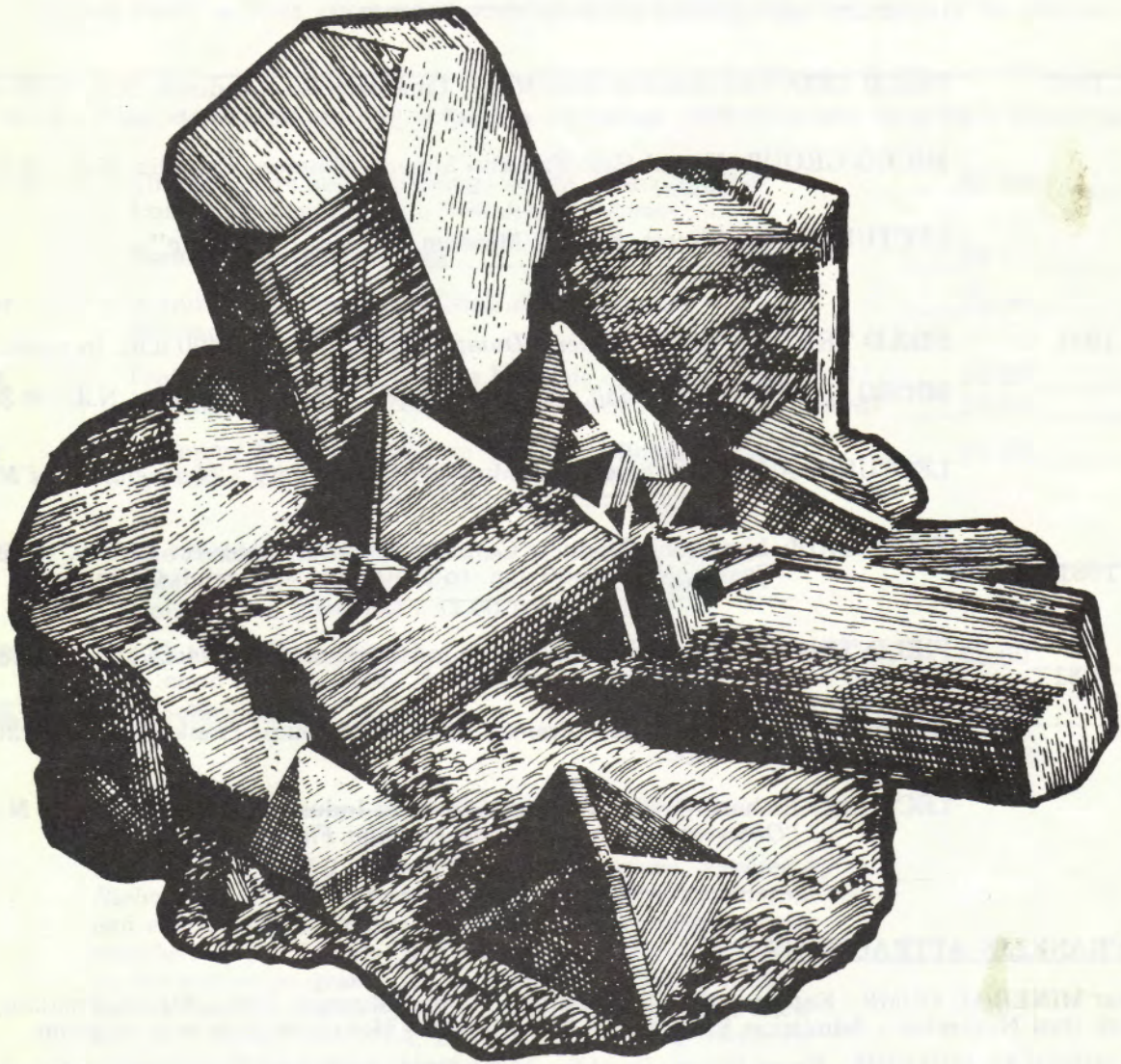


THE PICKING TABLE

JOURNAL OF THE FRANKLIN-OGDENSBURG MINERALOGICAL SOCIETY



Volume 22

March 1981

Number One



Spring Program

FRANKLIN-OGDENSBURG MINERALOGICAL SOCIETY, INC.

1981

Regular Society activities consist of field trips, micro-mineralogy study sessions and lecture programs. Field trips vary as to time and location according to schedule. Morning micro-mineralogy study sessions take place from 9:30 a.m. to noon in Kraissl Hall at the Franklin Mineral Museum. Afternoon lecture programs begin at 2:00 p.m. at the Hardyston Twp. School, Rt. 23, Franklin, N.J. - pre-meeting activities begin at 1:00 p.m.

Saturday
March 21, 1981

FIELD TRIP: Cancelled - this month only - See micro-mount meeting below.

MICRO GROUP: *Hardyston Twp. School, Rt. 23, Franklin, N.J. - 9:30 a.m. to noon.*
This meeting only due to closing of FMM.

LECTURE: R. William Selden, Rutgers University. "*Rutgers University and the Rowe Collection*"

Saturday
April 18, 1981

FIELD TRIP: *Old Andover Iron Mines, Limecrest Rd., Andover, N.J., 9:00 a.m. to noon.*

MICRO GROUP: *Kraissl Hall, Franklin Mineral Museum, Franklin, N.J. - 9:30 a.m. to noon.*

LECTURE: Alice Blount, Newark Museum. "*Crystal Twinning*"

Saturday
May 16, 1981

FIELD TRIP: *Buckwheat Mineral Dump, Franklin, N.J. - 9:00 a.m. to noon.*

MICRO GROUP: *Kraissl Hall, Franklin Mineral Museum, Franklin, N.J. - 9:30 a.m. to noon.*

LECTURE: Alfred Lombardi, N.J. Mineralogical Society. "*Photography of Microminerals*"

Sunday
May 17, 1981

FIELD TRIP: Limestone Products Corp. of America, Limecrest Quarry, Limecrest Rd., Sparta, N.J. - 9:00 a.m. to 3:00 p.m. - Interclub Outing.

Saturday
June 20, 1981

FIELD TRIP: Limestone Products Corp. of America, Franklin Quarry (formerly Farber), Cork Hill Rd., Franklin, N.J. - 9:00 a.m. to noon.

MICRO GROUP: *Kraissl Hall, Franklin Mineral Museum, Franklin, N.J. - 9:30 a.m. to noon.*

LECTURE: Richard C. "Dick" Bostwick, Spex Industries, Inc., Metuchen, N.J. - "*Observations on Collecting Franklin Fluorescents*"

DAILY FRANKLIN ATTRACTIONS

Buckwheat MINERAL DUMP - Entrance thru the Franklin Mineral Museum, Evans Street, Franklin, N.J. - Open April thru November - Admission \$1.50 adult; \$.75 student - Hours coincide with museum.

