the Mineralogical Record

Volume Fifteen, Number Four
July-August 1984 $5.00


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photo by Harold and Erica Van Pelt, Los Angeles

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See Vol. 15, no. 4, p. 195, or write for copy.

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COVER: NEPTUNITE crystal 4.5 cm long, on white natrolite from the Dallas Gem mine, San Benito County, California. For more on this locality see vol. 8, no. 6, p. 442–452. Collection of Wayne and Dona Leicht; photo © 1984 by Harold and Erica Van Pelt, photographers, Los Angeles.

notes from the EDITOR

Every couple of months I check my "Notes from the editor" file to see what has accumulated lately that might be of interest to our readers. Typically the column ends up running about a page in length, sometimes less. This time, however, my file runneth over, not only with internal news but also with notes on new journals, new societies, new publications available, a photo competition, and notices on the passing of some important people from our field.

LEATHER FANCIERS TAKE NOTE

The number of high-quality collectors' editions published in the field of mineralogy has been remarkably small over the years. In fact, the only recent example I can think of is the special leather edition of John Sinkankas's *Emerald and Other Beryls.* Numbering about 50 copies and priced at $125 in 1981, it sold out promptly (despite almost no advertising) and left many more people wanting one. It seems as if almost everything else of collector quality is *old.* Why should this be? Probably because most modern publishers operate on such a large scale that they can't be bothered with small specialty editions. That, of course, is a malady we don't suffer from here at the *Mineralogical Record;* consequently we are planning to produce some special editions of our own, and fill this gap for book lovers.

Special editions carry a number of advantages. For one thing, they are much more likely to be preserved and protected over future years. And they are items which we can take particular pride in, and which the lucky owners can be proud of too. Finally, of course, we make a few extra dollars but, being a non-profit corporation, we limit our margin. In most cases I like to think that the bulk discount we receive for having 50 or 100 or 300 copies bound at once, combined with the pro-rated cost of custom dies and artwork, will allow us to sell such volumes for less than the private individual would pay for a single copy bound that way, despite our markup. And the buyer will benefit further because publishers' editions have collector value and appreciation far beyond private rebindings.

Our first venture into this field is not widely known, and is already sold out. We had a special edition of the five Arizona issues prepared, primarily for sale to contributing authors, photographers, specimen owners, financial benefactors and board members who were somehow involved in the production of the Arizona issues. It has a new title page, comprehensive contents page, specimen photo index, a dedication page (numbered edition of 100 copies only), facsimile reprints of 1881 maps of northern and southern Arizona for end-papers, etc. We ended up with 17 copies left unclaimed, which sold out almost immediately at our booth at the Tucson Show when we offered them to the general public.

The second entry is the special edition of Peter Bancroft's *Gem & Crystal Treasures,* consisting of 300 numbered and signed copies (nearly half of which are already spoken for).

We plan to maintain a mailing list of people interested in such things . . . call it the *Leather Edition Club.* People who purchased the Arizona edition or the Bancroft edition are automatically members. Anyone else who is interested can get his or her name on the list simply by writing to me at the editorial office. Then, when another leather edition is planned or is ready, it will be offered first to members of the Leather Edition Club. Remaining copies, if any, will be offered through our Book Department ad and at our show tables. Notice of publication will later be printed in the *Mineralogical Record* for historical purposes, as evidence that these are official publisher's editions limited to a certain number of copies.

This arrangement has several advantages for all concerned. We need not employ saturation advertising if we can reach the few hundred book-fanciers directly. In addition, if we are wondering about the desirability of a particular project, we can easily poll the members by mail for their feedback and suggestions. We can send out detailed descriptions running to greater length than would be reasonable in the magazine. And we can contact members promptly, when necessary, instead of having to wait for publication of a notice in the next issue of the magazine.

We're excited about this new expansion for the Mineralogical Record, and are looking forward to producing some truly beautiful examples of the bookbinder's art. Let me know if you're interested in receiving mailings about future projects.

BOUND VOLUMES OF *MINERALOGICAL RECORD*?

Here is a subject on which we'd like some feedback from readers. It has occasionally been suggested that we offer complete bound volumes at the end of each year, as many other publications do. This relieves the subscriber of the task of looking about for a good bindery, learning enough details about binding procedures and alternatives to know what to ask for, and of packaging up and mailing off each year's-worth of issues. We could extend the service, as some journals do, to binding in identical fashion *earlier published* volumes of the *Mineralogical Record* which the subscriber owns and would ship to us. That way, though we might start the service in 1984, a collector could conceivably have a complete set (if he owns one to start with) bound by us, and not just the volumes beginning with 1984.

Could a subscriber send us *back* the six issues he received individually by mail during 1984, and have us bind those instead of sending him a *new* set bound? Certainly, but the cost would have to be about the same in either case, so it would pay the subscriber to keep his used copies for everyday use as a back-up set.

We need your advice on this. Would it be a service to our readers to offer bound volumes and back-issue binding? Would *you* sign up for a 1984 bound volume if we offer it? A fair amount of work would be involved for us to set this up . . . we'd want to have custom dies made for gold stamping, and would probably have custom end-papers printed. Also, at what level of quality (and therefore cost) should we design this binding? Simple buckram (paint-impregnated cloth)? Leather binding (available in a wide range of leather types, qualities and costs)? Perhaps *both*? Send your suggestions to:

Wendell E. Wilson, Editor & Publisher
Mineralogical Record
4631 Paseo Tubutama
Tucson, Arizona 85715

THE *RECORD* LIBRARY

I'm pleased to say that, thanks to the generous donations of a number of people, the *Mineralogical Record*'s reference library now contains essentially complete sets of *Lapidary Journal, Rocks and Minerals,* and *The Mineralogist.* In fact, we received an extra donation of a set of *Lapidary Journal,* and the donor is content for us to resell it. Interested parties should give me a call.

We still need vol. 1–38 of the *American Mineralogist,* and would be happy to receive donations of a number of other journals including *Gems & Gemology, The Mineral Collector, Mineralogical Magazine* and *Canadian Mineralogist.*

Our special thanks to those who have recently contributed library materials: Clifford Older, Dan Behnke, Glenn Elsfelder, Veryle Carnahan, Frank Melanson, Peter Bancroft, Leonard Morgan, Karl and Anne Vossbrinck, Ethel Glenn, Carl Krotki, Carlton Holt and Eric Elliott.

WE'RE *BUYING* BOOKS

The Board of Directors of the Mineralogical Record, Inc. agreed recently that building the reference library should be a priority. Accordingly they have approved a budget for the purchase of books and journals, and for binding as necessary. If you have rare or useful mineral-oriented books or journals which you would be willing to sell, please let us know. Offers from bookdealers worldwide are welcome, and we would particularly like to receive lists from bookdealers. All offers should include price (please do not ask us to "make an offer").

FINE MINERAL ART

I spoke with Frank Chambers recently, who is a book dealer and operates under the company name of *Francis Paul* (50 Church Street, Hoosick Falls, NY 12090). Frank deals largely in professional journals and geology publications, but also in mineralogy material, and has a current stock of around 50,000 items. He is currently advertising in the *Mineralogical Record* an item entitled *Minéraux,* which is a new French edition of *Mineralien* (German, 1969). The German edition has been impossible to obtain for many years, and the most people can usually find are a few loose sheets from the 162-print set. It's a magnificent collection of individual, unbound framing prints (a stack almost 5 cm tall), in color, of mineral specimen paintings by the German artist Claus Caspari. These are perhaps the finest examples of mineral art ever published, and a complete set is certainly worth having. The text is on the back of each print and does not show when the prints are framed, so it really doesn't matter which language it's in. There's no telling how long this French edition will remain in print . . . this could be the last opportunity to obtain a mint set of a true classic. I purchased my own set of the German edition almost ten years ago for $75, so the current price of $112 postpaid seems very reasonable.

BRITISH JOURNALS MERGE

The British journal *Gems,* now in its sixteenth volume, has merged with the more mineral-oriented British journal *Mineral Realm* to form a new publication: *Gems and Mineral Realm. Gems* catered partially to mineral collectors, but *Mineral Realm* was founded in 1981 as a response to the increasing number of British mineral collectors. Together they hope to achieve wider circulation and better coverage of collecting sites in the British Isles. The magazine is published four times a year, in a 15 x 21-cm format containing 64 pages and a modest amount of color photography. For American readers it has the very great virtue of being in English, and also of providing better access to British dealers who cannot afford to advertise internationally.

Some of the original *Mineral Realm* back issues are still available from David R. Neal, 27 Lower Meadow, Harlow, Essex, CM18 7RD, England. Sample copies of the new publication are available at £1.25 per copy (seamail postpaid), and four-issue yearly subscriptions at £5 (seamail postpaid) and £9 (overseas airmail postpaid), from The Randal Press Ltd., 9 Kennet Road, Crayford, Kent DA1 4QN England. Payment from the U.S. must be made by International Postal Money Order in £ sterling.

CHECKLIST FOR AUTHORS

All authors should take note of the following guidelines, particularly inasmuch as there have been some recent changes (noted by an asterisk*). Adhering to these guidelines will reduce the amount of time required to process your article through to publication.

1. Paper. All manuscripts must be submitted on 21.6 x 28-cm paper (8½ x 11 inches). Foreign authors please cut your paper down to this size . . . our files are not designed for larger sheets.

2. Typing. All manuscripts must be typed. Be sure to double-space all type, including references and figure captions. The first line of each new paragraph should be indented.

3. Word processors. Please do not submit manuscripts printed on non-letter-quality printers.*

4. Extra copies. Submit all manuscripts in triplicate.* Photos and figures may be submitted as one set of originals and two sets of photocopies.

5. References. References list must be typed according to standard *Mineralogical Record* format. See published articles for examples. Remember to give all journal titles in full . . . no abbreviations. Capitalize authors' names. Underline book titles and journal titles.

6. Photographs. Photos must be submitted loose, in numbered envelopes. Do not tape or glue photos, and do not write on the front or back of photos; doing so can ruin them for publication.

7. Measurements. All measurements should be given in metric units* except for historical purposes, direct quotes from other sources, parenthetical conversions for emphasis or clarity, and proper names.

8. Credits. Photos of specimens should be accompanied by caption data including name of the photographer, name of the specimen owner, size of the specimen, and color of the specimen (if the photo is in black and white).

9. Reservation. Please contact the editor before you progress very far, and reserve your article topic. It is not uncommon for duplication and wasted effort to occur when two authors unknown to each other begin working on identical articles. It may seem unlikely, but it has happened repeatedly. By contacting the editor you can also obtain suggestions and assistance in various ways which will benefit your article.

10. Reprints. About 50 reprint copies of each article are available to the senior author, but these *must be requested, in writing, following publication, from the Circulation Manager** or they will not be sent.

11. Page Charges. If your funding institution has a budget for page charges, please let us know. Our rate in such cases is $35 per page. Where no funding is available, there is no charge.

MINERALOGICAL SOCIETY OF MEXICO

The Geological Society of Mexico is the oldest professional earth science society in North America, having been formed during the 1700s. Mineralogy, however, was always a stepchild of that society, and never received the full organizational support which it needed. As a result, there has never been a real clearing-house for information and research regarding Mexican mineralogy and mineral localities; data has been scattered to the four winds, and the difficulty of pulling it back together for any particular purpose now represents a significant barrier to historical research.

At long last the need for a national society is being met, with the formation of the Mineralogical Society of Mexico (Sociedad de Mineralogico de Mexico). The society will publish a bulletin, and will accept articles in any language for translation and publication. Although the articles will be published in Spanish, there will be abstracts in other languages and, in any case, technical Spanish is not that difficult to muddle through. The goals of the society are, in particular, to foster the study of locality mineralogy and specimen mineralogy in Mexico. The newly elected President of the society is the well-known collector Miguel Romero (Apartado Postal 151, Tehuacan, Puebla, Mexico), and the membership secretary is William Panczner (640 N. La Cholla Blvd., Tucson, AZ 85745). Dues have not yet been established as I write this, but probably will have been by publication time. Interested readers should contact Panczner or Romero for more information.

UTAH COLLECTORS UNITE!

I recently received vol. 1, number 1 of *Crystalith,* the newsletter for the recently formed *Mineral Collectors of Utah* organization. It contains news and notes, book reviews, classified ads and display ads . . . looks interesting. I would imagine that collectors in adjacent states might also benefit from membership and increased contact with their brethren across the state border. Write to Mineral Collectors of Utah, P.O. Box 253, Sandy, UT 84091.

HOUSTON PHOTO COMPETITION

Aspiring mineral photographers wishing to test their mettle against each other are invited to submit their best work for the Houston Gem & Mineral Show Photo Competition. The deadline is September 12. Rules are as follows:

1. Amateurs and professionals are eligible.
2. Standard 35-mm slide mounts only, photographer's name marked on the mount.
3. Limit of two slides per entrant.
4. Include stamped, self-addressed envelope.
5. Include separate list showing mineral name, locality, photographer's name, address and phone number.
6. Mail entries to Ed Raines, 11902 Queensbury, Houston, Texas 77024.
7. Entries will be judged on the basis of subject, photographic skill and popular appeal.
8. Entrants by entering agree not to hold the Houston Gem & Mineral Show liable for loss or damage to entries.

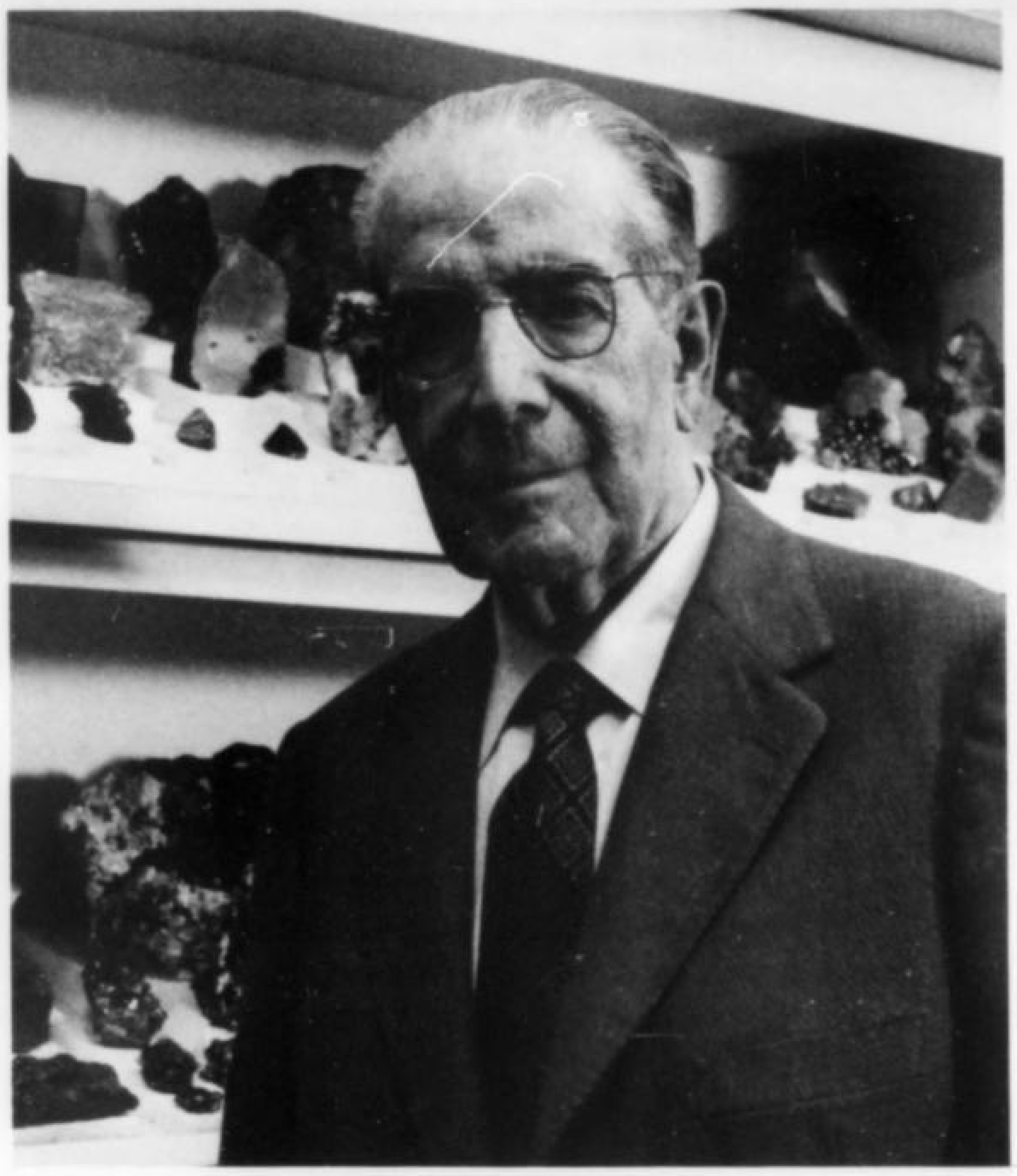
NOTICES

Died, Joaquín Folch y Girona, 91, in Barcelona, Spain. Señor Folch, as he was generally known, was until the time of his death the leading private collector of mineral specimens in Spain. His large and superb collection, currently numbering more than 13,000 specimens, was described in the *Mineralogical Record* by Arthur Montgomery (vol. 2, p. 14, 32–34).

Folch was born in Barcelona in 1892. He entered the School for Industrial Engineering in 1909, and received his Doctoral degree in engineering in 1916. Throughout his professional life he worked in the chemical industry, involved with the manufacture of alcohol, paints, varnishes, printing inks, and other chemicals, and also flour and ice.

When his father died in 1918, Folch, at the age of 26, assumed control of the family business. He directed the electrification of various Spanish mine shafts and facilities near Tarragona, Almadén, and other areas. Becoming prominent in these industries, he was awarded a number of medals and other honors.

He pursued his great hobby, mineralogy, for 81 of his 91 years, beginning at the age of ten while visiting mining properties owned by his family. The first of his publications on mineral occurrences was published in 1912, and the last in 1977. While still a young man he was elected to the governing board of the Natural Sciences Museums of Barcelona, was elected Honorary President in Perpetuity of the Spanish Mineralogical Society in 1979, and held membership in many mineralogical societies including the Friends of Mineralogy.



Joaquín Folch-Girona
1892–1984

Not reluctant to travel, Folch attended many geological congresses and meetings at locations in Japan, Algeria, Copenhagen, London, France, Switzerland, Italy, Canada, Mexico City, and the United States. He was particularly fond of the U.S., visiting it often and attending the Tucson Gem and Mineral Show every year from 1955 (the first year of the show) to 1976. He was clear-headed to the end, working in his office regularly until last December and entertaining visiting mineral friends until the day before his death. His son reports that on that day he reminisced . . . "To recall my trips to the United States, its enormous and beautiful nature, my friends there, and the gem and mineral shows, particularly that of Tucson, with the gatherings from room to room in the various motels, sitting down to talk and bargain about mineral specimens, is one of the most pleasant feelings that I can experience now. Should the arthritis in my knees improve, I would still fly there once more."

Señor Folch's son, Alberto Folch-Rusiñol, has decided to retain his father's collection intact, continuing to exhibit it by appointment at the spacious museum facility which his father built for it in Barcelona. Those wishing to visit should write to him at Industrias Titán, S.A., Av. Bogatell, 29-47, Barcelona-5, Spain.

Died, Vincent P. Gianella, 97, in Auburn, California. Gianella was a mining geologist and 59-year member of the American Institute of Mining Engineers (AIME). He served as head of the Geology Department at the Mackay School of Mines, University of Nevada, Reno, and was a Professor Emeritus there for many years. Remaining active well into his 90s, he was a leading authority on the geology and mineralogy of the famous Comstock Lode, where he worked in many of the rich silver mines. He was involved in mining throughout the United States and, as a young man, took part in the Alaskan gold rush. Gianella was also one of the first mineralogists to visit Nevada's now-famous Majuba Hill deposit. He published dozens of professional papers, and was honored in 1977 by having the mineral *gianellaite* named for him.

the Sterling Mine
Antwerp, New York

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Famous as the first and foremost American locality for the nickel sulfide millerite, the Sterling mine has produced specimens for nearly 150 years. In the past few years, collecting activity has brought to light numerous specimens of pecoraite pseudomorphs after millerite, the bright green sprays looking quite as attractive as the original millerite. Although mining ceased over 70 years ago, the Sterling mine continues to be among the most productive of the classic collecting localities in the northeastern United States.

LOCATION

The Sterling mine is situated in the northwest corner of the Antwerp quadrangle in Jefferson County, New York. The water-filled open pit (Fig. 1) appears on current topographic maps as a pond surrounded by low hills, southeast of U.S. Route 11 between the road and Hawkins Creek. The mine and dumps may be reached on foot via an unimproved lane which intersects Route 11, 5.3 kilometers north of the intersection of Routes 11 and 26 in the village of Antwerp.

The Sterling mine lies in the center of a band of hematite deposits known as the Antwerp-Keene belt. According to Smock (1889) the deposits from southwest to northeast were the Colburn, Ward, Dickson, White and Old Sterling mines (owned by the Jefferson Iron Company); the Keene, Caledonia and Kearney mines (owned by the Rossie Iron Works); and the Clark and Pike mines (owned by the Gouverneur Iron Ore Company). Of these mines, only the Sterling and Caledonia appear to have produced any significant mineral specimens, and millerite has been found only at the Sterling mine.

HISTORY

The first working mine in the Antwerp-Keene belt was the Caledonia mine, located about 1.6 km southeast of Somerville in St. Lawrence County (Hough, 1853). Operations commenced there in 1812, and by 1815 the mine was furnishing ore for the famous Parish Iron Works in Rossie (Durant and Pierce, 1878). By 1825, the discovery of the Kearney mine a short distance north of the Caledonia had increased the supply of ore to the furnace at Rossie. In the next decade, more deposits were located nearby and the mineral rights secured. One such deposit was situated on an island in the middle of a swamp on the farm of Hopestill Foster, about 5 km north of Antwerp. In 1836, David Parish sold this property to James Sterling for the sum of $200, thus marking the beginning of the Sterling mine (Hough, 1854; Haddock, 1895).

James Sterling, a prominent businessman of his time, soon became known as the "Iron King of Northern New York," and in 1837 he formed the Sterling Iron Company with a working capital of $20,000. Ore was first hauled to his furnace at Sterlingville, and later to Sterlingburgh (Louisburgh), at a cost of 50¢ per ton. Using a charcoal and cold-air blast, pig iron was wrought at approximately 12 tons per week, and marketed as "Sterling Iron." A hot-air blast was introduced in 1838, and production continued. Horse-powered pumps were used to drain the water from the pit, and the ore was raised in horse-drawn wagons. In 1840, the Philadelphia Iron Company was organized, as were several other companies in subsequent years, and more furnaces were erected.

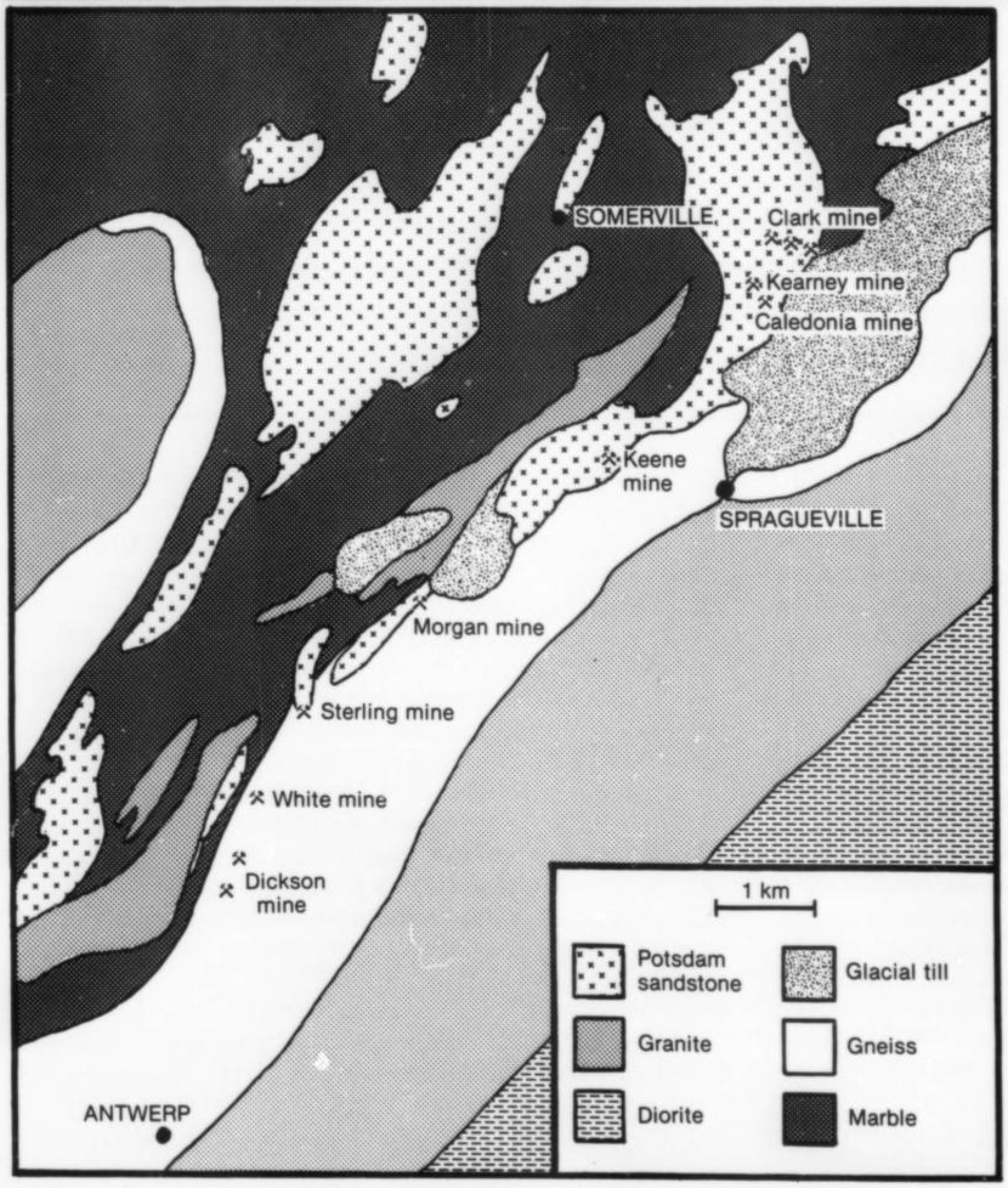


Figure 1. **Northern end of the water-filled open pit as it appeared September, 1983. The two islands show remnants of the cap of Potsdam sandstone. Photo by S. Chamberlain.**

Figure 2. **Geologic map of the Antwerp-Keene belt showing the location of the Old Sterling and other mines operated to exploit specular hematite orebodies. (Adapted from Buddington, 1934, and Newland, 1921).**

In 1852, James Sterling had attained sufficient wealth to purchase the entire village of Sterlingbush, and by the late 1850s the mine was being run chiefly by his brother, Samuel G. Sterling. In 1859, his son, A. P. Sterling, assumed title to the operations. James Sterling died in 1863, but his son continued to operate the mine until 1869, when it was sold to the Jefferson Iron Company in Antwerp (Emerson, 1898). Under the direction of Edward B. Bulkley, the Jefferson Iron Company incorporated many of the mines then working. Smock (1889) gives the following account of the operations:

> The open pit at the northeast is 115 feet deep and approximately 500 by 175 feet. The underground workings are south and southwest of it, and the ore has been followed for a distance of 900 feet, and to a depth of 185 feet. This deposit lies between the gneissic rocks on the southeast, 400 feet distant, and the sandstone (Potsdam) on the west side of the mine, but no walls have as yet been reached in the mine. A serpentine rock occurs with the ore, apparently without any order in its relations to it. The ore varies from a specular ore of metallic lustre and steel-gray shade of color to amorphous, compact masses of deep red. The crushed powder answers well as a paint, and stains deeply all with which it comes in contact. The ore stands up well, and, by leaving pillars, with arched roof in the galleries and drifts, no timbering is necessary. There is comparatively little water in the mine. The serpentine is not so firm as the ore, and is full of slickensided surfaces. Small mine cars are used on the narrow gauge tramways in the mine drifts. A skip track runs to the bottom of the open pit. A branch railroad three miles long, connects this mine and the Dickson with the main line of the R.W. & O. R.R., near Antwerp . . . .

By the 1880s many of the local furnaces had been abandoned, and most of the ore was shipped to Pennsylvania. Competition from the Mesabi Range in Minnesota, coupled with economic depression, gradually forced the closure of the mines in the belt. The Sterling mine was last worked between 1904 and 1910 and was the last operating mine in the district (Newland, 1921). Buddington (1934) estimates the total production of all these mines at 2.5 million tons, of which the Sterling mine and adjacent Dickson mine accounted for more than 750,000 tons (Smock, 1889).

The only mining activity to occur in recent years was a small-scale venture by the Rossie Iron Ore Company in the summer of 1942, with the ore being used to make iron-oxide pigments. In 1948 the Republic Steel Corporation conducted a diamond drilling program at the Caledonia and Sterling mines, but found that further development was unwarranted.

It is not precisely known when the Sterling mine first became known as an important source of mineral specimens, but by 1842 both Beck and Emmons made note of various crystallized species. The discovery of millerite, for which the locality is best known, may be credited to Franklin B. Hough, in 1848, marking the first reported occurrence of this mineral in the United States (Hough and Johnson, 1850).

Today the Sterling mine property is owned by Raymond Villeneuve. Permission to collect must be secured from Mr. Villeneuve

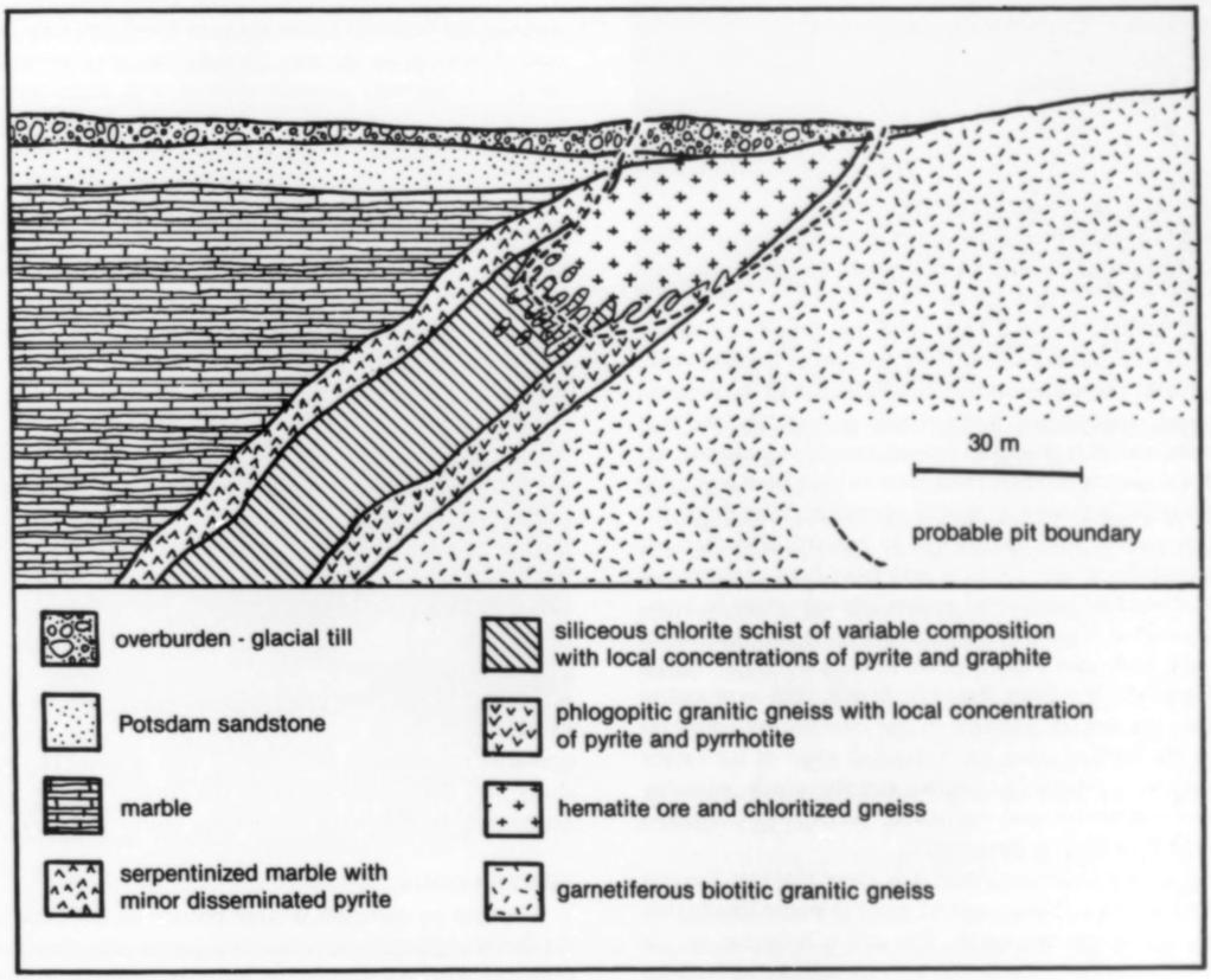


Figure 3. **Generalized hypothetical cross-section through the pit at the Sterling mine based on drill core data (Republic Steel Corporation). The section represents the view looking northeast along the strike.**

whose farm is on the east side of Route 11, approximately 1 km south of the old lane which leads to the mine. Good specimens (particularly micromounts) of all the species reported here can still be collected from the dumps.

GEOLOGY

The Sterling mine orebody is bounded by Grenville marble to the northwest, gneissic granite to the southeast, and is locally overlain unconformably by an outlier of the Potsdam sandstone (Fig. 2). The rock immediately adjacent to the ore is heavily chloritized and slickensided and forms an irregular and intimate contact with it (Emmons, 1842; Hough, 1853; Smyth, 1894a, b). This dark green chloritic rock appears to be an altered granite, and was observed by Smyth (1894a, b) to grade gradually and completely into pure granite in areas exposed in the mine workings. Buddington (1934) examined thin sections made by Smyth and concluded that "the evidence all confirms Smyth's conclusions as to the origin of the chlorite and sericitic schists through alteration and replacement of gneiss or granite." The ore itself contains open cavities with marked evidence of stalactitic and botryoidal deposition of hematite and quartz and subsequent crystallization or recrystallization of iron oxides, carbonates and silicates.

The origin of the orebody is uncertain. Earlier workers generally agreed that the ore originated in Precambrian times as a result of chemical replacement. However, the replacement of what, and by what, has been the subject of much debate (Smock, 1889; Smyth, 1894a, b; Crosby, 1902; Buddington, 1934). Emmons (1842) originally described the dark green chloritic rock as serpentine, and Shepard (1851) described it as a new mineral species, *dysyntribite*, which was later discredited by Smith and Brush (1853). Smyth believed that the ore resulted from the chemical action of iron-rich, acid solutions derived from the weathering of a nearby pyritic gneiss situated between the Grenville marble and granite gneiss. These solutions replaced the marble and altered the granite gneiss. Part of the iron was precipitated as carbonates and hydroxides, and the rest, along with calcium and magnesium from the marble, went into solution as sulfates, chloritizing the granite gneiss. Crosby, on the other hand, believed that the ore was originally a magmatic segregation of sulfides within a basic dike that underwent subsequent oxidation with accompanying chloritization of the dike rock.

Both the present and earlier studies conclude that all the deposits in the Antwerp-Keene belt are closely related geologically, and that whatever genetic model is proposed for one should in large part account for all. Geological processes that seem to have been operating at any given occurrence were probably operating throughout the belt. Hence, geological information lost to erosion, alteration, or general inaccessibility at one location may have been preserved at another, and should be considered potentially important in interpreting the geological history of all these deposits. Reexamination of core logs and geologists' reports (most notably by W. M. Sirola and E. F. Fitzhugh, Jr.) from Republic Steel's 1948 exploration program within the belt, in addition to our own mineralogical investigation at the Sterling mine, have clarified some of the earlier work and suggest a relatively complex history which probably began in the Precambrian and continued, perhaps in disjointed phases, into the Paleozoic or later times.

From the diamond drilling records it is clear that the Sterling mine is situated within a distinct unit of granitic gneiss locally rich in phlogopite, pyrite and pyrrhotite. The unit is bounded on the hanging wall by crystalline marble and by a garnetiferous, biotitic, granitic gneiss on the footwall (Fig. 3). It varies in thickness from 6 to approximately 30 meters, and becomes more siliceous, pyritic and graphitic to the north. Thus the presence of an altered basic dike as proposed by Crosby cannot be substantiated.

A complete and gradual chloritization of granite was observed in one of the cores, and the presence of unaltered phlogopite in many of the chloritized rocks in the dump leaves little doubt as to the validity of the model proposed by Smyth and Buddington regarding the origin of this rock. The abundant slickensides universally present in this rock may have developed from faulting, but considering their random, non-planar orientation, more likely resulted from volume changes during the chloritization process. At the same time, less ductile phases such as quartz and unaltered feldspars were probably sheared and brecciated.

Thus the sequence of events giving rise to the host rock are relatively well documented. However, the specific steps outlining the formation of the hematitic ores it hosts are much less obvious. Continued weathering of the pyritic schist may have provided some additional iron, but, considering the amount that was consumed by chloritization and the fact that the original schist may only have contained a maximum of 15-20% iron sulfides in localized bands, there would seem to be an additional source of iron required to account for the tonnages of oxide reported. Drill core data obtained at the Caledonia mine, a short distance north in the belt, help to resolve this problem.

At the Caledonia mine, numerous intersections were made through brecciated, basal (?) conglomerate zones composed of fragments of quartzite ± Potsdam sandstone ± altered pyritic schist, all cemented and replaced by hematite. Hematite seams were also encountered throughout the overlying Potsdam sandstone, and thin sections of sandstone collected *in situ* at the northwest end of the Sterling mine show clear evidence of hematite replacement. This is extremely significant because it not only proves that at least some of the hematite formed in post-Cambrian time, and is not entirely Precambrian, as once thought, but also extends the time interval for meteoric concentration of iron from external sources, perhaps even including the overlying sediments. In fact it may have been the infiltration of the overlying sands that rendered much of these ores uneconomical because of their high silica content.

At this point one should be reminded of the importance of time in geological history. Approximately 600 million years elapsed between the Grenville orogeny and the deposition of the Potsdam sandstone in the upper Cambrian, and about an equal amount of time has passed since. The first 600 million years of weathering and erosion succeeded in creating a vast peneplane that eradicated any record of events that many have been preserved in the eroded rocks. Such erosion and chemical weathering most certainly resulted in the development of Precambrian soils, karst features in the marble horizons, and perhaps bog iron formations in the lowlands. Next the region was buried in sediments of unknown total thickness at least through the Ordovician by the transgression of the Potsdam sea. Subsequent uplift commenced a second great erosional cycle that has continued to the present, again erasing much of the geological record. So much could happen in this time period that to know the precise "whats, hows, wheres and whens" is virtually impossible, and although we may observe and describe various features of these deposits, we can only speculate on the operative mechanisms and times of their origins. The results of this study and their implications in the context of the mineral paragenesis will be presented and further discussed below.

