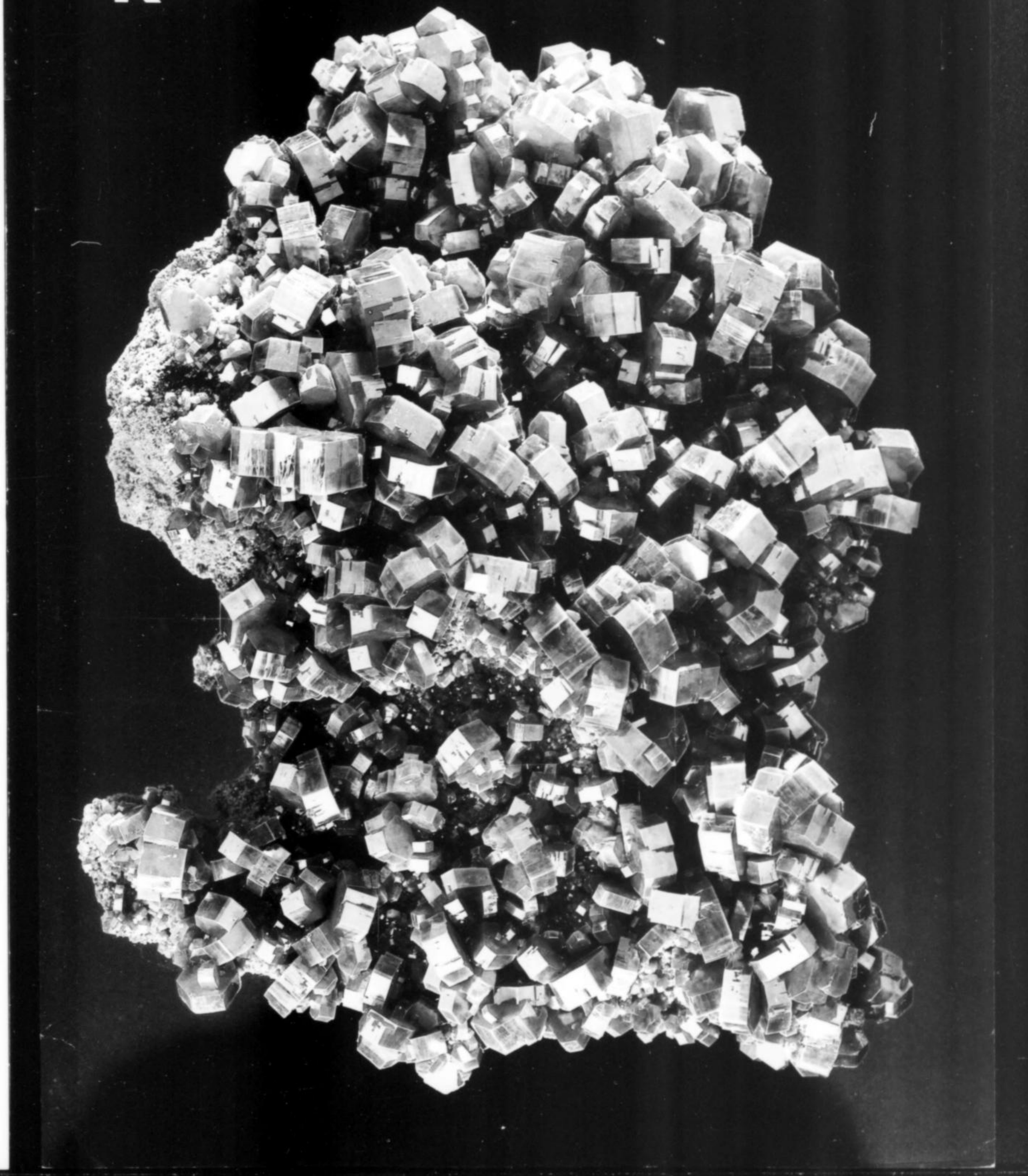
the Mineralogical Record

Volume Seventeen, Number Four July-August 1986 $7.50



The Mineralogical Record Inc. is a non-profit organization
The Mineralogical Record magazine (USPS-887-700) is published by the Mineralogical Record Inc., 7413 N. Mowry Place Tucson, Arizona 85741
Subscriptions
$27 per year, $52 for two years, $600 lifetime, domestic and foreign. Payment in U.S. dollars.

Mailing addresses & phone nos.:

Circulation, back issues, reprints
The Mineralogical Record
P.O. Box 35565
Tucson, Arizona 85740
602-297-6709

Editing, advertising
Wendell E. Wilson
Mineralogical Record
4631 Paseo Tubutama
Tucson, AZ 85715
602-299-5274

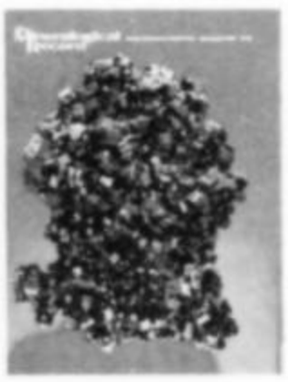
Special second class postage
Paid at Tucson, Arizona, and additional offices. POSTMASTER: send address changes to:
7413 N. Mowry Place
Tucson, AZ 85741

the Mineralogical Record®

July-August, 1986
Volume Seventeen, Number Four

Articles

Departments



COVER: VANADINITE group, 17 cm tall, from Mibladen, Morocco. Collection of Stephen Stolte and Achim Karl (*Mineralien Fossilien Galerie*, Frankfurt); photo by Harold and Erica Van Pelt.

GUEST EDITORIAL

Dangers to Science from Species Dealers

Pete J. Dunn
Department of Mineral Sciences
Smithsonian Institution
Washington, D.C. 20560

Carl A. Francis
Harvard Mineralogical Museum
24 Oxford Street
Cambridge, Massachusetts 02138

With the remarkable increase in the description of new mineral species in recent years has come a similar increase in the number of people who provide such material. Species dealers may do harm in two principal ways: the dissemination of incorrect information, and the physical damage to specimens, our topic here. Unfortunately, the few benefits to mineralogy from such commercial activity are compromised by the fragmentation and practically random distribution of these scientifically significant specimens. This is a concern widely shared in the professional curatorial community.

There has always been some partitioning and distribution of rare species; it benefits the science when such materials are deposited in large institutional research museums in various countries, thus preserving the rarest minerals in several regions of the world. However, the present wanton fragmentation by today's commercial dealers and collectors is a genuine disservice to the science of mineralogy. Although this is not a new activity, the scope of it has become staggering! The usual scenario is that dealers/collectors obtain a specimen of a rare mineral, and then break it into numerous small fragments, sometimes microscopic, which are either sold or exchanged. Despite the vigorous and indignant denials of some species dealers and collectors, this is a very prevalent practice, as those who collect or study rare species know too well. Such distribution is based mainly on a desire for profit, a goal unrelated to the advancement of mineralogy. Far too often fine samples are broken up into meaningless chips, some so small that they are packed in gelatin capsules! There seems to be no lower limit for such fragmentation; it seems to be a "seller's market" with no other controls. This is a sad situation, which is a result of irresponsible behavior. Not all species dealers are guilty, but those few with fine reputations are already well-known and need no exoneration here.

The subdividing of samples into tiny chips is harmful because it destroys associations, and thus much useful information about assemblages and parageneses which contain clues as to the conditions under which the mineral formed. It is crucial to remember that a new mineral description is but the *first* investigation of this naturally occurring material. Almost inevitably, other diverse studies will follow in subsequent years. The original description, done by descriptive mineralogists, may someday be followed by other investigations concerning the relations of the chemical system in which the mineral formed, the relative stability of the associated minerals, crystal structure analysis, thermochemical investigations, measurement of physical constants such as elasticity, compressibility, etc. For many new minerals, all of these factors are unknown, and when the specimens are irresponsibly broken down, the perpetrators might well be ensuring that such studies can never be done. For these studies, there must be complete assemblages, and substantial quantity, not merely tiny chips, broken from others to make many samples and more profit. Even if the fragments could be gathered together, any apparent information derived from such jigsaw puzzle activity would not meet the criteria of scientific inquiry. Hence, the fragmentation actions of species dealers will impede scientific investigations, and in some cases preclude them.

What is the answer to the problem? There might not be one; appeals for responsible behavior fall on ears slightly deafened by the ringing of cash registers. There are no laws, no rules, and there is little in the way of peer pressure of a positive sort in the mineral species marketplace. One could make pleas to different constituencies, for example:

1. A plea to species collectors to dampen the demand for such itty-bitty meaningless chips of doubtful integrity. In fact, were species collectors to inquire as to the true significance of such samples, they might not acquire them at all. However, the quest for profit coupled with other, more benign motivations of collectors, such as the "urge for completeness," might render such a plea ineffective.

2. A plea to mineral scientists not to provide samples to those dealers and collectors well-known for fragmentation activity. This is, unfortunately, not an action which benefits the hobby of mineral collecting. Given the low probability of success of other actions, however, this type of request might be the most effective.

One point should be seriously considered by the collector, and that is the relative worthlessness (scientifically and economically) of such tiny fragments. Without associations, and recognizable features, and without enough material for testing, verification, and careful curation of the remainder, such tiny fragments have little significance, and thus little real value, especially in the long term. For those interested in the investment aspects of mineral collecting, such concerns should be significant ones. Perhaps never before in the history of mineral collecting have so many held so much on so much faith, and little or no proof of even correct identity. These matters deserve careful consideration by the prudent collector.

Concerned collectors, curators and scientists can discourage the destructive fragmentation of rare minerals by employing the power of the mineral marketplace. Patronize only those dealers who avoid commerce in fragmented rare species. Refuse to do business with dealers who impede the advancement of science by such activity, and couple this with articulate, vocal and persistent criticism. Market forces created this problem, and market forces can solve it!

Submitted October 10, 1985; revision accepted January 8, 1986.

notes from the EDITOR

THE *RECORD* COPYRIGHT

The *Mineralogical Record,* as most people know, is a copyrighted publication. This means that it is illegal for unauthorized copies to be made of anything which appears in the magazine. Actually the situation isn't quite that simple, and we receive inquiries regularly to clarify various points of procedure. Here are some useful facts to know:

• Advertisements

An advertiser may retain the rights to his own ad, particularly if he provided it as camera-ready on his own. If we have designed his ad for him at no charge, as we often do, he may still use the ad anywhere else he wishes but may not have exclusive rights to particular illustrations we have provided.

• Illustrations (drawings)

Many drawings seen in the magazine are taken from old publications having expired copyrights. These are in the public domain, and anyone may use them. However, some drawings are recently created and may *not* be used by the public. Generally speaking, unless the art has been purchased outright by someone else, the artist retains ownership of the reproduction rights. I have seen artwork stolen from the pages of the *Mineralogical Record* and used on fliers, ads in other magazines, show posters, and even personal stationery. This exposes the user to legal action, and "ignorance of the law is no excuse."

• Illustrations (photos)

The *Mineralogical Record* does not pay for the use of photos, but even if we did we would have only "one-time" rights. Photographers in all cases retain the copyright on their photos.

• Article and Column Text

All text published in the magazine (except material reprinted from elsewhere) is thereafter owned exclusively by the *Mineralogical Record.* However, because we do not pay for articles, we are usually cooperative with authors who ask for permission to have their writings reprinted by another publisher.

Upon occasion some of our readers may wish to make photocopies of certain articles and columns. If they wish to make only a single copy, for private use, we hereby grant permission (no written permission required). If they wish to make multiple copies for distribution (e.g., in classrooms or for club bulletins) written permission is required and generally granted, provided that the copies will be given away free or sold at cost or less. All permissions granted in writing must be for *specific* items . . . blanket permission is almost never given.

Extracts for republication require no permission provided the extracts are short. It is common practice among professional journals to allow articles to be quoted or line figures (not photos) used in subsequent articles without written permission, but the source must be stated. If the extracts are long, or many illustrations are to be reproduced, written permission should be obtained.

Articles and columns to be reprinted should *not* be re-edited, reorganized, translated or abridged without the author's approval of the new version.

• Our Attitude on Reprinting

The purpose of the *Mineralogical Record* is to distribute information in a helpful, useful way, so we are not, in principle, opposed to reprinting. The additional circulation is good publicity which may help to introduce us to new readers. And we are always interested in helping our authors and photographers achieve wider exposure. Republication for commercial purposes is also negotiable but may involve royalties to authors and/or fees for the use of photos and art (payable to the photographers and artists). It is conceivable that under some circumstances republication would be detrimental to the image of the *Mineralogical Record,* or would be against our best interests in some other way. Permission might then be refused, but that is a relatively remote possibility. Our main wish is to facilitate the spread of information; to that end we strive to cooperate fully on matters of copyright.

(My thanks to Janet Cares for suggesting this note.)

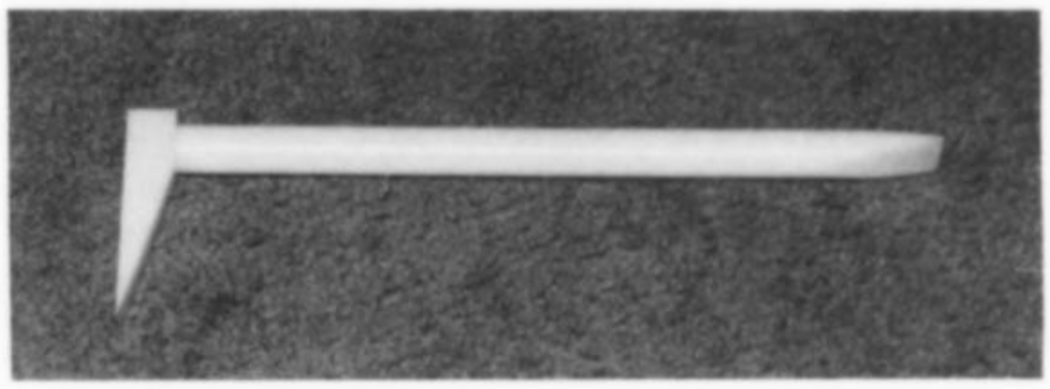
PHOTO COMPETITION

The honor of being the photographer for the 1987 Tuscon Show Poster is up for grabs, with a $250 award thrown in as a sweetener! The only catch is that entries for consideration must be *large format,* 4x5-inch color transparencies (not 35 mm). Furthermore, the mineral pictured, a single specimen or a group, must be *quartz* (any variety or varieties, any size).

Specimens pictured should, of course, be of high quality since the photo will be representing the show. Ownership of specimens must be established and owner permission granted for publication. The winner will be notified by October 20. It is customary for the photographer to be available at the show to autograph posters.

Entries should be mailed to Susan Angelon (2206 E. Jasmine Drive, Tucson, AZ 85706) so as to arrive no later than October 1, 1986. All entries will be returned; decision of the judges is final; right to choose none of the entries is reserved.

Incidentally, it will *not* be acceptable to have a 35 mm slide blown up to a 4x5 transparency; the photo must be shot originally on 4x5 film, using a large format camera. Color bars and a gray scale would be nice, but are not required.



NON-SCRATCHING TOOL

Larry Venezia (115 Coleridge St., East Boston, MA 02128) has come up with a collecting tool strong enough to pry apart rocks and soft enough to avoid scratching crystals. It's an 18-inch prybar made of solid nylon, which he has been field testing for two years. Though generally thought of as being rather flexible, nylon is quite rigid and hard when sufficiently thick. It can be hammered into crevices and vigorously levered with virtually no prospect of breaking or even bending much. It's also a lot lighter than tool steel . . . an important consideration in remote areas where specimens must be backpacked out. The price: $20 postpaid (wholesale lots available).

MINERALS IN CHINA

What will surely go down in history as the rarest important mineral book of modern times is the English edition of *Minerals in China.* This is a beautiful, full-color, hardcover book of 165 pages,

published by Shanghai Scientific and Technical Publishers in an edition limited (they say) to *only 200 copies.*

The original edition, of course, was in Chinese, but some intelligent and kindly soul thought it might be nice to run off a few copies in English, too. The Geology Museum in Peking traded many copies to their foreign correspondents for library materials, and sold the remainder to visitors . . . *and* to the Mineralogical Record. The edition is now sold out in China, but we have in stock 40 copies of the English edition and 7 copies of the *Chinese* edition. The price is $67 each, postpaid (foreign orders add $1), while they last. Some copies have minor mildew along the edge and are sold as is. Order from Mineralogical Record Book Dept., P.O. Box 1656, Carson City, NV 89702.

GONIOMETER PINS

Our bronze lapel pin depicting the Mineralogical Record's goniometer (see Vol. 16, no. 3, p. 169) sold briskly. So briskly, in fact, that we ran out of them in six months. We have recently placed another order with Josten's, however, and expect to have them back in stock in July. Readers can obtain one by sending $12 plus $2 postage and packaging ($3 foreign) to the Mineralogical Record Book Department, P.O. Box 1656, Carson City, NV 89702.

GREEK NEWSLETTER

A bimonthly, bilingual newsletter is being initiated in Greece. The title is *Oryktologika Nea — News on Minerals.* Apparently this will be the first newsletter of its kind in Greece. It will be published in English and Greek, and will deal with Greek mineral localities and collectors. Collectors wishing to advertise for trading partners in *Oryktologika* may do so for $1 per insertion. A one-year airmail subscription is $25. Send to: D. G. Minatidis, Editor, 70 Queen Sophia Avenue, Piraeus 185-32, Greece.

GOLDSCHMIDT'S ATLAS

Most collectors know about Victor Goldschmidt's monumental collection of crystal drawings, *Atlas der Krystallformen* (1913–1923). The work consists of nine volumes of crystal drawings and nine volumes of supporting text on localities, references, crystal forms, etc. The bound set in the Mineralogical Record Library occupies 61 cm (2 feet) of shelf space and is probably worth around $2500 on the rare book market. Obviously, few collectors can afford the luxury of owning an original set.

Finally a high-quality reprint of this invaluable work is being published by the Rochester Academy of Science. The first two volumes (text and figures combined, softbound) are now available from the Mineralogical Record Book Dept. (P.O. Box 1656, Carson City, NV 89702) at $70 for the two plus $4 postage ($1 more for foreign orders). We have in hand 60 copies of each volume, from a total softcover press run of 300 copies.

The RAS is publishing these by the bootstrap method, that is, sales of each volume must be more or less complete in order to finance subsequent publication of the next volume in the set. Purchasers of the first two volumes should be prepared to purchase each of the seven succeeding volumes as it becomes available, at the same price of $35 per volume. That will mean a total price of $315 for the nine combined volumes of text and figures. Consider it as a sort of subscription!

SAM WELLER CUSTOMERS

What could be worse for a mail-order dealer than to have all his customer records go up in smoke? That is unfortunately what happened on February 16 when the premises of *Sam Weller Minerals* were destroyed by fire. Rose and Sam will continue the business from a small house next door, and are even now rapidly replacing lost inventory, but they need to hear from previous customers so they can rebuild their mailing list. Their new listing of specimens should be ready to send out right about now. Write to: Sam Weller, "Chy-an-Stennack," Lower Boscaswell, Pendeen, West Cornwall, England.

CALL FOR PAPERS

The eighth Friends of Mineralogy–Mineralogical Society of America–Tucson Gem and Mineral Society symposium will be held on February 15, 1987, at the Tucson Community Center. The symposium topic will be quartz, the featured mineral for the Tucson Gem and Mineral Show, and papers covering any aspect of quartz mineralogy including structure, physical and chemical properties, paragenesis and localities are invited.

Presentations will be limited to 20 minutes with an additional 5 minutes for questions. An audience of knowledgeable amateurs as well as professional mineralogists is expected so the emphasis of papers should be topical rather than specialized.

Papers by students will be considered for the "Best Student Paper" award from Friends of Mineralogy. The award is intended to cover part or all of the travel expenses of the student attending the symposium.

Abstracts should be submitted to FM–MSA–TGMS 8th Symposium, Attn: Henry Truebe, St. Joe American Corp., 2002 North Forbes Blvd., Tucson, AZ 85745. Deadline is September 31, 1986.

CHECK YOUR GARAGE

If you have old copies of *Rock & Gem* magazine, you can trade them in for a credit toward your next subscription renewal for the *Mineralogical Record.* We're trying to complete our set, and will give a **$2 credit per copy** for issues we still need. (We'll also accept them as outright donations, of course.)

Check the following list of what we need and send a letter listing what you have available. I'll write back telling you which ones to send (this will avoid duplicates). Send to Editor, Mineralogical Record, 4631 Paseo Tubutama, Tucson, AZ 85715.

1971 All issues
1972 Jan., Feb., Mar., Apr., May, Aug., Sept., Oct.
1973 Jan., Mar., May, July, Aug., Sept., Oct.
1974 Jan., Mar., Aug., Sept., Oct., Nov., Dec.
1975 Jan., Feb., Apr., Aug., Sept., Nov.
1976 Jan., Mar., Apr., May, Oct., Dec.
1977 All issues
1978 Mar., Apr., May, Nov.
1979 Feb., Apr.
1981 July, Aug.
1982 May, July, Aug., Oct.
1984 June, Aug.

Incidentally, it turns out our set of *Gems & Minerals* isn't complete after all. The bindery found several seriously damaged copies needing replacement. So we make the same offer for the following copies of *Gems & Minerals*:

1964 Feb., Apr., May, Sept., Oct., Dec.
1965 May, Sept., Oct.
1969 Feb., Mar.
1985 Jan., Apr.

MINERAL MUSEUMS OF EUROPE BOOK

Uli Burchard, author of the recently published *Mineral Museums of Europe,* will be available to autograph copies at the *Mineralogical Record*'s table at the Denver Show, Sept. 12-14.

Great Pockets:

the National Belle mine

Arthur E. Smith, Jr.
9118 Concho Street
Houston, Texas 77036

Tom Rosemeyer
P.O. Box 586
Ouray, Colorado 81427

The National Belle mine became famous in 1883 when the first of several ore-lined caverns was discovered. A number of species including enargite, sphalerite, barite, quartz, pyrargyrite and tetrahedrite can still be collected on the dumps.

INTRODUCTION

South from Ouray, Colorado, U.S. Route 550 hugs the Uncompahgre River Canyon and twists and climbs into the heart of the San Juan Mountains. The only respite from the twisting and climbing is a quick, straight stretch across Ironton Park before a final tortuous assault on the mountains. Here the mountain sides are spotted with abandoned mines, the faded hopes of the past. There is the Silver King, Silver Bell, Cora Belle, American Girl, Yankee Girl, Belfast, Guston, Congress, Genessee, Vandervilt, Joker and many more. Some made money for their finders, owners and investors but many did not.

Evidence of mineralization is prominent. Shades of red and yellow iron oxide paint the looming Red Mountain peaks. In the warm sun the acrid smell of disintegrating sulfides lingers on abandoned mine dumps. As the road climbs again it twists and passes by the Treasury Tunnel trestle of the famous Idarado mine which is now closed. At approximately 3414 meters (11,100 feet) and about 16.1 km (10 miles) from Ouray is the climax, Red Mountain Pass. South from here it is all down hill to Silverton. Backtracking about 600 meters (2000 feet) north of the pass on the Ouray side, a dirt road leads east a short distance to the National Belle mine and what was the final location of the town of Red Mountain, which had several different settings on both sides of the pass.

HISTORY

In 1874 the inaccessibility of the San Juan Mountains made the "Ho, for the San Juans" rush more of a bust than a boom. In spite

Figure 1. **The National Belle mine (Lakes, 1905).**

of this problem, settlement and mining slowly progressed. It was not until 1881 that the mineral deposits of the Red Mountain area were discovered. The National Belle mine was discovered in 1882 by Richard Journey. Little is known about him except that he drowned in 1904 when the *Discovery,* out of Nome, sank; he had been returning from a prospecting and mining venture in Alaska.

The town of Red Mountain, located in the gulch below the mine, was built in 2 meters of snow during the winter of 1882–1883. The National Belle Silver Mining Company was organized and extensive development was started in the summer of 1883. Initial development consisted of drifts driven into the sides of the siliceous knob which led to the discovery of "cave deposits" in the oxidized zone.

In the summer of 1883, Ernest Ingersoll, a 31-year-old explorer, naturalist and writer, traveled about southern and central Colorado in three private narrow-gauge railroad cars. With him were his wife and three friends. Their adventures were published in a book entitled *The Crest of the Continent.* A side trip was made to Ouray and, while he indicates that they went on toward Red Mountain, he gives no description of the town or district. Excitement about the area was high at the time of his trip. After a brief history of the discovery of the district he relates the following:

> Upon the heels of this discovery there was a great rush of miners and speculators toward the scarlet heights, and several large settlements – principally Ironton and Red Mountain Town – sprang up on the rough and forested hillside. Claim stakes dotted the mountain as thick as the poles in a hop-field, and astonishing success attended nearly every digging. Among them all the first lode opened, the Yankee Girl, held supremacy, as is so often the case; but a few months later a neighboring property, the National Belle, leaped far to the front at a single bound.
>
> This occurred by the accident of a workman breaking through the tunnel wall into a cavity. Hollow echoes came back from the blows of his pick, and stones thrown were heard to roll a long distance. Taking a candle, one of the men descended and found himself in an immense natural chamber, the flickering rays of the light showing him the vaulted roof far above, seamed with bright streaks of galena and interspersed with masses of soft carbonates, chlorides and pure white talc. On different sides of this remarkable chamber were small openings leading to other rooms or chambers, showing the same wonderful rich formation. Returning from this brief reconnaissance a party began a regular exploration. They crept through the narrow opening into an immense natural tunnel running above and across the route of their working drift for a hundred feet or more, in which they clambered over great boulders of pure galena, and mounds of soft gray carbonates, while the walls and roof showed themselves a solid mass of chloride and carbonate ores of silver. Returning to the starting point they passed through another narrow tunnel of solid and glittering galena for a distance of forty feet, and found indications of other large passages and chambers beyond. "It would seem," cries the local editor in his account of this romantic disclosure, "as though Nature had gathered her choice treasures from her inexhaustible storehouse, and wrought these tunnels, natural stopping places and chambers, studded with glittering crystals and bright mineral to dazzle the eyes of man in after ages, and lure him on to other treasures hidden deeper in the bowels of the earth. . . . The news of the discovery spread like wildfire, and crowds came to see the sight, and to many of them it was one never to be forgotten."
>
> This was only the first of these surprises, for many cavities have since been divulged, great and small, in each of which crude wealth had been locked up since the world was made. The character of the ores, the occurrence of these cavities, and the extremely short distances beneath the turf at which rich ore is struck, have combined to cause much discussion among geologists as to the true history of the district.

Figure 2. **Illustration inspired by the National Belle mine discovery (Ingersoll, 1890).**

The *Red Mountain Pilot,* published in Silverton on July 19, 1883, was even more exuberant but gave even less factual information on the discovery of the caves.

> Wonderful! Miraculous! Astonishing!
> The wonder of Aladdin's Lamp!
> A million dollars in sight!
> Greatest discovery in the world!
> The Comstock bonanza discounted!
> The National Belle mine is boss!
>
> A Cave was opened in the National Belle on Wednesday last, 200 feet in length and 100 feet in width with other caves running in all directions and all a mass of richest ore. Reliable parties claim that there is a million dollars in sight. A responsible capitalist from the East offered, for a one fourth interest, cash down, more than the owners asked for the mine last week. This is not exaggerated, it is simply a mountain of mineral.

Although both of these accounts exaggerate the value of the ore, the caves were a spectacular sight. However, it was the ore values that concerned the miners and the caves' contents were soon mined, sacked and shipped by mule or wagon to the nearest rail line and then to the smelter.

A toll road across the San Juans from Ouray to Silverton, passing through Red Mountain, was completed in 1883 but it was not until 1888 that the railroad from Silverton reached the mine and provided cheap transportation. The mine was sold to the American Belle Mines Ltd. of London in 1891. They changed the name to the American Belle mine and continued mining operations.

When much of the town of Red Mountain was destroyed by a fire in August of 1892 the period of peak production was past. In May of 1897 production ceased and the mine closed, due to the low price of silver and the lack of high-grade ore. Lessees worked the mine for several years after that and the U.S. Bureau of Mines lists the National Belle as shipping ore for several years between 1906 and 1916.

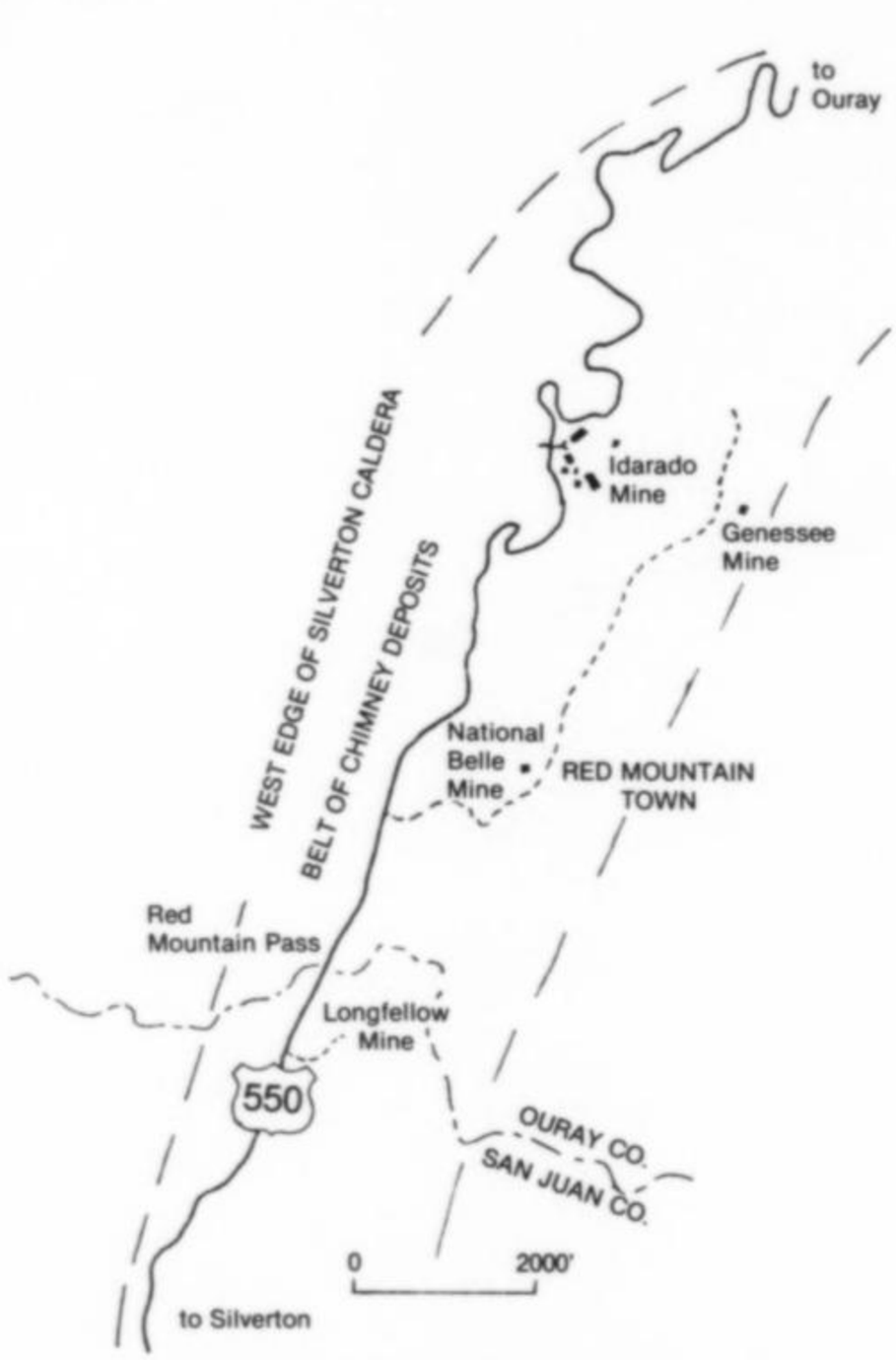


Figure 3. **Location of the National Belle mine, Red Mountain, Ouray County, San Juan Mountains, Colorado.**

GEOLOGY

The National Belle breccia pipe is located within the ring fault zone on the northwest side of the Silverton Caldera. The Silverton Caldera, a collapse structure, formed during middle Tertiary eruptions of large amounts of rhyolitic and latitic ash flows. Middle Tertiary Silverton volcanics, made up of layered volcanics, intrusive stocks, dikes and breccia bodies, comprise the rocks in the mine area. The layered volcanics are andesite, rhyodacite and rhyolite. The intrusive rocks range from rhyolite to quartz latites and andesites.

The National Belle pipe is a conspicuous siliceous knob approximately 120 meters in diameter and 60 meters high. The pipe is composed of an inner core of silicified and kaolinized breccia encircled by an envelope of silicified cavernous breccia. The outermost zone of the pipe is composed of pyritized illitic rock which grades into propylitized country rock.

In addition to the drifts into the sides of the knob, the mine was developed by a shaft which was sunk to a depth of 150 meters (490 feet). Development of the mine was from four levels. Much of the ore in the mine occurred in caves or vugs. Level 1 was in oxidized ore, level 2 was in mixed oxidized and sulfide ore, and levels 3 and 4 were in the sulfide zone. No paying ore was found below level 3. Level 4 consisted primarily of crumbly pyrite with small, isolated patches of ore minerals.

PRODUCTION

Complete production statistics for the mine were not available but estimates indicate a total production of several hundred thousand dollars to one million dollars. In 1883 the mine produced 980 tons of silver-lead ore worth $70,000, far short of the millions ballyhooed by the newspapers. This was from the oxidized ore which consisted of cerussite, probable anglesite and unaltered cores of galena from the caves. In 1890 the total production value was $87,000, of which $4,500 was from gold, $29,091 was from silver, and $54,000 was from copper. It is evident that this production was from the deeper sulfide ores which consisted primarily of enargite, tetrahedrite and pyrite with some galena (Ransome, 1901).

THE CAVES

There are no good, complete descriptions of any of the National Belle caves. Professor Arthur Lakes recalls an earlier visit to the mine and caves while writing for *Mines and Minerals* after a visit to the National Belle mine in 1900:

> In the little open valley in which the village of Red Mountain is located stands a prominent, isolated castle rock about 300 feet in height, the top part of which is composed largely of quartz in a columnar form and intersected by numerous minor veins of quartz which would appear to meet in a general center. The columnar sides of this mass are honeycombed with little caves and caverns. On the largest of the fissures intersecting the hill on the northeast side the original National Belle mine was opened in a fissure full of cavities and containing large bodies of kaolin and decomposed ore of various kinds. When I first visited the mine some years ago they were digging out the decomposed ore with pick and shovel, and mainly with a shovel. Not a shot had as yet been let off in the mine. I crawled in with the foreman through various cavern-like openings, and we had to be very careful not to shake down masses of decomposed ore and kaolin from the roof and sides, whilst it was difficut to keep our footing from the slippery and decomposed ore lying at our feet. They were at the time shoveling out brown mud and drying it on a big iron pan and shipping this rich dried mud in sacks. This was the beginning of the celebrated mine called the National Belle.

A more scientific description can be obtained from the following composite with Schwarz (1889), Ransome (1901) and Burbank (1941). T. E. Schwarz, a mining engineer, was the mine superintendent at the National Belle and nearby Yankee Girl mine in the 1880s. Ransome, a geologist with the U.S. Geological Survey, visited the National Belle mine in 1897 just after it was shut down. He also had the unpublished notes of S. F. Emmons, who visited the mine in 1886. Burbank, also a geologist with the U.S. Geological Survey, studied and wrote on the San Juans from the 1930s into the 1970s. Only the words in brackets have been added by the writers.

> These knolls [knobs] present a rough mass of quartz cut up by cross fractures, and showing small vugs and cavities on the exposed cliff faces. The ore-bearing caves which ramify throughout the mass, generally come to the surface along the cliff-base where they are partially or wholly covered by [rock]

Figure 4. **National Belle mine site showing prominent knob and headframe, September 1983; Tom Rosemeyer photo.**

slide. In size the caves vary up to chambers of 50 feet [15.4 m] in diameter which are connected by irregular rounded passages, branching out toward the surface but diminishing and coming together in depth. In some cases the formation of the caves along fracture or cleavage planes is evident but in others all traces of such planes are quite obliterated. The cave-walls are a porous sandy quartz, the sand from the disintegration of which forms part of the cave filling.

Down to an altitude of about 10,930 feet [3363 m, roughly the base of the knoll] in the mine workings, the sulphides within the caves and those that originally impregnated the walls have been removed by leaching. On the bottoms of some caves and lining the sides of others there are remnants of the less soluble ore and gang filling. These consist of porous spongy masses of minute quartz crystals, clay minerals, alunite, barite, partly oxidized galena and remnants of enargite. Much of the material is encrusted with ore stained with limonite. the ores are mainly carbonates of lead and iron together with iron oxide, lead sulfates, and arsenates. Kaolin [actually dickite but several other clay minerals are also present] occurs in considerable quantities, and zincblende is common. The latter occurs in botryoidal masses consisting of nearly concentric fibrous layers, and is usually found detached from the cave-walls. They are as large as 12 inches [30 cm] in diameter and emit a phosphorescent light on scratching with steel. Galena also occurs but generally as the core of an oxidized mass. The ores of adjoining or connecting caves are sometimes greatly different in [ore] grade.

The unoxidized ore [is] chiefly enargite in the deeper workings of the mine. Some caves are lined with interlocking quartz crystals between which the sulphides were deposited. Some of the enargite occurred lining caves, forming beautiful radiating clusters of orthorhombic prisms several centimeters in length. These prisms are usually covered with a thin moss-like film of malachite and often with minute crystals of quartz. It [enargite] carrying at its best as much as 30 ounces of silver and 40 percent copper was associated with both copper and iron pyrites, some tetrahedrite and galena in diminishing amount down to nearly the No. 4 level.

There is no doubt that these caves supplied some excellent crystallized mineral specimens. The five papers written in the late 1800s on National Belle minerals show the impact of this mine on mineralogy. Unfortunately few good specimens have survived. However, the mine dumps still provide good micromineral specimens for the serious collector. This material is mostly from the sulfide zone. The following mineral descriptions are a compilation from the literature, combined with what has been observed on the dumps.

MINERALS

Alunite $KAl_3(SO_4)_2(OH)_6$

Alunite is reported but analysis shows it to be closer to natroalunite (Hurlburt, 1894; Eckel, 1961).

Anglesite $PbSO_4$

Lead sulfate is reported from the oxidized ores in caves by Schwarz (1889) but anglesite has not been definitely identified.

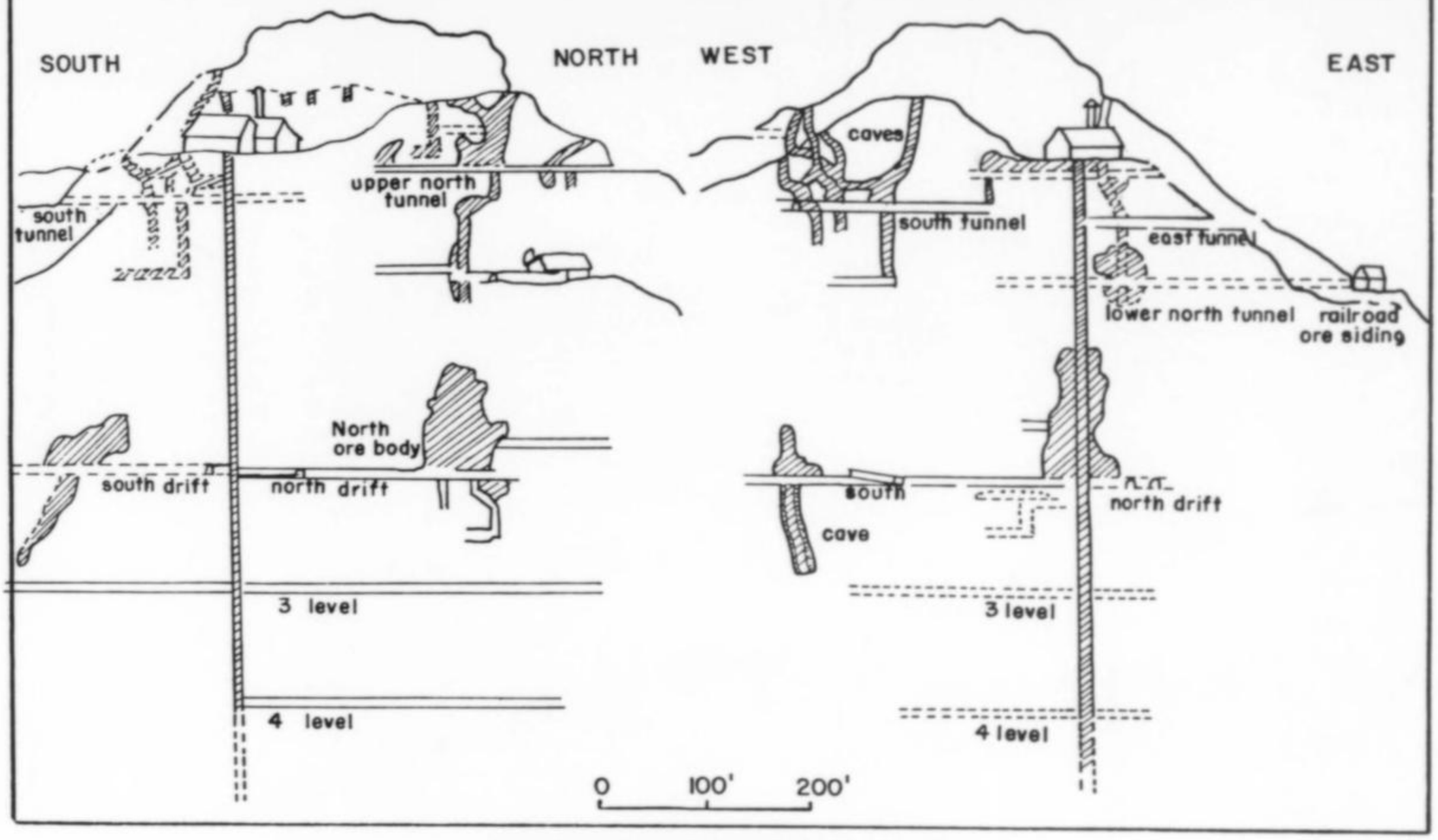


Figure 5. **Sections, National Belle mine showing ore bodies and natural caverns (Ransome, 1901).**

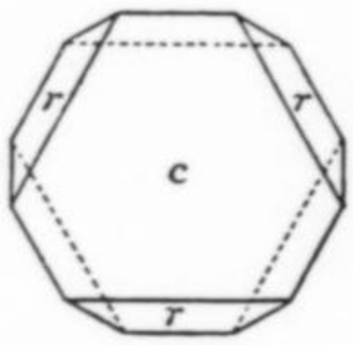


Figure 6. **Alunite, National Belle mine (Hurlburt, 1894).**

Barite $BaSO_4$

Barite was common in the oxidized ores. It is rare in the sulfide zone. It can be collected on the dumps as white, opaque to transparent, tabular microcrystals in vugs with quartz, enargite and pyrite crystals.

Cerussite $PbCO_3$

Cerussite is the primary ore of the oxidized zone. It occurs surrounding residual galena masses in the caves.

Chalcopyrite $CuFeS_2$

Chalcopyrite occurs with other sulfides in the deeper portions of the mine (Burbank *et al.,* 1972).

Colusite $Cu_3(As,Sn,V,Fe)S_4$

Colusite occurs with other sulfides in the unoxidized ore (Burbank, 1941). It is bronze-colored with a black streak. None has been collected in recent years.

Covellite CuS

Covellite is reported from mines in the Red Mountain district. Thin, iridescent blue coatings on some enargite may be covellite.

Diaspore AlO(OH)

Diaspore was reported from the National Belle mine by Ransome (1901).

Dickite $Al_2Si_2O_5(OH)_4$

Dickite was originally identified as kaolinite (Hills, 1884; Dick, 1888). In 1930 Ross and Kerr described it as a new mineral using the National Belle mine material as the basis for their description. They describe it as an incoherent glistening powder made up of six-sided plates averaging about 0.08 mm in diameter. Many of the crystals are in the form of curved or straight piles of plates that reach a maximum height of 0.3 mm. Dickite is common on the mine dumps in vugs with quartz crystals and sulfides.

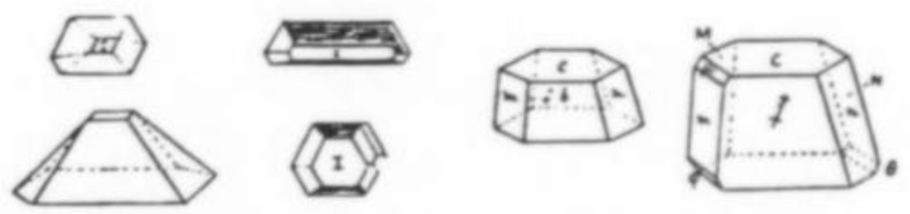


Figure 7. **Dickite, National Belle mine (Dick, 1888; Hills, 1884).**

Enargite Cu_3AsS_4

Enargite is the most abundant ore mineral in the sulfide zone. It occurs as masses, groups of radiating crystals, and single crystals up to several centimeters long (Ransome, 1901). Some crystals may have a coating of velvet malachite. Crystals from the dump, generally under 5 mm long, occur with quartz and pyrite crystals and may be coated with dickite. Enargite occurs in a variety of crystal forms.

