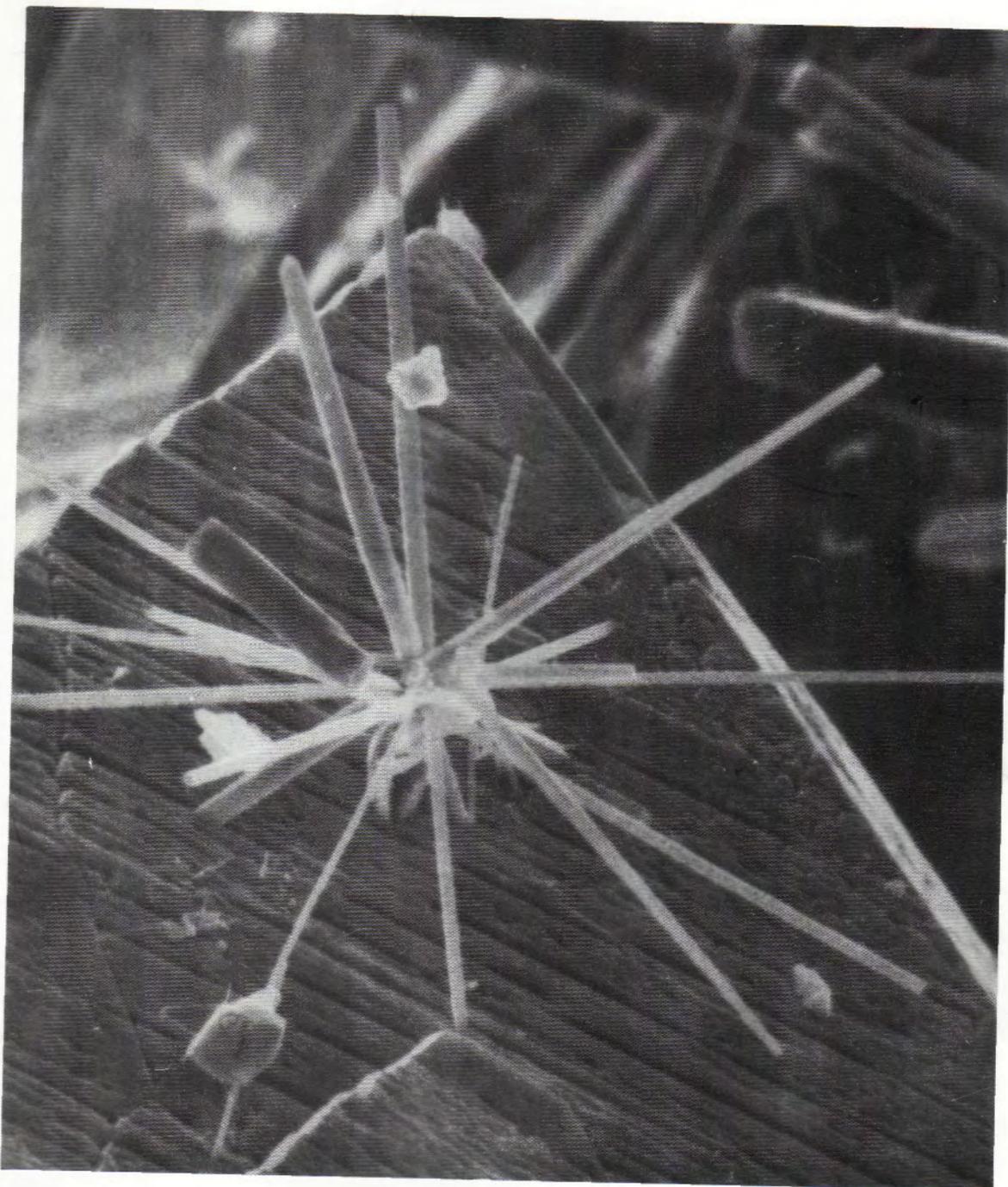


THE PICKING TABLE

JOURNAL OF THE FRANKLIN-OGDENSBURG MINERALOGICAL SOCIETY, INC.



VOLUME 34 NUMBER 2

AUTUMN/WINTER 1993

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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 \$10 for individual and \$15 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 non-profit 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 editor at the address listed above for further information.

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

The views and opinions expressed in *The Picking Table* do not necessarily reflect those of the FOMS, the editor, or the editorial board.



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ABOUT THE COVER PHOTOGRAPH

Willemite on hodgkinsonite. Franklin, NJ. Stellate aggregate of transparent willemite crystals on the naturally etched face of a pale-pink hodgkinsonite crystal. Minute grains visible at the 12 and 7 o' clock positions of the willemite aggregate are also hodgkinsonite. SEM photomicrograph. Field width 0.12 mm.

FROM THE EDITOR'S DESK

Herb Yeates
P.O. Box 46
White Plains, NY 10605

Greetings. Here is the Autumn/Winter 1993 issue, and it looks to be one of our best yet. Thanks are extended to those whose contributions have made it possible. We owe our contributing authors a debt of thanks for all of their hard work!

THE 1993 FRANKLIN-STERLING HILL AREA MINERAL SPECIES LIST

To conserve space in a full issue, we will summarize here the changes made to the species list since it appeared in last Autumn's issue of *The Picking Table*. **Spangolite** is added as a mineral new to the district, and Mn-stilpnomelane should be changed to **franklinphillite**.

FLUORESCENT MINERAL SWAP-SELL

Ralph Thomas wrote in to advise that there will be a "fluorescent minerals only" show-swap-sell event titled "Ultraviolation '93," on Saturday October 23rd from 10 AM to 4 PM. The event is sponsored by the Rock and Mineral Club of Lower Bucks County, and will be held at the Northminster Presbyterian Church at 140 Trenton Road, Fairless Hills, PA. Table space will be available for \$5, and visitor admission is only \$1. For more information please contact Ralph directly at (215) 295-9730. Be sure to bring your favorite fluorescent mineral specimen for the competition event!

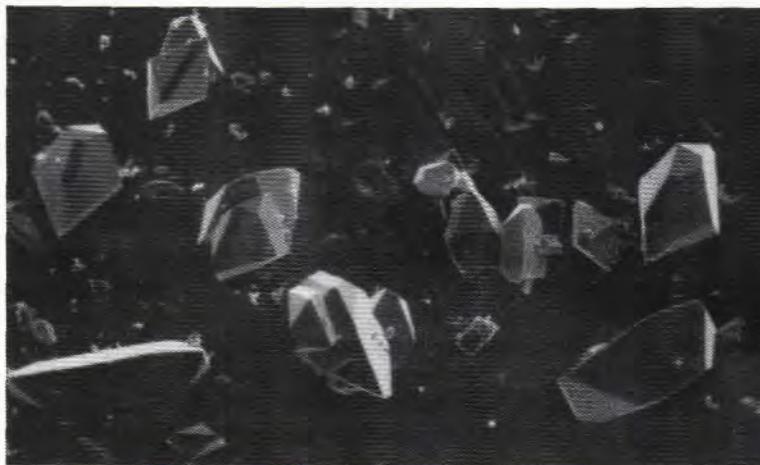
PT CLOSING DATE FOR AUTHORS

There is no "closing date" for articles submitted to *The Picking Table*. Submit them whenever you like. The length of the review cycle is simply too variable (dependent on the "ready-to-print" quality of the submission, as well as the spare time of our volunteer reviewers) to guarantee a particular date as "closing" for any specific issue.

The Picking Table is intended to arrive in your mailbox before the first meeting of each season, i.e. the third Saturday in September and March. To do this, the printer needs to have a complete issue in excess of one month in advance. This means a "picture-perfect" PT must exist in August and in February or you won't get it in time. To do this, the "finished" articles are fitted into an issue one or two months in advance of this August/February printer deadline. June and December therefore, are when the Editor **composes** the journal from the stock of "perfect," ready-to-print articles available to him/her. So, please send them in, and when they are reviewed, returned to you, adjusted, and returned to the Editor they will be available for insertion during the next PT-composing cycle.

PT CLOSING DATE FOR FOMS STAFF

For those members of the FOMS who have information for regular inclusion in *The Picking Table* such as local museum updates, lists of officers and their addresses, speaker and field trip schedules, official announcements etc., the situation is entirely



Hodgkinsonite. Franklin, NJ. Minute, transparent pale-violet hodgkinsonite crystals on one face of a larger hodgkinsonite crystal. SEM photomicrograph. Field width 0.35 mm.

different. Your input is **required** prior to the final journal composing process in June and December. Your deadline is, therefore:

December 15 for the Spring/Summer issue

June 15 for the Autumn/Winter issue

This input is *needed* for every issue; there are no surprises here. The Editor will not track you down and solicit this information. Please remember to send it in by these deadlines, and in writing (I can't guess at spelling etc.). To date I have gotten everything from nothing-at-all to fragmentary phone calls to crumpled notes passed to third parties for chance hand-delivery! Your journal arrives to you in the **mail**—use the same tool to send me this information on time please.

NEXT ISSUE

Our next issue will feature a very special article. Professor Paul B. Moore, of the University of Chicago, has agreed to provide *The Picking Table* with an illustrated introduction to the crystal chemistry of a number of our exotic local minerals, and share some of his insights in this field. He will introduce the reader to these minerals through the principles of **closest-packing** and **oxidation-reduction** potential. For those who have long ago packed away your Earth Science texts, I encourage you to grab one and brush the dust off before next March. Though this article will be targeted at a "general" audience, some familiarity with these most basic concepts will prove very rewarding.

NEXT EDITOR

Yes, it's that time already. The next issue, Spring/Summer 1994, will be the last of my two-year term. Chet advises no one has yet stepped forward to take over. It is time for one of you to give it a run!

There are some nice side benefits. You get a real sense of satisfaction from putting an issue together. You'll see what's in the next PT before anyone else! And the computer system that comes with the job is terrific (a really *fast* 486 and LaserJet setup)—and easy to use. A term goes by pretty quickly, and the job can truly be good fun.

In any case, other considerations prevent me from taking a second term at the post, and the Editorship must go to *someone* if we are to have a PT. Ideally, I would like to work with the candidate a bit on the next (my last) issue this winter. No kidding: no volunteer, no PT. Please contact Chet.



MESSAGE FROM THE PRESIDENT

Chet Lemanski, Jr.
309 Massachusetts Rd.
Browns Mills, NJ 08015

The first half of the 1993 activities schedule is now history. The spring Swap/Sell went off well with approximately the same amount of income as last year's event. The spring field trip schedule was eventful, highlighted by another super trip to the Lime Crest quarry and the discovery of a new species for the locale (axinite) by Ed Wilk [A write-up will appear in an upcoming PT issue—*Ed.*] Over the summer the FOMS participated, along with the two local museums, in a very short-fused operation at the Trotter dump property to explore for potential future collecting opportunities. Unfortunately, that effort uncovered very little quality material. The one major result was the excavation of several very large blocks of ore which, when cleaned up, may prove to be super museum exhibits.

The fall season of events is about to commence. The major concern is, of course, the show in October. The event will take place at the Franklin School on Washington Avenue, off Route 23. Setup for the show cannot begin until 3:00 PM Friday so we will need all of the help we can get. Let's all pitch in and make this show the best ever!

Perhaps the most significant activity pursued by the society is the publication of *The Picking Table*. Our Editor, Herb Yeates, has done a splendid job with this project since taking over the editorship; however, his term in the job is nearing an end, as announced in the spring issue. We will need a new editor after the spring 1994 issue, with a transition period starting over this coming winter. Can you imagine the FOMS without the PT? Please consider contributing to the society in this most meaningful fashion. This is an urgent appeal — no new editor, no more PT!

Finally, I wish to thank all those members who selflessly contributed to the FOMS team effort thus far this year. I also wish to thank Maureen Woods, who submitted her resignation as Secretary, effective the end of the spring season. She made a significant contribution to the society and we all owe her a debt of thanks. Thanks Maureen, a job well done! Tema Bostwick has graciously volunteered to assume the office of Secretary. Welcome aboard Tema!



AUTUMN 1993 ACTIVITY SCHEDULE

Saturday, September 18th 1993

9 AM - Noon — *Field Trip* — Collecting at the Sterling Hill Mining Company Dump, Ogdensburg, New Jersey. Fee: \$1 per pound; \$10. minimum.

1:30 - 3:30 — *Lecture* — Dr. Pete J. Dunn, "A Conversation with Pete Dunn."

Saturday and Sunday, October 2nd and 3rd 1993

The 37th Annual Franklin-Sterling Mineral Exhibit.

Please note that the show will be held at the Franklin Middle School on Washington Street in Franklin. The Annual Banquet will be held on Saturday night.

Saturday, October 16th 1993

9 AM - Noon — *Field Trip* — Collecting at the Old Andover Iron Mine, Andover, New Jersey.

1:30 - 3:30 — *Lecture* — Speaker and subject to be announced by flyer.

Sunday, October 17th 1993

9 AM - 3:00 PM — *Field Trip* — Collecting at the Lime Crest Quarry, Sparta, New Jersey.

Saturday, November 20th 1993

9 AM - Noon — *Field Trip* — Collecting at the Franklin Quarry, Franklin, New Jersey.

1:30 - 3:30 — *Lecture* — Speaker and subject to be announced by flyer.

Scheduled activities of the Society include meetings/lecture programs and field trips. The regular meetings are held on the third Saturday of March, April, May, June, September, October and November. Business meetings follow the lecture programs listed. Field trips are generally held on the weekend of a meeting/lecture program. Unless specified otherwise, all meetings/lectures are held in Kraissl Hall of the Franklin Mineral Museum, Evans Road, Franklin, New Jersey.

LOCAL NOTES

NEWS FROM THE FRANKLIN MINERAL MUSEUM

John Cianciulli
Assistant to the Curator,
Franklin Mineral Museum, Inc.

There has been a lot of activity at the museum during the summer of 1993. Improvements to the grounds around the museum will be apparent on your next visit. The ore car exhibit was completely overhauled. A new rail bed was installed. The museum swapped one old ore car for a more modern one from the Sterling Hill Mining Museum. A four foot chain link fence will be installed around the exhibit and the exhibit signs are being reconditioned.

The museum has received the final batch of mineral specimens from the collection of the late Will Shulman. There are some very fine world-wide minerals in this collection which are now available for sale at the museum. Dr. Standfast is still contributing to Franklin; the museum recently received the balance of his vast collection of mineral photographs and slides. He also donated some of his photomicroscopy equipment. The museum acquired a number of other collections recently. We purchased a large collection of New Jersey trap rock minerals from various quarries around the State. From the same source the museum acquired a dinosaur footprint collection collected from Great Notch, New Jersey. Lastly, the Hocking family donated a vast amount of minerals from the collection of the late Stanley Hocking. This collection is predominantly Franklin-Sterling but contains a fair amount of world-wide minerals also.

The Sterling Hill Mining Museum and the Franklin Mineral Museum are working together as one on several fronts. Both museums, in a cooperative effort with the Meadowlands Convention Center, have produced probably the largest, most spectacular fluorescent exhibition ever! This "fluorescent landscape," created by sculptor John Zidek is blending in nicely with the "Dinosaurs Alive" exhibit now on at the Meadowlands Convention Center. The show will continue until January 4, 1994. Special joint brochures promoting both museums were produced and are being distributed at the Meadowlands Dinomation exhibit. These brochures were also distributed at the Sussex County Farm and Horse Show in August where our two museums again shared in promoting their attractions. John Zidek provided a fluorescent sculpture of a mine scene for exhibition at the show.

Speaking of shows, **the 37th Annual Franklin/Sterling Gem and Mineral Show will be held on October 2nd & 3rd at a new location, the Franklin Middle School on Washington Avenue.** There will be plenty of swap and sell space and ample parking. The accessibility of this new location is far better than the old! See you there!

On Saturday August 28, 1993, a special mineral clearance sale was held at the Franklin Mineral Museum, the first of its kind. Also a reminder that museum membership is available at a

nominal fee. Annual individual membership is \$10.00, or you could sign up as a life member for \$50.00. Membership entitles you to free admission to the museum for the duration of your membership. You will still be charged for collecting. If you wish to join the museum or just support the museum by donation, send your check or money order to the Franklin Mineral Museum Inc., P.O. Box 54, Evans Street, Franklin, N.J. 07416.



NEWS FROM STERLING HILL

Gary Grenier
Editor, the *Sterling Hill News Letter*

The Sterling Hill Mining Foundation opened for its third year in March (a bit late due to snow and ice). Annual attendance figures are in excess of 20,000 visitors — from all over the world — revealing healthy growth.

When President Richard Hauck is not personally giving a tour, he is out collecting mining artifacts. Most recently, Richard led an expedition to the Mammoth mine in central Utah. This classic, turn-of-the-century gold and silver producing shaft mine was abandoned intact. Fortunately, Richard was able to gain access thanks to the cooperation of mine owner Greg Olson. Many new exhibits are planned as a result of this successful "collecting" trip.

A new display is being constructed on the grounds next to the concession building and is approximately 50% finished. The display is a stamp mill which was formerly located in Tuscon, Arizona. The wood timbers for the stamp mill were donated by Richard Graeme from Utah.

