minerals of the Buckwheat Dolomite franklin, new jersey

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The world famous zinc deposits of Franklin and Sterling Hill (Ogdensburg), New Jersey, have been the subject of intense scrutiny by scientists for almost two centuries. Most research has centered on the origin of the Franklin–Sterling Hill orebodies and the unique mineral assemblages contained within them. However, one aspect of Franklin mineralogy which has received scant attention is the occurrence of well crystallized minerals filling cavities in porous masses of dolomitic limestone.

INTRODUCTION

Dolomite limestone occurred as replacement bodies in the marble of the Buckwheat open pit. Collectors refer to this material as "sugary dolomite" but for the purposes of discussion only, we prefer to use the name "Buckwheat dolomite." Our usage is strictly informal. We will use the term Buckwheat dolomite as a field term with no formal stratigraphic nomenclature applicable.

This article documents the minerals found in this occurrence principally through the use of scanning electron microscopy (SEM). Identification of species was verified by X-ray diffraction (Gandolfi) techniques. Additional data were obtained using an electron microprobe equipped with an energy-dispersive spectrometer (EDS). An updated list of the species found in the Buckwheat dolomite is provided in Table 1.

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GEOLOGY

The geology of the Franklin–Sterling Hill area was described by Spencer *et al.* (1908) in the Franklin Furnace Folio included in the *Geological Atlas of the United States.* A reproduction of Spencer's Geologic Map of the Franklin Mining District appeared in Charles Palache's monumental work *The Minerals of Franklin and Sterling Hill, Sussex County, New Jersey* (1935) and is reproduced here in Figure 1.

A glance at this map shows that the Franklin–Sterling Hill orebodies are located at the contact between the Precambrian Pochuk gneiss, now known as the Median gneiss, and the Franklin marble. The orebodies are entirely enclosed within the marble. Frondel and Baum (1974) state that the Franklin marble is part of a series of sedimentary rocks which were intensely folded and regionally metamorphosed to the sillimanite grade during the late Precambrian, about 950 million years ago. They describe the geologic structure of the area as essentially an overturned isoclinal fold and the orebodies as synclinal hooks or pendants. The

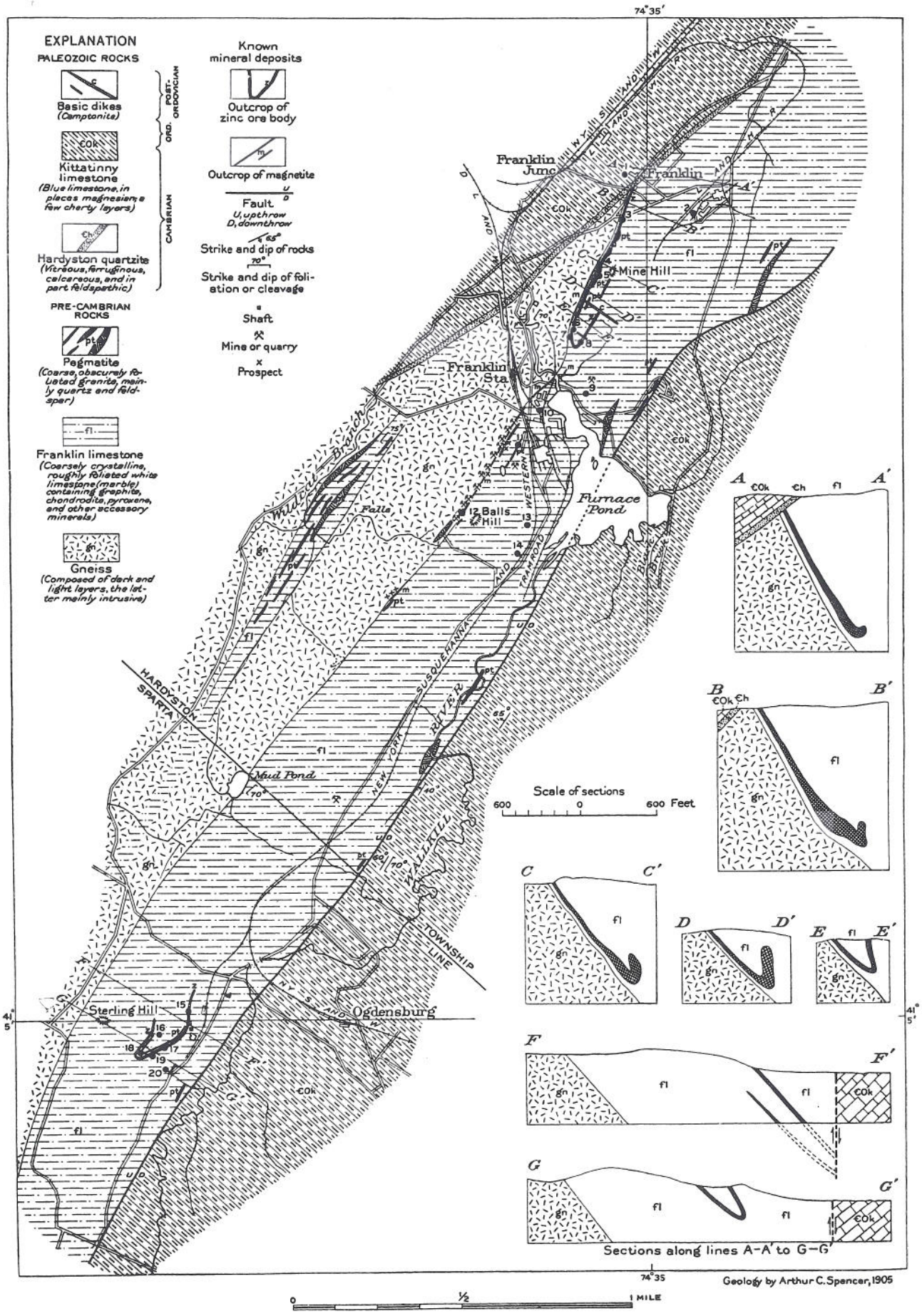


Figure 1. **Geologic map of the Franklin mining district, showing sites of principal mineral localities (Spencer *et al.*, 1908).**

Franklin marble and associated gneisses were intruded in later Precambrian time by post-metamorphic granitic and pegmatitic dikes. The Precambrian metamorphics are overlain to the west by the Cambrian Hardyston quartzite and the Ordovician Kittatinny limestone. The area was subject to faulting and minor folding in the Late Paleozoic and by the intrusion of basic igneous dikes (camptonite dikes on the map).

Very little information is available on the geologic setting of the Buckwheat dolomite alluded to in this study. Referring to the point on Spencer's map labeled No. 6, Palache (1935) states, "In the west wall of the Buckwheat open cut was exposed a veinlike mass of grey dolomite containing in its cavities crystals of quartz, dolomite, albite, sphalerite, pyrite, millerite and goethite." This occurrence was mined out prior to Palache's study, but large boulders of the dolomite can still be collected on the Buckwheat Dump.

MINERAL DESCRIPTIONS

The following are brief descriptions of the species which occur in cavities in the dolomite. The purpose of this investigation was to ascertain the species present as well as produce photodocumentation of these species. Presented in Table 1 is a list of species reported from this occurrence by various authors as well as those identified during the course of this study. Of 41 previously reported minerals, we have confirmed 22 species, 4 of which were visually identified due to paucity of material for analysis. Comments regarding this discrepancy of numbers will be discussed following the mineral descriptions.