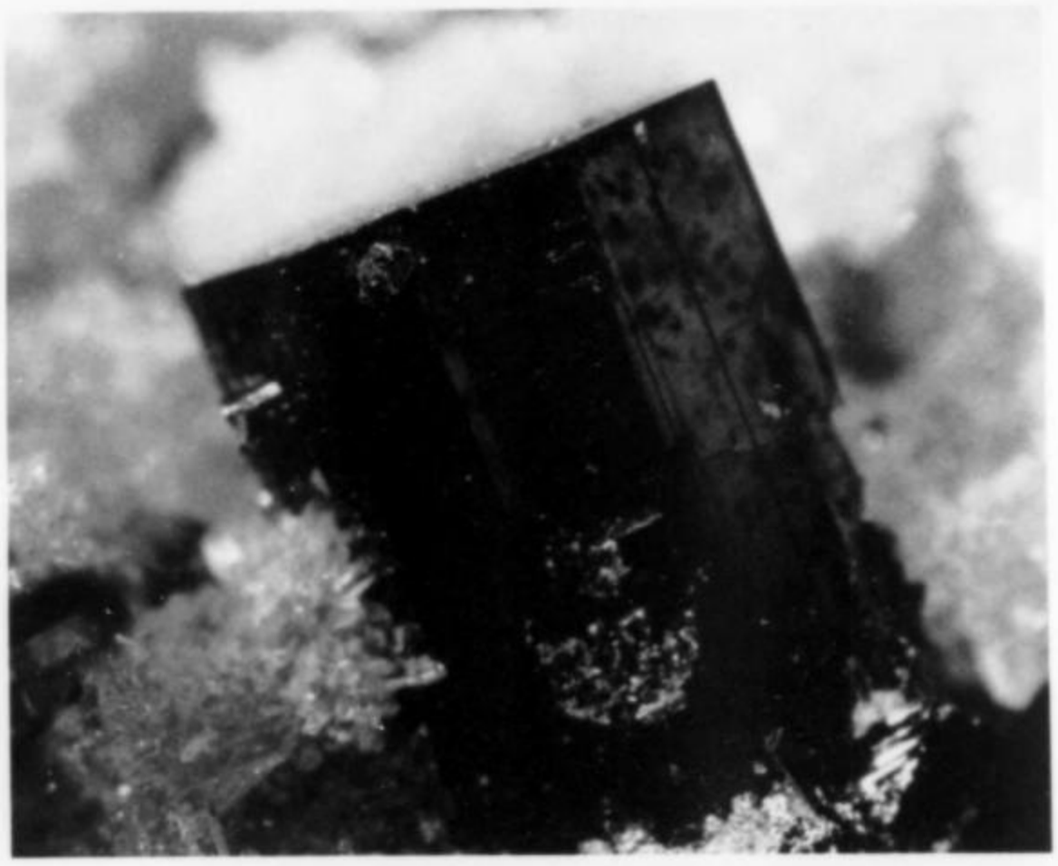


Figure 8. **Enargite crystal, 2.6 mm tall, with quartz crystals; National Belle mine, 1978; Dan Behnke photo.**

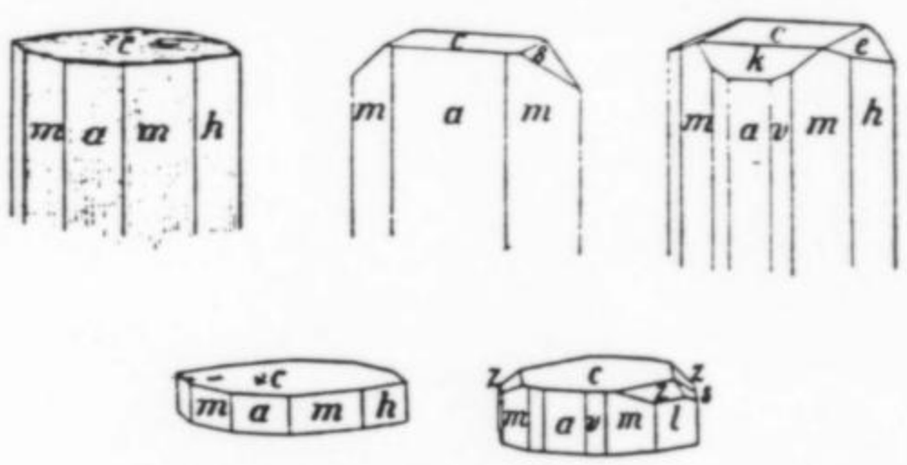


Figure 9. **Enargite, National Belle mine (Pirsson, 1894).**

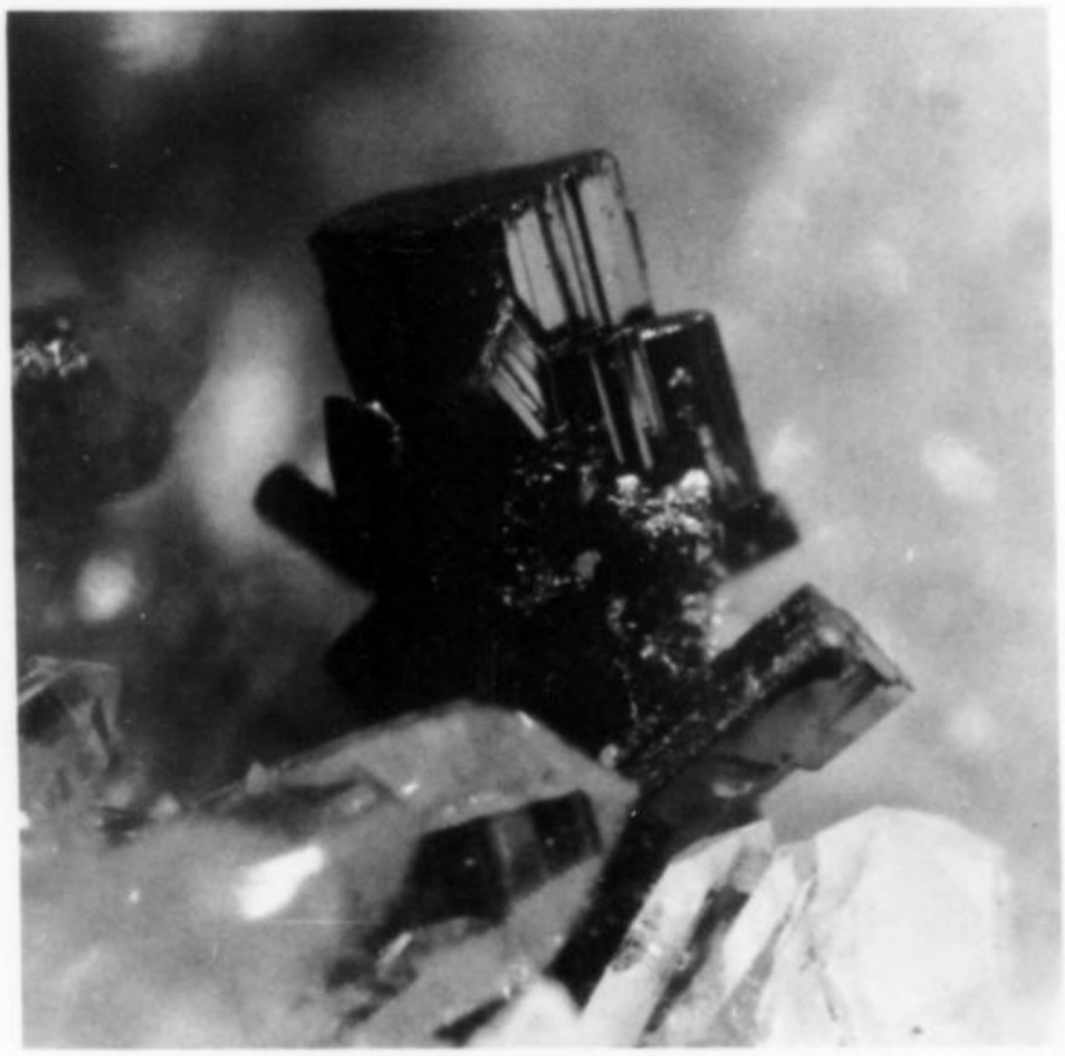


Figure 10. **Enargite crystal group. The largest crystal is 0.8 mm long; National Belle mine, 1978; Dan Behnke photo.**

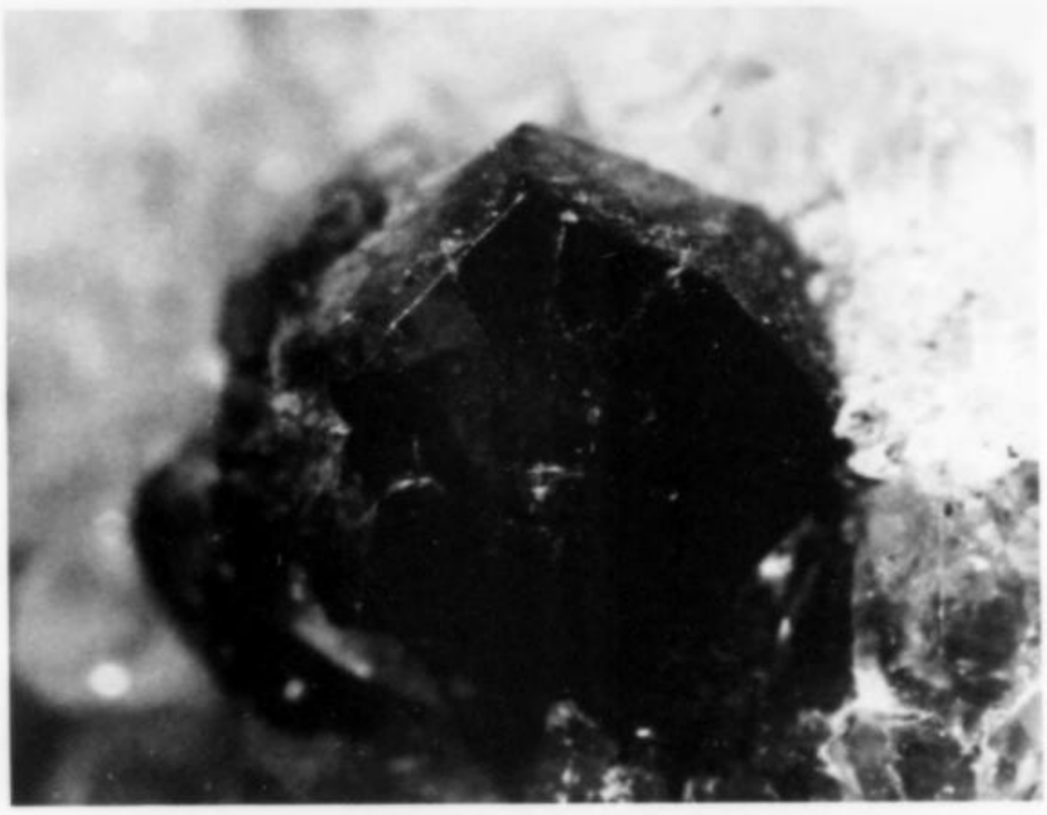


Figure 11. **Sphalerite crystal, 1.9 mm across, brownish red; National Belle mine, 1972; Dan Behnke photo.**

Figure 12. **White barite crystal 4.2 mm tall occurring with enargite and unidentified white crystals along its edge; National Belle mine, 1978; Dan Behnke photo.**

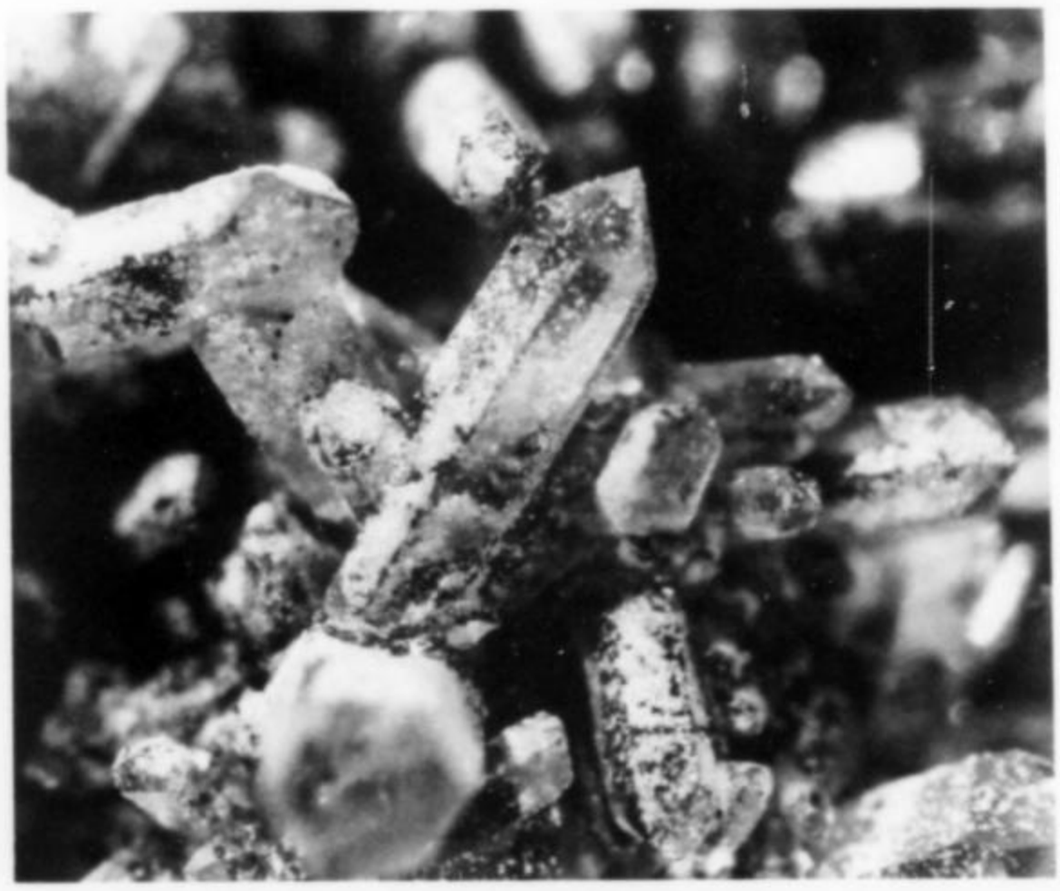


Figure 13. **Dickite coating clear quartz crystals. The largest quartz crystal is 1.2 mm long. National Belle mine, 1978; Dan Behnke photo.**

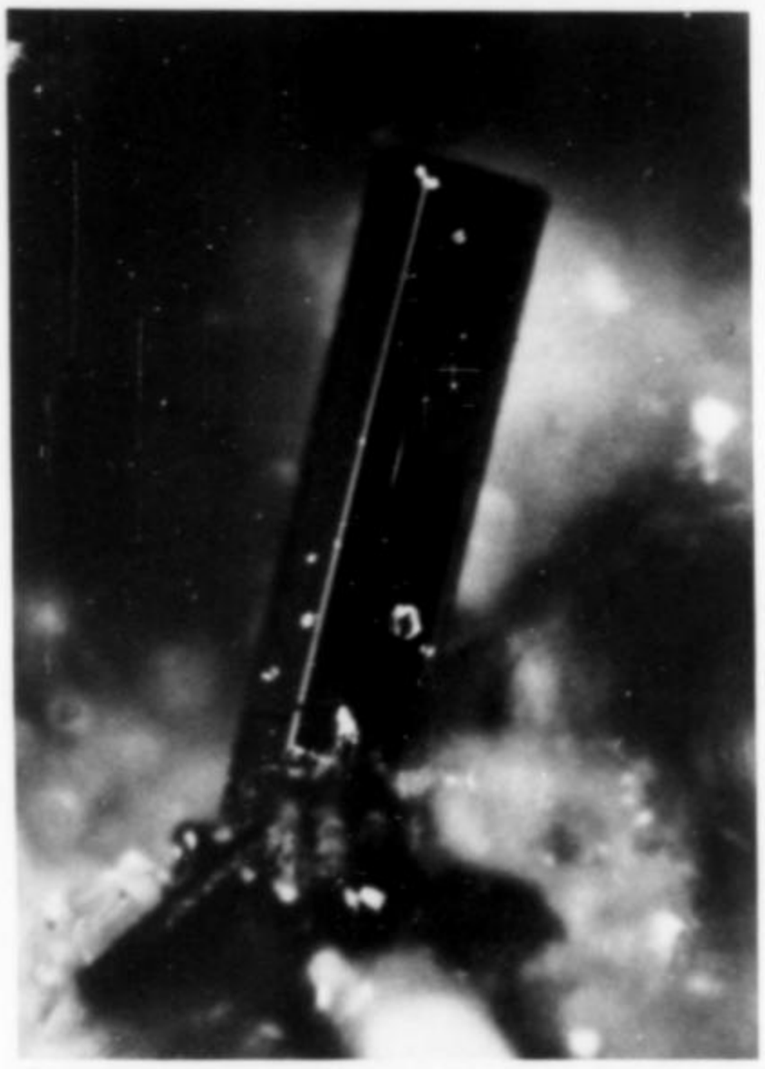


Figure 14. **Pyrargyrite crystal, 0.6 mm long in vug of enargite; National Belle mine, 1978; Dan Behnke photo.**

Galena PbS

In the oxidized zone galena occurs as cores of unaltered material surrounded by cerussite, probable anglesite, and spongy masses of quartz. In the sulfide zone it becomes less common with depth and is rare in the exposed dump material.

Gold Au

Free gold has been reported from the sulfide ore but it was not common.

Kaolinite $Al_2Si_2O_5(OH)_4$

The material described as kaolinite is dickite (Ross and Kerr, 1930). Studies on the clay minerals of the Longfellow mine just across the pass in San Juan County show a zonation from the center of the deposit outward. Besides dickite, Luedke and Hosterman (1971) identified high alumina montmorillonite, pyrophyllite, illite, and chlorite. A similar group of minerals and zonation may also occur at the National Belle mine.

Malachite $Cu_2(CO_3)(OH)$

Malachite occurs as stains and velvety coatings on enargite in the upper levels of the mine (Ransome, 1901).

Natroalunite $NaAl_3(SO_4)_2(OH)_6$

Natroalunite is present as aggregates of minute crystals which resemble dickite. It fills seams and pockets and occurs on quartz, pyrite and enargite. The largest crystals are 0.13 mm in diameter and 0.01 mm thick (Hurlburt, 1894).

Pitticite hydrous ferric arsenate-sulfate

Pitticite from the walls of a cave above the water level was identified by Charles Milton (Burbank *et al.*, 1972).

Pyrargyrite Ag_3SbS_3

Tiny, shiny black, elongated, prismatic crystals of pyrargyrite occur in small vugs. They are very rare in the dump material.

Pyrite FeS_2

Pyrite is abundant in the sulfide zone and on the dump where it seems to permeate much of the rock. It occurs as masses and numerous 0.1 to 3 mm octahedral crystals. Small, modified cubic crystals occur in some vugs but are much less common.

Quartz SiO_2

Clear bright quartz crystals up to 1 cm long and 3 mm wide line vugs of the sulfide zone. They were also abundant in the caves of the oxidized zone where they were mixed with dickite and other clay minerals. Crystals are abundant in the dump material and occur with dickite, pyrite, enargite and other minerals.

Scorodite $Fe^{+3}AsO_4 \cdot 2H_2O$

Scorodite has not been reported from the National Belle mine though it might have been one of the arsenate minerals in the oxidized zone. It occurs in the Charter Oak mine across the gulch as green botryoidal encrustations on enargite and on wall rocks (Penfield, 1893).

Sphalerite (Zn,Fe)S

Sphalerite occurs as large botryoidal masses on the floor of the caves in the oxidized zone (Schwarz, 1890). Small reddish brown, opaque crystals and more rarely yellow, frosted, translucent crystals occur with quartz and enargite in cavities in the mine dump material.

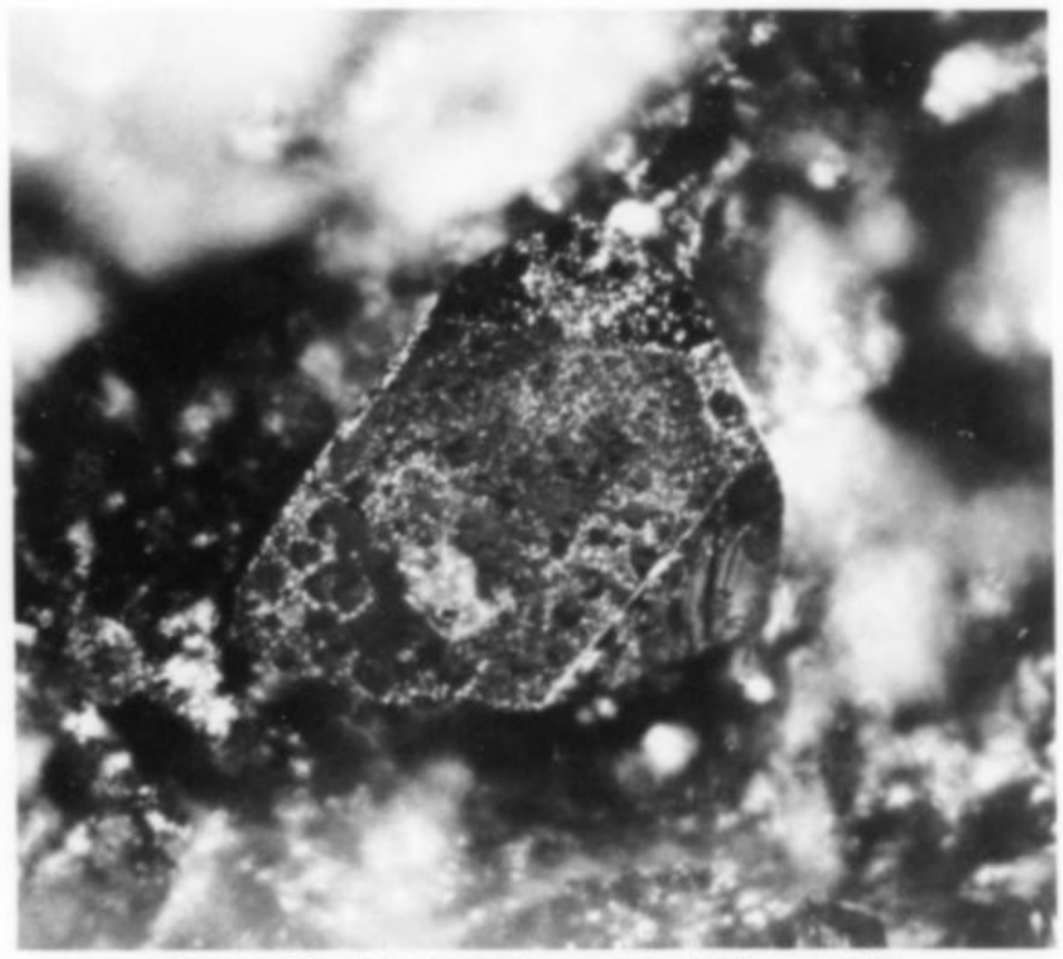


Figure 15. **Tetrahedrite crystal, 0.33 mm tall; National Belle mine, 1982; Dan Behnke photo.**

Tetrahedrite - Tennantite $(Cu,Fe)_{12}As_4S_{13}$ - $(Cu,Fe)_{12}Sb_4S_{13}$

Both tetrahedrite and tennantite have been reported from the National Belle mine (Hillebrand and Kelley, 1957; Burbank *et al.*, 1972). Black tetrahedral crystals, many with truncated corners and usually under 1 mm, occur in vugs. It also occurs as masses that show numerous small faces or are composed of intergrown crystals. Enargite and quartz crystals are the most common associated minerals.

COLLECTING

The National Belle is easily accessible by a short hike or drive east from U.S. 550 on a poor dirt road. The mine area has not been posted in recent years. Examination of some of the shallow caves in the knob by a miner from Ouray in 1966 revealed nothing of specimen interest. The deeper levels of the mine are flooded but good micromineral specimens from the sulfide zone may be collected from the exposed mine dumps.

ACKNOWLEDGMENTS

The authors would like to thank Ed Raines and Jack Murphy for reading the manuscript and for their helpful comments and suggestions. Dan Behnke took all the mineral photographs and prepared the others for publication. His work is much appreciated.

BIBLIOGRAPHY

BERMAN, H., and GONYER, F. A. (1939) Re-examination of colusite. *American Mineralogist,* **24**, 377–381.

BURBANK, W. S. (1941) Structural control of ore deposition in Red Mountain, Sneffels, and Telluride districts of the San Juan Mountains. *Colorado Scientific Society Proceedings,* **14**, 161–289.

BURBANK, W. E., LUEDKE, R. G., and WARD, F. N. (1972) Arsenic—An indicator element for mineralized breccia pipes in the Red Mountain area, western San Juan Mountains, Colorado. *U.S. Geological Survey Bulletin* **1364**, 31 p.

DICK, A. B. (1888) On kaolinite. *Mineralogical Magazine,* **8**, 15–27.

ECKEL, E. G. (1961) Minerals of Colorado: a 100-year record. *U.S. Geological Survey Bulletin* **1114**, 399 p.

FISHER, F. S. (1978) The National Belle pipe, Red Mountain mining district, San Juan County. *Guidebook on Fossil Fuels and Metals, eastern Utah and western-southwestern-central Colorado.* Colorado School of Mines Professional Contribution 9, 141–145.

HILLEBRAND, J. R., and KELLY, V. C. (1957) Mines and ore deposits from Red Mountain pass to Ouray, Colorado. *New Mexico Geological Society Guidebook,* 8th, 188–199.

HILLS, R. C. (1884) Kaolinite from Red Mountain. *American Journal of Science, 3rd series,* **27**, 472.

HURLBURT, E. B. (1894) On alunite from Red Mountain, Ouray County, Colorado. *American Journal of Science, 3rd series,* **48**, 130–131.

INGERSOLL, E. (1883) *The crest of the continent.* Donnelley & Sons, Chicago, 344 p.

INGERSOLL, E. (1890) *The Silver Caves: A Mining Story.* Dodd & Meade, New York, 202–204.

LAKES, A. (1901) Cave ore deposits: illustrations of peculiar deposits of silver and copper ores in caves at the Red Mountain mines, Colorado. *Mines and Minerals,* **21**, 333–334.

LAKES, A. (1905) *Geology of Western Ore Deposits.* Kendrick Company, Denver, p. 290.

LUEDKE, R. G., and HOSTERMAN, J. W. (1971) Clay minerals, Longfellow mine, San Juan County, Colorado. *U.S. Geological Survey Professional Paper* **750-C**, 105–111.

PENFIELD, S. L. (1893) Mineralogical notes. *American Journal of Science, 3rd series,* **45**, 396–399.

PIRSSON, L. V. (1894) On the crystallization of enargite. *American Journal of Science, 3rd series,* **47**, 212–215.

RANSOME, F. L. (1901) A report on the economic geology of the Silverton Quadrangle, Colorado. *U.S. Geological Survey Bulletin* **182**, 265 p.

ROSS, C. S., and KERR, P. R. (1931) The kaolin minerals. *U.S. Geological Survey Professional Paper* **165-E**, 151–180.

SCHWARZ, T. E. (1889) Notes on the ore occurrence of the Red Mountain district. *Colorado Scientific Society Proceedings,* **3**, 77–85.

SCHWARZ, T. E. (1890) Ore deposits of the Red Mountain, Colorado. *American Institute of Mining Engineers Transactions,* **18**, 139–144.

SCHWARZ, T. E. (1906) Features of the occurrence of ore at Red Mountain, Ouray County, Colorado. *American Institute of Mining Engineers Transactions,* **36**, 31–40.

SLOAN, R. E., and SKOWRONSKI, C. A. (1975) *The Rainbow Route:* an illustrated history of the Silverton railroad, the Silverton Northern railroad, and the Silverton Gladstone and Northern railroad. Sundance Limited, Denver, 416 p.

Phosphate Minerals from the Tip Top Mine, Black Hills, South Dakota

Thomas J. Campbell & Willard L. Roberts
Museum of Geology
South Dakota School of Mines & Technology
Rapid City, South Dakota 57701

First staked in the 1880s as a tin prospect, the Tip Top pegmatite has since yielded over 50 phosphate minerals including eight new species, and many specimens which are the finest known for their species.

INTRODUCTION

The Tip Top is one of a unique group of pegmatites noted for their phosphate minerals. The pegmatite has yielded approximately 80 mineral species, at least 54 of which are phosphates (Table 1). Eight new species have been identified from this locality: jahnsite, robertsite, segelerite, fransoletite, tinsleyite, tiptopite, ehrleite and a new phosphate which is presently under investigation. In addition to these new species, the authors and their colleagues have found 23 other minerals previously unreported from Tip Top (these are noted in Table 1). The total number of phosphate species from the Tip Top pegmatite is exceeded only by the Palermo No. 1 quarry in New Hampshire (64) (Segeler *et al.,* 1981) and possibly the Hagendorf pegmatites in Bavaria. Tip Top has also produced some of the finest crystals of pegmatite phosphates and probably holds the "best of species" title for many. These include lustrous, deep pink hureaulite crystals to 3 cm, colorless to yellowish 1-cm whitlockite rhombs, brown jahnsite crystals to 1 cm, 8-mm leucophosphite crystals and red montgomeryite crystals to 5 mm.

LOCATION

The Tip Top mine is located 200 meters southwest of the center of Section 8, R6E, T4S, 8.5 km southwest of Custer, Custer County, South Dakota. It is identified on the Fourmile quadrangle (U.S.G.S. 7.5-minute topographic map) and on the U.S. Forest Service map of the Black Hills. The mine is located in a very scenic portion of the southern Black Hills, an area known as Pleasant Valley, which, as all visitors soon realize, lives up to its name.

HISTORY

According to Fisher (1942), the Tip Top was originally staked in the 1880s as the Tip Top lode by William Nevin of Custer, South Dakota, who filed the claim as a tin prospect; the mine is still owned by the Nevin family of Custer. In the late 1800s and very early 1900s the Tip Top was mined sporadically and the workings consisted of only a few small pits. The property was idle for several years but Nevin restaked it in 1925. He opened a small pit for development work from which a load of triphylite was mined, but no market could be found for triphylite at that time. From about 1934 to 1936 Nevin mined the pegmatite for feldspar and later leased the property to Pierce Byers, who mined it through the 1940s. In the 1950s and 1960s the Tip Top was leased and mined intermittently on a rather large scale by the International Mineral and Chemical Company for feldspar and minor amounts of beryl, montebrasite, spodumene and columbite-tantalite. The mine was inoperative during the 1970s.

In 1981 the property was leased by a couple of local miners who

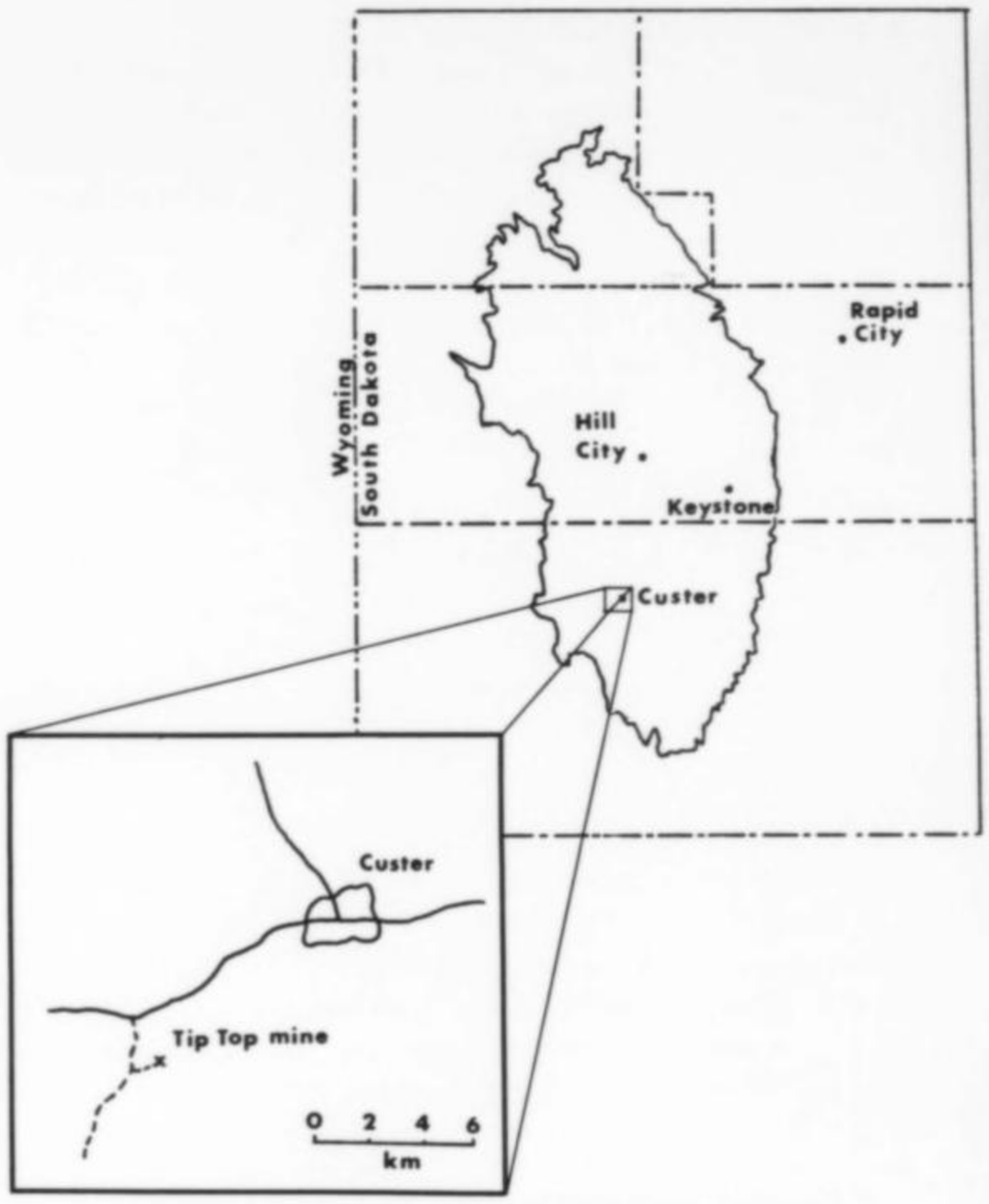


Figure 1. **Location of the Tip Top mine within the Black Hills.**

Figure 2. **A portion of the Tip Top pegmatite showing recent working in the bottom south side. Front-end loader for scale. Photo taken by T. J. Campbell in 1982.**

reopened it and started excavations in the bottom of the south side. They mined the pegmatite until late 1982 and produced beryl and feldspar along with small amounts of scrap mica and columbite-tantalite. Presently, the mine is again idle and filling with water. The pit dimensions are 60 x 120 meters and 42 meters deep.

GEOLOGY

The Tip Top pegmatite is located in the southern part of the uplifted Precambrian core of the Black Hills, which consists of low-grade to middle-grade metamorphosed eugeosynclinal sediments. The general trend of the rocks is northwest, but the detailed structure of the region has been complicated by several periods of folding (Kleinkopf and Redden, 1975; Norton, 1975). The Tip Top, like all Black Hills pegmatites, is Hudsonian (1.7 billion years) in age and, according to the classification of Ginsburg *et al.* (1979), it is a rare-element pegmatite (moderately enriched in Be, Li, Ta-Nb, Rb and Cs) of intermediate depth of formation (3.5 to 7 km).

The pegmatite itself, as described by Roberts *et al.* (1982), is a large, lenticular, zoned body which trends roughly N45°W and dips 40°SW. It is emplaced discordantly into a gray, fine-grained quartz-mica schist. The bedding and foliation strike N25°W and dip 35°SW. Locally, the foliation is parallel to the pegmatite contact. Alteration of the schist near the contact consists of a gray, fine-grained granulite. Tourmaline crystals to 5 cm can be found locally in the schist near the contact.

The pegmatite can be divided into five units consisting of four zones and one fracture filling unit. Perthite-quartz-biotite pegmatite makes up the wall zone which includes a thin border zone. The outer-intermediate zone consists of perthite-quartz-muscovite pegmatite and has a gradational outer boundary with the wall zone. This zone contains accessory beryl and fluorapatite. The inner-intermediate zone is a perthite-quartz-triphylite pegmatite having a gradational contact with the outer-intermediate zone. Accessory minerals of importance in this zone are beryl and columbite-tantalite. This is also the zone which hosts most of the secondary phosphate minerals. The core of the pegmatite is chiefly composed of quartz with minor amounts of montebrasite and spodumene (quartz-montebrasite-spodumene pegmatite) and its outer boundary is gradational with the inner-intermediate zone. Quartz-albite-muscovite pegmatite occurs as a fracture filling unit in the wall zone.

MINERALOGY

The descriptive mineralogy of the various primary and secondary phosphate minerals found at the Tip Top pegmatite is here subdivided into primary phosphates which formed as primary phases during pegmatite consolidation, and secondary hydrothermal alteration products that formed subsequent to the crystallization of the pegmatite or during a very late stage of pegmatite consolidation.

For the sake of brevity, associations of the various phosphate minerals are given in Tables 3 and 4; note also that all of the mineral species discussed herein have been confirmed by at least X-ray diffraction methods, and frequently by other methods as well. Miller indices of the various crystallographic forms for some of the minerals were determined by visual estimation and/or visual comparison.

Table 1. **Minerals of the Tip Top Pegmatite.**

Native Elements	*Phosphates*	ludlamite
bismuth	alluaudite	messelite
	autunite	mitridatite
Sulfides	**barbosalite**	montebrasite
arsenopyrite	**beraunite**	**montgomeryite**
galena	bermanite	**parascholzite**
marcasite	carbonate-hydroxylapatite	phosphoferrite
pyrite	collinsite	*robertsite
sphalerite	**crandallite**	rockbridgeite
	diadochite	**roscherite**
Oxides and Oxyhydroxides	**dufrenite**	**scholzite**
cassiterite	*ehrleite	*segelerite
columbite-tantalite	**englishite**	stewartite
goethite	**eosphorite-childrenite**	**strengite**
pyrolusite	fairfieldite	strunzite
todorokite	ferrisicklerite	**switzerite**
uraninite	fluorapatite	tavorite
	*fransoletite	*tinsleyite
Silicates	**frondelite-rockbridgeite**	*tiptopite
albite	**gordonite**	triphylite
almandine	heterosite	vivianite
beryl	hureaulite	**whiteite**
biotite	**hurlbutite**	whitlockite
elbaite	hydroxylapatite	xanthoxenite
microcline-perthite	**hydroxyl-herderite**	*Mineral X
muscovite	*jahnsite	
quartz	kryzhanovskite	*Unverified Phosphates*
schorl	laueite	cacoxenite
spessartine	leucophosphite	calcioferrite
zircon	**lithiophosphate**	ernstite
		kidwellite
Carbonates		sarcopside
siderite		

Minerals previously unreported from the Tip Top mine are shown in bold type.
*Minerals for which Tip Top is the type locality.

Primary Phosphates

Primary phosphates at Tip Top are largely anhydrous and crystallized throughout the various stages of pegmatite consolidation (Campbell, 1984). Some of the minerals included in this section are actually high-temperature metasomatic alteration minerals or products of alkali leaching, but were formed during late stages of pegmatite consolidation. Granular masses exhibiting little or no crystal form (i.e., alluaudite and heterosite) are typical of metasomatic minerals. Only half a dozen species are represented in this group but they constitute the largest amount of phosphates by volume.

Alluaudite $(Na,Ca)_4Fe^{+2}_4(Mn,Fe^{+2},Fe^{+3},Mg)_8(PO_4)_{12}$

Alluaudite is not common at the Tip Top mine; it was first reported from this locality by Roberts and Rapp (1965). It occurs as a massive, compact, granular, dull, greenish black, subtranslucent to opaque, metasomatic alteration product of triphylite.

Ferrisicklerite $Li(Fe^{+3},Mn^{+2})PO_4$

Ferrisicklerite is the iron end-member of the ferrisicklerite-sicklerite series; it occurs only in massive form as an alteration product of triphylite and is rather abundant. It is generally found as a brown, subtranslucent to almost opaque rind several millimeters to a few centimeters thick around partially or totally altered pods of triphylite.

Fluorapatite $Ca_5(PO_4)_3F$

Fluorapatite is a ubiquitous primary phosphate mineral and can be found from the wall zone to the intermediate zone. The degree of crystallinity ranges from predominantly anhedral to occasionally euhedral. Blue-gray to green anhedral masses up to a few kilograms are not uncommon in the intermediate zone. Some euhedral blue-gray crystals to 1 cm were found in one cavity. Blue, euhedral, 2-mm to 5-mm crystals were found associated with beryl. Recent workings in the intermediate zone showed an abundance of fluorapatite partially to totally dissolved and replaced by carbonate-hydroxylapatite and minor whitlockite.

Heterosite $(Fe^{+3},Mn^{+3})PO_4$

Heterosite is the iron end-member of the heterosite-purpurite series and is moderately abundant. It is found as an outer rind on altered triphylite pods as a massive alteration product of triphylite. On fresh fracture surfaces heterosite is deep rose to reddish purple with a satiny luster and weathers to brown or brown-black with an earthy luster.

Montebrasite $(Li,Na)AlPO_4(OH,F)$

Montebrasite is a moderately abundant primary phosphate mineral found in the outer portion of the core zone and in the inner-intermediate zone. It occurs as large, white to grayish, subtranslucent, cleavable masses up to several kilograms. Montebrasite is commonly associated with quartz and minor amounts of columbite-tantalite and altered spodumene. No secondary alteration products of montebrasite have been discovered to date.

Triphylite $Li(Fe,Mn)^{+2}PO_4$

Triphylite is the most abundant primary phosphate found at the Tip Top mine. The mineral occurs as giant subhedral crystals or nodules of which the largest recorded from this locality was 4 by 4.5 by 5 meters. This nodule was encountered in the recent working shown in Figure 2. Chemically, triphylite from the Tip Top is Fe-rich as shown by the chemical analysis in Table 2.

Most of the triphylite at the Tip Top has an outer rind of heterosite and ferrisicklerite with some alluaudite, and most shows some degree of alteration to secondary phosphates. Large masses of unaltered triphylite are rare. Triphylite is also the host for bismuth and many of the sulfides, with pyrite and sphalerite being the most abundant.

Secondary Phosphates

This group of phosphates represents the greatest diversity, scarcity and complexity of species at the Tip Top mine and includes chemical components derived from triphylite as well as from beryl, muscovite, albite, microcline-perthite and to a lesser extent sphalerite and uraninite. Triphylite supplied phosphate anions, transition elements and lithium; the silicates provided alkali metals. Cations and anions that were released subsequently produced alkali metal phosphates, and also reduced, oxidized and mixed-valence-state transition metal phosphates, some of them alkali-bearing.

Autunite $Ca(UO_2)_2(PO_4)_2 \cdot 10\text{–}12H_2O$
Meta-autunite $Ca(UO_2)_2(PO_4)_2 \cdot 2\text{–}6H_2O$

Autunite and meta-autunite are not abundant at Tip Top. The two minerals are found in close proximity to uraninite and are rarely associated with other phosphates. Autunite and meta-autunite occur as thin, tabular, bright yellow-green, vitreous, crystals up to 1 mm.

Barbosalite $Fe^{+2}Fe^{+3}_2(PO_4)_2(OH)_2$

Barbosalite is not common and generally occurs as dark blue-green to almost black, very thin veinlets and powdery crusts associated with tavorite in triphylite. Very rarely it is found as lustrous, black, short prismatic crystals less than 0.25 mm

associated with hureaulite, and less commonly with jahnsite and rockbridgeite.

Beraunite $Fe^{+2}Fe_5^{+3}(PO_4)_4(OH)_5 \cdot 4H_2O$

Beraunite is rare and is found as dark green radial sprays of translucent, vitreous to dull crystals less than 0.5 mm in size. These crystals are elongated and striated parallel to [010]. Tip Top beraunite is very similar to the material reported by Segeler *et al.* (1981) from the Palermo No. 1 quarry in New Hampshire. The oxidized variety, which is very rare, is bright orange. Beraunite has only been observed in association with leucophosphite and a jahnsite-group mineral.

Bermanite $Mn^{+2}Mn_2^{+3}(PO_4)_2(OH)_2 \cdot 4H_2O$

Bermanite is common and was first reported from this locality by Roberts *et al.* (1974). Bermanite occurs as vitreous to sub-resinous, brown-red, tabular, pseudo-orthorhombic crystals up to 1.5 mm and as rosette-like aggregates which form druses on earlier formed secondary phosphates such as robertsite and messelite. Dominant forms are pinacoids. A partial microprobe analysis of bermanite is given in Table 2.

The Tip Top pegmatite, along with the Palermo No. 1 pegmatite in New Hampshire (Segeler *et al.,* 1981), is one of the few localities where triphylite is the primary phosphate hosting bermanite; triplite or lithiophilite is the primary phase at most other localities.

Carbonate-hydroxylapatite $Ca_5(PO_4,CO_3)_3(OH,F)$

Carbonate-hydroxylapatite is abundant and occurs in a variety of forms. The most common form is very pale green to yellowish, botryoidal to stalactitic or finger-like growths coating fractures in perthite and quartz. These crusts have a radial-fibrous structure, are often banded, can be up to 5 mm thick and cover large surfaces. This apatite species forms a base upon which other phosphates are sometimes deposited. Carbonate-hydroxylapatite is also found as colorless to white, transparent to translucent, silky, acicular, hexagonal crystals less than 1 mm in size, in cavities in quartz and triphylite.

Collinsite $Ca_2(Mg,Fe)(PO_4)_2 \cdot 2H_2O$

Collinsite is rather uncommon and was reported from the mine by Roberts *et al.* (1974). It occurs as white to pale pinkish brown radiating bundles of silky, translucent, tabular to bladed crystals less than 4 mm in size. This is probably one of the best occurrences for fine collinsite crystals, especially when compared to the type material described by Wolfe (1940) from Francois Lake, British Columbia, where it is found as crusts with a radial fibrous structure.

Crandallite $CaAl_3(PO_4)_2(OH)_5 \cdot H_2O$

Crandallite occurs as minute white balls associated with ehrleite (Grice and Robinson, 1984).

Diadochite $Fe_2^{+3}(PO_4)(SO_4)(OH) \cdot 5H_2O$

Diadochite occurs as brown to red-brown botryoidal crusts that are sometimes hollow. It is usually found encrusting earlier formed minerals such as mitridatite, rockbridgeite and jahnsite, rarely roscherite and montgomeryite.

Dufrenite $Fe^{+2}Fe_4^{+3}(PO_4)_3(OH)_5 \cdot 2H_2O$

Dufrenite occurs as botryoidal, dark green, concentrically banded crusts displaying a radial fibrous structure. It can easily be confused with some forms of mitridatite and rockbridgeite. Dufrenite can be distinguished from the other two by X-ray diffraction techniques.

Table 2. **Chemical analyses of some Tip Top phosphates.**

Mineral Species	Li_2O	Na_2O	K_2O	CaO	MgO	BeO	ZnO	FeO	MnO	Fe_2O_3	Mn_2O_3	Al_2O_3	P_2O_5	H_2O	Total
Bermanite [3] §§	–	–	–	–	1.3	–	–	–	13.3	0.7	32.8	0.3	30.5	21.1*	100.0
Englishite [4]	–	0.9	3.6	15.8	0.1	–	–	2.5	–	–	–	21.8	41.0	14.9**	100.6
Fransoletite [5]	–	–	–	28.8	–	9.3	–	–	0.3	–	–	–	47.3	14.3*	100.0
Hureaulite [3]	–	–	–	0.8	0.8	–	0.8	0.2	46.2	–	–	–	40.1	–	
Hureaulite [1]	–	–	–	–	–	–	–	0.91	47.09	–	–	–	–	–	
Messelite [1]	–	–	–	–	–	–	–	13.62	6.54	–	–	–	–	–	
Montgomeryite [6]	–	–	–	19.1	3.5	–	–	–	0.5	–	–	17.1	36.6	23.2*	100.0
Montgomeryite [1]	–	–	–	17.2	3.62	–	–	0.92	0.52	–	–	19.21	–	–	
Rockbridgeite [1] §	–	–	–	–	–	–	–	5.73	0.91	56.22	–	–	–	–	
Rockbridgeite [1] §	–	–	–	–	–	–	–	3.49	3.33	55.36	–	–	–	–	
Frondelite [1] §	–	–	–	–	–	–	–	1.37	5.19	56.87	–	–	–	–	
Roscherite [2]	–	–	–	10.3	3.52	9.97	0.95	7.03	11.72	–	–	3.66	40.40	12.62*	100.0
Switzerite [3]	–	–	–	0.2	0.6	–	–	–	45.3	–	–	–	32.7	–	
Tavorite [1]	8.47	–	–	–	–	–	–	–	–	45.58	–	0.09	–	–	
Tinsleyite [7]	–	–	12.4	–	–	–	–	–	–	5.2	1.1	26.6	42.2	12.5*	100.0
Tiptopite [8]	4.5	6.1	9.9	4.3	–	15.1	–	–	0.2	–	–	0.3	55.1	3.4	98.9
Triphylite [2]	9.24	–	–	0.3	1.36	–	–	32.17	10.07	–	–	–	–	–	

* – H_2O by difference.
** – H_2O from theoretical value.
[1] – atomic absorption analysis by TJC.
[2] – atomic absorption analysis by Donald R. Campbell, General Tire and Rubber Co., Akron, Ohio.
[3] – microprobe analysis by PJD.
[4] – Dunn *et al.* (1984a).
[5] – Peacor *et al.* (1983).
[6] – Dunn *et al.* (1983).
[7] – Dunn *et al.* (1984b).
[8] – Grice *et al.* (1985).
§§ – Mn was proportioned between Mn^{+3} and Mn^{+2} based on the known valence requirements for bermanite.
§ – Fe was proportioned between Fe^{+3} and Fe^{+2} based on the known valence requirements for rockbridgeite.