MINERALOGY

As might be expected, a large portion of the minerals found at the Sterling mine contain iron. The species of greatest interest to the collector occur in cavities in the hematite-quartz-carbonate ore. These cavities range in size from a few millimeters to over 25 centimeters across. Hough (1853, page 683) gives the following description:

> These red ores impart their color to whatever comes in contact with them, giving a characteristic tinge to every person and ob-

ject about the premises. They are never crystallized, but occur in every variety of lamellar, slaty, botryoidal, and pulverulent forms, and in some cases, cavities are found lined with beautiful and peculiar crystallizations of carbonate of lime, spathic iron, heavy spar, aragonite, quartz, iron pyrites, and more rarely cacoxene, or chalcodite, and millerite, the latter being the rarest and most beautiful of its associates. It occurs in brilliant needle-shaped crystals, radiating from a centre like the fibres of a thistledown, having the color and brilliancy of gold. Groups of crystalline specimens of these minerals often form objects of great beauty.

Although perhaps the best specimens were collected a century ago, there are extensive dumps at the Sterling mine which have not been heavily dug by collectors. Good micromounts are relatively abundant, and larger specimens may also be found, though cavities over 5 cm are not commonly encountered. Millerite is rather difficult to find, but a number of good micromounts and thumbnails have been recovered from the dumps since 1979. Siderite, quartz, dolomite, stilpnomelane and magnetite pseudomorphs after hematite are more readily available.

The individual descriptions which follow are for only those minerals occurring in the vugs in the hematite ore, since they are the ones of primary interest to collectors. Species found in the marble, granite gneiss and chloritic rock such as graphite, phlogopite, chlorites, etc., will not be discussed. These descriptions are based on the examination of several hundred specimens and, in general, only the more common habits and associations are noted. Chemical data, where given, were obtained by energy-dispersive electron microprobe analyses. The detection limit for the method used is estimated at approximately 0.25 weight % oxide for each element, and the data presented have been averaged unless noted otherwise.

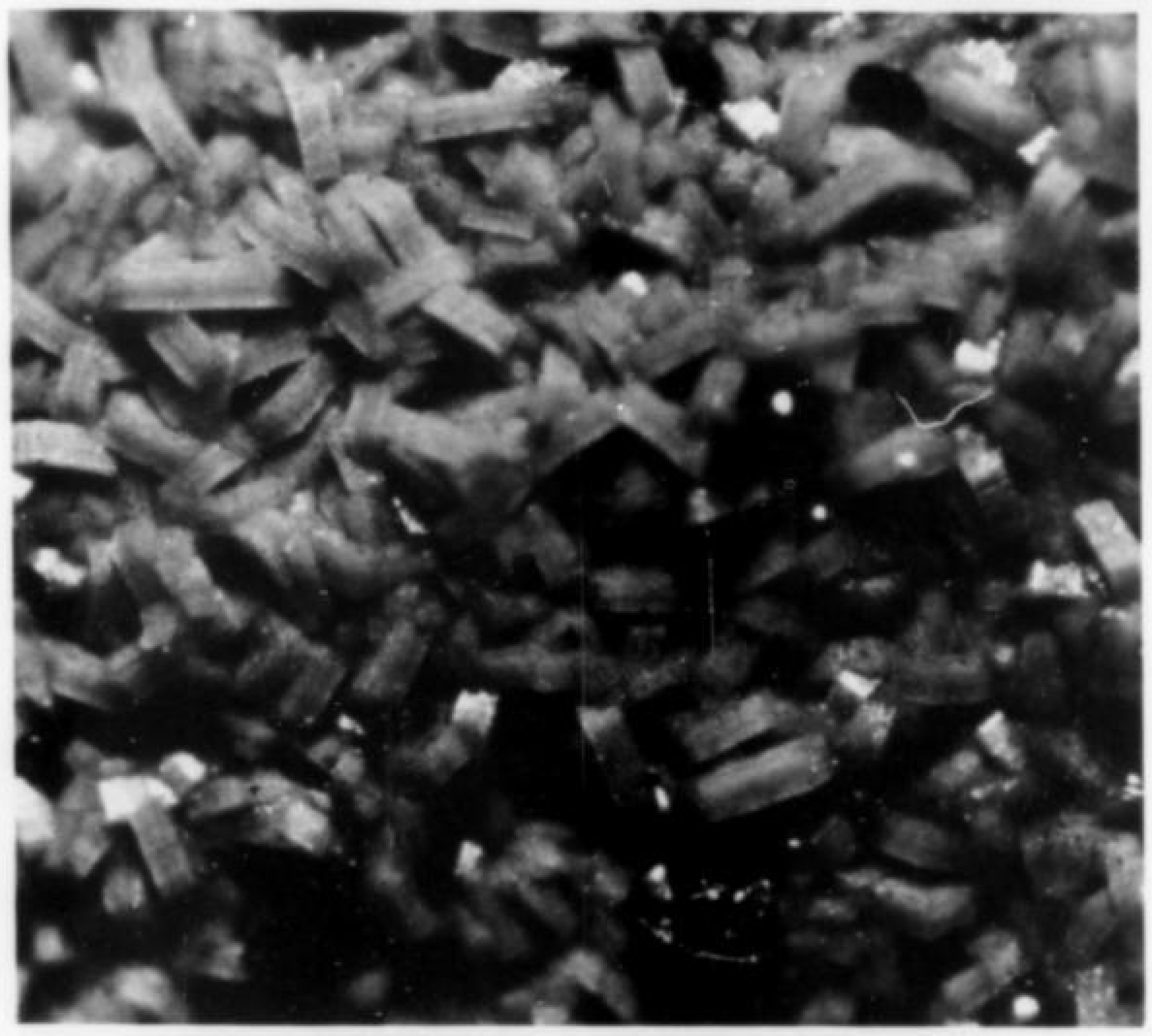


Figure 4. **Pink carbonate apatite crystals with black magnetite pseudomorphs after hematite crystals. The field of view is about 1.5 mm. Collection of Ron Waddell, Syracuse, New York. Photo by S. Chamberlain.**

Apatite group

Apatite occurs rather sparingly at the Sterling mine as microscopic, pink to brown crystals associated with quartz and magnetite pseudomorphs after hematite. The strongest reflections observed in the X-ray powder pattern are, in order of decreasing intensity, 2.79, 3.42, 2.69, 2.24, 1.92, 1.83, and 2.59 Å. Based on this data and an observed slow effervescence in hydrochloric acid, this apatite is probably a carbonate apatite. The only crystal forms observed thus

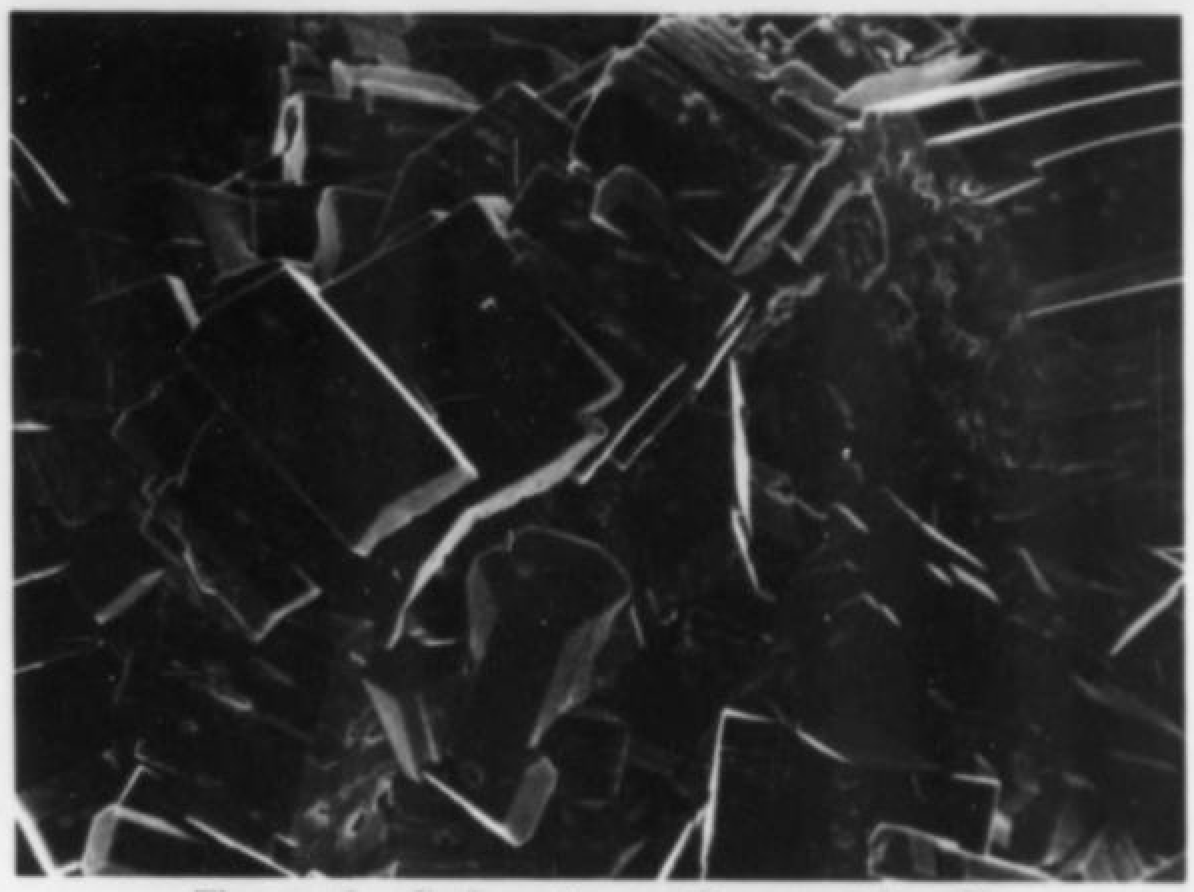


Figure 5. **Carbonate apatite crystals. The magnification of the SEM photomicrograph is about 135x. Photo by G. Robinson.**

Figure 6. **Aragonite crystals. The magnification of the SEM photomicrograph is about 180x. Photo by G. Robinson.**

far are the hexagonal prism and basal pinacoid, rarely modified by the hexagonal dipyramid (Figs. 4 and 5).

Aragonite $CaCO_3$

Aragonite has been observed as clear to white crystals up to 1 mm in length in a few of the vugs examined. The crystals appear late in the paragenetic sequence and are shown by SEM photomicrographs to be relatively simple combinations of orthorhombic prisms, pinacoids and dipyramids (Fig. 6).

Barite $BaSO_4$

Although this mineral was reported to occur at the Sterling mine by Hough (1853), its presence could not be verified in the present study. It is nonetheless a likely possibility because verified specimens from the nearby Caledonia mine are relatively common.

Calcite $CaCO_3$

Well formed crystals of calcite occur sparingly in some of the vugs in the hematite-quartz ore, and at least three generations can be documented. The earliest is preserved as pseudomorphs of stilpnomelane after calcite scalenohedrons, and is not often encountered. The second generation exists as translucent, milky white crystals of predominantly rhombohedral habit, which have been described in detail by Whitlock (1910), who listed the following forms: o$\{0001\}$, b$\{10\bar{1}0\}$, p$\{10\bar{1}1\}$, K$\{21\bar{3}1\}$, g$\{6.7.\overline{13}.2\}$, $\pi\{11\bar{2}3\}$, m$\{40\bar{4}1\}$, $\phi\{02\bar{2}1\}$ and e$\{41\bar{5}6\}$ (Fig. 7d, e, f). The third generation is typically of the "nailhead" habit and shows the forms

$b\{10\bar{1}0\}$, $\delta\{01\bar{1}2\}$, $v\{90\bar{9}1\}$, $g\{6.7.\overline{13}.2\}$ and $s\{13.0.\overline{13}.1\}$(Fig. 7a, b, c). Whether the milky white calcite cleavages that completely fill some of the vugs merely represent a continued growth of one of these generations, or is perhaps yet another, is unknown.

Chalcopyrite $CuFeS_2$

Chalcopyrite is uncommon at the Sterling mine, and only a few specimens are known. The crystals may be up to a centimeter across, but are usually only a few millimeters. The forms present include a combination of positive and negative disphenoids {hhl} and $\{h\bar{h}l\}$, two sets of tetragonal scalenohedrons {hkl} and the tetragonal prism {110}. Most specimens have a bright, metallic luster with occasional irridescence. One specimen shows a darkened surface with minute sprays of acicular malachite. The common associates of chalcopyrite are calcite, quartz and magnetite pseudomorphs after hematite. A microprobe analysis (of one sample only) showed only Cu, Fe and S to be present.

Dolomite $CaMg(CO_3)_2$

Dolomite occurs as white, saddle-shaped crystals up to 5 mm, and as spheroidal aggregates of curved rhombohedrons up to 1.5 cm in diameter. It is commonly associated with quartz, stilpnomelane and millerite. Microprobe analyses show that this dolomite is actually a ferroan dolomite of composition $Ca(Mg_{0.62}Fe_{0.31}Ca_{0.07})(CO_3)_2$.

Many of the dolomite crystals have epitaxial overgrowths of siderite, which result in zoned crystals. The siderite overgrowths may be either a light tan or dark red-brown color. Microprobe analyses of such zoned crystals give the following compositions: ferroan dolomite cores – $Ca(Mg_{0.66}Fe_{0.30}Ca_{0.02}Mn_{0.02})(CO_3)_2$, tan colored siderite overgrowths – $(Fe_{0.75}Mg_{0.16}Ca_{0.08}Mn_{0.01})CO_3$, and dark red-brown siderite overgrowths – $(Fe_{0.81}Mg_{0.10}Ca_{0.08}Mn_{0.01})CO_3$.

Although the literature lists ankerite as a common species at the Sterling mine (Buddington, 1934; Roberts, Rapp, and Weber, 1974; Jensen, 1978; Palache, Berman, and Frondel, 1951), neither X-ray nor microprobe studies have confirmed its presence. It seems most probable that wet chemical analyses of the zoned ferroan dolomite-siderite crystals could have easily given Fe/Mg ratios of greater than 1.00, thus leading to their misidentification as ankerite by the early investigators.

Goethite FeO(OH)

Goethite is not particularly common at the Sterling mine. It most commonly occurs either as massive, brown "limonite" or as microscopic tufts of golden acicular crystals in and on quartz or siderite which make very attractive micromounts (Figs. 8 and 9). More rarely goethite occurs as crystalline botryoidal coatings on hematite crystals (Fig. 30) or as brown, translucent pseudomorphs after platy crystals of hematite (which may actually be goethite pseudomorphs after magnetite pseudomorphs after hematite).

Hematite Fe_2O_3

Hematite is plentiful at the Sterling mine, as it was the principal ore mined. It occurs most commonly as red, earthy masses, with the specular and botryoidal forms (Fig. 10) being much less common. Actual crystals of hematite are rarely encountered, as most of what appear to be crystals of hematite are actually magnetite pseudomorphs after hematite.

Magnetite Fe_3O_4

As stated above, what appears to be crystallized hematite is almost always a replacement of that mineral by magnetite. These pseudomorphs are typically small, black, lustrous, thin-bladed individuals. Some crystal aggregates resemble the familiar *eisenrose.*

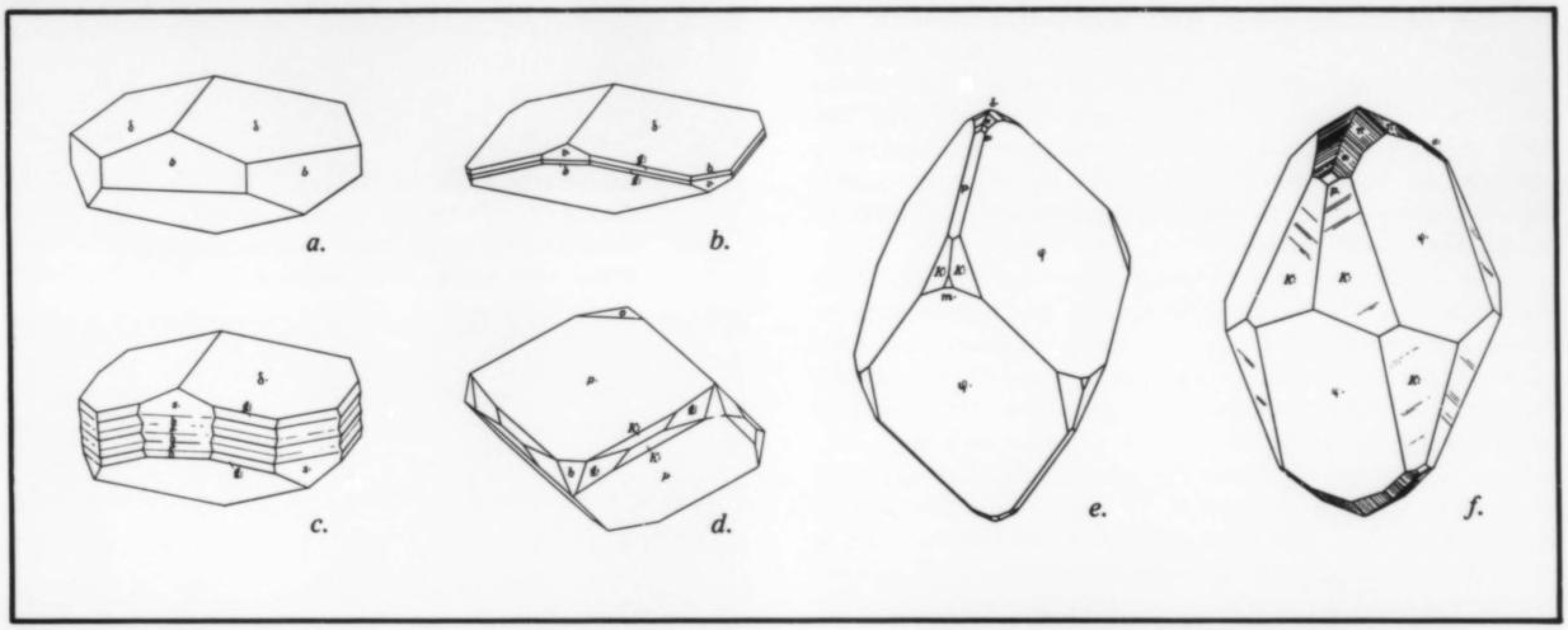


Figure 7. **Habits of calcite crystals from the Old Sterling mine. (Adapted from Whitlock, 1910.)**

Figure 8. **Golden sprays of acicular goethite on quartz. The field of view is about 3 mm. From the collection of Georgia and Everett Shaw, Cortland, New York. Photo by S. Chamberlain.**

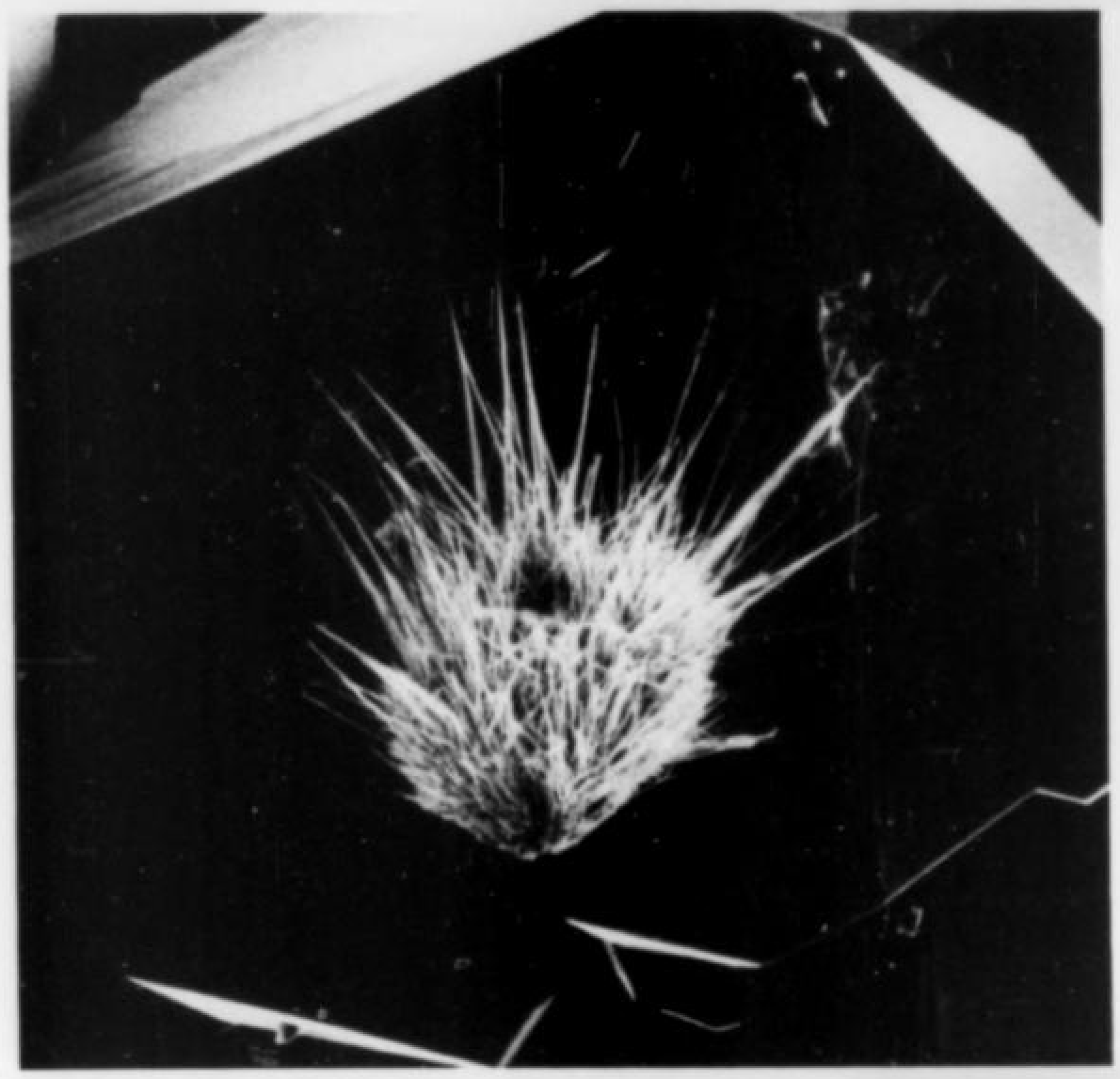


Figure 9. **Acicular goethite crystals on the termination of a quartz crystal. The magnification of the SEM photomicrograph is about 85x. Photo by G. Robinson.**

They occur in geode-like cavities of the iron ore, which are lined with crystallizations of spathic iron, specular iron, quartz, calcite, cacoxene, and sulphuret of iron; from among these crystals the tufts proceed, attached generally to the spathic iron, more rarely to the crystals of iron. It is not an abundant mineral; only perhaps one or two dozen specimens have been procured since its discovery. . . . In a specimen which the writer procured of a miner, . . . a crystal was found completely transfixing a rhomb of spathic iron, and supporting it in air, at a distance of 1/8 inch above the inner surface of the cavity.

Millerite occurs in sprays of acicular crystals up to 3 cm in length. Besides the more common, sturdy, striated prisms (Figs. 16 and 17), curved crystals and crystals showing spiral growth patterns along the *c*-axis are known (Fig. 18). In addition, tufts and sprays are occasionally seen radiating outward from a single larger crystal in a broom-like appearance as shown in Figure 20. A particularly rare and beautiful example is shown in Figure 21.

Pecoraite $Ni_3Si_2O_5(OH)_4$

Some of the millerite shows a pale yellow to bright green alteration. The degree of alteration ranges from a thin, partial surface coating on some specimens to complete replacement on others (Figs. 22 and 23). Powder diffraction patterns were obtained on the altered material using a 57.3-mm powder camera with a Gandolfi mount. All the resulting patterns showed broad, diffuse lines, suggesting the presence of a poorly crystallized or somewhat disordered phase. The observed *d*-spacings (in Å) and their relative intensities are 7.69 (S), 4.48 (W), 3.77 (S), 2.64 (S), 2.46 (W), 1.53 (S), and 1.32 (W). This pattern bears similarities to several secondary nickel minerals. In the absence of more data the sample was tentatively identified as jamborite, possibly admixed with some other poorly crystallized nickel hydroxide phases (Morandi and Dalrio, 1973; Jambor and Boyle, 1964). One film showed only three diffuse lines at 7.71Å, 2.64Å, and 1.53Å, closely resembling a pattern obtained for a similar green alteration of millerite from Hall's Gap, Kentucky (Morandi and Dalrio, 1973).

Further examination by SEM equipped with an energy-dispersive X-ray detector yielded several interesting observations: (1) the vast majority of samples contained appreciable but variable silica and iron, with or without minor calcium and sulfur; (2) one spot analysis showed no Si present; and (3) the more yellow alteration showed overall greater iron content than the greener material.

Because jamborite does not contain silica or iron, the X-ray data was re-evaluated and found to also closely resemble the three serpentine polymorphs, pecoraite, nepouite and Ni-antigorite, but with considerably larger 00*l* reflections, which may be due to a

Figure 10. **Red botryoidal hematite with minor quartz and specular hematite. The specular hematite has been reduced to magnetite, the botryoidal form remains hematite. The specimen is 20 cm in length; #H269, Oren Root collection, Hamilton College, Clinton, New York. Photo by S. Chamberlain.**

Although they appear visually to be hematite, they are strongly magnetic, have a black streak, and their X-ray powder diffraction patterns clearly show strong magnetite lines. Nearly all the vugs in the ore contain at least a few of these pseudomorphs, usually with quartz (Figs. 11–13).

Millerite NiS

Without a doubt, the single species for which this locality is most famous is millerite. Antwerp millerites achieved world fame long ago, and are considered by many to be among the world's finest examples of this species (Bancroft, 1973). Millerite was first noticed at the Sterling mine in 1848, by Franklin B. Hough, a noted collector, scientist, and historian, who lived in the nearby village of Somerville. An excerpt from Hough's original description follows (Hough and Johnson, 1850, page 287):

It was first noted by the writer about two years since, and attracted his attention for its delicate capillary appearance, brilliant lustre and the difference of its crystalline form from that of sulphuret of iron, which in color and association it so nearly resembles. It occurs mostly in radiating tufts of exceedingly minute and slender crystals of brass-yellow color, and a very brilliant lustre, which when highly magnified present the appearance of flattened hexagonal prisms with striated faces, the striae being parallel with the principal faces of the prism. . . .

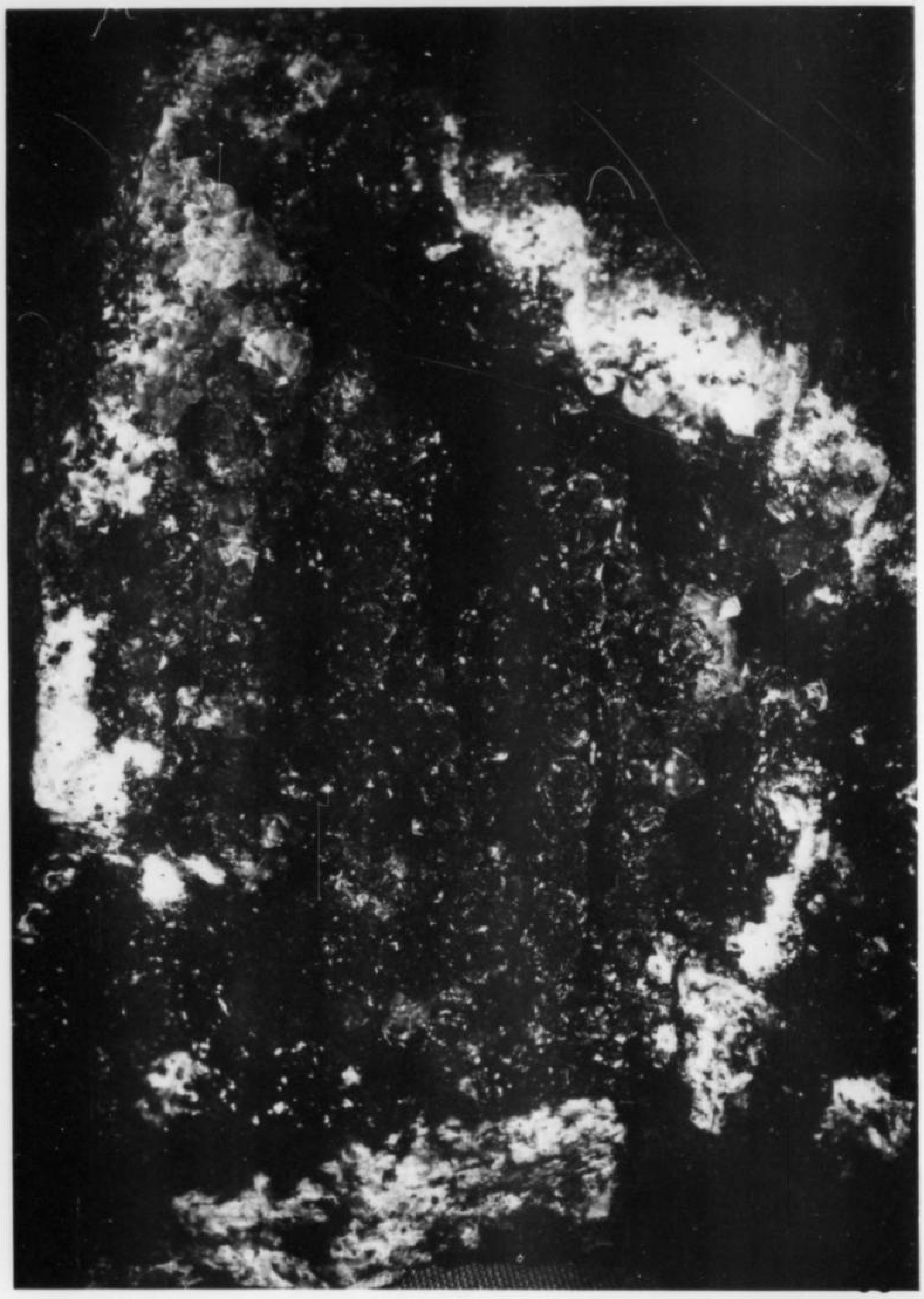
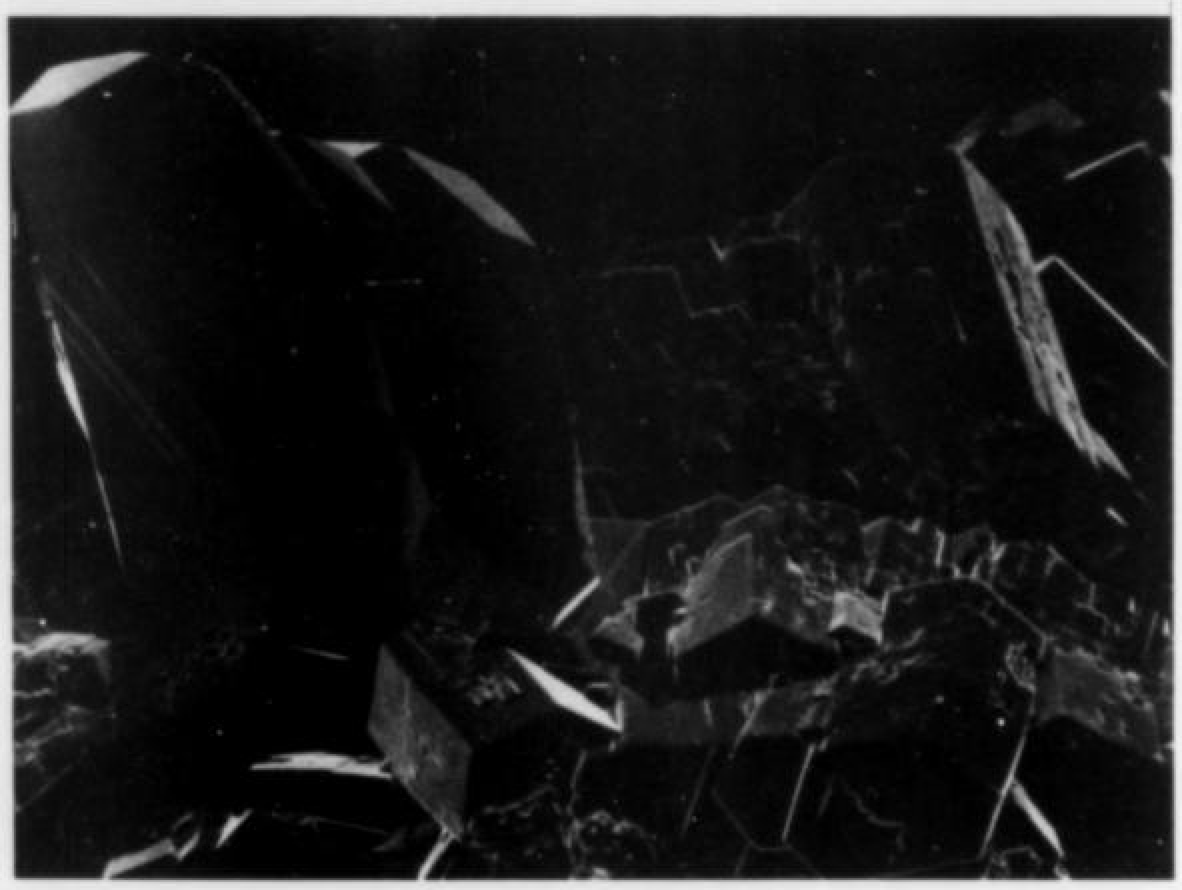


Figure 11. **Black magnetite pseudomorphs after hematite crystals with quartz, calcite and siderite in a matrix of quartz and hematite. The specimen is 11 cm high; #2433, S. Chamberlain collection. Photo by S. Chamberlain.**

Figure 12. **Magnetite pseudomorphs after hematite crystals on carbonate apatite crystals. The magnification of the SEM photomicrograph is about 135x. Photo by G. Robinson.**



large amount of adsorbed water (Faust *et al.*, 1969; Martin *et al.*, 1967; Brindley and Wan, 1975; Milton *et al.*, 1983). A TGA-EGA analysis by Robert Ramik (personal communication, 1983) showed a 9% weight loss under vacuum at 22° C, a 22% loss (mainly H_2O, but with some CO_2) from 40–710° C with a peak at 285° C, and an additional 2% loss from 710–900° C.

Microprobe analysis gave SiO_2 = 20.9, Fe_2O_3 = 2.2, NiO = 40.6, MgO = 0.6, CaO = 1.4, K_2O = 0.2, total H_2O (TGA) = 33, sum = 98.9 weight %. A small amount of sulfur (estimated at 0.1–1.0 weight % SO_3) was also observed, but not analyzed. Assuming the Ca, K and S are present as impurities (probably largely in form of calcite, gypsum and residual millerite), excess H_2O as adsorbed water, and following the suggestions of Wicks (1979), the formula calculated on the basis of 14 oxygens (28 negative charge method) gives $(Ni_{5.87}Mg_{0.16})(Si_{3.76}Fe_{0.30})O_{10}(OH)_8$; in excellent agreement with the theoretical composition $2[Ni_3Si_2O_5(OH)_4]$.

Precisely which polymorph of $Ni_3Si_2O_5(OH)_4$ is present cannot be positively ascertained, due to its poorly crystallized nature, the lack of reliable standards for comparison and the paucity of published data. However, based on the close similarity of the powder diffraction pattern for pecoraite (Faust *et al.*, 1969; Milton *et al.*, 1983), the dissimilarity of the TGA data to both nepouite and Ni-antigorite (Brindley and Wan, 1975; Martin *et al.*, 1967), and considering that Ni-antigorite is presently known only as a synthetic phase (Martin *et al.*, 1967; Wicks, 1979), we believe this mineral is most likely pecoraite. Since the majority of samples examined were found to be the same, we propose that unanalyzed specimens be tentatively labeled as pecoraite pseudomorphs after millerite, but note that other phases may also be present.

Because nearly all the pecoraite specimens in circulation have been collected from the mine dumps in recent years, it could well be argued that this mineral was likely formed by weathering processes as a result of being on the dump. Indeed pecoraite is known to form under atmospheric conditions (Faust *et al.,* 1969). However, it should also be mentioned that a few "old" specimens in the collection of the New York State Museum also show a similar green alteration. Furthermore, unaltered millerite may still be collected in the same areas of the dumps as pecoraite, and even in the same vugs with it. Finally, pecoraite has also been observed completely enclosed in calcite, thus suggesting that at least some specimens have not formed as the result of post-mining weathering.

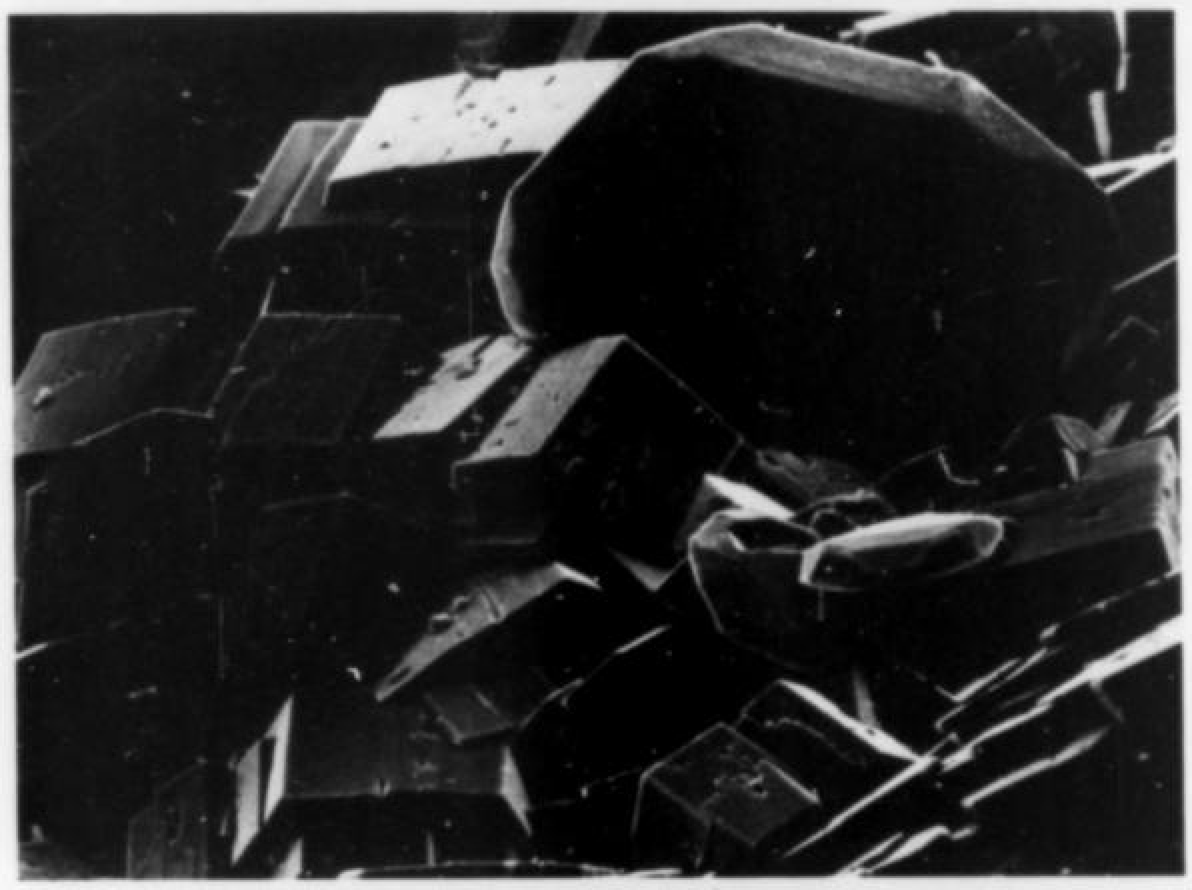


Figure 13. **Magnetite pseudomorphs after hematite crystals on carbonate apatite crystals. The magnification of the SEM photomicrograph is about 160x. Photo by G. Robinson.**

Figure 14. **Pyrite crystal on brown siderite crystals. The pyrite crystal is about 1 mm across; #162, New York State Museum, Albany. Photo by S. Chamberlain.**

Pyrite FeS_2

Pyrite is relatively uncommon in the mineralized cavities at the Sterling mine. When present, it is usually found as small cubes or octahedrons, seldom exceeding a few millimeters across. The most interesting pyrite specimens are rosettes of octahedral crystals occurring on rhombohedral siderite crystals (Fig. 14). Electron microprobe analysis showed the presence of no elements other than Fe and S.

