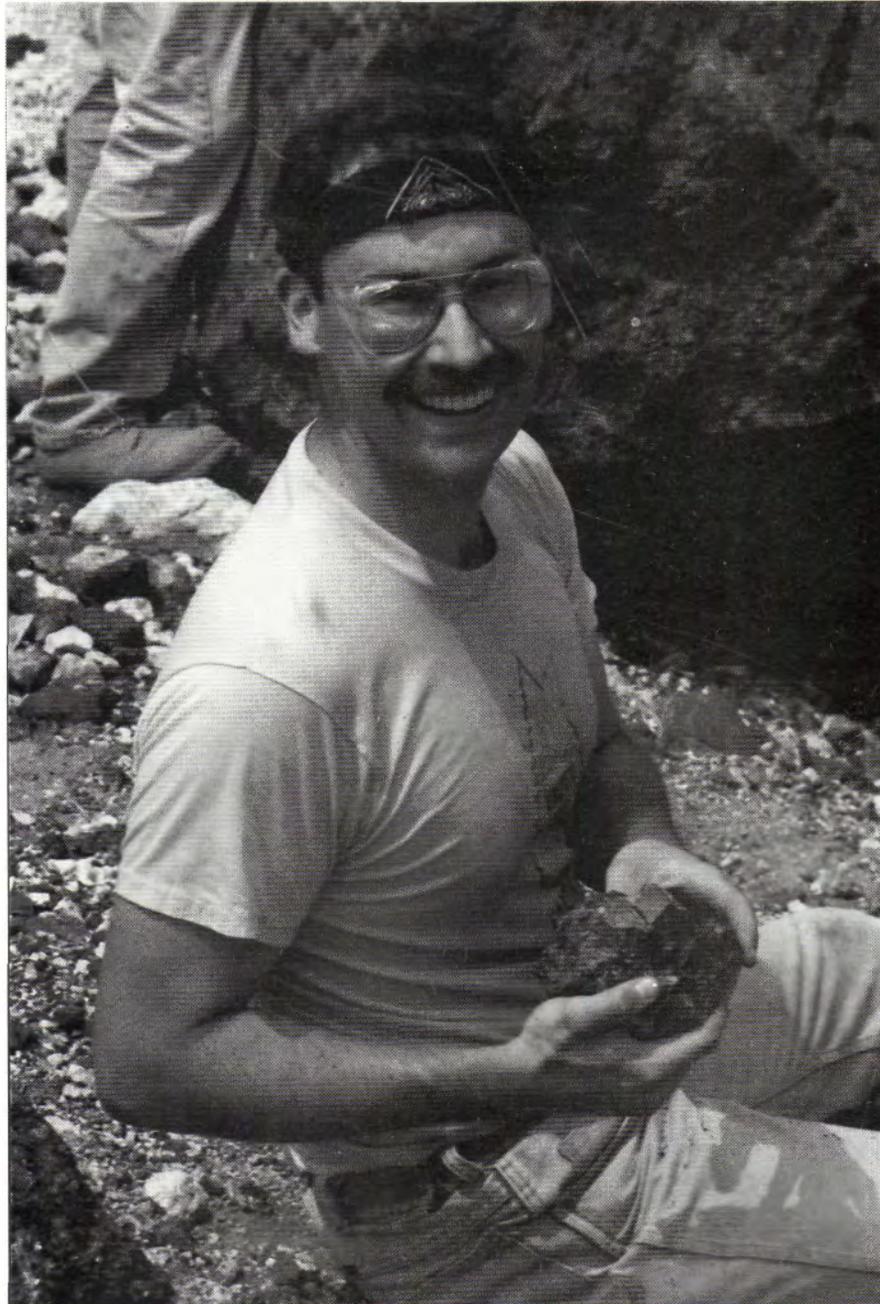


THE PICKING TABLE

JOURNAL OF THE FRANKLIN-OGDENSBURG MINERALOGICAL SOCIETY, INC.



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FALL/WINTER

1995

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Anyone interested in the minerals, mines, or mining history of the Franklin-Ogdensburg, New Jersey area is invited to join the Franklin-Ogdensburg Mineralogical Society, Inc. Membership includes scheduled meetings, lectures and field trips; as well as a subscription to *The Picking Table*. Dues are \$15 for individual and \$20 for family memberships. Please make check or money order payable to **FOMS**, and send to:

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THE PICKING TABLE

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The Picking Table is the official journal of the FOMS, and publishes articles of interest to the mineralogical community which pertain to the Franklin-Ogdensburg, New Jersey area.

Articles related to the minerals or mines of the district are welcome for publication in *The Picking Table*. Prospective authors should contact the Editors at the address listed above for further information.

Subscription to *The Picking Table* is included with membership in the FOMS. For membership, back-issues, and information on available publications, see the opposite page and the inside back cover.

The views and opinions expressed in *The Picking Table* do not necessarily reflect those of the FOMS, the Editors, or the Editorial Board.



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AUTUMN/WINTER 1995

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ABOUT THE COVER

Donald Lapham holding a nice, fresh 4.5 cm garnet crystal collected in the Passaic Pit, Sterling Hill, on June 3, 1995. See FROM THE EDITORS' DESK, p. 3, *Passaic Pit Field Trip*.

FALL 1995 ACTIVITY SCHEDULE

Saturday, September 9, 1995

9:00 A.M. - 3:00 P.M. — Collecting at the Passaic Pit, Sterling Mine, Ogdensburg, N.J.
For members of the Sterling Hill Mining Museum.

Saturday, September 16, 1995

9:00 A.M. - Noon — F.O.M.S. Field Trip — Collecting on the "Mine Run Dump" of the Sterling Hill Mining Museum, Ogdensburg, N.J. Fee: \$1.00 per pound, \$10.00 minimum.

1:30 - 3:30 P.M. — F.O.M.S. Meeting and Lecture.

History and applications of fluorescence, by Dr. Howard Heitner.

Location: the Lyceum Hall of Immaculate Conception Church,
75 Church Street, at the South end of Main Street, Franklin, N.J.

Friday, Saturday, and Sunday, September 29 and 30 and October 1, 1995

The 39th Annual Franklin-Sterling Gem and Mineral Show,
sponsored by the Franklin Mineral Museum.

Franklin Elementary School, Washington Ave., Franklin, N.J.

Show hours: Friday, 5:00 - 9:00 P.M.; Saturday, 9:00 A.M. - 6:00 P.M.;

and Sunday, 10:00 A.M. - 5:00 P.M. Admission: adults \$4.00
and children \$2.00, with multiple-day admission discounts.

During the show, *The Pond* swap-and-sell session will take place all day Saturday and Sunday
on the school grounds, rain or shine. Show admission is necessary to attend.

This is an F.O.M.S.-sponsored event. For information, contact
Chester S. Lemanski, Jr. after 7:00 P.M. at (609) 893-7366.

Saturday, September 30, 1995, beginning at 6:30 P.M.:

The Annual Banquet of the F.O.M.S.

Location: the Lyceum Hall of Immaculate Conception Church, Franklin, N.J.

Banquet Speaker: Dr. William Henderson, *Geological and mineralogical curiosities*.

Auction of minerals, memorabilia, books, and miscellanea.

Tickets (\$17.50) may be reserved by calling Joe Cilen, (201) 427-4550.

Saturday, October 21, 1995

9:00 A.M. - Noon — F.O.M.S. Field Trip — Collecting at the Buckwheat Dump,
Franklin Mineral Museum, Evans St., Franklin, N.J.

10:00 A.M. - Noon — Micro Group, at the Franklin Mineral Museum.

1:30 - 3:30 P.M. — Meeting and Lecture, at the Franklin Mineral Museum.

A photographic essay on the minerals of Franklin and Ogdensburg, N. J.:
a slide collection formed by the late Victor Cianciulli, by Steven Kuitems, D.D.S.

Sunday, October 22, 1995

9:00 A.M. - 3:00 P.M. — F.O.M.S. Field Trip — The Lime Crest Quarry,
Limecrest Road, Sparta, N.J. This is an invitational field trip hosted by the F.O.M.S.
It is open to members of mineral clubs which carry EFMLS membership and liability insurance;
proof of membership and insurance will be required.

Saturday, Oct. 28, 1995

6:30 P.M. — Saturday night collecting at the "Mine Run Dump,"
Sterling Mine, Ogdensburg, N.J.

For members of the Sterling Hill Mining Museum.

Saturday, November 18, 1995

9:00 A.M. - Noon — F.O.M.S. Field Trip — Collecting at the Franklin Quarry,
Cork Hill Road, Franklin, N.J.

1:30 P.M. - 3:30 P.M. — Meeting and Lecture, at the Franklin Mineral Museum.

Micro-minerals of the Buckwheat Dump:

a study of species found over the years, by Ralph Thomas.

Following the lecture, Dr. Pete J. Dunn will address the members
concerning his research program and the publication of his monograph.

Scheduled activities of the Society include meetings, field trips, and other events. Regular meetings are held on the third Saturdays of March, April, May, June, September, October, and November, and generally comprise a lecture and a business meeting. Field trips are held on the mornings before regular meetings, with occasional exceptions such as the Lime Crest Quarry field trips.

Unless specified otherwise, all meetings are held in Kraissl Hall at the Franklin Mineral Museum, 5 Evans Street, Franklin, N.J., and are open to the public.

Regular field trips are open only to F.O.M.S. members. The Lime Crest Quarry field trip is hosted by the F.O.M.S. and is open to members of clubs which have E.F.M.L.S. liability insurance or equivalent coverage. Proof of membership is required for all field trips, along with proper safety gear (a hard hat, protective goggles or safety glasses, gloves, and boots). The minimum age for field trips is 13.

FROM THE EDITORS' DESK

DR. PETE J. DUNN'S MONOGRAPH

Fliers announcing the availability of the first two parts of this monograph should have reached you by now; whether they have or not, please read the announcement on page 6. While doing so, remind yourself that this monograph is in all likelihood the most significant and comprehensive publication in the past, present, or future history of the Franklin-Sterling Hill district. If this seems like an extravagant claim, consider the extreme improbability of this accomplishment ever being repeated. Dr. Dunn is one of the most energetic, accomplished, and *driven* of mineral scientists; Franklin and Sterling Hill are the world's most complex and enigmatic mineral deposits. It is a fitting match. It is not enough just to say that this monograph is the culmination of two decades of focused labor and careful thought, or that it is, simply, Dr. Dunn's life's work, his heart's work. It is also the case that Franklin and Sterling Hill are unlikely to be so completely understood, appreciated, and described by anyone else. The Dunn monograph is not the last word on Franklin and Sterling Hill; no one will ever have that. But it is the most thorough, careful, honest, and inclusive work on these deposits that we will ever have. Every FOMS member should support this project and by a copy.

THE PASSAIC PIT FIELD TRIP (COVER STORY)

Don Lapham's garnet crystal specimen was certainly not the only fine piece recovered on June 3, although perceptible shock waves rippled over the dump as his fellow collectors realized what he had found. Excellent garnet crystals emerged, as did some top-quality fluorescent specimens: very attractive hydrozincite with calcite, for example. Still, major cabinet specimens of Sterling Hill garnet don't pop out into anyone's hands often. Don expressed the hope that featuring this photo might lure more collectors to the Passaic Pit, and provided this account of the find itself: *The garnet...was found in a large boulder that had evidently been removed from the Edison Tunnel excavation. It consisted primarily of mica schist with anhedral garnets to 1 inch in diameter. A calcite pod or vein ran through the schist about one third of the way across the boulder. Garnets protruding into the calcite showed good crystal...outlines and intruded me to attempt to break open the pod. The large garnet in the picture was exposed upon splitting a large section of the main boulder that had been broken off earlier. The largest garnet obtained is approximately 1.75 inches in diameter and exhibits prominent dodecahedral faces with minor trapezohedral faces. It is in intimate association with a pyroxene...and fluorescent calcite and willemite. Other minerals found in close proximity...were sphalerite with brightly fluorescent hydrozincite coatings, galena, and a white feldspar that shows the blue flash associated with labradorite.*

THE FRANKLIN-STERLING HILL MINERAL SPECIES LIST

It has been customary to print the complete list of confirmed mineral species in *The Picking Table* once a year. Dr. Pete J. Dunn, co-author of the List with John L. Baum, has suggested that this year it might be simpler to announce that there have been no deletions from the list since last September, and only one addition: chloritoid. Tony Nikischer's description of this find appears on page 11 of this issue.

THIS ISSUE'S FEATURE ARTICLES

Al Jehle deserves our thanks for going to the trouble of describing the "mine pearls" and other cave-type formations which formed fairly recently in the Sterling Mine. These may not have the respect accorded large crystals or rare mineral species, but they are certainly distinctive, and it was important to document their occurrence and recovery. John Jaszczak of Michigan Technological University, known to *Picking Table* readers for his articles about Sterling Hill graphite, has now given us the saga of an extraordinary zincite specimen, preserved in the MTU mineral collections for over a century, which recently yielded crystals of unusual size and habit. Paul Moore has graciously provided another in his series of articles about closest-packing in Franklin-Sterling Hill crystals. It was too large for one issue, and had to be divided; the second half will appear in the Spring/Summer 1996 *Picking Table*. We reiterate our conviction that Dr. Moore's articles are significant and profound, and will more than repay careful reading. Contrary to our expectations, we received more articles than we could fit in one issue, including an excellent treatise by Gary Grenier on the photographing of Franklin-Sterling Hill minerals; this also will appear in the next *Picking Table*. As for the rest of our potential authors - please don't stop writing! Finally, we move on to...

ULTRAVIOLATION 1995

This is the sixth year of a unique mineral show where two-thirds of the time the lights are off. As far as we know, no one has ever been kicked out for trying to sell or trade a specimen which was not fluorescent, but it is possible that no one has ever tried. The price is right - \$1.00 for admission, or \$5.00 for each four feet of table space if you are selling - and the atmosphere is happily informal. This year's location is the Northminster Presbyterian Church, 140 Trenton Road, Fairless Hills, Pa., and the show's Big Daddy is Ralph Thomas, (215) 295-9730. The hours are 10 AM to 4 PM. This year's show jingle (choke, gag) is "Come to Ultraviolation if you are able... You'll find you won't hafta crawl under the table!"



MESSAGE FROM THE PRESIDENT

A. Lee Lowell
53 Foxtail Lane
Hamburg NJ 07419

The FOMS spring activities were successfully completed thanks to the efforts of the chairpersons and members of the program, field trip, and spring swap-and-sell committees. We owe thanks also to the *Picking Table* editors for their efforts in publishing a great journal.

I would like to offer some comments on several significant events which occurred last spring and during the summer. First, the long-anticipated publication of Dr. Dunn's monograph was realized at the FOMS meeting in May. At that historic meeting, Part One of the monograph was released. The FOMS is the sole distributor of the monograph, and all profits from its sale will be shared by the FOMS and the Franklin Mineral Museum's Research and Education Fund. This publication is receiving high praise from the "F/SH Critics." The schedule for the publication of the remaining parts is uncertain at this time.*

Second, progress is being made at the two museums. Ground-breaking for the Franklin Mineral Museum's addition occurred in June. It is hoped that this work will be completed prior to the Franklin show. At the Sterling Hill Mining Museum, the Edison Tunnel was dedicated in April. It is important to note that FOMS members contributed significantly to these projects, as they do to the daily operations of these two great museums throughout the year.

Several major events are scheduled for this fall. Foremost of these, of course, is the 39th Annual Franklin-Sterling Gem and Mineral Show. This year the show will be held over the course of three days, from Friday, September 29, to Sunday, October 1. Children from schools in the area will have an opportunity to visit the show during school hours on Friday, the public will be admitted from 5 to 9 that afternoon and evening, and from 9 to 6 on Saturday and 10 to 5 on Sunday. Setup for this show will take place on Thursday the 28th. Tom Webb, the Show Chairman, requests that we give him our full support during the setup and over the three days of the show to assure a successful event.

Plans are being finalized to conduct another field trip on the Trotter mine property. Efforts to make this trip better are being explored, including consulting Trotter old-timers to identify the most productive locations for specimens. It will be a worthwhile experience digging up those Trotter "Rosetta Stones."

So let's all support and enjoy your society's fall activities and offer a pat on the back to those officers, chairpersons, editors, and support volunteers who are making the FOMS a world-class organization for the 36th year.

*[Editors' Note: Part Two was released shortly before this *Picking Table* went to press.]



LOCAL NOTES

NEWS FROM THE FRANKLIN MINERAL MUSEUM

John Cianciulli
Franklin Mineral Museum
P.O. Box 54
Franklin NJ 07461

The Franklin Mineral Museum has finally broken ground for its new addition. It is hoped that the building will be completed by this fall's mineral show. There will be some temporary changes in the layout of our gift shop due to construction, but disruption of most museum activities is not expected. The reception area and gift shop are located for the moment in Kraissl Hall. The SPEX-Gerstmann collection has been carefully logged and packed, and is presently in locked storage until construction of the museum addition is complete. Also currently under way is the computerization of the FMM's collections catalog; our estimated 15,000 artifacts and mineral specimens are being logged into a central database. The same is being done for our growing museum archive.

There are several new exhibits installed in the cases which once displayed the fine mineral specimens of Richard, Robert, and Elna Hauck. Our gratitude is extended to the Haucks for their support of the Franklin Mineral Museum through the long-term loan of their specimens and artifacts. The new exhibits include the

following: miners' lamps and headgear, on loan from Lee Lowell; an FOMS exhibit of specimens found on recent field trips; minerals which can still be found on the Buckwheat Dump; and finally, mineral species first described from Franklin and Sterling Hill which are named for people. More thematic and educational exhibits are being planned for the future.