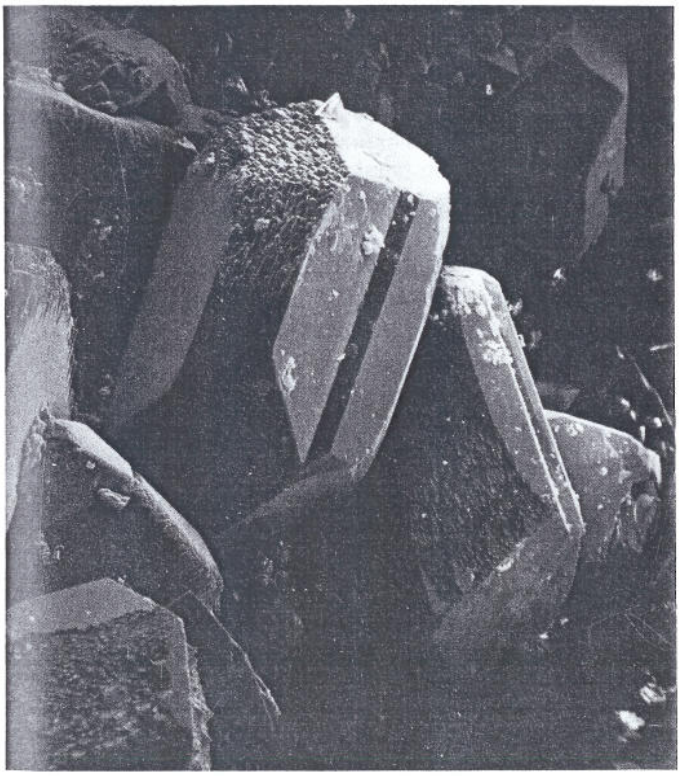


Figure 2. **Albite twinned on the albite law. Colorless, 2 mm long.**

Albite $NaAlSi_3O_8$

Albite occurs as colorless to white crystals, always twinned according to the albite law (Fig. 2). Associated species: quartz and microcline.

Anatase TiO_2

Only a single specimen of anatase is known from the Buckwheat dolomite. It consists of a dark blue crystal, approximately 0.5 millimeters along [001], on dolomite. The specimen is in the collection of Ralph Thomas. Identification was visual. It should be stated that many purported anatase crystals which we have examined from the Buckwheat dolomite can be identified undoubtedly as brookite on the basis of crystal morphology. We have seen blue brookite crystals, so color is not diagnostic.

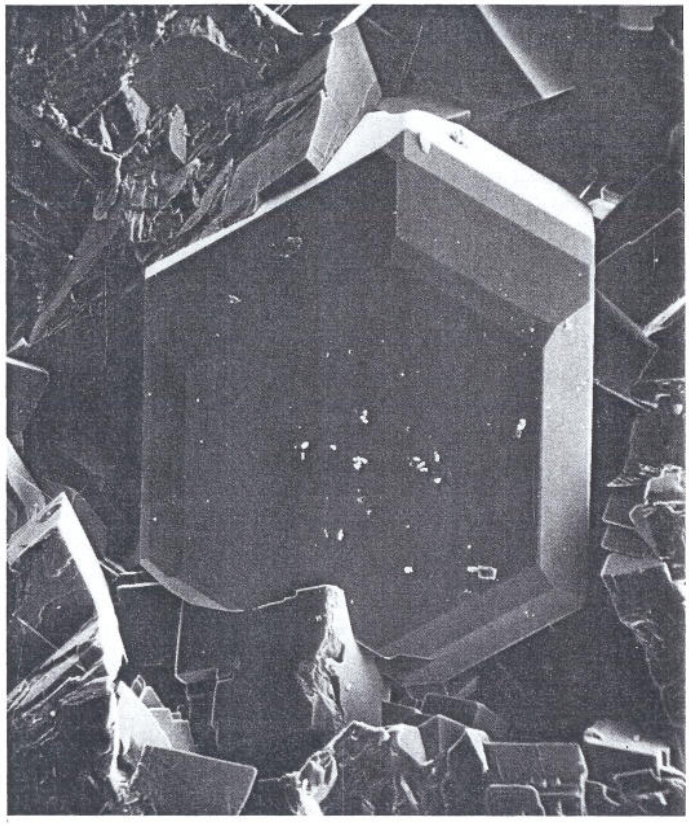
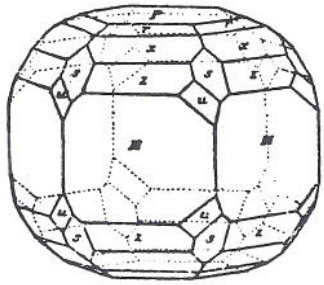


Figure 3. **Apatite – tabular, hexagonal, colorless crystal, approximately 600 micrometers in diameter. Inset: crystal drawing exhibiting similar morphology (Goldschmidt, 1916–23).**



"Apatite"

The exact species in the apatite group is unknown but is most probably fluorapatite, $Ca_5(PO_4)_3(F,OH)$. Palache (1935) reported the analysis of a Franklin apatite which is clearly fluorapatite. Apatite from the Buckwheat dolomite is found rarely as colorless to slightly pink to blue, tabular, hexagonal crystals. Associated species are usually chlorite in spherical aggregates and goethite needles enveloping rutile needles. Figure 3 shows a tabular crystal on dolomite.

Arsenopyrite FeAsS

A prismatic crystal of arsenopyrite in dolomite was kindly provided for examination by Alice L. Kraissl. It is quite a rare occurrence. Identification was made visually.

Aurichalcite $(Zn,Cu)_5(CO_3)_2(OH)_6$

Two specimens of aurichalcite are known, in the collections of Andrew Dilatush and Alice L. Kraissl. On both specimens the aurichalcite consists of extremely thin blue-green plates on dolomite. Due to the paucity of available material, only a visual identification could be made.

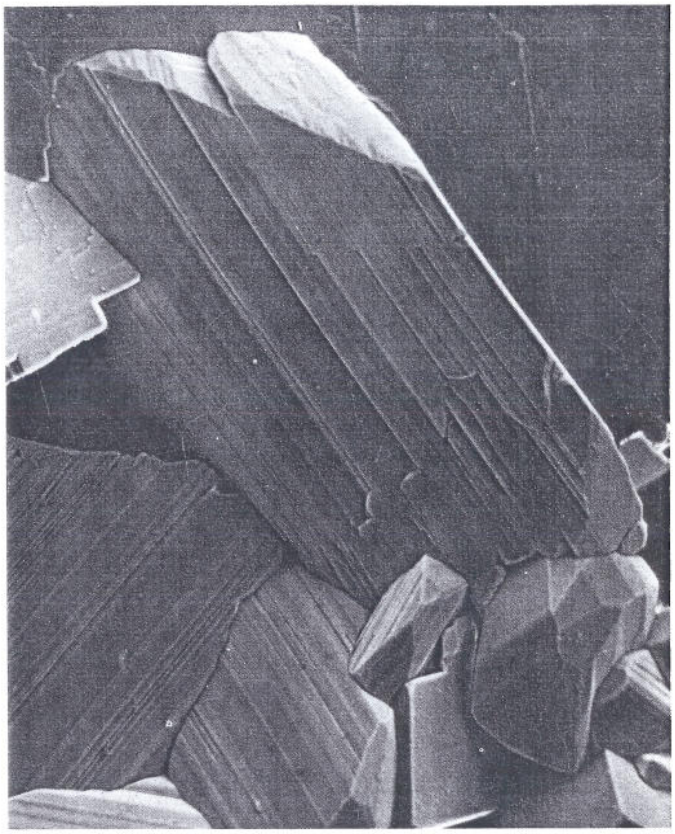


Figure 4. **Brookite—two habits occur on this specimen. A preponderance of tabular, prismatic crystals up to 130 micrometers long with a few equant crystals in the lower right-hand corner.**

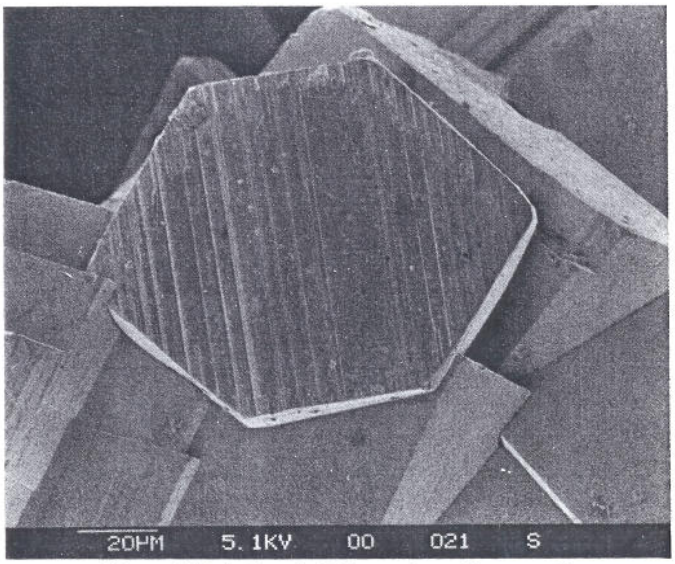


Figure 5. **Tabular, dark-brown brookite crystals exhibiting pseudo-hexagonal habit. The scale bar is 20 micrometers.**