Franklin MINERAL MUSEUM - Evans Street, Franklin, N.J. - Open April thru November - Admission \$1.50 adult; \$.75 student - Closed Monday. Open Tuesday and Wednesday by group reservation only. Open Thursday thru Sunday with daily schedule, except Sunday morning.

Gerstmann FRANKLIN MINERAL MUSEUM - 14 Walsh Rd., Franklin, N.J. - Open year round DAILY. No admission fee - Donations accepted - Mr. Ewald Gerstmann, Curator, in daily attendance.

Trotter MINERAL DUMP - Main Street (behind Boro Hall), Franklin, N.J. - Open year round except during inclement weather - Admission \$2.00 - Mr. Nick Zipco on call.

F.O.M.S. - OFFICERS FOR THE YEAR - 1981

President Ralph E. Thomas, 11 Riverdale Road, Yardley, PA 19067
1st Vice President Joseph Cilen, 92 Westervelt Avenue, Hawthorne, NJ 07506
2nd Vice President Richard C. Bostwick, RD-1, Rt. 32, Box 71A, Lebanon, NJ 08833
Secretary Helen Warinsky, 695 Suffern Road, Teaneck, NJ 07666
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Warren Cummings '82	Frederick Kraissl '81
John Kolic '81	John E. Sebastian '81
Bernard T. Kozykowski '82	Robert Svecz '81
Warren Miller '82	

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<i>Auditing</i>	Rudolph C. Appeld
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<i>Identification</i>	Ewald Gerstmann
<i>Mineral Exchange</i>	Richard C. Bostwick
<i>Museum</i>	John L. Baum
<i>Nominating</i>	Warren Miller
<i>Program</i>	Joseph Cilen

F.O.M.S. NOTES

SPEX / Gerstmann Mineral Collection

Hostages and elections notwithstanding, for Franklin mineral collectors 1980 will always be the year the Gerstmann Collection was sold. As long as the F.O.M.S. has existed, Ewald Gerstmann, his museum, and his minerals have been a center of things: Franklin without Ewald is unimaginable. Ordinarily when an important collection changes hands, it disappears. Either it vanishes behind museum walls, or is scattered by the winds of the mineral marketplace. Ewald's is a significant exception: as the SPEX / Gerstmann collection it remains on display at 14 Walsh Road in Franklin, where it is still curated and managed by the man who put it all together.

This unique arrangement, with its obvious advantages for the Franklin collecting community, is the result of collaboration between Mr. Gerstmann and the new owners, Arthur and Harriet Mitteldorf. To them, the Gerstmann Collection is a major resource for present and future students of Franklin mineralogy, one which can never be duplicated and should be maintained intact. Ewald is also a resource, one whose perceptiveness and determination have led to the finding and preservation of many new or unusual species. Hence the current situation, where Ewald can realize his dreams of fulltime involvement with minerals while still improving the collection and continuing his quest for the undiscovered.

The Mitteldorf's company, SPEX Industries Inc. in Metuchen, N.J., has been making spectroscopic instruments and supplies for as long as Ewald has been acquiring specimens. Arthur and Harriet's interest in minerals is of long standing, but was further stimulated by Dr. Warren Miller, F.O.M.S., Past President and head of SPEX's spectrochemical division.

Having acquired what is often termed "the best Franklin collection in private hands," it is no wonder that the Mitteldorfs are looking forward to participating in a period when the significance of Franklin and its minerals is finally becoming appreciated by the world at large.

N.J.E.S.A., We thank you.

We would like to make special mention of and express our thanks to the New Jersey Earth Science Association for its outstanding support of the Franklin Mineral Museum and Annual Franklin-Sterling Hill Mineral Show in 1980. Watch for the N.J.E.S.A.'s "Seton Hall Show" in August.

GUERINITE and HAWLEYITE from STERLING HILL

by Pete J. Dunn

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

INTRODUCTION

Research on the minerals of Franklin and Sterling Hill over the last three years has provided six species new-to-the-science (*marsturite*, *kolicite*, *lawsonbauerite*, *johnbaumite*, *hauckite* and *sterlinghillite*) and also has provided some twenty additions to the list of previously known species which have been found at Franklin or Sterling Hill.

Most of these have been introduced into the mineralogical literature and subsequently abstracted in the Picking Table by the editor. In one paper, recently reprinted in the Picking Table, some of these species new-to-the-deposit were announced. Other new occurrences are sometimes introduced within papers on other Franklin/Sterling Hill minerals, in this way assuring that they are formally published. For example, the occurrence of romeite was announced in the paper on yeatmanite (American Mineralogist 65, 196); the occurrence of mimetite will be included in a paper on johnbaumite; the occurrence of caryopillite will be announced in a paper on schallerite, and on, and on. Brief descriptions of two additional species not previously published, together with other notes, are given below. I am pleased to have the opportunity to publish this material in the Picking Table.

GUERINITE



Guerinite, $\text{Ca}_5\text{H}_2(\text{AsO}_4)_4 \cdot 9\text{H}_2\text{O}$, was found in the Sterling Hill mine by John Kolic. It occurs on white calcite which contains small amounts of graphite, realgar and arsenopyrite. The guerinite is found on a surface of the calcite matrix and occurs as opaque white pearly aggregates of crystals (Fig. 1). The crystals have a markedly prismatic, sub-parallel habit, and are differentiated from other white Sterling Hill minerals by the opaque white color and the pearly luster.

It was identified on the basis of its unique X-ray diffraction powder pattern. Guerinite was originally discovered at two localities: the Daniel mine, Schneeberg, Sachsen, Germany; and from Richelsdorf, Hessen, Germany. Both occurrences were described by Nefedov (1961)(abstract in American Mineralogist 47, 416-417). A subsequent occurrence at Sainte-Marie-aux-Mines, Alsace, France, provided the above chemical formula (abstract in American Mineralogist 50, 812).

Figure 1.

HAWLEYITE

Hawleyite, CdS , occurs in the Sterling Hill mine. The specimen was found many years ago but was mislabeled. Subsequent investigation indicated its true identity. Sterling Hill hawleyite occurs as bright yellow powdery encrustations, associated with sphalerite and hemimorphite on a decomposed specimen. The hawleyite was identified on the basis of its color and unique X-ray diffraction powder pattern.

YEATMANITE

Subsequent to the previously cited description of yeatmanite, yet a fourth occurrence has been discovered. Unlike the previous three parageneses, this one is from the Sterling Hill mine. The Sterling Hill yeatmanite is brown with high luster and does not differ in appearance from other known yeatmanite samples. However, the Sterling Hill material is very sparse on the four examined specimens, on which it is associated with adelite, barite, willemite, calcite and franklinite. A separate occurrence, some 360 feet distant from the above noted occurrence, also contained yeatmanite, but in association with willemite and tilasite. The occurrences might be related. The identity of the discussed species was confirmed by X-ray diffraction powder photography.

