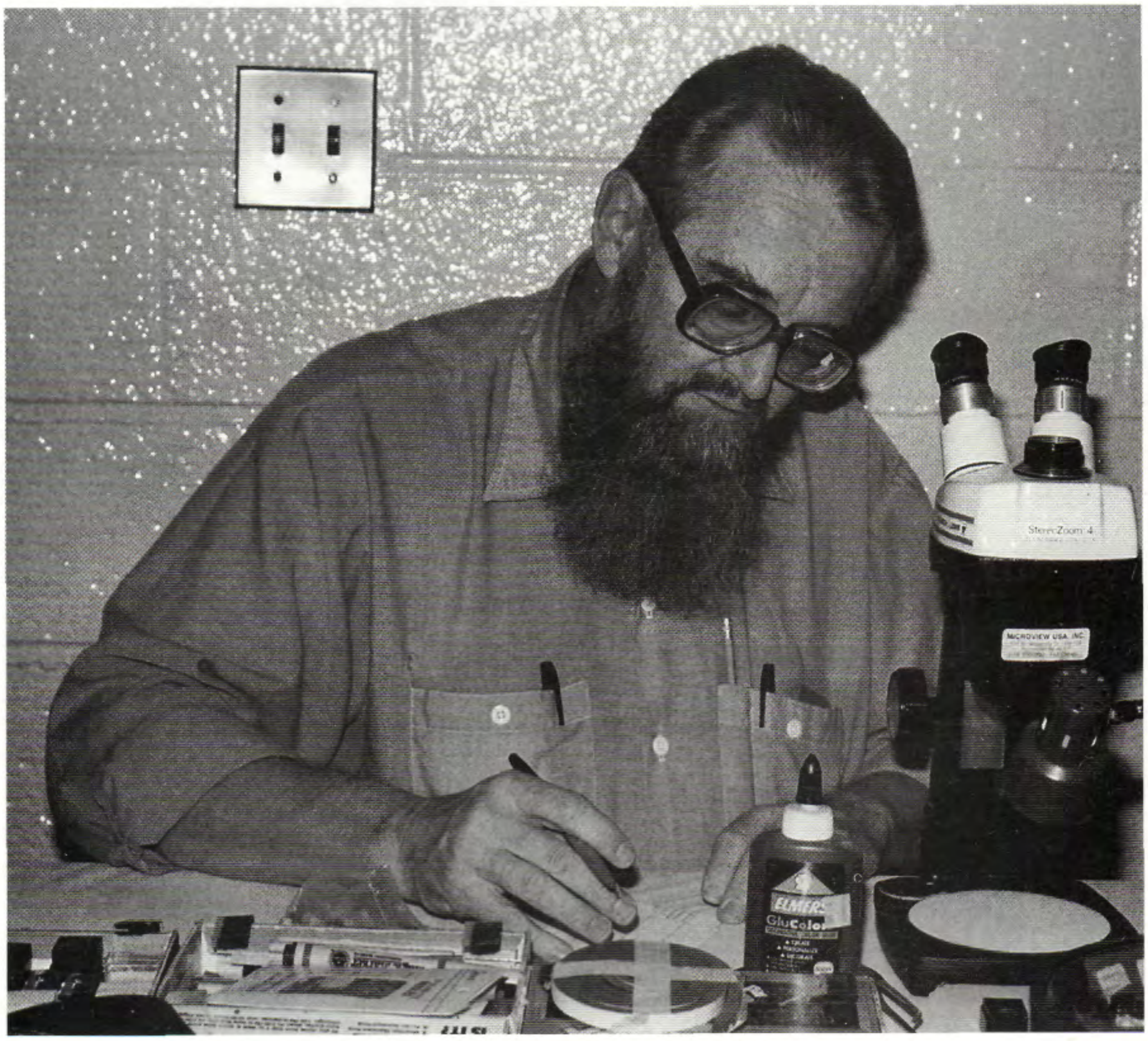
THE PICKING TABLE

JOURNAL OF THE FRANKLIN-OGDENSBURG MINERALOGICAL SOCIETY, INC.



VOLUME 37 NUMBER 1 SPRING/SUMMER 1996 $7.50

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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 published twice each year, in March and September, by the Franklin-Ogdensburg Mineralogical Society, Inc. (FOMS), a nonprofit organization.

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 FOMS is a member club of the Eastern Federation of Mineralogical & Lapidary Societies, Inc. (EFMLS)

THE PICKING TABLE

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ABOUT THE COVER

Dr. Pete J. Dunn preparing a micromount of petedunnite for John Ebner at the 1995 Franklin-Sterling Gem & Mineral Show. Dr. Dunn's monograph is described on page 7 of this issue. T. Hecht photo.

The EFMLS Convention and Show, titled *The Earth Sparkles*, is being held at the IBM Heritage Convention Center in Endicott, New York, on April 26-28. For information, call Tom Milligan at (607) 687-2859.

SPRING 1996 ACTIVITY SCHEDULE

Saturday, March 16, 1996
10:00 A.M. - Noon — F.O.M.S. Micro Group — Franklin Mineral Museum
Host: Ed Wilk, (201) 438-8471
1:30 - 3:30 P.M. — F.O.M.S. Meeting and Lecture, Franklin Mineral Museum
Tucson People, Places, and Things, by George Elling

Saturday, April 20, 1996
9:00 A.M. - Noon — F.O.M.S. Field Trip — Mine Run Dump,
Sterling Hill Mining Museum. Fee: $1.00 per pound.
10:00 A.M. - Noon — F.O.M.S. Micro Group —Sterling Hill Mining Museum
Host: Modris Baum, (201) 625-2229
1:30 - 3:30 P.M. — F.O.M.S. Meeting and Lecture, Franklin Mineral Museum
Franklin Macro-Photography, by Steven M. Kuitems, D.M.D.
*6:00 P.M. — Night collecting at the Mine Run Dump, Sterling Hill Mining Museum,
for members of the SHMM Foundation. Fee charged.

Saturday-Sunday, April 27-28, 1996
*New Jersey Earth Science Show, Westfield Armory, Westfield, N.J.
Hours: 9:00 A.M. - 6:00 P.M. Sat., 10:00 A.M. - 5:00 P.M. Sun.

Saturday-Sunday, May 4-5, 1996
F.O.M.S. Spring Swap-and-Sell, Sterling Hill Mining Museum
Hours: 6:00 A.M. - 6:00 P.M. Sat., 9:00 A.M. - 5:00 P.M. Sun.
Fee for dealers: contact Chester S. Lemanski, Jr., (609) 893-7366 after 8:00 P.M.
*Sunday, 1:00 P.M., at the Franklin Mineral Museum:
Old Miners Day, the Dedication of John L. Baum Hall at the
Franklin Mineral Museum, and a concert by the famous Franklin Band.
*Sunday, 4:00 P.M., at the Sterling Hill Mining Museum:
a mineral auction for the benefit of the SHMM Foundation.

Saturday, May 18, 1996
9:00 A.M. - Noon — F.O.M.S. Field Trip — Buckwheat Dump, Franklin Mineral Museum
10:00 A.M. - Noon — F.O.M.S. Micro Group, Franklin Mineral Museum
1:30 P.M. - 3:30 P.M. — F.O.M.S. Meeting and Lecture, Franklin Mineral Museum
The Origin of Species (Minerals), by Dr. Paul B. Moore

Sunday, May 19, 1996
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, May 25, 1996
*9:00 A.M. - 3:00 P.M. -- Field trip to the Passaic Pit, Sterling Hill Mining Museum,
for members of the SHMM Foundation. Fee charged.

Saturday, June 15, 1996
9:00 A.M. - Noon — F.O.M.S. Field Trip — Franklin Quarry, Franklin, N.J.
1:30 P.M. - 3:30 P.M. — F.O.M.S. Meeting and Lecture, Franklin Mineral Museum.
A Conversation with Pete Dunn, by Dr. Pete J. Dunn

*Activities marked with an asterisk are not sponsored by the F.O.M.S., but may be of interest to F.O.M.S. members. F.O.M.S. membership is not a criterion for attending these functions, and fees may be charged by the sponsoring organization.

Scheduled activities of the F.O.M.S. include meetings, field trips, and other events. Regular meetings, comprising a business meeting and lecture, are held in Kraissl Hall, Franklin Mineral Museum, 5 Evans St., Franklin, N.J. on the third Saturdays of March, April, May, June, September, October, and November. Field trips and Micro Group meetings are usually held in the morning before regular meetings. Regular meetings and Micro Group meetings are open to the public. Field trips are open only to F.O.M.S. members aged 13 or older; proof of membership is required, as is proper safety gear: a hard hat, protective goggles or safety glasses, gloves, and sturdy footwear.

FROM THE EDITORS' DESK

First, our apologies for the lateness of this issue. There were objective difficulties in its production, chief among them the crashing of the hard drive in the FOMS computer. We were also slowed down considerably by our participation in the Fluorescent Mineral Society's 25th Anniversary display at Tucson in February. That being said, we wish to thank our readership for being patient and courteous under increasingly trying conditions; please understand that this delay has not been easy on your editors.

Second, our thanks to Dr. Paul Moore and Gary Grenier, Jr. for contributing two important articles to *The Picking Table*. Dr. Moore's article, which concludes in this issue, is the third of a series on closest-packing in minerals from Franklin and Ogdensburg. Those of you who were able to attend the May FOMS meeting heard him explain, clearly and carefully, the principle of closest-packing and its growing importance in mineral studies. The next day at the Lime Crest field trip he was available for mineral identification and general consultation - one of many gifts from a remarkable man. We are honored that he is a *friend of Franklin*. Gary Grenier's piece on macrophotography of mineral specimens distills the essence of many years of experience; what his article does not say is that he has produced what is by far the most significant body of high-quality color photos of Franklin and Sterling Hill hand-specimens. Much of the intensity Gary brings to his photography comes from love of minerals; it is noteworthy that his display of fluorescent minerals at Tucson this year took first place.

Since last fall's *Picking Table* there have been two occasions of major significance for the local "mineralculture." One is the completion of publication of Dr. Pete J. Dunn's monograph, *Franklin and Sterling Hill, New Jersey: the world's most magnificent mineral deposits*. To be blunt, it is the most important work about the world's most remarkable mineral locality; your editors believe this judgement will stand centuries from now. Every FOMS member should own a copy! The other event alluded to was a birthday: Jack Baum's 80th, on March 25. The Franklin Mineral Museum, whose curator Jack has been for nearly 30 years, named its new expanded lobby for him on Old Miner's Day, May 4. If every individual and group he has benefited were to rise up at once and so honor him, the resulting seismic ripple would obliterate much of Sussex County's topography. For starters, we owe him. ("We" being the fellowship of Franklin - Sterling Hill mineral collectors, the good, the bad, and the cosmetically challenged. Think just of the many contributions he has made to *The Picking Table* over the years.) Add to our swarming throng the Borough of Franklin, the Franklin and Sterling mines, Harvard and the Smithsonian, every visitor to the Franklin Mineral Museum, and the many other institutions and individuals who have cause to thank Jack, and the total is prodigious. His achievement is all the more impressive in that Jack has never asked to be wined, dined, speechified, or deified for what he has done. We think all FOMS members will join the *Picking Table* editors in saying, "Thank you, Jack. Thank you very, very much."

Minerals from Franklin and Sterling Hill finally made a loud splash at Tucson this year, as a major part of the largest display of fluorescent minerals in history. The occasion was the 25th anniversary of the Fluorescent Mineral Society, whose founder, Don Newsome, began planning the display in 1990. The Tucson Gem & Mineral Society provided a dark cavern in the bowels of the Convention Center, and 40 cases; Tom Heffron of Raytech generously loaned most of the ultraviolet lamps. Many West Coast FMS members brought cases and lamps as well. How big was the display? There were 76 cases holding over 1200 specimens. 22 of those cases were filled with specimens exclusively from Franklin and Sterling Hill, placed by The Franklin Mineral Museum (4½ cases), the Sterling Hill Mining Museum (5½ cases), Richard Bostwick (3 cases), Gary Grenier and Earl Verbeek (2 cases each), and Joe Daley, Elna Hauck, Pete Mackey, Claude Poli, and Don Snyder (1 case each). Over a ton of this material (2433 pounds to be exact) was driven to Tucson and back in Bob Hauck's and Joe Kaiser's vans. The largest specimen in the display was a 225-pound Sterling Hill barite in calcite, borrowed from the Rainbow Room; it occupied an entire case. Other locals who helped with setting up, tearing down, and myriad other duties included Steve Misiur, Ron DeBlois, Dick Hauck, Rhea Hauck Cianfichi and Vince Cianfichi, Dave Wellbrock, Jerry McLaughlin, Ralph Thomas, and Bill Trost. Warren Miller had planned on 3 cases' worth, but stayed home with an injured back and his best Franklin pieces, deputizing Mark Leger to install 2 cases of "foreign" specimens. Jack Baum and Steve Chuka also stayed behind, but loaned many of their best pieces through the Franklin Mineral Museum. Your editors installed lamps and liners, proofread labels, created a slide show for the Convention Lobby, took photos (for which there is no room here), gave speeches, and in general spread themselves thin. All this was done, they would like to believe, to enhance public awareness of fluorescent minerals, and for the greater glory of Franklin and Sterling Hill.

MESSAGE FROM THE PRESIDENT

A. Lee Lowell
53 Foxtail Lane
Hamburg NJ 07419

Wow! What a year the Society had in '95. The highly successful sales of Dr. Dunn's monograph and the record attendance at the Franklin mineral show are but two of that year's highlights.

So what's to be expected in '96? Well, it will be difficult to top '95's achievements, but no doubt, given the energetic nature of our own "Great Society," some exciting surprises will spring forth. The officers and staff of the F.O.M.S. will be working diligently to assure that this great mineral mecca remains visible and vibrant.

FOMS members continue making significant contributions to the Franklin Mineral Museum and the Sterling Hill Mining Museum. Both of these museums will be dedicating new facilities this year, and this progress illustrates the vitality of the efforts to preserve the mineral, mining, and scientific heritage of these fascinating deposits.

On behalf of the officers and staff, I wish the FOMS family, nearly 400 strong, a happy, healthy, and mineralogically prosperous New Year.

LOCAL NOTES

NEWS FROM THE FRANKLIN MINERAL MUSEUM

John Cianciulli
Assistant Curator
Franklin Mineral Museum, Inc.
P.O. Box 54
Franklin NJ 07416

The Franklin Mineral Museum, Inc. and its Board of Directors are pleased to announce the completion of the new addition. The museum has taken on a new look with an old flavor. The front entrance to the museum is now reminiscent of the architecture of the familiar N.J. Zinc Co. buildings on Main Street. The lobby/sales area has been doubled in size and now features a built-in sales booth for fluorescent minerals. The new handicap-accessible restrooms are larger and more accomodating. Kraissl Hall is isolated from the sales area, making it more suitable for lectures, seminars, and classroom activities. A handicap-accessible ramp leads the way to the Buckwheat Dump and the entrance to Kraissl Hall. There are far too many improvements to describe here; you are invited to visit the museum and see for yourself.

The museum participated in The World's Largest Fluorescent Mineral Display at the Tucson Gem and Mineral Show in February. We sent fifty-nine specimens, twelve of which were Jack Baum's. Among the specimens to appear on our behalf were the famous "Jack Baum esperite," a fifty-pound margarosanite, a thirty-pound solid fibrous wollastonite, and an array of astoundingly beautiful Franklin classics. Our thanks go to Bob Hauck for lugging five hundred pounds of FMM rocks to Tucson and back safely. Special thanks also go to Dick Bostwick, Tema Hecht, Steve Misiur, Ron DeBlois, and others who made this effort a great success.

Dedication of the museum's new addition is planned for Old Miner's Day on May 5; the ceremony will begin at 1:00 P.M. Please try to attend. As of March 1, the Franklin Mineral Museum will be open during regular hours on weekends or by appointment during the week. April 1 will see a resumption of the museum's full seven-days-a-week schedule. Hours will be 10:00 A.M. to 4:00 P.M. Monday through Saturday, and 12:30 P.M. to 4:30 P.M. on Sunday

NEWS FROM THE STERLING HILL MINING MUSEUM

Joe Kaiser
40 Castlewood Trail
Sparta NJ 07871

The Sterling Hill Mining Museum is planning to extend its educational programs to teachers in New York and Pennsylvania. It is hoped this can be achieved with the support of grants and in-kind contributions, such as the recent $50,000 grant from the Geraldine R. Dodge Foundation. Consideration is being given to holding a tri-state educators conference sometime in 1997 or 1998.

At the Rock Discovery Center, a new collecting site for children, there are more than eighteen truckloads of imported broken rock. In addition to Franklin Marble (a metamorphosed limestone) there are piles of red Newark Formation sandstone, basalt (trap rock), slate, coal, granite, sphalerite, pyrite, and Gore Mountain garnet, as well as ten loads of fluorescent material from the Edison Tunnel project. Children are given a compartmented box and a list of the rocks and minerals to be found at the Center; as they find each item on the list, they take a piece for themselves. When they leave, it is with an enhanced knowledge of rocks and minerals, as well as their own personal mini-collection.

Some time in 1996 the Landmesser Tunnel, which runs off the Edison Tunnel and connects to the basement of the mill complex, will be dedicated. The lower stope of this tunnel is the roof pillar of the East Vein surface outcrop. The remaining East Vein ore in this stope is highly fluorescent, and after the surface of this ore has been sandblasted, up to twenty shortwave ultraviolet lamps will be installed to illuminate about 75 feet of the stope's ceiling.

