.526 (20). ***Optical data:*** Uniaxial (–), ω 1.599, ε 1.570, pleochroic. ***Chemical analytical data:*** Means of three sets of electron microprobe data for the mineral from Mont Saint-Hilaire: MgO 0.85, MnO 1.00, FeO 44.92, Al_2O_3 17.05, CO_2 (7.31), H_2O (26.84), F 0.17, sum 98.14, less O = F 0.07, Total 98.07 wt.%. CO_2 and H_2O by stoichiometry; the presence of CO_3, OH, and H_2O was confirmed by IR spectra. Empirical formula: $(Fe^{2+}_{3.77}Mg_{0.13}Mn_{0.08})_{\Sigma 3.98}Al_{2.01}[(OH)_{11.94}F_{0.05}]_{\Sigma 11.99}(CO_3)_{1.00}{\cdot}3.00H_2O$. ***Relationship to other species:*** The Fe^{2+}-dominant analogue of charmarite and quintinite. Structurally and chemically related to the hydrotalcite and manasseite groups. The difference between this group of minerals and the hydrotalcite and manasseite groups is the ratio of 2+ cations to 3+ cations. In this group the ratio is 4:2 and in the hydrotalcite and manasseite groups it is 6:2. Also, the octahedrally coordinated cations are ordered in the 4:2 compounds but not in the 6:2 compounds.

Name: For Stephen Cares (1909–) and Janet Cares (1921–) amateur mineralogists from Sudbury, Massachusetts, U.S.A., who found the mineral. ***Comments:*** IMA No. 92-030. Only the -*3T* polytype is known; the -*2H* polytype has not been found. The crystal drawing for this abstract was produced from the data and the SEM image in the paper. The color given in the paper is green-black, but I have been informed by Mr. Gault that it should be given as noted above.

CHAO, G. Y. and GAULT, R. A. (1997) Quintinite-*2H*, quintinite-*3T*, charmarite-*2H*, charmarite-*3T* and caresite-*3T*, a new group of carbonate minerals related to the hydrotalcite-manasseite group. *Canadian Mineralogist* **35**, 1541–1549.

Charmarite — Hexagonal and Hexagonal (trigonal)

$Mn^{2+}_4Al_2(OH)_{12}CO_3{\cdot}3H_2O$

Locality: Demix Quarry, Mont Saint-Hilaire, Rouville County, Quebec, Canada.

Occurrence: In miarolitic cavities and in pegmatite bodies within nepheline syenite. Associated minerals are: analcime, natrolite, microcline, aegirine, astrophyllite, tetranatrolite, catapleiite, calcite, siderite, rhodochrosite, burbankite, kutnohorite, and an amorphous phase.

General appearance: Tabular hexagonal crystals (up to 0.5 mm across) commonly stacked along [001] to form pagoda-like aggregates up to 1 mm long, and as thin mica-like plates sometimes forming star-shaped aggregates.

Physical, chemical and crystallographic properties: *Luster:* vitreous. *Diaphaneity:* transparent. *Color:* orange-brown, pale brown, pale blue, or colorless. *Streak:* white. *Luminescence:* non-fluorescent. *Hardness:* about 2. *Tenacity:* brittle. *Cleavage:* {001} perfect. *Fracture:* uneven. *Density:* 2.47 (-*2H*) and 2.48 (-*3T*) g/cm^3 (meas.), 2.50 (-*2H* and -*3T*) g/cm^3 (calc.). ***Crystallography:*** Hexagonal (-*2H*), $P6_322$, a 10.985, c 15.10 Å, V 1578 Å^3, Z 4, c:a = 1.3746; and hexagonal (trigonal) (-*3T*), $P3_112$ or $P3_212$, a 10.9885, c 22.63 Å, V 2366 Å^3, Z 6, c:a = 2.0601. Morphology: forms, {001} and {100}. Twinning: the -*3T* polytype is twinned by a rotation of 180° about [001] to give hexagonal pseudosymmetry. ***X-ray powder diffraction data:*** The -*2H* polytype, 7.53 (100), 3.768 (60), 2.578 (50), 2.221 (40), 1.856 (40), 1.585 (20), 1.552 (40); the -*3T* polytype, 7.55 (100), 3.770 (90), 2.670 (70), 2.346 (70), 1.973 (60), 1.586 (30), 1.562 (30). ***Optical data:*** Uniaxial (–), (-*2H*) ω 1.587, ε 1.547; (-*3T*) ω 1.587, ε undetermined; pleochroism O = brown, E = pale brown. ***Chemical analytical data:*** For the -*2H* polytype, means of fourteen sets of electron microprobe data: MgO 0.10, MnO 47.07, FeO 0.58, Al_2O_3 17.21, CO_2 7.30, H_2O 26.70, F 0.10, sum 99.06, less O = F 0.04, Total 99.02 wt.%. CO_2 and H_2O by TGA-EGA. Empirical formula: $(Mn^{2+}_{3.99}Fe_{0.05}Mg_{0.01})_{4.05}Al_{2.03}(CO_3)_{1.00}[(OH)_{12.16}F_{0.03}]_{12.19}{\cdot}2.82H_2O$. For the -*3T* polytype, means of four sets of electron microprobe data: MnO 46.53, Al_2O_3 16.49, Fe_2O_3 0.26, CO_2 (7.20), H_2O (26.54), Total 97.02 wt.%. CO_2 and H_2O by stoichiometry. Empirical formula: $Mn^{2+}_{4.02}(Al_{1.98}Fe^{3+}_{0.02})_{\Sigma 2.00}(CO_3)_{1.00}(OH)_{12.02}{\cdot}2.99H_2O$. ***Relationship to other species:*** The Mn^{2+}-dominant analogue of caresite and quintinite. Structurally and chemically related to the hydrotalcite and manasseite groups. The difference between this group of minerals and the hydrotalcite and manasseite groups is the ratio of 2+ cations to 3+ cations. In this group the ratio is 4:2 and in the hydrotalcite and manasseite groups it is 6:2. Also, the octahedrally coordinated cations are ordered in the 4:2 compounds but not in the 6:2 compounds.