HODGKINSONITE

The summer of 1980 witnessed a new find of hodgkinsonite quite unlike previous material. The new hodgkinsonite was found in the Sterling Hill mine. The crystals are, in many cases, doubly-terminated, with very simple morphology. At first glance, they appear to be barite, having the same simple morphology and a light brownish-gray color. The monoclinicity of the crystals is apparent upon closer inspection but the similarity to barite is remarkable. The hodgkinsonite was identified on the basis of its unique X-ray diffraction powder pattern and optical properties.

(Editor's note: We would like to thank Mr. Dunn for his special consideration in permitting us to present this article in the Picking Table. Hopefully, it will also serve to encourage other such articles from both professionals and amateurs alike.)

A MINERAL NEW TO SCIENCE

STERLINGHILLITE

In the Fall 1980 issue of the Picking Table we were fortunate to again announce the discovery of a mineral, new to science, as being found in a specimen recovered from the Franklin mine many years ago. We are again pleased to announce the discovery of yet another mineral, new to science, this time from the Sterling Hill mine, Ogdensburg, N.J. Your editor quotes from recent communication with Pete J. Dunn, Department of Mineral Sciences, Smithsonian Institution, Washington, D.C. 20560.

"A new mineral has been found at Sterling Hill, Ogdensburg, Sussex County, New Jersey. It is white to light-pink in color and occurs as round clusters of sub-microscopic crystals or in fascicles. It is found in association with altered iron arsenates. The new mineral has been named sterlinghillite for the locality at which it has first been found. Subsequent to the formal description, further details will be published on this species in the Picking Table."

MINERAL NOTES

Research Reports

Johnbaumite - $\text{Ca}_5(\text{AsO}_4)_3(\text{OH})$

(Editor's note: In the Fall 1980 issue of the Picking Table we announced the discovery of a mineral new to science as being found in a specimen recovered from the Franklin mine many years ago. The new mineral was named johnbaumite in honor of John L. Baum of Hamburg, New Jersey, retired resident geologist for the New Jersey Zinc Company at the Franklin mine and present curator of the Franklin Mineral Museum. The formal description of johnbaumite has been published and the following abstract is quoted from the describing article entitled "Johnbaumite, a new member of the apatite group from Franklin, New Jersey," by Pete J. Dunn, Donald R. Peacor and Nancy Newberry, which appeared in the American Mineralogist, Vol. 65, pp. 1143-1145, (1980).

Introduction

"The type specimen was found in the Franklin mine in Franklin, New Jersey in 1944, and was retained because of its unusual mineralogy and the occurrence of specks of native copper within it. Subsequent study of this specimen in 1978 resulted in the description of a second paragenesis for yeatmanite (Dunn and Leavens, 1980). The yeatmanite is enclosed in a massive grayish-white mineral which is the new mineral, $\text{Ca}_5(\text{AsO}_4)_3(\text{OH})$, the arsenate analog of hydroxylapatite and the hydroxyl analog of svabite. We take great pleasure in naming it johnbaumite in honor of John L. Baum of Hamburg, New Jersey. Mr. Baum is the retired resident geologist for the New Jersey Zinc Company and is presently the curator of the Franklin Mineral Museum in Franklin, New Jersey. He is the geologist who found the specimen, preserved it, and called it to our attention. Its discovery is due entirely to his efforts. Mr. Baum has played an important role in the development of our knowledge of the mineralogy of Franklin and Sterling Hill and continues to be a strong contributor in his role as curator.

Holotype material for johnbaumite is preserved in the Smithsonian Institution as NMNH # 144444; in the Harvard University collection under catalog # 116461; and in the mineral collection of Mr. Baum. The mineral and the name have been approved by the IMA Commission on New Minerals and Mineral Names."

Physical and optical properties

"Johnbaumite occurs as massive anhedral grayish-white granular material with individual grains approximately 8mm or less in diameter. It is colorless in thin section and has a white streak. The Mohs hardness is approximately $4\frac{1}{2}$. The luster is vitreous on cleavage surfaces and slightly adamantine to greasy on fracture surfaces. Cleavage is distinct, parallel to [100]. The density, determined using heavy-liquid techniques, is $3.68(3) \text{ g/cm}^3$, which compares favorably with the calculated value of 3.73 g/cm^3 .

Johnbaumite is uniaxial (-) with refractive indices $w = 1.687$, $\epsilon = 1.684$, both ± 0.003 . The Gladstone-Dale relationship, calculated using the constants of Mandarino (1976), yields $K_c = 0.184$ for the chemical composition and $K_p = 0.187$ for physical properties, indicating superior agreement between the analytical and physical data (Mandarino, 1979). Johnbaumite is fluorescent in short-wave UV radiation with a medium pinkish-orange response color. There is no response to long-wave UV radiation, and no phosphorescence in either range of wavelengths. Since many calcian mimetites from Franklin and Sterling Hill fluoresce in a similar manner, this property should not be considered diagnostic."

Chemistry

"Johnbaumite was chemically analyzed with an ARL-SEMQ electron microprobe using an operating voltage of 15 kV and a beam current of $0.15 \mu\text{A}$. The standards used were fluorapatite for Ca, P, and F; hornblende for Mg and Fe; manganite for Mn; synthetic olivenite for As; and chlorapatite for Cl. The data were corrected using a modified version of the MAGIC-4 computer program of the Geophysical Laboratory, Carnegie Institution of Washington. Water was determined by DTA-TGA. A microprobe scan indicated the absence of elements with atomic number greater than 8 except those reported herein. Johnbaumite is chemically homogeneous over 10μ intervals. The resultant analysis yields the empirical formula $(\text{Ca}_{9.71}\text{Fe}_{0.03}\text{Mg}_{0.03})(\text{As}_{5.68}\text{P}_{0.30})\text{O}_{23.92}(\text{OH}_{1.80}\text{F}_{0.13}\text{Cl}_{0.04})$ calculated on the basis of the unit-cell parameters and the observed density. This formula is in excellent agreement with the ideal end-member formula $\text{Ca}_5(\text{AsO}_4)_3(\text{OH})$ with $Z = 2$.