Figure 3. **Collinsite showing typical bladed habit. Crystals are 1.5 mm in length. Julius Weber specimen and photo.**

Ehrleite $Ca_4Be_3Zn_2(PO_4)_6 \cdot 9H_2O$

Ehrleite (Grice and Robinson, 1984) occurs as colorless to white, triclinic crystals up to 2 mm, associated with parascholzite, roscherite and crandallite. Only two specimens of this mineral are known.

Englishite $Na_2K_3Ca_{10}Al_{15}(PO_4)_{21}(OH)_7 \cdot 26H_2O$

The discovery of englishite at the Tip Top mine represents the first pegmatite occurrence for this mineral and the second world occurrence (Dunn *et al.,* 1983). Previously it had been known only from the variscite nodules found in a sedimentary deposit near Fairfield, Utah (Larsen and Shannon, 1930). Englishite is a relatively abundant mineral in the most recently found phosphate assem-

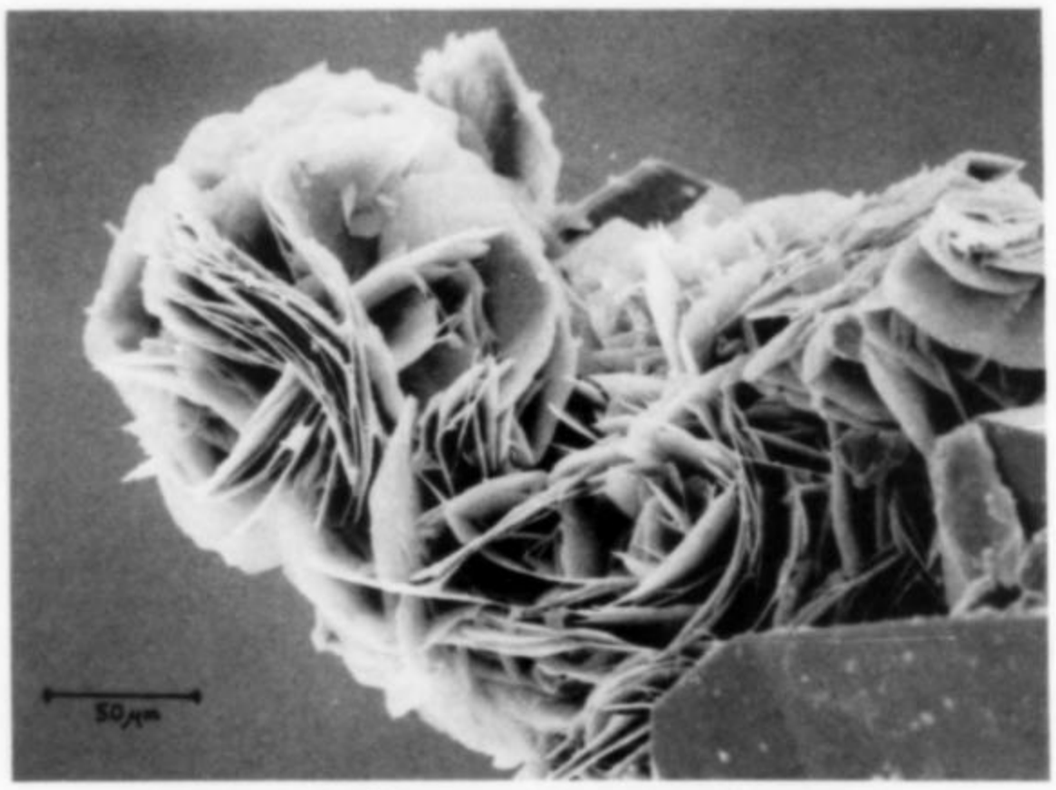


Figure 4. **SEM photomicrograph of englishite depicting the typical aggregation of platy crystals. Large rosette is 0.5 mm across.**

blages at Tip Top, where it occurs with other alkali-metal phosphates. It is found as pearly white spherules and hemispherules up to 1 mm that are composed of platy, micaceous crystals and as white massive seams and scaly crusts which, with roscherite, fill fractures in beryl. Englishite has been redefined chemically by Dunn *et al.* (1984b) and their analysis (Table 2) resulted in the formula given above.

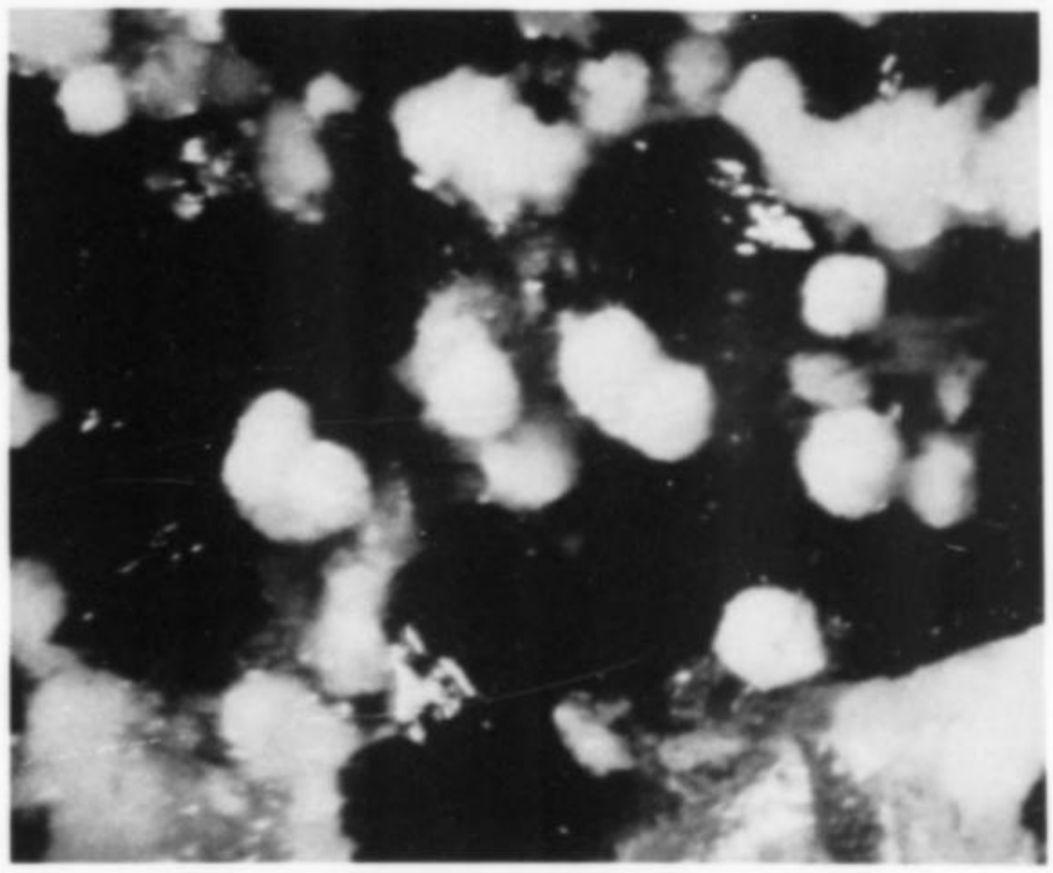


Figure 5. **White, spherical aggregates of englishite associated with roscherite (dark olive-green) and eosphorite-childrenite (pale brown). Field of view is 6 mm. T. J. Campbell specimen and photo.**

Figure 6. **Bladed eosphorite-childrenite crystals with englishite. Cluster is 0.75 mm tall. T. J. Campbell specimen, Dan Behnke photo.**

Eosphorite-Childrenite $(Mn,Fe)^{+2}Al(PO_4)(OH)_2 \cdot H_2O$

Eosphorite-childrenite is uncommon and occurs as pale brown, fan-like aggregates of transparent, platy to bladed, 0.5-mm crystals. Single crystals are similar in morphology to the material from Black Mountain and Red Hill, Rumford, Maine, as described by Hurlbut (1950). Crystals are flattened parallel to {010} with well developed {100} and poorly developed {010} faces; the {110} form is either not present or very poorly developed. The prisms are terminated by small {121} faces. Optical studies indicate that most of the material is an intermediate member of the series.

Fairfieldite $Ca_2(Mn,Fe)^{+2}(PO_4)_2 \cdot 2H_2O$

Fairfieldite is the manganese end-member of the fairfieldite-messelite solid solution series and is moderately abundant. The mineral occurs as bundles and lamellar aggregates of white, translucent, 0.5 to 5-mm, platy crystals which have a vitreous to pearly luster. It is also found as stacked, parallel aggregates of transparent to translucent crystals of similar size and luster. Less commonly,

fairfieldite is found as 0.3 to 3-mm thick fracture-fillings in beryl, commonly associated with dark olive-green roscherite. It also occurs with whitlockite and red montgomeryite; in these occurrences, the mineral is almost pure end-member fairfieldite. Pseudomorphs of todorokite after fairfieldite are common.

Figure 7. **SEM photograph of fransoletite showing how aggregates of subparallel individuals create a large curved crystal. Aggregate is 0.5 mm across.**

Fransoletite $H_2Ca_3Be_2(PO_4)_4 \cdot 4H_2O$

Fransoletite (Peacor *et al.*, 1983) is a new mineral from the Tip Top and occurs as translucent, milky to white, arrowhead-shaped aggregates up to 3 mm. These aggregates are composed of hundreds of microcrystals which are slightly offset relative to each other. Dominant forms of the composite crystals are {100}, {011} and {010}. Crystals are tabular on {010} and elongate parallel to [101]. Fransoletite is intimately associated with other Be-bearing minerals such as tiptopite, roscherite and hurlbutite. A chemical analysis of fransoletite, from Peacor *et al.* (1983), is given in Table 2.

Gordonite $MgAl_2(PO_4)_2(OH)_2 \cdot 8H_2O$

Gordonite has been found on only one specimen and occurs as colorless, transparent, vitreous, 1.5-mm prismatic crystals in subparallel groups, associated with robertsite and collinsite.

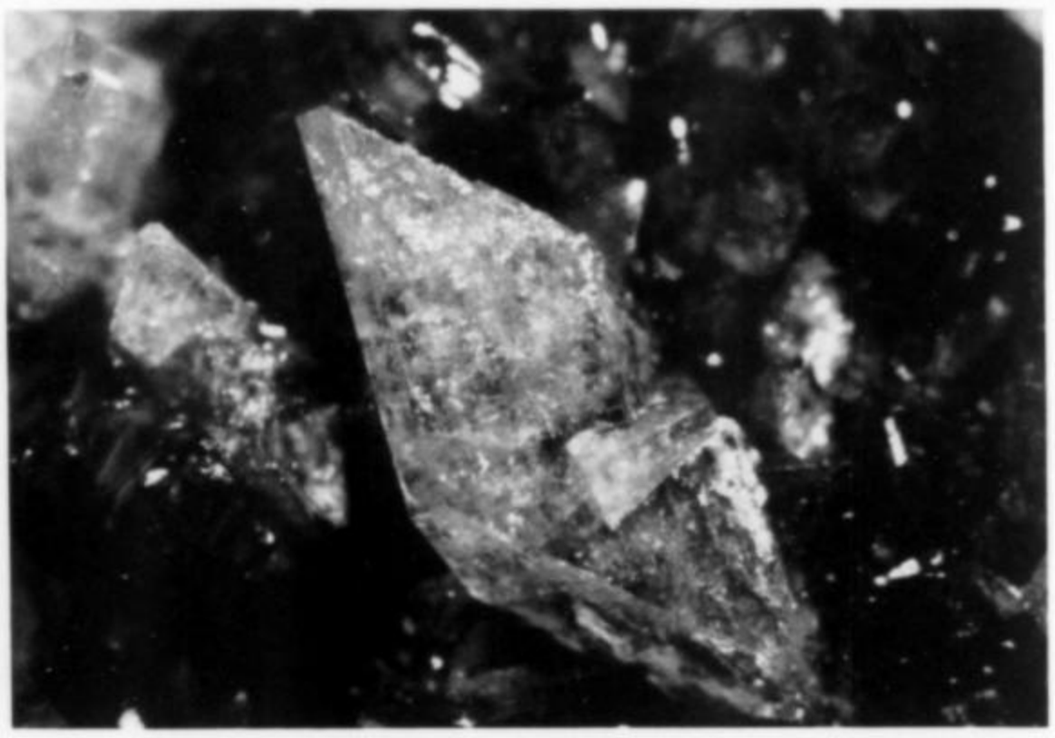


Figure 8. **Hureaulite crystals to 3.2 mm on jahnsite. T. J. Campbell specimen, Dan Behnke photo.**

Hureaulite $H_2(Mn,Fe)_5(PO_4)_4 \cdot 4H_2O$

Hureaulite is one of the most common secondary phosphates found at Tip Top. It occurs as vitreous, transparent to translucent, prismatic crystals, rarely tabular or equant. Dominant forms are {110}, {101} and {100}. It is found in a variety of colors ranging from very pale pink to deep orange-pink to red-brown. Crystals occur singly and in groups. Size ranges from a fraction of a millimeter up to 3.2 cm, some of which may be the largest and finest crystals in the world. Hureaulite is commonly associated with rockbridgeite and leucophosphite. Partial chemical analyses of Tip Top hureaulite are given in Table 2.

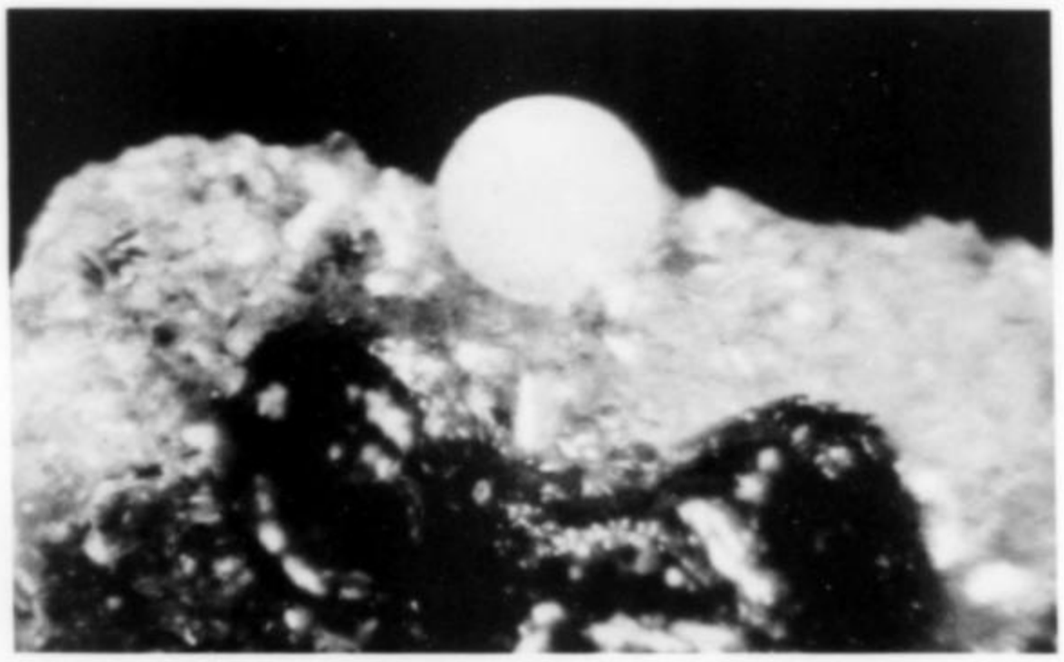


Figure 9. **Hurlbutite spherule, 0.7 mm, on whitlockite with roscherite (red). T. J. Campbell specimen and photo.**

Hurlbutite $CaBe_2(PO_4)_2$

Hurlbutite occurs as pale pink to bluish white, pearly spherules to 1 mm with a radial fibrous structure and is often associated with tiptopite, englishite and montgomeryite. These spherules are unlike hurlbutite from the type locality at the Smith Mine, Chandler's Mill, New Hampshire, where it occurs as stout prismatic crystals over 2.5 cm in length (Mrose, 1952).

Hydroxylapatite $Ca_5(PO_4)_3OH$

Hydroxylapatite is not common and is the least abundant apatite group mineral at this locality. It is similar in occurrence to carbonate-hydroxylapatite found in quartz or triphylite. Hydroxylapatite is found as colorless to white, hexagonal, bipyramidal crystals up to 0.5 mm. Members of the apatite group can easily be distinguished by their indices of refraction.

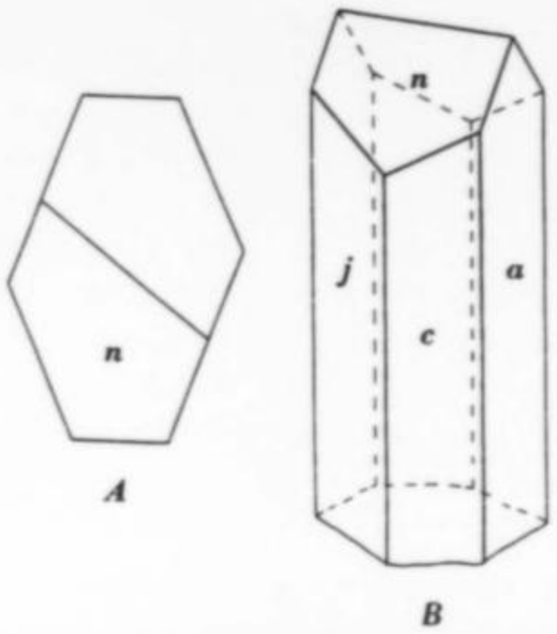
Hydroxyl-herderite $CaBePO_4(OH)$

Hydroxyl-herderite is chemically related to hurlbutite; the two minerals are very similar in appearance at the Tip Top mine but can be distinguished by X-ray diffraction methods. Hydroxyl-herderite most commonly occurs as colorless to white spherules associated with parascholzite and ehrleite (Grice and Robinson, 1984).

Jahnsite $CaMn^{+2}(Mg,Fe^{+2})_2Fe_2^{+3}(PO_4)_4(OH)_2 \cdot 8H_2O$

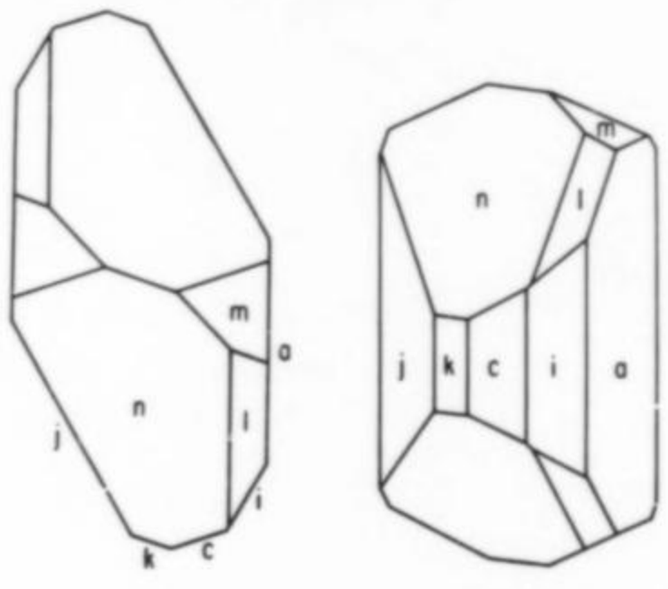
Jahnsite is abundant at the Tip Top mine and its varieties can be differentiated basically by color and occurrence.

The first type is the "brown" jahnsite examined by Moore (1974) in the first description of the species. It occurs as light to dark brown, deep red-brown and red-orange, vitreous, short to long prismatic crystals up to 1 cm in length which are vertically striated parallel to [010] and are often tabular parallel to {100}. The dominant forms include {001}, {100}, {$\bar{2}$01}, {201} and {$\bar{1}$11} with striae on {$\bar{2}$01} and {100} (Moore, 1974). Jahnsite is found as single crystals, clusters and subparallel groups of crystals. Brown jahnsite is generally found in triphylite pods which are moderately



A B

Figure 10. **Crystal showing the typical forms of jahnsite and whiteite. The forms $c\{001\}$, $a\{100\}$, $j\{\bar{2}01\}$ and $n\{\bar{1}11\}$ are indicated. A. Plan view. B. Clinographic projection (b-axis polar) (Moore, 1978).**



A B

Figure 11. **Crystal drawing of jahnsite showing the forms $c\{001\}$, $a\{100\}$, $i\{201\}$, $j\{\bar{2}01\}$, $k\{\bar{1}01\}$, $l\{011\}$, $m\{110\}$ and $n\{\bar{1}11\}$. A. Plan view. B. Clinographic projection (Moore, 1974).**

altered. It is associated with rockbridgeite, hureaulite, leucophosphite and sometimes tavorite.

The second type of Tip Top jahnsite is the "green-yellow" variety. It is morphologically identical to the brown jahnsite but differs somewhat chemically in that it is lower in FeO and slightly higher in MgO and MnO. Color ranges from yellow-green to green-yellow to pale green. The green-yellow variety is largely restricted to more highly altered portions of triphylite nodules in or near the heterosite or ferrisicklerite rind. Common associated minerals include leucophosphite and messelite.

Kryzhanovskite $MnFe_2^{+3}(PO_4)_2(OH)_2 \cdot H_2O$

Kryzhanovskite is rare and was more commonly encountered in earlier mine workings along with ludlamite, phosphoferrite and siderite. Kryzhanovskite occurs as red-brown, vitreous to dull, translucent crystals which replace pseudo-octahedral phosphoferrite crystals.

Laueite $MnFe_2^{+3}(PO_4)_2(OH)_2 \cdot 8H_2O$

Laueite is a polymorph of strunzite and stewartite and occurs sparingly. It is found as vitreous, yellow-orange, transparent to translucent, wedge-shaped crystals up to 1.5 mm in length which are longitudinally striated. Dominant forms are {100}, {010}, {110}, $\{1\bar{1}0\}$, $\{0\bar{1}1\}$ and {011}. Laueite from the Tip Top is almost indistinguishable in habit from the material first described by Strunz (1954) from the Hagendorf pegmatite in Bavaria.

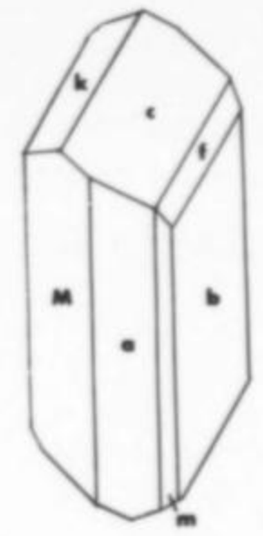


Figure 12. **Crystal drawing of laueite showing the forms $a\{100\}$, $b\{010\}$, $m\{110\}$, $M\{1\bar{1}0\}$, $k\{0\bar{1}1\}$ and $f\{011\}$. Slightly modified from Strunz (1954).**

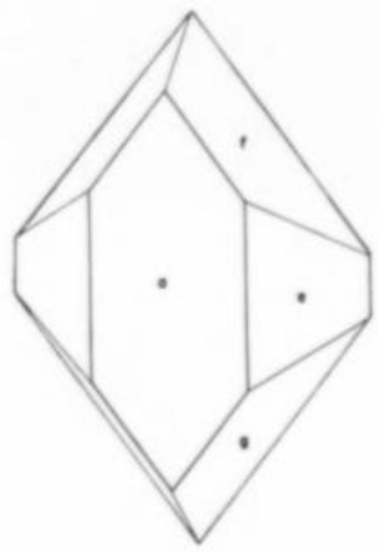


Figure 13. **Crystal drawing depicting typical forms for leucophosphite and tinsleyite; $a\{100\}$, $e\{210\}$, $f\{111\}$, $g\{11\bar{1}\}$ (Lindberg, 1957).**

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

Leucophosphite forms a series with the new mineral tinsleyite, the aluminum analogue (Dunn *et al.*, 1984a). Leucophosphite is one of the most abundant and earliest formed secondary phosphates found at Tip Top. It occurs as vitreous, pale brown to green-brown and brownish purple, short to long prismatic, diamond-shaped crystals up to 1 cm, though 1 mm crystals are most common. Dominant forms are {100}, {210}, {111} and {111}. These forms are identical to those found on crystals from the Sapucaia pegmatite, Brazil, as described by Lindberg (1957). The {100} and {210} forms may be slightly striated. Some crystals show large {100} and {210} faces and poorly developed {111} and $\{11\bar{1}\}$ faces. A parting surface along {100} is evident in some crystals. This parting was mistakenly reported as a cleavage by Lindberg (1957). Crystals of leucophosphite occur singly and sometimes doubly terminated, and as parallel to subparallel groups of crystals. Leucophosphite crystals in stacked parallel growth on rockbridgeite needles are not uncommon. Leucophosphite also occurs as green to green-brown, granular masses up to several cm^3 as a replacement of triphylite. Leucophosphite can be differentiated from tinsleyite optically and by microprobe analysis.

Lithiophosphate Li_3PO_4

Lithiophosphate occurs as blocky, translucent, colorless to turbid, dull vitreous, 0.5-mm crystals in clusters up to 2.5 mm associated with leucophosphite, hureaulite, switzerite, jahnsite and rockbridgeite. This is the first reported occurrence of this mineral at the mine.

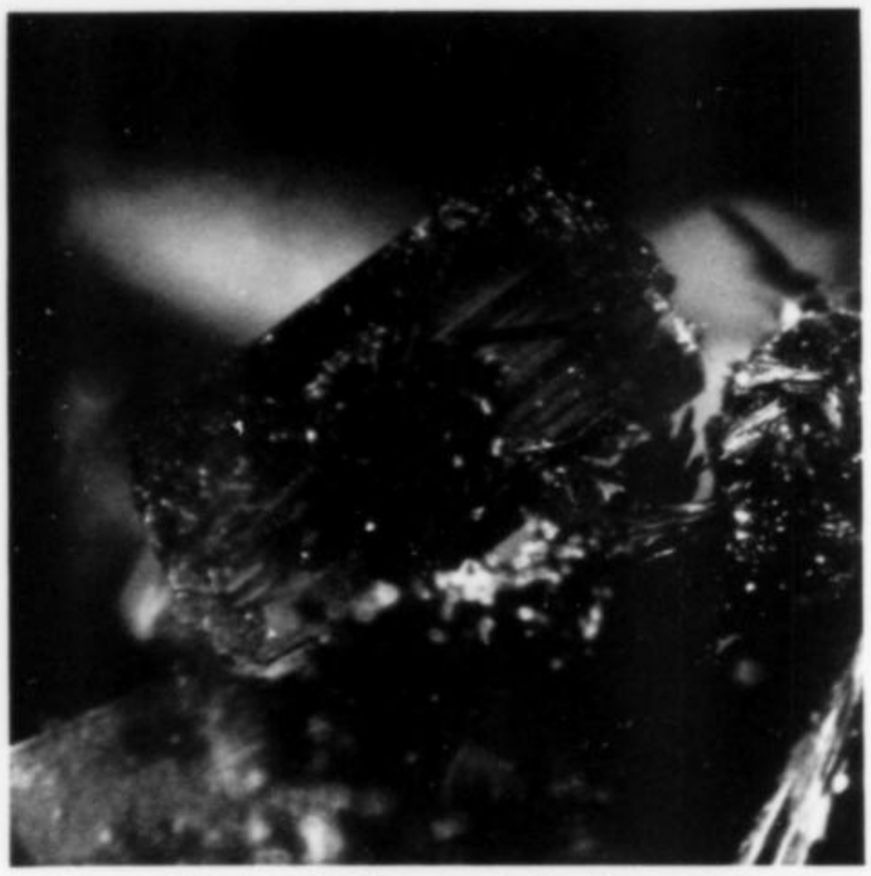


Figure 14. **A typical brown jahnsite crystal on rockbridgeite. Jahnsite crystal is 0.7 mm in length. T. J. Campbell specimen and photo.**

Figure 15. **Prismatic laueite crystal 0.7 mm long. T. J. Campbell specimen, Dan Behnke photo.**

Figure 16. **Jahnsite crystal group 0.8 mm tall. T. J. Campbell specimen, Dan Behnke photo.**

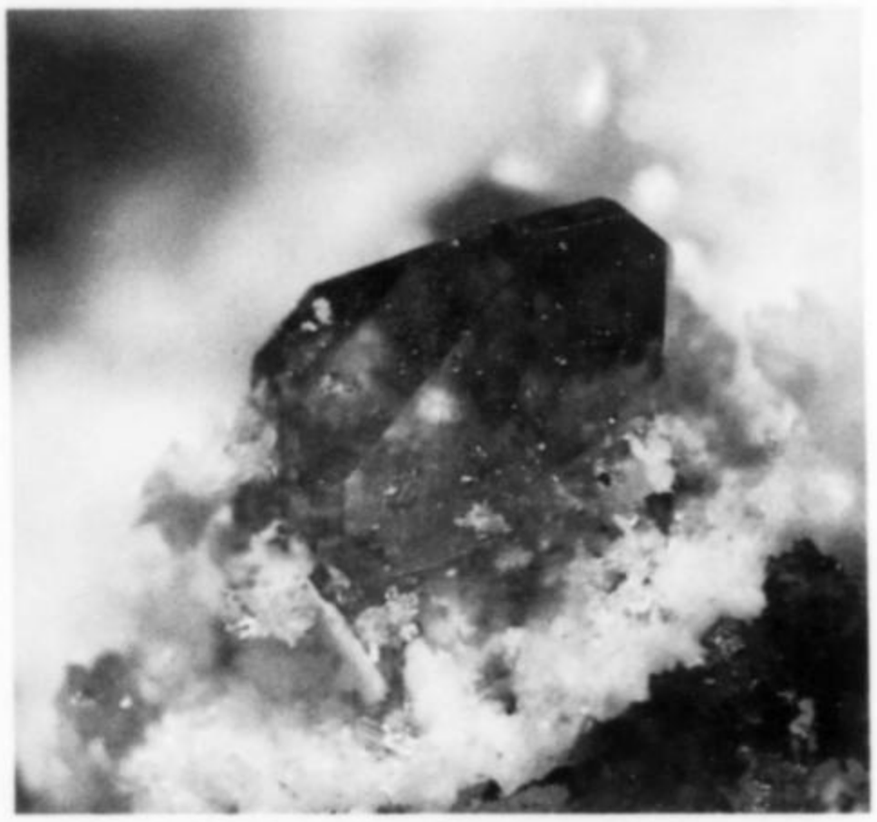


Figure 17. **Leucophosphite crystal 1.1 mm in length. T. J. Campbell specimen, Dan Behnke photo.**

Ludlamite $Fe_3^{+2}(PO_4)_2 \cdot 4H_2O$

Ludlamite is uncommon now, but was more abundant in the earlier workings. It occurs as vitreous transparent to translucent, pale green to bright green, thick, tabular crystals up to 3 mm. Ludlamite is also found as granular masses up to 2 cm^3 replacing triphylite and is generally associated with siderite.

Messelite $Ca_2(Fe,Mn)^{+2}(PO_4)_2 \cdot 2H_2O$

Messelite, the iron analog of fairfieldite, is moderately abundant at the Tip Top mine. Although messelite is morphologically identical to fairfieldite and has many of the same physical properties such as color, luster, hardness and cleavage, it can be distinguished from fairfieldite chemically and optically. The occurrences of fairfieldite and messelite are distinct; messelite is largely restricted to highly altered pods of triphylite and is very commonly associated with green jahnsite whereas fairfieldite is chiefly found with montgomeryite and roscherite in fractures in beryl and quartz. A partial chemical analysis of messelite is given in Table 2.

Mitridatite $Ca_3Fe_4^{+3}(PO_4)_4(OH)_6 \cdot 3H_2O$

Mitridatite, the iron analog of robertsite, is a very abundant secondary phosphate at this mine. It usually occurs as green stains and crusts coating broad surfaces of pegmatite exposures which have been subjected to weathering.

Other than occurring as a weathering product, mitridatite occurs as deep red to bronze-red, platy crystals up to 2 mm which commonly form spherical aggregates and thin crusts in altered triphylite. Mitridatite can also be found lining fractures in beryl and quartz. Prismatic, barrel-shaped crystals of mitridatite, very similar to robertsite, have been found, in some cases as a nucleus on which a thin continuous rind of robertsite has been deposited. Mitridatite can be distinguished from robertsite by its green streak.

Montgomeryite $Ca_4MgAl_4(PO_4)_6(OH)_4 \cdot 12H_2O$

Montgomeryite as described by Dunn *et al.* (1983), is found as bladed, prismatic crystals, striated parallel to [001]. The morphology is similar to that of the type material described by Larsen

Figure 18. **Spherical aggregate of mitridatite 0.56 mm in diameter. T. J. Campbell specimen, Dan Behnke photo.**

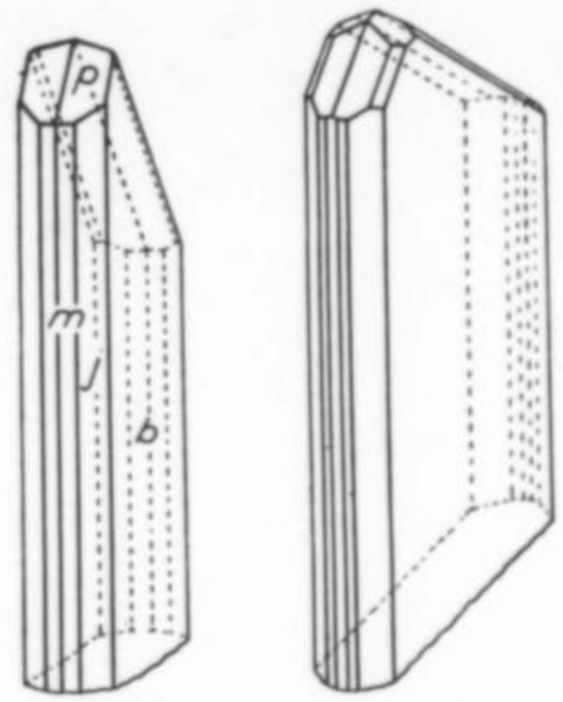


Figure 19. **Crystals of Fairfield, Utah, montgomeryite which show forms that are very similar to those from Tip Top (Larsen, 1940).**

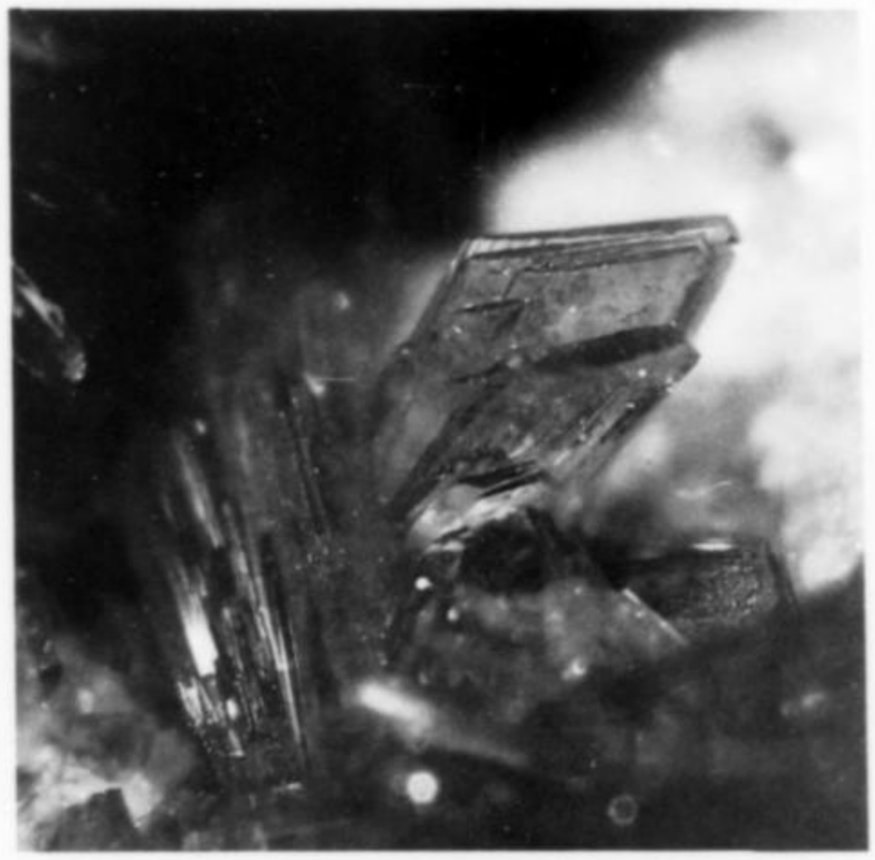


Figure 20. **Red montgomeryite crystals with englishite. Largest crystal is about 1 mm tall. T. J. Campbell specimen, Dan Behnke photo.**

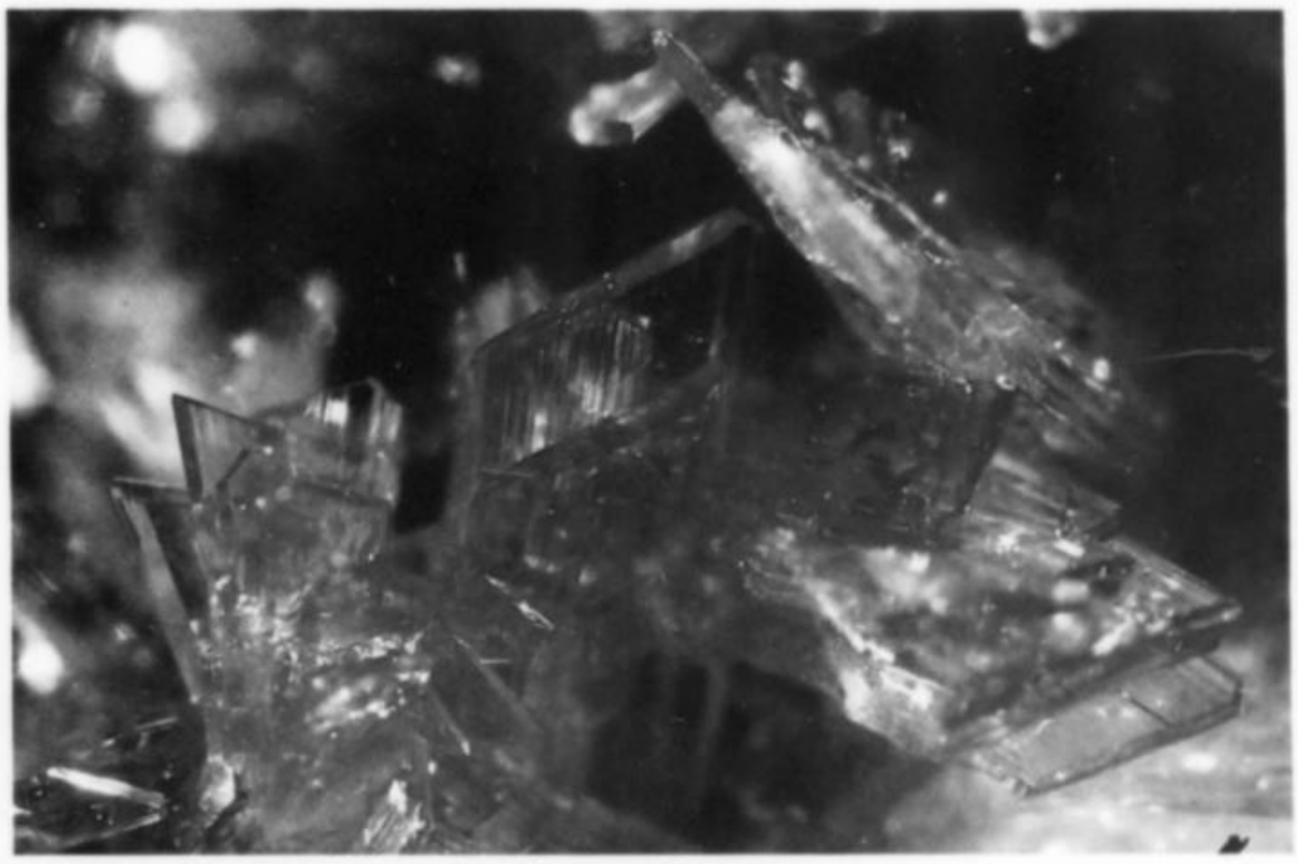


Figure 21. **Red montgomeryite crystal group. Largest crystal is 1.25 mm in length. T. J. Campbell specimen, Dan Behnke photo.**

(1940) from the variscite nodules found near Fairfield, Utah, except that crystals from the Tip Top mine are markedly elongate parallel to [001]. Montgomeryite commonly occurs as radial clusters and divergent fascicles up to 6 mm in diameter and as single crystals to 5 mm. Montgomeryite from this locality is found in a variety of colors ranging from colorless to shades of yellow and pink to bright red, with pink to red colors dominant. Montgomeryite crystals are often zoned and on many specimens the crystals are bright red at the base and gradually grade to pink or colorless, rarely to yellow or green-yellow. Certain colors of montgomeryite, along with roscherite, help characterize the different phosphate suites as discussed below. Chemical analyses of montgomeryite are given in Table 2.

Parascholzite $CaZn_2(PO_4)_2 \cdot 2H_2O$

Parascholzite was described by Sturman *et al.* (1981) from the Hagendorf pegmatite, Bavaria, and is dimorphous with scholzite. Only two specimens containing parascholzite have been found to date at the Tip Top mine. The mineral occurs as colorless to white, vitreous crystals elongated parallel to [001] and measuring up to 1 mm. Dominant forms are the prism and pinacoid.

Phosphoferrite $(Fe,Mn)_3(PO_4)_2 \cdot 3H_2O$

Phosphoferrite is the iron end-member of the phosphoferrite-reddingite series and is not abundant. Like ludlamite and kryzhanovskite, it was more abundant in the earlier workings. Phosphoferrite occurs as colorless to pale green, vitreous to resinous, translucent, 0.5-mm, pseudo-octahedral crystals and as small granular masses associated with ludlamite and siderite.

Robertsite $Ca_3Mn_4^{+3}(PO_4)_4(OH)_6 \cdot 3H_2O$

Robertsite was first described from Tip Top by Moore (1974). The mineral is moderately abundant at this locality and occurs in a variety of forms. It is most commonly found as brown-red, cleavable, massive seams up to 3 mm thick in triphylite and quartz, rarely in perthite or beryl. In open spaces, robertsite is found as vitreous, translucent to almost opaque, deep red to black, tabular,

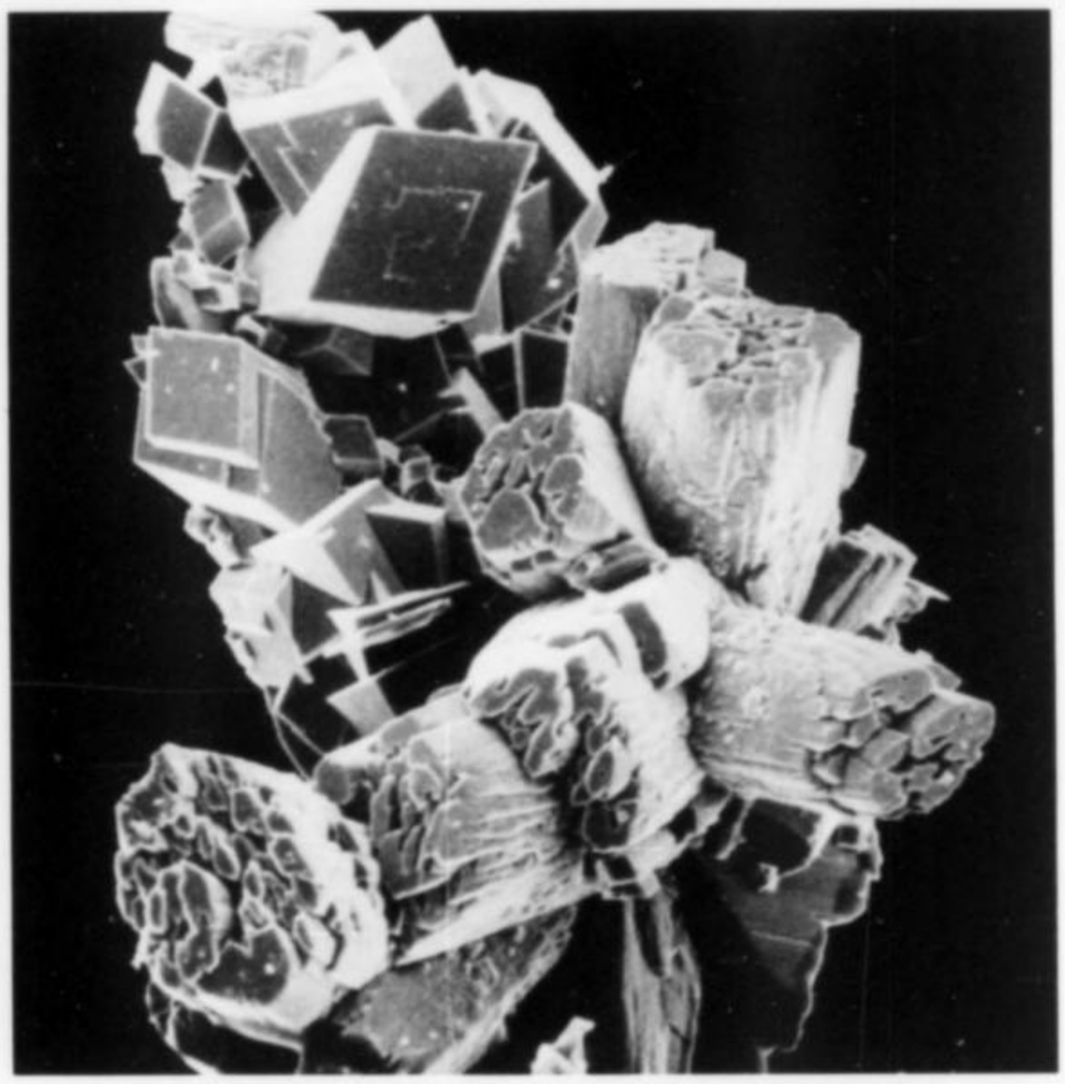


Figure 22. **SEM photomicrograph of robertsite crystals in parallel growth intergrown with whitlockite. Cluster is 1.5 mm tall.**

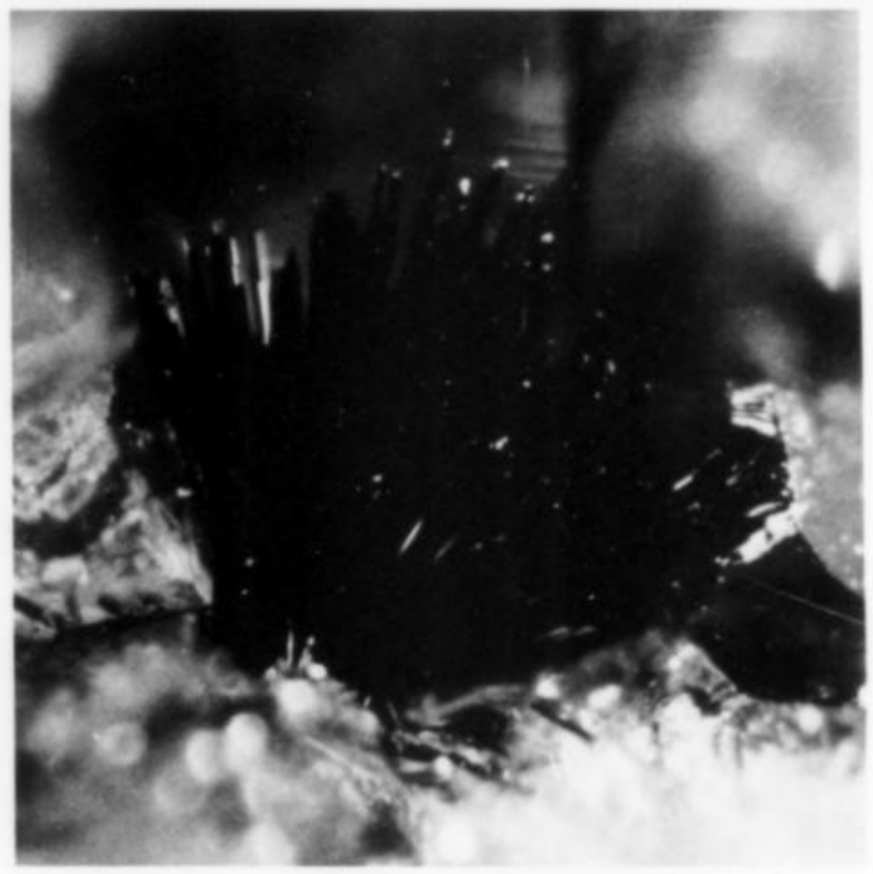


Figure 23. **A 0.9-mm rockbridgeite spray. T. J. Campbell specimen, Dan Behnke photo.**

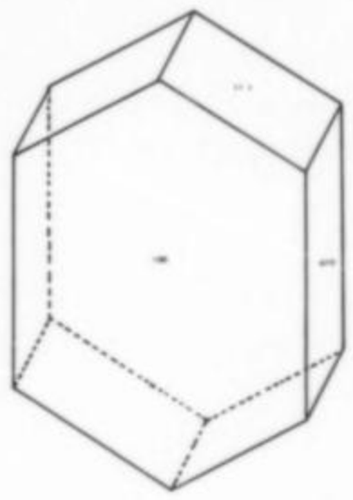


Figure 24. **Crystal of roscherite showing the forms *a*{100}, *b*{010} and *K*{111} (Lindberg, 1958) (Sapucaia pegmatite).**

prismatic crystals to 1 mm; as black, spherical or botryoidal aggregates to 7 mm with a radial-fibrous structure and less commonly as thin platy pseudo-hexagonal crystals. Common forms are {001}, {100} and {031} as determined by Moore (1974). Crystals are sometimes twinned by rotation normal to {100}. Robertsite is present in most of the phosphate assemblages at Tip Top.