Mineral research activities are keeping the curator and his assistant quite busy. Collectors are encouraged to bring in their unknowns for identification. We'll even look at quarry finds! For example, Steve Kuitens brought in some suspected heulandite xls from the Lime Crest quarry, in a thin seam in a matrix of feldspar, quartz, and calcite. They are colorless xls, no larger than 0.5 mm but with the typical coffin-shape of heulandite; they were confirmed by optics. Tony Nikischer added another species, chloritoid, to the Franklin-Sterling Hill list. [The report is in this issue.] While working the Buckwheat dolomite, Tony DenUyl uncovered what appeared to be an unusual light-brown sphalerite in crystal form. This proved to be pseudomorphs after sphalerite of a fine-grained mixture of sphalerite and smithsonite. Last but not least, Jim Rumrill has set the pace for finding uraninite and other as-yet-undiscovered radioactive minerals on the Buckwheat Dump.

Keep in mind that the Franklin Mineral Museum has a growing reference collection of rare mineral species from Franklin and Sterling Hill. We will be happy to let you see and study these

specimens at the museum. Microscopes are set up in the archive for this purpose. Study sessions may be arranged with John Cianciulli.

The Franklin Mineral Museum will sponsor the 39th Annual Franklin-Sterling Gem and Mineral Show on Sept. 29th and 30th and Oct. 1, 1995. It will be held at the Franklin Elementary School on Washington Avenue in Franklin. Show time is when the local collector community and Franklin townfolk pull together for a common cause. The success of this Gem and Mineral Show helps to insure the survival of the Franklin Mineral Museum, with its important role in preserving the area's geological, mineralogical, and historical heritage.

This October the Museum will be 30 years old, a time during which it has become a icon of accomplishment for mining and mineral preservationists and an international mecca for mineral collectors. The support of the FOMS and the former Kiwanis Club of Franklin has been essential to our success. The Staff and Board of Trustees of the Franklin Mineral Museum, Inc., would like to take this opportunity to thank the members of the Franklin Kiwanis Club and the FOMS, and the long list of museum supporters, for making the Franklin Mineral Museum what it is today.

NEWS FROM THE STERLING HILL MINING MUSEUM

Joe Kaiser
40 Castlewood Trail
Sparta NJ 07871

The Sterling Hill Mining Museum has received a challenge grant from the Geraldine R. Dodge Foundation to establish Sterling Hill as a site for science education in New Jersey. The grant provides stipends for twelve teachers to work at Sterling Hill this summer and fall. They will be trained in the geology, mineralogy, history, and mining technology of the region. In addition, they will develop a rough draft of a Teacher's Guide to Sterling Hill, which will be distributed to interested schools. The purpose of this guide will be to inform the schools of the educational value of the region and to prepare teachers for their visit. Lastly, the grant funds part of the development of a Geology Field Trip, a new project at Sterling Hill. At a special location on the mine property, students will be able to collect and identify several different and distinct mineral species and rocks. They will then be able to take their new-found treasures home for their collections.

On April 8, 1994, the Edison Tunnel Complex was dedicated. This completes an important stage of this ongoing project. To enlarge the Complex, it was decided to aim one of the new tunnels toward an abandoned section of the mine which had been discovered during prior underground explorations. This section now helps to connect the Edison Tunnel with the basement of the old mill. The once-abandoned tunnel along this route shows signs of being hand-driven, and could have been used to gain access to the east vein in the 1840s. This new extension of the Edison Tunnel Complex is expected to be part of the mine tour next year, and suggests many possibilities for the tour, and the project as a whole.

On June 3 the Passaic Pit was open for collecting to members of the Sterling Hill Mining Museum Foundation. A few excellent specimens were found. This field trip, the first to this part of the property in 30 years, will be run twice a year. For information, contact the Museum at (201) 209-7212.

MICRO NEWS

Modris Baum
173 Valley View Drive
Rockaway NJ 07866

The March 1995 meeting of the new Micro Group saw the largest and most enthusiastic turnout to date. The theme was "Micros from the Buckwheat Dump," and many fine Buckwheat specimens, both classics and recent finds, were available to enjoy. The latter included exceptional crystals of brookite, hemimorphite, albite, sphalerite, and rutile. In addition, we saw some rather spectacular lustrous brown tourmaline crystals and fluorescent aragonite collected on the Buckwheat by the Archers of the Clifton mineral club. No micros these! When you add to all this the "hot" radioactive minerals which have been turning up lately, it should be obvious that the Buckwheat Dump is still worth visiting.

By popular demand there was a mini-meeting in May. Due to work pressures I was unable to provide advance publicity to everyone. Attendance was small, but we had a great time examining fine Franklin and Mont Saint-Hilaire material.

Our next meeting will be on Saturday, Oct. 20, from ten to noon. No special theme: bring your favorites, recent or classic. It is always a treat for everyone to see what to strive for. New material from active collecting sites is especially welcome. Franklin-Sterling Hill material is always available and we also expect to see new material from Maine and Mont Saint-Hilaire.

There is always material to be traded, purchased, or given away. Bring your 'scope and illuminator. There will be an extra 'scope at the next meeting, so don't let lack of equipment hold you back.

FIELD TRIP REPORT

Steven M. Kuitems, D.M.D.
272 Arnold Ave.
North Plainfield NJ 07063

THE STERLING HILL MINING MUSEUM DUMP March 18, 1995

The most notable specimen recovered was a large (27 x 18 cm) example of pale green willemite pseudomorphs after gypsum. These were thin, fan-like plates in a vein traversing a substantial block of willemite-franklinite ore. Also found were rhodonite masses, mixed with gahnite, originally from 600 level; when broken open these revealed the typical pale pink coloring of Sterling Mine rhodonite. A few of these pieces included calcite pods with crude, blocky crystals of rhodonite and sharp one-centimeter gahnite octahedra. The youngest collector present found a franklinite crystal a little over one centimeter in size. Micromineral enthusiasts had ample material to explore, including numerous hand-sized specimens which yielded crystals of siderite and hetaerolite. The best fluorescent minerals that turned up were veinlets of hydrozincite, fluorescing strong blue under shortwave ultraviolet radiation, and ore samples rich in sphalerite which fluoresces moderate orange under longwave ultraviolet radiation. Also noted on the dump was an abundance of frankinite slickensides, many with mirrorlike surfaces.

THE BUCKWHEAT DUMP, May 20, 1995

The hot rock of the day was found right on the surface, with no digging necessary; this was a 15 x 15 x 4 cm slab of dark greenish-gray pegmatitic rock with a grain of uraninite about 1 cm across centered on its surface. Several specimens were found of andradite crystals in a matrix of calcite and feldspar. Dark brown nonfluorescent uvite was encountered with green scapolite in blocks of white Franklin Marble. Numerous micro specimens came from the still-abundant gray dolomite, including crystals of calcite, dolomite, quartz, sphalerite, chlorite, goethite, and twinned albite. Specimens with three or four of the following fluorescent minerals present were found on the surface of the dump: willemite, calcite, sphalerite, and hydrozincite.

THE LIME CREST QUARRY, May 21, 1995

The predicted rain held off and 130 people turned out for a fine day of collecting. Among the highlights were sharp 2.5 cm norbergite crystals of a deep orange color, with good yellow fluorescence under shortwave ultraviolet radiation. Well-formed spinel crystals with lustrous faces were found in two sites at opposite ends of the quarry. The spinels less than 0.5 cm in size were often red to purple in color, but as the size of the crystals increased to about 2 cm, their color darkened toward black. The Perseverance Award goes to the collectors who spent four-and-a-half hours recovering a 5 x 10 cm dark-brown uvite crystal. Typical cubic crystals of pyrite were found, as well as pyrite of an unusual, almost stalactitic (and iridescent) habit. Searchers for fluorescent minerals were rewarded with typical norbergite, tremolite, diopside, and scapolite. As at the last several Lime Crest field trips, some ferroaxinite was retrieved with much hard work from slip faces on several large pegmatite boulders. Comic relief came in the form of oddly-shaped concretions recovered from the recently quarried areas of the upper weathered zone.

THE FRANKLIN QUARRY, June 17, 1995

A great deal of active quarrying had produced a wealth of newly broken rock to search through. Several significant specimens were found, including two separate examples of excellent green uvite crystals, 2.5 to 3 cm in size, in a matrix of pale gray calcite. Both were sharply formed; one was typical medium-green and the other was deep oil-green and partly gemmy. Some exceptional tremolite crystals of unusual habit, on the order of 9 x 4 cm, were discovered in white, fine-grained calcite (photo below). Radial sprays of acicular tremolite 5 cm across were also noted. Much effort was required to retrieve a pocket of quartz crystals, some of which were at least 3.5 cm long. Worthwhile sulfide finds included a 2.5 cm pyrite crystal with a reddish iridescent coating, 5-cm masses of pyrrhotite, and a well-formed 1.5 cm arsenopyrite crystal. Other material recovered included margarite, brown uvite, and phlogopite.



Tremolite crystal, 9 x 4 cm, in calcite.
Franklin Quarry, Franklin, N.J.
S. Kuitems Collection, T. Hecht photo.



ANNOUNCING DR. PETE J. DUNN'S MONOGRAPH

A new monograph, entitled *Franklin and Sterling Hill, New Jersey: the world's most magnificent mineral deposits*, by Pete J. Dunn, began publication on May 20, 1995. Parts One and Two are now available. Both are 8½ x 11 inch softcover editions, illustrated with line drawings and black-and-white photographs.

Part One contains xiii pages of front matter and 160 pages of text, and includes 46 illustrations. It consists of a 66-page bibliography; Chapter 1, *Introduction*; Chapter 2, *Historical perspective of local iron mining and processing*; and Chapter 3, *Historical perspective of local zinc mining*.

Part Two contains xvi pages of front matter and 160 pages of text, and includes 133 illustrations. It consists of Chapter 4, *Quarries in the Franklin Marble*; Chapter 5, *The major zinc-mining companies in the Franklin-Sterling Hill area*; Chapter 6, *Beneficiation of the zinc ores*; Chapter 7, *Cultural aspects of Franklin and Sterling Hill*; Chapter 8, *Regional and local geology of the Franklin-Sterling Hill area*; Chapter 9, *Geology and structure of the zinc deposits*; Chapter 10, *Geochemistry*; Chapter 11, *Fluorescence of minerals in ultraviolet*; and Chapter 12, *Mineral Assemblages*.

The Franklin-Ogdensburg Mineralogical Society, Inc., is the sole distributor for the first printings of Parts One and Two of this monograph. The officers of the F.O.M.S. have set the price without consultation with Dr. Dunn, who receives no income from this publication. Proceeds from sales are divided. For each copy sold, \$10 is donated to the Research and Education Fund of the Franklin Mineral Museum, which supports Dr. Dunn's research; the F.O.M.S. receives the greater portion of the proceeds with no conditions.

Each volume is available by mail for \$30 plus \$5 postage-and-handling. Checks should be payable to F.O.M.S. and mailed to:

John Cianciulli, F.O.M.S.

60 Alpine Road
Sussex NJ 07461

or

Steven Misiur, F.O.M.S.

309 Fernwood Terrace
Linden NJ 0703

As quantities are limited, orders are filled on a first come, first served basis.



THE 39TH ANNUAL FRANKLIN-STERLING GEM & MINERAL SHOW

SEPTEMBER 29 - 30, AND OCTOBER 1, 1995

For many collectors of Sussex County's minerals, few of whom live in Franklin, *The Show* is the climactic event of the year. So it is for the community, which has hosted this event since its inception in 1956, first at Neighborhood House, then at the Franklin armory, and now at Franklin Elementary School. While *The Show* is today sponsored by the Franklin Mineral Museum, we should never forget that both of these Franklin institutions had much of their impetus from the now-defunct Kiwanis Club of Franklin (the Show Chairman, Tom Webb, is an ex-Kiwanian),

and that neither museum nor show could exist without considerable and continuing local support.

To celebrate the Borough of Franklin's ongoing contributions to *The Show*, we present this article by the music teacher at the Franklin Elementary School. Her appreciation of the event, from the perspective of teacher *and* student, is most welcome. The accompanying photographs also help to demonstrate the diversity of attractions found at Franklin during showtime. Be there!

THE SHOW: A SCHOOLTEACHER'S PERSPECTIVE

Judy Gutlerner
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Sussex NJ 07461

There's something special about a rock and mineral show coming to your school. The day before, trucks and cars from all over the United States pull up to the school playing fields and start to unload. Bearded collectors, mineralogists, and geologists walk the halls carrying natural wonders from all over the world: geodes, crystals, rare gems, exotic mineral species.. Back and forth, carrying heavy, cryptic boxes, they bustle around the gymnasium and auditorium stage, talking about where they have been, which minerals they have discovered and collections they have bought. The metamorphosis of the auditorium stage into a fluorescent mineral display or the gymnasium into a rock and mineral show is an incredible sight to behold. Even in the basement there is much going on, as members of the Home and School Association of Franklin unwrap soda and hot-dog buns, preparing for the next days' food concession, and parents and teachers sign up to help. For once, students with after-school detentions get a special treat as they witness the transformation of their school into a wonderland of earth science.

When the Franklin-Sterling Gem and Mineral Show officially opens, people from all over the community flock to visit. Out in the recess field, collectors and mineral dealers have set up shop. A food

cart pushed by a parent volunteer moves up and down among them. With their parents and teachers in attendance, numerous students attend the show, curious to see exactly what is happening at their school. Many of them walk from table to table in awe. "Look at this...!" "Did you see...?" "What did you get?" Younger children who have tired of looking congregate at the playground and enjoy one another's company as their parents continue to roam.

More than just a hobby event for the rock and mineral lovers of New Jersey, "The Show" has become an important educational and social event for everyone at the Franklin Elementary School, from principal to custodian. As a result of this show taking place here, many young rock-hobbyists have also emerged. Throughout the year they bring their new knowledge and rock specimens to class to share.

This year all the children at the Franklin Elementary School will truly become a part of this show. The exhibitors will be holding a special session for schoolchildren on Friday during school hours. Now all of them will have the chance to see the spectacular fluorescent display on their auditorium stage, or converse in their own gym with the mineralogists and collectors who have unearthed some of these magnificent specimens.

Twenty years from now, many of the boots that will once again tramp into the school to set up exhibitions will belong to Franklin School children who were inspired during these special, impressionistic years. As one of the school teachers in Franklin I would like to thank you for bringing us these wonders and sharing such an exciting and special experience. 



Subdued feeding frenzy for man and animal alike - *The Pond Swap-and-Sell* at the Franklin-Sterling Mineral Show, 1994. T. Hecht photo.



Dr. Pete J. Dunn and Herb Yeates installing a display of Dr. Dunn's formal notebook, now a monograph-in-progress. 1994 Franklin-Sterling Show. T. Hecht photo.



Show chairman Tom Webb up in the air stringing electrical cord. Note the halo effect of the basketball net. 1994 Franklin-Sterling Show. T. Hecht photo.



Mineral collectors in various stages of ecstasy. The mineral auction at the F.O.M.S. banquet. 1994 Franklin-Sterling Show. T. Hecht photo.



Volunteers feeding a starving mineral collector at *The Pond*. 1994 Franklin-Sterling Show. T. Hecht photo

STERLING HILL OPENINGS

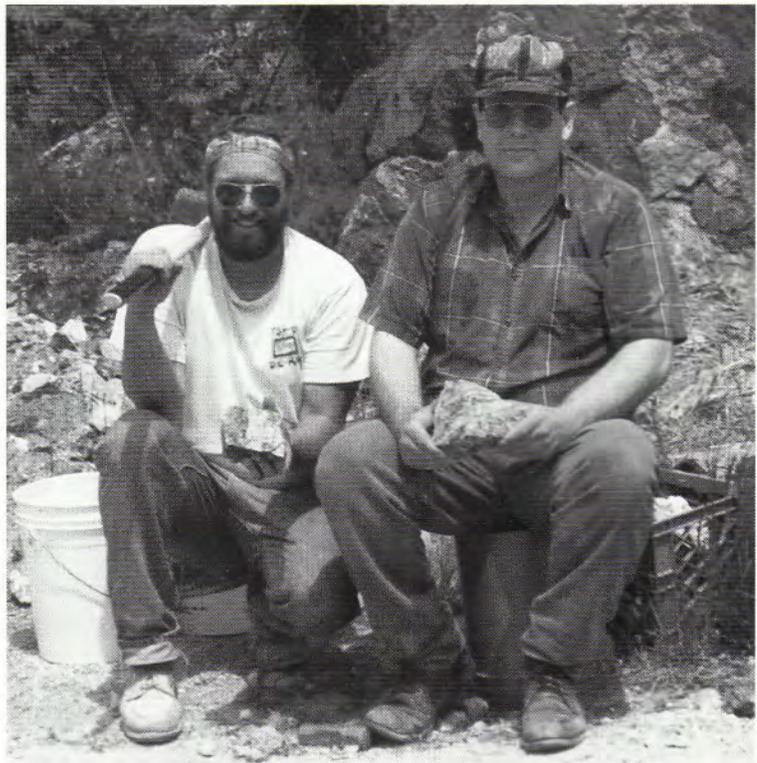


Ribbon-cutting at the opening of the Edison Tunnel, April 8, 1995. Left to right: Robert Hauck; Robert Murry and Tom Smoot of the Edison Foundation; August Rutkowski, Mayor of Ogdensburg, and Richard Hauck. T. Hecht photo.