Brookite TiO_2

Brookite was first confirmed by Gordon (1951) on the basis of crystallographic measurements. He considered it quite rare. Recent collecting by Helen and Joseph Warinsky (Warinsky, 1979) has shown that brookite is not rare but only uncommon in occurrence. Because of the small crystal size (less than 0.5 mm) they are easily overlooked. They occur in black, brown, yellow, wine-red and dark blue crystals. The crystals are usually prismatic and striated (Fig. 4)

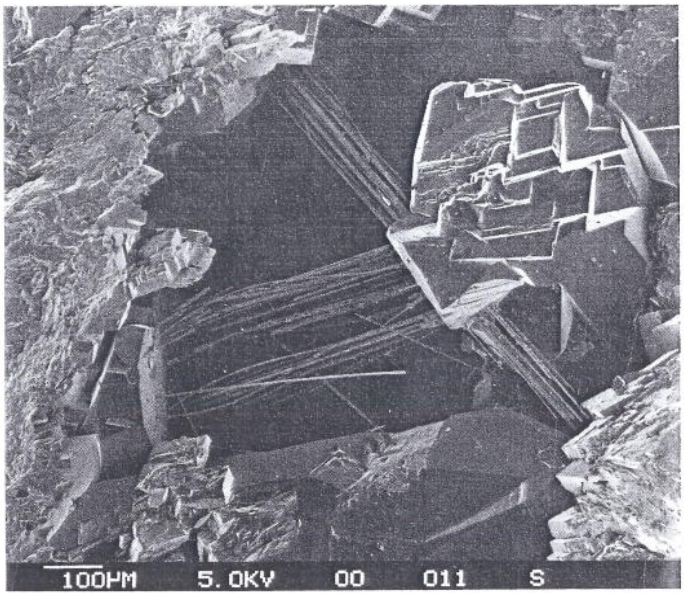
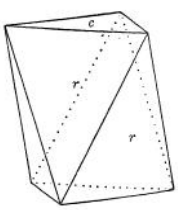


Figure 6. **Brookite-rutile intergrowths, tabular brookite crystals nucleated around rutile needles. The scale bar is 100 micrometers.**

but equant crystals are also known (Figs. 4 and 5). Much of the brookite is associated with its polymorph, rutile, in the form of needle-like crystals (Fig. 6). Although at some localities the polymorphs of TiO_2 (namely rutile, brookite and anatase) have been found together on the same specimen, at Franklin only brookite and rutile are found to coexist. It is our observation that brookites are much more readily found in dolomite which is more weathered than the "normal" Buckwheat dolomite. This weathered dolomite is characterized by large amounts of green chlorite and goethite. Cavities in this type of material usually yield brookite as brilliant, opaque, black equant crystals. "Normal" Buckwheat dolomite which contains rutile needles and pink microcline crystals should also be carefully scrutinized for brookite.

Figure 7. **Pseudo-octahedral crystals of calcite, 700 micrometers in diameter. The crystals are white in color. The octahedral aspect is the result of the combination of the rhombohedron and pinacoid. See inset (Palache, 1935).**



Calcite $CaCO_3$

Calcite in dolomite cavities occurs in a myriad of crystal habits. Figure 7 illustrates crystals that resemble octahedrons but are actually a combination of the rhombohedron (6 faces) and the pinacoid (2 faces) (Knoll, 1972). The two forms are nearly equal in their development, thus producing a pseudo-octahedron. These pseudo-octahedrons are almost always associated with graphite and dolomite. Calcite crystals are frequently found alone on dolomite rhombohedrons or commonly in pockets of dolomite rhombohedrons as disc-like crystals in which are included goethite sprays. Hemimorphite in radiating groups of platy crystals is also found in this assemblage.

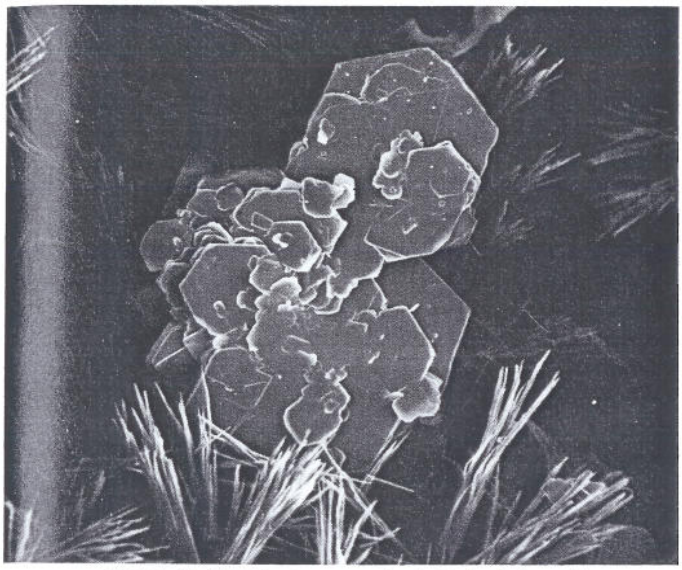


Figure 8. **Pseudo-hexagonal stacked plates of gray-green chlorite, 50 micrometers in diameter, with goethite needles.**

Figure 9. **Chlorite, a rosette of intergrown, pseudo-hexagonal plates 100 micrometers in diameter.**

"Chlorite" complex iron–magnesium silicate

An unidentified member of the chlorite group is commonly found as exceedingly small, rosette-like aggregates of gray-green, pseudo-hexagonal plates (Figs. 8 and 9). Oxidation of the ferrous iron to the ferric state imparts a rusty, orange-brown color to some specimens. Typical associates include goethite, rutile, brookite, sphalerite, hemimorphite, calcite and quartz. Muscovite can easily be mistaken for chlorite, especially in assemblages containing brookite and rutile. The distinguishing factor is the stark white color of the thin muscovite flakes.

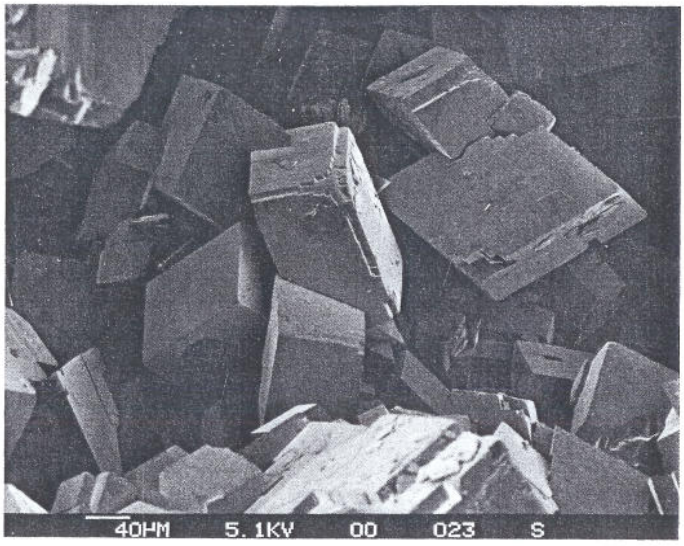


Figure 10. **Intergrown rhombohedrons of dolomite. Dolomite, usually white or colorless, is the host mineral upon which all other minerals crystallized. The scale bar is 40 micrometers.**

Dolomite $CaMg(CO_3)_2$

Dolomite crystals form the matrix for all of the species described here. While dolomite usually occurs as saddle-shaped, curved crystals, this is not the case at Franklin. Well-formed, isolated or step-like stacking of euhedral rhombohedrons are most commonly observed (Fig. 10).

Fluorite CaF_2

We have found two specimens of fluorite. The first consists of a 1-millimeter transparent cube on dolomite in the collection of Andrew Dilatush. The second consists of 3- to 4-millimeter amethyst-colored crystals composed of the cube and hexoctahedron. This second specimen is in the Gerstmann Franklin Mineral Collection. Fluorite appears to be rare in the dolomite at Franklin.