Rockbridgeite-Frondelite Series $(Fe,Mn)^{+2}Fe_4^{+3}(PO_4)_3(OH)_5$

Members of the rockbridgeite-frondelite series are the most abundant of all secondary phosphates at this pegmatite with rockbridgeite by far the dominant species in the series. Rockbridgeite is chiefly found as a massive replacement of triphylite. It sometimes occurs as fracture fillings in quartz and rarely in beryl or perthite. The appearance is characteristic: compact fibrous to bladed, deep green to black masses when unoxidized; or brown, bladed fibers when highly oxidized. Fracture-fillings of rockbridgeite may exceed 1 cm in thickness. In open spaces, rockbridgeite commonly occurs as black, botryoidal aggregates that are radial-fibrous in cross-section and as sprays of more isolated, greenish black, prismatic crystals up to 1 mm, rarely up to 1 cm.

Some intermediate members of this series found at Tip Top are termed frondelite-rockbridgeite; they have compositions and optical properties between frondelite and rockbridgeite. Some of this material is more Mn-rich and is thus frondelite. Frondelite-rockbridgeite and frondelite are associated with tinsleyite, robertsite and tavorite in highly oxidized pods of triphylite. Partial chemical analyses of minerals in the rockbridgeite-frondelite series are given in Table 2.

Roscherite $Ca(Al^{+3},Fe^{+2}Mn,Mg)_3Be_2(PO_4)_3(OH)_3 \cdot 2H_2O$ (?)

Roscherite occurs as 0.5 to 3 mm spherical aggregates and loose clusters composed of vitreous to resinous, tabular, pseudohexagonal, 0.3-mm crystals. Most crystals are composed of the forms {100}, {010} and {111}, listed in order of dominance. They appear to be identical to forms found by Lindberg (1958) on crystals from the Sapucaia pegmatite, Brazil. Additional forms, however, have been observed. Roscherite also occurs as 0.5 to 4 mm thick granular massive fracture fillings in beryl. Roscherite is found in a variety of colors such as orange, lavender, red-orange, red-brown and dark olive-green to almost black. Some of these colors have been used as an aid to help characterize the various phosphate suites as discussed below. Chemical data for Tip Top mine roscherite are listed in Table 2.

Scholzite $CaZn_2(PO_4)_2 \cdot 2H_2O$

Scholzite was just recently found at Tip Top and only one specimen is known. It occurs in two different morphologies on this specimen: colorless, slender prismatic, 3-mm crystals striated parallel to [001] and white, translucent, blocky crystals to 0.5 mm; both associated with mitridatite.

Segelerite $CaMgFe^{+3}(PO_4)_2(OH) \cdot 4H_2O$

Segelerite is the iron analog of overite and is chemically related to jahnsite. It was first described by Moore (1974) from Tip Top and is also known from Milgun Station, Western Australia. The mineral is rare and occurs as vitreous, pale green, orthorhombic prisms up to 1 mm. Crystals have a nearly square cross-section, are striated parallel to [001] and are terminated by the pyramid. Common forms determined by Moore (1974) are {100}, {010}, {110} and {121}. Segelerite is restricted to altered triphylite and is in close association with robertsite, collinsite and jahnsite. Segelerite can be

Figure 25. **Aggregates of dark olive-green roscherite associated with englishite (white) and eosphorite-childrenite. Field of view is 4 mm. T. J. Campbell specimen, Dan Behnke photo.**

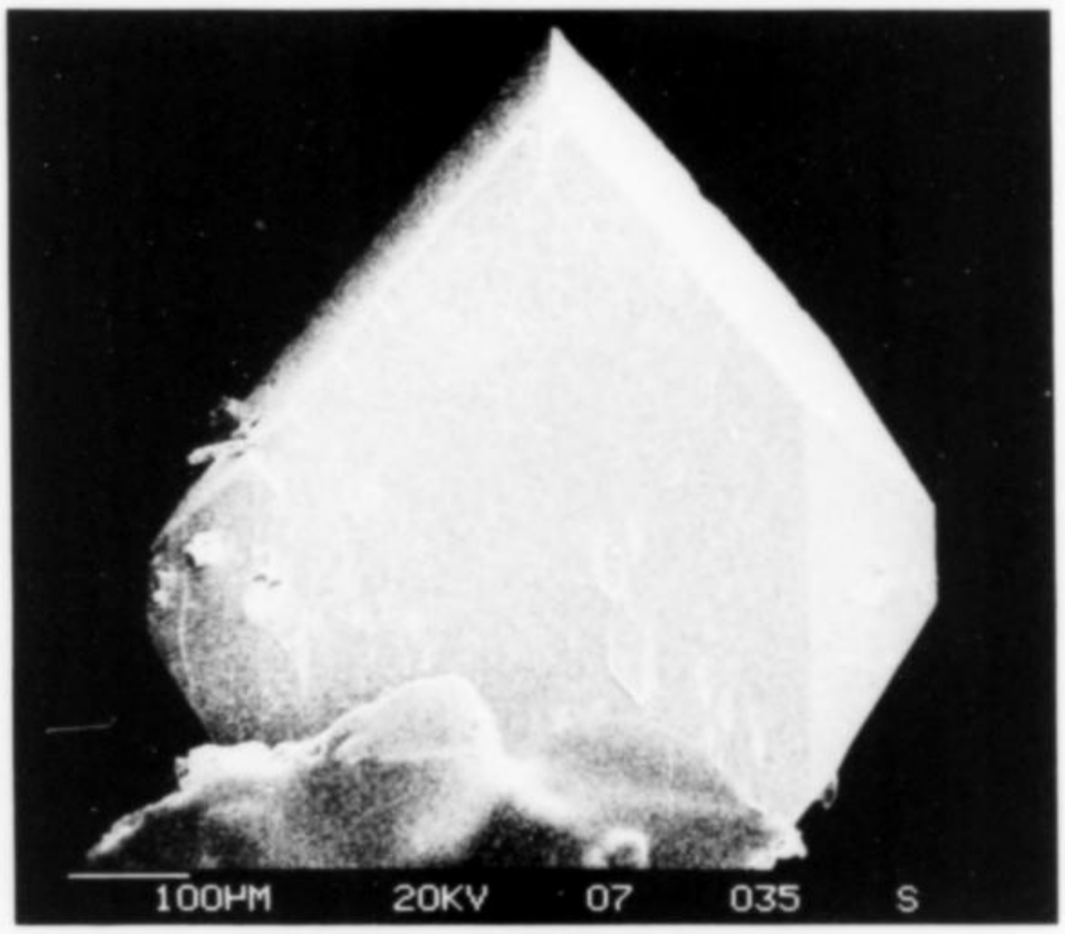


Figure 26. **SEM photomicrograph of tinsleyite. The large face is {100}.**

visually confused with jahnsite but can be distinguished by chemical or X-ray diffraction methods.

Stewartite $Mn^{+2}Fe_2^{+3}(PO_4)_2(OH)_2 \cdot 8H_2O$

Stewartite is a polymorph of laueite and strunzite and is rare at this mine. It occurs as yellow to yellow-brown, vitreous, bladed, triclinic crystals which do not exceed 0.3 mm and can be easily confused with laueite. Stewartite can be distinguished from laueite by its steeper termination and lack of striations.

Strengite $FePO_4 \cdot 2H_2O$

Strengite has been found on one specimen as white granular aggregates (J. Van Velthuizen, personal communication, 1984).

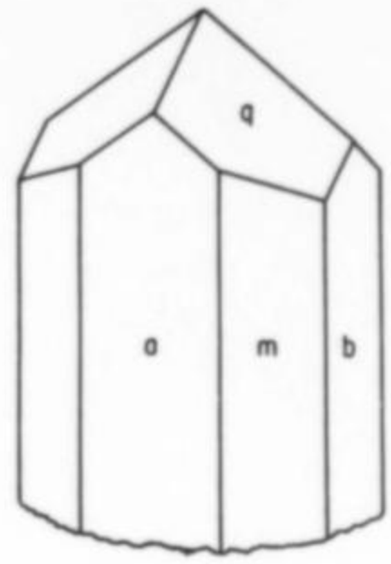


Figure 27. **Segelerite crystal showing the forms *a*{100}, *b*{010}, *m*{110} and *q*{121}. (Moore, 1974).**

Figure 28. **Radial spray of tiptopite associated with roscherite (red) and montgomeryite (pale brown). Spray is 2 mm across. T. J. Campbell specimen and photo.**

Strunzite $Mn^{+2}Fe_2^{+3}(PO_4)_2(OH)_2 \cdot 8H_2O$

Strunzite is not presently abundant; it was more abundant in earlier mine workings. It is found as divergent tufts and felted aggregates composed of straw-yellow, silky, lath-like crystals flattened on {010}.

Switzerite $(Mn,Fe)_3(PO_4)_2 \cdot 4H_2O$

Switzerite is not abundant and occurs as silky, white to pale pink or yellowish interlocking aggregates up to 5 mm composed of thin,

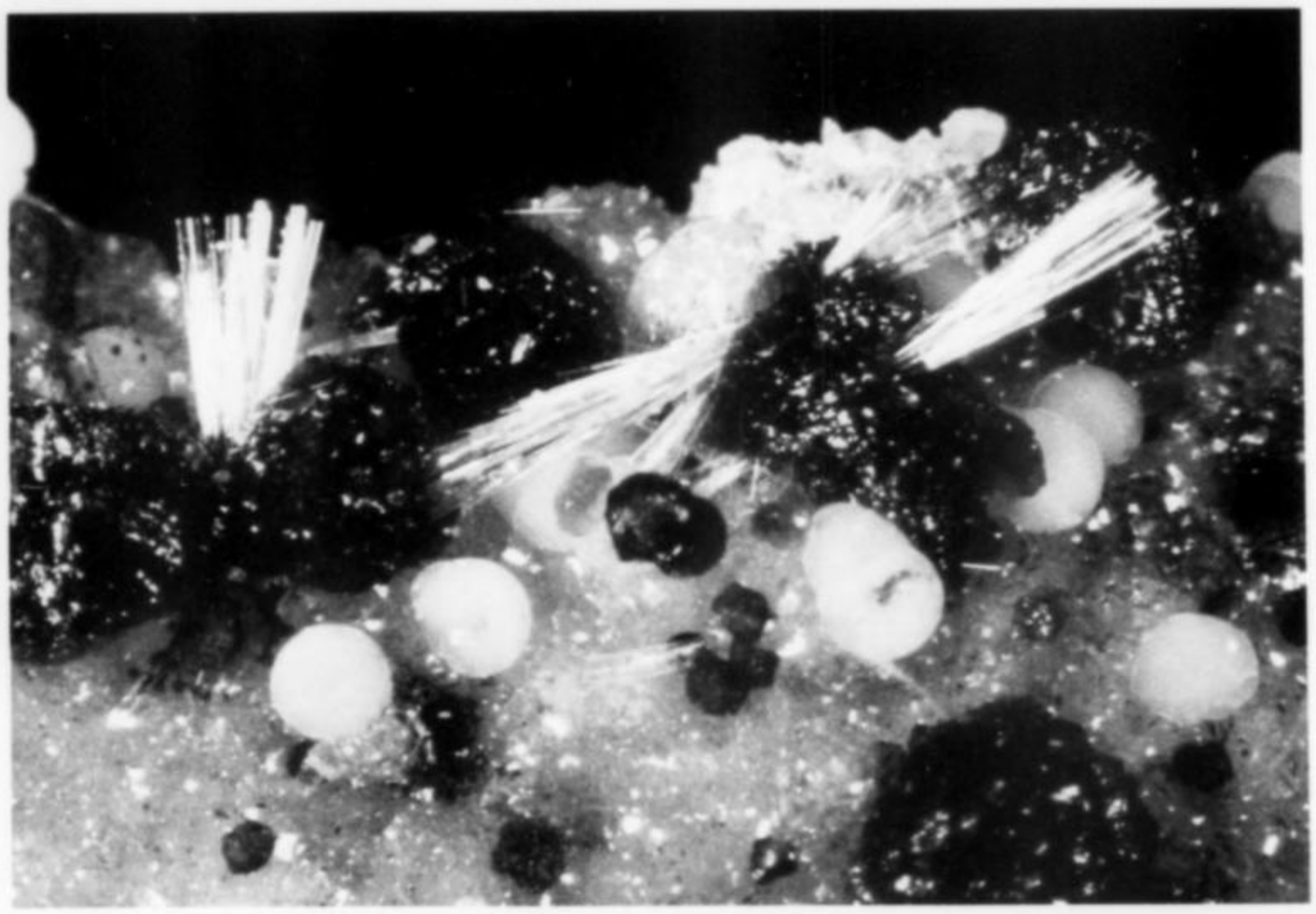


Figure 29. **Rounded aggregates of red roscherite with tiptopite, hurlbutite and todorokite (black). Field of view is 4 mm. T. J. Campbell specimen and photo.**

Figure 30. **A group of tinsleyite-coated leucophosphite crystals. Largest crystal is 0.9 mm tall. T. J. Campbell specimen, Dan Behnke photo.**

bladed crystals, striated and elongated parallel to [001]. Switzerite is, without exception, associated with hureaulite which generally displays a certain degree of dissolution. Microprobe data for switzerite is given in Table 2.

Tavorite $LiFe^{+3}PO_4(OH)$

Tavorite is isostructural with montebrasite. It is moderately abundant in small amounts and occurs as bright yellow-green, fine-grained crystalline aggregates or earthy blebs disseminated in triphylite. Tavorite has been found rarely in masses up to 7 cm^3 replacing triphylite. Although crystals are not common, this is probably the world's best locality for tavorite crystals; they are transparent to translucent, equant to short prismatic, with a vitreous to dull luster and can be found up to 2 mm in maximum dimension, though 0.3 mm crystals are most common. A chemical analysis for tavorite is given in Table 2.

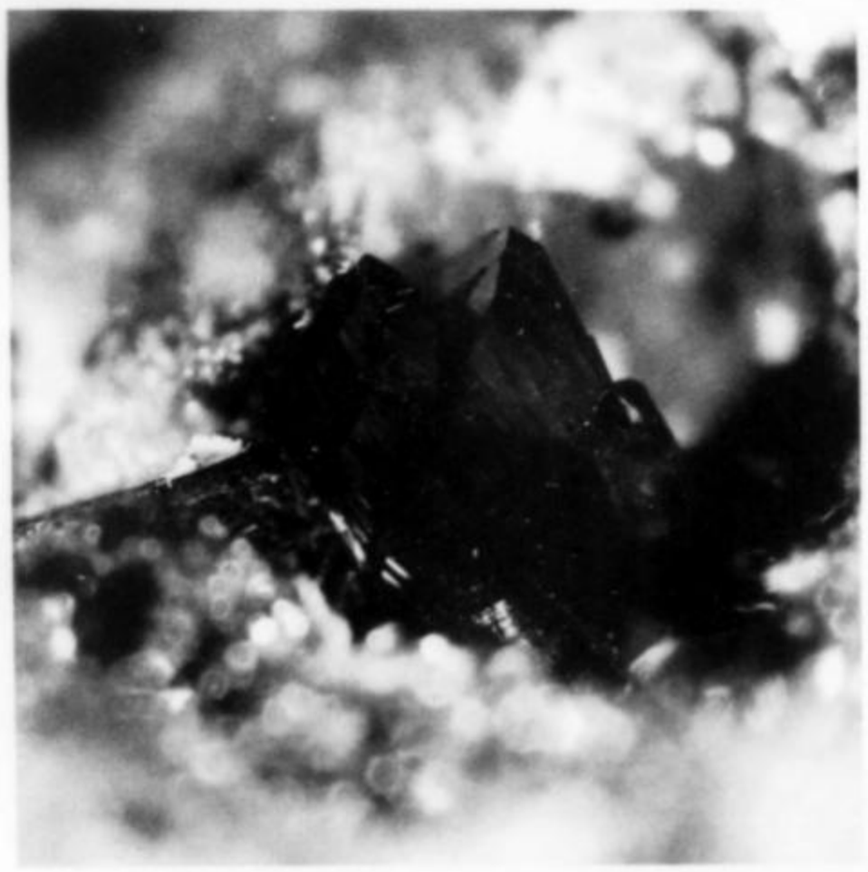
Tinsleyite $KAl_2(PO_4)_2(OH)\cdot 2H_2O$

Tinsleyite (Dunn *et al.,* 1984a) is a new mineral from the Tip Top mine and is the aluminum analog of leucophosphite. It commonly occurs as magenta-red, thin («0.1 mm), morphologically continuous layers on earlier formed leucophosphite; parting surfaces occur between the two. Tinsleyite is rarely found as magenta-red short prismatic crystals morphologically identical to leucophosphite. A chemical analysis of tinsleyite is given in Table 2. It should also be noted that not all magenta colored material is tinsleyite. Some of the magenta colored specimens analyzed were essentially pure leucophosphite with only traces of Al (Dunn *et al.,* 1984a). Therefore, the dark red-purple color is not a diagnostic property. Optical examination (refractive indices) and microprobe analysis are the most reliable means for differentiating between tinsleyite and leucophosphite.

Tiptopite $(Li,K,Na,Ca,\square)_8Be_6(PO_4)_6(OH)_4$

Tiptopite (Grice *et al.,* 1985) was the first new mineral encountered in recent work at the Tip Top. It occurs as radial sprays and divergent fascicles composed of vitreous, colorless, acicular, prismatic crystals terminated by the pinacoid. Crystals are sometimes cavernous or hollow.

Tiptopite was moderately abundant at the mine in 1982 but subsequent mining activity removed most, if not all, of the area where it was found. Tiptopite occurred predominantly along fracture surfaces in beryl, occasionally in quartz and rarely in perthite. Its occurrence is discussed in detail by Grice *et al.* (1985).



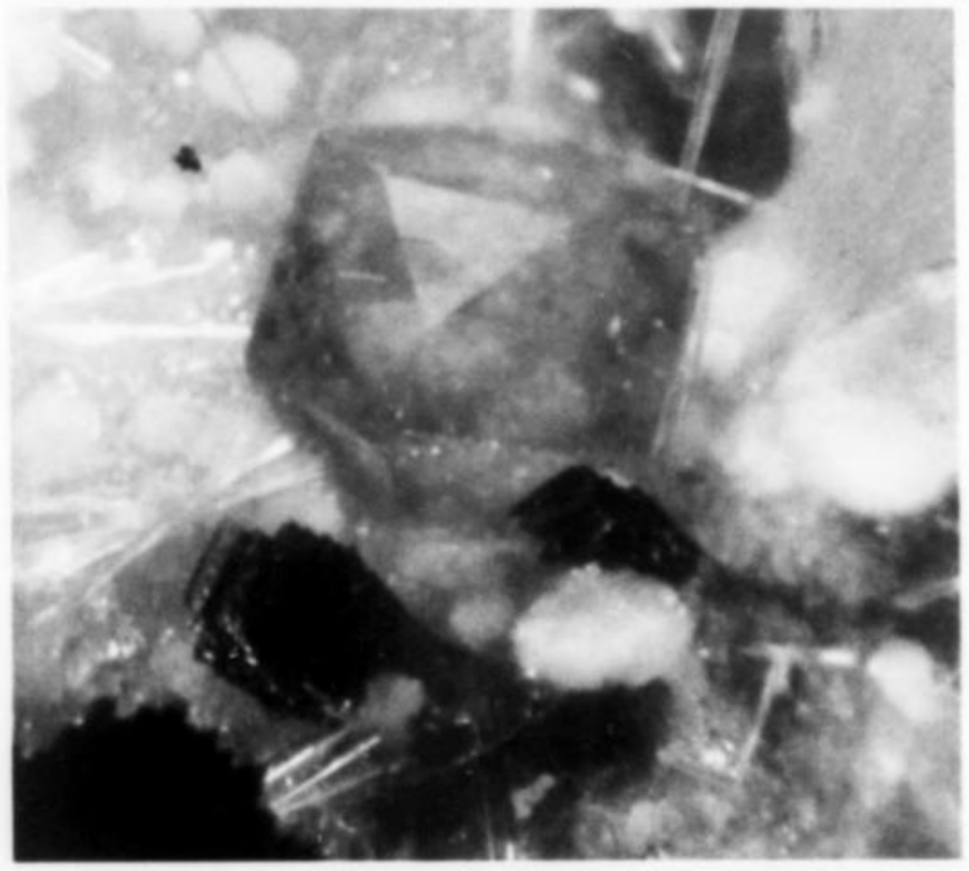


Figure 31. **Photomicrograph of a 0.5-mm crystal of the undescribed phosphate with roscherite (dark olive-green), englishite (white spherules), and tiptopite (colorless needles). T. J. Campbell specimen and photo.**

Figure 32. **SEM photomicrograph of a tiptopite spray showing the cavernous nature on a few of the crystals.**

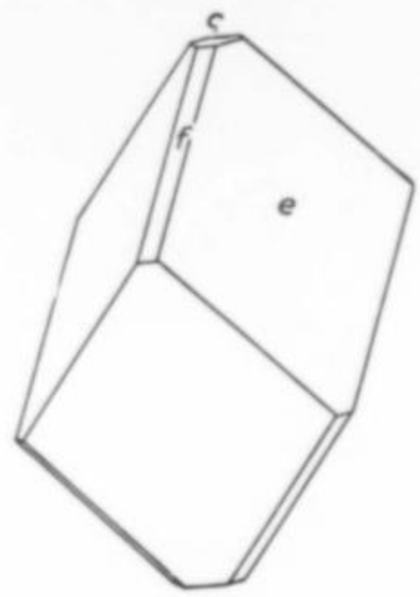


Figure 33. **Crystal of whitlockite showing the forms $a\{11\bar{2}0\}$, $e\{01\bar{1}2\}$, $f\{10\bar{1}4\}$ and $p\{10\bar{1}1\}$ (Frondel, 1941).**

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

Vivianite is one of the more abundant and earliest formed secondary phosphates found at the mine. It occurs as pale to dark blue, cleavable, massive veinlets or small pod-like masses replacing triphylite and as blue, 1 to 3-mm, tabular, bladed or prismatic crystals often flattened on {010} and somewhat elongate parallel to [001]. Several crystals exceeding 4 cm have been collected. Vivianite has a vitreous luster, a fibrous fracture and a perfect {010} cleavage which is easily produced. Thin lamellae are flexible. Fresh, unaltered vivianite is generally pale green, the color darkening slowly upon exposure. Some of the larger vivianite crystals show inclusions of 0.2 mm sprays of rockbridgeite. Vivianite also alters to a yellow, granular, unidentified mineral.

Whiteite $Ca(Fe,Mn)^{+2}Mg_2Al_2(PO_4)_4 \cdot 8H_2O$

Whiteite is the aluminum analog of jahnsite (Moore and Ito, 1978). Whiteite is not abundant here and has a restricted mode of occurrence. It is restricted to roscherite-bearing assemblages that occur as fracture-fillings in beryl and the adjacent quartz, rarely in fractures cutting perthite and triphylite. Whiteite occurs as yellowish, vitreous to resinous, small («4 mm), prismatic crystals and subparallel groups. Some crystals display a morphology almost identical to Tip Top jahnsite and to jahnsite from the Sapucaia pegmatite in Brazil. Dominant forms include {001}, {100}, {201} and {011}. It is not uncommon to find partially dissolved whiteite crystals displaying a pink core. Some intermediate compositions between jahnsite and whiteite have also been found.

Whitlockite $HCa_9Mg(PO_4)_7$

Whitlockite is rather abundant, especially in recent workings. Crystals are simple rhombs, rarely modified, are transparent to translucent and have a vitreous luster. Visual inspection shows the modified rhombs to be identical to those from the Palermo No. 1 quarry, New Hampshire, as described by Frondel (1941). Crystals range in size from 0.2 to 5 mm. A crystal measuring 1 cm on edge was measured by one of us (TJC). Color varies from colorless, white to gray, yellowish and pink. Inclusions of less than 0.05 mm robertsite crystals sometimes give whitlockite a pale red color. Whitlockite also occurs as granular massive fracture-fillings up to 5 mm in thickness in quartz, beryl and sometimes perthite and triphylite.

Xanthoxenite $Ca_4Fe_2^{+3}(PO_4)_4(OH)_2 \cdot 3H_2O$

Xanthoxenite was reported to occur at this locality by Moore (1973).

New Phosphate

A new phosphate mineral recently discovered at the Tip Top pegmatite is presently under investigation by the authors. This mineral is very rare and its occurrence is restricted to dark, olive-green roscherite-bearing assemblages. It occurs as glassy, colorless to pale pink or pale yellow-green, 1-mm, isometric crystals.

PARAGENESIS

Secondary phosphate minerals at the Tip Top pegmatite were formed by percolating meteoric waters at depth and/or by an aqueous residual fluid remaining after core consolidation. The origin of secondary phosphates at this locality is discussed in detail by Campbell (1984). Various stages of phosphate mineral formation at Tip Top are similar to those outlined by Segeler *et al.* (1981) for the Palermo No. 1 pegmatite, and are as follows:

1) Crystallization of primary phosphates (~700°–600°C).
2) Metasomatism and initial oxidative reactions (600°–300°C).
3) Hydrothermal attack and remobilization (300°–25°C).

The first step involved the crystallization of primary phosphate minerals such as triphylite and fluorapatite. These phosphates formed directly from the pegmatite melt or vapor with triphylite largely being restricted to the inner-intermediate zone near the core. Triphylite and other primary phosphates are largely anhydrous and contain no bonded water molecules (H_2O ligands). Bonded water molecules are not stable at temperatures above about 250°C.

During step two, triphylite suffered extensive retrograde oxidative and metasomatic alteration. This involved Li-leaching, oxidation of some Fe and Mn and, to a lesser extent, the addition of Na and Ca. These processes may be the result of the action of hydrothermal fluids which may have carried excess Ca, Mg and Na. Again, these minerals are essentially anhydrous. Granular to cleavable massive minerals are characteristic of metasomatic minerals at the Tip Top pegmatite. Examples include heterosite, ferrisicklerite, alluaudite and some apatite.

The third step involved the hydrothermal alteration of triphylite, muscovite, microcline-perthite, beryl, albite and quartz. This alteration was facilitated by fractures that formed during and after pegmatite consolidation and served as conduits for these hydrothermal fluids. Because temperatures at this stage are below about 250°C, H_2O ligands are stable and become incorporated into the crystal structures of some of the many secondary phosphate species produced (Moore, 1973). Eh-pH conditions probably spanned a rather wide range and the solution chemistry changed temporally as well as spatially in the pegmatite.

Table 3. **Mineral associations of secondary phosphates that represent products resulting from hydrothermal attack of silicate minerals and triphylite. Not all of the minerals have been included.**

	Carbonate-apatite	Englishite	Eosphorite/Childrenite	Fairfieldite	Fransoletite	Hurlbutite	Hydroxyl-herderite	Mitridatite	Montgomeryite	Robertsite	Roscherite	Tiptopite	Whiteite	Whitlockite	New Phosphate	Ehrleite	Parascholzite
Carbonate-apatite	•	R	R	C	C	C	R	NC	VC	C	NC	C	NC	VC	R	?	*
Englishite	R	•	C	NC	C	C	C	NC	C	C	C	C	NC	C	C	*	*
Eosphorite/Childrenite	R	C	•	NC	*	NC	C	R	NC	R	C	C	R	C	C	*	*
Fairfieldite	C	NC	NC	•	*	NC	NC	NC	VC	C	C	VC	NC	C	R	*	*
Fransoletite	C	C	*	*	•	C	NC	R	VC	C	VC	VC	NC	NC	*	*	*
Hurlbutite	C	C	NC	NC	C	•	*	R	VC	C	VC	VC	R	VC	*	*	*
Hydroxyl-herderite	R	C	C	NC	NC	*	•	R	NC	R	C	C	*	R	NC	C	C
Mitridatite	NC	NC	R	NC	R	R	R	•	NC	C	NC	NC	C	C	R	NC	NC
Montgomeryite	VC	C	NC	VC	VC	VC	NC	NC	•	C	VC	VC	C	VC	C	*	*
Robertsite	C	C	R	C	C	C	R	C	C	•	C	NC	NC	VC	R	*	*
Roscherite	NC	C	C	C	VC	VC	C	NC	VC	C	•	VC	C	C	C	C	C
Tiptopite	C	C	C	VC	VC	VC	C	NC	VC	NC	VC	•	C	C	VC	*	*
Whiteite	NC	NC	R	NC	NC	R	*	C	C	NC	C	C	•	C	R	*	*
Whitlockite	VC	C	C	C	NC	VC	R	C	VC	VC	C	C	C	•	NC	*	*
New Phosphate	R	C	C	R	*	*	NC	R	C	R	C	VC	R	NC	•	*	*
Ehrleite	?	*	*	*	*	*	C	NC	*	*	C	*	*	*	*	•	C
Parascholzite	*	*	*	*	*	*	C	NC	*	*	C	*	*	*	*	C	•

Legend: VC = very common, C = common, NC = not common, R = rare, ? = association uncertain, * = not associated.

The secondary phosphates encountered at the Tip Top pegmatite have two distinct hydrothermal origins which help categorize them into the following two groups:

Group 1: products of direct solution, oxidation, and recrystallization of primary phosphates

Group 2: products resulting from hydrothermal attack on silicate minerals and triphylite. These phosphates usually crystallize along fracture surfaces in the pegmatite.

Group i consists of phosphate Suites I and II; Group 2 consists of phosphate Suites III, IV and V.

The paragenetic sequences in Suite I through V are rather complex as manifested by the variety of cations that were present in the system. The following is a discussion of the mineral parageneses of the various suites accompanied by paragenetic diagrams. Because of the complexity and variance of the parageneses, only generalized paragenetic trends are presented here.

Group 1

Group 1 phosphates largely incorporate metals of the first transition series such as Fe and Mn with minor amounts of K, Ca, Mg and Al. The action of hydrothermal solutions on triphylite liberated the phosphate anion along with Fe, Mn and Li. Ca and Mg were brought in by a late hydrothermal fluid that may have represented a residuum from a higher temperature metasomatic fluid. Calcium may also have been released from the dissolution of fluorapatite. Potassium and Al were released by the hydrothermal alteration of muscovite, which often coexists with triphylite. Secondary phosphates formed from these solutions are largely restricted to solution cavities in triphylite and within fractures that transect the adjacent quartz.

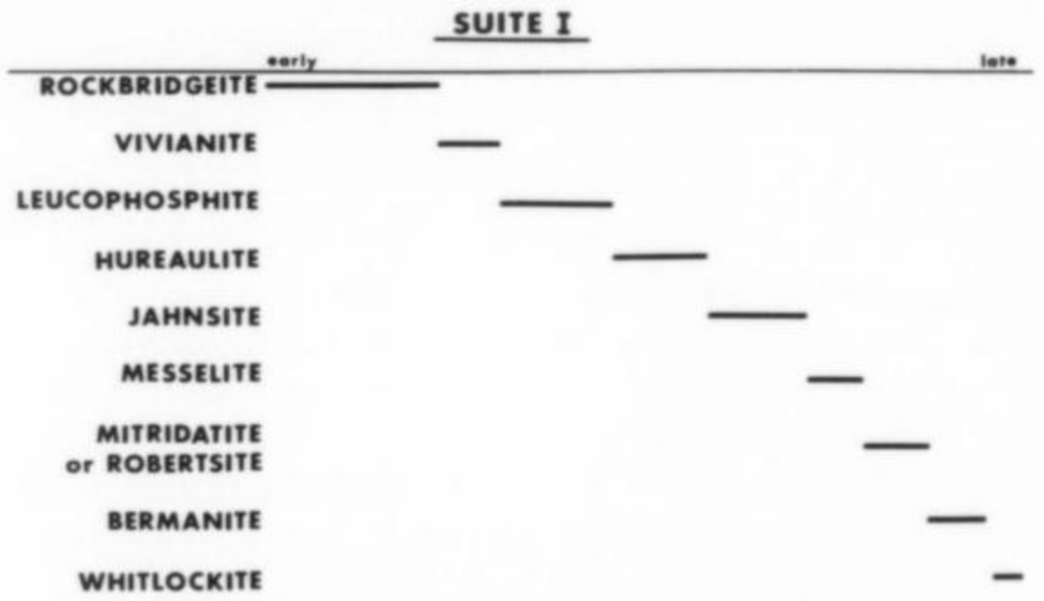


Figure 34. **Paragenetic sequence of Suite I minerals.**

Phosphate Suite I

Minerals of the Suite I assemblage are dominated by transition metals with subordinate amounts of alkaline earth metals and K as the persistent alkali metal. Minerals represented here in order of decreasing abundance are rockbridgeite, leucophosphite, hureaulite, jahnsite, mitridatite, robertsite, vivianite, messelite, bermanite and whitlockite. Carbonate-hydroxylapatite or hydroxylapatite, collinsite, quartz, tavorite and laueite may also be present. These minerals are found in fractures or solution cavities in triphylite and quartz. Some minerals, such as robertsite, mitridatite and jahnsite, occur as at least two generations, complicating the paragenetic sequences. The following, therefore, is a generalized sequence.

Rockbridgeite and vivianite, without exception, were the earliest minerals formed and were followed closely by leucophosphite. Hureaulite formed after leucophosphite and brown or green

Table 4. **Mineral associations of secondary phosphates that chiefly represent products resulting of direct solution, oxidation and recrystallization of triphylite. Not all of the minerals have been included.**

	Barbosalite	Beraunite	Bermanite	Collinsite	Dufrenite	Hureaulite	Jahnsite	Kidwellite	Kryzhanovskite	Laueite	Leucophosphite	Ludlamite	Messelite	Mitridatite	Montgomeryite	Phosphoferrite	Robertsite	Rockbridgeite	Segelerite	Switzerite	Tavorite	Tinsleyite	Vivianite	Whitlockite
Barbosalite	•	*	*	*	*	C	C	*	*	*	R	*	*	*	*	*	*	C	*	*	C	*	R	*
Beraunite	*	•	*	R	*	*	C	R	*	*	C	*	R	R	*	*	R	*	*	*	*	*	*	*
Bermanite	*	*	•	*	*	R	NC	*	*	R	R	*	R	NC	*	*	VC	NC	*	*	NC	C	R	R
Collinsite	*	R	*	•	*	*	NC	R	*	R	NC	*	?	NC	*	*	C	C	C	*	*	R	*	R
Dufrenite	*	*	*	*	•	*	R	*	*	*	NC	*	*	*	*	*	*	C	*	*	*	*	*	*
Hureaulite	C	*	R	*	*	•	VC	*	*	*	VC	*	NC	NC	*	*	C	VC	*	VC	C	*	C	C
Jahnsite	C	C	NC	NC	R	VC	•	C	*	NC	VC	*	VC	C	*	*	VC	VC	C	C	C	C	C	C
Kidwellite	*	R	*	R	*	*	C	•	*	*	C	*	*	R	*	*	C	C	*	*	*	*	*	*
Kryzhanovskite	*	*	*	*	*	*	*	*	•	NC	*	C	*	*	*	VC	*	C	*	*	*	*	NC	*
Laueite	*	*	R	R	*	*	NC	*	NC	•	C	NC	*	NC	*	NC	NC	C	R	*	*	C	*	*
Leucophosphite	R	C	R	NC	NC	VC	VC	C	*	C	•	*	C	C	R	*	C	VC	C	C	C	VC	C	C
Ludlamite	*	*	*	*	*	*	*	*	C	NC	*	•	*	*	*	C	*	C	*	*	*	*	NC	*
Messelite	*	R	R	?	*	NC	VC	*	*	*	C	*	•	VC	*	*	C	VC	?	*	*	*	R	R
Mitridatite	*	R	NC	NC	*	NC	C	R	*	NC	C	*	VC	•	R	*	C	C	NC	*	*	NC	NC	NC
Montgomeryite	*	*	*	*	*	*	*	*	*	*	R	*	*	R	•	*	R	R	*	*	*	*	*	R
Phosphoferrite	*	*	*	*	*	*	*	*	VC	NC	*	C	*	*	*	•	*	C	*	*	*	*	NC	*
Robertsite	*	R	VC	C	*	C	VC	C	*	NC	C	*	C	C	R	*	•	C	NC	R	R	VC	NC	C
Rockbridgeite	C	*	NC	C	C	VC	VC	C	C	C	VC	C	VC	C	R	C	C	•	C	NC	C	C	VC	NC
Segelerite	*	*	*	C	*	*	C	*	*	R	C	*	?	NC	*	*	NC	C	•	*	R	R	*	*
Switzerite	*	*	*	*	*	VC	C	*	*	*	C	*	*	*	*	*	R	NC	*	•	*	*	R	*
Tavorite	C	*	NC	*	*	C	C	*	*	*	C	*	*	*	*	*	R	C	R	*	•	NC	R	*
Tinsleyite	*	*	C	R	*	*	C	*	*	C	VC	*	*	NC	*	*	VC	C	R	*	NC	•	*	R
Vivianite	R	*	R	*	*	C	C	*	NC	*	C	NC	R	NC	*	NC	NC	VC	*	R	R	*	•	R
Whitlockite	*	*	R	R	*	C	C	*	*	*	C	*	R	NC	R	*	C	NC	*	*	*	R	R	•

Legend: VC = very common, C = common, NC = not common, R = rare, ? = association uncertain, * = not associated.

jahnsite formed subsequently. White interlocking plates of messelite formed toward the end of, and after, jahnsite deposition. Spherical aggregates and plates of mitridatite or robertsite, the species depending on the amount of Fe or Mn left in the solution, crystallized after messelite. Red-brown, platy aggregates of bermanite are among the last minerals formed, followed by whitlockite. This particular sequence has also been observed by Moore (1973 and 1974).

Phosphate Suite II

Minerals of Suite II are restricted to highly altered and oxidized pods of triphylite in which the muscovite has been altered. This assemblage contains frondelite-rockbridgeite, leucophosphite, robertsite, carbonate-hydroxylapatite, tinsleyite and laueite in approximate order of decreasing abundance.

Brown, slightly oxidized, fibrous masses and isolated sprays of frondelite-rockbridgeite and yellow-green blebs of tavorite are among the earliest phosphates formed; frondelite-rockbridgeite is dominant. Green, prismatic crystals of leucophosphite formed after frondelite-rockbridgeite and tavorite. Tinsleyite formed after leucophosphite and commonly occurs as morphologically continuous overgrowths on leucophosphite. Deep magenta-colored single crystals of tinsleyite, which are morphologically identical to leucophosphite, are also present. Black spherical aggregates of robertsite formed near the end of and subsequent to leucophosphite and tinsleyite deposition. Yellow prismatic crystals of a jahnsite-group mineral or crystals of yellow-green jahnsite formed during and after robertsite. Segelerite, where present, formed after the jahnsite-

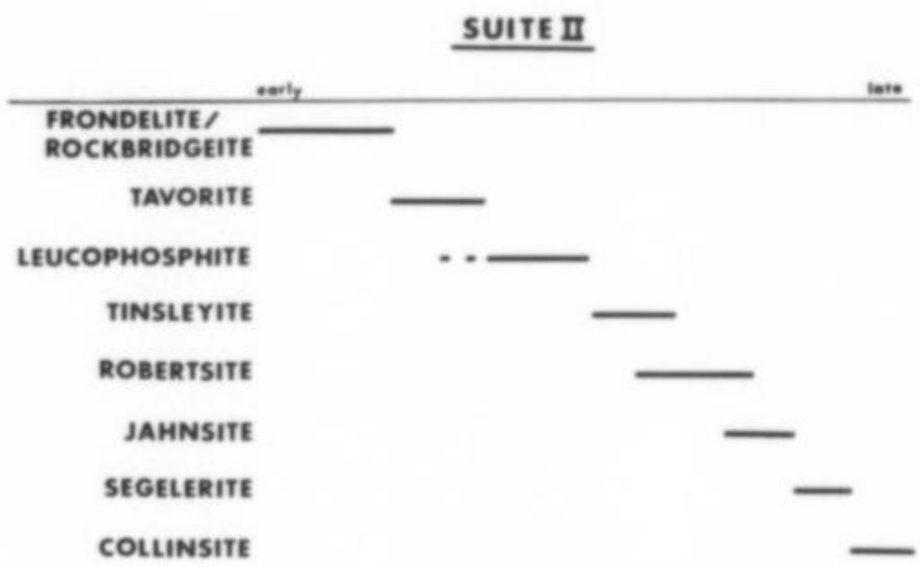


Figure 35. **Paragenetic sequence of Suite II minerals.**

group minerals and was followed by bladed, rosettes of collinsite; robertsite, and possibly some mitridatite may be intimately associated with these two minerals as well. Other minerals paragenetically younger than the previously described phosphates include white, radial sprays of carbonate-hydroxylapatite and orange, prismatic crystals of laueite.

Group 2

Reactions resulting in the formation of Group 2 phosphates involve the attack of phosphate-rich hydrothermal fluids on primary silicate minerals such as perthite, beryl and albite. The solutions probably came in contact with triphylite which supplied the phos-

phate anion along with Fe, Mn and Li. Subsequent attack on the aforementioned silicates by solutions supplied K, Al, Be, Ca and Na, and upon crystallization the phosphates proceeded to fill fractures in these primary silicate minerals.

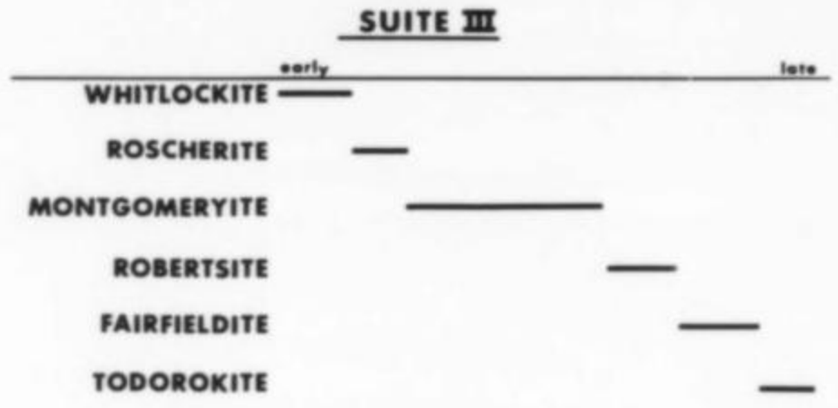


Figure 36. **Paragenetic sequence of Suite III minerals.**

Phosphate Suite III

Suite III is characterized by whitlockite, carbonate-hydroxylapatite, red to pin. montgomeryite, pyrolusite, robertsite, lavender roscherite, fairfieldite and todorokite, in order of decreasing abundance. These minerals are found lining fractures in quartz, perthite, beryl and albite, rarely in triphylite.

In most cases, the fractures are coated with a crust of carbonate-hydroxylapatite and/or a microcystalline druse of colorless to pink whitlockite. Some specimens show continued whitlockite crystallization through the entire sequence. Tabular crystals and small clusters of lavender roscherite were then deposited, followed by fascicles of red to pink montgomeryite. Deep red to almost black, prismatic, sometimes twinned, crystals of robertsite formed during and after montgomeryite. Plates of fairfieldite crystallized after robertsite and black, submetallic, 0.5-mm, radial tufts of pyrolusite formed subsequent to fairfieldite. Gray-black, submetallic, spherical aggregates of todorokite were the last mineral to form. This sequence is slightly modified from the one outlined in Dunn *et al.* (1983).