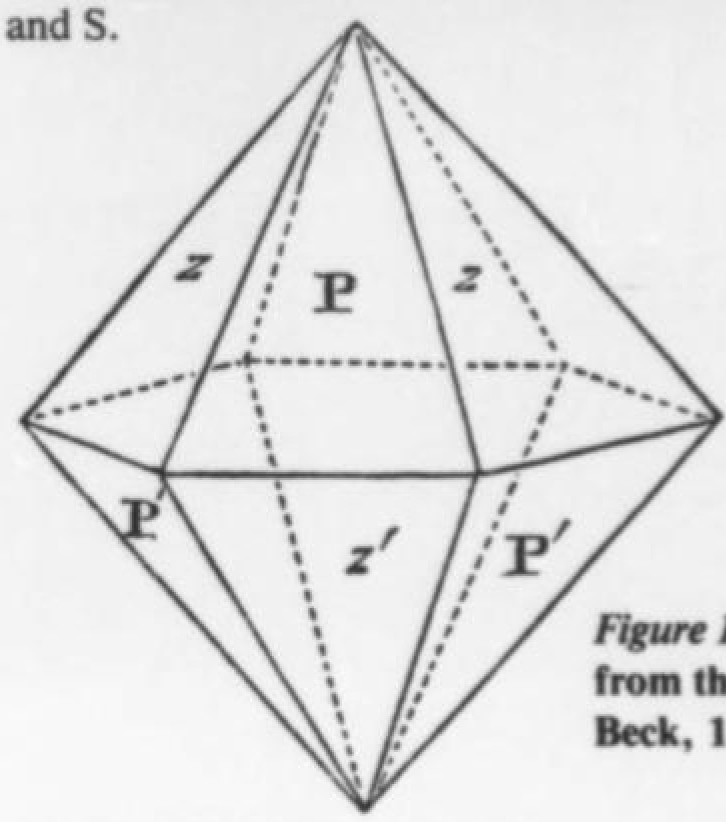


Figure 15. **Typical habit of quartz from the Old Sterling mine (from Beck, 1842).**

Quartz SiO_2

Quartz occurs in nearly all the vugs as clear, drusy crystals seldom larger than a centimeter. Crystals are occasionally ferruginous (Figs. 29 and 30), and stalactitic growths are found in some of the cavities. Individual crystals are equant with very small prism faces, and thus resemble hexagonal dipyramids (Fig. 15). Fluid-inclusion studies (T. Ottaway, personal communication, 1983) show the presence of small 2-phase (L + V) inclusions which homogenize between 145° and 150° C. A few 3-phase (L + V + S) inclusions were also observed in which the salts dissolved at approximately 122° C with the rest of the inclusion becoming homogenized between 135° and 145° C. There was no observable ice formation or salt precipitation even at − 80° C, and no difference in homogenization temperature between primary and secondary inclusions.

Because of its ubiquitous nature, quartz is associated with all the other species found in the vugs. Yellow-brown jasper is also found interbanded with quartz and magnetite pseudomorphs after hematite.

Siderite $FeCO_3$

Siderite is one of the most commonly encountered species at the Sterling mine. Two distinct types are found with about equal frequency, and are distinguishable by color. One is a light tan color (Fig. 31), the other dark red to red-brown (Fig. 33). Both types oc-

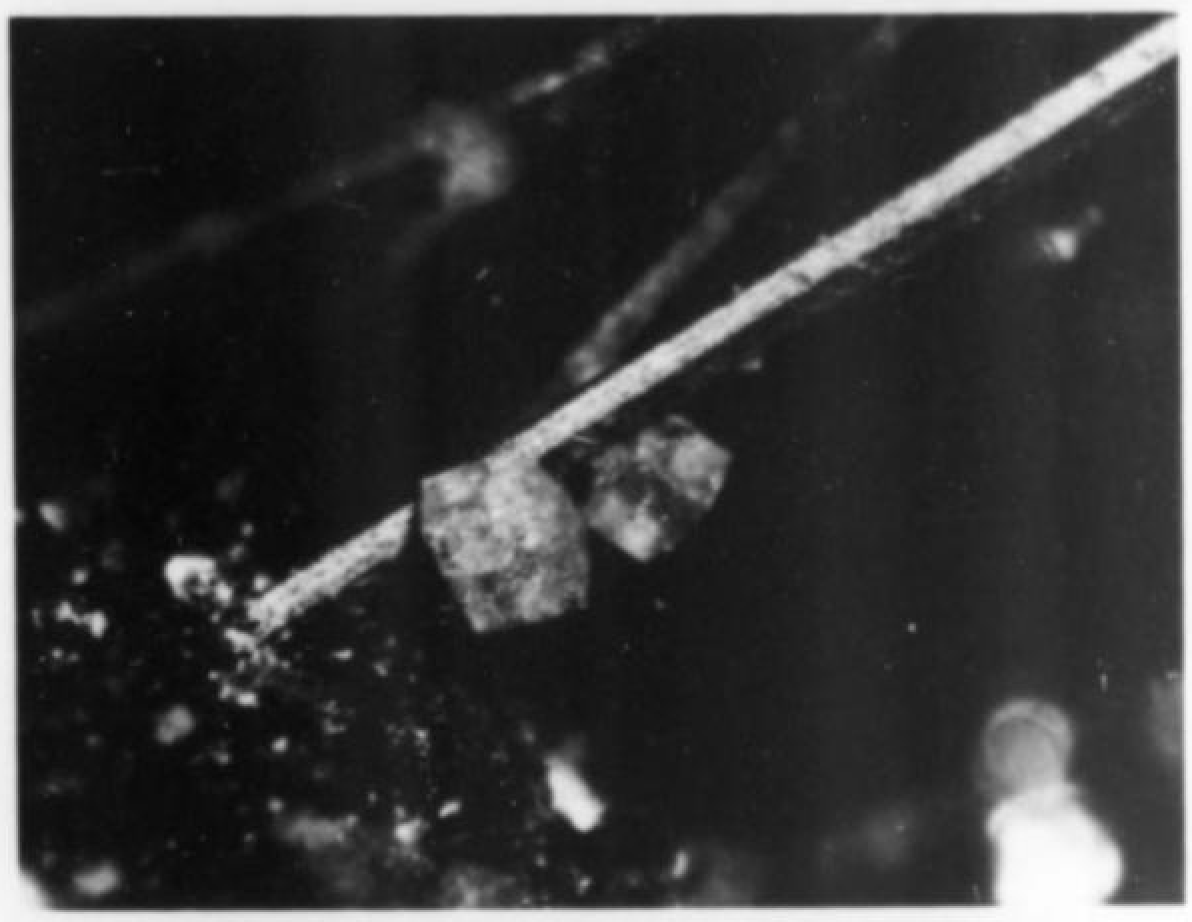


Figure 16. **Golden siderite rhombohedrons on a brassy millerite crystal. The largest siderite crystal is about 0.5 mm; #163, New York State Museum, Albany, New York. Photo by S. Chamberlain.**

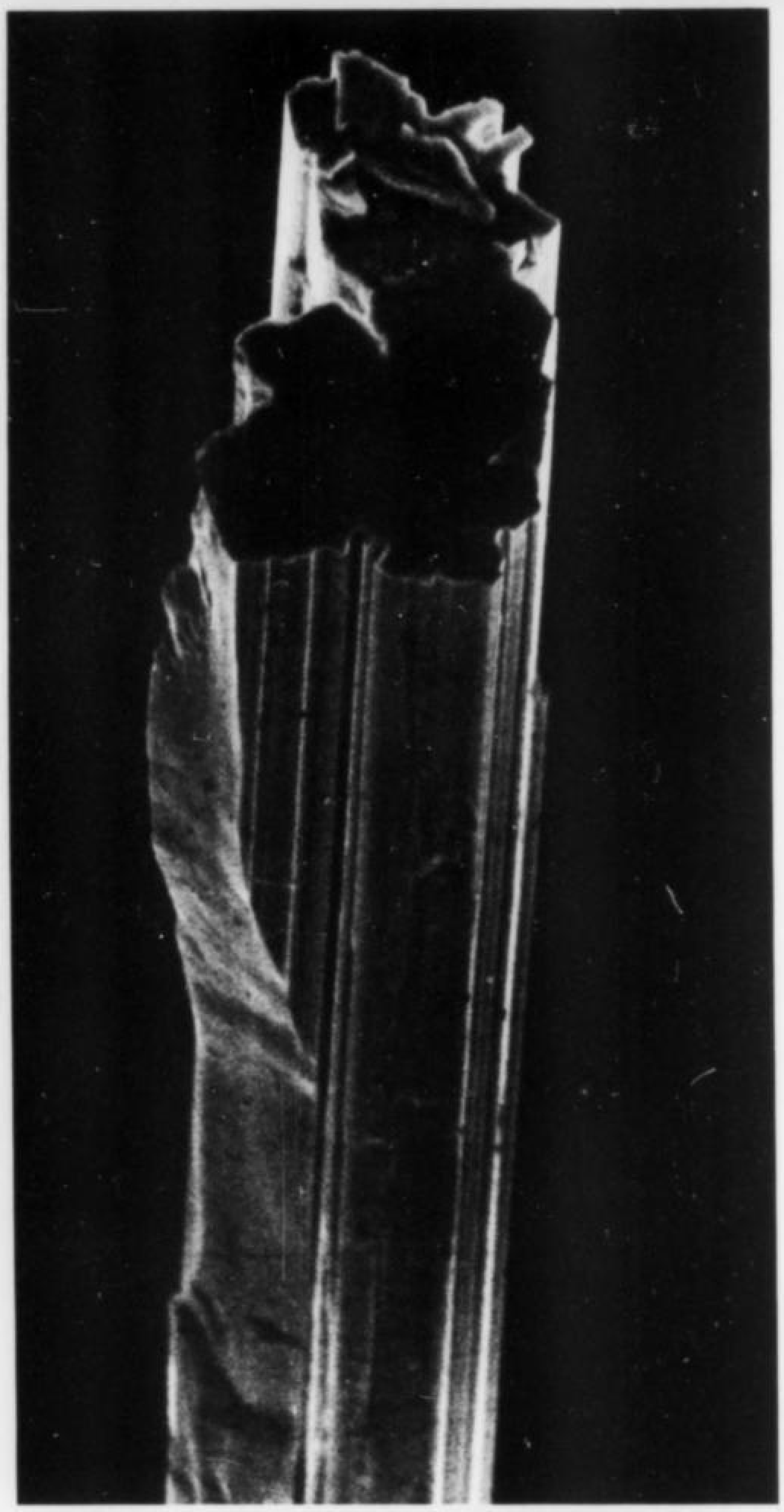


Figure 17. **Termination of millerite crystal. The magnification of the SEM photomicrograph is about 600x. Photo by G. Robinson.**

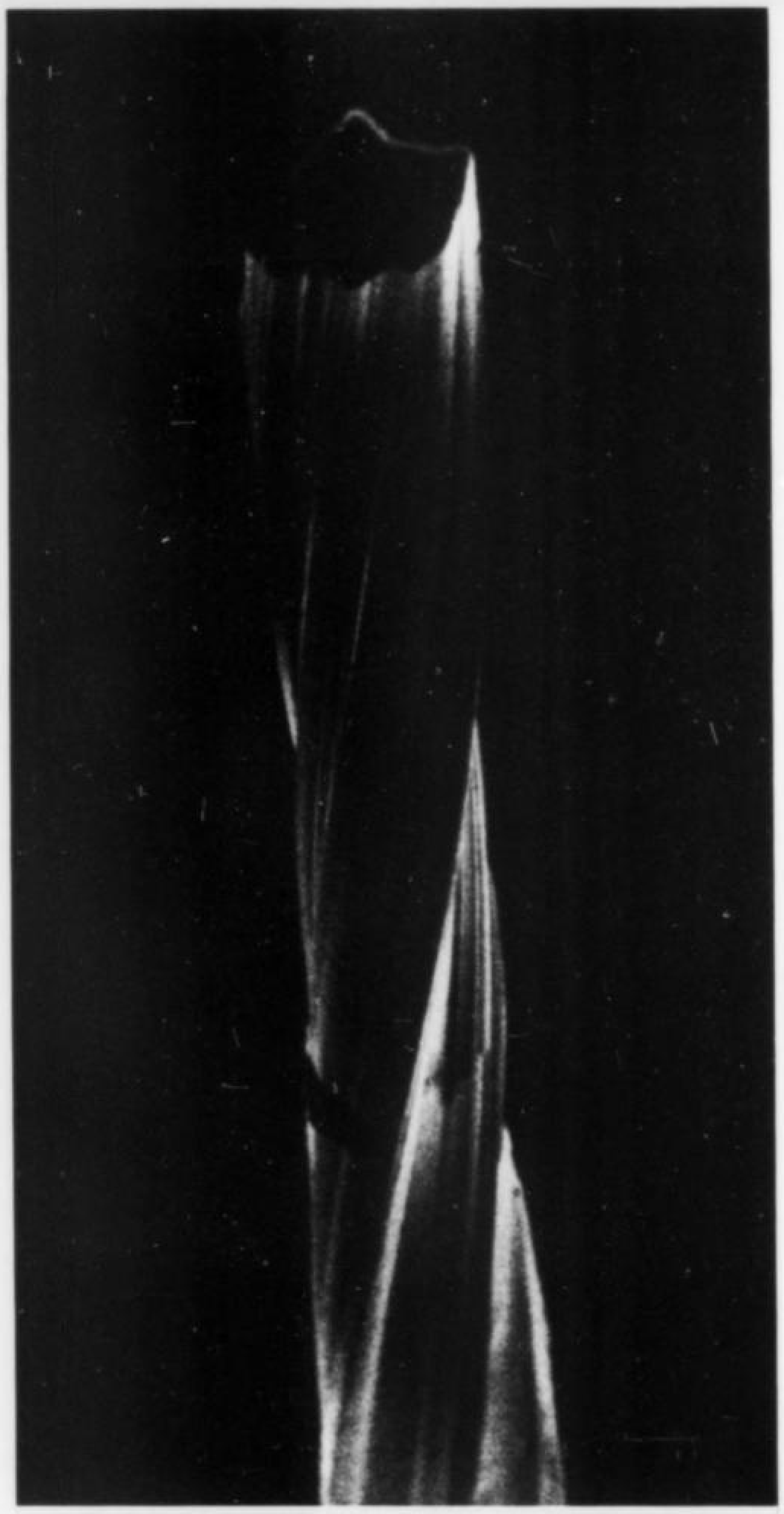


Figure 18. **Millerite crystal showing spiral growth. The magnification of the SEM photomicrograph is about 2000x. Photo by G. Robinson.**

cur as rhombohedral crystals up to 5 mm or as parallel groups up to several centimeters in association with all the other minerals found in the vugs in the ore. The light tan crystals are occasionally found impaled on millerite needles (Fig. 16).

Microprobe analyses show the lighter colored crystals to be $(Fe_{0.77}Mg_{0.13}Ca_{0.10})CO_3$, and the darker ones $(Fe_{0.81}Mg_{0.10}Ca_{0.08}Mn_{0.01})CO_3$. One specimen of the darker red type was shown by X-ray diffraction to contain a minor amount of admixed goethite, which may have enhanced its red-brown color. Since the presence of goethite would also contribute to an erroneous FeO content for the siderite, the analysis for this sample was not considered when calculating the formula given above.

Sphalerite $(Zn,Fe)S$

Sphalerite appears to be rare at the Sterling mine. Figure 19 shows a complex, twinned crystal of waxy brown color from a specimen in the Oren Root collection at Hamilton College. This crystal occurs in a vug with dolomite, siderite, calcite, quartz, chalcopyrite and magnetite pseudomorphs after hematite.

Stilpnomelane $K(Fe,Al)_{10}Si_{12}O_{30}(OH)_{12}$

This species was originally identified as cacoxenite by early investigators (Emmons, 1842; Beck, 1842), and was described as the

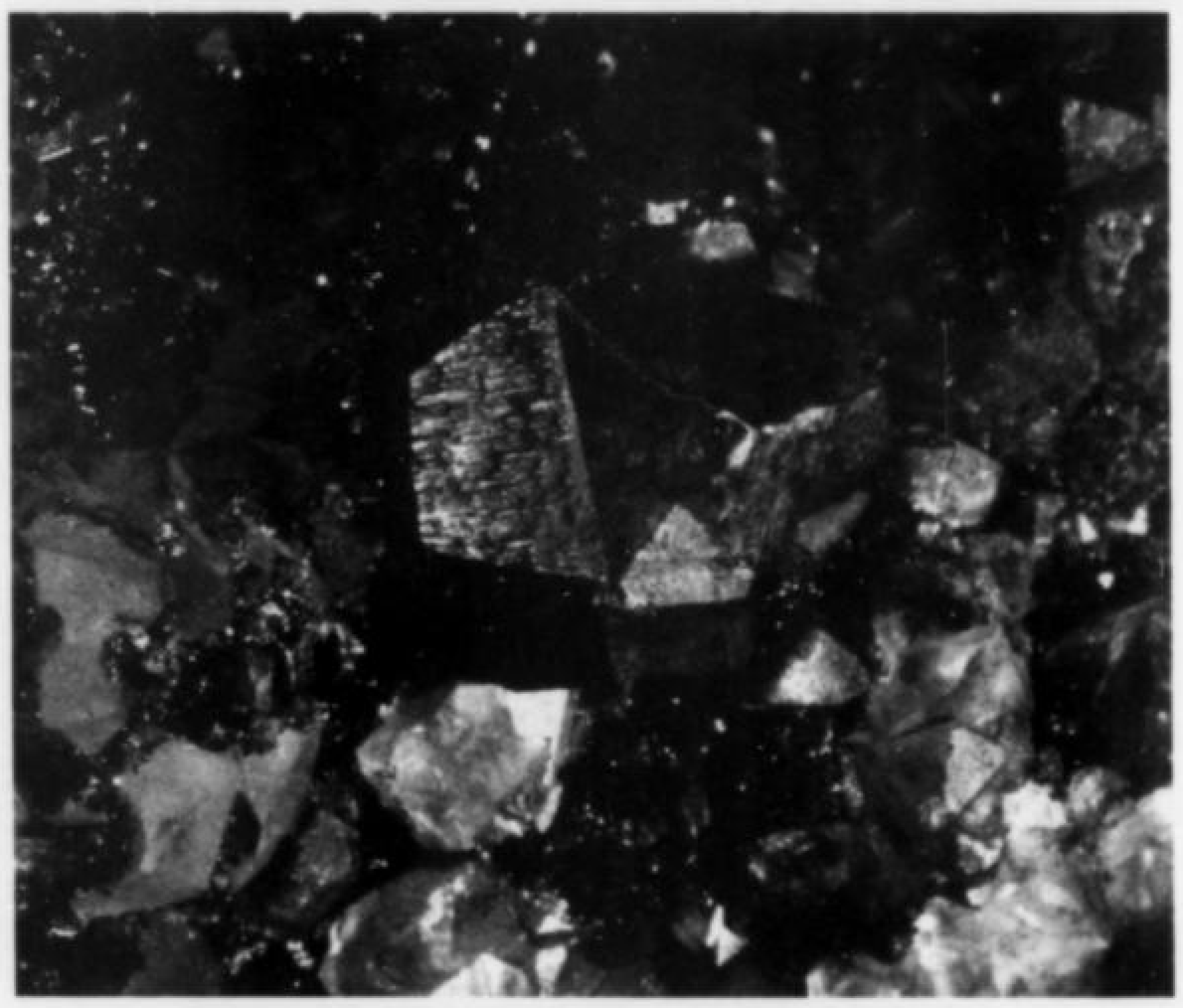


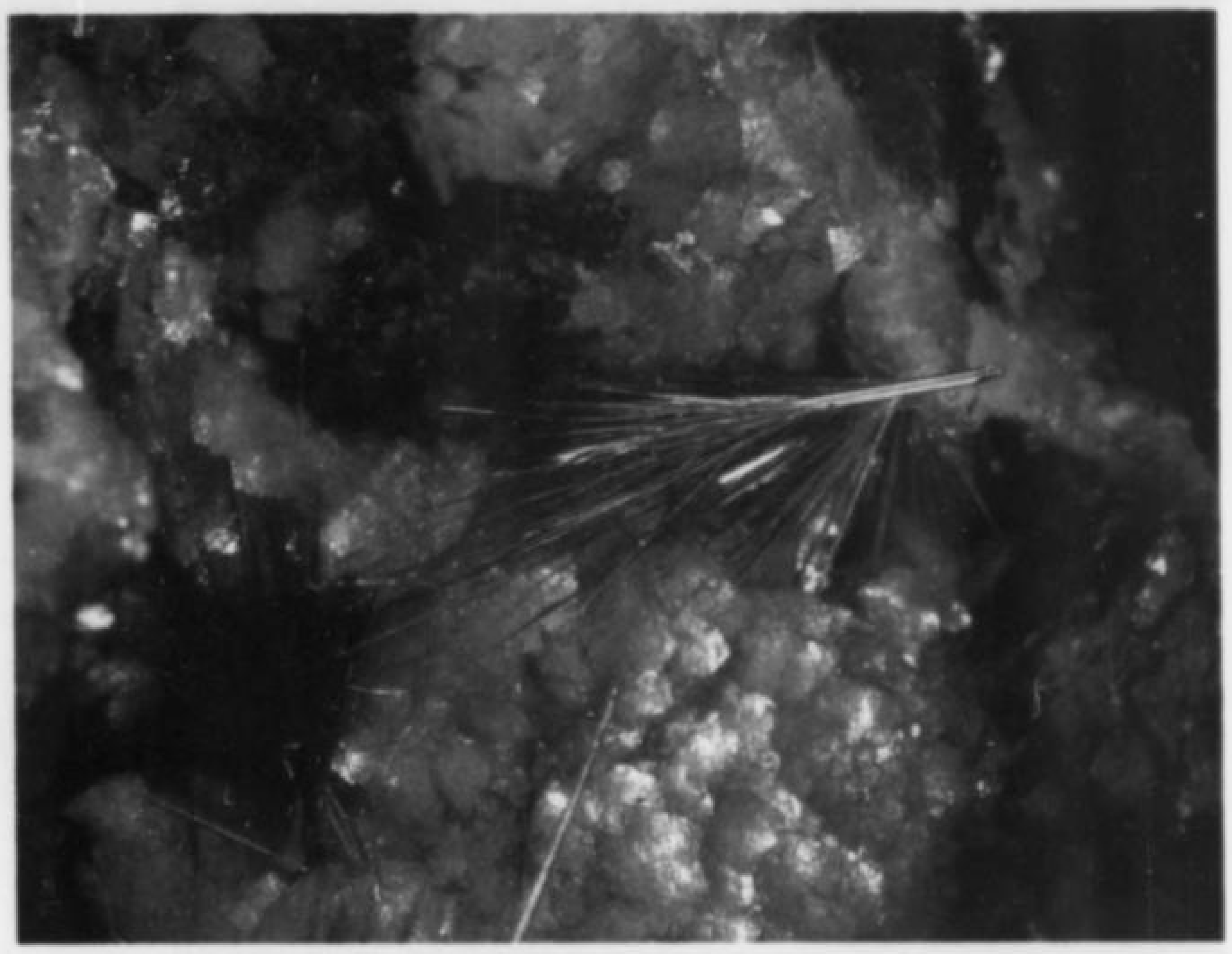
Figure 19. **Twinned brown sphalerite crystal. The twin is 6 mm; #H228, Oren Root collection, Hamilton College. Photo by S. Chamberlain.**

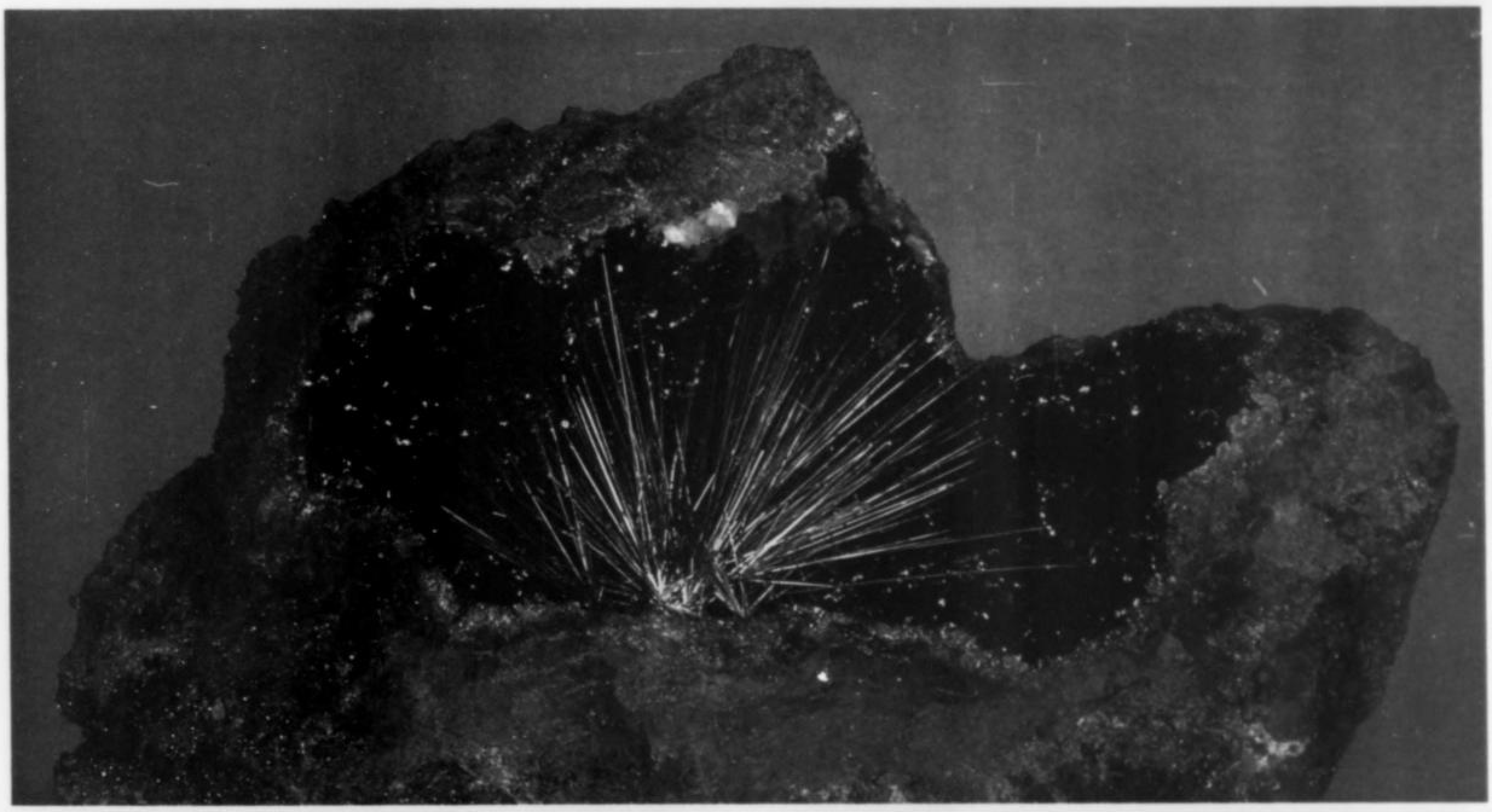
Figure 20. (right) **Millerite spray showing broom-like habit. The spray is 13 mm long; #1407, George Robinson collection. Photo by G. Robinson.**

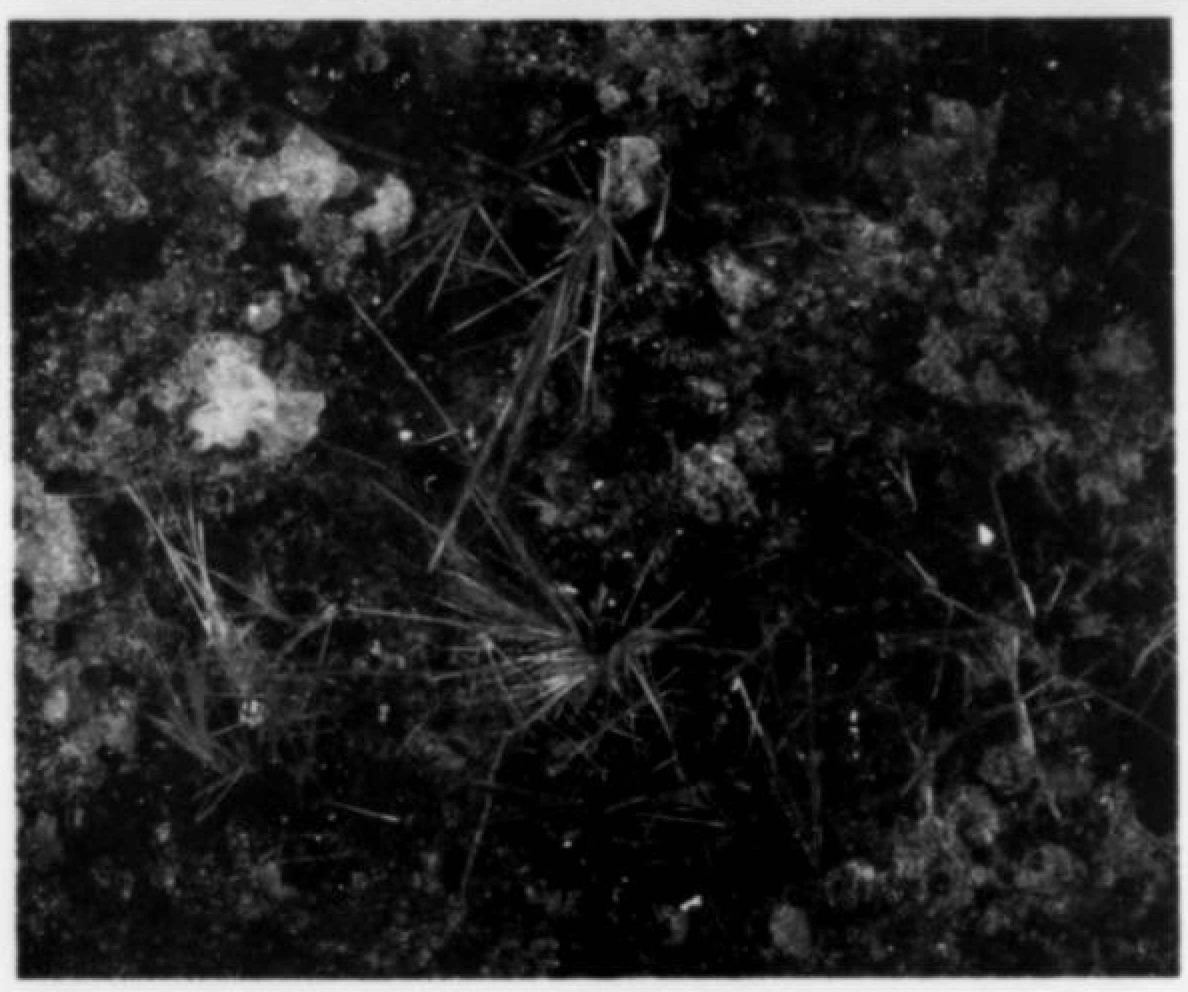
Figure 21. (center) **Millerite crystals on magnetite pseudomorphs after hematite crystals. The spray is about 4 cm across; #C24, Canfield collection, Smithsonian Institution, Washington, D.C. Photo by Katherine H. Jensen.**

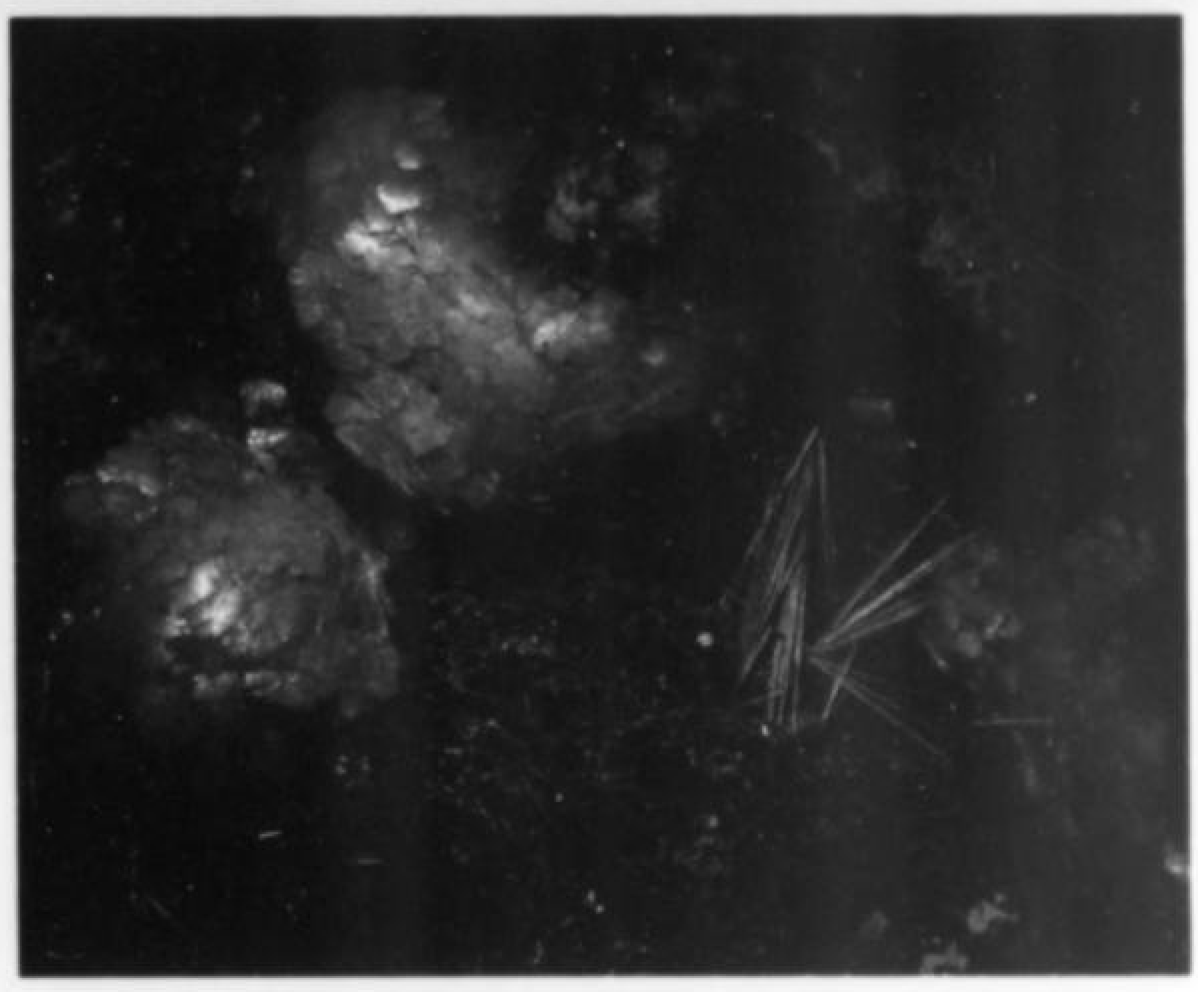
Figure 22. (lower left) **Pecoraite pseudomorphs after millerite crystals. The field of view is 2 cm; #1233, G. Robinson collection. Photo by G. Robinson.**

Figure 23. (lower right) **Dolomite crystal aggregates with millerite spray 1.3 cm long. G. Robinson collection and photo.**









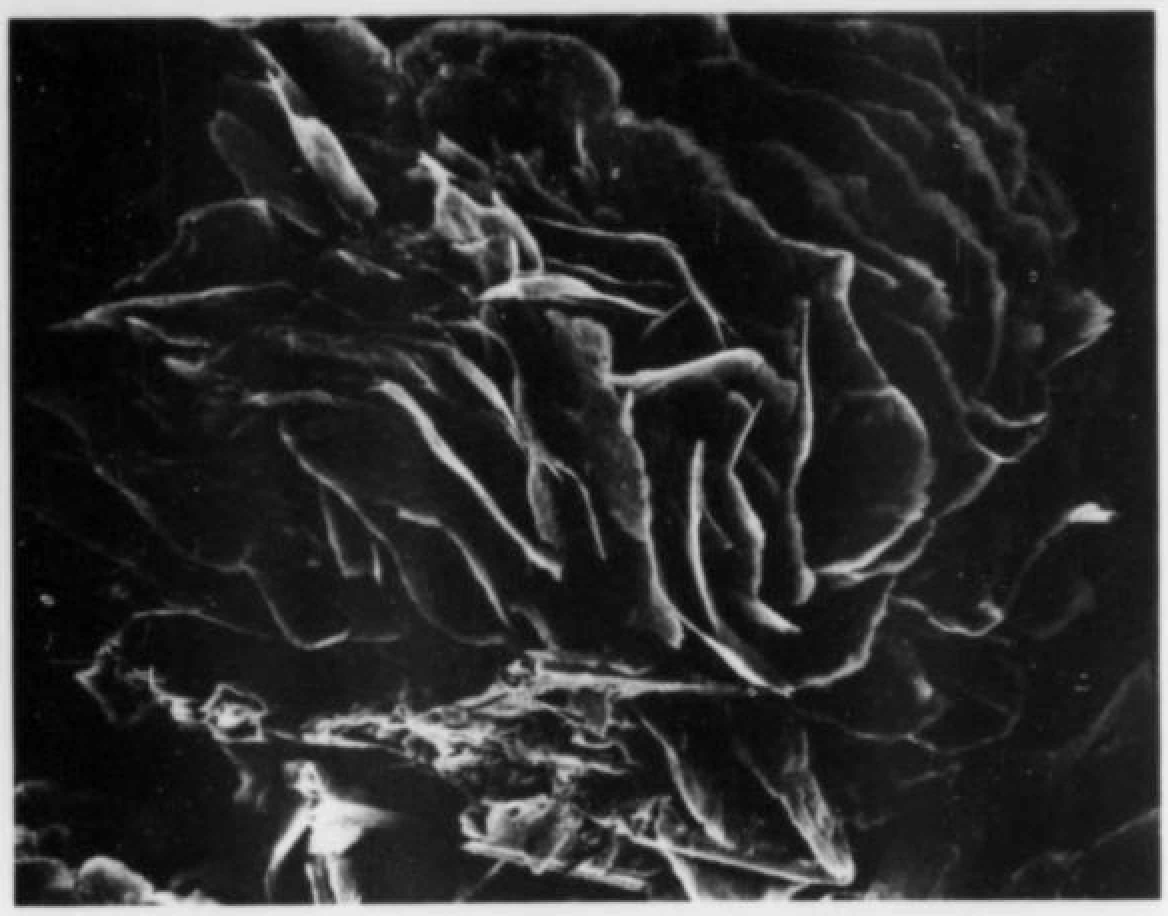


Figure 24. **Stilpnomelane. The magnification of the SEM photomicrograph is about 37x. Photo by G. Robinson.**