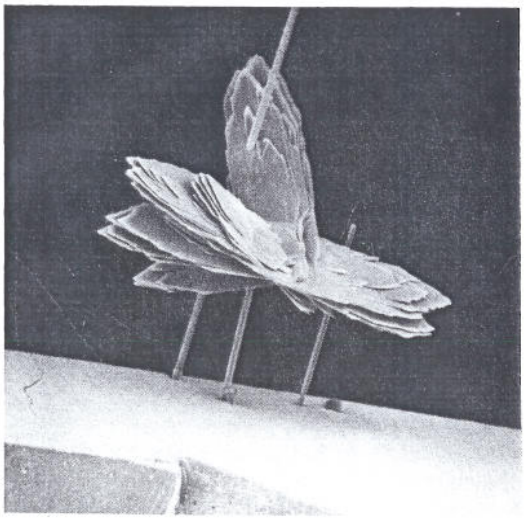


Figure 11. **Goethite – composed of slightly divergent platelets nucleated around rutile needles. Both species are perched on dolomite. The goethite is 120 micrometers in diameter. See inset (Goldschmidt, 1916–23).**

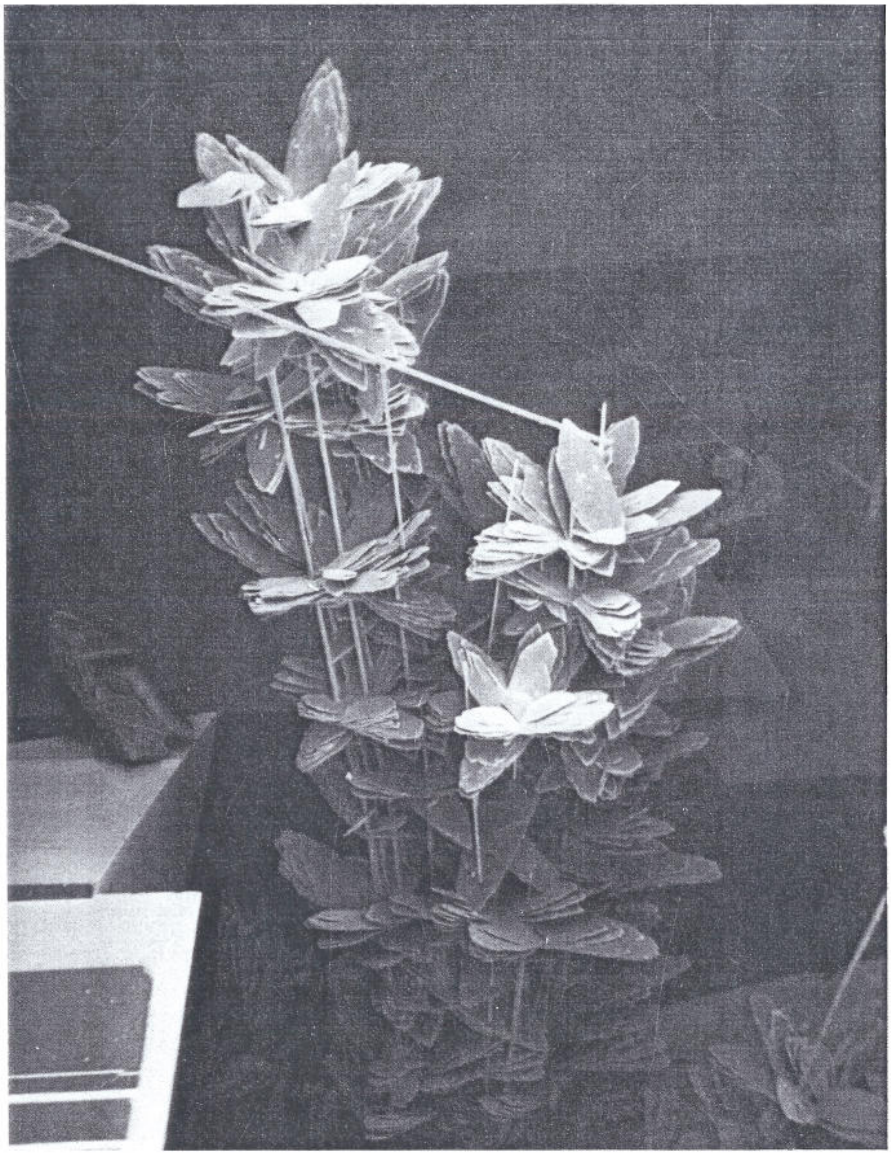


Figure 12. **Goethite – composed of light brown, divergent platelets nucleated on rutile. The rutile measures 600 micrometers long.**

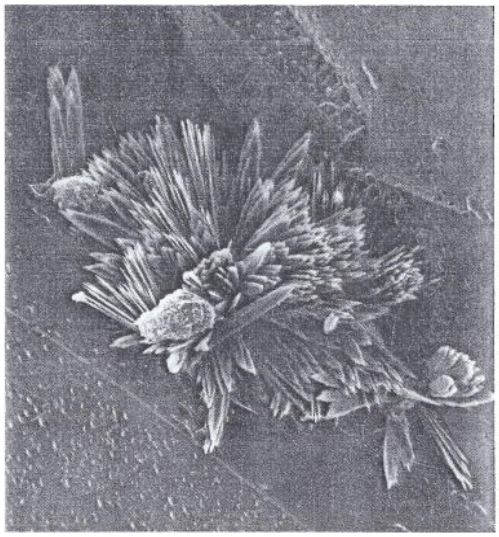
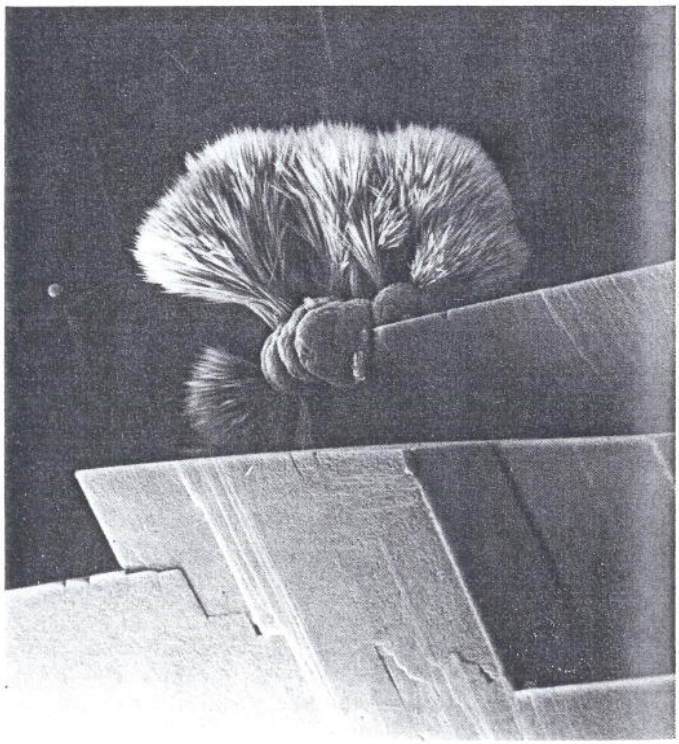


Figure 13. **Goethite – a radiating group of bladed crystals growing on a dolomite rhomb. The grouping is 200 micrometers in diameter.**

Figure 14. **Goethite-hematite – a goethite spray composed of extremely fine, hair-like crystals, 100 micrometers in diameter, growing around a nucleus of botryoidal hematite (dark red to black).**



Goethite FeO(OH)

Goethite occurs in a number of different habits: as slightly divergent platelets nucleated on rutile needles (Figs. 11 and 12), as radiating groups of bladed crystals forming around a sphere-like aggregate of hematite (Fig. 15), and as extremely fine, hair-like crystals surrounding a spherical hematite core (Fig. 14). Goethite is one of the most common minerals found in the dolomite.

Graphite C

Graphite crystals (sometimes pseudo-hexagonal in outline) are usually found in dolomite cavities without associated species; but quartz, hemimorphite, and pseudo-octahedral calcite are sometimes associated.

Hematite Fe_2O_3

Hematite most commonly occurs as spherules sprinkled on dolomite. The spherules are frequently surrounded by the hydration product, goethite. Hematite occurs uncommonly as isolated rosettes of platy crystals.

