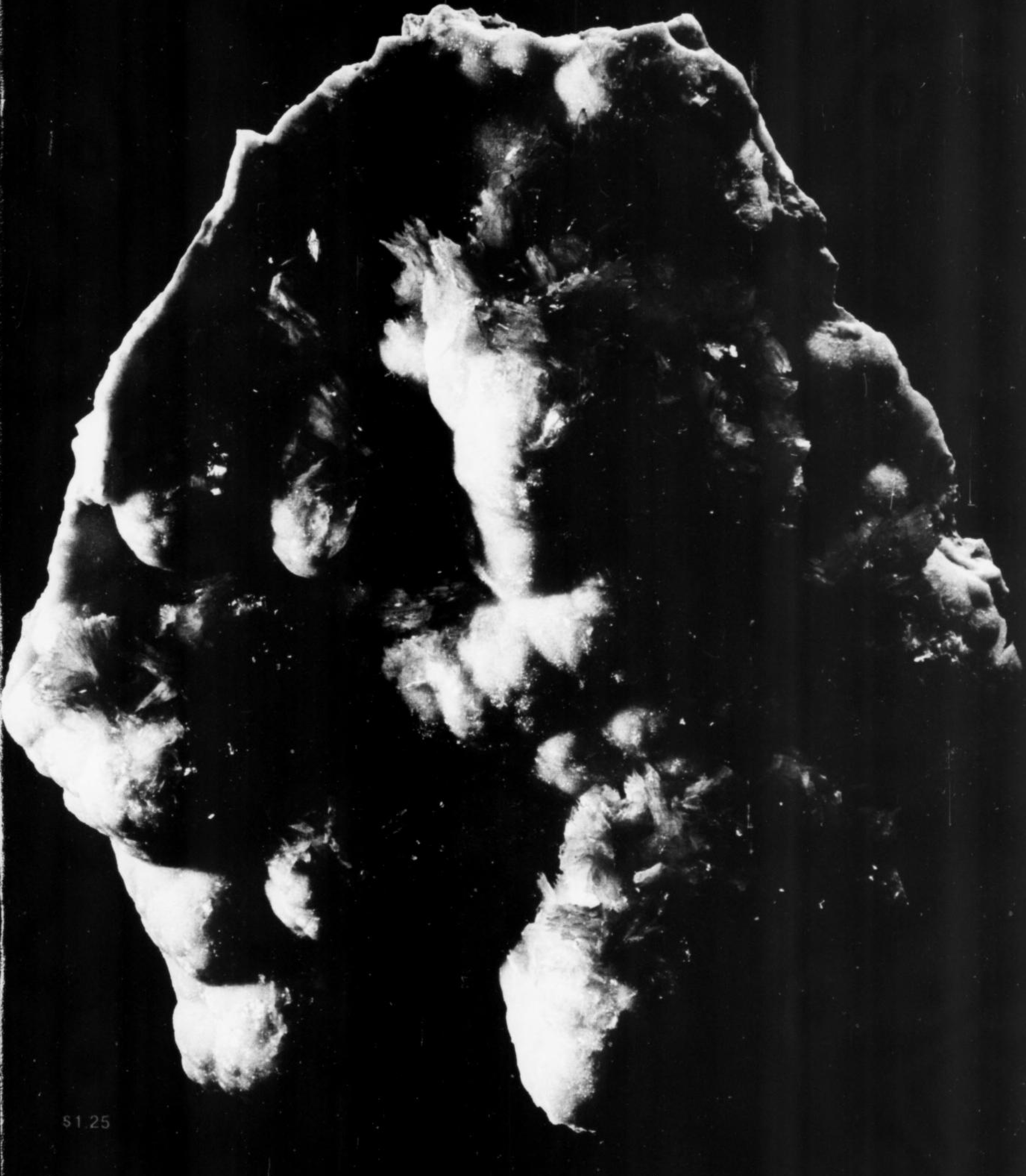
the Mineralogical Record

volume Four Number Three



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Volume Four/Number Three

affiliated with the Friends of Mineralogy

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Editorial

Computerization Comes to the RECORD

Maintenance of the subscription and mailing list for the *Mineralogical Record* has become such an extremely difficult and time-consuming task that it can no longer be done efficiently by the staff alone. Therefore we have gone to the computer. Of the many benefits that will accrue to all, the most significant is that the address labels will now indicate when each subscription is due for renewal. Both the month and year will be shown. Please examine the label on the envelope in which this issue arrived so you will know when your subscription runs out. If it already has expired, or is about to, we would be grateful if you will forward your renewal without the necessity of billing. In spite of rapidly escalating paper costs, the subscription rate will not be increased this year.

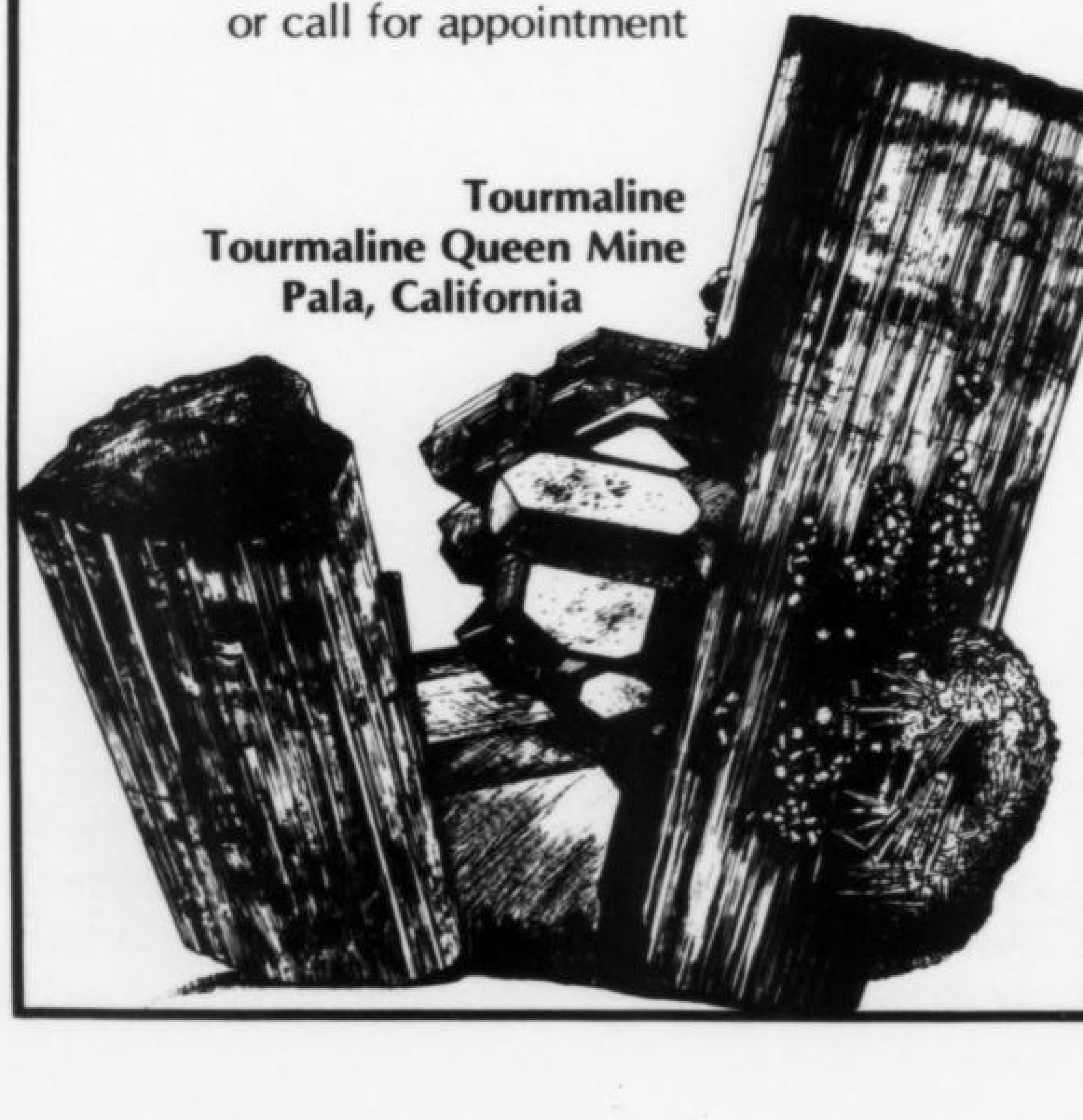
BACK ISSUES

Due to an extraordinary demand for back issues by readers who want complete sets, we have completely sold out all we have of Volume I, number 1. However, we are now making arrangements to print more of these and we urge that readers who would like to own every issue place their orders right away. The cost is $6.00 per volume ($7.00 overseas), or $1.00 per issue except for Volume I. There were only four issues in Volume I, so individual issues cost $1.50 each.

SPECIAL BINDING

We are negotiating with a bindery for an exclusive contract that will make it possible for our readers to have the first three volumes of the *Mineralogical Record* bound in one book for a very reasonable price. The binding will be library type, stitched, and you will have a large number of colors to choose from. Watch for the notice in a subsequent issue. There is no better way to keep your magazines in superb condition while still keeping them at hand for ready reference.

John S. White Jr.



The Museum Record

by Paul E. Desautels

It is always a matter for rejoicing when a long-dormant, institutional mineral collection shows signs of renewed life. When those signs of life pulse loud and clear it is enough to give any mineral specimen lover a psychic uplift. As a case in point, I've just attended the dedication, or rather re-dedication, of the mineral collection in the Department of Geology of the University of South Carolina in Columbia. It was a pleasant and exhilerating experience.

This collection has been around a long time. Dr. Laurence L. Smith, emeritus head of the Department and for 13 years State Geologist, has written a short history of the collection covering a century and a half. It is necessarily a short history because so much in the way of recorded history and specimens has been destroyed or lost in the interim since the collection originated in 1820. However, any collection having historic names such as Thomas Cooper, Lardner Vanuxem, Richard Brumby, etc., connected with it is historic indeed. The published history is available by writing to the Department of Geology Museum, University of South Carolina, Columbia, South Carolina.

Perhaps the collection, begun by Professor Cooper so long ago, would be far greater today had it not been almost destroyed by Federal troops during the "War Between the States". As it says in the brochure with no obvious rancor, "It had been housed and displayed in what is now Longstreet Gymnasium until Sherman came to Columbia and requisitioned that building for use as a hospital. The Federals wantonly tossed it out upon the ground. From this ignominious disposition the specimens were devotedly gathered up by Dr. Joseph Le Conte and Dr. James Woodrow and taken to a room in Harper College. Later they were moved to the present Barnwell College and finally to the Geology Museum in Le Conte College. Through the vicissitudes of being moved, lack of attention, lack of space, loss of labels, etc. the original several thousand specimens have been reduced to probably less than one hundred that can now be identified with certainty as Cooper's."

Ever since this disaster period the collection has been slowly rebuilt with numerous purchases and gifts and at the same time suffered through phases of neglect. In modern times the most important addition was the very large collection of the late Burnham S. Colburn which was acquired in 1945. Mr. Colburn was an engineer, industrialist and banker from Asheville, North Carolina, and his collection was particularly rich in the minerals of North Carolina. This is the same Mr. Colburn for whom the mineral museum in Asheville is named. The suite of hiddenite specimens in his collection from Alexander County, North Carolina, and those superb quartz crystal groups with cavernous crystals and striking clay inclusions are unmatched in most collections. Pyrope, amethyst, corundum, rutile and all those other good things, for which his part of the world is famous, are present in quantity. Some are surprisingly good specimens.

Nowadays the University of South Carolina's collection cannot be classed as one of the great collections even with all these fine acquisitions. However, it is a good collection containing some things that are well worth going off the beaten trail to see. Certainly it is the only public mineral exhibit available to serve such a large geographic area.

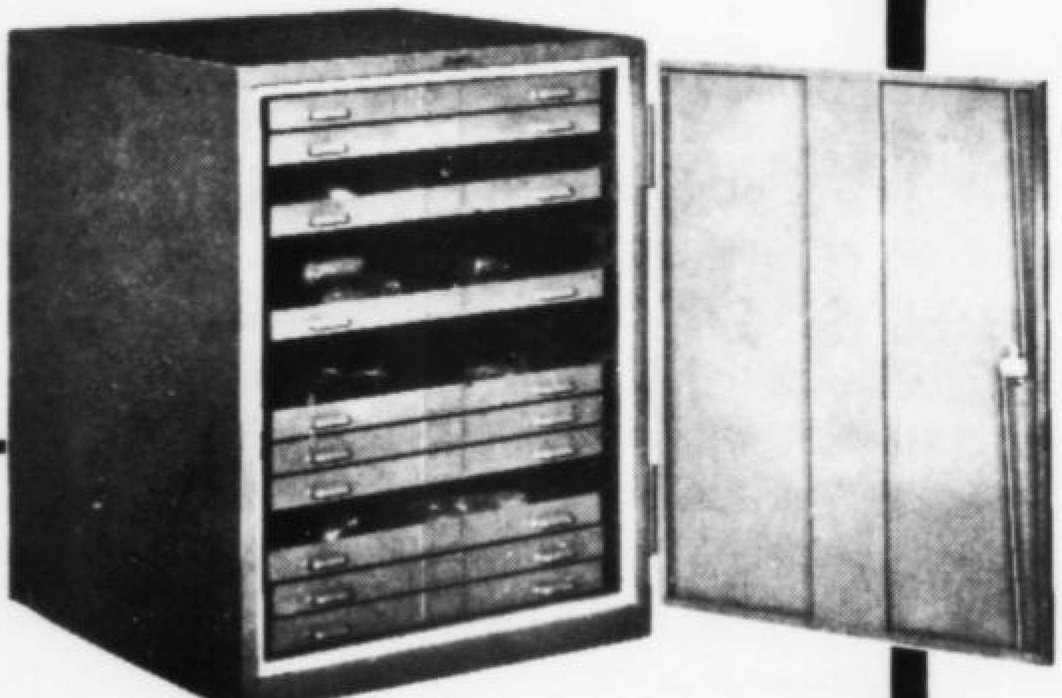
A good part of the current revival of interest in the University's collection and renewal of activity has been generated by the new curator, Bob Middleton. Some of you will remember Bob as the enthusiastic and hard working curator who, only a short time ago, was at the Blue Ridge Parkway Museum of North Carolina Minerals over near Spruce Pine. In his short curatorial career at the University some remarkable changes have occurred there. Money has been made available and the museum room is completely renovated, air conditioned, carpeted and made secure. A good part of the collection has been cleaned, cataloged and computerized. The rest will be completed as rapidly as possible. Funds have also been made available for incidental expenses and for the acquisition of new specimens. Visitors to the newly refurbished collection will be pleasantly surprised at what they see.

The dedication, at which I was the invited speaker, was a gala affair. Once again I was shown how good "Southern Hospitality" can be. Bob Middleton had managed to assemble a goodly crowd the size of which I'm sure surprised him as much as it did the University officials present. Before my talk Dr. Smith gave a brief history of the collection. In his turn Bob Middleton rose and, after a few remarks, revealed that the collection was henceforth to be known as the Laurence L. Smith Collection. By the time the large group had made its way over to inspect the new museum and to partake of refreshments a name sign had magically appeared on the door honoring Dr. Smith.

And so we can all rejoice because new life has been breathed into one of the oldest mineral collections in the United States. The University is to be commended for its action and encouraged to continue its support. I was careful to point out in my dedication remarks the dim view I have always had about how Universities in general fail to live up to their responsibilities and have, through neglect, destroyed many fine collections. Let us hope that the University of South Carolina has the patience and persistence to keep the collection going for another 150 years.

While the news from South Carolina is good we are presented with news of a different kind from New York. As a sort of weight on the opposite side of the balance — lest we become too complacent about the stability of our world of mineral museums — there is disturbing news from the American Museum. Dr. Vincent Manson, its curator of minerals, has decided to resign his position. Since Dave Seaman, able and knowledgeable assistant to the last three curators there, had already retired this leaves one of the most important collections in the United States without a caretaker. Of course, Vince Manson will be around for at least another year and hopefully a suitable new curatorial staff can be built in the interim. While in service at the American Museum Dr. Manson succeeded in bringing his Institution back into contact with the public and the amateur mineral movement. He also brought to maturation the plans for a long-needed new exhibit hall which will be in the construction stage shortly but to be completed perhaps after his departure. Currently he has also been representing, as its president, our curator's organization, the Mineral Museums Advisory Council. Obviously the American Museum and other organizations are going to be hard pressed to fill the vacuum he leaves.

The past month has also brought museum activity from the West. The Smithsonian was honored in April by a visit of members of the Board of Governors and Directors of the Foundation of the Los Angeles County Natural History Museum. It was my pleasure, and John White's also, to be invited to a welcoming dinner where we had the opportunity to meet again some good friends and supporters of that Museum led by Giles Mead, the Director. The next day it was fun dazzling some of those most interested in gems and minerals with a guided tour of the Smithsonian's storage and laboratory facilities, affording a peek at some of the treasures in our security vault. To me it is as much fun showing off the Museum's gem and mineral treasures as it would be if they were my own. This is especially true when I have such an appreciative audience.



Yedlin on Micromounting

What this country needs are more weekends. With hundreds of mineral societies scheduling their conventions, exhibits, symposia and colloquia into 52 available weekends one of the basic axioms of physics rears its head: "a body can occupy but a single space at any given time". or colloquially: "you can't attend two or more shows at once."

We were confronted with a dilemma for the May 5th weekend. We had to choose among 4 events. (The April, 1973, issue of *Lapidary Journal* lists 27 events on that weekend.) Should we attend the roundup of the Micro Mineralogists of the Capital Area; the convention at Rochester, New York; the exhibition of the New Haven, Connecticut, Mineral Society; or the Annual meeting of the Walker Mineral Society of Toronto, Ontario?

A fortuitous visit by Ross and Vi Anderson, of Toronto, on April 24th, solved everything. They spent the evening doing micromounts and photography. They told of an April 28th and 29th conclave of the Canadian Micro Mineral Association, to be held at the Royal Ontario Museum in Toronto. They advised that the museum had some 80 pounds of Laurium, Greece, slags that were just waiting to be broken up and studied. They had room in their car. Our old friend Lou Perloff was to be the speaker at the Walker Club a week after the micromount meeting. Such blandishments were irresistible. We went to Toronto, the promised land, and the promises were fulfilled.

The Canadian Micro Mineral Association had come into existence at Brantford, Ontario, some 10 years previously under the aegis of George S. Huff and Louise Dawson. It was an active organization, holding annual conferences in the city of its origin until it was decided to transfer its venue to Toronto. This was the first session in the new meeting place, and it was a decided success. Ross Anderson and his cohorts arranged a spectacular workshop conference. Dr. D. P. Gold of Pennsylvania State University was the guest speaker, and his subject was dear to the hearts of the participants. He is an authority on carbonatites, and has done much work on the mineralogy of the Oka, Quebec, area, a favorite collecting ground of most of the attending members. A panel of experts, including Dr. Gold, Dr. D. H. (Digger) Gorman of the Department of Geology, Toronto University, and Dr. J. A. Mandarino, Curator of Mineralogy of the Royal Ontario Museum, sat in session on Sunday morning and discussed "Mineral Associations." A well informed audience sat through some 2 hours of give-and-take at this meeting, and the questions and answers provided a clue to the interest of the listeners and the excellence of the projections of the panel members.

A slide program by Violet (Mrs. Ross) Anderson was outstanding. Her photographs of minerals taken through the microscope showed a scientific as well as artistic concept of this phase of the mineral art, and promised an outstanding future.

Larry La Chapelle demonstrated the techniques of mounting specimens, and introduced several pieces of well functioning home made equipment, among them several box holders, a goniometer, and a spectroscope, tools to aid in identifications. Material was available as giveaways, exchanges, and sales items, with the preponderence of Mt. St. Hilaire minerals in evidence, although other areas were well represented. Both Cliff Vickery and Frank Melanson had outstanding material — the former showing labuntsovite and nenadkevitchite from Hilaire and the latter interpenetrating twin cubes of thorianite from Huddersfield County, Quebec. Their addresses: Vickery — 4 Brendon Road, Toronto 17, Ontario; Melanson — 192 Durham Street, P. O. Box 370, Madoc, Ontario.

A week later the dinner of the Walker Club. Perloff presented a series of slides of phosphate minerals in his collection; outstanding photographs all taken through the microscope. He posed an interesting question, "Are there any arsenate minerals occurring in pegmatites?"

Let's discuss some equipment, trimmers and breakers. Getting material down to size has always been a problem. A heavy handed approach defeats the purpose of micromount collecting. And when rare things occur in a mass of unimportant rock it behooves a collector to pause and contemplate a course of procedure. A diamond saw is an ideal tool. Its use affords a minimum of shock and vibration, and a technique for its use is sketched herewith. There are a number of trimmers on the market today, and the purchase of one of them is a worthwhile investment. Bill Yost, 9802 Redd Rambler Drive, Philadelphia, Pennsylvania 19115, has a trimmer, available in two sizes. We've used these most of our micromount career, and can vouch for their efficiency. Slow, even pressures are generated, and a minimum of damage is done. Prices $32.50 and $25.50. Extra cutters are available. You've seen these at the Baltimore Symposia and elsewhere.

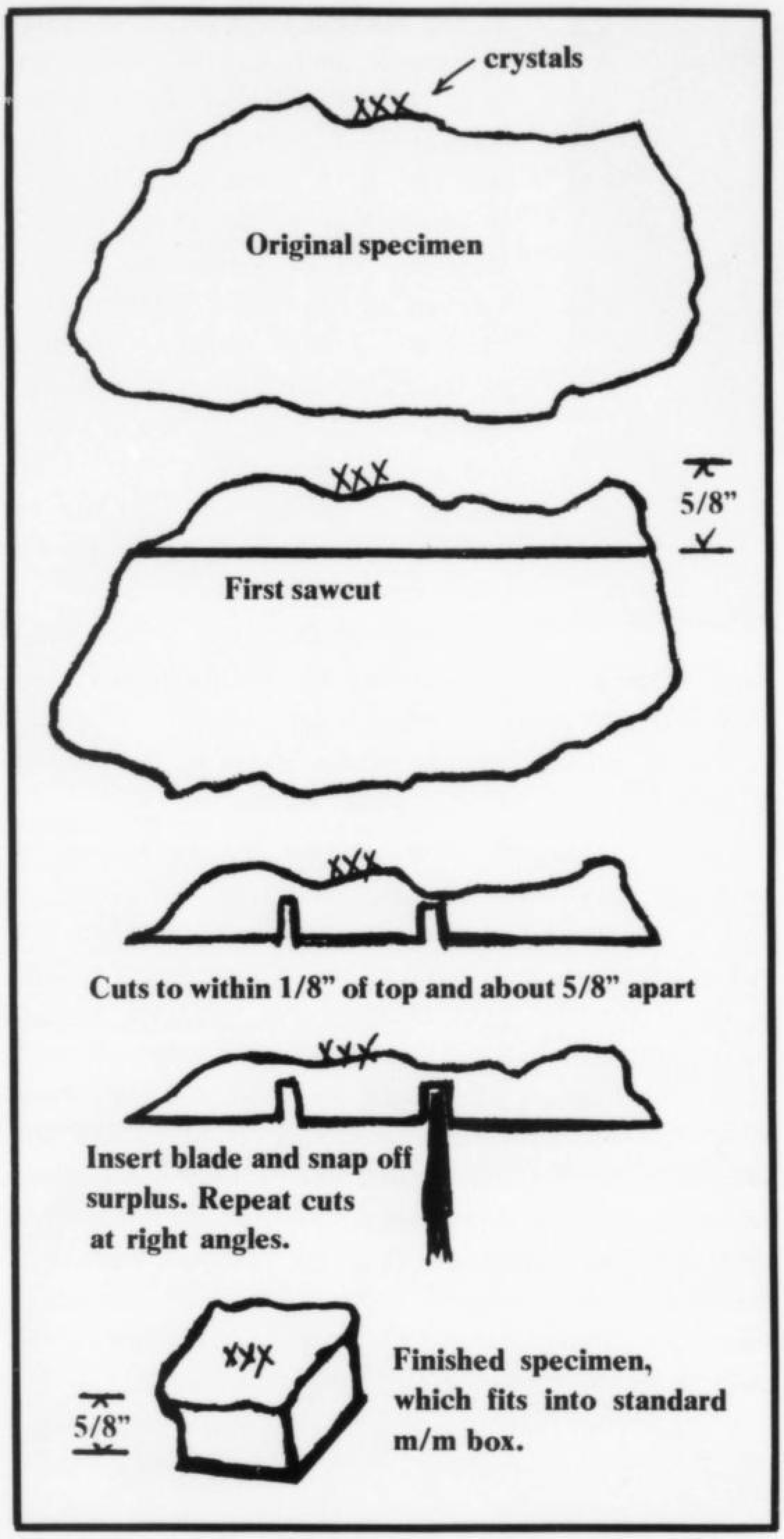


Fig. 1. **A method for using a diamond saw to remove specimen crystals from a large mass.**

We've recently seen a couple of different cutters. Friar Minerals and Lapidary Supply Company, 139 Mackenzie Street, Brooklyn, New York 11235, sent us some photographs, which we include in this article. One seems to be an adaptation of a machinist's vise, with cutters inserted between moving jaws. It has the advantage of a screw thread, which makes for steady, even movement. It seems limited in scope to small things, for the distance from the cutters to the base cannot be more than a couple of inches. Two sizes and prices on this model: $27.50 and $37.50 for 1-3/4 and 2-3/4 inch openings, respectively. The other can be used for larger specimens. It has a rated pressure of 1000 pounds per square inch, will take a 3 inch specimen and seems good for original rough cuts. Price, $65.00.

We'd suggested the use of a magnet for removing iron or other magnetic materials from a mixture of loose sand.

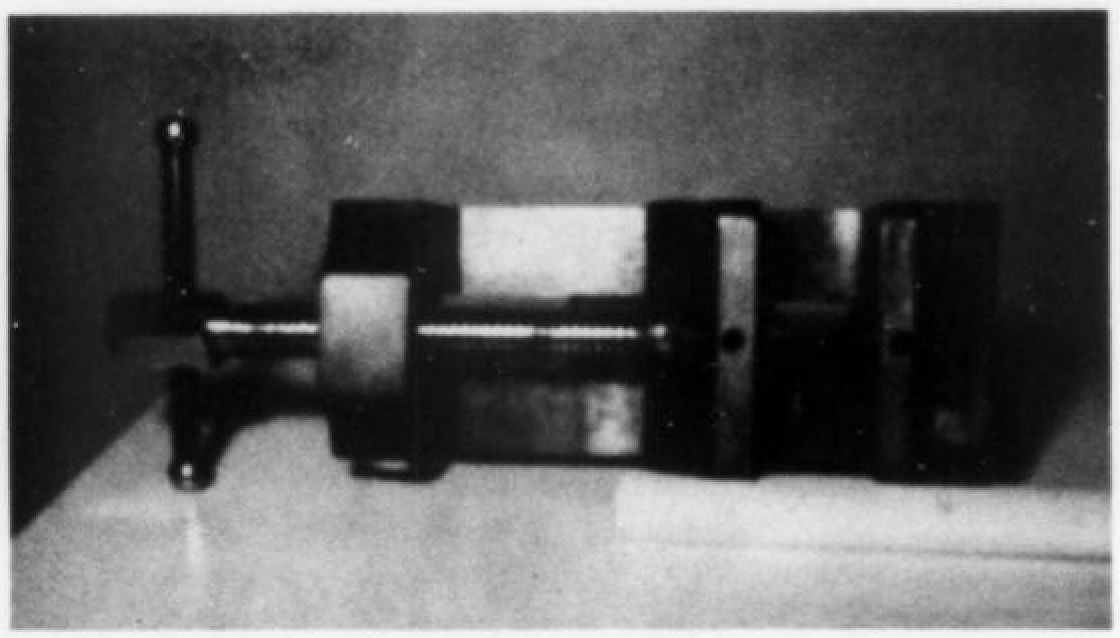


Fig. 2. Rock Trimmer. Friar Minerals and Lapidary Supply Co. 2 models, at $27.50 and $37.50.

A modification of the method was suggested by George W. Shokal, of San Carlos, California, who says it is a must, to save time and the frustrating effort of picking off the tiny particles that persist in hanging on to the magnet. "Encase the magnet in a piece of thin plastic wrap before approaching the sand. On transferring the adhering material to another container slide the magnet out of the plastic and all the grains will drop free, leaving the magnet clean". We've tried it. Works fine. Thank you, George.

We recommend Toni Galgano's work, *Micromounting for Everyone,* a publication of the West Essex Mineral Club, P. O. Box 131, Verona, New Jersey 07044. Price, $1.35, postpaid. A practical guide, with details, sketches, references and all.

We suggest that in taking specimens apart, either with pliers or trimmer, you "eyeball them down to size". We used to work on a large specimen and take it down to box sizes before examining the pieces. As a result many fine crystals and worthwhile areas were destroyed. Now, after each break, we suggest you examine all fragments for possible sections with concentration and care. You may want to leave a piece "as is" and mount it in a larger box to preserve an interesting surface. Comparably, use a target rifle rather than a shotgun approach.

For many years superb minerals have been coming out of the Jeffrey mine at Asbestos, Quebec. The grossulars, prehnites, diopsides, pectolite, vesuvianite and others show up in cabinet sizes at all shows. We've uncovered a

continued on page 143

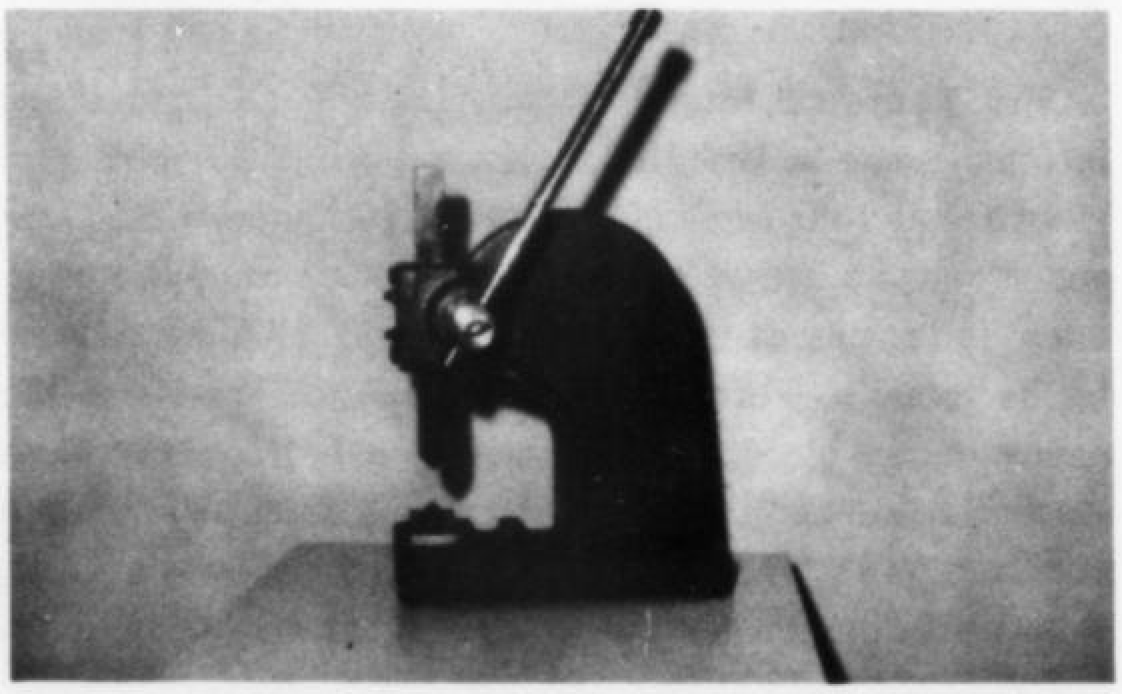


Fig. 3. **Rock Trimmer. Friar Minerals and Lapidary Supply Co. $65.00.**

Pegmatite Phosphates:
Descriptive Mineralogy and Crystal Chemistry

by Paul Brian Moore
Department of the Geophysical Sciences, University of Chicago, Chicago, Illinois 60637

INTRODUCTION

The phosphate minerals, which occur at all stages of pegmatite genesis, are among the most extensive of any mineral group. Relatively inconspicuous to the casual observer and rarely of economic importance, systematic investigations on these fascinating compounds have been few. Much of our knowledge on the subject is recent and the older literature is fraught with confusion, uncertainty and erroneous results. Yet their chemistry is of interest to us, for many fall into a group of inorganic compounds known as transition metal complexes. Chemists perhaps find more interest in them than mineralogists.

No doubt, the pegmatite phosphates prove most rewarding collecting material to the micromounter. Very few groups of minerals enjoy species diversity as extensive as these compounds, particularly at the late stage and low temperature portion of the paragenesis. Most of the late stage phosphates crystallized in open cavities as crystals ranging from a few microns to a millimeter in maximum dimension and elegant hand specimens are infrequently encountered. The crystals are usually well-developed and afford a fair challenge to the perspicacious mineralogist. They are among the few groups of minerals left where the diligent collector can still cull fine micromount specimens without resorting only to exchange. Since many of these species occur in an outwardly dull matrix most collectors overlook them so that many of the classical pegmatite localities, presently abandoned, still may yield good specimens for the micromounter.

The pegmatite phosphates are practically confined to well-zoned and very coarse granite pegmatites where the primary parent phases crystallized, usually toward or in the pegmatite's core, and where subsequent hydrothermal attack at the final stages of core consolidation by the residual aqueous-rich fluid altered these parents. Outwardly, such "nodules" of altered primary phosphates stain the enclosing quartz, perthite and albite brown to black with ferric and manganic oxy-hydroxides and are themselves dull brown to black in appearance, often porous as coke. Another origin for secondary phosphates is the transport and accumulation of transition metal complexes and phosphate anions away from the source with subsequent mineral crystallization elsewhere. These phases usually crystallize along cracks and joint surfaces in the pegmatite, as at the Foote mine near Kings Mountain, North Carolina.