Name: For *Char*les (1917–) Weber and *Mar*celle Weber (1918–), amateur mineralogists from Guilford, Connecticut, U.S.A., who found the -*2H* polytype. ***Comments:*** IMA No. 92-026 and 92-027. Note that the -*2H* and -*3T* polytypes are known.

CHAO, G. Y. and GAULT, R. A. (1997) Quintinite-*2H*, quintinite-*3T*, charmarite-*2H*, charmarite-*3T* and caresite-*3T*, a new group of carbonate minerals related to the hydrotalcite-manasseite group. *Canadian Mineralogist* **35**, 1541–1549.

Chrisstanleyite — Monoclinic

$Ag_2Pd_3Se_4$

Locality: Hope's Nose, northern side of Tor Bay, Torquay, Devon, England, United Kingdom (Lat. 58°28′ N, Long. 3°28′ W).

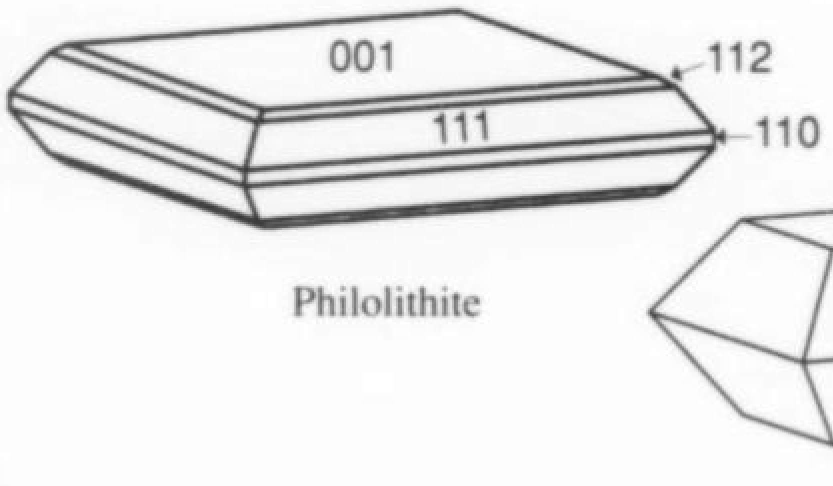
Occurrence: In calcite veins cutting limestones. Associated minerals are: calcite, gold (argentian and palladian varieties), fischesserite, clausthalite, a mineral similar to oosterboschite, two new compounds ($PdSe_2$ and Pd_2HgSe_3), tiemannite, eucairite, umangite, possibly mertieite II, cerussite, and bromian chlorargyrite.

General appearance: Composite grains of anhedral crystals from a few to several hundred microns.