Hemimorphite $Zn_4Si_2O_7(OH)_2 \cdot H_2O$

Hemimorphite typically occurs in radiating, divergent sprays of colorless, transparent crystals (Fig. 17). Only occasionally are isolated blades observed in which the hemimorphic nature is readily

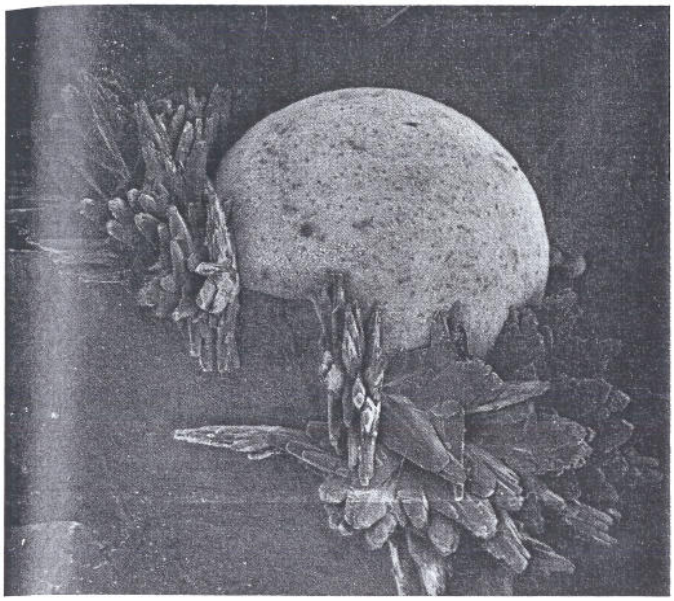


Figure 15. **Goethite-hematite – goethite crystals somewhat coarser than those usually collected. The spherule is hematite and is 250 micrometers in diameter. The goethite crystals are 60 micrometers in length.**

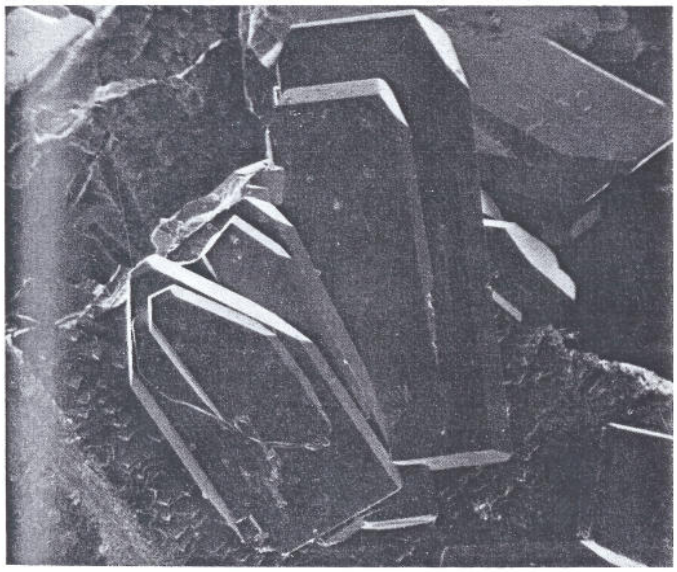


Figure 16. **Hemimorphite – these hemimorphite crystals are notable in that their hemimorphic nature is readily apparent. These colorless crystals are a maximum of 350 micrometers long.**

evident (Figs. 16 and 18). Associated species include sphalerite, quartz, chlorite and platy calcite crystals.

Marcasite FeS_2

Marcasite is found in rosettes of pseudo-hexagonal platy crystals. Under high magnification an unknown mineral can be observed partially coating the crystals (Fig. 19). Marcasite is rather uncommon.

Microcline $KAlSi_3O_8$

Microcline occurs in pink, parallel groupings of blocky crystals (Fig. 20). Associated minerals include sphalerite, rutile, brookite, quartz and albite.

Muscovite $KAl_2Si_3O_{10}(OH)_2$

Muscovite occurs as stark, snow-white, exceedingly thin plates coating cavities in dolomite. Associated minerals include rutile, brookite, sphalerite and pyrite.

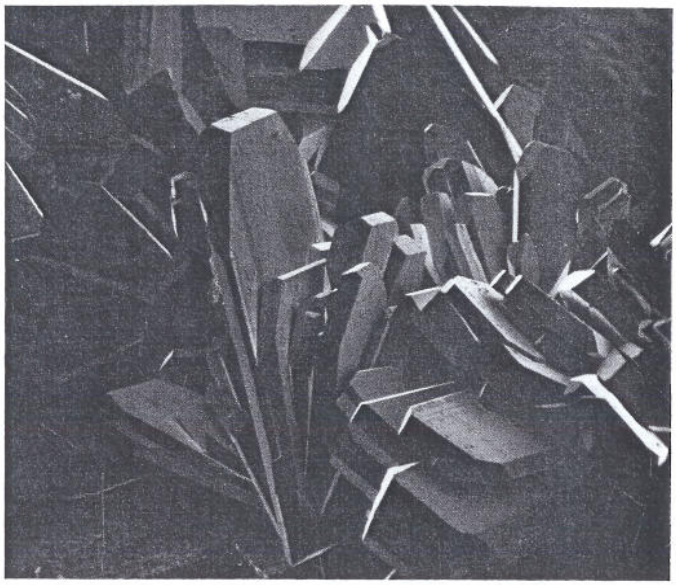


Figure 17. **Hemimorphite – a divergent spray of bladed crystals. The longest is 700 micrometers.**

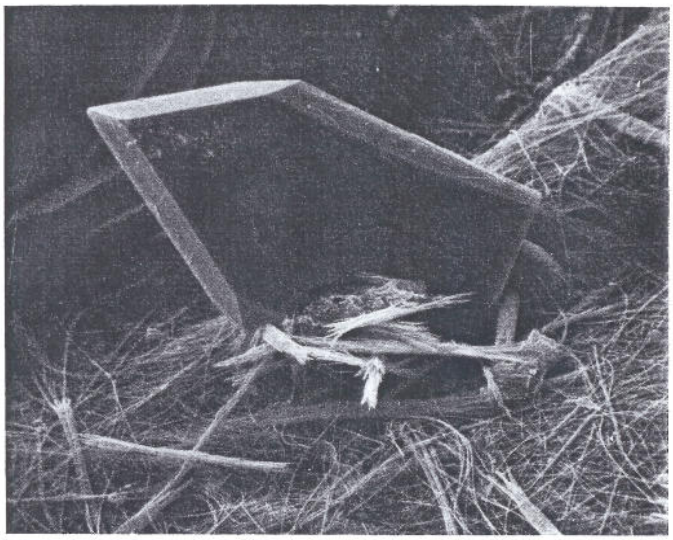


Figure 18. **Hemimorphite – this crystal exhibits the hemimorphic symmetry. The crystal rests in "mountain leather." The exact mineralogical nature of this "mountain leather" has not been determined. The crystal is 15 micrometers long.**

Pyrite FeS_2

Pyrite is found as golden yellow crystals, frequently tarnished (in particular the pyritohedron face). They may be surficially altered to iron oxides (goethite and/or hematite). Crystal forms noted include the pyritohedron (with sphalerite), cube-pyritohedron, cube, dodecahedron (modified by the octahedron and trapezohedron) and octahedron. Of all the crystal forms noted, only the cube and pyritohedron occur on elongated crystals. Pyrite is almost always alone on dolomite, but may sometimes be found with sphalerite or quartz. Figures 21 through 24 illustrate the diversity of habits.

Quartz SiO_2

Although quartz is one of the most common minerals found on earth, its occurrences at Franklin are limited primarily to the dolomite cavities, where it is quite common. Quartz is rarely found in the orebody. This species provides striking crystals, including some crystals with the rare "s" ($11\bar{2}1$) faces (Fig. 25) and also beautiful rutilated quartz (Fig. 26). It is not unusual for some of the rutile needles in the quartz to be curved.