The new tunneling project, which is intended to connect the current Rainbow Room tunnel to the concession parking lot has commenced. By early August there have been seven (7) shots which have produced 50+ feet of new tunnel! In the process of tunneling, workers have exposed lean franklinite and willemite ore in fluorescent calcite with minor amounts of fluorite.

There has been a hint of matching grant support for the tunneling project that could, if successful, provide funds to complete the tunnel. The "Buy-a-Foot" of the tunnel for \$160 fund raiser has been very well received. This fund raising activity is made more important as every foot of the tunnel purchased buys a second foot if and when the grant is awarded. So, "buy-a-foot" today — it is doubly important — and add your name to the growing list of supporters.

The Sterling Hill Mining Museum Foundation continues to grow and install new displays, of both mining artifacts and minerals. Your continued support and interest in the project is most appreciated. Be sure to stop in and see what is new when you are next in the area.



The Franklin Mineral Museum

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

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

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

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

Operating Schedule:

Open to the public

March 1 to December 1

Monday through Saturday: 10AM - 4 PM

Sunday: 12:30 PM - 4:30 PM

Closed: Easter, July 4th and Thanksgiving

Groups by reservation, please

Admission fees:

Adults: \$3.00

Grammar & High School Students: \$1.00

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

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



The Sterling Hill Mining Museum, Inc.



30 Plant Street Ogdensburg, NJ 07439

Museum phone: (201) 209-7212

Don't miss the RAINBOW ROOM!

Featuring 30 acres of things to see indoors, outdoors and underground, including:

- Antique mining equipment displays
- Mining memorabilia displays
- Historical buildings
- Underground guided tours
- Gift Shop - stocked with minerals, books, T-shirts, caps etc.
- Food concession and picnic area,
- Nature trails, and much more!

Learn about the importance of the mining industry
to northwestern New Jersey.
See historic mine workings!

Schedule of operation:

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

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

March 1 — December 1

Admission prices:

Adults: \$6.50

Children: \$4.50

Senior Citizens: \$5.50

Call for group rates

Note:

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

β -DUFTITE

FROM THE

STERLING MINE

OGDENSBURG, NEW JERSEY

Robert E. Jenkins II
Mining Technology
E.I. Du Pont de Nemours & Company
Wilmington, Delaware
19898

INTRODUCTION

Duftite, $\text{PbCu}(\text{AsO}_4)(\text{OH})$, was described as a new mineral from the Tsumeb mine, Namibia by Pufahl (1920). Using X-ray methods, Guillemin (1956) re-examined the species from Tsumeb and from additional localities, including Cap Garonne, France, Mapimi, Durango, Mexico, etc. He reported that what had been described as a single mineral was in fact two phases with essentially the same chemical composition but different crystal structure, one isomorphous with mottamite, and the other with conicalcite. Guillemin designated these α -duftite and β -duftite respectively. The duftites have since been reported from several other localities (e.g. Murdoch and Webb, 1966; Anthony *et al.*, 1977; and Waisman, 1992) where primary As-bearing sulfide minerals have undergone oxidation. The duftites are thus not rare minerals, and β -duftite appears to be the more abundant of the two species.

Although arsenate compounds are common among the numerous secondary minerals at the Sterling mine, in Ogdensburg, New Jersey, duftite has heretofore gone unrecognized there. β -duftite, however, has now been verified in specimens from two separate localities adjacent to the mine's 180 Level. At both sites the species occurs as fracture coatings, readily visible to the naked eye, together with tennantite, galena, azurite, malachite, and other minerals.

The two β -duftite localities, one in the Gravity Tram and the other in an old open stope in the East Limb, north of the East Shaft, 150 Level station, were discovered during geologic mapping by the author in the second half of 1992. About 60 specimens were recovered from the two sites, all but 6 of them from the Gravity Tram. Both localities are now flooded.

GEOLOGY

Figure 1 is a simplified geologic map showing the location of the two β -duftite localities in relation to the zinc deposit and mine access. Geology is projected onto the plane of 180 Level. The Gravity Tram site lies at approximate mine coordinates -1185, 1055N, 1172W. The location along the East Limb lies at approximate mine coordinates -1194, 1175N, 1175W. Coordinates follow the nomenclature of the New Jersey Zinc Company, as described by Sanford (1992).

At the Gravity Tram site β -duftite was exposed at two localities in very close proximity. It was found in the ceiling just north of the center of the Gravity Tram decline, and also high on the south wall. The entire area of exposure totalled about 1 m². At the East Limb locality the mineral was exposed on the east side of an old open stope. Little sampling was done at this site, and no attempt was made to measure the area of exposure because of danger from an unstable floor and from severe sloughing of the stope wall.

Host lithologies and geologic structure at the two β -duftite localities are very similar. At the Gravity Tram site the mineral occurs in fractured marble about 0.8 to 3 m structurally below the footwall contact of East Limb ore. At the East Limb locality β -duftite is also hosted by fractured marble, approximately 0.5 m structurally above the hanging wall contact of the ore.

The marble at both localities is white to pale grey and fine- to medium-grained. The marble has been slightly to moderately dolomitized and contains 1-2 vol% disseminated silicate minerals (major phlogopite, minor diopside, trace andradite and tremolite, all confirmed by X-ray powder photography). It also contains 1-4 vol% dispersed sulfide minerals, as angular to rounded masses

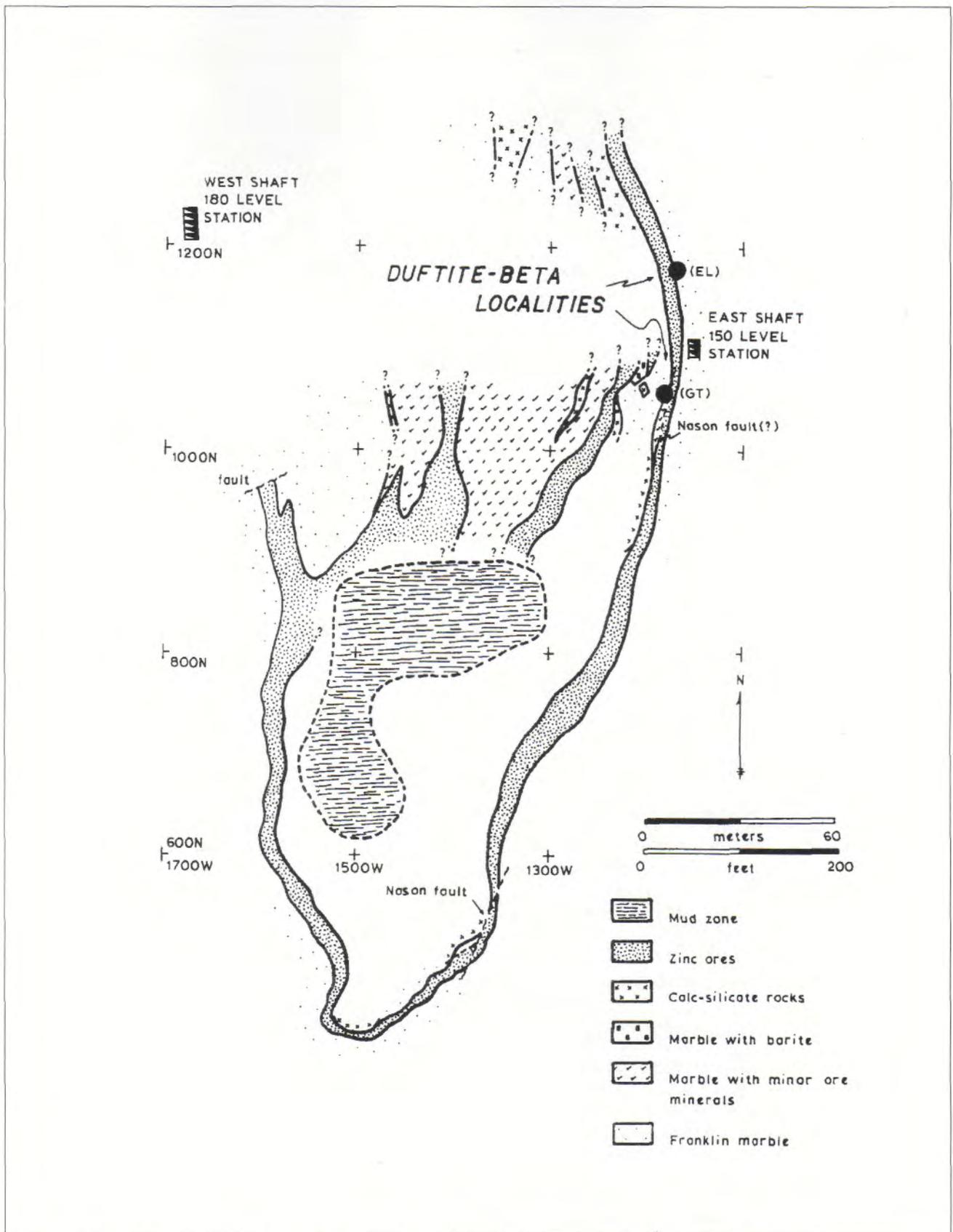


Figure 1. Simplified geologic map of 180 Level, Sterling mine, Ogdensburg, New Jersey, showing locations of the two β -duftite localities (GT=Gravity Tram, EL=East Limb), based on geologic mapping by the author, July-November 1992; and New Jersey Zinc Company drift outline survey, 1979. Indicated north is New Jersey Zinc Company grid north, $19^{\circ} 5'$ east of True North.



Figure 2. β -dufite in place (top-center), ceiling of Gravity Tram decline. Drill hole is 5 cm in diameter.



Figure 3. Fault cutting mylonitized ore, Gravity Tram decline, south wall. Lens cap is 5 cm in diameter.

averaging about 2 mm in maximum dimension. Many sulfide mineral grains exhibit replacement (embayed) contacts against calcite of the marble.

At the Gravity Tram site β -duftite is developed as discontinuous coatings on the surface of a single minor fault in a set of faults, oriented N15W, 47NE (Figure 2). These faults cut sulfide-containing marble. Other faults at the locality strike N35E and dip 55NW, but these do not host β -duftite. At the East Limb locality, also, β -duftite occurs as discontinuous coatings on the surfaces of several closely spaced faults, which are oriented essentially parallel to the East Limb hanging wall contact. No other fault set was observed at the East Limb site. Other oxidized copper minerals occur on the fault surfaces with β -duftite, but more commonly they replace sulfide masses in the adjacent wall rock.

Ore in the East Limb close to the Gravity Tram exposure is also strongly sheared, as indicated by streaking and mylonitization of the ore minerals (Figure 3). The zone of shearing is about 1.5 m in width and strikes parallel to the trend of the East Limb but dips more steeply to the east. A little galena is dispersed along shear planes as isolated grains and small lenses. This shear zone may be the Nason Fault or a related subsidiary structure.

MINERALOGY

General mineralogy, together with relative abundance of species, for the two β -duftite localities is shown in Table 1. All species were confirmed by X-ray powder photography using a 114-mm Gandolfi camera, or by X-ray bulk diffractogram, both on a modified Philips Automated X-ray Diffractometer, with DEC VAX II hardware control. All species were also studied by SEM-EDS methods using a JEOL JSM-840 scanning electron microscope (SEM) or a JEOL JXA-35 electron probe microanalyzer, both equipped with Kevex energy dispersive spectra (EDS) detector. Semiquantitative chemical analyses reported for tennantite were performed with the microprobe using the Tracor "SQ" program and DEC PDP-11/73 hardware control. Fourteen specimens from the two localities were studied by instrumental methods. About thirty others were examined subsequent to instrument study to establish the relative abundance of phases. Selected species are described below.

β -duftite $PbCu(AsO_4)(OH)$

β -duftite occurs at both localities as dull to bright apple-green coatings averaging 0.5 mm in thickness and covering areas ranging from a few mm² to 150 cm². The largest and richest specimens are from the Gravity Tram site and reside in the reference collection of the Sterling Hill Mining Museum and in the private collection of Mr. Fred Parker. SEM magnification resolves discontinuous β -duftite coatings from the Gravity Tram site into aggregates of rough orthorhombic prisms with simple rectangular terminations. These average about 20 μ m in maximum dimension and are commonly overlain by euhedral mimetite (Figure 4). Other associated minerals include anglesite, azurite, brochantite, galena, goethite, greenockite, and malachite. At the East Limb locality β -duftite is present as sharper prisms with steep terminations, which average only about 1 μ m in maximum dimension (Figure 5). Associated minerals at the East Limb site are brochantite, goethite, tennantite, and two unknown Pb-Cu-Ca-As compounds.

Table 1.

MINERALOGY OF THE β -DUFTITE LOCALITIES			
Sulfide Assemblage		Oxidized Assemblage	
Chalcopyrite	M	Anglesite*	R
Covellite*	R	Azurite	M
Galena	C	Brochantite	M
Pyrite	M	Calcite**	R
Pyrrhotite*	R	β -Duftite	C
Sphalerite	R	Goethite	C
Tennantite	C	Greenockite*	R
Gypsum*	R		
Hemimorphite	R		
Hydrozincite	M		
Malachite	M		
Mimetite*	M		
"Serpentine"	M		
Unknowns**	R		

C = common; M = minor; R = rare

* found at Gravity Tram locality only
** found at East Limb locality only

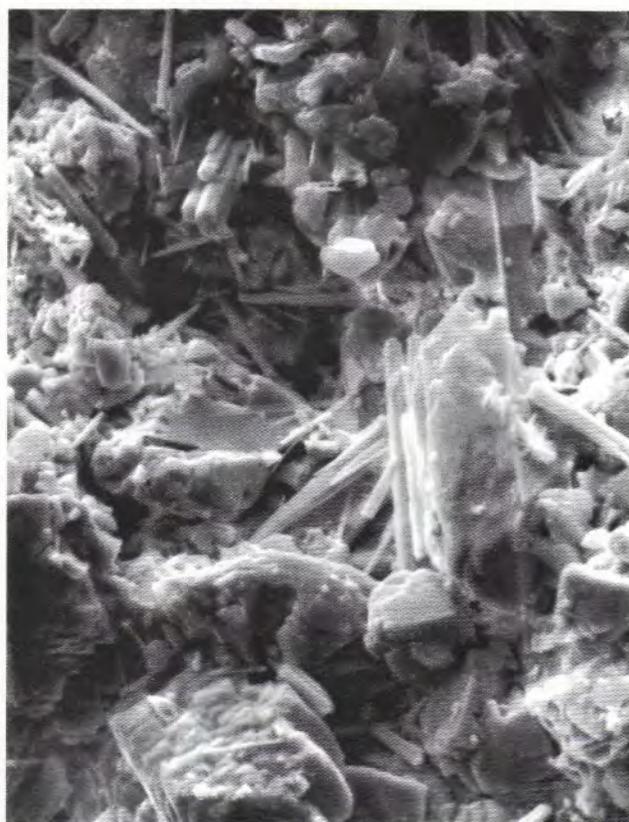


Figure 4. Subhedral to euhedral β -duftite (lower left) overlain by euhedral mimetite (center, top-left), Gravity Tram locality. Scale in μ m at lower right, secondary electron image.



Figure 5. Euhedral β -duftite on calcite, East Limb locality. Scale in μm at lower right, secondary electron image.

Galena PbS

Galena is the second-most abundant sulfide mineral at each locality, although it is more common at the Gravity Tram site. It is blue-grey to grey-black and exhibits typical cubic cleavage, readily visible to the naked eye. Some of the galena appears fresh and unaltered, but much is blackened and somewhat porous in appearance at grain margins. A little galena at the Gravity Tram site is coated by β -duftite.

Mimetite $\text{Pb}_5(\text{AsO}_4)_3\text{Cl}$

Mimetite occurs at the Gravity Tram locality, as sharp hexagonal prisms averaging about $30\ \mu\text{m}$ in length, which coat β -duftite. A few of the largest mimetite crystals are visible under the binocular microscope at $40\times$. They appear as minute white needles, but the hexagonal symmetry is not resolvable.

Tennantite $(\text{Cu,Fe})_{12}\text{As}_4\text{S}_{13}$

Tennantite is the most abundant sulfide at both localities. It occurs as grey to grey-black, finely granular aggregates, whose lack of cleavage readily distinguish them from galena. Much of the tennantite from both sites has a brassy to bronzy tarnish, perhaps from incipient alteration. A little from the Gravity Tram site has been replaced by covellite, and some from the East Limb locality is coated by β -duftite. Some tennantite at both sites has been replaced by malachite and azurite. The "SQ" semiquantitative chemical analyses of Table 2 suggest an approximate composition of $\text{Tn}_{95}\text{Tet}_5$ for tennantite from the Gravity Tram locality. At the East Limb site tennantite contains significant Zn and trace Sr.

It is not known whether Sr is contained within the mineral's crystal lattice or represents submicron inclusions of other phases. Tennantite was originally reported from an unspecified locality on the 900 Level of the Sterling mine by Palache (1935).