Physical, chemical and crystallographic properties: *Luster:* metallic. *Diaphaneity:* opaque. *Color:* silvery grey. *Streak:* black. *Hardness:* VHN_{100} 395 kg/mm^2, Mohs about 5. *Tenacity:* slightly brittle. *Cleavage:* none mentioned. *Fracture:* none mentioned. *Density:* could not be determined, 8.31 g/cm^3 (calc.). ***Crystallography:*** Monoclinic, $P2_1/m$ or $P2_1$, a 6.350, b 10.387, c 5.683 Å, β 114.90°, V 340.0 Å^3, Z 2, a:b:c = 0.6113:1:0.5471. Morphology: no forms were observed. Twinning: polysynthetic twinning is characteristic of the mineral. ***X-ray powder diffraction data:*** 2.868 (50b), 2.742 (100), 2.688 (80), 2.521 (20), 2.367 (50), 1.956 (100), 1.918 (20), 1.829 (30). ***Optical data:*** In reflected light: very light buff to slightly grey-green, moderate anisotropism, weak bireflectance, slightly pleochroic. R_1, R_2; ${}^{im}R_1$, ${}^{im}R_2$: (39.7, 47.2; 26.2, 34.4 %) 470nm, (43.1, 48.8; 29.3, 35.15 %) 546nm, (44.3, 49.4; 30.4, 35.55 %) 589nm, (44.4, 49.2; 31.0, 35.6 %) 650nm. ***Chemical analytical data:*** Means of twenty-six sets of electron microprobe data: Cu 0.18, Pd 37.64, Ag 25.09, Se 36.39, Total 99.30 wt.%. Empirical formula: $(Ag_{1.99}Cu_{0.02})_{\Sigma 2.01}Pd_{3.03}Se_{3.95}$. ***Relationship to other species:*** None apparent.

Name: For Dr. Chris J. Stanley (1954–) of The Natural History Museum in London, in recognition of his contributions to ore mineralogy. ***Comments:*** IMA No. 96-044.

PAAR, W. H., ROBERTS, A. C., CRIDDLE, A. J., and TOPA, D. (1998) A new mineral, chrisstanleyite, $Ag_2Pd_3Se_4$, from Hope's Nose, Torquay, Devon, England. *Mineralogical Magazine* **62**, 257–264.



Philolithite

Philolithite — Tetragonal

$Pb_{12}O_6Mn(Mg,Mn)_2(Mn,Mg)_4(SO_4)(CO_3)_4Cl_4(OH)_{12}$

Locality: The Långban mines, Bergslagen ore district, Värmland, Sweden (Lat. 59.86° N, Long. 14.27° E). Three of the specimens are noted as coming from the Amerika workings and one specimen is from the Rämsorten drift, but the provenance of all other specimens is unknown.

Occurrence: In calcite-rich manganese oxide ore. Associated minerals are: calcite, braunite, hausmannite, native lead, a litharge-like phase, pyrochroite, manganoan phlogopite, hydrocerussite, and rare allactite.

General appearance: Crust-like overgrowths on lead, fissure fillings, and euhedral crystals (up to 0.3 mm on edge).

Physical, chemical and crystallographic properties: *Luster:* adamantine. *Diaphaneity:* not given but appears to be transparent to translucent. *Color:* pale to medium apple-green. *Streak:* white. *Luminescence:* non-fluorescent. *Hardness:* 3 to 4. *Tenacity:* brittle. *Cleavage:* none obvious. *Fracture:* conchoidal. *Density:* could not be measured, 6.05 g/cm^3 (calc.). ***Crystallography:*** Tetragonal, $P4_2/nnm$, a 12.627, c 12.595 Å, V 2008 Å^3, Z 2, c:a = 0.9975. Morphology: forms, {001} and {111}; also probably {110} and {112}, but these could not be measured optically. Twinning: sector twinning noted. ***X-ray powder diffraction data:*** 8.95 (20), 7.30 (20), 3.99 (30), 2.975 (100), 2.752 (30), 2.473 (20), 1.716 (20). ***Optical data:*** Anomalously biaxial (+), 2V ≈ 60°, indices of refraction greater than 1.92, but could not be measured because crystals decompose in high index liquids; very weak pleochroism, pale green to pale yellow-green. ***Chemical analytical data:*** Means of three sets of electron microprobe data: PbO 75.0, MnO 9.0, MgO 2.2, SO_3 1.7, CO_3 3.0, H_2O (3.0), Cl 4.1, sum 99.9, less O = Cl 0.9, Total 99.0 wt.%. H_2O deduced from the crystal structure analysis. Empirical formula: $Pb_{12.42}Mn_{4.69}Mg_{2.02}(SO_4)_{0.78}(CO_3)_{4.12}Cl_{4.27}$-$OH_{12.31}O_{6.72}$. ***Relationship to other species:*** Related to the lead oxychloride "family."

Name: From the Greek *philos* (= loving, friendly toward) and *lithos* = stone) "in honor of the Friends of Mineralogy, Inc. and in recognition of the friends and lovers of minerals everywhere who enthusiastically and with great zeal offer (and give) their help to the mineralogical community." ***Comments:*** IMA No. 96-020. The paper also includes some information on the crystal structure. The drawing of the stout crystal for this abstract was produced from the crystal data and an SEM image in the paper.

KAMPF, A. R., MOORE, P. B., JONSSON, E. J., and SWIHART, G. H. (1998) Philolithite: A new mineral from Långban, Värmland, Sweden. *Mineralogical Record* **29**, 201–206.