A large boulder 10-15 feet in diameter buried at the entrance to the Passaic Pit was found to contain large vugs of unusual botryoidal hemimorphite. Many specimens of this material show a distinct uranium-green fluorescence. This discovery was made during the last week of November, 1995. In addition, work has also begun on a trail system to connect the Passaic and Noble Pits. It is hoped that, in the future, tours can be taken from one pit to the other, and out the Trotter Tunnel to Plant Street.

A complete stamp mill complex dating to 1911 has been found in Canada. This will be lost to scrap-metal dealers if funds are not found. An effort will be made to save at least part of this irreplaceable bit of mining history, and install it alongside the foundation of the old Sterling Mine mill to showcase the evolution of milling technology.

The Sterling Hill Mining Museum participated in the 1996 Tucson Gem & Mineral Show, which this year featured mineral fluorescence. Two vanloads of Franklin/Ogdensburg fluorescent minerals were hauled to Arizona and back, including many prizes from local collections and the area's two museums, as well as some of the large pieces from the Rainbow Room.

The Museum has also acquired portions of the Joe and Helen Warinsky Collection. It was rich in material from the Lime Crest Quarry in Sparta, and some of these pieces have been incorporated in the Museum's displays.

As mentioned above, in March of 1996 the Museum received a $50,000 grant from the Geraldine R. Dodge Foundation for further support of the Geological, Environmental, & Mineralogical Science (GEMS) project.

The weekend of May 4-5 saw two Sterling Hill firsts. On Saturday, Pat and Susan Radomski were married in the Rainbow Room, and on Sunday a mineral auction was held in the lamp room. Both events were successful.

FIELD TRIP REPORT

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

THE STERLING HILL MINING MUSEUM DUMP
Sept. 16, 1995

The collectors of fluorescent minerals did very well on this trip. A number of bright-blue-fluorescing hydrozincite specimens were located, some coating altered ore while others were associated with orange-fluorescing sphalerite. A little digging uncovered examples of orange-fluorescing wollastonite grains in weakly red-fluorescing calcite; these are presumably from the 430 level find.

Remnants of the sulfide "boulder" from the Passaic Pit yielded two-color fluorescent specimens: galena associated with small anglesite crystals, yellow-fluorescing cerussite crystals, and films of fluorescent hydrozincite. The most unexpected find of the day was an 11 x 11 cm plate of ore covered with white secondary willemite of radiating habit. It fluoresced bright green but had a very striking pattern when phosphorescing.

Other finds of note were brown friedelite veins cutting ore, gahnite crystals as large as 1.5 cm, and blocks of ore with black mirror-faced slickensides.

THE LIME CREST QUARRY, October 22, 1995

The quarry operators were busy rearranging old work areas and opening up new benches; this will certainly provide surprises in future field trips. Still in evidence were remnants of the Mississippi-Valley-Type (MVT) vein system worked earlier, producing sphalerite, fluorite, barite plates, calcite crystals, and druses of pyrite. The lapidary crowd had been at work on material found previously, and several faceted colorless fluorites, as well as a cabochon of oil-green gem-grade sphalerite.

With much work several dark-brown uvite crystals were extracted, some blocky and 3 x 5 cm in size while others were thinner and in elongated sprays as much as 15 cm in length. Light green scapolite crystals, some 4 x 9 cm in size, were found at the contact between marble and pegmatite. Within some of the darker pegmatite masses were abundant large allanite crystals and brown crystals of sphene.

Boulders of dolomitic marble contained lenticular vuggy pods of fluorite, calcite, and quartz; the pods were as long as 20 cm, with cm sized crystals of all three minerals. Tremolite surfaced in white radiating sprays, and as pale green masses with a few isolated prismatic crystals. Prismatic crystals of fluorapatite were found in three colors: green (1 x 1.5 cm), blue (3 x 10 mm) and purple (2 x 5 mm). Much fluorescent norbergite/chondrodite was removed, including some subhedral crystals 3 cm long. Rich, thick bands of nonfluorescent granular norbergite/chondrodite in calcite were also found.

Sharp crystals of pyrrhotite as large as 5 x 8 mm were seen, in contrast to the anhedral grains typical of Lime Crest. Similarly sized arsenopyrite crystals were found in several parts of the quarry. An interesting 1 x 1.5 cm elongated crystal of pyrite was successfully recovered.

The lowest bench of the quarry produced gemmy green actinolite crystals 3 cm long, as well as dark green to black pyroxene crystals. The same area yielded attractive specimens of bright green serpentine coating a slip; adjacent pink massive grossular gave this material lapidary potential.

The find of the day was a large corundum-bearing boulder which was dismantled by three persistent collectors. The best crystals occurred in calcite pods in a fine-grained olive-gray matrix, varied in color from blue to violet to purple, and were associated with rutile crystals and an occasional arsenopyrite crystal. The corundum crystal shapes varied from flattened blades to stout barrels to scepters, and were as large as 2 x 5 cm; some fluoresced red in longwave ultraviolet light.

THE FRANKLIN QUARRY, Nov. 11, 1995

Numerous crystals of tremolite were recovered, including colorless single crystals and radial crystal clusters, and gray and green single crystals, many of these fluoresced pale blue in shortwave ultraviolet light. These were often acompanied by grains of blue-fluorescing diopside and yellow-fluorescing norbergite, yielding three-color fluorescent specimens. Margarite plates were found with microcrystals of rutile, but alas, without corundum. Yellow-fluorescing phlogopite was there in relative abundance, as well as brightly-fluorescent norbergite. The best crystal specimen reported was a 4 cm cube of pyrite.

John Kolic and Bob Hauck of the Sterling Hill Mining Museum at the Passaic Pit with the "boulder" of eroded calcite found at the eastern edge of the Mud Zone in Novermber, 1995. From the surface craters of this calcite mass were removed many specimens of botryoidal hemimorphite of unusual habit, some with the moderate green fluorescence characteristic of trace amounts of uranium. S. Misiur photo.

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Tucson AZ 85740

FLUORESCENT MINERAL SOCIETY REGIONAL MEETING, JULY 20, 1996

At the home of Chester and Mary Bridget Lemanski,
309 Massachusetts Road, Browns Mills NJ 08015.

FMS members and guests are welcome; food and drink will be provided. The meeting will run from 10 AM to 4 PM, and will consist of presentations, show-and-tell, trading, and the chance to view the the Lemanski collection. R.S.V.P. For information, call (609) 893-7366 after 8 PM, or the FMS Regional VP, Richard Bostwick, at (212) 749-5817.

Member's Advertisement

Items for sale:

- ❖Dana's *System of Mineralogy, 7th Edition* (3 vol.).
- ❖Gude's three-dimensional crystallographic models; 116 models fully assembled and outlined in black.
- ❖*Mineralogical Record*, complete set in mint condition.
- ❖Swift binocular microscope, 15X & 30X magnification; made in England - brand new.

Items wanted:

- ❖Quality microminerals from Franklin - Ogdensburg (or worldwide) to purchase or trade.

Write to: Eugene Stueben, P.O. Box 223,
Westtown NY 10998
All serious responses will be acknowledged.

FLUORESCENT MINERAL SOCIETY

The Fluorescent Mineral Society is devoted to increasing the knowledge of its members in the luminescence of minerals, with an emphasis on fluorescence and phosphorescence. It promotes increased knowledge with emphasis on collecting, displaying, studying and understanding. It publishes a bi-monthly newsletter, the ***U.V. Waves*** and an annual or biennial periodical, ***The Journal of the Fluorescent Mineral Society***.

Membership information may be obtained by writing to:
The Fluorescent Mineral Society
P.O. Box 572694
Tarzana CA 91357-2694

www.FOMSNJ.org

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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. It consists of Parts One through Five, and a First Supplement. Each is an 8½ x 11 inch softcover book, illustrated with line drawings and black-and-white photographs.

Part One contains xiii pages of front matter and 160 pages of text, and includes 23 black-and-white illustrations and 23 line drawings. 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 Frankin Marble*; Chapter 5, *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*.

Part Three contains xii pages of front matter and 142 pages of text, and includes 126 black-and-white illustrations, 49 line drawings, and 12 tables of chemical data. It consists of Chapter 13, *Lists of minerals*; Chapter 14, *Descriptive mineralogy*; Chapter 15, *Nesosilicates*; Chapter 16, *Sorosilicates and cyclosilicates*; and Chapter 17, *Inosilicates - chain silicates*.

Part Four contains xii pages of front matter and 164 pages of text, and includes 149 black-and-white illustrations, 48 line drawings, and 22 tables of chemical data. It consists of Chapter 18, *Phyllosilicates - layer silicates*; Chapter 19, *Tectosilicates and silicates with unknown structures*; Chapter 20, *Elements*; Chapter 21, *Sulfides, arsenides, antimonides, and sulfosalts*; Chapter 22, *Oxides and hydroxides*; and Chapter 23, *Halides and carbonates*.

Part Five contains xii pages of front matter and 168 pages of text, and includes 50 black-and-white illustrations, 19 line drawings, and 3 tables of chemical data. Following the text is a duplicate set of front matter for the entire monograph. Part Five consists of Chapter 24, *Sulfates, borates, tungstates, and molybdates*; Chapter 25, *Arsenates, arsenites, phosphates, and vanadates*; Chapter 26, *Unnamed minerals*; Appendix I, *List of obscure or general mineral names*; Appendix II, *Glossary of local terms*; Appendix III, *Sterling mine operations, 1966*; Subject index; and Mineral index.

The First Supplement contains xii pages of front matter and 98 pages of text, and includes 104 black-and-white illustrations, 74 of which are photos, plus 6 tables and 2 graphs of chemical data. It consists of Chapter S1, *Chemical data for the east and west limbs of the Sterling Hill orebody;* Chapter S2, *The Passaic Zinc Company;* Chapter S3, *19th-century obserations on geology and mining;* Chapter S4, *Mineral images;* and Chapter S5, *"A Trip to Franklin Furnace" by John A. Manley.*

The Franklin-Ogdensburg Mineralogical Society, Inc., is the sole distributor for the first printing of this monograph. The officers of the F.O.M.S. have set the price without consulting with Dr. Dunn, who receives no income from this publication. Proceeds from sales are divided. For each copy of Parts One through Five 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. For each copy of the First Supplement sold, $5 is donated to this fund.

Each of Parts One through Five is available by mail for $30 plus $5 postage and handling.
The First Supplement is available by mail for $25 plus $5 postage and handling.
The set of six volumes is $175 plus $15 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 07036

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

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 workings, 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 fossils, Native American relics, 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.

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"The Fluorescent Mineral Capital of the World"

The Sterling Hill Mining Museum, Inc.

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MINERAL PHOTOGRAPHY: TABLE-TOP TRIPOD METHODS IN PHOTOMACROGRAPHY

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INTRODUCTION

Photography of Franklin and Sterling Hill mineral specimens has been attempted over the years by many amateur and professional photographers. In the past, to achieve high-quality photos the more successful photographers had to develop their own techniques and equipment, often at considerable expense, while the majority settled for below-average results. With recent improvements in lighting equipment and 35mm single-lens reflex (SLR) cameras, amateur photographers are now able to take highly satisfactory photographs of mineral specimens at relatively low cost.

The photographic methods best suited to Franklin and Sterling Hill minerals are photomicrography, which entails taking photographs through a microscope, and photomacrography, often called close-up photography. Taking photographs of the area's fluorescent minerals has become a specialized branch of photomacrography.

Over the past decades three photographers have stood out in their efforts to record Franklin and Sterling Hill minerals on film. Dr. Alfred Standfast of Binghamton, N.Y. used a variety of equipment, much hand-made, to produce outstanding photomicrographs of most local mineral species; his collection of slides is now curated by the Franklin Mineral Museum. Likewise, Henry Van Lenten of Goshen, N.Y. obtained truly remarkable photos of fluorescent minerals; made with simple equipment and techniques of his own devising, his work has extablished a benchmark for all who follow. Omer Dean, formerly of Norwalk, Conn. and now of San Antonio, Texas, set standards of excellence in both photomicrography and photomacrography. His framed and signed photos of Franklin and Sterling Hill crystals were often the highlight of the annual banquet and auction of the Franklin-Ogdensburg Mineralogical Society, Inc.

These photographers, amateurs all, achieved a high degree of success through persistence, ingenuity, and the skillful adaptation of equipment not designed for what they wanted to do. Amateurs can now achieve excellent results in photomacrography, at less expense, with equipment available at most camera stores. The most commonly used camera today, available in many brands and with a wide variety of interchangeable lenses and standard accessories, is the 35mm SLR camera, and it is such a camera that is used in the methods described here.

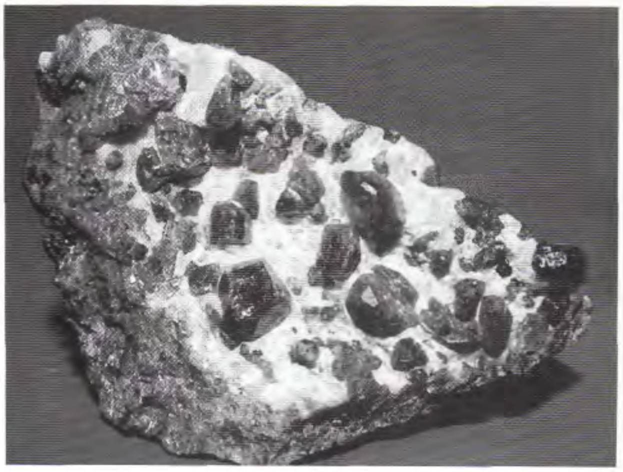
The *Table-Top Tripod* method of photomacrography is most often used in documentary or scientific photography. This method easily conforms to the basic requirements of documentary photography, which include: accuracy of image, use of distortion-free lenses, sharpness of image, distraction-free backgrounds, balanced shadowless lighting, and accurate recording of details. It is well to remember the purpose of documentary photography, which is to represent on film all features of the subject as accurately as possible. Precise reproduction of color and texture are as important as image sharpness.

Documentary photography, while not necessarily as dramatic or artistically expressive as magazine-cover photography, has a wide array of applications. Its most common uses for mineral collectors include photo displays, specimen cataloging and marketing, lectures and presentations, and illustrations for articles.

There are perhaps as many methods for the photographer to choose from as there is variety in photographic equipment. What is here described represents a small proportion of the many ways in which useful documentary photographs can be achieved. Regardless of the method you choose, for consistent results you will need thorough preparation, skill with equipment, and well-rehearsed procedures. Following the steps outlined below, you should be able to do this with a table-top, props, a 35mm SLR camera, a tripod, a handful of interchangeable lenses, a few well-chosen accessories, and the proper lighting equipment.

EQUIPMENT: CAMERA AND LENSES

In specimen photography, the most important decision you will make is which equipment you select. The most versatile camera will prove to be a 35mm SLR camera which can be set for



Uvite crystals in calcite, 6.3 x 7.5 cm, Franklin, N.J. Pentax camera with 50mm macro lens, ASA 100 print film @ f/16, 1/60 sec. exposure.

manual operation, has through-the-lens viewing, and accepts interchangeable lenses. A light meter, hand-held or in-camera, is not necessary, as a trial-and-error exposure-ranging method is used. A wide range of lenses, including telephoto lenses, is important and will allow the camera to get close to the specimen. The most popular lens for photomacrography is the macro lens, usually a 50mm or 55mm lens with a maximum aperture of f/3.5 to f/4. The macro lens will allow the camera to come within 4" of the specimen, and provide a 1-to-1 magnification factor. The 50mm f/1.8 lens which is usually included with a newly purchased camera does not have this flexibility, but can be used for photomacrography with accessories such as a reverse ring, which will increase the lens's magnification.

Magnification is obviously an important factor in successful photomacrography. To determine magnification or reduction, two measurements are required. First measure the specimen, then measure the image of the specimen on the slide or negative. (Magnification of the specimen cannot be determined from a print image, since prints are enlargements of the image on the negative.) Compare the size of the slide or negative image to the size of the specimen to determine the ratio. A 1-to-1 ratio is said to be life-size, meaning that a ½" specimen has a ½" image on its negative or slide. If the same ½" specimen's image on film measures 1", then 2-to-1 magnification has occurred. If a 2mm crystal on the same specimen measures 20mm on film, its magnification is 10-to-1. Reduction takes place when the film image is smaller than the specimen: if a 12" specimen measures 1½" on film, a 1-to-8 reduction has taken place. So the scale of the photograph can later be established, always include in your log the size of the specimen.

Whenever image magnification is desired, there is a range of accessories for addition to a macro lens. Any or all of these accessories may be needed, and can be used in various combinations as depicted in figure 1. The most commonly used accessories for lens combinations are as follows:

2X, 3X, 4X lenses: these are single-element magnifying lenses which are placed on the front of the main lens (like a filter), and can be used alone or in combination. They are inexpensive and often used by beginners, but are not mentioned further in the method described here.

Extension tubes: tubes of various lengths which are placed between the camera body and the main lens to increase magnification.

Bellows: a flexible extension tube placed between the camera body and the main lens to increase magnification by 2-to-1. Some include a focusing rail.

2X converter: also called a doubler, this is a lens (often with an iris) which is placed between the main lens and the camera body to increase magnification by 2-to-1.