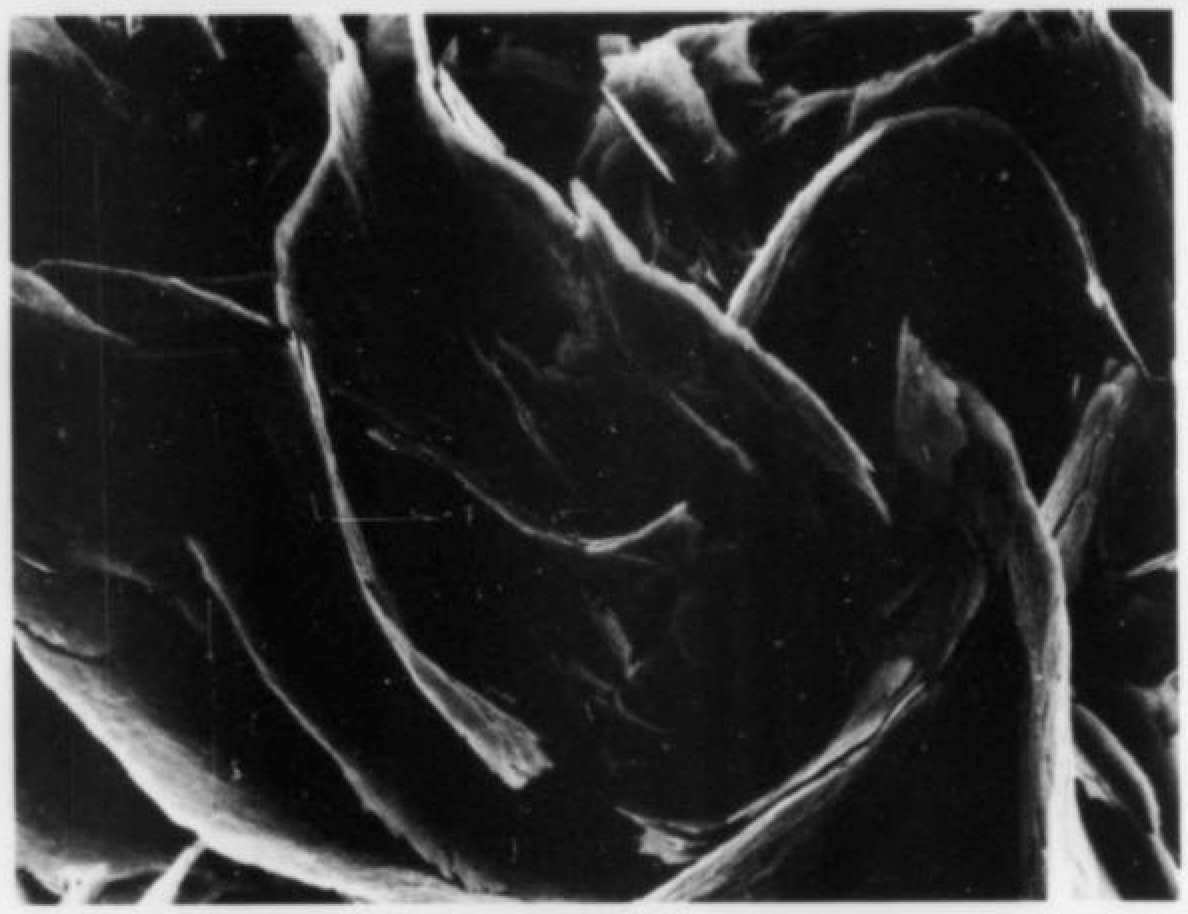


Figure 25. **Stilpnomelane. The magnification of the SEM photomicrograph is about 115x. Photo by G. Robinson.**

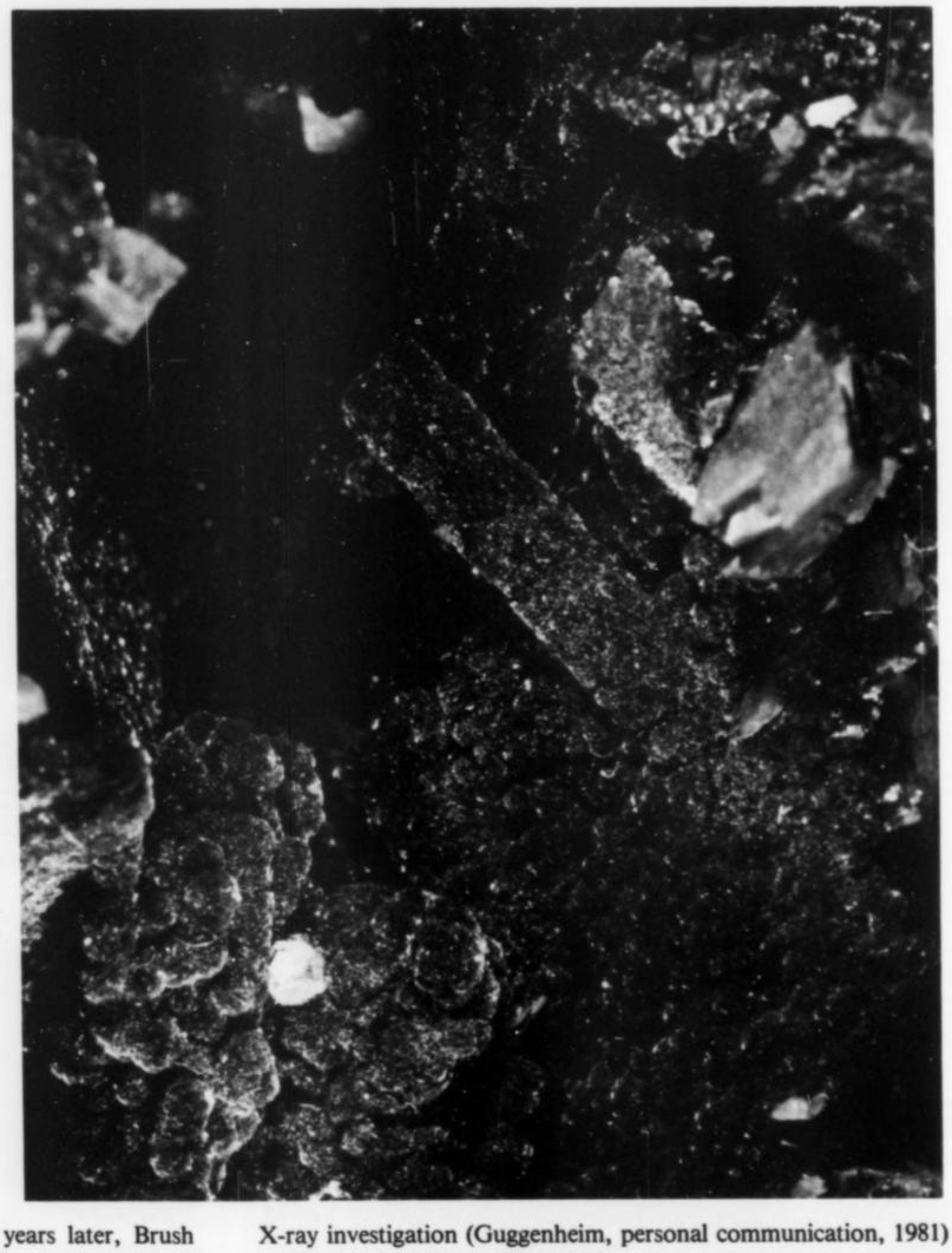


Figure 26. **Stilpnomelane encrustation pseudomorph after an unknown mineral, possibly anhydrite, with siderite. The crystal is 1 cm long; #2435, S. Chamberlain collection. Photo by S. Chamberlain.**

species *chalcodite* by Shepard (1852). A few years later, Brush (1858) suggested that chalcodite was probably stilpnomelane, based on its physical properties and chemical similarity to that mineral. Both X-ray and microprobe analyses in addition to independent X-ray investigation (Guggenheim, personal communication, 1981) confirm its identity as stilpnomelane.

The mineral occurs as velvety green, green-brown and golden-brown (Fig. 32) coatings which, upon closer examination, appear as micaceous crystals up to 2 mm in diameter (Figs. 24 and 25). It commonly fills fractures in both the chloritic rock and the hematite-quartz ore, and is frequently found in vugs with quartz, ferroan dolomite, siderite, millerite and magnetite pseudomorphs after hematite. It also occurs more rarely as pseudomorphs after calcite and after an unknown orthorhombic (?) mineral (perhaps anhydrite) (Fig. 26).

The variability of color and close association with the reduced hematite ore prompted a closer look at the stilpnomelane. In general, the greener stilpnomelane is associated with rocks less rich in magnetite than the green-brown varieties. Hand-picked samples of green, green-brown and golden brown stilpnomelanes were first X-rayed to verify their purity and then analyzed by wet chemistry for ferrous and ferric iron, which yielded the following results: green stilpnomelane from magnetite-poor ore contained FeO = 9.94, Fe_2O_3 = 25.26 weight %; green-brown stilpnomelane from magnetite-rich ore contained FeO = 8.46, Fe_2O_3 = 31.37 weight %; and golden brown stilpnomelane from magnetite-rich ore contained FeO = 2.18, Fe_2O_3 = 35.54 weight %.

It is generally thought that ferrous iron is oxidized to ferric iron after the formation of stilpnomelane (Zen, 1960; Brown, 1967, 1971; Hutton, 1938). Thus the association of stilpnomelane rich in ferric iron with magnetite-rich ore may be significant, and suggests the possible coupled redox reaction:

hematite + (ferrous) stilpnomelane → magnetite + (ferric) stilpnomelane + oxygen

rangement. Single-crystal precession photographs show only diffraction rings, thus indicating that what appear to be single crystals are in fact composite crystallites, and not true single crystals (Guggenheim, personal communication, 1981).

A TGA-EGA analysis of some of the massive iron-rich talc associated with magnetite-rich ore showed a 4.5% loss of H_2O and H_2 at approximately 750° C and a 0.5% loss of O_2 at 1195° C, suggesting the presence of hydrogen and both ferrous and ferric iron

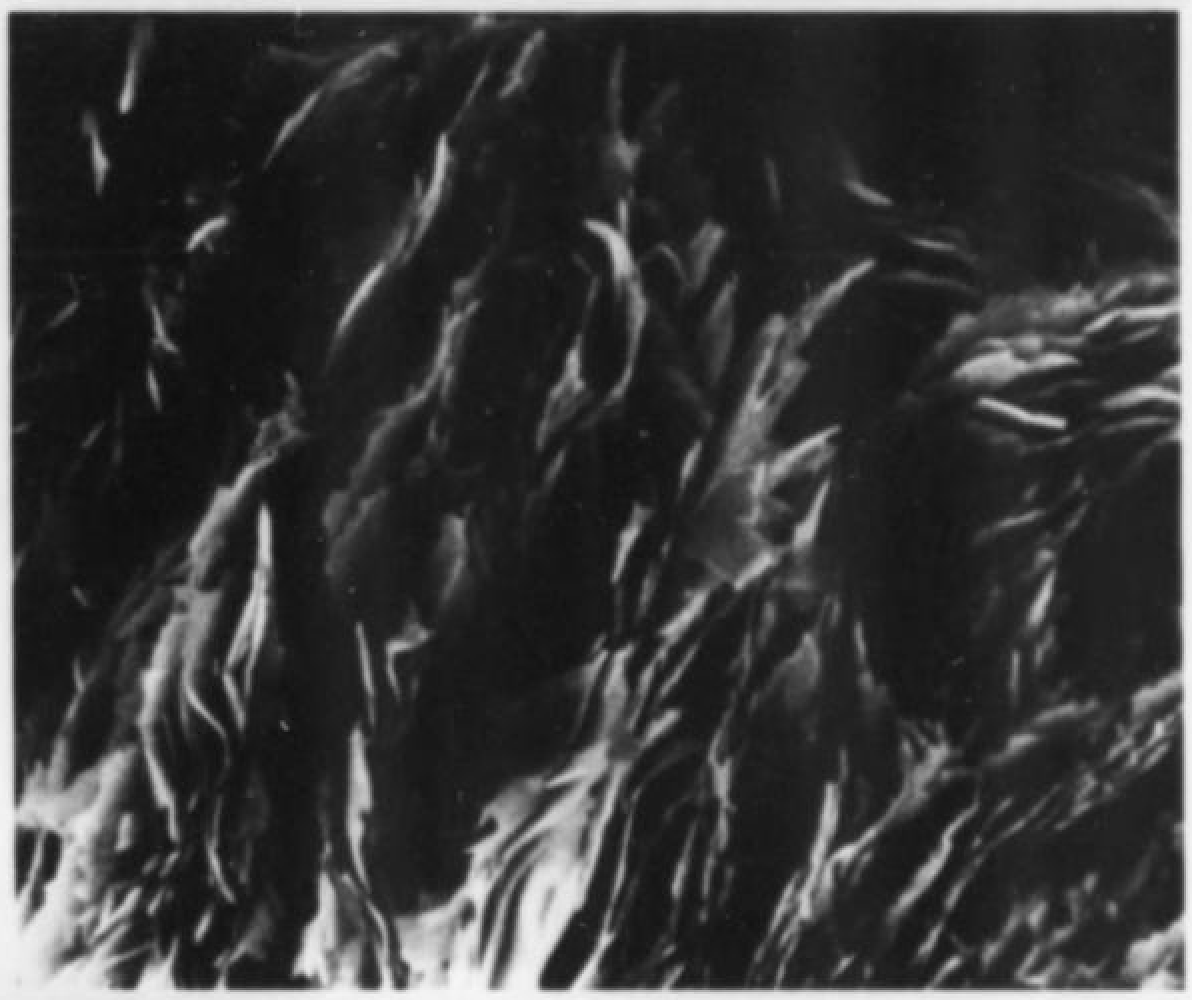


Figure 27. **Iron-rich talc. The magnification of the SEM photomicrograph is about 1240x. Photo by G. Robinson.**

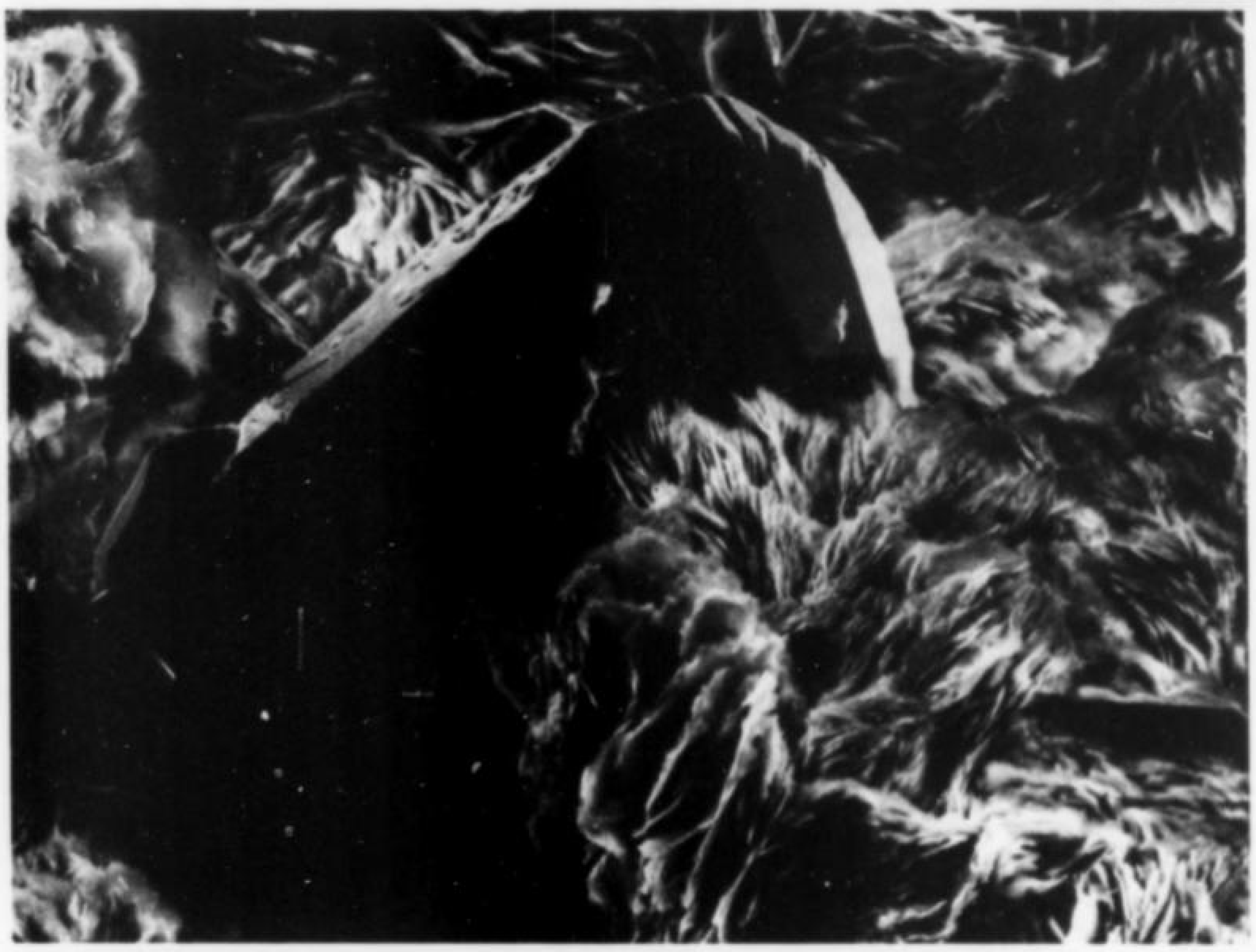


Figure 28. **Iron-rich talc and magnetite pseudomorphs after hematite. The magnification of the SEM photomicrograph is about 315x. Photo by G. Robinson.**

Talc $(Mg,Fe)_3Si_4O_{10}(OH)_2$

A talc with an unusually high content of iron has been found at the Sterling mine. It occurs as gray clay-like masses in the walls of some of the vugs, and as spheroidal aggregates of cream-white, microscopic crystals in others (Figs. 27 and 28). It is most commonly associated with quartz, stilpnomelane and magnetite pseudomorphs after hematite. Rarely, striated crystal molds of an unknown mineral, possibly anhydrite, are observed in the massive iron-rich talc.

The X-ray powder diffraction pattern for this material is similar to that of normal talc. The major observed *d*-spacings (in Å) and their relative intensities are: 9.33 (VS), 4.57 (MW), 3.123 (S), 2.549 (W), 1.733 (W), 1.530 (M), and 1.323 (W). Some of the reflections appear smeared, which may be due to a disordered stacking ar-

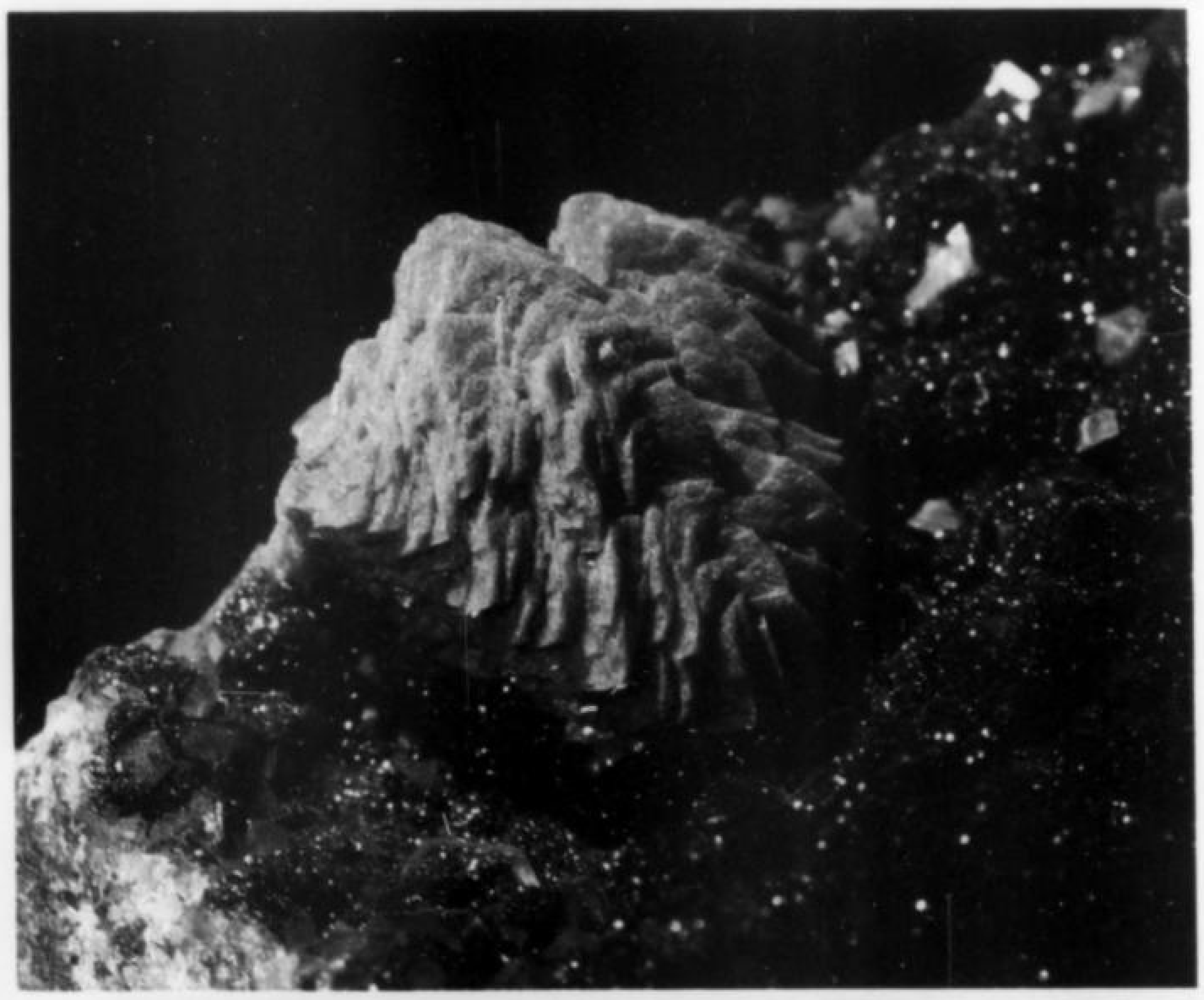
(R. Ramik, personal communication, 1983). Subsequent wet chemical analysis showed the presence of an average 4.7% Fe_2O_3 and 12.6% FeO. An average composite analysis based on microprobe, TGA and wet chemical data yields: SiO_2 = 54.5, Al_2O_3 = 0.2, Fe_2O_3 = 4.7, FeO = 12.6, MgO = 17.2, H_2O (+) = 4.5, H_2O (−) = 0.5, sum = 94.2 weight %. Based on a total of 7 cations, the resulting empirical formula is $(Mg_{1.90}Fe^{+2}_{0.78}Fe^{+3}_{0.26}Al_{0.02})Si_{4.04}O_{10.06}(OH)_{2.23}$, closely approximating the general talc formula $(Mg,Fe)_3Si_4O_{10}(OH)_2$.

Forbes (1969) demonstrated the effect of iron on the d_{003} spacing in synthetic iron-rich talcs and its dependency on oxygen fugacity, noting the greatest increase for the hematite-magnetite buffer series. The substitution of $Fe^{+3} + H^+ = Si^{+4}$ with the formation of hydroxyl ions on the basal surface was proposed to explain the

Figure 29. Ferruginous quartz enclosing red hematite. The field of view is 5.6 cm; #H241, Oren Root collection, Hamilton College. Photo by S. Chamberlain.

Figure 30. Quartz crystals on botryoidal goethite coating hematite crystals. The field of view is 7 cm; #H248, Oren Root collection, Hamilton College. Photo by S. Chamberlain.

Figure 31. Siderite crystals on quartz and magnetite pseudomorphs after hematite crystals. The field of view is 4.5 cm; #H241, Oren Root collection, Hamilton College. Photo by S. Chamberlain.



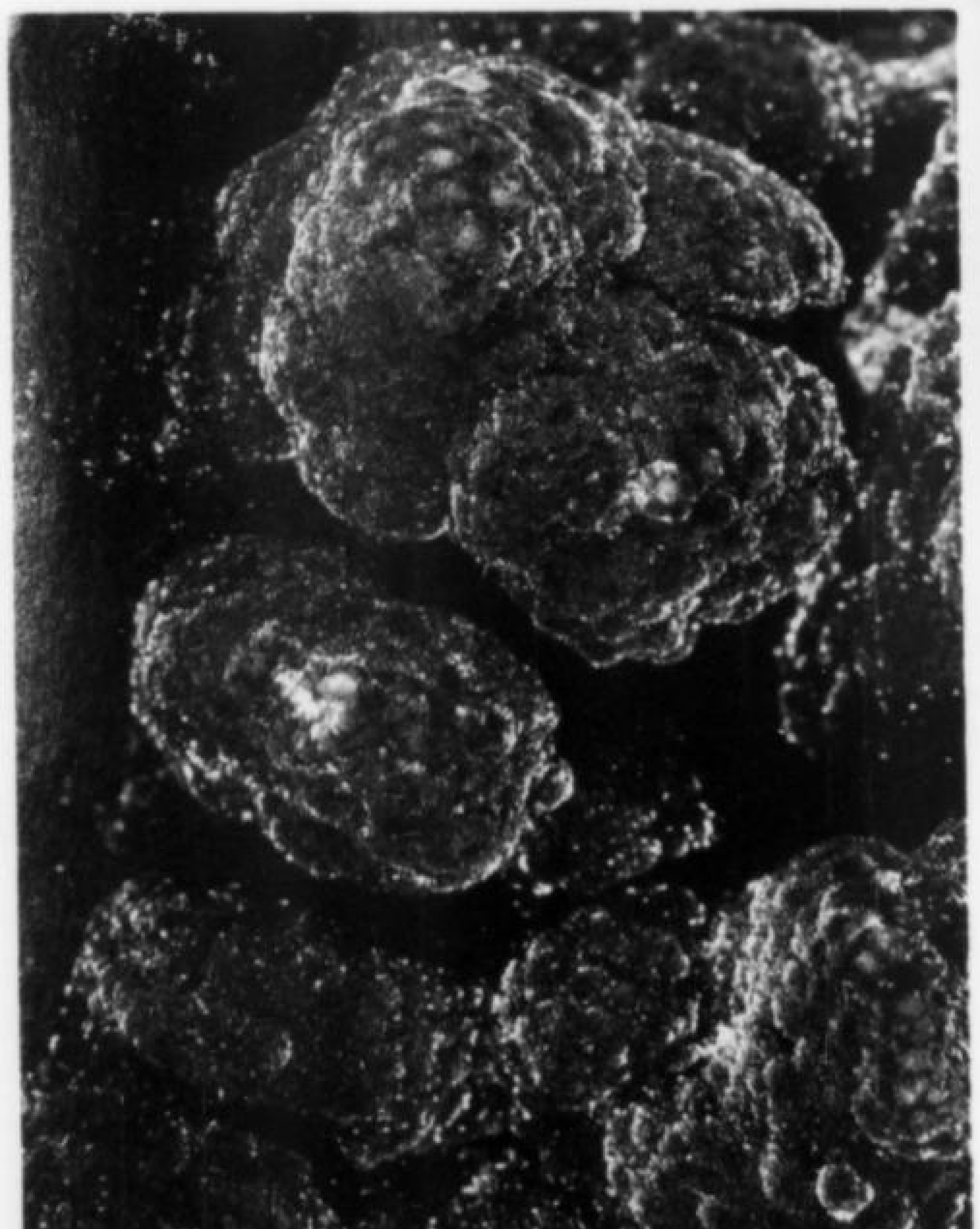


Figure 32. Stilpnomelane. The field of view is 3.2 cm; #H185, Oren Root collection, Hamilton College. Photo by S. Chamberlain.

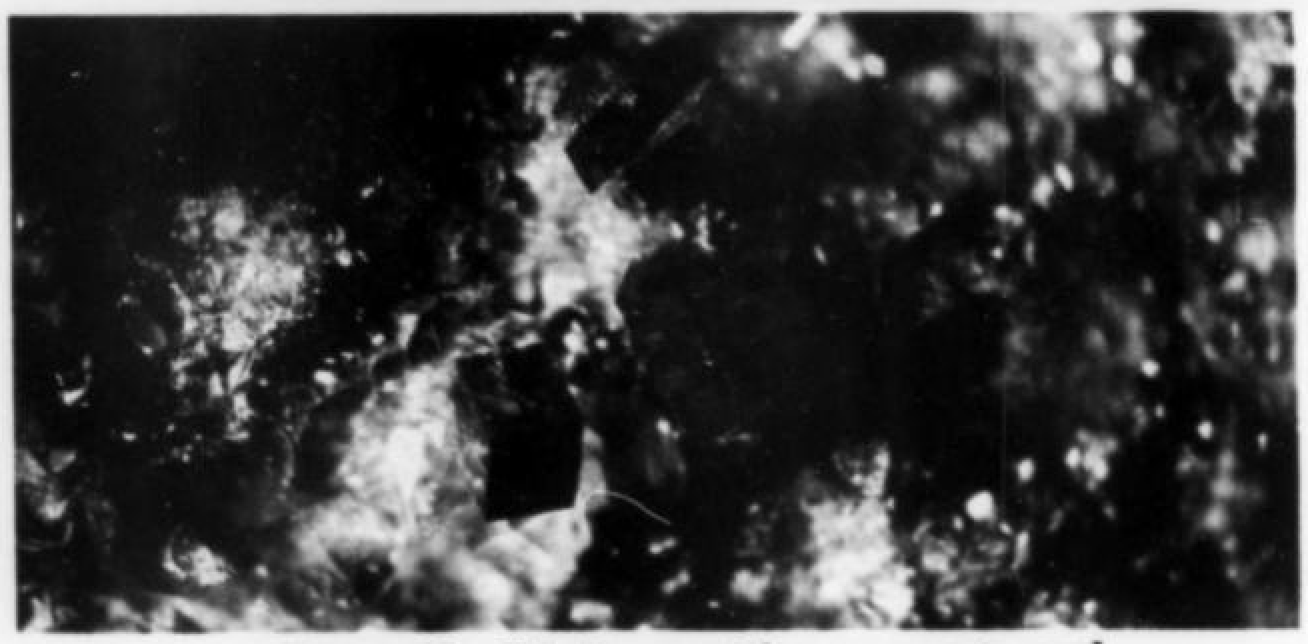
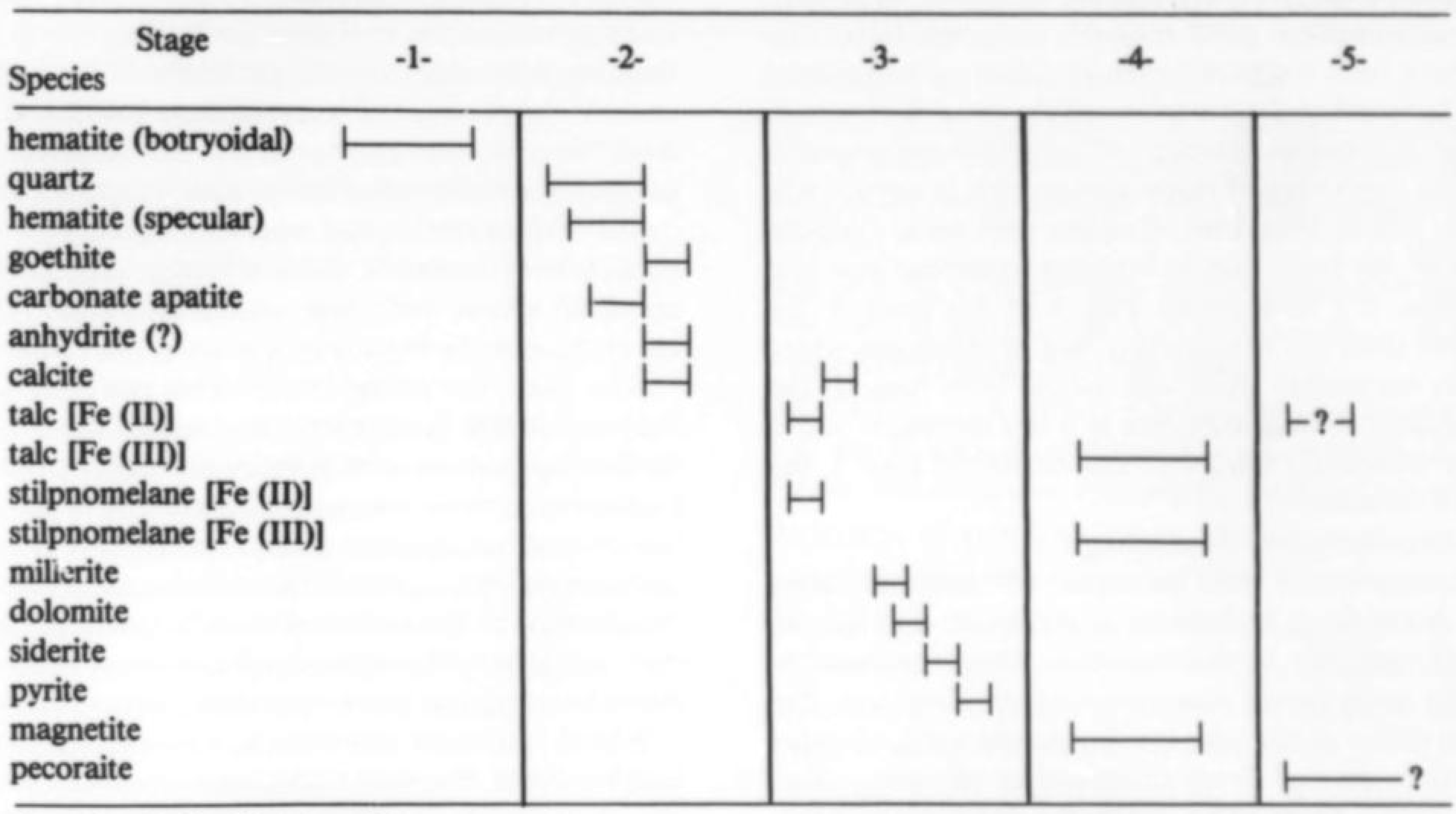


Figure 33. Siderite crystals on quartz and magnetite pseudomorphs after hematite crystals. The largest crystal is 0.5 mm; #326, S. Chamberlain collection. Photo by S. Chamberlain.

observed increase in the c dimension. Although the present study indicates the presence of an excess of 0.23 $(OH)^-$, effectively balancing the 0.28 excess positive charge due to the presence of Fe^{+3} and Al^{+3}, the tetrahedral site appears to be completely filled by Si^{+4}, and a correspondingly proportionate increase in d_{003} is not observed. Based on Forbes's conclusions, the observed d_{003} = 3.123 and d_{060} = 1.530 would indicate formation at an oxygen fugacity at or below the magnetite-iron buffer series, which seems unreasonable since the observed hematite-magnetite transformation should have buffered the oxygen fugacity at a value more closely corresponding to that reaction. This discrepancy may be explained by the fact that Forbes used synthetic iron-rich talcs in which Fe^{+3} substituted for Si^{+4} in the tetrahedral site. The chemical data suggest that in the iron-rich talc from the Sterling mine, both the Fe^{+2} and Fe^{+3} substitute for Mg^{+2} in the octahedral site, and Forbes's data are thus applicable. Such substitution may also increase the mineral's stability by reducing the structural misfit due to differences in lateral dimensions of the tetrahedral and octahedral sheets (Guggenheim, personal communication, 1984).



Stage 1 – Stalactitic Deposition
Stage 2 – Ferric Mineral Deposition
Stage 3 – Ferrous Mineral Deposition
Stage 4 – Coupled Oxidation-Reduction
Stage 5 – Late Deposition and Weathering

Figure 34. **Paragenesis of the principal mineral species at the Sterling mine.**

PARAGENESIS

The paragenesis of the minerals can be considered in three parts: (1) the minerals remaining from the original marble; (2) those remaining from the original granite gneiss; and (3) those formed during the deposition of the ore. Minerals remaining from the original marble include flakes of graphite and phlogopite found in a calc-silicate rock that has been partially replaced by hematite. Minerals remaining from the original granite gneiss are found as grains and plates in the green, chloritic rock and include quartz, feldspar, phlogopite and minor tourmaline. The paragenesis of the minerals found in cavities in the ore has been determined from examination of numerous hand specimens and, while not exhaustive, should be indicative of the general paragenetic pattern (Fig. 34). The observed sequence of mineral formation coupled with additional observations suggests the following five paragenetic stages: (1) stalactitic deposition; (2) ferric mineral deposition; (3) ferrous mineral deposition; (4) coupled oxidation-reduction; and (5) late deposition and weathering.

Stage 1 – Stalactitic Deposition

It is obvious that open spaces must have existed in order for the crystals observed in the vugs to have formed. These voids may have resulted from dissolution of the marble by acidic solutions derived from decomposing sulfides or meteoric water with dissolved carbon dioxide. Some may simply have existed as fractures in the sandstone or other rocks, or as voids in a poorly sorted, unconsolidated, basal or slump-formed breccia. The change in volume resulting from the chloritization process may have produced openings in or around the altered gneiss. Regardless of their origin, the fact remains that open spaces were present for solutions to enter and deposit botryoidal and stalactitic hematite. Ocherous to botryoidal hematite is a universal feature of cavity walls, and thin sections of stalactitic aggregates of later-formed minerals commonly show a core of this hematite phase. The original precipitates may have been amorphous ferric hydroxides or oxyhydroxides that gradually recrystallized as hematite, possibly after passing through an intermediate goethite phase. This stage of deposition may well have occurred at or near surface conditions in late Precambrian time.

Stage 2 – Ferric Mineral Deposition

The minerals of this stage include quartz, specular hematite, carbonate apatite, crystallized goethite, calcite and anhydrite (?). Fluid inclusion studies indicate an elevated temperature (140–150° C) during this phase of mineralization. The first two minerals to form were hematite and quartz. The walls of many cavities are a banded mixture of these two minerals. Hematite crystals are commonly embedded in quartz crystals and the quartz is encrusted with hematite, suggesting a simultaneous or alternating crystallization. The few specimens of carbonate apatite that were available for study suggest that it also crystallized at this time. The next mineral to form appears to have been goethite, since delicate golden sprays of acicular crystals commonly lay partially within the terminations of quartz crystals. The anhydrite (?) laths and calcite scalenohedrons that formed during this stage were subsequently dissolved away leaving crystal molds in later-formed minerals. Since these minerals certainly did not form under surface conditions, considerable time may have elapsed between stages 1 and 2.