Phosphogartrellite — Triclinic

$PbCuFe^{3+}(PO_4)_2(OH,H_2O)_2$

Locality: The type locality is about 200 meters south of Hohenstein, near Reichenbach, Odenwald, Germany (map coordinates r: 3479140 h: 5508000, topographic map sheet TK 6218). A second occurrence is approximately 700 meters south of the center of Gadernheim, Odenwald, Germany (map coordinates r: 3481300 h: 5508150, topographic map sheet TK 6218).

Occurrence: In a silicified barite vein. Associated minerals are: hentschelite and malachite.

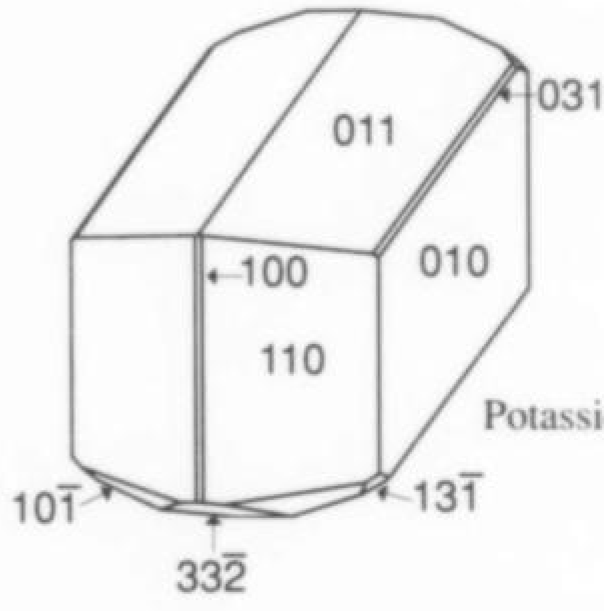
General appearance: Crystal aggregates (up to 0.2 mm) of individual crystals (less than 50 µm).

Physical, chemical and crystallographic properties: *Luster:* vitreous to adamantine. *Diaphaneity:* transparent in small fragments. *Color:* bright green. *Streak:* yellow. *Luminescence:* non-fluorescent. *Hardness:* 4½. *Tenacity:* not mentioned. *Cleavage:* none observed. *Fracture:* not mentioned. *Density:* could not be determined, 5.05 g/cm^3 (calc.). ***Crystallography:*** Triclinic, $P\bar{1}$, a 5.320, b 5.528, c 7.434 Å, α 67.61°, β 69.68°, γ 70.65°, V 184.5 Å^3, Z 1, a:b:c = 0.9624:1:1.3448. Morphology: no forms could be identified. Twinning: none observed. ***X-ray powder diffraction data:*** 4.720 (67), 4.502 (61), 4.360 (100), 3.250 (70), 3.138 (57), 2.885 (89), 2.868 (69), 2.459 (53). ***Optical data:*** Biaxial (+), α 1.90, β 1.93 (calc.), γ 2.00, 2V(meas.) 70°;

no distinct dispersion observed; no distinct pleochroism observed; Y is almost perpendicular to the tabular face of the crystals. ***Chemical analytical data:*** Means of twelve sets of electron microprobe data: CaO 0.20, CuO 14.41, PbO 39.02, Fe_2O_3 14.14, P_2O_5 22.05, As_2O_5 4.58, H_2O (4.83), Total (99.23) wt.%. Water was calculated from the ideal formula. Empirical formula: $(Pb_{0.99}Ca_{0.02})_{\Sigma 1.01}Cu_{1.02}Fe^{3+}_{1.00}[(PO_4)_{1.76}(AsO_4)_{0.23}]_{\Sigma 1.99}$-$[(OH)_{1.09}0.97H_2O]_{\Sigma 2.06}$. ***Relationship to other species:*** The phosphate-dominant analogue of gartrellite.

Name: For the relationship with gartrellite. ***Comments:*** IMA No. 96-035. Note that the mineral gartrellite has been redefined with the new chemical formula $Pb(Cu,Zn)(Fe^{3+},Zn,Cu)$-$(AsO_4)_2(OH,H_2O)_2$. That and the formula for gartrellite have been changed slightly from those given by the authors after consultation with Dr. Krause.

KRAUSE, W., BELENDORFF, K., BERNHARDT, H.-J., and PETITJEAN, K. (1998) Phosphogartrellite, $PbCuFe^{3+}(PO_4)_2$-$(OH)\cdot H_2O$, a new member of the tsumcorite group. *Neues Jahrbuch für Mineralogie, Monatshefte* **1998**, 111–118. KRAUSE, W., BELENDORFF, K., BERNHARDT, H.-J., McCAMMON, C., EFFENBERGER, H., and MIKENDA, W. (1998) Crystal chemistry of the tsumcorite-group minerals. New data on ferrilotharmeyerite, tsumcorite, thometzekite, mounanaite, helmutwinklerite, and a redefinition of gartrellite. *European Journal of Mineralogy* **10**, 179–206.