The ultraviolet fluorescence of johnbaumite is quite similar to that of Franklin mine samples which have been called hedyphane and svabite in the past (Palache, 1935). Analytical examination of those specimens labelled "hedyphane" indicates that with few exceptions, they are all highly calcian mimetites with

56-70 percent PbO. Of twenty-one Franklin samples labelled hedyphane, seventeen were mimetite, containing calcium and strontium in substitution for lead. We were unsuccessful in finding additional samples of johnbaumite. Inasmuch as the mineralogy of Langban, Sweden is similar to that of Franklin in some respects, we also analyzed Langban "hedyphanes" in search for additional samples of johnbaumite. Of 25 samples, 22 are mimetite containing calcium and barium in substitution for lead. Hence, Langban "hedyphanes" are mostly mimetite. Johnbaumite remains a most rare mineral. The type specimen is the only one known at this time."

X-ray crystallography

"Cleavage fragments were studied using standard precession and Weissenberg techniques. These results verified that the space group is $P6_3/m$ or $P6_3$. As all data indicate that johnbaumite is a member of the apatite group, we assume that the true space group is $P6_3/m$. Photographs were carefully examined for the occurrence of superstructure reflections or deviations from hexagonal symmetry, as some apatites have been shown to be monoclinic with one a translation doubled over that of common apatites. No superstructure reflections were observed.

Powder X-ray diffraction data was obtained using a polycrystalline sample with Si as an internal standard mounted in a 114.59mm-diameter Gandolfi camera. Lattice parameters ($a = 9.70 \pm 0.02$ and $c = 6.93 \pm 0.02 \text{ \AA}$) were obtained through least-squares refinement of the powder data. The data were obtained with $\text{CuK}\alpha$ X-radiation."

Occurrence

"Johnbaumite is known on only one specimen which was collected by John Baum in the Franklin mine in 1944. The appearance of the hand specimen originally suggested it might be a copper-bearing feldspar and it was recognized as being unique on that basis. The specimen was found in a small lenticular body located at 830S, 170E, elevation -760 in the 730 S Palmer shaft pillar, in the third sub-level below 750 level. The lenticular body was surrounded on both sides by calcareous ore bands. The sample was taken 52 feet from the hanging wall and 54 feet from the footwall contact.

Johnbaumite is the massive host for a number of other species which occur within it in small amounts. The most important of these is yeatmanite (*Dunn and Leavens, 1980*), which occurs in euhedral lath-like crystals in apparent chemical equilibrium with johnbaumite. In addition to yeatmanite, johnbaumite is host to diopside and andradite (both containing approximately 8 percent MnO), franklinite, copper, and romeite, a species new to the deposit. The texture of the specimen is similar to that of a typical metamorphic karn assemblage and there is no evidence of replacement. Thin-section examination indicates that diopside was the first phase to form; it is rimmed by andradite with inclusions of romeite in the andradite. Romeite is moderately abundant in the specimen, occurring as formless blebs within andradite, franklinite, yeatmanite, and johnbaumite. The yeatmanite $(\text{Mn}_5\text{Sb}_2)(\text{Mn}_2\text{Zn}_8\text{Si}_4)\text{O}_{20}$, is essentially arsenic-free, and johnbaumite is essentially antimony-free. We observed no epitaxy among any of these species."

Relationship to other species

"Johnbaumite, $\text{Ca}_5(\text{AsO}_4)_3(\text{OH})$, is a member of the apatite group. It is the arsenate analog of hydroxylapatite, $\text{Ca}_5(\text{PO}_4)_3(\text{OH})$, and the hydroxyl analog of svabite, $\text{Ca}_5(\text{AsO}_4)_3\text{F}$. The three arsenate analogs of the common apatites are now known."

Acknowledgments

"We are indebted to Mr. Robert Ramik of the Royal Ontario Museum for assistance with DTA-TGA data; to Mr. Charles Obermeyer for microprobe assistance; and to Mr. Richard Johnson and Mr. Frank Walkup for preparation of polished sections. Special thanks are due Mrs. Esther Claffy for assistance. This project was supported, in part, by a grant from Mrs. E. Hadley Stuart, Jr."

(Editor's note: Tables pertaining to chemical data, X-ray powder diffraction data and the apatite group, 1 thru 3 respectively, have not been included in this abstraction. You are directed to the original describing article for this detailed information.)

GENESIS OF THE STERLING HILL ZINC DEPOSIT, SUSSEX COUNTY, NEW JERSEY

SAMUEL F. SQUILLER

McClellan Central Laboratory, 1155 TCHOS. McClellan Air Force Base, California 95652

CHARLES B. SCLAR

Department of Geological Sciences, Lehigh University, Bethlehem, Pennsylvania 18015

ABSTRACT

The Sterling Hill zinc deposit is a folded and metamorphosed stratiform deposit of oxide and silicate minerals of zinc, iron, and manganese enclosed in Precambrian marble. The ore is a unique high-rank metamorphic rock composed of willemite, franklinite, and zincite disseminated through calcitic marble; there is a virtual absence of sulfides. The Franklin zinc deposit 4 km to the north is the mineralogical and structural counterpart of the Sterling Hill deposit, but it was subjected to a more intense post-metamorphic hydrothermal overprint. The unusual mineralogy of these deposits and their complex structure has given rise to numerous genetic hypotheses. Most of these are epigenetic and include: (1) igneous injection followed by desulfurization, (2) contact metasomatism by dikes, (3) direct deposition of present mineralogy through selective replacement of favorable marble beds by magmatic emanations from an unknown igneous source, (4) surface weathering of sulfides to hydrous oxides and silicates and perhaps carbonates followed by deep burial and metamorphism. Recently, the syngenetic view expressed by Kitchell in 1855 has been resurrected (Callahan, 1966; Frondel and Baum, 1974).

Based on the results of an electron-microprobe study of the intergranular and intragranular chemical homogeneity of franklinite at Sterling Hill (Squiller and Sclar, 1976) and the results of a structural study by Metsger, et al. (1969), we have adopted the syngenetic view and propose a model in which the original zinc deposits are considered to be a marine chemical precipitate. It is proposed further that the metal-bearing sedimentary progenitor of the present ore minerals may have been a zincian-ferroan-manganous dolomite in the form of a carbonate mud intimately mixed with iron and manganese oxides and silica gel. Zincian dolomites containing up to 14 wt % Zn in solid solution have been reported. During subsequent high-rank regional metamorphism, the hypothetical zincian dolomite would undergo dedolomitization and give rise to a calcite (ss) and an oxide (ss). The oxide phase would be expressed as either zincite or a spinel (franklinite) depending on the local metal ratios in the dolomite and the local availability of original iron and manganese oxides. The composition of the spinel would depend in part on the f_{O_2} that would govern the Fe^{+3}/Fe^{+2} ratio. The release of CO_2 on dedolomitization would result in relatively oxidizing conditions and, hence, the formation of franklinite (ideally $ZnFe_2^{+3}O_4$). The absence of graphite in the ore zone, despite its general distribution in the Franklin marble, may be explained through reaction of graphite with CO_2 released by dedolomitization of the dolomite zinc-rich interval in the carbonate sequence. Willemite may be interpreted as the reaction product of zincite with local concentrations of silica. The present ore mineralogy may thus be explained through local metamorphic reactions on a volume scale of .05 - .5 cm^3 as follows: (1) franklinite occurs where oxides with a high Fe/Mn ratio were present and silica gel was absent, (2) willemite occurs where silica gel was present and oxides of iron and manganese were virtually absent, (3) zincite occurs where both silica gel and iron and manganese oxides were absent. An electron-microprobe study of gahnite-franklinite exsolution intergrowths from Sterling Hill, coupled with the experimentally determined solvus for the system $ZnAl_2O_4 - ZnFe_2O_4$, indicates that the minimum peak temperature reached during regional metamorphism was $760^\circ C$ (Carvalho, 1978). This temperature would have been high enough to dedolomitize the hypothetical zincian dolomite. The key to the genesis of the Franklin deposit appears to be its counterpart at Sterling Hill.