Granitic pegmatites known for the presence of primary and secondary phosphates include the New England region, the Black Hills of South Dakota, some pegmatites in southern California; numerous Brazilian pegmatites; pegmatites in Portugal; occurrences in Bavaria, northern Sweden and Viitaniemi in Finland; and the Buranga pegmatite, Rwanda, central Africa. Curiously, there are vast regions where phosphates in granitic pegmatites (other than apatite) seem to be poor in species or absent. Here, we can include England, Norway, the Soviet Union (with exceptions), India, China, Japan and Canada. It is important to note that these areas have but few representatives, if any, of the parent phase triphylite from which most secondary phosphates of great diversity were derived. The United States is particularly blessed with phosphate-bearing granite pegmatites: of some 100 pegmatites I visited in the Black Hills, nearly all contain some primary phosphates and a few (such as the Bull Moose, Tip Top and White Elephant pegmatites) yield most of the known species with little difficulty. At these pegmatites, the corroded triphylite occurs in great abundance.

How are the myriad species distinguished and identified with certitude? Each physical and biological science has its own tools appropriate to the problem under investigation. As the lepidopterist has discovered that the analyses of wing venation and genital structure are the most reliable techniques for distinguishing and classifying butterfly species and subspecies, so the mineralogist has evolved analytical techniques utilizing electron probes and X-ray diffraction experiments performed on individual crystals. And for the amateur, there are some good inexpensive techniques. I submit that the best field method still remains the eye aided by the hand lens. Here, the approach is similar to the oenologist's approach to wines: to personally experience each species and variety by examining authentic specimens. This is one of the valuable services offered by a good museum. Good diagnostic clues include crystal morphology, cleavage, luster and (often neglected!) paragenesis. A mineral's paragenesis is the sequence in time in which it crystallized with respect to other minerals. Such sequences are duplicated from locality to locality and are repeated because the stability of a crystallizing phase (= mineral species) is dependent on thermodynamic criteria such as pressure, temperature, oxygen fugacity, hydrogen ion concentration and composition of the fluid. The paragenesis can help us understand under what conditions the mineral crystallized.

What service can the student of pegmatite phosphates render the profession? Here, the contribution of the diligent amateur is very vital. Form developments of crystals (especially unusual habits), paragenesis, frequency of occurrence — all are vital information. Sadly, the paragenesis of a mineral sequence is usually overlooked or not reported by collectors, yet this is the most valuable information of all! For complete and thorough studies, reliable reports of mineral parageneses at different localities are important. Thus, the diligent amateur will strive to uncover as yet unreported information for locations which have not been previously studied in detail. To do this, a good knowledge of geology is also needed and knowledge of a mineral's paragenesis is of tantamount importance. Elaborating on the sage advice of Neal Yedlin: buy and use good mineralogy *and* geology *and* elementary chemistry books.

OUTLINE OF PRESENTATION

I have tried to be thorough, yet space and the level of most readers limit many important details. Accordingly, I have sacrificed most specialized discussion (crystal structure, etc.) but will inject some elementary inorganic chemistry where it is warranted. In the descriptive section, a brief discussion of outstanding physical properties and paragenesis is included. Some of the noteworthy localities are listed, but this is far from exhaustive. Many species, such as strunzite and laueite, should occur in variable amounts wherever triphylite has been corroded. A list of locations for each species appears in Table 2.

The tabular section should prove fruitful. The chemical formula, outstanding diagnostic features, status (rare or common, local or ubiquitous) in Table 1 and references are meant to be used. The diagnostic features must be employed with caution: like wine and cheese tasting, description is always inadequate as it is highly subjective. This tabulation is meant to assist only if documented specimens of the mineral are examined visually in a comparative way. But even here, aberrant colors and forms can be deceptive and X-ray or optical examination may have to be the final arbiters. Status is important but misleading, for information is lacking since most occurrences remain only incompletely studied. Casual recognition or "guessing" does not single out a particular species and only adds to the confusion in the literature. The references include recent papers on a given species. These articles will provide further references for the serious investigators and provide additional detailed information. Species whose atomic structure are known have asterisks. Knowledge of the atomic structure provides the correct chemical formula and the most solid definition of a species we can have. Many of the formulae in the older literature are erroneous or incomplete.

Finally, I remark that Dr. Kenneth Keester shall, in a subsequent article, provide computer simulated drawings of crystals for most of the species discussed here. Many of the drawings are new and shall prove to be of great diagnostic value to the micromounter who is acquainted with form development and habit.

THE PRIMARY PHOSPHATES

Primary Phosphate Compositions and Distributions.

There are no quantitative studies on primary phosphate distributions in general. Such a problem is of great general interest in pegmatite genesis but requires an intimate knowledge of the original fluid composition of the pegmatite. Here, we may begin with a granitic composition (feldspar, quartz, mica) and consider the *accessory* compositions. For example, the accessory composition may include excess Li_2O, K_2O, Na_2O, CaO, Al_2O_3, $[PO_4]^{3-}$, $[BO_3]^{3-}$, $(OH)^-$. Combinations of these and their amount determine the primary accessory phase. Certain "excesses" (that is, compositions outside of the field of feldspar-quartz-muscovite compositional range) are rare or not observed in natural systems: Na_2O alone, K_2O alone, CaO alone, Al_2O_3 alone, or Fe_2O_3, $CaO + Fe_2O_3$, etc. Such excesses would be too reactive and would have been earlier eliminated through reaction with silica and alumina encountered at the source. Other accessory compositions are common, such as $[PO_4]^{3-} + (Fe, Mn)O$; $Li_2O + Al_2O_3$; $CaO + (OH)^- + [PO_4]^{3-}$; $Li_2O + (Fe,Mn)O + [PO_4]^{3-}$ and lead to the accessory primary phases graftonite; spodumene; apatite; triphylite-lithiophilite respectively. But pegmatites are generally more complicated and most frequently, the accessory phases constitute only a small fraction of the body compared with the granitic phases. For example, excess $[PO_4]^{3-} + Li_2O + Al_2O_3$ $(Fe,Mn)O + CaO$ would lead to the crystallization of triphylite until $(Fe,Mn)O$ is exhausted, then amblygonite crystallizes until Li_2O is exhausted and finally apatite forms. This sequence has been established by field observations on mineral parageneses. If $[PO_4]^{3-}$ was present only in minor amount, spodumene would form instead, as the principal accessory phase. Again, at final crystallization, no highly reactive "excesses" remain behind, such as $[PO_4]^{3-}$, CaO, $(Fe,Mn)O$. If they did, they would have reacted with the chemical pool of granitic composition. But such situations are evidently rare or non-existent since phase compositions like $NaAl(OH)[PO_4]$, $KAl(OH)[PO_4]$, $Al[PO_4]$, $Ca_3[PO_4]_2$, $CaAl(OH)_2[PO_4]$ are extremely rare to non-existent in pegmatites.

There never appears to be a "phosphate excess" in pegmatites since sufficient $(Fe,Mn)O$, Al_2O_3, Li_2O, CaO and $(OH)^-$ are available to form amblygonite, triphylite, etc. Whitlockite, $Ca_3[PO_4]_2$, has never been observed as a primary phase. Instead, apatite forms, suggesting that sufficient $(OH)^-$(or water) is available in a pegmatitic magma. Indeed, pegmatitic magmas are rather "wet" and increase

TABLE 1. THE PEGMATITE PHOSPHATES

In Table 1, I have tried to provide names and formulae for all the phosphates which have been recorded with certitude from pegmatites, with two notable exceptions: the rare-earth phosphates (such as xenotime and monazite) and the uranyl-bearing phosphates (such as autunite, phosphuranylite, etc.). This is because they are in many ways special problems beyond the scope of this survey. Many of the uranyl phosphates, for example, need further study. In any event, the rare-earth phosphates crystallize early, along with beryl, columbite-tantalite, amblygonite-montebrasite, and triphylite-lithiophilite. The uranyl phosphates occur as coatings on earlier minerals and have formed at the latest stages, usually as a result of phosphatic water acting upon decomposed primary uranium oxides. Very rarely do they intertwine with the transition metal phosphate paragenesis discussed herein.

Starred names belong to known structure types; hence, their formulae can be written with some certitude.

Some comments regarding status are in order. *Abundant* (a) means that the mineral occurs in practically every complex granite pegmatite. *Local* (l) means that the mineral may be abundant only at certain pegmatites but rare or absent at others. *Very local* (vl) means that but few pegmatites have been recorded, in most cases only one or two. *Common* (c) implies frequent occurrence; *occasional* (o), occurrence in moderate amount; *uncommon* (u), occurrence in only small amount; *rare* (r), occurrence very restricted; and *very rare* (vr), only a handful of known specimens. Status, of course, changes; at present, reliable recordings of pegmatite phosphates are but few. It is my general experience that the more the altered phosphate nodules are examined from a pegmatite, the more species that will be added to the list of that location. The most complete studies to date appear to be on the Branchville, Palermo #1, Tip Top, Sapucaia and Hagendorf pegmatites.

The references do not embrace all the literature but provide papers which contain additional sources of information. Many of the references contain crystal drawings, perhaps the most important means of visual identification.

THE PRIMARY PHOSPHATES

Subdivision I: Subhedral to Euhedral Primary Phases

Species	Formula	Characteristics	Status	Reference
triphylite*	$\mathrm{Li(Fe,Mn)^{2+}[PO_4]}$	blue-grey, rectangular cleavage	a, c	Mason (1941)
lithiophilite*	$\mathrm{Li(Mn,Fe)^{2+}[PO_4]}$	clove-brown, rectangular cleavage	l, c	Brush and Dana (1890)
sarcopside*	$\mathrm{(Fe,Mg)_3^{2+}[PO_4]_2}$	grey, lamellae with graftonite	l, o	Moore (1972a)
graftonite*	$\mathrm{(Ca,Fe)^{2+}(Fe,Mn)_2^{2+}[PO_4]_2}$	pink, usually as lamellae	l, c	Hurlbut and Aristarain (1968)
beusite*	$\mathrm{(Ca,Mn)^{2+}(Mn,Fe)_2^{2+}[PO_4]_2}$	red brown, as lamellae	l, u	ditto
amblygonite*	$\mathrm{LiAl(F,OH)[PO_4]}$	white, perfect cleavage	l, c	Černá, Černý and Ferguson (1972)
montebrasite*	$\mathrm{LiAl(OH,F)[PO_4]}$	white, perfect cleavage	l, c	ditto
triplite*	$\mathrm{(Mn,Fe)_2^{2+}(F,OH)[PO_4]}$	reddish-brown, good cleavage	l, c	Heinrich (1951)
zwieselite*	$\mathrm{(Fe,Mn)_2^{2+}(F,OH)[PO_4]}$	reddish-brown, good cleavage	l, c	ditto
wyllieite*	$\mathrm{(Na,Ca)_2(Fe,Mn)_2^{2+}(Al,Mg)[PO_4]_3}$	deep green, like hornblende	vl, o	Moore and Ito (1973)
arrojadite	$\mathrm{(Na,Ca)_2(Fe,Mn)_5^{2+}[PO_4]_4}$(?)	bottle green, parting surfaces	l, o	Lindberg (1950)
dickinsonite	$\mathrm{(Na,Ca)_2(Mn,Fe)_5^{2+}[PO_4]_4}$(?)	green, micaceous	l, r	Brush and Dana (1890)

Subdivision II: Anhedral "Primary" Phases (metasomatic exchange products)

Species	Formula	Characteristics	Status	Reference
alluaudite*	$\mathrm{NaCa(Fe,Mn)_2^{2+}[PO_4]_3\text{-}Mn^{3+}Fe_2^{2+}[PO_4]_3}$	greenish-black fine-grained nodular	l, c	Moore (1971a)
natrophilite*	$\mathrm{Na(Mn,Fe)^{2+}[PO_4]}$	colorless to pale yellow cleavage	vl, r	Moore (1972b)
lazulite*	$\mathrm{(Mg,Fe)^{2+}Al_2(OH)_2[PO_4]_2}$	blue nodular	l, r (?)	
scorzalite*	$\mathrm{(Fe,Mg)^{2+}Al_2(OH)_2[PO_4]_2}$	deep blue nodular	l, u	Pecora and Fahey (1949a,b)
triploidite*	$\mathrm{(Mn,Fe)_2^{2+}(OH)[PO_4]}$	reddish-orange, good cleavage	l, u	Brush and Dana (1890)
wolfeite*	$\mathrm{(Fe,Mn)_2^{2+}(OH)[PO_4]}$	red-brown, good cleavage	l, c	Frondel (1949)
heterosite*	$\mathrm{(Fe,Mn)^{3+}[PO_4]}$	rich purple, after triphylite	a, c	Mason (1941)

purpurite*	$(Mn,Fe)^{3+}[PO_4]$	rich purple, after lithiophilite	l, c	ditto
griphite	$Na_4Ca_2(Mn,Fe)^{2+}_8(Al,Fe)^{3+}_4[PO_4]_{12}$	deep brown, resinous	vl, c	McConnell (1942)

THE SECONDARY PHOSPHATES

Subdivision I: Ligand Addition, Alkali-leached Products, Oxidation of Some Metals

barbosalite*	$Fe^{2+}Fe^{3+}_2(OH)_2[PO_4]_2$	deep greenish-black, bluish streak	l, r	Lindberg and Pecora (1955)
rockbridgeite*	$(Fe,Mn)^{2+}Fe^{3+}_4(OH)_5[PO_4]_3$	green-black to red-brown botryoidal, fibrous	a, o	Moore(1970a)
frondelite*	$(Mn,Fe)^{2+}Fe^{3+}_4(OH)_5[PO_4]_3$	ditto	l, o	ditto
dufrenite*	$CaFe^{2+}_2Fe^{3+}_{10}(OH)_{12}(H_2O)_4[PO_4]_8$	green to brown tabular, fibrous	vl, r	ditto
beraunite*	$Fe^{2+}Fe^{3+}_5(OH)_5(H_2O)_4[PO_4]_4 \bullet 2H_2O$	deep orange to blue needles	l, r	ditto
souzalite	$(Mg,Fe)^{2+}_3(Al,Fe)^{3+}_4(OH)_6[PO_4]_4 \bullet 2H_2O$	green bladed, replaces scorzalite	vl, r	ditto
kryzhanovskite*	$Fe^{3+}_3(OH)_3[PO_4]_2$	bronze-brown to reddish, after phosphoferrite	vl, r	Moore (1971b)
phosphosiderite*	$Fe^{3+}(H_2O)_2[PO_4]$	deep red, yellow to pink orthorhombic crystals	l, u	
strengite*	$Fe^{3+}(H_2O)_2[PO_4]$	red (crystals) to violet (crusts)	l, u	
leucophosphite*	$KFe^{3+}_2(OH)(H_2O)[PO_4]_2 \bullet H_2O$	greyish-green to purple-grey crystals	l, u	Moore (1972c)
bermanite	$Mn^{2+}Mn^{3+}_2(OH)_2(H_2O)_4[PO_4]_2$	deep red-brown, small plates	l, u	Hurlbut and Aristarain (1968)
laueite*	$Mn^{2+}Fe^{3+}_2(OH)_2(H_2O)_6[PO_4]_2 \bullet 2H_2O$	orange striated prismatic crystals	l, u	Strunz (1954)
pseudolaueite*	$Mn^{2+}Fe^{3+}_2(OH)_2(H_2O)_6[PO_4]_2 \bullet 2H_2O$	pale orange thick tabular crystals	vl, r	Strunz (1956)
stewartite	$Mn^{2+}Fe^{3+}_2(OH)_2(H_2O)_6[PO_4]_2 \bullet H_2O$	yellow spear-shaped laths	l, u	Schaller (1912)
strunzite	$(Mn,Fe)^{2+}Fe^{3+}_2(OH)_2(H_2O)_6[PO_4]_2$	tan to greenish-yellow fibers	l, u	Frondel (1957)
xanthoxenite	$(Mn,Fe)^{2+}_3Fe^{3+}_3(OH)_3(H_2O)_7[PO_4]_4$	yellow-orange, greenish twinned striated prismatic	l, u	Laubmann and Steinmetz (1920)
cacoxenite	$Fe^{3+}_9(OH)_{15}(H_2O)_3[PO_4]_4 \bullet 15H_2O$	golden yellow needles	vl, r	Moore (1970a)
mitridatite	$CaFe^{3+}_2(OH)_2[PO_4]_2 \bullet nH_2O$	olive-green stains, reddish-black masses	a, o	
cyrilovite*	$NaFe^{3+}_3(OH)_4(H_2O)_2[PO_4]_2$	orange small tetragonal tablets	vl, r	Lindberg (1957)
tavorite*	$LiFe^{3+}(OH)[PO_4]$	lively greenish-yellow films and masses	l, u	Lindberg and Pecora (1955)
faheyite	$Mn^{2+}Fe^{3+}_2Be_2[PO_4]_4 \bullet 6H_2O$	white to brownish-white small fibers	vl, vr	Lindberg and Murata (1953)

Subdivision II: Ligand Addition Products, No Oxidation of Metals

a. Derivatives of primary transition metal phosphates

hureaulite*	$(Mn,Fe)^{2+}_5(H_2O)_4[PO_3(OH)]_2[PO_4]_2$	pink, yellow, red-brown prismatic crystals	l, u	Moore and Araki (1973)
phosphoferrite*	$(Fe,Mn)^{2+}_3(H_2O)_3[PO_4]_2$	reddish-green crystals	vl, r	Moore (1971b)
reddingite*	$(Mn,Fe)^{2+}_3(H_2O)_3[PO_4]_2$	pale pink crystals	vl, r	Brush and Dana (1890)
ludlamite*	$Fe^{2+}_3(H_2O)_4[PO_4]_2$	pale apple green cleavages, tabular crystals	l, u	Wolfe (1949)
switzerite	$(Mn,Fe)^{2+}_3(H_2O)_4[PO_4]_2$	golden-brown micaceous	vl, u	Leavens and White (1967) (not in references)

b. Hydrothermal products derived from amblygonite-montebrasite, beryl, etc.

hurlbutite	$CaBe_2[PO_4]_2$	white stout crystals, massive, no cleavage	vl, r	Mrose (1952)
beryllonite*	$NaBe[PO_4]$	colorless complex crystals, perfect cleavage	vl, r	Dana and Wells (1889)
herderite*	$CaBe(F,OH)[PO_4]$	white, greenish-white prismatic crystals	l, u	Penfield (1894)
hydroxyl-herderite*	$CaBe(OH,F)[PO_4]$	white, greenish-white prismatic crystals	l, u	Volborth (1954)
väyrynenite*	$Mn^{2+}Be(OH)[PO_4]$	rose-red granular	vl, r	ditto
brazilianite*	$NaAl_3(OH)_4[PO_4]_2$	chartreuse complex prismatic crystals	l, u	Pough and Henderson (1945)

lacroixite*	$NaAl(OH)[PO_4]$	greenish-yellow granular	l, r	Mrose (1971)
augelite*	$Al_2(OH)_3[PO_4]$	colorless to pale blue, prismatic cleavage	l, r	Fisher and Runner (1958)
wardite*	$NaAl_3(OH)_4(H_2O)_2[PO_4]_2$	white to grey pseudo-octahedral crystals	l, r	ditto
morinite	$NaCaAl(F,OH)_3(H_2O)[PO_4]$	pale pink columnar aggregates	vl, r	ditto
goyazite	$SrAl_3H(OH)_6[PO_4]_2$	white rhombohedra, perfect cleavage	l, r	Mrose (1953)
palermoite	$SrLi_2Al_4(OH)_4[PO_4]_4$	colorless striated prismatic	vl, r	ditto
bertossaite	$CaLi_2Al_4(OH)_4[PO_4]_4$	ditto	vl, r	Von Knorring and Mrose (1966)
lithiophosphate*	$Li_3[PO_4]$	colorless prismatic, massive, perfect cleavage	l, r	White (1969)
whitlockite	$Ca_8(Mg,Fe)^{2+}[PO_4]_6$	white rhombohedra, poor cleavage	l, u	Frondel (1941)
bøggildite	$Na_2Sr_2Al_2F_9[PO_4]$	flesh-red crystalline	vl, r	Bøgvad (1951)
fairfieldite*	$Ca_2(Mn,Fe)^{2+}(H_2O)_2[PO_4]_2$	tan to white micaceous	l, u	Brush and Dana (1890)
messelite*	$Ca_2(Fe,Mn)^{2+}(H_2O)_2[PO_4]_2$	white micaceous	l, u	
eosphorite*	$(Mn,Fe)^{2+}Al(OH)_2(H_2O)[PO_4]$	pink prismatic crystals	l, r	Brush and Dana (1890)
childrenite*	$(Fe,Mn)^{2+}Al(OH)_2(H_2O)[PO_4]$	tan to brown prismatic crystals	l, u	
bjarebyite*	$Ba(Mn,Fe)_2^{2+}Al_2(OH)_3[PO_4]_3$	green complex prismatic crystals	vl, vr	Moore, Lund and Keester (1973)
crandallite*	$CaAl_3H(OH)_6[PO_4]_2$	white small trigonal prismatic crystals	l, u	
montgomeryite	$Ca_4Al_5(OH)_5[PO_4]_6 \bullet 11H_2O$(?)	small colorless laths	vl, vr	Moore (1964)
moraesite	$Be_2(OH)[PO_4] \bullet 4H_2O$	white needles and sprays	vl, r	Lindberg, et al. (1953)
roscherite*	$Ca(Mn,Fe)_2 Be_3(OH)_3[PO_4]_3 \bullet 2H_2O$	greenish to brown tabular crystals	l, r	Lindberg (1958)

in their water content as the early formed anhydrous phases (feldspar and quartz) crystallize out. A pegmatite of average granite composition containing a great quantity of accessory $[PO_4]^{3-}$ would result in an apatite-bearing pegmatite with the feldspars more sodic than the average granite. This is because apatite formation has "robbed" the granite melt of enough calcium to form this accessory phase. Observations on relationships or correlations between accessory giant crystal phases and their enclosing silicates are very valuable in addition to the observations on the sequence of crystallizing primary phases.

How can such pegmatites be compositionally classified on a general basis? One intriguing approach is to take all possible accessory compositions which are added to an average granite melt and follow the sequence of crystallizing phases. This would require a knowledge of primary phase paragenesis (or thermochemical stability) and the use of high speed computers since the combinations are very great (the components are SiO_2, Al_2O_3, K_2O, Na_2O, Li_2O, H_2O, CaO, FeO, MnO, etc.). Numerous laboratories are presently pursuing this problem; the most outstanding review on this problem and on pegmatites in general — an already classic work — is the study of JAHNS (1955).

One possible argument for the persistence of primary phosphate compositions like $Ca_5(OH)[PO_4]_3$, $LiAl(OH)[PO_4]$, $Li(Fe,Mn)[PO_4]$ and the absence of compositions like $Li_3[PO_4]$, $Na_3[PO_4]$, $Ca_3[PO_4]_2$ and $CaAl(OH)_2[PO_4]$ is that these compositions were "predetermined" in the melt prior to injection of the pegmatite. Such a process is likely since liquids, like solids, must obey mass balance and charge balance, and have reactions which came to completion (i.e., no reactive accessories). In addition, anions like $[PO_4]^{3-}$ are "scavengers": segregated from silicates (there are no crystallized "silicophosphates" in pegmatites), the $[PO_4]^{3-}$ anion has strong affinities for FeO, Li_2O and Al_2O_3 in wall rocks. There is the possibility that triphylite-rich provinces occur in association with "dirty" country rocks while apatite-rich assemblages are found in "clean" country rocks. Another well-known scavenger is $[BO_3]^{3-}$: boron-rich pegmatites invariably show a great abundance of tourmaline, particularly the Fe^{2+}-rich schorl, which crystallized at the earliest stages of pegmatite consolidation. To answer these intriguing questions, much more field and laboratory study will be necessary.

Another intriguing observation on accessory phosphates in granitic pegmatites is that *no* primary phosphates are known which contain ferric iron (Fe^{3+}) in substantial amounts. When present, it occurs, as in tourmaline, in very small amounts. When Fe^{3+} is abundant in granitic pegmatite, arfvedsonite- or biotite-rich units are encountered and phosphates are usually absent. Pegmatites in the Black Hills which carry much biotite (such as the St. Louis mine) appear to have resorbed much wall-rock and show extensive brecciation. Li-Fe-$[PO_4]^{3-}$-rich pegmatites appear to have formed under conditions where the oxygen fugacity was very low. Another observation which supports this is the presence of minor amounts of sulfides and arsenides co-existing with the phosphates.

An outline of important compositions in granitic pegmatites appears in Table 3.

APATITE

Apatite is treated separately from the other pegmatite phosphates since its varieties are known to occur at all stages of pegmatite formation. The earliest formed apatites, like the other primary phases which contain additional anions, are fluoride (F^-) or hydroxyl (OH^-) bearing apatites and usually contain significant (up to 4%) amounts of Mn^{2+}. Primary apatite in pegmatites, unlike apatites which have crystallized in contact metamorphic assemblages, rarely occur as euhedral or even subhedral crystals. An exception is a remarkable primary apatite from the Hugo pegmatite near Keystone, South Dakota, recorded by ROBERTS and RAPP (1965). Portions of prism faces were uncovered and it was estimated that the original crystal was perhaps the largest ever recorded for the species, at least a half ton in weight. Most typically, the appearance of "gum drop" to ellipsoidal and eutectoid-type textures of apatite-silicate associations are common. Here, apatite "fingers" occur in parallel growth with sodic plagioclase or cleavelandite, tourmaline and quartz. Perhaps many of these apatites belong to replacement units in the pegmatite. Truly primary apatite usually occurs as small to medium-sized lumps from the wall zone to the core, embedded in coarse quartz masses. The color is grey to bluish-green or pinkish-grey, inclining toward greenish-blue and deep blue and rarely purple in the varieties containing Mn^{2+}. Many of these apatites fluoresce orange under ultraviolet excitation. The lack of good cleavages distinguishes apatite from triphylite with which it is often confused but the deep blue varieties are easily confused with tourmaline, except for the striations parallel to the prism in the latter mineral.

Apatite occurs as a druse or miarolitic cavity mineral, formed during the hydrothermal stage in pegmatites. In this assemblage, smoky quartz, multi-colored tourmaline, beryl and herderite usually occur, overlain by a fine yellow dust of cookeite. Apatites in druses are often very well crystallized with complex forms, from thick tabular to prismatic development. Such crystals are frequently gemmy and possess a pink to rich purple color owing to the presence of minor Mn^{2+} and Fe^{2+}.

Apatite is also a typical product of metasomatic exchange reactions where Ca^{2+} was added to pre-existing primary phosphates and the alkalies were removed. Such calcium metasomatism occurs at a late stage, usually after sodium metasomatism. Thus, at the Pleasant Valley pegmatite, near Custer, South Dakota, euhedral triphylite pseudomorphs up to a foot across are observed possessing a core of triphylite, a thick zone of alluaudite and a dull red to pink outer zone or shell of fine-grained mixture of apatite and subordinate hematite. Apatite is known to replace triphylite directly (but only rarely), alluaudite, triplite, amblygonite-montebrasite and rarely graftonite.

Finally, apatite may occur in very late stage low temperature assemblages, usually of the carbonate-apatite varieties (francolite, dahllite) as botryoidal crusts of a dull grey color or white prismatic crystals of simple development.

It is well known that apatite of the druse period is confined only to certain pegmatite regions. Several pegmatites in Maine were made famous in mineralogical literature for magnificent gem quality crystals (see WOLFF and PALACHE, 1902). Yet, in other provinces such as the Black Hills, gemmy hydrothermally grown apatites are very rare and only local in occurrence. Unfortunately, no detailed studies exist regarding apatite distributions in pegmatites throughout the world and reported chemical analyses of pegmatite apatites are but few. This is yet another example of the tendency for mineralogists of the past to concentrate mostly on the more peculiar minerals and their occurrences, rather than the far more abundant primary phases.

Subdivision I: subhedral to euhedral primary phases.

Included in the division of primary phosphates are the giant crystals and lenticular masses, often of enormous dimension, which crystallized toward or in the core of the pegmatite. Dimensions of crystals up to a foot across are common, although triphylite giant crystals include some pegmatites in New England (Palermo No. 1, N. Groton, New Hampshire), the Black Hills of South Dakota (Dan Patch pegmatite, Keystone; Tin Mountain lode, and the Bull Moose pegmatite, Custer); the Sapucaia pegmatite in Brazil; and Hagendorf Süd in Bavaria. The primary phosphates tend to be concentrated in a limited volume of the pegmatite, indicating crystallization at a particular period over a narrow temperature range. The crystals are usually embedded in bull quartz, also of large dimension, and occur associated with beryl, tantalates, tourmaline and minor sulfides and arsenides.

It is difficult to unambiguously distinguish the two subdivisions of the primary phosphates. The second subdivision differs only in including seemingly primary phases which, in fact, are metasomatic exchange products of the original crystallized phases. In the case where the metasomatic exchange involved gross changes in the atomic structure, the subhedral to euhedral outlines of the original crystals usually lost their integrity and appear as rounded forms such as ellipsoidal nodules. In addition, instead of broad cleavage surfaces typical of the primary giant crystals, the grain size of the metasomatic product is usually quite small — of the order of millimeters — even though the nodule may be ten orders of magnitude as large.

TRIPHYLITE-LITHIOPHILITE

The most typical of the phosphate giant crystals includes the triphylite-lithiophilite series which may occur in pegmatites rich in phosphate anion, lithium and metals of the first transition series. The two end-members constitute a *series*, that is a complete range of iron and manganese solution in the crystal is possible. The atomic arrangement belongs to the olivine structure type; a particular Fe: Fe + Mn ratio is usually characteristic for a pegmatite. Compositional zoning with respect to position in a particular pegmatite appears to be the exception for the triphylite-lithiophilite series but this may simply result from the localized position of the species in any given pegmatite, and quantitative crystallization of the (Fe,Mn)O in the magma. Compositions toward the lithiophilite end of the series, $Li(Mn,Fe)(PO_4)$, occur relatively infrequently, reflecting the greater geochemical abundance of iron with respect to manganese as well as their crystal-chemical similarity. Manganese phosphate-rich pegmatites are "late" pegmatites; that is, they were rich in water and contain an abundance of giant crystals. Pegmatites known for lithiophilite include Branchville and Portland (Strickland quarry) in Connecticut; Buckfield, Poland and Newry in Maine; the Custer Mountain lode, near Custer, South Dakota; Pala, California; and Mangualde, Portugal. Where lithiophilite occurs, it is not always safe to assume that the initial pegmatitic fluid was richer in Mn^{2+} than Fe^{2+}; rather, it is possible that Fe^{2+} was preferentially removed at the earlier stage of pegmatite crystallization in a scavenger mineral such as tourmaline.

The triphylite side of the series, $Li(Fe,Mn)(PO_4)$, occurs in many pegmatites throughout the world (see Table 2). Most pegmatites of New England and the Black Hills contain triphylite in minor amounts; some pegmatites are particularly blessed with the species. The former abundance of triphylite at the Palermo No. 1 pegmatite in New Hampshire was attested by stockpiles scores of tons in weight. Large crystals were encountered at the Dan Patch (near Keystone), Tip Top, Bull Moose and Big Chief (near Custer) pegmatites in the Black Hills. Other noteworthy localities include Hagendorf Süd, Bavaria; Varuträsk and Norrö, Sweden.

Triphylite-lithiophilite, when exposed to sunlight and rain, rapidly oxidize superficially to a coppery black thin coating of ferric and manganic oxides. This feature, combined with the brittle character of the mineral and its tendency to break into rectangular blocks, the bluish-grey to clove brown color of fresh surfaces and the relatively high density, distinguish the series from other pegmatite accessories such as garnet, tourmaline and amphiboles.

SARCOPSIDE

Sarcopside is a relatively rare species but its structural relationship with triphylite warrants its entry here. Its atomic arrangement, revealed recently by MOORE (1972a), is based on hexagonal close-packed oxygen atoms akin to the triphylite-lithiophilite series and the iron atoms are arranged in an ordered relationship derivative of that series.

Sarcopside has never been observed as single crystals. It invariably occurs as exsolution lamellae from triphylite and graftonite. This suggests that the triphylite and graftonite which crystallized at high temperature allowed extensive compositional solubility, *viz.* $Li_2Fe_2[PO_4]_2 - (\square Fe)Fe_2[PO_4]_2$ for triphylite-sarcopside, where □ is a "hole" in the structure. The existence of sarcopside exsolution lamellae from triphylite hints that the Li and Fe atoms and the "holes" in triphylite "mix" at higher temperature but order at some lower temperature, with sarcopside separating out. Structure analysis on triphylite at room temperature by FINGER and RAPP (1970) reveals that the Li and Fe atoms are not mixed together in the crystal but occur over separate sites. Since the Li^+ and Fe^{2+} cations have nearly identical radii which would encourage solid solution, the ordering is evidently due to the difference in charge between these cations.

The sarcopside individual lamellae are usually only 1 mm thick and occur rhythmically intergrown with graftonite, where the species alternate in layers of nearly equal proportion. When exsolved from the triphylite, sarcopside is by far the subordinate phase. Caution must be expressed in distinguishing sarcopside from triphylite; the latter is also observed as an exsolution product from graftonite (although the graftonite lamellae are usually much thicker than those of triphylite) and physical distinction between these two blue-grey minerals is practically impossible without recourse to optical and X-ray study (or a test for the absence or presence of lithium!).

A noteworthy account of graftonite-sarcopside lamellae from E. Alstead, New Hampshire is reported by HURLBUT (1965). Sarcopside exsolved from triphylite occurs in abundance at the Bull Moose pegmatite, Custer, South Dakota.

GRAFTONITE-BEUSITE

Graftonite and beusite are the Fe^{2+} and Mn^{2+} dominant members of a solid solution series which also includes essential Ca^{2+}, at least in natural systems. Although CALVO (1968) reports pure synthetic $Fe_3[PO_4]_2$ (hence, a dimorph of sarcopside) and $Mn_3^{2+}[PO_4]_2$ with the graftonite structure, natural samples always contain significant amounts of calcium. The atomic structure of graftonite suggests that the upper limit of calcium in graftonites would be $Ca(Fe,Mn)_2^{2+}[PO_4]_2$.