Reverse ring: used to reverse the main lens for higher magnification. Easily converts a standard 50mm lens for photomacrography.

Any of the above accessories may be used to produce a wide variety of results. Experimentation with each piece of this equipment, singly or grouped in various combinations, will reveal its limits. Several of the general characteristics of magnification equipment are:

1) As magnification is increased, the depth of field decreases, and the amount of light needed for proper exposure increases.

2) The closer the camera is to the specimen, the farther the lens must be from the camera body, and the harder it will be to focus.

3) As the number of lens elements increases, image sharpness decreases.

4) The higher the magnification, the more likely it is that any vibration will cause the picture to be out of focus.

There are many ways to compensate for these effects, and publications are available to help overcome these and other problems.

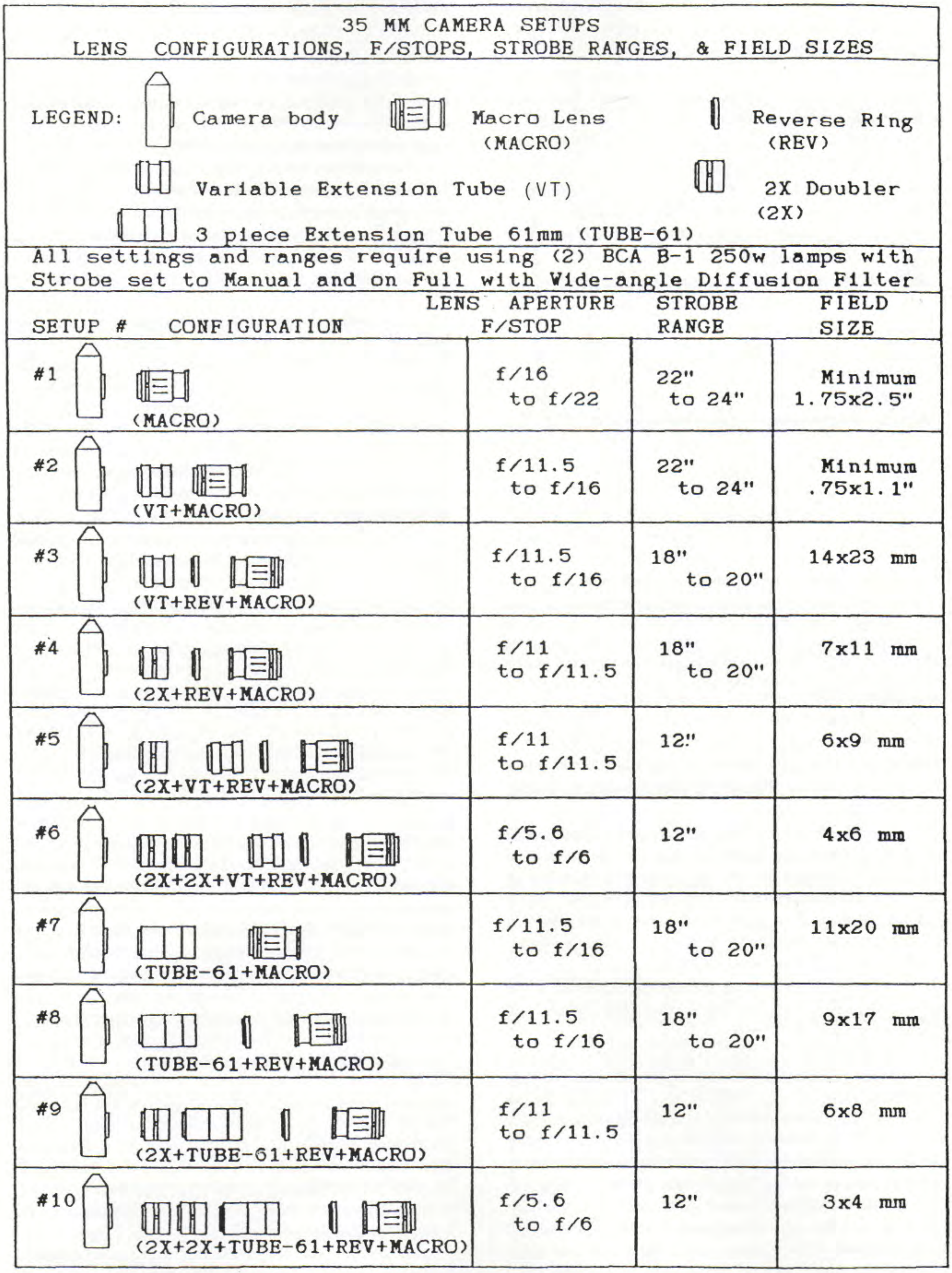
TECHNIQUE: TRIPOD, PROPS, BACKDROPS

After you have acquired your photomacrography equipment, you must establish and perfect your technique. The following equipment and methods have been chosen to be highly portable, and to allow the photographer to work on tabletops or in confined areas.

The technique I term *Table-Top Tripod Photomacrography* will prove both versatile and inexpensive for documentary photography. An essential piece of equipment is a sturdy, locking twelve-inch metal tripod which will allow camera positioning both vertically and horizontally. A micro-focusing rail is optional but will make sharp focusing much easier. A shutter-release cable for the camera will also be necessary.

You will also need to build a shelf to support the specimen and a vertical stand to support a backdrop behind it. Placed together and seen from the side, the stand and shelf form the letter L; a typical set-up is shown in figure 1. The shelf should be 12" x 14" in size, and can be made from thick plywood, plate glass, steel, or other rigid, vibration-absorbing material. The stand can be made from ¼" plywood, Lexan, etc. Pairs of wood blocks of different sizes kit will enable you to raise or lower the shelf.

An assortment of colorful, matte-finish *Color-Aid* craft paper should be available in 18" x 24" size from your local art-supply store. Placing the paper in the L of the shelf-stand will provide a seamless background. Typical office-supply binder



35 MM CAMERA SETUPS
LENS CONFIGURATIONS, F/STOPS, STROBE RANGES, & FIELD SIZES

LEGEND:
Camera body
Macro Lens (MACRO)
Reverse Ring (REV)
Variable Extension Tube (VT)
2X Doubler (2X)
3 piece Extension Tube 61mm (TUBE-61)

All settings and ranges require using (2) BCA B-1 250w lamps with Strobe set to Manual and on Full with Wide-angle Diffusion Filter

SETUP #	CONFIGURATION	LENS APERTURE F/STOP	STROBE RANGE	FIELD SIZE
#1	(MACRO)	f/16 to f/22	22" to 24"	Minimum 1.75x2.5"
#2	(VT+MACRO)	f/11.5 to f/16	22" to 24"	Minimum .75x1.1"
#3	(VT+REV+MACRO)	f/11.5 to f/16	18" to 20"	14x23 mm
#4	(2X+REV+MACRO)	f/11 to f/11.5	18" to 20"	7x11 mm
#5	(2X+VT+REV+MACRO)	f/11 to f/11.5	12"	6x9 mm
#6	(2X+2X+VT+REV+MACRO)	f/5.6 to f/6	12"	4x6 mm
#7	(TUBE-61+MACRO)	f/11.5 to f/16	18" to 20"	11x20 mm
#8	(TUBE-61+REV+MACRO)	f/11.5 to f/16	18" to 20"	9x17 mm
#9	(2X+TUBE-61+REV+MACRO)	f/11 to f/11.5	12"	6x8 mm
#10	(2X+2X+TUBE-61+REV+MACRO)	f/5.6 to f/6	12"	3x4 mm

Figure 1

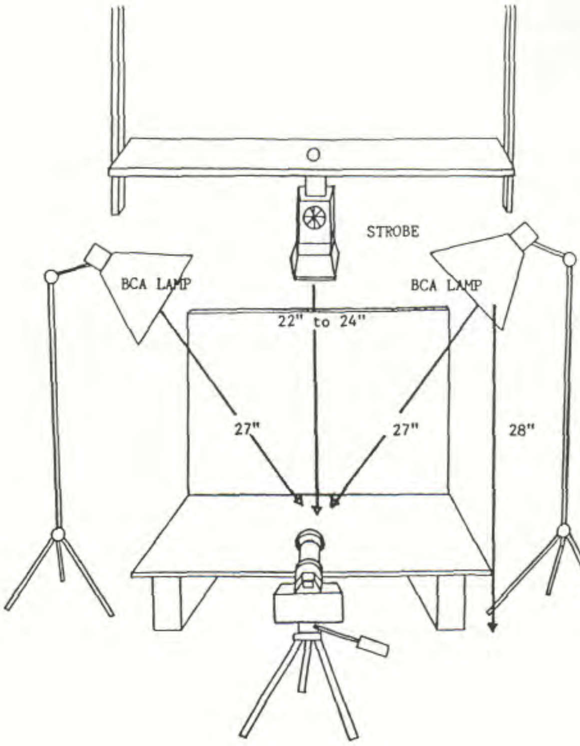


Figure 2. The author's set-up for photomicrography. ◆The specimen is placed on the L-shaped stand, at the convergence of the arrows. ◆The strobe is usually positioned above and behind the camera, and may be mounted or hand-held. It may be moved to the left or right to minimize reflections. ◆The BCA lamps are usually positioned above and on both sides of the specimen, with their reflectors aimed so that no direct light hits the camera.

clips can be used to attach the paper to the stand. Do not crease the paper at the junction of the shelf and stand, but allow it to bend in a gentle curve.

Color fabrics can be used with success as background materials, provided they have very tight weaves and are not shiny. Glossy, silk-like finishes will give glaring reflections on film. A reflecting background will add colorful highlights where they are not wanted or cause overexposure of the film. In documentary-style photography a "busy" or confusing background is not useful and should be avoided.

Once the shelf and backdrop are prepared, set up your tripod and camera, select your lens configuration, and prepare your lighting (see figure 2).

Many photography enthusiasts have copystand equipment for document reproduction. While the copystand technique is not specifically discussed here, much of what is presented for the *Table-Top Tripod Method* can be easily adapted for the copystand. While use of a copystand will restrict the size of specimens which can be photographed, it has greater stability than a shelf-and-backdrop set-up, and may allow more precise focusing. In addition, the use of an elevated glass shelf to support the specimen, with the colored background placed several inches below the shelf, is much more practicable with a copystand. Many of the artistic mineral photographs seen on magazine covers are produced in studios with this technique, albeit with sophisticated and costly equipment.

LIGHTING EQUIPMENT

Becoming familiar with photo lighting is essential to correctly expose the film, and just as importantly, to achieve correct color reproduction. Most color print and slide films are "daylight-balanced" to a rating of 5500 K, which is intended to match the color spectrum normally experienced in sunlight at noon. Professional tungsten slide film rated at 3200 K is an exception and requires the use of an ECA photoflood bulb and an 80A filter. Normal incandescent bulbs and fluorescent tubes should be avoided as sources of primary light. They are inconsistent in their spectral output and it is very difficult to color-compensate for them with filters.

Most electronic strobe (flash) equipment is "daylight-balanced" between 6000 and 6500 K. A second source of light is needed to balance the output of the strobe to the K-rating of the film, as well as to provide fill-in light for the reduction of shadows. The General Electric or Sylvania BCA, B-1, 250-watt photoflood bulbs, with a rating of 4500 K, will balance the strobe's 6500 K to a rating of 5500 K, which is suitable for daylight-balanced films. Using a secondary source of constant light provides the added benefit of having more than enough light by which to focus most lens configurations.

While this combination of light sources is unconventional and generally not recommended by professionals, it will overcome several lighting problems. Most amateur photographers have a strobe for family picture-taking, and with a little extra cost can add photoflood lamps, giving them an effective light source without the expense of professional lighting equipment. When a strobe is used as the primary light source it has proven unable to reproduce the unique color combinations present in most Franklin and Sterling Hill minerals. The combination of strobe and BCA photofloods will also eliminate the need for long exposure times, as the camera's shutter speed is set to a constant 1/60th of a second when using a strobe light-source.

To eliminate "shadowing," use two BCA 250-watt bulbs mounted in clamp-on fixtures with aluminum reflectors, placed above and to either side of the specimen at 45-degree angles (fig. 2). The distance from the base of the specimen to each photoflood bulb should be about 27 inches. For front illumination with this method, place a single strobe above the camera and approximately 22" to 24" from the specimen. Never use an in-camera flash unit or attach a strobe to the camera. Also remember to keep the strobe at a high enough angle so that the shadow of the camera does not reach the specimen. The exact angle of the strobe to the plane of the stand is otherwise a matter of experimentation, as is the decision to swing the strobe to the right or left of the camera, but maintaining the proper strobe-to-specimen distance is critical. In aiming the strobe, you will need to be particularly concerned about avoiding reflections from crystal faces, and reducing shadows. Setting the strobe on "full-manual," adding a wide-angle diffusion filter, and turning off the strobe's automatic-intensity sensor will allow procedural repetition and yield consistent results. Some strobes are equipped with half-power settings; experimentation with these will make possible different aperture settings and distance-to-specimen ranges. Strobe exposure guides should be ignored since the strobe is being used in a nonstandard environment.

Depending on the lens configuration, you may try moving the strobe closer to the specimen and varying the lens aperture. A reference table is included in figure 1 for easy recall of f/stop settings and strobe distances. This table is based on the use of ASA 100 print or slide films. There are so many variables involved that it is often necessary to shoot a series of exposures, varying the aperture by a half to a full f/stop for each shot. This "series-shooting" method (a.k.a. "trial-and-error") should produce at least one correctly exposed image. Among the other exposure factors which will influence the photographic results is the specimen itself.

A specimen's color, texture, or crystal habit can influence exposure settings. Solid white minerals such as calcite, aragonite, margarosanite, and some willemite may be overexposed when "normal" averaged settings are used. The reflected light from shiny, well-crystallized franklinite or andradite may not only overexpose the film but also wash out the background color. Very small specimens, which require the camera to be moved as close as possible, may be overexposed if adjustments are not made to the lighting or the lens aperture. Intensely colored minerals, notably green willemite, will give better color fidelity if slightly underexposed. Coarsely textured minerals will often be underexposed, as greater surface absorption of light will occur regardless of color. Awareness of the specimen's reflective characteristics and use of the "series-shooting" method should yield a correctly exposed photograph.

An additional benefit of using this setup, as shown in fig. 2, is that of having consistent, measurable light sources. The variables in photographic lighting mentioned here reduce to the relationship between the lens-aperture setting and the closeness of the light source to the specimen. Remember that as the lens aperture is closed (as the f/stop is increased) the depth of field is greater and the light reaching the film is less. Lighting will always be an area of experimentation for the mineral photographer, and should be accepted as a challenge.

FILM

A great deal can be said about film selection, although the choice is best left to individual taste. Here are some simple guidelines for film selection:

1) Avoid using a film with an ASA rating over 100, as the higher the ASA value, the less detail will appear in a print or slide.

2) Once satisfactory, predictable results are achieved, stay with the film you are using. Do not experiment with different films unless necessary.

3) For publication work, slide film may be required (ask the publication editor).

4) For collection cataloging, print film is required.

5) For lectures and presentations, slide film is required.

6) Ektachrome ASA 100 film is "cooler," emphasizing blues and greens.

7) Kodachrome ASA 64 film is "warmer," emphasizing reds and yellows. It is preferred for photos of fluorescent minerals dominated by red and green fluorescences.

While there are many film charts and sensitivity graphs which can be used to compare films, you should select the film which gives you the best color reproduction and clarity of image. In 35mm format, images which will be enlarged to print sizes of 8" x 10" or larger require print film. (Large prints can be made from slides but the color and detail may suffer.). For the highest resolution and clarity a low-ASA print film should be used.

Franklinite crystals in willemite, 7.5 x 7.5 cm, Franklin, N.J. Pentax camera with 50mm macro lens, ASA 100 print film @ f/16, 1/60 sec. exposure.

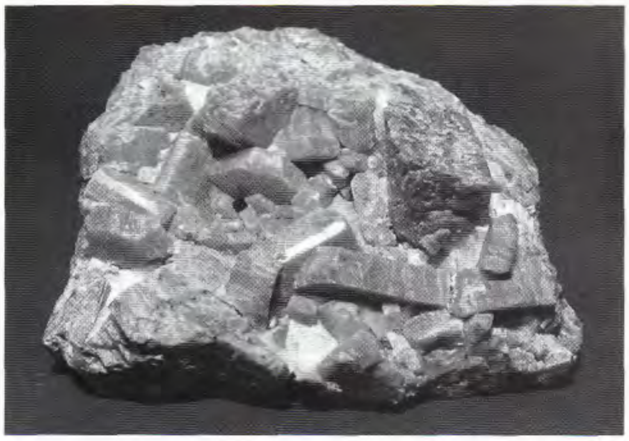
VARIATIONS IN COLOR REPRODUCTION

Some Franklin and Sterling Hill minerals will not photograph as seen in daylight unless they are in fact lit by daylight. For example, massive glaucochroite, blue-gray when viewed in daylight, may appear on film as greyish pink to a pronounced reddish-pink when photographed under artificial light. Likewise, the characteristic grey of tephroite may shift on film to a lively purple.

Due to the emulsion-sensitivity balance of the majority of films, the red colors of some minerals will be greatly enhanced in photographic prints, while greens and blues will be weaker than expected. The pinkish-red of rhodonite is likely to appear stronger or brighter on film than it does to the eye, while a specimen of bright, vibrant green willemite will photograph a weaker green. Likewise, the blue of vesuvianite var. cyprine may be less dramatic and intense on film than expected. The pinkish and purplish hues of minerals like leucophoenicite and jerrygibbsite may also be difficult to reproduce, as the amount of magenta dye added during print processing may vary.