Stage 3 – Ferrous Mineral Deposition

After the final deposition of quartz, specular hematite and goethite, a new association of minerals began to be deposited, starting with iron-rich talc and stilpnomelane. As discussed above, there is good evidence to suggest that both of these silicates initially formed as ferrous iron species, marking the beginning of a new stage in the paragenesis. After stilpnomelane, a second generation of calcite of predominantly rhombohedral habit formed, followed in order by millerite, dolomite, siderite and pyrite (probably concurrently with sphalerite and chalcopyrite). Thin sections of the overlying Potsdam sandstone clearly show replacement by hematite, carbonates and stilpnomelane, which strongly suggests that stages 2 and 3 occurred in the Paleozoic after the formation of the sandstone. Although Smyth (1894a) observed distinct pebbles of ore completely enclosed within the overlying sandstone and interpreted this as proof of a Precambrian origin for the ore, certainly not all the ore formed at that time.

Stage 4 – Coupled Oxidation-Reduction

The nearly universal reduction of the hematite crystals in the cavities to magnetite appears to have been a major event in the paragenesis. The evidence presented above suggests that a coupled oxidation-reduction reaction occurred in the open cavities between hematite and stilpnomelane (and probably iron-rich talc). This reaction may have been triggered by an elevation in temperature and pressure subsequent to the deposition of the minerals involved, as stilpnomelane is a typical indicator of low-grade metamorphic conditions. In the conversion of stilpnomelane rich in ferrous iron to stilpnomelane rich in ferric iron, electrons were made available to reduce some of the ferric iron in hematite to ferrous iron and produce magnetite. We have placed stage 4 at this point in the paragenesis based upon the observations that in specimens where the cavities were completely filled with calcite from stage 5, the hematite was reduced to magnetite, but in a few specimens where the cavities were completely filled with dolomite from stage 3, the hematite was not reduced.

Stage 5 – Late Deposition and Weathering

Late in the paragenesis, a third generation of "nailhead" calcite was deposited. Some finely crystallized iron-rich talc also appears to have formed very late in the sequence. Small amounts of hematite, acicular goethite and aragonite were also deposited. The remainder of the events in this stage involve the alteration of earlier minerals. Malachite formed from chalcopyrite; pecoraite, from millerite; and goethite, from pyrite, magnetite and siderite. These alterations can take place under atmospheric conditions and may still be occurring in the dumps today. At some point or points in this final stage, some vugs were completely filled with calcite, or more rarely with calcite and gypsum. As noted above, pecoraite pseudomorphs after millerite crystals have been found within this calcite, as have magnetite pseudomorphs after hematite crystals.

DISCUSSION

In the course of this study, several unresolved problems arose which may merit further research. These questions are briefly outlined in the following paragraphs.

Were there time gaps separating any of the stages in the paragenesis? If so, where in the sequence were they, and how long did they last? It is possible that the initial stalactitic deposition occurred in the late Precambrian. The deposition of later phases, however, seems to postdate the formation of the Potsdam sandstone in the upper Cambrian, and some processes may still be ongoing today. Thus the sequence of events leading to the present mineralogy might have stretched over enormous periods of geologic time. Clearly, additional information will be required, perhaps including additional diamond drilling, paleomagnetic studies or isotope dating to help resolve these questions.

What was the source of the elevated temperatures during the deposition of the quartz and hematite? Was there an increase in temperature and/or pressure which triggered the proposed oxidation-reduction reaction between stilpnomelane and hematite? The diamond drilling records show no strong evidence of an intrusion at depth, other than a few localized bands of serpentinized or silicated marble similar to hundreds of others throughout the area. Furthermore, the survival of vugs from the initial stages, without subsequent collapse, indicates that pressures after the original deposition of the botryoidal hematite were modest at best. Finally, can the reduction of hematite to magnetite be solely explained by the corresponding oxidation of iron in the stilpnomelane (and possibly the iron-rich talc), or was there an additional supply of ferrous iron to or removal of oxygen from the system? Might the reaction be more closely related to Eh-pH changes?

Although there is a band of related deposits, why are several minerals unique to the Sterling mine? Millerite, stilpnomelane, iron-rich talc, and magnetite have not been found at any of the other similar deposits in the Antwerp-Keene belt. What was the original source of the nickel in the millerite? If there were local concentrations of nickel in either the pre-existing marble or granite gneiss, what was the primary nickel mineral, and why was it present only at the Sterling mine site? Both pyrite and pyrrhotite are known to be present in the unaltered gneiss from the drill core logs, but since the core itself is no longer available for analysis, we cannot confirm the presence of nickel in these sulfides. It is interesting to note, however, that pyrrhotite was not observed in the unaltered gneiss at the Caledonia mine or other properties drilled.

The unique presence of magnetite appears to be related to the unique occurrence of stilpnomelane and iron-rich talc. As presented above, ferric iron usually substitutes for silicon in talc, but in this case the ferric iron appears to share magnesium sites with ferrous iron. The oxidation-reduction reaction involving ferrous-ferric conversion in stilpnomelane suggests that the iron-rich talc at the Sterling mine may have formed as ferroan talc and later been oxidized in part to ferrian talc. Harder (1978) has shown that "the low temperature synthesis of iron silicate minerals with clay structures is possible . . . only under reducing conditions." In summary, the presence of these minerals is difficult to explain except to say that compositional variation of geological processes of a local rather than regional nature must have been involved.

Why is there no ankerite at the Sterling mine? Numerous analyses failed to reveal a single specimen of ankerite. Instead, a consistent pattern of siderite overgrown on dolomite was observed. The observed $Fe/(Fe+Mg+Ca+Mn)$ ratios were below a maximum of 0.45 for the dolomite and above a minimum of 0.75 in the siderite phase. No intermediate values were noted. The relatively sharp boundary observed between these two phases may simply reflect an abrupt compositional change to more iron-rich solutions with or without an accompanying time gap during crystallization. However, there may also have been some other processes in effect which limited the ankerite stability field during carbonate deposition. These possibilities merit further investigation.

NOTES FOR COLLECTORS

Although there is no substitute for good original documentation by a specimen's collector, we would like to offer here a few observations useful for separating Sterling mine specimens from those of similar nearby localities. Since there are a number of localities which produced fine specimens, but only the Sterling mine achieved a fame which persists to this day, there is a growing tendency to lump all specimens which look like Sterling mine pieces into a pile and call them that. Several points may prove useful in this regard. First, our observations and the older literature both indicate that only the Sterling mine produced millerite specimens. Second, we have observed stilpnomelane only at the Sterling mine. Third, only the Sterling mine produced specimens of magnetite pseudomorphs after hematite crystals, although not all specimens from the Sterling mine are so altered. (Fortunately all specimens we have observed which had vugs filled with dolomite and whose hematite crystals were not altered to magnetite also had associated stilpnomelane.)

The specular hematite and quartz specimens from a number of localities in the towns of Fowler, Pitcairn, Pierrepont, Edwards and Hermon in St. Lawrence County, New York, are usually more coarsely crystallized, especially the quartz, than those from the Sterling mine. Their matrix is often unaltered marble, and there was little or no marble excavated at the Sterling mine. Ocherous hematite is uncommon at these localities. Barite is a much more common associated mineral at these localities than it is at the Sterling mine (where we were unable to find a single barite specimen). Finally, the hematite crystals are not magnetic.

The other mines in the Antwerp-Keene belt are the most troublesome. We have collected and examined specimens from only one other mine, the Caledonia mine. None of the hematite crystals from the Caledonia appear to be magnetic. Other habits and associations characteristic of the Caledonia mine include: spherical aggregates of pyrite up to 2.5 cm in diameter; large, lustrous single pyrite crystals in cavities with quartz, siderite and hematite; calcite crystals of predominantly scalenohedral habit in cavities with other minerals; vugs containing flos ferri (reported); and large vugs lined with a lattice of unaltered hematite crystals accompanied by parallel groupings of nailhead calcite and barite.

Though such specimens are rare, the only other locality of which we are aware that may show the association of stilpnomelane and magnetite pseudomorphs after specular hematite is the Wallbridge mine, north of Madoc, Ontario, Canada. Further investigations may reveal others.

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Pseudomorphs from the Burra Mine, South Australia

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The Burra mine in South Australia has yielded thirteen different types of pseudomorphs involving pyrite, limonite, malachite, azurite, cuprite, chalcocite, libethenite, chrysocolla and pseudomalachite.

INTRODUCTION

The purpose of this paper is to document the occurrence of some fine and interesting pseudomorphs collected from outside the libethenite zone during the second life (1971–1981) of the Burra copper mine. The libethenite zone and the pseudomorphs encountered within it (with one exception, described here) have been previously described by Bywater (1984).

The minerals discussed here were all encountered by a team of collectors between September of 1980 and February, 1981, in stockpiled ore and in the pit itself.

The relative abundances of the pseudomorphs encountered outside of the libethenite zone, grading from common to very rare (based on observations by the author and other collectors), are as follows: malachite after azurite, chalcocite after pyrite, chrysocolla after azurite, malachite after cuprite, "limonite" after pyrite, chrysocolla after cuprite, "limonite" after azurite, chrysocolla after copper, "limonite" after malachite and azurite after pseudomalachite. Pseudomorphs of azurite, malachite and chrysocolla after libethenite are known from within the libethenite zone (Bywater, 1984).

GEOLOGICAL SETTING

The carbonate-silicate orebody of the Burra mine is emplaced in the Skillogalee dolomite member of the Adelaidean Burra group. Secondary ore in commercial quantity and quality was localized between two easterly dipping and northwesterly trending faults; Kingston's and Tinline's, outside and toward which mineralization diminishes rapidly (Wright, 1976).

The source of Burra's large but irregular oxidized zone was finally uncovered in 1980. The hypogene zone was found to comprise a low-grade chalcocite-chalcopyrite-pyrite-bornite-bearing porphyry of early Paleozoic age, centrally located beneath the main orebody (Noble, 1980). The oxidized portion of the Burra deposit consisted largely of malachite-azurite-chrysocolla and lesser cuprite mineralization which formed characteristic veins, nodules and disseminations. Local lithology consists predominantly of kaolinized shale, siltstone and dolomite breccia.

PSEUDOMORPHS

Malachite after azurite

An astonishing array of habits is exhibited by this common replacement, which frequently shows only partial and sometimes alternating alteration. Although not markedly large in crystal size (up to 3 cm), their beauty, particularly in the micro to miniature size, is unsurpassed, at least within South Australia. Some interesting plates of crystals show small, unaltered azurites on one portion with a distinct line of transition showing partial replacement, followed by complete malachite pseudomorphs after azurite. Habits exhibited are typically blocky to pseudo-cubic or pseudo-rhombohedral, and rarely thin, bladed, tabular prismatic.

Near the base of the oxidized zone in a block of low-grade ore some interesting malachite pseudomorphs of long-prismatic and blocky morphology were found. They form dense groups of free-standing crystals to 3 by 8 mm or larger, and isolated individuals reading 0.5 by 1.5 cm in size, which are almost without exception coated with transparent shells of drusy quartz. Rarely the underlying crystals are leached away leaving only a shell of quartz (D. Winstanley, personal communication, 1983).

Chalcocite after pyrite

This unusual pseudomorph (partial and rarely complete) was encountered in the narrow zone of primary ore uncovered at the base

Figure 1. **Twinned, doubly terminated crystals of malachite after azurite. Central crystals are 4 mm in length. Bywater specimen (B53;80) and photomicrograph.**

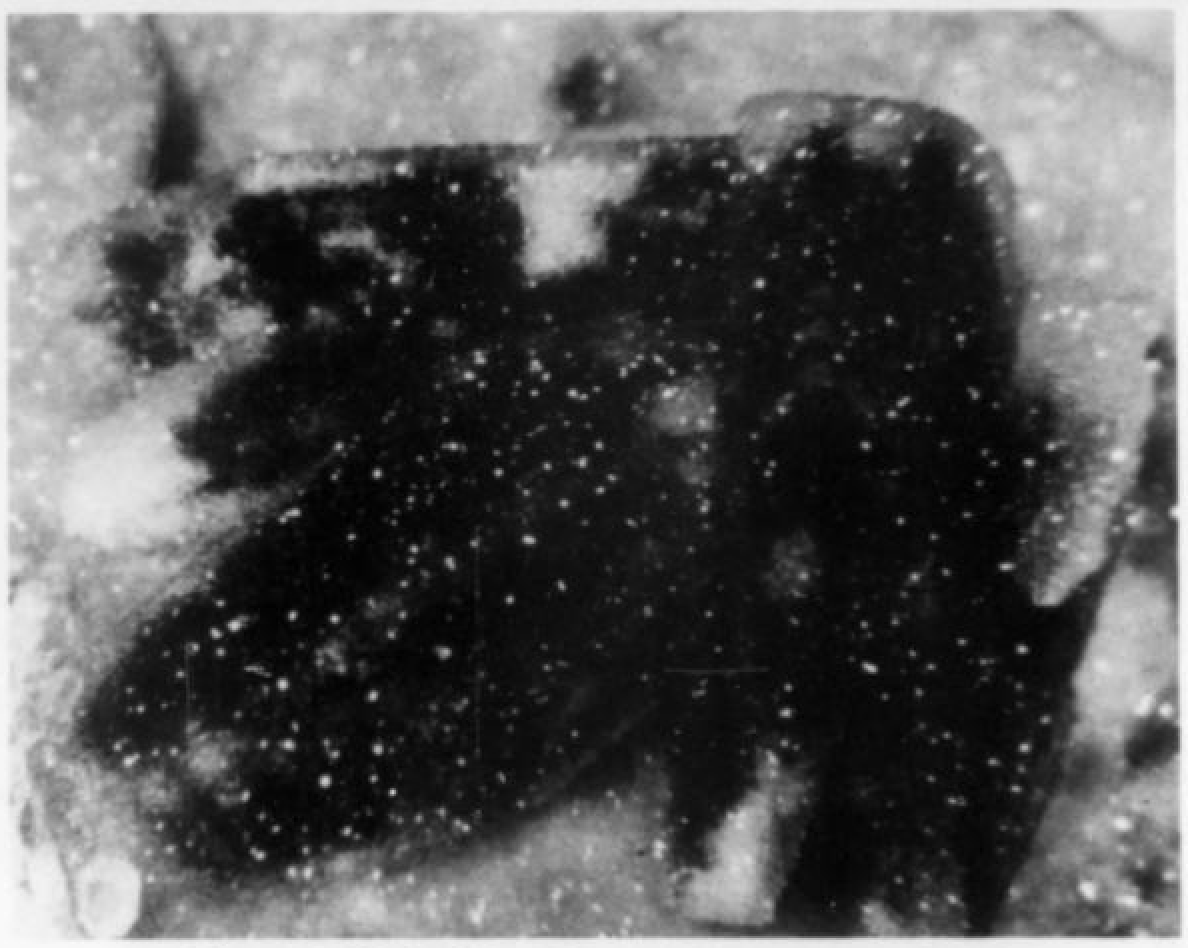

Figure 2. **Malachite after azurite, encrusted with drusy quartz. Each crystal is 1 cm in length. Bywater specimen (B96;81) and photomicrograph.**

of the pit. The pyrite forms sharp pyritohedrons or octahedrons in drusy-quartz-lined vugs within a granular, bone-white sulfide-bearing quartzite. The crystals frequently exhibit interpenetrating growth, being sometimes minutely cracked and veined with chrysocolla. The largest individuals reach 5 cm in size although, unfortunately, these and many of the smaller crystals usually separate from the matrix during removal.

Figure 3. **Partial pseudomorphs of chrysocolla after azurite, coated with drusy quartz. Major crystal is 4 mm in length. Bywater specimen (B98;81) and photomicrograph.**

Chrysocolla after azurite

This is an uncommon pseudomorph at Burra, occurring both as incomplete and complete replacements. Individual crystals generally reach some 3 mm in size, the majority of them representing replacements after pseudo-rhombohedral azurite crystals which form densely packed, frequently uniformly oriented crystals on leached azurite. As with pseudomorphic malachite, some interesting drusy-quartz-coated chrysocolla replacements were encountered near the base of the pit. Chrysocolla rarely forms both partial and complete replacements, sometimes with malachite dovetailing into otherwise unaltered azurite crystals which reached 8 mm in size.

Malachite after cuprite

Surficial pseudomorphs of malachite after cuprite are relatively widespread throughout the deposit, generally forming compact aggregates of small, modified cubes. Complete replacements occur only very rarely associated with chrysocolla after cuprite and malachite, reaching to 1 or 2 mm in maximum size.

"Limonite" after pyrite

Small chocolate-brown pyritohedrons were found totally embedded in dolomite breccia in a low-grade carbonate ore which formed in the deepest portion of the oxidized zone beneath and adjacent to the libethenite zone. Their occurrence may well have been widespread in this region just above the primary-zone.

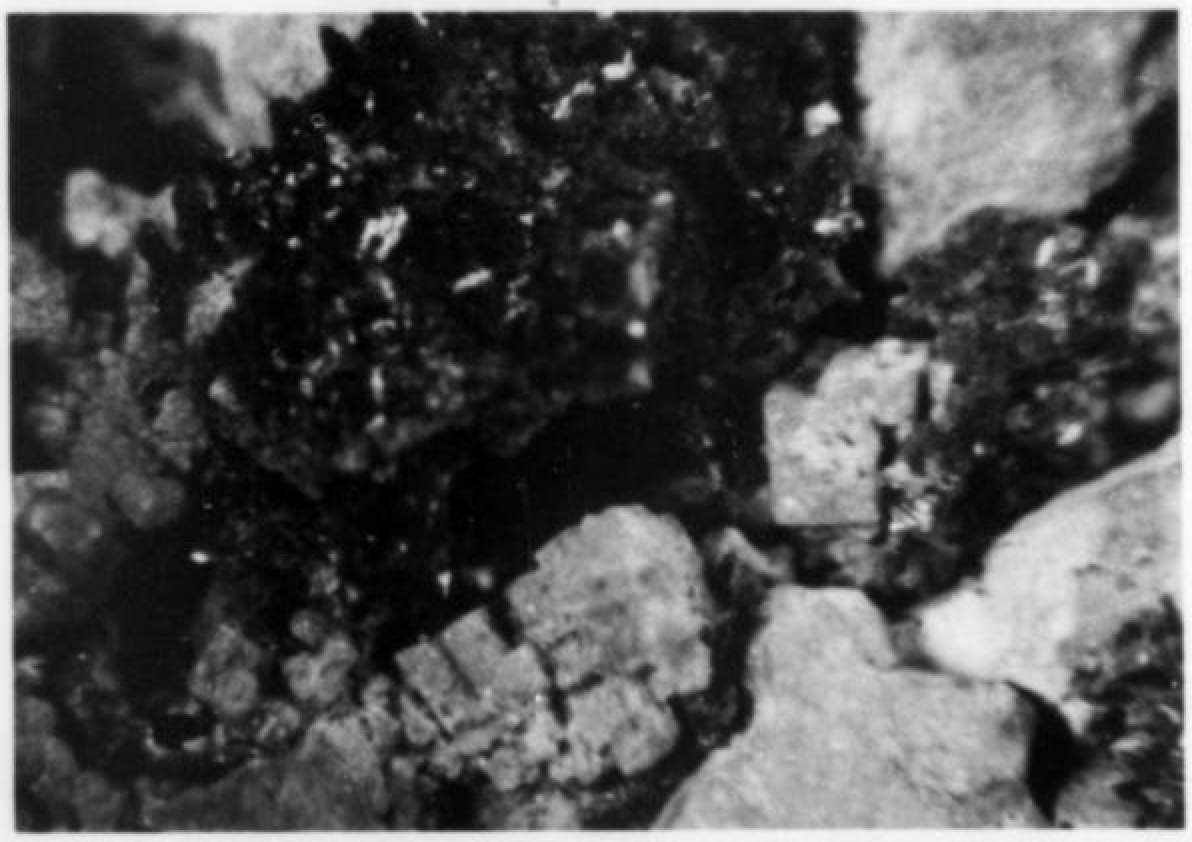

Figure 4. **Chrysocolla after cuprite, with second generation cuprite octahedrons on malachite. Distinct crystal is 3 mm along an edge. Bywater specimen (B61;80) and photomicrograph.**

Chrysocolla after cuprite

This exceedingly uncommon pseudomorph was found encrusting a small boulder of compact siltstone on a stockpile of high-grade ore in November, 1980. Olive-green to bright sky-blue chrysocolla was found to have completely and faithfully replaced cubic and octahedral cuprite crystals, including individuals and multiple-intergrowths which typically form "trains" of perfect cubes, supported by thin tubes of chrysocolla. These pseudomorphs reach 6 mm in size and characteristically possess a surface sprinkling of small, complex azurite crystals and deep green, surficially crystallized malachite or a second generation of minute, sparkling cuprite octahedrons. Sometimes these pseudomorphs have a core of malachite indicating an initial change from cuprite to malachite followed by a subsequent alteration to chrysocolla.

Figure 5. **"Limonite" after azurite, grading from complete at left to partial at right. Minute cuprite octahedrons stud the pseudomorphs. Field of view is 1.5 cm. Bywater specimen (B89;81) and photomicrograph.**

"Limonite" after azurite

Aggregates of acute pseudo-rhombohedral azurite crystals to about 2 mm each were found totally to partially replaced by "limonite" in a small boulder during January, 1981. The crystals occurred in voids which reached 6 cm in width, within an alternating malachite, azurite, "limonite" matrix. Some of the crystals, particularly those verging on tabular morphology, exhibit a distinct sub-metallic tarnish of reds, greens and purples. Small perfect octahedrons of cuprite commonly stud these pseudomorphs.

Chrysocolla after copper

Occurs as very thin, rarely hollow, tubes of a bright sky-blue or olive-green hue supporting chrysocolla pseudomorphs after cuprite. They are confined entirely to this association and typically possess small interpenetrant octahedrons of cuprite which were ubiquitous in the section of ore encountered during 1980 and 1981.

"Limonite" after malachite

This pseudomorph was analyzed by the South Australia Mines Department in 1980 and identified as "limonite" after brochantite. The replaced crystals have since been determined to have been malachite instead, occurring as thin diamond-shaped, striated tablets reaching 1 mm in size, and associated with quartz, cuprite and malachite.

Azurite after pseudomalachite

During a recent perusal of some libethenite-zone specimens collected during January, 1981, an interesting pseudomorph was encountered. Thin hemispherical plates of pseudomalachite to about 4 mm were seen to be partially altered to and partially overlain with azurite, the color contrast being quite stunning.

Non-pseudomorphic malachite

Six distinct habits have been noted for Burra's malachite crystals. Reaching 4 by 5 mm in size, their perfection of form, color and luster and fine attendant species render them a noteworthy feature of the Burra deposit.

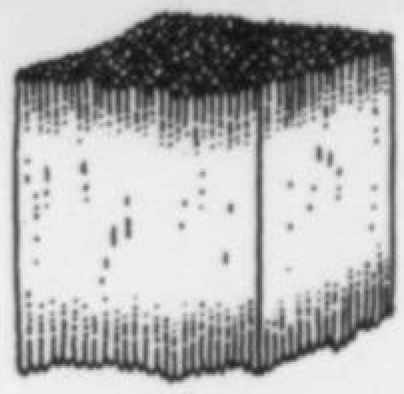

Figure 6. **Pseudo-cubic malachite showing parallel growth of prisms at the edges of the major crystal.**

Tabular-blocky

Fine, blocky, vaguely V-shaped crystals of malachite reaching 4 mm in size occur widely, although sparsely, within the Burra deposit. They occur as distinct individuals or sub-parallel groups characteristically associated with crystallized and leached massive cuprite which forms veins, leached smears and disseminations. Fine, bladed barite crystals were also found associated with those crystals encountered during 1980 and 1981. The non-pseudomorphic malachite crystals retrieved in small quantity from the Cole shaft, Bisbee, Arizona (1400 level, 26L stope) are virtually identical in habit (Graeme, 1981).

Acicular

Tufts or, more rarely, carpets of hair-like, tapering malachite crystals frequently twinned on *a*(100) occur uncommonly within the Burra deposit. The crystals thickly encrust matrix to several square cm, although the individual crystals reach only 1 or 2 mm in size.

Divergent acicular

Fine sprays of acicular crystals radiating from a single point, in some cases clustered in two directions (i.e. "bow-ties"), were encountered in February, 1981. They occur in groups reaching to 4 mm which in turn form encrustations to 3 square cm. Malachite of this morphology has only been identified on a handful of specimens, in association with leached azurite crystals and rare, nearly white cubes of chrysocolla after cuprite.

Diamond-tabular

Small, thin to thick tabular, striated diamond-shaped crystals of a magnificent emerald-green hue are sometimes found associated with cuprite. They also form as "arrowheads" on the surface of some of the mammillary malachite from this locality.

Pseudo-cubic

Distinctly blocky, vaguely pseudo-cubic crystals which break into parallel groups of eight-sided prisms at the edges are the most unusual form of malachite from this locality. Individual crystals reach 4 by 5 mm in size and are frequently color-zoned, with blackish green cores giving way to lighter green extremities, the color transition being marked by a very distinct, thin line.

Stout-prismatic

Rarely, malachite occurs as brilliant, translucent prisms with blunt terminations reaching 3 mm in size. On one specimen these crystals can be seen to have deposited on, and partially within, their terminations, small minutely crystallized aggregates of libethenite. This gives credence to the hypotheses which predicted that libethenite occurred fairly widely throughout the orebody rather than being confined to one distinct zone. This specimen came from the base of a pre-1900 waste dump.

DISCUSSION

The pseudomorphs mentioned, coupled with the unique replacements encountered within the "libethenite-zone" qualify the Burra deposit as one of the world's richest sources for unusual and unique pseudomorphs. Although crystal size and abundance is generally far from remarkable, no other world locality can boast the pseudomorphic diversity possessed by the Burra deposit.

ACKNOWLEDGMENTS

The author thanks Peter Russ, Geology Department, Flinders University of South Australia, for use of the micrographer.

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new data on Lotharmeyerite

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INTRODUCTION

The new species lotharmeyerite from the Ojuela mine, Mapimi, Durango, Mexico was recently described by Dunn (1983). Unfortunately, the very small crystals in drusy growths which that author had at his disposal did not permit the determination of a number of important characteristics. The availability of larger, individual crystals from the same locality now makes possible a more complete description of the species.

OCCURRENCE

The lotharmeyerite used in this study, like that described by Dunn, is found in vugs occurring in a matrix of massive manganese oxides. We identified both cryptomelane and chalcophanite as major constituents of the matrix, although locally only one is likely to be prevalent. Subhedral, colorless to pale yellow adamite crystals are intergrown with the matrix, while euhedral, colorless to pale violet adamite crystals occur on the surfaces of the vugs.

Unlike Dunn, who observed the vugs on his specimen to be lined by a druse of brown, fibrous cryptomelane, we found, in most cases, that a druse of a brown, platy mineral forms the vug linings on our material. X-ray powder diffraction and energy-dispersive X-ray analysis showed this mineral to be the manganese analogue of arseniosiderite. (Work is currently underway to describe this new mineral.)

Lotharmeyerite crystals occur on the platy druse and also on and included within the euhedral adamite crystals (see Fig. 1). Lotharmeyerite was noted on only a small percentage of the specimens bearing violet adamite. Spherical aggregates of chalcophanite were observed on vug surfaces in association with lotharmeyerite and in other vugs as individual crystals. Austinite was noted in considerable amounts as druses on vug surfaces in this same general paragenesis, but was not observed in direct association with lotharmeyerite.

Figure 1. **Adamite crystal, 2 mm long, with inclusions of lotharmeyerite and the unnamed Mn analog of arseniosiderite. Clusters of lotharmeyerite crystals on the unnamed mineral surround the adamite crystal.**

X-RAY CRYSTALLOGRAPHY

The crystals used in our study provided somewhat diffuse and split spots on precession films, but these proved sufficient for the determination of the unit cell parameters.

Lotharmeyerite was determined to be monoclinic. Systematic ex-

Figure 2. **Scanning electron photomicrograph of a group of lotharmeyerite crystals. A druse of blades of an unnamed mineral (the Mn-analog of arseniosiderite) is visible in the background. The doubly terminated lotharmeyerite crystal near the center is 0.15 mm long.**

tinctions indicated the space group to be either *C*2, *Cm*, or *C*2/*m*. *C*2/*m* seems most likely from the morphology. The cell constants, determined from precession films and refined by the least-squares method using powder diffraction data, are a = 9.066(4), b = 6.276(2), c = 7.408(2)Å, β = 116.16(3)°, V = 378.3(4)Å³. The indexed powder diffraction data determined in this study are given in Table 1 along with the data obtained by Dunn. The data from the two studies match closely, although Dunn's results yield a slightly smaller unit cell.

MORPHOLOGY

Unlike the very small, equant crystals in drusy coatings which were described and illustrated by Dunn, those encountered in this study are predominantly tapering, blade-shaped crystals in loose intergrowths or as isolated crystals (Fig. 1). The crystals are typically 0.1 to 0.2 mm in maximum dimension, but range up to 1 mm in crude parallel growths. Doubly terminated crystals are common and are suggestive of centro-symmetry (hence, the presumed *C*2/*m* space group).

The blades are elongated in the *b* direction. On most crystals only the {001} form, corresponding to the edges of the blades, yields a distinct signal on the two-circle reflecting goniometer. The broad surface of the blade is roughly split longitudinally into two faces exhibiting prominent curvature about both the *b* and *c* axes. If considered parallel to the *b*-axis, these faces would correspond approximately to the forms $\{10\bar{1}\}$ and $\{20\bar{1}\}$. On the larger, parallel-grown crystals terminal faces sometimes are evident (Fig. 2). These were measured using the reflecting goniometer and correspond to {110} and {111}.

Although no definitive evidence of twinning was detected from X-ray precession photographs, the reflection of light from the {001} faces was occasionally split latitudinally. This is suggestive of twinning about an axis perpendicular to *b*; however, no twin law is proposed here.

PHYSICAL PROPERTIES

In concurrence with Dunn, we found lotharmeyerite to have a Mohs hardness of approximately 3 and a pale orange (yellow-

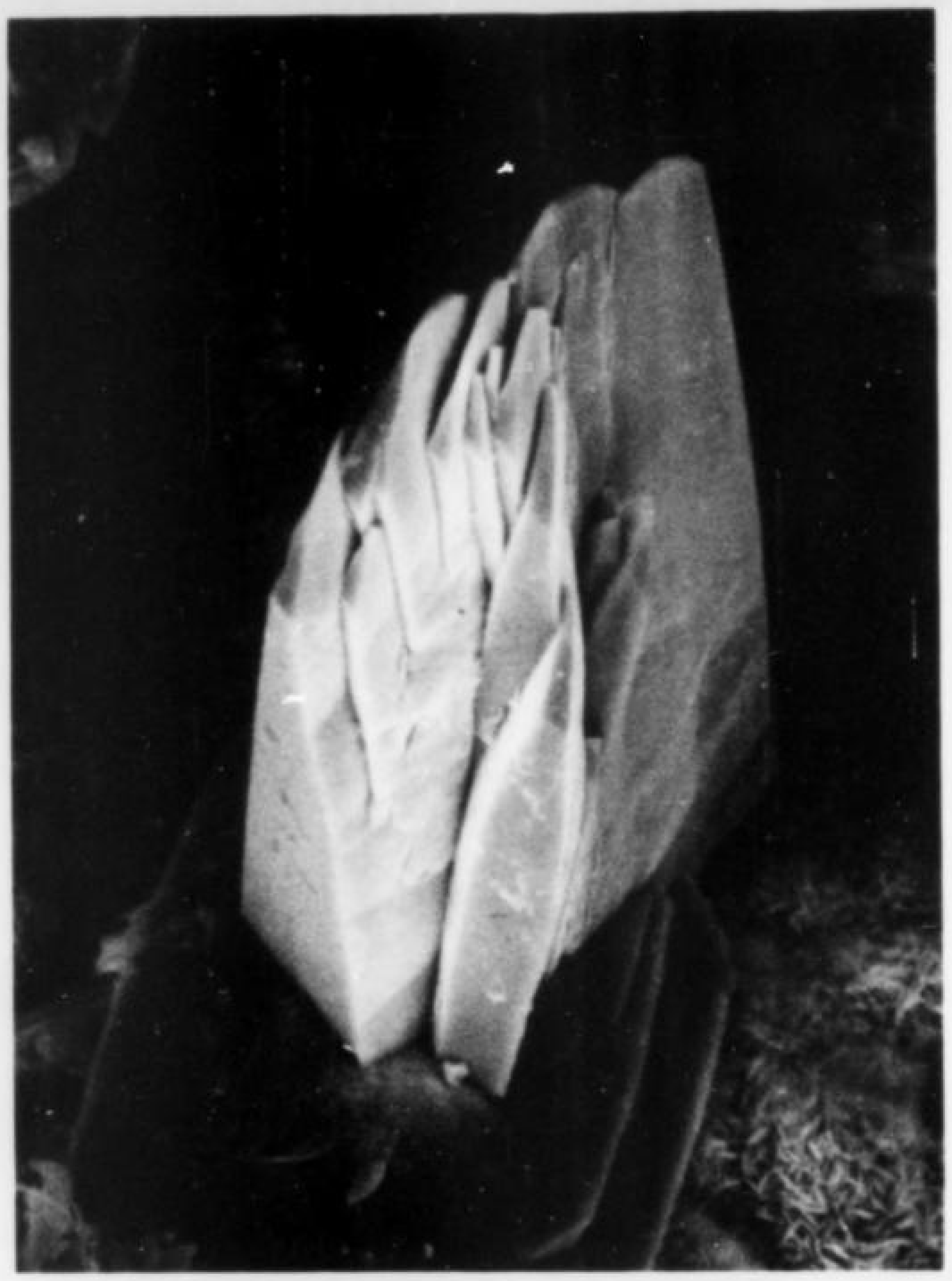

Figure 3. **Scanning electron photomicrograph of a sub-parallel aggregate of lotharmeyerite crystals exhibiting the {110} and {111} forms on their terminations. The aggregate is 0.05 mm across.**

orange) streak. Additionally our crystals exhibited a good cleavage parallel to {001}. Dunn reported an approximate density of 4.2 g/cm³ determined on a granular aggregate. Our determination carried out on single crystals using the sink-float technique in Clerici solution yielded a value of 4.23(5). By comparison the calculated density based upon our analysis #1 and two formula units (Z = 2) in the unit cell is 4.29.

OPTICAL PROPERTIES

Non-uniform, rolling extinction was typical of all crystals studied and somewhat hindered the measurement of optical constants and particularly the determination of the optical orientation. Nevertheless, with the aid of the spindle stage, lotharmeyerite was determined to be optically biaxial positive with indices of refraction: α = 1.797(5), β = 1.804(5), γ = 1.815(5). 2V ≈ 80°; strong inclined dispersion, $r \gg v$. The optical orientation is b = Y, $c \wedge Z = -40°$. The mineral is strongly pleochroic with X = orange-yellow, Y = red-brown, Z = yellow-orange, $Z < X \ll Y$. Our crystals did not exhibit a tendency to dissolve in index of refraction media as Dunn reported for his material.

CHEMICAL COMPOSITION

Chemical analyses were performed using an MAC-5 electron microprobe at an operating voltage of 15 kV and a beam current of 0.05 μA. Standards used were wollastonite for Ca, synthetic ZnO for Zn, garnet for Mn and Fe, and synthetic olivenite for As. Results are provided in Table 2 along with those of Dunn and the theoretical values. Mn is reported as trivalent in accordance with Dunn. In general, our results confirm the chemical data reported by Dunn. Our analyses show less ZnO and more Mn_2O_3 than do Dunn's, implying substitution of Mn^{+3} for Zn^{+2}.

A direct determination on 99 μg sample using a 903-H DuPont

Table 1. **X-ray powder diffraction data for lotharmeyerite.**

This study				Dunn (1983)	
hkl	d(calc)	d(obs)	I	d(obs)	I
001	6.65	6.64	20	6.66	10
110	4.97	4.98	40	4.94	80
$11\bar{1}$	4.622	4.654	30	4.587	50
$20\bar{1}$	4.453	4.452	10	4.473	10
111	3.549	3.539	20	3.513	20
$20\bar{2}$	3.416	3.432	50	3.414	90
$11\bar{2}$	3.188	3.205	60	3.175	90
020	3.138	3.139	20	3.116	20
201	2.941	2.935	50	2.912	90
021	2.838	2.840	50	2.822	80
$31\bar{1}$	2.721	2.726	40	2.710	80
$22\bar{1}$	2.565	2.571	100	2.557	100
220	2.485	2.475	50	2.468	50
112	2.473			2.455	50
$22\bar{2}$	2.311	2.318	10	2.307	20
022	2.282	2.278	10	2.267	20
$40\bar{2}$	2.226	2.223	10	2.227	5
003	2.216			2.204	5
202	2.151	2.146	20	2.129	50
221	2.146				
311	2.073	2.079	10	2.056	2
400	2.034	2.044	10	2.023	2
$40\bar{3}$	2.001	2.003	10	1.994	2
$13\bar{1}$	2.000				
$22\bar{3}$	1.933	1.939	10	1.929	2
131	1.882	1.881	10	1.872	2

This study				Dunn (1983)	
hkl	d(calc)	d(obs)	I	d(obs)	I
$20\bar{4}$	1.851	1.850	20	1.833	20
113	1.848				
$13\bar{2}$	1.821	1.822	20	1.817	20
023	1.810				
222	1.774	1.774	10	1.763	10
				1.752	10
$11\bar{4}$	1.722	1.720	30	1.713	70
$33\bar{1}$	1.720				
312	1.691	1.693	30	1.687	80
$42\bar{3}$	1.687				
004	1.662	1.668	10	1.663	10
				1.649	10
$22\bar{4}$	1.594	1.600	20	1.589	60
040	1.569	1.569	20	1.562	70
421	1.523	1.523	20	1.513	40
331	1.515				
$60\bar{3}$	1.484	1.493	10	1.485	5
$20\bar{5}$	1.470	1.469	20	1.465	20
223	1.469			1.457	20
$24\bar{2}$	1.426	1.424	10	1.420	10
133	1.420			1.412	10
511	1.404	1.402	10		
313	1.398				
241	1.384	1.384	10	1.377	20
$53\bar{2}$	1.369	1.366	10	1.360	20
600	1.356				

114.6 mm Gandolfi camera. CuKa radiation, visually estimated intensities.

moisture evolution analyzer yielded a total water content (less absorbed water) of 8.39%. This value is in good agreement with the difference values in both studies, 7.4% to 8.7%, and the theoretical value, 9.16%. (Because actual water content may be somewhat variable, difference values are provided in Table 2.) All water was released between 570° C and 600° C, implying tightly bound structural water in the form of OH and/or AsO_3OH rather than H_2O.