Figure 19. **Marcasite – a parallel grouping of tabular plates of dark brown marcasite crystals with an unknown coating. The grouping is 160 micrometers in diameter.**

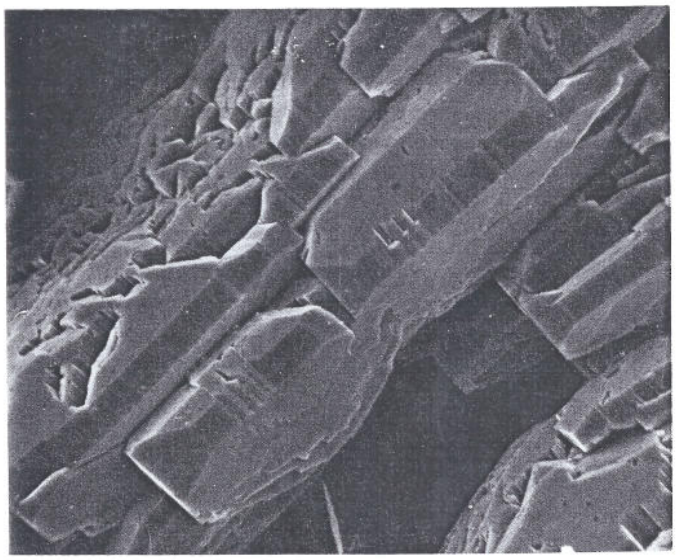


Figure 20. **Microcline – a parallel grouping of microcline crystals. The crystals are pink and are approximately 10 micrometers long.**

Rutile TiO_2

All metallic, radiating crystals found in the cavities, whether black, golden brass or bronze in color, have proven to be rutile, based upon X-ray diffraction examination of selected samples. No millerite has been verified from the dolomite cavities despite a careful search. Energy-dispersive analysis of rutile samples reveals, in addition to major titanium, small amounts (less than 1 percent by weight) of chromium. Rutile needles are usually terminated but the terminations are only visible at extremely high magnification (Fig. 28). Specimens containing rutile should always be carefully examined for the presence of its polymorph, brookite. Rutile apparently crystallized quite early in the sequence, as it usually is found not only directly upon but penetrating into the host dolomite. Quartz, smithsonite, brookite, goethite and muscovite are common associates.

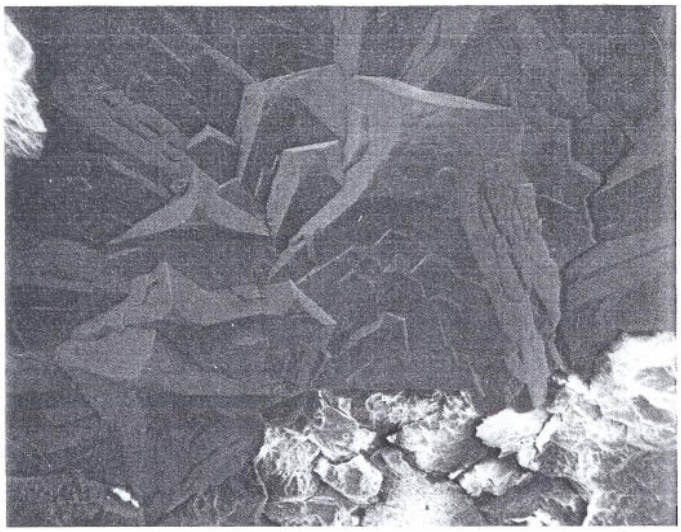
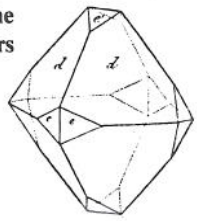


Figure 21. **Pyrite – octahedron modified by the pyritohedron. The crystal is 500 micrometers across. See inset (Goldschmidt, 1916–23).**



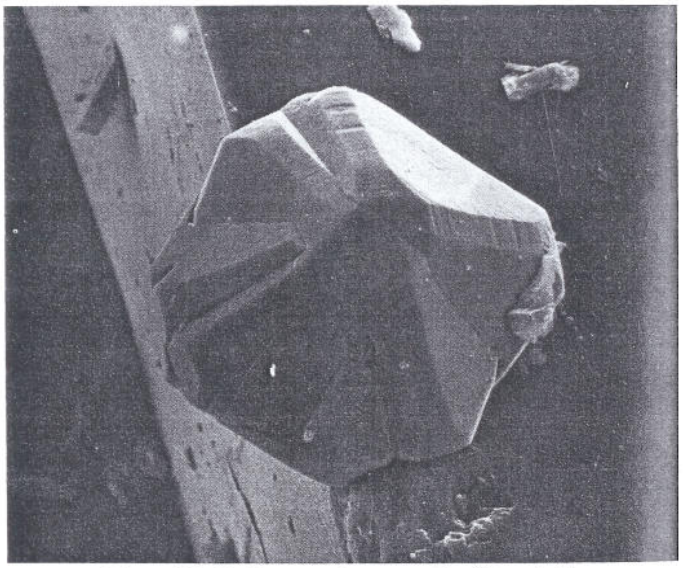


Figure 22. **Pyrite – an intergrowth of two individuals. The crystals are dominantly octahedrons modified by the cube and dodecahedron. Crystals of this type are usually embedded in the edges of dolomite rhombohedrons.**

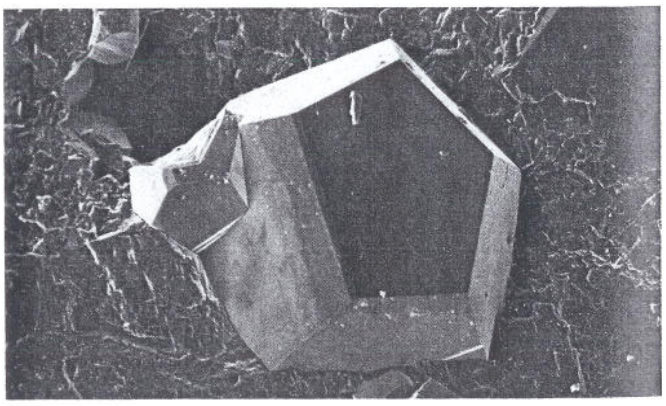


Figure 23. **Pyrite – a pyritohedron. The crystal is 800 micrometers in diameter. See inset (Goldschmidt, 1916–23).**

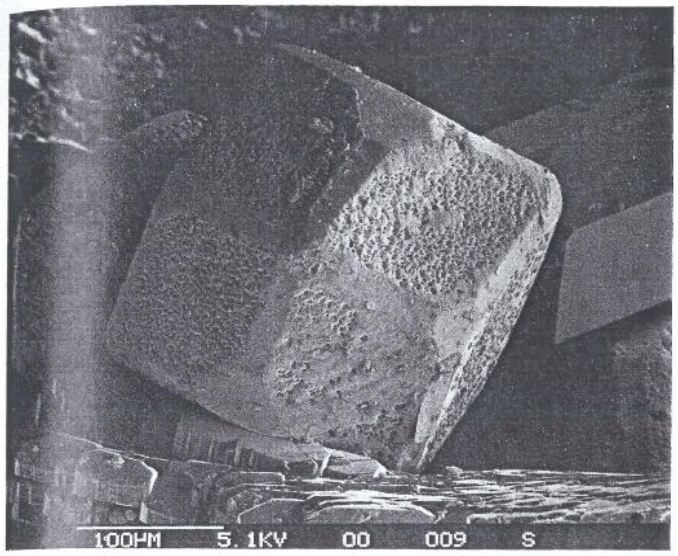


Figure 24. **Pyrite – a rare dominant form for pyrite is the dodecahedron. It shows octahedral and trapezohedral modification. The scale bar is 100 micrometers.**