THE REOPENING OF THE PASSAIC PIT TO COLLECTING, JUNE 3, 1995



Joe Kaiser at the weighing-out ceremony. By 3 P.M. the Pit was over a thousand pounds lighter. R. Bostwick photo.



Dump "regulars" Claude Poli (on left) and Jeff Bubrow with the catch of the day. R. Bostwick photo.



The Cyborg. An aficionado of fluorescence, intimately joined with his infernal machine. R. Bostwick photo.



Collectors swarming over the East Vein outcrop. R. Bostwick photo.



Another collector "in the bag." What better place on a hot day than under a suffocating plastic tarpaulin? Proof that fluorescent-mineral fanatics *are* different from the rest of us, and probably crazier. R. Bostwick photo.

TECHNICAL NOTES

CHLORITOID ADDED TO THE FRANKLIN LIST

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1000 North Division Street
Peekskill NY 10566

The mineral chloritoid, an iron aluminum silicate hydroxide, has been discovered on a single Franklin specimen from the Buckwheat Dump collected over twenty-five years ago. The specimen, purchased by the author from the estate of G. Fred Lincks, was field-collected by Mr. Lincks in the late 1960s or possibly 1970, and was subsequently labeled stilpnomelane. The material occurred as a two-centimeter-wide group of greyish-green to dark-green foliated, somewhat radiating scales (up to one-half centimeter in width) on a matrix of cinnamon-brown garnet of undetermined phase. Curious about the stilpnomelane-like mineral and suspecting it might be franklinphilite, the author split the specimen and submitted the richer half for analysis.

The piece was labeled "Excalibur Unknown #048" and sent to Mr. Andy Roberts of the Geological Survey of Canada for preliminary X-Ray work and comparison to the Standards File at the CGS. Roberts found the mineral to have a triclinic chloritoid structure (data at the Canadian Geological Survey under file #X-

76625, dated October 7, 1994). He suggested further analysis via SEM to nail down the specific phase.

This specimen was returned to the author and then forwarded to Cannon Microprobe of Seattle, Washington for SEM work. A small polished section was prepared and carbon-coated, then analyzed using EDS and WDS X-Ray spectrometers in an ARL SEMQ electron microprobe. (Probe operating conditions: accelerating voltage 25 kV, beam current 50 na. XRD operating conditions: beam current 8 mA, accelerating voltage 35 kV, Ni filter, Cu K-alpha.)

The platy green mineral was shown to be Mg-free, with no detectable Na or K (the latter essential for franklinphilite and lennilenapeite). It also contained, in descending order of abundance, Al, Si, and Fe, with approximately 7% Mn, which is known to substitute for iron in chloritoid.

The specimen was then submitted for examination to John Baum and John Cianciulli at the Franklin Mineral Museum, and the analytical date forwarded for review to Pete J. Dunn of the Department of Mineral Sciences, Smithsonian Institution. Based on their mutual assessment of the mineral's appearance in matrix, its triclinic structure, and its chemical composition, it is confirmed as Franklin chloritoid. Samples reside in the Franklin Mineral Museum and the author's private collection.



SAMFOWLERITE

A full description of this new mineral, a brief announcement of which appeared on page 12 of the Autumn/Winter 1994 *Picking Table*, has been published in *The Canadian Mineralogist*, Vol. 32, pp. 43-53 (1994), titled:

Samfowlerite, a new Ca Mn Zn beryllsilicate mineral from Franklin, New Jersey: its characterization and crystal structure.

The authors are Roland C. Rouse, Donald R. Peacor, Pete J. Dunn, Shu-Chun Su, Peter H. Chi, and Herb Yeates. Samfowlerite is monoclinic, with ideal formula $\text{Ca}_{14}\text{Mn}_3\text{Zn}_2(\text{Zn},\text{Be})_2\text{Be}_6(\text{SiO}_4)_6(\text{Si}_2\text{O}_7)_4(\text{OH},\text{F})_6$. It is extremely rare, although one specimen of samfowlerite, a micromount from the Standfast Collection, is on exhibit at the Franklin Mineral Museum.

The Rouse et al. paper is relatively lengthy, with most of its content devoted to the chemistry and structure of samfowlerite. Those topics are omitted in the following excerpts from that paper, which are concerned with the provenance and physical description of samfowlerite, subjects of paramount interest to collectors. These excerpts are copied from the paper rather than abstracted, for the simple reason that any such abstracts would have been nearly as lengthy as the original text and not as well-written.

Introduction

During an examination of late-stage minerals occurring in vugs in ore from Franklin, New Jersey, the properties of one of the minerals found could not be identified with those of any known species. Although it occurs in exceedingly minute quantities, precluding the measurement of some properties, we have nevertheless been able to characterize the mineral and define it as a new species. We have named it *samfowlerite* in honor of Dr. Samuel Fowler, M.D. (1779-1844), the pre-eminent figure in the history of the Franklin mining district. Dr. Fowler, a physician, scientist, industrialist, and entrepreneur, was instrumental in bringing most of the great American naturalists and scientists of his time to Franklin and encouraging mineralogists in Europe and elsewhere to study the zinc deposits at Franklin. *Fowlerite*, now known to be a zincian variety of rhodonite, had previously been named for Dr. Fowler. The new mineral and the name were approved by the Commission on New Minerals and Mineral Names, IMA. The holotype specimen is deposited in the Smithsonian Institution under catalogue number M04254.

Occurrence

Samfowlerite was originally found on only one small specimen from the Franklin mine, in Franklin, Sussex County, New Jersey. The holotype material occurs in a vug in granular willemite

- franklinite - andradite ore. The vug is partly lined with massive white garnet of the andradite - grossular series, the surfaces of the garnet crystals being light orange-pink in color. The single cluster of samfowlerite crystals in the specimen occurs on the garnet. The holotype specimen is a micromount and is part of a famous Franklin cahnite assemblage found in 1927 and described by Palache (1935).

Subsequent to IMA-CNMMN approval of samfowlerite, an additional specimen was found, and this permits a more detailed description of the assemblage. The specimen consists of franklinite - willemite - andradite granular ore, which has vuggy areas. These vugs are lined with various minerals, including sparse 2-cm crystals of willemite and barite. Garnet (andradite - grossular solid solution) which crystallized contemporaneously with and subsequent to the barite crystals, also lines the vugs. Minor johnbaumite is included in the garnet. Indeed, garnet is the most notable feature of the assemblage, varying in color and texture from yellow-brown granular material, to whitish, fine-grained, zoned material forming dodecahedra, to a thin pinkish orange outer zone. Of particular interest are very small, submillimeter-sized crystals that occur as late-stage crystallites on the pinkish orange material. These crystals are euhedral, twinned, colorless cahnite, pseudo-hexagonal light brown clinocllore [called biotite by Palache (1935)], thin druses of very pale pink leucophoenicite, and euhedral crystals of colorless samfowlerite (Fig. 1). Although only a very few specimens are available for study, it can be said that samfowlerite tends to occur alone in vugs, with or without clinocllore, and also occurs

interstitially to platy crystals of barite.

Inasmuch as cahnite and associated barite are colorless to white, other specimens of samfowlerite may exist unrecognized and perhaps mislabeled as cahnite in systematic collections.

Physical and Optical Properties

The holotype material is a 0.5-mm-diameter group of crystals, with each crystal being approximately 0.05 mm in diameter. On that specimen, and on the small number of specimens subsequently discovered, the crystals form aggregates like those shown in Figure 1. Single crystals of samfowlerite have very smooth, highly reflective faces and are colorless, with a vitreous luster and white streak; they may appear white in the aggregate. No cleavage was observed, but the amount of material studied was so small that cleavage, if present, could well have gone undetected. The hardness was not directly determined, but the mineral is very soft, the estimated Mohs hardness being no more than 3.... There is some similarity in appearance between samfowlerite and some nontypical crystals of clinohedrite.

....Samfowlerite fluoresces with a very weak red color in both longwave and shortwave ultraviolet radiation.

Acknowledgements

We are indebted to Neal Yedlin, now deceased, who preserved the type specimen of samfowlerite in his collection under the name clinohedrite, which the new mineral physically resembles....

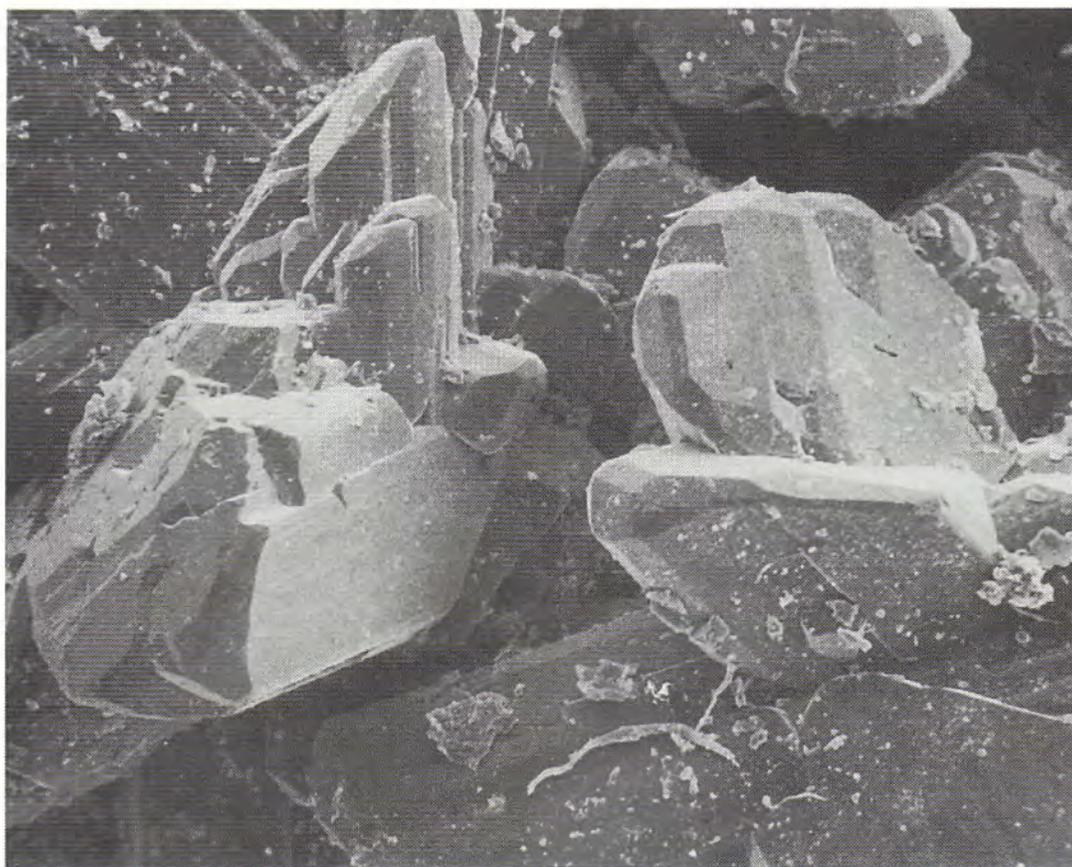


Photo and text taken from *Canadian Mineralogist*, Vol. 32, pp. 43-53 (1994).



RECENT STALAGMITES, STALACTITES, AND "MINE PEARLS" FROM THE STERLING HILL MINE

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Shortly after the Haucks acquired the Sterling Hill mine property, a massive exploratory and salvage operation was begun underground. Gradually a group of devoted volunteers became involved in this endeavor. Constantly rising mine waters gave their efforts a sense of urgency. The emphasis was on saving equipment and memorabilia, and systematically collecting mineral specimens. Although the Sterling Mine amounted to a man-made cave system with miles of tunnels, given the urgency of the task there was little time to contemplate the importance of the occasional cave-type feature.

In this crew of multi-talented people, not all were interested in minerals. To some the old mine workings were uninteresting, damp, and dirty holes in the ground; to mineral buffs they were sources of wonder. While descending many hundreds of feet down laddered manways, these amateur miners began to encounter striking white cave-type formations in some of the old tunnels and working-places. It seemed to them as if part of Carlsbad Caverns had been transplanted to New Jersey. In the total darkness of the mine their cap-lamps picked out sheets and pillars of flowing stone. Rusted mining paraphernalia was overgrown with small stalagmites, and the opposing stalactites hung dripping from the ceiling (fig. 1). Also encountered were thin curtains of slender "soda-straws," stalactites so fragile that a sneeze would have demolished them (fig. 2). These ghostlike apparitions - particularly the stalagmites on the floor - stood out like sentinels guarding against further assaults by invading miners (figs 3-4). The mine was really healing itself, using dissolved rock and tailings from the levels above to refill the voids left by the miners.

Bob Winters was one of the volunteer workers who was particularly impressed by the beauty of these strange formations. The excitement of his personal encounters with them can be best

expressed in his words, reconstructed from my notes of a conversation with Bob about his underground trips circa 1990:

AJ: Bob, where did you see most of the stalagmites?

BW: Hell, they were all over the place. Every level we went into had some kind of cavelike formations dripping from the roof.

AJ: Where did the ones I got from you come from?

BW: Oh, those: they came mostly from the 900- and 1000-foot levels. But wait a minute; actually they came from a place called the "hanging room." It's a place that cuts almost at right angles under the 1000-foot level.

AJ: How did you find out about that place?

BW: John Kolic told me; he knows the mine like the back of his hand.

[Editors' note: according to John Kolic 1120 stope was mined from 1100 level to one cut below 1000 level, where one area of the stope threatened to undermine the 1140 crosscut drift on its way to the powder magazine. Here a floor pillar of ore was left in place to support the drift. The "hanging room" was an access tunnel (scram drift) about 8 feet below the level, driven through that supporting pillar of ore into the part of 1120 stope which was mined through to 1000 level.]

AJ: What made this "hanging room" or 1120 [stope] so special?

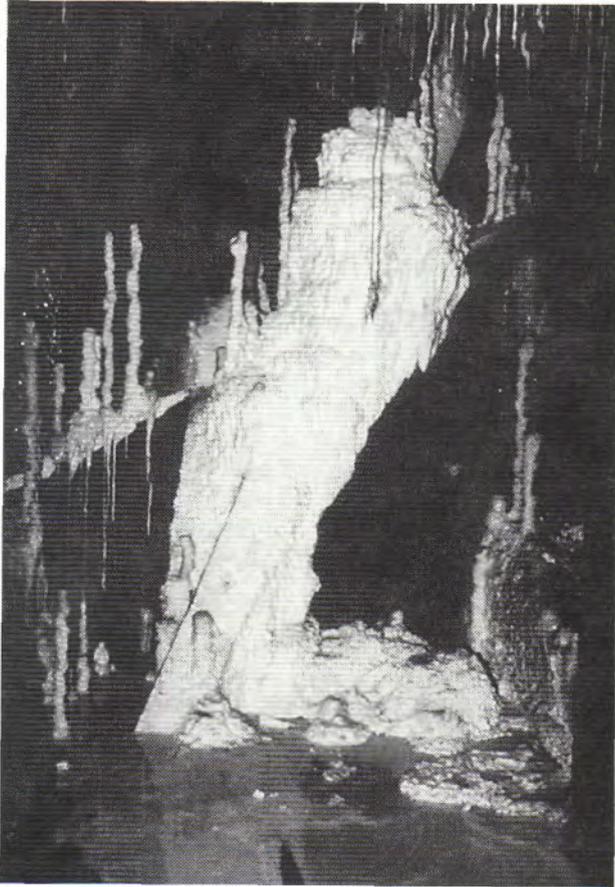


Figure 1. Post-mining flowstone covering timber prop and iron pipe. Note stalagmites atop pipe, and stalactites below it. 800 level, Sterling Mine. B. Kozykowski photo.



Figure 2. "Soda-straw" stalactites hanging from roof of drift, with stalagmites below. Sterling Mine. B. Kozykowski photo.

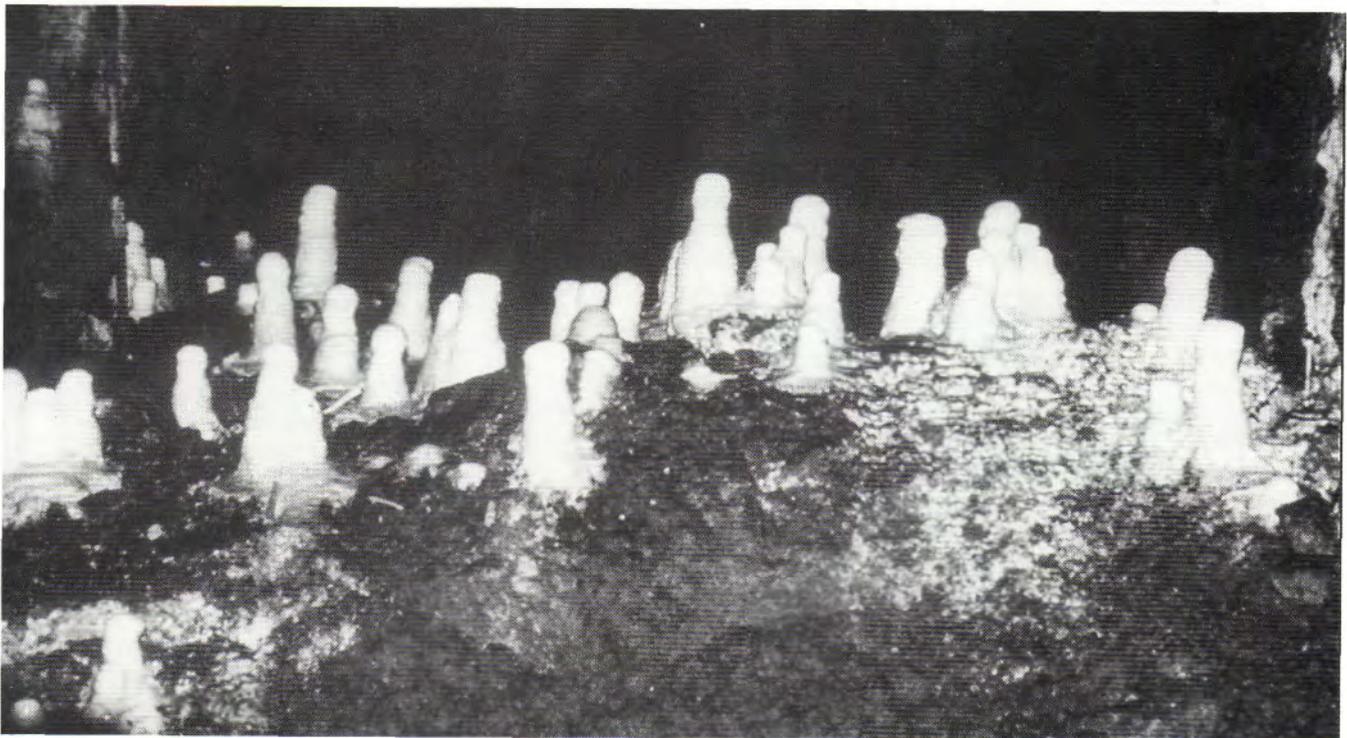


Figure 3. Stalagmite sentinels on floor of drift. 900 level, Sterling Mine. B. Kozykowski photo.