The species are not as rare as once suspected. Crystals are very infrequently encountered since the minerals usually crystallize as ellipsoidal nodules, but these nodules may in fact be products of metasomatic exchange and properly fall into Subdivision II. PENFIELD (1900) reported crude single crystals from the type locality at Melvin Mountain near Grafton, New Hampshire; exsolution of sarcopside often occurs in the crude crystals. The most detailed description of graftonite-beusite is that of HURLBUT and ARISTARAIN (1968). The color ranges from flesh-pink to salmon-pink (graftonite) to reddish-brown (beusite). A characteristic (though not necessarily invariant) feature is the presence of exsolved lamellae of sarcopside (if Li was absent in the high temperature parent

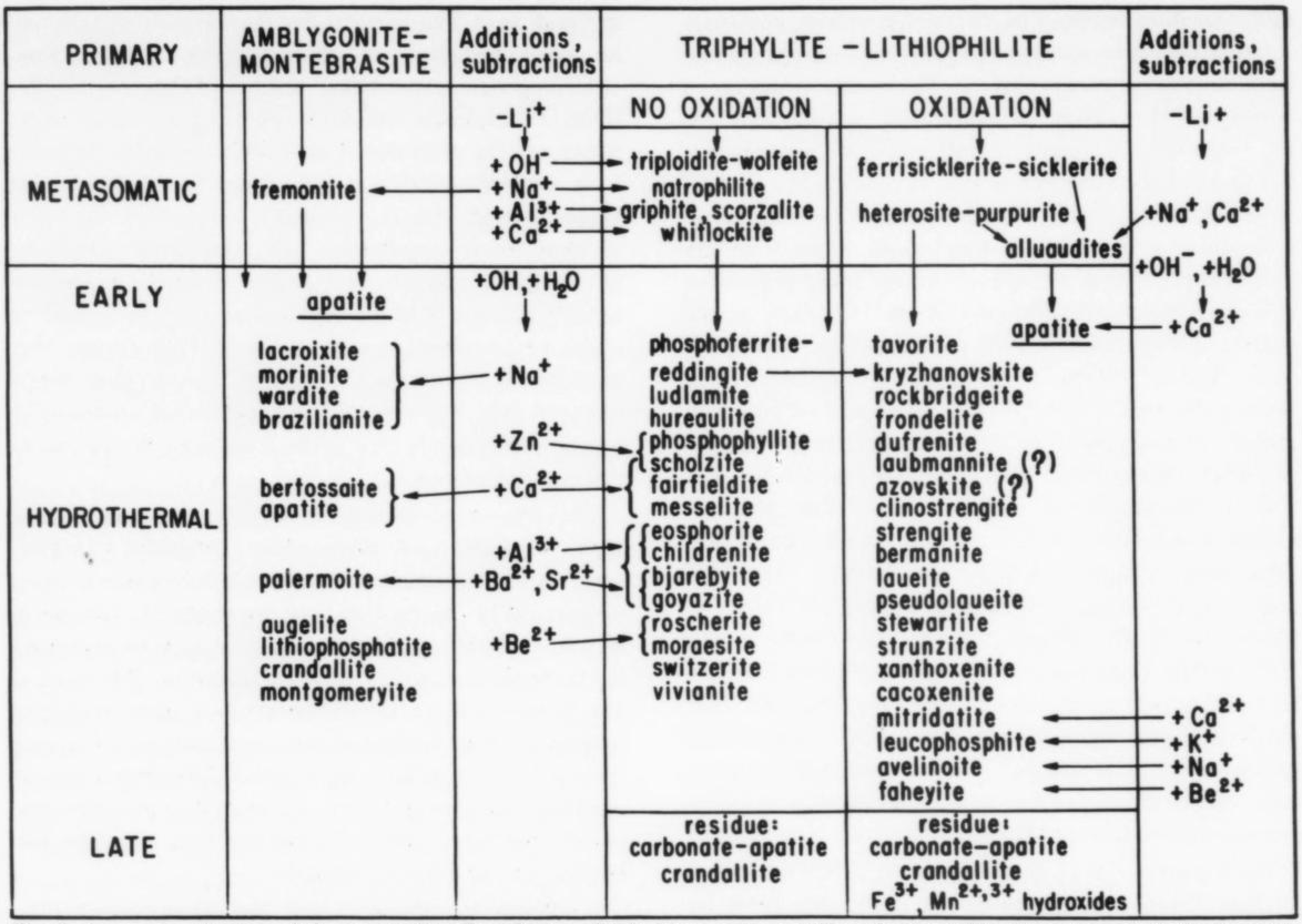


Fig. 1. **A paragenetic tree of the pegmatite phosphates, divided into primary (directly crystallized), metasomatic (volumetrically replaced), and hydrothermal (recrystallized) stages. Decreasing temperature approximately runs from "early" to "late". Additions and subtractions include ions taken from the fluid and those removed from the host crystal.**

phase) or triphylite-lithiophilite (if Li was present). Graftonite-beusite are fairly resistant to weathering and rarely display the oxidation sequences typical for triphylite-lithiophilite.

Outstanding localities include the Palermo and Rice pegmatites, N. Groton, New Hampshire; the Bull Moose pegmatite near Custer, South Dakota (graftonite); and the Los Aleros pegmatite, Argentina (beusite).

AMBLYGONITE-MONTEBRASITE

The amblygonite-montebrasite series is in quantity and distribution even more abundant than triphylite-lithiophilite and on occasion constitute ores of lithium. Except for the higher density (3.0 gm/cm³ vs. 2.6 gm/cm³), the perfect cleavage and characteristic milk-white color often lead to confusion with the feldspars. Amblygonite-montebrasite usually occur as ellipsoidal nodules or crude crystals up to a foot across in a paragenesis similar to spodumene. ROBERTS and RAPP (1965) report masses up to 200 tons in weight from the Beecher lode southeast of Custer in the Black Hills. Good crystals of the species are rare: a noteworthy exception is the spectacular Tin Mountain mine west of Custer. Here, large euhedral crystals up to a foot across occur in bull quartz, closely bunched together along a vein-like lens. Giant spodumene crystals up to 20 feet in length occur in the vicinity but not in contact with the amblygonite.

Amblygonite-montebrasite characteristically surficially display a pulverulent coating of kaolinite. Unlike triphylite-lithiophilite, the series does not suffer easy corrosion and only infrequently surrenders to exotic species as a result of hydrothermal action. Without recourse to chemical study, the portion of the series is difficult to establish.

NATROMONTEBRASITE (FREMONTITE)

A geochemically interesting fact is that natromontebrasite is a very rare mineral. It is quite possible that the species is an early hydrothermal product and that the composition at primary phosphate crystallizing temperatures is unstable. In any event, it is included under amblygonite-montebrasite with reservation, since the lithium-rich series invariably contains some sodium as a substituent.

Properties are similar to amblygonite-montebrasite; localities include Eight Mile Park, Colorado and Jeclov, Moravia.

TRIPLITE-ZWIESELITE

This series is not rare but it is difficult to identify in the field for want of simple distinguishing features. The (F,OH) solution extends only slightly toward the triploidite-wolfeite series suggesting extensive immiscibility between the double series. WALDROP (1969) has established structural differences between the double-series on grounds of detailed atomic arrangements analysis.

A very extensive study on the chemistry of triplite appears in HEINRICH (1951). He notes no less than 80 occurrences for the mineral, and observes that triplite may have a magmatic origin where large single crystals occur, but usually appears in a metasomatic or early hydrothermal product as ellipsoidal nodules embedded in sodic plagioclase. Thus triplite, like apatite and perhaps arrojadite, belongs to the next subdivision as well. Triplite surrenders itself to relatively few late stage products, quite distinct from the triphylite-lithiophilite series. Here, are included phosphosiderite, strengite, vivianite, bermanite and "dufrenite" (= rockbridgeite?). Metasomatic exchange may lead to replacement by apatite (Ca-metasomatism) or alluaudite (Na-metasomatism). The minerals also occur in tin-bearing hydrothermal vein paragenesis which includes cassiterite and the beryllium phosphate herderite.

The color is nut brown to reddish-brown with a distinctly resinous appearance. Except for a good pinacoidal cleavage, the series can be easily mistaken for garnet. Crystals are rare and when they occur, are usually large and crude.

WYLLIEITE

This recently christened species is structurally allied to the alluaudite group which belongs to subdivision II. The new species occurs abundantly as large (up to 6 inch) euhedral crystals embedded in coarse bull quartz, perthite and albitized perthite from the Victory mine near Custer, South Dakota. Large masses of interlocking crude crystals up to 50 pounds in weight are scattered throughout the dump. With a deep green to greenish-black color and perfect cleavage, the mineral deceptively resembles hornblende in appearance. The olive-green streak and powder is a good field guide to its identification.

Compositionally, wyllieite is $Na(Na,Ca)(Fe^{2+},Mn^{2+})Fe^{2+}(Al^{3+},Mg)[PO_4]_3$, or stated simply, $Na_2Fe_2^{2+}Al[PO_4]_3$. The Victory pegmatite is interesting and unique since the primary transition metal phosphates are sodium-rich and absent in lithium. Wyllieite is yet another example of a primary phase where Fe^{2+} is the formal valence state. Ferric iron (Fe^{3+}) appears to be practically absent in documented examples of euhedral crystals but persists in the metasomatic exchange products of subdivision II.

ARROJADITE-DICKINSONITE

It is difficult to establish whether or not some of the specimens in this series truly represent primary phases. The chemistry of the species is very complex, similar to wyllieite, and probably involves essential K^+ and Ca^{2+} as well as Na^+. The series occurs as large deep bottle-green to pale yellow-green masses with broad parting surfaces, or as granular pale green aggregates. It can be easily confused with triphylite and is distinguished in the field by the absence of the bluish grey tinge of that mineral. Dickinsonite from a hydrothermal paragenesis, not belonging to this category, is micaceous green in appearance with a tabular aspect to the crystals. The parting planes in massive arrojadite have been attributed to exsolved phases such as triphylite and cassiterite.

Some arrojadites, especially those from the Nickel Plate pegmatite near Keystone, South Dakota ("headdenite") and a prospect above the Palermo pegmatite, N. H., are probably primary phases *in sensu stricto*, even though their appearances are anhedral and ellipsoidal. The Victory mine pegmatite yielded pale yellow-green broad parting surfaces of the arrojadite coexisting with wyllieite. Some of these surfaces show subhedral crystal outlines and the phase is almost certainly primary. Arrojadites from the Victory mine, the Nickel Plate mine, and the Smith mine, near Newport, New Hampshire often are rimmed and partly replaced by a deep greenish-black mineral which proves to be alluaudite of subdivision II.

Subdivision II: anhedral "primary" phases
(metasomatic exchange products)

Grouped here are the phases which replaced earlier-formed primary phases during the last stages of pegmatite core consolidation. Their genetic connection with subdivision I is close and often indistinguishable. Characteristically, they occur replacing the parent materials or as ellipsoidal masses, the interiors of which show no crystallographic continuity.

Typical metasomatic reactions in pegmatites involve Na^+, K^+, and Ca^{2+} displacing Li^+. In most instances, the product is not crystallographically related to the parent, and a small volume change may have taken place, hence the appearance of anhedral lumps with fine grain size. A typical example of a metasomatic reaction is the replacement of Li^+ by K^+, Na^+, Ca^{2+} and/or H^+. Such a reaction involving parent spodumene, $LiAl(Si_2O_6)$, results in the formation of "cymatolite," a mechanical mixture of muscovite, $KAl_2(OH)_2[AlSi_3O_{10}]$, and albite, $Na[AlSi_3O_8]$. In the case of the phosphates, the new products are also phosphates, but usually contain Na^+, $(OH)^-$ and Ca^{2+}, that is, mobile ions, in contrast with the relatively immobile Fe^{2+} and Mn^{2+} which remained behind and whose Fe/Fe+Mn ratios reflect the compositions of the original crystal. In addition, Fe^{2+} is partially oxidized to the Fe^{3+} state.

ALLUAUDITES

These curious phases were once believed rare, but many localities throughout the world are presenty on record and they are very common at some pegmatites, particularly in the Black Hills. The species occurs as dense fine-grained nodules, sometimes up to a foot across, with a characteristic deep opaque dull-green color which is enhanced upon mild soaking in dilute HCl. Their distribution is rather interesting: many pegmatites in the Black Hills yielded alluaudite nodules, which on account of their nondescript appearance, have usually been overlooked.

Extensive crystal-chemical study on alluaudites by MOORE (1971a) reveals that this species has invariably arisen from $Na^+ + Ca^{2+}$ replacing Li^+ in parent triphylite-lithiophilite, ferrisicklerite and heterosite-purpurite. In some instances, the crude outline of the triphylite parent still remains and alluaudites which have only partly replaced earlier phases rim these phases along the borders and along fracture surfaces. A paragenetic tree of the exchange appears in Fig. 1. The alluaudites include the interesting mixed valence series $NaCaMn^{2+}Fe^{2+}_2[PO_4]_3$—$Mn^{3+}Fe^{3+}_2[PO_4]_3$, the deep green color arising from mixed valence homonuclear electron transfer. Members of the alluaudites include manganalluaudite, manganvarulite, varulite, hühnerkobelite, and hagendorfite but these names should be abandoned. Other noteworthy localities besides the Black Hills pegmatites include Varuträsk and Norrö, Sweden; Chanteloube, France; Buranga, central Africa; and Hagendorf Süd, Bavaria. As mentioned earlier, alluaudite also occurs as black rims bordering triphylite and arrojadite from Smith mine, Newport, New Hampshire.

NATROPHILITE

Essentially a one locality mineral, natrophilite occurs in a paragenesis very similar to the alluaudites. First described by BRUSH and DANA (1890) from the Branchville pegmatite, Connecticut, it replaces the isostructural lithiophilite. The replacement, discussed by these authors, and in more detail by MOORE (1972b) is another example of the $Na^+ \rightarrow Li^+$ metasomatic reaction, akin to and contemporaneous with the cymatolitization of spodumene. Natrophilite is clear yellow in color and possesses one perfect and one good cleavage; it is easily confused with lithiophilite.

Why is natrophilite so rare? MOORE (1972b) has advanced the argument that it should only occur where lithiophilite occurs, since such metasomatic exchange reactions always seem to involve oxidation of some iron to Fe^{3+} in triphylites and the subsequent formation of alluaudite instead. Mn^{2+}, on the other hand, is far more resistant to oxidation. Accordingly, lithiophilites should be routinely checked for this mineral, distinguished from lithiophilite by the presence of Na^+ instead of Li^+ as the major alkali cation.

TRIPLOIDITE-WOLFEITE

These species are relatively rare and resemble spessartine garnet and, in some instances, lithiophilite in general appearance; they are distinct in possessing good pinacoidal cleavage and a reddish-orange color distinguishing the species from the clove-brown to tan lithiophilite. But distinction from the triplite-zwieselite series is difficult. They are frequently found in association with triphylite and alluaudites, and like the latter species, appear to replace the triphylite. Wolfeite from the Palermo pegmatite, N. H. and triploidite from the Ross Lode near Keystone, S. D. occur as disseminated granular aggregates, the latter often as large masses associated with löllingite.

PURPURITE-HETEROSITE

The series is the most ubiquitous and typical of alkali-leaching with concomitant oxidation of Fe^{2+} and Mn^{2+}. It can be explicitly expressed as a progressive series where the original Fe/Fe +Mn chemical ratio is preserved. The sequence can be summarized:

$Li(Fe,Mn)^{2+}[PO_4] \rightarrow Li_x(Fe,Mn)^{2+}_x Fe^{3+}_{1-x}[PO_4] \rightarrow$
triphylite-lithiophilite ferrsicklerite-sicklerite
$(Fe,Mn)^{3+}[PO_4]$
heterosite-purpurite

Remarkable is the maintenance of the integrity of the crystal structure throughout the sequence: although the Li^+ cations are progressively removed and the transition metals oxidized, the oxygen arrangement remains intact. The series is apparently not stable thermodynamically, since the fully oxidized end-members have not been synthesized directly but always derive from the existence of the primary unoxidized series. Typical examples of the progressive sequence includes an outer shell of heterosite-purpurite surrounding ferrisicklerite-sicklerite which in turn surrounds triphylite-lithiophilite. In some instances, primary crystals are completely replaced by their oxidized equivalents. In others, the oxidized equivalents themsleves are replaced by members of the secondary phosphates through the addition of $(H_2O)^\circ$ and $(OH)^-$.

Physical characteristics of heterosite-purpurite afford easy recognition: when powdered or washed briefly in warm dilute HCl solution, the rich magenta color characteristic of the species appears. Distinction between the ends of the series is more difficult and requires chemical analysis. The series occurs practically anywhere the triphylite-lithiophilite series is found. Ferrisicklerite-sicklerite becomes rich brown when treated with HCl solution.

GRIPHITE

This curious phase has been recorded from the Sitting Bull and Everly (Riverton Lode) pegmatites, near Keystone, South Dakota; and Mt. Ida, Northern Territory, Australia. At the South Dakota pegmatites, the mineral can be seen in place as nodular resinous yellowish-brown to reddish brown lumps up to six feet in diameter. The presence of actinides in its formula results in a metamict structure, the actual crystallinity restored only by heating.

McCONNELL (1942) has proposed that griphite possesses a structure related to garnet. A garnet-like cell of lower symmetry was confirmed in a recent study by PEACOR and SIMMONS (1972). MOORE and MOLIN-CASE (1973) note that the griphite formula is similar to that of wyllieite and advance the argument that the wyllieite-griphite relationship is identical to that of the caryinite-berzeliite paragenesis at Långban, Sweden. Berzeliite, which possesses a garnet structure, was observed by several investigators to replace the caryinite, the latter compound isostructural with wyllieite. They conclude that griphite is, in all likelihood, a metasomatic product of some previously existing phase, perhaps wyllieite itself.

LAZULITE-SCORZALITE

Compositionally akin to wyllieite and the amblygonite group, it is difficult to establish with certainty the paragenetic position of this series. The sky-blue to deep blue color and hardness are good visual aids in their identification.

Lazulite in association with high grade pyrophyllite and kyanite metamorphic assemblages usually appears as euhedral to subhedral crystals. In pegmatites, the series invariably occurs as nodular aggregates. Scorzalite was originally described from the Corrego Frio pegmatite by PECORA and FAHEY (1949a) and shortly after by PECORA and FAHEY (1949b) from the Victory mine, South Dakota, associated with wyllieite (= triphylite of Pecora and Fahey). Here, the mineral borders and rims the wyllieite in a relationship which physically suggests replacement of wyllieite by the scorzalite.

MOORE (1965) drew attention to a large mass of scorzalite which once was exposed at the Palermo No. 1 pegmatite, New Hampshire. This nodule was in close contact with a large hydrothermally attacked triphylite crystal, the latter completely gone to ludlamite, siderite and other secondary minerals. Again, the scorzalite postdated the primary phase, which was once triphylite, but owing to its resistance to hydrothermal attack, did not suffer the decomposition as did the triphylite.

THE SECONDARY PHOSPHATES

The largest diversity of species includes compounds derived from parent triphylite-lithiophilite where some phosphate anions have been leached out, water and hydroxyl groups are added to the system bonded to the transition metals, and where some of the transition metals have been oxidized. Triphylite-lithiophilite is evidently very reactive in the presence of water and the aqueous medium has spanned a range of temperature. Since bonded $(H_2O)^\circ$ molecules are fairly unstable at temperatures above 250°C and since these molecules participate in coordination about the metals, reactions leading to the formation of many of the compounds in this group have probably occurred below 250°C.

Recently, we have gained much new knowledge about the structural chemistry of the basic transition metal phosphate hydrates. Such compounds are called *transition metal complexes*. They consist of a transition metal cation core (such as Fe^{2+}, Fe^{3+}, Mn^{2+}, etc.) to which are bonded oxygen atoms from water molecules $(H_2O)^\circ$), hydroxyl groups ($(OH)^-$) and phosphate anions ($[PO_4]^{3-}$) at the vertices of an octahedron. The groups to which the oxygens belong are called *ligands*. Fig. 2 is a simplistic sketch showing a possible route of formation of such a coordination complex. Water molecules may octahedrally arrange about Fe^{3+} in solution. These octahedra can condense to form polymers, where an $(OH)^-$ ligand joins them at a common vertex. Further ligand bridging by $[PO_4]^{3-}$ tetrahedra leads to an even larger aggregate. Condensation of such aggregates leads to a crystalline substance if the conditions are suitable. One of the most fascinating studies in modern chemistry and mineralogy is to trace back these steps and actually characterize and reveal the clusters that exist in the solution from which a crystal is growing. This leads to a very elegant understanding of mineral paragenesis in a total sense, in what we may call the "sociology" of minerals!

The great diversity of species is attributed to the mixed valence states of the metals, the different ways in which the ligands can cluster around these metals and the different ways in which the octahedra can condense to form clusters. The paragenetic distribution of the species of secondary phosphates is shown diagrammatically in Fig. 3. As temperature of crystallization decreases the degree of octahedral condensation also decreases.

Oxidative conditions were important in the formation of many of these phases. It is generally observed that the Fe^{2+} cation oxidizes to Fe^{3+} more readily and easily than Mn^{2+} to Mn^{3+}: thus, many of the species reveal Fe^{3+} along with Mn^{2+} in the same crystal. At such a late stage of mineral formation — most likely in a shallow open environment — the immobile metal cations were left behind, but much of the $[PO_4]^{3-}$ and nearly all of the alkalies were removed. Consequently, the species characteristically occur in spongy open cavities consisting of siderite (the major carbonation product of triphylite-lithiophilite) and mixtures of basic ferric and manganic oxides. The species are easily distinguished by morphological characteristics, since most form as small (up to 1 mm) single crystals. They are perhaps the most interesting and challenging in the entire phosphate suite, and afford aesthetic rewards as well as intellectual contests for the diligent micromounter.

Subdivision I: ligand addition, alkali-leached products, oxidation of some metals.

BARBOSALITE

Barbosalite, and many of the species which follow in the description, are based on a common structural principle: an octahedral Fe^{3+} -Fe^{2+} -Fe^{3+} face-sharing trimer. The mixed oxidation of the iron results in valence transfer and extremely dark blue to greenish-black colors. Barbosalite occurs as deep bluish-black fine-grained compact aureoles lining and filling cavities in reworked triphylite, often in association with pyrite and arsenides. Important localities include the Sapucaia pegmatite, Brazil; the Palermo pegmatite, N. H. and the Bull Moose pegmatite near Custer, S. D. Rarely the mineral occurs as very small (50 microns) short prismatic crystals, a lustrous black in appearance.

ROCKBRIDGEITE-FRONDELITE

Next to the heterosite-purpurite series, this series is the most typical and abundant. Large fibrous masses up to one foot across were gathered from the Fletcher mine, N. Groton, N. H. and the Tip Top pegmatite, near Custer, S. D. In many instances, the species directly replaces triphylite and occurs along fracture systems in the primary giant crystals which afforded access by aqueous solutions. The appearance is characteristic: compact bladed to fibrous deep black masses when unoxidized to brown bladed fibers for the fully oxidized varieties. Often, the species occurs as botryoidal aggregates in open cavities and is among the earliest of the hydrothermal products to form. The cross-sections of the spherules are radial-fibrous. Only rarely do good crystals form, which are of very small dimension and tabular in habit. Distinction between the series is only possible through chemical analysis. MOORE (1970a) has offered a detailed crystallochemical study of members of the basic ferric phosphates including rockbridgeite-frondelite, lipscombite, barbosalite, dufrenite, beraunite and laubmannite and concluded that careful study is required to distinguish these phases. In pegmatite assemblages at least, rockbridgeite-frondelite appears to be by far the most abundant of the members.

DUFRENITE

Most specimens labelled dufrenite are in fact rockbridgeite-frondelite. Although a common species in limonite gossans and goethite beds in novaculite which have been acted upon by phosphatic waters, the only certified example of dufrenite in pegmatite is a specimen collected by the author from Palermo #1. It occurs as minute flat tabular crystals, a distinct greyish-green in transmitted light, upon heterosite. Fibrous varieties are easily confounded with rockbridgeite-frondelite and only the skilled eye can distinguish them.

BERAUNITE

Beraunite has been noted from several pegmatites but appears to be another rare species, although it is abundant in gossans in a paragenesis similar to dufrenite. The oxidized variety ("eleonorite") is rich orange-red in color, more vivid than and easily distinguished from rockbridgeite-frondelite. Crystals are long prismatic. More frequently it occurs as radial tufts of fine needles associated with laueite and possessing a bluish-green (unoxidized) to deep orange color. Confusion with strunzite and other fibrous ferric phosphates is easy. Their distinction usually requires X-ray study.

SOUZALITE

Souzalite has been noted only from the Corrego Frio pegmatite, Brazil by PECORA and FAHEY (1949a). It is a hydrothermally reworked product of scorzalite as evidenced by similarities in composition. Structurally, the species is related to dufrenite, according to MOORE (1970a). It occurs as grouped aggregates of rich green bladed crystals and scorzalite-lazulite nodules should be carefully examined for the possible presence of this unusual species.

LAUBMANNITE

Although laubmannite has never been reported from a pegmatite, its occurrence with phosphatic reworked goethite beds in novaculite suggests that the species may appear along with rockbridgeite and dufrenite. Paragenetic study by MOORE (1970a) indicates that laubmannite is often replaced by dufrenite. As a result of its yellow-green fibrous habit, distinction from dufrenite is practically impossible without recourse to X-ray powder study.

AZOVSKITE

The only detailed study of azovskite (unpublished by the author) indicates that the species is related to the above group of minerals. It occurs in clayey concretions which show remnants of organic material from Greenbelt, Maryland, as deep red prismatic crystals with one perfect cleavage parallel to the prism axis. Although never reported from pegmatites, it might occur in association with a rockbridgeite assemblage, postdating that mineral and possibly replacing it.

KRYZHANOVSKITE

This unusual mineral was originally described from a pegmatite in the Soviet Union where the species crystallized upon hydrothermally attacked triplite. A recent investigation by MOORE (1971b) has revealed that kryzhanovskite is the oxidized analogue of the phosphoferrite group of minerals and is consequently the ferric member of the series $Fe_3^{2+}(H_2O)_3[PO_4]_2-Fe_3^{3+}(OH)_3[PO_4]_2$. The compound can be synthesized by merely heating phosphoferrite in air at 180°C. Kryzhanovskite has been noted from the Bull Moose pegmatite by PEACOR (pers. comm.) along thin fractures in triphylite. At the Dan Patch pegmatite near Keystone, S. D. phosphoferrites in triphylite cavities are sufficiently deep brown to suggest at least some oxidation.

Kryzhanovskite probably forms directly from the oxidation of phosphoferrite and is consequently pseudomorphous. It is brown in color with a bronzy cleavage surface. "*Landesite*" from the Berry quarry, Poland, Maine, is a member of the reddingite-phosphoferrite-kryzhanovskite triple series and is properly a ferrian reddingite.

PHOSPHOSIDERITE

Also called metastrengite, this mineral is a late stage species occurring in open cavities of altered triphylite. The crystals are yellow, greenish yellow to delicate pink and are thick prismatic with striations parallel to the prism. Its most typical association is with leucophosphite, laueite, and hureaulite, easily confused with the last mentioned mineral. Rockbridgeites which have themselves been hydrothermally attacked often show druses of this mineral lining fractures and cavities.

Exquisitely beautiful magenta red crystals of phosphosiderite up to an inch in length in cavities in barbosalite from the Bull Moose pegmatite were once abundant. Like most of the species to be discussed, it occurs in minor amounts wherever triphylite shows alteration and the presence of vuggy cavities.

STRENGITE

The orthorhombic dimorph of phosphosiderite, this species rarely occurs as fine crystals in pegmatites with the exception of the old occurrence at Hagendorf, Bavaria. More characteristically, it occurs as the last mineral to form in open cavities in rockbridgeite, as botryoidal aggregates of a distinctive rich purple color. Specimens from the Fletcher pegmatite, N. H. showed the spectacular association of black rockbridgeite, orange hureaulite, yellow stewartite, red-brown bermanite, all lined with the violet strengite druses.

LEUCOPHOSPHITE

Once a mineralogical curiosity found as chalky masses resulting from bat dung leachings acting upon ferric ox-

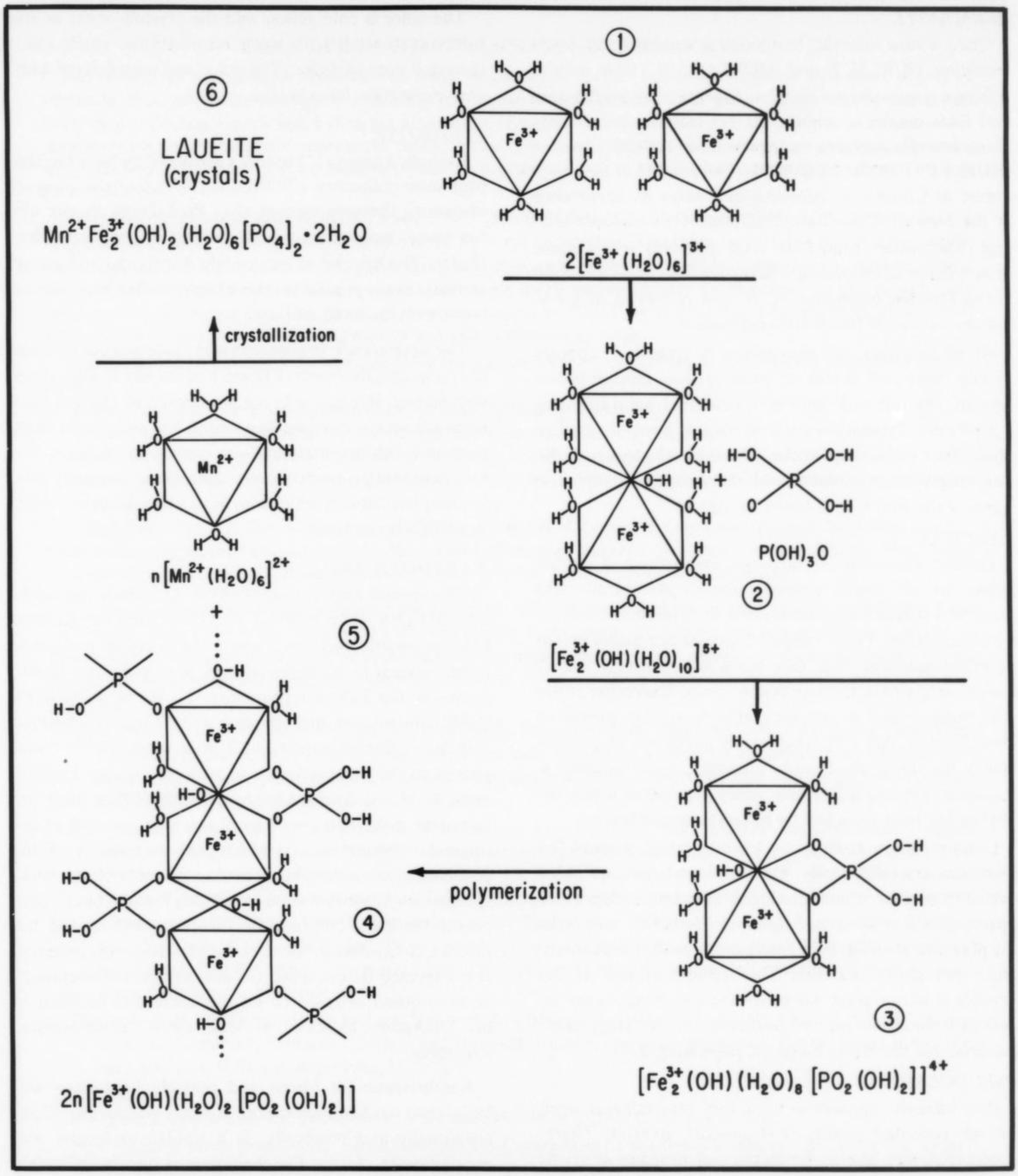


***Fig. 2.* A hypothetical sequence of condensation reactions in a fluid which, through several additive steps, yields a crystal. This sequence would roughly correspond to a series of reactions with *increasing* temperature, and is utilized to show how a coordination complex, like laueite, may form.**

ides, leucophosphite has recently been reported from numerous pegmatites. This flamboyant mineral is greyish-green in daylight but purplish-grey in incandescent light. Invariably well-crystallized, the leucophosphite morphology is a good means of identification. It finds consort with hureaulite and rockbridgeite, often replacing the latter mineral. LINDBERG (1957b) first recorded its pegmatite occurrence at the Sapucaia pegmatite, Brazil, but numerous pegmatites in the Black Hills have surrendered fine specimens of this mineral. The Tip Top and White Elephant pegmatites have afforded many specimens culled from the dumps by cracking rockbridgeite nodules. The leucophosphite usually occurs where hureaulite occurs in abundance.

BERMANITE

Once a rare mineral, bermanite is appearing at many localities. HURLBUT and ARISTARAIN (1968) record it from a pegmatite in Cordoba, Argentina where the mineral lines cracks in triplite. Its original occurrence was along fracture surfaces on triplite from Hillside, Arizona (HURLBUT, 1936). LEAVENS (1967) found it in a pegmatite at Coosa Co., Alabama and notes its occurrence at the Stewart mine, Pala, California. The dubious mineral "*salmonsite*" from Pala, most probably is a mixture of bermanite and hureaulite. Bermanite was once abundant at the Fletcher pegmatite, N. H. and occurs in minor amounts at several Black Hills pegmatites.

At all localities, the appearance is typical. It appears as thin films and druses of small tabular reddish-brown crystals, the rich red color in transmitted light affording a good clue. Typical associations include hureaulite, phosphosiderite and rockbridgeite. The mineral appears at the final stages where oxidation was extensive enough to raise some of the Mn^{2+} in solution to Mn^{3+}.