Unknown Minerals

BSE (back-scattered electron) fields of chips from the East Limb locality reveal the presence of two compounds with brightness level intermediate between tennantite and β -duftite. These two phases are present as scattered grains $5\text{--}10\ \mu\text{m}$ across. Brightness is homogenous for each, and EDS indicates that both contain Pb, Cu, Ca, and As; similar to β -duftite, but in different proportions. Neither compound contains S. In that BSE brightness is proportional to average atomic number, both phases probably contain a light element(s) undetected by EDS, such as oxygen. Both may therefore be intermediate arsenates in the alteration of tennantite to β -duftite. Grains of the two phases are too small and too sparse for characterization.

DISCUSSION

The β -duftite assemblage is somewhat different from the familiar Mn-Zn-Fe arsenate associations at Sterling Hill in that it is Cu and Pb dominant, with very little of the other metals. There are, however, some striking parallels among the assemblages. Component metals in the β -duftite paragenesis appear to have been locally derived from tennantite and galena. There is a strong wallrock control on the distribution of minerals in that both sulfides and secondary species are restricted to fractured marble within small areas. These features of Sterling Hill arsenates in general were first recorded by Parker and Troy (1982).

β -duftite and associated secondary minerals have developed via a two stage process: (1) oxidation of the sulfide minerals by water solutions, apparently circulating through the NW-striking fracture system, followed by (2) reprecipitation of new phases under the appropriate physical-chemical conditions. These phenomena have been understood in at least general terms for a number of years, a notable reference being Garrels and Christ (1965).

Sulfide oxidation reactions in general are not only favored by high oxidation state in solution, but result in the liberation of free acid (H_2SO_4), lowering solution pH. A typical pH value resulting from sulfide oxidation is in the range 2-4, generally closer to the higher figure (Anderson, 1982). Other conditions being equal, such as temperature, pressure, and the concentrations of ions in solution, pH has a profound influence on which mineral or assemblage of minerals will be deposited from solution. Keller (1977) showed that Tsumeb duftite (polymorph not specified) precipitated contemporaneously with some malachite and cerussite, probably close to solution neutrality at $\text{pH}=7$. Guillemin (1956) was able to synthesize a duftite at $\text{pH}=5\text{--}6$. Similar conditions probably prevailed at Sterling Hill.

Precipitation of β -duftite at Sterling Hill would have required some neutralization of the mineralizing solutions to raise pH, as it must have at Tsumeb. This could have been readily accomplished by reaction with the marble wallrocks along the host fractures. One may speculate that had tennantite and galena been hosted by ore, containing much less carbonate, oxidation and reprecipitation might have resulted in the deposition of entirely

Table 2.

TENNANTITE CHEMICAL ANALYSES									
("SQ" SEMIQUANTITATIVE)									
all values in wt.%									
	As	S	Sb	Cu	Zn	Fe	Sr	Total	χ^2
GT	19.3	26.2	5.2	45.7	3.6	—	—	100.0	1.95
EL	20.4	29.1	1.4	40.4	6.7	1.3	0.7	100.0	1.99

GT = Gravity Tram locality
EL = East Limb locality

Analyses normalized to 100%.
 χ^2 = Chi-square value (goodness-of-fit test for quality of analysis, ideal value is 1.00).
Reported values are the average of 2 analyses each for 3 spots.
Operating conditions: 25 kV, 200 seconds count time.

different secondary mineral assemblages, such as: brochantite + anglesite, conchalcite + anglesite, etc. These phases are stable at lower pH than duftite (Keller, 1977). Limited deposition of brochantite, anglesite, malachite, and azurite at the β -duftite localities probably reflects very local variations in pH or concentration of Cu^{+2} , AsO_4^{-3} , etc.

The origin of Sterling Hill β -duftite thus seems clear, but the timing of formation is less obvious. Parker and Troy (1982) suggested that secondary As-bearing compounds at Sterling Hill may have formed during several different periods, some perhaps during retrograde metamorphism. The latter is probably not the case here. Formation of minerals like the duftites is a low-temperature process, and the distribution of these minerals at Sterling Hill is controlled by fractures which postdate the metamorphism. Metsger (1990) attributed the presence of oxidized copper minerals adjacent to the Sterling Hill Mud Zone to deposition from oxidizing ground waters within the last 2-3 million years. This would seem a more likely time frame for the formation of the β -duftite assemblage.

The origin of the sulfide minerals, which are precursor to the β -duftite assemblage, bears brief discussion. Replacement contacts against calcite of the marble indicate that these minerals are also post-metamorphic. The occurrence of galena in the adjacent shear zone, in the footwall of the East Limb at the Gravity Tram site, may suggest furthermore that sulfide minerals were deposited by hydrothermal solutions circulating in and near the shear structure. Sulfide minerals would therefore have formed subsequent to shearing, but the timing of formation of the shear zone is unknown.

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RECENT MINERAL FINDS

FROM THE

STERLING MINE

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INTRODUCTION

The Sterling mine has been providing the world with beautiful crystals, fine fluorescent minerals and exotic species for well over one hundred years, and at times the fund appeared inexhaustible. However, when the mine ceased production on Good Friday, 1986, an era ended and the steady flow of minerals stopped. There followed a few bleak years, but when the Sterling Hill Mining Company was formed and began reopening the mine, hope was rekindled and specimens began to emerge once again. Many of these recent finds have yielded specimens of superb quality, and a few have surpassed all found previously. This article was written to preserve information on the location and occurrence of important mineral finds made since the reopening of the Sterling mine in 1989.

The finds are listed here by the level on which they were discovered. Levels are the locations of the "stops" or stations — up and down the shaft — at which extensive systems of drifts and manways have been developed. They are somewhat analogous to floors in a building, and at the Sterling mine they are generally spaced 100 feet apart. In instances where specimens were recovered from locations above or below these levels, vertical location information is referenced to the nearest level; *e.g.* "40 feet above the 600 Level." Many of the finds reported herein, however, were in fact made in the various drifts, manways and other passages on the levels themselves.

Since today there is no pumping operation to keep the ground water out, the Sterling mine is slowly flooding. This listing begins with the levels which were first flooded and follows the rising

waters upward. When exploration began in 1989, the water level was 50 feet below the 1300 Level. In the autumn of 1993 all underground levels are flooded; only the adit level remains accessible. This report begins with the 1200 Level and chronicles most of the important finds made on the levels from there up to the surface.

For ease of reference we use a level and letter notation to refer to each find. For example, "1200A" would be location "A" on the 1200 Level. These numbers have no other purpose or meaning. The locations are noted by letter alone on the simplified plan view level maps which accompany this article. These are based on maps drafted by the New Jersey Zinc Company (NJZ) and dated 1933 (map series 7-AA-1650). The maps shown here were traced directly from NJZ originals, which appear to have been added to over time. For example, in many places manways or stopes are shown to dead end — but then appear to continue on. Also, note that the Mud Zone was encountered on several levels although its position was only sketched in on the 430 Level map. In any case, it is apparent that for the levels reported on here much of the ore body was already located and development work well under way by the time these maps were drawn.

Where available, the date of find and additional location information is listed within the text below each find number. This information may include stope, crosscut or pillar numbers, and north and west coordinates. All of these are based on the NJZ coordinate system for the Sterling mine. Unless stated otherwise, references such as "south of..." or "east of..." employ NJZ directions, and are not based on true or compass directions.

1200 LEVEL

Magnussonite 1200A

November 11, 1989
 1020 Stope, 30' above the 1200 Level; 1075N,
 750W

Recent workers made a find of magnussonite while salvaging equipment at this location. It occurs massively, and fills seams generally 9 to 12 mm thick in normal gneissic ore. The magnussonite is predominantly brown with patches of green. This stope was unusual in that it was situated at the juncture of the West Limb and the East branch of the West Limb and thus contained portions of both legs of ore. This particular find was in the West Limb about halfway

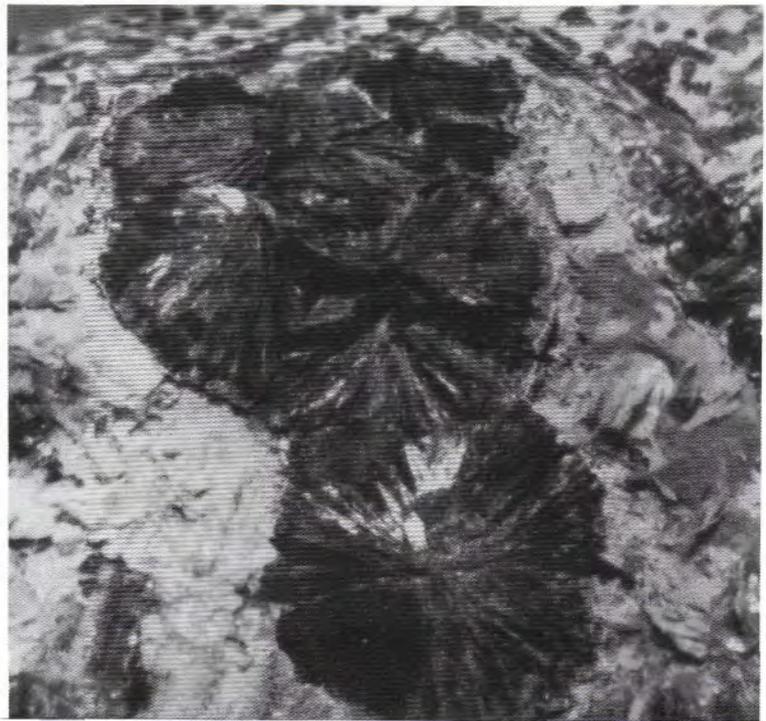
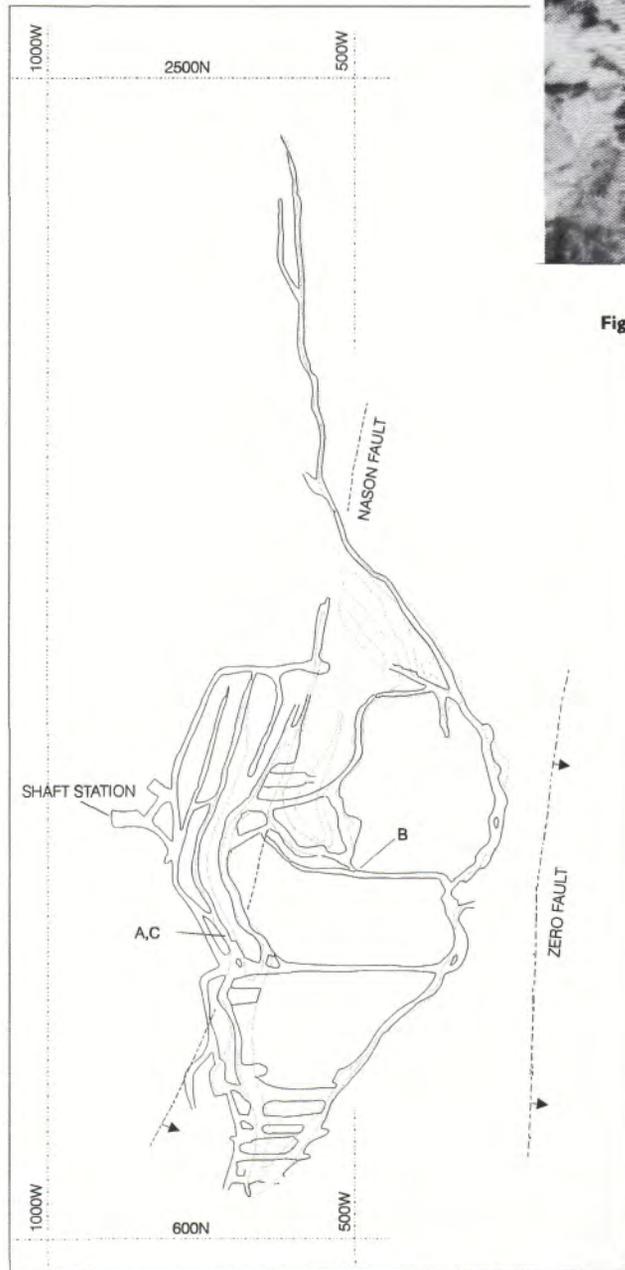


Figure 1. Megovernite rosettes (2 cm across), from find 900G, Sterling mine.



Simplified plan view of 1200 Level, Sterling mine. Outline of ore body is lightly dotted; workings appear as solid lines.

along the along the length of the working place in the footwall, and just beneath the zincite band. An earlier find of magnussonite was made in the same stope in 1983, farther up the plunge of the ore. The earlier find was characterized by thicker veins which occasionally contain euhedral crystals of zincite and an unidentified foliated mineral. This recent find is 50 feet below and 40 feet north of the 1983 discovery.

Fluorapophyllite 1200B

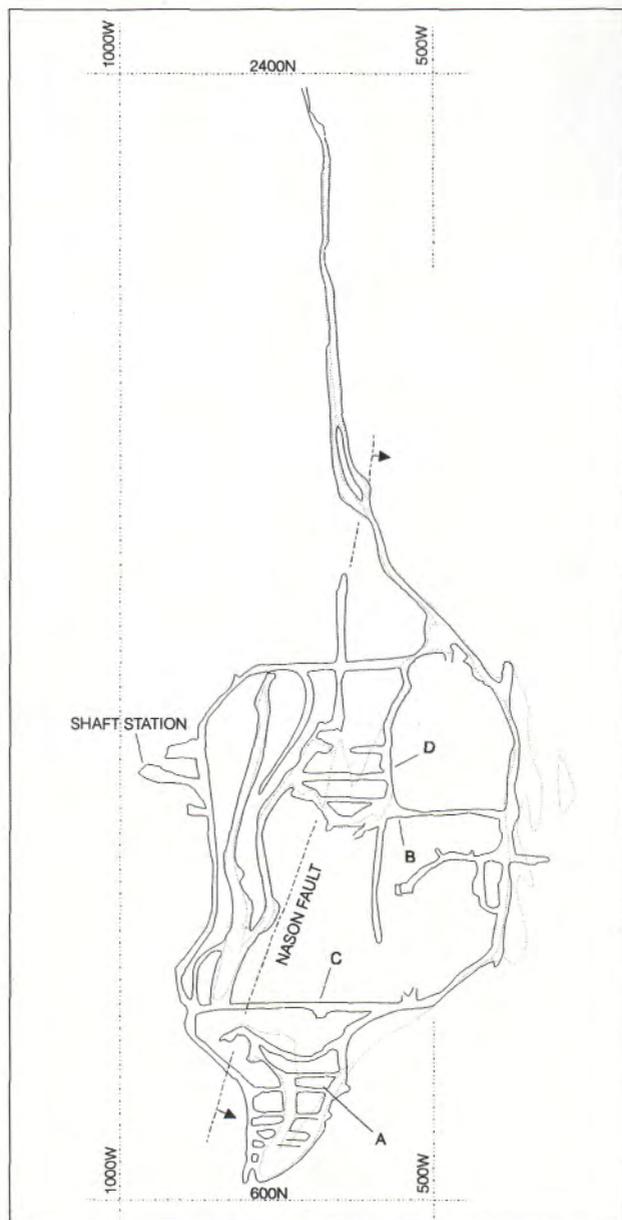
Worked from December 4, 1989 to January 4, 1990
 1200 Crosscut, 470W

At this location a series of cavities was found in gneiss within the mine's central core. These contain pink euhedral octahedra of fluorite up to 2.5 cm on an edge with water clear apophyllite and sparse heulandites of typical habit. The cavities appear to have formed by dissolution of a mineral in the enclosing gneiss. Translucent yellow or dark brown 2-10 mm crystals of sphalerite were also found occasionally.

Franklinite 1200C

January 22, 1990
 1020 Stope 1090N, 790W

Small (up to 5 mm) crystals of euhedral franklinite were recovered from a shear zone about 12 feet north of the magnussonite locality 1200A. The matrix is typical gneissic willemite/franklinite ore, and the crystals are highly distorted.



Simplified plan view of 1100 Level, Sterling mine. Outline of ore body is lightly dotted; workings appear as solid lines.

1100 LEVEL

Gypsum, Brochantite 1100A

January, 1990
780 Pillar; 670W, 780N

The 780 Pillar is the location for the major find of selenite gypsum at the Sterling mine. This find provided masses up to 16.5 cm across. Some of these contain 1-2 mm tufts of brochantite crystals. The gypsum occurs in a series of solution cavities within lean franklinite ore in the footwall of the East Limb. The lower portions of these pockets are filled to about one-third of their volume with massive transparent selenite. Similar features were encountered just north of the keel on levels ranging from the 1400 Level to the 700 Level.



Figure 2. Stilbite, from find 900F, Sterling mine. Specimen width 9 cm.

Arsenic-bearing minerals 1100B

February 1990
1220 Crosscut, 540W

Realgar, rediscovered during the last years of commercial mining, was found here in minor quantities in marble in the hanging wall of the black ore of the Crossmember. It was found in greater amounts on the 900 Level (see 900B) and on the 800 Level (see 800B). At this find 2-3 mm specks of realgar and arsenopyrite are present.