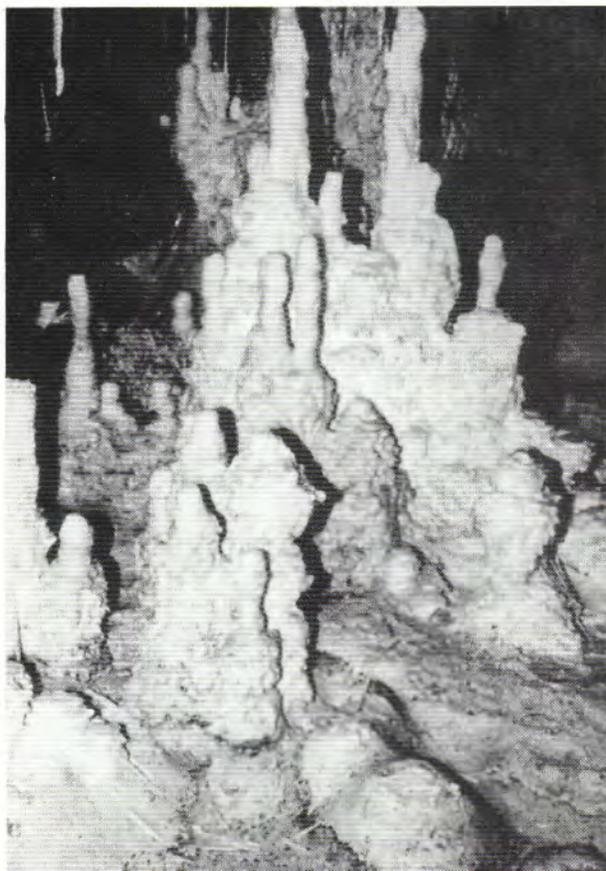


Figure 4. A cluster of stalagmites. 800 level, Sterling Mine. B. Kozykowski photo.

BW: That's where I saw the largest numbers of stalactites and stalagmites in one place....Man, it was something to see. When my light hit the floor there were at least two hundred stalagmites sitting there, stark white, unbelievable! The ceiling dripped with stalactites, real pointy things of all different lengths. There were some things that looked like drapes on the walls. I had never seen anything like this before; I still can't get over it. I hated to walk into the place because I couldn't help stepping on things.

AJ: You must have felt a little funny about busting up the show.

BW: Well, in a way, yes, but some people didn't really feel that these things were part of the mine. Rare crystals, minerals, and all that sort of thing was their bag.

AJ: The question is, did Dick [Hauck] say that it was okay to collect them?

BW: Sure! He was real generous. Most of the guys, though, except Pat [Radomsky] and myself and a couple of others didn't think they were important, so I collected what I could.

AJ: Well, Bob, what I'd really like to know is where the mine pearls were found.

BW: They were distributed over several areas in the mine, but I got the best ones from the 900-foot level. I remember that they were under an ore chute that was pouring water; the lips of the chute were encrusted with layers of calcite. The water must have been loaded with calcium carbonate. It poured on the floor, partially into a small pool which contained a lot of free-moving concretions that looked like small different-sized eggs [fig. 5]. On the lip of the pool there were all kinds of different carbonate growths, some of which looked like brain coral. The nodules at the bottom of the pool were in constant motion; they seemed to be undulating. There were different shades, mostly white, but some were chocolate-colored. They were many different sizes, some as small as a grain of rice (these were mostly around the edge of the pool) and others ranging up to two inches. There were also some that apparently had been splashed out of the pool and were distributed around the outside in their own little groups. All I can say is that it was the damndest thing I'd ever seen!



Figure 5. "Robin's nest" of mine pearls on drift floor. Note damage from boots. Sterling Mine. B. Kozykowski photo.

Initially these roughly spherical concretions from the mine were called cave pearls, but to differentiate them from the more common ones occurring in natural caves, it was decided to call them mine pearls. Some of those described above were turned over to Pat Radomsky, who was particularly interested in whether their cores were the same as those of similar concretions he had studied which were from a cave. When broken open, one of the mine concretions proved to contain a small piece of zinc ore at its center (fig. 6). The concretions from the cave had cores of sand. Not only were the mine pearl cores different, but those with willemite and/or calcite present fluoresced, the willemite green and the calcite red under shortwave ultraviolet radiation.

Once the uniqueness of these mine pearls became evident, a great many of them were cut in half and checked for fluorescence. Further study of mine pearl sections revealed that most of their nuclei were fragments of Sterling Hill ore, largely consisting of franklinite, willemite, calcite, and zincite, with zincite the least

frequent. Occasionally a mine pearl contained only one of these minerals at its center, but often there were two or more. Mine pearls with a center of fluorescing willemite and calcite are especially prized by collectors. As the concentric layers of mineralization outside the core generally fluoresce and phosphoresce a moderate pale blue, these three fluorescences together create a very attractive effect.



Figure 6. Sterling Hill mine pearls in the round, and cut-and-polished. The largest mine pearl is approx. 2 cm across. R. Thomas photo.

The shapes of these mine pearls varied from spherical to ovoid to pear-shaped. There were erratically shaped concretions which had formed around irregular fragments of ore, but these should probably not be called pearls. One concretion contains a core made up of ore fragments and small blebs of metal, which are magnetic and are probably the residue from a welding operation. There was rubbish in the mine, and there is reason to believe that anything which washed into the type of "pearl pool" Bob Winters describes could become the nucleus for a mine pearl.

Dr. Robert E. Jenkins II has examined a Sterling Hill mine pearl at the DuPont Experimental Station, using X-ray diffraction (XRD) and a scanning electron microscope with energy-dispersive X-ray fluorescence (XRF) capability. Prior to study, the mine pearl, about 1.5 cm in diameter, was polished to a 0.25-micron finish using diamond pastes and gamma-alumina (Personal communication from Robert Jenkins, dated May 30, 1995). These are his findings:

The "mine pearl" [outside of its nucleus] consists of CaCO_3 containing small quantities of Si, Mg, Fe, and perhaps Zn and Mn. Divalent ions presumably substitute for Ca. Si is probably present as micro-inclusions of opaline silica. None of the trace elements are present in quantities greater than 600 ppm. No satisfactory XRD powder photograph of the CaCO_3 phase could be obtained. Radiating morphology of mineral grains in SE [scanning electron] views suggest that it may be aragonite. Calcite pseudomorphs after aragonite cannot be ruled out, however.

The "mine pearl" is megascopically color-zoned with alternating concentric bands in white, various shades of yellow-white, and various shades of brown. Individual bands vary from 0.2 to 1 mm in thickness. One wants to presume that color bands correspond to changes in chemical composition, but repeated attempts to show this by X-ray elemental mapping were not successful. Areas enriched in the various trace elements appear as diffuse patches, rather than distinct bands. This may be related to 1) pixel size in our images, or more likely 2) poor counting statistics for very low concentrations of trace elements (200-400 ppm is generally regarded as maximum sensitivity for the electron microprobe).

Mine pearls were not the only cave-type (speleothem-like) formations saved from the mine, although they may be the oddest. Unlike stalactites, etc., cave pearls and mine pearls have no point of attachment, and form in running water around a nucleus. Numerous examples of mine stalactites and stalagmites were recovered, however, and there is a case full of them on exhibit at the Sterling Hill Mining Museum (fig. 7). For skeptics concerned about provenance, Sterling Hill stalagmites often incorporate ore fragments, and in some cases mine pearls, in their bases. Some of these stalagmites are particularly prized for their odd appearance;



Figure 7. Mine stalactite/stalagmite display at the Sterling Hill Mining Museum. T. Hecht photo.

individuals may reach lengths of over 30 cm with diameters of 8 to 10 cm, and groups are known (fig. 8).



Figure 8. The author with Sterling Mine stalagmites at the 1994 Franklin-Sterling Gem and Mineral Show. The piece in the center is titled *Family Group with Strange Dog* and is 35 cm high. T. Hecht photo.

When the speleothem-like formations found at Sterling Hill are compared with those found at Carlsbad Caverns in New Mexico (or almost any other cave in the world), there are great structural and morphological similarities. In the March, 1991 *National Geographic* there is an article describing and illustrating the cave pearls which occur in Lechuguilla Cave, the newly discovered extension to the Carlsbad cave system. However, the Carlsbad formations are considered to be thousands of years old, with a slow rate of growth. The Sterling Hill formations apparently took only decades to form.

How long have the formations at the Sterling Mine been growing? When experienced miners such as John Kolic and Bob Svecz were consulted, their consensus was that the mine had been relatively lacking in cave-type formations before hydraulic backfilling operations were started in the early 1970s. Before this time, exhausted working-places were filled with dry mill tailings, for the most part finely crushed calcite; this was not terribly satisfactory because such fill does not pack tightly and often “runs” when given the chance. (In 1964 at Sterling Hill a miner was suffocated by dry fill which ran into his working-place and covered him.)

During hydraulic filling operations at Sterling Hill, fill was mixed with water to make a slurry, which was piped into the dammed, worked-out areas at the conclusion of each mining cycle. The water enabled the fill to settle firmly in place. Initially the fill material was crushed slag brought back from the Palmerton smelter

in the same railroad cars used to ship out the milled ore. Later the company switched to fill trucked in from local sources: sand from glacial deposits and crushed marble from the quarries. As the fill did not provide firm footing for the miners or support for their equipment, near the end of each filling operation cement was added to the slurry, forming a hard cap from which further mining could be conducted. Much water was required, and was pumped in from the nearby Wallkill River. Before the period of hydraulic backfilling the Sterling Mine was considered fairly dry, even though an extensive system of ditches, sumps, and pumping stations was necessary to get rid of the groundwater as it seeped in. Once hydraulic backfilling began, the mine became rather wet.

It is generally accepted that most cave formations, or speleothems, result from the precipitation of minerals dissolved in groundwater. While such precipitation is most likely to take place from mineral-saturated solutions which cool or evaporate at the point of deposition; the pH of the water and its velocity may also be factors. In Carlsbad Caverns, located in one of the drier parts of North America, groundwater flow is restricted and speleothems develop slowly. At the Sterling Mine in the 1970s and 1980s the natural seepage of groundwater into the mine was sharply augmented by water runoff from hydraulic filling. By the time it entered the mine, the mildly acidic groundwater had already been flowing through the Franklin Marble, picking up substantial amounts of CaCO_3 . The hydraulic fillwater, drawn from local sources and already somewhat carbonate-rich, would have then leached additional carbonates from the cement in the fill cap, and possibly from the fill itself, depending on the type then in use. With the available groundwater, this fillwater would then have flowed downward to the mine-drainage system through the most accessible channels, which often included old working-places filled with crushed calcite. When this heavily carbonate-enriched groundwater/fillwater mix emerged into open areas underground, CaCO_3 immediately began to precipitate. The result was the abundance of cave-type formations which Kolic, Svecz, Winters, and many others saw in the Sterling Mine during its last decades, months, and days.

In naturally occurring caves in the United States it is a Federal crime to vandalize speleothems. However, in the case of Sterling Hill, where the water now reaches a few fathoms below the surface, what remained in place of the mine’s stalagmites, stalactites, and mine pearls is probably now being dissolved. Bob Winters, Pat Radomsky, and their fellow vandals are to be commended for preserving another curious feature of a very great mineral locality. The Sterling Mine is already world-famous for its abundance of mineral varieties and rarities, and its mine pearls, small as they are, can only enhance that fame.

ACKNOWLEDGEMENTS

Without the generosity and cooperation of Dick and Bob Hauck none of this would have been possible. Special thanks are also due to the few, notably Bob Winters and Pat Radomsky, who had the foresight to bring the Sterling Hill cave-type formations to the attention of the mineral-collecting community. Photographs of these formations were graciously made available by Bernie Kozykowski and Ralph Thomas. The assistance of Bill Kroth, Steve Misiur, and Wally Radomsky was also invaluable. Last but not least I commend Warren Langill for helping me to edit and untangle this article.



aug 12 / 89 25

Michigan Mining School.
To Ward + Howell, Dr.

3	st. Graphite	Leicester N.Y.	
7	"	Chalcopyrite	Ga.
1	"	"	Nevada
6	"	Marcasite	Mexico
1	"	Bartholite	Bergen Hill N.J.
1	"	Talc.	Calif.
7	"	Rose Quartz	Bedford N.Y.
13	"	Thulite	Norway
3	"	Chalcedony	Yellow St. Pt

Figure 1 (a). First of 100 pages of a Ward and Howell inventory dated August 12, 1889 for the purchase of over 4600 specimens by the Michigan Mining School.

		\$1593 80
	Zincite + Franklinite	N.J. 1 50
2	Clay Iron Stone;	Barbadoes 35 70
"	"	" 50
"	"	" 60
	Limonite,	Trinidad 25
"	"	Tenn 25
"	"	Mo. 35
"	"	" 25
"	"	" 30
	Pisolitic Limonite,	France 60
	Hematite,	Trinidad 30

Figure 1 (b). A separate page of the 1889 Ward and Howell inventory showing the \$1.50 price for a specimen of zincite with franklinite from New Jersey.

ZINCITE COMES TO LIGHT

John A. Jaszczak and Stanley J. Dyl, II

Seaman Mineral Museum
Michigan Technological University
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Houghton, Michigan 49931-1295

Careful preparation has revealed several rare, complete zincite crystals from Franklin, N.J., which were previously hidden within their calcite matrix. Labels and archived inventories associated with the specimen track the history of the Seaman Mineral Museum back to 1889.

Shortly after the Michigan Mining School was established in 1885, the school began purchasing mineral specimens for its teaching collections. In 1886, the school's first year of operation, these purchases were authorized by the Principal, Albert Williams, Jr. By 1887 his successor, President Marshman E. Wadsworth, took over this task, which by 1892 was delegated to his assistant and soon-to-be Geology Department Head, Professor Arthur Edmund Seaman.

Specimens purchased by the college were organized into several collections having specific academic purposes. The main collection was called the Lecture Collection. It consisted of miniature to cabinet-size pieces that were available to faculty for classroom demonstration, and as reference material for students. The Lecture Collection specimens were labeled and catalogued according to a system adopted by Professors Brush of Yale and Cooke of Harvard, whereby in the original collection, successive specimen numbers increased by ten. New specimens were interpolated into the collection without having to renumber those already in the lecture collection (*Catalogue of the Michigan Mining School: 1891-1892*. This numbering system now allows one to identify which specimens were part of the original Lecture Collection and which were added later.). The collection was organized in drawers according to Dana's *System of Mineralogy*, 6th Edition. A second collection consisting of mineral fragments and crystal portions, mostly miniature to small cabinet-size samples often purchased by the kilo, was called the Working or Practice Collection. Like the Lecture Collection it was well organized, but it was left unlabeled as these minerals were given to mineralogy students for practice in sight identification during mineralogy lab recitations. Other collections included "special collections" of natural crystals, those highlighting important physical properties, and a small exhibition collection as well.

In 1902 Prof. Seaman established the college's mineralogical museum and selected approximately 10% of the lecture collection, combined with the exhibition and special collections, for display in the Geological-Mineralogical Museum in Science Hall (later

known as Hubbell Hall). In 1932 the museum was named the A. E. Seaman Mineralogical Museum in honor of Prof. Seaman.

Inventories of these early specimen purchases date back to 1886, and record purchases from A. E. Foote, Ward and Howell, G. L. English, and Dr. Krantz. One such inventory from Ward and Howell listed approximately 4,600 specimens purchased for \$1,612.45, on August 12, 1889 (see figure 1a). On the last page of this 100-page inventory is listed a specimen of "zincite and franklinite" from "New Jersey" priced at \$1.50 (figure 1b). No other listing of "zincite and franklinite" occurs among any of the other Ward and Howell inventories in the museum's archives. The writing and description in the inventory match perfectly with a specimen in the original lecture collection numbered 14150, whose accompanying Ward and Howell label is shown in figure 2. This label more completely identifies the locality as "Franklin, New Jersey".