INTRODUCTION

The Sterling Hill zinc deposit at Ogdensburg, Sussex County, New Jersey, is one of a pair of mineralogically unique folded and metamorphosed stratiform ore deposits that occur in the Precambrian Franklin marble along the northwestern edge of the New Jersey Highlands. The other member of the pair is the Franklin deposit 4 km to the north from which zinc ore was mined for more than a century. The Franklin deposit is world renowned for the occurrence of more than 200 mineral species; the mineralogy of the Sterling Hill deposit is relatively simple and monotonous (Frondel, 1972). Both deposits contain the same principal ore minerals of zinc, namely, franklinite, willemite, and zincite, all of which are disseminated through manganous calcitic marble. Sulfides are essentially absent. These two zinc deposits are unusual geochemically because of the intimate association of zinc, iron, and manganese, the lack of segregation of the iron and manganese, and the occurrence of the zinc in the form of two oxides (franklinite and zincite) and a silicate (willemite) rather than as a sulfide or a carbonate.

The large number of mineral species at Franklin developed principally as the result of post-metamorphic hydrothermal activity and subordinately through thermal effects localized at the contacts of post-metamorphic dikes. These minerals tend to obscure primary genetic relationships in the Franklin deposit. Thus, the Sterling Hill deposit, which is devoid of igneous intrusions and has only a weak post-metamorphic hydrothermal overprint, is the more promising of the two deposits with respect to the development of the genetic concepts regarding the mineralogical occurrence of zinc, iron, and manganese in the precursor of these regionally metamorphosed stratiform deposits.

The origin of these mineralogically and geochemically exceptional deposits has intrigued geologists for over 150 years so that the literature is replete with genetic speculation. A recent electron-microprobe study of the ore minerals at Sterling Hill (Squiller, 1976; Squiller and Sclar, 1976) has provided the basis for a new hypothesis on the genesis of this deposit that is presented in this paper.

GEOLOGICAL SETTING

The Sterling Hill deposit has the form of a complex isoclinal syncline that plunges northeast and is conformable with the mineralogical banding in the enclosing Franklin marble (Metsger, et al., 1958; Metsger, et al., 1969). The white, coarsely crystalline marble is a member of a group of Precambrian sedimentary and igneous (?) rocks that were intensely folded and regionally metamorphosed to sillimanite-zone rank about 1050×10^6 yrs. ago (Dallmeyer, et al., 1975). The Sterling Hill deposit probably was exhumed in late Precambrian time and subsequently covered by the Cambrian Hardyston quartzite.

The mineralogical banding in the marble is due to graphite, mica, amphibole, pyroxene, and chondrodite. The banding in the marble is parallel to the foliation in the adjoining gneisses and has been attributed to bedding (Hague, et al., 1956). Graphite is ubiquitous in the marble except in and near the ore zone, so that an envelope of graphite-free marble encloses the orebody (Metsger, et al., 1958).

INTERNAL ZONING AND TEXTURE

Metsger et al. (1958) have shown that the Sterling Hill deposit can be divided into mappable zones that are characterized by their mineralogy. Although these zones are lenticular, several may be traced throughout the deposit, and they are conformable with the broad synclinal structure of the deposit as a whole. The deposit thus appears to be made up of a consistent sequence of mineralogically distinctive zinc-rich layers. This sequence may represent original beds of discrete bulk chemical composition.

The ore is a high-rank metamorphic rock composed of franklinite, willemite, and zincite disseminated through manganoan calcite. Franklinite is the dominant ore mineral, willemite is somewhat subordinate, and zincite is relatively minor. The ore ranges from massive to gneissic and typically has a granular salt-and-pepper texture with a grain size ranging from 1-7 mm. Locally, the ore minerals may attain a grain size of several cm. The relative proportions of the ore minerals to each other and to the calcite matrix are highly varied, and this variation commonly is expressed as a fine-scale mineralogical layering in the ore which is conformable with the overall zonation and structure of the deposit.

RESULTS OF ELECTRON-MICROPROBE STUDY OF FRANKLINITE

Seven suites of ore samples were collected from widely dispersed locations in the mine. An electron-microprobe study of the franklinite in these samples, using statistical criteria for intragranular homogeneity, showed that the franklinite grains are not compositionally zoned and that they are chemically homogeneous with respect to zinc, iron, and manganese (Squiller, 1976). A corresponding statistical assessment of the intergranular homogeneity of the franklinite showed that there is pronounced chemical inhomogeneity of the franklinite grains as close as 3 mm to each other in polished sections no more than 2.25 cm^2 in area (Squiller, 1976). This study also showed that the grains of franklinite differ in composition both parallel and normal to the mineralogical layering although the magnitude of these variations generally is greater normal to the layering. Thus, chemical equilibrium appears to have been achieved during regional metamorphism in spherical volumes of the order of 0.07 cm^3 (grains of franklinite with a radius of 0.5 cm) but not, in general, on a larger scale. Inasmuch as the ore is a high-rank metamorphic rock, the high degree of intragranular homogeneity and the lack of intergranular homogeneity exhibited by the franklinite indicates that the metamorphic event was isochemical and that there was no long-range transport of heavy metals. In other words, the present ore minerals appear to have developed in the absence of aqueous fluids. Inasmuch as franklinite is a spinel, and the spinel structure permits wide variations in chemical composition through atomic substitution, it is possible that the compositional variations in the franklinite grains perpendicular and parallel to the layering in the ore may reflect the original distribution of iron, zinc, and manganese in the sedimentary carbonate rock before the regional metamorphism which produced the franklinite and transformed the limestone into marble.