Potassicpargasite

Potassicpargasite

Monoclinic

$(K,Na)Ca_2(Mg,Fe,Al)_5(Si,Al)_8O_{22}(OH,F)_2$

Locality: Probably from Pargas, Turku-Pori, Finland (see comments).

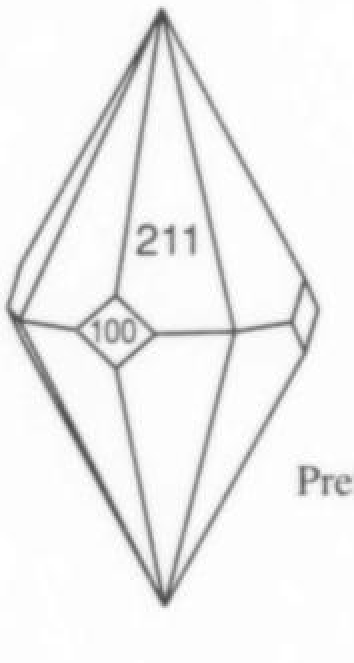
Occurrence: From a metasomatic or skarn-type deposit. The only associated mineral is calcite.

General appearance: Euhedral crystals (up to 2 x 1 x 0.7 cm).

Physical, chemical and crystallographic properties: *Luster:* not given, but probably vitreous. *Diaphaneity:* opaque, but translucent in thin splinters. *Color:* black. *Streak:* brownish green. *Luminescence:* non-fluorescent. *Hardness:* Mohs 6 to 6½. *Tenacity:* brittle. *Cleavage:* {110} perfect. *Fracture:* conchoidal to uneven. *Density:* 3.25 g/cm³ (meas.), 3.25 g/cm³ (calc.). ***Crystallography:*** Monoclinic, C2/m, a 9.9199, b 18.0591, c 5.3180 Å, β 105.36°, V 918.65 Å³, Z 2, a:b:c = 0.5493:1:0.2945. Morphology: forms, dominant {110}, {011}, {010}; minor {100}, $\{10\bar{1}\}$, {0kl} (probably {031}), $\{hk\bar{1}\}$ (possibly $\{13\bar{1}\}$), $\{hh\bar{l}\}$ (possibly $\{33\bar{2}\}$). Twinning: none mentioned. ***X-ray powder diffraction data:*** 8.45 (95), 3.283 (45), 3.140 (100), 2.707 (35), 2.344 (70), 2.018 (35), 1.652 (40). ***Optical data:*** Biaxial (–), α 1.654, β 1.664, γ 1.670, 2V(meas.) 79°, 2V(calc.) 75°; dispersion none; pleochroism X = pale gray-green, Y = olive green, Z = dark olive green; X ∧ a = 40° (in obtuse angle β), Y = b. ***Chemical analytical data:*** Means of five sets of electron microprobe data: Na_2O 1.55, K_2O 2.83, MgO 11.86, CaO 12.33, MnO 0.16, FeO 11.00, Al_2O_3 13.13, Fe_2O_3 2.20, SiO_2 41.63, TiO_2 0.87, H_2O 0.90, F 1.78, sum 100.24, less O = F 0.75, Total 99.49 wt.%. Empirical formula: $(K_{0.54}Na_{0.44})_{\Sigma 0.98}$-$(Ca_{1.99}Na_{0.01})_{\Sigma 2.00}(Mg_{2.66}Fe^{2+}_{1.38}Al_{0.59}Fe^{3+}_{0.25}Mn^{2+}_{0.02})_{\Sigma 5.00}(Si_{6.26}Al_{1.74})_{\Sigma 8.00}$-$O_{22.00}[(OH)_{0.90}F_{0.85}O_{0.25}]_{\Sigma 2.00}$. ***Relationship to other species:*** A member of the amphibole group.

Name: From the new (1997) amphibole nomenclature. ***Comments:*** IMA No. 94-046. The Finnish locality is listed as "probably" because the original label referred to the specimen as "hornblende" from Franklin, New Jersey. However, the authors found that the amounts of Mg, Fe, Mn, and Sr in the calcite matrix of the type specimen were much closer to the amounts of those elements found in Pargas calcite than to those in calcite from the Franklin orebody and Franklin marble. Note that the modifier "fluorian" could be applied to this species. The authors kindly supplied the SHAPE data from which I was able to reproduce their crystal drawing for this abstract.

ROBINSON, G. W., GRICE, J. D., GAULT, R. A., and LaLONDE, A. E. (1997) Potassicpargasite, a new member of the amphibole group from Pargas, Turku-Pori, Finland. *Canadian Mineralogist* **35**, 1535–1540.