INFRARED SPECTRUM

To further test the likelihood that all water in the structure is in the form of OH and AsO_3OH, an infrared absorption was performed on a sample consisting of 246 μg of lotharmeyerite suspended in 40 mg of potassium bromide. The spectrum (Fig. 4) confirms the presence of OH rather than H_2O and further suggests that the OH is part of an acid arsenate unit. The broad absorption centered at about 2800 cm^{-1} arises from an O-H stretching motion and occurs in a region where absorptions from the strongly hydrogen-bonded OH in PO_3OH (Ross, 1974), AsO_3OH (Sumin de Portilla *et al.*, 1981) and VO_3OH (Harlow *et al.*, 1984) units occur. It is readily distinguished from the sharper absorptions from an OH group not associated with an acid arsenate such as that in adamite which absorbs at 3580 cm^{-1} (Sumin de Portilla, 1974). Absent from the infrared pattern is an absorption band due to the H-O-H bending motion of H_2O which would occur at about 1630 cm^{-1} with an intensity comparable to that of the OH stretching band near 2800 cm^{-1}.

In light of the above, Dunn's proposed ideal formula, $CaZnMn^{+3}(AsO_4)_2(OH)\cdot 2H_2O$, must be discarded. We propose the ideal formula, $CaZnMn^{+3}(AsO_3OH)_2(OH)_3$, for lotharmeyerite. This formula differs from Dunn's only in hydrogen assignments and, therefore, yields the same theoretical chemical analysis. Recently, structures containing both hydroxyl and acid oxy-anion groups have been suggested for brackebushite and gamagarite (Harlow *et al.*, 1984) and bayldonite (Sumin de Portilla *et al.*, 1981) based upon IR spectra similar to that of lotharmeyerite.

Table 2. **Microprobe analyses of lotharmeyerite.**

	This study		Dunn (1983)		$CaZnMn^{+3}$
	#1	#2	#1	#2	$(AsO_3OH)_2(OH)_3$
CaO	11.4	11.2	11.9	11.3	11.42
ZnO	14.2	14.2	17.5	18.3	16.56
Mn_2O_3	18.7	20.5	16.3	13.4	16.07
Fe_2O_3	–	–	1.1	2.7	–
As_2O_5	47.0	46.7	45.8	45.7	46.79
H_2O*	8.7	7.4	7.4	8.6	9.16

*Water by difference.

ACKNOWLEDGMENTS

The authors would like to thank Ronald Bentley who provided samples of lotharmeyerite on behalf of the Perkins Sams Collection and Kent England who provided additional specimens. Carol Stockton of the Gemological Institute of America prepared the SEM photographs. Randy Heuser and James Conca of the California Institute of Technology performed the microprobe analyses and the water determination, respectively.

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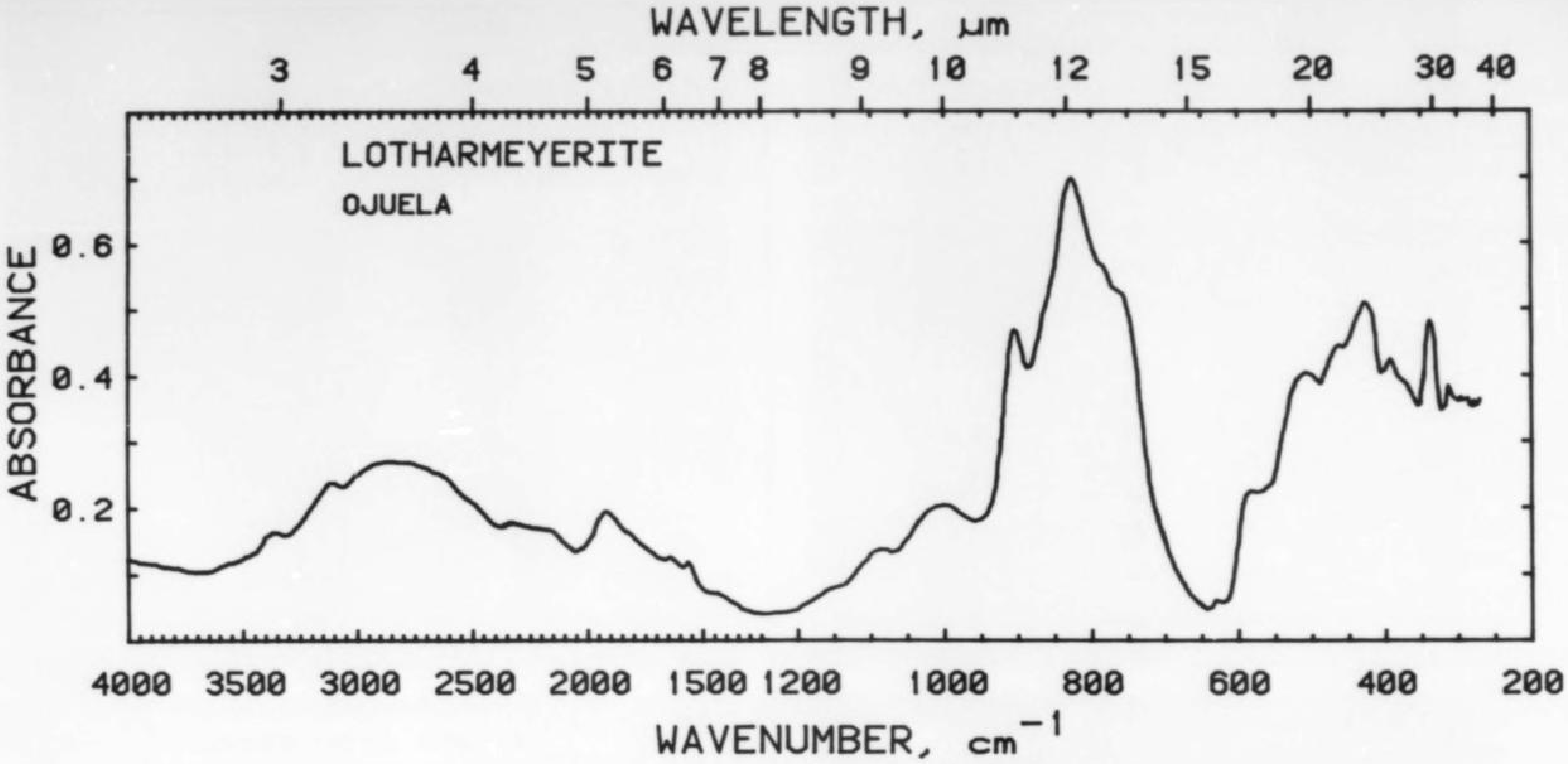

Figure 4. **Infrared absorption spectrum of lotharmeyerite.**

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Hematite Overgrowths

delineating dauphiné twinning in quartz

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SUMMARY

Hematite overgrowths on quartz from the Upper New Street quarry, West Paterson, New Jersey, are occasionally found completely coating one of the two sets of terminal rhombohedron faces of crystals not twinned on the Dauphiné law. On associated twinned crystals, the overgrowths cover irregular areas on the terminal faces, and these areas constitute maps of the areas making up the two halves of Dauphiné twins.

INTRODUCTION

Quartz crystals from the Upper New Street quarry, Paterson, New Jersey, were sent to the author by Ralph E. Thomas of Yardley, Pennsylvania. These crystals show preferential growth of hematite on certain areas of the terminal faces of the quartz, and Thomas suggested that the areas covered are governed by Dauphiné twinning in the quartz.

OCCURRENCE

The Upper New Street quarry is situated in the Watchung basalt, in the First Watchung Mountain, the easternmost of three northeast-southwest trending trap ridges in northern New Jersey. The Watchung basalt is Triassic in age, and is composed of extrusive flows of mafic rock sandwiched between beds of red sandstone and shale. While most of the basalt is of little interest to collectors, those parts composed of pillow lavas are world-famous as repositories for fine specimens of zeolites and zeolite associates formed by low temperature hydrothermal reactions in the cooling basalt. These specimens are to be seen in all the major mineralogical museums of the world, and have been well described by Mason (1960). The quartz crystals described here are associated with such zeolites.

DESCRIPTION

Typical material is composed of euhedral, short columnar quartz crystals showing alternating areas on the terminal faces which are deep brick-red and dusted with very fine hematite crystals or colorless, transparent and uncoated (Fig. 1). The crystals vary from 0.5 to 2 mm in diameter.

Certain of the crystals (Fig. 2) have hematite completely coating alternate rhombohedron faces, the areas of coverage coinciding exactly with the crystal edges. That is to say, the three faces of one rhombohedron form are preferentially coated with hematite, while the (alternating) three faces of a different rhombohedron form are uncoated. By far the most common faces on quartz crystals are the rhombohedrons *r* and *z* and the prism *m*. Since the rhombohedron

***Figure 1.* Quartz crystals coated red on the terminal faces by hematite. Field of view about 10 by 15 mm.**

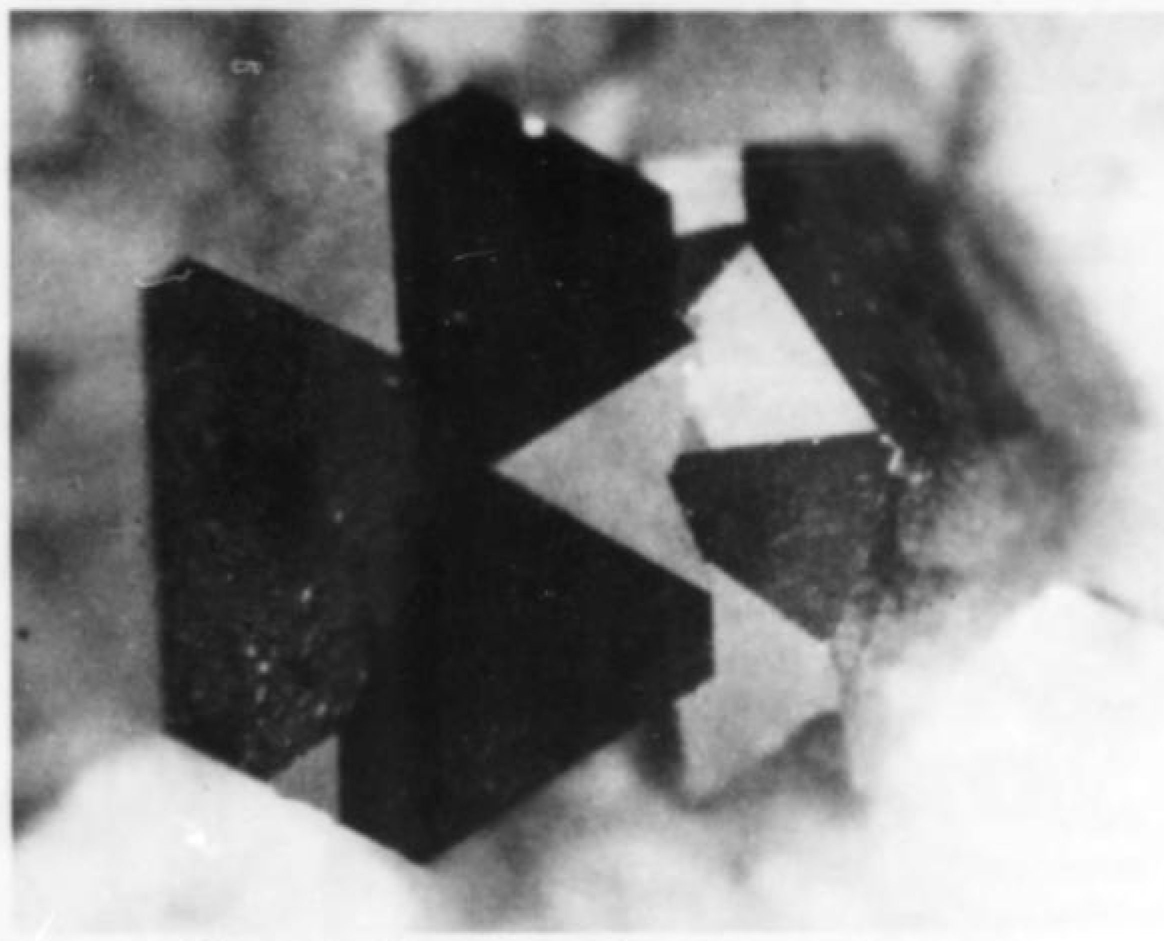


***Figure 2.* Quartz crystal coated on the larger rhombohedron faces, presumably *r*, with hematite. The lesser rhombohedron faces, presumably *z*, are uncoated. Size of crystal, 2 mm in diameter.**

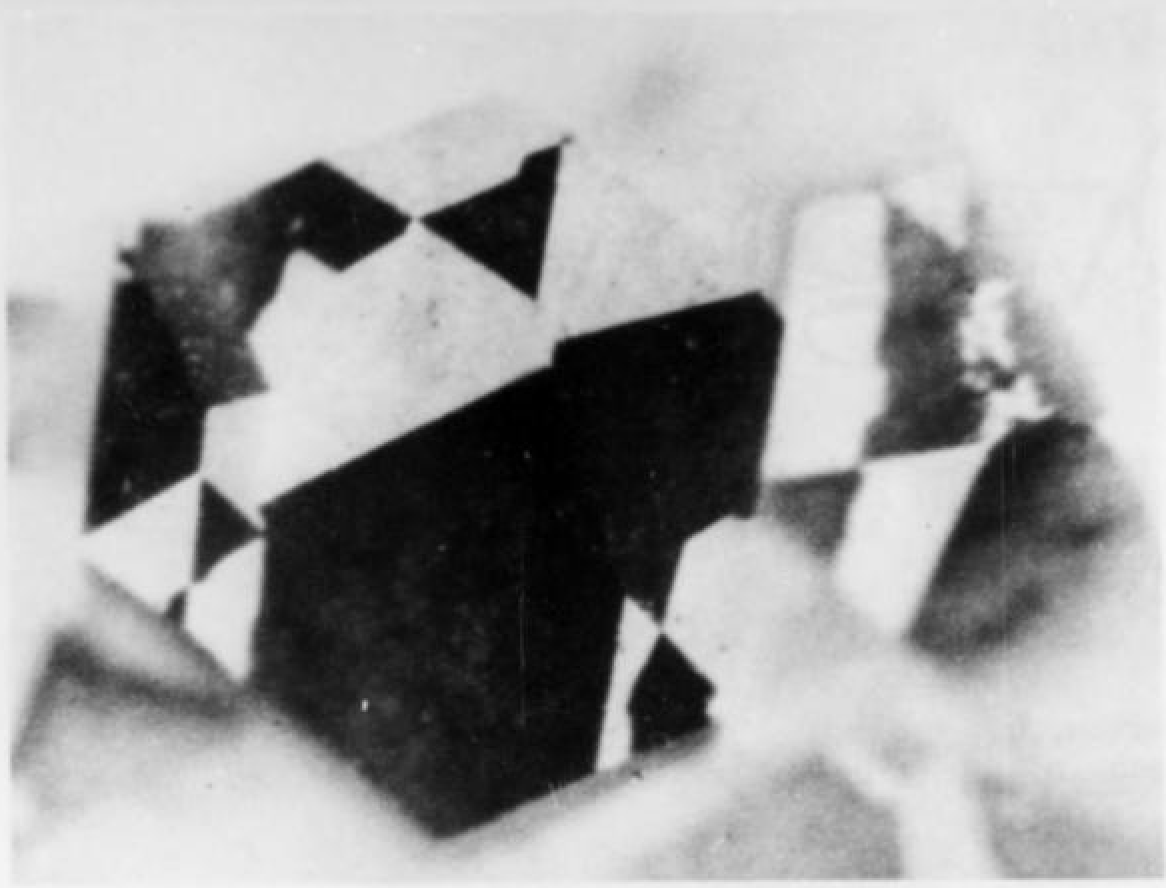


Figure 3. **Quartz crystal with terminal faces partially or wholly coated with hematite. Hematite covers areas composed of the *r* rhombohedron in crystals twinned by the Dauphiné law. Major crystal is 1.5 mm in diameter.**

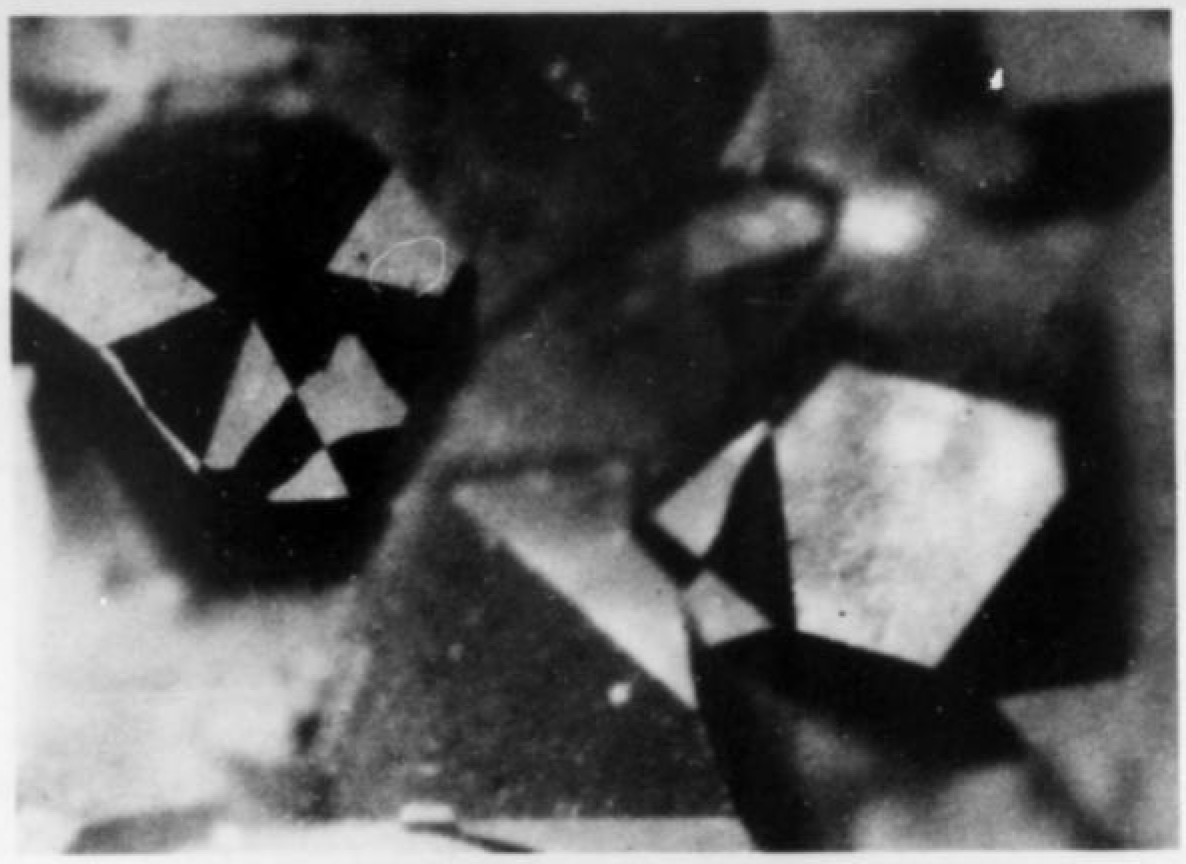
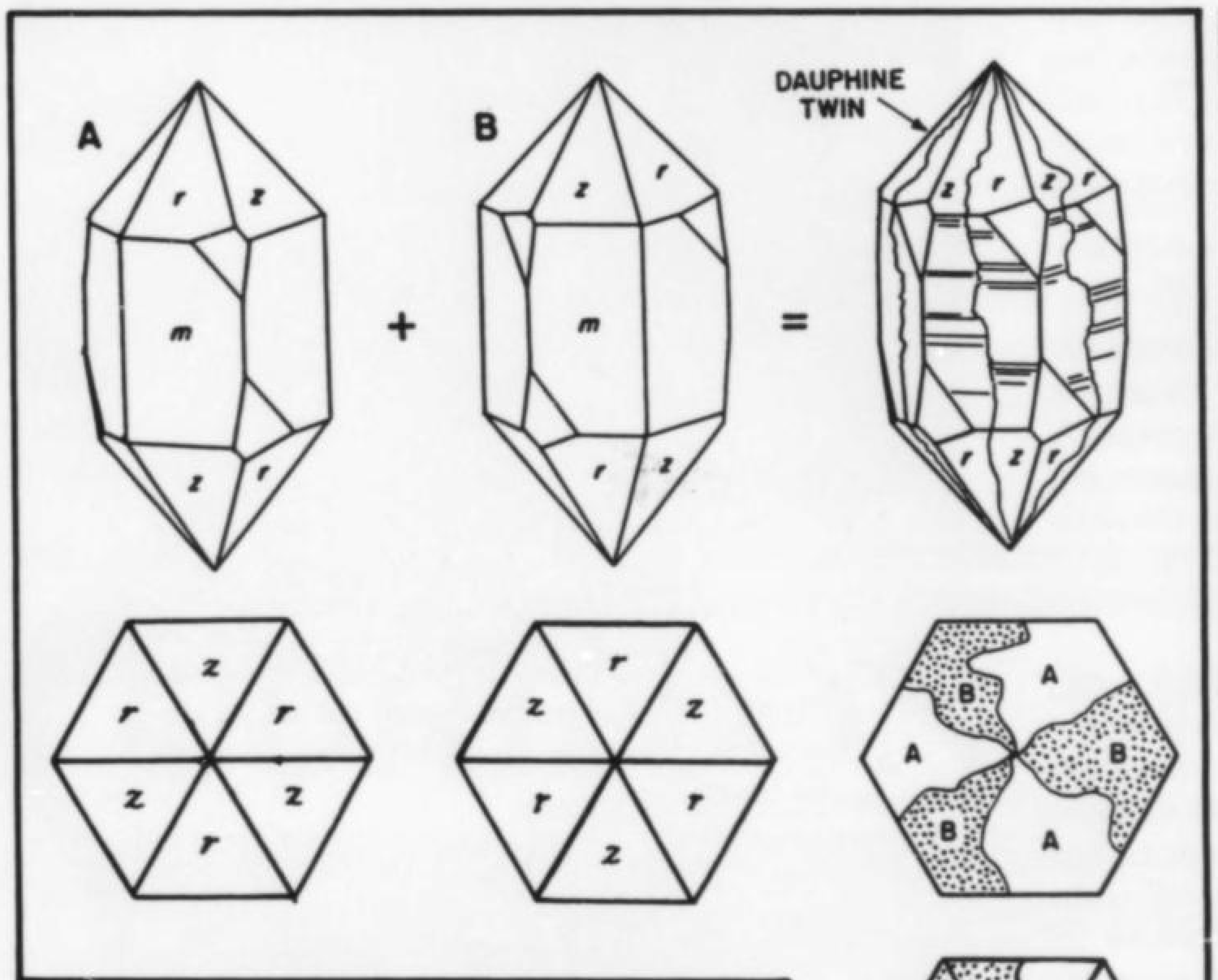


Figure 4. **Quartz crystals showing Dauphiné twinning. Note that where twinning crosses a crystal edge, hematite coats opposite quadrants. Crystals are 1 mm in diameter.**



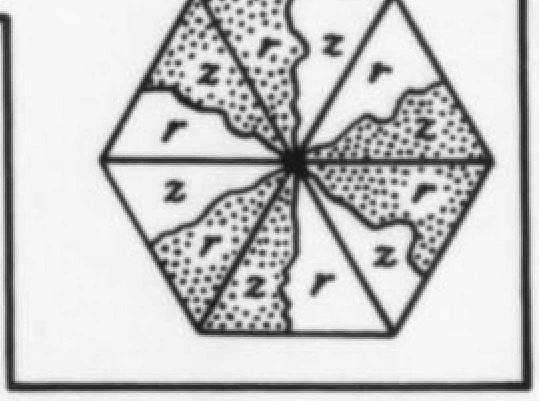


Figure 5. **The nature of Dauphiné twinning in quartz. Two individuals, A and B, having different orientations about their *c* axes, interpenetrate to form the twin shown at top-right. Vertical views (below) show the arrangement of *r* and *z* faces for A and for B (left and middle diagrams). The diagram at center-right shows a cross-section illustrating how the two individuals A and B are intergrown inside the crystal. At bottom right the termination of the twin is shown, with individual B stippled, showing the reversal of *r* and *z* faces across each twin boundary.**

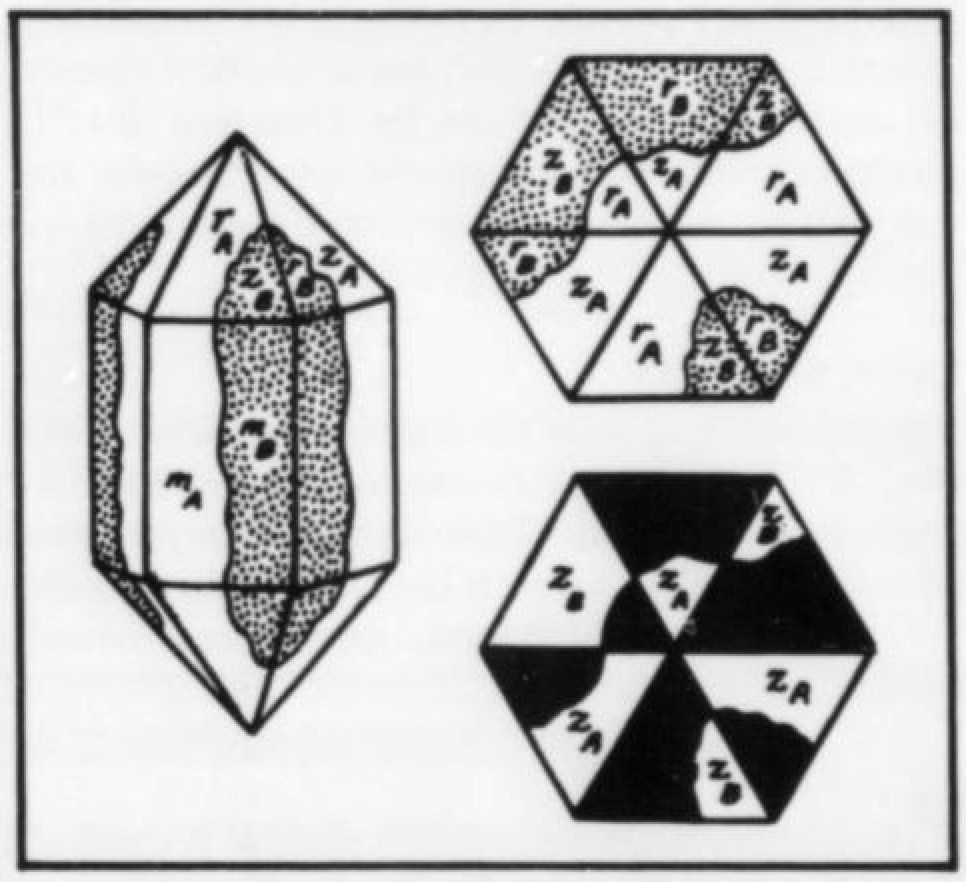


Figure 6. **Explanation of the hematite overgrowth pattern on Dauphiné twins. Individuals A and B are intergrown as shown at left, B portions stippled. Termination faces are shown at upper-right, B portions stippled. At lower-right the *r* faces of both the A and B individuals are shown in black; this is the pattern produced by the hematite overgrowth.**

r is usually relatively large compared to the rhombohedron *z* (Frondel, 1962), it can be tentatively concluded by inspection of a number of crystals like the one shown in Figure 2 that hematite is preferentially deposited on the *r* faces, and not on *z*. For the sake of discussion, it will be assumed that the coated form is indeed the rhombohedron *r*.

How, then, are the irregularly coated faces of quartz crystals such as those in Figures 3 and 4 to be explained? It appears that such crystals exhibit Dauphiné twinning.

The nature of Dauphiné twins is illustrated in Figure 5 (part of which is taken from Sinkankas, 1964). In the case shown, the twin is formed by the intergrowth of two right-handed quartz crystals, A and B. (Of course, left-left Dauphiné twins are equally common.) The two crystals making up the halves of the twin are identical except that B is rotated 180° about the *c*-axis with respect to A, and the two are then intergrown along irregular surfaces such that a twin like that shown in the third part of Figure 5 is formed. The last part of the figure is a "map" of the areas composed of A and B in the twin, as seen when looking down the *c*-axis.

Not infrequently, it is possible to discern Dauphiné twinning in quartz as interruptions in the striations on the prism zone, the *m* faces of the crystal. The interruptions follow irregular suture lines which map the areas composing the two halves of the twin (Fig. 5). At other times, certain of the oblique *s* and *x* faces of quartz used to determine the handedness of the crystal will be repeated more frequently in a Dauphiné twin than on other crystals. Compare, for example, the crystals A and B (not Dauphiné twinned) in Figure 5, where the oblique faces occur every 120°, with the twin in Figure 5, where the oblique faces appear every 60°. Of course, if the volumes composing the A and B portions of the twin were arranged differently, fewer or none of the oblique faces would appear. Dauphiné twinning can also be recognized in a small number of cases through the presence of natural etching, the *z* areas of the twin being dull while the *r* areas are bright. Such etching can always be produced on terminal faces or sawn sections by artificial means, and this constitutes the most reliable means of identifying Dauphiné twins.

Still another method of identifying and mapping Dauphiné twins is provided by the crystals described here. Consider the typical Dauphiné twin shown at left in Figure 6, and shown as viewed down the *c*-axis at upper-right in Figure 6. As before, the area made up of the "B" half of the twin is stippled in these two sketches, and the stippling constitutes a map of the areas of parts A and B of the twin. The notation r_A denotes a portion of the *r* rhombohedron donated by the A individual of the twin, while z_B indicates a portion of the *z* rhombohedron of the B individual of the twin, so that each pseudopyramid face is in this case made up of portions of A and B and of portions of the rhombohedrons *r* and *z*. Hematite coating the crystal, however, does not distinguish between A and B. It simply prefers to coat those parts of the terminal faces made up of the rhombohedron *r*, and it avoids those parts made up of the rhombohedron *z*. Hence, the red areas coated with hematite will be those *r* areas shown in black at lower-right in Figure 6, and these too will constitute a map showing the areas composed of the two halves of the Dauphiné twin. The areas shown in black (i.e., coated by hematite) are seen to fall in opposite quadrants wherever the twinned area boundary crosses a crystal edge.

This phenomenon is perfectly duplicated in Figures 3 and 4, and it is concluded that these crystals show Dauphiné twinning as above. Interestingly, the crystals show neither the striations in the prism zone nor the oblique faces occasionally used to identify such twins.

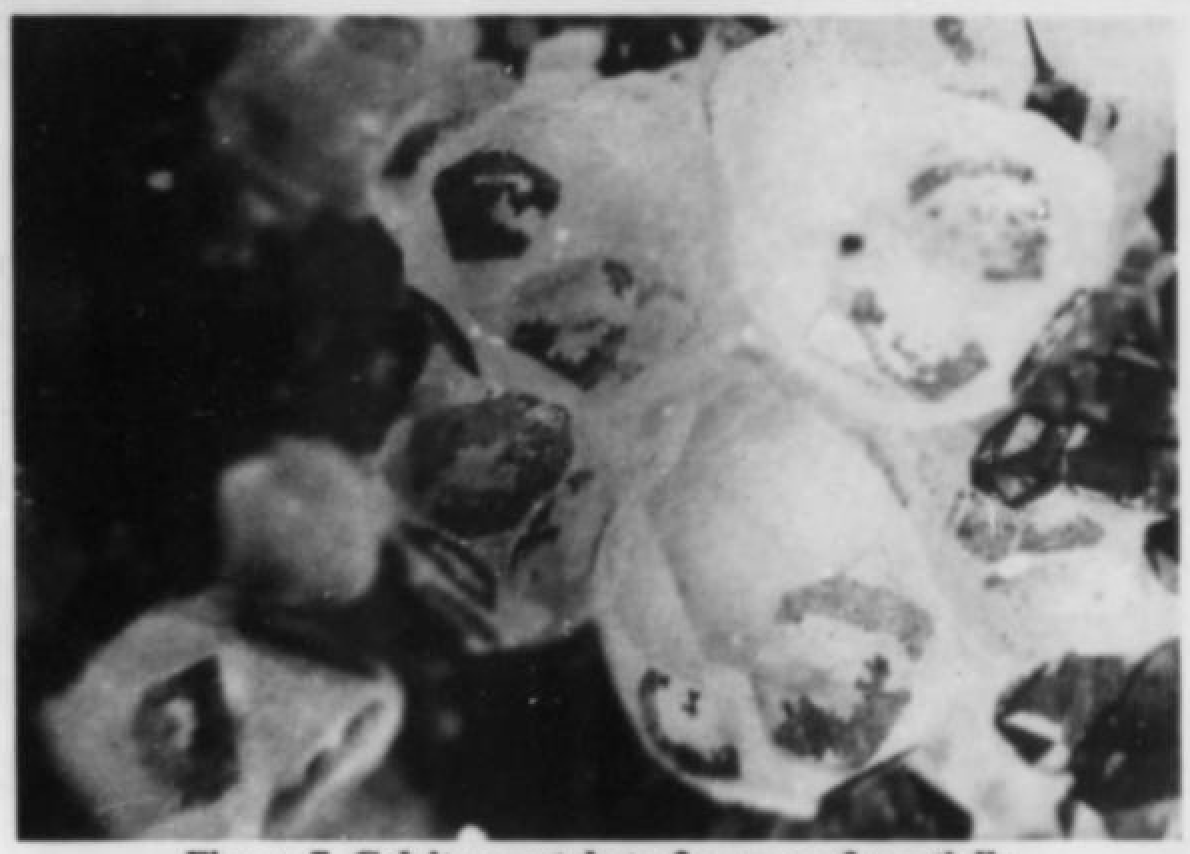


Figure 7. **Calcite crystals to 3 mm preferentially coated by hematite on one of the four rhombohedron forms present.**

It might be mentioned in passing that calcite crystals occurring with the quartz also show preferential coating of certain faces by hematite. Hematite covers only one of the four different rhombohedron crystal forms on the crystals and neither of the other two forms present (see Fig. 7).

While hematite overgrowths showing areas of Dauphiné twinning in quartz are not common, the author has similar material from another trap rock occurrence at Summit, New Jersey. He would be pleased to hear from readers who have such material from other localities.

ACKNOWLEDGMENTS

The author is grateful to Ralph E. Thomas for supplying the material described and to Carl A. Francis for his helpful counsel.

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THE LEGACY OF JACK BOYLE

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Are children today being given proper exposure to mineralogy? Do they receive the training and encouragement during their formative years which will spur them on to satisfying professions in the sciences? The career of Jack Boyle as educator is a case history worth looking at.

On many weekends in the 1920s, one could find Jack Boyle and friends from the Philadelphia Mineral Club collecting specimens on the dumps of the magnetite mines at French Creek, Pennsylvania. At that time the mines were still in operation and the dump material was fresh and unweathered. Many superb specimens of pyrite and chalcopyrite ended up on the dumps because sulfur-containing minerals had to be removed from the iron ore for processing purposes. For many years Boyle displayed his French Creek pyrite and chalcopyrite specimens with great pride. To him, those rewarding days in the field were the experience of a lifetime.

Boyle began collecting minerals around 1905 and soon earned a reputation for his knowledge and enthusiasm. The career of Jack Boyle as a mineralogist at the Brooklyn Children's Museum stems from his involvement with the Philadelphia Mineral Club.

Many names familiar to mineralogists are associated with the Philadelphia Mineral Club. Outstanding among them is Dr. Edgar T. Wherry (wherryite). A student and protégé of Dr. Wherry was Samuel Gordon (gordonite). Sam Gordon is famous for contributions to mineralogy through his work at the Philadelphia Academy of Natural Sciences from 1913 through 1948. His work has been chronicled in a series of *Mineralogical Record* articles entitled *An American mineralogist,* by Arthur Montgomery (1973–1975). In one of these articles, Montgomery describes Sam Gordon as "one of the greatest collectors of all times."

Sam Gordon encouraged a number of protégés. Some of them went on to distinguished careers in the academic world and others made their mark without benefit of a formal degree. Jack Boyle was among the latter. Like Sam Gordon, Boyle was largely self-taught. His formal education ended in 1905 when he graduated from Central High School in Philadelphia. At that time, Central High School was the only high school offering a classical education for boys. His education served him well because it enabled him to continue to learn and grow intellectually for the rest of his life. He wrote concise descriptions that could be understood by ten-year-olds, although the content was college-level. His love for learning and his respect for the work of great scientists was transmitted to youngsters along with a love for minerals.

Boyle's first hobby was plants, not minerals. During his teen years he spent long hours studying the plants in the Horticultural Hall of Fairmount Park, Philadelphia, and he became knowledgeable in tropical botany. In later years, a field trip with Jack Boyle always included comments on native wildflowers and trees as well as minerals and geology.

The influence of Sam Gordon made itself felt in many of the interests that Boyle developed in his students. Boyle's collection included fine specimens from South America, Greenland and South Africa, from the famous expeditions of Sam Gordon. He was particularly proud of his part in helping Gordon set up the first museum display of mineral fluorescence at the Academy of Natural Sciences in 1928, a first for the country. He also learned the gnomonic projection method for diagramming crystals from Gordon, who had gone to Heidelberg to study crystallography

Figure 1. **John Claudius Boyle, 1887–1955.**

under Victor Goldschmidt.

Along with the interest in fluorescence and phosphorescence, Boyle developed a collection of rare-earth and radioactive minerals. Some of his students from the Children's Museum were, in later life, involved in the Manhattan project and other aspects relating to atomic energy and mining.

Another friend of Jack Boyle in the Philadelphia Mineral Club was Charles R. Toothaker, Curator of the Commercial Museum in Philadelphia. Among the services of the Commercial Museum was the distribution of rock and mineral specimens to the public schools of Pennsylvania. Boyle put his knowledge of these school sets to good use when he went to the Children's Museum in Brooklyn.

In 1929 Toothaker was contacted by Anna Billings Gallup, Curator-in-Chief of the Brooklyn Children's Museum. She wanted someone to sort out and label a mineral collection that had been given to her museum. Toothaker sent Jack Boyle, who was then invited to join the museum as staff mineralogist. Boyle had previously worked as a ticket agent for various railroads and as a travel agent for Thomas Cook and Sons. This was his first venture into professional museum work. So, armed with a rich background in mineralogy and a great love for learning and science, he undertook a task that was unthinkable in the educational establishment of the day: he was going to teach mineralogy to young children! Everyone else naturally assumed that mineralogy belonged on the college level. But there followed a record of 18 years of extraordinary success.

Lou Perloff (1979) described the atmosphere in the basement laboratory as it appeared to youngsters of ages ten or twelve: "There were drawers full of minerals that we could handle, break, scratch and weigh. There were hammers and streak plates, magnets and balances, and best of all, there was Jack Boyle. His knowledge and wit were, to us at least, dazzling. . . . Learning about minerals from him . . . was an experience to be treasured forever. There was so much sheer fun in having him for a teacher that we sopped up knowledge at a rate that would have staggered our teachers back at public school."

The earliest crop of students included the late Neal Yedlin (yedlinite, nealite), Lou Perloff (perloffite), and Julius Weber (coauthor of the well-known *Encyclopedia of Minerals* and staff photomicrographer for the *Mineralogical Record*), Milton Hirschorn (a dealer specializing in fluorescent minerals) and Jane Kessler Hearn, who was one of the early protégés. Hearn assisted in setting up the collection and the boxes that later became the formal course of study. After Boyle passed away, she was given first choice to purchase his collection, which she now owns.