EARLIER GENETIC VIEWS

The Sterling Hill and Franklin zinc deposits have a unique mineralogy and geochemistry and, thus, cannot be placed readily into the conventional classifications of ore deposits. The origin of these

deposits has long been an enigma, and the proposed hypotheses regarding their origin span the range of theories on the origin of mineral deposits in general and reflect the evolutionary trends of the science of mineral deposits over the last 150 years. Much of the problem of genetic interpretation is due to the unusual mineralogy of the orebodies, their complex structural relationships with the surrounding rocks, and the effects of high-grade regional metamorphism which have obscured the original mineralogical relationships in the rocks which constitute the ore zone. Previous discussions of ideas on the genesis of these deposits are given by Spencer, et al. (1908), Ries and Bowen (1922), Palache (1935), Pinger (1950), and Ridge (1952). Most of these older hypotheses were epigenetic in character and included the following:

- (1) igneous injection followed by desulfurization.
- (2) contact metasomatism by dikes.
- (3) direct deposition of present mineralogy through selective replacement of favorable marble beds by magmatic emanations from an (*unknown*) igneous source.
- (4) surface weathering of sulfides to hydrous oxides and silicates and perhaps carbonates followed by deep burial and metamorphism.

The epigenetic hypotheses dominated discussion during the first half of the 20th century. Nevertheless, as early as 1855, William Kitchell suggested that the zinc ores originally were chemical sediments deposited with the enclosing limestone and that the ore minerals resulted from metamorphic processes with little or no addition of material. This view was held by geologists of the New Jersey State Geological Survey until the end of the 19th century. The syngenetic view was recently resurrected by Callahan (1966), Metsger, et al. (1969), Frondel (1972), and Frondel and Baum (1974) who consider the deposits to be marine sediments rich in zinc, iron, and manganese that were subsequently deformed and recrystallized during regional metamorphism. Frondel and Baum (1974) suggest that the zinc, iron, and manganese in the original sediment occurred as carbonates and / or hydrous oxides, such as woodruffite or hydrohetaerolite, and / or amorphous gels.

PROPOSED HYPOTHESIS ON THE ORIGIN OF THE STERLING HILL ZINC DEPOSIT

In view of the evidence marshalled above, we have adopted the syngenetic view and invoke a model in which the ore deposit is considered to be an unusual chemical sediment intercalated with the enclosing carbonate mud in normal stratigraphic succession. As a result of folding and regional metamorphism, the deposit now has a conformable nappe-like structure in a folded carbonate sequence. The mappable mineralogical zones and small-scale mineralogical layering in the deposit may be interpreted as original beds, laminae, and lenticles of differing bulk composition in a sedimentary sequence. Mappable layers of distinctive texture and mineralogy, which can be traced through the deposit, may be interpreted as sedimentary strata of relatively uniform composition and greater areal continuity.

The granular salt-and-pepper texture of the Sterling Hill ore suggests that heavy metals were intimately associated with each other and finely dispersed in the sedimentary precursor. The lack of intergranular chemical homogeneity of the franklinite, despite its high degree of intragranular chemical homogeneity, however, indicates that the ratios of the heavy metals to each other in the original sediment differed markedly over distances smaller than a centimeter, and, in much of the ore, over distances smaller than 0.5 cm. Furthermore, these geochemical characteristics of the franklinite point to the probable absence of hydrothermal fluids and heavy-metal transport during nucleation and growth of the franklinite during high-grade regional metamorphism, but they are wholly consistent with the concept of dry isochemical metamorphism of a sediment that was chemically heterogeneous on a small scale both parallel and normal to the original bedding. It should be noted here that modern sediments accumulating in the Red Sea brine pools are gel-like muds rich in iron oxides and hydroxides, opaline silica, carbonate minerals such as dolomite and siderite, and manganese oxides and hydroxides. Individual samples of these sediments reportedly contain up to 17% Zn, 60% Fe, and 4% Mn (Stanton, 1972). Reconstitution of such sediments through deep burial and metamorphism might yield the oxide-silicate mineralogy and the geochemical association of zinc, iron, and manganese observed in the Sterling Hill ore.

The question of the mineralogical occurrence of zinc in the original sediment has presented a problem with respect to the syngenetic hypothesis. Low-temperature oxides, such as woodruffite and zincian todorokite, have been proposed, but they contain too little zinc relative to manganese to account for the zinc-rich Sterling Hill ore. Furthermore, the thermal decomposition of sedimentary zincian manganese oxides during regional metamorphism could not account for the occurrence of zincite inasmuch as such oxides would yield hetaerolite or franklinite (*in the presence of iron*). Zincite, however, could be the thermal decomposition product of a carbonate, but the occurrence of smithsonite as a primary marine precipitate appears to be highly improbable.

In adopting the syngenetic view, we propose that the sedimentary pregenerator of the Sterling Hill ore deposit was a lens of marine carbonate mud composed of zincian-ferroan-manganous dolomite intimately mixed with silica gel and colloidal iron and manganese oxides. Such a heavy-metal dolomite might be produced by chemical reaction of calcite precipitated from marine waters with hot brines low in sulfide ion carrying zinc, iron, and manganese ions in solution. Evidence for the possible existence of this hypothetical

heavy-metal dolomite has increased markedly during the last two decades. Kutnahorite [$\text{CaMn}(\text{CO}_3)_2$] and ankerite [$\text{CaFe}(\text{CO}_3)_2$] are well-established mineral species that are isostructural with dolomite. Hurlbut (1957) described zincian dolomite from Tsumeb, South West Africa, which contained 7.0 wt % Zn, and Geier (in Strunz, 1970, p. 238) reported that zincian dolomite from Tsumeb contained up to 14.0 wt % Zn. Zabinski (1959) found that zincian dolomite from the Warynski mine, Upper Silesia contained 8.8 wt % Zn, and re-examination of this material by electron-microprobe analysis showed that it contained 10-14 wt % Zn with a Zn/Mg atomic ratio equal to or slightly greater than 1 (Jasienska and Zabinski, 1972).

During high-rank regional metamorphism, the hypothetical zincian dolomite would undergo dedolomitization and give rise to a calcite solid solution and an oxide solid solution. The oxide phase would be either a zincite solid solution or a spinel depending on the local composition of the dolomite solid solution and the local availability of admixed iron and manganese oxides. Thus, the composition of the spinel would depend on the bulk composition of the impure dolomitic mud at each point, that is, in some places the spinel would be a franklinite solid solution whereas at others it might be a magnetite solid solution. The composition of the spinel also would depend on the oxygen fugacity (f_{O_2}) during dedolomitization inasmuch as the f_{O_2} will govern the $\text{Fe}^{+2}/\text{Fe}^{+3}$ and $\text{Mn}^{+2}/\text{Mn}^{+3}$ ratios. The release of CO_2 on dedolomitization would result in oxidation of most of the original Fe^{+2} to Fe^{+3} whereas very little of the original Mn^{+2} would be oxidized during this reaction (Stern and Weise, 1969). As a result, the formation of franklinite (*ideally* $\text{ZnFe}_2^{+3}\text{O}_4$ with some Mn^{+2} in solid solution) would be favored.