Pretulite

Pretulite

Tetragonal

$ScPO_4$

Locality: The type locality is 100 m southwest of Höllkogel, which is 12 km south-southwest of Mürzzuschlag, Fischbacher Alpen, Styria, Austria (Lat. 47°30′56″ N, Long. 15°37′25″ E, 1020 m above sea level). The mineral has been found at other localities in the area including Fürstenbauer, Pretulalpe, Styria, Austria.

Occurrence: In lazulite-quartz veins in phyllite-micaschist. Associated minerals are: lazulite, fluorapatite, chlorapatite, quartz, muscovite, clinochlore, paragonite, kyanite, pyrophyllite, augelite, wardite, hydroxylherderite, goyazite, florencite-(Ce), xenotime-(Y), bearthite, rutile, pyrite, corundum, and an AlO(OH)-phase.

General appearance: Bipyramidal crystals (up to 60 x 60 x 120 μm).

Physical, chemical and crystallographic properties: *Luster:* adamantine. *Diaphaneity:* transparent. *Color:* pale pink. *Streak:* white. *Luminescence:* weak orange fluorescence in short-wave UV (254 nm) and bright blue cathodoluminescence. *Hardness:* about 5. *Tenacity:* brittle. *Cleavage:* {100} perfect. *Fracture:* splintery. *Density:* could not be determined, 3.71 g/cm³ (calc.). ***Crystallography:*** Tetragonal, $I4_1/amd$, a 6.589, c 5.806 Å, V 252.1 Å³, Z 4, c:a = 0.8812. Morphology: forms, {211} dominant, {100} small, {111} rounded; see Comments. Twinning: none observed. ***X-ray powder diffraction data:*** 3.293 (100), 2.4636 (42), 2.1777 (14), 2.0546 (14), 1.6927 (45), 1.3697 (15). ***Optical data:*** Uniaxial (+), ω 1.790, ε 1.86, nonpleochroic. ***Chemical analytical data:*** Means of fifty sets of electron microprobe data: Sc_2O_3 47.38, Y_2O_3 1.45, P_2O_5 50.02, Total 98.85 wt.%. Empirical formula: $(Sc_{0.98}Y_{0.02})_{\Sigma}(PO_4)_{1.00}$. ***Relationship to other species:*** The scandium-dominant analogue of xenotime-(Y).

Name: For the mountain Pretul one of the localities at which the mineral occurs. ***Comments:*** IMA No. 96-024. The forms {211} and {111} are ditetragonal bipyramids. The crystal drawing produced for this abstract is highly idealized and shows the fully developed forms {211} and {100}. It has been approved by Dr. Bernhard, who informed me that the crystals are usually distorted and do not always show all the faces of the {211} form or show them of unequal size.

BERNHARD, F., WALTER, F., ETTINGER, K., TAUCHER, J., and MEREITER, K. (1998) Pretulite, $ScPO_4$, a new scandium mineral from the Styrian and Lower Austrian lazulite occurrences, Austria. *American Mineralogist* **83**, 625–630.

Tschörtnerite Cubic

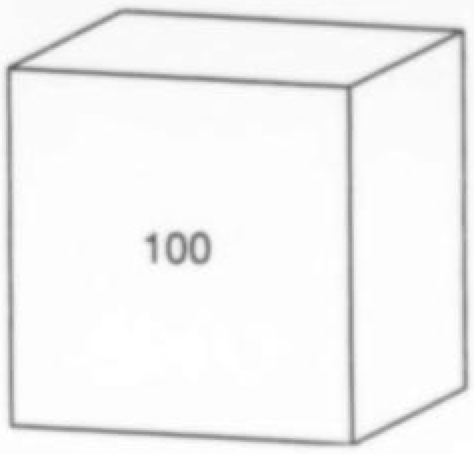
$Ca_4(Ca,Sr,K,Ba)_3Cu_3(OH)_8(Si_{12}Al_{12}O_{48})\cdot xH_2O$ x ≥ 20

Locality: The Bellberg volcano (Bellerberg on older maps), near Mayen, in the Lacher See volcano area, Eifel, Germany.

Occurrence: In fragments of a calcium-rich xenolith in leucite tephrite lava. Associated minerals are: chalcopyrite, cuprite, willhendersonite, phillipsite, gismondine, strätlingite, and bellbergite.

General appearance: Isolated cubes (up to 0.15 mm) and, rarely, as parallel intergrowths.