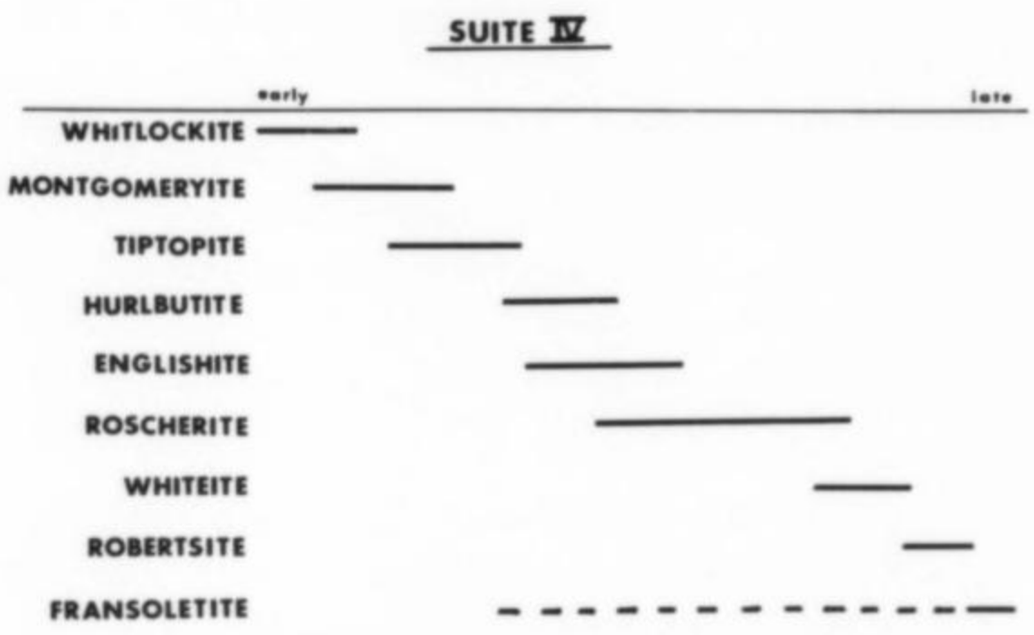


Figure 37. **Generalized paragenetic sequence of Suite IV minerals.**

Phosphate Suite IV

Suite IV is similar to Suite III but is dominated by alkali metal-bearing and Be-bearing phosphates with subordinate amounts of alkaline earth and transition metal phosphates. This suite of phosphates represents a chemically very diverse assemblage of minerals. These phosphates also prove to be exceedingly colorful and very esthetic. The colors of montgomeryite and roscherite characterize this suite; montgomeryite in shades of yellow and pink with roscherite which varies from orange-red to red-brown. In addition to montgomeryite and roscherite, this assemblage includes whitlockite, tiptopite, englishite, carbonate-hydroxylapatite, hurlbutite, robertsite, whiteite, todorokite, fairfieldite and fransoletite, in order of decreasing abundance. Minerals of this assemblage occur as fracture fillings in beryl and quartz. Many of the fractures are lined with a druse of 0.2-mm whitlockite crystals while others are lined with white to pale green, botryoidal crusts of carbonate-hydroxylapatite. In general, whitlockite is the dominant early phase. Pink to red clusters of montgomeryite formed contemporaneously with whitlockite and are frequently covered by subsequent whitlockite crystallization (Dunn *et al.*, 1983). This portion of the sequence may be related to Suite III mineralization. Yellow to yellow-brown fascicles of montgomeryite formed toward the end of whitlockite crystallization. Tiptopite formed just after the crystallization of yellow montgomeryite; then pale pink to bluish white spherules of hurlbutite and pearly white hemispherules of englishite, which appear to be contemporaneous, were formed. Spherulitic aggregates of orange-red to red-brown roscherite then formed during and after hurlbutite and englishite formation. Deep-red to red-black clusters and single crystals of robertsite or robertsite-mitridatite crystallized just before or during roscherite formation, and whiteite formed subsequent to roscherite. Fairfieldite, which is not abundant in this assemblage, crystallized after whiteite. Fransoletite, generally present in the absence of fairfieldite, was the last phosphate to form, although a few specimens show it as an earlier formed phase. Gray-black, submetallic, spherical aggregates and crusts of todorokite formed last.

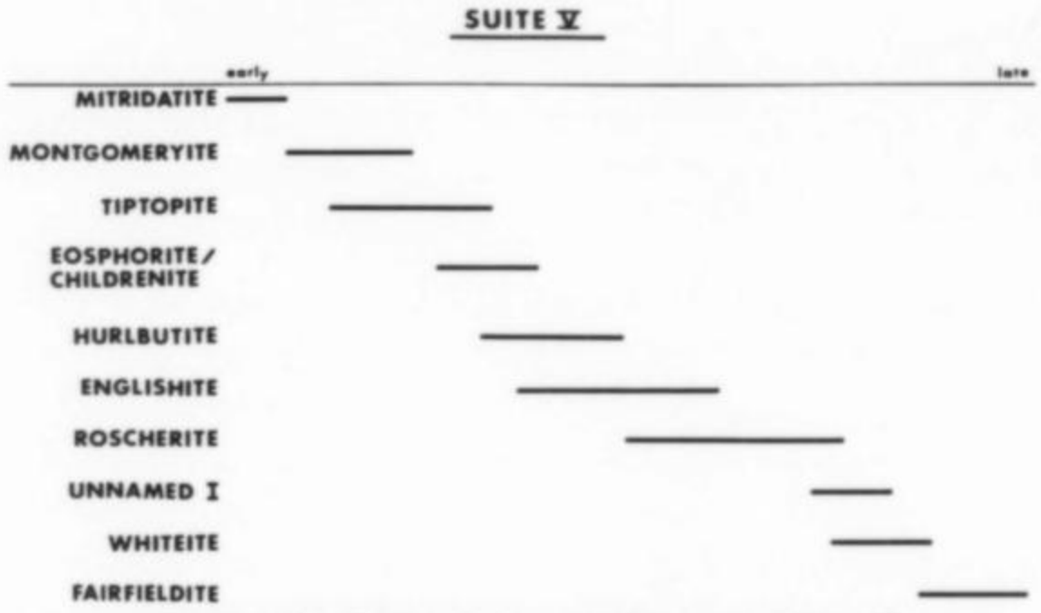


Figure 38. **Paragenetic sequence of Suite V minerals.**

Phosphate Suite V

Suite V consists of dark, olive-green roscherite, tan to colorless montgomeryite, fairfieldite, tiptopite, englishite, whitlockite, mitridatite, eosphorite-childrenite, hurlbutite, whiteite and the undescribed phosphate. This suite of phosphates is mineralogically similar, but distinct, compared to Suite IV, as described by Grice *et al.* (1985). An obvious difference between the two assemblages is the overall color, as exemplified by olive-green roscherite and colorless to tan montgomeryite. Another difference is that this suite contains mitridatite and eosphorite-childrenite, lacks fransoletite and does not have whitlockite as a dominant early phase. This sequence is restricted to fracture surfaces in beryl.

Dark red-brown, lamellar aggregates of mitridatite formed a crust on which montgomeryite and later-formed phosphates were deposited. After the onset of montgomeryite crystallization, sprays of tiptopite formed; the two minerals are commonly found intergrown. Montgomeryite and tiptopite also crystallized directly on beryl fracture surfaces. During and after the deposition of montgomeryite and tiptopite, eosphorite-childrenite crystals formed, followed by pale-brown spherules of hurlbutite. Toward the end of hurlbutite formation, spherulitic aggregates of englishite formed and are sometimes impaled on acicular tiptopite crystals. Roscher-

ite was deposited contemporaneously with, and was partially covered by, subsequent englishite crystallization. Crystals of the new phosphate formed with englishite. Whiteite, if present, formed after roscherite. Stacked, parallel aggregates of fairfieldite were the last phase formed and whitlockite, where present, occurs as a druse on the other minerals.

SUMMARY

The Tip Top pegmatite is the type locality for eight phosphate mineral species. These are jahnsite, robertsite, segelerite, fransoletite, tinsleyite, tiptopite, ehrleite and a soon-to-be-described phosphate; the last five are unique to this deposit. This mine has also produced some of the most esthetic specimens of secondary phosphate minerals ever encountered in a pegmatite, with crystals ranging from sub-millimeter size up to tens of millimeters for some species. The majority of these minerals can still be collected on the dumps.

The Tip Top mine easily parallels Palermo in diversity of phosphate species and equals or surpasses it in terms of complexity of paragenesis. Through continued research, the number of phosphate species from the Tip Top pegmatite may surpass that from Palermo.

Secondary phosphates at the Tip Top formed during a moderate to low temperature (300°–25°C) hydrothermal alteration and remobilization stage. All of these secondary phosphates formed below 250°C; above this temperature H_2O ligands, which play an essential role in secondary phosphate formation, are not stable (Moore, 1973). These phosphates can be subdivided into two groups: 1) products of direct solution, oxidation and recrystallization of primary phosphates, and 2) products of the hydrothermal alteration of silicate minerals and triphylite. The majority of the metasomatic and secondary phosphate minerals are produced largely by the hydrothermal attack of primary minerals by percolating meteoric waters at depth and/or by an aqueous residual liquid remaining after core consolidation. Future work using light stable isotopes and fluid inclusion studies may give some insights to the source of the fluids and the origin of secondary phosphates at this locality.

ACKNOWLEDGMENTS

The authors would like to thank Jerry Van Velthuizen, George Robinson and Joel Grice of the National Museums of Canada for information they supplied on some of the Tip Top phosphates. We also thank Peter Modreski, Eugene Foord, John Anthony, Richard Erd, and Anthony Kampf for reviewing various drafts of the manuscript. Many thanks are also extended to Cindy Campbell and Tina Brisbois for typing the final manuscript and its several preliminary drafts.

REFERENCES

CAMPBELL, T. J. (1984) Phosphate Mineralogy of the Tip Top Pegmatite, Custer, South Dakota. Master of Science Thesis, South Dakota School of Mines and Technology, 172 pp.

DUNN, P. J., ROBERTS, W. L., CAMPBELL, T. J., and LEAVENS, P. B. (1983) Red montgomeryite and associated minerals from the Tip Top pegmatite with notes on kingsmountite and calcioferrite. *Mineralogical Record,* **14**, 195–197.

DUNN, P. J., ROUSE, R. C., CAMPBELL, T. J., and ROBERTS, W. L. (1984a) Tinsleyite, the aluminum analogue of leucophosphite, from the Tip Top pegmatite, South Dakota. *American Mineralogist,* **69**, 374–376.

DUNN, P. J., ROUSE, R. C., and NELEN, J. (1984b) Englishite: New chemical data and a second occurrence, from the Tip Top pegmatite, Custer, South Dakota. *Canadian Mineralogist, 33,* 469–470.

FISHER, D. J. (1942) Preliminary report on some pegmatites of the Custer district. *South Dakota Geological Survey Report of Investigations, No.* **44**.

FRONDEL, C. (1941) Whitlockite: A new calcium phosphate. *American Mineralogist,* **26**, 145–152.

GINSBURG, A. I., TIMOFEYEV, I. N., and FELDMAN, L. G. (1979) *Principles of Geology of the Granitic Pegmatites.* Nedra, Moscow, 206 pp.

GRICE, J. D., and ROBINSON, G. W. (1984) New phosphate minerals from the Tip Top mine, Black Hills, South Dakota. *GAC-MAC Program with abstracts,* **9**, 68.

GRICE, J. D., PEACOR, D. R., ROBINSON, G. W., VAN VELTHUIZEN, J., ROBERTS, W. L., CAMPBELL, T. J., and DUNN, P. J. (1985) Tiptopite, a new mineral from the Black Hills, South Dakota. *Canadian Mineralogist,* **23**, 43–46.

HURLBUT, C. S. (1950) Childrenite-eosphorite series. *American Mineralogist,* **35**, 793–805.

KLEINKOPF, M. D., and REDDEN, J. A. (1975) Bouger gravity, aeromagnetic, and generalized geologic maps of part of the Black Hills of South Dakota and Wyoming. *Geophysical Investigations Map GP-903, U.S. Geological Survey, Washington, D.C.,* 1–11.

LARSEN, E. S. (1940) Overite and montgomeryite: two new minerals from Fairfield, Utah. *American Mineralogist,* **25**, 315–326.

LARSEN, E. S., and SHANNON, E. V. (1930) The minerals of the phosphate nodules from near Fairfield, Utah. *American Mineralogist,* **15**, 307–337.

LINDBERG, M. L. (1958) The beryllium content of roscherite from the Sapucaia pegmatite mine, Minas Gerais, Brazil, and from other localities. *American Mineralogist,* **43**, 824–838.

LINDBERG, M. L. (1957) Leucophosphite from the Sapucaia pegmatite mine, Minas Gerais, Brazil. *American Mineralogist,* **42**, 214–221.

MOORE, P. B. (1973) Pegmatite phosphates: descriptive mineralogy and crystal chemistry. *Mineralogical Record,* **4**, 103–130.

MOORE, P. B. (1974) Jahnsite, segelerite and robertsite, three new transition metal phosphate species. *American Mineralogist,* **59**, 48–55.

MOORE, P. B., and ITO, J. (1978) Whiteite, a new species, and a proposed nomenclature for the jahnsite-whiteite complex series. *Mineralogical Magazine,* **42**, 309–316.

MROSE, M. (1952) Hurlbutite: a new mineral. *American Mineralogist,* **37**, 931–935.

NORTON, J. J. (1975) Pegmatite minerals *in* Mineral and Water Resources of South Dakota, *Geological Survey Bulletin* **16**, 132–149.

PEACOR, D. R., DUNN, P. J., ROBERTS, W. L., CAMPBELL, T. J., and NEWBURY, D. (1983) Fransoletite, a new calcium beryllium phosphate from the Tip Top pegmatite, Custer, South Dakota. *Bulletin de Mineralogie,* **106**, 449–503.

ROBERTS, W. L., CAMPBELL, T. J., MacLEOD, R. J., and FRENCH, G. MC N. (1982) The Tip Top pegmatite *in GAC-MAC Fieldtrip Guidebook, Trip 12,* 14–16.

ROBERTS, W. L., RAPP, G., and WEBER, J. (1974) *Encyclopedia of Minerals.* Van Nostrand Reinhold Co., New York, U.S.A.

ROBERTS, W. L., and RAPP, G. (1965) *Mineralogy of the Black Hills.* South Dakota School of Mines and Technology Bulletin No. 18.

SEGELER, C. G., ULRICH, W., KAMPF, A. R., and WHITMORE, R. W. (1981) Phosphate minerals of the Palermo No. 1 pegmatite. *Rocks and Minerals,* **56**, 197–214.

STRUNZ, H. (1954) Laueite, ein neues Mineral. *Naturwissenschaft,* **41**, 256.

STURMAN, B. D., ROUSE, R. C., and DUNN, P. J. (1981) Parascholzite, a new mineral from Hagendorf, Bavaria, and its relationship to scholzite. *American Mineralogist,* **66**, 843–851.

WOLFE, C. W. (1940) Classification of minerals of the type $A_3(XO_4)_2 \cdot nH_2O$. *American Mineralogist,* **25**, 738–754.

the Stoneham Barite Locality Colorado

Norman L. Bennett
5609 Pike Street
Golden, Colorado 80403

Known at least since the 1870s, the Stoneham barite locality has long been considered among the country's best barite occurrences. Superb blue crystals ranking with the best ever found were collected in May of last year.

LOCATION

The Stoneham deposit is located about 1 mile east and 3 miles north of the town of Stoneham, Weld County, Colorado (R56W, T8N, Sec. 16). Access is by paved road except for the final 3 miles, which are a well-maintained dirt road. The principal mineralized area covers about 20 acres, with the best collecting centered along the western edge. The dirt road passes directly in front of the property owner's home, where permission to collect must be obtained.

Early references commonly refer to the locality as Sterling, Colorado, but the town of Sterling is about 26 miles away, in Logan County. All such labels should be corrected to read Stoneham, Weld County.

HISTORY

The locality was apparently discovered in the middle 1870s; it is not mentioned in the fifth edition of Dana's *System* (1874), but was noted by Endlich (1878) in his annual report for the year 1876. Thorough descriptions have not been published, probably because the occurrence has never been commercially mined and has remained of significance to collectors only.

Since that time, the locality has remained famous as a source of fine blue barite crystals (Dana, 1892; Ellermeier, 1948; Eckel, 1961; Pearl, 1972). Over the past 25 years, it has been periodically closed to collectors, but the owners are currently granting permission provided that all workings are filled in before collectors leave the site.

In May of 1985, I visited the Stoneham locality with long-time Stoneham collectors Luke and Cathy Westervelt. During the course of 8 days, a major pocket of specimens was discovered and removed. Several of the best pieces are pictured here.

GEOLOGY

The Stoneham region consists predominantly of rocks of the Oligocene-age White River formation. Calcium-rich montmorillonite clays of the lower part of the formation are altered volcanic ash, and occur interbedded with barite-bearing shale, coarse sediments, and lenses of fresh-water limestone. Recent erosion has produced a badlands topography.

Barite was probably deposited by circulating groundwater and associated alteration of the volcanic ash. The blue color, commonly compared to that of aquamarine, is thought to be due to natural irradiation by trace elements.

Barite is found as loose crystals on the hill slopes, as cavity linings and as vein or fracture linings. Small, loose singles and fragments can be collected by the hundreds on the hillsides.

Along the western flank of the mineralized area, the silty white to tan clay layer which contains barite is overlain by 1 to 2 meters of sand, gravel and cobbles. Within the clay layer are calcite-barite seams following a joint system which dips at 15° to 45°. Pockets are found where the joints are most horizontal. These pockets are generally very tight, usually resulting in crystals which contact both the top and bottom faces of the seam. Careful collecting is therefore necessary. Pocket size reaches 2 to 5 meters.

MRL

Figure 1. **Stoneham barite crystal illustrated in R. Braun's *Das Mineralreich* (1903).**

Figure 2. **Excellent single crystal of blue barite, 2.3 cm wide, partially removed from an overgrowth of calcite. This and the other four specimens pictured here are from the 1985 find.**

Figure 3. **Lustrous, well-formed group of barite crystals 6 cm long.**

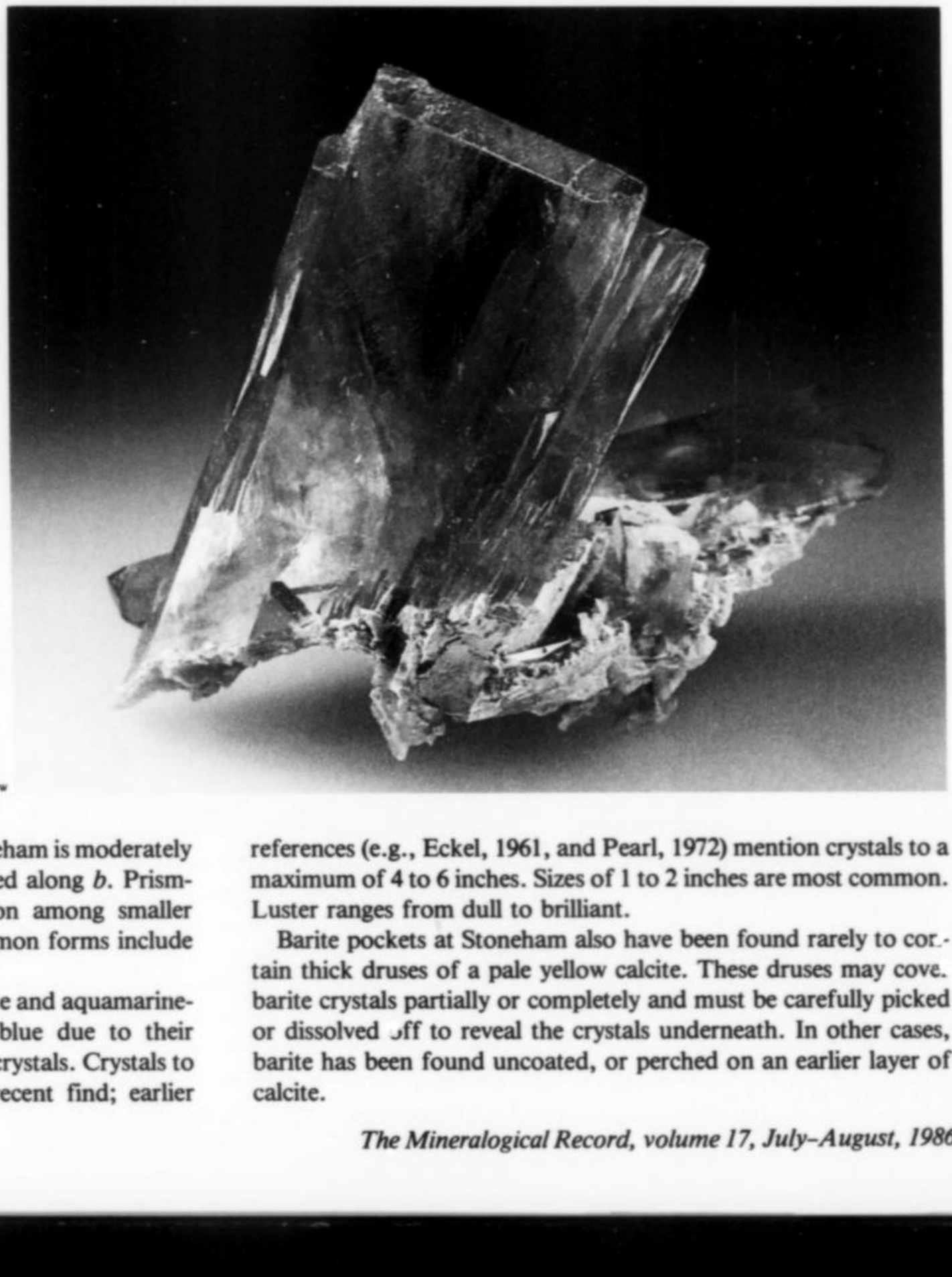


Figure 4. **Large, tabular crystal 6.8 cm long, perched on another crystal 8 cm long.**

BARITE

The most common barite crystal habit at Stoneham is moderately tabular on *c* with a rectangular outline elongated along *b*. Prism-like habits elongated on *b* are not uncommon among smaller crystals, but are rare in larger specimens. Common forms include *c*{001}, *d*{101}, *o*{011}, *m*{210} and *b*{010}.

Color ranges from nearly colorless to gray-blue and aquamarine-blue; larger crystals appear to be a deeper blue due to their thickness, and are less transparent than smaller crystals. Crystals to 16.5 cm (6½ inches) were recovered in the recent find; earlier references (e.g., Eckel, 1961, and Pearl, 1972) mention crystals to a maximum of 4 to 6 inches. Sizes of 1 to 2 inches are most common. Luster ranges from dull to brilliant.

Barite pockets at Stoneham also have been found rarely to contain thick druses of a pale yellow calcite. These druses may cover barite crystals partially or completely and must be carefully picked or dissolved off to reveal the crystals underneath. In other cases, barite has been found uncoated, or perched on an earlier layer of calcite.

Figure 5. **Superb barite crystal group 11.5 cm (4.5 inches) long.**

Figure 6. **Barite group, 9 cm tall, partially coated with pale yellow calcite crystals.**

Barite "roses" or rosettes also occur in the area, generally on the upper slopes of the bluffs a short distance below the top of the escarpment (Cook, 1952; Ellermeier, 1948). The rosettes are the same blue color as the single crystals commonly found but tend to be opaque. Opal, which fluoresces green, and delicate crystals of golden barite (Pearl, 1972), and yellow-green barite (Eklund, 1965) have also been found.

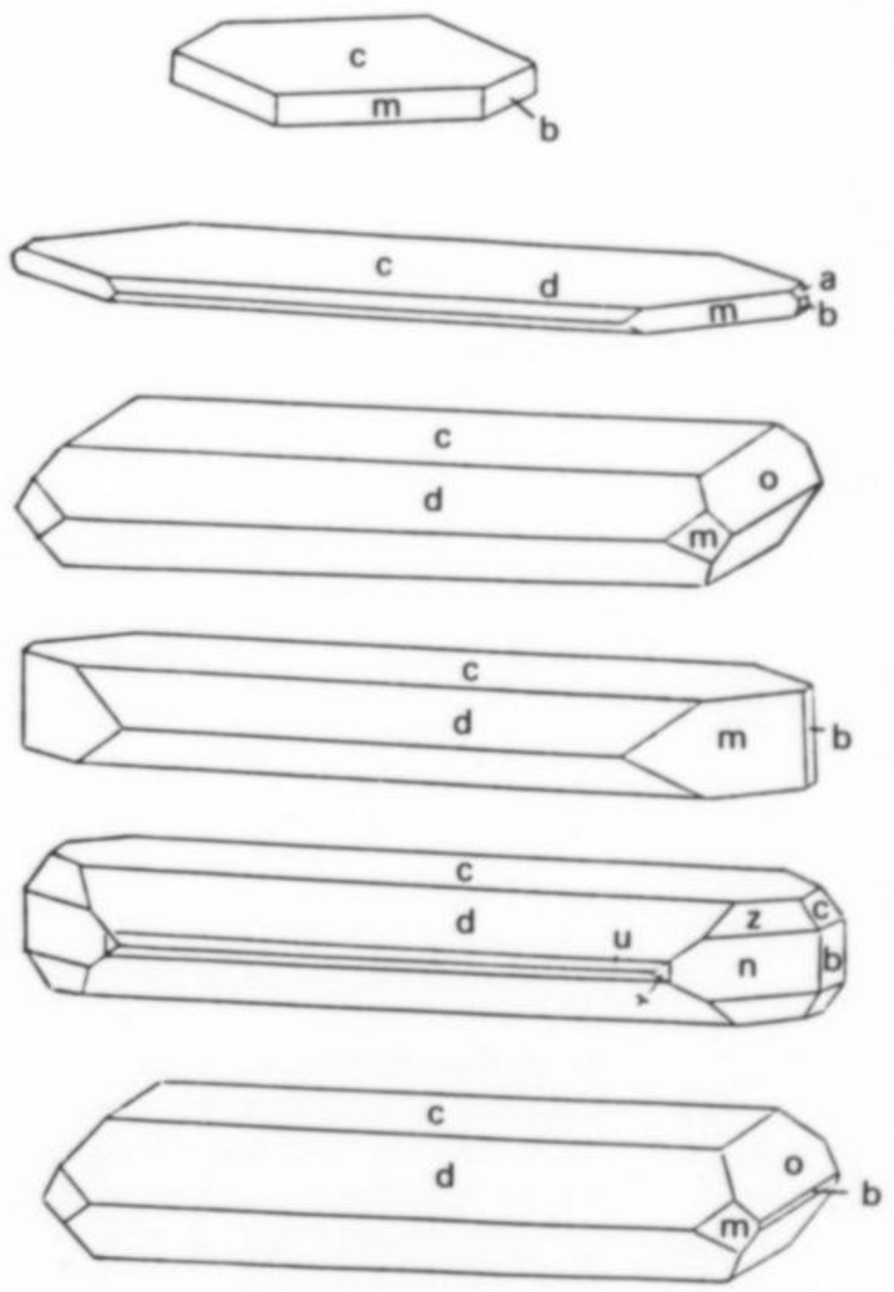


Figure 7. **Barite crystal habits from Stoneham (Workman, 1964).**

Figure 8. **Two pockets in the calcite seam; a pinched out zone separates them.**

Figure 9. **Excavations in the main pocket area.**

CONCLUSION

Stoneham has long been a heavily collected area. Nevertheless, the barite mineralization is sufficiently extensive that much virgin ground remains. Significant finds will probably continue to be made for many years, provided that collectors maintain a good relationship with the property owner.

BIBLIOGRAPHY

COOK, M. R. (1952) Colorado barite. *The Mineralogist,* **20**, 364.

DANA, E. S. (1892) *The System of Mineralogy of James Dwight Dana.* Sixth edition, John Wiley, New York, 904.

DANA, J. D. (1874) *A System of Mineralogy.* Fifth edition, John Wiley, New York, 827 p.

ECKEL, E. B. (1961) Minerals of Colorado; a 100-year record. *U.S. Geological Survey Bulletin,* **1114**, 28, 65–66.

EKLUND, R. E. Jr. (1965) Blue barite in Colorado! *Rocks and Minerals,* **40**, 538–539.

ELLERMEIER, G. B. (1948) Blue barite near Sterling, Colorado. *Rocks and Minerals,* **23**, 21.

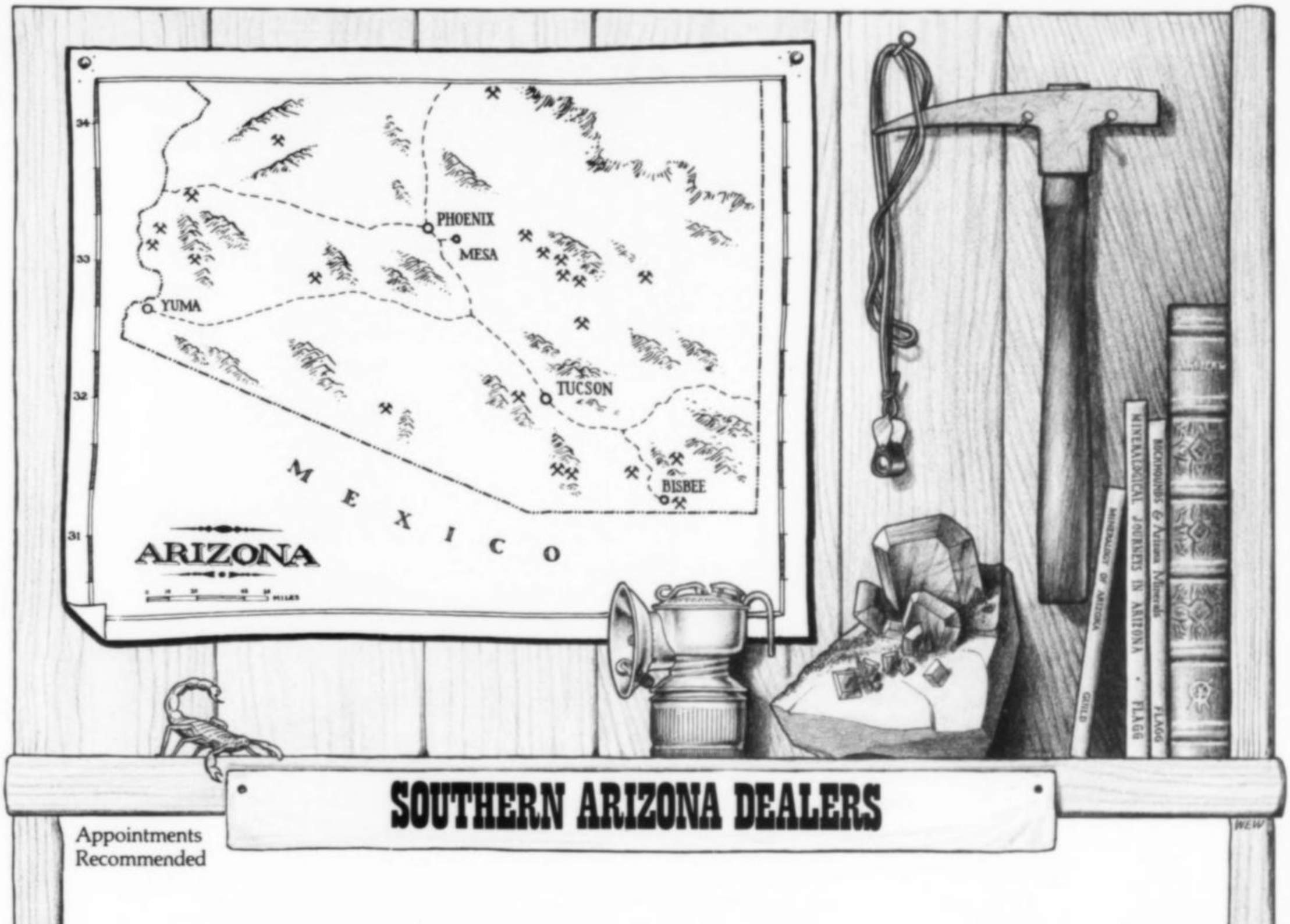
ENDLICH, F. M. (1878) Mineralogical Report: Hayden Survey, 10th Annual Report 1876, 133–159.

LAWLER, T. E. (1923) On the occurrence of sandstone dikes and chalcedony veins in the White River Oligocene. *American Journal of Science,* **5**.

PEARL, R. M. (1972) *Colorado Gem Trails and Mineral Guide.* Sage Books, Chicago, 220–222.

SINKANKAS, J. (1959) *Gemstones of North America.* Vol. **1**, Van Nostrand Reinhold, New York, 490.

WORKMAN, W. E. (1964) Barite from the White River formation of northeastern Colorado. University of Virginia Masters Thesis.



SOUTHERN ARIZONA DEALERS

Appointments
Recommended

Bitner's, Inc.
42 West Hatcher
Phoenix, Arizona 85021
(602) 870-0075

Cureton Mineral Company
Forrest & Barbara Cureton
P.O. Box 5761
Tucson, Arizona 85703
(602) 743-7239

De Natura
Les & Paula Presmyk
P.O. Box 2512
Mesa, Arizona 85204
(602) 830-1406

Kino Rocks & Minerals
6756 S. Nogales Highway
Tucson, Arizona 85706
9-11:15/Noon-5:30 (Closed Sun.)
(602) 294-0143

Michels Minerals
Harold & Wilma Michel
1030 W. Tenth Street
Mesa, Arizona 85201
(602) 969-0105

David Riley Minerals
529 W. Pepper Place
Mesa, Arizona 85201
(602) 898-0740

David Shannon Minerals
David, Colleen & Mike
1727 W. Drake Circle
Mesa, Arizona 85202
(602) 962-6485

Maudine & Bob Sullivan
Geological Specimens Int'l.
3202 Saguaro West Trail
Tucson, Arizona 85745
(602) 743-0081
See us at the major shows only

BACK ISSUES!

Mineralogical Record

Vol.	#1	#2	#3	#4	#5	#6
1		$17	$17	$17		
2						
3			$17	$17	$17	$17
4						
5		$17			$17	
6	$17					
7						$175
8					$7	$7
9		$7	$7	$7	$7	$7
10	$7	$7	$7	$7	$17	$7
11	$7	$17			$7	$7
12	$7	$7	$7	$7		$7
13		$7	$7			
14	$7	$17	$7	$7	$17	
15				$7		
16	$9	$7	$9	$7	$12	$10
17	$12	$10	$9	$9		
	#1	#2	#3	#4	#5	#6

Quantities limited.
Order from: **Mineralogical Record**
P.O. Box 35565
Tucson, AZ 85715

Postpaid price per issue is shown

Mineralogical Record

Show Schedule

Reno, NV	July 12-13
IMA Stanford, CA	July 15-18
Houston, TX	Aug. 5-7
Seton Hall, NJ	Aug. 16-17
Waverly, Austraila	Aug. 29-31
Denver, CO	Sept. 12-14
Hague, Netherlands	Sept. 20-21
FM Pacific-NW Symp.	Sept. 26-28
Breda, Netherlands	Oct. 5
Milano, Italy	Oct. 4-5
Turino, Italy	Oct. 10-12
Detroit, MI	Oct. 10-12
Adelaide, Australia	Oct. 18-19
Munich, W.G.	Oct. 17-19
Pasadena, CA	Nov. 1-2
Phoenix, AZ (R.M. Fed.)	Nov. 21-23
Amsterdam, Netherlands	Nov. 29-30
Paris PLM, France	Nov. 29-30

MAGAZINES! *See Us There!* BOOKS!

LYON MINERAL & GEM SHOW
November 7-8-9, 1986

11th ANNUAL

"Palais des Congres de Lyon"

The Best Show in France
The Best Dealers
The Best Quality
The Best Programs

Best of Species Competitions
in:
Copper Minerals
Gold

A total of 10,000 francs in Prizes!

the Buca della Vena mine Tuscany, Italy

Paolo Orlandi
Department of Earth Science
Pisa University
Via S. Maria 53
56100 Pisa, Italy

Francesco Checchi
Via Valle Cava, 48
Massarosa
Lucca, Italy

The Buca della Vena mine has recently become well-known among Italian mineralogists and collectors as the type locality for apuanite and versiliaite. Several other rare and interesting species are found there as well.

INTRODUCTION

This article arose from a common interest the authors have shared in the Buca della Vena mine over a number of years. In 1976 F. Checchi, at that time a final-year student in geology, was the first to bring samples from the mine dump to the University of Pisa for identification. These had been collected as part of his thesis research dealing with geological prospecting. It was for P. Orlandi, then Curator of Minerals, the first contact with Buca della Vena minerals and the beginning of a series of studies (with S. Merlino and M. Mellini). As a result, two new species, apuanite and versiliaite, were characterized (Mellini *et al.,* 1979), and several other very rare minerals were identified including derbylite and stibivanite.

The Buca della Vena mine (formerly known only as a small iron and barite deposit) has since become a popular collecting site among local mineralogists and mineral collectors.

LOCATION

The mine is situated on the north slope of Mount Stazzema in Tuscany, Italy. Access is from the town of Pietrasanta on the Pietrasanta-Castelnuovo Garfagnana Road. Four kilometers past the village of Seravezza is a junction, in one direction leading to Stazzema-Ponte Stazzemese; from this village, it is 1 km on the road to Cardoso, then a right turn onto a small road closed by a gate. The mine is a 20-minute hike from the gate.

HISTORY

The iron deposit was worked intermittently from Roman times up until the eighteenth century, when B. Paci reopened it on a more continuous basis. From that time until World War II, the iron produced was used locally by various craftsmen and blacksmiths. In 1948, the Society Nuovo Pignone began a more commercial exploitation of the iron. In 1960 the Sima society began quarrying barite there for use in oil well drilling. Recent production from the mine has been used extensively in the construction of the Enel nuclear power plant. Fifteen miners are currently employed at the mine.

GEOLOGY

The Buca della Vena mine is located in the southern part of the Apuan Alps tectonic "window"; here the metamorphic units of the Apuan massif include rocks dated from Paleozoic to Oligocene, which crop out below the unmetamorphosed Tuscan Nappe and Liguride sequences.

The metamorphic basement, containing pre-Alpine deformation fabrics, is represented by phyllites and lenses of Silurian black shale and dolomite. This basement is unconformably overlain by the Permo-Triassic "verrucano" consisting of a volcanoclastic sequence, quartzitic sandstone and conglomerate, followed by a Mesozoic calcareous sequence. This latter sequence includes the Marmo formation wherein are located the famous Carrara marble quarries. A deposit of Oligocene flysh concludes the Alpine sediments.

In the metamorphic sequence two tectonic units, the Autoctone and the Massa, have been recognized (Carmignani *et al.,* 1978). The Autoctone unit is the most important, comprising the core of the Apuan massif. It is considered to be the lowermost outcrop (i.e., "window") in the entire northern Appenine Mountain belt. The

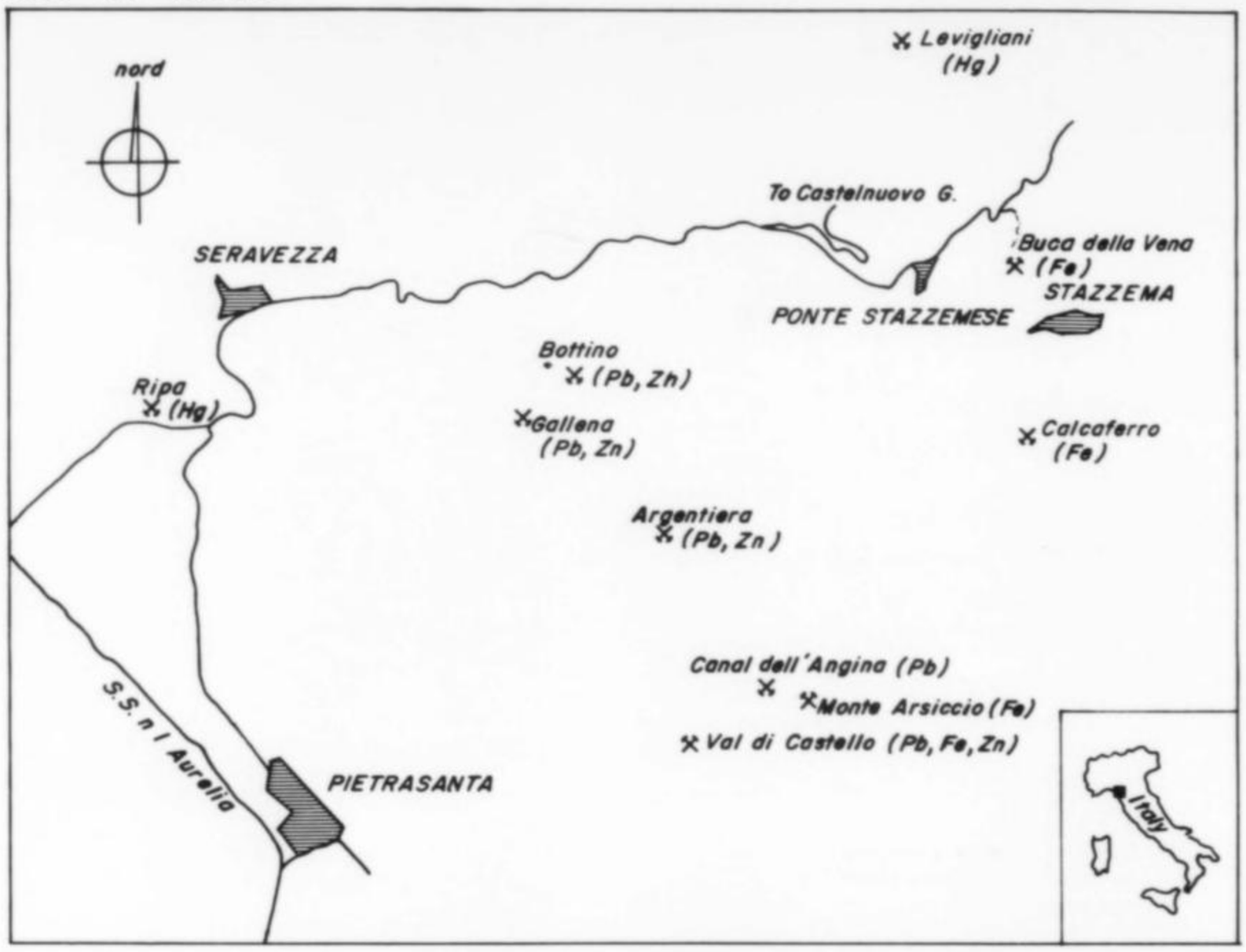


Figure 1. **Location map showing the Buca della Vena and surrounding mines, Apuan Alps, northern Tuscany, Italy.**

Figure 2. **Miners employed at Buca della Vena. All photos by P. Orlandi.**

Massa unit, originally a shallow marine sequence of middle and upper Triassic age, crops out in the western area of the window between the Autoctone rocks and the Tuscan Nappe.

In the southern part of the Apuan massif, in the Stazzema area, a number of "tectonic wedges" crop out, and in these wedges are located many of the most important ore deposits of the Apuan Alps. Unfortunately, the geological nature of these wedges has yet to be fully clarified. For a more thorough treatment of the problem, the reader is referred to the studied by Carmignani *et al.* (1978) and Ciarapica and Passeri (1982).

The ore deposit at Buca della Vena is located in the lowermost wedge formed by two carbonate lenses (dolomite and marble) interbedded with lenses of phyllite. Its top is cut by a tectonic breccia. Mineralization consists of a fine-grained mixture of barite and iron oxides, except at the contact between phyllite and iron oxides where replacement by pyrite has taken place. Carmignani *et al.* (1976) and Checchi (1978) considered the deposit to be a metasomatic replacement of carbonate rocks. The lower of the two calcareous lenses, almost entirely replaced by barite, iron oxides and pyrite, has produced most of the ore. The upper lens is less extensively replaced and has been worked only rarely. Spheroidal relics of unaltered carbonate rock, from a few centimeters to several meters in diameter, are encountered frequently. Small amounts of granular pyrite have been found in the phyllite but have never been mined.

Recently, Cortecci *et al.* (1984), on the basis of sulfur isotope analysis of barite and sulfides, concluded that the deposit is sedimentary in origin.

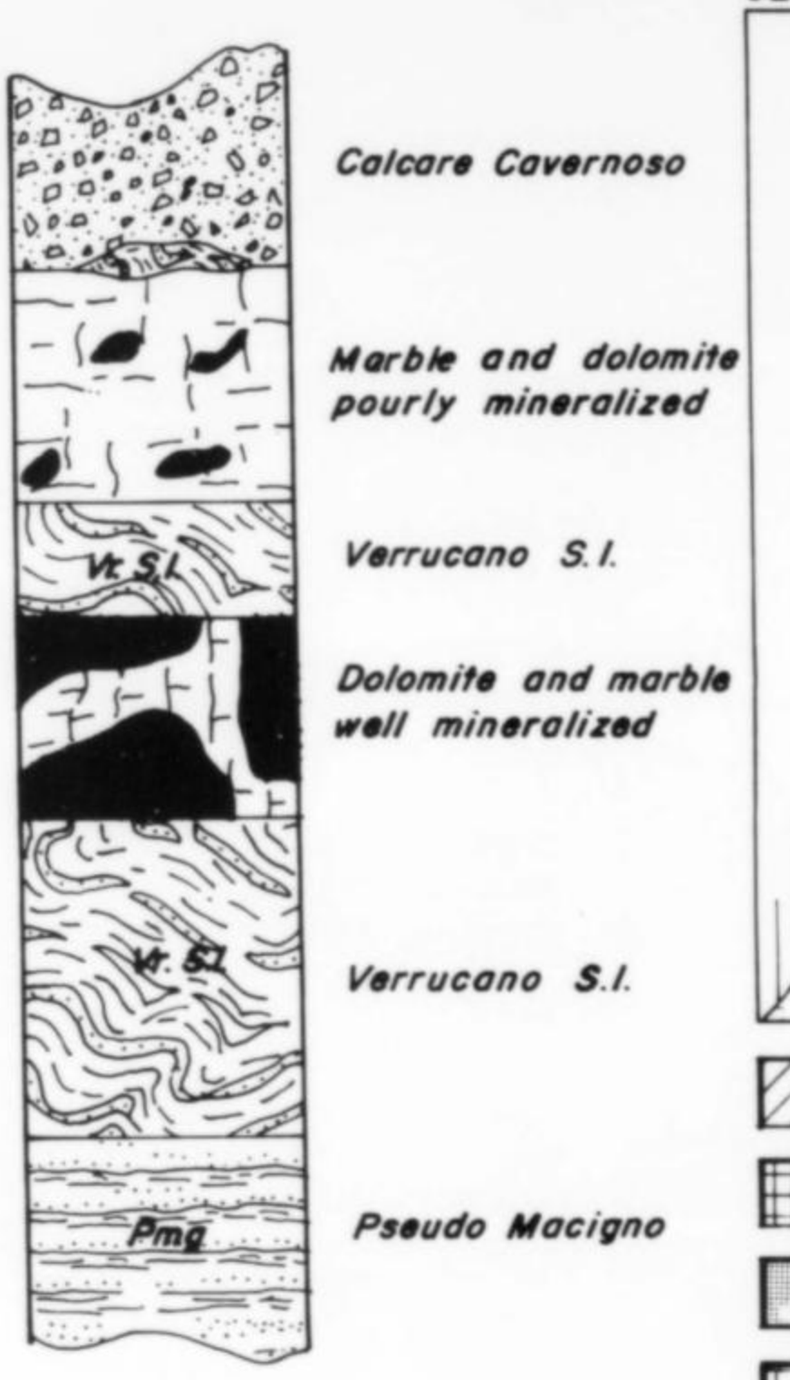


Figure 3. **Relationships between the rock units of the mine area.**

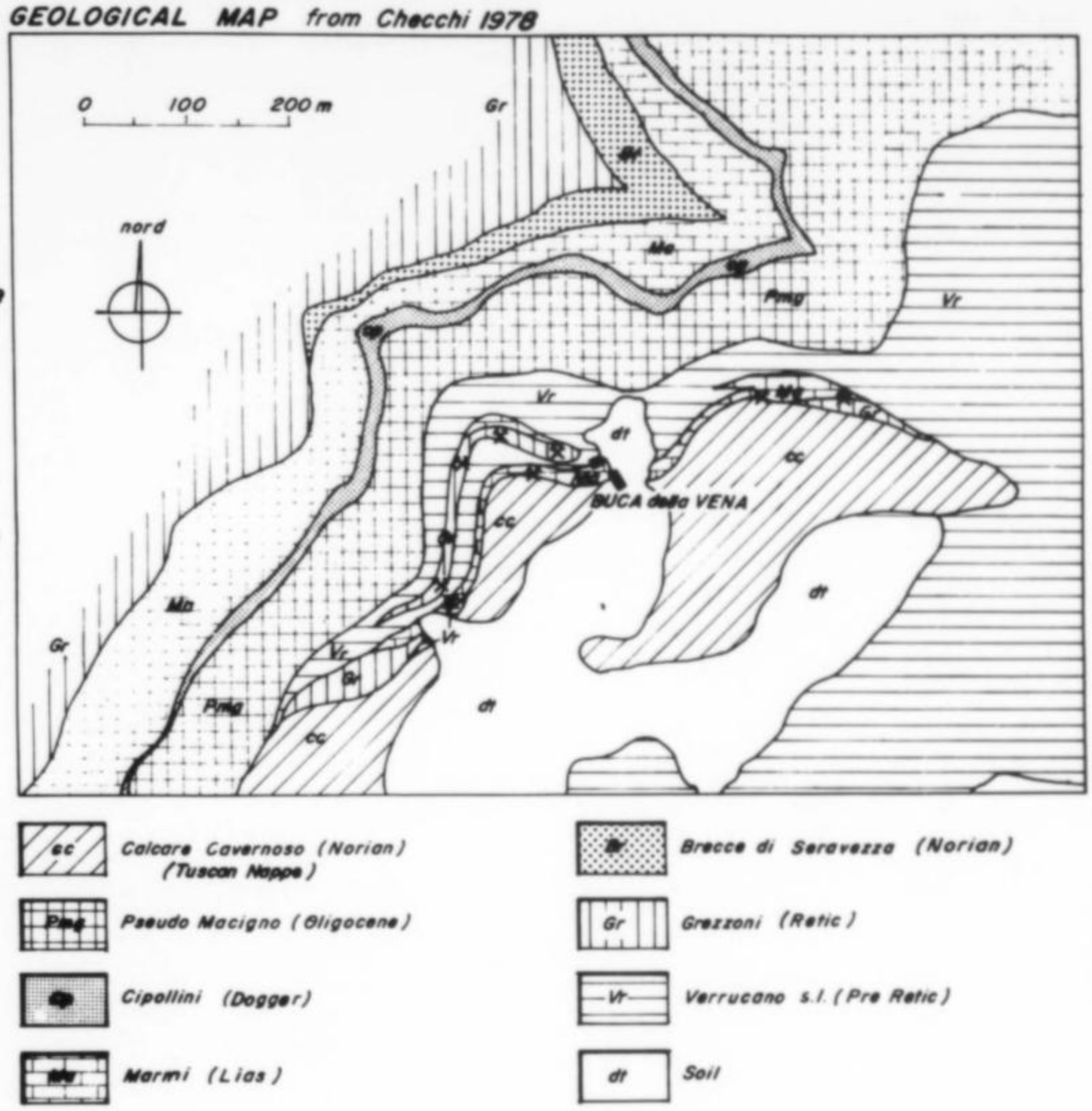


Figure 4. **Geologic map (from Checchi, 1978).**

Figure 5. **Entrance to the mine.**

MINERALS

The minerals listed below were identified by X-ray analysis (Burger, Weissenberg and Gandolfi methods) and optical study. In addition, qualitative chemical analyses by X-ray fluorescence and by SEM/EDS have been employed where necessary.