LAUEITE

Laueite, pseudolaueite, strunzite, stewartite and xanthoxenite are all closely related minerals structurally and occur in a similar paragenesis often in intimate association with each other. These beautiful species are highly prized by micromounters. The first three are relatively "new," named only within the last twenty years. Excepting strunzite, their crystal morphology affords a good means of identification. All, with the possible exception of pseudolaueite (so far, a one locality mineral), occur in small amount as very late minerals at many pegmatites where triphylite has been attacked by hydrothermal solutions.

Laueite occurs as small (<1 mm) orange striated flat prismatic crystals usually well-developed and sprinkled over the surface of rockbridgeite and ferri-sicklerite in open cavities. The orange color is distinctive and lacks the pink and greenish hues found in hureaulite, leucophosphite and phosphosiderite. The triclinic outline of the crystals is also a good aid to distinction. Noteworthy localities include Palermo #1 pegmatite, N. H.; Hagendorf, Bavaria; and the White Elephant pegmatite, S. D.

PSEUDOLAUEITE

Pseudolaueite appears to be a very rare mineral since its only recorded locality is Hagendorf, Bavaria. There, it occurred with laueite, stewartite and strunzite as crusts coating strengite in porous altered triphylite and Fe,Mn oxides. The crystals are thick tabular, rarely striated and of a pale orange color, distinct from the deeper shade of laueite. Confusion with xanthoxenite (which see) is possible.

STEWARTITE

Originally described by SCHALLER (1912) from the Stewart mine, Pala, California, the species has subsequently been noted from many localities, invariably in small amount. It was quite abundant at the Fletcher pegmatite in vugs in rockbridgeite.

The color is pale yellow and the crystals occur as thin prismatic crystals with steep terminations, much like a flattened spire or spike. The color and morphology admit easy distinction from laueite.

STRUNZITE

Casually known as "Frondel's whiskers" by New England pegmatite collectors, FRONDEL (1957) had the pleasure of naming the new species after Prof. Hugo Strunz who has always maintained a keen interest in pegmatite phosphates. The mineral is very widely distributed and occurs at nearly every pegmatite where triphylite has been altered, but usually in small amount.

The appearance is characteristic: pale yellow to white fibers, sprays, thin mats of fibers and usually in association with laueite. But strunzite is a problematical mineral since some specimens show a pale greenish hue and can be easily confused with beraunite and cacoxenite. In addition, several unidentified, perhaps new, phases occasionally arise in phosphate studies which also have a pale yellow to white straw-like appearance.

XANTHOXENITE

This species requires redefinition. Originally named by LAUBMANN and STEINMETZ (1920) from the Hühnerkobel pegmatite, Bavaria, it was noted as yellow platy crystalline masses in fractures of porous siderite and Fe-Mn oxides at the Palermo pegmatite, N. H. by FRONDEL (1949). The present interpretation is that Frondel's material is in fact a distinct species while true xanthoxenite corresponds to the composition and structure of the Fletcher mine, N. H. material studies by MROSE (1955). Most unfortunate is the apparent loss of the type material of the original investigators. To add to the complexity of the problem, so often the case in taxonomic mineralogy, many specimens of "xanthoxenite" are being found from pegmatites in the Black Hills and Brazil which yield related, but distinct, X-ray data to those of the Fletcher mine material. It is expected that at least two new names will eventually be established as research on this entangled problem in my laboratory indicates at least three "xanthoxenite" structures.

Xanthoxenite (of Mrose and possibly Laubmann and Steinmetz) has been uncovered at many pegmatites. Compositionally and physically, it is similar to laueite and pseudolaueite. At the Fletcher mine it occurs intimately interspersed with deep green rockbridgeite as orange-yellow bladed masses (= "golden rockbridgeite" of New England collectors). At the Taquaral pegmatite in Brazil, it appears as tan flattened laths implanted upon rose quartz crystals. This material is invariably twinned. Crystals of a related but probably distinct species from the White Elephant and Tip Top pegmatites in South Dakota occur as striated tabular to prismatic crystals often repeatedly twinned to form "cockscomb" aggregates. The color ranges from wine yellow to yellowish-green, pale green to deep orange and brown. Association with leucophosphite is

TABLE 2. PEGMATITE PHOSPHATES: LIST OF LOCATIONS

I have tried to assemble all the locations where a particular species has been recorded with some degree of certitude. It is, naturally, incomplete and is limited by the scanty information in the literature and by limitations in my own collecting experience. Extension of the list is urgently needed and care must be taken to ascertain *which* member of a series the phase represents. Sadly, many reports of triphylite in the literature may actually mean lithiophilite or *vice versa*, or even another phase! As incomplete as it is, the list is meant as a springboard for further additions.

Valuable references include ROBERTS and RAPP (1965); MORRILL (1958a) and (1958b). The former work is very reliable as most of the species were identified by X-ray techniques. The latter two works record many important localities but the species listed, particularly the primary phosphates, must be treated with caution. These works contain, in addition, valuable maps or quadrangle locations, and I have listed below, for this reason, only the names of the pegmatites. The classic professional papers by PAGE, *et al.* (1953) and CAMERON, *et al.* (1954) are invaluable; they describe the pegmatites and offer outstanding maps.

Pegmatites which have proven especially rich for a great diversity of primary and secondary phosphate species include:

North Carolina: Foote spodumene mine (present collecting, good)
Connecticut: Branchville and Strickland quarries (present collecting difficult)
New Hampshire: Palermo #1, Fletcher, G. E. Smith, and Buzzo pegmatites (present collecting fair)
Maine: Neville tourmaline, Newry, Berry quarry (Poland), Tamminen mine, Lord Hill (present collecting poor to fair)
Black Hills: Tip Top, White Elephant, Bull Moose, Big Chief, Linwood, Gap Lode (present collecting good)

Outstanding pegmatites abroad include Mangualde, Portugal; Buranga, Rwanda (central Africa); Hagendorf-Süd, Bavaria; and Sapucaia, Brazil, but I don't know of their present status or accessibility.

The more recently mined the pegmatite the better since the phosphate minerals tend to disintegrate with time. At present, there is little hope that new finds will appear since pegmatite mining and prospecting is at an ebb: it is a matter of economics. It must be remembered that most operators lost money on their pegmatites, except during war years when beryl and mica were in demand.

triphylite

Black Hills, South Dakota: Bob Ingersoll, Don Patch, Etta, Big Chief, Highland lode (John Ross), High View, Helen Beryl, Hugo, Wright lode, Dyke lode, Gap lode, Old Mike, Pleasant Valley, Rainbow #4, Red Spar, Rock Ridge, Soda Spar, Tin Mtn., Tip Top, Warren Draw, White Elephant, Bull Moose, Linwood, Sutherland Spring, Townsite lode.

New England area: Palermo #1, Palermo #2, Fletcher, Alstead, E. E. Smith mine, Fitzgibbon mine, Sargeant mine, Deering, DeMott mine, Ruggles mine, Eastman mica prospect, Nancy #1 and 2, Union mine, G. E. Smith mine (Newport), Keyes prospect, Playter beryl and mica mine, Parker Mtn. mine (Buzzo quarry), Nimms mica mine, Chickering mine (all in New Hampshire); Mt. Apatite, Paul Bennett quarry, Mt. Binford, Tamminen mine, Newry (Neville tourmaline mine), Newry mine, Whitehall working, Scotty mine, BB mine, Mt. Mica mine, Ryerson Hill, Nate Perry petalite prospect, Lobokis mica mine, Black Mtn. mine, Goddard's ledge mine, Red Hill mine, Cole mine, Lord Hill, Topsham (Fisher Extension) (all in Maine); Cobalt, Connecticut; Huntington, Massachusetts.

Pointe de Bois, Manitoba: Hagendorf and Hühnerkobel, Bavaria; Sukula and Tammela, Finland; Norrö, Skrumpetorp and Varuträsk, Sweden; LaVilate and Huréaux, France; Sapucaia pegmatite, Brazil; Dolni Bory, Western Moravia; Kalbinsk pegmatite, U. S. S. R.

lithiophilite

Black Hills, South Dakota: Custer Mtn., Earl lode, Hot Shot, Elkhorn, Townsite lode.

New England area: Branchville, Strickland quarry, Connecticut; Paul Bennett quarry, Mt. Rubellite mine(?), Neville tourmaline mine, Newry mine, Tamminen mine, Berry quarry, Black Mtn. mine, Lord Hill (all in Maine).

Pala, California: Foote spodumene mine, North Carolina; Mangualde, Portugal; Varuträsk, Sweden, Wodgina, Western Australia; Karibib, South West Africa; Namaqualand, South Africa.

sarcopside

East Alstead, G. E. Smith mine (Newport), DeMott mine and Deering, New Hampshire; Bull Moose mine, Victory mine, and Lofton prospect, South Dakota; Michelsdorf, Silesia; Dolni Bory, Western Moravia.

graftonite

Black Hills, South Dakota: Highland lode (John Ross), Lofton prospect, Victory mine, Bull Moose, Elk Ridge, Nickel Plate mine.

New England area: East Alstead, Rice mine, DeMott mine, Palermo #1 and #2, Melvin Mtn., G. E. Smith mine, Playter Beryl and mica mine, Eight Ball mine, Keyes mica mine, Union #2 mine, Nancy #1 and 2, Ruggles mine, Deering, Sargeant mine (all in New Hampshire); Greenwood (Waisenen quarry), Maine; Brisago, Switzerland; São Luiz do Paraitinga, Brazil; Olgiasca, Italy; Kondakovo dist., Siberia; Ranquel and C. Canchuleta, Argentina; Sidi Bou Othmane, Morocco.

beusite

Amanda, San Salvador and Los Aleros, Argentina.

amblygonite-montebrasite

Very few analyses have been published to definitely establish the correct side of the series. In addition, amblygonite-montebrasite have been reported from so many localities that a list of occurrences would be pointless.

triplite-zwieselite

See HEINRICH (1951) who lists 80 localities. In addition, triplite has been recorded from the Elk Ridge pegmatite, near Custer, South Dakota.

wyllieite

Victory pegmatite and Nickel Plate pegmatite, South Dakota.

arrojadite

G. E. Smith mine, Rice mine, Nancy #2, Palermo #1, Palermo #2, New Hampshire; Nickel Plate, Victory pegmatite, South Dakota; Serra Branca, Brazil; Mangualde, Portugal.

dickinsonite

Branchville and Strickland quarry, Connecticut; Neville tourmaline mine, Berry quarry (Poland), Maine.

alluaudites

Black Hills, South Dakota: Custer Mtn., Earl lode, Elkhorn, Etta, Green, Dyke lode, Highland lode, High View, Helen Beryl, Hot Shot, Wright lode, Lofton prospect, Old Mike, Pleasant Valley, Rainbow #4, Red Spar, Rock Ridge, Tip Top, Warren Draw, Linwood, Sutherland Spring, Townsite.

Palermo #1 and G. E. Smith mine, New Hampshire; Hagendorf, Bavaria; Skrumpetorp and Norrö, Sweden; Sukula, Finland; Chanteloube, France; Buranga, Rwanda, central Africa; Sidi Bou Othmane, Morocco; Dolni Bory, Western Moravia.

natrophilite

Branchville, Connecticut.

lazulite-scorzalite

Palermo #1 and G. E. Smith mine, New Hampshire; Scotty mine, Maine; Victory mine and White Cap mine, South Dakota; Corrego Frio pegmatite, Brazil; Buranga pegmatite, Rwanda. All of these are probably the scorzalite side of the series.

triploidite

Branchville, Connecticut; Highland lode, South Dakota; Wien, Czechoslovakia.

wolfeite

Palermo #1, New Hampshire; Big Chief mine and Bull Moose mine, South Dakota; Skrumpetorp, Sweden; Cyrillhof, Czechoslovakia; Hagendorf, Bavaria.

heterosite

See localities for triphylite.

purpurite

See localities for lithiophilite.

griphite

Sitting Bull pegmatite and Everly pegmatite, South Dakota; Mt. Ida, Northern Territory, Australia.

barbosalite

Palermo #1 pegmatite, New Hampshire; Bull Moose pegmatite, South Dakota; Sapucaia pegmatite, Brazil.

rockbridgeite-frondelite

See triphylite-lithiophilite. Nearly every pegmatite known to show these primary phases contain some rockbridgeite-frondelite in small amount. Most "dufrenite" from pegmatite belongs to this series.

dufrenite

Palermo #1 pegmatite, New Hampshire. Easily confused with rockbridgeite.

beraunite

Palermo #1 pegmatite and Fletcher pegmatite, New Hampshire; Hesnard mine, Big Chief mine, Tip Top pegmatite, White Elephant pegmatite (all in Black Hills), South Dakota; Hühnerkobel, Wildenau, and Kreuzberg, Bavaria.

souzalite
Corrego Frio pegmatite, Brazil.

kryzhanovskite
Kalbinsk pegmatite, U. S. S. R.; Bull Moose and Dan Patch (?) pegmatites, South Dakota.

phosphosiderite
Palermo #1, Fletcher, and Fitzgibbon pegmatites, New Hampshire; Bull Moose, Highland lode, Hesnard mine, Etta mine, White Elephant mine, South Dakota; Pala, California; Coosa Co., Alabama; Kreuzberg and Hagendorf, Bavaria; Chanteloube, France; El Criollo pegmatite, Argentina; Sapucaia pegmatite, Brazil. Probably widespread.

strengite
Palermo #1 and Fletcher pegmatites, New Hampshire; Bull Moose pegmatite, South Dakota; Pala, California; Mangualde, Portugal; Pleystein and Hagendorf, Bavaria; Sapucaia pegmatite, Brazil.

leucophosphite
Palermo #1 pegmatite, New Hampshire; Tip Top pegmatite, Gap lode, White Elephant, Linwood, Bull Moose pegmatites, South Dakota; Sapucaia pegmatite, Brazil.

bermanite
Palermo #1 and Fletcher pegmatites, New Hampshire; Coosa Co., Alabama; Pala, California; Hillside, Arizona; Hesnard mine, Tip Top, White Elephant and Bull Moose pegmatites, South Dakota; Mangualde, Portugal; Sapucaia pegmatite, Brazil; El Criollo pegmatite, Argentina.

laueite
Palermo #1, Fitzgibbon and Fletcher pegmatites, New Hampshire; Cobalt, Connecticut; Paul Bennett quarry, Neville tourmaline mine, Maine; High Climb, Etta, Big Chief, Hesnard, Linwood and White Elephant pegmatites, South Dakota; Hagendorf, Bavaria. Probably widespread.

pseudolaueite
Hagendorf, Bavaria.

stewartite
Palermo #1 and Fletcher pegmatites, New Hampshire; Pala, California; Hesnard mine, Linwood, Tip Top and White Elephant pegmatites; South Dakota; Newry, Maine; Chanteloube, France. Probably widespread.

strunzite
Palermo #1, Fletcher, G. E. Smith mine, Buzzo quarry, Fitzgibbon pegmatite, New Hampshire; Neville tourmaline mine, Unity, Red Hill, BB mine, Maine; Cobalt, Connecticut; Big Chief, Hesnard and Etta pegmatites, South Dakota; Hagendorf, Bavaria. This species is probably widespread but inconspicuous, and confusion with other pale-colored fibrous minerals is easy.

xanthoxenite (of Mrose, 1955)
Fletcher pegmatite, New Hampshire; Tip Top, Linwood and White Elephant pegmatites, South Dakota; Hühnerkobel, Bavaria. This species usually occurs with leucophosphite and may be more widespread than previously suspected.

cacoxenite
Palermo #1 pegmatite, New Hampshire; White Elephant pegmatite, South Dakota. Most cacoxenite from pegmatites is strunzite.

mitridatite
Nearly all pegmatites where triphylite occurs; as dull olive-green stains and concretionary aggregates. Abundant at Palermo #1, New Hampshire; White Elephant, Linwood and Tip Top pegmatites, South Dakota.

cyrilovite
Sapucaia pegmatite, Brazil.

tavorite
Palermo #1 and Fletcher pegmatites, New Hampshire; Custer Mtn., Hot Shot, Elkhorn, Tip Top, Bull Moose, Hesnard, Linwood and White Elephant pegmatites, South Dakota; Hagendorf, Bavaria; Sapucaia pegmatite, Brazil.

faheyite
Sapucaia pegmatite, Brazil.

hureaulite
New England area: Branchville and Strickland quarry, Connecticut; Palermo #1, Fletcher pegmatites, New Hampshire.

Black Hills: Gap lode, Custer Mtn., Elkhorn, Highland lode (John Ross), Hot Shot, Rock Ridge, Hesnard, Tip Top, Big Chief, White Elephant, Bull Moose, Linwood and Ferguson lode pegmatites.

Pala, California: Mangualde, Portugal; LaVilate and Chanteloube, France; Hagendorf, Pleystein and Hühnerkobel, Bavaria; Varuträsk, Sweden; Viitaniemi, Finland; Sapucaia pegmatite, Brazil.

phosphoferrite

Dan Patch pegmatite, Bull Moose mine, South Dakota; Palermo #1 pegmatite, New Hampshire; Hagendorf, Bavaria.

reddingite

Branchville, Connecticut; Maine Feldspar quarry, Paul Bennett quarry, Neville tourmaline mine, Poland (incl. var. "landesite"), Black Mtn. mine, Maine.

ludlamite

Palermo #1 mine, New Hampshire; Bull Moose mine, Big Chief, Hesnard, Ferguson lode, Etta mine, Dan Patch, Tip Top pegmatites, South Dakota; Hagendorf, Bavaria.

switzerite

Foote spodumene mine, North Carolina.

vivianite

As blue stains at all localities which provide triphylite. Exceptional localities include Palermo #1, New Hampshire; Tip Top, Bull Moose, Big Chief pegmatites, South Dakota.

phosphophyllite

Palermo #1 mine, New Hampshire; Hagendorf, Bavaria.

hurlbutite

G. E. Smith mine, New Hampshire; Viitaniemi, Finland; Otov, Czechoslovakia.

beryllonite

Mills feldspar quarries, Neville tourmaline mine, McAllister farm, Maine; Viitaniemi, Finland.

herderite-hydroxyl-herderite

Paul Bennett quarry, Emmons mine, Beryllium Corporation mine, Harvard quarry, Tamminen mine, Tiger Bill mine, Mt. Rubellite mine, Neville tourmaline mine, Newry mine, Mt. Mica mine, Poland (Berry quarry), Lord Hill, Fisher quarry (Topsham), all in Maine; Charles Davis mine, Palermo #1, Fletcher mine, all in New Hampshire; Ehrenfriedersdorf, Saxony; Epprechtstein, Bavaria; Mursinsk, Ural Mountains; Viitaniemi, Finland.

väyrynenite

Viitaniemi, Finland.

brazilianite

Palermo #1, Fletcher mine, Charles Davis mine, G. E. Smith mine, New Hampshire; Harvard quarry and Neville tourmaline mine, Newry, Maine; Conselheira Peña, Minas Geraes, Brazil; Buranga pegmatite, Rwanda.

lacroixite

Strickland quarry, Connecticut; Greifenstein, Saxony; Montebras, France.

augelite

Palermo #1 pegmatite, G. E. Smith mine, New Hampshire; Hugo pegmatite, South Dakota; Mbale, Uganda; Buranga pegmatite, Rwanda.

wardite

Beryl Mtn. pegmatite, New Hampshire; Neville tourmaline mine, Maine; Hugo pegmatite, South Dakota.

morinite

Hugo pegmatite, South Dakota; Viitaniemi, Finland; Montebras, France; Broken Hill, N. S. W., Australia.

goyazite

Palermo #1 mine, New Hampshire; Paul Bennett quarry, Harvard quarry, Mt. Rubellite mine, Mt. Mica mine (?), Black Mtn. mine, Lord Hill, Maine.

whitlockite

Palermo #1 mine, New Hampshire; Tip Top pegmatite, South Dakota.

palermoite

Palermo #1 mine, New Hampshire.

bertossaite

Buranga pegmatite, Rwanda, central Africa.

bøggildite

Ivigtut, Greenland.

lithiophosphate

Foote mine, North Carolina; Kola Peninsula, U. S. S. R.; Bernic Lake, Manitoba.

fairfieldite

Branchville, Connecticut; Paul Bennett quarry, Tamminen mine, Neville tourmaline mine, Berry quarry (Poland), Black Mtn. mine, Maine; Foote spodumene mine, North Carolina; Hühnerkobel, Bavaria.

messelite

Cobalt, Connecticut; Palermo #1 mine, New Hampshire; Tip Top, White Elephant and Linwood, Bull Moose pegmatites, South Dakota; Foote spodumene mine, North Carolina. Chemical analysis may show that some messelites are fairfieldite and *vice versa.*

eosphorite-childrenite

Branchville, Connecticut; Palermo #1, G. E. Smith mine, New Hampshire; Paul Bennett quarry, Tamminen mine, Neville tourmaline mine, Mt. Mica mine, Ryerson Hill, Berry quarry, Black Mtn. mine, Cole mine, Maine; Foote spodumene mine, North Carolina; Hugo mine, Helen Beryl mine(?), South Dakota; Greifenstein, Saxony; Hagendorf, Bavaria; Mangualde, Portugal; Sapucaia pegmatite, Brazil. Although Fe/Mn +Fe ratio in this series and in the fairfieldite-messelite series usually follows the ratio in the parent triphylite-lithiophilite, chemical analysis is usually necessary to establish the end of the series.

bjarebyite

Palermo #1 mine, New Hampshire.

crandallite

Palermo #1 mine, Fletcher mine, New Hampshire; Everly mine, Hugo mine, Tip Top mine, South Dakota; Buranga pegmatite, Rwanda. Crandallite probably occurs in small amount as a late stage mineral at many other pegmatites.

montgomeryite

Etta mine, South Dakota.

moraesite

Palermo #1 pegmatite, New Hampshire; Sapucaia pegmatite, Brazil.

scholzite

Hagendorf, Bavaria; Otov, Czechoslovakia.

roscherite

Paul Bennett quarry, Neville tourmaline mine, Maine; Sapucaia pegmatite, Brazil; Greifenstein, Saxony.

typical. A good eye on its crystal morphology allows distinction from laueite and pseudolaueite.

The "xanthoxenite" of Frondel occurs as a late stage mineral at the Palermo #1 pegmatite, N. H. coating other species in siderite open cavities. Its color is straw yellow and the material is composed of soft laths and tablets of morphology akin to gypsum.

CACOXENITE

A common mineral is gossans and novaculite deposits, this golden yellow fibrous mineral has been attributed to many pegmatites where, in fact, the actual material is strunzite. The deeper yellow color of cacoxenite may assist in distinguishing it from pale-colored strunzite. But I have yet to confirm its occurrence in a pegmatite since specimens labelled cacoxenite have afforded powder patterns of strunzite. It should occur, though, but certain identification will probably require an X-ray study.

MITRIDATITE

Undoubtedly one of the most ubiquitous of late stage phosphates in pegmatites, mitridatite is also one of the big problems. To date, its chemistry is uncertain and a good species definition is wanting, doubtless a result of its reluctance to appear in any approach to single crystal material.

Mitridatite fills cavities in highly porous altered triphylite, and occurs as stains, coatings and nodular aggregates. The color is dull olive green to bile green which is very distinctive. Occasionally, however, very fine-grained rockbridgeite may be mistaken for this mineral. A firm specific status for mitridatite must await the discovery of single crystal material and a structure analysis. Presently, I am studying a remarkable specimen which shows iron black stubby hexagonal crystals with a perfect basal cleavage and a red-brown color in transmitted light. Its powder pattern is so similar to mitridatite to suggest that the desired and much sought after crystals have been found!

At the Tip Top pegmatite in South Dakota, large lumps of compact massive dull green mitridatite occur filling cavities in rockbridgeite and heterosite. But it invariably occurs wherever triphylite appears, as a thin dull green stain on the enclosing silicates.

CYRILOVITE

Also called "avelinoite," the species is the ferric analogue of wardite. Crystals are small, thick tabular with a tetragonal outline. The color is orange to brownish yellow. It occurs in small amount with leucophosphite and phosphosiderite in cavities of frondelite from the Sapucaia pegmatite, Brazil. Similar material from the Palermo #1 pegmatite may be this mineral.

TAVORITE

Another recent species, tavorite is the ferric analogue of montebrasite. Originally described by LINDBERG and

PECORA (1955) from the Sapucaia pegmatite in Brazil, the mineral occurs as a hydrothermally reworked product of triphylite along with frondelite, barbosalite, ferrisicklerite, etc.

Recently, tavorite has been found at several other pegmatites, particularly in the Black Hills, but always in small amount. It occurs abundantly with barbosalite from the Bull Moose mine, and along cleavage planes in triphylite and heterosite from the Tip Top, Linwood, Hesnard and White Elephant pegmatites. Small amounts also occur as thin films and small patches in the lithiophilite from the Custer Mountain, Hot Shot and Elkhorn pegmatites.

The mineral is a lively greenish-yellow color and very easy to sight identify. Large specimens are very rare, the mineral usually occurring as small aggregates interspersed with rockbridgeite and ferrisicklerite along the zone of alteration in triphylite-lithiophilite.

FAHEYITE

Faheyite is another species recently described by LINDBERG and MURATA (1953) from the Sapucaia pegmatite in Brazil. Its curious crystal chemistry would suggest that occurrences of the mineral would be very limited.

The species only occurs as fibrous aggregates ranging up to 0.1 mm in length and possessing a white, bluish-white or brownish-white color. These fibers coat other minerals in cavities of frondelite and occur with other late stage species such as vivianite, roscherite, hureaulite, and manganian variscite.

Subdivision II: ligand addition products, no oxidation of metals

a. Derivatives of primary transition metal phosphates

In many instances, paragenetic sequences are observed in which the secondary phosphate hydrates involve cations whose charges are the same as the parent material. Such sequences must have occurred under relatively reducing conditions where the oxygen fugacity was quite low, since Fe^{2+} is very susceptible to rapid oxidation in solution in the presence of even minor amounts of oxygen. Attending these secondary phases are often minor amounts of sulfides and arsenides, compounds which typically form under relatively reducing conditions.

It is necessary to add that Fe^{2+} oxidizes to Fe^{3+} far more easily than Mn^{2+} to Mn^{3+}. In addition Fe^{2+} is relatively unstable when bound to $(OH)^-$ groups (there are but few "basic" ferrous phosphates) while Mn^{2+} is stable (the basic manganous arsenates and phosphates). Such differences in the oxidation potentials between $Fe^{2+} \rightarrow Fe^{3+}$ and $Mn^{2+} \rightarrow Mn^{3+}$ have a profound influence in the paragenesis. Starting with Mn^{2+} poor parent triphylite, solution of the crystal by hydrothermal attack and oxidative conditions leads to the formation of highly insoluble Fe^{3+} – $((OH)^-, [PO_4]^{3-}, (H_2O)^\circ)$ complexes which precipitate out. Accordingly, these solutions become enriched in Mn^{2+} until at the final stages, the last compounds to crystallize are the manganous phosphate hydrates. Our first entry in this category, hureaulite, is a good example.

HUREAULITE

Few minerals have enjoyed more confusion in the literature than hureaulite. Names like "*baldaufite,*" "*wenzelite,*" "*palaite,*" "*pseudopalaite*" and "*bastinite*" all proved to be hureaulite upon further investigation by various workers. It is one of the most ubiquitous and one most difficult to unambiguously sight identify of the secondary phosphate hydrates.

Hureaulite appears at the latest stages of secondary phosphate crystallization, occurring upon the earlier crystallized ferric compounds such as rockbridgeite and leucophosphite. Where lithiophilite has been attacked, hureaulite usually forms directly since there are no ferric intermediaries. The color of the mineral is usually transparent palest pink through greenish-pink, to pale red, orange-red and reddish-brown. Morphologically, it is easily confused with leucophosphite. A good test is for the *absence* of Fe^{3+} in hureaulite. In addition, hureaulite is morphologically distinct from the ferrous and other manganous phosphates. The mineral also occurs as cinnamon-colored and flesh-pink granular masses invariably showing occasional faceted outlines. It was one of the characteristic secondary phases at the famous Branchville pegmatite. Connecticut, and was formerly abundant at the Fletcher and Palermo #1 pegmatites, New Hampshire (with rockbridgeite). Large dull pink to orange granular masses and fine crystals up to an inch across occur at the Bull Moose, Tip Top and White Elephant pegmatites in South Dakota, occurring after rockbridgeite, leucophosphite and barbosalite.

PHOSPHOFERRITE-REDDINGITE

This species belongs to an homologous series $(Fe,Mn)_3^{2+}(H_2O)_n[PO_4]_2$, where n =O(sarcopside), 3(phosphoferrite), 4 (ludlamite), and 8 (vivianite). As n increases, the phase occurs later in the sequence. Thus, the last phosphate of the series to appear is vivianite, which forms at the lowest temperature.

The series occurs directly upon solution cavities in fresh triphylite-lithiophilite and is usually accompanied by ludlamite, the homologue later in the sequence. The color is pale pink (reddingite) to pale green and brownish-green (phosphoferrite). The orthorhombic "pseudooctahedral" appearance of the crystals distinguishes it from the other homologues and from hureaulite. Confusion with leucophosphite is easy, but the latter mineral occurs in an *oxidized* environment. The Fe:Mn ratios usually reflect the ratios in the parent triphylite-lithiophilite crystals.

Phosphoferrite-reddingite is relatively uncommon and probably has a small field of stability. The far more abundant ludlamite should be routinely examined for small crystals of this earlier appearing species. Phosphoferrite which is bronzy to brown in color possesses partial oxidation of Fe^{2+} to Fe^{3+} and grades into kryzhanovskite.

LUDLAMITE

Although structurally related to phosphoferrite, ludlamite does not seem to allow much solid solution of Mn^{2+} and is a rather pure compound. Its color is pale green to apple green and the mineral possesses one perfect cleavage direction.

Ludlamite is a rather common mineral and often directly replaces parent triphylite such that a continual gradation from triphylite into ludlamite can be seen. It is often associated with siderite, $(Fe,Mn)^{2+}(CO_3)$, which appears wherever CO_2 was present in the hydrothermal fluids. Ludlamite was abundant at the Palermo #1 pegmatite, N. H. as large granular masses and crystals with broad cleavage surfaces. It also occurs with siderite replacing triphylite, sometimes in large cleavable masses, at the Dan Patch pegmatite near Keystone, S. D. Ludlamite appears only when triphylite has been attacked by fluids under reducing conditions. Toward the lithiophilite end of the series, reddingite and especially hureaulite are the typical products. Ludlamite is usually followed by pale blue to deep blue micaceous flakes of vivianite.

VIVIANITE

Vivianite is a persistent phase which crystallized at low temperature, below the boiling point of water under standard conditions. It occurs as nodular masses replacing organic material in marls, sands and soils and its bright blue color and perfect cleavage are good visual means of identification. The intensity of the blue color is a function of the amount of Fe^{3+} present: only 0.1% Fe^{3+} is needed to color the mineral a distinct blue. Completely unoxidized fresh vivianite is a very pale green, the color darkening to blue under exposure to air.

Vivianite occurs as stains at many pegmatites where it is a recent product of formation. The crystals occur in cavities of ludlamite and siderite and are usually the last to form. The combination of blue vivianite upon pale green ludlamite is prized by connoisseurs of micromounts. Vivianite also occurs as blue coatings along fractures in triphylite giant crystals and may form after triphylite is tossed on the dumps and is exposed to weathering.

PHOSPHOPHYLLITE

A rare species, phosphophyllite contains essential zinc and derives from the solution of early sphalerite which accompanied triphylite. Such a combination is rare but it demonstrates the importance of examining the primary phases in any pegmatite: the presence of sphalerite with triphylite at a pegmatite may lead to the occurrence of phosphophyllite in a paragenesis akin to ludlamite.

Phosphophyllite is similar to ludlamite in every respect of its appearance but it tends to exhibit a delicate bluish-green color. A test for zinc is the most reliable means of distinguishing the two. Its only authenticated pegmatite locality is Hagendorf, Bavaria.

SWITZERITE

A new species, switzerite occurs only at the Foote spodumene mine, near Kings Mountain, North Carolina in association with vivianite along fractures and seams. The mineral is soft and micaceous, pale pink when fresh but becoming golden brown and bronze-colored when exposed to weathering. At the locality, the mineral is abundant but local, although fresh samples are rare. The physical properties are practically unique among phosphate minerals.

b. Hydrothermal products derived from amblygonite-montebrasite, beryl, etc.

Numerous species occur in close association where transition metals are absent or occur only in minor amount. These compounds are pale-colored and occasionally occur as fine hand specimens. Although noteworthy localities are few, some of the species may occur in very small amount at many pegmatites where amblygonite and beryl occur. Because these species are inconspicuous, they are often overlooked.

Included here are hurlbutite, herderite, väyrynenite, brazilianite, beryllonite, morinite, lacroixite, montgomeryite, crandallite, apatite, augelite, whitlockite and several rare and poorly understood species. Not infrequently do several of these minerals occur together, usually implanted upon smoky quartz and albite and albitized perthite in druses and open cavities. A typical associate is cookeite, which usually postdates these minerals and overlays them. When massive, many of the species are difficult to distinguish from feldspar, beryl, quartz or amblygonite.

Paragenetically, it is difficult to define their origin. Some are hydrothermally reworked products of a parent phase, notably amblygonite and the assemblage shows all the evidence of such reactions: etching, solution cavities, compositional similarities. Others, like herderite which occurs as crystals on smoky quartz, probably crystallized directly from fluids enriched in Be^{2+} and $[PO_4]^{3-}$ not necessarily derived from some pre-existing parent phase. VOLBORTH (1954) established the sequence beryllonite → hurlbutite → herderite on the basis of microscopic examination of beryllonite alteration products from the Viitaniemi pegmatite in Finland. It appears that these minerals crystallized at moderate temperatures, with the low temperature species possessing much larger quantities of water in their atomic structure.