Fibrous and radially crystallized minerals are difficult to capture in photographs. Often color is sacrificed for texture, or vice versa. A good example of blue fibrous magnesioriebeckite may show excellent fibrous structure on film but appear very pale blue. The reverse may be true for radiating willemite, where the pale color may register faithfully in a photo but the details of the radial aggregates cannot be clearly distinguished. No matter how intense they are, the colors of minerals with glassy luster are difficult to reproduce on film due to reflection of light from the specimen.

These and other visual characteristics of specimens can present serious challenges for the photographer. Some of these



Rhodonite crystals, 8 x 10 cm, Franklin, N.J. Pentax camera with 50mm macro lens, ASA 100 print film @ f/16, 1/60 sec. exposure.

problems can be overcome by moving light sources or changing their intensity to improve contrast and reduce glare. Non-glare agents should never be used on crystal faces, as they defeat the purpose of documentary photography

PHOTOGRAPHING FLUORESCENT MINERALS

Franklin and Sterling Hill minerals provide the photographer with another challenge: bright fluorescent colors. To achieve good photographic results with any source of ultraviolet light, very little in the overall setup is changed. A UV Haze 2A filter is placed over the camera lens, and the camera shutter is set for long exposures. A shutter release cable is also necessary, as is a timer such as a stopwatch which can be read in the dark. Also, obviously, all light sources other than the ultraviolet lamp(s) must be shut off during the actual shot.

By focusing on the specimen in photoflood light and then photographing it under ultraviolet light, a well-focused print or slide image should be produced. Using the "series-shooting" method for achieving correct exposure of fluorescent minerals is more complex than shooting in visible light. Exposure times will be in the 3- to 6-second area, and camera-lens aperture settings will range from f/5.6 to f/8. A "series-shooting" may involve exposing film at 3, 4, 5, and 6 seconds for each f/stop chosen. Once experimentation is completed, shorter "series-shooting" efforts will be necessary.

Successful photographers of fluorescent minerals must rely largely on trial-and-error methods for estimating exposures, as no two fluorescent specimens are exactly alike in their overall fluorescent intensity. Hand-held or in-camera lightmeters are usually not sensitive beyond exposures of two seconds, and their use for this application should be avoided. Estimating exposure times is further complicated by specimens which have two or more fluorescent minerals present, each of which may have a different fluorescent intensity. Bright fluorescence (such as that of most willemite) will quickly saturate the film, while weaker fluorescence (such as that of many calcites) will require much longer exposures. It can be very difficult to get two such minerals properly exposed in the same print or slide. This "exposure problem" can be seen in many photos of willemite and calcite together; if one mineral is exposed correctly, the other is not. If the calcite is a properly bright red, the willemite is yellow to white instead of green. If the willemite is bright green, as expected, the calcite may appear weak red. The simplest solution is to find a specimen where the fluorescence of both minerals is of comparable intensity.

The best photographic results are often due to choosing the correct film. However, a barrier filter such as the UV Haze 2A cannot stop certain unwanted color-shift effects often referred to as "reciprocity failure." This is the loss of sensitivity to light which some films exhibit when exposure times are longer or shorter than those for which the film is designed. Additionally, it seems to be impossible to obtain some pastel shades due to film insensitivity. Such pastel colors as the "peach" fluorescence of Franklin prehnite will not reproduce on film. The result will most often be an indistinct pale gray.

In other cases the sensitivity of the film emulsion will cause colors to be recorded which the eye would ignore. For instance, to the eye a rich crystallized margarosanite can fluoresce a uniform bright pale-blue, yet when viewed on film it will show obvious areas of red fluorescence. While it is true that margarosanite fluoresces red as well as blue, most film emulsions are formulated to be sensitive to flesh-tones, so that the red tones are more likely to be recorded by the film than registered by your eyes. Generally speaking, though, you should be aware that exposure will be the most persistent problem to overcome in photographing fluorescent minerals, and that print films have special problems which slide films do not.

Color prints made from film negatives frequently have errors of reproduction which are the result of automated print processing. Automated processors are set to both focus and expose the print by using the background as a reference. As most backgrounds in fluorescent photos are dark and have no relief for the processor to fix on, you may expect out-of-focus and overexposed prints as a matter of course. To compensate for this the photographer should fill the frames of his photos with as much specimen as possible, or work with fluorescent backgrounds (more of this later). Note that most automated print processors will add extra magenta dye to enhance flesh-tones, and that this can cause noticeably odd effects in photographic prints of minerals whether they were photographed under visible or ultraviolet light.

Slide films traditionally have produced better photos of fluorescent minerals, and can yield superb ones when the proper film is selected. The best red and green separation with the least reciprocity failure occurs with Kodachrome ASA 64 slide film. As a general-purpose film for fluorescence photography, Ektachrome ASA 100 slide film is used. Try a "series-shooting" with either film at an aperture range of f/5.6 to f/8 and a series of exposures at 3, 4, and 5 seconds at each aperture setting. If the specimen is unusually bright, an exposure series of 2, 3, and 4 seconds can be tried. These exposure durations are predicated on filling the camera frame with as much of the specimen as possible, and holding the ultraviolet lamp(s) just out of the picture, often within inches of the specimen.

Ultraviolet lamps vary considerably in size, intensity, and price. Successful results with the aforementioned camera settings have been achieved with the D-15 shortwave ultraviolet lamp and the UVGL-55 shortwave/longwave ultraviolet lamp, both manufactured by UVP, Inc. Almost any size and brand of ultraviolet lamp can be used, but the condition of the shortwave filter and tube can make quite a difference in exposure times and overall effect. If you are using a shortwave ultraviolet lamp with a fused-quartz grid, particularly one with a worn filter, let it warm up for at least five minutes before taking photographs; when first switched on, such lamps emit excessive reddish light.

Careful positioning of the specimen, to place its fluorescing face parallel to the plane of the film, and careful positioning of the ultraviolet lamp, to eliminate as much shadowing as possible, should become second nature. An enemy to every attempt at photographing fluorescence is dust. Many airborne dust particles derive from laundered clothing, fluoresce blue-white, and are very distracting when seen in a print or slide. Mineral specimens also "shed" when handled, or can be coated with extraneous mineral grunge and other fluorescing contaminants. If you wash a fluorescent specimen before photographing it, use a plain soap, such as Ivory; most detergents fluoresce. After rinsing the specimen thoroughly, let it air-dry, as using towels of any kind will probably coat the specimen with fluorescent lint. In every case, illuminate the specimen and background in ultraviolet light prior to shooting, and air-brush lint or other debris away.

Nonfluorescent backgrounds are readily available, but the material you have already used for daylight photo efforts should be tested for fluorescence. Often it can be adapted for the photographing of fluorescent minerals. In most cases a low-intensity, dark-blue fluorescing background will be more attractive than a pitch-black background. Careful selection and matching of complementary colors in the specimen and the background may yield more attractive or dramatic results. However, the more brightly the background fluoresces, the more likely reflected background colors are to distort and overshadow the fluorescent responses of the specimen, and this should be avoided. The aforementioned camera settings were used successfully with both a low-intensity blue-fluorescing fabric and a dark-colored, almost nonfluorescent paper as backgrounds.

Even though a moderately or brightly fluorescing background has the drawbacks mentioned above, it may resolve the focus and exposure problems associated with automated print processing. In this connection Henry Van Lenten's technique deserves mention. For background he used art and construction papers carefully selected for their weak to moderate fluorescence, rather than papers made to be fluorescent, which glow more brightly than minerals and are useless for this application. He also illuminated the specimen with two ultraviolet lamps, one fixed close to the specimen and the other circled around the specimen by hand. At its best this technique yields photos where the specimen is in focus and has a sense of depth, while the illuminated background balances the fluorescent qualities of the specimen. However, it is fair to say that this technique requires much experimentation.

Fluorescent specimens are often dramatic by themselves without the need for background enhancement; however, whether to use a fluorescent background or not is a matter of personal taste. For specimen documentation purposes the specimen itself is what counts, and the integrity of its reproduction is measured by the accuracy of color and the sharpness of image of the specimen, not its background.

While fluorescence photography is now a common scientific technique, Kodak has not yet manufactured a film to overcome reciprocity failure and other problems inherent in the photographing of fluorescent mineral specimens. Still, in the world of professional photography there are many special-purpose films, custom development processes, and other innovations which may help in attaining that elusive goal of accuracy. I refer to these to suggest territories you may wish to explore in the pursuit of solving specific photographic problems. Careful study and testing will be needed to appreciate fully the limits of any new equipment, technique, or process.

Willemite var. troostite, 3.5 cm crystals in calcite, Sterling Mine, Ogdensburg, N.J. Pentax camera with 50mm macro lens, ASA 100 print film @ f/16, 1/60 sec. exposure.

GENERAL SUGGESTIONS

1) Never accept an underexposed or overexposed photo; try again.

2) Never accept an incorrect color rendition; try again.

3) Always work with clean specimens.

4) Always work with clean equipment.

5) Have a color wheel handy to select the best color background.

6) Have backup equipment handy in case of breakdowns, especially for lighting.

7) If a certain film works well, stick with it. Experiment with other films only with a control group of specimens.

8) Always align, tilt, center, and fill the frame of the camera by viewing the specimen through the lens. Remember that your angle of view when standing over the equipment will not be matched through the camera.

9) Stabilize the specimen with props and mineral "tac" as needed, but to the rear and out of view.

10) Wait for the results of any previous photographic effort before changing your setup or experimenting with new exposures, lenses, etc.

11) Accept the limits of your equipment and be creative in changing its elements to achieve improved results.

12) Always write down your equipment settings, and

include in your log the description and size of each specimen photographed.

These methods and tips come from experience, and from reading. I encourage you to visit your local library and photography store. Good luck with your mineral photography!

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For banquet tickets and information, contact:
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Closest-Packed Mineral Structures of Franklin-Ogdensburg: Kepler's Gift of the Snowflake

Part two of two parts

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

INTERESTING CLOSEST-PACKED STRUCTURES IN THE FO PARAGENESIS

CUBIC CLOSEST-PACKED STRUCTURES: MANGANOSTIBITE, GERSTMANNITE, CLINOHEDRITE, HOLDENITE, KOLICITE

These very complicated yet aesthetically pleasing crystals required structure analysis to properly elucidate their formulae. In fact, the initial formulae for manganostibite and holdenite proved to be erroneous.

It will be remembered that these structures are based on the filling of available slots in cubic closest-packing with limiting $MT_2\phi$. Diverse ionic species and elaborate partitioning over some of the slots lead to rather complex cells. Note that projection along [100], the octahedral vertex; $[110] = [\bar{1}\bar{1}0]$ and $[01\bar{1}] = [0\bar{1}1]$, octahedral edges, lead to translations for these oxysalts which are about $2M-\phi \sim 4.2\,m$, $\phi-\phi' \sim 3.0\,n$, and $3.0p$ Å, where (m,n,p) are integers, see Moore and Araki (1977). Because these crystals contain predominant large Mn^{2+} cation, the $\phi-\phi'$ separations are somewhat larger than the sum of two oxide radii (2 x 1.40Å = 2.80Å). A brief outline of the cell parameters and orientations for these crystals is given in Table 9.

I submit a remark about the coordinate transformation, $A^{-1'}$, when projecting along t^*, the normal to closest-packed layers. The choice of such a layer from the original published cell is straightforward for these structures. For example in kolicite, the cell relations and diagrams in Peacor (1980) show that, for the holosymmetric *Cmca* cell which has |G| = 16 equivalences, the closest-packed planes are (130), $(1\bar{3}0)$; (021, $(0\bar{2}1)$. Note that they occur pairwise, each pair related by symmetry. These associate with the four t^* vectors normal to the closest-packed layers which arise only for the cubic closest-packed sequence, •*ccc*•, all other sequences having only one t^*, or axis normal to closest-packing. The "orthohexagonal" cell is now chosen, as discussed early in this study; this is recovered from the plane normal to the long crystallographic axis, which is a = 18.59Å in kolicite. The normal to the closest-packed plane in kolicite is $[0\bar{1}1] = t^*$, the axis of projection for all these closest-packed structures. The $|t^*|$ values range from 14.8 to 15.8Å in all four structures, which corresponds to the •cccccc• 6-layer repeat with $h \sim 2.5$Å.

A comment is made about the structure representations. The cell transformation for kolicite is $A' = [110/021/0\bar{1}1]$ and the coordinate transformation is $A^{-1'} = [100\,/\,{}^0\!/_3\,{}^1\!/_3\,{}^1\!/_3\,/\,{}^0\!/_3\,{-}^1\!/_3\,{}^2\!/_3]$. It is seen that some elements of reflection-translation (glide) symmetry are destroyed in the process of choosing this new cell, but fixed points such as inversions ($i = \bar{1}: xyz \rightarrow \bar{x}, \bar{y}, \bar{z}$) are not. To recover all atoms in the new cell, a list of the inversion centers in the old cell is made. These fixed points are then transformed according to $A^{-1'}$ and the new centroids define loci of inversions in the transformed cell. Finally, equivalences related by reflection-translation which are destroyed in the new cell are written out. For kolicite's *Cmca* (=Cbcb), these are $E = xyz$; $b(a) = \tfrac{1}{2}-x, \tfrac{1}{2}+y, z$; $c(b) = x, \tfrac{1}{2}-y, \tfrac{1}{2}+z$; $b(c) = x, \tfrac{1}{2}+y, \tfrac{1}{2}-z$. A list is then made, and the coordinates are transformed onto the new cell. In the figures, the reflection-translation equivalences are often noted by primed atom site labels. As there are two kinds of inversions, $i(1) = (000)$ and $i(2) = (\tfrac{1}{4}\,\tfrac{1}{4}\,0)$ and as all reflection-translation equivalences occur pairwise, $|G| = |E| \cdot |i| \cdot |b(a)| \cdot |c(b)| \cdot |b(c)| = 1 \times 2 \times 2 \times 2 \times 2 = 16$, and all equivalences are recovered. I belabor this point because the underlying concepts are elementary and powerful. (I recommend again Ayers, Jr. (1962) for matrices and Rider (1949) for trigonometric identities). At no point was computer intervention necessary. In fact, it would hardly speed up the process as most time is spent in setting up the problem in the first place. My entire effort on kolicite (from start to finish) took about four hours, the most difficult part being the proper matrix transformations. Perhaps more efficacious display of the structure by computer assistance may replace hand-drawn figures; indeed, such programs are making their appearance.

The structure diagrams along t^* are beautiful in their own right; for aficionados, they could well constitute the basis for wall-paper designs! The first figures are projections of the structure one layer thick (=h). The elements of admissible equivalence operations are added in so that the entire structure can be drawn out and analyzed. The second figures exploit the tetrahedral framework linkage for gerstmannite, clinohedrite, holdenite and kolicite. Here I begin with a tetrahedron, find its corner-links to other tetrahedra, and continue until all links are completed. The tetrahedral fraction, such as $^{4}[Zn_4As_2^{5+}Si_2O_{16}(OH)_4]^{10-}$ in kolicite, appears to be the underlying principle among these structures, the tie which binds them to each other.

Manganostibite

Manganostibite, $^{6}[Mn_5^{2+}Sb^{5+}]O_2[^{4}(Mn_2^{2+}As^{5+})O_{10}]$, is presently known only from the Bergslagen district in Sweden where it occurs as grains with Mn-humites and katoptrite in Mg-rich marble. A zinc analogue could conceivably exist in a paragenesis akin to yeatmanite (which has an ordered relation to katoptrite) at Franklin, with a formula $[Mn_5^{2+}Sb^{5+}]O_2[Zn_2As^{5+}O_{10}]$. Manganostibite is part of an extended family of cubic closest-packed homologous structures with tetrahedral and octahedral cation populations. The general formula for the homologous series is $M_{2s}O_{s-1}[T_sO_{3s+1}]$. For $s = 1$, there is $M_2[TO_4]$ or spinel; $s = 2$, $M_4O[T_2O_7]$ or wadsleyite ("β-Mg_2SiO_4"); $s = 3$, $M_6O_2[T_3O_{10}]$ or manganostibite. In manganostibite, units of three corner-linked tetrahedra and three octahedra alternate with rows of populated octahedra along the c'-direction, see Moore (1970). As the insular tetrahedral units do not fuse further, no additional figure is required.

Table 10 presents an example which tracks closely to the ideal closest-packed populations, with cell deviations within 2% and atom centroid deviations within 0.3 Å of the perfect model. Note that the greatest expansion is along the b'-direction. This is a consequence of cation-cation repulsions along shared polyhedral edges.

Gerstmannite

Gerstmannite, $^{6}[MnMg](OH)_2[^{4}(ZnSi)O_4]$, metrically akin to manganostibite, is based on a quite different structural principle. Here, the zincosilicate tetrahedra form pyroxene-like chains which in turn are corner-linked to the octahedral edge chains in Figure 8a. Symmetry equivalences admit construction of the three-dimensional edifice from this slab which is one layer thick. The full tetrahedral $T_2O_4 = 2TO_{2.00}$ portion is shown in Figure 8b. This component is an elegant polar slab of tetrahedra oriented parallel to $b'(010)'$. It links to the octahedral component via the O(1) terminal to Si. The octahedra, which possess centers of inversion and which bridge the tetrahedral slabs, create a centrosymmetric crystal for the entire arrangement. Note the hint of the incomplete $\{3_1\}$ and $\{3_2\}$ screw operations we encountered in cubic ^{4}ZnO. The central tetrahedra are three-connected (ZnZnSi, as in willemite), and the terminal tetrahedra are two-connected (ZnSi) and one-connected (Si).