Albite $NaAlSi_3O_8$

Albite occurs within the dolomite matrix but close to the contact with ore.

Allanite $(Ce,Ca,Y)_2(Al,Fe^{+3})_3(SiO_4)_3(OH)$

Allanite occurs as well-developed, prismatic, black crystals rarely exceeding 2 mm in narrow barite veins.

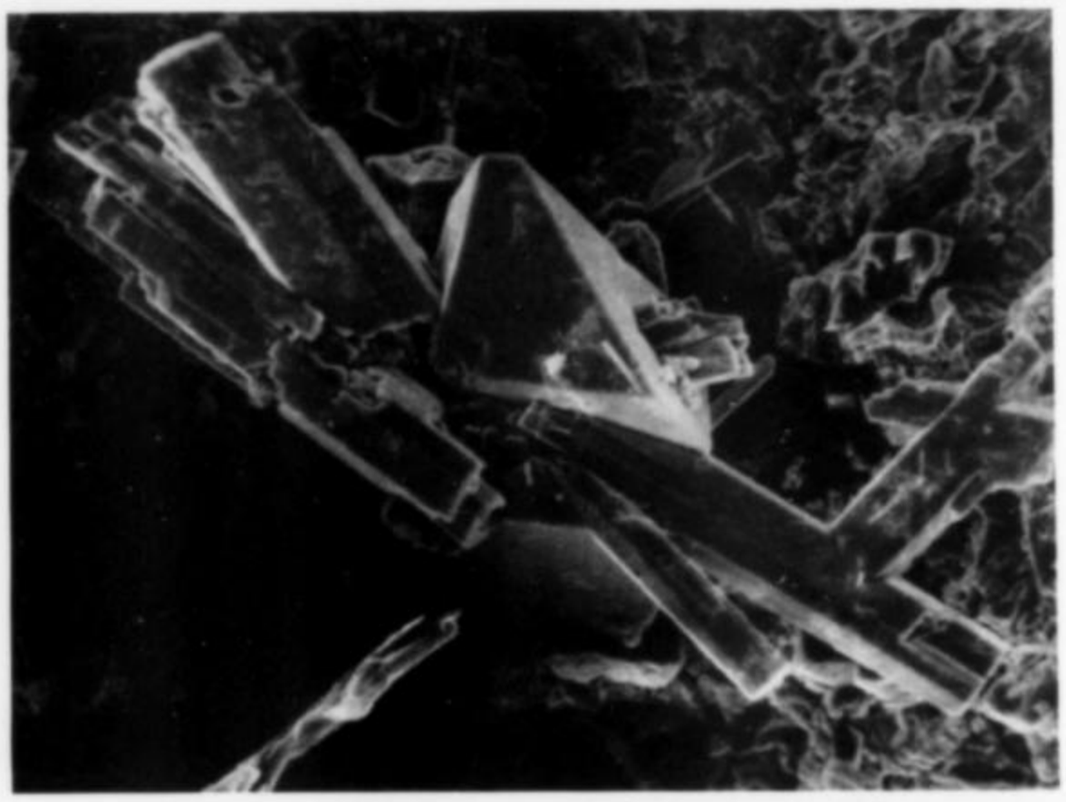


Figure 6. **Prismatic, vanadium-rich derbylite with dipyramidal anatase (SEM photo, 400 X).**

Anatase TiO_2

Two habits of anatase occur at Buca della Vena. One is characterized by the form {111}, in small (1–2 mm) brown crystals in cavities in dolomite. The other is characterized by {113} in black crystals in small cavities associated with vanadium-rich derbylite, stibivanite and vanadinite.

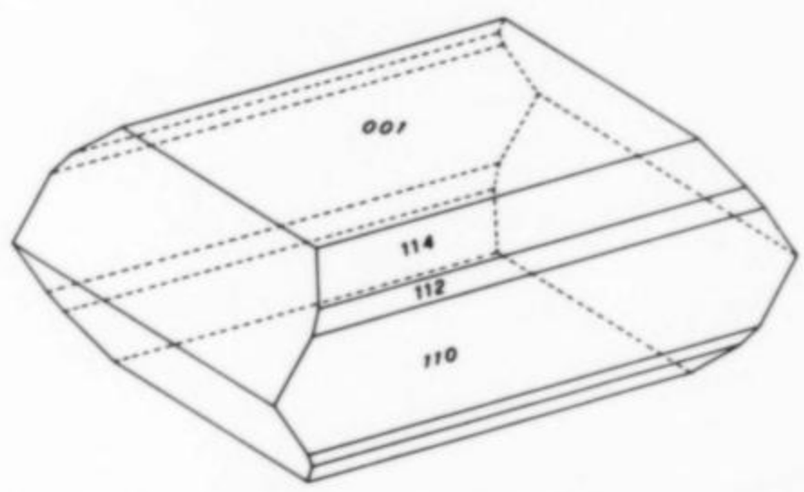


Figure 7. **Apuanite crystal, idealized (Mellini *et al.*, 1979).**

Apuanite $Fe^{+2}Fe_4^{+3}Sb_4^{+3}O_{12}S$

At present, the Buca della Vena mine is the only known occurrence of apuanite. Apuanite and versiliaite were described as new species from there by Mellini *et al.* in 1979. The mineral occurs disseminated as aggregates of crude microcrystals filling fractures and cavities in dolomite. Some of these aggregates exceed 5 cm in diameter. Single crystals are black with a metallic luster; they are prismatic in habit, consisting of the forms {001}, {110}, {112} and {114}. A few very rare crystals have been found to exceed 1 cm in size. Apuanite is more abundant than either versiliaite or schafarzikite.

Barite $BaSO_4$

Barite is a principal constituent of the mineralization. It occurs as microcrystalline to saccharoidal masses and rarely as distinct, tabular, secondary crystals in dolomite cavities and veins.

Beryl $Be_3Al_2Si_6O_{18}$

Gemmy, prismatic, emerald-green crystals up to 2 cm in size have been found in veins in barite and dolomite. Single crystals and vein fillings have also been found near the (verrucano) schist. Associations commonly include pyrite and tetrahedrite.

Figure 8. **Intergrown crystals of apuanite (SEM photo, 50 X).**

Figure 9. **Aquamarine beryl in prismatic crystals with quartz and hematite. Field of view: 5 mm. Marco Baldi collection.**

Blue-green crystals, perfectly transparent and measuring 3 mm long by 1–2 mm in diameter, occur in small cavities in massive magnetite-hematite.

Bournonite $PbCuSbS_3$
Seligmannite $PbCuAsS_3$

Crystals in the bournonite-seligmannite series occur as prisms to 2 cm, in some cases covered by a green malachite crust. Irregular sphalerite-rich nodules have also been found.

Figure 10. **Prismatic emerald-green beryl with pyrite in a barite vein. Field of view: 3 cm.**

Calcite $CaCO_3$

Milky rhombohedral to scalenohedral crystals of calcite occur in cavities in dolomite.

Chalcostibite $CuSbS_2$

Only a single, elongated, tabular, millimeter-size crystal of chalcostibite has been found, in a small cavity in a dolomite vein.

Cinnabar HgS

Cinnabar is very rare at Buca della Vena, usually associated with tetrahedrite in veins of secondary dolomite.

Chlorite group

Platy crystals of chlorite occur in dolomite and as vermicular aggregates of thin, green, tabular crystals in cavities.

Derbylite $Fe_4^{+3}Ti_3Sb^{+3}O_{13}(OH)$

Derbylite is very rare at Buca della Vena (Mellini *et al.,* 1983). It occurs as lustrous, metallic, black crystals with striated faces, in secondary barite-dolomite veins. Crystals reach 2 mm in size; trilling twins are common.

Recently, vanadium-rich and arsenic-rich varieties of derbylite have been found. The vanadium-rich crystals are acicular-prismatic, very small («1 mm), and always associated with black pyramidal crystals of anatase in cavities lined with black dolomite crystals.

Dolomite $CaMg(CO_3)_2$

Clear, rhombohedral dolomite crystals 2–3 cm on an edge occur in veins and cavities in dolomitic rocks.

Hematite Fe_2O_3

Hematite is a major constituent of the replacement bodies. It occurs as microcrystalline lamellae and large (to 1 cm on edge) rhombohedral crystals in secondary veins in dolomite.

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

Magnetite occurs as granular, microcrystalline lenses and irregular masses chaotically associated with irregular blocks of dolomite. Single crystals have been found in secondary veins in dolomite and barite.

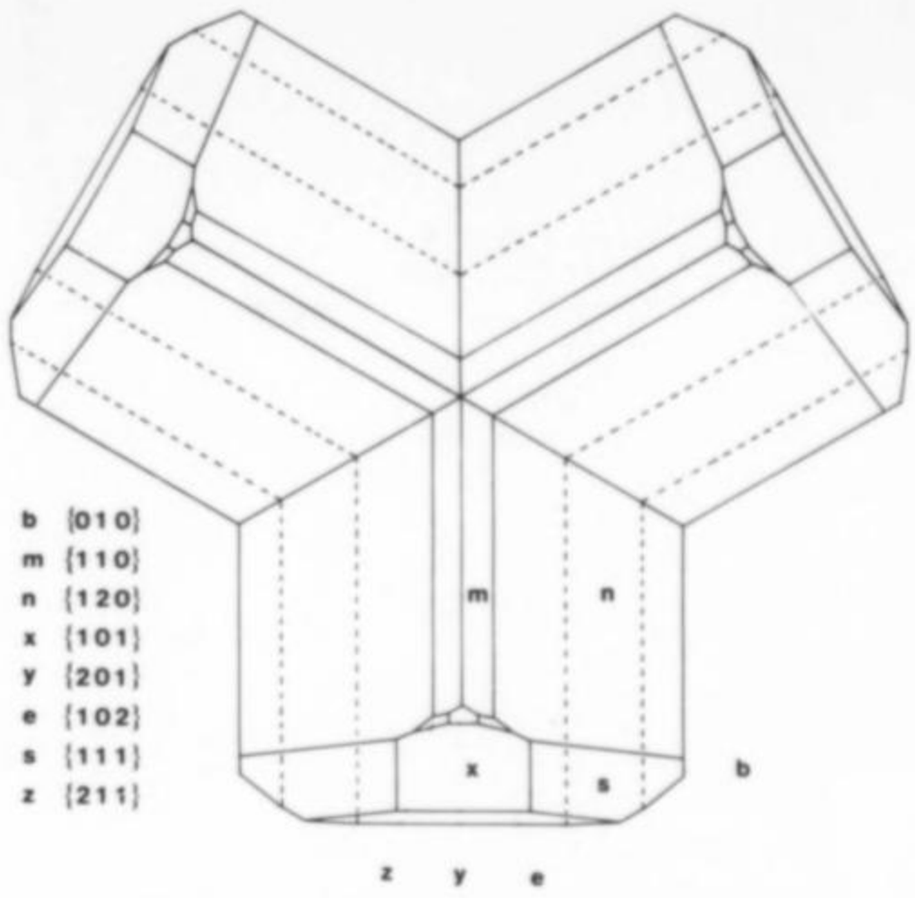


Figure 11. **Derbylite: idealized drawing showing typical trilling twin.**

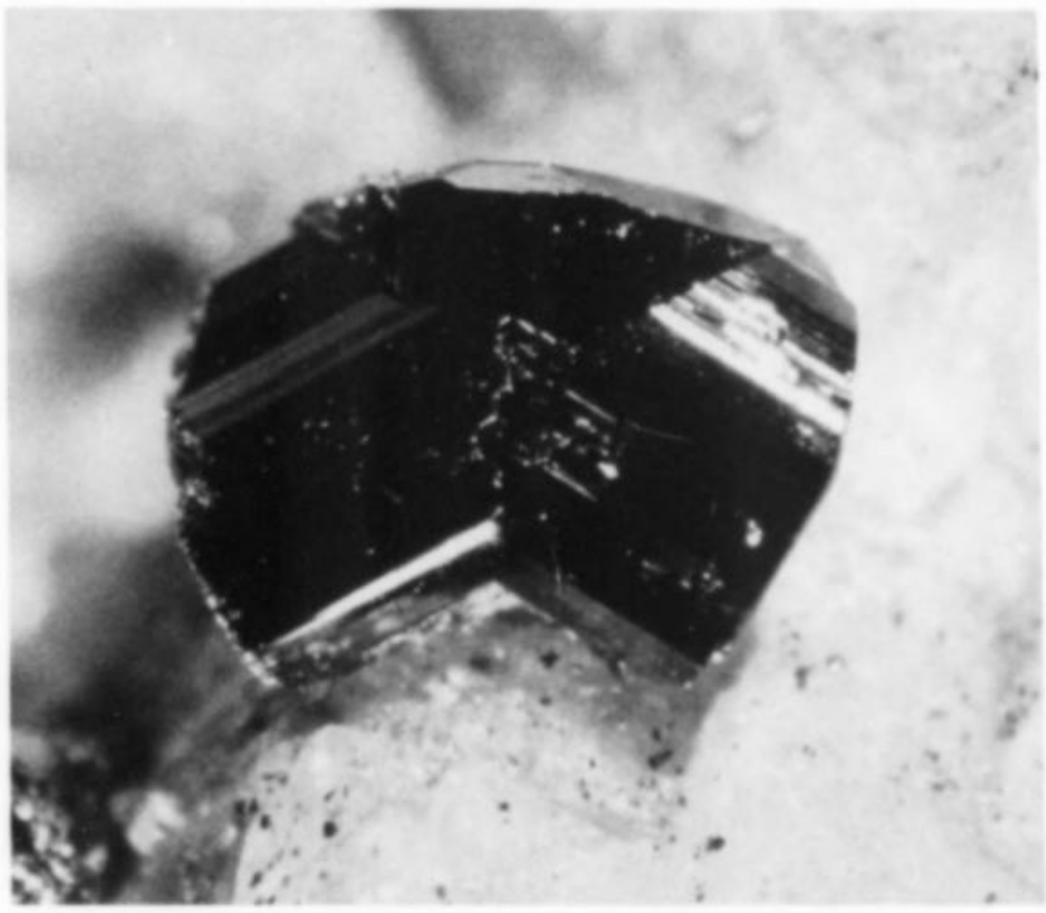


Figure 12. **Superb, 1.5-mm derbylite crystal. University of Pisa collection.**

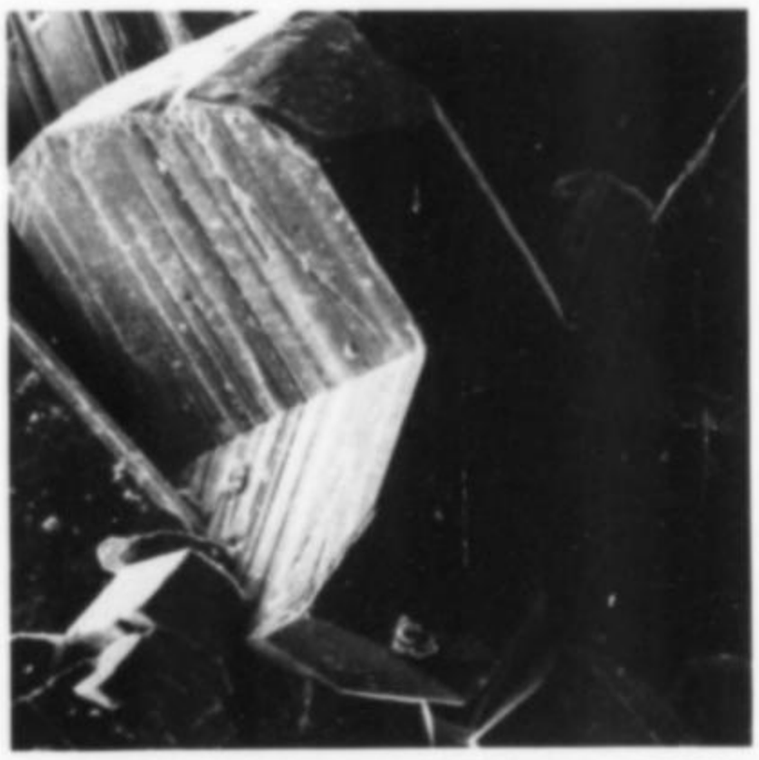


Figure 13. **Derbylite twin (SEM photo, 150 X). Riccardo Mazzanti collection.**

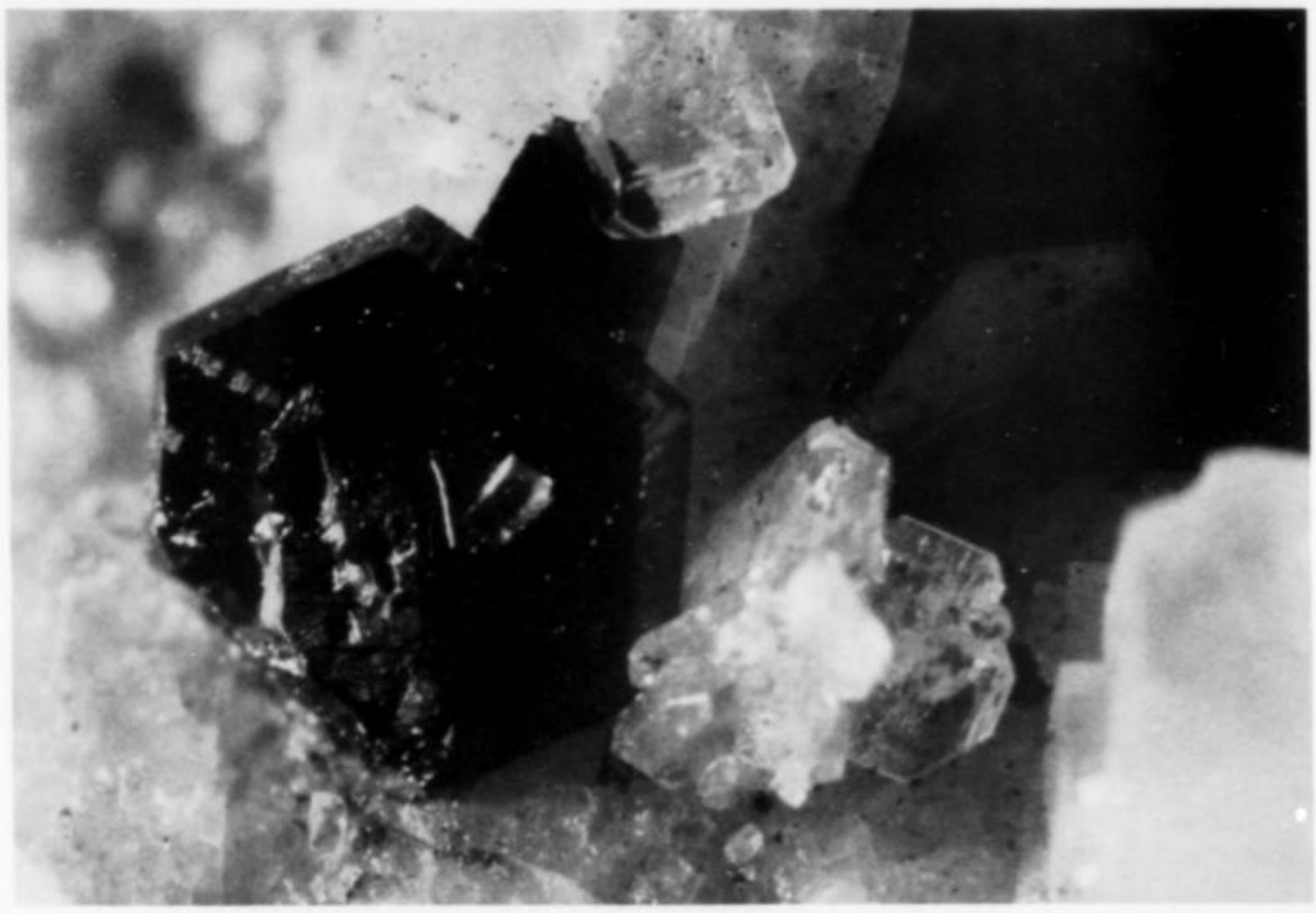


Figure 14. **Flattened, rhombohedral hematite crystal 0.5 mm on edge.**

Figure 15. **Octahedral magnetite crystal in a vein with barite and dolomite. Field of view: 1 cm.**

Malachite $Cu_2(CO_3)(OH)_2$

Malachite occurs as disseminated or spherical aggregates of acicular crystals on bournonite and tetrahedrite crystals.

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

"Phengite," a silica-rich variety of muscovite, occurs associated with albite and chlorite in dolomite near the contact with replacement bodies.

Pyrite FeS_2

Pyrite is the most abundant sulfide in the deposit. With barite, it forms microcrystalline lenses near the schist contact. Sporadic well-formed crystals (pyritohedrons) occur in cavities and in massive dolomite and calcite.

Quartz SiO_2

Rare, small, prismatic crystals occur associated with calcite and dolomite.

Rutile TiO_2

Rare, black, prismatic crystals of rutile occur in cavities in dolomite and marble.

Schafarzikite $Fe^{+2}Sb_2^{+3}O_4$

Scharfarzikite is particularly rare at Buca della Vena, rarer than versiliaite and much rarer than apuanite. Of the three species, schafarzikite has the dullest luster.

Siderite $Fe^{+2}CO_3$

Siderite forms veins in the iron ore and also occurs as well-developed crystals in secondary veins in dolomite.

Spessartine $Mn_3Al_2(SiO_4)_3$

Spessartine occurs as millimeter-size, orange-brown, trapezohedral crystals in marble.

Sphalerite (Zn,Fe)S

Sphalerite is generally found as rare anhedral individuals in ore, with small pyrite crystals associated. Rare, honey-yellow, tetrahedral crystals occur in cavities in dolomite, and tiny, ruby-red crystals have been observed with altered aggregates of apuanite.

Stibivanite $Sb_2^{+3}V^{+4}O_5$

Stibivanite is extremely rare, forming as a green felt of acicular crystals in cavities in pinkish dolomite. The largest crystal seen measures more than 3 mm; most are much smaller (Merlino and Orlandi, 1983).

Stibnite Sb_2S_3

Metallic, gray, prismatic, striated crystals of stibnite occur associated with hematite in dolomite veins.

Stolzite $PbWO_4$

We have observed only three crystals of stolzite since beginning this study. They are yellow-brown with typical resinous luster and occur associated with hematite in veins.

Tetrahedrite $(Cu,Fe)_{12}Sb_4S_{13}$
Tennantite $(Cu,Fe)_{12}As_4S_{13}$

Tetrahedrite-tennantite occurs associated with beryl and pyrite as lustrous black crystals in cavities in dolomite. The habit consists of a very large number of small faces of different forms.

Vanadinite $Pb_5(VO_4)_3Cl$

Small («1 mm), lustrous, yellow, prismatic crystals of vanadinite occur with aggregates of altered apuanite.

Versiliaite $Fe_2^{+2}Fe_4^{+3}Sb_6^{+3}O_{16}S$

Buca della Vena is the type locality for versiliaite. The mineral is very rare and occurs intimately associated with the much more

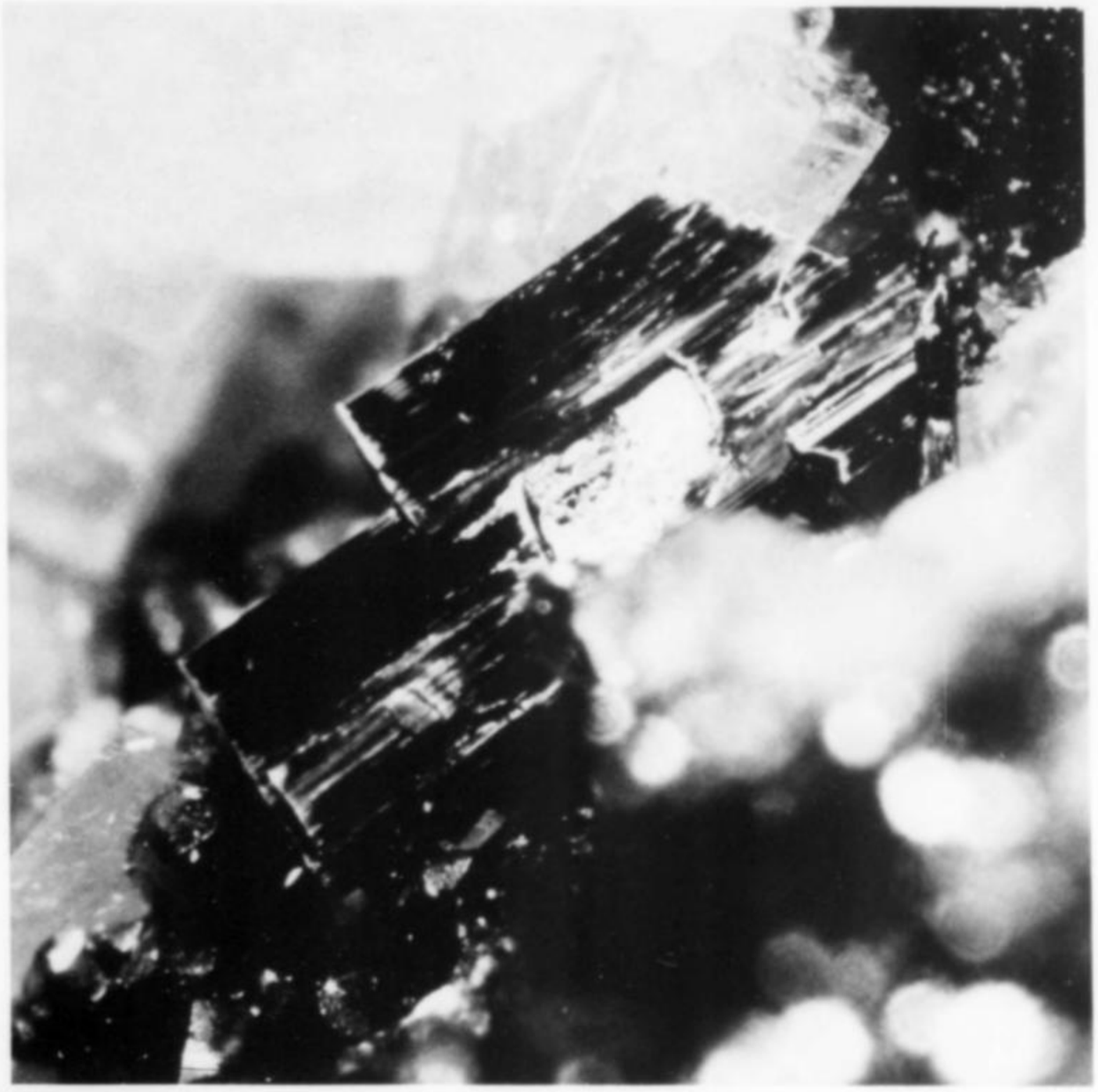


Figure 16. **Superb platy, green stibivanite crystal, 3 mm across. Pierluigi Pierotti collection.**

Figure 17. **Prismatic vanadinite crystals with anatase (SEM photo, 240 X).**

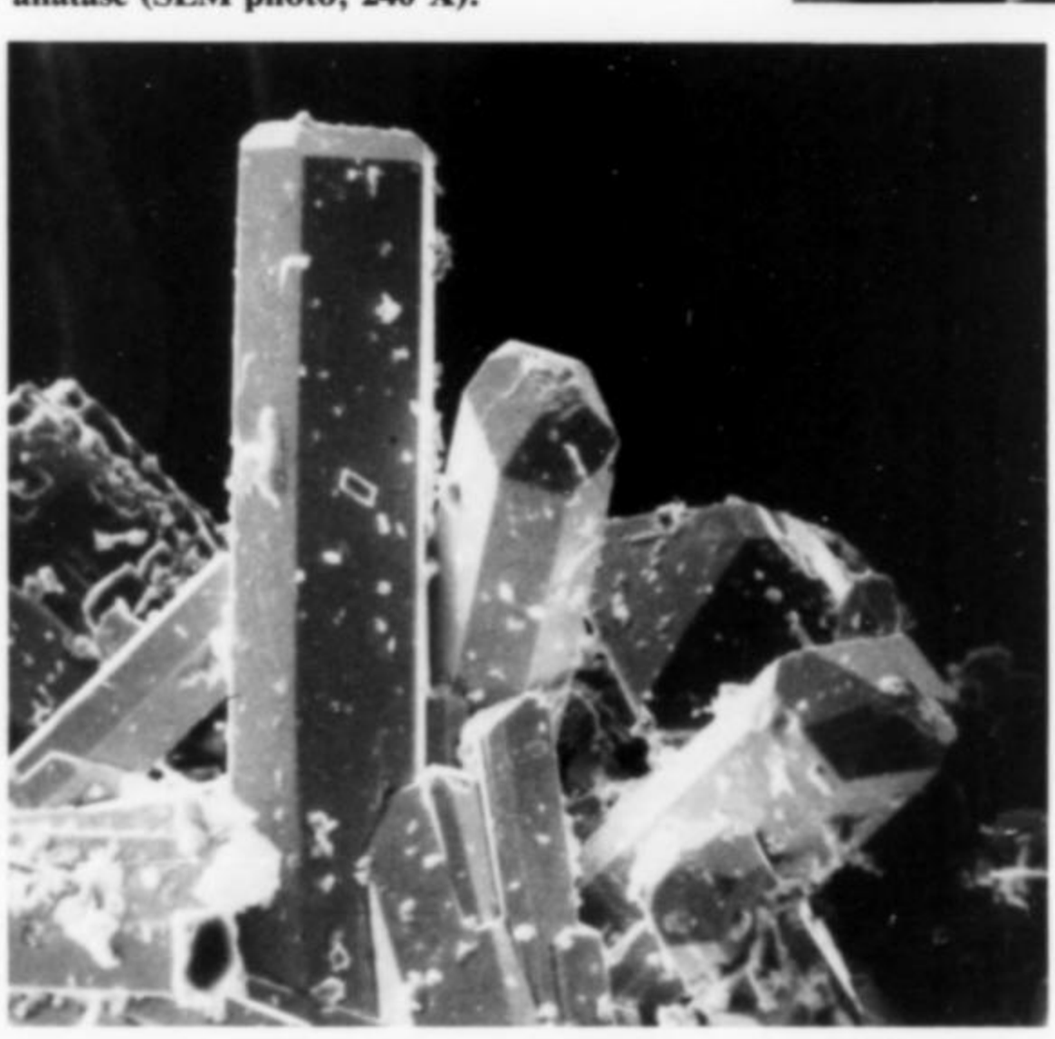


Figure 18. **Large crystal of versiliaite, 5 mm on edge. Checchi collection.**

abundant apuanite. A TEM study (Mellini *et al.*, 1981) has shown versiliaite, apuanite and schafarzikite intergrown down to the unit cell scale.

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

Small, millimeter-size aggregates of granular, apple-green vivianite crystals occur associated with hematite and sphalerite.

Acicular Unknowns

Two different (new?) species, occurring in platy-acicular, metallic, black crystals, have been under preliminary X-ray study. A qualitative SEM/EDS analysis revealed the presence of Sb, Pb and S in both phases. A full description is in preparation.

PARAGENESIS

All of the minerals described here were collected mostly from the dump. However, a careful study of the interior surfaces of the mine itself has helped to deduce the original location of the various species.

Minerals of the schafarzikite group appear to have occupied a very restricted area near the zone where the upper verrucano lens becomes thinner and the two carbonate lenses come in close contact. Of the three minerals, schafarzikite contains Fe^{+2} only, whereas the others contain Fe^{+2} and Fe^{+3}. The Fe^{+3}/Fe^{+2} ratio of apuanite exceeds that of versiliaite. These minerals are very well-crystallized in veins and in massive carbonate rock. Therefore, we think that the conclusions drawn by Carmignani *et al.* (1976) re-

garding siderite, magnetite and hematite are relevant to the schafarzikite group as well. Carmignani *et al.* observed siderite in the nucleus of magnetite crystals, and hematite along fractures in magnetite, suggesting the sequence of formation/alteration: siderite → magnetite → hematite (i.e., $Fe^{+2} \rightarrow (Fe^{+2} + Fe^{+3}) \rightarrow Fe^{+3}$). We think the sequence schafarzikite → versiliaite → apuanite took place in parallel, as a function of the iron oxidation state in these minerals.

Beryl and allanite, normally found in pegmatites, occur at Buca della Vena in veins and along the contacts surrounding carbonate relics in the lower ore lens. Rare titanium and vanadium minerals have also been observed, suggesting that fluids responsible for replacement of the carbonate lenses leached Be, Ti and V (originally present only to traces in the carbonate rocks) and precipitated the rare minerals. A detailed study of the paragenetic interrelationships of *all* species at Buca della Vena might allow an expansion of the genetic model of Carmignani *et al.* (1976).

REFERENCES

CARMIGNANI, L., DESSAU, G., and DUCHI, G. (1976) I giacimenti a barite ed ossidi di ferro delle Alpi Apuane, Studio minerogenetico e strutturale. Nuove osservazioni sui giacimenti polimetallici. *Bollettino Societá Geologica Italiana,* **95**, 1009–1061.

CARMIGNANI, L., GIGLIA, G., and KLIGFIELD, R. (1978) Structural evolution of the Apuan Alps: An example of continental margin deformation in the northern Apennines, Italy. *Journal of Geology,* **86**, 487–504.

CIARAPICA, G., and PASSERI, R. (1982) Panoramica sulla geologia delle Alpi Apuane alla luce delle piu recenti ricerche, *Memorie Societá Geologica Italiana,* **24**, 193–208.

CHECCHI, F. (1978) Studio strutturale e giacimentologico della zona compresa tra Pontestazzemese e Foce di Mosceta. Alpi Apuane. Unpublished degree thesis.

CORTECCI, G., LATTANZI, P., and TANELLI, G. (1984) Barite-iron oxide-pyrite deposits from Apuan Alps (northern Tuscany, Italy). Paper presented at the 27th International Geological Congress – Section 12 Moscow.

MELLINI, M., AMOURIC, M., BARONNET, A., and MERCURIOT, G. (1981) Microstructures and nonstoichiometry in schafarzikite-like minerals. *American Mineralogist,* **66**, 1073–1089.

MELLINI, M., MERLINO, S., and ORLANDI, P. (1979) Versiliaite and apuanite, two new minerals from the Apuan Alps, Italy. *American Mineralogist,* **64**, 1230–1234.

MELLINI, M., ORLANDI, P., and PERCHIAZZI, N. (1983) Derbylite from Buca della Vena mine, Apuan Alps, Italy. *Canadian Mineralogist,* **21**, 513–516.

MERLINO, S., and ORLANDI, P. (1983) A second occurrence of stibivanite: Buca della Vena mine (Apuan Alps), Italy. *Canadian Mineralogist,* **21**, 159–160.

Microminerals

Bill Henderson

This column will be a veritable witch's brew, with a bit of this and a smitch of that. However, I hope it will be a bit more palatable. First, a few items which will no doubt appear in future editions of the *Guinness Book of Records.* Figure 1 is a black and white print of a hand-colored illustration from *Unterhaltung aus der Naturgeschichte,* by Gottlieb Tobias Wilhelm (*Das Mineralreichs,* 2 volumes, Vienna, 1825–1828). Sent me by Carlo Cassinelli, it undoubtedly shows the world's first micromounter, for why else would the gentleman in the top hat be employing a magnifying glass?

The colorless and very shapely epistilbite crystal in Figure 2 ranks as the oldest micro specimen in the author's collection. As the labels in Figure 3 show, the specimen was collected in 1877, and passed through the University of Copenhagen.

The bertrandite in Figure 4 was the very first micromount in the author's collection, and thus might also qualify for the *Book of Records.* Decades ago, in 1957 to be exact, I didn't know beans about minerals. All I had had were two or three university courses in the subject. At that time, while a poor graduate student at Yale, I was given to traveling as far as I could on weekends in search of new specimens. At the Strickland quarry in Portland, Connecticut, I collected some tiny crystals, diamond shape in cross section, and very thin. They were transparent and a very faint pink in color when viewed on edge. Their identity was a mystery to me, and also to the faculty at Yale, so I took them one night to Neal Yedlin. Neal not only identified them on sight as bertrandite but also mounted them in one of his own cardboard boxes as shown. This first meeting was the beginning of a friendship lasting many years, and was the starting point for my own micromounting activities.

Turning to other topics, it is interesting how often a mineral can be either missing from a micromounter's collection for years or else represented by only mediocre specimens, and then, within the space of a month or so, he receives not one but several much finer specimens from two or more locations. Such happened to me recently with respect to thomsonite, an unusual but not rare member of the zeolite family. Recently, I received really superb crystals of thomsonite such as those shown in Figure 5 from Jon Mommers (P.O. Box 219, Sunshine, Victoria 3020, Australia). The square, tabular crystals from the basalts of Simmons Bay are much larger and better formed than any I had seen previously, and are frequently associated with what appearss to be natrolite in epitaxial growth. Only months later, equally fine single crystals (Fig. 6) and groups (Fig. 7) of thomsonite were received from Domenico Forloni (Via Trento 19, 20017 Passirana-Rho [Milano], Italy).

Figure 1. **Reproduction of a hand-tinted illustration showing, perhaps, the world's first micromounter. From a book by Gottlieb Tobias Wilhelm published in 1825.**

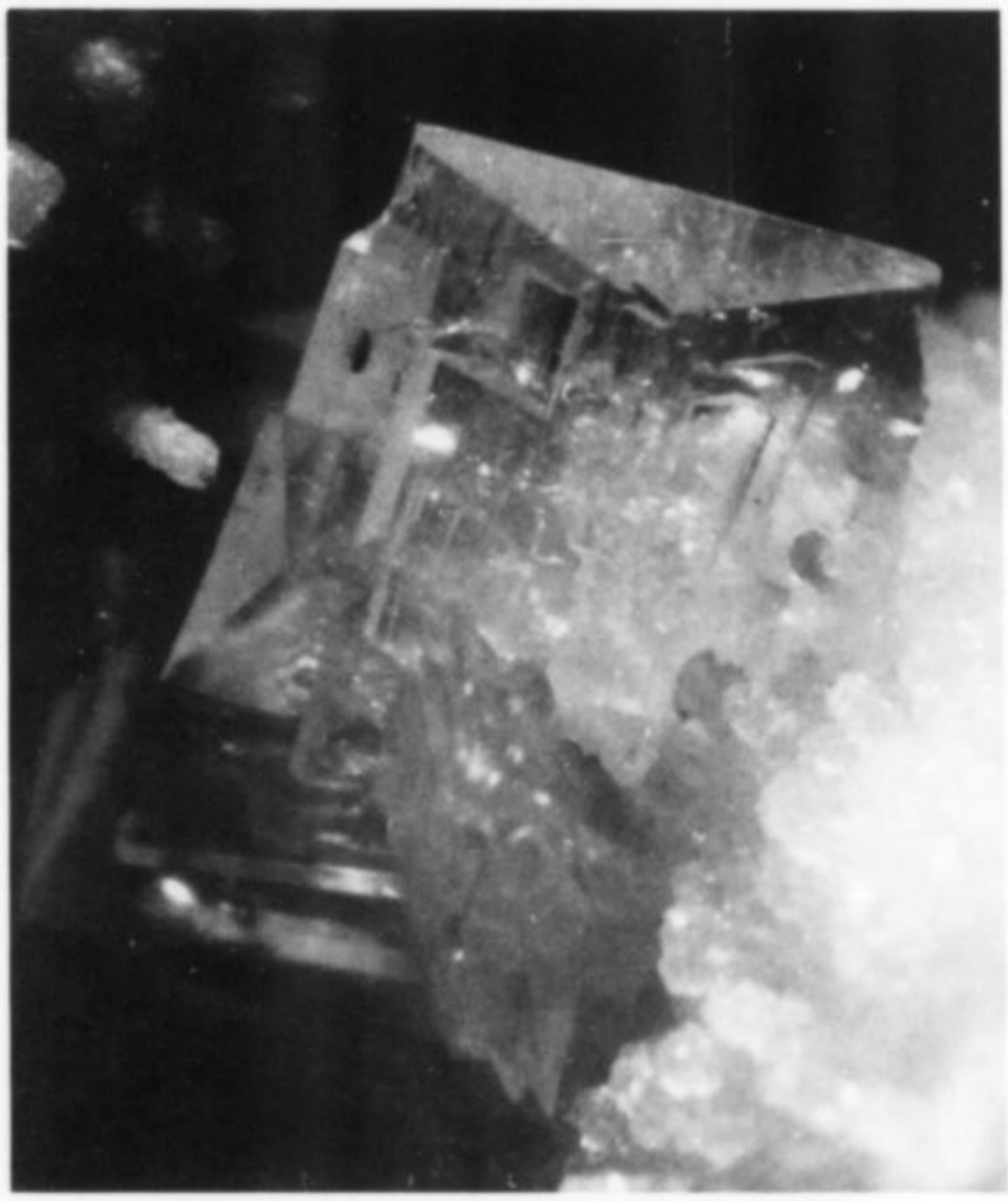


Figure 2. **Colorless, 5-mm crystal of epistilbite from the Teigarhorn, Iceland, collected in 1877.**

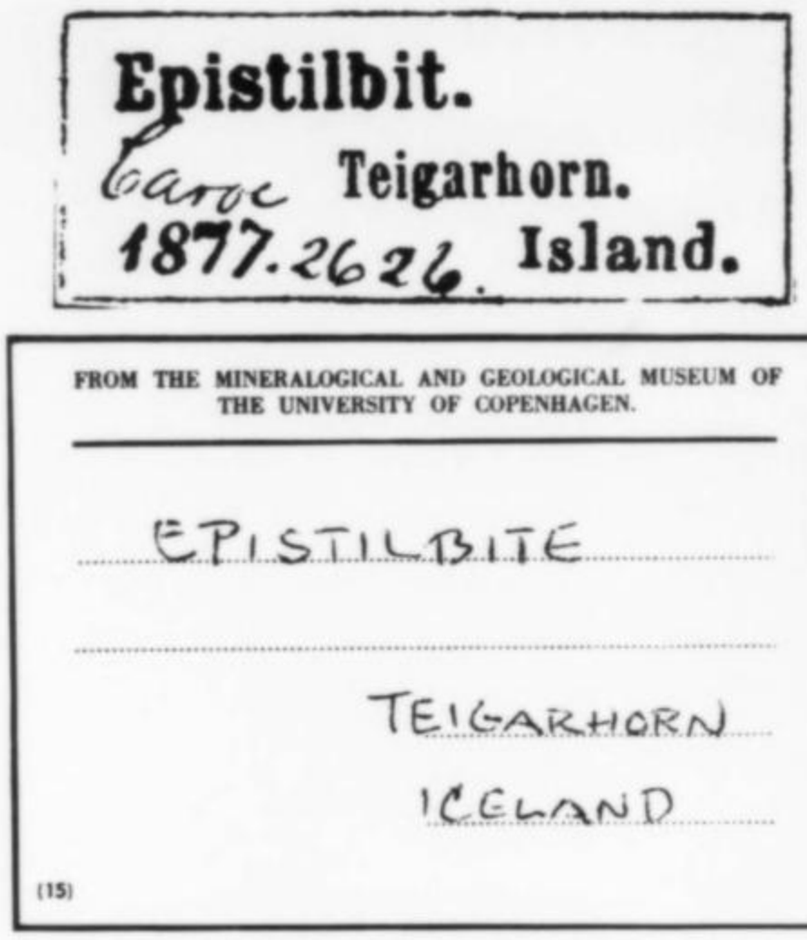


Figure 3. **Earlier label and University of Copenhagen label for the specimen shown in Figure 2.**

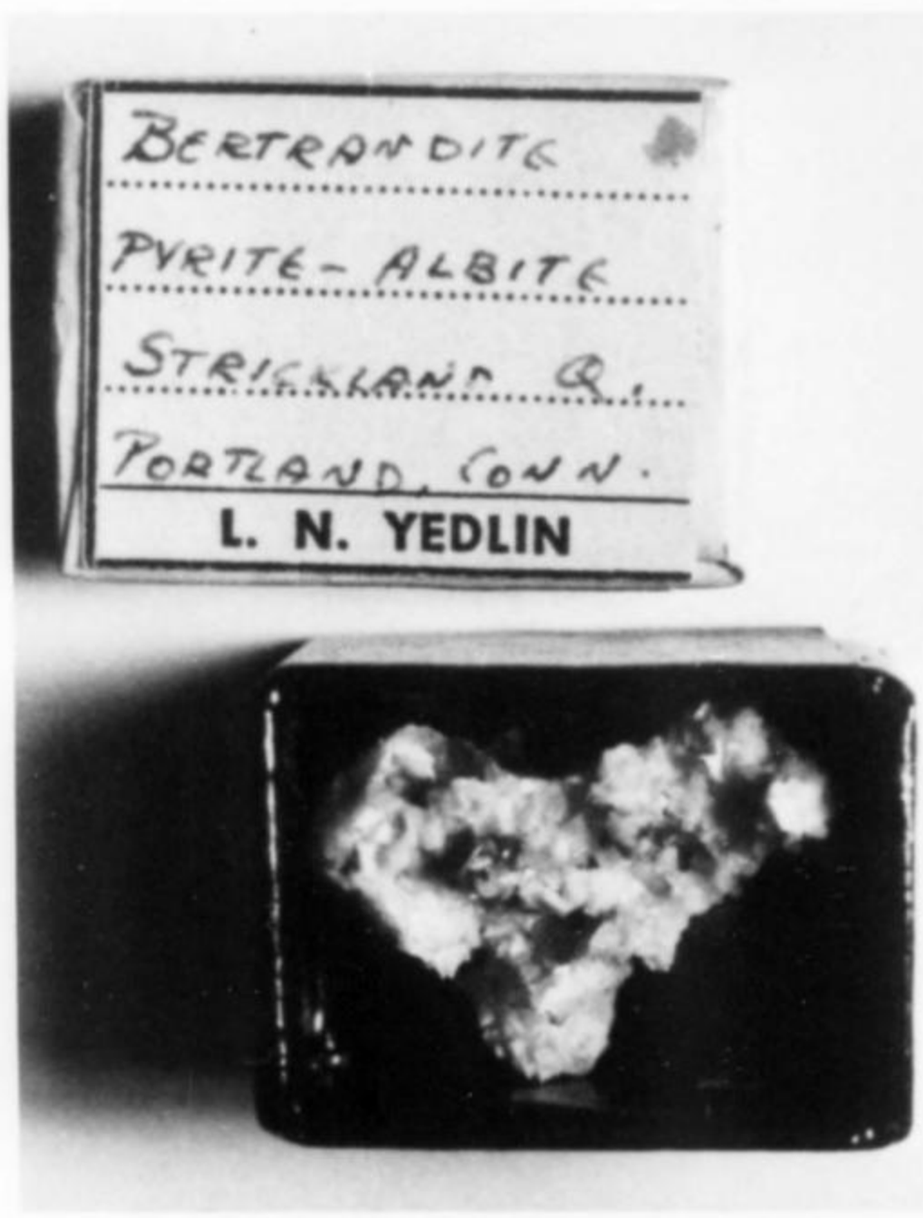


Figure 4. **Bertrandite, faintly pink, 2-mm crystals from the Strickland quarry, Portland, Connecticut, in Neal Yedlin paper micromount box.**

These crystals from the slopes of Monte Somma are even larger than those from Australia, and it is very hard to decide which are the finer specimens.