In 1897 the name of the school was changed to Michigan College of Mines (MCM). Subsequently the Lecture Collection was renumbered when it was formally listed in the MCM catalog. For the zincite specimen, both the original Ward and Howell label (fig. 2) and Prof. Seaman's original Michigan College of Mines label (fig. 3) indicate the new catalog number as 17760. Figure 3 also shows that the specimen was yet again renumbered as 3065 (see also figure 4), perhaps after 1927 when the name of the school was changed to Michigan College of Mining and Technology.

In 1976 the Seaman Mineralogical Museum moved to its current location on the fifth floor of the Electrical Energy Resource Center, still on the campus of what is now called Michigan Technological University. In 1978, specimen 3065 was renumbered as DM19734-K and placed in storage. The convention used in the assignment of catalog numbers at this time was that "DM" designated "display mineral" (in storage or not) while the "K" denoted that the specimen was part of the remainder of the Lecture Collection, which was transferred to the museum in 1977 from the Geology Department when headed by Dr. Jorma O. Kalliokoski.

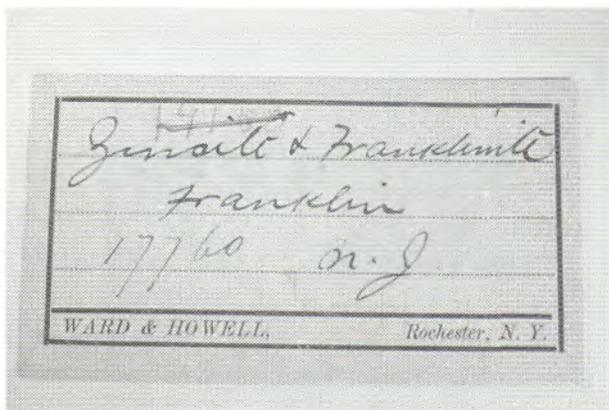


Figure 2. Original Ward and Howell label from specimen 14150 corresponding to the inventory listing shown in figure 1(b).

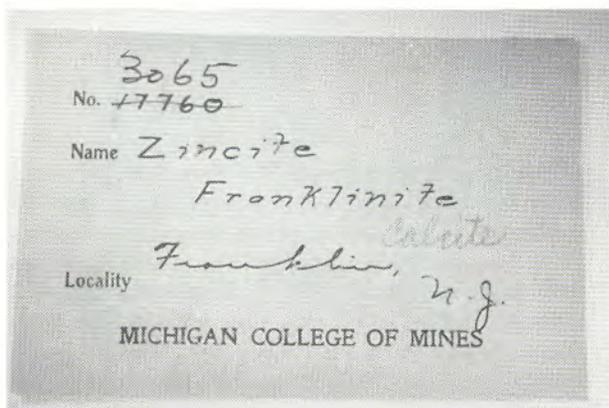


Figure 3. Michigan College of Mines label 17760.

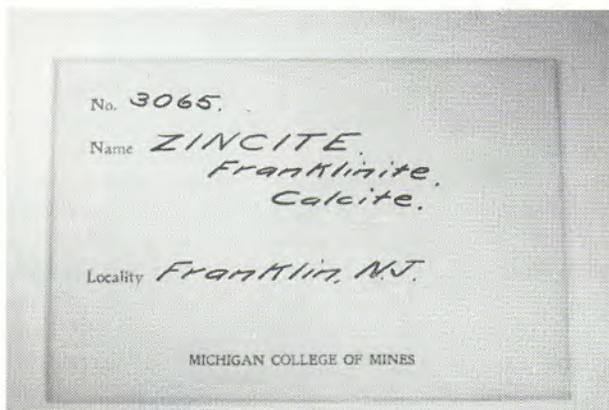


Figure 4. Michigan College of Mines, or perhaps, Michigan College of Mining and Technology label 3065.

In 1994 Mr. Cal Graber was contracted to conduct an appraisal of the Seaman Museum's "world-wide" collection (excluding minerals from the Lake Superior and midwestern U.S. regions). During a preliminary visit to the museum in October, Mr. Graber noted some potential in the underappreciated reference specimen, wondering if there might be some complete crystals of zincite hidden and protected within the calcite matrix. With the permission of Curator Stanley J. Dyl II, Mr. Graber took the

specimen back with him to California for careful preparation. To everyone's delight, Mr. Graber's suspicions proved correct and his skillful preparation exposed two *complete* crystals, the larger measuring an impressive 2 cm across (figure 5). The crystals are red-brown in color and stand out nicely against the cream-colored calcite. Overall the dimensions of the specimen are 7 x 4.5 x 3 cm. Associated minerals are subhedral black franklinite crystals to 5 mm, brownish anhedral willemite crystals to 2 mm, and minor yellow coatings of an unidentified mineral. Under shortwave ultraviolet radiation, the calcite fluoresces bright orange-red while the willemite fluoresces bright green and is also phosphorescent. In contrast to open-vein crystals of zincite (Bancroft, 1984; Palache, 1935), the crystals are opaque and have rounded edges and corners. The largest exposed face on the largest crystal seems to be the negative base (000 $\bar{1}$). The crystal seems to show its hemimorphic symmetry; however, the rounded corners and the fact that the crystal is still partially embedded in calcite make it difficult to be certain. Close inspection of the negative base of the large crystal shows that it is actually a composite of two crystals (perhaps twinned) with a boundary running in an irregular fashion from the top of the crystal (at the apparent 90° corner) to the bottom. This accounts for the asymmetry of the crystal (see figure 5).

Among the many other zincite specimens in the museum's collection, one other specimen of some significance is a partial crystal that is approximately 1.5 x 1 x 1 cm in size. This translucent red-orange crystal shows some fairly sharp pyramidal faces and hemimorphic symmetry, although it is only about 2/3 complete. The crystal is kept in its original small black Riker box, on the back of which is a Foote label and a \$10.00 price. A January 27, 1911 inventory shows that the specimen was purchased from the Foote Mineral Company by Prof. Seaman. The inventory listing states:

Zincite, crystal, very rare, N.J. ————— 10.00.

Undoubtedly there are many other treasures in the Seaman Mineral Museum from the Franklin and Sterling Hill mines. While some of these remain to be "rediscovered", as in the case of no. DM19734-K, known treasures include a type specimen of bementite from Franklin, obtained by Prof. George A. Koenig from C. S. Bement. We hope to tell more about this specimen in a future article.

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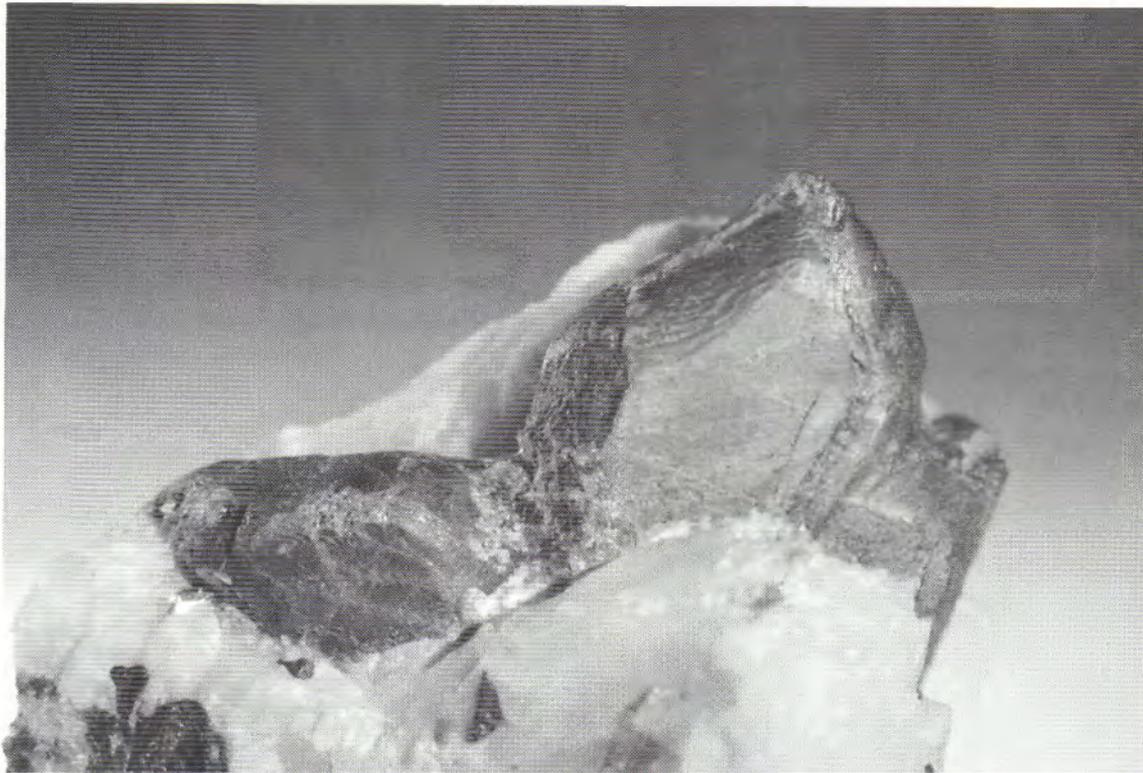


Figure 5. Zincite with franklinite in calcite after preparation by Cal Graber. The largest of the zincite crystals is 2 cm across. Seaman Mineral Museum specimen DM19734-K. J.A. Jaszczak photo.



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The 39th Annual Franklin-Sterling Gem and Mineral Show

Presented by the Franklin Mineral Museum

New Weekend and Location

Friday, Saturday and Sunday
September 29-30 and October 1
Hours: Friday, 5:00 P.M. - 9:00 P.M.
Saturday, 9:00 A.M. - 6:00 P.M.
Sunday, 10:00 A.M. - 5:00 P.M.

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At 2:00 P.M. on Saturday and Sunday, Henry Kennedy will make a presentation about catseye chrysoberyl, one of the world's most remarkable gemstones.



Cortes' Emeralds

The Gemmery will exhibit emeralds once in the possession of Hernan Cortes, the leader of the small band of Conquistadores who defeated the Aztec empire in 1519-21. These emeralds were being sent to Spain in 1757, when the ship carrying them burned and sank off the coast of Florida. The wreck was discovered recently and the emeralds and many other artifacts salvaged.

The Gemmery's display includes 900 carats of emerald crystals, three gems cut in the 1500s, two rings set with recut stones, and a replica of Cortes' signet ring. A 30-minute video of related salvage operations will be shown.

During the show, be sure to visit...

THE POND Swap-and-Sell area on the Franklin School grounds. THE POND is sponsored by the Franklin-Ogdensburg Mineralogical Society, Inc. For further information about THE POND contact:
Chester Lemanski Jr., Phone: (609) 893-7366.

After the show on Saturday night...

Attend the F.O.M.S. banquet, held at the Lyceum Hall of the Immaculate Conception R.C. Church at the intersection of Church St. and Main St. in Franklin. Socializing begins at 6:30 P.M. and the buffet dinner at 7:00 P.M. Dress is informal and the atmosphere likewise. After dinner there will be a lecture by Dr. William Henderson, *Geological and Mineralogical Curiosities*. This will be followed by an auction of mineral specimens and memorabilia.

For banquet tickets and information, contact:
Joe Cilen, Phone: (201) 427-4550

Announcements

Fluorescent Mineral Society Northeastern Regional Meeting

Saturday, October 14, 1995

This year's meeting will be held at the home of Charles Ward, 37 Deerwood Manor, Norwalk CT 06851, Phone: (203) 849-3366. Hours: 10 to 4. Call for directions and details, and to let the Wards know if you are coming.

Meetings typically include talks and presentations, as well as opportunities to trade information and specimens. If you are one of the many Franklin-Sterling Hill collectors who appreciate fluorescent minerals, this is an excellent opportunity to enjoy them in the presence of others so inclined. Non-F.M.S. members are welcome as guests. Snacks and beverages will be provided, but bring your own lunch. Again, R.S.V.P.

Ultraviolation 1995

Saturday, October 28, 1995, from 10 to 4

Northminster Presbyterian Church, 140 Trenton Road, Fairless Hills, PA

This is the only mineral show exclusively devoted to fluorescent minerals, and it offers an intense experience of this phenomenon for every mineral collector from beginner to veteran to your average middle-aged burnout. There are remarkable displays, as might be expected. There are also tables covered with fluorescent minerals, an unusual sight in itself, which can be bartered or bought. So far this almost sounds like most shows, but Ultraviolation, now in its sixth year, takes place for the most part in the dark: weird, but nice. If you have ever felt discriminated against by daylight-lovers, this is your event.

Admission is \$1.00.

Information may be obtained from Ralph Thomas, 11 Riverdale Road, Yardley, PA 19067, Phone: (215) 295-9730. Table space is \$5.00 for four feet. Advance registration for table space is strongly recommended.

New Jersey Earth Science Association, Inc. 10th Annual Micromount Assembly

Saturday, November 11, 1995, from 10 to 4:30

Wesley United Methodist Church, 1500 Plainfield Avenue, South Plainfield, NJ

Swap/Auction/Silent Auction/Giveaways

Table Space \$5.00 at door, Visitor \$1.00

Pre-Registration \$3.00 (received by November 4th)

For information call: (908) 264-2593.

42nd Annual Tucson Gem & Mineral Show

February 8-11, 1996

Tucson Convention Center, Tucson, Arizona

Thursday and Friday, 10-7; Saturday, 10-6:30; Sunday, 10-5

For information, contact: Tucson Gem & Mineral Society Show Committee, P.O. Box 42543, Tucson AZ 85733

Phone: (520) 322-5773, FAX: (520) 322-6031

The Tucson show is generally considered the finest as well as the largest mineral show in this hemisphere. In 1996, for the first time, there will be a serious effort to feature fluorescent minerals. The Fluorescent Mineral Society is co-sponsoring a symposium on that subject, and organizing a display room with a lecture area and 60 (!) cases of displays.

With Franklin's reputation at stake as *The Fluorescent Mineral Capital of the World*, there are plans underway for participation at Tucson '96 by the Franklin Mineral Museum, the Sterling Hill Mining Museum, and many Franklin-area collectors. There will be a caravan to help transport cases, ultraviolet lamps, and specimens to Arizona and back. If you are interested in contributing to this effort, please contact the *Picking Table* co-editor, Richard Bostwick, at (212) 749-5817.

The Franklin Mineral Museum

Evans Road/P.O. Box 54, Franklin, NJ 07416
(between Main Street and Buckwheat Road)
Phone: (201) 827-3481

Exhibiting by means of guided tours Franklin-Sterling Hill mineral specimens, educational exhibits in mining methods and history including a life-sized replica of underground working, artifacts, gem stones, zinc uses, and a 32 foot long fluorescent display. Included in the tours is the Jensen Memorial Hall built especially to contain the Wilfred Welsh collections of native American relics, fossils, and world-wide minerals and rock specimens assembled for teaching purposes.

Mineral collecting on the Buckwheat Dump. Ample parking, and picnic grounds.

Offering for sale: Minerals, fluorescent specimens, micromounts, mineral sets, amethyst crystal groups, agate slabs, onyx carvings, UV lamps, hammers, lenses, mineral books, 35mm slides of fluorescent minerals by Henry van Lenten, T-shirts, patches, postcards, dinosaur models, crystal growing kits and refreshments.

Operating Schedule:

Open to the public

March 1 to December 1

Monday through Saturday: 10AM - 4 PM

Sunday: 12:30 PM - 4:30 PM

Closed: Easter, July 4th and Thanksgiving

Groups by reservation, please

Admission fees:

Adults: \$4.00

Grammar & High School Students: \$2.00

Separate admission fee to the Buckwheat Dump is the same as the Mineral Museum fee. Admission to museum includes guided tour.

Franklin, New Jersey
"The Fluorescent Mineral
Capital of the World"



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Museum phone: (201) 209-7212

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- Historical buildings
- Underground guided tours
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See historic mine workings!

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7-days-a-week 10A.M. to 5P.M.

(last tour at 3:30P.M.)

Open March & December on weekends or by appointment, weather permitting

Admission prices:

Adults: \$7.50

Children: \$5.00

Senior Citizens: \$6.50

Call for group rates

Note:

On the last Sunday of each month (or other times for groups by prior arrangement) a collecting site will be open for a nominal additional fee. Contact the mine office for details.

CLOSEST-PACKED MINERAL STRUCTURES OF FRANKLIN-OGDENSBERG: KEPLER'S GIFT OF THE SNOWFLAKE

Part one of two parts

Paul B. Moore

5559 South Blackstone Avenue, #3
Chicago, Illinois 60637-1833
U.S.A.

*This paper is dedicated to the doyens of world mineralogy —
Clifford Frondel and Hugo Strunz*

INTRODUCTION

In this third installment toward a more comprehensive understanding of the remarkable minerals of Franklin-Ogdensburg (FO), I have maintained a common theme: that of the closest-packing of equal and hard spheres. One of the most fundamental concepts in Nature, it is at the same time one of the most abstract for nowhere is it intuitively obvious. In Moore (1994), I offered a brief skeleton of closest-sphere packing with some fundamental constructions. In Moore (1995), I began and concluded with statements that the principle of closest-packing seems to pervade the natural world of minerals, particularly those structure types which crystallized in certain environments such as prevailed at the onset and evolution of Franklin-Ogdensburg parageneses. Because the hydrogen (H) atom plays a central role as hydroxyl (OH)⁻, and water (H₂O)⁰ as aquo and/or hydrate units in crystal structures of many, if not most, species which crystallized from an initially basic (pH > 7) and reducing (Eh < 0.0V) environment in the FO sequence, it was necessary to concentrate on hydrogen bonding, see Moore (1995). Even here, an important bonding property, such as hydrogen bonding, appears to be geometrically constrained by closest-packing of the remaining structure. Nature's *parsimony* appears to underlie closest-packing in the physical world. In crystals, I tried to convey the notion that closest-packing often has to be "teased" out of the crystal structures as they are presented to us in earlier studies. Closest-packing is fundamental and is not constrained by the symmetry groups, human devices of cataloguing. My vehicle for demonstrating closest-packing throughout this series in *The Picking Table* is through matrix transformation of earlier commonly accepted structure representations. But representations can be misleading particularly if, through the perception of the eye, they disguise the underlying structural principle, closest-packing for obvious reasons being the most fundamental.