HURLBUTITE

MROSE (1952) first described this recent discovery from the G. E. Smith mine, near Newport, New Hampshire. Stout prismatic white to greenish white simple orthorhombic crystals up to an inch across were found embedded in smoky quartz and siderite. The lack of any good cleavage aided in its distinction from feldspar. Crystals tend to be etched and striated parallel to the prism axis.

VOLBORTH (1959) recorded hurlbutite as a not rare but relatively inconspicuous mineral from the Viitaniemi pegmatite, near Eräjärvi, central Finland. It occurs with montebrasite, beryllonite and lithiophilite as fine-grained symplectic aggregates which are colorless to brownish in appearance.

BERYLLONITE

Beryllonite still remains a very rare and very local species since its original description by DANA and WELLS

(1889). It occurred in a pegmatite vein 4 to 6 feet wide which was entirely decomposed to kaolinized feldspar and fragments of the more resistant minerals such as smoky quartz, columbite, cassiterite, beryl, apatite and triplite. Crystals range up to an inch in greatest dimension and are highly faceted with a perfect basal cleavage. Up to twenty distinct forms have been recorded for the colorless monoclinic, pseudo-orthorhombic crystals.

The species has also been recorded from the Mills feldspar quarries in Hebron and the Neville tourmaline mine in Newry, Maine, associated with smoky quartz, cassiterite and herderite. It appears that beryllonite, like herderite, occurs in a paragenesis which includes tin minerals as well as beryllium and phosphate bearing phases.

HERDERITE–HYDROXYL-HERDERITE

A species of long standing, herderite is the most abundant and widely distributed of the beryllium phosphate minerals although, like the other minerals, it is a relatively rare species. The herderite-hydroxyl-herderite series occurs in a paragenesis akin to brazilianite, beryllonite, hurlbutite and gem tourmaline, that is, a moderate temperature assemblage where open miarolitic cavities have been allowed to develop. Localities for the series are numerous but the species generally occur in rather small amount.

Localities include Ehrenfriedersdorf, Saxony; Epprechtstein, Bavaria; Viitaniemi, Finland; Stoneham, Newry, Poland and Buckfield in Maine; Palermo and Fletcher pegmatites in New Hampshire. The Maine and New Hampshire pegmatites appear to frequently carry at least some beryllium phosphate minerals yet in the hundreds of Black Hills pegmatites, not one beryllium phosphate mineral has been recorded. It is also noteworthy that herderite occurs frequently as druses in miarolitic cavities, associated with smoky quartz, cleavelandite, cookeite and gemmy tourmaline, associations which are consistently absent in the Black Hills.

The crystals are complex like beryllonite, and often show up to twelve distinct forms. Twinned crystals are the rule, but the pseudo-orthorhombic geometry of the cell, like beryllonite, often disguises twinning except for the occasional appearance of small reentrant angles. Herderite is colorless to pale greenish-white and, unlike beryllonite and brazilianite, displays no good cleavage directions. In addition, crystals tend to have a prismatic development with steep terminations unlike the thick nearly equant crystals of hurlbutite and beryllonite. Crystals may attain a length up to two inches and usually occur attached to smoky quartz and well-crystallized muscovite.

Like beryllonite, herderite always occurs where tin minerals are present, notably cassiterite, suggesting a "pneumatolytic" or vapor phase origin for the species. The mineral may be easily confused with topaz (a well-known vein and pocket mineral in a similar paragenesis and often occurring in "tin" veins) but differs in lacking the cleavage and luster of that mineral.

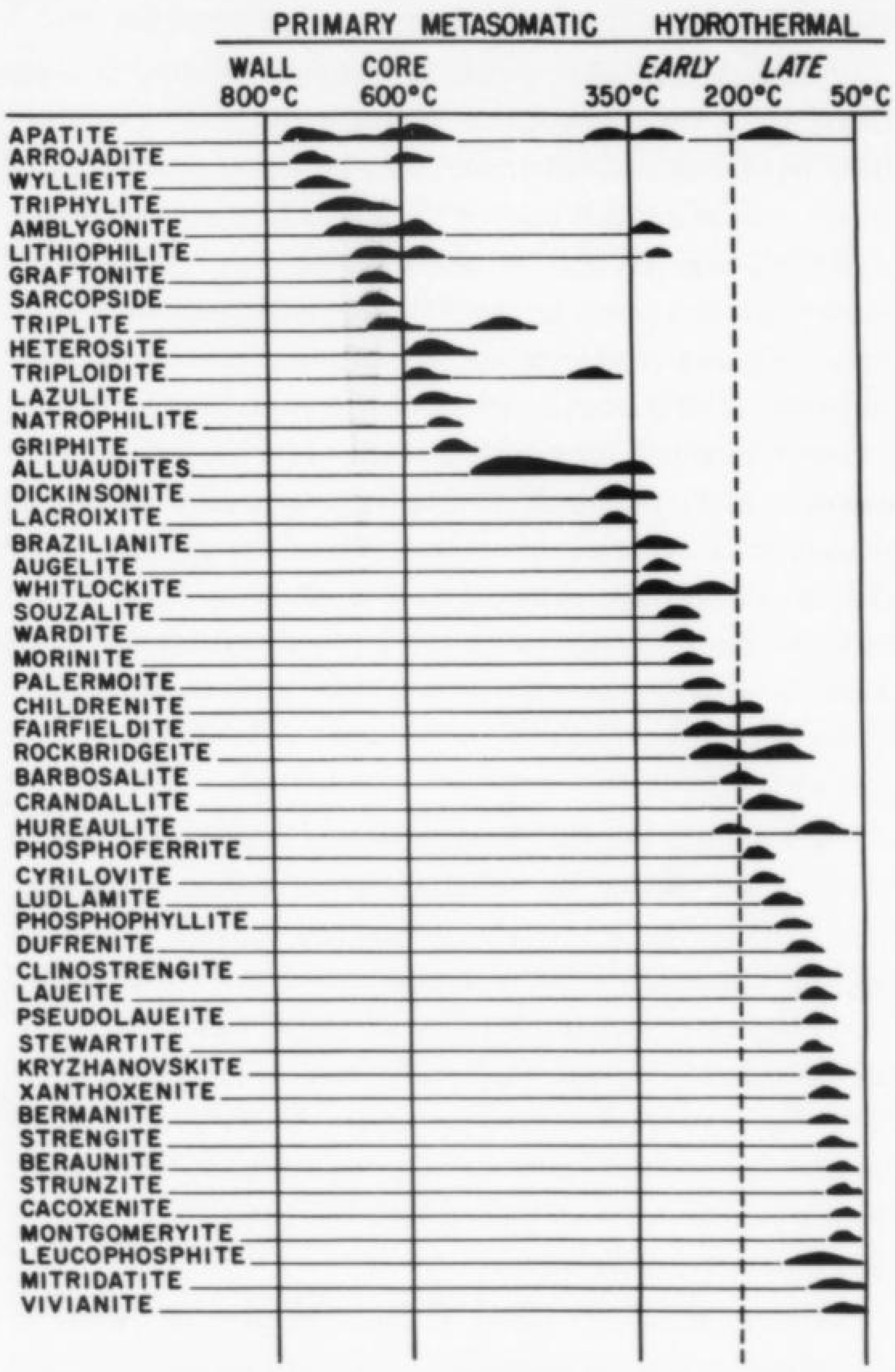


***Fig. 3.* A "classical" paragenetic scheme for pegmatite phosphates. The temperatures are only approximate. Shaded "lumps" show where in the sequence the species appears. The dashed line at 200°C indicates approximately where water molecules are stable as bonded units to the transition metal cations. Note the large number of compounds to the right side of this line.**

VÄYRYNENITE

Presently a one-locality mineral, väyrynenite is the Mn^{2+}-analogue of hydroxyl-herderite. VOLBORTH (1954) described this species from the Viitaniemi pegmatite in Finland where it is associated with herderite, hurlbutite and montebrasite. The color is rose to pale carmine red, with no developed cleavages. Its color and paragenesis together distinguish the species from the low temperature phosphates such as hureaulite, strengite, etc.

BRAZILIANITE

Only infrequently does a new mineral species appear in considerable abundance as fine crystals. Thus, POUGH and HENDERSON (1945) revealed their surprise when specimens of this new species appeared from several pegmatites in the State of Minas Geraes, Brazil. Crystals up six inches in length and drusy aggregates of etched prismatic crystals up to 100 pounds in weight have been recovered.

In color, the species is reminiscent of chrysoberyl, for which at first it was mistaken. The color is a pale chartreuse yellow to yellow-green and crystals reveal a perfect {010} cleavage. The crystals are usually highly faceted, lustrous and prismatic to equant in shape. Commonly, they group in near-parallel growth to present "pine cone" druses. It occurs in open solution cavities with well-developed muscovite crystals, cleavelandite, eosphorite and siderite. The low indices of refraction detract from the desirability of cut stones, but its color is appealing.

Brazilianite has also been found at the Palermo #1 and G. E. Smith pegmatites in New Hampshire as aggregates of spear-shaped crystals associated with montebrasite, siderite, quartz and potash feldspar in solution cavities.

LACROIXITE

Only recently has the chemistry of lacroixite been understood. According to MROSE (1971), the mineral is a dimorph of natromontebrasite (fremontite) and isotypic to sphene. Originally described by SLAVIK (1914) from Greifenstein, Saxony, the mineral occurred with jezekite, apatite, childrenite, roscherite, etc. as druses in pegmatite. Mrose adds several additional localities, including the Strickland quarry near Portland, Connecticut where it replaces amblygonite.

The color is pale yellow to greenish-yellow, and it lacks the perfect cleavage found for amblygonite. Lacroixite appears to be another metasomatic product of amblygonite and for this reason all amblygonite-montebrasite specimens showing alterations or suspicious zoning should be carefully inspected for this interesting species.

Here I mention the name JEŽEKITE, a species which has been contested as a variety of morinite or of lacroixite. Confusion arose in the literature on account of the close association of the three minerals and inadvertent investigation of the wrong material. Recent study in another laboratory indicates that ježekite may indeed have specific status and until this study is completed, further discussion on the mineral shall be held in abeyance.

AUGELITE

Augelite is a basic aluminum phosphate which derived from the thermal metamorphism of phosphate rocks in peraluminous sediments. It is often associated with lazulite, trolleite, kyanite, rutile, quartz and pyrophyllite. The mineral also occurs rarely in certain pegmatites, usually with morinite, apatite and wardite in solution cavities in amblygonite-montebrasite. The mineral is colorless to pale blue or pale pink with perfect prismatic cleavage.

Recorded localities include the Hugo pegmatite near Keystone, South Dakota (FISHER and RUNNER, 1958) and the Palermo #1 and G. E. Smith pegmatites in New Hampshire; and Mbale, Uganda where it replaces amblygonite-montebrasite.

WARDITE

Wardite is a fairly abundant phase in basic sodium aluminum phosphate nodules of low temperature origin from Fairfield, Utah (LARSEN, 1942). It also occurs rarely as a solution product of amblygonite-montebrasite. The mineral is readily identified by its tetragonal bipyramidal development, affording a pseudo-octahedral appearance. The color is grey, white, or tinged yellow, pink or pale bluish-green. Crystals have been found from the Beryl Mountain pegmatite, W. Andover, New Hampshire and with augelite, apatite and morinite from the Hugo pegmatite, Keystone, South Dakota.

MORINITE

Morinite has been found at a sufficient number of pegmatites to warrant serious acquaintance with the mineral. It has been found in altered amblygonite at Montebras, France and once occurred as a locally abundant solution product of amblygonite-montebrasite from the Hugo pegmatite, Keystone, South Dakota, an occurrence which FISHER and RUNNER (1958) described. According to Mr. W. L. Roberts (priv. comm.) up to several hundred pounds of such material occurred at the locality. Morinite has also been described from the Viitaniemi pegmatite (VOLBORTH, 1954) and from a pegmatite near Broken Hill, N. S. W., Australia (I. Threadgold, priv. comm.).

The color is pale rose-red to pink with a fair cleavage. It usually occurs as columnar aggregates of prismatic crystals in intimate association with pale blue apatite and amblygonite-montebrasite.

GOYAZITE

Chemically and paragenetically related to palermoite, the mineral is structurally related to the crandallite group. In pegmatites it is rare but is easily overlooked and can be confused with whitlockite. The color is colorless, dull white to palest pink and the habit is flattened rhombohedral with a trigonal outline. Crystals usually show a prominent c {0001} face. Occasionally, the development is pseudocubic.

Goyazite has been recorded from numerous pegmatites in Maine, usually in association with herderite and apatite. The mineral occurs with palermoite and whitlockite from the Palermo #1 pegmatite in New Hampshire. A perfect basal cleavage distinguishes it from whitlockite, and certain identification is assured in a test for strontium.

WHITLOCKITE

Whitlockite is another recently defined species (FRONDEL, 1941) which lately has been enjoying a large number of discoveries whose sources span a range of conditions. "Zeugite," "martinite" and "pyrophosphorite," all poorly defined substances, are constituents of phosphate rock and bird guano deposits, and contain variable amounts of whitlockite. Whitlockite is also a component of dental enamel and a rare constituent of urinary and bladder calculi. In addition, whitlockite is one of the phosphates recently discovered in certain meteorites.

Large crystals of whitlockite are known only from pegmatites. There, the mineral has formed at moderate to low temperatures in porous cavities with siderite, quartz and apatite derived from the solution of pre-existing phases. Crystals are simple rhombohedral in habit, white in color and show no good cleavage surfaces. It can be confused with goyazite which sometimes occurs in a similar paragenesis, although the perfect cleavage of goyazite assists in correct identification.

Whitlockite was formerly abundant at the Palermo #1 pegmatite in New Hampshire but it recently has been found on the dumps of the Tip Top pegmatite near Custer, South Dakota where small white rhombohedral crystals occur with colloform apatite cementing cracks in smoky quartz. Here, small lustrous colorless whitlockite crystals also occur in open cavities implanted upon a species related to fairfieldite.

PALERMOITE

This curious basic lithium, strontium, aluminum phosphate was recently described by MROSE (1953) from the Palermo #1 pegmatite. It is a relatively late stage mineral, occurring in porous cavities in decomposed montebrasite, scorzalite, siderite, quartz and Fe-Mn oxyhydroxides. It is usually earlier in the paragenesis than most of the other druse minerals.

The habit is characteristic: crystals long prismatic (up to 5 mm), colorless to palest pink, rectangular outline and striated parallel to the prism axis. Terminations are rare and when present, impart a blunt chisel-shaped appearance to the crystal.

BERTOSSAITE

The calcium analogue of palermoite, bertossaite was recently described by Von KNORRING and MROSE (1966) from the Buranga pegmatite, Rwanda, Central Africa. It is massive, faintly pink in color and is associated with amblygonite. Bertossaite is distinguished from amblygonite by its less pronounced cleavage.

LITHIOPHOSPHATE

Originally described from a pegmatite in the Kola Peninsula, U. S. S. R., the species is nearly pure $Li_3[PO_4]$. It was found to replace montebrasite and occur as fist-sized masses, colorless to white, occasionally with a light rose tint. One perfect cleavage and its low specific gravity (2.46) are important diagnostic clues in the field.

Recently, WHITE (1969) has described the species from the Foote spodumene mine, Kings Mountain, North Carolina. Crystals are up to 1cm in length, colorless, and occur implanted on quartz-albite druses which line clefts in the massive pegmatite. They resemble topaz in development and show perfect cleavage perpendicular to the prism axis. A late origin was suggested for this mineral.

BØGGILDITE

This species is a recent discovery, described by BØGVAD (1951) from the famous cryolite deposits of Ivigtut, Greenland. Compositionally, it bears similarities to palermoite and goyazite but contains large quantities of the fluoride anion, suggesting that the mineral would occur only in pegmatites which yield fluorite, cryolite and other fluoroaluminates in addition to the phosphate minerals. The color is flesh-red and crystalline aggregates always show polysynthetic twinning. Its paragenesis appears to be similar to minerals like herderite and beryllonite.

FAIRFIELDITE-MESSELITE

Fairfieldite and the minerals which follow are chemically and paragenetically related to the species which derive from amblygonite-montebrasite but contain transition metals in the divalent state as well. Like the products of amblygonite disintegration, there is no change of valence states relative to the parent phase but transition metals, alkaline earths and/or aluminum are mutually present.

The fairfieldite-messelite series is usually dependent on the compositions of the primary phosphate such as triphylite-lithiophilite, as there is an observed similarity in the Fe/Fe+Mn ratios for a particular locality. Thus, lithiophilite-bearing pegmatites such as Branchville, Connecticut and Poland and Buckfield in Maine yield fairfieldite and triphylite-bearing pegmatites as Palermo #1, New Hampshire and the Tip Top pegmatite in South Dakota provide messelite. The Foote spodumene mine near King's Mountain, North Carolina yields abundant fairfieldite and some messelite as well, along fractures in a rather unzoned pegmatite with no obvious anhydrous transition metal phosphate parents.

The series occurs as micaceous brittle gypsum-like foliae and plates, and as botryoidal aggregates of radiating masses of a tan to buff-white, white or pale greenish color. Magnificent specimens of large foliated crystals were recently culled from the Foote mine. Fairfieldite and messelite are earlier than most other vug-filling phosphates, but many specimens, such as at the Tip Top pegmatite can reveal laths in a clearly late stage paragenesis.

EOSPHORITE-CHILDRENITE

Another continuous Fe/Mn+Fe series, childrenite-eosphorite are fairly persistent but rarely abundant pegmatite phosphates occurring in a paragenesis akin to fairfieldite-messelite. Eosphorite tends to be pink or rose-red in color, while childrenite is yellowish-brown to brown. The minerals invariably occur as crystals of an orthorhombic thin prismatic habit showing good pyramidal terminations. Occasionally, these crystals will be flattened and lath-like. Crystals are often aggregated to form a comb-like or bristly surface.

Recently, enormous crystals of eosphorite up to four inches in length have been appearing in specimens from certain pegmatites in the State of Minas Geraes, Brazil. Eosphorite occurs along cleavelandite plates at Newry, Maine and with fairfieldite at Branchville, Connecticut. It also appears with roscherite, smoky quartz and herderite covering miarolitic cavities. Childrenite is fairly abundant at the Palermo #1 pegmatite projecting into cavities in siderite, quartz and ludlamite.

BJAREBYITE

A recent discovery (MOORE, LUND and KEESTER, 1973), bjarebyite occurs in a paragenesis identical to pa-

TABLE 3. IMPORTANT PEGMATITE PHASES AND THEIR COMPOSITIONS

Granite Pool			Common Accessories		Unknown (or rare) Phosphate Accessories
orthoclase		$K[AlSi_3O_8]$	lepidolite	$K(Li,Al)_3(OH)_2[AlSi_3O_{10}]$	$Li_3[PO_4]$
albite	plagioclase	$Na[AlSi_3O_8]$	petalite	$Li[AlSi_4O_{10}]$	$Ca_3[PO_4]_2$
anorthite		$Ca[Al_2Si_2O_8]$	pollucite	$(Cs,Na)[AlSi_2O_6] \bullet H_2O$	$Na_3[PO_4]$
muscovite		$KAl_2(OH)_2[Si_3AlO_{10}]$	spodumene	$LiAl[Si_2O_6]$	$NaAl(OH)[PO_4]$
quartz		SiO_2	tourmaline	$Na(Mg,Fe)_3Al_6(OH)_4[BO_3]_3[Si_6O_{18}]$	$CaAl(OH)_2[PO_4]$
			beryl	$Al_2[Be_3Si_6O_{18}]$	
			spessartine	$(Mn,Fe)_3Al_2[SiO_4]_3$	
			apatite	$Ca_5(OH,F)[PO_4]_3$	
			graftonite	$(Ca,Fe)(Fe,Mn)_2[PO_4]_2$	
			triphylite	$Li(Fe,Mn)[PO_4]$	
			amblygonite	$LiAl(F,OH)[PO_4]$	
			columbite	$(Fe,Mn)[(Nb,Ta)_2O_6]$	

lermoite from the Palermo #1 pegmatite, New Hampshire. Its color is bluish emerald-green, darker than ludlamite and arrojadite. Two perfect cleavages distinguish it from the ludlamite, the latter appearing in a later paragenesis. Bjarebyite has been found on only one specimen in an altered mass of corroded amblygonite, scorzalite, quartz and siderite. The exquisite crystals up to 2 mm in length are monoclinic prismatic, very lustrous and highly faceted, showing up to 16 distinct forms.

ROSCHERITE

Roscherite, like moraesite and faheyite, occurs in association with both beryl and primary phosphates, as a late stage hydrothermal product of these earlier-formed minerals. It occurs as botryoidal aggregates, often with globular grey carbonate-apatite, as leaves of thick tabular crystals, or as a granular ground mass upon which later minerals, like frondelite and faheyite, are implanted. At the Sapucaia pegmatite occurrence, it replaces the frondelite which is associated with beryl as well. In the Maine occurrences, it usually occurs as thick tabular wedge-shaped crystals which form aggregates of warty crusts in cleavelandite vugs. The color is transluscent greenish-grey, but ranges from olive-green to dark brown or reddish-brown. Childrenite is a common associate in the roscherite paragenesis.

CRANDALLITE

The most abundant phase in the phosphate nodules from Fairfield Utah as the variety "pseudowavellite," crandallite occurs commonly but inconspicuously at pegmatites in very late stage low temperature assemblages. Much of the ill-defined pulverulent to chalcedonic masses of white, yellowish or greyish material coating more resistant minerals are in the crandallite mineral group. Lack of any detailed studies on these compounds (including deltaite and millisite, the latter in the wardite group) render certain identification of the phase difficult. Crandallite and carbonate-apatites ("francolite" and "dahllite") occur in a similar paragenesis and are practically indistinguishable without recourse to X-ray study.

At the Palermo #1 pegmatite, crandallite occurs as white to greyish colloform to pulverulent cavity fillings in porous Fe and Mn oxyhydroxides derived from the leaching and oxidation of triphylite. Small hexagonal prismatic crystals of a whitish color are probably carbonate-apatite. Crandallite occurs occasionally as small rosettes of prismatic crystals with a triangular (trigonal) outline. The mineral is doubtlessly common but inconspicuous at many other pegmatites.

MORAESITE

Another new mineral from the Sapucaia pegmatite in Brazil and described by LINDBERG *et al.* (1953), moraesite, too, has been subsequently found at other pegmatites. It formed late in the paragenesis and occurs as spherulitic aggregates of snow-white tufts, needles and thin lath-like crystals implanted upon frondelite-rockbridgeite, muscovite, beryl, etc.

The mineral evidently derived from simultaneous hydrothermal attack by fluids upon triphylite and beryl. The species always occurs close to beryl adjacent to the basic ferric phosphate minerals, which affords a good hint to its occurrence and paragenesis at other pegmatites. At the Palermo #1 mine, delicate felted aggregates of white moraesite occur along fractures in beryl crystals which have crystallized adjacent to triphylite giant crystals. Beryl-amblygonite associations may also provide a source for this peculiar species.

MONTGOMERYITE

Yet another species from the phosphate nodules of the Fairfield, Utah deposits, montgomeryite has been identified with certainty as a rare mineral from the Etta pegmatite, near Keystone, South Dakota by MOORE (1964). It occurs sparingly as small glistening white laths coating fractures in highly oxidized phosphate nodules largely filled with mitridatite.

Many other minerals from Fairfield, Utah may occur in pegmatites in a similar late stage paragenesis. Included here are lehiite, variscite, gordonite, englishite and overite. Such minerals may occur especially in association with apatite and porous cavities in amblygonite-montebrasite. Study of pale-colored late-stage phosphate minerals is urgently needed and for the most part, X-ray analysis would be a necessary tool in such a study.

SOME REMARKS ON PEGMATITE PHOSPHATE RESEARCH

Unlike the silicates, most pegmatite phosphates are of no economic worth nor are they important constituents of rock-forming mineral suites. Thus, such a family of compounds in a pragmatic and utilitarian age like our own present culture, does not receive the full measure of research required for their specific clarification and understanding. Problems of this type were of interest in the 19th Century, when great naturalistic pursuits were undertaken if for no other reason than basic human curiosity. Just as the days of the great expeditions are over (excepting technologically oriented missions as the lunar expeditions, but even here the great 19th Century naturalist A. R. Wallace suffered more physical trials and uncertainties in his Amazonian and Malayan expeditions, and with much less fanfare), so it is difficult to imagine in a society as technologically oriented as our own, that much, if any, professional interest would be stirred in such a family of compounds as the phosphates. Reflecting this, is the consistent appearance of but few names in the references: names like Fisher, Frondel, Lindberg and Mrose constitute the bulk of careful and continued interest in such problems. Perhaps it is to the diligent and dedicated amateur who is not tarnished by the cult of business-like professionalism that we can hope to see yet more advances in this field.

On this note, I remark that nearly every collection of pegmatite phosphates contains unknown material. Most of the "unknowns" will prove to be well-established species with some unusual color or crystal habit. Information like this is sorely needed. But phosphate species new to science appear at a rate of about two per year and, thanks to X-ray and microchemical techniques, this rate should continue for quite some time. My laboratory, for example, is studying at least six new species, all culled within the past year.

It is appropriate to conclude with a quote from a great naturalist of our own Century, Evelyn Cheeseman, who, with the assistance of a few natives, doggedly collected butterflies and other exotic insects in the remotest regions of the New Guinean jungles, enduring every torment mortal flesh can bear:

"A great deal of work of course remains to be done; a great deal more collecting — dogged systematic collecting in out-of-way places — and a great deal more taxonomic work in museums is needed ... every unravelling of a knot gets us somewhere — a few steps forward on the road" (CHEESEMAN, 1930).

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Wyllieite, $Na_2Fe_2^{2+}Al(PO_4)_3$, A New Species

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INTRODUCTION

After two field and collecting excursions to 102 Black Hills pegmatites in the summers of 1971 and 1972, it became clear that the Victory mine pegmatite was chemically unique, so peculiar in fact that a major mineralogical investigation is now in progress. Not only is the pegmatite of interest to the mineralogist for an unusual abundance of Na-rich primary phosphates rarely encountered elsewhere, but the textures of the cocrystallizing phases are in themselves a source of interest to petrologists as well. Our account concerns a new species which evidently occurred in considerable abundance during operation of the pegmatite.

The Victory mine pegmatite is located two miles northeast of the center of Custer, Custer County, South Dakota on the Custer Quadrangle, Section 18, SE 1/4, SW 1/4, T. 3S, R. 5E. It is one of the hundreds of pegmatites distributed around Harney Peak and mined during the Second World War. Compared with the dimensions of many other worked pegmatites, the Victory mine was small. According to Pray, et al. (1953) it cropped out as a lenticular form about 23' x 93' in dimension. Hanging wall and foot wall dip from 40°to 50°, defining a tabular sausage-like body with a length to width ratio of about 5:1 concordantly intruded into the enveloping schists. From 60' to 120' in depth, a second sausage-like pegmatite lens was encountered. Two shafts were driven, a 40' inclined shaft and a 70' vertical shaft, the latter eventually sunk to 120' with a crosscut to the pegmatite. Drifts facilitated removal of the rock.

The pegmatite consisted of two zones, a wall zone ranging from 1' to 7' in thickness and consisting of albite-quartz-muscovite which grades into the coarse quartz-perthite-albite core. High grade mica books were confined to the wall zone. Despite the small dimension of the pegmatite, it was the largest producer of high grade mica during 1944 and rewarded its owners with $500,000 from 360 tons of mined and cobbed mica. The mica crystals ranged up to 18" across and were of prime ruby quality.

The interesting accessory minerals appeared to be confined to the region between the wall zone and the core. Pray et al. (1953) mention accessory tourmaline, blue phosphates (probably scorzalite) and triphylite-lithiophilite nodules (probably wyllieite) in the wall zone. No triphylites were encountered in our study. Pray et al. (1953) mention that optical studies indicated a 70% triphylite composition. We have good evidence that this phase was indeed the wyllieite. A 70% triphylite would have a mean index of refraction around 1.695, the value found by Pecora and Fahey (1949) for their "triphylite" from the Victory mine, the sample of which we found to be in fact not triphylite but wyllieite. This index of refraction is practically identical to our observations on wyllieite. Finally, we remark that our wyllieite specimens show abundant coarse quartz and perthite as well as the plagioclase, suggesting that the mineral crystallized toward the end of the wall zone formation and during early core consolidation. Pray et al. (1953) mention that the "triphylite" nodules were rare but we find the dumps reveal a fairly abundant wyllieite. But the core of the Victory mine was probably investigated only casually since only the wall zone was of principal economic interest.

All specimens were collected on the dumps which had suffered severe diminution through back-filling and removal for road gravel. The entrances to the pegmatite's interior are largely caved in and the interior chamber filled with dump debris and water. We secured about 100 specimens for further study which shall form the basis of our chemical investigations on the Victory mine paragenesis and it is urged that what does remain of the dump be protected from total obliteration through cartage since to our knowledge aspects of its crystal chemistry are unique and the crystal textures spectacular.

One of us (PBM) has found that all geological reports which list accessory phosphate phases in the Black Hills pegmatites are notoriously unreliable in the correctness of mineral identification of these phases. Commonly grouped as "lithiophilite" or "heterosite" or simply "Fe, Mn phosphates", many are in fact in the triphylite-lithiophilite series, the arrojadite-dickinsonite series, the graftonite-beusite series, the alluaudites, the heterosite-purpurite series, the ferrisicklerite-sicklerite series, the triplite-zwieselite series, the triploidite-wolfeite series, griphite, etc. Studies on the compositional variation of the Fe/Fe+Mn ratio within a pegmatite and among pegmatites, important problems which bear on theories of pegmatite genesis, are virtually absent in the literature. In fact, the labyrinthine mineralogical problem of secondary phosphate paragenesis and chemistry is closely rivalled by the

TABLE 1 CHEMICAL ANALYSES OF WYLLIEITE AND ARROJADITE FROM THE VICTORY MINE

	1	2	3	4	5	6	7
K_2O	0.05	0.0	-	-	1.09	1.80	2
Na_2O	8.0	9.75	8.9	5.26	7.55	19.44	18
Li_2O	0 .01	n.d.	-	-	n.d.	-	
H_2O^+	0.70	n.d.	0.7	1.44	n.d.	-	
CaO	2.5	2.21	2.3	0.77	5.39	7.68	8
MgO	1.97	1.80	1.9	0.86	1.38	2.72	
MnO	4.3	3.62	4.0	1.03	3.62	4.12	48
FeO	29.2	29.9	29.6	7.58	37.01	41.20	
ZnO	0.04	n.d.	-	-	0.0	-	
Al_2O_3	7.9	8.46	8.2	2.96	2.85	4.48	4
Fe_2O_3	0.33	n.d.	-	-	n.d.	-	
SiO_2	0.8	0.0	-	-	0.0	-	
P_2O_5	43.8	45.27	44.5	11.57	42.26	48.00	48
	99.56	100.99	100.1		101.15		

[1] Wet chemical analysis on wyllieite in weight percent. Jun Ito, analyst. W. K. Sabine provides 0.47% H_2O^+ determined calorimetrically. Spectrographic traces of Sr, Ba, Pb, and Be were detected.

[2] A.R.L. electron probe microanalysis. G. R. Zechman, analyst.

[3] Average of 1 and 2.

[4] Atoms in the unit cell.

[5] ARL electron probe microanalysis on arrojacite from the Victory Mine. G. R. Zechman, analyst.

[6] Atoms based on P = 48 for arrojadite.

[7] Suggested ideal limits, atoms in cell.

chemical problems of the primary giant crystal phases. Much of this derives from the principal emphasis of geological reports during and after the war years (when pegmatites supplied virtually all the mica, beryllium and lithium minerals) on the economics of the deposits rather than their systematic crystal chemistry. Consequently, pegmatite structures were emphasized. This proves a boon to the mineral chemist since many excellent maps appeared in the literature and are especially important when a section of a pegmatite was obliterated by further operations and whose phases can be found only on the dumps. Broad surveys like Page et al. (1953) are rapidly becoming classics in the field of pegmatite description.

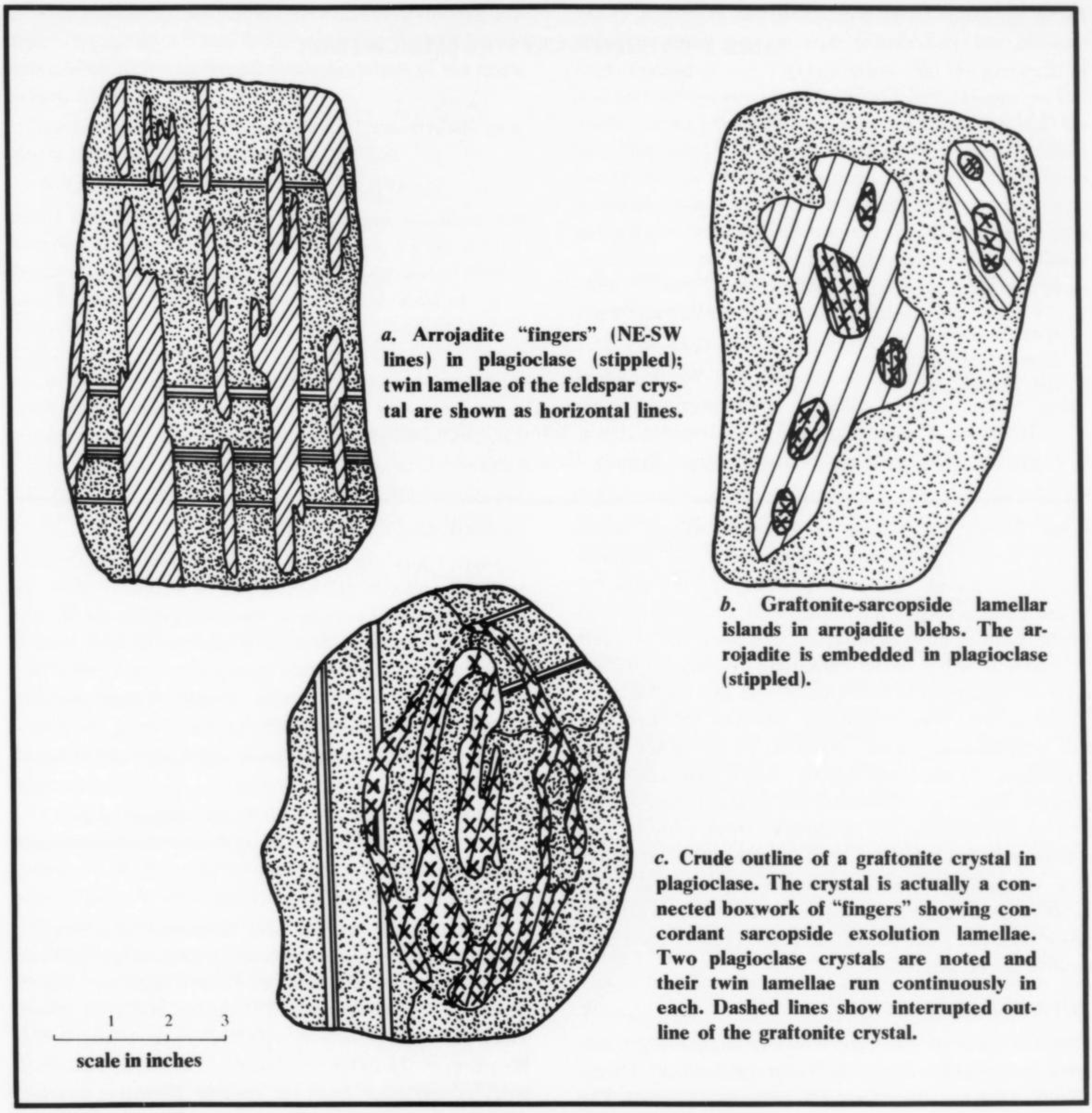
As noted before, the new species was recorded by Pecora and Fahey (1949) during their investigation on the Victory mine scorzalite but it was erroneously identified as triphylite. Identity with our new species was assured through an X-ray investigation on one of the samples used in their study and kindly donated by the late W. T. Pecora.