Youngsters came from far and wide. Professor Charles B. Sclar, Chairman of the Department of Geological Sciences, Lehigh University, writes (personal communication to Martin Starfield), "As a teenager in the summer and fall of 1942, I took the mineralogy course taught by Mr. Jack Boyle. Although I lived in Upper Manhattan, I look the long subway trip to the Brooklyn Children's Museum six or seven times in order to receive instruction from Boyle in general mineralogy and sight identification. He was an excellent teacher who combined a ready wit and good humor

Figure 2. **Pyrite with magnetite from one of Boyle's favorite localities: French Creek, Pennsylvania. Collection of the author; photo by J. Weber.**

with high instructional standards and demanded that students learn and pass each unit before proceding to the next."

The actual nature of the mineralogy course conducted by Boyle can best be described in his own words from the December, 1935 issue of the *Children's Museum News:*

THE MINERALOGY DIVISION

by J. Claudius Boyle

The Mineralogy Division of the Brooklyn Children's Museum enables boys and girls to become familiar with minerals and to wrest from these inanimate objects the secret of their origin and nature. It encourages children to use initiative and ingenuity. From the beginning, the basis of procedure is the observation, handling and testing of mineral substances. In this, the children are guided by helpful suggestions which relate their investigation of these materials to everyday experiences. Projects are carried forward in a way

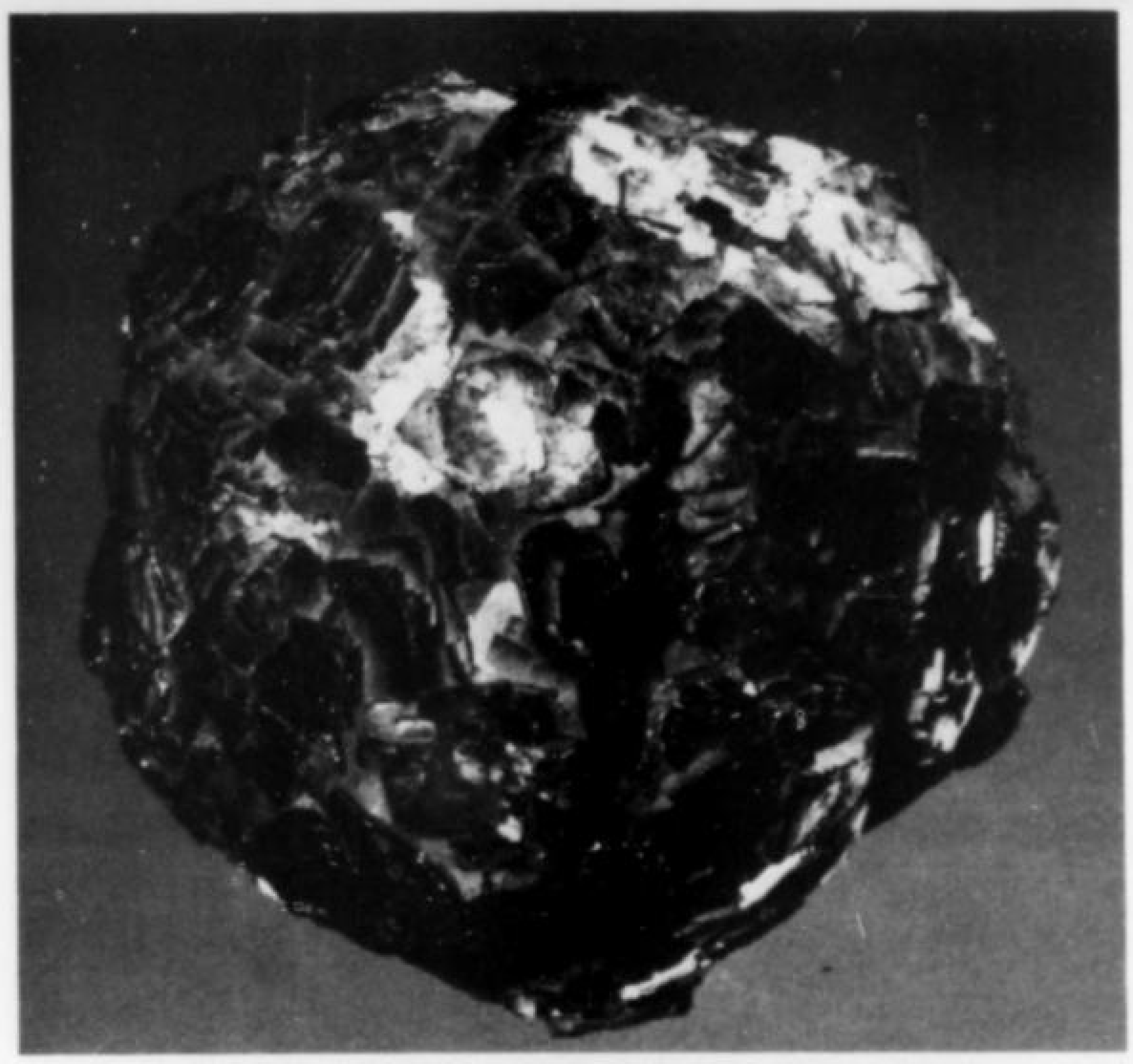


Figure 3. **Another French Creek pyrite, a 6-cm ball composed of oriented cubes. Jack Boyle collection, now in the Jane K. Hearn collection. Photo by R. Fagley.**

that insures the maximum of freedom and convenience to the individual. Each child adopts the speed best suited to his time requirements in following the whole plan of learning by doing.

As various projects are completed, credits are given toward the totals necessary for Museum Awards. In addition, a special *Certificate in Mineralogy* crowns the achievements of those who pass an examination covering all the work of the Division.

The *Beginner's Guide,* which introduces children to mineralogy, is a questionnaire with reference to specimens in the Mineral Exhibition Room. Here the minerals are specially arranged to show the meaning of such terms as streak, color, luster and hardness and their special applications to this science. The Guide asks questions regarding these properties and the child finds the answers by referring to the designated cases. When the beginner shows that he understands the use of the terms covered by the Guide, he acquires a card of admission to the Mineral Laboratory and is also certified by the Loan Division to borrow mineral loans from the Beginner's series.

Figure 4. **Jack Boyle in the mineral lab with his students in 1935. (From *Children's Museum News.*)**

On a long table which occupies the center of the Laboratory are trays containing groups of minerals. Each group illustrates some property such as hardness, cleavage or fracture to be recognized in determining minerals. Each tray also contains a paper which explains the characteristics shown by the specimens. When the laboratory worker has examined these minerals and understands their properties, he is given the first in a series of twenty specimens, for independent, critical examination. He is told the name of the mineral and handed a printed slip in the blank spaces of which he writes answers to questions about its color, hardness, cleavage and other properties, constantly checking his work by reference to the trays of standards. He next submits his completed description to the instructor for detection of possible errors and, by following verbal suggestions, makes the necessary corrections. The remaining nineteen specimens are given him in sequence for similar examination. The twenty specimens he thus studies in detail, with the accompanying paper slips, become his property and serve as a nucleus for his private collection and as reference data in the recognition of other mineral substances.

The beginner is now ready to find the specific gravities of twenty minerals. After being shown how to make accurate weighings on a small Specific Gravity balance, the child weighs the specimens first in air, then in water, one by one, and tabulates the results of these weighings on printed slips. The specific gravity of each is determined by simple arithmetical operations based upon his records. The instructor helps in detecting errors which are eliminated until final results are correct. The project is then credited in full.

The next project shows a method of separating magnetic iron ore from mixtures of various pulverized minerals by means of a small electro-magnet. Each mixture is weighed, the iron is extracted by the magnet, and the separated ore is weighed. By simple arithmetic, the percentage of iron ore in the mixture is calculated.

At any time, after the completion of the first project, a review test may be taken which, if passed, entitles the student to borrow the Large Loan Boxes.

The succeeding projects acquaint children with new minerals by application of the knowledge already gained to the study of minerals in groups. The groups consist of specimens which have in common some prominent characteristic, as for instance, foliated structure, black or white color.

With each group is furnished a booklet descriptive of the minerals emphasizing similarities and differences. By means of this booklet, the student determines those characteristics of the specimens which must be known for identification. His record of determinations is submitted and errors are pointed out for correction. As each group is properly completed, credit is given as in the other projects. There are eight of these groups, covering the most valuable and common minerals of commerce, such as white minerals, black minerals, micas, yellow sulfides, and others.

A General Review Set of Minerals is now submitted for identification. The worker follows through without written text, basing his conclusions entirely on knowledge gained in former projects. Credits are given for the proper completion of this work.

Having finished the projects above outlined, the student may take an examination for a special certificate. If he passes, he is awarded the CERTIFICATE OF PROFICIENCY IN FIELD DETERMINATION OF MINERALS. This

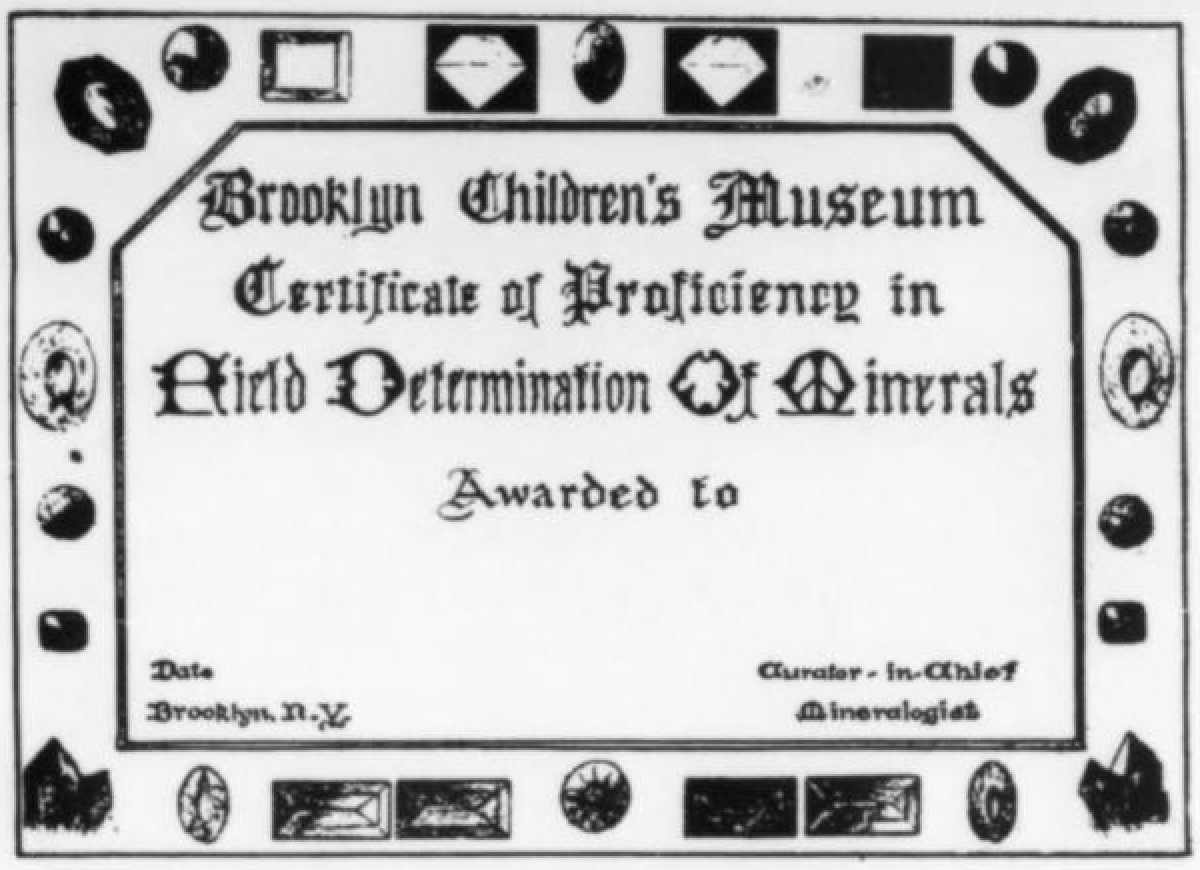


Figure 5. **Certificate awarded to children for proficiency in the field determination of minerals.**

certificate is hand-executed in water colors on the best art paper. It is the work of an artist who excels in the field of engrossing, and it is worthy of a place of honor wherever it may be displayed.

Two series of circulating Mineral Loan Boxes are available in connection with the Mineral Laboratory Program: The Beginners' Series of small boxes, each containing three specimens and a small descriptive booklet; the Large Mineral Loan Boxes containing twenty specimens apiece, and a larger booklet. The latter gives a much more detailed account of each mineral, including identification, sources, uses, and other data of general interest.

In addition to the foregoing studies in mineralogy, the Division also makes available, for those desiring it, an opportunity to learn how to read topographic maps and to construct geologic and land surface models. Many fine and accurate examples have been finished and some of them have taken prizes at the annual Children's Science Fair held in Manhattan, New York City.

For those who have done a specified amount of work in the Division, field trips are conducted to localities in and around New York City where numerous interesting geologic phenomena may be examined, and specimens collected. That a thing so mute as a mass of rock can be made to yield vivid and interesting history is a source of great and perpetual fascination for those who take part in these field trips.

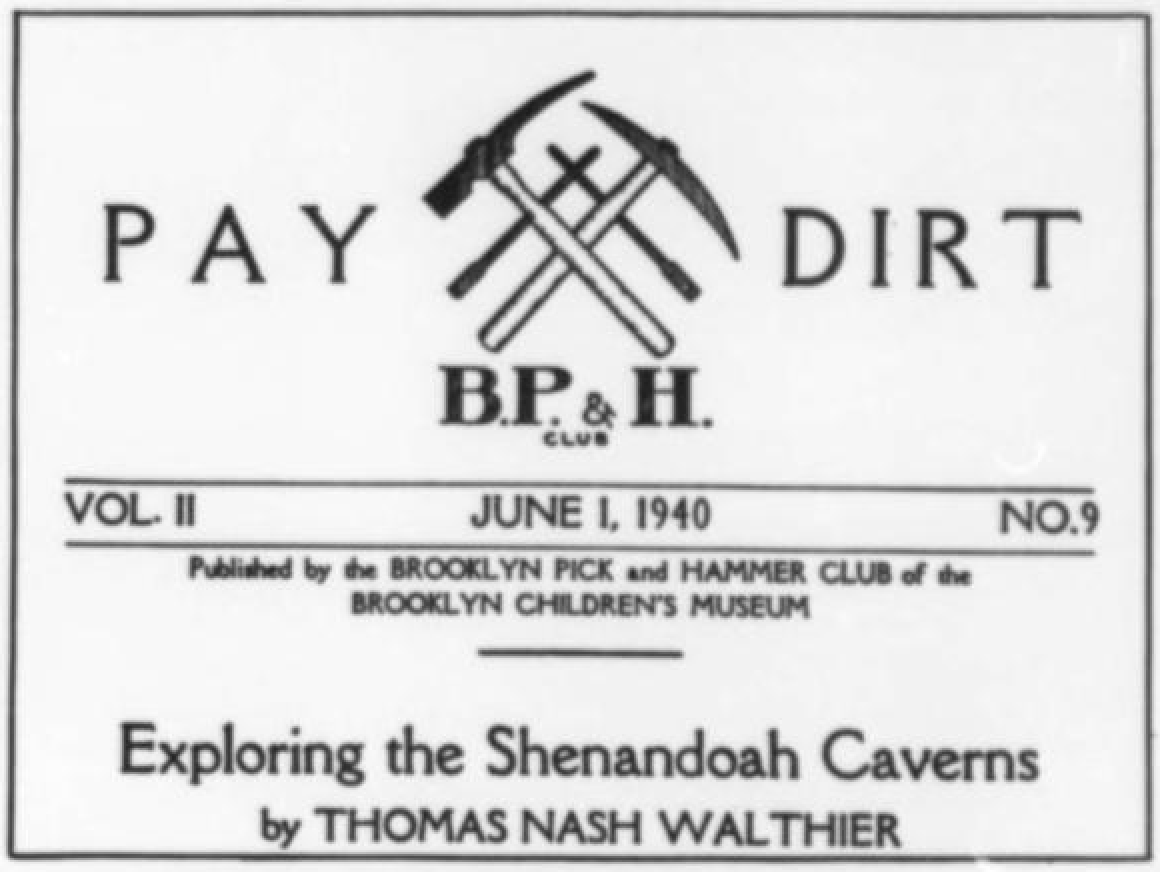
The Mineral Division cooperates with teachers, students, Scout Masters, and others desiring its services, through the Loan Boxes for classroom work, and by personal services of more direct application. The latter consist of the identification of rocks and minerals; giving special talks on mineral deposits and their effect upon trade and international relations to groups and classes; and furnishing special loan sets not covered by the regular series.

Figure 6. **Photos of mineralogy field trips on the cover of *Children's Museum News,* 1937.**

What was the secret of Jack Boyle's success as a teacher? Clearly, he did very little "teaching" but his students did a lot of learning. He achieved the ideal in science teaching, to have his students learn by doing. He transmitted his personal reverence for the wonders of nature. Despite his sophisticated level of mineral collecting, which included the rarest species and also micromounting, he never lost a spontaneous enthusiasm for the most ordinary minerals. A youngster would bring him a piece of common feldspar from the neighborhood lot, and Boyle would say, "that's a good piece of feldspar!" and mean it. There were no pieces of junk. Each specimen was worthy of respect. Even when a specimen was weathered, it told a story. This was an attitude that rubbed off on the many ten-year-old boys and girls who came to the mineral lab. It was a time of economic depression, but the youngsters were trusted to handle gold and opal specimens. The monetary value rarely came up as a question, but there were many questions about the origin and the story behind the many fine specimens in those basement cabinets.

Figure 7. **Jack Boyle (front row center) with members of the Brooklyn Pick and Hammer Club in 1939. Front row, left to right: Joseph Venuto, Irving Horowitz, Boyle, Edward Fairstein, Martin Plotkin. Second row: Saul Schein, Thomas Walthier, Jay Croft, Joseph Kantor, Leon Dressner, Steven Luchter. Standing: Seymour Scharf, Ralph Scharf, Elliot Juni, Daniel Luchter.**

Figure 8. **Elliot Juni lectures on polarized light and the petrographic microscope at a 1938 meeting of the Brooklyn Pick and Hammer Club. Photo by Jack Boyle.**



PAY DIRT

B.P. & H. CLUB

VOL. II JUNE 1, 1940 NO. 9

Published by the BROOKLYN PICK and HAMMER CLUB of the BROOKLYN CHILDREN'S MUSEUM

Exploring the Shenandoah Caverns

by THOMAS NASH WALTHIER

Figure 9. **The Brooklyn Pick and Hammer Club, under Jack Boyle, typeset and published their own journal, and also came up with an interesting variation on the crossed pick and hammer emblem.**

Graduates of the Children's Museum mineralogy course became members of the Brooklyn Pick and Hammer Club which Boyle sponsored. This became a vehicle through which the youngsters continued their contact with Boyle through high school and college. The club met weekly on Saturday afternoons. Boyle gave special talks, like the one on making crystallographic diagrams by the Goldschmidt method. At other times the more advanced members gave talks on topics such as radioactivity and optical mineralogy. The Brooklyn Pick and Hammer Club also enjoyed field trips taken with the museum truck to most of the major collecting sites in New York, New Jersey and Connecticut. Members who visited more distant localities often brought specimens for the others. Neal Yedlin would often come by with specimens for the younger members.

A lasting record of club activities and interests is preserved in a publication typeset by the members of the museum print shop under supervision of professional printers. These printers and the artists who made the certificates were employed in the Works Project Administration (WPA). The paper was called *Pay Dirt*. As one pages through the issues of *Pay Dirt,* one sees reflected in the articles, written by the youngsters, the special interests and favorite topics of Jack Boyle.

The list of youngsters who drew inspiration from Boyle is too long to be mentioned here. Suffice it to say that he fired the imaginations and ambitions of many boys and girls who later went on to professional careers in science. Boyle was proud of them, and in their success, somehow, he was vicariously realizing his own ambitions. He gloried in the achievements of his daughter, Marie Boyle, when she graduated Phi Beta Kappa from Barnard College and went on to become an award-winning teacher of high school biology. Similarly, he showed genuine satisfaction in the achievements of all his students who went on to professional careers.

In the end, ironically, the accomplishments of Jack Boyle went unrewarded. In 1947, after 18 years of service, he was abruptly fired from his position at the museum. The reason given by the Governing Committee of the Children's Museum was that ". . . the Museum can no longer afford the luxury of a separate Department of Mineralogy. We are merging the Department of Mineralogy into a Department of Science, where mineralogy can be handled by someone who will also be capable of handling other branches of science." Boyle was never given the opportunity to take on the broader responsibilities. In losing the services of Jack Boyle, the Brooklyn Children's Museum was diminished as an institution.

The lack of an academic degree was a serious handicap when Boyle sought a new position. Finally, a position which did not require the usual degree was found in the Geology Department of the City College of New York. He worked there until 1954, when his failing health forced him to quit.

In a striking parallel with the case of his mentor, Sam Gordon, Jack Boyle's life was probably shortened by his dismissal from a museum position; he died in 1955. In accordance with his will, his body was cremated and his ashes were scattered over the tailings of the French Creek magnetite mines.

The legacy of Jack Boyle is unique because the position he held as mineralogist of the Brooklyn Children's Museum was one-of-a-kind. His influence lives on in the careers of his many protégés. Many carried his message into university lecture halls and high school classrooms.

His personality as well as the substance of his course acted as a magnet attracting the intellectually gifted and science-oriented youngsters during their most impressionable years. He dealt with the young women and young men as friends and the admiration was mutual. Thus, through the study of minerals, Jack Boyle helped to nurture a large number of budding mineralogists, geologists, engineers and science teachers. Perhaps our current problems with science education could be alleviated if we would take a page from the story of Jack Boyle.

ACKNOWLEDGMENTS

Thanks to Marie Boyle for contributing information relating to her father's background and for critically reading the manuscript; to Jane Kessler Hearn for her contribution of photographs of specimens from the Boyle collection; to Martin J. Starfield whose queries about Jack Boyle stimulated me to write this article, and for his contribution of personal correspondence; to Julius Weber for preparing photographs suitable for reproduction, and for his support of this project; and to all the members of the Brooklyn Pick and Hammer Club.

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ZODAC, P. (1946) Uranium exhibit furnishes background for popular topic of the day. (Describes an exhibit of radioactive minerals which Jack Boyle set up at the Brooklyn Children's Museum.) *Rocks and Minerals,* **21**, 564–567.

Issues of the *Children's Museum News,* Brooklyn Children's Museum, relating to the Mineralogy Department: 23 (1935), no. 3; 24 (1937), no. 6; 25 (1937), no. 2; 25 (1937), no. 3; 26 (1938), no. 1; 26 (1938), no. 3; 30 (1943), no. 4.

Notes from Mexico

by **Bill Panczner**

BENNY J. FENN

At the outset of this column, I mentioned that at times I would write about people from Mexico who are involved in minerals; this is the first of such articles.

Within the field of modern Mexican mineralogy, there are few native-born field collectors. Most of the mineral specimens on the collectors' shelves were originally found by miners working in the many large mining operations within Mexico. Spending full time looking for new specimen locations or developing older ones is relatively unheard of within Mexico, especially for a native collector.

Benny J. Fenn, of Colonia Juarez, Chihuahua, is just such a rarity in Mexico. Benny, a tall cattleman/miner who speaks perfect English and looks like he just walked out of a cigarette ad, is a second-generation Mexican whose Mormon grandfather came to Mexico to mine for gold and silver in Sonora and Chihuahua. Benny's father continued the family tradition in mining, but in later years became a cattle rancher, too. Benny was born and raised with his eight brothers and sisters in Colonial Juarez near Nuavo Casas Grandes in western Chihuahua. As a youngster he was fascinated with the rocks and minerals at the family ranch and mine, but it was not until after his marriage in 1965 that he became seriously interested in minerals. He and his wife Elva, during these early years, mined opal and agate from the famous silica fields of Chihuahua, but soon their interest turned to crystallized mineral specimens. Their work over the following 19 years proved very fruitful for museums and collectors around the world, whose collections are now rich with Fenn specimens.

Their travel in search for minerals took them throughout Mexico, but their major efforts were concentrated in northern and central Mexico. In 1966 they began to supply wholesale mineral dealers in Tucson and California with mineral finds from Mexico.

One of their first major finds was in 1968, when a large pocket of legrandite was discovered at Mapimi, Durango, which the Fenns quickly obtained. The legrandite crystals were found in bright sprays reaching 5 cm or more and were the largest known to that time. Many collectors and museum curators still consider this discovery to be the most esthetic legrandite ever found.

In 1969, Susie Davis, a Tucson wholesale mineral dealer (now deceased) received word during the Tucson Gem & Mineral show about a new meteorite fall in southern Chihuahua. She passed this information on to Benny and his wife, who quickly left the show for the site. They reached Pueblito de Allende, the site of the fall, to find the villagers extremely afraid of the objects that had exploded above their small village. The Fenns, who were the first collectors to arrive at the site, quieted the people and began to organize the collecting of the meteorites. Over a ton of this rare stony chondrodite meteorite was collected with pieces ranging from tiny fragments to some weighing over 20 kilograms.

Later in 1969, Benny and his wife discovered and mined out a watercourse in a gold/silver mine near Flores Magon in western Chihuahua, which was lined with botryoidal white calcite containing blue celestite crystals.

Near the end of 1969 and early 1970, an extensive series of pockets of wulfenite was discovered at the Ahumada lead/silver mine at Las Lomentos, Chihuahua. The Fenns again were involved and, as Benny describes it, ". . . for several months the floor of my barn in Colonial Juarez was totally covered with the most fantastic wulfenite you could imagine . . . thousands of pieces." This wulfenite find provided many exceptional specimens that today grace the shelves of collections around the world.

Luck was still with the Fenns, for in the later part of 1970 they discovered and mined out several pockets of brilliant yellow-orange botryoidal mimetite from the Congresso-Leon mine at San Pedro Corralitos, Chihuahua. Also from the same area but from a smaller prospect to the north, they discovered several small pockets of delicate yellow wulfenite which added to the excitement in the mineral world. The Smithsonian Institution benefited in particular, because two years later they purchased Benny's personal collection of thousands of fine Mexican specimens, including many of these mimetites and wulfenites.

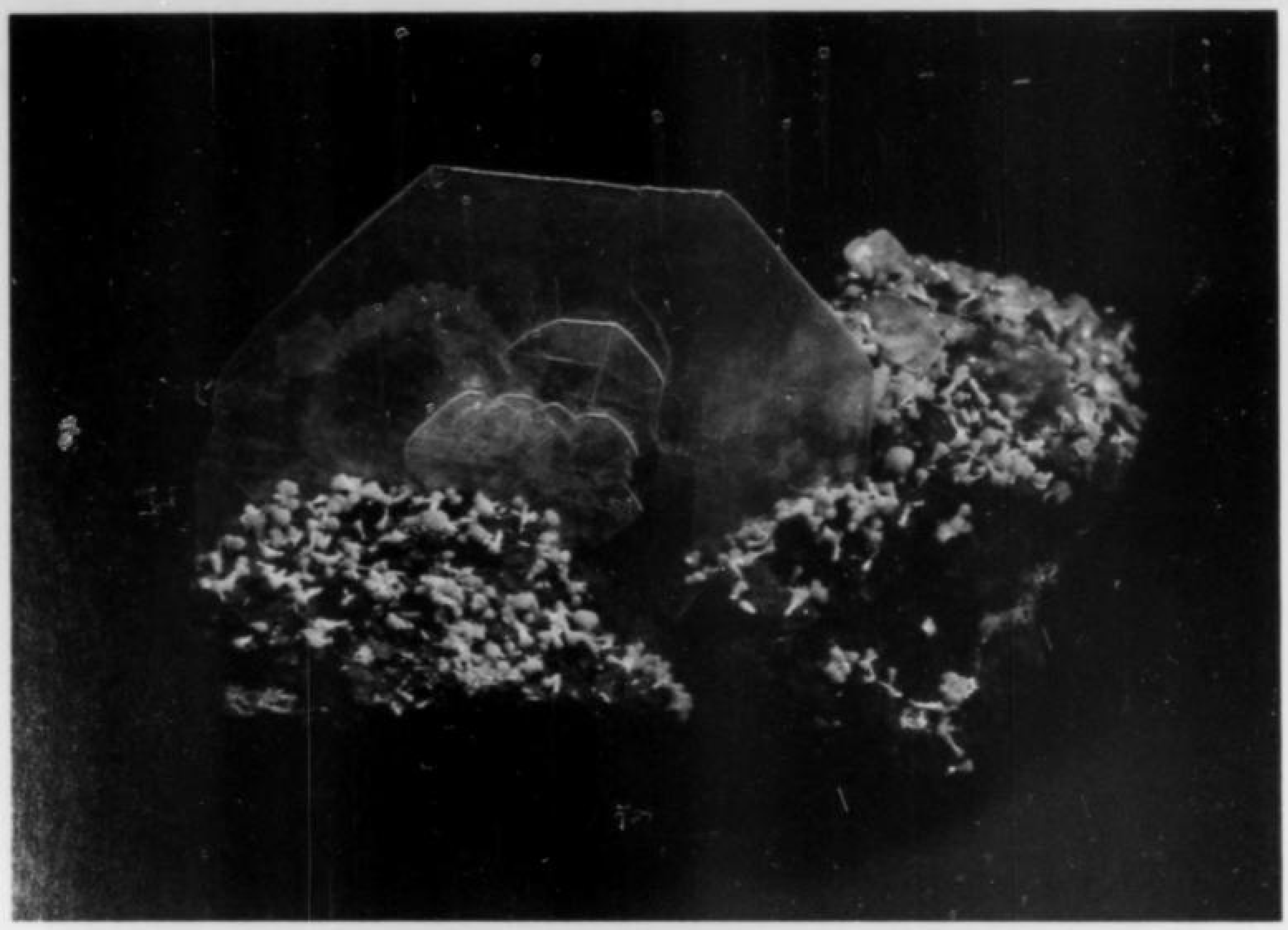
In the later part of 1974 and early 1975 the Fenns were again fortunate to be able to purchase another discovery at Mapimi. This time it was what the miners at the Mina de Ojuela called "blue legrandite," koettigite, with crystal sprays reaching 5 cm in length. Also with the koettigite were two other minerals of note, symplesite and parasymplesite.

In 1977 the Fenns, now accompanied by their two boys Benny Lee and David, discovered at a small prospect, a cave of gypsum crystals which became known as the "Cave of the Candles" to the mineral world. The Arizona-Sonora Desert Museum in Tucson replicated this discovery in their Congdon Earth Sciences Center.

Benny, his wife and boys are not the only ones in the family who are interested in minerals; his sister Verla and her husband, Harold Jorgenson, operate a mineral shop in Lordsburg, New Mexico. Harold often worked with Benny in his specimen mining ventures in Mexico. Benny and family worked with his sister and brother-in-law at their wholesale booth at the Tucson Gem and Mineral Show in the late 1960's. Benny became a retail show dealer (the first Mexican mineral dealer) at the Tucson Show in 1971.

The Fenns also have mined and brought out of Mexico smithsonite from Choix, Sinaloa; erythrite, azurite and smithsonite from Alamos, Sonora; pyrite, jamesonite, azurite and malachite from Concepcion del Oro, Zacatecas; and many many other minerals as well.

Over the past several years the Fenns have been involved in the old family gold mining project in Sonora near the Chihuahua border. They also have been developing a gem bytownite field in



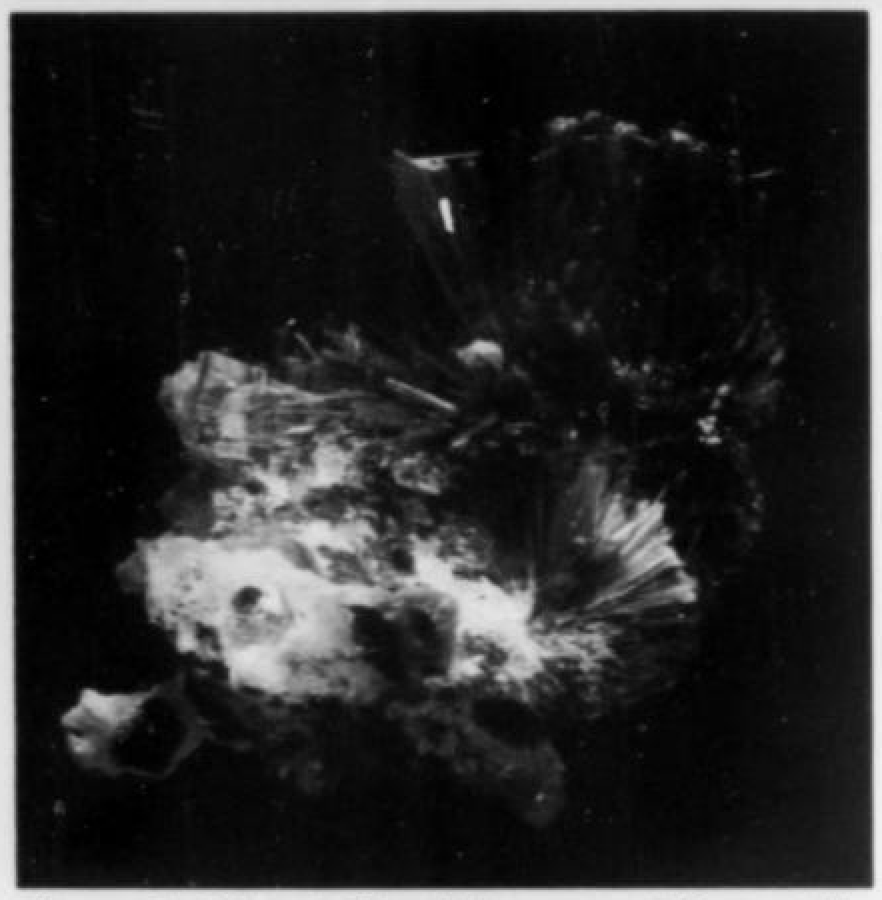


Figure 1. (above) **Koettigite spray 3.8 cm tall from the Ojuela mine, Mapimi, Durango.**

Figure 2. **Wulfenite crystal 5 cm across from San Pedro Corralitos, Chihuahua.**

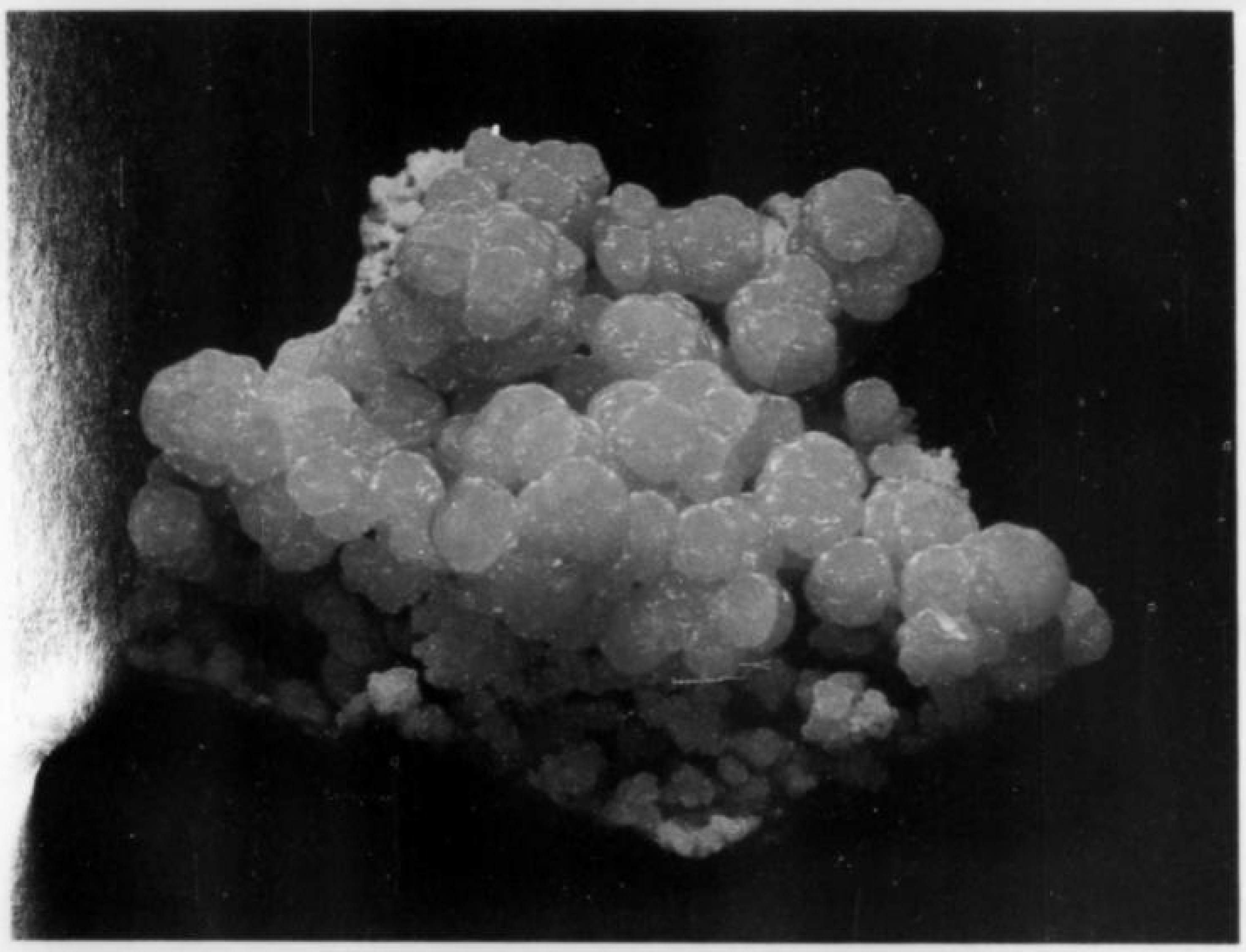


Figure 3. **Mimetite, 7.5 cm across, from San Pedro Corralitos, Chihuahua.**

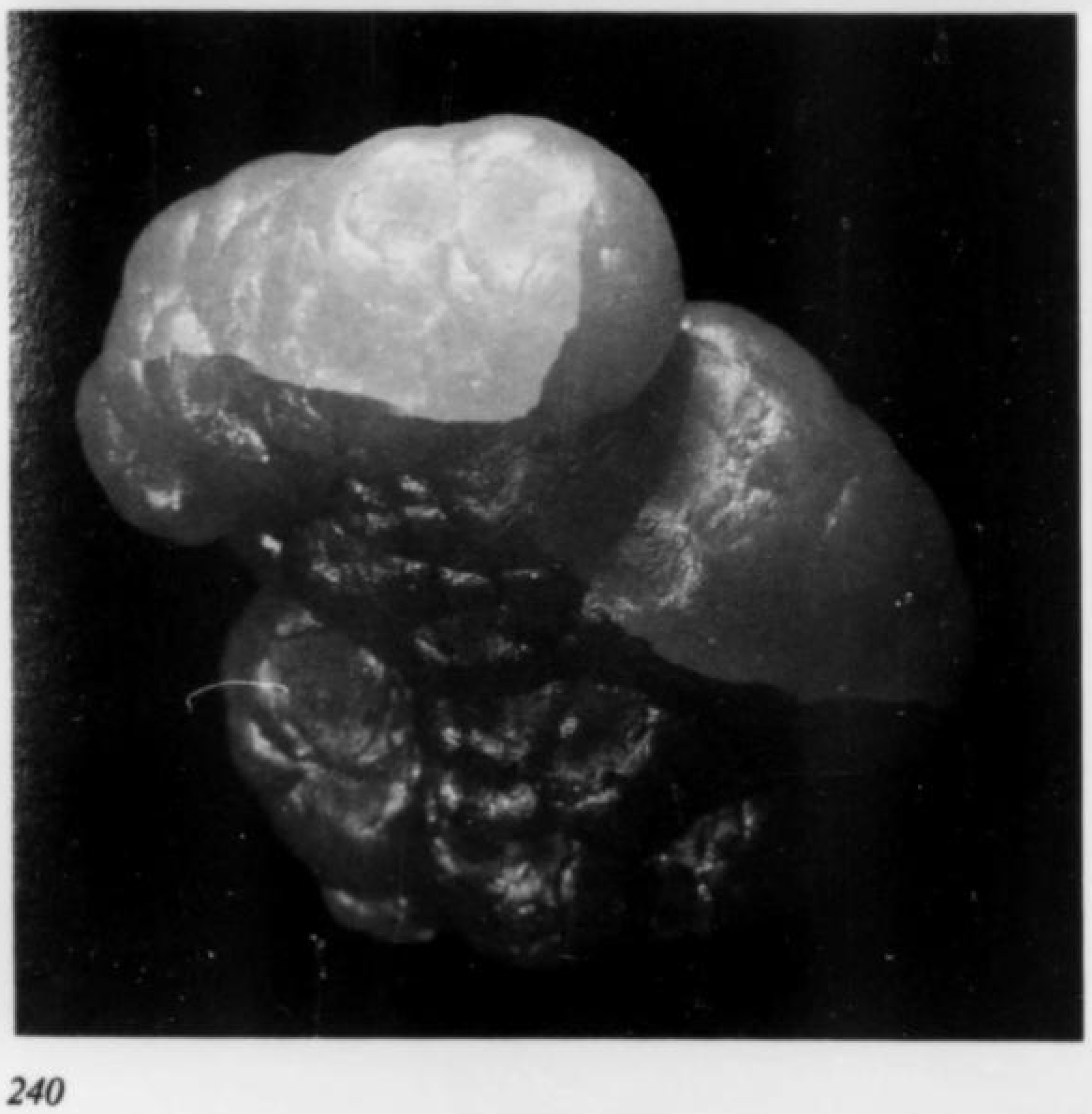
the mountains of Chihuahua and, at the present time, some of the feldspar rough is in pieces weighing over 300 carats. The largest cut stone to date is just over 80 cts, which is the largest faceted bytownite from Mexico and probably the world.