The present ore-mineral assemblage at Sterling Hill may thus be explained by local metamorphic reactions on a volume scale of .05-.5 cm^3 . Willemite would be developed by local reaction with silica of the oxide solid solution produced by dedolomitization. If the composition of the dolomite was such that an MnO solid solution was produced by dedolomitization, it would react with silica to yield tephroite or rhodonite. Correspondingly, franklinite would occur where the ZnO solid solution formed on dedolomitization reacted with oxides with a high Fe/Mn ratio in the absence of silica. Zincite would be expected to persist only in the absence of both silica and oxides of iron and manganese. The large-scale mineralogical zoning and small-scale mineralogical layering in the Sterling Hill deposit thus would be due to the nonuniform distribution of zinc, iron, manganese, and silica in the original sediment. The proposed process of dedolomitization and local metamorphic reactions for the development of the ore minerals at Sterling Hill is summarized schematically in Figure 1.

Dolomitic Mud

(zincian dolomite progenitor containing variable concentrations and variable proportions of Zn^{+2} , Fe^{+2} , and Mn^{+2} proxying for Mg^{+2})

+

Local concentrations of Silica Gel and/or
Oxides of Iron and/or Manganese

Dedolomitization During Regional Metamorphism and Reaction of
Oxide Solid Solution (ZnO_{SS}) with Local Constituents in
Volumes of 0.05 - 0.5 cm^3

Zincite (ss) (where
silica gel and oxides
of iron and manganese
are locally absent)

Willemite (where
silica gel is present
and oxides of iron
and manganese are
virtually absent)

Franklinite (where
silica gel is absent and
oxides with a high Fe/
Mn are locally abundant)

Figure 1. Development of the ore minerals at Sterling Hill through dedolomitization and local metamorphic reactions.

As noted above, graphite is ubiquitous in the Franklin marble, but the Sterling Hill deposit is free of graphite and is enclosed in an envelope of graphite-free marble (Metsger, et al., 1958). The release of CO₂ through dedolomitization of those layers in the carbonate sequence now represented by the ore deposit may account for the absence of graphite by reaction of graphite with CO₂ to produce fugitive CO.

The question that remains is whether the peak temperature attained during regional metamorphism (*Grenville Orogeny*) was high enough to result in dedolomitization of the hypothetical zincian dolomite. If the precursor of the Sterling Hill zinc deposit is assumed to be a geochemically unusual metal rich carbonate mud in an otherwise normal carbonate sequence, the peak temperature reached during the Grenville Orogeny should be the temperature to which the zinc deposit was subjected. The peak temperature deduced from petrologic studies of the Precambrian gneisses of the Highlands of New York and New Jersey lies between 700° C - 775° C (Dallmeyer and Dodd, 1971; Young, 1971). On the basis of thermodynamic considerations, Takahashi and Meyers (1963) concluded that the zinc ores at Sterling Hill and Franklin developed at temperatures from 557° - 827° C. Frondel and Klein (1965) gave a minimum temperature of formation from 650° - 700° C based on exsolution intergrowths of franklinite and hetaerolite from Franklin using the equilibrium diagram for the system Fe₃O₄ - Mn₃O₄ - ZnFe₂O₄. The results of a recent electron-microprobe study of gahnite-franklinite exsolution intergrowths from the Sterling Hill deposit intergrated with the experimentally determined solvus (*miscibility gap*) for the system ZnAl₂O₄ - ZnFe₂O₄ showed that the minimum peak temperature attained during regional metamorphism at Sterling Hill was 760° C (Carvalho, 1978).

Although dedolomitization in pure magnesian dolomite occurs at 815° C at 1 kb pressure and increases markedly with pressure, Hurlbut (1957) has shown that the substitution of zinc for magnesium in the dolomite structure markedly lowers the temperature at which the MgCO₃ layers decompose so that, for a dolomite with a Mg/Zn atomic ratio of 3.3, dedolomitization occurs at 725° C at low pressure. It is also known that at 1 kb pressure, the dedolomitization temperatures of rhodochrosite, siderite, and smithsonite are only about 700° C, 450° C and 350° C, respectively. Although pressure will increase temperature of dedolomitization, the composition dependence of the temperature of dedolomitization appears to be far greater than the pressure dependence in the metamorphic pressure range of 3-5 kb. Thus, a dolomite in which there is appreciable substitution of zinc and iron for magnesium should undergo dedolomitization in the peak temperature range (700° - 800° C) attained during regional metamorphism at Sterling Hill.

The proposed syngenetic hypothesis is that the stratiform Sterling Hill deposit was an impure carbonate mud containing a dolomite rich in zinc, iron, and manganese. This mud was deeply buried, folded, and subjected to dedolomitization and very localized metamorphic reactions during regional metamorphism. These events appear to be compatible with what is known of the geology, mineralogy, and geochemistry of this deposit. Additional studies on the geochemical relationships of the major ore minerals with the electron microprobe should provide further tests of the validity of this hypothesis. The key to understanding the genesis of the famed Franklin deposit appears to be its counterpart at Sterling Hill where the intensity of post-metamorphic hydrothermal effects is relatively weak so that important "primary" genetic relationships are more readily resolved.

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(Editor's note: A comment - Recently the *Picking Table* (Vol. 20, No.2) presented an article entitled "*Franklin and Sterling Hill in the Beginning*" by Warren Cummings. Now in this issue, the *Picking Table* brings you the reprint of a paper entitled "*Genesis of the Sterling Hill Zinc Deposit, Sussex County, New Jersey*," by Samuel F. Squiller and Charles B. Sclar, which was presented to the *Fifth Quadrennial of the International Association on the Genesis of Ore Deposits* (IAGOD), by its authors, last year, in Stuttgart, Germany. As is usual in geological papers dealing with these highly metamorphosed deposits, there are some differences of opinion between the two.

Cummings' view is a broad-scope picture describing the total environment surrounding the deposition, from submarine hot springs, of protores (proto-ores) whose major components were sulfides (spahlerite, pyrite, etc.) with minor carbonates and oxides. Similar deposits are forming today in deeps on the Red Sea floor. To derive today's sulfur-free willemite and franklinite ores Cummings envisions a period at the surface of weathering and oxidation to convert them to oxides before metamorphism.

On the other hand, Squiller and Sclar focus closely on the protores. After presenting their evidence, they conclude the ores to have been hydrothermal deposits of a heterogeneous zinc, iron and manganese dolomite (with some fine silica). Upon metamorphism, the dolomite broke down into zincite and franklinite, and, when combined with the silica, formed willemite. This type of protore requires no premetamorphic surface exposure).