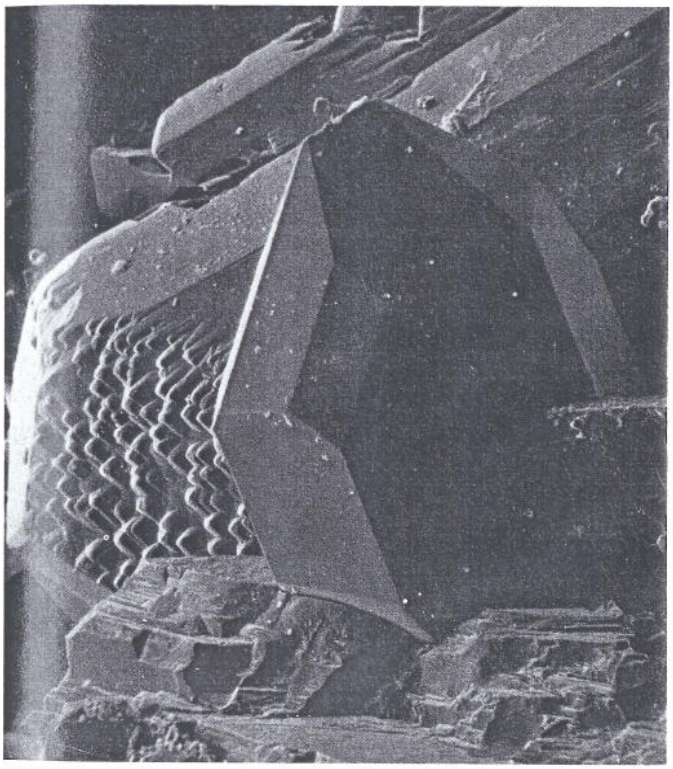


Figure 25. **Quartz – a typical prismatic crystal showing the *s* face (parallelogram) which is typical for specimens found in this dolomite. The quartz is 100 micrometers tall.**

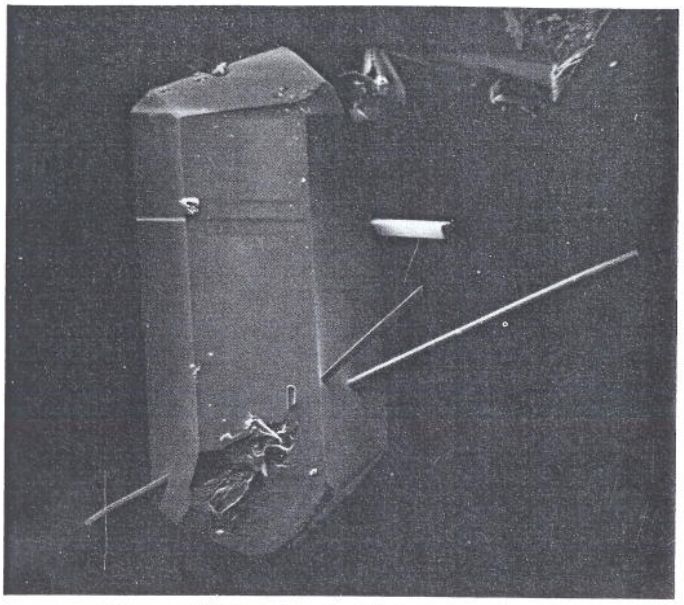


Figure 26. **Quartz – doubly-terminated, prismatic quartz crystal with rutile inclusions (rutilated quartz). The quartz is 370 micrometers long.**

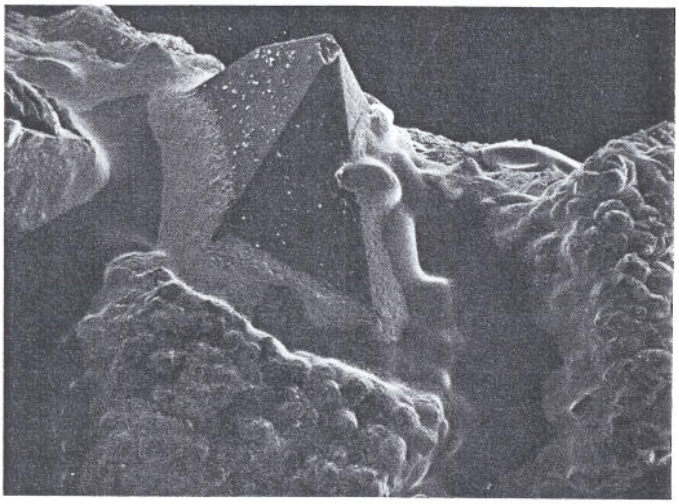


Figure 27. **Smithsonite overgrowth on a quartz crystal. The quartz is approximately 1 mm in diameter.**

Smithsonite $ZnCO_3$

Smithsonite occurs in several different habits: (1) as "caps" or overgrowths on dolomite (Figs. 29 and 30) (the dolomite may break away, revealing a smithsonite mold or cavity after dolomite); (2) as rosettes or hexagonal single crystals growing around rutile needles (Figs. 31 and 32); and (3) as coatings completely covering and par-

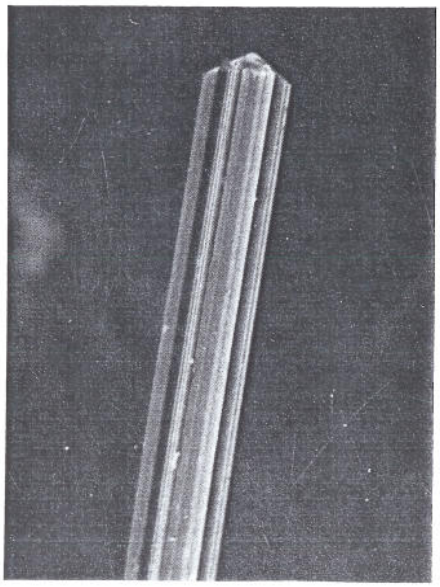


Figure 28. **Rutile – a terminated, prismatic black crystal of rutile. The rutile is 140 micrometers long.**

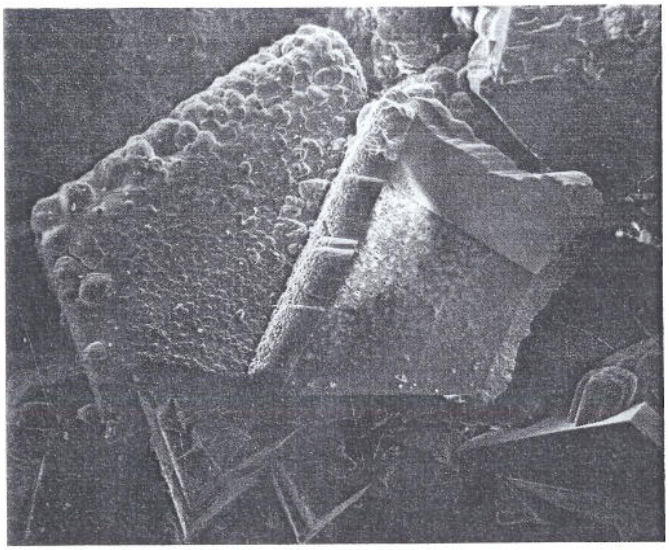


Figure 29. **Smithsonite – smithsonite overgrowths on dolomite rhombohedrons. Illustrated here is a cavity after dolomite which formed when the dolomite core broke away. The smithsonite crystals are colorless and are 1 mm in diameter.**

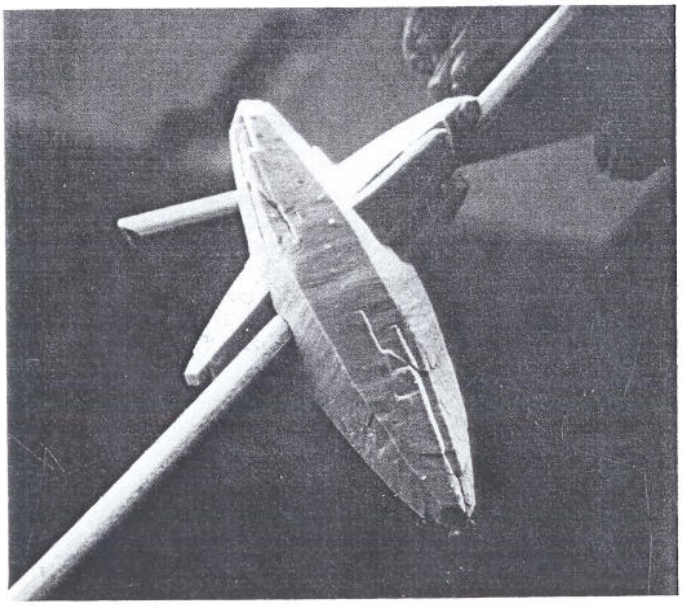


Figure 32. **Smithsonite – a tapering, doubly-terminated crystal of smithsonite growing around a rutile needle. The smithsonite is 100 micrometers long.**

Figure 30. **Smithsonite – a parallel grouping of smithsonite in sheave-like aggregates as overgrowths on dolomite. Each smithsonite aggregate is 600 micrometers long.**