Polar symmetry among the tetrahedral units in zincosilicates is common, and this is believed to be a limiting condition imposed by corner-linked, closest-packed frameworks where electrostatically unfavored edge-sharing and face-sharing tetrahedral units are unlikely. Indeed, zincite's polar $P6_3mc$ symmetry is forced from this condition because, for ZnO with exactly half the tetrahedral centers occupied, corner-links only must lead to polar and/or pyroelectric crystals in closest-packings, in order to avoid any edge- or face-sharing among the tetrahedral units.

Cell criteria and deviations, Δ(Å), are presented in Table 11 for gerstmannite and clearly demonstrate that it is a cubic closest-packed structure.

Clinohedrite

I have already discussed clinohedrite in part two of this *Picking Table* series (Moore, 1995). This polar crystal is included with gerstmannite because both phases enjoy the same $[ZnSiO_4]^{2-}$ tetrahedral condensation principle. Clinohedrite's Figure 9 can be directly compared with the preceding gerstmannite tetrahedral fraction. Note that the present clinohedrite drawing adopts the transformed cell in Table 4 of Moore (1995), and that $t^* = c'$, the approximate normal to the closest-packed layers.

The clinohedrite entry in Table 12, which relates it among gerstmannite and other cubic closest-packed structures, can be directly related to Table 4 in Moore (1995). The original cell is transformed to the entry in Table 9 via $A' = [10\bar{1} / 010 / 101]$. The gerstmannite transform in Table 11 is $A'' = [101 / 010 / \bar{1}02]$. The clinohedrite entry in Table 4 of Moore (1995) sends the original cell directly into its closest-packed representation via $A''' = [100/001/103]$.

The relationships among these transformations can be immediately seen when it is remembered that matrices are algorisms for conveniently solving linear equations. Multiple matrix transformations constituting a chain segment could be abstractly written $A'' \wp A' = A'''$ where $\wp$ is some operator.

A'' corresponds to $[a''/b''/c'']$, A' corresponds to $[a'/b'/c']$
or and or
$1a'' = 1a' + 0b' + 1c'$ $1a' = 1a + 0b - 1c$
$1b'' = 0a' + 1b' + 0c'$ $1b' = 0a + 1b + 0c$
$1c'' = -1a' + 0b' + 2c'$ $1c' = 1a + 0b + 1c$

Solve (a'', b'', c'') in terms of (a, b, c). This gives $1a'' = 1a + 0b - 1c + 1a + 0b + 1c = 2a + 0b + 0c$; $1b'' = 0a + 1b + 0c$; $1c'' = -1a - 0b + 1c + 2a + 0b + 2c = 1a + 0b + 3c$. Note that $1a'' = 2a + 0b + 0c$ is factorable by 2. This means that $1a''$ contains two identical cells (prove it!). The transformation A''', thus, is [100/010/103] which is identical to the direct transformation in Table 4 of Moore (1995).

The condensation of tetrahedra around oxides for clinohedrite [and gerstmannite] can be listed: O(2)[O(3)]:Zn+Si; O(3)[O(2)]:Zn+Zn+Si; O(4)[O(3)]; Zn+Si; O(5)[O(1)]:Si. The $[ZnSiO_4]^{2-}$ tetrahedral fraction is itself polar, as are the complementary $CaO_4(H_2O)_2$ octahedra and the entire crystal for clinohedrite, but the complementary octahedrally coordinated Mg^{2+} in gerstmannite resides on an inversion center, thus creating a centrosymmetric crystal. The crystal-chemical relation is:

Clinohedrite	*Cc*	$Ca(H_2O)$	$[ZnSiO_4]$	*1/m*
Gerstmannite	*Bbcm*	$MnMg(OH)_2$	$[ZnSiO_4]$	*2/m 2/m 2/m*

Holdenite

Holdenite$^6Mn_6(OH)_2[^4Zn(OH)_4][^4(Zn_2As_2^{5+}Si)O_{12}(OH)_2]^{8-}$, the latter tetrahedral aggregate $T_5\phi_{14} = 5T\phi_{2.80}$ is, after manganostibite, the most open of the tetrahedral structures. Figure 10a shows its slab. Here, the octahedral edge-sharing was noted by Peacor (1980): "A principal difference between the octahedral units of holdenite and kolicite is that in holdenite there are four octahedra sharing edges to form a short chain, rather than three as in kolicite". These octahedral short chain components can be immediately recognized in Figures 10a and 11a. Note that the tetrahedral component includes a $T_5\phi_{16}$ crescent.

The populated tetrahedra, Figure 10b in holdenite, bear an almost precise match with the companion arrangement in kolicite except for one feature: kolicite is a condensed version of holdenite, e.g. $8T_5\phi_{14} = T_{40}\phi_{112}$ (holdenite), $5T_8\phi_{20} = T_{40}\phi_{100}$ (kolicite). In addition, holdenite has insular zincate, $[Zn(OH)_4]^{2-}$, tetrahedra surrounded by the octahedra.

The more condensed nature of kolicite may result from the phase having formed either at higher temperature or in an even more basic environment than holdenite. In any event, other as yet undiscovered zincoarsenosilicates may exist in this remarkable paragenesis, hidden by the close appearance these minerals usually have, augmented by the only major chromophores being Mn^{2+}, Mn^{3+}, Fe^{3+}.

Holdenite's cell criteria and difference, Δ(Å), appear in Table 13.

Kolicite

Kolicite, $^6Mn_7(OH)_4[^4(Zn_4As_2^{5+}Si_2)O_{16}(OH)_4]^{10-}$ or $T_8\phi_{20} = 4T_2\phi_5 = 8T\phi_{2.50}$, is an elaborate structure with slab in Figure 11a and tetrahedral linkage in Figure 11b. This projection had some surprises because several new features appeared. First, the octahedra at the cell's origin form a $M_7\phi_{24}$ "coronene-like" unit, and the tetrahedra form as a component the $T_8\phi_{24}$ ring.

Actually, the populated tetrahedra form an elaborate thick sheet parallel to (001′) which consists of one- and two-connected tetrahedra, leading to the $T_4\phi_{10}$ stoichiometry akin to the micas. Note the suggestion of incomplete $\{3_1\}$ and $\{3_2\}$ pseudo-screws in the tetrahedral unit, revealing its underlying principle to cubic ^4ZnO. The sheet is itself polar which, through linkage to the octahedra, is inverted to form the complementary sheet, thus rounding out the entire structure.

Kolicite's cell criteria and difference, Δ(Å), appear in Table 14.

OTHER CLOSEST-PACKED STRUCTURES

Hodgkinsonite

I used hodgkinsonite, $^6Mn^{2+}(OH)[^4Zn_2(OH)^4SiO_4]$, as the example for matrix transformations in Moore (1994). An idealized drawing was presented but the real tetrahedral framework in brackets is now shown as Figure 12.

The structure is based on hexagonal closest-packing •hhhhhh• with average layer thickness h = 2.49Å, mean Δ = 0.39Å, range 0.15 – 0.96 Å. The greatest deviant is O(4) which bonds to 2 Zn + 1 Si nearly in a plane and suggests that distortion is a result of two large $[ZnO_4]^{6-}$ tetrahedra and one small $[SiO_4]^{4-}$ tetrahedron. The anions O(1) and O(3) also bond to 2Zn + 1Si but these cations are not in the same plane; their distortions are more moderate, 0.62 and 0.59 Å respectively. The OH(6) anion bonds solely to the $Mn\phi_6$ octahedra.

Figure 12 displays the classical appearance of •AB• hexagonal closest-packing. The tetrahedral framework shows distorted hexagonal "windows" passing along t*. These "windows" are capped by the $Mn\phi_6$ octahedral populations.

Flinkite

Flinkite, $Mn_2^{2+}Mn^{3+}(OH)_4(AsO_4)$, was originally reported by Hamberg (1889) from the Bergslagen district, Sweden. More recently, it was found in small amount from FO. Its crystal structure was reported by Moore (1967). As that publication includes structure diagrams, Table 15 is reported here instead.

Inspection of the structure study indicates that flinkite's arrangement is quite distorted owing to the pronounced Jahn-Teller distortion of $Mn(1)^{3+}$. In fact, the three pairs of unique Mn(1) – ϕ distances are 1.80, 1.91, 2.29 Å, indicative of an prolate ellipsoidal distortion. This distortion appears in the cell parameters which deviate -5.2% to +6.1% from the ideal model, see Table 15.

It is not possible to construct a perfect closest-packed model from the cell parameters and the space group, as the $^a/_2$-glide plane does not allow an exact superposition along the a-axis projection. Consequently, the perfect layer in Moore (1967) formed the basis of the calculation. For this reason, ΔO(5) = 0.78 Å probably represents a slight misfit. The OH(1), OH(2), and OH(3) are bonded to $Mn(1)^{3+}$; consequently, they evince deviations from Jahn-Teller distortion. This intrinsic distortion is believed to create the misfit between closest-packed layers.

Flinkite is based on •chch• "topaz" closest-packing.

Synadelphite

Synadelphite, $^6Mn_9^{2+}(OH)_9(H_2O)_2[^4As^{3+}O_3\psi][^4As^{5+}O_4]_2$, is one of the more typical basic arsenates from Bergslagen, Sweden, where it occurs in crack assemblages with barite, pyrochroite, allactite, hematolite, and sarkinite. Moore (1967) examined basic arsenates of manganese from Nordmarken and concluded that synadelphite and "hemafibrite" are similar, if not identical, species. It was hinted that "hemafibrite" is an oxidized version of synadelphite. Crystal structure analysis of synadelphite by Moore (1970) revealed an elaborate structure based on "topaz" closest-packing, •chch• . The title formula reveals arsenic in two states of oxidation (see hematolite) and *aquo* water in a rather basic compound. Synadelphite was more recently reported by Moore (1978) from FO.

As the earlier structure study presents adequate diagrams, I submit only a rather detailed Table 16. In this table, beyond the cell criteria is given a detailed account of atom difference, Δ(Å). The fractional coordinates, decimal equivalents, real coordinates, and stacking sequence are also listed. The mean $\Delta = 0.32$ Å (range 0.13-0.66 Å) indicate a rather well-behaved closest-packed structure. The $[\mathrm{As}(1)^{5+}\psi^{2-}]^{3+}$ lone-pair cation has the second most deviant $\Delta = 0.60$ Å distance.

One anion vacancy, □, occurs in the structure. This site can only accommodate a water molecule based on stoichiometry; occupancy at this site was inconclusive in the structure study.

Hematolite

Hematolite, ${}^{6}(\mathrm{Mn,Mg})_{13}{}^{2+}\,{}^{6}\mathrm{Al}_2(\mathrm{OH})_{23}[{}^{4}\mathrm{As}^{3+}\mathrm{O}_3\psi][{}^{4}\mathrm{AsO}_4]_2$, presents a magnificent example of the power and efficiency afforded by matrix transformations. A rather difficult and intractable problem becomes an exercise of elegant simplicity, almost bordering on the trivial.

Hematolite is one of the phases found in the Bergslagen district, Sweden. A "hematolite-like phase" and arguably related mcgovernite have been documented in the FO workings.

It will be recalled that closest-packed systems often present themselves as projections along the [110] direction of the octahedron, or the octahedral edge. Such arrangements often belong to orthogonal cells, as in cubic closest-packed manganostibite, gerstmannite, kolicite, and holdenite. In these structures, it is a simple matter to seek out appropriate t^*, perform the cell and coordinate transformations, and construct the arrangements as closest-packed layers normal to t^*.

Orthogonalization along t^* leads to the $\{3^6\}$ nets which form the basis of the plane closest-packings, see Moore (1994). Any hexagonal cell ($a_1 \times a_2$, $\gamma = 120°$) can be transformed to the orthohexagonal unit ($a_0 \times b_0 = \sqrt{3}\,a_0$, $\gamma_0 = 90°$) with two times the area of the hexagonal unit. Note that in Moore (1994, p. 9), this orthohexagonal unit has, as the basis, the integral multiples (p,q,r): $a(=pl) \times b\,(=q\sqrt{3}\,l) \times c\,(=r\frac{\sqrt{2}}{\sqrt{3}}\,l)$. The edge length $l = \phi—\phi'$ = 2.8 Å, is the most sensible basis for elementary calculations because $r_\phi = 1.40$ Å is the Pauling radius for oxide, O^{2-}. The orthohexagonal unit contains four ϕ in a volume $V_0 = l \times \sqrt{3}\,l \times 2\frac{\sqrt{2}}{\sqrt{3}}\,l = 2\sqrt{2}\,l^3$. Setting $l = 2.80$ Å, we get $V_0 = 62.09$ Å^3, or 15.52 Å^3 per ϕ, which we already obtained in p. 9 in the earlier study. This is an important value to remember because calculations of V_E, or effective volume per ϕ (packing efficiency), are obtained simply by calculating the unit cell volume and dividing by total ϕ (=O^{2-}, OH^-, $\mathrm{H_2O}$, ψ) in that cell. For large ${}^6\mathrm{Ca}^{2+}$, ${}^6\mathrm{Mn}^{2+}$, and ${}^4\mathrm{Zn}^{2+}$, $V_E \sim 21.0$ Å^3 are typical.

Note that the orthohexagonal unit is a convenient basis for transforming closest-packing structures. This is because Figure 3 in Moore (1994, p.9) can be decomposed into the $\{3^6\}$ net which leads to an orthogonal grid $^0/_2$, $^1/_2$, $^2/_2$ (= $^0/_2$) along l and $^0/_6$, $^1/_6$, $^2/_6$, $^3/_6$, $^4/_6$, $^5/_6$, $^6/_6$ (=$^0/_6$) along $\sqrt{3}\,l$. The centroids along t^* are likewise obtained as integral fractions. Through exploiting (p,q,r), a three-dimensional grid of all possible M, T, and ϕ centroids in closest-packings can be quickly obtained. The perfect model is evaluated this way.

Because the orthohexagonal basis cell is contained within the assembly of $\{3^6\}$ layers, it follows in closest-packing that any cell orthogonal to t^* can be transformed into a $pl \times q\sqrt{3}\ l$ orthogonal unit (prove it!). This is one of the triumphs of linear algebra and the algebra of modules.

Hematolite possesses an $a_1 \times a_2$ hexagonal cell whose outline is the same kind as that found in welinite, dixenite, kraisslite, and mcgovernite. Moore and Araki (1978) portrayed the hematolite structure as sequential designs on the regular $\{6^3\}$ net, which is the dual of our familiar $\{3^6\}$ net. This cell can now be orthogonalized to conform with the orthohexagonal unit. Note $\bar{a}' = 3\,\bar{a}_1 + \bar{a}_2$ and $\bar{b}' = \bar{a}_1 + 5\bar{a}_2$, the bar superscripts denoting cell edges as vectors. The cell transformation matrix is A′ = [310/150/001], |A′| = 14, and the coordinate transformation matrix is $A^{-1\prime} = [^5/_{14}\,{}^{-1}/_{14}\,{}^0/_{14} / {}^{-1}/_{14}\,{}^3/_{14}\,{}^0/_{14} / 0\ 0\ 1]$. The new orthohexagonal cell is $a' = 7l = 21.89$, $b' = 7\sqrt{3}\,l = 37.91$, $c' = 15\frac{\sqrt{2}}{\sqrt{3}}\,l = 36.60$ Å. This new cell has $4 \times 7 \times 7 \times 15 \times {}^1/_2 = 1470$ ϕ nodes or anion slots. It has 14 times the volume—the determinant of the cell transformation matrix—of the conventional hematolite cell. All calculations, including atom differences (Δ), were completed from the starting parameters of Moore and Araki (1978) with the aid of matrices within four hours! [From a standard trigonometric approach, the problem would have been almost insurmountable].

Hematolite's cell transformation and atom centroid differences (Δ,Å) between real and perfect structure are summarized in Table 17. The greatest cell expansion occurs in the plane normal to t^* because most cation-cation repulsions between shared polyhedral edges are within the planes and not between them. The differences are less than half the Pauling oxide radius for 23 non-equivalent non-hydrogen atoms. The exception is $\Delta\mathrm{As}(2) = 0.84$Å, the one cation with a lone pair of electrons attached. It should be recalled that lone-pairs are repulsive to contiguous bond pairs and therefore distort the environment away from the perfect spherical model.

UNCONVENTIONAL CLOSEST-PACKED STRUCTURES

Up to now, I have discussed only those structures whose non-hydrogen atom centroids can be *directly* ascertained from the perfect closest-packing model. The centroids of the large closest-packed ϕ anions automatically define the centroids of the small M and T cations in the octahedral and tetrahedral interstices. However, what if these small cations occur in interstitial sites other than ideal M and T? The frame comprised of ϕ still remains closest-packed but the cations reside in sites of lower maximal geometry than octahedral and tetrahedral. Some of these arrangements have been overlooked as candidates in the past but they are really valid candidates, for with closest-packed ϕ, they can enjoy potential epitaxial relationships with other closest-packed structures. Some interesting mineral structures are now discussed.