LAW and ORDER in FRANKLIN, NEW JERSEY

by John L. Baum

With the consolidation of the varied mining interests at Franklin in 1897, subsequent to the sinking of the Palmer Shaft and building of the separating plant near the railroad junction, a mining town developed, and with it the problems associated with mining towns everywhere. Boarding houses were run by enterprising widows and miner's wives, and a rowdy population with little better to do than drink, fight and steal when not working, made Franklin a real frontier town. Drifters would stay at a boarding house long enough to become acquainted with the habits of the other boarders and then suddenly leave town taking any property worth stealing. Men quit the works often without notice, and it should have come as no surprise when a skeleton was found in an abandoned shaft off Main Street. It was never identified and no one volunteered, but it seems likely that a score had been settled.

With an obvious need for a change, the Zinc Company arranged for a one man police force, and Chief Herbert C. Irons was selected, to start a new era on October 1, 1915. Chief Irons was born in Brooklyn in 1890 and following public school he became a carpenter for a few years. In late 1909 he enlisted in the army for three years, following which he served in the Panama Canal Zone Constabulary for a year and a half. This was followed by a stint with the Pennsylvania State Police from which he joined the private police of the Hercules Powder Co. before coming to Franklin. Chief Irons was one of the largest men I ever knew, and dressed the part in an enormous greatcoat, leather puttees and black boots. His office before my time was a small jail since incorporated into the ambulance squad's headquarters near the pond, and at that time he rode a horse.

It is said that when there were misunderstandings among the citizens, Chief, his horse and lasso, would show up and the more guilty party would lead the way to the jail, at the end of a short rope, running and stumbling to avoid the hooves of the rearing horse. If the Bill of Rights and shrill cries of police brutality were unknown in that day, the appreciation of the law abiding was obvious as was their satisfaction. A story, probably of little validity, state that a stranger was loafing near the pond and the Chief sizing him up as a probable foreign born, asked "Are you an anarchist?" to which the new arrival, wishing to be accepted, replied "Me anarchist, me anarchist." This was the wrong answer in a strong Company town in those days, and the fellow was soon sprinting toward the pokey at the end of the trusty lasso.

The Chief's big case was known as the Cat Swamp Murders. A truck load of silk had been hijacked and the driver and helper left shot in a swamp above Sparta. The Chief had been at pains to befriend a tribe of gypsies which often visited the area selling yard goods, presumably so that they would know just what the law situation was at Franklin, and from his gypsy friends Chief learned where the head of the murderous gang was holding out. With the State Police and a posse Chief stormed the farm, centered on the barn and with a pitch fork attacked the hay stored there. One highwayman surrendered but the head bandit came out shooting. The Chief found this irritating. When the headstrong bandit was well enough to stand trial, the gang was convicted. Two men electrocuted, two received life, and two from twenty to thirty years. There is much to be said for the good old days.

An incident in my time involved the German American Bund Camp near Andover. Here a bunch of misguided German Americans played at being domestic Nazis, marching in uniforms and saluting the swastika flag. Chief stood this as long as he could and then one day assembled a posse and invaded the Bund camp. There was some struggle on the part of the bewildered Bundists, but no one was ever a match for the Chief when he was defending his interpretation of the law, and the unequal struggle was soon over and Old Glory, brought along for the purpose, replaced the swastika on the flag staff.

Chief Irons was wonderful with kids and they all called out to him when they saw him. He had little trouble finding out who was responsible for what juvenile prank, and generally a talk with the parents with a recommendation of specified punishment was enough to make a kid see the light. Mine certainly did. Chief had two children, products of his marriage to Mary Rowe, daughter of George Rowe, Mine Captain at Franklin. Indeed, when "Cap" Rowe gave his mineral collection to Rutgers, it was with the wish that scholarship aid would be made available to certain of his grandchildren, including Chief's two. The Chief was the right man for Franklin when firm law enforcement was needed and the community was much better for his presence here. It is a delight to recall these memories of one of Franklin's truly influential men.

WHAT TO DO

(Until the rarer "franklins" come)

by

"Wecant Tell"

A great many collectors of minerals from Franklin and Sterling Hill are easily discouraged when their collection of "franklins" fails to grow to their satisfaction. What many collectors overlook, however, is the possibility of assembling suites of minerals such as calcite, franklinite and willemite. Suites of these minerals may add much to their collection.

A suite of Franklin calcite may be assembled according to its physical characteristics. Calcite occurs in a variety of colors, from colorless or pure-white through grey to black; from yellow-orange to brown. This variation in color is attributed to corresponding amounts of manganese impurities which also affect fluorescence in a similar manner. The appearance of the crystallization of this mineral may influence yet another suite. It occurs in fine-grained to coarse-grained crystalline masses to masses from which perfect rhombohedrons may be cleaved to well formed euhedral crystals of various form. The fluorescent characteristics of this mineral demand particular attention. Calcite will fluoresce yellow-orange, orange, red-orange, red, red-violet to violet and a variety of colors in between.

A suite of the many forms of franklinite may be assembled in bold black contrast to the suites of other minerals. Franklinite occurs in massive form without notable structure through granuals to crystals of unique form and luster.

A suite of Franklin willemite may be assembled, as with the others, according to its physical characteristics. This is a mineral of many guises. It appears white or black and nearly every color in between. Its manner of crystallization is equally varied. It occurs in nearly characterless masses, formless granuals and in crystals of unmatched beauty. It is, perhaps, in the latter that this mineral excels. Crystals may be microscopic or "freaks" nearly a foot across. Some crystals may be poorly formed, stubby and black, while others may be remarkable colorless, lime-green or yellow-green transparent prisms of astounding beauty. Some occur alone, while others occur in clusters; yet, others may form unusual radiating structures that mesmerize the beholder. Second, only to the perfection of its crystals, is willemite's remarkable response to ultraviolet light. Willemite will fluoresce green, yellow-green, yellow and yellow-orange, and a variety of colors in between. Emphasizing this attractive property is the frequent occurrence of phosphorescence as well.

A suite of all three of these minerals, in combination, may be assembled according to the manner in which they compliment each other. Suites of this type are frequently very colorful and tease the imagination with an interplay of colors and patterns, particularly under ultraviolet light.

So, try assembling one or more of these suites until the rarer "franklins" come your way. The result of your effort will most likely become a permanent part of your collection. More importantly, in addition to supplementing the growth of your collection, it will increase your knowledge of these minerals as they occur at Franklin and Sterling Hill.

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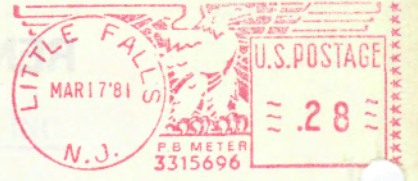
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