DESCRIPTION OF THE SAMPLES (PBM)

Phases identified in this study include major quartz, muscovite (some of high grade, occurring as thick ruby-red books), plagioclase showing superb lamellar twinning, perthite, albite var. cleavelandite, and schorl. Subordinate minerals, some occurring locally in considerable abundance, include wyllieite, graftonite, sarcopside, and arrojadite. More rarely appear scorzalite, arsenopyrite, hydration products of the primary phosphates such as ludlamite and vivianite, garnet and numerous inconspicuous unidentified phases. Noteworthy is the persistent absence of lithium minerals. Instead sodium-rich phases appear.

The largest mass of wyllieite recovered from the dump weighed about 20 kilograms of which the mineral comprises 70% of the total mass. It occurs as coarse, rude euhedral interlocking crystals with one perfect cleavage, of a deep greenish-black color, closely resembling hornblende. Earliest formed was muscovite and minor black tourmaline followed by the wyllieite and plagioclase and perthite feldspars, the former showing lamellar twinning, and finally quartz. Several hundred kilograms of similar specimens were noted and doubtless the species was abundant *in situ.*

Most remarkable are the textures of arrojadite in association with the wyllieite. Arrojadite, its chemistry discussed later, was apparently completely overlooked by earlier investigators. It occurs as perfect parting surfaces of a pale greenish-yellow color, sometimes superficially altered wine yellow or orange. The arrojadite occurs as droplets and "fingers" whose extremities are crystallographically concordant to each other and immersed in or interfingered with crystallographically concordant plagioclase. Grain size of individuals, some of them showing incompleted crystal faces, range up to ten centimeters in length and two centimeters in thickness. More remarkable are vermiform intergrowths of rhythmic arrojadite and plagioclase, with a rude outline of the arrojadite morphology. Everywhere, thin films of wyllieite rim the arrojadite. Specimens exposing up to 150 square centi-



a. **Arrojadite "fingers" (NE-SW lines) in plagioclase (stippled); twin lamellae of the feldspar crystal are shown as horizontal lines.**

b. **Graftonite-sarcopside lamellar islands in arrojadite blebs. The arrojadite is embedded in plagioclase (stippled).**

c. **Crude outline of a graftonite crystal in plagioclase. The crystal is actually a connected boxwork of "fingers" showing concordant sarcopside exsolution lamellae. Two plagioclase crystals are noted and their twin lamellae run continuously in each. Dashed lines show interrupted outline of the graftonite crystal.**

Fig. 1. **Sketches of hand specimens of phosphate-silicate intergrowths, Victory mine.**

meters of crystallographically concordant patches of plagioclase and complementary arrojadite were collected.

Graftonite-sarcopside intergrowths were also collected, showing the same textures in association with plagioclase as the arrojadite. In some instances, tourmaline "sausage rolls" occur growing parallel to the sarcopside-graftonite laths. The scorzalite is later than the other phosphates and crystallized in the interstices left by the wyllieite, or as isolated grains in mica aggregates.

Fig. 1a shows a sketch of an arrojadite-plagioclase intergrowth. Here, the parting planes of the arrojadite fingers are mutually parallel. The host mass of plagioclase shows broad twin lamellae. The twin lamellae of the plagioclase do not penetrate the arrojadite but are continuous throughout the mass. Fig. 1b shows blebs of arrojadite in plagioclase, which poikilitically include graftonite-sarcopside lamellae. Although the arrojadite mass is crystallographically uniform, the graftonite-sarcopside blebs are not in themselves crystallographically concordant. Fig. 1c shows a graftonite-sarcopside bleb in plagioclase. This bleb and others like it show a rude euhedral outline, the interior of which is constituted of connected crystallographically homogeneous material, with a texture like marble cake. Everywhere, the plagioclase is crystallographically concordant, as in Fig. 1a.

These textures, so reminiscent of graphic granite, cannot be explained solely on simple models of replacement or primary crystallization of one phase in the absence of the

TABLE 2. WYLLIEITE. CRYSTAL CELL CRITERIA

	1	2
a(Å)	11.868(15)	12.004(2)
b(Å)	12.382(12)	12.533(4)
c(Å)	6.354(9)	6.404(1)
β	114.52(8)°	114.4(1)°
V(Å^3)	849.5Å^3	877.4Å^3
space group	$P2_1/n$	$C2/c$
cell formula	$Na_{5\cdot26}Ca_{0\cdot77}Mg_{0\cdot86}Mn_{1\cdot03}Fe^{2+}_{7\cdot58}$ $Al_{2\cdot96}[(P_{11\cdot57}(H_4)_{0\cdot36})O_{46\cdot95}]$	$Na_{2\cdot5}Li_{0\cdot1}Ca_{0\cdot5}Mn^{2+}_{4\cdot5}Mg_{0\cdot2}Fe^{3+}_{7\cdot9}[PO_4]_{12\cdot0}$
specific gravity	3.601(3)	3.45
density (gm/cm^3)	3.60	3.62
sum of cations	30.5	27.7

[1] This study. The specific gravity was determined by a Berman torsion balance.

[2] Fisher (1955) for alluaudite from Buranga, Ruanda, Central Africa.

other. Rather, the patches of phosphate-silicate assemblages, their crystallographic concordance, the preservation of continuous exsolution profiles, and the morphological outlines suggest a phosphate-silicate eutectoid fluid which, prior to co-crystallization, possessed the property of a smectic liquid or gel permitting crystallographically oriented separation of individual phases like marble cake. These textures were repeatedly observed for arrojadite and graftonite-sarcopside. Wyllieite, on the other hand, crystallizes idioblastically against quartz, plagioclase and perthite when it is not rimming the arrojadite fingers. We sum up by proposing the paragenesis (from early to late) tourmaline-mica-arrojadite and plagioclase (graftonite and sarcopside)-wyllieite-scorzalite-perthite-quartz. Wyllieite evidently grew as homogeneous crystals as a primary phase and, like later scorzalite, is enriched in aluminum relative to the arrojadite.

PHYSICAL PROPERTIES

Wyllieite is deep bluish-green to deep oily green, greyish-green (not unlike triphylite) to greenish-black. Grains about 0.5 mm are transparent and pale green in color. The luster is vitreous to submetallic and the mineral lacks the shiny black surface of the associated tourmaline. The streak and powder are dirty olive-green, hardness 4+, cleavage {010} perfect with distinct {$\bar{1}$01} . The mineral is very brittle and removal of the quartz matrix around crystal surfaces usually results in shattering. In appearance, cleavage surfaces of wyllieite are strikingly similar to hornblende. The specific gravity is 3.601 ± 0.003 determined in triplicate on a Berman microbalance.

Crude crystals up to 10 cm across were encountered. Favorable fracture of the quartz occasionally reveals superior single crystals of the mineral. One specimen, 6 x 8 x 12 cm, shows a superior euhedral crystal 2 x 2 x 3 cm embedded in quartz and yellow mica. Morphologically, wyllieite crystals are similar to those of "hühnerkobelite" (= alluaudite group) illustrated by Moore (1965).

CHEMICAL COMPOSITION

Table 1 lists one partial and one complete analysis of wyllieite, and one partial analysis of arrojadite from the Victory mine. The wyllieite analyses, performed by two different techniques, show fairly good agreement when it is realized that composition from grain to grain may vary somewhat and that the larger samples contain poikilitically included mica and quartz.

Average of the two analyses and computation based on the unit cell contents provide

$H_{1\cdot44}Na_{5\cdot26}Ca_{0\cdot77}Mg_{0\cdot86}Mn^{2+}_{1\cdot03}Fe^{2+}_{7\cdot58}Al_{2\cdot96}P_{11\cdot57}O_{46\cdot95}$

Interpretation of the formula appears in the subsequent section on the X-ray analysis.

OPTICAL PROPERTIES

Wyllieite is biaxial (+). Owing to its weak birefringence, thick grains were studied in order to observe pleochroism and to obtain reliable indices. The results are α1.688, β1.691, γ1.696, all ± 0.002, 2V (obs) $\backsim$ 50°, r<v strong. Thick plates are pleochroic with Z (green) > Y (smoky bluish-green) $\backsim$ X(smoky bluish-grey). The mean calculated index of refraction from the specific refractive energies of Larsen and Berman (1934), the specific gravity and the average chemical composition is $\langle n \rangle$ calc = 1.680, in fair agreement with $(\alpha+\beta+\gamma/3) = 1.692$ and adds confidence to the cumulative data in this study. We note that the "triphylite" (= wyllieite) in Pecora and Fahey (1949) revealed $\beta = 1.690$, a large 2V and Y = blue-green, essentially in accord with our results.

X-RAY CRYSTALLOGRAPHY

Fragments of wyllieite single crystals were prepared for Weissenberg photography. In addition, a thorough three-dimensional crystal structure analysis has been completed and allows us to interpret the wyllieite crystal chemistry with some reliability. Discussion of the structure, because of its inherent specialty, is deferred to a separate paper to be published elsewhere. The crystal cell parameters for wyllieite are presented in Table 2. The indexed powder pattern, utilized for the refinement of the cell parameters, appears in Table 3. Correct assignment of indices was facilitated by the intensity measurements of the single crystal study.

The crystal structure analysis reveals that wyllieite possesses the general crystal-chemical formula

$$X(1a)_2X(1b)_2X(2)_4M(1)_4M(2a)_4M(2b)_4[PO_4]_{12}$$

in the unit cell, where X are large cations whose oxygen coordination numbers are greater than 6, M are octahedrally coordinated cations, and P is in tetrahedral coordination. Least-squares refinement of the structure converged to X(1a) = $Na_{1\cdot82}+\square_{0\cdot18}$, where $\square$ is a hole; X(1b)= $Ca^{2}_{1\cdot0}+Mn^{2+}_{1\cdot0}$, X(2) = $Na_{2\cdot78}+\square_{1\cdot22}$; M(1) = $Fe^{2+}_{3\cdot0}+Mg_{1\cdot0}$; M(2a)= $Fe^{2+}_{4\cdot0}$; and M(2b)= $Al_{3\cdot0}+Fe^{2+}_{1\cdot0}$ in the unit cell. Summation of the individual cationic species reveals a formula similar to the average obtained in the chemical analyses, a result which is at best approximate owing to the complex nature of the crystal structure. Ideally representing the compound as an end-member composition by grouping the large cations together, we obtain

$$(Na,Ca,Mn^{2+})^{[6]}_{8}(Fe^{2+},Mg)^{[6]}_{8}(Al,Fe^{2+})^{[6]}_{4}[(P,H_4)^{[4]}O_4]_{12}.$$

With 4 such molecular units in the cell, the formula is condensed to

$$Na_2Fe^{2+}_2Al[PO_4]_3,$$

which we propose as the wyllieite limiting end-member composition with all cationic positions occupied in the structure.

We have investigated the thermal behavior of wyllieite in greater detail. A dehydration curve provided by W.K. Sabine for wyllieite powder in pure nitrogen atmosphere shows three distinct peaks at 525°C, 775°C and 955°C. The first peak accounts for 81.6% of the total H_2O^+. It is possible that the loss of water at this stage is accompanied by the oxidation of Fe^{2+} to Fe^{3+} through cleavage of the protons by an auto-oxidation-reduction reaction. The peak at 775°C accounts for 14.8% additional water. Wyllieite powder was heated *in vacuo* at 775°C for 40 hours; X-ray examination of the product revealed increasing diffuseness and merging of the extra 'ordering' powder lines, demonstrating that solid solution of Al^{3+} and Fe^{2+} takes place at higher temperature. The peak at 955°C ended at 1040°C and accounted for 3.6% of the H_2O^+. This terminal temperature is probably the melting temperature since Fisher (1965) notes that the "melting point of alluaudite is very close to 1000°C;" alluaudite is compositionally similar to wyllieite.

We also provide an analysis of Victory mine arrojadite in Table 1. The arrojadite differs in containing significant K_2O, more CaO, more FeO and less Al_2O_3 than wyllieite, but their compositions are sufficiently close to suggest a possible dimorphic relationship. Fisher (1965) observed that arrojadites heated in air begin to change to the alluaudite structure at 405°C. In vacuum, the compound apparently inverts to a ferrofillowite beginning about 745°C. It is clear that oxidation leads to alluaudite as the stable structure type at high temperature but fillowite forms instead *in vacuo.* It is possible that the presence of K_2O and the absence of oxidation of Fe^{2+} inhibits the formation of an alluaudite and fillowite forms instead. On the other hand, the absence of K_2O in wyllieite inhibits the growth of arrojadite through heating. Victory mine arrojadite contains the highest amount of Al^{3+} yet reported in the arrojadite-dickinsonite series. This series usually contains only minimal amounts of trivalent species. Based on the results of the analysis in Table 1, arrojadite from the Victory mine approaches the ideal limit

$$K_2Na_{18}Ca_8(Fe,Mn,Mg)^{2+}_{48}Al_4(PO_4)_{48}$$

in the unit cell. But structure analysis will be necessary to better comprehend the chemistry of this complex series.

DISCUSSION

Wyllieite is structurally and compositionally related to the alluaudite group of minerals, a very complicated but important mineral group which occurs naturally as Na-metasomatic products of primary phosphate phases in granitic pegmatites (Moore, 1971). It differs from the alluaudites in the following ways, which are sufficient to warrant its specific status. *First,* it is a primary phase while alluaudites are derived from later Na-autometasomatic reactions of earlier phases, particularly triphylite-lithiophilite. *Second,* wyllieite occurs as idioblastic crystals while alluaudites are fine-grained nodular phases. *Third,* wyllieite crystallizes in space group $P2_1/n$ as a result of ordering over the general equivalent octahedral M(2) positions in the $C2/c$ space group of alluaudites. *Fourth,* Al^{3+} is an essential constituent in wyllieite and is minimal or absent in alluaudites. *Fifth,* the large alkali sites are extensively occupied in wyllieite, while they are largely empty in alluaudites. *Sixth,* the transition metals are unoxidized in wyllieite and occur in the Fe^{2+} and Mn^{2+} states. In alluaudites, these cations are extensively oxidized.

We have good evidence that wyllieite or wyllieite-related phases occur at other pegmatites as well, in fact at those pegmatites where arrojadite is known to occur. At the Nickel Plate pegmatite near Keystone, South Dakota, a deep green phase occurs with abundant arrojadite. This phase, physically practically identical to the Victory mine material, reveals a powder pattern very similar to wyllieite and quite distinct from alluaudite. A similar phase occurs sparingly at the Smith mine, Newport, New Hampshire, rimming and occurring interstitially with large granular masses of yellow-green arrojadite. Owing to the intricacies of the wyllieite crystal chemistry, it will be necessary to thoroughly investigate these phases chemically in order to properly define them.

NAME

Wyllieite was approved as a species by the International Commission on New Minerals and New Mineral Names by a vote of 13-1, the dissenter feeling that ordered and disordered forms should not be given different names. We

TABLE 3. WYLLIEITE: POWDER DATA[a]

I/Io	*d*(obs)	*d*(calc)	*hkl*
4	8.12	8.14	110
6	6.15	6.19	020
3	5.37	5.40	200
5	3.449	3.456	310
4	3.047	3.040	$\bar{1}12$
2	2.998	3.008	131
2	2.907	2.890	002
4	2.848	2.844	$\bar{3}12$
3	2.807	2.807	$\bar{2}22$
2	2.726	2.729	041
10	2.693	2.699	400
10	2.674	2.685	240
2	2.621	2.619	022
2	2.585	2.577	$\bar{4}02$
5	2.498	2.497	$\bar{1}32$
		2.489	112
1	2.472	2.474	420
3	2.385	2.379	$\bar{4}22$
2	2.302	2.305	$\bar{1}51$
2	2.201	2.194	$\bar{5}12$
3	2.163	2.157	151
3	2.123	2.127	510
4	2.079	2.070	$\bar{3}13$
3	2.036	2.040	350
2	1.968	1.962	$\bar{5}32$
1	1.926	1.928	$\bar{6}02$
		1.928	260
1	1.914	1.913	530
1	1.888	1.889	$\bar{3}52$
1	1.881	1.879	312
2	1.845	1.841	$\bar{6}22$
2	1.793	1.796	351
2	1.774	1.775	511
2	1.749	1.745	$\bar{2}43$
4	1.726	1.727	332
		1.726	$\bar{2}62$
2	1.703	1.703	$\bar{1}71$
1	1.659	1.659	$\bar{6}41$
		1.656	$\bar{6}23$
3	1.639	1.630	133
1	1.611	1.611	$\bar{4}62$
2	1.603	1.602	422
3	1.577	1.579	$\bar{1}53$
3	1.555	1.556	640
1	1.528	1.531	710
2	1.514	1.513	$\bar{3}72$
1	1.498	1.495	081
		1.495	$\bar{5}53$
1	1.484	1.481	$\bar{8}02$
1	1.465	1.464	371
2	1.453	1.452	172

20 more lines, each <2

[a] FeK$_\alpha$, 114.6 mm camera diameter. Film corrected for shrinkage.

feel our six criteria for differences between wyllieites and alluaudites are sufficient evidence for warranting a new species. The name was approved by 12-2, the dissenters feeling that the name was too difficult to pronounce and too close to wilkeite. Wyllieite should be pronounced WI'-LE-AIT.

It is named for Peter J. Wyllie, Professor of Petrology and Geochemistry, the University of Chicago, who has added much to our knowledge of granite melting in dry and aqueous conditions and who is a leader in the fields of petrogenesis, chemistry of ultramafic rocks, granite melts, and pedagogy in the earth sciences. In 1965, he won the Mineralogical Society of America award. With his interest in rock-forming minerals, it was only fitting that a mineral which occurs in rock-forming quantities be named after him.

The type specimen and the specimen displaying the large single crystal are preserved in the collections of the National Museum of Natural History. In addition, several kilograms of wyllieite have been donated to the museum for exchange purposes.

ACKNOWLEDGEMENTS

Messrs. G. R. Zechman and W. K. Sabine provided additonal analytical results to our study. Dr. P. Toulmin and the late Dr. W. T. Pecora arranged for loan of an original sample of the "triphylite" from the Victory mine. Mr. W. L. Roberts and Dr. D. H. Garske of Rapid City, South Dakota assisted in collection of the samples.

This study was supported by the NSF GA-10932 grant to P.B.M. and an Advanced Research Projects Agency grant awarded to the University of Chicago.

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QA column

Q. In the *Glossary of Mineral Species* siegenite is shown to have an identical composition as linnaeite; however, Dana describes linnaeite as a cobalt sulphide and siegenite as its nickel variety. Which is correct?

Karl F. Estes
Booneville, Arkansas

A. Your question calls attention to one of the difficult areas of mineral chemistry formulation. The *linnaeite group* minerals are isostructural with the spinel family of minerals and their formulas should be written in the form AB_2X_4, where A is a divalent metal, B is a trivalent metal, and X is sulfur or selenium. One-third of the cobalt in linnaeite is divalent and two-thirds trivalent. The formula should be written $CoCo_2S_4$, just as magnetite should be written $FeFe_2O_4$ (not Fe_3O_4). Very few, if any, of the modern texts have adopted this usage for the linnaeite group. The use of the formula $(Co,Ni)_3S_4$ in the *Glossary* for linnaeite is, in a way, unfortunate for all it means is that some nickel is found in linnaeite specimens. Although written the same way for siegenite, the significance here has changed. In the case of siegenite nickel is the dominant metal in either the A or the B position in the formula, but cobalt is still the dominant metal in the mineral. When nickel beomes the dominant metal the mineral should then be called polydymite, which may be written Ni_3S_4, $(Ni,Co)_3S_4$, $NiNi_2S_4$, or even $(Ni,Co)(Ni,Co)_2S_4$. The next to last form should probably be preferred.

In order to permit consistency in writing linnaeite group formulas, analyses must be performed in which the divalent and trivalent amounts of the two or three major metals present are determined. A sticky problem.

Q. I have acquired a specimen of chrysocolla from Gila County, Arizona, which has some minute yellow crystals scattered over the surface with some showing a divergent spray habit. Any idea what they could be?

Karl F. Estes
Booneville, Arkansas

A. Our best guess is mimetite.

Q. Is hedyphane a distinct species or a variety of mimetite?

Karl F. Estes
Booneville, Arkansas

A. Hedyphane is a distinct species. There is a simple way to make this determination on your own. Apart from the fact that varietal names are not entered in the *Glossary of Mineral Species* (except a very few which are clearly labelled as varieties), the style in which the formulas are written may be used as a guide. When more than one metal is enclosed in parentheses, with a comma between them, that given first is the dominant one. The formula shown for hedyphane is $(Ca,Pb)_5(AsO_4)_3Cl$. This indicates that hedyphane is the calcium analog of mimetite which is shown as $Pb_5(AsO_4)_3Cl$, but could also be written $(Pb,Ca)_5(AsO_4)_3Cl$.

Q. I have heard some talk of an organization called ULW. Can you tell me something about it?

Joseph Pasternak
Chicago, Illinois

A. The following answer was supplied by John Patrick... The first Lapidary and Mineral Trade Show was held May 1972 in Peoria, Illinois, under the management of United Lapidary Wholesalers (ULW). This differed greatly from the hobby club hosted gem and mineral shows or a few wholesalers set up in motel rooms on the coattails of such a show. Over 100 companies took advantage of the centralized location of ten prominent wholesalers to stock up for their summer trade. Retailers representing 14 states came from as far as Massachusetts, New York and Florida, with the bulk coming from a 600 mile radius of Peoria. ULW members are well satisfied that these retailers supported the theory that the mineral and lapidary industry had sufficiently matured to warrant a trade show and plans were made to expand this concept to include seven shows per year; February in Tucson and Spring and Fall Shows in May and September in Reno, Peoria and Valley Forge. Thus they are now able to service dealers throughout the country on a regular basis.

The United Lapidary Wholesalers was formed in 1969 by Lowell Gordon of the Gordon Company, Long Beach, California. It is a nonprofit and unstructured group consisting of five members operating very much as a board of directors. Those members are Dan Gordon, The Gordon Company; George Nielsen, Nielsens; Walt Miller, The Millers; Dom Pardo, M-Line; and John Patrick, Geo-Aids International. The broad range of the mineral and lapidary field is virtually covered by enlisting additional wholesalers so that retailers can replenish their stocks from one location. Further they can see the type of merchandise offered which increases their confidence in ordering by mail.

As a result of a survey conducted by the American Gem and Mineral Suppliers Association in 1970, a number of serious problems in the lapidary industry were brought to light. Among these problems was the difficulty of controlling access to wholesale areas in club hosted gem and mineral shows. This poses a very real problem to club members, some of whom are opposed to having a wholesale section only because it appears to generate animosity among those fringe dealers and non-dealers who cannot satisfy the requirements. If the fringe dealers and non-dealers are admitted, the retailers on the floor give vent to their wrath and the wholesaler who is committed to the support of his retail customer must also complain.

ULW has solved the problem of admittance to the wholesale trade shows they manage through the simple expedient of issuing invitations to retail dealers. No invitation – no admittance. The exception to this rule is when retailers can be vouched for by one or more of the wholesalers present. Thus retail dealers are protected as much as is humanly possible against unauthorized entry by fringe dealers and non-dealers and are able to shop openly in discussing phases of the business with other retailers as well as with the wholesalers.

Seminars demonstrating various phases of lapidary and jewelery work are planned for those with limited technical experience. As retail dealers indicate additional needs for demonstrations, seminars and the like, they will be accommodated. ULW's philosophy is that the success of the wholesaler is dependent upon the merchandising capabilities of the retail dealer, therefore, it is in the best interest of both to insure that the retail dealer is well informed and well prepared to operate his business in a highly successful manner.

Retailer reaction to the Mineral and Lapidary Trade Shows sponsored by ULW has been phenomenal and gratifying, and many comments have been made concerning the much needed and now fulfilled need to absolutely separate retail and wholesale. Among the many comments is a letter from a retail dealer in New York State: "... Hope you had a pleasant trip home from the show in Peoria. We arrived home about 9:30 P.M. on Friday after travelling 1,560.2 miles round trip, very tired but very pleased with the show. Both Dick and I feel that the idea of a Wholesale Dealers Show gave us an opportunity to meet the people we deal with and a chance to 'see' the material, rather than pick from a catalog when we need stock for our own use. We like the idea of a central location – we could never get to see all the West Coast Dealers if we just 'took off' for a visit. Do hope the shows will continue yearly and that we will be invited to attend in '73."

Any retail dealer wishing an invitation to any of the ULW shows should write Dom Pardo, M-Line, P. O. Box 50005, Tucson, Arizona 85703. Any wholesale dealers desiring space should write John Patrick, P. O. Box 636, Station A, Richmond, California 94808.

Q. What is the present status of "Unknown #2" from the Foote mine, Kings Mountain, North Carolina? It occurs in lustrous brown plates or scales, looks a little like a chlorite. As far as I know they've called it #2 for years. What is its approximate composition?

John S. Whatley, Jr.
Macon, Georgia

A. This is one subject on which your editor can speak with authority as it is I who assigned the temporary name of unknown #2 to the mineral in question. There have been a number of new or not readily identifiable species discovered at the Foote mine. For convenience each has been given a number. Several of these are now established species: switzerite (formerly unknown #1), eakerite (#3), and brannockite (#7). Unknown #2 is a particularly difficult problem because it appears to have suffered alteration through oxidation. It is essentially a manganese-iron silicate, probably hydrated, and appears to be a chlorite-like mineral. Work on its description is not presently in progress but we do expect to complete it one of these days.

FRIENDS OF MINERALOGY

by Raymond W. Grant

FM Activities in Pennsylvania — Region 3

In the Spring of 1971 several FM members in Pennsylvania formed an action group to promote FM goals in the State. Founders of the groups were Raymond W. Grant, Lafayette College, Easton; Eleanor M. Kaufell, Philadelphia; and Davis M. Lapham, Pennsylvania Geological Survey, Harrisburg. This was prior to the formation of FM Regions and the organization was called the Conference on Preservation of Pennsylvania Mineral and Fossil Localities. The first meeting was held in Harrisburg on November 6, 1971, at the William Penn State Museum. Attending were 42 persons, with 18 State mineral clubs and 5 colleges represented. Efforts were thus begun, under the impetus of Friends of Mineralogy, to bring together in Pennsylvania all persons and groups interested in conservation of mineral and fossil localities.

A second meeting was held at Pennsylvania State University, University Park, on April 15, 1972. Attending were 52 persons, with 21 State mineral clubs represented. Since Pennsylvania and southern New Jersey had now become FM Region 3, it was decided to combine the Conference and FM Region 3 into one organizational unit, with FM acting as the sponsoring and coordinating agent. Membership of participants in FM would be encouraged, but not required; and chief emphasis would be placed on bringing together in common educational-conservational cause as many of the State clubs as possible. Dr. Lapham, who had accepted the Region 3 directorship, would act as chairman of the combined preservational organization.

The third meeting was held at the William Penn Museum in Harrisburg on December 9, 1972, under adverse weather conditions. Attending were 37 persons, with 10 State mineral clubs represented. Some of the major topics discussed are summarized below from the Minutes of the meeting:

The meeting began at 10:45 a.m. with vice-chairman Eleanor Kaufell presiding. Dr. Lapham's resignation from the Conference and Region 3 chairmanship because of serious illness was accepted regretfully, while heartfelt thanks was expressed for his dedicated services to FM and FM Region 3. A new chairman, Martin L. Anne, was elected by unanimous vote to replace Dr. Lapham later in the meeting, such action serving to place Anne's name as a nominee for an FM national directorship on the slate to be voted in at the FM Annual Meeting in Tucson, February 10, 1973.

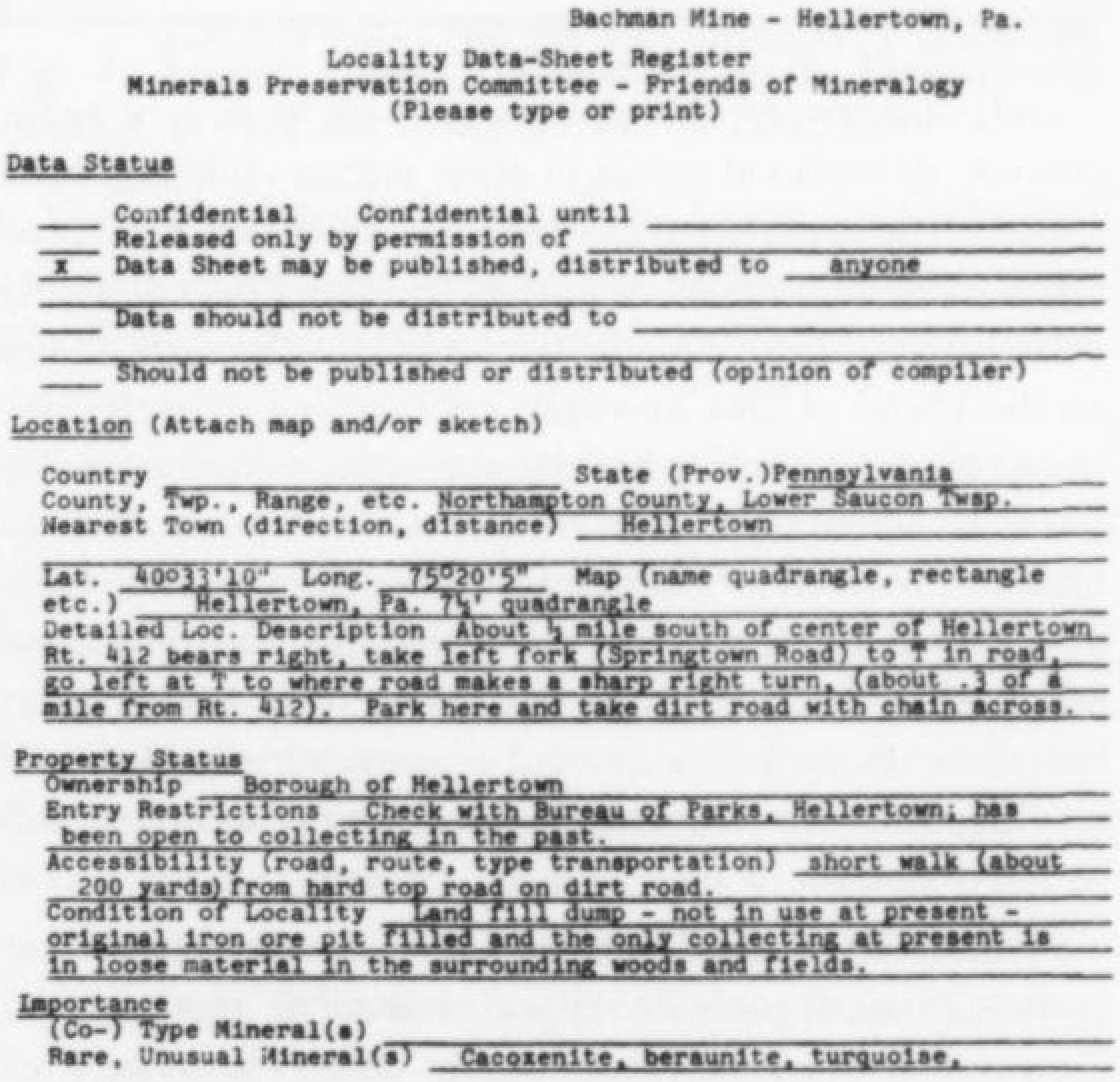
The Newsletter editor, Donald Schmerling, reported that the Region 3 newsletter was being sent to all FM Regions in the country as well as to FM Region 3 members.

Publicity chairman, Jay Lininger, quoted prices on the reprinting of Samuel G. Fordon's *Mineralogy of Pennsylvania.* The book would be hardbound and the original large-size format. It was approved that 1,000 copies be printed, provided enough shares to finance the project could be subscribed by Region 3 members in advance.

Education chairman James D. Stauffer submitted a two page report on future activities and priorities of the education committee.

Suggestions for possible projects of the museum committee were made by members to be sent to the Museum chairman.