Allacite

Originally found in fracture systems with pyrochroite from

Nordmark in the Bergslagen district, Sweden and named by Sjögren (1885), this attractive purplish-red pleochroic mineral was more recently found in the basic crack assemblage at FO. The crystal structure analysis by Moore (1968) revealed a pyrochroite fragmented arrangement along $t^* = [100'] = [101]$, see Table 18.

The structure drawing in the earlier paper shows the general polyhedral outline and need not be repeated here. Writing the distinct octahedra in the formula as $Mn(1)Mn(2)_2Mn(3)_2Mn(4)_2(OH)_8(AsO_4)_2$, Mn(3) and Mn(4) define a pyrochroite chain fragment which runs parallel to $c' = c$; and Mn(2) resides as an octahedral population above and below this fragment sharing a face with it. Mn(1) at the cell's origin, however, does not occur at a classical M centroid position and this was the reason why the structure was initially overlooked as being hexagonal closest-packed, •hhhh• , with respect to ϕ anions.

Mn(1) resides, in fact, at an edge center in the ϕ closest-packing and for mean $<l>$ = 3.10 Å, 4 Mn(1)- ϕ = 2.69 and 2Mn(1)- ϕ = 1.55 Å for the perfect model. These distances correspond to OH(3), O(7), and O(8) in Table 18, the largest deviants (Δ = 0.51-0.66 Å) in the table. The anion range is 0.11-0.66 Å (mean 0.37 Å). Allactite is based on hexagonal closest-packed ϕ, •hhhh• (layer separation h = 2.53 Å) and, excepting Mn(1), is a conventional closest-packed structure.

Arsenoklasite

Arsenoklasite was a relatively recent discovery of Långban where its flesh red color mimicked that of the far more abundant sarkinite. It is not yet known from FO. Perfect cleavage for arsenoklasite was its distinguishing feature, and Aminoff (1931) gave the mineral its name accordingly. Structure solution and refinement by Moore and Molin-Case (1971) of this moderately complicated structure revealed a double hexagonal closest-packing •chch• principle for ϕ. However, that study is incomplete because not all anions bonding to cations were retrieved.

Table 19 outlines the arsenoklasite cell parameters and coordinate difference. The mean 0.36 Å for all 19 unique non-hydrogen atoms is satisfactory, but two cations, Mn(1) and Mn(5), are not located in conventional centroids but reside in the *same* (001) plane as some coordinating anions. In addition, these cations force unconventional bonds into their coordination sphere. These longer distances, missed in the earlier study, are ^{6}Mn(1) - O(7) = 2.43 and ^{5}Mn(5) - O(5) = 2.32 Å. The O(5) and 2O(8) occur in the C layer, and OH(1) and O(11) in the A layers above and below defined the $Mn(1)O_5$ trigonal bipyramidal coordination in the original structure study.

Here, additional O(7) is moved toward Mn(1) through the additional Mn(1)-O(7) bond. Mn(5) likewise is nearly coplanar with O(4), O(10), and O(12) in the A layer. OH(2) in the C layer below and O(5) in the B layer above complete the coordination, with O(5) moved toward Mn(5) through the Mn(5)-O(5) bond. The coordination numbers are thus $^6Mn(1)^6[Mn(2)Mn(3)Mn(4)]^5Mn(5)(OH)_4[^4AsO_4]_2$ about the cations. The Mn(2)-Mn(4) in brackets define the same kind of octahedral pyrochroite fragment as found in gerstmannite.

A diagram featuring the centroids of asymmetric cations and bonding anions is presented in Figure 13. The •chch• packing is approximately preserved; the O(5) and O(7) are moved farthest away from the perfect centroids of the $\{3^6\}$ net.

The cell and the edge of the $\{3^6\}$ net are based on the perfect mean cell, obtained from $<l>$ = 3.08Å in Table 19. As this calculation obtains from the algorisms based on perfect closest-packing, we obtain the regular $\{3^6\}$ net which is outlined in Figure 13. The orientation of the net with respect to the $P2_12_12_1$ cell was fixed by the 2_1 screw axes parallel to the *a*, *b*, and *c* crystallographic axes. The •ABAC• = •chch•, stacking centroids are denoted on the figure. Note that A is at the $\{3^6\}$ nodes for anions at $z \sim 0, {}^1/_2$; C is at left-pointing triangle centroids at $z \sim {}^1/_4$; and B is at right-pointing triangle centroids at $z \sim {}^3/_4$. All anions fall close to their respective ideal centroids except O(5) and O(7) for reasons explained earlier.

CODA AND PROMISES

In this study, I have demonstrated that closest-packed structures projected along [100], [110], etc., or [111] of the octahedron, can be transformed into the standard orthohexagonal cell. This cell is based on integers (p,q,r); $a' = pl$, $b' = q\sqrt{3}\,l$, $c' = r\frac{\sqrt{2}}{\sqrt{3}}\,l$. The standard cell appears in Moore (1994), p.9. Included are the earlier defined integers (m,n,p), structures with $a = m\sqrt{2}\,l = 2M - \phi$, $b = nl$, $c = pl$ of closest-packed structures. Everywhere, computations are based on the $\phi — \phi' = l$ octahedral (M) or tetrahedral (T) edge distance.

Beyond the structures examined here, I have explored even more complicated structures with the closest-packed layers in some generalized (that is, triclinic) orientation. It appears that all these closest-packed structures could be tranformed as well to get the final orthohexagonal representation. This is very exciting because, for the first time, all closest-packed structures can be placed in a rational representation. It will be exciting to explore the designs as presented to us in this rational representation; almost certainly, fundamental bonding, building, and classification principles will be revealed to us!

The kernel question can now be addressed: can all closest-packed arrangments be transformed into the rational (p,q,r) orthohexagonal representation? I am presently struggling with the formal mathematical proof of this problem which turns out to be rather detailed and tedious but seems not to be intractable.

In the meantime, I offer a conjecture: **All closest-packed structures can be transformed to the rational *(p,q,r)* representation.**

In my series for *The Picking Table*, one paper remains. As yet, I have not discussed structures which involve anionic radicals in triangular coordination such as $[BO_3{}^{3-}]$ and $[CO_3{}^{2-}]$. Examples include sussexite, fluoborite, roweite, loseyite, and sclarite. Many of these structures are very elaborate and some are based on the principle of closest-packing. Other examples, such as yeatmanite, katoptrite, friedelite, schallerite, pyrosmalite, and bannisterite may be included. Finally, a synopsis is needed of all the species from FO and those whose structural principle is closest-packing. This will be the tiara of that final remaining paper in *The Picking Table*.

Table 9: Relations Among Cubic Closest-Packed Structures

	Manganostibite				Gerstmannite			Clinohedrite†			Kolicite			Holdenite		
a(Å)	8.727	$[10\bar{2}]$*	a'(Å)	14.938	8.185	[101]	10.30	8.216	[101]	5.090	18.59	[100]	18.59	11.99	[102]	21.13
b(Å)	18.847	[010]	b'(Å)	18.847	18.65	[010]	18.65	15.829	[010]	15.829	8.789	[021]	21.31	31.46	[010]	31.46
c(Å)	6.062	[101]	c'(Å)	10.626	6.256	$[10\bar{2}]$*	14.95	6.506	$[\bar{1}02]$*	15.787	12.04	$[0\bar{1}1]$*	14.91	8.697	$[1\bar{0}1]$*	14.81
β	90°		β'	89°02'	90°		85°48'	93°20'		84°59'	90°		91°44'	90°		91°22'
S.G	Ibmm				Bbcm			—			Cmca			Abma		
(m,n,p)	2,6,2				2,6,2			2,5,2			2,6,4			2,10,4		
c.p.	$(310),(\bar{3}10)$				$(310),(\bar{3}10)$			—			$(130),(\bar{1}30)$			$(015),(0\bar{1}5)$		
planes	$(101),(10\bar{1})$				$(101),(10\bar{1})$			—			$(021),(0\bar{2}1)$			$(102),(10\bar{2})$		

* The t* direction.

† Original cell in Table 4 of Moore (1995) transformed as A' = $[-10\bar{1}/010/101]$.

Table 10: Manganostibite

$Mn_7^{2+}Sb^{5+}As^{5+}O_{12}$

$(1\ 0\ \bar{2}\ /\ 0\ 1\ 0\ /\ 1\ 0\ 1)$ cell

$(^1/_3\,0\,-^1/_3\ /\ 0\ 1\ 0\ /\ ^2/_3\,0\,^1/_3)$ coordinate

Z	4	Z′	12		ℓ	$<\ell>$	Δ(%)
a	8·727	a′	14·938	$6\frac{\sqrt{2}}{\sqrt{3}}\ell$	3·049	15·118	-1·2
b	18·847	b′	18·847	6ℓ	3·141	18·516	+1·8
c	6·062 Å	c′	10·626 Å	$2\sqrt{3}\ell$	3·067	10·690 Å	-0·6%
		β′	89° 02′	h = 2·49Å	<3·086> Å		
Ibmm		V_E'	20.8Å^3	· c c c c c c ·			

Moore (1970), R = 0.011 / 657 F_o

Difference:	Δ Mn(1)	0·00	ΔO(1)	0·24
	Δ Mn(2)	0·17	ΔO(2)	0·28
	Δ Mn(3)	0·25	ΔO(3)	0·31
	Δ Sb	0·00	ΔO(4)	0·15
	Δ As	0·12	ΔO(5)	0·19 Å
	Δ T(1)	0·23	mean	0·18 Å
			range	0·00 - 0·31 Å

Table 11: Gerstmannite

$MnMg(OH)_2[ZnSiO_4]$			$[101/010/\bar{1}02]$		cell		
			$[^2/_3 0 ^1/_3/010/^{-1}/_3 0 ^1/_3]$		coordinate		
Z	8	Z' = 24			ℓ	$<\ell>$	Δ(%)
a	8·185	a'	10·30	$2\sqrt{3}\,\ell$	2·97	10·53	-2·2
b	18·65	b'	18·65	6ℓ	3·11	18·24	+2·2
c	6·256Å	c' (t*)	14·95 Å	$6\frac{\sqrt{2}}{\sqrt{3}}\ell$	3·05 Å	14·89 Å	+0·4%
Bbcm		β'	85°48'	h = 2·49 Å	<3·04> Å		

Moore and Araki (1977) V_E = 19·9 Å^3 ·cccccc·

R = 0.04 / 1091 F_O

Difference:				
	Δ Mn	0·40	Δ O(2)	0·59
	Δ Mg	0·00	Δ O(3)	0·34
	Δ Zn	0·32	Δ OH(1)	0·35
	Δ Si	0·30	Δ OH(2)	0·26 Å
	ΔO(1)	0·06	mean	0·29 Å

Table 12: Clinohedrite

$Ca(H_2O)[ZnSiO_4]$

			[100/010/103]		cell		
			$[10\,^{-1}/_3\,/010/00\,^1/_3]$		coordinate		
Z	4	Z'	12		ℓ	$<\ell>$	Δ(%)
a	5·090	a'	5·090	$\sqrt{3}\ell$	2·939	5·385	-5·9
b	15·829	b'	15·829	5ℓ	3·166	15·545	+1·8
c	5·386Å	c' (t*)	15·787 Å	$6\frac{\sqrt{2}}{\sqrt{3}}\ell$	3·223	15·231 Å	+3·5%
β	103°16'	β',	84°59'	h = 2·63 Å	<3·109> Å		
Cc		V_E	21·1Å^3	·cccccc·			

Venetopoulos and Rentzeperis (1976), R = 0·04 / 1294 F_O

Difference:				
	Δ Ca	0·39	ΔO(2)	0·45
	Δ Zn	0·02	ΔO(3)	0·70
	Δ Si	0·20	ΔO(4)	0·36
	Δ OW(1)	0·21	ΔO(5)	0·42 Å
			mean	0·34 Å
			range	0·02 - 0·70 Å

Table 13: Holdenite

$Mn_6(OH)_2[Zn(OH)_4][Zn_2As_2SiO_{12}(OH)_2]$

$(1\ 0\ 2\ /\ 0\ 1\ 0\ /\ 1\ 0\ {-1})$ cell
$({}^1/_3\ 0\ {}^1/_3\ /\ 0\ 1\ 0\ /\ {}^2/_3\ 0\ {}^1/_3)$ coordinate

Z	8	Z′ = 24		ℓ	<ℓ>	Δ(%)
a	11·99	a′ = 21·13	$4\sqrt{3}\,\ell$	3·05	21·29	-0·8
b	31·46	b′ = 31·46	$10\,\ell$	3·15	30·73	+2·3
c	8·697 Å	c′ (t*) = 14·81 Å	$6\frac{\sqrt{2}}{\sqrt{3}}\ell$	3·02	15·05 Å	-1·6%
		β′ = 91° 22′	h = 2·47Å	<3·07> Å		
Abma		V_E' = 20.5$Å^3$	· c c c c c c ·			

Moore and Araki (1977)
R = 0.064 / 3478 F_o

Difference:	Δ Mn(1)	0·03	ΔO(3)	0·29
	Δ Mn(2)	0·16	ΔO(4)	0·35
	Δ Mn(3)	0·28	ΔO(5)	0·15
	Δ Mn(4)	0·23	ΔO(6)	0·16
	Δ Zn(1)	0·27	ΔOH(1)	0·20
	Δ Zn(2)	0·21	ΔOH(2)	0·19
	Δ As	0·24	ΔOH(3)	0·24
	Δ Si	0·18	ΔOH(4)	0·32
	Δ O(1)	0·18	ΔOH(5)	0·14 Å
	Δ O(2)	0·37	mean	0·22 Å
			range	0·03 - 0·37 Å

Table 14: Kolicite

$Mn_7(OH)_4[Zn_4As_2Si_2O_{16}(OH)_4]$

$[1\ 0\ 0\ /\ 0\ 2\ 1\ /\ 0\ \bar{1}\ 1]$ cell
$[1\ 0\ 0\ /\ 0\ {}^1/_3\ {}^1/_3\ /\ 0\ {-}{}^1/_3\ {}^2/_3]$ *coordinate*

Z	4	Z′ =12		ℓ	<ℓ>	Δ(%)
a	18·59	a′ =18·59	6ℓ	3·10	18·43	+0·9
b	8·789	b′ = 21·306	$4\sqrt{3}\,\ell$	3·08	21·30	+0·0
c	12·04 Å	c′ (t*) = 14·907 Å	$6\frac{\sqrt{2}}{\sqrt{3}}\ell$	3·04	15·05 Å	-1·0%
		β′ = 91° 43′	h = 2·48Å	<3·07> Å		
Cmca		V_E' = 20.5$Å^3$	· c c c c c c ·			

Peacor (1980)
R = 0.059 / 893 F_o

Difference:	Δ Mn(1)	0·00	ΔO(3)	0·20
	Δ Mn(2)	0·15	ΔO(4)	0·19
	Δ Mn(3)	0·26	ΔO(5)	0·34
	Δ Zn	0·11	ΔOH(1)	0·18
	Δ As	0·11	ΔOH(2)	0·32 Å
	Δ Si	0·10	mean	0·19 Å
	Δ O(1)	0·15	range	0·00 - 0·34 Å
	Δ O(2)	0·31		

Table 15: Flinkite

$Mn_2^{2+}Mn^{3+}(OH)_4(AsO_4)$

Z = 4			ℓ	$<\ell>$	Δ(%)
a(t*)	9·55	$4\frac{\sqrt{2}}{\sqrt{3}}\ell$	2·92	10·05	-5·2
b	13·11	4ℓ	3·28	12·31	+6·1
c	5·25Å	$\sqrt{3}\ell$	3·03 Å	5·33 Å	-1·5%
Pnma		$V_E = 20{\cdot}5Å^3$	<3·08> Å	•chch•	h = 2·39 Å

Moore (1967), R = 0·14 / 171 F_O

Difference:

Δ Mn(1)	0·00	ΔOH(3)	0·32
Δ Mn(2)	0·22	ΔO(4)	0·33
Δ As	0·34	ΔO(5)	0·78
Δ OH(1)	0·66	mean	0·39 Å
ΔO(2)	0·43	range	0·00 - 0·78 Å

Table 16: Synadelphite

$^6Mn_9^{2+}(OH)_9(H_2O)_2[^4As^{3+}O_3\psi][^4As^{5+}O_4]_2$

Z	4		ℓ	$<\ell>$	Δ(%)
a	10·754	$2\sqrt{3}\ell$	3·104	10·707	+0·4
b	18·865	6ℓ	3·144	18·546	+1·7
c(t*)	9·884 Å	$4\frac{\sqrt{2}}{\sqrt{3}}\ell$	3·026 Å	10·095Å	-2·1%