Jean Jenks (Prices Road, RD 2, Upper Moutere, Nelson, New Zealand), has over the years sent me a number of very nice micromineral specimens. Recently, she sent some distorted pyrite associated with chabazite and a most interesting rhombohedral carbonate, all in basalt from Lyttelton Borough, New Zealand. The

Figure 5. **Colorless, transparent fans of square, tabular thomsonite crystals. From Simmons Bay, Flinders, Victoria, Australia; the largest group is 3.5 mm across.**

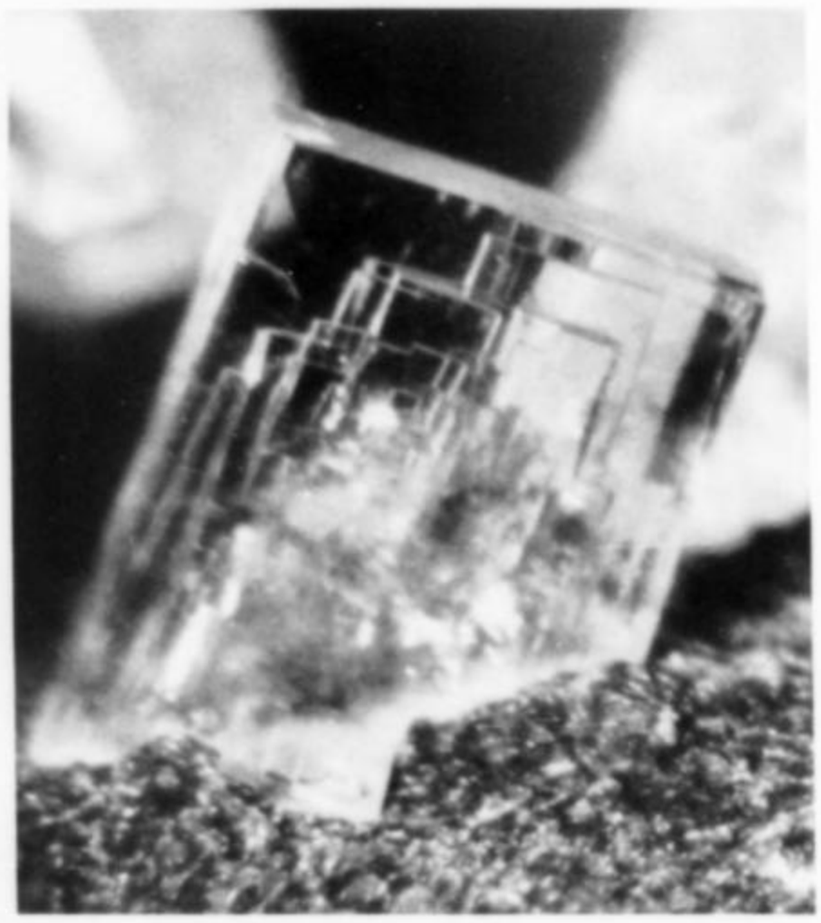


Figure 6. **Transparent single thomsonite crystal, 1.5 mm high, from Monte Somma, Vesuvius, Italy.**

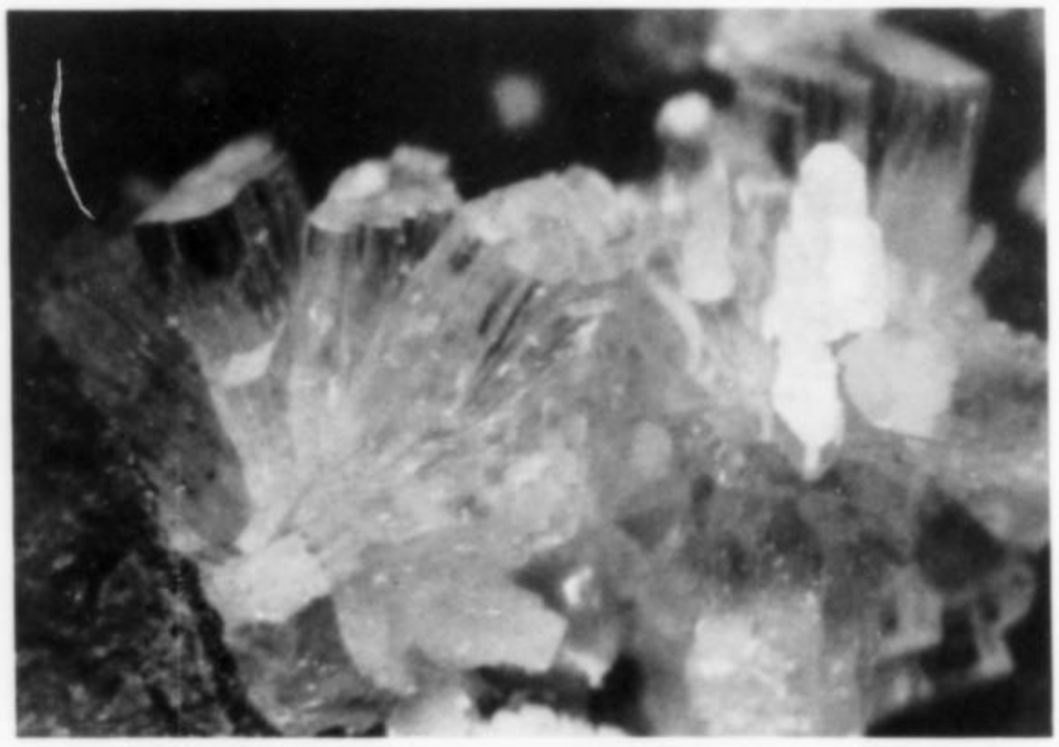


Figure 7. **A 2.5-mm group of thomsonite crystals from Monte Somma, Vesuvius, Italy.**

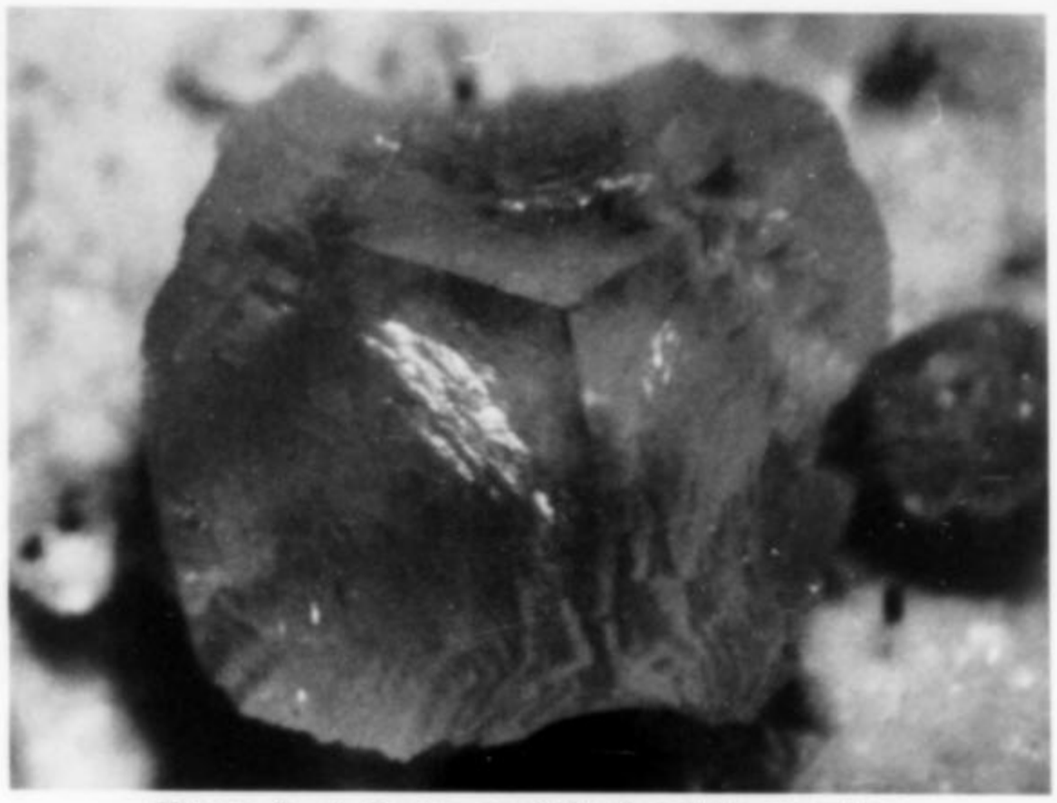


Figure 8. **A 3-mm crystal of calcite showing both rhombohedral and saddle-shape crystal forms, from Lyttelton Harbor Board quarry, Lyttelton Borough, New Zealand.**

Figure 9. **White needles of mesolite on orange heulandite in a bean-shape, 4-mm cavity. From Rock Creek, Stevenson, Skamania County, Washington.**

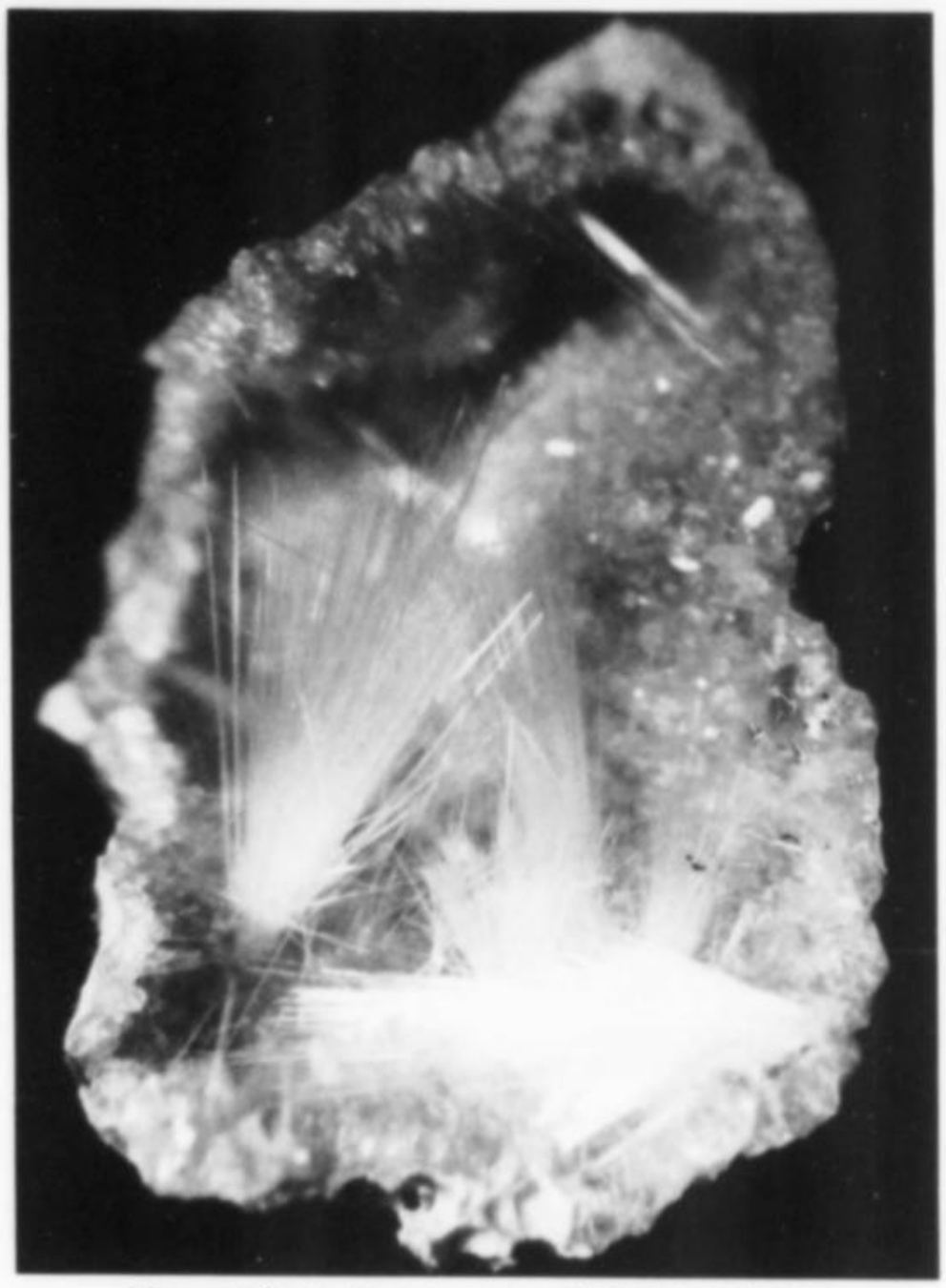


Figure 10. **A 6-mm group similar to that in Figure 9.**

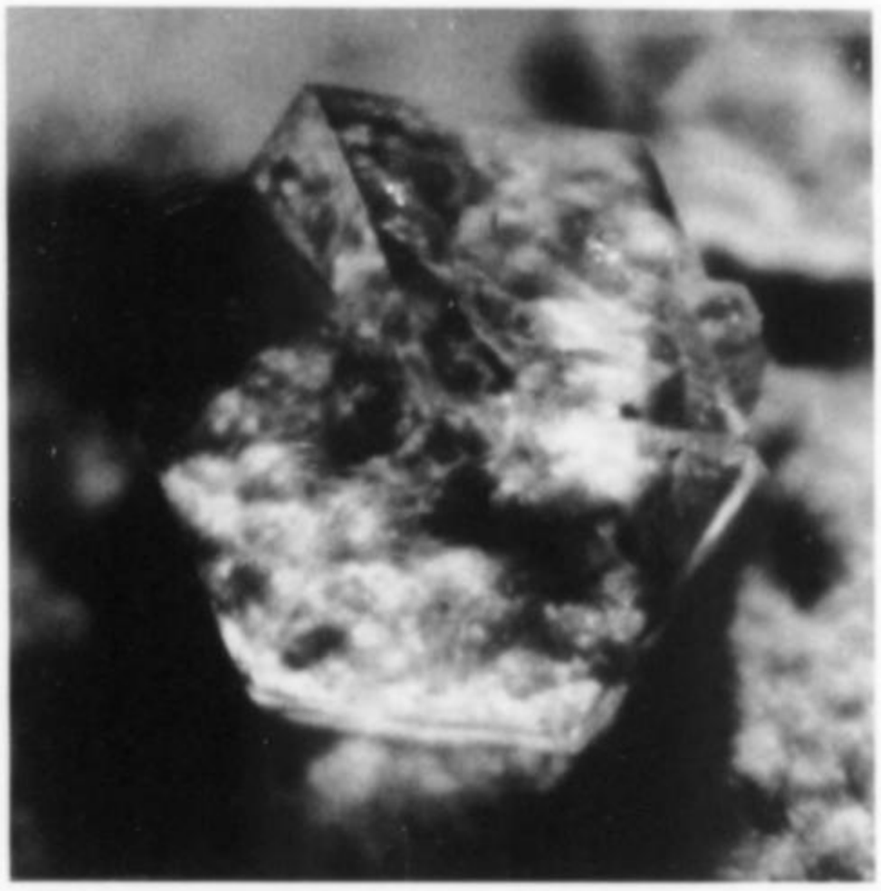


Figure 11. **Extremely large (0.5 mm) transparent, colorless crystal of paulingite with yellow inclusions; Three Mile School, near Ritter, Grant County, Oregon.**

carbonate (Fig. 8) looks for all the world as though it began growth as a simple rhomb such as one sees in calcite, but it then changed habits to the saddle shape characteristic of dolomite and, to a lesser extent, rhodochrosite. The crystals are colorless to white, and their optics fit perfectly for calcite. To be certain of its identity, a crystal was analyzed by microprobe, and found to contain more than 98% calcium (carbonate) plus minor amounts of magnesium and iron. The saddle-shaped crystals are therefore definitely calcite of a fairly unusual habit.

Returning to the wonderful world of zeolites, readers might like to inspect the beautiful mesolites shown in Figures 9 and 10. These were sent to me by Janice M. Healy (P.O. Box 5414, Aloha, Oregon 97006) (Yes, Oregon, not Hawaii). They occur on a white to pink background of minute heulandite crystals in tiny, loose, bean-shaped vugs, and are from Rock Creek, Stevenson, Washington. Janice would be pleased to exchange these "beans" for micros from your area.

Before leaving zeolites, I have to mention the colorless, absolutely transparent paulingites from Three Mile School, near Ritter, Oregon, sent me by Vi Frazier (P.O. Box 27, Point Arena, California 95468). These are nice not only for the yellow inclusions visible at the point of attachment of the crystals (see Figs. 11 and 12) but also for their size. The largest crystals are 0.4–0.5 mm across, and those familiar with the mineral will understand that these are truly humongous giants for the species. Vi has sent me many other zeolites over the years, including a very interesting suite from

Figure 12. **Two 0.4-mm crystals of paulingite; Three Mile School, near Ritter, Grant County, Oregon.**

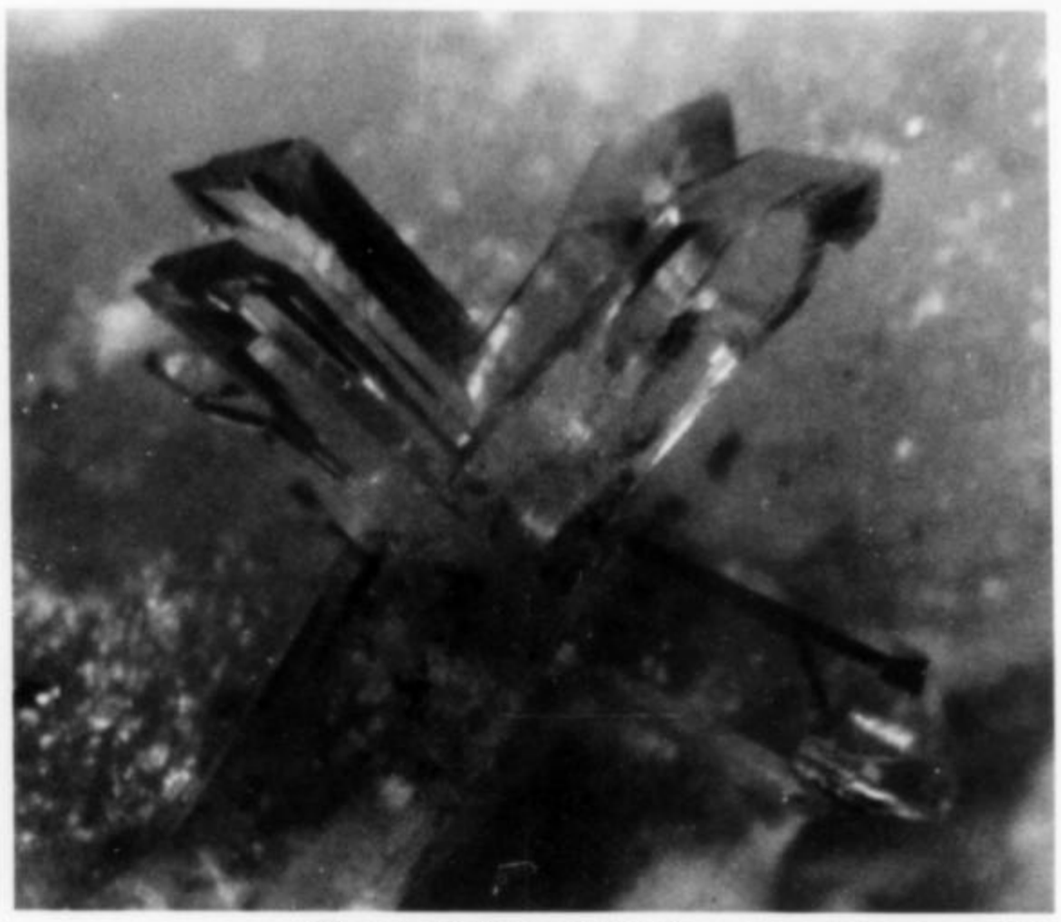


Figure 13. **Pale violet, 3-mm crystals of creedite from the Liberty mine, Tonopah, Nye County, Nevada.**

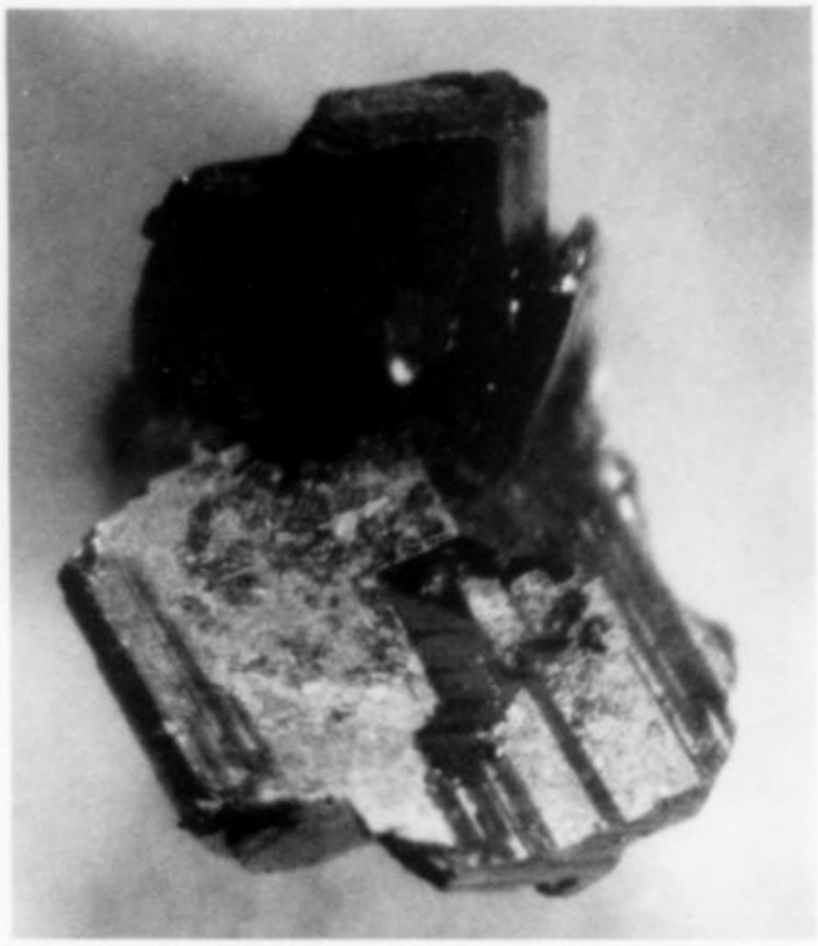


Figure 14. **A 2-mm group of brass-yellow cubanite crystals; locality, the Strathcona mine, Onaping, Ontario, Canada.**

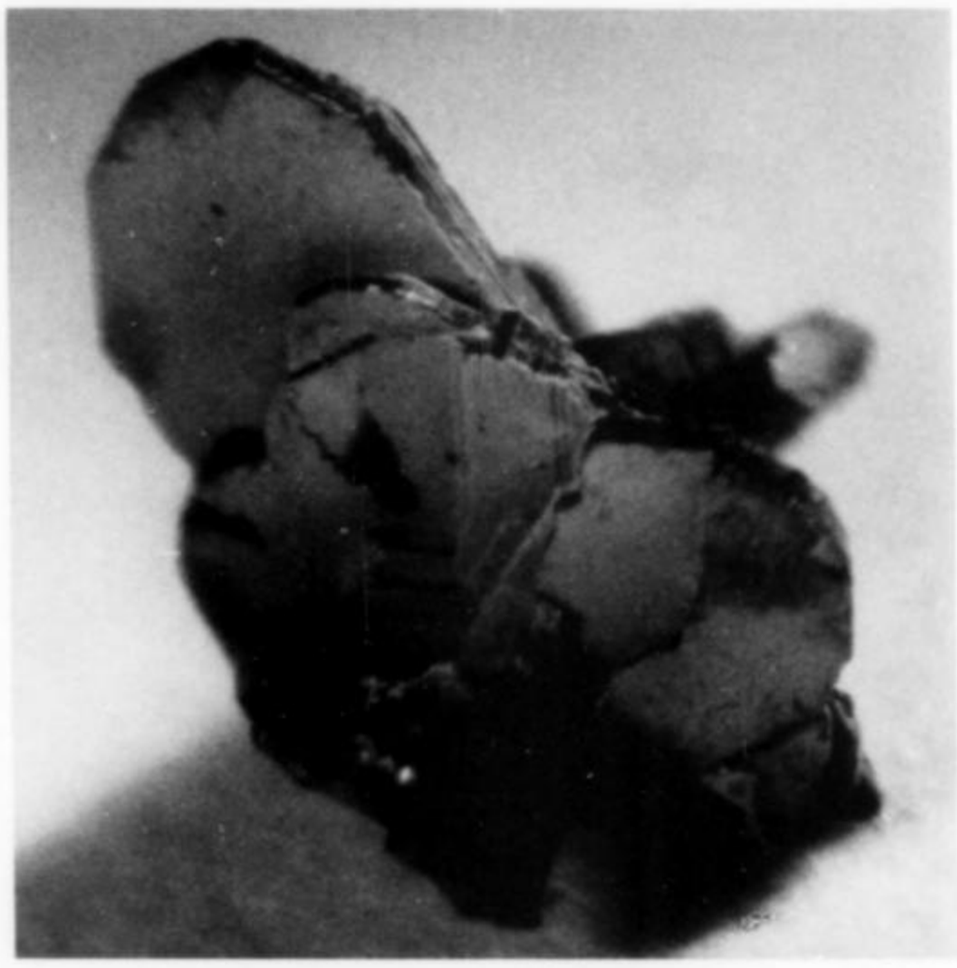


Figure 15. **Tabular and rounded brass-yellow crystals of cubanite to 1.5 mm across, from the Strathcona mine, Onaping, Ontario, Canada.**

basalts associated with the borates at Boron, California.

Walter Lombardo (4728 Elm Avenue, Las Vegas, Nevada 89110) is a collector-dealer who recently sent me some superb micros of creedite from the Liberty mine, Tonopah, Nye County, Nevada. The crystals (Fig. 13) are very sharp, transparent, and vary from colorless to pale amethyst. While not as large as the ones recently found in Santa Eulalia, Mexico, the sharpness and transparency of the crystals makes them very worthwhile. Walter has other choice micro species such as vanadinite from the Ruth mine, Goodsprings, Nevada, in crystals which rival those from Arizona for color; and blue celestite from the Billie mine, Death Valley, California.

Wayne DeBrusk, *the Rare Earth,* has been advertising 3–5 mm cubanite crystals from the Sudbury, Ontario, area in recent issues of the *Mineralogical Record.* Rather than receive a single rather large crystal as advertised, I asked him to send two smaller, micro size crystals. As can be seen in Figures 14 and 15, the crystals of this rare mineral are indeed excellent, and I urge you to write for some while they last.

Many micromounters think that, because the specimens they work with are so small, they can do little in the way of chemical testing to prove their identity. This is hardly the case, and a small number of advanced collectors have developed a variety of spot tests and other analytical methods that are elegant for very small fragments of crystals. Dana's *Manual of Mineralogy* and *Textbook of Mineralogy* list simple tests for the elements, and also describe diagnostic chemical tests for the more common minerals. Not long ago, I had occasion to use some simple closed tube tests to distinguish between various suspected minerals. While Dana

describes the use of ⅛ inch diameter tubes or larger, I used melting-point capillaries. These closed-end tubes, about 1 mm in inside diameter, are readily available from scientific supply houses.

The first specimen to be checked was one from the Noyes mine, Madoc, Ontario, and might have been arsenopyrite (FeAsS) or marcasite (FeS_2) on the basis of its twinned crystals. Dana's *Textbook* says of arsenopyrite, "In the closed tube, gives . . . a conspicuous sublimate of metallic arsenic which is of bright grey crystals near the heated end and of a brilliant black amorphous deposit farther away." For marcasite in the closed tube, Dana's *Manual* describes a copious yellow sublimate of sulfur. To test for this pair, tiny fragments of known arsenopyrite, marcasite and the unknown were placed in three melting-point capillaries. A microscope was needed even to see that the fragments were indeed in the capillaries! Always, always, always, when able, run known minerals alongside the unknowns. It's a lot safer, as tests sometimes don't match those described in the literature, and another element sometimes masks or confuses tests for the element being sought. Since both arsenopyrite and marcasite are of low melting point, it was sufficient to heat the capillaries in nothing more than a candle flame. After a few seconds, the resulting sublimates were those shown in Figure 16, showing conclusively that the unknown gave a sublimate of sulfur like that of marcasite, and completely unlike the arsenic crystals and mirror of arsenopyrite.

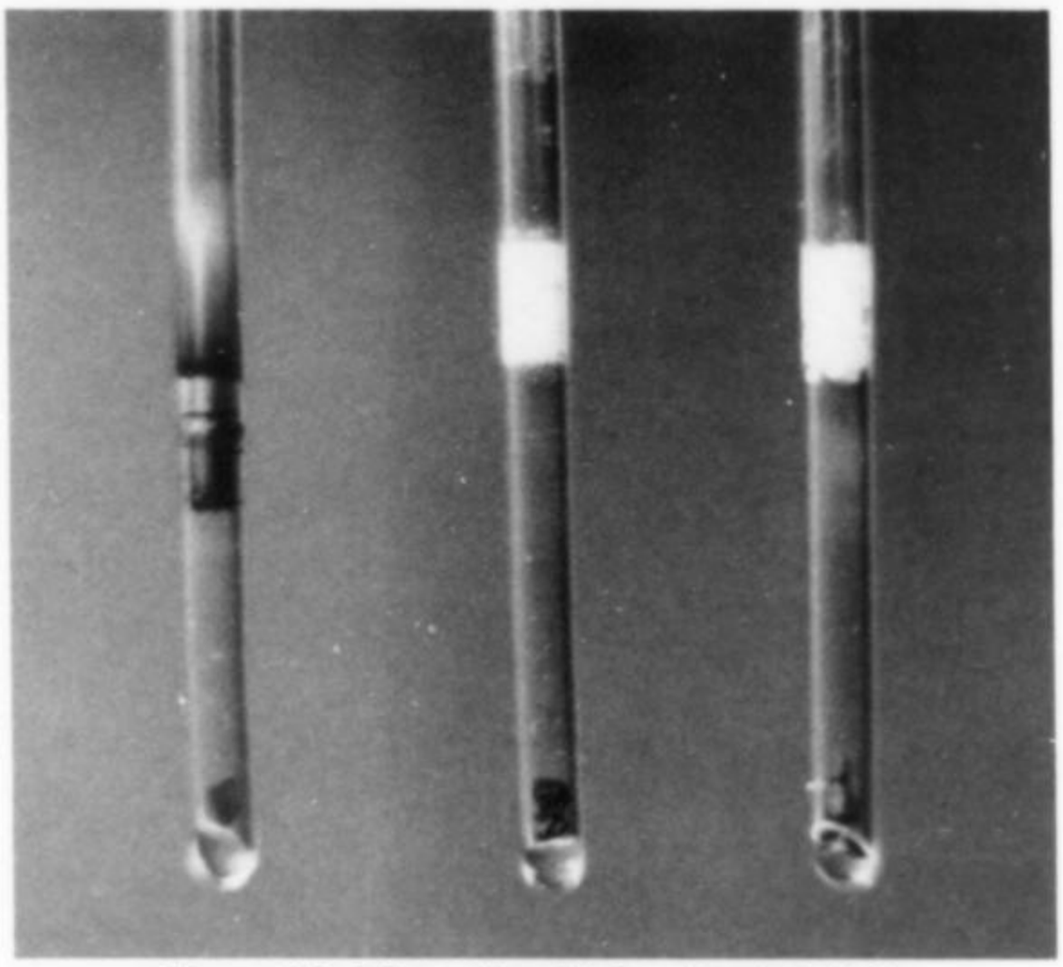


Figure 16. **Micro closed-tube chemical tests showing: (left) a shiny black mirror above black crystals, characteristic of arsenic in known arsenopyrite; (center) light yellow sublimate from an unknown mineral; and (right) light yellow sublimate of sulfur from known marcasite.**

In the second case, I was concerned with a specimen showing black, acicular crystals from Arizona. These were variously described as being groutite (MnO(OH)), a very difficultly fusible mineral, or stibnite (Sb_2S_3), a mineral which fuses very readily. A similar series of tests using a candle flame and capillary tubes gave the results shown in Figure 17. While known groutite and the unknown failed to fuse and gave no sublimate, known stibnite gave the red antimony oxy-sulfide and yellow sulfur sublimates described in the textbooks for stibnite. Again, the distinction was unmistakable, and, given a choice of these two species only, the mineral was taken as being groutite.

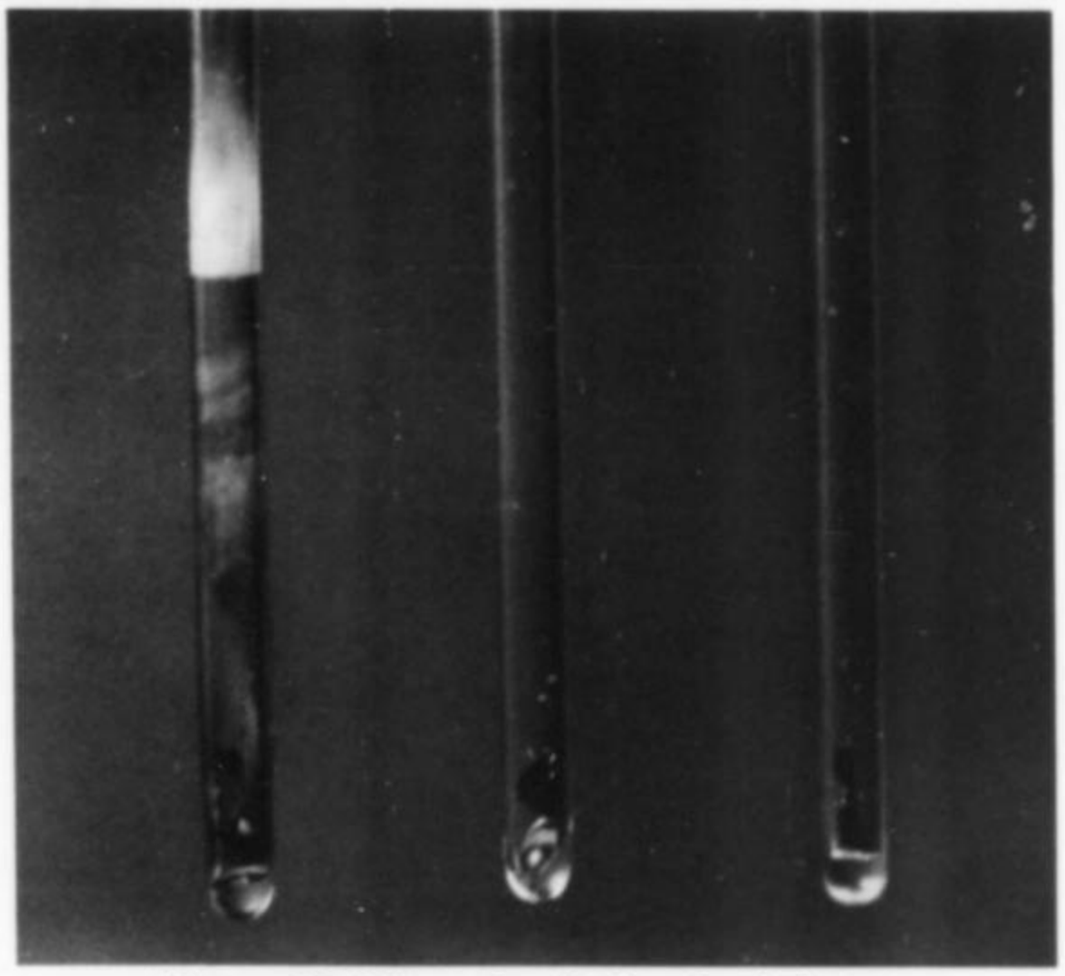


Figure 17. **Micro closed-tube chemical tests showing: (left) light yellow sublimate of sulfur above a less distinct band of red antimony oxy-sulfide from known stibnite; (center) no reaction from infusible unknown; and (right) no reaction from known groutite.**

These tests are highly useful, and readers will have fun devising diagnostic micro tests of their own. Samples as small as those shown in Figure 18 or even smaller are all that are required, and almost every micro specimen has an inconspicuous or broken crystal which can be sacrificed for such testing. As Neal Yedlin used to say, "Read a good mineral book," and learn to do your own identifications.

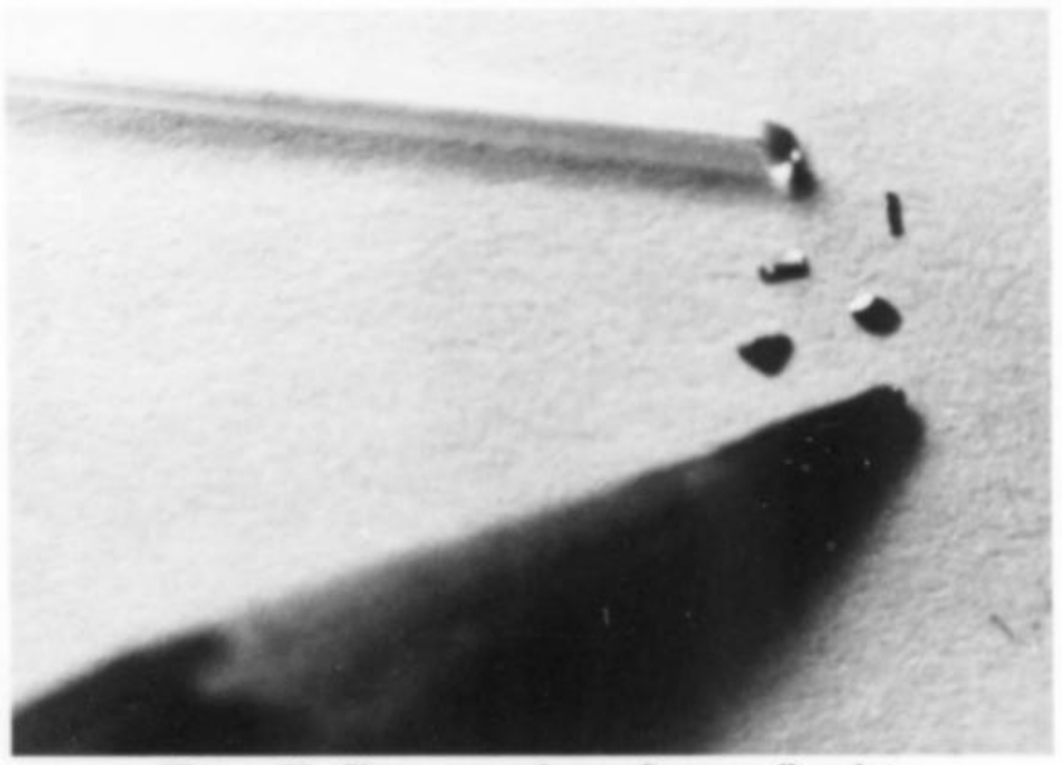


Figure 18. **Size comparison of a pencil point with samples for closed tube chemical tests in melting-point capillaries.**

Not long ago, I was sorting tiny crystal groups found in gravel collected at Mont St-Hilaire, Quebec in 1981. Found in the gravel were pink ancylite "asters," extremely thin rosettes of catapleiite, pink rhombs of rhodochrosite, colorless epididymites, fragile needles of aegirine, natrolite, fluorite and sphalerite. The groups were so tiny, though, that they were frequently crushed and broken or else dropped while transferring them to medicine capsules. What to do? The solution was to glue two short sections of thin rubber

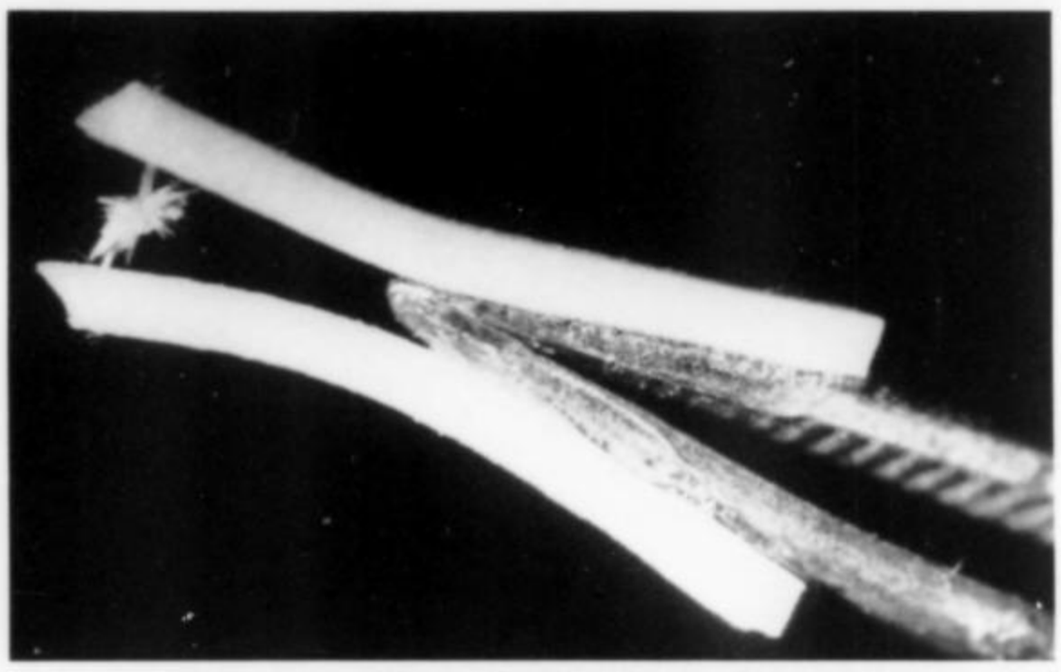


Figure 19. **Design of metal tweezers tipped with portions of rubber bands for handling very fragile crystal groups. Being held: a 0.5-mm group of very pale pink ancylites from Mont St-Hilaire, Quebec, Canada.**

bands to the *outside* edge of the tips of a pair of fine tweezers. As shown in Figure 19, it was then possible to pick up and transfer the smallest crystal groups without crushing or dropping them. Further, it was found that even quite large and blocky crystals could be transferred with ease, as the rubber tips had amazing sticking power. Putting the rubber bands on the outside of the tweezer tips means that pressure can be exerted to completely close the metal tweezer tips without either deforming and bending the rubber tips or applying excess pressure to the specimen. While almost certainly a patentable idea, I bequeath this freely to the micromineralogical fraternity. On this note of outstanding generosity, the column is closed.

Happy hunting!

Wm. A. Henderson, Jr.
174 East Hunting Ridge Road
Stamford, CT 06903 U.S.A.

Letters

PEGMATITIC DANBURITE

Regarding Lanny Ream's letter (vol. 17, no. 2, p. 145) in which he states that Butte, Montana, and Anjanabonoina, Madagascar are the only known pegmatitic occurrences of danburite, I can point out two more. Large, prismatic crystals of danburite up to 15 cm in size were found in a pegmatite, with green tourmaline, near La Huerta, Baja California, Mexico (personally collected by Josephine Scripps and myself in 1969). Danburite has also been found in the J-27 pegmatite near Riverside, California.

Al Ordway
Bloomington, CA

There is a pegmatite occurrence of danburite in Norway. Specimens collected from the Tangen quarry near Kragerø, in southern Norway, were sent to the Mineralogy-Geology Museum in Oslo for identification in 1906–1908. They were provisionally identified as topaz, but were recognized as danburite by I. Oftedal in 1963. The specimens measure up to 20 cm in size and are all fragments of two large crystals.

Alf Olav Larsen
Stathelle, Norway

John Sinkankas pointed out another locality listed in his *Gemstones of North America*: the Chuqui pegmatite mine near the El Fenomeno tungsten mine near Rosa de Castilla, Baja.

Lanny Ream

EXCHANGES

I am an advanced systematic collector and a *Mineralogical Record* subscriber since 1979. My own collection consists of about 10,000 specimens representing 2244 valid species (as listed by Fleischer). Roughly 180 square meters (1900 square feet) of my house has been taken over by the collection.