Wollastonite 1100C

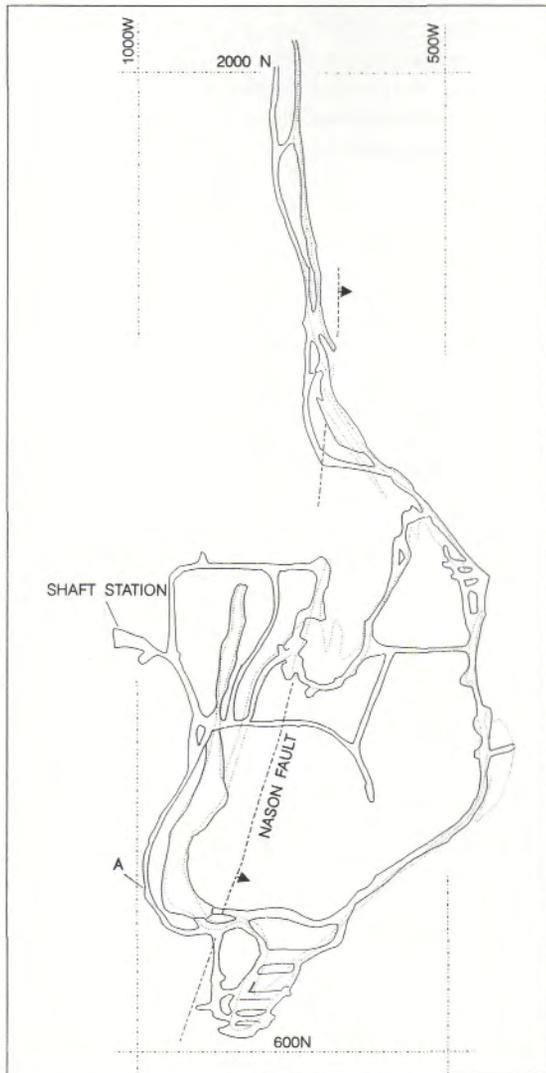
February 1990
900 Crosscut, 700W

A minor find of wollastonite was made here. It fluoresces a weak pale pink under shortwave ultraviolet radiation — a somewhat disappointing response for Sterling Hill wollastonite. This find was the trickle that presaged the torrent, however, for brightly fluorescent wollastonite was later found abundantly at several localities within the mine (see 340A).

Erythrite 1100D

January 1990
1300 Pillar, 540W

Erythrite was found here in the gouge of the Nason Fault in the hanging wall of the black willemite ore of the Crossmember. Erythrite was discovered at several places in the mine in the same relative positions within the ore body. In addition, this cobalt mineral has been found in a few gneiss blocks at the core of the Sterling Hill ore body. In all these places it occurs as aggregations of vivid pink acicular crystals. These spherules of crystals range from 0.5 to 1.0 mm in diameter.



Simplified plan view of 1000 Level, Sterling mine. Outline of ore body is lightly dotted; workings appear as solid lines.

1000 LEVEL

Fluorite

1000A

June 1990
890N, 950W

Exploration along the footwall drift of the West Limb disclosed an occurrence of fluorite. The find is typical of this species' marble paragenesis: in daylight the mineral is indistinguishable from the white marble, but under shortwave ultraviolet radiation it fluoresces moderately bright yellow white, while the rock does not respond at all. Associated minerals include graphite, norbergite/chondrodite, spinel, and phlogopite. A similar find was made at 900A.



Figure 3. Frankinite crystal, from find 700F, Sterling mine. Crystal face 6 cm across.

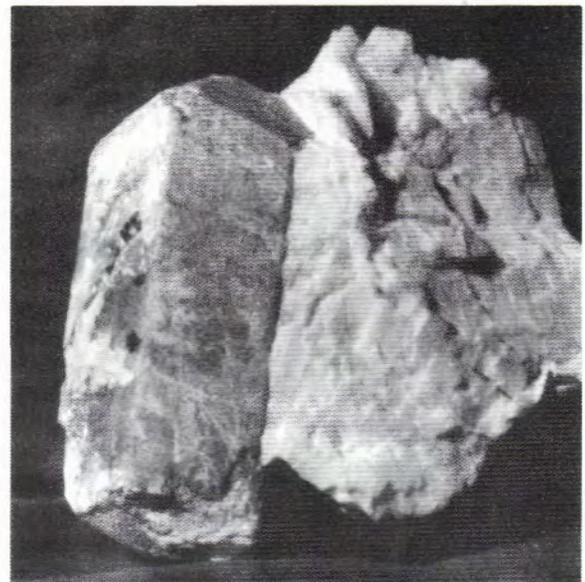
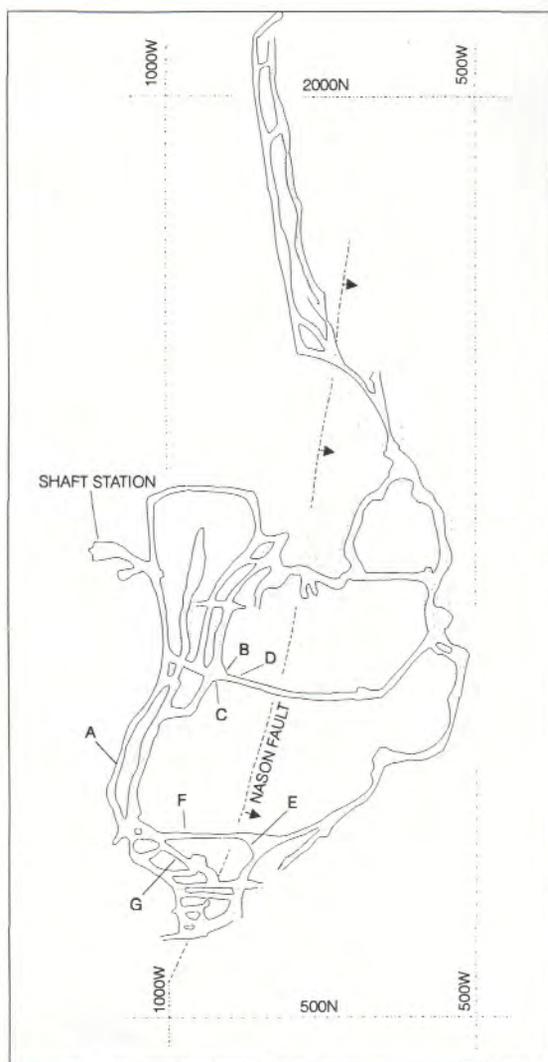


Figure 4. Willemite crystal, from find 430A, Sterling mine. Crystal 7 cm in length.



Simplified plan view of 900 Level, Sterling mine. Outline of ore body is lightly dotted; workings appear as solid lines.

900 LEVEL

Fluorborite 900A
 July 1990
 900N, 1090W
 This find is entirely comparable to 1000A.

Arsenic-bearing minerals 900B
 July 21, 1990
 1050N, 880W

A significant discovery of an arsenic-bearing assemblage in medium-grained marble was made here. Specimens were abundant, well-developed and frequently showy. The first find was located in the hanging wall of the East branch of the West Limb. Spectacularly rich blood-red realgar, silvery-gray masses of zinkenite (up to 8.1 cm in size) and rarely, in sparse vugs, minute gray spheres of native arsenic are present. In addition, crystals of arsenopyrite up to 4.0 cm long in marble were collected. The arsenic minerals occur adjacent to quartz-rich boudins.

Erythrite 900C
 July 1990
 (near 900B)

Erythrite was found in the hanging wall of the East branch of the West Limb, just a few feet below the arsenic-bearing minerals listed in 900B. Here a block of green gneiss is the matrix for numerous pink-crimson rosettes and spherules of crystals deposited on fracture surfaces.

Wollastonite 900D
 July 1990
 (adjacent to 900B)

Also in close proximity to the arsenic minerals of 900B is a band rich in weakly fluorescing wollastonite. Some occurs as elongated blades, up to 7 cm long and 1 cm across, with a diamond-shaped cross section. These blades are embedded in white plagioclase feldspar.

Barite 900E
 August 25, 1990
 780N, 870W

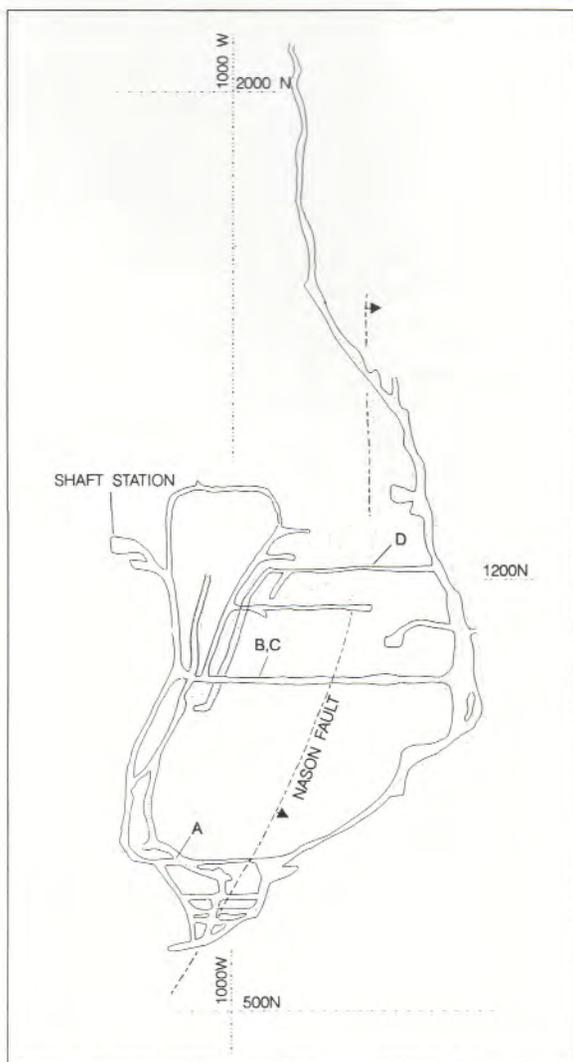
Barite is found in related occurrences within the Franklinite Zone on levels ranging from 900 to 340. Many specimens from these finds are very similar in appearance. The barite occurs as grains up to 2 cm across in calcite. Locally they are thickly disseminated; interlocking grains form masses several centimeters across. Under shortwave ultraviolet radiation the barite fluoresces bright cream to bluish-white, and the enclosing calcite vivid red, usually of moderate intensity. The number of specimens recovered at each level was highly variable; the find at 700B was the largest. The fluorescent response also varied, some of the 600 Level barite is probably the brightest. In some places, such as that on 600 Level, the barite concentrations formed elongate, flattened tube-like pods 7.5-10.0 cm in width and up to two meters long.

Zeolites 900F
 July 25, 1990
 800 Level Crosscut, 960W

At this location irregularly-shaped solution cavities, 2.5 to 3.0 cm across, occur in gneiss blocks of the central core. Calcite, present in the gneiss, appears to have been etched out by a natural corrosive agent thus forming the cavities. They contain fine, yellow-brown groups of stilbite crystals in fair abundance (Fig. 2). Some of the crystals are as much as 1.5 cm in length. A few of the vugs contain dark green pyroxene crystals, many of them covered by stilbite sprays, minor natrolite and (characteristically) rhomb-shaped amber chabazite euhedra. Some of the latter fluoresce, responding pale green under shortwave ultraviolet radiation.

Mcgovernite 900G
 July 25, 1990
 780 Pillar, 980W

Lastly on our list of 900 Level finds, but certainly not least, is an exceptional find of mcgovernite. This is located in the West Limb and in the keel pillar. Superb rosettes of bright golden mcgovernite were found in fractures cutting salt-and-pepper ore. This species is known only from the Sterling mine's keel and West Limb. Some of the pieces recovered rival — if not exceed — the finest found in earlier years. The best pieces removed have several 2.0-2.5 cm golden rosettes strewn across thin fractures in ore (Fig. 1). On one specimen, boxworks of pink rhodochrosite accompany the mcgovernite.



Simplified plan view of **800 Level**, Sterling mine. Outline of ore body is lightly dotted; workings appear as solid lines.

800 LEVEL

Mcgovernite 800A

August 1990
740 Crosscut, 1080 W

The mcgovernite find at this location is less spectacular than that of 900G. Here it occurs mostly as scattered flakes and, less frequently, as 1.0 cm rosettes.

Arsenic-bearing minerals 800B

September 1990
1040 Crosscut, 980W

A find of zinkenite and a minor find of realgar was made here. In contrast to 900B, the quartz-rich boudins here contain the arsenic minerals. Often seen in specimens from 800B are fine black needles embedded in grains of quartz, which closely resembles classic stibnite. These needles are zinkenite. An earlier report of stibnite may have been a mistake for zinkenite. However, genuine stibnite is found here as a rare member of this assemblage. Orange patches of realgar several cm across are also present in quartz at this location.

Wollastonite 800C

September 1990
1040 Crosscut, 960W (adjacent to 800B)

A rather undistinguished find of barely fluorescent wollastonite was made here. The spatial relation of this find to the minerals of 800B strongly recalls that between 900B and 900D. Note that this area is in the hanging wall of the East branch of the West Limb rather than near the Franklinite Zone; *i.e.* where the wollastonite is often showy orange and yellow under shortwave ultraviolet radiation.

Norbergite 800D

October 1990
1220 Crosscut, 760W

Norbergite in yellow to green grains 2.5-5.0 cm in diameter was found here. The norbergite occurs in the marble near the hanging wall contact of the black willemite ore in the eastern portion of the Crossmember. Larger masses of norbergite are typically green, grading smoothly into the more common yellow.

700 LEVEL

Wollastonite 700A

November 6, 1990
740 Crosscut, 980W

If one were to proceed eastward along the crosscut on the 800 Level, and climb the raise there to the 700 Level above, a number of nice mineral occurrences in the southern end of the ore body could be reached. This portion of the workings was inaccessible from the shaft station on the 700 Level itself by the time the mine was reopened. The wollastonite from this find fluoresces a bright, pleasant yellow under shortwave ultraviolet radiation. In places near the ore the calcite fluoresces red and the wollastonite orange. The grains (7-8 mm across) are generally rather thin disseminated in non-fluorescent calcite, but rarely thicker concentrations provide quite colorful fluorescent specimens.

Barite 700B

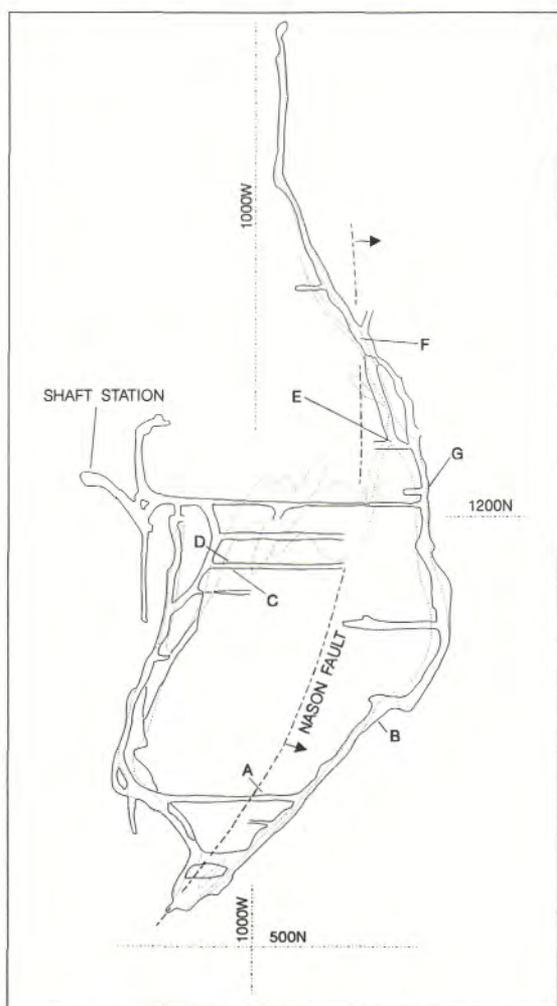
November 9, 1990
879N, 820W

This was one of the best and most abundant finds of fluorescent barite. A layer of barite 2.5 cm in thickness is present in calcite and is, as usual, concordant with the gneissic banding of the enclosing Franklinite Zone. These specimens frequently break along the barite layer and many beautiful, flat pieces of cream fluorescent barite and vivid red fluorescent calcite were recovered. The largest of these, an impressive slab measuring 96 x 60 cm, is on display at the Sterling Hill Mining Museum. The majority of specimens contain barite grains (8-9 mm across) which provide 30% of the surface area with cream fluorescence. The remaining surface is typically comprised of red fluorescent calcite and sparse franklinite.

Black tourmaline 700C

January 1991
1120 Crosscut, 1030W

Elongate, lustrous striated black blades of tourmaline were found at this location. Some crystals are 3.5-4.0 cm in length. This spot was accessible from the shaft station and is in the hanging wall of the East branch of the West Limb. The location is in the gneiss zone at Sterling's core, and the tourmaline was in a late



Simplified plan view of 700 Level, Sterling mine. Outline of ore body is lightly dotted; workings appear as solid lines.

stage vein composed mostly of quartz and feldspar crosscutting a gneiss block.

Rhodonite, Gahnite 700D

January 1991
1130N, 1040W

Intergrowths of massive rhodonite and gahnite are present here in large quantities. The find was made in the hanging wall of the East branch of the West Limb just above the mined-out 1010 Stope.