Physical, chemical and crystallographic properties: *Luster:* vitreous. *Diaphaneity:* transparent. *Color:* light blue. *Streak:* pale blue. *Luminescence:* non-fluorescent. *Hardness:* VHN_{30} 350 kg/mm^2, Mohs 4½. *Tenacity:* not mentioned. *Cleavage:* no distinct cleavage. *Fracture:* conchoidal. *Density:* 2.1 g/cm^3 (meas.), 2.00 g/cm^3 (calc.). ***Crystallography:*** Cubic, $Fm\bar{3}m$, a 31.62 Å, V 31614 Å^3, Z 16. Morphology: forms, only {100} was observed. Twinning: none observed. ***X-ray powder diffraction data:*** (calculated); 18.256 (100.0), 15.810 (23.5), 9.128 (7.7), 3.863 (3.1), 3.471 (2.1), 2.887 (2.0). ***Optical data:*** Isotropic, n 1.504. ***Chemical analytical data:*** Means of thirteen sets of electron microprobe data: K_2O 1.37, CaO 13.10, CuO 9.64, SrO 4.49, BaO 1.93, Al_2O_3 25.21, Fe_2O_3 0.30, SiO_2 30.25, H_2O (13.71), Total (100.00) wt.%. Water calculated by difference from 100 %. Empirical formula: $Ca_{4.00}(Ca_{1.56}Sr_{1.03}K_{0.69}Ba_{0.30})_{\Sigma 3.58}Cu_{2.88}(OH)_{9.50}(Si_{11.99}Al_{11.77}O_{48.00})\cdot 13.86H_2O$. ***Relationship to other species:*** A member of the zeolite group.



Tschörtnerite

Name: For Jochen Tschörtner (1941–) the mineral collector who found the mineral. ***Comments:*** IMA No. 95-051. Although only about 14 H_2O molecules appear in the empirical formula, the crystal structure indicates the true amount to be approximately 20 molecules.

EFFENBERGER, H., GIESTER, G., KRAUSE, W., and BERNHARDT, H.-J. (1998) Tschörtnerite, a copper-bearing zeolite from the Bellberg volcano, Eifel, Germany. *American Mineralogist* **83**, 607–617.

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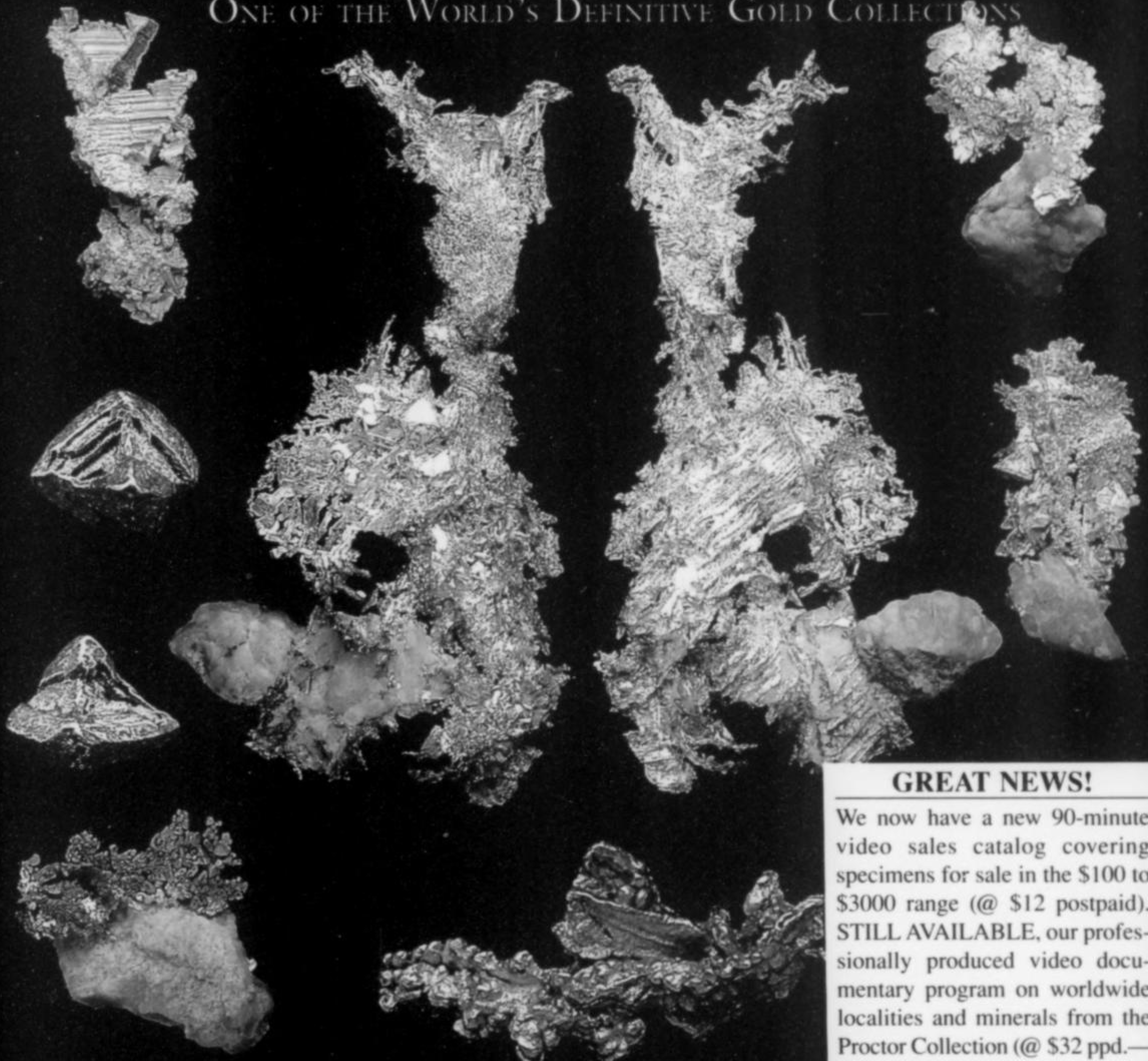