The great Lutheran mystic, astronomer, and mathematician Johannes Kepler (1571-1630) was arguably the first person to develop and unveil the concept of closest-packing of equal and hard spheres to us, especially in his *De Nive Sexangula* ("On the hexagonal snowflake") in 1611 and in his *Epitome Astronomiae Copernicanae* ("Summary of Copernican astronomy") written in 1618-1621. In his search for God's perfection in Nature (the basis of his mysticism) Kepler chose the planetary orbs and fixed stars combined with his underlying awe and wonder at the five regular Platonic solids—the tetrahedron, octahedron, cube, icosahedron, and pentagonal dodecahedron—which are also the embodiments of all the symmetries in crystals as we presently know them.

Many of Kepler's remarkable insights arose from a series of accidents and coincidences of good fortune: his analysis of closest-packed spherical "loculi" (seeds) in pomegranates and the hexagonal {6³} net in honeycombs, and the knowledge at his time of only six planetary orbs (Mercury, Venus, Earth, Mars, Saturn, and Jupiter) about the Sun. [In Kepler's time, Copernicus' (1473-1543) notion that the Sun is the center of the universe was accepted.] In *Epitome*, which is presented as a dialogue of questions and answers between Kepler and his alter ego, a question begins the analysis: do you think centers of stars lie on one spherical surface? Kepler's answer expressed uncertainty. Either faint stars could be farther away from us than bright stars (assuming that stars are of equal luminosity, which we know today is not true) with the Sun the fixed star nearest us, or there exist bright and faint stars equidistant from us. [In Kepler's *De Nive Sexangula*, his New Year's Gift to patron Wackher von Wackenfels, he offers a mathematical account of the cuboctahedron, an Archimedean semiregular solid with 12 vertices, 8 triangular and 6 square faces, and 24 edges—the fundamental polyhedron of cubic closest-packing.] Kepler assumed, in a universe with stars of equal intrinsic luminosity and indefinitely

distributed, that the stars' distribution would be based on the principle of closest-packing. *This would mean that 12 nearest neighbor stars would occur contiguous to the Sun.* Because this does not correspond to the appearance of the night sky, Kepler concluded that the distribution of fixed stars cannot be uniform.

Literature on Johannes Kepler is rather extensive, although much of it is archaic and out of print or in Latin or German. Two outstanding books are, however, readily available and make for fascinating reading. Caspar (1993), a scholar in Germany, devoted his life to Kepler's origins and thoughts, culminating in his fine biography which has been translated into English. Field (1988), a curator at the Science Museum in London, wrote a fine book on Kepler's geometrical cosmology. It is clear in this book that closest-packing formed the underpinning of many of Kepler's demonstrations and inferences about the structure of the universe.

Closest-packing is a wonderful universe of its own as it is rich with little demonstrations and expositions which require small proofs and derivations, a few of which I offer in this present study. The most difficult problem still remains in the exposition of crystal structures which are in fact based on the principle of closest-packing. Although it appears that the majority of mineral crystal structures are not closest-packed [I offered bonding criteria which militate against closest-packing, see Moore (1994, 1995)], a large number, probably several hundreds, have been overlooked through misrepresentation in earlier studies. Closest-packed representation can be beautiful in its own right, a veritable harmony of the spheres, particularly as Pauling octahedra and tetrahedra. The present study includes pyrochroite, chalcophanite, gerstmannite, clinohedrite, holdenite, kolicite, hodgkinsonite, flinkite, synadelphite, hematolite, and allactite from FO; and zenzénite, quenselite, manganostibite, and arsenoklasite from Bergslagen in Sweden. Consistent with the earlier studies, demonstration of closest-packing follows from *difference*, $\Delta(\text{\AA})$, between "mean" and real (transformed) cell parameters, and between real and ideal (perfect) atom coordinates.

SOME PROOFS AND DERIVATIONS

The geometrical restrictions incumbent upon the principles of closest-packing are manifold and with them appear a large number of algorithms, small proofs, derivations, and even theorems waiting to be mined and milled. Often, many different approaches toward a derivation lead to the same conclusion. Rather than utilizing the most contemporary mathematical tools, I will try to employ the more accessible, although often more cumbersome, geometrical-trigonometrical approaches. It is remarkable how many fundamental relationships are embedded within the most elementary of convex polyhedra: the regular Platonic solids. For example, the $\phi - T - \phi'$ tetrahedral angle is $\Theta = 109^\circ 28' 15.6''$, $\cos \Theta$ being exactly $-1/3$.

A TETRAHEDRAL RELATION

In closest-packing, it is often necessary to evaluate the centroid (T) of the perfect tetrahedron with respect to the tetrahedral edge ($\phi - \phi' = l$), the centroid of the tetrahedral base (τ), and the centroid of the opposing tetrahedral vertex (ϕ'). The strategy is to determine the ratio between $(T - \tau)$ and $h = (\tau - \phi')$.

By definition, $\tau - \phi' = h$ or the distance between contiguous closest-packed layers [do not confuse this symbol with h for the layer sequence $\bullet A B A \bullet$]. Set $t = T - \tau$. The problem is to get t/h . Obtaining $h = \sqrt{2/3} l$ is straightforward (derive it!), but t , the distance between the tetrahedral and tetrahedral base centroids, is

a bit more elaborate. I took advantage of trigonometric identities which are found in Rider (1949). An outline of the procedure is given in Table 1 and Figure 1. The t/h ratio is effectively obtained through solutions in terms of tetrahedral edge length l .

Diagrams A and B of Figure 1 afford a quick solution to h . Diagram C contains the heart of the problem. The derivations exploit complementary and supplementary angles, trigonometric identities, and the $\Theta = \phi - T - \phi'$ tetrahedral angle with $\cos \Theta = -1/3$. The resulting right triangle has edges $1 : \sqrt{8} (= 2\sqrt{2}) : 3$, the remaining leg providing a supplement to the tetrahedral angle. As the ratio $t/h = \sqrt{1/6} = 1/4$, the centroid can be immediately obtained.

ORTHOHEXAGONAL REPRESENTATION: TRANSFORMATION OF CELLS IN CLOSEST-PACKING

In Moore (1994), I emphasized the orthohexagonal representation as the key for deriving the coordinates for perfect closest-packing to compare with the real structure. A similar representation was applied by Moore and Araki (1977) for cataloguing cubic closest-packed structures by exploiting the principal projections of the regular octahedron. Here, [001] corresponds to twice the $M - \phi$ distance, or $\sim 4.2 \text{ \AA}$. This identifies the octahedral vertex. The translation $\phi - \phi' = l$ is the edge distance or $\sim 3.0 \text{ \AA}$, that is [110]. Orthogonal to these two is the $\phi - \phi' = l$ edge distance, also $\sim 3.0 \text{ \AA}$ with orientation $[\bar{1}10]$. (The third principal direction is the octahedral face normal or $t^* = [111]$. This is the projection we usually seek for closest-packings). Distances selected are those typically met for the larger ${}^4\text{Zn}^{2+}\phi_4$ and ${}^6\text{Mn}^{2+}\phi_6$ edge lengths, $\phi - \phi' = l = 3.0 \text{ \AA}$, $\sqrt{2} l = 2M - \phi = 4.2 \text{ \AA}$, $\sqrt{3} l = 2.5 \text{ \AA}$.

Figure 2 outlines the $a_o \times c_o$ basis cell toward orthohexagonal representation. Exploiting equivalences among the octahedral elements, $ma_o = m\sqrt{2} l$, $nb_o = nl$, $pc_o = pl$ where (m, n, p) are integers for the full cell. I now show that the $ma_o \times nb_o \times pc_o$ orthogonal cell can be transformed to the closest-packed representation on page 9 of Moore (1994). Note on Figure 2 that $a_o = \sqrt{2} l$ and $c_o = l$. The manganostibite (or gerstmannite) cell is outlined $a_m \times c_m$ and has $(m, p) = (2, 2)$. The manganostibite cell transformed to the orthohexagonal representation has $a'_m = [10\bar{2}] = t^*$, $c'_m = [101]$. Note that $t^* = a'_m$ is normal to closest-packed layers. It is clear that a'_o and c'_o , the orthohexagonal representations of the basis cell, are each exactly half the a'_m and c'_m (m, p would be 1, 1). The problem is to prove that β' , the angle between a'_o and c'_o , is exactly 90° for the perfect closest-packing.

My approach is to exploit the law of cosines. For any triangle with edges a, b, c and interior angles α, β, γ respectively, the relation, say, $a^2 + c^2 - 2ac \cos \beta = b^2$ holds (the two other identities are isomorphic). The organization and procedure for this proof is epitomized in Table 2 which applies directly to Figure 2. The relation $(3c_o)^2 = a_o'^2 + c_o'^2 - 2a_o' c_o' \cos \beta'$ immediately holds. Through substitution,

$$(3l)^2 = (\sqrt{6} l)^2 + (\sqrt{3} l)^2 - 2 \sqrt{6} \sqrt{3} l^2 \cos \beta'$$

$$\text{or}$$

$$9l^2 = 6l^2 + 3l^2 - 2 \sqrt{18} l^2 \cos \beta'$$

$$\text{or}$$

$$0 = -2 \sqrt{18} l^2 \cos \beta'$$

Since $l = 3.0 \text{ \AA}$, $\cos \beta' = 0$; therefore $\beta' = 90^\circ$ and the proof is ended.

CLOSEST-PACKED ZNO POLYMORPHS

Zinc oxide, ZnO, is an interesting example of diverse polymorphism among closest-packed arrangements. So far as is reported, zincite, $P6_3mc$, $\cdot hh\cdot$, is the only polymorph known from FO and from anywhere else in Nature. It is a piezoelectric and polar (pyroelectric) crystal, and belongs to the wurtzite, β -ZnS, structure type. A second polymorph of ZnO has symmetry group $F43m$, $\cdot ccc\cdot$, which is polar and has no center of symmetry (inversion) and is therefore piezoelectric. It was reported by Bragg and Darbyshire (1932) from electron diffraction patterns taken off thin films of ZnO on holey zinc, and belongs to the sphalerite, α -ZnS, structure type. Both these ZnO polymorphs have tetrahedrally coordinated zinc by oxide, ${}^4Zn\ {}^4O$. A high pressure polymorph exists in the 100kb pressure range and remains stable as such for at least several weeks after quenching to room temperature and pressure according to Bates, et al. (1962). This polymorph belongs to symmetry group $Fm\bar{3}m$ and zinc is octahedrally coordinated by oxide, ${}^6Zn\ {}^6O$, belonging to the familiar rocksalt structure type, $\cdot ccc\cdot$. It is noteworthy that conversion to the high pressure structure with zinc in octahedral coordination required ammonium chloride solution as a catalyst and that sodium carbonate solution produced no detectable conversion at high pressure. Note that NH_4Cl is a salt of strong acid and weak base but that Na_2CO_3 is a salt of strong base and weak acid. This corresponds to Zn tending to be octahedrally coordinated in acid environments and tetrahedrally coordinated in basic environments by oxide anions.

Figures 3 and 4 are designs of the ZnO zincite $\cdot hh\cdot$ and $F43m\ \cdot ccc\cdot$ structure types. The atoms have no degrees of freedom. The Zn^{2+} has a completely filled $4d^{10}$ -orbital and no e_g - t_{2g} transitions can take place. Consequently, pure ZnO is colorless. Furthermore, the Zn^{2+} ion is fairly large, with radius ratio ${}^4Zn^{2+}/{}^4O^{2-} = 0.43$ and ${}^6Zn^{2+}/{}^6O^{2-} = 0.53$ Å from Shannon and Prewitt (1969), which suggests that octahedral coordination of oxide and zinc ion would be the more stable configuration. The ZnO polymorphs have all the properties of reasonably ionic crystals. In such crystals, we would expect tetrahedral corner-sharing only to be stable, because the (T - T') separation between tetrahedral centers in closest-packing would be very short for edge- and/or face-sharing tetrahedra (derive these distances!), and the cation-cation repulsion effect would be too destabilizing.

Table 3 outlines the cell criteria for the ZnO polymorphs. As their cells are fundamental and relatively simple, transformations were deemed unnecessary.

COMPLEX OXIDES OF MANGANESE

Manganese is among the most versatile of elements in the Periodic System. The number of mineral species which contain essential manganese is quite large. My colleague Mr. Richard A. Bideaux reports that he has 437 species listed as of June, 1993 in his mineral data file. Virtually all valence states are known, from the metal, Mn^0 , to the naked ion, Mn^{7+} ; the former is a reducing agent and the latter is a powerful oxidizing agent. Few crystal environments and geochemical mechanisms are oxidizing enough to create valence states beyond Mn^{4+} . In fact, Mn^{2+} , Mn^{3+} , and Mn^{4+} are by far the characteristic valences in Earth systems. Of these, Mn^{3+} has four electrons in its d suborbital and, in an oxide environment, high spin occurs leading to Jahn-Teller or tetragonal distortion, an electrostatic effect owing to one electron being situated close to bonding electrons of the coordinating ligand. Similar Jahn-Teller distortion occurs for $4d^9$ Cu^{2+} . Both ions usually have their unpaired repelling electron in the e_g suborbital

which points from the transition metal ion's center to the oxide centroid.

To more fully appreciate the interaction of charged ions in solution and mineral associations, I refer you to Moore (1994) and the oxidation-reduction diagram of water. Latimer (1952) has provided standard oxidation potentials of reaction in basic solutions (intercepts at pH = 14) for key ion charges which will interest us, and I outline these in Table 4.

The energies in volts are established from measurements of ionic electromotive forces in solution. Values of such energies in crystals will vary somewhat, but the relative order of ions in the crystal is expected to follow the order in solution. For example, Fe^{2+} oxidizes before Mn^{2+} . We would expect coexisting Fe^{3+} and Mn^{2+} in a crystal as in jacobsonite, $Fe_2^{3+}[Mn^{2+}O_4]$. The combination Fe^{2+} and Mn^{3+} coexisting in a crystal, such as hypothetical $Mn_2^{3+}[Fe^{2+}O_4]$, is not known. Note further that $Pb^{2+} \rightarrow Pb^{4+}$ occurs at even more oxidizing conditions than $Mn^{2+} \rightarrow Mn^{3+}$ or $Mn^{2+} \rightarrow Mn^{4+}$. The combinations (Pb^{2+} , Mn^{2+}), (Pb^{2+} , Mn^{3+}), (Pb^{2+} , Mn^{4+}), (Pb^{2+} , Mn^{3+} , Mn^{4+}), can occur in solutions or, by extension, in crystals. Also note that standard *oxidation* potentials in solution do not need to follow from *ionization* potentials, the latter determined from atoms or ions in the gaseous state.

At least twelve discrete oxide and hydroxide phases involving Mn^{2+} , Mn^{3+} and/or Mn^{4+} have been documented from FO and Långban, Sweden. Four of these phases now follow in discussion. All are layered structures and all are closest-packed. One phase, chalcophanite (and its Mn^{2+} analogue auroraite) played a big role in the calamine (hemimorphite) pits at Sterling Hill. Two other phases, quenselite and zenzénite, involve essential Pb^{2+} in their crystal structures. The Pb^{2+} cation plays a role akin to the O^{2-} closest-packed layers owing to its similar ionic size, and these two ions are considered together as structural units.

Pyrochroite

Pyrochroite, ${}^6Mn^{2+}(OH)_2$, is the common and simple basic phase which occurs in basic reduced vein assemblages, particularly at FO and Bergslagen in Sweden. I discussed this phase extensively in Moore (1994) and Moore (1995) and little need be added here except for the cell criteria in Table 5 and the diagram of the planar octahedral sheet in Figure 5.

Pyrochroite's crystal structure belongs to space group $P\bar{3}m1$ and attendant symmetry (equivalence) operations are shown in Figure 5. It is hexagonal closest-packed, $\cdot hh\cdot$, and is based on ordering of octahedral vacancies in the ${}^6Ni_2{}^6As_2$, $\cdot hh\cdot$ aristotype. Infinitely many ordered arrangements can lead to $M\bar{\square}\phi_2$ where exactly half the octahedra and all the tetrahedra are empty in hexagonal closest-packing, but only one arrangement leads to the planar sheet of edge-sharing octahedra as found for pyrochroite. The surface atmosphere is too oxidizing for pyrochroite's stability. As a consequence, the mineral is pink when first taken from the mine but rapidly oxidizes to black Mn^{3+} - and Mn^{4+} - oxidation products.

Pyrochroite is arguably the most important mineral in assessing the basic reduced vein paragenesis both at FO and Bergslagen.