I'd be most appreciative if you could publish my name and address for the purpose of exchanging specimens. I am seeking rare minerals of systematic interest, any size, from localities worldwide. I specialize in minerals from Vesuvius; a list of all specimens available for trade, as well as a list of satisfied trading partners, can be provided.

(Enclosed is a photo showing about a third of my showcases.)

G. Galvani
Via de Amicis 35
20123 Milano, Italy

MISLABELING

We applaud the recent article on mislabeling on mineral specimens (vol. 17, no. 2, p. 99). Correct and specific locality documentation is important not only as a guide to further collecting but as a key to understanding the geochemical conditions which contributed to a mineral's crystallization, and thereby perhaps being able to predict where else it might occur. Consequently, we are particularly attentive to locality data accompanying specimens in the Harvard collection. We adopted the British Museum's square bracket convention for indicating attributions several years ago. We also like your suggested attribution labels and are having some printed for use in the museum.

Carl A. Francis
William C. Metropolis
Harvard Mineralogical Museum

The article on mineral specimen mislabeling was most interesting. I was surprised to see no comments on the American Federation of Mineral Societies practice of replacing chemical formulas with "simplified compositions" (for labels in competitive displays).

T. J. Schmierer
Albuquerque, NM

Personally I have always found that to be an odious practice which encourages mental laziness and sloppiness. "Simplified" compositions are by definition incorrect in most cases because of the omissions; how is the viewer to know what has been left out? Encouraging the use of simplified formulas merely panders to those collectors who are determined to avoid learning anything (such as the meaning of a few simple symbols). The AFMS would do better by its constituents if it set a higher standard.

Ed.

GENSTAR QUARRY

This is to inform your readers that the Genstar Medford quarry in Carroll County,

Maryland (see vol. 17, no. 2, p. 151–152) is effectively closed to collectors; to my knowledge, no entry has been granted this year, even to clubs which previously enjoyed a good relationship with Medford. This is supposedly due to some incidents in which collectors refused to leave a dangerous area when asked to do so by quarry officials, or who caused problems in other ways.

Fred J. Parker
Columbia, MD

SAINTE-MARIE aux MINES

Regarding Werner Lieber's brief reference to Sainte-Marie aux Mines, France, in the recent Silver Issue (vol. 17, no. 1, p. 6), I would like to offer some additional information. Although native silver and proustite from this area are today rather rare in collections, the early written records are quite informative.

In 1530 (not 1539) a mass of silver weighing 50 kg was broken loose in a stope; two pieces of it were presented as a gift to Emperor Charles the Fifth of Spain. In 1755 one of the mines yielded specimens of such beauty that they were sold as collection pieces. The most spectacular find, however, was made on October 17, 1581, by a miner named Klaus Shirbald; he found a block of native silver weighing 592 kg (1304 pounds!). The Chronicles describe it as a mass of "fir branches, feathers and curled grass."

Altogether more than 120 species are known from Sainte-Marie aux Mines, including seven new species and many of exceptional quality. The deposits were apparently first worked in the 8th century. By the 19th century approximately 800 named mines and concessions had been exploited in the district. In recent years, archeological work at Sainte-Marie aux Mines has revealed much about the history and mining technology of the 16th century.

Alain Martaud
Bersee, France

MAILERS & MAILBOXES

Thank you for acting on Henry Fisher's suggestion to add "Please Do Not Fold" to the mailers. I was amused by your suggestion to consider buying a larger mailbox; I did so three years ago, with that very purpose in mind. It stands to reason, of course, that my latest issue was delivered to my neighbor (in a small mailbox) by mistake.

John Jaszczak
Columbus, OH

EPITAXIAL or EPITACTIC?

I was interested to read about marsturite epitaxial on rhodonite in the latest *Mineralogical Record* (vol. 17, no. 2, p. 123–125). I write to point out, in the true fashion of a nit-picking editor sent on this earth to torment authors, that use of the word *epitaxial* is inappropriate. There is nothing "axial" about the relationship described. In fact, the root, which gives rise to the word *tactile,* refers to a surface or plane. I would advise a switch to one of the two adjectival forms, *epitactic* or *epitaxic,* proposed by International Mineralogical Association and the International Union of Crystallography (see, for example, *Canadian Mineralogist,* **16**, 113–117, and in particular point M on p. 115).

Robert F. Martin
Editor, *Canadian Mineralogist*
Montreal, Quebec

RESPONSE FROM *NATIONAL GEOGRAPHIC*

I just recently had the opportunity to see some issues of the *Mineralogical Record*; it is handsome and well written. I particularly appreciate the locality descriptions that present the site history and geology as well as the mineralogy. As proof of my sincerity I enclose a check for a subscription.

Now about that statement (vol. 16, no. 6, p. 440), "Try sending *National Geographic* an old back issue in trade for a full year's subscription and see what they say!" We suggest you ransack your attic for a copy of *National Geographic,* vol. 1/no. 1 (1888) . . . it's currently worth about $7000!

Best of luck with your very fine publishing venture.

Thomas Y. Canby
Science Editor
National Geographic Magazine
Washington, DC

California Dealers

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

California Rock and Mineral Co.
P.O. Box 86
Brea, California 92622
Tel: (714) 990-5073

Faust & Faust Wholesale Minerals
Peter M. Faust
723 N. La Paloma Avenue
Ontario, California 91764
Tel: (714) 984-4198

Frazier's Minerals and Lapidary
Si and Ann Frazier
2000 Centre Street, Suite 1177
Berkeley, California 94704
Tel: (415) 848-9541

Galas Minerals
Chris and Agatha Galas
1419 N. Commons Road
Turlock, California 95380
Tel: (209) 632-6222

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: (818) 357-6338
Wholesale Only

Kassionas
John and Dolores Kassionas
P.O. Box 578
Alviso, California 95002
Tel: (408) 263-7784

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

A. L. McGuinness
Al McGuinness
4305 Camden Avenue
San Mateo, California 94403
Tel: (415) 345-2068

James Minette
25918 Cherryhill
Boron, California 93516
Tel: (619) 762-5308

Oxcart Minerals
Hollis & Priscilla Oxley
989 Leo Drive
San Jose, California 95129
Tel: (408) 255-1495

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

Pathfinder Minerals
Mary Jean & Larry Cull
41942 Via San Gabriel
Fremont, California 94538
Tel: (415) 657-5174

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

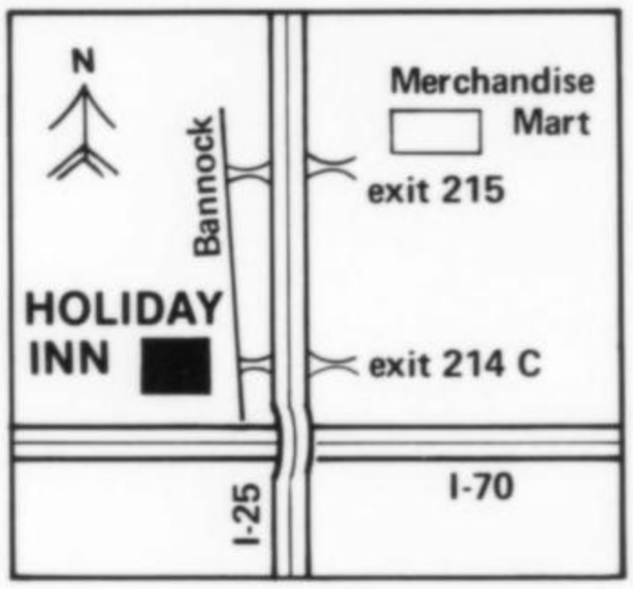
Whatever you're looking for in the way of fine display specimens, rare species material, moderately priced specimens for beginning and intermediate collectors, bulk material for research and study, wholesale or retail, you'll find it in California. Plan to stop in when you're in our area. Many of us do shows, so it's always best to call first.

Fast becoming the "Tucson of the North"!

THE DENVER IMD-MINERAL TRADE SHOW™

at the Holiday Inn North - Denver, Colo. • 4849 Bannock St. at I-25 & I-70

September 10, 11, 12, 13, 14, 1986 **9 a.m. to 9 p.m. daily**



INDEPENDENT MINERAL DEALERS TRADE SHOW

Held in conjunction with the Denver Council of Mineral Societies Show at the Merchandise Mart, Sept. 12-14.

Shuttle bus transportation available hourly between both shows!
Guest rooms available; call Holiday Inn, 303-292-9500

— DEALERS —

Room		Room		Room	
117	Topaz-Mineral Exploration	137	Resource Enterprises	189	Jose Chaver
119	Tierra Minerals	139	B & W Minerals	191	Crystals Ltd.
121	Bones & Stones	141	Mitch Abel	192	Ikon Mining & Exploration
123	Tideswell Dale (England)	143	Sierra Nevada Minerals	193	Freedom Valley Gems
124	Dyck's Minerals	180	Graeber Minerals	194	Rough & Ready Gems
125	Mineral Suite	182	Rock Hut	195	Mountain Minerals Intl.
126	Virgin Mining Co.	183	Crystal Cavern Minerals	196	North Star Minerals
130	Crystal-Linn International	184	Jeffrey Mining Co.	197	Lee's Minerals
131	Den's Petrified Critters	185	Crystal Cavern Minerals		
132	David Shannon	186	Blackhawk Fossils		
133	Minerals International	187	Cataract Lode Mining Co.		
135	Quahada Minerals	188	Silver Scepter Minerals		

A Gathering of the Country's Finest Gem, Mineral & Fossil Suppliers!
Offering the Finest for Dealers, Museums and Collectors

Motel room shopping is half the fun of coming to Denver!

Show Coordinators — Tom Palmer
1800 Arnold Palmer Dr.
El Paso, TX 79935
915-593-1800

Marty Zinn
31751 Buffalo Creek Rd.
Evergreen, CO 80439
303-670-1960

Colorado Dealers

** by appointment only, except as noted*

M. P. Abel Minerals

P.O. Box 440356
Aurora, CO 80044
303-695-7600
Superb Worldwide Specimens

Collector's Edge

Bryan & Kathryn Lees
5250 Allison Street, #1
Arvada, CO 80002
303-421-8061

Collector's Stope

Jim & Patti McGlasson
7387 S. Flower Street
Littleton, CO 80123
303-972-0376
Fine Minerals, Species, Micromounts

Crystal-Linn International

Martin Zinn
P.O. Box 2433
Evergreen, CO 80439
303-670-1960
Fine Minerals, Tourmaline

Eldorado Enterprises

Don Belsher
P.O. Box 219
Eldorado Springs, CO 80025
303-494-7785
Fine Minerals

Geology Museum & Shop

Colorado School of Mines
Golden, GO 80401
303-273-3823
Mon-Sat 9-4, Sun 1-4

Golden Minerals

Don E. Knowles
13030 West 6th Place
Golden, CO 80401
303-233-4188
Largest Stock in Colorado

L & T Creations

Tag & Lee McKinney
6780 S. Logan
Littleton, CO 80122
303-794-7803
Colorado-Utah Minerals

Mineral Treasures

Dee Belsher
P.O. Box 1204
Broomfield, CO 80020
303-466-4128
Old Collections

Denver IMD Satellite Show

September 10-14, 1986
Holiday Inn-North
35 Dealers!
Open til 10 p.m.

Mountain Minerals International

George & Cindy Witters, Dudley Blauwet
P.O. Box 302
Louisville, CO 80027
303-665-7366
Specializing in Asian Minerals

Resource Enterprises

R. Theodore Hurr
P.O. Box 115
Wheat Ridge, CO 80033
303-421-3893

Tavernier

3355 S. Wadsworth, G123
Lakewood, CO 80227
303-985-9646
Fine Minerals & Gems

Williams Minerals

Keith & Brenda Williams
P.O. Box 1599
Idaho Springs, CO 80452
303-567-4647
Colorado Minerals & Mineral Mounts

Worldwide Resources

Dennis O. Belsher
P.O. Box 636
Golden, CO 80402
303-494-7785
South American Minerals

Columbine Mineral Shop

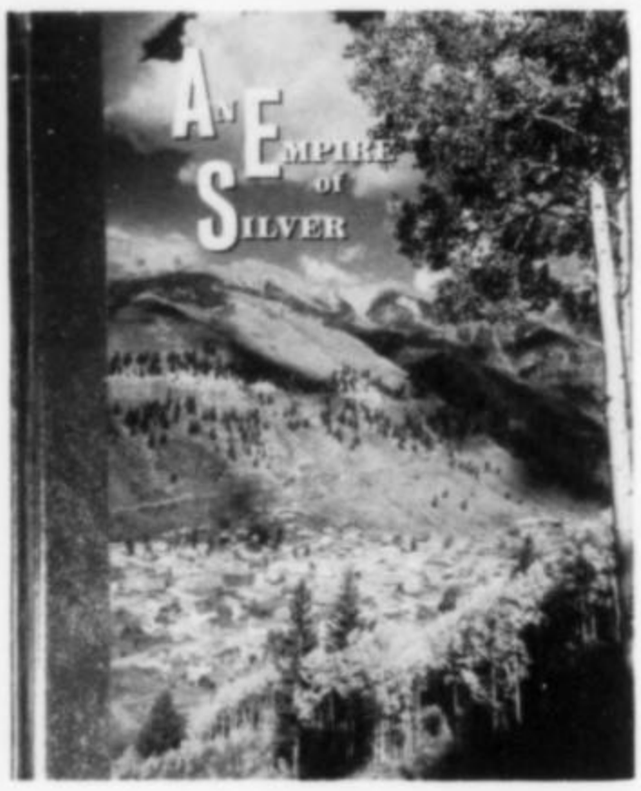
Benjy & Liz Kuehling
633 Main Street
Ouray, CO 81427
303-325-4345
Open 7 days, May 1-Oct. 31
9 a.m. to 9 p.m.
Off-season by Appointment
Fine Minerals for Collectors

Mike Madson Minerals

3201 Snowberry Court
Grand Junction, CO 81506
303-243-2234
Wholesale Minerals

The Rock Hut

Gus Seppi, Jim & Irene Witner
706 Harrison Avenue
Leadville, CO 80461
303-486-2313
Specimens, Unique Gifts, Jewelry



The Cliff by Donald Chapin
America's First Great Copper Mine

Species Mineralogy

The Tourmaline Group
☐ Dietrick's modern classic on tourmaline, an important work. **$38 postpaid** (H)

Emeralds & Other Beryls
☐ The definitive work on beryl occurrences worldwide. **$44 postpaid** (H)

Benitoite
☐ Reprint of Louderback's classic 1907–1909 papers, with numerous illustrations. **$6 postpaid** (S)

Opal, South Australia's Gemstone
☐ The definitive review of South Australian opal localities. **$10 postpaid** (S)

Glossary of Mineral Species
☐ Comprehensive catalog of the names and compositions of all known species. **$10 postpaid** (S)

Field Guide to Rocks & Minerals
☐ Great for beginners, one of our favorites. **$14 postpaid** (S) **$20 postpaid** (H)

Indexes

Index to the Mineralogical Record
☐ A 14-year cumulative index for vol. 1–14. Extremely handy. **$21 postpaid** (S)

Foreign Mineralogies

Mineralogy of Great Britain & Ireland
☐ Reprint of the 1858 classic by Greg & Lettsom; 550 pages! **$49 postpaid** (H)

Catalogue of South Australian Minerals
☐ Describes over 400 species; 169 color photos, maps. **$21 postpaid** (S)

Mineralogy of Llallagua, Bolivia
☐ Reprint of Bandy's 1944 classic monograph on Llallagua. **$5 postpaid** (S)

Minerals of Western Australia
☐ Reprint of the 1948–1951 classic by E. S. Simpson, three volumes, hard-bound. **$106 postpaid (foreign add $3)** (H)

Minerals in China
☐ Rare English edition of the only modern work on the mineralogy of China; 246 color photos. *Quantity limited!* **$67 postpaid** (H)

Collectibles

Billings Microscope Collection
☐ 244-page compendium on an important collection; 475 photos. **$20 postpaid** (S)

A Collector's Guide to Antique Miners' Candlesticks
☐ The definitive work on these interesting mining collectibles. Nearly 450 illustrations. **$25 postpaid** (S)

Illustrated Mining Histories

De Re Metallica
☐ Reprint of the 1912 English edition of Agricola's 1556 classic on mining. **$23 postpaid** (H)

Empire of Silver
☐ Illustrated mining history: San Juan Mountains of Colorado. **$42 postpaid** (H)

The Cliff: America's First Great Copper Mine
☐ Illustrated mining history: the Cliff mine and others, Upper Michigan. **$23 postpaid** (H)

The Last Gold Rush
☐ Illustrated mining history: Cripple Creek and Victor, Colorado. **$14 postpaid** (S)

Mining History in South Australia
☐ Illustrated mining history: South Australia. **$23 postpaid** (H)

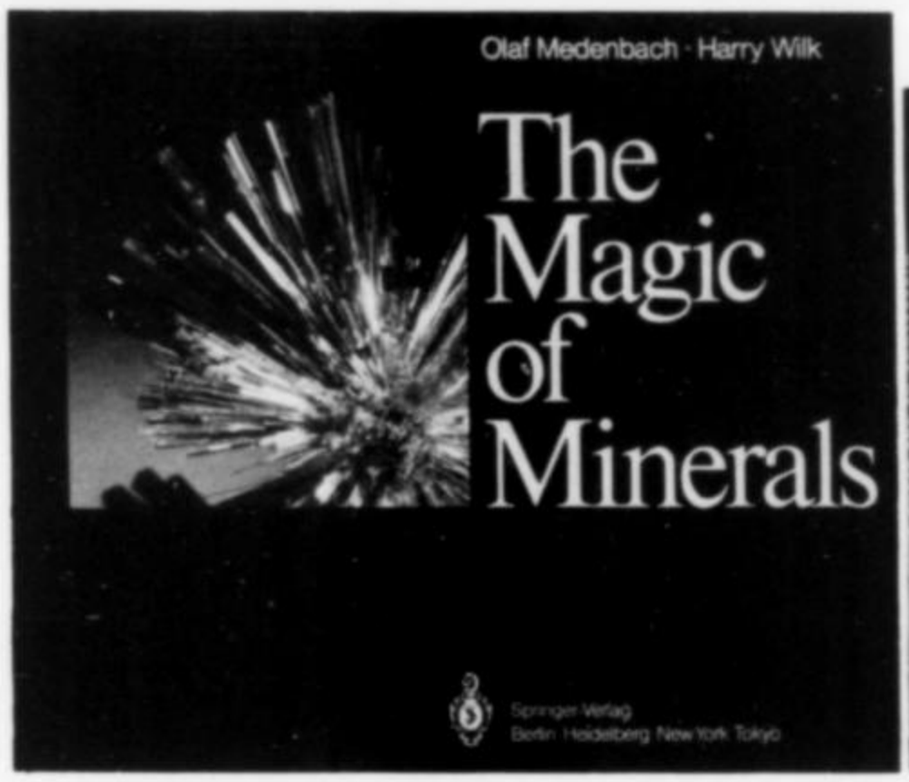
Mining Town
☐ Illustrated mining history: Coeur d'Alene, Idaho. **$28 postpaid** (H)

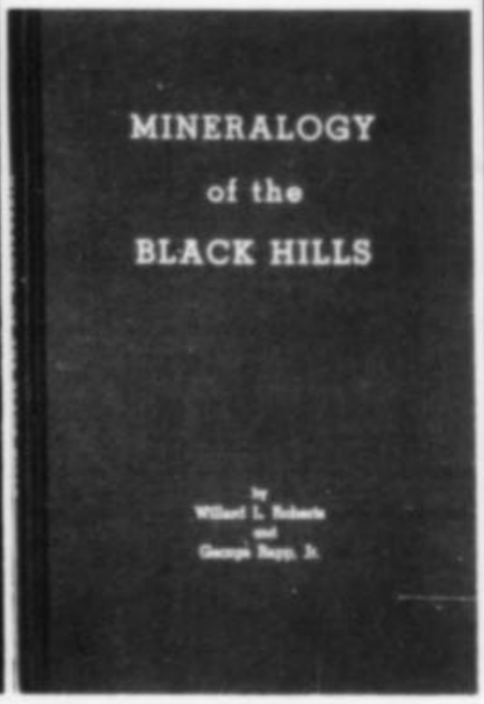
Bisbee: Queen of the Copper Camps
☐ Illustrated mining history: Bisbee, Arizona. **$23 postpaid** (H)

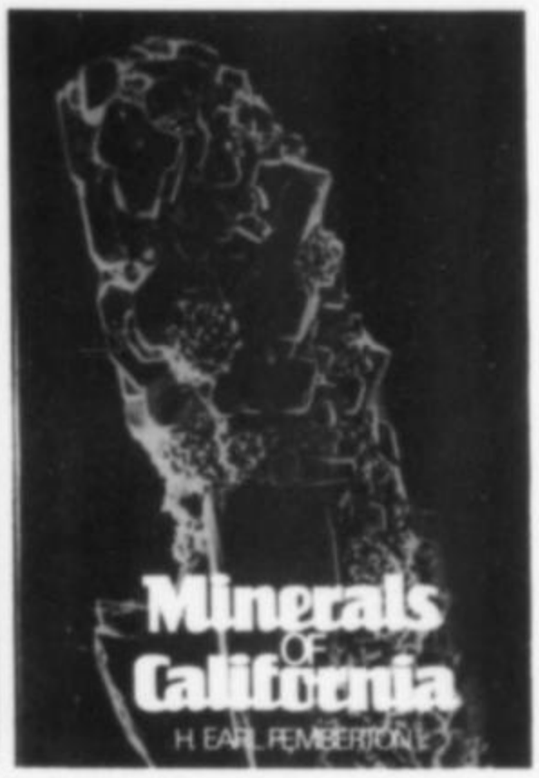
Gold Camps & Silver Cities
☐ Illustrated mining history: the famous mining districts of Idaho. **$14 postpaid** (S)

Prepaid orders only except by previous arrangement. Allow 4-6 weeks for delivery. SORRY – Credit cards not accepted.

Mineralogical Record Book Dept.
P.O. BOX 1656, CARSON CITY, NEVADA 89702
TEL.: 702-883-2598







"Coffee Table" Books

The Magic of Minerals

☐ Gorgeous "coffee table" book, Olaf Medenbach photography. 110 oversize color photos. **$49 postpaid** (H)

Gem & Crystal Treasures

☐ Fascinating background on 100 famous localities, over 300 color photos. **$65 postpaid** (H)

Gem & Crystal Treasures Leather Edition

☐ Strictly limited edition, very finely bound. **$230 postpaid (foreign add $35)** (H)

Brazil, Paradise of Gemstones

☐ Superb color photography of many fine Brazilian crystal specimens by the Van Pelts. **$25 postpaid** (H)

Mineral Museums of Europe

☐ Unique and interesting review of 80 Western European mineral museums. **$53 postpaid** (H)

Gemstones

☐ Time-Life's excellent review of the major gem minerals, well illustrated. **$15 postpaid** (H)

Noble Metals

☐ Time-Life's excellent review of gold, silver and platinum, well illustrated. **$15 postpaid** (H)

State Mineralogies

☐ **Mineralogy of Alabama** (1982) Cook & Smith **$20 postpaid** (S)

☐ **Mineralogy of Arizona** (1977) Anthony *et al.* **$30 postpaid** (H)

☐ **Mineralogy of Arizona** (1977) Anthony *et al.* **$17 postpaid** (S)

☐ **Mineralogy of the Black Hills** (1965) Roberts & Rapp **$18 postpaid** (H)

☐ **Mineralogy of the Black Hills** (1965) Roberts & Rapp **$12 postpaid** (S)

☐ **Minerals of California** (1983) Pemberton **$36 postpaid** (H)

☐ **Minerals of Georgia** (1978) Cook **$12 postpaid** (S)

☐ **Minerals of Maine** (1958–59) Merrill **$9 postpaid** (S)

☐ **Mineralogy of Michigan** (1976) Heinrich **$9 postpaid** (S)

☐ **Mineral Sites in North Carolina** (1978) Wilson **$12 postpaid** (S)

☐ **Minerals of Utah** (1981) Bullock **$20 postpaid** (S)

☐ **Minerals of Virginia** (1970) Dietrich **$10 postpaid** (S)

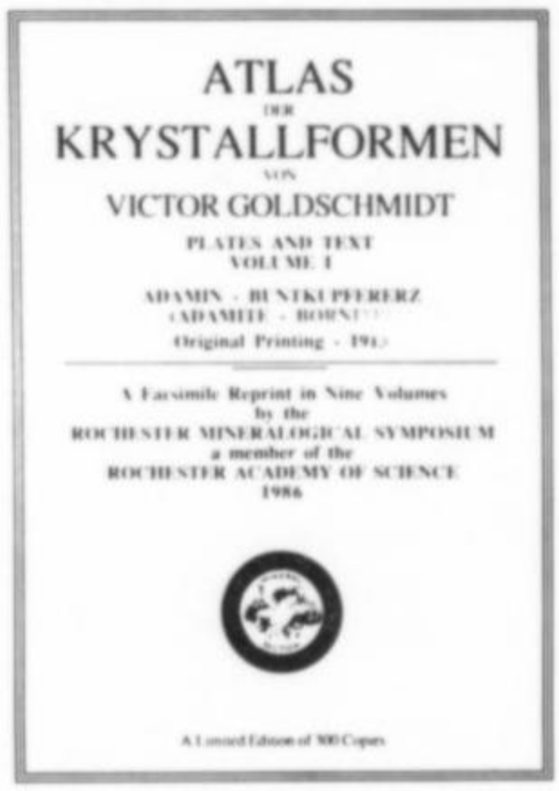
☐ **Minerals of Washington** (1975) Cannon **$7 postpaid** (S)

☐ **Minerals of Washington** (1985) Ream (New Edition) **$9 postpaid** (S)

☐ **Minerals of Washington, DC** (1980) Berstein **$9 postpaid** (S)

All Foreign Orders Add $1 per Book except as noted

H = Hardcover; S = Softcover



Goldschmidt's Atlas, vol. 1 & 2

☐ Text and figures. (Vol. 3–9 are in preparation.) **2 vols., $74 postpaid**

Prepaid orders only except by previous arrangement. Allow 4-6 weeks for delivery. SORRY – Credit cards not accepted.

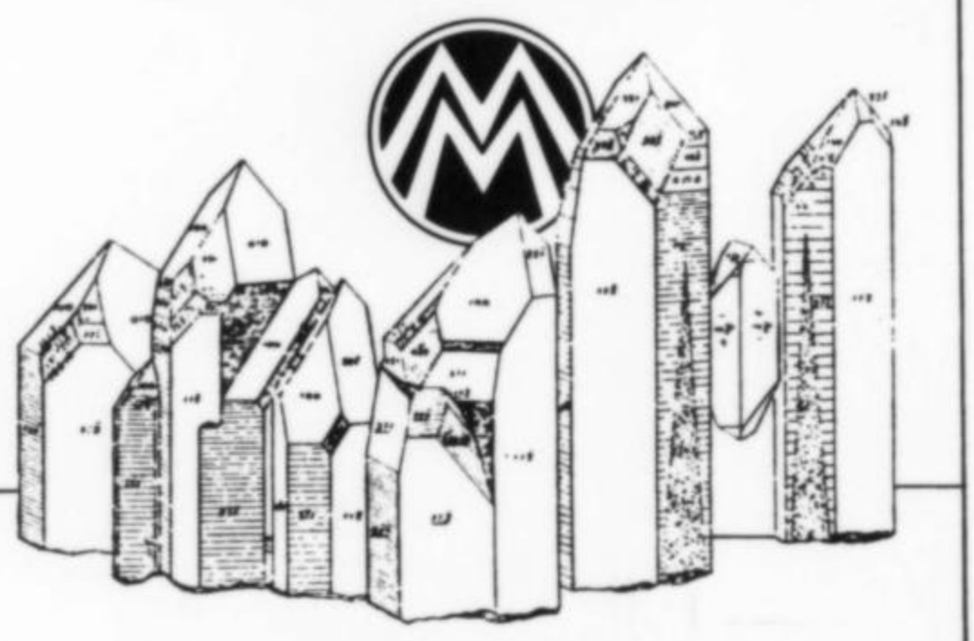
Mineralogical Record Book Dept.

P.O. BOX 1656, CARSON CITY, NEVADA 89702
TEL.: 702-883-2598

The 23rd annual

Munich

Mineral & Gem & Fossil-Show



Remarkable Classics from
Europe's Top Show

October 17, 18, 19

Friday, Saturday, Sunday 9-6

Three great days in the Exhibition Centre of Munich & more than 320 top dealers & spectacular exhibits of mineral specimens from dealers, museums and privat collections & old classic localities & the best assortement of high quality Europe minerals and fossils & new discoveries from the international market & great competitive show-exhibits & rare geological literature & demonstrations and meetings ... it's an event!

By the way, there are other top-quality shows throughout Europe you should not miss: **September** 6,7 Altdorf/Switzerland; 13,14 Brussels/Belgium; 27,28 Stuttgart-Fellbach/Germany; 28 Walbrzych/Poland; **October** 4,5 Colmar/France; 10,11 Bourges/France; 12,13 Genf/Switzerland; 17-19 Munich/Germany; 26 Bern/Switzerland; **November** 1,2 Hannover/Germany; 15,16 Zurich/Switzerland; 28-30 Hamburg/Germany.

INFORMATION MINERALIENTAGE MÜNCHEN
☎ 089/613 47 11 · P.O. Box 60 · D-8024 Oberhaching

Keeping in time with Franklin and Sterling Hill

Join us for field trips, lectures and "The Picking Table" as it presents the latest information about these famous localities.

Membership Fee: $10.00

The Franklin - Ogdensburg Mineralogical Society, Inc.
Box 146MR, Franklin, N.J. 07416 Membership $8.00

Grayson Lapidary

• Mineral Specimens •
• Micromounts to Museum Pieces •

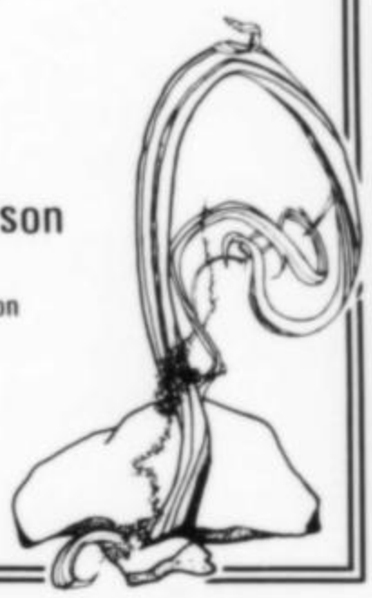
. . . From India, Tsumeb, South Africa, Italy, Russia, Norway, U.S.A., Sweden, England, China, Mexico, Spain, Morocco, Ireland, Peru, Canada, Australia, New Zealand, Romania, Brazil, and lab grown.

Ettringite (South Africa)
Scheelite (Russia)
Crocoite (Tasmania)
Phosphates (Florida)
Okenite geodes (India)
Cassiterite (New South Wales)

Grayson Lapidary
5135 Washington • Hillside, IL 60162
Tel: (312) 449-1399

Tysons'

fine mineral specimens



Rod & Helen Tyson

8507 111 St, Edmonton
Alberta, Canada
T6G 1H6
(403) 433-5075

SILVERHORN

MIKE & CAROLE RIDDING
• Fine Minerals

1155 Coast Village Road, Santa Barbara, California 93108

Tel: (805) 969-0442

August is European Mineral Clearance Month!

the Rocksmiths

Eldon, Jean & Jaye Smith

Box 157 • Tombstone, Arizona 85638

SHOWS

Aug. 2-3	San Francisco, CA
Aug. 6-10	Spruce Pine, NC
Aug. 8-10	Medford, OR
Aug. 16-17	Shreveport, LA
Sep. 5-7	Toledo, OH
Sep. 5-7	Houston, TX
Sep. 12-14	Denver, CO
Sep. 20-21	Long Beach, CA
Sep. 27-28	Victoria, TX

Simon Harrison Minerals

Fine Minerals

15 Queenwood Avenue
Fairfield Park
Bath, Avon
BA1 6EU ENGLAND

Russell E. Behnke

Specializing in World-class Miniature and Cabinet Specimens from Classic Localities, Brazil, China. Inquire about my Gem Crystals and Unsurpassed Chinese Collection.

•

161 Sherman Avenue
Meriden, Connecticut 06450
(203) 235-5467

I'm Buying!

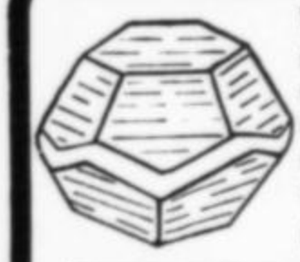
TOP QUALITY DISPLAY PIECES
CABINETS AND MINIATURES
Especially Gem xls & Gold

Keith Proctor

303-598-1233

88 Raven Hills Court
Colorado Springs, CO 80919

LUIZ MENEZES



We have fine Jacupiranga mine specimens, Brazilian minerals, excellent crystal specimens, and rutilated quartz.

Visit our showroom in São Paolo (by Appt.).

RUA ENG. AGENOR MACHADO,
108 CEP 04710 - S. PAULO - S.P. -
BRASIL. TELEPHONE (011) 521-0538

NORTHERN CRYSTALS

Beautiful, Interesting and Unique Minerals from Canada and Selected Countries

Canadian: LAZULITE, WARDITE, AUGELITE, ARROJADEITE, KULANITE, WHITEITE, BETAFITE, GROSSULAR. **British:** FLUORITE, CASSITERITE, BARITE, CHALCOCITE, WITHERITE, HEMATITE. Send for List: 2518 Skeena Dr., Kamloops, B.C. Canada V2E 1V5 (604) 828-2803.

RED METAL MINERALS

is announcing
The Re-Opening of
THE CALEDONIA MINE
in Michigan's Copper Country

Newly mined Copper Country minerals available!

For price list write to:
Richard Whiteman
P.O. Box 45
Hancock, Michigan 49930
(906) 482-9560

Carousel

GEMS AND MINERALS

1202 Perion Drive
Belen, New Mexico 87002
505-864-2145
★ SEND SASE FOR LIST ★

Fine Rare Books

Geology, Mineralogy, Paleontology, Mining, Gemology, and Jewelry

Send $1.00 for Catalog

THE GEMMARY, INC.

P.O. Box 816, Redondo Beach, Ca. 90277

connaisseur minerals

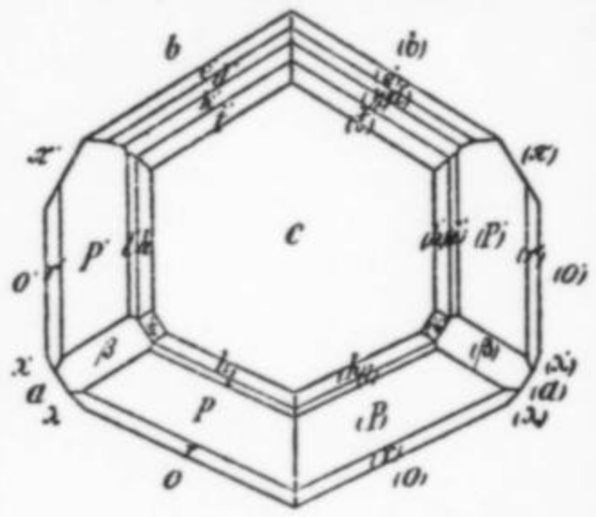
Over 1000 Species • Send Your Want-List • (705) 924-2976

IRWIN KENNEDY
R.R. 4, Warkworth,
Ontario K0K 3K0

Just returned from EUROPE
with NEW MINERALS!
See me in ROOM 130
at the IMD SHOW, DENVER

H. Obodda
Box 51
Short Hills, N.J. 07078
(201) 467-0212

Rare Species? Common Minerals?

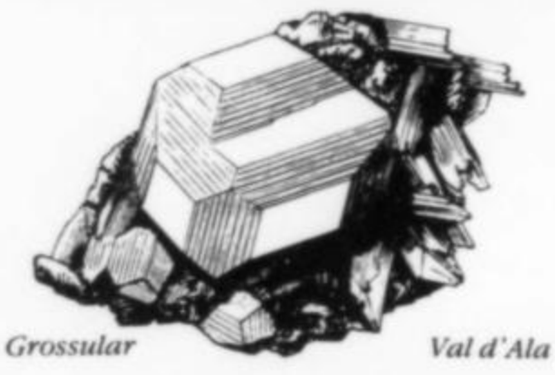


Our customers say: "Quality material, accurate labels, excellent wrapping." Find out why! $1 brings 20 pages of listings. $2 puts you on our mailing list for a year

Minerals Unlimited
P.O. BOX 877-MR
RIDGECREST, CALIF. 93555

G. Carlo Fioravanti

mineralogist



Grossular *Val d'Ala*

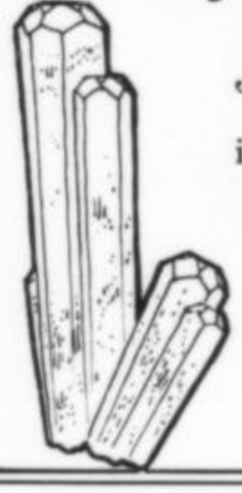
19/20 Via Pie di Marmo
Rome, Italy

Located between Piazza Venezia and the Pantheon

Mon. 5-8 pm; Thurs. & Fri., 11-1 pm, 5-8 pm; Sat. 11-1 pm

Phone: 06-6786067

Geary Murdock



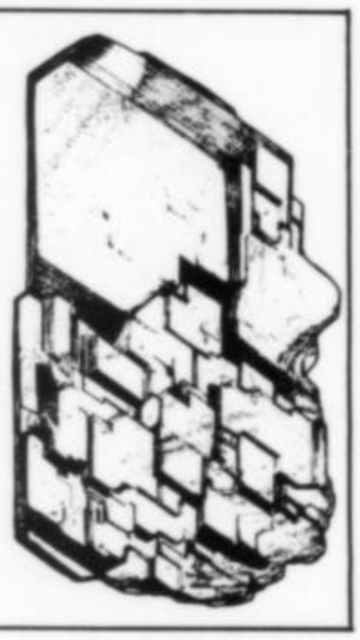
Specializing
in Idaho Aquamarine, and Fine Worldwide Mineral Specimens

•

628 Whittier Street
Idaho Falls, Idaho
83401

•

Colorado Gem and Mineral Company



Specializing in
Pegmatite Specimens
Jack Lowell
(602) 966-6626
Post Office Box 424,
Tempe, Arizona
85281

FINE MINERAL SPECIMENS
TN's to cabinet size
Write for Free list
New Showroom
1002 So. Wells Ave.

HARVEY M. GORDON, JR.
SIERRA NEVADA MINERAL CO.
500 Ballentyne Way
Reno, Nevada 89502
702-329-8765—(O)
702-329-4866—(H)

Silver scepter minerals

• WE BUY COLLECTIONS •

Fine Minerals
Oriental Carpets

Shown by Appointment

P.O. Box 141605, Spokane, WA 99214
Tel: (509) 928-6407

Opal Fields

Specializing in
Opal • Opal Specimens
Fine Mineral Specimens

5618 Odana Rd., The Atrium
Madison, Wisc. 53719
Tel: (608) 273-0399

713-862-5858

Collector's Choice

One of the nation's finest mineral showrooms.

Dalton & Consie Prince

5021-A Augusta, Houston, Texas 77007

Mineral List Available

WHOLE EARTH MINERALS
P.O. BOX 50008
RENO, NEVADA 89513

Mary & Gardner Miller
Missoula, Montana

Mineral Collectors

GEOMAR

Rare minerals for the species collector.
Free list of European
and African material available.
P.O. Box 62, 4020 BB Maurik (Gld.) Holland

the Mineralogical Record

Graphic Production
Capitol Communications, Crofton, MD

Printing
Waverly Press, Easton, MD

Color Separations
Effective Graphics, Compton, CA

Book sales
P.O. Box 1656
Carson City, NV 89702
702-883-2598

Affiliated with the Friends of Mineralogy, an independent, non-profit organization devoted to furthering amateur and professional interests in mineralogy. For membership information contact Don Zowader, 97 Leamington Rd., Somerville, NJ 08876.

Replacement copies
Availability of replacement copies usually extends for several months following publication, but is not guaranteed. Requests for replacements should be made as soon as possible.

Advertising Information
All advertising in the Mineralogical Record must be paid in advance of the closing date. Discounts apply when more than two ads are paid for at a time. Telephone orders not accepted. Write to the editor for rates.

Closing dates:

Jan.-Feb. issue	Oct. 15
March-April issue	Dec. 15
May-June issue	Feb. 15
July-Aug. issue	April 15
Sept.-Oct. issue	June 15
Nov.-Dec. issue	Aug. 15

An additional 30 days past the closing date are allowed in which advertisers may make changes (excluding size changes) in ads already paid for.

* Take advantage of our free typesetting and layout service!

* Write for our free 24-page brochure on how to advertise minerals!

Editing, advertising
Wendell W. Wilson
Mineralogical Record
4631 Paseo Tubutama
Tucson, AZ 85715
602-299-5274

Foreign Payments
Remittance may be made in local currency, at *prevailing exchange rates*, without surcharge, to the following people:

Australia
Piers Foa, Kovac's G. & M.
291-293 Wattletree Rd.
East Malvern, Victoria 3145

Belgium:
Paul Van Hee
Marialei 43
B-2120 Schoten

France:
ADIDOM
32, rue Servan
75011 - Paris

Great Britain
Simon Harrison
15 Queenwood Avenue
Fairfield Park
Bath, Avon BA1 6EU

Canada:
Mrs. J. W. Peat
36 Deepwood Crescent
Don Mills, Ontario M3C 1N8
Books & Back Issues Only:
Patrick W. Collins
Madawaska House
Calabogie, Ontario K0J 1H0

Italy:
Renato Pagano
Via S. Anna 1/B
I-34074 Monfalcone

Japan
Tsukasa Kikuchi
P.O. Box 18, Hongo
Tokyo 113-91

Netherlands:
W. J. R. Kwak
Kabeljauwallee 23
6865 BL Doorwerth (Gld)

South Africa:
Horst Windisch
30 Van Wouw Street
Groenkloof, Pretoria

Spain & Portugal
Bailey Minerals
Paseo de la Castellana, 171
28046 Madrid, Spain

West Germany
Christian Weise Verlag
Oberanger 6
D-8000 München 2

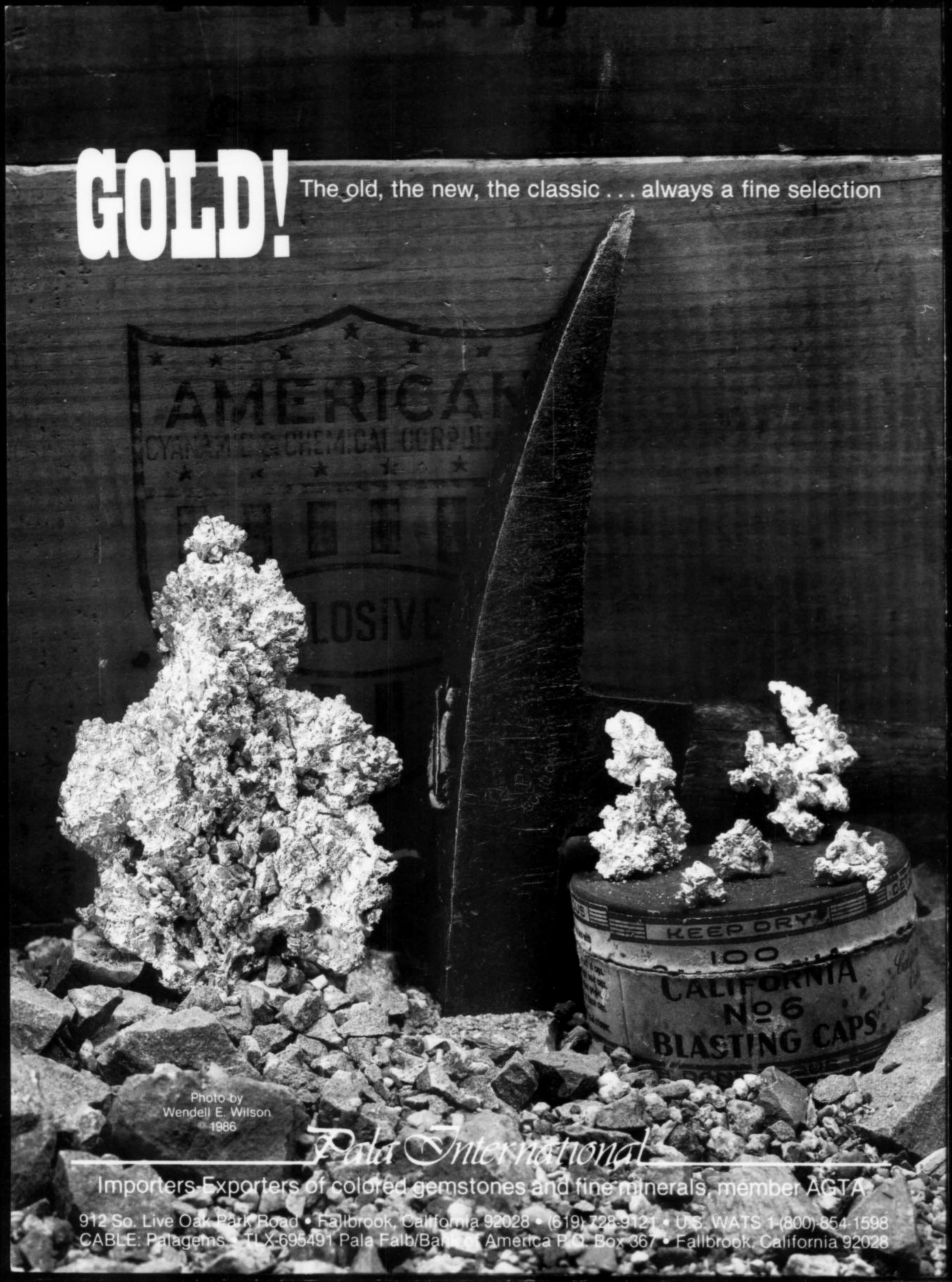
Contributed Manuscripts
Contributed manuscripts are welcome. Acceptance is subject to the approval of the editor.

Suggestions for authors
See Vol. 16, no. 2, p. 105, or write for copy.

Back Issues
Write to the Circulation Manager for a list of issues still in print. For **out-of-print issues** contact *Mineralogical Research Co.*, 15840 E. Alta Vista Way San Jose, CA 95127. A list of other dealers in back issues is available on request.

The Mineralogical Record accepts specimens on loan for photography and study, but can accept no responsibility for loss or damage.

ADVERTISERS INDEX


GOLD!
The old, the new, the classic . . . always a fine selection
AMERICAN
KEEP DRY
100
CALIFORNIA
No 6
BLASTING CAPS
Photo by
Wendell E. Wilson
© 1986
Pala International
Importers-Exporters of colored gemstones and fine minerals, member AGTA
912 So. Live Oak Park Road • Fallbrook, California 92028 • (619) 728-9121 • U.S. WATS 1-(800)-854-1598
CABLE: Palagems • TLX 695491 Pala Falb/Ban • America P.O. Box 367 • Fallbrook, California 92028