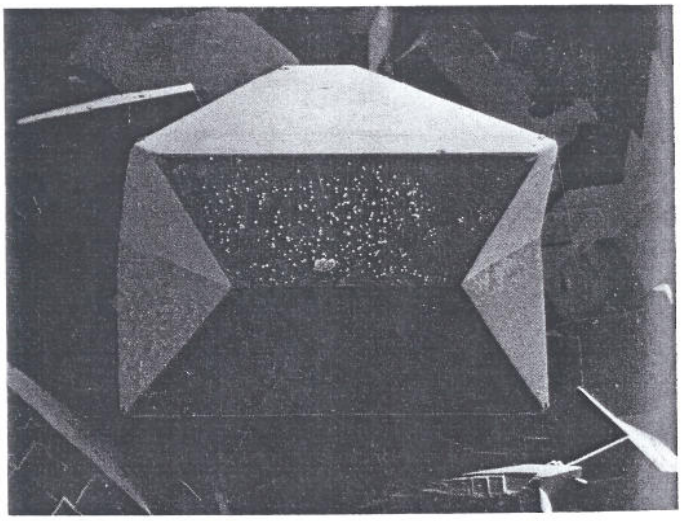


Figure 33. **Sphalerite – a spinel-law twin. The twin is 1.4 mm across.**

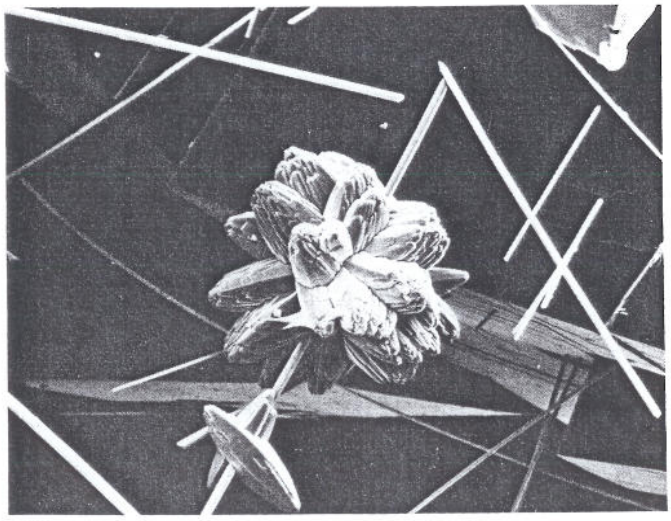


Figure 31. **Smithsonite-rutile – a rosette-like grouping of smithsonite crystals on rutile needles. The rosette is 130 micrometers across.**

tially replacing crystals of sphalerite. This alteration is only a thin veneer, however; broken crystals reveal an unaltered core of sphalerite. Smithsonite is also observed as an overgrowth on quartz (Fig. 27).

Sphalerite ZnS

Sphalerite is considered to be one of the most esthetic species to be found in this occurrence. It is of particular interest mineralogically as well, because it commonly exhibits vivid spinel-law twinning, sometimes in complex groupings. It is found in light to dark brown, orange, reddish orange, oil-green and almost black single or twinned crystals up to 5 mm. Sphalerite has been found as cavernous crystals; others have been collected that are round due to partial dissolution. Associated species are dolomite, quartz, rutile, pyrite, microcline, brookite, calcite and hemimorphite (see Figs. 33 and 34).

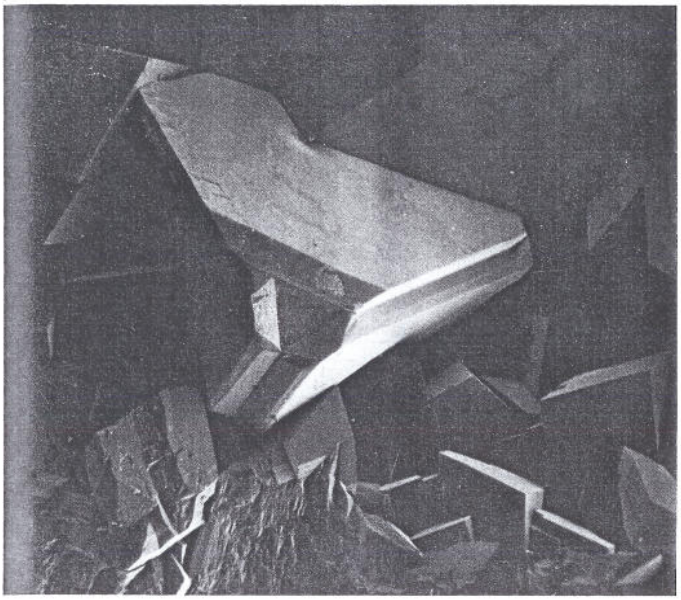


Figure 34. **Sphalerite – a complex, multiply twinned fouling of sphalerite crystals, twinned by the spinel law. The largest plate is 2 mm wide.**

COMMENTS

Table 1 presents an attempt to collate all previous lists of Buckwheat dolomite minerals in order to compare and contrast them with the results of this study. It lists all minerals previously listed from the Buckwheat dolomite, and also the authors of each list. We report 18 X-ray verified species as well as an additional 4 identified visually. Of the additional 19 species cited in the literature, we feel that six (barite, celestite, greenockite in massive coatings, gypsum, stilpnomelane and talc) are likely future additions to our list. All of these minerals have been found in other assemblages within the deposits. The remaining 13 minerals seem doubtful for the following reasons: anglesite is unlikely to be found due to the absence of galena; bornite and chalcopyrite are unlikely because of a decided lack of availability of copper; heulandite and stilbite are probably misidentifications of the mineral hemimorphite; orthoclase is likely misidentified microcline; millerite has been diligently searched for and has yet to be verified; siderite seems unlikely due to the fact that the carbonates appear in large quantities as the minerals dolomite and calcite; finally ilmenite, manganite, pyrrhotite and zircon are unlikely on the basis of chemistry and mineralogical environment.

CONCLUSION

Extremely well-crystallized, millimeter-sized minerals are currently available on the Buckwheat dump, located on Evans Road in Franklin, Sussex County, New Jersey. Once the collector is familiar with the Buckwheat dolomite, he can easily collect a sackful of material which can later be taken apart to find exquisite minerals tucked away in hidden cavities. The reader is urged to visit the Franklin-Kiwanis Mineral Museum on Evans Road, where a fee of $1.50 is charged to collect on the dumps. A tour of the museum and its mine replica will be very rewarding. The museum is open to the public on Fridays and Saturdays from 10 a.m. to 4 p.m. and Sundays from 12:30 to 4:30 p.m. Summer hours are Wednesday through Sunday. It closes for the season on November 15th. In addition, a visit to the Gerstmann Franklin Mineral Museum, located at 14 Walsh Road (near Franklin High School), will provide additional mineralogical pleasures.

***Table 1.* Minerals occurring in dolomite veins, Franklin, New Jersey.**

Species	*Palache (1935)*	*Gordon (1951)*	*Frondel (1972)*	*Thomas (1967)*	*Kraissl (1979)*	*Present Study*
Albite	X	X	X	X	X	X
Anatase			X			X
Anglesite				X		
"Apatite"		X		X		X
Arsenopyrite					X	X
Aurichalcite					X	X
Barite				X		
Bornite				X		
Brookite			X	X	X	X
"Byssolite"				X		
Calcite	X	X		X		X
Celestite				X		
Chalcopyrite				X	X	
"Chlorite"				X	X	X
Dolomite	X	X	X	X	X	X
Fluorite						X
Goethite	X		X	X	X	X
Graphite			X	X	X	X
Greenockite				X		
Gypsum				X		
Hematite	X		X	X	X	X
Hemimorphite		X		X	X	X
Heulandite			X	X		
Ilmenite				X		
Manganite				X		
Marcasite	X				X	X
Microcline					X	X
Millerite	X	X	X			
Muscovite						X
Orthoclase		X				
Pyrite		X	X	X	X	X
Pyrrhotite				X		
Quartz	X	X		X	X	X
Rutile			X	X	X	X
Siderite				X		
Smithsonite					X	X
Sphalerite	X	X	X	X	X	X
Stilbite			X	X		
Stilpnomelane				X	X	
Talc				X	X	
Zircon			X	X		

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