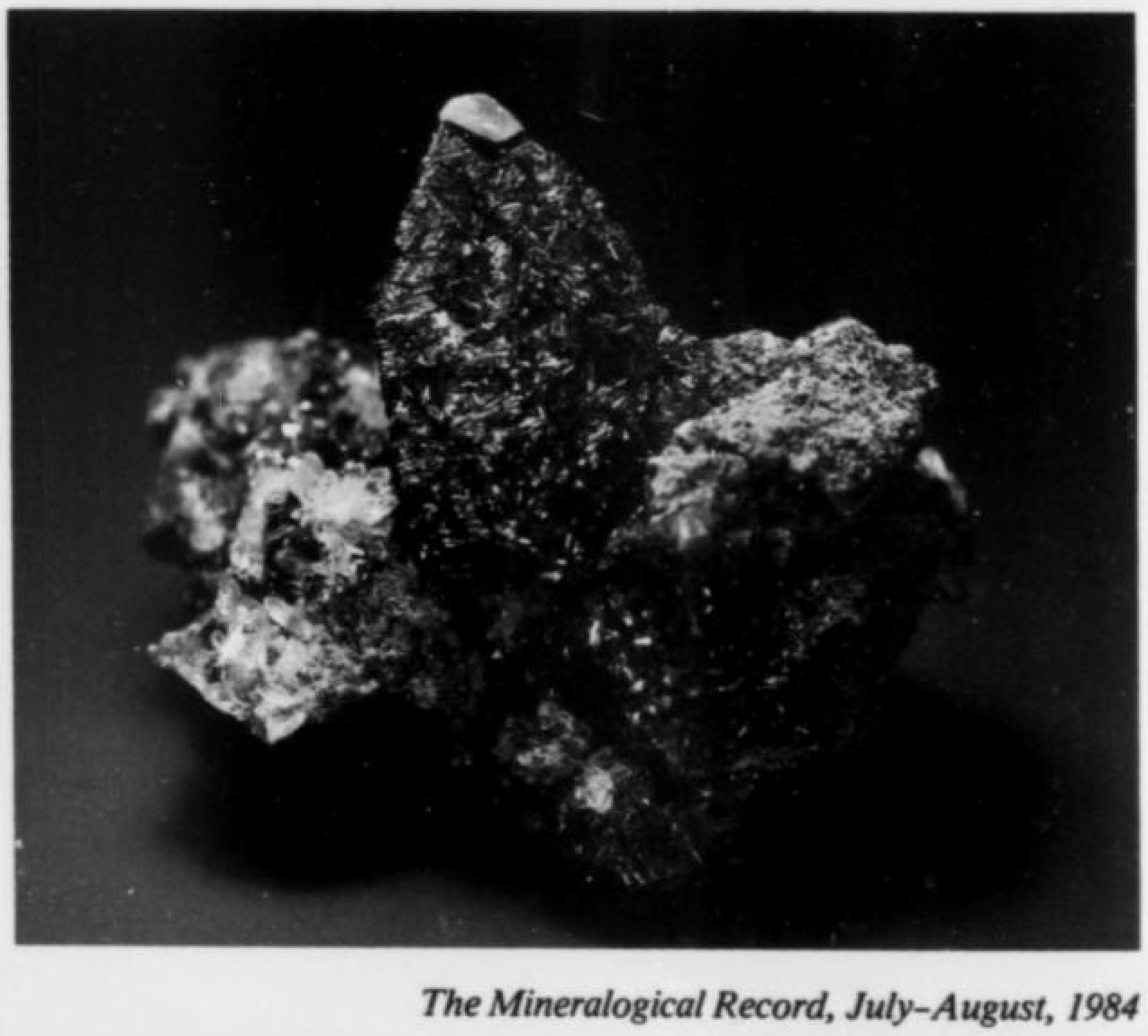
Combining all of these activities with running a 5,000-acre cattle ranch high in the Sierra Madre, Benny stays extremely busy, but never too busy to stop and talk about his family or Mexican minerals, his two loves.

William D. Panczner
640 N. LaCholla Blvd.
Tucson, AZ 85745

Figure 4. (lower left) **Smithsonite, 7.5 cm across, from Choix, Sinaloa.**

Figure 5. **Atacamite pseudomorph after a 5-cm azurite crystal from Conception del Oro, Zacatecas.**





neral Dealers

Southern

Bourget Bros.
1636 11th Street
Santa Monica, California 90404
Tel: (213) 450-6556

California Rock and Mineral Co.
2587 Pomona Boulevard
Pomona, California 91768
Tel: (714) 594-7134

Geoscience Minerals and Old Books
Russ and Alix Filer
13057-MC California St.
Yucaipa, California 92399
Tel: (714) 797-1650

Cal Graeber
P.O. Box 47
Fallbrook, California 92028
Tel: (619) 723-9292

Hamel Minerals
6451 West 84th Place
Los Angeles, California 90045
Tel: (213) 645-1175

Jewel Tunnel Imports
Rock H. Currier
1212 S. Mayflower Avenue
Arcadia, California 91006
Tel: (213) 357-6338

Kristalle
332 Forest Avenue, #8
Laguna Beach, California 92651
Tel: (714) 494-7695

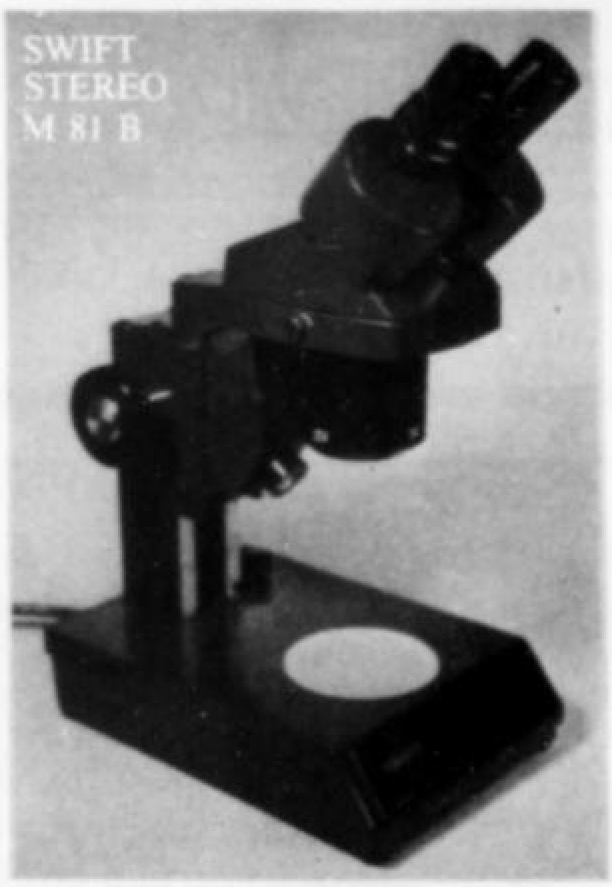
Pala International & The Collector
912 So. Live Oak Park Road
Fallbrook, California 92028
Tel: (619) 728-9121
US Wats 1-(800)-854-1598

Mark and Jeanette Rogers
P.O. Box 1093
Yucaipa, California 92399
Tel: (714) 797-8034

Schneider's
13021 Poway Road
Poway, California 92064
Tel: (619) 748-3719

Seibel Minerals
20308 Sears Drive
P.O. Box 95
Tehachapi, California 93561
Tel: (805) 822-5437

Weber's Minerals
605 San Dieguito Drive
Encinitas, California 92024
Tel: (619) 436-4350



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Letters

MOROCCAN ANGLESITES FAKED

Concerning the amber-red anglesite crystals from Touissit, Morocco: I have just returned from the Touissit area, and have confirmed that the red anglesites are fakes. The red color is produced in colorless and pale yellow crystals by dipping them in a strong bleach solution (La Croix-brand, imported from France). The chemical reaction takes only a few seconds. A local dealer discovered this by accident, and word leaked out to other miners and dealers in Morocco who, being less scrupulous, decided to "upgrade" their material in this manner.

I am offering a refund and an apology to anyone who has purchased one of these specimens from me.

Victor Yount
Warrenton, VA

Studies at the Smithsonian confirm Victor Yount's report; the color is present as a thin skin covering crystal faces and broken surfaces alike. Amazingly, the process leaves the beautiful luster intact, and the resulting color, unlike a dye, will not wash off. According to George Rossman at Cal Tech, immersion in a saturated bromine-water solution will reverse the reaction without damaging the luster. Bromine is highly dangerous, however, and should only be handled by experts.

Ed.

MICROMOUNT DONATIONS

I have been a micromounter for many years, and am now coming to the stage where I must consider what will become of my collection when I am gone. I recall reading Pete Dunn's guest editorial, "When you are all through collecting" (March-April 1979), in which he suggests that one consider the nature of the collection to be donated relative to the specialties and interests of the recipient. Which brings me to my question: are there any institutions or museums which specialize in microminerals and which have public displays of micromounts?

Klaus-D. Bausch
Mulheim/Ruhr, West Germany

Probably the best use to which institutional micromount collections can be put is for research. I have seen no significantly large or truly effective public displays of micromounts, and this is probably because of the need for expensive magnification equipment and the associated technical difficulties. Some collections are available for individuals to study on a controlled basis, as for example at the Smithsonian's Naturalist Center (see vol. 8, p. 395). If there are curators reading this who are interested in receiving donations and bequests of micromounts I invite them to write to me, explaining the type of use to which such donations will be put, and I will publish the information for the consideration of our readers.

Coincidentally, I recently received an announcement from the Morris Museum of Arts and Sciences (Normandy Heights Road, Morristown, New Jersey). On May 7 they unveiled their own unique micromount display. Starting with an idea originated by Kenneth Borden (a member of the museum's mineralogical society), technical consultant Leonard Pavia developed an apparatus combining an automatic prefocusing turntable, a stereoscopic microscope, a color video camera and a 48-cm (19-inch) color television monitor. The turntable rotates a selection of micromounts under the camera-microscope and they are displayed in all their glory on the television screen. This exhibit, made possible by private funding, is now a permanent fixture in the mineralogy area and is believed to be the first such public exhibit in the United States.

Ed.

MORE ON MOROCOCALA, BOLIVIA

I was in Morococala and Quiruvilca, Peru, recently, and obtained more information on the bournonite discovery (vol. 15, p. 43) which your readers might find interesting.

The locality stated as La Oroya is not correct; La Oroya is actually the name of the smelter owned by Centromin (the Peruvian State Mining Company). The La Oroya facilities are not far from the famous Casapalca, Morococala, San Cristobal and Yauli mines which provide ore for smelting there, but there is no mine *at* La Oroya itself.

Furthermore, the bournonite is not from any of those mines near La Oroya. I spoke with a miner, Señor Haro, who obtained the specimens himself from the Quiruvilca mine, Department of La Libertad, in Northern Peru, between June and August of last year. In recent years Haro has been responsible for mining the best specimens that have come out of Quiruvilca. Some of the bournonite in this latest find resembles bournonite which came from Quiruvilca at other times during the past 5 years, but previous discoveries were typically small in number and rarely very lustrous. This recent occurrence is somewhat of a fluke, so many fine quality specimens having been found in such a short period of time. The misidentification of the locality is apparently due to a few Lima dealers who wished to conceal their source.

I also read with interest the recent notes on Bolivian vivianite (vol. 14, p. 388–389; vol. 15, p. 45). The location is the Morococala mine, not the Santa Fe mine. Due east of the city of Oruro and northeast of the famous Huanuni mine is a trio of mines all run by Comibol (Corporacion Minera de Bolivia). These are the Japo, Santa Fe and Morococala mines (the Santa Fe and Morococala being about a kilometer apart). The Santa Fe mine serves as the administrative center for the three. The recent vivianites come only from the Morococala mine, specifically from the Veta Crucera (Crucera vein), 250 level. Therefore, a fully accurate label would read "250 level of the Veta Crucera (or Crucera vein), Mina Morococala (or Morococala mine), Dalence Province, near Oruro, Bolivia."

Morococala is a very old tin mine, and has produced fine vivianite sporadically in the past. A good many vivianites end up mistakenly labeled as from Llallagua, when in fact they are from Morococala. Llallagua specimens often have associated phosphates such as childrenite or paravauxite; Morococala specimens do not.

Morococala is typical of Andean mines, situated on an undulating plateau unprotected from harsh, cold winds. The rainy season (December-January) makes travel miserable, with erratic rain and hailstorms, endless miles of muddy roads, and periodically dense fog. On the other hand, the winter months (June through August in the Southern Hemisphere) are bone-dry with bitterly cold nights ill-suited to a weekend of rockhound fun with the family camper.

A significantly increased influx of dealers in the last year has caused some problems in the area. There has been a change of management at the Santa Fe mine, and the new superintendant is determined to eliminate collecting by miners. In addition to collecting on company time, the miners sell their specimens for money which they use to sustain themselves during strikes; the dealers inadvertently end up in the middle of a labor dispute. In February I had my briefcase searched for vivianite by the mining police (they didn't find any). This is the first time in 6 years of work in the Andean mining camps that I have actually been searched for specimens.

Incidentally, I have found that a solution of sodium hydrosulfite will remove iron staining from vivianite specimens without damaging their luster as acids and bases invariably will. One teaspoon is dissolved in a liter of distilled water; the specimen is gently warmed in the solution for a few hours. Oxide can then be gently brushed off with a toothbrush under running water. Heavy coatings may require several treatments. When the solution has turned olive-green it is exhausted and must be replaced. I've found this treatment also works well in some cases for ludlamite and apatite crystals.

Terry Szenics
Lima, Peru

RECOLLECTIONS ON MARK BANDY

Your publication of the fascinating Mark C. Bandy collecting diaries stirred memories of my first vicarious contact with him – a post-script to his thesis studies, which may be of interest to you (and possibly your readership). In the fall of 1940 I began graduate studies at Harvard University supported by a part-time job as "Assistant to the Curator" at the princely salary of $700 per 10 months from the Holden Fund. One of the very first jobs Harry Berman assigned me was "to clean up the Bandy collection" – several drawersfull of once extraordinary specimens, chiefly supergene copper sulfates and chlorides, mainly from Chuquicamata and other localities in northern Chile (see *American Mineralogist*, **23**, 669–760, 1938).

Although the minerals (bandylite, antofagastite, atacamite, brochantite, etc.) had sojourned in the high-humidity atmosphere of the Cambridge/Boston area for but a few years, some had collapsed completely and many were at least partially damaged. In some cases enough hydrochloric or sulfuric acid had been generated by reaction with atmospheric moisture that it had not only burned through and disintegrated the holding cardboard trays but had also strongly charred the wooden drawers. Many fine specimens were a total loss; a few that we imprisoned in chemical dessicators survived, but in very delicate condition.

The effect of humidity on mineral specimens was also classically documented during the uranium boom when specimens of uranyl phosphates assigned (at the Atomic Energy Commission's lab in the dry air of Grand Junction, Colorado) to the meta-autunite group, were sent to the U.S. Geological Survey's "Gun Factory" lab in Washington, D.C. In this new cloudy clime they all became fully hydrated new species, converting to members of the autunite group.

My only contacts with Mark, many years later, were by letter, but I do know that he was one of several individuals who supplied funds that grub-staked Charles A. Steen, enabling him to quit his job in South America and prospect independently for uranium on the Colorado Plateau. Charlie's search culminated in his discovery of the famous Mi Vida deposit in the Lisbon Valley area of eastern Utah. This orebody was the very first find of unoxidized uranium ores ("black ores") on the Plateau and revolutionized not only the uranium search but ideas on the genesis of Plateau-type deposits. Thus Bandy, indirectly and in some small part, influenced the entire U.S. uranium industry.

To those of us who are pegmatite afficianados, we also remember well Mark's contributions to the mineralogy and geology of the extraordinary pegmatites of the Ribaue-Alto Ligonha district of Mozambique (see *Rocks and Minerals*, **26**, 512–521, 1951) with fantastic specimens of samarskite, allanite, monazite, etc. May his memory long remain.

E. Wm. Heinrich
Prof. of Mineralogy, Emeritus
University of Michigan at Ann Arbor

MISSOURI SIEGENITE

In the introduction to his article on siegenite from the Buick mine, Bixby, Missouri (vol. 15, p. 37), Mark LeFont states that siegenite in Missouri has been found as crystals only at the Buick and Sweetwater mines, and is found only as disseminated grains at the La Motte mine. My own specimen of siegenite from the La Motte mine consists of groups of 1-mm truncated octahedrons in and on sandstone, with small rounded masses of chalcopyrite. The siegenite crystal faces are smooth and lack the triangular polysynthetic twinning lamellae found on Buick mine crystals.

Rare small crystals of siegenite from the La Motte mine, and also from the St. Joe mine, St. Francois County, were reported as early as 1882 (Leonard, A. V., *St. Louis Academy of Science*, vol. 4, p. 401–413). Tarr reported in 1936 that siegenite crystals to 1 cm were not uncommon, and had been found with chalcopyrite at the La Motte and Missouri Cobalt mines (*Economic Geology*, vol. 31, p. 712–754).

Galena was first discovered at the La Motte mine location north of Fredericktown by a Frenchman named La Motte in 1720. The shallow deposits were worked intermittently until the early 1900s. Deeper mining on a large scale was undertaken in 1902 and continued with interruptions until 1959. The Fredericktown area has produced copper, lead, nickel and cobalt, and is located in the Southeast Missouri Lead District, now known as the Old Lead Belt. The prolific Viburnum Trend is called the New Lead Belt. Ore deposits in the Fredericktown area take the form of sinuous lenses in the upper part of the La Motte sandstone and overlying Bonneterre dolomite. They are fairly flat and occur at depths of 60 to 120 meters. Galena, chalcopyrite, marcasite, siegenite and very small amounts of sphalerite and bravoite occur disseminated in the country rock around the lenses (*Mineral and Water Resources of Missouri*, 1967).

Arthur E. Smith Jr.
Houston, TX

FLUORITE, GEOCRONITE, SYLVITE AND STOLZITE

Reading through my issues of the *Mineralogical Record* for 1982, I noticed items requiring some comment.

In Dennis Belsher's article on pink octahedral fluorite from Peru (vol. 13, p. 30) he briefly discusses other occurrences, and mentions "Chamonix, France, where deep red octahedrons are generally less than 1 cm in size." Actually the Mont Blanc Massif, also known as Chamonix, has yielded the largest crystals of pink fluorite known from the Alps. An additional locality which may be added to the list is Gräben, Striegau, Silesia, East Germany; examples of Gräben pink fluorite crystals are on display at the British Museum (Natural History) in London and at the Humboldt University in East Berlin.

In the article by Cassedanne and Lowell on the Virgem da Lapa pegmatites (vol. 13, p. 27) the authors describe a V-shaped twin of geocronite which "consists of two individuals, each about 7.5 cm long . . . by far the finest geocronite ever found." Crystals slightly larger (to 8 cm) have been found at Pietrasanta in the Castello Valley of Tuscany, Italy. Large examples are on display at Pisa University, and smaller ones can be seen at the School of Mines in Paris and the Mining Academy in Freiberg, East Germany. It is rumored that the former owner of the Pietrasanta mine still has about 100 geocronite crystals!

In the note by Mark Rogers on octahedral sylvite from California (vol. 13, p. 42) he states that the crystals, which reach a maximum of 10 cm, are "undoubtedly the world's finest, far exceeding in quality the finest from Germany . . . ." Actually the crystals from Germany are quite good. High-quality, perfectly formed crystals to 6 cm have been found at Stassfurt and are on exhibit at the Mining Academy in Freiberg, East Germany.

In Foord and Conklin's article on stolzite from Tsumeb (vol. 13, p. 149) the authors state that the size of the 2.5-cm crystal ranks it as "the world's largest known crystal for the species." Actually, crystals of stolzite to 3 cm were not uncommon in the Sainte-Lucie mine near Saint-Léger, Lozère, France. The largest recorded crystal from Sainte-Lucie is 6 cm (see *Monde & Mineraux,* no. 43, p. 4–11). Some of these crystals are on exhibit at the University of Paris.

Eric Asselborn
Dijon, France

As an editor and an author, I don't mind having such things pointed out. It's impossible for any writer to have seen or heard of every known crystal or occurrence. And yet, when some find appears to be a candidate for "world's best," that's interesting and worth noting. Should it turn out that some relatively less known find is better, that's even more interesting. I am always amazed by the knowledge of our readers. In the future, any reader seeing something written of as "world's best" should consider that a challenge . . . let us know if you've seen better somewhere.

Ed.

ARIZONA WULFENITE AND CUPRITE

In reading through the Arizona-V issue (vol. 14, no. 5, 1983) I particularly enjoyed the article about Dick Jones. I should point out, however, that the Red Cloud mine wulfenite illustrated was not collected by Dick, but was one which I collected myself in late 1973 (about 6 months after the find which Bob Jones described in *Lapidary Journal,* December 1973, p. 1364–1368). I later sold it to Tom McKee. The specimen is rather unusual in that it was the only crystal in the pocket.

Michael R. Smith
Yerington, NV

In the article by Jones and Wilson on the Ray mine (vol. 14, p. 311–322), reference is made to a pair of fine cuprite specimens reportedly stolen from the Arizona State University collection. The two specimens were actually from the Czar shaft at Bisbee (not from Ray). One was indeed stolen in the late 1960s or early 1970s, but the other was returned to the owner, from whom this and other Bisbee pieces had been held on loan since 1949.

Also, the cuprite shown in Figure 11 of that article is not from the ASU collection, but is one I purchased myself from John Mediz. ASU does have a fine specimen from the same discovery; it contains four or five octahedrons measuring up to 1 cm in size.

David London
Norman, OK

SHOW COMMENTS

I appreciated your kind remarks about the Detroit Show (vol. 15, p. 46). Detroit has been unfairly given a bad image by the media, when in reality it is a world-class city with a great symphony and other famous institutions. I have taken my family to the Detroit Show for the last five years, and we always stay several days. Motel rates are reasonable, and the visit always proves to be quite an educational experience.

Eric Elliott
Holland, MI

I have to agree with your comments about the Gun and Knife Show in Los Angeles (vol. 15, p. 2). Personally I can't think of any show more likely to stir the interests of a mineral collector, outside of a regular mineral show. Certainly there are enough weapons and ammo to hold off the Russian Army for an afternoon or two, but there are so many other things as well. Many of the gun dealers become involved in trades that include fossils, faceted gemstones, minerals, gem carvings, microscopes, assay equipment and mining memorabilia. I purchased eight oval-cut good-quality andalusites (⅓ to ½ carat apiece) for $10 from a gun dealer who was amazed I knew what they were and was glad to get rid of them. I've seen fine trilobites, fossil shark teeth, gold crystals in quartz, ivory scrimshaw, and many other interesting items. It takes diligent looking to find such things at this huge show, but reasonable deals can be made. As the sign says in many booths, "Heck yes, we'll trade!"

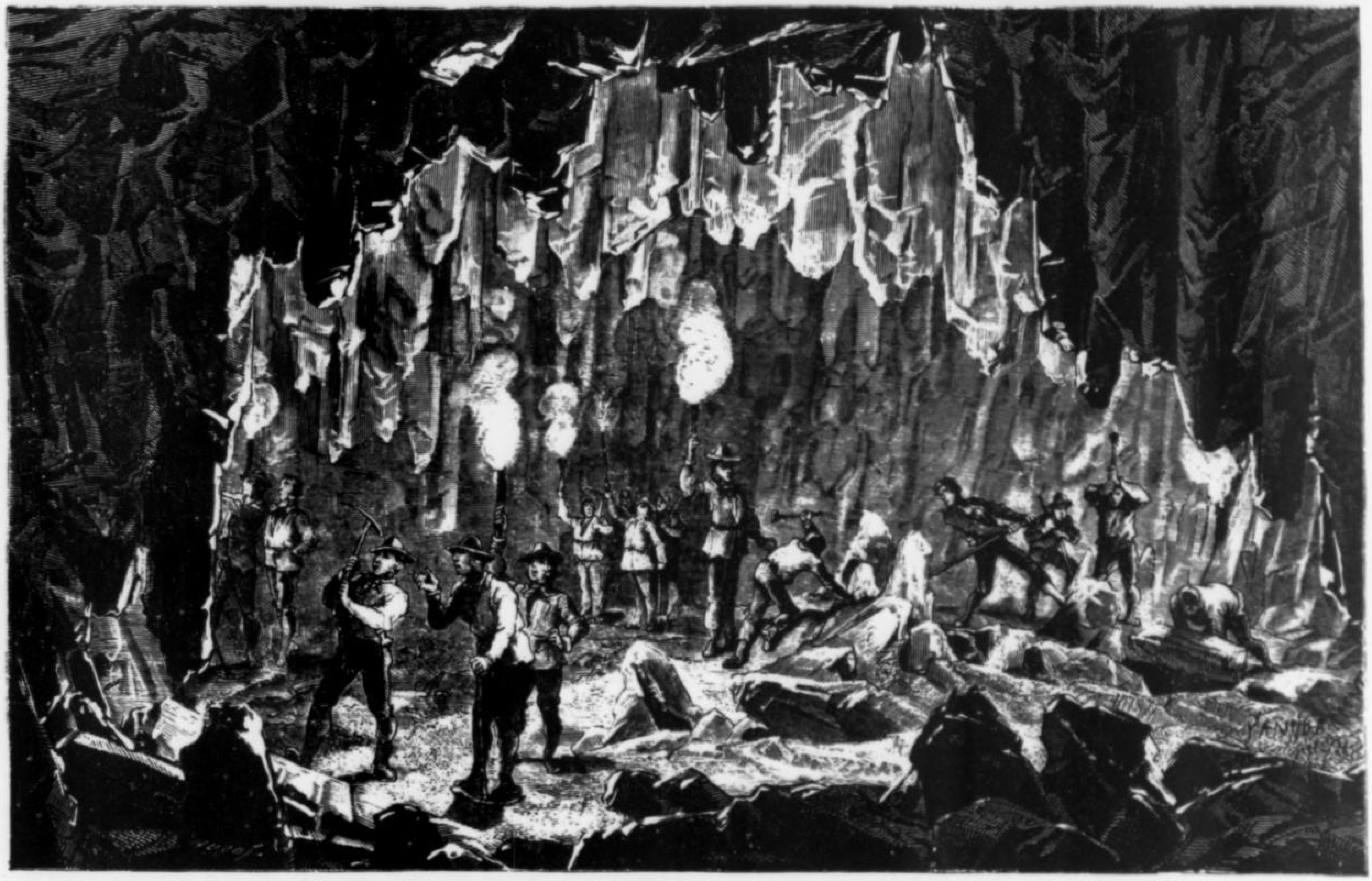
Michael T. Evans
Garden Grove, CA

FAN MAIL

With the latest issue just received, I am happy to have my first complete volume of the *Mineralogical Record.* Your marvellous magazine has already become a part of the things I should not want to miss in my life, even if I had to live on bread and water for the rest of my days! It's difficult to express the warm and joyful feeling I get reading through the splendid articles and looking at the magnificent photographs . . . you provide the very best service for the dedicated mineral collector.

W. J. R. Kwak
Wijchen, Netherlands

the Tiefengletscher Quartz Grotto



Beautiful smoky quartz crystals are occasionally found even today in small cavities and pockets in the hard granite of the Swiss Alps. But in 1868 an unbelievable walk-in pocket was discovered which in a short time yielded 10 metric tons of exceptional crystals.

Wendell E. Wilson
4631 Paseo Tubutama
Tucson, Arizona 85715

Over the years a vast number of interesting mineral occurrences have been exploited around the world. Of these, a special few stand out for sheer awe-inspiring magnificence at the moment of discovery . . . these are the walk-in pockets, the bejeweled caverns and dazzling crystal-lined vugs which cause even the seasoned miner to stare in wonder. For a mineral collector, these are the discoveries that dreams are made of. And the stories surrounding such finds make interesting reading as well. This article is the first in a series dealing with such occurrences: the Great Pockets.

THE DISCOVERY

In September of 1868 a small party of mountaineers was working its way up the valley of the Tiefengletscher (Tiefen Glacier), in the Canton of Uri in the Swiss Alps. On the northern side of the valley rose a mountain known as the Gletschhorn. A Berne pharmacist by the name of Lindet was a member of the party, and he noticed, high up on the cliff face, what looked like a large vein of quartz. He pointed this out to his guides, Peter and Andreas Sulzer from the nearby town of Guttannen, but the location appeared virtually inaccessible and so the party continued on without attempting a close inspection.

For two weeks following that climb, Andreas Sulzer thought about the quartz vein, and finally decided that it had to be checked out for crystals. Mountain guides or *strahlers* occasionally supplemented their income by finding and selling crystals from small clefts; any possible clue to the location of such a cleft was worth pursuing. Sulzer went back to the Tiefengletscher on his own and accomplished the difficult climb to the vein. Making a rapid survey of the deposit, he found some small pockets in the upper part of the vein from which he extracted fine sand and some fragments of black quartz crystals. Thus encouraged, he went home and enlisted the help of eight or ten other experienced climbers from Guttannen.

Heavily loaded with tools and supplies, the team followed Sulzer up the glacier to the foot of the Gletschhorn. He pointed out the spot high above, and they began working their way up, probably utilizing pitons left in the rock from his first climb to the vein. The work was extremely difficult, strung to the face of a cliff while attempting to pry out pieces of the hard granite with hand tools and an occasional charge of explosives. Strahlers have been known to follow a solid quartz vein for several meters into a mountain in the hope that it will open up into a small crystal-lined pocket at some point. In this case they were not disappointed.

The granite finally broke away to reveal a small black opening. No doubt in great excitement, they enlarged the opening until a man could squeeze through into the pocket. What they found was almost unheard of in the Alps: a room fully 6 meters long, 4 meters across and up to 2 meters in height. Piled high in the room was a huge mass of chloritic clay studded with great smoky quartz crystals.

During the next eight days the entire population of Guttannen abandoned normal duties and chores to assist in the cleaning out of the great pocket. To their joy, they found that the earthy mass of chlorite, which in places extended nearly to the ceiling of the room, was literally filled with quartz crystals. Apparently many of these crystals had grown while suspended in the clay, because they were doubly terminated and showed no point of attachment. In all, approximately 10,000 kilograms (22,000 pounds) of crystal specimens were removed from the cleft. Strahlers in the pocket carefully wrapped each specimen so that it could be lowered down a long rope to people standing on the glacier. There the specimens were packed on sleds and pulled down the long and difficult route to meadows below the snow-line, then carried along the trail to the Furca Pass and eventually down to the town of Oberwald.

Figure 1. (previous page) **Removal of quartz crystals from the interior of the Tiefengletscher grotto in 1868 (Rambosson, 1870).**

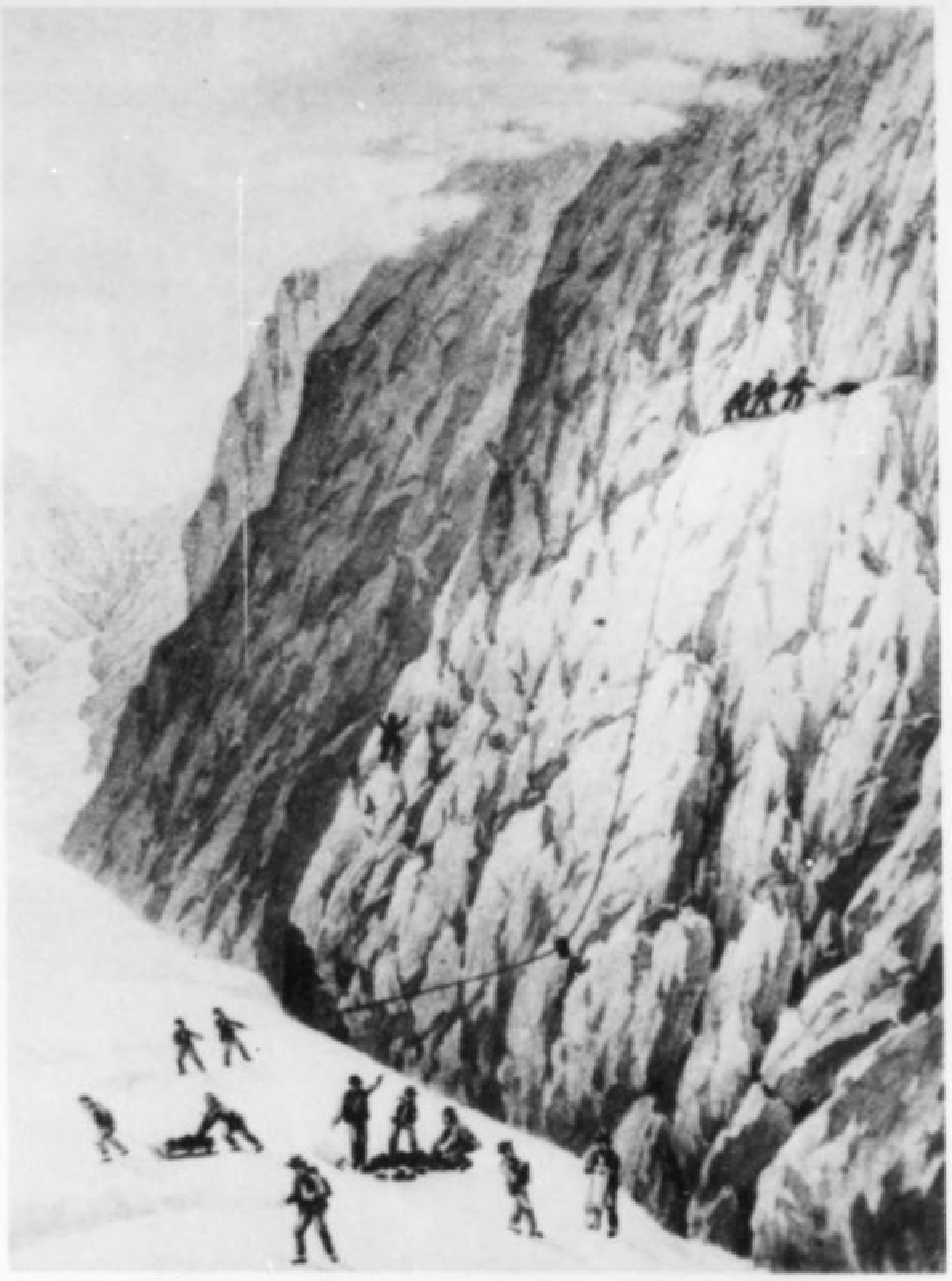


Figure 2. **Early watercolor depicting the transport of quartz crystals from the Tiefengletscher cleft down to men on the glacier who are loading the specimens onto sleds (Weibel, 1966).**

THE SPECIMENS

Nearly all of the quartz crystals recovered are of a smoky dark brown to black color and, because most of them were protected by the enclosing chloritic clay, are remarkably free from damage. A few were even given names. "The Grandfather" measures 69 cm (27 inches) and weighs 133 kg (293 pounds). "The King" measures 87 cm and weighs 127.5 kg. . . . this crystal is very darkly colored and is the most esthetically perfect crystal from the pocket. Then there is "Carl the Fat," weighing in at 105 kg and measuring 68 cm in length. Finally there is "The Big Doublepoint," an 82-cm doubly terminated "floater" with deep smoky color and no visible point of attachment. The longest crystal found, though not quite as esthetic as these, measures 95 cm and weighs over 150 kg; it has some imperfections and contains imbedded chlorite.

Other minerals were found as well, including pink fluorite, calcite, galena, leadhillite, wulfenite, cerussite, chalcopyrite and laumontite, about 10 kg all together.

The most beautiful of the Tiefengletscher quartzes found their way to the Natural History Museum of Berne, Switzerland, where they are on public display today. Others were sold to museums throughout Europe and the rest of the world.

POSTSCRIPT

One would think this surely must have been the greatest quartz

Figure 3. **Smoky quartz crystals from the Tiefengletscher grotto currently on display in the Natural History Museum of Bern. "The King" (87 cm) is at center; "Carl the Fat" is at left. Photo courtesy of H. A. Stalder, Natural History Museum of Bern.**

pocket ever discovered in the Alps. But no, there was a greater one, of which almost nothing has survived. In 1719 a consortium of strahlers led by the four Moor brothers of Geissholz, while climbing the Zinggenstock, discovered a similar quartz vein. Using hand-chisels and black powder they tunneled straight into the granite for 15 grueling meters along the solid vein before giving up in that direction. The leader of the party had an inspiration at that point which to this day no one can figure out. He directed the tunnel *away* from the quartz vein at a 90° angle, through barren granite devoid of indications. After tunneling blindly for almost 5 more meters they broke into a 10-meter pocket situated on a quartz vein which did not outcrop! Fifty metric tons of quartz crystals measuring up to 50 cm in size were removed, *five times* the production of the Tiefengletscher cleft.

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