Rhodonite 700E

Spring 1991
1320N, 780W

At this location there is a shear zone in the footwall of the East Limb parallel to the contact with the brown willemite of the eastern Crossmember. Lenticular bodies of calcite several cm in length were found here. Upon dissolution of this calcite in dilute HCl, remarkably beautiful three-dimensional "curtains" and delicate box-works of rhodonite are revealed. These curving pink sheets are up to 1 cm across.

Franklinite crystals 700F

1989-1991
1250 Stope 50' below 700 Level; 1450N, 800W

An elongate pod of calcite was found here in an open, recently worked stope (1250 Stope). It was found near the stope's footwall and in the East Limb. The pod is approximately 7 meters long, and is oriented roughly north-south. Within it are numerous sharp octahedra of franklinite, ranging from 0.9 to as much as 10 cm on an edge (Fig. 3). Over time this location provided many exceptionally fine specimens.

Copper sulfides 700G

August 8, 1990
1250 Stope 70' below the 700 Level; 1245N, 710W

Also in the 1250 Stope, at its southern end, workers encountered a curious assemblage of copper sulfides. Some are fracture-related minerals and may have come from a shear present near the ore. They are in close proximity to the worked-out 935 Stope. Most of the copper sulfides appear unaltered, but there is some evidence of oxidation in the local abundance of secondary species. A large number of minerals are present. The copper minerals occupy a one meter segment of the shear zone in the hanging wall of the 1250 Stope. This unusual occurrence, and the identity of the species present, is under study by Dr. Robert E. Jenkins II.

600 LEVEL

Barite 600A

April 15, 1991
700 Crosscut, 1150W

Barite was found on the 600 Level in the same relative position as on the other levels, *i.e.* in the Franklinite Zone of the East Limb. Here the barite bearing mass has the form of a tube-shaped pod, and is about 12.5 cm thick and 2 meters long. This barite fluoresces the brightest of any barite from Sterling Hill, and the calcite responds to shortwave ultraviolet radiation with a moderately bright red color.

Wollastonite 600B

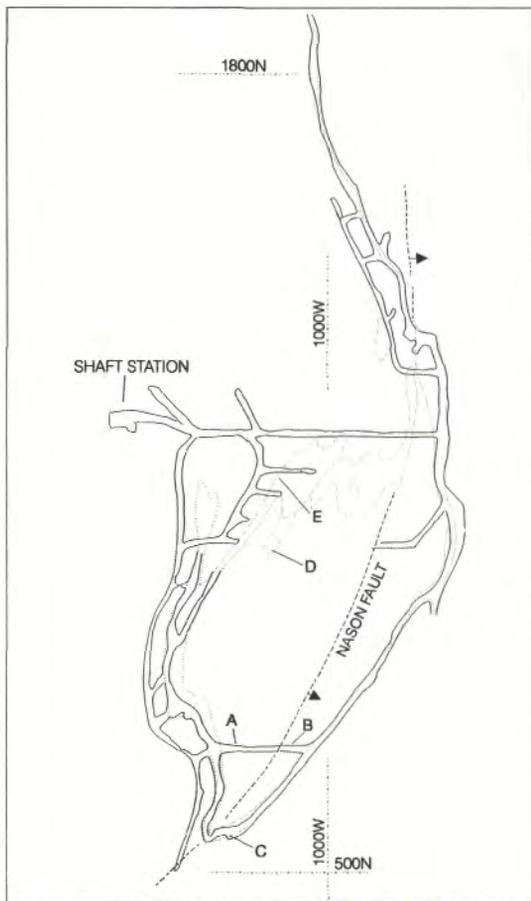
April 16, 1991
700 Crosscut, 1075W

Just east of the Nason fault on this level a shear cuts through the gneissic core of the Sterling ore body and fluorescent wollastonite was found. The fluorescent response of most of the wollastonite is orange. Most specimens contain moderately abundant grains (4-5 mm across) of wollastonite in calcite matrix. Three pieces, however, were found that exceed any other Sterling material in the beauty of their fluorescent response. They are masses 20-25 cm across comprised of interlocking grains as much as 2.5 cm in size. They fluoresce a brilliant orange and some of the larger grains have yellow fluorescent cores. At the periphery of the compact masses the wollastonite is thinly disseminated in calcite, and also yields attractive specimens.

Apatite, Zircon, Mica 600C

May 1991
560N, 1170W

On the 600 Level a drift in the ore was driven north from the keel to meet a drift from the East Limb headed south. The two met, but at different elevations, so there is a one meter step-up in the floor of the drift there. For some years while the mine was in commercial operation this location was known for nice 0.5-2.5 cm



Simplified plan view of 600 Level, Sterling mine. Outline of ore body is lightly dotted; workings appear as solid lines.

dodecahedral franklinite crystals. When the recovery crew revisited the spot in 1991 few franklinite crystals were found, but several other species were recovered. These include yellow fluorescent apatite, whose appearance in visible light is a pale, washed-out green. There were also typical garnet crystals, black mica and zircon. The latter occurs as 0.5-1.0 mm long stout prisms with a moderate yellow fluorescence. Another rarer associated mineral is barite in large grains (2 cm) which fluoresce blue-cream under shortwave ultraviolet.

Hemimorphite 600D

May 1991
1000N, 1020W

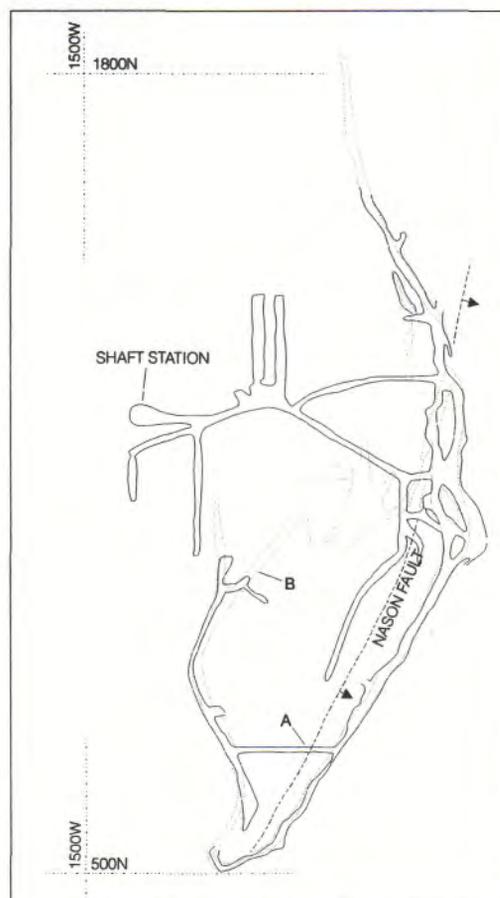
The Mud Zone, which bottoms out approximately 600 feet below the surface, is well developed on this level. This find was located in the marble of the hanging wall of the mud. Here a solution surface was encountered which resembled calcite that had been attacked by acid. Directly below this was a 10-cm-thick seam of mud cemented by 0.5 cm layers of hemimorphite crystals. Also in the mud, adjacent to where the zone approaches the Crossmember, hemimorphite occurs as small spherules (2.5 cm across) of crystals.

Sphalerite, Covellite 600E

April 25, 1991
1140 Pillar, 1060W

Sphalerite, yellow in color, was found here in pods up to 13 cm in width and more than two meters in length within layered ore. The pods are concordant with the gneissic banding of the ore.

These were in the footwall of the East branch of the West Limb, near the 1440 Pillar's north end. In places the sphalerite was intergrown with, and possibly partially replaced by, covellite. This mixture has the cleavage of sphalerite, but is metallic blue. The pure sphalerite has a moderate orange fluorescence under longwave ultraviolet radiation, but blue (mixed) specimens respond only slightly if at all. It is worthy of note that there seems to be a persistent trend of sulfide mineralization in this section of the ore body ranging from the 1680 Level to 180 Level, up and down the plunge relative to 600E. Secondary copper minerals present near the Mud Zone on the 340 Level may also be related.



Simplified plan view of 500 Level, Sterling mine. Outline of ore body is lightly dotted; workings appear as solid lines.

500 LEVEL

Wollastonite 500A

July 2, 1991
700 Crosscut, 1130W

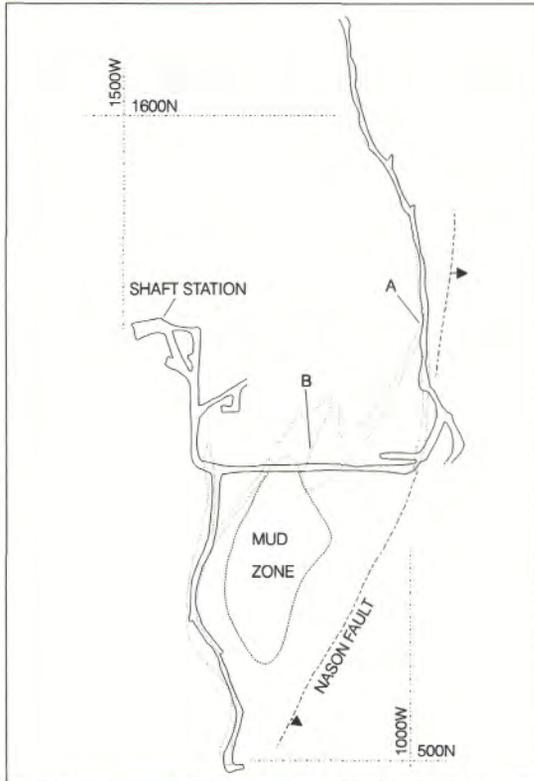
At this location a 7-8 cm thick layer of wollastonite disseminated in calcite was found. None was removed. The location is in the same general position within the ore body that provided most of the more notable finds of wollastonite; *i.e.* in the footwall of the East Limb near the contact with the gneiss zone and the central core of graphitic marble. Some specimens, usually from nearer the ore, contain orange fluorescent wollastonite in red fluorescent calcite (under shortwave ultraviolet radiation). More commonly the wollastonite responds yellow and the calcite weak red or not at all.

Chalcophanite

500B

March 16, 1991
1000N, 1210W

An extremely curious find of chalcophanite was made here in an area adjacent to the Mud Zone. This find was in the 1010 Stope and in the East branch of the West Limb. Here the hanging wall of the ore appeared altered and resembled, in part, the Mud Zone. Large, soft dark brown rosettes and fans of chalcophanite were found. Fibers of the mineral have a slight coppery cast. The dark rosettes reach 2.0 cm in diameter and fan-shaped crystal aggregates are as much as 4.0 cm in length. Their resemblance to todorokite is strong.



Simplified plan view of 430 Level, Sterling mine. Outline of ore body is lightly dotted; workings appear as solid lines.

430 LEVEL

In reviewing finds from the 430 Level it should be noted that large quantities of calcite and willemite with a vivid red and green fluorescence were removed from this level and brought to a new dump on the surface for collectors. Due to lack of accessible exposures on this level, no barite or wollastonite was recovered.

Willemite

430A

March 20, 1991
1340N, 980W

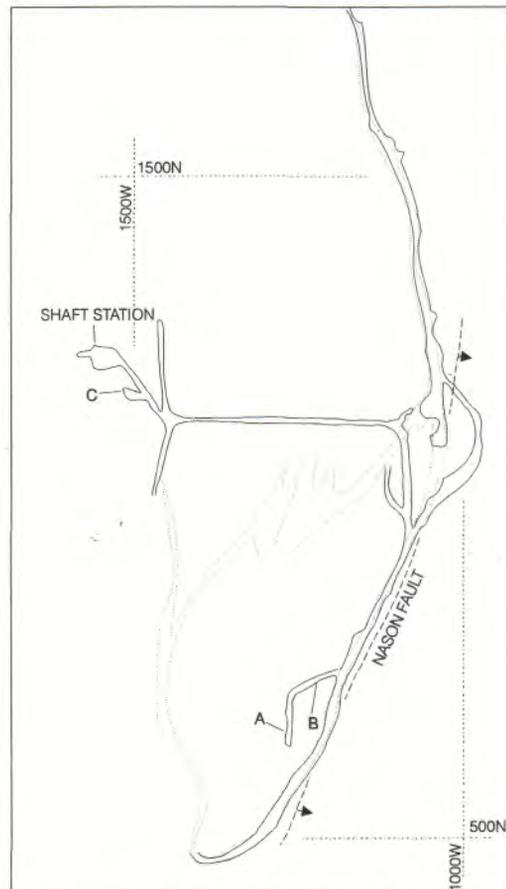
Abundant prismatic red willemite crystals up to 10 cm in length were found in a calcite pod 1 meter wide and 10 meters long. The calcite body was located in a pillar beneath the old Pierce shaft in the East Limb. Many of the willemite crystals are nicely terminated and a pleasing pale red color (Fig. 4). A few franklinite octahedra and massive zincite "spots" accompany them. The calcite body pinched out upwards, limiting the number of crystals recovered.

Arseniosiderite

430B

August 8, 1991
1020 Crosscut, 1020 Pillar, 1160W

Although reported by Palache in Professional Paper 180, this earlier "arseniosiderite" has since been described as bostwickite, and an authentic find of arseniosiderite from the district waited until the early 1980's to be confirmed. It was discovered then in the 1020 Pillar on 430 Level at the Sterling mine. Arseniosiderite occurs here as thin, shiny brown flakes covering fracture surfaces up to 30 cm across on black ore. This discovery was at the contact of the red and black ores of the Crossmember in the south side of the pillar. Arseniosiderite was encountered in abundance during the driving of the crosscut here in the early 1980's.



Simplified plan view of 340 Level, Sterling mine. Outline of ore body is lightly dotted; workings appear as solid lines.

340 LEVEL**Wollastonite**

340A

First widespread knowledge of this location arose during the mid 1970s.
640N, 1272W

An excellent find of fluorescent wollastonite was made here almost 20 years ago by staff of the New Jersey Zinc Company. As seen on their map, it came from the same general region of the ore body as other good fluorescent wollastonite. While most is fluorescent bright yellow and associated with non-fluorescent calcite, some occurs in orange fluorescing 3-4 mm grains embedded in pale red fluorescing calcite.

Realgar, Guerinite 340B

First located in 1979
740N, 1220W

As a minor note, guerinite was found as a white efflorescence on the rib of a drift near the footwall of the East Limb. It is a post-mining growth and probably developed from arsenopyrite or other primary arsenic minerals. It occurs in crusts and sprays of tabular white microcrystals.

Corundum assemblage 340C

August 8, 1991
1180N, 1515W

Following tales of old-timers, recent investigators searched the motor shanty on the 340 Level for traces of what had long ago been the most abundant corundum occurrence in the mine. These stories recount the discovery of purple corundum in crystals and grains 0.3-1.0 cm long, granular feldspar, green plates of margarite 0.5-1.5 cm across, and fine silvery euhedral arsenopyrite crystals up to 1.0 cm long. The minerals were found in normal Franklin Marble in the room where mine locomotives recharged their batteries at night: the motor shanty. In 1991 investigators had to dig a pit in order to reach the solid rock floor of the charging station. It was one meter deep, but the effort was rewarded by the discovery of the tail end of the corundum pocket. Two five-gallon buckets of material typical of this assemblage were recovered.

180 LEVEL

Chromium muscovite 180A

September 23, 1991
920 Crosscut; 917N, 1500W

Bright green chromium muscovite was found in a boudin of silicates within marble host-rock in the footwall of the East branch of the West Limb near its northern termination. The boudin is one of several in the footwall at this location, and all contain plagioclase, quartz and muscovite. Only one boudin, however, was found to contain green muscovite; others examined contain only brown mica. Flakes and books of both brown and green mica are up to 2.0 cm across.

Diopside 180B

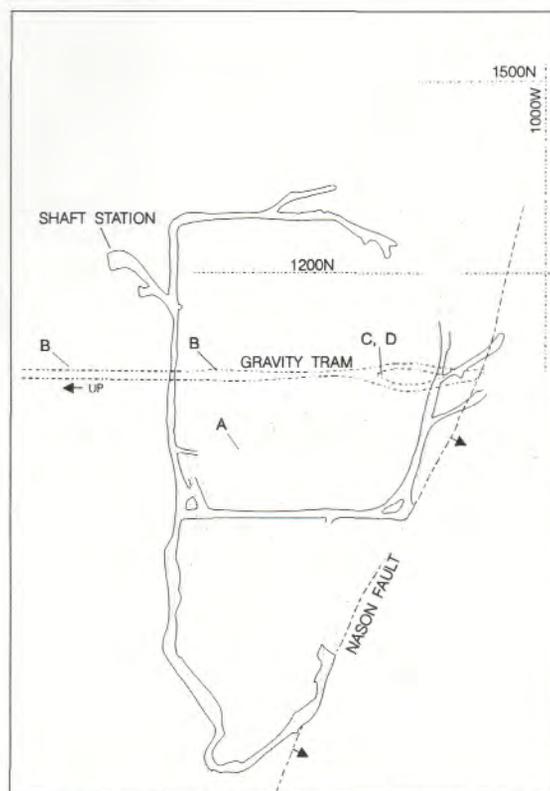
October 3, 1991
1040N, 1550W and 1750W

An inclined tunnel called the Gravity Tram was driven from near the top of the mine at a surface fill quarry called the "glory hole," down through the marble eastward and through both limbs of the ore body to a point below the 180 Level. Locations in this tramway are mentioned here because the 180 Level is the nearest modern working level. Two finds of fluorescent diopside in non-fluorescent marble were made here. The higher, western-most find yielded fine cream to pale blue fluorescent diopside in granular masses 2.0 cm across. Diopside at the lower, 1550W location responds to shortwave ultraviolet radiation with an electric blue fluorescence.