Dr. Grant, Mineral and Fossil Locality Preservation chairman, discussed changes needed in the earlier-approved official letter of introduction to be used by responsible groups of FM Region 3 members and FM-coordinated State mineral club members to facilitate access to localities otherwise closed to collectors. A number of limiting specifications on use of the letter to guard against unauthorized use by non-FM-sponsored individuals or groups would be necessary. Dr. Grant then distributed State maps showing assignment of County areas to particular State mineral clubs for responsibility in the compiling of information for and resultant filling in of the Locality Data Sheets with respect to localities within those areas. A filled-in Data Sheet covering a well-known locality, the Bachman mine near Hellertown, was also handed out as a guide to any club or collector involved in the procedure.



Bachman Mine - Hellertown, Pa.

Locality Data-Sheet Register
Minerals Preservation Committee - Friends of Mineralogy
(Please type or print)

Data Status

___ Confidential Confidential until ___
___ Released only by permission of ___
x Data Sheet may be published, distributed to anyone
___ Data should not be distributed to ___
___ Should not be published or distributed (opinion of compiler)

Location (Attach map and/or sketch)

Country ___ State (Prov.) Pennsylvania
County, Twp., Range, etc. Northampton County, Lower Saucon Twsp.
Nearest Town (direction, distance) Hellertown

Lat. 40°33'10" Long. 75°20'5" Map (name quadrangle, rectangle etc.) Hellertown, Pa. 7½' quadrangle
Detailed Loc. Description About ½ mile south of center of Hellertown Rt. 412 bears right, take left fork (Springtown Road) to T in road, go left at T to where road makes a sharp right turn, (about .3 of a mile from Rt. 412). Park here and take dirt road with chain across.

Property Status
Ownership Borough of Hellertown
Entry Restrictions Check with Bureau of Parks, Hellertown; has been open to collecting in the past.
Accessibility (road, route, type transportation) short walk (about 200 yards) from hard top road on dirt road.
Condition of Locality Land fill dump - not in use at present - original iron ore pit filled and the only collecting at present is in loose material in the surrounding woods and fields.

Importance
(Co-) Type Mineral(s) ___
Rare, Unusual Mineral(s) Cacoxenite, beraunite, turquoise,

continued on page 148

THE COLLECTOR

by Richard A. Bideaux

The most abundant sulfide mineral by far is pyrite, FeS_2. Its brilliant metallic luster and attractive color, sometimes nearly golden, with world-wide availability of specimens, makes it among the first minerals to be added to any collection. Crystallizing in a rarely represented class of the isometric system, it has given its name to one of the special forms of this class, the pyritohedron (pentagonal dodecahedron). It crystallizes most commonly in cubes, octahedrons or pyritohedrons, alone or in combination. Another possible special form, the 24-faced diploid, is not uncommonly seen as small faces modifying pyritohedral edges. Both the pyritohedron and diploid are families of forms; some exceedingly complex crystals have been found with several of each of these, as well as the simpler forms.

The mineral occurs in nearly every geological environment. Its crystal habit is subtly controlled by impurities as well as conditions of formation, but these controls are not well understood. Half a dozen and more distinct periods of deposition of pyrite have been noted in some deposits, each with different characteristics. Occasionally two entirely different crystal habits can be seen on the same specimen, a condition rare for any other mineral.

Only in a few deposits is it worked for its iron or sulfur content, or enclosed values of other metals such as gold or copper. The massive pyrite orebodies, such as at Rio Tinto, Spain, contain millions of tons of the fine-grained, nearly pure mineral, but produce few crystals. The iron mines on the Island of Elba however, contain fine crystals associated with outstanding hematite crystals, or embedded in specular hematite. These mines, worked since Roman times for ore and still worked sporadically for specimens, have provided tons of fine crystallized material, with crystals up to six inches in diameter. Their form is characteristically pyritohedral but can be quite varied. Diploidal modifications are frequent, and very rarely a diploid will be the dominant or only form on a crystal.

Pyrite twins in a manner such that two interpenetrant pyritohedrons form with edges crossed at right angles. Especially from Elba, symetrically perfect examples of these twins have been found with cube faces truncating the cross, whence the name iron-cross twin law.

Vein-type deposits, where there was open space allowing unrestrained crystallization, can give outstanding examples. Mining operations at Quiruvilca, Peru, during the last decade encountered some beautiful octahedral pyrites. The best examples are crystals projecting from a base of the massive mineral, unassociated with any other species. These crystals are usually composite, with tiny octahedrons overlapping to form the larger crystals; rarely the faces will be mirror-smooth. In either case, their brilliance does credit to the species, and when the crystals reach a maximum size of seven or eight inches they are among the world's best mineral specimens. Other Peruvian underground properties at Morococha and Cerro de Pasco are also prolific pyrite sources, although not supplying the quality of those from Quiruvilca. Peruvian mining engineers and geologists I have spoken with tell of the large masses of crystals once used to cap the pillars at the entranceway to a local country club, and the fine samples to be seen on the mantles in miners' homes.

Vein deposits around Leadville and Central City, Colorado, are perhaps the best U. S. pyrite localities. Singles and groups of cubic crystals, often from four to six inches on an edge, can be seen in most major museum collections. These are clean, brilliant crystals, sometimes with entirely smooth faces, or more often lightly striated parallel to the cube edges. One variety, in which deep striations close off in arches, tending towards pyritohedral forms, earned the local name cathedral pyrite. Fine large octahedral crystals similar to those from Peru came from the Tucson

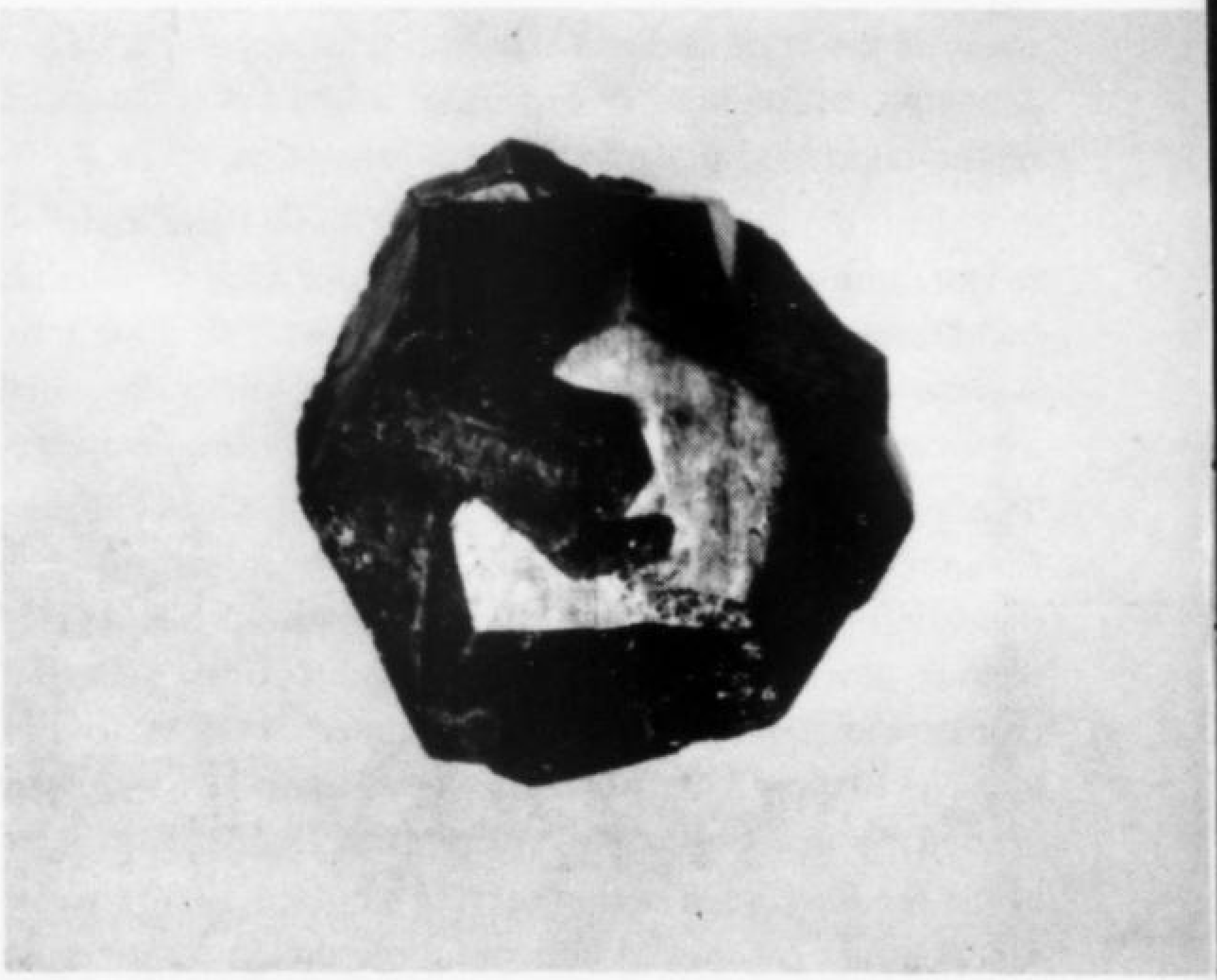


***Fig. 1.* Island of Elba, Italy. Four cm diameter "Iron Cross" twin.**

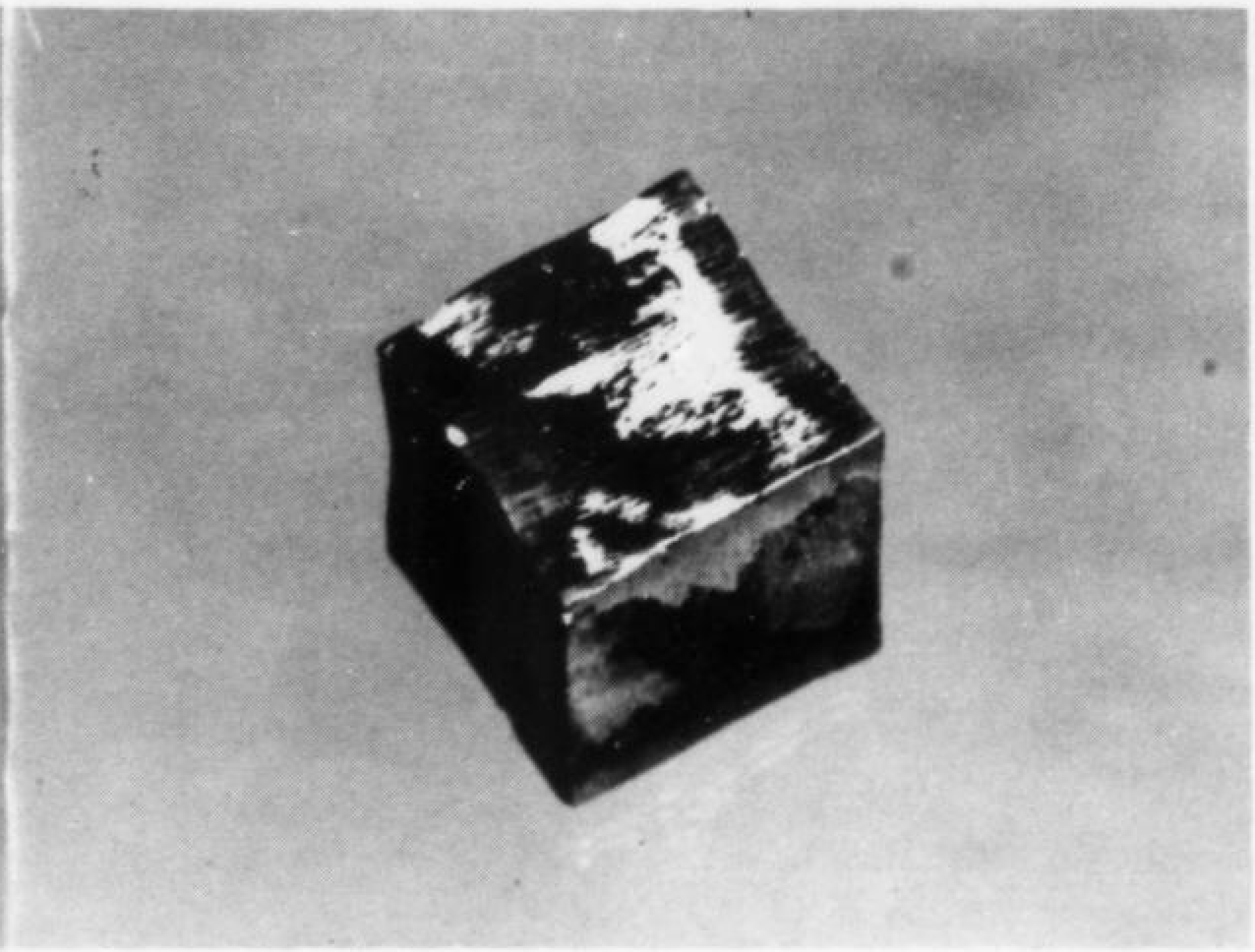


Fig. 2. **Logrono, Ambassaguas, Spain. Striated cube 2.5 cm on an edge.**

mine; these are among the best pyrites in the extensive suites on display at the Colorado School of Mines.

Sharp cubo-octahedral crystals with quartz have come from the veins around the porphyry deposits at Butte, Montana. Many of the other copper and molybdenum porphyry deposits of the Western U. S. have produced fine pyrite crystals, but in limited quantity. The best of these seem to come from clay-filled pockets in which the crystals have been able to reach full development. I have heard of notable occurrences of this type from Questa, New Mexico; Climax, Colorado; and Ajo, Arizona. Turn of the century operations at Santa Rita, New Mexico, and Morenci, Arizona, found pyrite crystals in the outer clay alteration zones. Rarely reaching two inches, these are interestingly filmed with black sooty chalcocite. They were widely distributed, and are still occasionally turned over on dealers' shelves.

Fine striated complete crystals and groups have been on the market lately from Logrono, Ambassaguas, Spain. These will certainly become minor classics in years to come. A clay matrix specimen has been pictured in the *Record,* vol. 1, p. 66.

Fine crystals can form completely imbedded in less hospitable matrices. Greenstones, schists, shales, etc., among metamorphic rocks, can be studded with pyrite crystals which may not be injured on splitting the rock. Sharp cubes and octahedrons, although not too large, are scattered attractively in chlorite schist at a talc mine near Chester, Vermont. Highly desirable because of their perfection, but unfortunately in short supply, are the octahedrons, sometimes symetrically distorted, from French Creek, Pennsylvania, found in similar materials. Many of these have been lost to decomposition since being placed in collections around 1900.

Sedimentary rocks, such as limestones and dolomites, will also allow good crystals to form by replacement. Crystals from the Westinghouse property, Duquesne, Arizona,

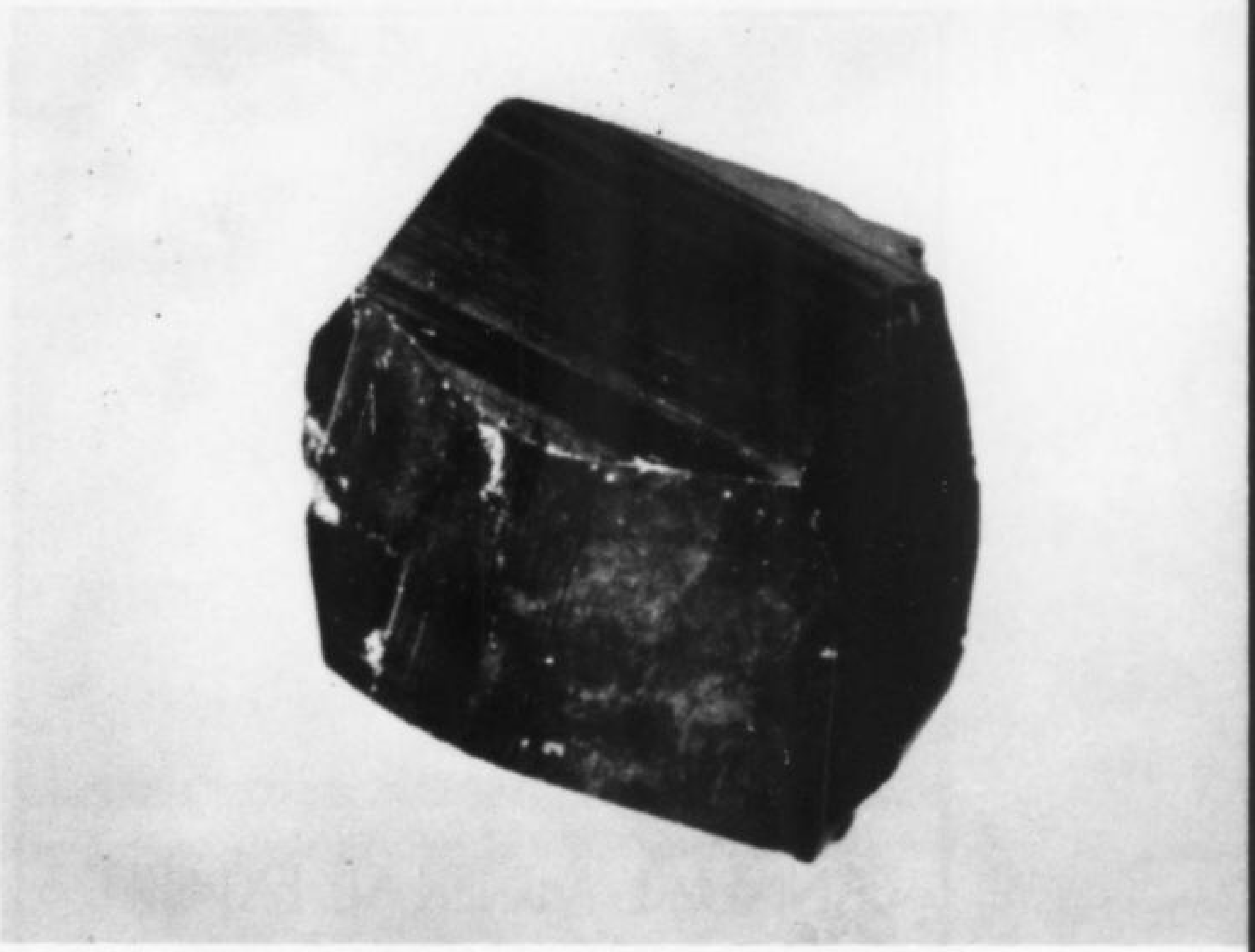


Fig. 3. **Trench mine, Arizona. Striated cubo-pyritohedron 7.5 x 7.5 cm.**

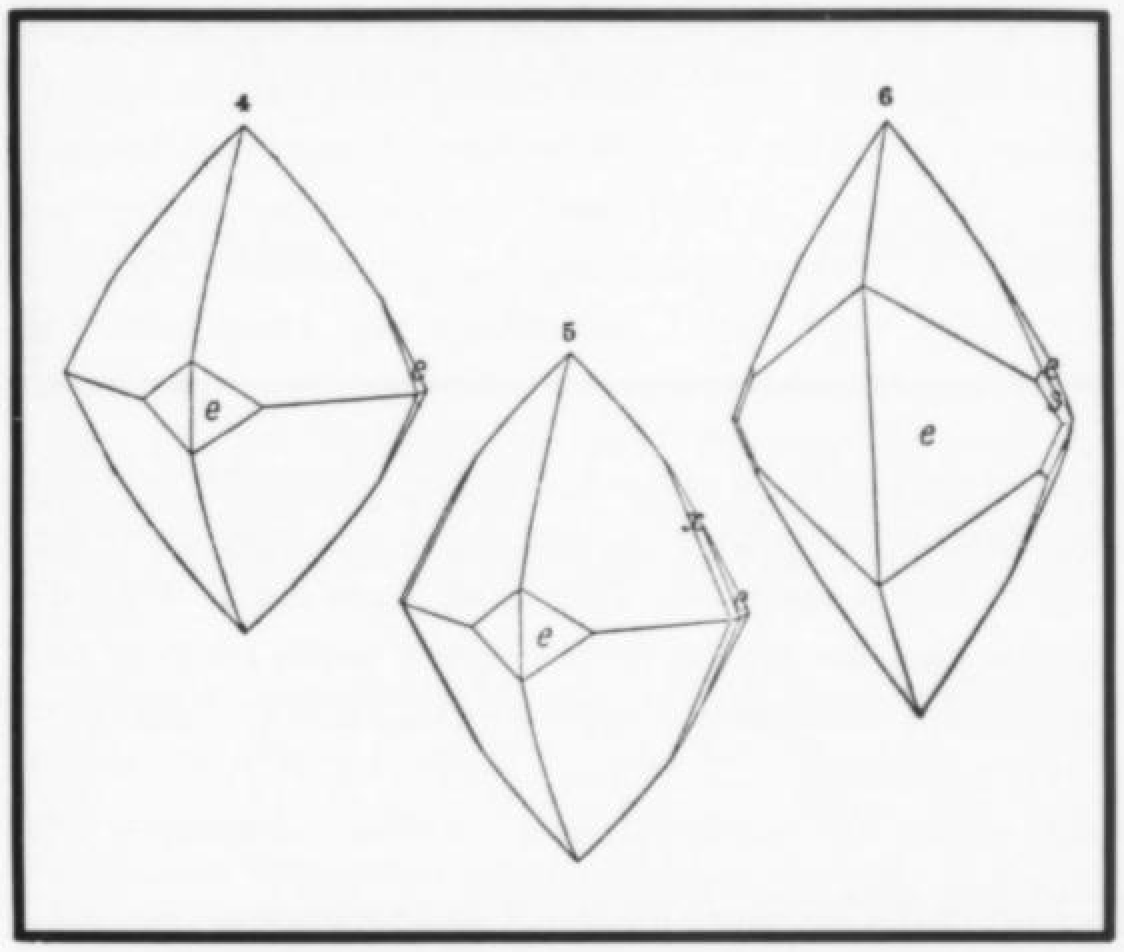


Fig. 4. **French Creek, Delaware County, Pennsylvania (from S. L. Penfield,** ***Amer. J. Sci.,*** 37, **211, 1889).**

to four inches; from Franklin, New Jersey, up to one and one half inches, and smaller but highly perfect crystals from Binn, Switzerland are among the best of these occurrences.

Pyrite can form exceedingly large crystals, but the quality of these never seems to be outstanding. There are many older references to large crystals from Cornwall, England, but these were probably only several inches across. Large cubic crystals were found around the margins of the Santa Nino orebody, Duquesne, Arizona, but were frozen in the matrix. Single crystal fragments recovered weigh well over a hundred pounds.

Dana's System (VII ed.) states: "Large octahedrons are records from Orlandini tin mine, Ubina, Bolivia." I wonder how these would compare to the octahedrons presently being imported into the U. S. from an unnamed, rediscovered prospect in Sonora, Mexico. Only the smallest hand-sized crystals have smooth faces, showing combinations of forms somewhat like those from Elba. With increasing size, the crystal faces become much rougher and stepped, but reasonably complete octahedral crystals reach around a foot, tip-to-tip. While a cubic foot of pyrite would weigh about 300 pounds, such a one foot octahedron will weigh only about one-sixth as much.

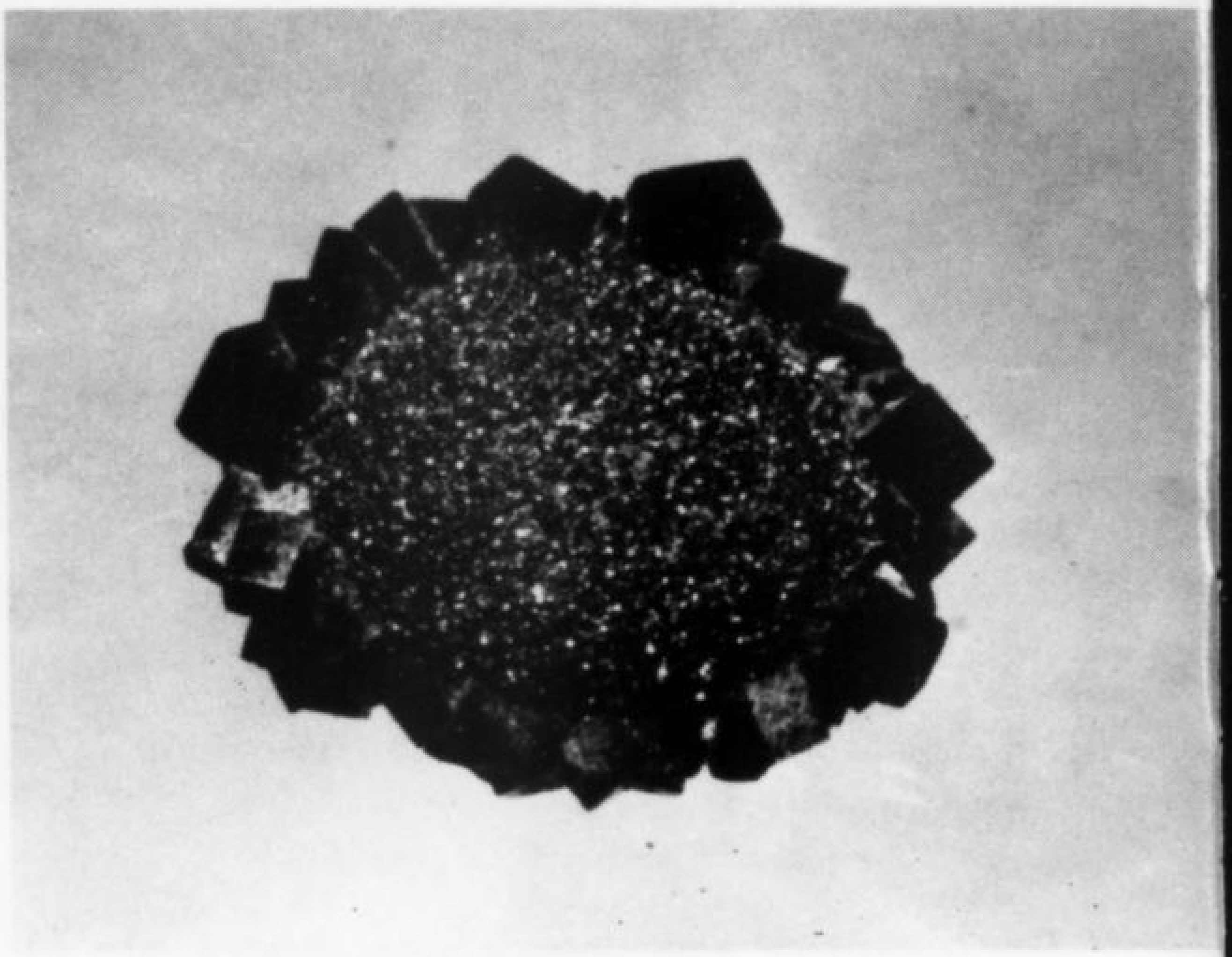


Fig. 5. **Dallas, Texas. Four cm across.**

Even larger faced fragments of crystals have been brought in, nearly three feet along an octahedral edge, and topping 300 pounds. Growth of these crystals has been interfered with by their matrix, a dense white opaque mica, with a texture very like coarse styrofoam.

Pyrite sometimes forms capillary crystals. Those from Rock Island dam, Washington, in vesicles in basalt with zeolites, notably paulingite, sometimes take a dozen three-dimensional right-angle turns in making their way across the cavity.

Other unusual occurrences worth mentioning which give nice specimens are the half inch or so pyritohedrons "floating" in clear quartz, from a pegmatite cross-cut by gold mining operations in Minas Gerais, Brazil. Drainage ditches dug during construction of the new Dallas-Ft. Worth jetport exposed curious jewelry-like pyrite aggregates. Larger cubes surround a pincushion-like central dome incrusted with minute cubes.

Preliminary Announcement of a Mineralogical Meeting in Tucson

REMEMBER
REMEMBER
REMEMBER

A mineralogical meeting will be held in Tucson, Arizona, Sunday and Monday, February 10 and 11, 1974, in conjunction with the 19th Annual Tucson Gem and Mineral Show, February 9, 10, and 11.

The meeting will be sponsored jointly by the Mineralogical Society of America, the University of Arizona, the Tucson Gem and Mineral Society, Friends of Mineralogy, and the Mineral Museums Advisory Council.

Two symposia are to be presented:
Mineralogy and Paragenesis of the Porphyry Copper Deposits
Impact of Modern Analytical Techniques on Mineral Nomenclature

Abstracts of papers to be considered for presentation at the general sessions should be sent to:

John W. Anthony, General Chairman, or Spencer R. Titley, Program Chairman
Department of Geosciences
University of Arizona
Tucson, Arizona 85721

Field trips are being developed to porphyry copper deposits in the region and probably to another outstanding mineral locality in Southern Arizona.

Yedlin on Micromounting, continued from page 102

source for micromount material, and have specimens that justify our enthusiasm. Write to Francesco Spertini, 105 Greenshields, Asbestos, Quebec. His material is fairly priced, and is superb in quality.

Mineralogical Research Company, 14770 Whipple Court, San Jose, California 95127, has furnished us with some excellent specimens. They're good, clean (Sharon Cisneros, who operates the company with her husband, cleans every specimens ultra-sonically before sending it out) fair-sized and low priced. After acquiring narsarsukite from last fall's find at St. Hilaire we sought similar material from other localities. Crystals of the mineral from Greenland were listed in the Cisneros' price list. We got enough for 5 mounts for less than five dollars, with a couple of duplicates for trading. Other things equally as good are available: arsenopyrite from Japan (with Japanese labels, yet!), California spinel, vesuvianite and black and gold garnets, to name a few. Send a stamp for a catalogue.

We have a notice of a meeting of the Rocky Mountain Micromounters, to be held in conjunction with the Denver Council of Gem and Mineral Societies 6th annual show. This will have taken place on May 12th, and the program will have included some interesting events: Richard Tripp of the United States Geological Survey, Denver, Colorado, on pseudomorphs, and Roy Sheppard, Denver Microscope Service, on care and cleaning of microscopes. Both of these subjects are of utmost interest to micromounters and should be included in the agendas of all clubs.

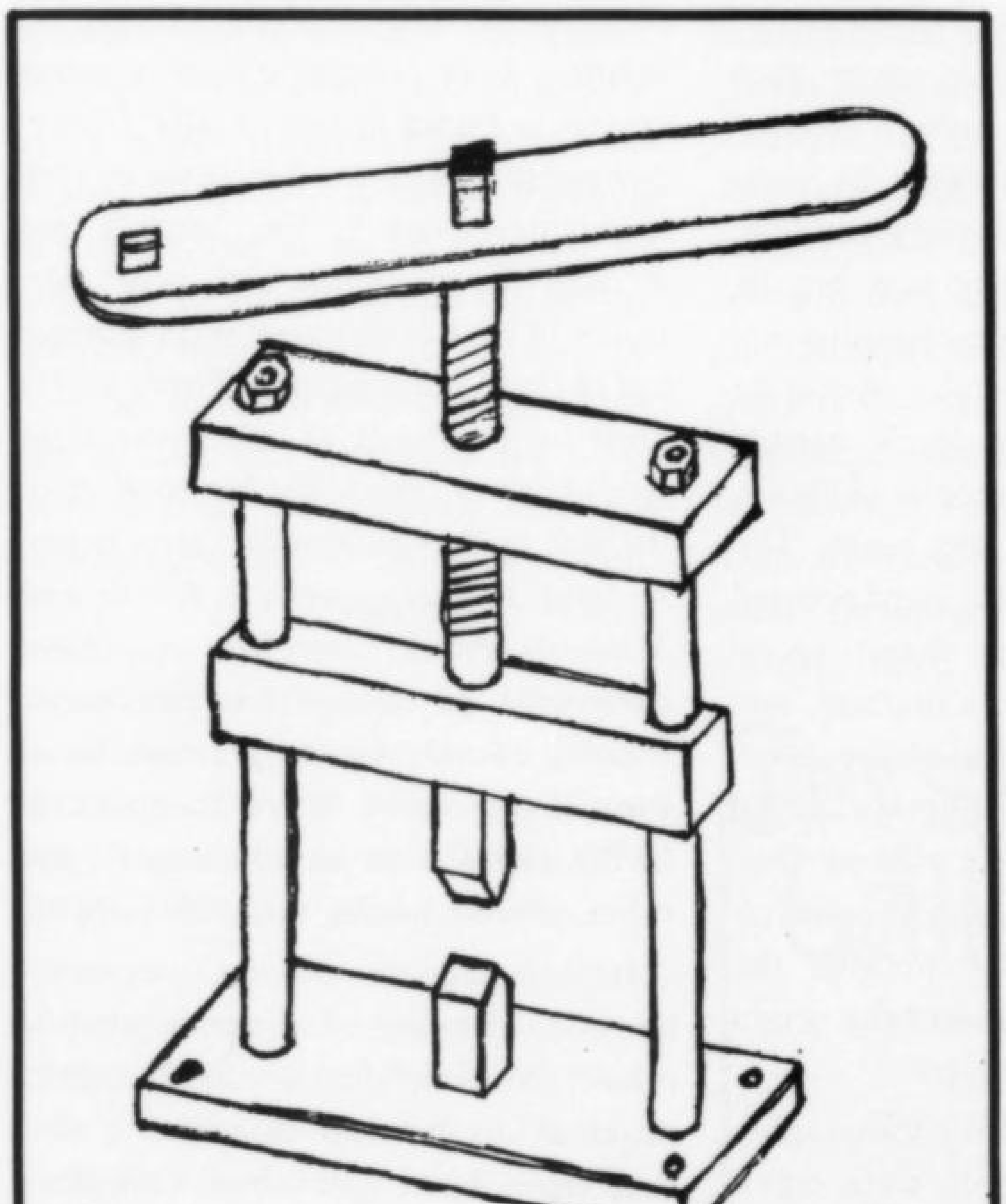


Fig. 4. **Yost Specimen Trimmer. 2 models at $32.50 and $25.50. Extra cutters available.**

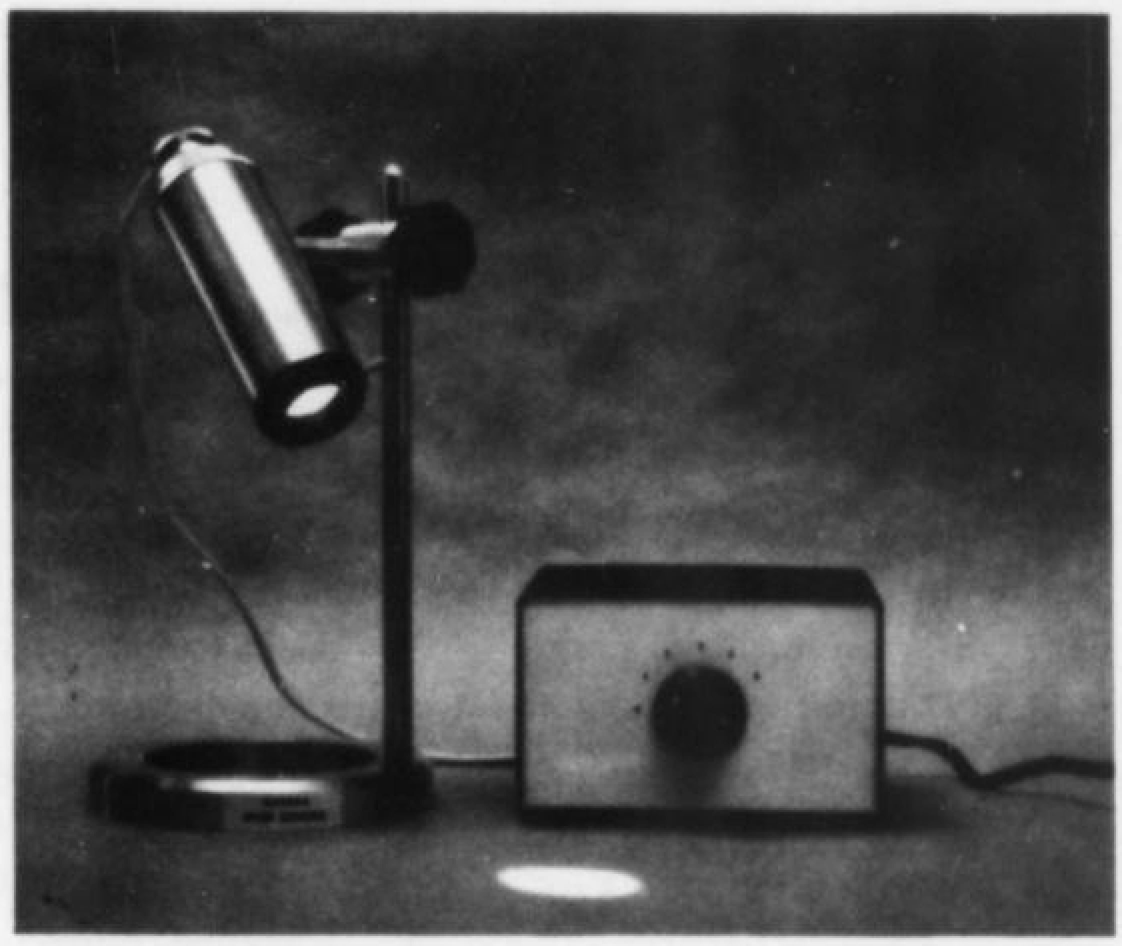


Fig. 5. **Microscope light by deHaas, Optical Engineering. Price $54.00.**

Time and again we have expressed the need for good lighting. Unfortunately, the lights sold by the producers of microscopes are expensive, running from about $85.00 to $135.00 for the best. Lesser ones just will not do well enough to justify the saving involved. So that the news of a superb instrument for about $54.00 is welcome. Designed somewhat similar to the Nikon light it is versatile, good looking, powerful and more than adequate. It includes the light and stand, the transformer, bulb, filter holder and iris diaphragm. It is manufactured and distributed by deHaas, Optical Engineering, 2734 Midvale Avenue, Los Angeles, California 90064. This is the light we are currently using. The designer is a micromounter, and knows what is needed.