Chalcophanite

Chalcophanite, $Zn_2(H_2O)_6[Mn_6^{4+}\square O_{14}]^{4-}$ where \square is an ordered cation vacancy, was recently structurally analyzed by Post and Appleman (1988), superseding the earlier study by Wadsley (1955) who reported a triclinic orientation. Auroraite is the ${}^6Mn^{2+}$ analogue in lieu of ${}^6Zn^{2+}$; neither phase has yet been found at

Långban. Chalcophanite is 3(chh•), that is, a nine-layer structure involving (H₂O)^o and O²⁻ in the closest-packed frame. One layer, Figure 6, corresponds to Table 6. The transformation matrix used orthogonalizes the entire system and is identical to the one discussed further on under hematolite. In fact, hematolite (a reduced phase) has one layer of approximate composition [Mn₂²⁺Al₄³⁺O(OH)₁₃]¹⁺ which consists of the same kind of ∞ [M₃φ₇] ordered octahedral sheet as chalcophanite.

In the chalcophanite design of small octahedral cations of high charge, vacant octahedra in the sheet are separated by edge-sharing columns of two octahedra in thickness. The vacant sites are capped above and below by [ZnO₃(H₂O)₃]⁴⁻ octahedra. Chalcophanite is a surface oxidation product and has never been found in the basic reduced veins. In fact, octahedrally coordinated ⁶Zn²⁺ by oxide anions is relatively infrequently encountered at FO, and is confined to oxidation zone material, suggesting that ⁶Zn²⁺ is indicative of oxidizing and ⁴Zn²⁺ of reducing environments, both in this case occurring under rather basic conditions. As oxidized environments usually correspond to relatively more acid settings, the important role of hydrogen-bonded water molecules is readily apparent. In short: basic environments lead to more compact structures, acid environments to more open structures. Yet chalcophanite is a very "tight" closest-packed arrangement with but small deviations from the perfect model (range Δ = 0.04 - 0.23 Å for all non-H atoms).

Quenselite

Quenselite, Mn³⁺[O₂OHPb²⁺], the formula written to express the occurrence of the large plumbous cation in the anion layers, is not known from FO, but occurs in basic vein assemblages at Långban. Except for kentrolite-melanotekite, (Mn,Fe)₂³⁺Si₂[O₇O₂Pb₂²⁺] (very rare at FO but once in considerable abundance at Långban), Pb²⁺ - Mn³⁺ or Pb²⁺ - Mn⁴⁺ combinations are not known in crystals from FO. Oxidation at FO was evidently not high enough for the formation of Pb⁴⁺ oxysalts, and the Pb²⁺ silicates, for which the Franklin workings were once famous, occurred in more reduced assemblages, with associated native copper and lead. Rouse (1971) established quenselite's structure. Table 7 outlines the packing principle for quenselite. It is a 4-layer hexagonal closest-packed arrangement with the large Pb²⁺ cations occurring in alternate anion layers. The ionic radii of Pb²⁺ and Ba²⁺ approach the size of the O²⁻ anion. Indeed, Ba²⁺ oxysalts are known where the cation is in contact with twelve nearest neighbor anions, the ion coordination about Kepler's cuboctahedron in the cubic closest-packed frame. The Pb²⁺ cation, however, has a lone-pair of stereoactive nonbonding electrons (ψ²⁻) remaining in its valence shell, the ion aggregate written [Pb⁴⁺ψ²⁻]²⁺. The lone-pair is repelling to neighboring anions and is fixed in space owing to the Pb - O bond pairs which remain. The result is an off-centered coordination polyhedron about the Pb cation. Moore (1994) has offered a neat electrostatic explanation for the behavior of [Pb⁴⁺ψ²⁻]²⁺ in crystals. In calculating the difference, Δ(Å), for the closest-packed model for quenselite, we would expect the greatest displacement for Pb to be away from its ideal centroid.

Another important electrostatic distortion occurs for quenselite. As discussed above, Mn³⁺ with one unpaired electron pointing toward a coordination anion and repelling it, the Jahn-Teller tetragonal distortion prevails. Such a distortion is manifest in the entire crystal and should be seen as

deviations of cell translations from the perfect model. These distortions are indeed noted in Table 7: the ΔPb = 0.94 Å compares with Δ(Mn³⁺, O²⁻, OH⁻) = 0.02 - 0.16 Å for these ion centroids, and cell deviations range from ca. -5.8% to +8.6% owing to 4d⁴Mn³⁺.

Zenzénite

Zenzénite, (Fe, Mn)₄³⁺Mn₃⁴⁺[O₁₅Pb₃²⁺], is a recent discovery from Långban; like quenselite, it has not yet been reported from FO. The packing principle is given in Table 8, and an outline of its octahedral sheet appears in Figure 7. Its principle is based on 6-layer hexagonal closest-packing, •hhhhhh•. Every third layer consists of [(Pb⁴⁺ψ²⁻)₆²⁺O₆²⁻], not shown in the figure.

Zenzénite's stoichiometry suggests that difference in the Pb centroids should be as pronounced as in quenselite but that cell deviations should be not nearly as pronounced as in quenselite, both criteria which are met in Table 8. The range in ions other than Pb²⁺ is Δ(Fe³⁺, Mn³⁺, Mn⁴⁺, O²⁻) = 0.00 - .29 Å, and the cell deviations range from -2.3% to 1.2%. This adds credence to the difference method (real parameters vs. perfect closest-packed parameters) in evaluating closest-packed structures, and in the deviations inherent in electrostatic distortions about (Pb⁴⁺ψ²⁻)²⁺ and (4d⁴Mn³⁺).

Table 1: A Tetrahedral Relation

<i>l</i>	tetrahedral edge length
<i>τ</i>	centroid of tetrahedral base
<i>φ</i>	tetrahedral vertex
<i>T</i>	tetrahedral centroid
<i>h</i>	tetrahedral height (layer separation)
<i>h'</i>	opposing tetrahedral vertex
<i>t</i>	T - <i>τ</i> distance
<i>φ</i>	<i>h</i> - <i>t</i> = T - <i>φ</i> ' distance
<i>θ</i>	tetrahedral angle = 109° 28' 15.6"

From A and B in Figure 1: $h = \sqrt{2/3} l$

Goal: get *t*/*h* ratio [(tetrahedral centroid to tetrahedral base)/ tetrahedral height]

$$1. \varphi = l/2\cos(90^\circ - \theta/2)$$

$$2. t = \varphi \sin(\theta - 90^\circ)$$

$$3. t = \frac{l \sin(\theta - 90^\circ)}{2\cos(90^\circ - \frac{\theta}{2})}$$

$$4. t = \frac{-l \cos \theta}{2\sqrt{\frac{1 - \cos \theta}{2}}}$$

$$\text{identity: } \sin(\theta - 90^\circ) = -\cos \theta$$

$$\text{identity: } \cos(90^\circ - \frac{\theta}{2}) = \sin \frac{\theta}{2}$$

$$\text{identity: } \sin \frac{\theta}{2} = \sqrt{\frac{1 - \cos \theta}{2}}$$

$$5. t/h = - \frac{\sqrt{3} l \cos \theta}{2\sqrt{2}\sqrt{\frac{1 - \cos \theta}{2}} l}$$

$$6. t^2/h^2 = \frac{3\cos^2\theta}{4(1 - \cos\theta)}$$

$$7. \text{ Now } \theta = 109^\circ 28' 15.6'' \text{ and } \cos \theta = -0.3333... = -\frac{1}{3}, \cos^2\theta = \frac{1}{9}$$

$$8. t^2/h^2 = \frac{3(\frac{1}{9})}{4(1 + \frac{1}{3})} = \frac{3}{9} \cdot \frac{3}{16} = \frac{1}{16}$$

$$9. t/h = \sqrt{\frac{1}{16}} = \frac{1}{4}. \text{ The derivation is ended.}$$

Table 2: A Criterion for Orthohexagonal Transformation

l	$\phi - \phi'$		edge length
a_0	$2M - \phi$	$\sqrt{2} l$	
c_0		l	
a_m	$4M - \phi$	$2\sqrt{2} l$	manganostibite, gerstmannite
c_m		$2 l$	" "
a'_m	$t^* = [10\bar{2}]$		vector normal to closest-packed layers
c'_m	$= [101]$		
$a_0'^2$	$= a_0^2 + (2c_0)^2$		
$a_0'^2$	$= (\sqrt{2} l)^2 + (2l)^2 = 6l^2$		
a'_0	$= \sqrt{6} l$		
$c_0'^2$	$= a_0^2 + c_0^2$		
$c_0'^2$	$= 2l^2 + l^2 = 3l^2$		
c'_0	$= \sqrt{3} l$		
$a_0'^2$	$= a_0^2 + (2c_0)^2$		
$a^2 = b^2 + c^2 - 2bc \cos \alpha; b^2 = a^2 + c^2 - 2ac \cos \beta; c^2 = a^2 + b^2 - 2ab \cos \gamma$ (law of cosine)			
$(3c_0)^2 = a_0'^2 + c_0'^2 - 2a'_0 c'_0 \cos \beta'$			
$(3l)^2 = (\sqrt{6}l)^2 + (\sqrt{3}l)^2 - 2\sqrt{6}\sqrt{3} l^2 \cos \beta'$			
$9l^2 = 6l^2 + 3l^2 - 2\sqrt{18} l^2 \cos \beta'$			
$0 = -2\sqrt{18} l^2 \cos \beta'$			
$\therefore \cos \beta' = 0$ and $\beta' = 90^\circ$			

Table 3: Cell Criteria for ZnO Polymorphs

Rocksalt Structure Type		Sphalerite Structure Type		Wurtzite Structure Type			
a	4.28 (Å)		4.63 Å		3.250		
c	—		—		5.207 Å		
	Fm $\bar{3}$ m		F $\bar{4}$ 3 m		P6 ₃ mc		
	Bates <i>et al.</i> (1962)		Bragg and Darbyshire (1932)		l	$\langle l \rangle$	$\Delta(\%)$
a'	10.48	$\sqrt{3}\sqrt{2a}$	$2\sqrt{3}l$	11.34	3.250	l	3.250 3.230 +0.6
b'	6.05	$\sqrt{2a}$	$2l$	6.55	5.629	$\sqrt{3}l$	3.250 5.595 +0.6
c'	7.41 Å	$\sqrt{3a}$	$3\frac{\sqrt{2}}{\sqrt{3}}l$	8.02 Å	5.207 Å	$\frac{2\sqrt{2}}{\sqrt{3}}l$	3.189 Å 5.275 Å -1.3%
			$l = 3.03$ Å	$l = 3.28$ Å			$\langle 3.230 \rangle$ Å
	•ccc•		•ccc•		•hh•		
	$h = 2.47$ Å	1	$h = 2.67$ Å				
	$V_{E'} = 19.6$ Å ³		$V_{E'} = 24.8$ Å ³		$V_{E'} = 23.8$ Å ³		

Table 4: Standard Oxidation Potentials
in Basic Solution[†]

Reducing			Energy (volts)
H ₃ O ⁺ + OH ⁻	=	2H ₂ O + 2e ⁻	-0.828 V
Fe ²⁺ (OH) ₂ + OH ⁻	=	Fe ³⁺ (OH) ₃ + e ⁻	-0.56 V
Mn ²⁺ (OH) ₂ + OH ⁻	=	Mn ⁴⁺ O ₂ + 2H ₂ O + 2e ⁻	-0.05 V
Mn ²⁺ (OH) ₂ + OH ⁻	=	Mn ³⁺ (OH) ₃ + e ⁻	+0.1 V
Pb ²⁺ O(red) + 2OH ⁻	=	Pb ⁴⁺ O ₂ + H ₂ O + 2e ⁻	+0.248 V
4OH ⁻	=	O ₂ + 2H ₂ O + 4e ⁻	+0.401 V

Oxidizing

[†] From Latimer (1952).

Table 5: Pyrochroite

		Mn(OH) ₂		cell			
		[210/010/001]		coordinate			
		[1/2 00/-1/2 2/2 0/001]					
Z = 1	Z' = 2			<i>l</i>	< <i>l</i> >	Δ(%)	
a ₁	3.323	a'	3.323	<i>l</i>	3.323	3.182	+4.2
a ₂	3.323	b'	5.756	√3 <i>l</i>	3.323	5.511	+4.2
c(t*)	4.738 Å	c'(t*)	4.738 Å	2√2/√3 <i>l</i>	2.901	5.196 Å	-9.7%
P3ml	V _E = 22.7 Å ³	•hh•		<3.182>Å	<i>h</i> = 2.369 Å		

Watanabe, *et al.* (1960)

Table 6: Chalcophanite

$Zn_2(H_2O)_6[\square Mn_6^{4+}O_{14}]$

[310/150/001]
[$5/14^{-1}/14^0/14^{-1}/14^3/14^0/14/001$]

cell
coordinate

Z=3		Z' = 42		<i>l</i>	< <i>l</i> >	Δ(%)
a ₁	7.541	a'	19.952	7 <i>l</i>	2.850	19.915 +0.2
a ₂	7.541	b'	34.558	$7\sqrt{3}l$	2.850	34.494 +0.2
c	20.824 Å	c'(t*)	20.824 Å	$9\frac{\sqrt{2}}{\sqrt{3}}l$	2.834 Å	20.906 Å -0.4 %
R3	$V_E = 17.09 \text{ \AA}^3$	3•chh•			<2.845>Å	<i>h</i> = 2.31 Å

Post and Appleman (1988), R = 0.041/587 F₀ (S.H.)

Difference:	Ideal				Real			Δ(Å)
Δ Zn	$0/14^0/40^2/18$	0.0000	0.0000	0.1111	0.0000	0.0000	0.1000	B 0.23
Δ Mn	$3/14^3/40^0/18$	0.2143	0.0750	0.0000	0.2154	0.0724	-0.0005	B 0.09
Δ O(1)	$2/14^4/40^1/18$	0.1429	0.1000	0.0556	0.1441	0.0958	0.0470	A 0.23
Δ O(2)	$1/14^1/40^1/18$	0.0714	0.0250	0.0556	0.0782	0.0256	0.0504	A 0.18
Δ O(3)	$3/14^1/40^1/18$	0.2143	0.0250	0.0556	0.2143	0.0238	0.0455	A 0.21
Δ W(4)	$4/14^0/40^9/18$	0.2857	0.0000	0.5000	0.2833	0.0040	0.4979	B 0.15Å
								mean 0.18 Å
								range 0.09 - 0.23 Å

$$d^2 = 398.082 \Delta x^2 + 1194.255 \Delta y^2 + 433.639 \Delta z^2$$

Table 7: Quenselite

$Mn^{3+}[O_2(OH)Pb^{2+}]$

Z	4		No transform		
			<i>l</i>	< <i>l</i> >	Δ(%)
a	5.61	$\sqrt{3}l$	3.24	5.13	+8.6
b	5.70	2 <i>l</i>	2.85	5.93	-4.0
c(t*)	9.15 Å	$4\frac{\sqrt{2}}{\sqrt{3}}l$	2.80 Å	9.68 Å	-5.8%
β	93.0°		<2.96> Å	Jahn-Teller distortion!	
P 2/a		<i>h</i> = 2.29 Å	• h h h h •		

Rouse (1971) R = 0.106 / 691 F₀ V_E (1 Pb²⁺ + 3 O²⁻) 18.3 Å³

Difference:	Δ Pb	0.94	Δ O(1)	0.16
	Δ Mn(1)	0.02	Δ O(2)	0.15
	Δ Mn(2)	0.06	Δ OH	0.10 Å
			mean (no Pb)	0.10 Å
			range (no Pb)	0.02 - 0.16 Å

Table 8: Zenzénite

Pb ₃ (Mn ₃ ⁴⁺ Mn ₂ ³⁺)(Fe,Mn) ₂ ³⁺ O ₁₅					
Z	4		No transform		
			<i>l</i>	< <i>l</i> >	Δ(%)
a	10.008	2√3 <i>l</i>	2.89	9.89	+1.2
a√3	17.334	6 <i>l</i>	2.89	17.14	+1.1
c(<i>t</i> *)	13.672 Å	6 $\frac{\sqrt{2}}{\sqrt{3}}$ <i>l</i>	2.79 Å	13.99 Å	-2.3%
P6 ₃ / m cm		h = 2.28 Å	<2.86> Å		
Holtstam et al. (1991)			· h h h h h ·		
R = 0.028 / 372 F ₀					
V _E (3 Pb ²⁺ + 15 O ²⁻)	16.5 Å ³				
Difference:	Δ Pb(1)	0.53	Δ M(4)	0.00	
	Δ Pb(2)	1.01	Δ O(1)	0.11	
	Δ M(1)	0.02	Δ O(2)	0.23	
	Δ M(2)	0.29	Δ O(3)	0.14	
	Δ M(3)	0.00	Δ O(4)	0.14 Å	
			mean (no Pb)	0.12 Å	
			range (no Pb)	0.00 - 0.29 Å	

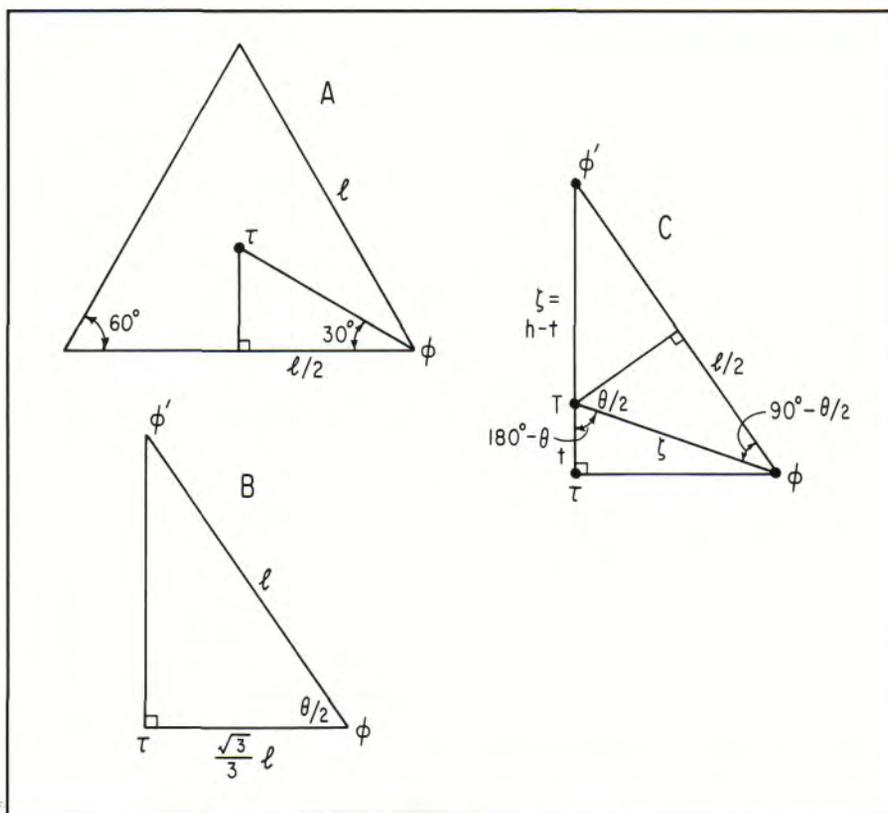


Figure 1. Construction of triangles to accompany Table 1. The $\phi - \phi' = l$ is the edge, τ the base centroid, ϕ' the opposing tetrahedral vertex, h the layer thickness, and T the tetrahedral centroid.