Pnma <3·091 Å>

Moore (1970), R = 0.089 / 1249 F_o h = 2·471 Å •chch•

Difference:	Ideal						Real				Δ(Å)
Δ M (1)	$^4/_{12}$	$^9/_{12}$	$^3/_8$	0.3333	0.7500	0.3750	0.2941	0.7500	0.3868	C	0.44
Δ M (2)	$^7/_{12}$	$^8/_{12}$	$^3/_8$	0.5833	0.6667	0.3750	0.5613	0.6635	0.3729	C	0.25
Δ M (3)	$^{10}/_{12}$	$^7/_{12}$	$^3/_8$	0.8333	0.5833	0.3750	0.8269	0.5863	0.3614	C	0.16
Δ M (4)	$^1/_{12}$	$^6/_{12}$	$^3/_8$	0.0833	0.5000	0.3750	0.0887	0.5039	0.3627	C	0.15
Δ M (5)	$^4/_{12}$	$^5/_{12}$	$^3/_8$	0.3333	0.4167	0.3750	0.3564	0.4225	0.3575	C	0.32
Δ As(1)	$^{12}/_{12}$	$^9/_{12}$	$^5/_{16}$	1.0000	0.7500	0.3125	0.9672	0.7500	0.3618	A	0.60
Δ As(2)	$^4/_{12}$	$^7/_{12}$	$^9/_{16}$	0.3333	0.5833	0.5625	0.3225	0.5811	0.5654	C	0.13
Δ O (1)	$^2/_{12}$	$^9/_{12}$	$^2/_8$	0.1667	0.7500	0.2500	0.1151	0.7500	0.2854	B	0.66
Δ OH (2)	$^6/_{12}$	$^9/_{12}$	$^4/_8$	0.5000	0.7500	0.5000	0.4748	0.7500	0.4832	A	0.32
Δ O (3)	$^3/_{12}$	$^8/_{12}$	$^4/_8$	0.2500	0.6667	0.5000	0.2401	0.6535	0.5163	A	0.32
Δ O (4)	$^5/_{12}$	$^8/_{12}$	$^2/_8$	0.4167	0.6667	0.2500	0.4018	0.6818	0.2373	B	0.35

Table 16: Synadelphite

(continued)

Difference:	Ideal				Real				Δ(Å)
Δ O (5)	${}^{6}/_{12}\ {}^{7}/_{12}\ {}^{4}/_{8}$	0.5000	0.5833	0.5000	0.4714	0.5867	0.5176	A	0.36
Δ OH (6)	${}^{8}/_{12}\ {}^{7}/_{12}\ {}^{2}/_{8}$	0.6667	0.5833	0.2500	0.6630	0.5927	0.2420	B	0.20
Δ OH (7)	${}^{9}/_{12}\ {}^{8}/_{12}\ {}^{4}/_{8}$	0.7500	0.6667	0.5000	0.7158	0.6491	0.4997	A	0.50
Δ O (8)	${}^{9}/_{12}\ {}^{6}/_{12}\ {}^{4}/_{8}$	0.7500	0.5000	0.5000	0.7417	0.4940	0.4987	A	0.15
Δ OH (9)	${}^{11}/_{12}{}^{6}/_{12}\ {}^{4}/_{8}$	0.9167	0.5000	0.2500	0.9293	0.5115	0.2381	B	0.28
Δ OH(10)	${}^{12}/_{12}{}^{7}/_{12}\ {}^{4}/_{8}$	1.0000	0.5833	0.5000	0.9757	0.5726	0.4980	A	0.33
Δ O (11)	${}^{2}/_{12}\ {}^{5}/_{12}\ {}^{2}/_{8}$	0.1667	0.4167	0.2500	0.1838	0.4225	0.2349	B	0.26
Δ W (12)	${}^{5}/_{12}\ {}^{4}/_{12}\ {}^{2}/_{8}$	0.4167	0.3333	0.2500	0.4170	0.3306	0.2232	B	0.27
Δ □	${}^{6}/_{12}\ {}^{9}/_{12}\ {}^{0}/_{8}$		—			—		A	—
							mean	0.32 Å	
							range	0.13 – 0.66 Å	

$$d^2 = a^2\Delta x^2 + b^2\Delta y^2 + c^2\Delta z^2 = 115.649\ \Delta x^2 + 355.888\Delta y^2 + 97.693\Delta z^2$$

Table 17: Hematolite

$(Mn,Mg)^{2+}{}_{13}Al_2(OH)_{23}(As^{3+}O_3\Psi)(AsO_4)_2$ Z = 3

[3 1 0 / 1 5 0 / 001] cell

$[{}^{5}/_{14}\,{}^{-1}/_{14}\,{}^{0}/_{14}\ /\ {}^{-1}/_{14}\,{}^{3}/_{14}\,{}^{0}/_{14}\ /001]$ coordinate

					ℓ	$<\ell>$	Δ(%)
Z = 3		Z′ = 42					
a_1	8·275	a′	21·89	7ℓ	3·128	21·57	+1.5
a_2	8·275	b′	37·92	$7\sqrt{3}\,\ell$	3·128	37·36	+1.5
c	36·60	c′ (*t**)	36·60Å	$15\frac{\sqrt{2}}{\sqrt{3}}\ell$	2·988 Å	37·73 Å	-3·1%
R3		$V_E{}'$ = 20·7 Å^3		3•chhhh•	<3·081> Å	*h* = 2·44 Å	

Moore and Araki (1978), R = 0.11 / 1471 F_o

Difference:

Δ M(1)	0·00	ΔAs(2)	0·84	ΔOH(2)	0·04
Δ M(2)	0·62	ΔAs(3)	0·40	ΔOH(3)	0·59
Δ M(3)	0·34	ΔO(1)	0·33	ΔOH(4)	0·34
Δ M(4)	0·39	ΔO(2)	0·29	ΔOH(5)	0·27
Δ M(5)	0·29	ΔO(3)	0·51	ΔOH(6)	0·52
Δ M(6)	0·34	ΔO(4)	0·57	ΔOH(7)	0·39
Δ M(7)	0·51	ΔO(5)	0·52	ΔOH(8)	0·16
Δ As(1)	0·40	ΔOH(1)	0·44	ΔOH(9)	0·39 Å
				mean	0·40 Å
				range	0·00 Å - 0·84 Å

Table 18: Allactite

$Mn_7(OH)_8(AsO_4)_2$

[101/010/001] cell

[100/010/-101] coordinate

					ℓ	$<\ell>$	Δ(%)
Z	2	Z′	2				
a	11·03	a′ (t*)	10·12	$4\frac{\sqrt{2}}{\sqrt{3}}\ell$	3·10	10·13	-0.1
b	12·12	b′	12·12	$4\,\ell$	3·03	12·41	-2.4
c	5·51 Å	c′	5·51 Å	$\sqrt{3}\,\ell$	3·18 Å	5·37 Å	+2·5%
β	114°04′	β′	84°16′	h = 2.53 Å	<3.10> Å		
$P2_{1/a}$		$V_E{}'$	21·02 Å^3	•hhhh•			

Moore (1968), R = 0.077 / 838 F_o

Difference:

*Δ Mn(1)	0·00	†ΔOH(3)	0·51
Δ Mn(2)	0·43	ΔO(4)	0·45
Δ Mn(3)	0·10	ΔOH(5)	0·11
Δ Mn(4)	0·28	ΔOH(6)	0·20
Δ As	0·34	†ΔO(7)	0·66
Δ OH(1)	0·18	†ΔO(8)	0·66 Å
Δ O(2)	0·20	mean	0·32 Å
		range	0·00 Å - 0·66 Å

* unconventional centroid

† bonded to Mn(1)

Table 19: Arsenoklasite

$Mn_5(OH)_4(AsO_4)_2$

Z = 4			ℓ	$<\ell>$	Δ(%)
a 18·29		6ℓ	3·05	18·46	-0.9
b 5·75		$\sqrt{3}\ell$	3·32	5·33	+7.3
c(t*) 9·31 Å		$4\frac{\sqrt{2}}{\sqrt{3}}\ell$	2·85 Å	10·05 Å	-7·9%
$P2_12_12_1$	V_E	20·4 Å^3	<3.08> Å	•chch•	h = 2.33 Å

Moore and Molin-Case (1971), R = 0.07 / 1800 F_o

Difference:

*Δ Mn(1)	0·57	ΔOH(1)	0·23	†ΔO(7)	1·04
Δ Mn(2)	0·31	ΔOH(2)	0·32	ΔO(8)	0·31
Δ Mn(3)	0·25	ΔOH(3)	0·39	ΔO(9)	0·26
Δ Mn(4)	0·09	ΔOH(4)	0·30	ΔO(10)	0·20
*Δ Mn(5)	0·39	†ΔO(5)	0·76	ΔO(11)	0·63
Δ As(1)	0·29	ΔO(6)	0·00	ΔO(12)	0·71
Δ As(2)	0·24			mean	0·36 Å
				range	0·00 Å - 1·04 Å

* unconventional centroid

† unconventionally bonded to Mn(1) and Mn(5)

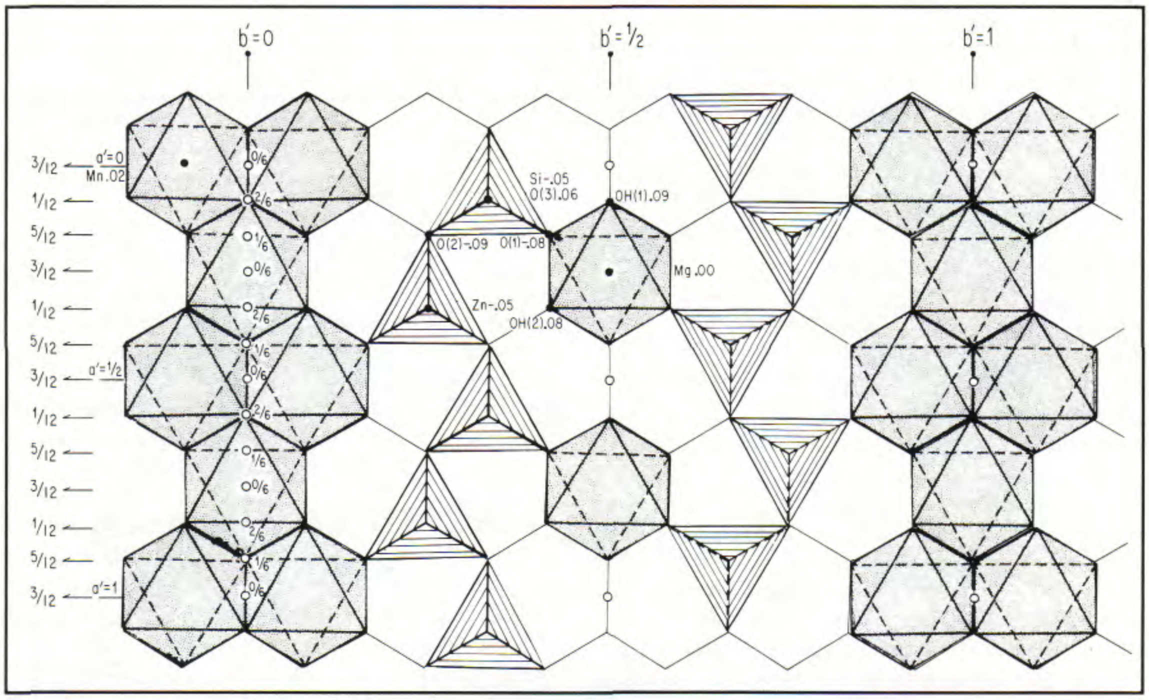


Figure 8a. One slab of the gerstmannite transformed structure idealized along *c′*. Some unique atoms are labeled and heights are given as fractional coordinates in *z′*. Initial parameters from Moore and Araki (1977).

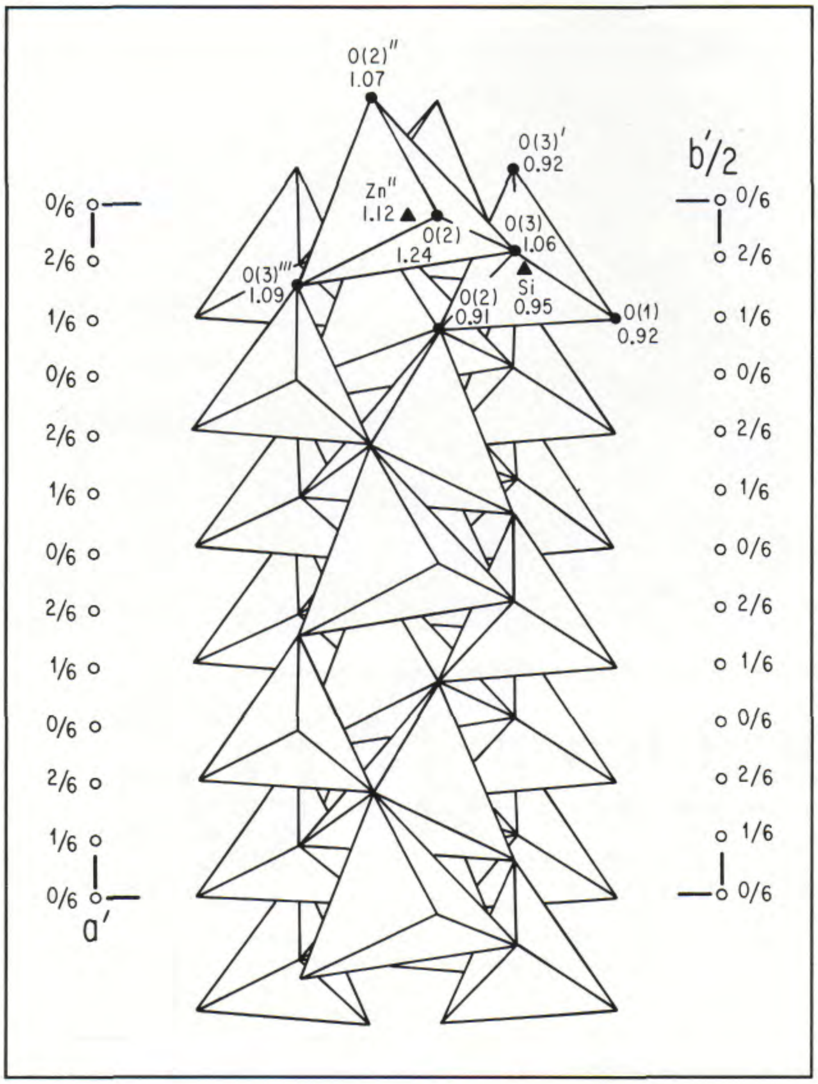


Figure 8b. The real tetrahedral $[ZnSiO_4]^{2-}$ fraction in transformed gerstmannite. Heights are given in fractional coordinates and primes denote equivalences. Parameters from Moore and Araki (1977).

Figure 9. The real tetrahedral $[ZnSiO_4]^{2-}$ fraction in transformed clinodedrite. Crosses denote origin equivalences forced by the C-centered cell. This unit is isomorphic to gerstmannite in Figure 8b. Parameters from Venetopoulos and Rentzeperis (1976).

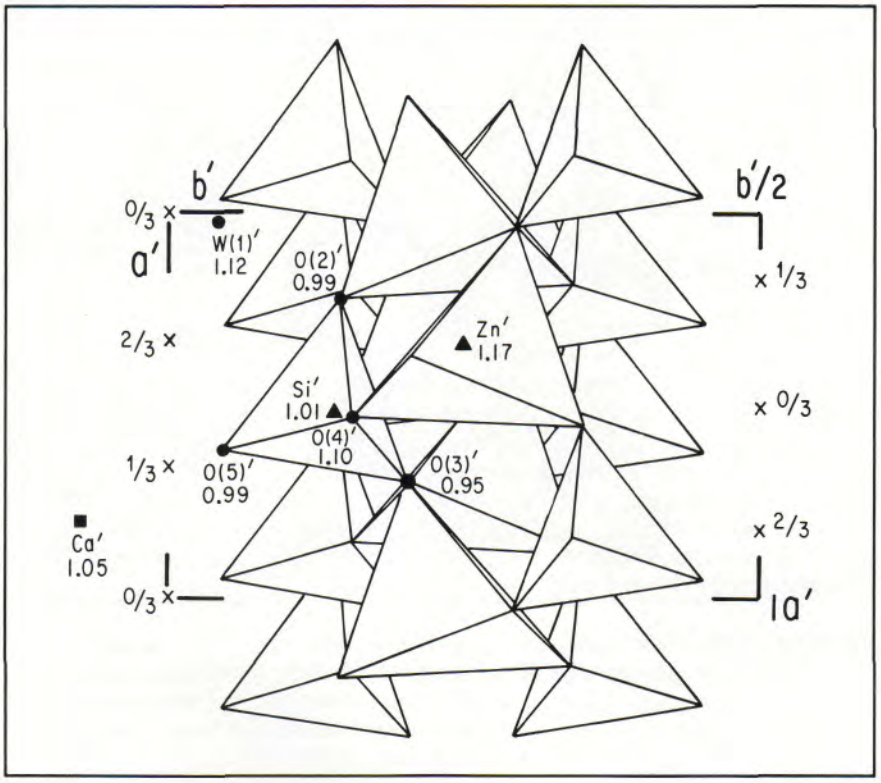
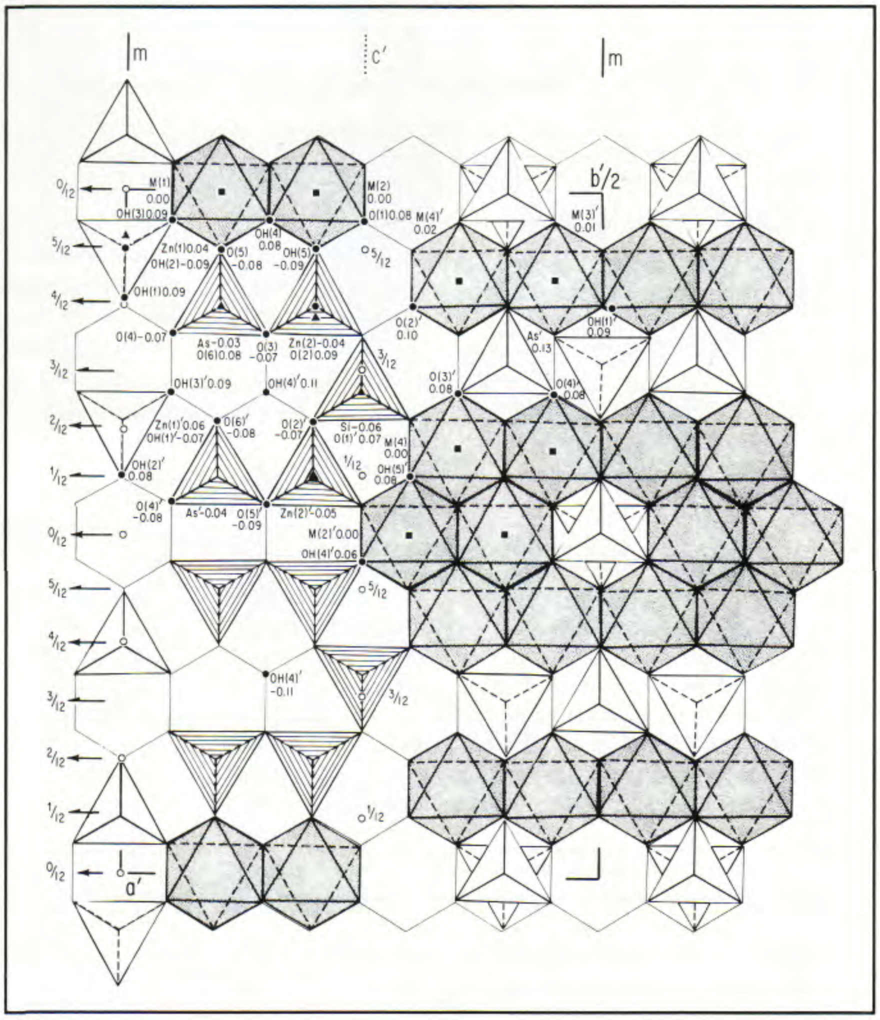


Figure 10a. One slab of transformed holdenite idealized on the $\{6^3\}$ net. Some equivalences are primed and heights are given as fractional coordinates in *z'*. Initial parameters from Moore and Araki (1977).