Powellite, Uraninite 180C

November 21, 1991
1040N near 1270W

Of the many marble-hosted calcsilicate bodies present in the Gravity Tram, at this location one provided 1.5-2 cm grains of



Simplified plan view of 180 Level, Sterling mine. Outline of ore body is lightly dotted; workings appear as solid lines.

yellow fluorescent powellite. Here the calcsilicate matrix is comprised of smoky quartz, calcite and a dark green amphibole. Also, uraninite is present at this find as minute inclusions.

SURFACE

Adit level 130N, 1700W

During the driving of the drift known as the Rainbow Tunnel, some very nice specimens of pale yellow fluorescing norbergite/chondrodite and blue fluorescent diopside were found in marble.

ACKNOWLEDGMENTS

It is appropriate to mention here the indispensable help of Messrs. Richard and Robert Hauck for their permission to write this article and for their tireless effort to establish and maintain the mine and the museum.

Very important also was the assistance of the editor and the editorial board, for drafting all of the maps used and making many worthwhile comments on this article, and John Cianciulli for computer assistance.



THE FLUORESCENCE OF BARYLITE

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INTRODUCTION

Barylite, $\text{BaBe}_2\text{Si}_2\text{O}_7$, is included in most lists of fluorescent minerals from Franklin. It was originally reported by Palache and Bauer (1930) to have vivid blue fluorescence. However, much confusion has subsequently arisen among collectors who have tried to identify barylite on that basis. There are numerous specimens from Franklin labeled barylite which fluoresce vivid blue under the filtered mercury vapor shortwave ultraviolet lamps in use now and since the 1930's. Most of these specimens are margarosanite. Authentic barylite has little apparent fluorescence unless it is seen as Palache and Bauer saw it; *i.e.* under the iron arc, also called the iron spark or iron-arc spark-gap.

Clarification of this problem requires a brief examination of the history of fluorescent minerals and ultraviolet energy sources in general and at Franklin; a description of barylite's occurrence, chemistry, and appearance; documentation of barylite's actual fluorescence; and a discussion of its perceived fluorescence under different sources of ultraviolet light. It is hoped that as a result collectors will be able to more accurately evaluate the status of "barylite" specimens in their possession.

A BRIEF HISTORY OF MINERAL FLUORESCENCE AND ULTRAVIOLET LIGHT SOURCES

Human beings have always been fascinated by the unusual and distinctive properties of gemstones and other minerals, and human awareness of mineral luminescence probably dates back thousands of years. Much of the foundation of modern science was laid down by medieval alchemists, and among their work on "fossils" (a term embracing not only petrified animal remains but also minerals, gems, stone axes, etc.) are observations about the phosphorescence of "Bologna stone" (calcined barite), precious stones, and other materials. Robert Boyle, an early physicist and chemist, published the first scientific study of a fluorescent mineral in 1663; his subject was the phosphorescence of diamond.

In the eighteenth and nineteenth centuries researchers in the physical sciences were well aware that when sunlight was passed through a prism, not only was it split into the colors of the rainbow, but also there were invisible rays below the red (*infra* red) and beyond the violet (*ultra* violet). One way of determining the properties of these rays was to direct them at various form of matter, including minerals. Sir George Stokes was the first to deduce that the glow given off by minerals such as fluorite when

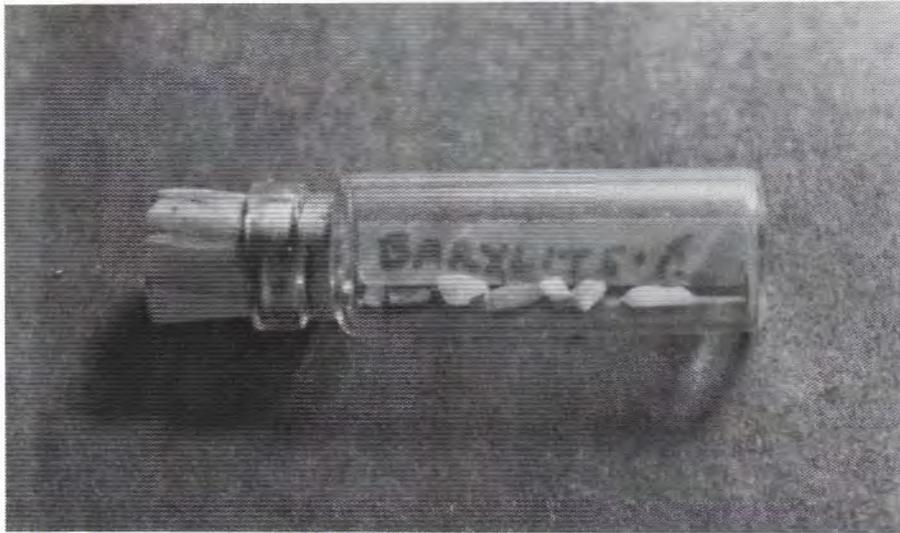


Figure 1. Vial of barylite fragments etched from matrix by Lawson Bauer. Bauer label. Collection of RCB, specimen RCB101. Length 4.2 cm.

irradiated by certain wavelengths of visible and ultraviolet energy was in fact emitted light, not the “internal dispersion” of light such as one sees in opals or shallow sea water. To describe this emission of light, in 1852 he coined the word “fluorescence” after the phenomenon seen in fluor spar (fluorite), in analogy with the term “opalescence” as applied to opal.

It was also discovered that if light was passed through a prism it could reveal much about the elemental composition of the light source. For example, the element helium was discovered in 1868 through study of the spectrum of sunlight. Electric arcs between electrodes of different metals were similarly studied, and were known to yield different spectra characteristic of those metals. The emission spectrum of iron (experienced firsthand by anyone who has stared at a welder’s arc) is noted for the large amount of ultraviolet light it includes. Consequently, iron electrode arc/spark devices were developed expressly for the production of ultraviolet light.

Research into the effects of invisible rays was much accelerated in the late nineteenth century by the discoveries of new regions of invisible energy: “Roentgen rays,” also known as X-rays, in 1895, and radioactivity in 1896. The early source of X-rays was the Crooke’s tube, similar to the tubes still used in medical X-ray units. Many Crooke’s tubes were immediately built for scientific use. By 1896 papers were published noting the effects of X-rays on gemstones, among other things. For a source of radioactivity scientists generally obtained vials of radium compounds from the Curie Institute in Paris.

The best-known early study of mineral fluorescence is that of Dr. George Kunz and Professor Charles Baskerville, who in 1903 reported their examination of the gem and mineral collections at the American Museum of Natural History under X-rays, ultraviolet light, and radioactivity (Kunz and Baskerville, 1903). The two mounted a Crooke’s tube and a Piffard lamp (an early iron arc) on rollers, with 200 feet of electrical cable attached. Armed with this apparatus and a vial of radium bromide they walked through the collections from case to case, taking notes as they went. Hyalite

opal, wernerite, hydrozincite, fluorite, and other now-familiar fluorescent minerals caught their attention, but they seem to have been especially fascinated by willemite and calcite from Franklin, New Jersey:

“The calcite from Franklin, N. J., showed a distinct red glow with the ultra-violet rays. This mineral, as well as the associated willemite, showed very marked peculiarities of color, the willemite green and yellow-green, the calcite a red glow. These effects were so characteristic that it required but a moment to identify specimens in various parts of the collection as being from Franklin, N.J.”

At Franklin, mineral fluorescence is reputed to have been first noticed around the turn of the century, when the Franklin mine and mill were electrified with direct current. The details of this discovery do not appear to have been recorded, but it is believed that sparks from electrical motors or broken electrical contacts caused observable fluorescence in nearby willemite.

Around 1910 the Franklin mill and mine were converted to alternating current. Mine management, conscious of the potential of mineral fluorescence as an ore-dressing technique, asked the General Electric Company to develop a convenient, portable iron arc source which could be operated on that source of power. GE complied, and designed and marketed such a unit (Fig. 2) about 1915 (Andrews, 1916). A brief description of the GE Ultra Violet Radiation Generator, as given by Andrews, follows:

“This outfit comprises: 1. A small transformer that steps up 60-cycle, 110-120 volt alternating current to about 4000 volts. 2. A suitable condenser. 3. An adjustable spark gap with removable iron terminals, the whole being protected in a chamber of insulating material. 4. Sundry fittings with connecting cords and plugs, etc. All

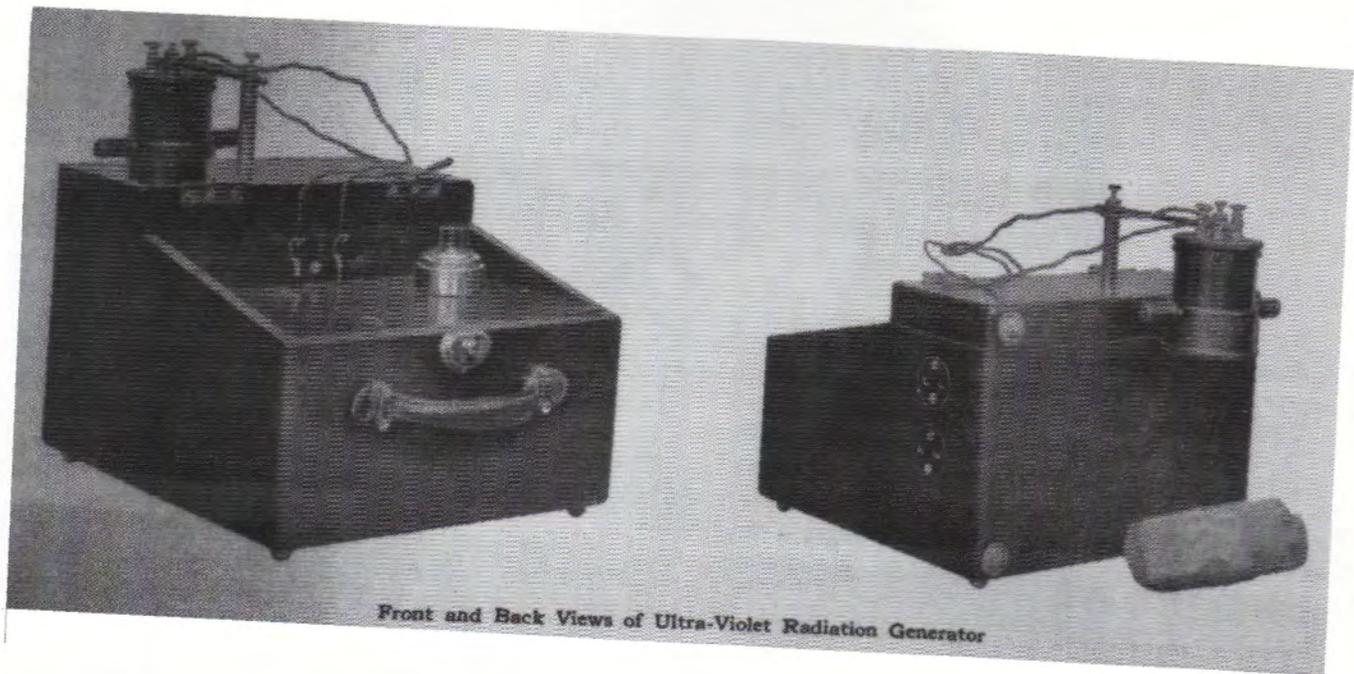


Figure 2. Portable iron arc unit manufactured by the General Electric Company.



Figure 3. Franklin mill worker viewing fluorescent response of ore concentrate using an early iron arc unit.

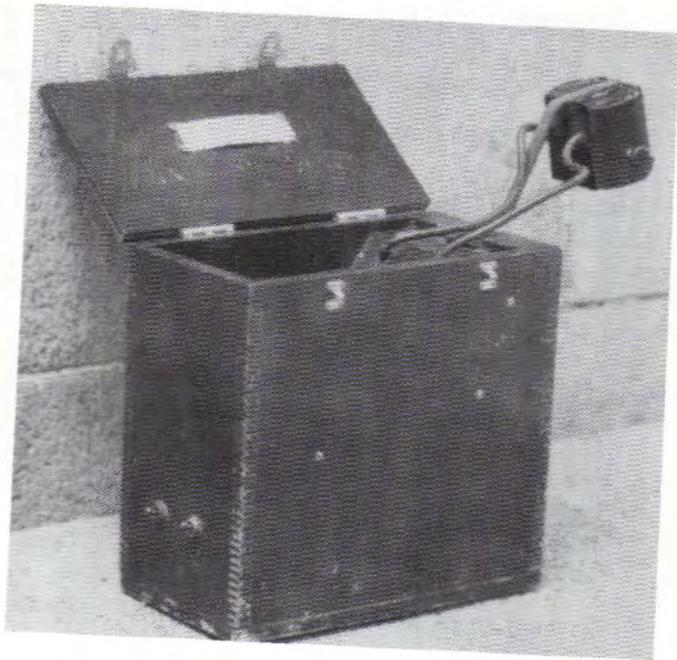


Figure 4. Typical iron arc unit. Collection RCB.

of the above parts are fitted into a neat mahogany box for convenient transportation..."

The GE units were rather widely sold, not only in Franklin but elsewhere as well, to mineral collectors and others who needed a convenient source of ultraviolet light. Many other iron arc units, including the one used by Palache at Harvard, were home made. When Palache published the first list of Franklin's fluorescent minerals (Palache, 1928), he wrote:

"The use of ultra-violet light as yielded by the iron-arc spark-gap to determine the presence of willemite in mill-tailings has long been an important practice at Franklin. From it has grown up the constant use of this apparatus in determining the presence in the Franklin ores not only of willemite but also of a number of other minerals which give characteristic reactions to this form of stimulus."

Apparently the New Jersey Zinc Company experimented further with the iron arc source and built a number of units in its own shops (Fig. 3). These were used in the Franklin mill to monitor the quantity of willemite in tailings from the jigs; to monitor the recovery of willemite on the sand tables; and at the picking table to distinguish ore from waste rock. Here it was also used to "high-grade" specimens of esperite and other highly fluorescent minerals. In the N.J.Z. chemistry laboratory at Franklin, Lawson Bauer and others did much investigative work with the iron arc, including that on barylite. The iron arc also triumphed as a publicity tool; visitors to the laboratory were amazed and astonished by the hissing and flashing of the iron arc and the beautiful fluorescence it caused in the local minerals.

While the "iron-arc spark gap", as Palache called it, produced much ultraviolet light, it suffered the disadvantages of being rather noisy and generating much electrical static and visible light. During the 1930's a more tractable source of ultraviolet energy came of age: the low-pressure mercury vapor lamp. The heart of these lamps is a sealed tube of quartz or high-silica glass fitted with electrodes at either end and filled with argon and a few droplets of mercury. An electric current passed through the tube excites the mercury atoms, generating mostly shortwave ultraviolet light and minor amounts of longwave ultraviolet light and visible light. Lamps made with these tubes were widely called "cold quartz lamps" because their tubes generated little heat and were made of fused quartz. Although the first models were large and expensive, they gave satisfactory results, especially when fitted with a filter to reduce the output of visible light. Minerals which had fluoresced under the iron arc also responded to the new lamps, and in most cases superior results were achieved.

Another source of ultraviolet light which will be remembered by many older collectors was the argon bulb. This simple device had the advantage of being inexpensive (fifty cents) but emitted only longwave ultraviolet light, and very weakly at that when compared to other sources. For one of us (RVG) the argon bulb was for a long time the only affordable source of ultraviolet light.

Gradually, as the mercury vapor lamps were improved and reduced in price, the iron arcs were relegated to the attic or the trash pile; by World War II few were still in use. Today it is difficult to find one at all, except around Franklin where a few working models survive. Iron arcs are on exhibit at the Franklin Mineral Museum and the Sterling Hill Mining Museum (Lawson Bauer's iron arc unit may be seen at the latter). Today mineral collectors have access to an impressive variety of sizes and configurations of filtered mercury vapor ultraviolet lamps, both longwave and shortwave, whose emissions cause vivid and varied fluorescence in hundreds of minerals. In 1928 Palache described ten fluorescent minerals from Franklin; in the 1992 Check-List there are eighty (Bostwick, 1992).

OCCURRENCE OF BARYLITE

The first description of barylite was by Blomstrand (1876) from the Langban Mine, Varmland, Sweden. He regarded the mineral as a barium aluminum silicate. In 1923, barylite was restudied by Aminoff, who proved it to be a barium beryllium silicate with the formula $BaBe_2Si_2O_7$.

In early 1930 the second occurrence of barylite was reported by Palache and Bauer from Franklin, New Jersey (Palache and Bauer, 1930). This find is discussed at length later in this paper.