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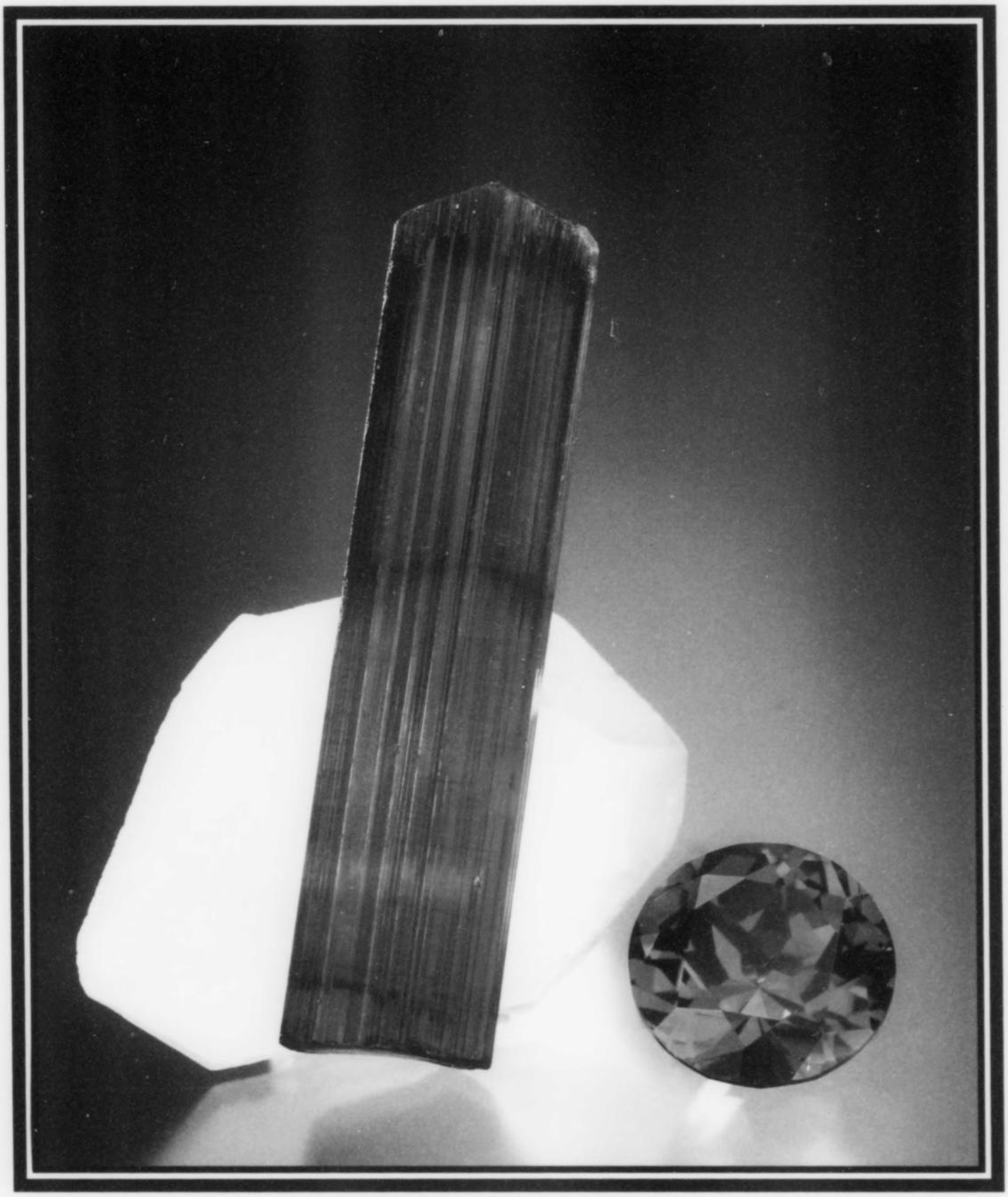

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