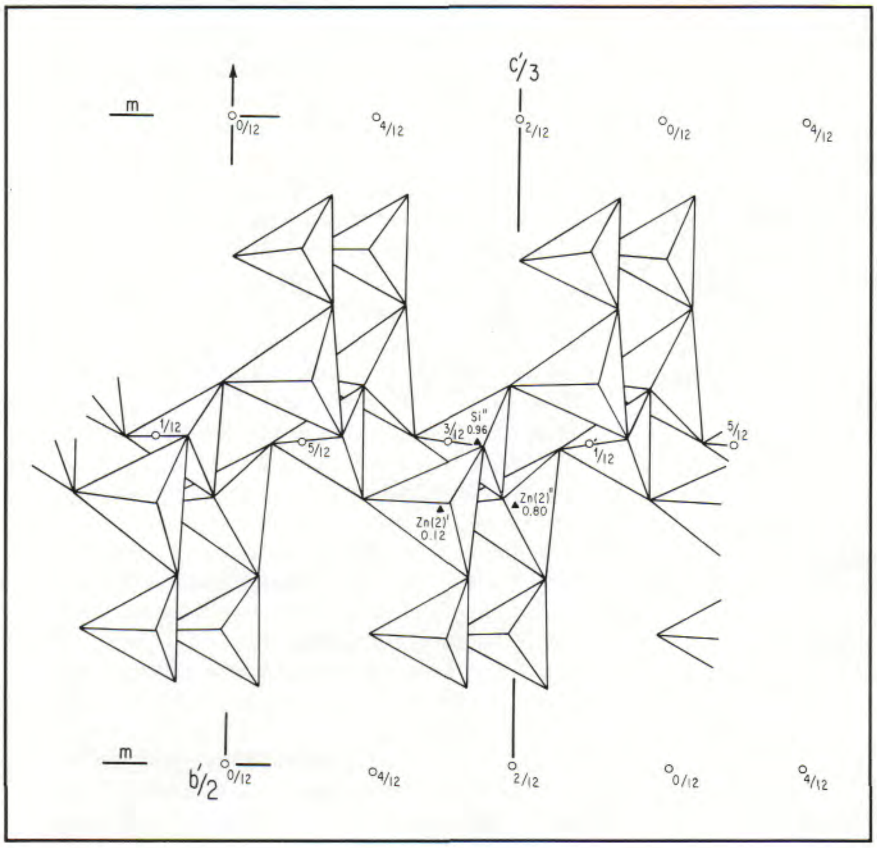


Figure 10b. Real tetrahedral fraction of transformed holdenite. Note that this is an alternative transformation (*c'*) of Figure 10a (*a'*). Invariant symmetry elements are drawn in. Parameters from Moore and Araki (1977).

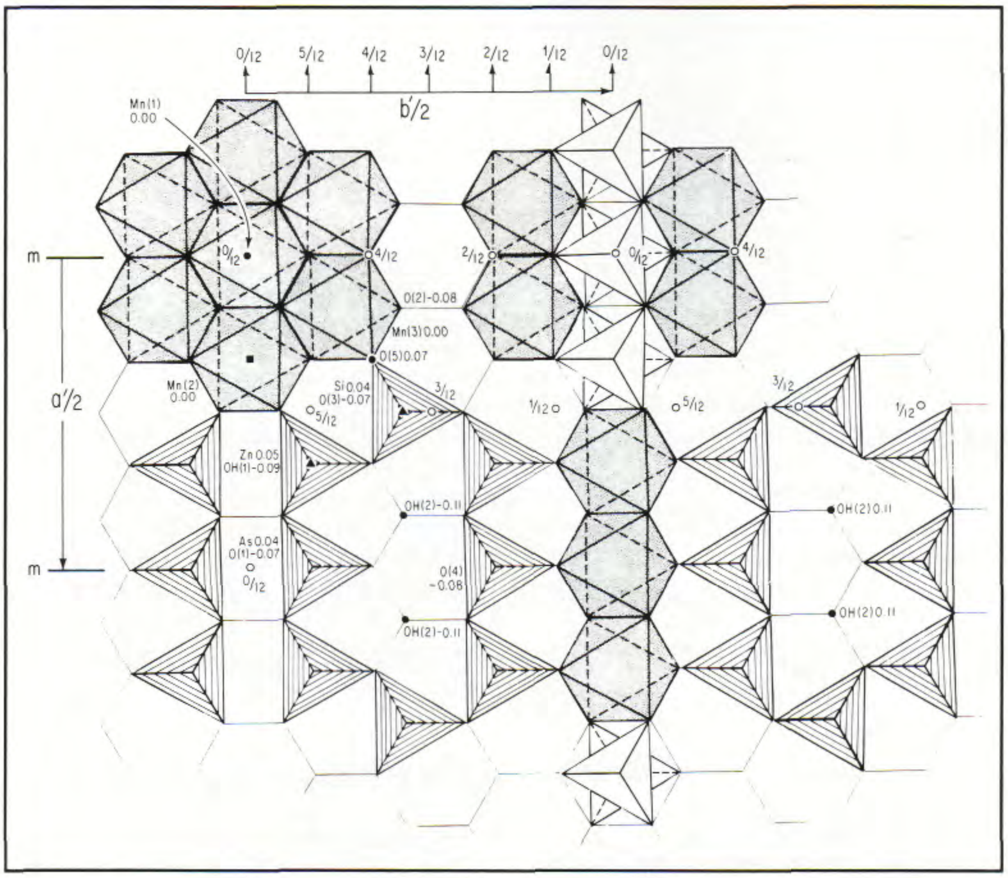


Figure 11a. One slab of transformed kolicite idealized on the {6³} net. Compare with holdenite (Figure 10a). Note appearance of elaborate tetrahedral ring, and coronene-like octahedral unit at origin. Initial parameters from Peacor (1980).

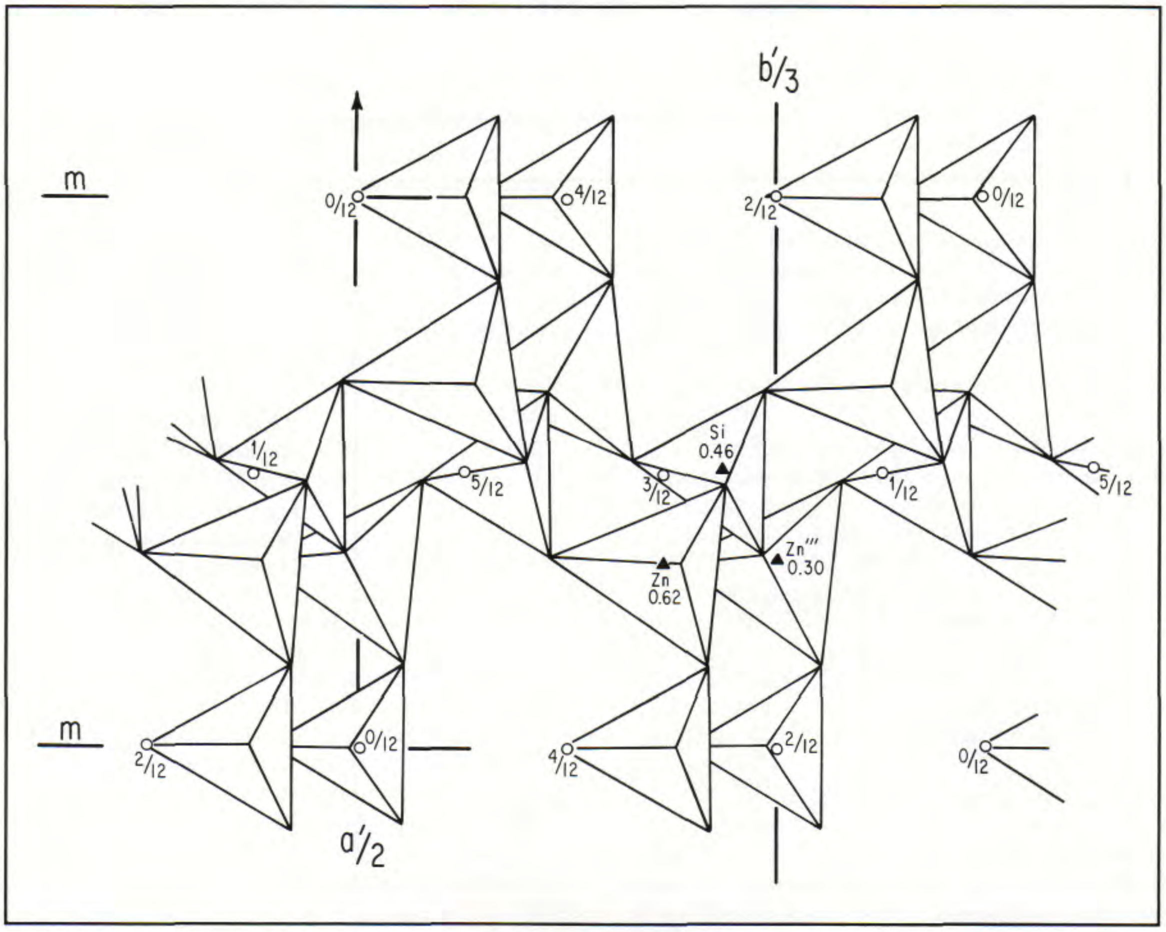


Figure 11b. Real tetrahedral fraction of transformed kolicite. Compare with holdenite (Figure 10b). Parameters from Peacor (1980).

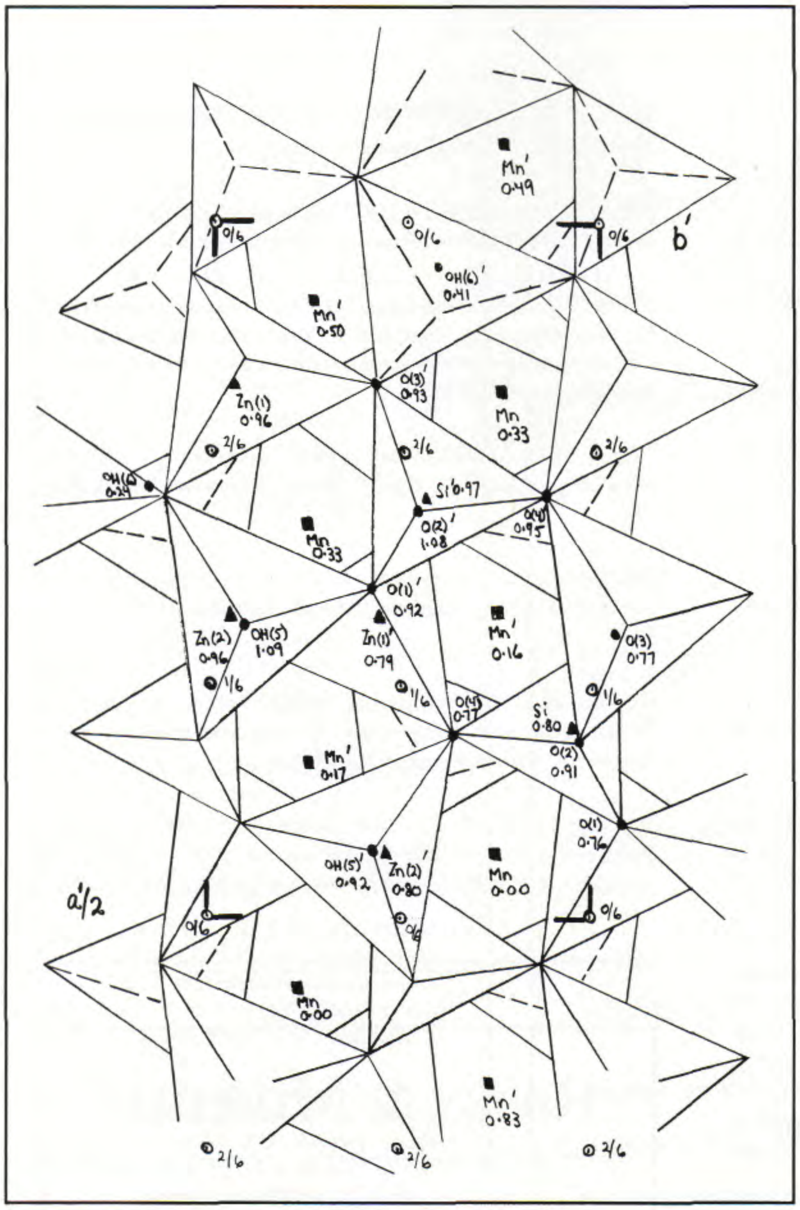


Figure 12. Real tetrahedral fraction of transformed hodgkinsonite, ·hhhhhh·. Note hexagonal "windows" sealed by [Mnϕ_6] octahedra. Parameters from Rentzeperis (1963).

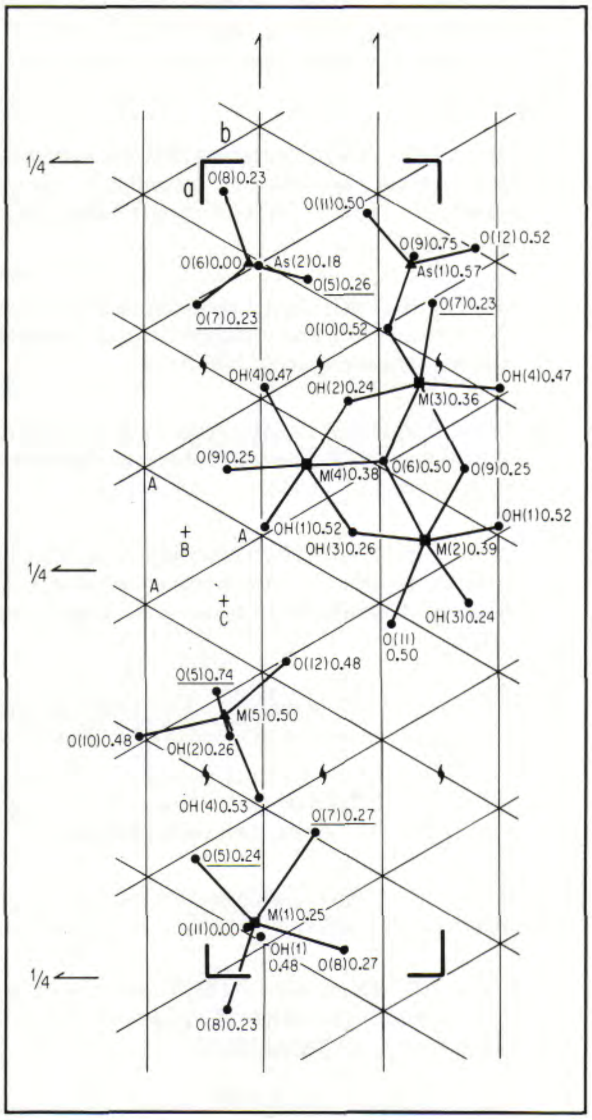


Figure 13. Asymmetric polyhedral bonds in arsenoklasite superimposed on perfect {3^6} net. Heights in z are in fractional coordinates. Deviants O(5) and O(7) are underlined. See text for other details. Parameters from Moore and Molin-Case (1971).

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