Subsequently barylite was found at Letitia Lake ("Seal Lake"), Labrador, Canada (Nickel and Charette, 1962; Mulligan, 1968); Mont St. Hilaire, Quebec, Canada (Chao and Baker, 1979); Park County, Colorado (White, 1972); Vishnevyy Gory, Urals, Russia (Zhabin and Kasakova, 1960); on the northern slopes of the Urals (Yefimov *et al.*, 1971); at Bratthagen, Langendal, and Orve, Aro, Langesundfjord, Norway (Saebo, 1966a, 1966b); and at Narssarsuk, Greenland (Petersen and Johnson, 1980). The crystal structure was revised by Robinson and Fang (1977). Euhedral crystals have been noted from the Park County, Colorado occurrence and from Narssarsuk, Greenland.

CHEMISTRY OF BARYLITE

As part of this study, six barylite samples from various localities were analyzed by ARL-SEM-Q electron microprobe utilizing an operating voltage of 15 kV and a beam current of 0.15 μ A. The data were corrected for background, back scatter, absorption, and fluorescence using the MAGIC-4 program of the Geophysical Laboratory. The standards used were barite for barium; celestine for strontium; PbO for lead; hornblende for iron, calcium, and magnesium; and manganite for manganese. Beryllium was calculated from the theoretical formula. The resultant analyses are presented in Table 1.

The analytical data indicate that there is very little solid solution of cations such as Ca, Mn, Sr, and Pb which would be

Table 1. Barylite analyses.

Locality	NMNH #	SiO ₂	BaO	PbO	BeO*	Total
Franklin, New Jersey	#C6224	37.4	45.9	1.5	15.5	100.3
Franklin, New Jersey	#96423	37.7	46.2	1.8	15.5	101.2
Franklin, New Jersey	#R6490	37.8	45.8	1.1	15.5	100.2
Franklin, New Jersey	#142815	37.2	44.6	2.6	15.5	99.9
Langban, Sweden	#94945	38.3	48.3	0.2	15.5	102.3
Park Co., Colorado	#123856	37.9	47.5	0.0	15.5	100.9
$BaBe_2Si_2O_7$	Theory	37.1	47.4	—	15.5	100.0

*BeO from theoretical composition

Accuracy of data: +/- 3% of the amount present for all major elements.

All samples from the collection of the National Museum of Natural History, Smithsonian Institution.

expected to proxy for barium in barylite. Indeed, of the foregoing, only lead was found in measurable quantities. Hence, our results confirm those of investigators who described other occurrences; the mineral conforms closely to the theoretical composition, $\text{BaBe}_2\text{Si}_2\text{O}_7$. Except for the essential constituents of barylite, lead is the only cation present in amounts greater than 0.2%, and no barylite has been found which contains more than 2.6% PbO. Franklin specimens contain more lead than the specimen from Langban, and the Colorado material contains no lead detectable under the probe used.

PHYSICAL DESCRIPTION OF FRANKLIN BARYLITE

Palache and Bauer's 1930 description of Franklin barylite should be familiar to all Franklin collectors, as it is essentially repeated in Professional Paper 180 (Palache, 1935). Here are excerpts from the original 1930 account:

"Barylite was first found at Franklin last August in specimens of hedyphane and calcite. It was first seen on the picking table but was later found in the mine in 960 pillar, 20 feet below the 400 foot level North about 15 feet from the hanging wall.

Attention was first drawn to the mineral by its vivid blue fluorescence in ultra-violet light, a color not previously yielded by any Franklin mineral...

The Franklin barylite is in plates embedded in hedyphane with some willemite. The single specimen seen is clearly part of a well banded vein, the succession of bands from a surface of ore being (a) brown calcite and native copper; (b) gray calcite; (c) narrow zone of willemite and serpentine; (d) white calcite in curved rhombohedra, strongly fluorescent in ultra-violet light; (e) barylite, hedyphane and willemite. The barylite plates are more or less brecciated and are cemented with thin films of serpentine. Barylite is white, 7 in hardness, and shows two good cleavages..."

As accurate as Palache and Bauer's description was, it did not stop many collectors from erroneously identifying other Franklin specimen material as barylite. Much of the reason for this lies in barylite's described "vivid blue fluorescence," and this matter is treated at length later in this paper under "Fluorescence Studies" and "Conclusions." However, in the interests of assisting collectors and others to distinguish true barylite from false, there follows a supplemental description of the barylite assemblage. It is based on the observation of ten Franklin barylite specimens in the collections of the Harvard Mineralogical Museum and the National Museum of Natural History, Smithsonian Institution, and three in private hands.

Not all the specimens seen preserve the full assemblage, nor is Palache and Bauer's "well banded vein" always clearly defined in the examined hand specimens. However, where the banding can be distinguished its sequence matches that described above.

The ore (as in Palache and Bauer's "surface of ore") occurs in angular fragments, typically several cm across, and is comprised of pale gray to gray calcite rich in 2-3 mm grains of franklinite (visible in Figs. 5 and 6). Willemite is present as colorless 2-3 mm grains, and also finely disseminated as a film covering surfaces of ore fragments which face Palache and Bauer's band "a." The ore fragments are in rough alignment with each other and to the

described layering. They range from several mm to over 10 cm in size, and are separated by veins several mm thick of fine-grained pale gray calcite.

All the willemite in the barylite assemblage is colorless and is relatively difficult to distinguish from the calcite matrix without the aid of a shortwave ultraviolet lamp. This willemite fluoresces typical bright yellowish-green under shortwave ultraviolet radiation. All the calcite in this assemblage, whether gray and compact or white with conspicuous curved cleavage, fluoresces bright orangeish-red under shortwave ultraviolet radiation.

Of Palache and Bauer's bands, band "a" (brown calcite and native copper) is irregular in distribution and varies from 1 mm to over 1 cm thick. The color of the calcite is pinkish-brown and is due to finely disseminated copper, which is for the most part visible as metallic copper only under magnification. Band "b" (gray calcite) is a fine-grained pale gray calcite; there is no boundary between bands "a" and "b" other than that defined by the distribution of the disseminated copper in band "a." Bands "a" and "b" taken as a unit are consistently present and are generally 1 cm to 1-1/2 cm in thickness.

Band "c" is the best defined of many dark brown serpentine veinlets which penetrate all parts of the assemblage. Most of the veinlets of band "c" are very thin, but in places thicken to about 6 mm. They are generally free of copper, but it may be present in thin irregular sheets. Band "c" also contains irregularly distributed colorless grains of willemite up to 1 cm across and larger clusters of grains. Many of the willemite grains in this band are surrounded by a thin film of serpentine.

The "white calcite with curved rhombohedra" of band "d," in most specimens, separates by 1 cm or more the distinctive willemite-serpentine boundary characterized as band "c" from the barylite and hedyphane of band "e." The color of barylite is barely distinguishable from that of the enclosing calcite, although its luster and cleavage are different. Here again a shortwave ultraviolet lamp is valuable in distinguishing the two. In size and form barylite varies considerably, from small (1 x 5 mm) isolated plates with rectangular outlines to solid masses up to 3 cm thick. Rarely it is present as thin plates in fan-like arrays, one of which is at least 6 cm long and nearly 3 cm wide. In a few specimens the isolated barylite plates, with their rectangular outline and parallel sides, are strongly suggestive of euhedral crystals. None are known to have been measured.

Hedyphane is not present in the majority of those barylite specimens seen, but when found it occurs in conspicuous pale yellow to honey-colored masses; the largest seen is 3 x 6.5 x 9 cm and had clearly been part of a larger mass of hedyphane.

Part of the "single specimen seen" in Palache and Bauer's original description of barylite was preserved by Bauer and later given to his secretary, Thelma Stevens. This remnant, 4 x 4.5 x 8 cm in size, is now in the Bostwick collection, numbered RCB100. It bears Bauer's label, which includes the inscription "Part of original type specimen" (Fig. 5). Adjacent to the label, which is glued to a sawn surface of the specimen, the ore fragments adjacent to band "a" can be seen. Some idea of Palache and Bauer's banding can be obtained from an end-on view of this specimen (Fig. 6), and a schematic drawing derived therefrom. The copper in band "a" cannot be seen without a hand-lens, and there is no copper in the serpentine veinlets. Band "c" is well-defined by the presence of willemite. Barylite is

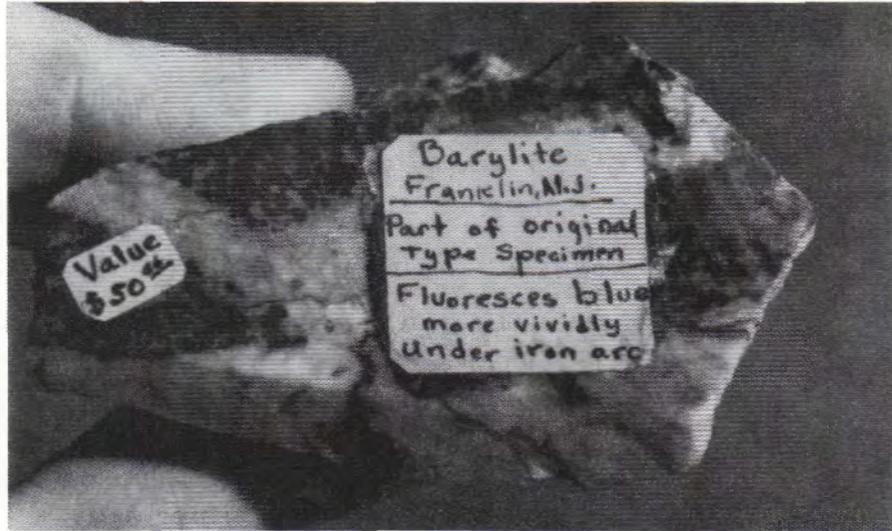
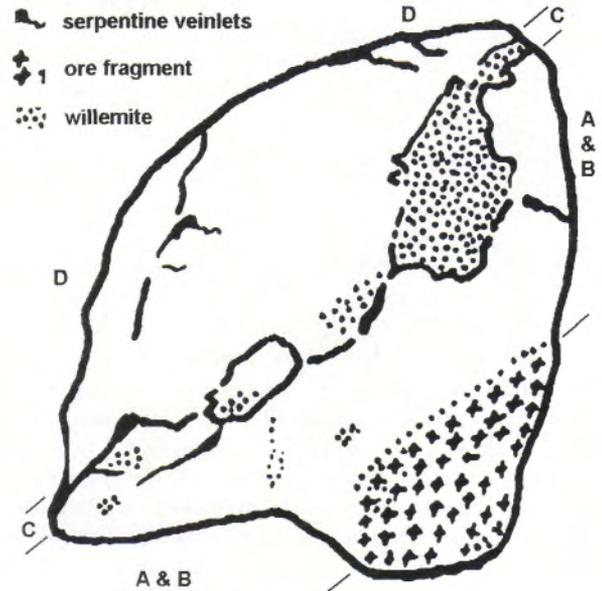


Figure 5. Barylite specimen, Franklin, New Jersey. Sawn surface shown. Gift of Lawson Bauer to his secretary Thelma Stevens. Bauer label and valuation (the latter perhaps to keep her from throwing it out). Ore fragments and serpentine veinlets visible. Maximum dimension 8 cm. Specimen RCB 100.



Figure 6. Barylite specimen, Franklin, New Jersey. View of specimen RCB 100 showing some of the "banding" noted by Palache and Bauer (1930). Barylite plates are present (out of view) beyond the upper left edge visible here. Maximum dimension 6 cm.



Sketch of specimen shown in photograph at left. Letters denote areas which correspond to bands noted by Palache and Bauer (1930).

present as small (typically 1 x 5 mm) rectangular laths thickly clustered in a 2 x 2 cm patch of calcite, associated with specks of willemite. The barylite is separated from band "c" by about 1 cm of white calcite which corresponds to band "d."

Much of the balance of this specimen was apparently dissolved in an attempt to recover barylite for analysis, and plates and fragments of barylite saved by Bauer are preserved in several collections (Fig. 1).

FLUORESCENCE STUDIES

Mineral fluorescence can be investigated with a spectrofluorometer, which is an instrument that both controls the wavelength of exciting radiation directed at a sample and records the wavelengths of radiation emitted by that sample. The SPEX Fluorolog-2 Model 212 was used for this study, and it records fluorescence in the shortwave ultraviolet, longwave ultraviolet, and visible regions. It can also excite the sample over the same spectral range to determine at which excitation wavelength the fluorescence is at maximum intensity.

Fragments of Franklin barylite from two specimens were used in this study. Sample A (RCB 102) is a 3.2 mm fragment of barylite which had been etched out of matrix and saved by Lawson Bauer during his work on that mineral. This was used for the initial excitation and emission determinations. Sample B (RCB 106) is a cleavage fragment of similar size which had been obtained from a matrix specimen of barylite. The species identity of samples A and B was determined by X-ray diffraction.

The excitation spectrum of barylite (Figure 7) was determined by exposing sample A to nearly the full range of shortwave and longwave ultraviolet energy, from 220 nm to 350 nm, and recording at which wavelength the fluorescence was the brightest. The excitation maximum for Franklin barylite occurs at about 237 nm. Note that as the exciting wavelength increases above 237 nm there is a sharp drop in the intensity of barylite's fluorescence, with very little fluorescence apparent at an excitation frequency of 254 nm — that characteristic of mercury vapor shortwave ultraviolet lamps.

The emission spectrum of Franklin barylite (Fig. 8), determined on samples A and B with an excitation wavelength of 237 nm, is a broad band covering the entire longwave ultraviolet region (300 to 380 nm) and the violet (380-440 nm) and blue (440-465 nm) regions of the visible light spectrum. Barylite's fluorescence is strongest at around 375 nm, close to the transition point between ultraviolet and visible light. Additional emission spectra were acquired at an excitation frequency of 254 nm. They are identical in wavelength distribution to those acquired at 237 nm, but are much weaker in intensity.

As might be expected from an emission spectrum peaking in the violet, to the eye the fluorescence of Franklin barylite is a deep (saturated) violet. When viewed using a filtered mercury vapor shortwave ultraviolet lamp, the fluorescence is of moderately weak intensity. (The fluorescence is in fact very similar in hue to that of hardystonite.) Barylite's fluorescence can be difficult to see in matrix specimens as the matrix of barylite is predominantly calcite which fluoresces very bright orangeish-red under the same lamp. When isolated fragments of barylite are examined under a conventional shortwave lamp their fluorescence is still not bright, and is easily mistaken for visible light emitted from the lamp and reflected from a white mineral.

In contrast, under the iron arc Franklin barylite appears a bright pale bluish-violet, which stands out sharply against the

surrounding calcite, the fluorescence of which is partly masked by the violet-blue light emitted by the iron arc. The apparent fluorescence of isolated fragments under the iron arc is also very bright. Certainly Lawson Bauer was aware of the difference in appearance of barylite under the two sources of ultraviolet energy; his label for the "part of the original type" specimen from Franklin (Figs. 5 and 6) reads:

"Fluoresces blue more vividly under iron arc."

This difference is due in part to the comparative inefficiency of filtered mercury vapor lamps in causing barylite to fluoresce. The strongest (and shortest) mercury emission wavelength is 254 nm, comprising about 86% of the output of a typical low-pressure mercury vapor tube. This wavelength is simply outside the range of greatest excitation sensitivity for Franklin barylite. The iron arc spectrum, however, has two clusters of emission wavelengths below 250 nm, one of weak to moderate intensity between 238 and 241 nm and another of moderate to strong intensity at 248-249 nm (Meggers *et al.*, 1961). Even though the 254 nm output of a typical mercury vapor lamp is much stronger than the sub-250 nm output of an iron arc, one would still expect barylite to fluoresce more brightly under the iron arc because of that mineral's distinctive excitation sensitivity.

The brightness of barylite under the iron arc is also in part due to the enhancement of its actual fluorescence by reflection of the violet-blue light produced by the iron arc. Unfiltered mercury vapor and iron arc units both emit a considerable amount of light in the violet and blue regions. In modern shortwave lamps this light is largely blocked by a filter of cobalt-tinted phosphate glass; such filters were not available to the designers of iron arcs. When either iron arc units or mercury vapor lamps are used without a filter, the visible light they emit typically makes it difficult to distinguish the true colors of most mineral fluorescence, and may obscure fluorescence simply by overwhelming it. Less commonly fluorescence will be perceived where none exists; *i.e.* light from the lamp is reflected from a pale-colored mineral or a cleavage plane and is seen as fluorescence. Still more rarely a mineral's fluorescence is augmented (and our perceptions of it altered) by similarly colored light emitted by the lamp and reflected from the fluorescing mineral. Such appears to be the case with Franklin barylite under the iron arc.

CONCLUSIONS

Barylite from Franklin is indeed fluorescent, but notably so only under radiation produced by the iron arc lamp. This was the source used by Palache and Bauer in their 1930 description. Collectors in later years, being unaware of the nature of Palache and Bauer's ultraviolet energy source, tried to observe barylite fluorescence using filtered shortwave mercury vapor lamps, with unsatisfactory or apparently negative results.

The hue of barylite's fluorescence is violet. The statement by Palache and Bauer that barylite fluoresced vivid blue was undoubtedly prompted by the fact that the iron spark emits much visible blue light which, reflected from barylite, influenced their perception of its fluorescence. They reported what they saw; some of the other observations of mineral fluorescence made by Palache with the aid of the iron arc do not match those made today using contemporary shortwave lamps either.