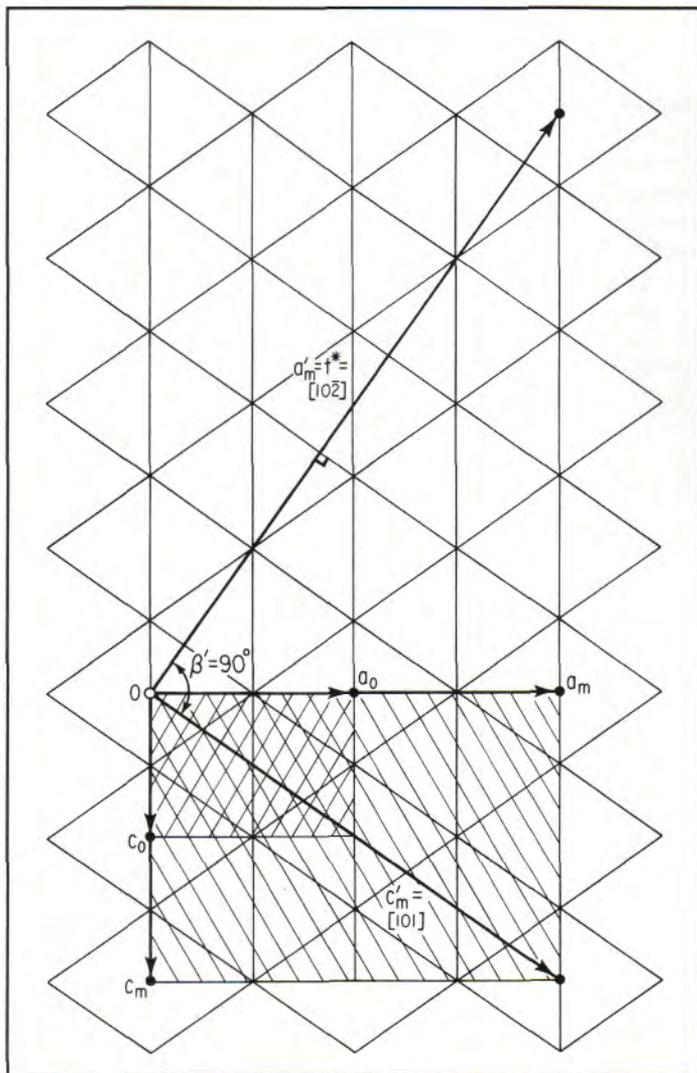
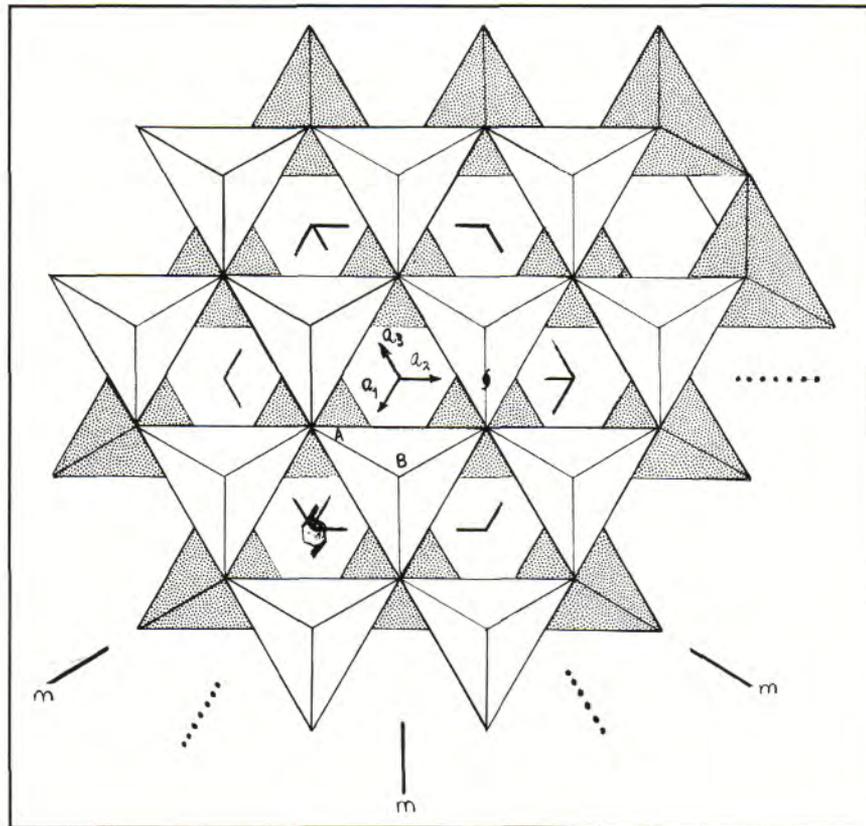


Figure 2. Construction of (m,n,p) closest-packed orientation to $a_o \times c_o$ basis cell ($m,p = 1,1$) and $a_m \times c_m$ manganostibite (gerstmannite) cells ($m,p = 2,2$). The $a'_m = t^* = [10\bar{2}]$ is the normal to closest-packed layers.

Figure 3. Sketch of the zincite, polar $P6_3mc$, structure. The hexagonal cell outline and some symmetry elements are drawn in. Note two layers of $[ZnO_4]$ tetrahedra, hexagonal closest-packing, and polar orientation. Also note open hexagonal rods inherent upon $\bullet hh\bullet$.



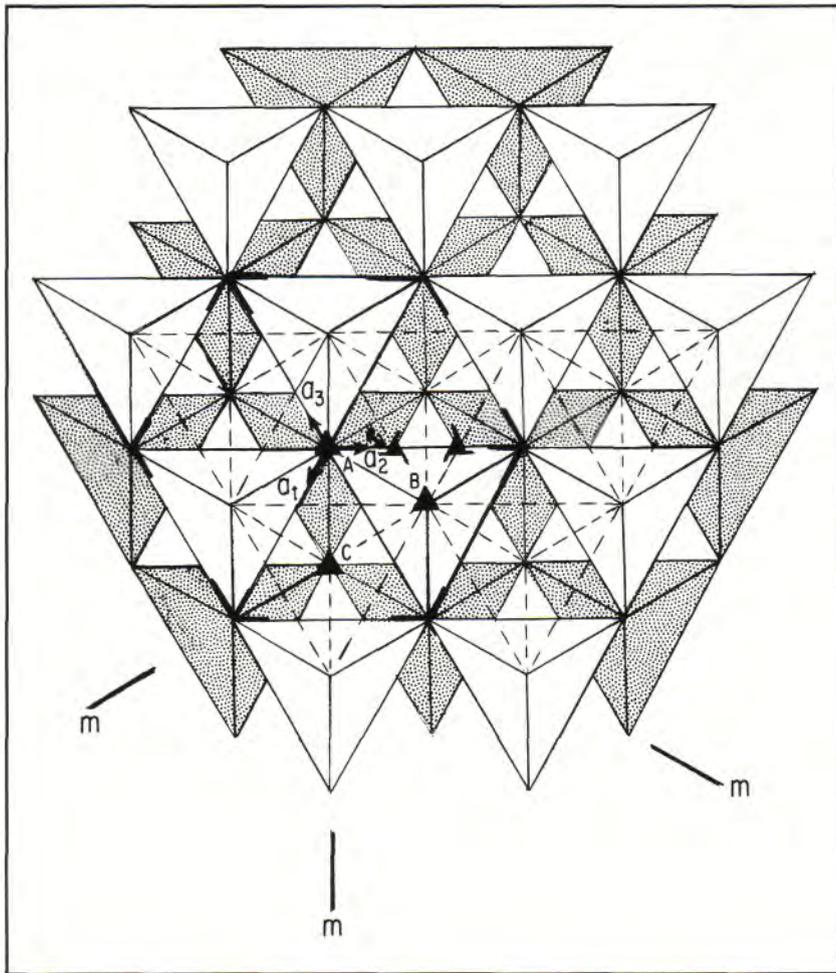


Figure 4. Sketch along $[111]$ of the $F\bar{4}3m$ polymorph of ${}^4\text{ZnO}$, $\bullet ccc\bullet$. Here, three layers of polar tetrahedra occur (stippled-plain-dashed) and some symmetry elements are drawn in, including 3-fold rotors, 3_1 - and 3_2 -screw axes.

Figure 5. The pyrochroite, ${}^6\text{Mn}^{2+}(\text{OH})_2$, $P\bar{3}m1$, planar sheet with hexagonal cell and some symmetry elements superimposed. Note its superposition on the $\{6^3\}$ net.

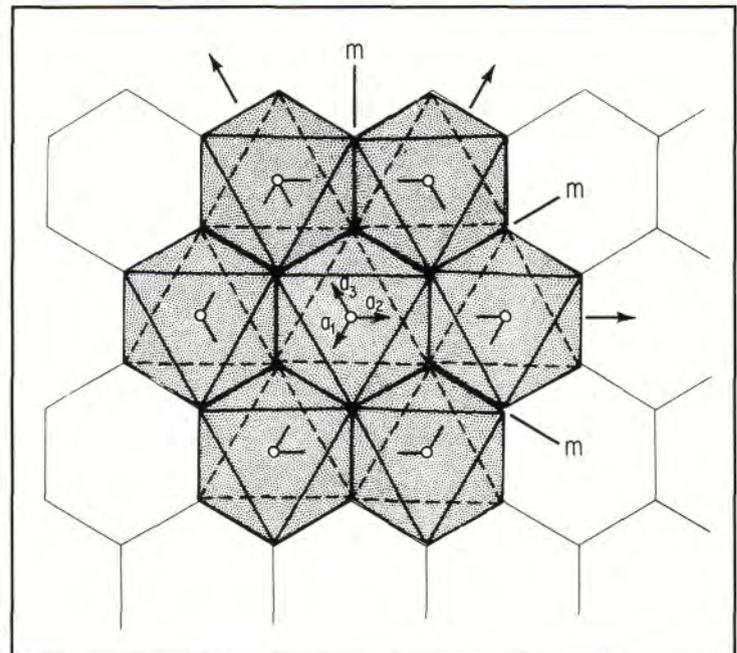


Figure 6. The chalcophanite $\infty[\text{Mn}_6^{4+}\square\text{O}_{14}]$ octahedral sheet idealized and its hexagonal cell. Heights are given as fractional coordinates in z and inversions are drawn in. Note interlayer $[\text{Zn}^{2+}\text{W}_3(\text{W}=\text{H}_2\text{O})\text{O}_3]$, superimposed on the $\{6^3\}$ net. Initial parameters from Post and Appleman (1988).

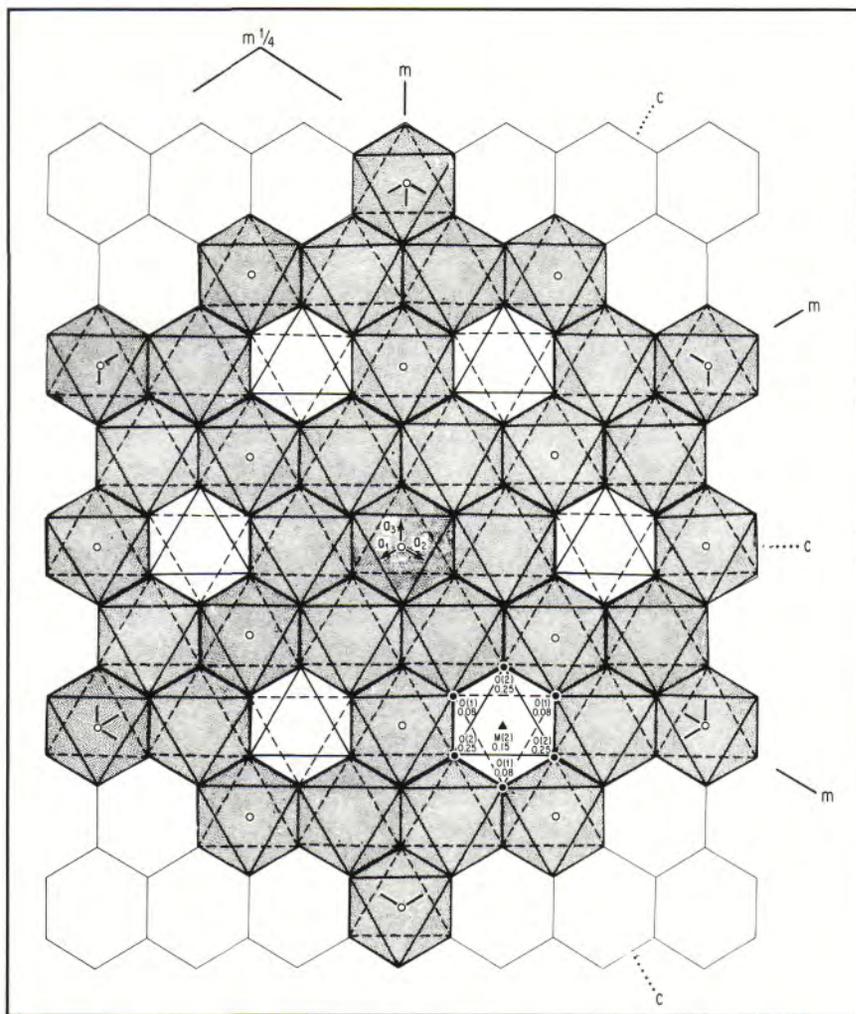
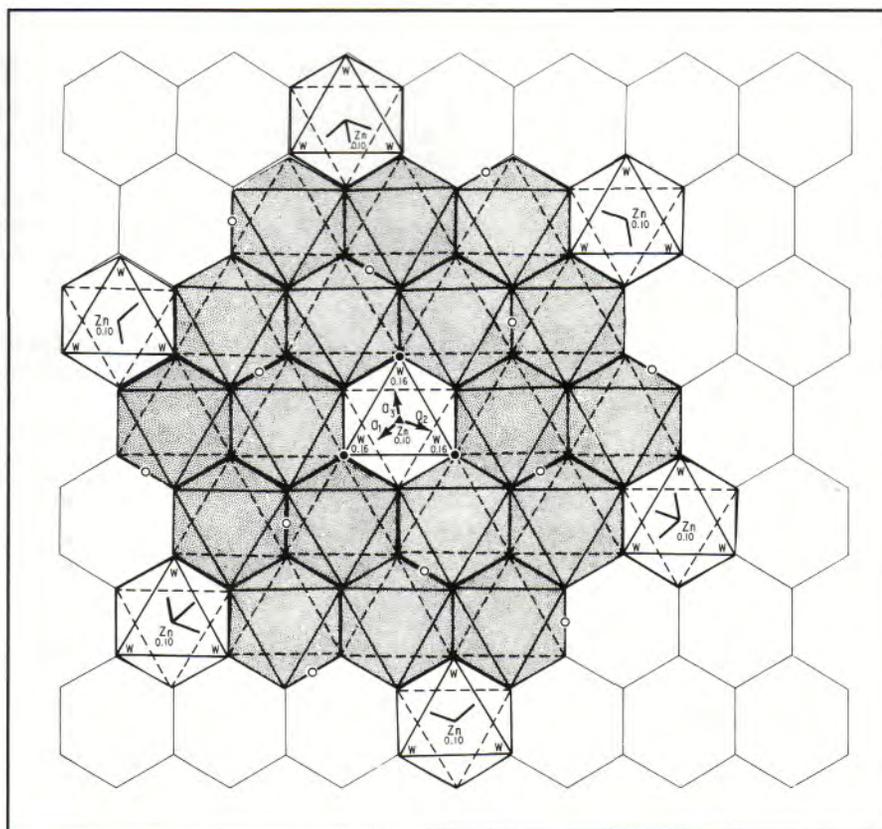


Figure 7. The zenzénite octahedral sheet idealized and its hexagonal cell. Some elements of symmetry are drawn in. Read Figure 6 for other instructions. Initial parameters from Holtsman, *et. al.* (1991).

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