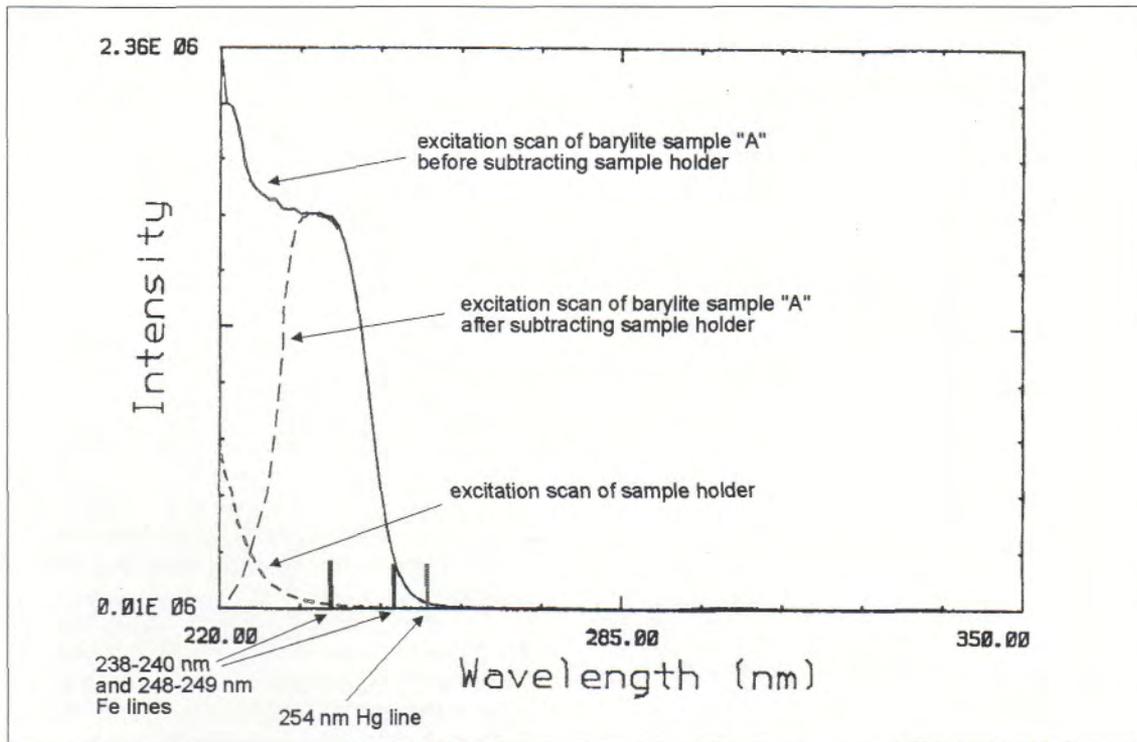


Figure 7. Barylite excitation spectrum, showing a maximum fluorescent response from radiation of 237 nm. Fluorescence intensity scale in arbitrary units. The positions of iron (Fe) and mercury (Hg) lines are superimposed for reference.

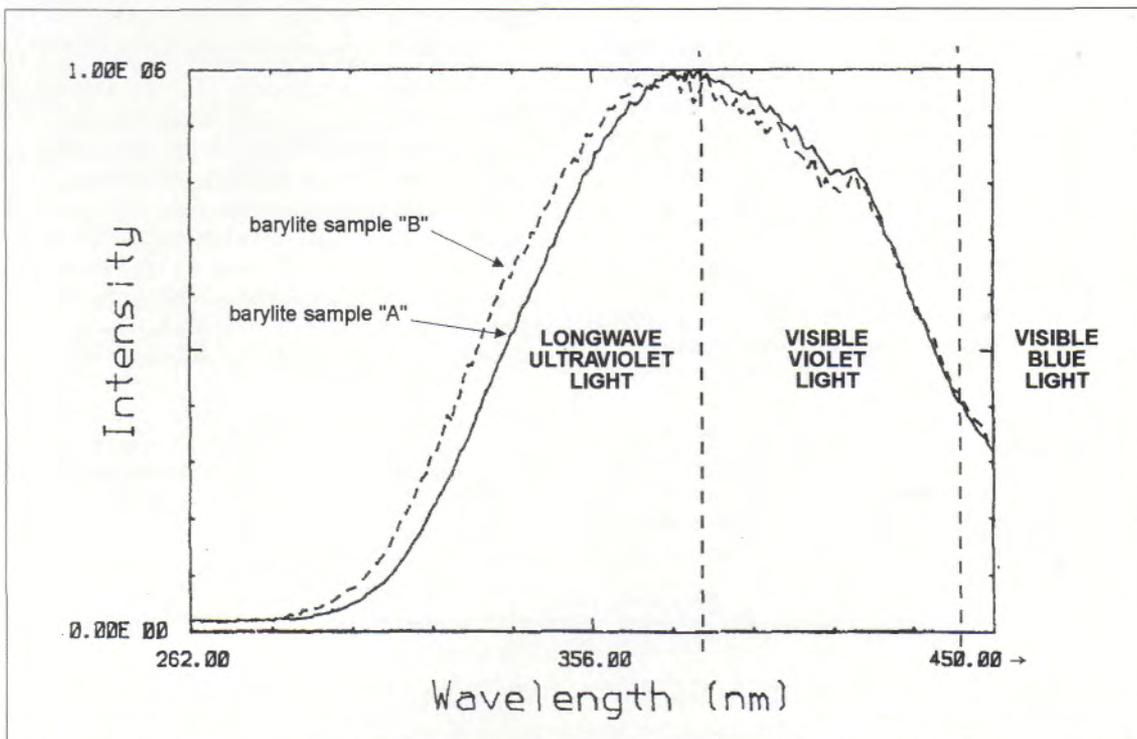


Figure 8. Barylite emission spectrum, showing barylite's fluorescent response to be in the longwave ultraviolet to violet region. Fluorescence intensity scale in arbitrary units.

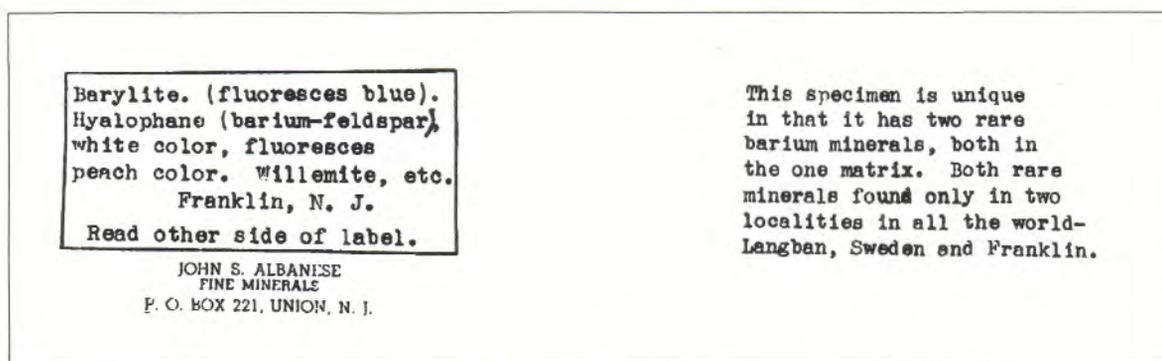


Figure 9. Front (left) and back (right) of a typical Albanese "barylite" label. The blue-fluorescing mineral present is most likely margarosanite.

Over the years, many collectors have acquired "barylite" samples which emit a bright blue fluorescence under conventional shortwave filtered mercury vapor lamps. Often these specimens were originally obtained from John Albanese, a prominent mineral dealer of the 1940's and 1950's. Some of his labels (Fig. 9) mention the association of blue-fluorescing "barylite" with hyalophane or barium-feldspar. Unlike most collectors of the period, Albanese had access to the collections and curatorial staff of the major museums with Franklin holdings, so his opinions, however arrived at, carried weight.

Without exception, all of the bright-blue-fluorescing "barylite" which was chemically tested has proven to be margarosanite, of the relatively abundant variety typically intergrown with feldspar and associated with andradite, hendricksite, manganaxinite, grossular, clinohedrite, lead, etc. In these "barylite" specimens margarosanite and feldspar together form whitish fine-grained masses which have the fluorescence of margarosanite and the hardness of feldspar. Collectors trying to talk themselves into having an authentic barylite may have reasoned that the hardness and fluorescence combined were enough to validate the species, regardless of matrix. (Margarosanite has a Mohs hardness of 3, feldspar 6, and barylite 7.)

Misidentified barylite specimens outnumber authentic ones by a considerable margin. Barylite is in fact a rare Franklin mineral, having been found in one occurrence, as far as is known, with perhaps a score of specimens preserved. Being inconspicuous and nearly the same color as the associated calcite, it may also have been overlooked if encountered subsequently. Certainly the portable filtered mercury vapor lamps in use during the latter years of the Franklin mine would have been of little help in locating it. Most of the preserved Franklin barylite specimens are in museums outside the Franklin area, chiefly at the Harvard Mineralogical Museum and the National Museum of Natural History of the Smithsonian Institution. Many Franklin collectors have seen only the vials of barylite chips etched out and preserved by Lawson Bauer. Under these conditions it is perhaps not too surprising that many false barylites have emerged to satisfy collectors.

Franklin barylite can be visually identified with reasonable certainty by its vivid augmented fluorescence under the iron arc and its characteristic associated minerals: abundant orangeish-red fluorescing calcite, often with curved cleavage; grains of green-fluorescing willemite; veinlets of brown serpentine, occasionally with copper; and (in some specimens) masses of honey-colored

hedyphane. Palache and Bauer's 1930 description still holds — Franklin barylite has not been found in a different mineral assemblage.

Collectors having a Franklin specimen labeled barylite would be well advised to check it first with a filtered shortwave mercury vapor ultraviolet lamp. If a bright blue fluorescence is observed, it is probable that the identification as barylite is not correct. If a fairly weak violet fluorescence is seen, then the specimen should be further examined under an iron spark lamp if one is readily available. If the mineral fluoresces an apparent bright pale bluish-violet under the iron arc, and the specimen matches the Palache and Bauer description in other respects, barylite is probably present. In the absence of an iron arc or if there is any doubt, conventional physical and chemical tests followed by X-ray diffraction would be required to positively identify the mineral as barylite.

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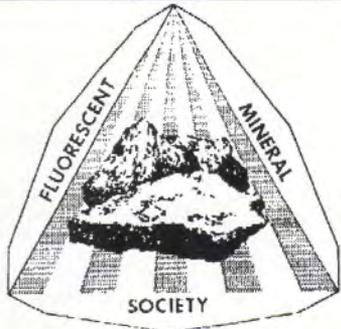
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RESEARCH REPORT

THE CRYSTAL STRUCTURE OF BANNISTERITE

Reference

Heaney, P.J., Post, J.E. and Evans, H.T. (1992) *The Crystal Structure of Bannisterite*. *Clays and Clay Minerals*, 40, no. 2, pp. 129-144.

Introduction

The crystal structure of bannisterite has been solved and refined for specimens from Franklin, New Jersey (USNM C6253), and Broken Hill, Australia. The crystals are monoclinic in space group $A2/a$, and for Franklin bannisterite $a = 22.265(1) \text{ \AA}$, $b = 16.368(1) \text{ \AA}$, $c = 24.668(2) \text{ \AA}$, $\beta = 94.285(5)^\circ$. Previously, a general description of the crystal structure of "partially dehydrated" bannisterite from Broken Hill appeared in abstract form (Threadgold, 1979), but no detailed solution had been published. With the aid of Threadgold's abstract and unpublished studies, the authors have solved the structures of two natural, hydrated bannisterite samples with differing chemical compositions.

Structure

Bannisterite is a mica-like, modulated 2:1 trioctahedral layer silicate, structurally closely related to ganophyllite and stilpnomelane (Fig. 1). The octahedral sheet is fully trioctahedral, and is undulatory along b (Fig. 2). The predominance of Mn^{2+} and Fe^{2+} in the octahedral sites of this sheet enlarges it beyond that of ordinary micas. The wave-like nature of the sheet can be explained as a means of achieving congruency between the tetrahedral and octahedral sheets. These trioctahedral layers are bonded above and below to tetrahedral layers. The tetrahedral layers are comprised of irregularly shaped 5-, 6-, or 7-fold rings of tetrahedra; some tetrahedra point towards the octahedral sheet, and some are inverted and point away from the octahedral sheet. These inverted tetrahedra cross-link the layers of the bannisterite structure, and their relatively inflexible bonding contributes to the brittle quality of this mineral. Water and interlayer cations reside

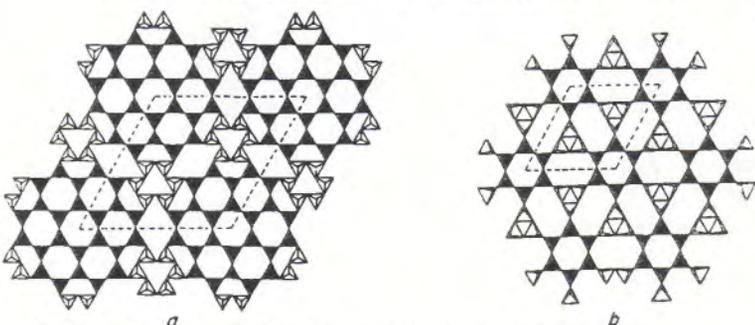


Figure 1. Tetrahedral layers of related structure types viewed on the (001) plane: a) stilpnomelane; b) zussmanite; c) ganophyllite; d) bannisterite. (Light tetrahedra point "up" towards viewer, and dark point "down.")

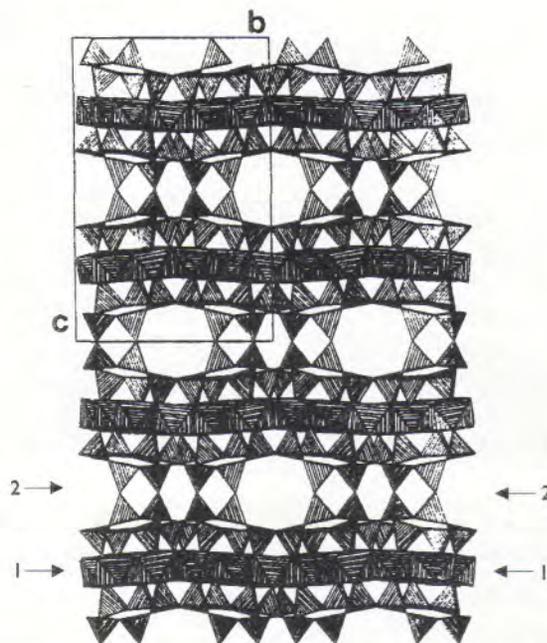
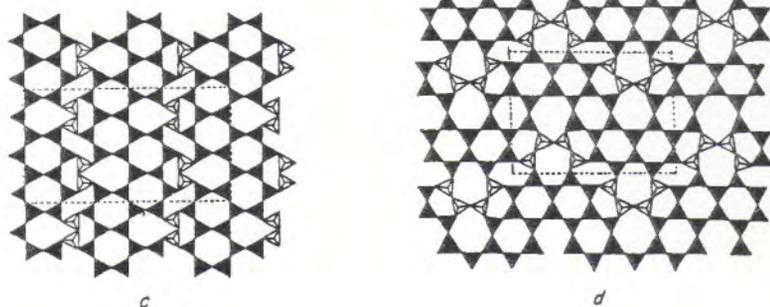
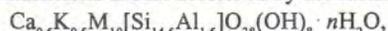


Figure 2. Bannisterite structure. Projection on the b - c plane, showing the wave-like character of the octahedral sheet (1), and the cross-linking via inverted tetrahedra (2).

within large open regions enclosed by these cross-linking tetrahedra. The results of the structural refinement of both samples were nearly identical. The R -factor for the refinement of Franklin bannisterite was 0.039.

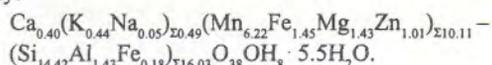
Site populations

The authors found no evidence for octahedral site preference by Zn or Mg in either the Franklin or Broken Hill bannisterite. Variation of bond length in tetrahedra and octahedra is considerable, but consistent between the compositionally different Franklin and Broken Hill samples. Based on bond length calculations, Al is interpreted to be partitioned strongly into the central group of inverted tetrahedra. The interlayer species Ca, K and H_2O are highly disordered, and the predicted amounts of H_2O are at variance with previous chemical studies. The authors suggest that bannisterite is best described by the idealized formula:



where M is the octahedrally-coordinated divalent cation (Mn, Fe, Zn, Mg), and n ranges from 2 to 6.

When the analysis of C6253 presented in Dunn *et al.* (1981) is renormalized to 38 oxygens and 8 hydroxyl groups, the empirical formula for this Franklin bannisterite is approximately:



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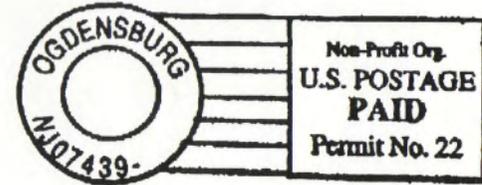
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