Let's see what else. Marcelle Weber has found wardite at the G. E. Smith mine, Newport, New Hampshire; Demetrius Pohl, 51 Whaling Road, North Sydney, New South Wales, has sent some superb allanite crystals, in micros, of course, from the Mary Kathleen Uranium mine, Queensland, Australia, where they occur in a calcite, associated with uralite, garnet and some sulphides. Pohl promises an article for the *Record*, and we'll leave details of the find to his report; Louis Shrum advises that the Foote quarry at Kings Mountain, North Carolina, is not producing the rare minerals at present, and that a pocket of apophyllite was recently uncovered; advice from Toronto (May 1, 1973) has it that the quarry at Mt. St. Hilaire is closed to collectors — someone's crack hammer left on the dump got into the crusher doing much damage; Santa Monica's February micromount meeting turned up 76 microscopes, 160 participants, much swapping, fine lectures and, this year, no earthquake.

Buy and use a GOOD mineral book, affix labels to the specimens, take care of your microscope, and save your eyes — get a good light.

Neal Yedlin
129 Englewood Drive
New Haven, Connecticut 06515

The Record Bookshelf

***Rocks and Minerals*, by Joel Arem, Bantam Books Inc., Dept. KTC-1, 666 Fifth Avenue, New York, N. Y. 10019, (1973), 160 pp., 209 color plates, printed in Italy ($1.45).**

Considering the small size of this paperback (4 1/4 X 7 X 5/16 inch), it is amazing in both the number of good color photographs it contains, and the amount of mineralogy covered in the text. Basic rock and mineral groups are described and briefly discussed, as are about 180 mineral species, 20 gem materials, and 60 rock types. A table at the end lists physical properties of 235 mineral species, and is followed by a comprehensive index. Chapters are included which briefly cover ions and bonding, crystals and structures, determination of physical properties, color, classification, general rock groups and their origin, and even lunar rocks, all in a paperback only 5/16-inch thick! Information is boiled down so concisely and reads so smoothly that I would be inclined to recommend the book as a good review for reading prior to the final examination in a beginning, college-level mineralogy course. Unfortunately *Rocks and Minerals* has a significant number of errors and oversights.

Hundreds of terms and definitions are loosed upon the reader, and a few are not entirely accurate. The definition of the term *mineral,* for instance, is grossly inadequate. Only two (natural, inorganic) of the five basic determining factors are mentioned. The important qualities of being solid, having a definite atomic arrangement and a chemical composition varying within given limits are omitted — a serious oversight. Other terms are used in the text which are inadequately defined, such as *formation, traprock, tuff,* and *low* vs. *high symmetry.*

The statement that *granitization* refers to the *melting* of sedimentary rocks to form granite is clearly wrong, since granitization really indicates a metasomatic transformation without the formation of a magma. The definition of *fossil* would seem to include someone buried yesterday, or even cigarette ashes in a tray. The resurrection of the terms *basic* and *acidic* for mafic and felsic rocks is unfortunate, as these misnomers of the past have been out of use for a long time and are best forgotten. Other corrections might include the fact that not *all* basalts contain olivine (only olivine basalts), and certainly not all volcanoes are cone-shaped.

Omitted is the study of phase diagrams and stability diagrams essential to a real understanding of igneous and metamorphic rocks, but the casual reader would only skip over such information. The petrology section is therefore rather meager in comparison to the mineralogy section, although the color diagrams are interesting. The rock descriptions are not particularly useful. Accurate identification of rock types usually requires lab work or special skills far beyond the scope of this book. The novice reader would be hard-pressed to distinguish between hand specimens of, say, a basalt, a diabase, and an andesite on the basis of the information given. A tiny photograph of such rocks is completely useless. Despite all these inadequacies the petrology section still serves to give the reader a general overview of the origin and diversity of rock types.

As to the mineral photography, 15 of the 160 photographs were taken by Dr. Arem and 145 were taken by Lee Boltin. Technical quality is uniformly good; Dr. Arem makes use of his "internal explosion of light" technique with several specimens, and Lee Boltin's professional, dramatic use of backgrounds and lighting is a pleasure to behold. Apparently all of the specimens are from the Smithsonian Institution, and most are of exceptional quality.

Some of the photographs suffer from the extremely small format; a few are actually printed *smaller* than the size of a 35mm transparency. Others range in size up to full-page (4 X 7 inches) but most are small.

The specimen photographs are all labelled with species and locality, but as usual, no scale is given, so the reader is completely in the dark regarding the size of these great specimens.

A quick check revealed that at least 22 photographs by Lee Boltin have previously been used in such publications as Desautels' *Mineral Kingdom* and *Gem Kingdom,* White's *Color Underground,* and *Rock and Gem* magazine. The transparencies for some of these have been cropped or reversed, but were still obviously the same photographs. At least 8 more were of previously published specimens with only a slight change in lighting. One photograph of a sulfur crystal is found in both *Color Underground* and *Mineral Kingdom* as well as this new book by Dr. Arem. I find it difficult to sympathize with Mr. Boltin in his desire to get such mileage out of these photographs. There surely must be hundreds of other excellent specimens of sulfur, for instance, than the one he has published three times. At least 30 photographs in *Rocks and Minerals* should therefore not have been used. In my opinion the reader is being cheated by this practice; however, if the reader is not an avid collector and will never own any of the other mineral books, no harm is done.

It seems to me that far too many books on "Rocks and Minerals" simply rehash oversimplified crystallography, physical properties, localities, etc. that have been published countless times before. With the publication of Dr. Arem's compact *Rocks and Minerals* I feel sure that there are now plenty of books for beginners in mineralogy and mineral collecting, and that no more are needed. Publishers probably feel that unless they appeal to beginners they are limiting their potential market too severely; I disagree. What is now needed is a book or series which leaves the basics to others and concentrates only on presenting rare and beautiful minerals. The text could consist of pertinent information on the particular specimens, e.g. locality, size, collector, owner, market value, date collected, circumstances at the time of collection, a history of the specimen, etc. Detailed discussion of some of the localities would not be out of place. But certainly we have seen enough explanations of the six crystal systems.

Although rather uneven, *Rocks and Minerals* is nonetheless adequately written, photographed and produced. The price is reasonable, especially in view of the large quantity of information in the text, and the graphics are nicely done. *Rocks and Minerals* is for people desiring a colorful, concise little book which takes an academic rather than anecdotal approach to mineralogy. However if Dr. Arem's intention was to replace the classic *Rocks and Minerals* of Zim and Schaeffer, it is this reviewer's opinion that he has failed. Dr. Arem's version is far too technical to be enjoyed by most 12 - 16 year-olds, and the petrology sections are badly in need of reworking. In many instances the paintings in Zim and Schaeffer are more illustrative of the minerals than are the photographs in Dr. Arem's version.

Wendell E. Wilson

***The World of Minerals,* by Vincenzo de Michele; photographs by Carlo Bevilacqua. World Publishing Company, Times Mirror, New York, 1972, 128 pp., 185 color plates, ($5.95).**

Vincenzo de Michele and Carlo Bevilacqua have teamed up again on another fine mineral book. As with their previous work, *Color Treasury of Crystals* (reviewed here, V. 3, no. 6, p. 276), all specimens were photographed by Bevilacqua at the Natural History Museum of Milan. And again it is difficult to find fault with the photographic technique. Skillful use of backgrounds and lighting in most cases, as well as good color reproduction, has produced plates of a reasonably high quality.

The text by Dr. de Michele is well-written and informative. Newcomers to mineralogy should enjoy the clear, concise mineral descriptions. Knowledgeable collectors will be surprised to find that this book contains some valuable data on European localities. Certain localities listed as *major* occurrences are not to be found in Sinkankas' *Mineralogy for Amateurs* (the best, modern, domestic source of locality data) and were probably unknown in Dana's time. For instance, under important argentite localities the Czechoslovakian deposits at Kremnica and Banska Stiavnica are listed, as well as the well-known Pribram deposit. Good crystals of autunite are noted from Sabugal, near Guarda, Portugal. Italian localities are recorded in great numbers; it is surprising to see how many different, attractive minerals come from localities in Sardinia.

Contained in this 9 X 12 inch hardbound volume are 185 handsome color plates. Some are as large as 10 X 13, many are 8 X 10, and none are smaller that about 3 X 5. The *average* plate size is about 5 X 8, hence the volume contains over 50 square feet of color photographs! About 80% of the page space is devoted to photographs; the remainder is taken up by text and crystal drawings. About 40% of the specimens are from Italy and 26% are from other European countries. The remaining third of the specimens are from Asia, Africa, Australia, and North, South and Central America. A mere 8% of the specimens are from the U. S. The only serious criticism is that this work, like so many others, gives no scale for estimating the size of the specimens. Bevilacqua did include size data in his *previous* volume, but he has inexplicably dispensed with it in *The World of Minerals.*

About 30 of the 185 specimens pictured are of rather low quality ("study grade") and could have been replaced. The remaining 155 specimens range in quality from good to incredible. A wide variety of very rare minerals are illustrated; photographs of many of these species have probably never before appeared in print. Examples include nagyagite, jordanite, cotunnite, sphaerocobaltite, *unaltered* borax, cornetite, euchroite, bazzite, bavenite, nepheline *crystals,* and hauyne. Of course there is an abundance of unusual (to Americans) localities. Stateside collectors will be amazed by the fine Sardinian silver, Romanian pyrrhotite, Australian stibnite, Italian scheelite, Mongolian turquoise(!), and Finnish harmotome.

Some of the old favorites are there too, including a Harz proustite, Bohemian cassiterite, Sardinian phosgenite, Red Cloud wulfenite, and many others.

Considering the average cost of 3 cents per color plate, no one can say the price is exorbitant, especially in view of the large size of the plates. In fact, if you are thinking of papering your wall with mineral photos, the cost works out to about $1 per square yard — not bad!

With the publishing of *The World of Minerals* and *Color Treasury of Crystals,* the collection of the Natural History Museum of Milan has been documented beyond anyone's expectations. Most of us will never have the opportunity to visit Milan, and so are lucky to have these works available to us. Hopefully books will be published in the future which document collections in other prominent European museums. Bevilacqua, are you listening?

Wendell E. Wilson

***Color Underground,* photographs by Lee Boltin; text by John S. White, Jr., Charles Scribner's Sons, Publishers, New York, N. Y., (1971), 63 pp., 49 color plates, ($6.95).**

This 10-1/2 X 7-1/2 inch, hardcover volume by the editor of the *Mineralogical Record* contains brief, layman-level discussions of general mineralogy, crystal systems and habits, mineral formation and twinning. Each mineral photograph is accompanied by a paragraph discussing such details as mode of formation, common habits, colors, and occasionally a diagnostic physical property. In general, though, the tabulation of great quantities of data on physical properties, crystallography, world localities, etc., has been left to other tomes. The purpose is not so much to teach as it is to serve as a guide behind the scenes to some superb specimens from the Smithsonian. The captions present, in a conversational way, interesting facts and anecdotes relating to the specimens photographed.

The primary focus of this volume is on large, color photographs of fine mineral specimens from the Smithsonian Institution. Lee Boltin has done an excellent job of photographing the 49 specimens with only a few exceptions; the dark gray quartz crystal on a dark gray background is rather drab, as is the gray pectolite on a gray background. The hematite, goethite and barites are not particularly attractive or interesting specimens to this reviewer. *Color Underground* curiously includes about 20 minerals which *have* no color (i.e. are black, white or gray), but skillful use of lighting and colorful backgrounds in most cases have yielded beautiful, high-quality plates.

Reproduction is excellent and the plate size is generous, ranging from about 3-1/2 X 4-1/2 inches to 7 X 8-1/2 inches, with most plates on the large side. Specimens worthy of special note are the magnificent Brazilian tourmaline, the Smithsonian's justly-famous chrysoberyl sixling, a supremely beautiful Daybreak autunite, and an exceptional New Jersey stilbite. Also pictured are a veritable *boulder* of crocoite crystals, and an immense Tzumeb azurite. Boltin has an interesting technique of balancing specimens on one point, without other visible means of support. The result is quite elegant. Except for the azurite, scale is not given, so size is a mystery to readers who have never seen the real specimens.

Although the text is aimed at the mineralogical newcomer, the color plates should be a joy to anyone, no matter what his background. The price is comparable to the price per color plate of Desautels' *Mineral Kingdom* (1st edition) and *Gem Kingdom,* but is much higher than the price of mineral books printed in Europe. My only

serious complaint about *Color Underground* is that is should have been six times as long.

Wendell E. Wilson

Nambu, M., Chairman, Editorial Committee, *Introduction to Japanese Minerals*, Geol. Surv. Japan, 208 pp., 123 photos & fig., 10 color & 17 monochrome pl., 4 maps, 1970.

(This book was distributed at the Seventh General Meeting of the International Mineralogical Association in Japan in 1970, and is not available for purchase. However, copies have been made available to interested libraries so your local or institutional library may very well have it.)

This is the first book dealing with Japanese minerals to be published in English since Wada's *Minerals of Japan* was published in 1904. Japan's 596 mineral species are surveyed in 210 pages with remarkable success. There are ten color plates, twenty-seven monochrome plates, and numerous photographs and line drawings throughout the text making this book unusually well-illustrated.

The book is divided into five chapters. The first is a brief account of the development of mineralogy in Japan. In the second chapter the 596 mineral species occurring in Japan are briefly surveyed. Arranged according to Strunz's *Mineralogische Tabellen*, each species is entered with its chemical composition, space group, unit cell dimensions, and localities. The list is complete through April, 1970.

Chapters three and four are devoted to careful descriptions of the new mineral species described from Japan. In chapter three are treated the twenty-seven valid new species. Chapter four treats the thirty-eight discredited species. The descriptions are quoted from the original papers with corrections where necessary. Remarks include mention of more recent occurrences, reason for discreditation, etc. Each description is well-referenced.

Chapter five, "Characteristic Minerals of Japan," is devoted to a more complete discussion of fifty minerals such as stibnite, chalcopyrite, axinite, pyroxmangite, and scorodite for which the Japanese localities are especially notable. It also includes a table for correlating the presently used prefecture system with the old provincial system, which is of great use for updating nomenclature. Also listed are the major mineralogical museums and collections.

An index of mineral names appears at the back and four separate locality maps are included in a pocket.

In summary, the book's strengths are: its broad coverage, the well-referenced descriptive data, and the abundant illustrations. To the professional mineralogist this book should prove to be a useful reference. To the amateur, it should prove especially stimulating for its focus on the rare minerals and notable occurrences of Japan.

Carl A. Francis

Friends of Mineralogy, continued from page 139

rockbridgeite, strengite
Rare Crystal(s)/Size Small single crystal of wavellite - Wherry(1918)
Unusual Abundance of Wavellite
Gem Source of
Historical Operated from 1887 to 1892 for iron ore - about 15,000 tons of ore removed before the mine was abandoned.

Endangered by has been land filled and can easily be lost to building

Loc. Uncertain ____ Loc. Unknown ____ Unusual Genesis ____
Unique Genesis ____ Unusual or Unique Associations ____

Resources (incl. potential) very small but should be checked.

Other

Recommendations (for FM activity/program, include any cost estimate)

1. That permission for an FM sponsored trip by obtained and the area checked carefully for any remaining material which could be collected and distributed to schools, museums, etc., because the locality could still yield some specimens, but it will become more and more difficult.
2. Specimens in existing collections be preserved as far as possible. (R.W.G.)

Minerals Description (note if verified (V) or reported (R), also quality

Wavellite (v) - radiating groups and single crystals (white)
Cacoxenite (V) - radiating yellow fibrous spheres
Strengite (V) - very small globular groups - slightly pink
Beraunite (V) - radiating clusters of brownish red crystals
Rockbridgeite (V) - very small dark green crystalline coatings
Cryptomelane (V) - black coating and botryoidal crusts
Goethite (V) - the usual brown fibrous masses and granular brown material making up the matrix of most specimens
Turquoise (V) - pale, blue-green micro crystals and botryoidal crusts

Geology (Resumé, incl. unusual genesis or associations)

The iron ore is in the Cambrian quartzite and conglomerate known as the Hardyston formation. This rock has been brecciated and mineralized with the formation of jasper and iron oxide (goethite) after which the phosphate minerals formed in cavities and cracks in the sandstone and goethite.

References (To locality and/or mineral, include specimens in important Museums)

Miller, B. L., Geology of Northampton County, Pa., Pa. Geol. Survey, Bull. C48, 1939, p. 459 to 461 - also No. 40 on geologic map and in text p. 339.
Wherry, E. T., U.S. Nat. Mus. Proc. vol. 47, pp.501 to 511, 1914
Wherry, E. T., U.S. Nat. Mus. Proc. vol. 54, pp.373 to 381, 1918
Zodac, P., Rocks and Minerals, Vol. 28, p. 13, 1953
Montgomery, A., Mineralogy of Pa., Acad. of Nat. Sci. of Phila., s.p. 9, p. 19, 32, 1969
Montgomery, A., MSP Keystone Newsletter, Nov. 1964 and Nov. 1968
Also a master's thesis at Lehigh University by Louis H. Koch of which no copies could be located in the past. (R.W.G.)

Submitted
By Marge and Vincent Matula (with additions by R.W.Grant) Date Nov. 1972
Address

A number of reports on specific State localities were made: *New Galena, Pa.* will, in the near future, be under water. Minerals found in this area should be listed and specimens preserved. Mrs. Betty Clauser, member and editor for the Bucks County Earth Science Club, very active in this area, gave a slide presentation and commentary on New Galena, past and present, its historical importance and the future of this area. She made available copies of the report "A Brief History of Lead Mining at New Galena" and the minerals reported or suspected at this locality. Betty and John Clauser also had free samples from New Galena for everyone.

Cornwall, Pa. — Bob Smith, Pa. Geological Survey, reported Cornwall is open for field trips and requests should be made through the office of Bethlehem Steel Corporation at Cornwall, Pa.

Hellertown, Pa. — Dr. Grant showed slides of the old Bachman iron mine which was described on the locality data sheet that he handed out. It has been filled with garbage by the city of Hellertown, but some specimens can be found in boulders in the surrounding fields.

Bellwood, Pa. — John Way of the Pennsylvania Geological Survey showed slides of the type locality for celestite in Bellwood. It is accessible but the area is small and would not be a good place for a large number of collectors.

Rossville, Pa. — Jay Lininger reported that the copper minerals from the road cut are no longer available.

Audubon mine, Ecton, Pa. — George Buchanan reported that nothing is happening at present in this area, although eventually some building will probably take place.

Chester Co. mine, Pickering Hunt Club, Phoenixville, Pa. — Joe Varady stated that this property will be sold in the near future and we should watch the area to see what the new owners will do with it.

Solebury copper mine, Washington's Crossing State Park, Pa. — the Clausers investigated this at Davis Lapham's suggestion that it might be the oldest copper mine in the U. S. Apparently it is completely covered and there is no material available.

Following the meeting was a banquet and later an illustrated talk on "Mineral Collecting in Brazil" by Dr. Richard V. Gaines of Kawecki-Berylco.

Anyone interested in securing more detailed information on these meetings and the program of FM Region 3 in Pennsylvania, should contact Region Secretary, Mrs. Eleanor Kaufel, 4028 Benson Street, Philadelphia, Pa. 19136.

Material for the Friends of Mineralogy column should be sent to A. Montgomery, Geology Department, Lafayette College, Easton, Pa. 18042.

MIDWEST FEDERATION CONVENTION AND SHOW

Site of the 1973 Midwest Federation Show is fossil-famous Cincinnati, the hilly Queen City nestled in the Ohio Valley along the curve of the Ohio River. The show will be held July 26 - 29 and will use the entire facilities of the Cincinnati Convention-Exposition Center, a modern air-conditioned building on the edge of downtown Cincinnati and adjacent to I-75. Stouffers Cincinnati Inn has been designated as convention headquarters; it is connected to the Convention Center by a covered walkway.

Headlining the speaker program are the following well known experts: from the Smithsonian Joel Arem, Paul Desautels, and John White; from the Lizzadro Museum Russell Kemp; from the Lapidary Journal staff June Zeitner; mineral collector and author Richard Bideaux; fossil collector Cecile Dulak. Lecturer for the Friends of Mineralogy is William Pinch.

Augmenting the speaker program will be a series of Earth Science films to be shown throughout the show. For the children, cartoon hours are planned.

More than 200 exhibits will be on display; some coming from as far away as Hong Kong. Exciting exhibits from the Smithsonian Institution and the Lizzadro Museum as well as from well known craftsmen and collectors in the hobby will be featured.

The popular "swapper dollars" will be available to all hobbyists who wish to use the swap area; these always insure an active exchange of specimens. Swapper dollars may be accumulated and used at retail and equipment dealers to purchase their wares.

Run-of-the-mill show? We don't think so! Would you believe arrangements have been made for you to go caving within minutes from the Convention Center? The city's Museum of Natural History boasts a life-sized replica of a real cave, complete with flora and fauna, nooks, crannies, winding passageways, and a waterfall.

The traditional Saturday night banquet will be in the form of a Banquet-on-a-Boat, a four-hour Ohio River cruise and buffet supper complete with music for listening or dancing.

A complete information packet can be yours by writing show chairman Terry Huizing, 5341 Thrasher Drive, Cincinnati, Ohio 45239. Included is general information, a list of dealers, advanced registration form, motel and parking directory, application for display space, and camping information.

Display Chairman is Mr. G. W. Claybaugh, 5331 Thrasher Drive, Cincinnati, Ohio 45239.

To the Editor

PHOTOGRAPHS – A REPLY

Dr. Gaines' comments about some recent cover photographs on the *Record* have been voiced by others, namely that the colors are "inaccurate". This viewpoint cannot be logically supported, nor is it consistent with the fact that numerous other photos, taken exactly the same way, would be generally considered "accurate".

"The color" of a mineral specimen is a consensus among observers, given a particular standard of lighting conditions. Most observers choose "room light" as a standard. For my photographs, I choose a more intense source. It should be noted that I use *only* white light sources (photofloods, microscope illuminators, etc.) and Kodachrome film, no filters or colored lights. The colors of minerals in my photos are absolutely accurate. I can demonstrate this in seconds to anyone, using the original specimen and comparing what is seen to the photograph. The cinnabar (vol. 3 no. 5) and rhodochrosite (vol. 2 no. 3) specimens are, in "normal light", drab brown objects of little photographic interest (except perhaps in black and white). Add a *single* strong light source to the incident illumination and both specimens are transformed into glowing objects of breathtaking beauty. Is this "trick lighting"? Is it a misfortune that I would personally prefer to see the specimens lit "properly" than in light far too dim to appreciate their "true color"? By the reasoning used by Dr. Gaines the elbaite on the cover of Vol. 2, no. 4 is grossly inaccurate. As displayed in the Gem Hall of the Smithsonian the specimen is illuminated with small, low intensity lamps. If lit more intensely its "true" color (that seen in the photograph) would be evident.

Dr. Gaines' opinion regarding the esthetics of some cover photographs seen on the *Record* is not unique, and he is entitled to it. But, in fairness, to criticize these photos on the basis of standards he has not chosen to define is logically unacceptable, and esthetically questionable. I am truly sorry that Dr. Gaines has never seen a cinnabar like that on the *Record* cover. I see such things constantly, because I choose to look for them. It is hard for me to believe that Dr. Gaines works in such dim light. Just think of all the beauty he has missed through the years!

Joel E. Arem
Smithsonian Institution

DEFINING MINERALS

Dear Sir:

I have tried to find a definition of a mineral, and I think it could be described in the following terms:

1. A mineral is a mono-phase chemical compound that occurs in nature, as a rule, and is the result of natural actions, without the active planning of mankind.

2. If a mineral is secondary, i.e., virtually resulting from a chemical reaction, the reaction partners must have a natural origin.

3. Never can a physical mixture, an aqueous reaction or a gas be called a mineral.

With this attempted definition, I include things like ice, calclacite, armalcolite, and butlerite. I think that the calclacite had its origin in natural factors (the generation of acetic acid from wood under the influence of certain micro-organisms; this acetic acid subsequently reacted with the calcium phosphate in the bone that was displayed), and occurred without the active planning of humans to make it! After all, there are easier ways to prepare a compound with the composition of calclacite. The same could be said about butlerite.

It is true; had there been no fire in the mine butlerite would, most probably, not have been found; and if the fossil bone had not been stored in a box made of that particular wood, the acetic acid would not have been formed. If there had not been Armstrong, Aldrich and Collins shot towards the moon, no armalcolite would have been brought back. But we cannot say that they were sent to the moon *in order* to bring armalcolite back; it just happened, so to say "by accident", and so man's active planning has, at least in this respect, not been obvious. And that can be said about so many minerals that are not questioned at all.

On the other hand, I exclude things like the aromatic principles of plants, the gasses that make up air, and, of course, the man-made chalcanthite crystals you refer to. It should be stressed that a mineral has a locality where it has been found, and this locality is *in nature* (exception: calclacite). The chalcanthite crystals from flooded mines could, in my opinion, actually be called minerals; the mines were not flooded with the aim of obtaining these crystals or even this compound.

I am aware that a "must" is that the mineral dealer or the person that offers the spectacular chalcanthite crystals, the pink halite, and so on, is honest;

that is, he states clearly that the superb-looking material is, in fact, artificial. If he does so I cannot see any objection against his activities. And if he is not honest, he will have lost his name forever once the trick has been found out. And shouldn't we trust the human race as such?

Lourens Wals
Beerse, Belgium

KIND WORDS

Dear Sir:

The Nov/Dec issue of *MR* was enjoyable and informative. Being a part time micro collector, I always turn first to Neal Yedlin's column which never fails to intrigue me. The article on the 79 mine was also interesting. Many of the terms used by Mr. Keith were strange to me, and I attempted to look them up in some standard works. I found some of them, and some I didn't.

By the way, I made good use of the *Glossary of Mineral Species 1971.* It was all very stimulating, but perhaps your authors could be a bit more informative on the terms they use — we are not all professional geologists or mineralogists. The particular terms I mention are *supergene* and *hypogene* solutions. I understand these are involved in the deposition of ore bodies. This is pure speculation because of my incomplete understanding of the article.

My general assessment of your magazine is that it is excellent. You probably get a lot of troublesome letters, which you adequately answer; and I am glad to note you tread the middle ground. I feel it is better for subscribers to disclose their sentiment than to remain silent. This gives one a basis for subsequent action.

E. W. Easter
Norwalk, Connecticut

***Supergene** = enrichment through descending solutions, **hypogene** = enrichment through ascending solutions. Ed.*

NOT PIOUS

Dear Sir:

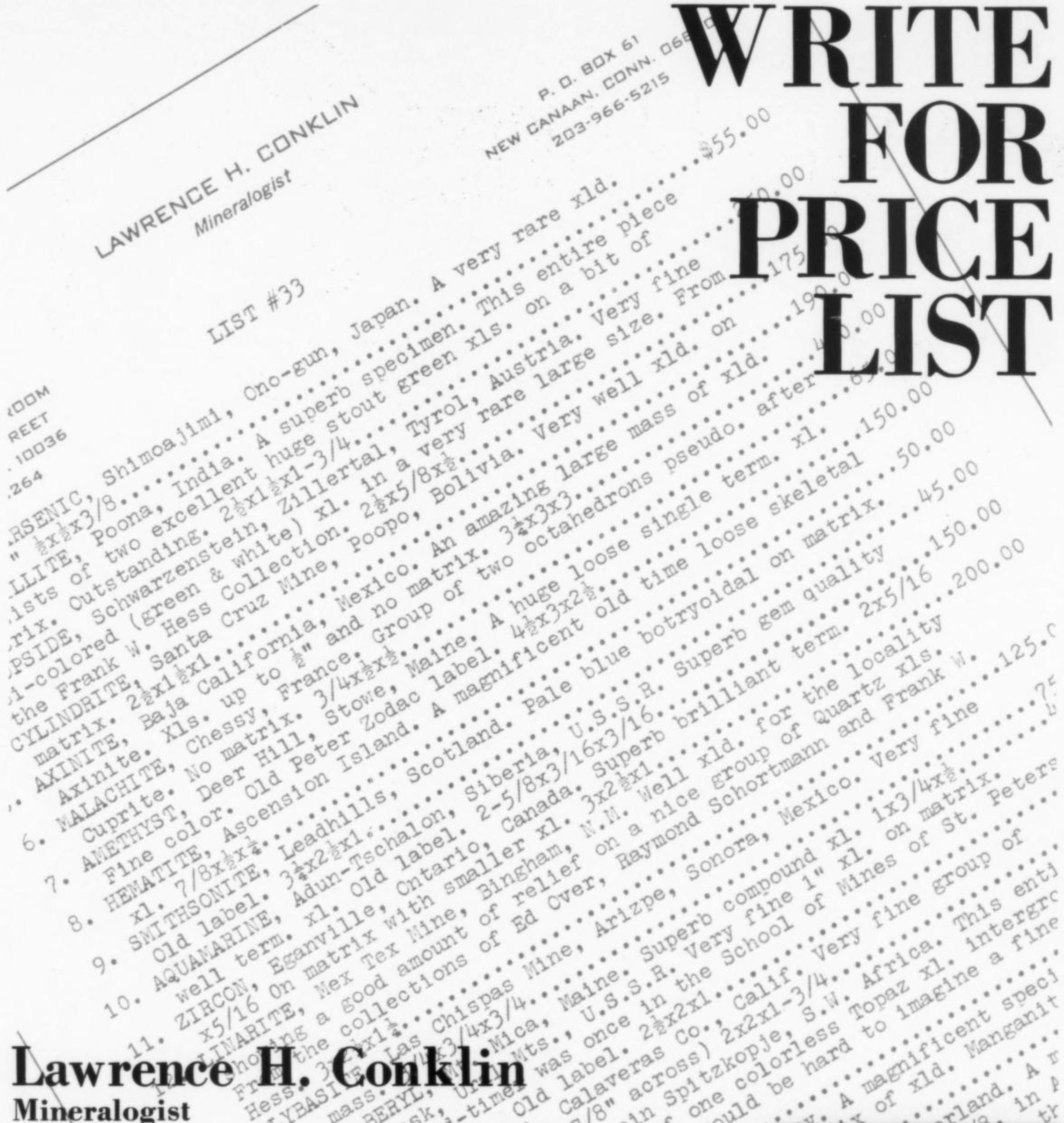
I was a little amused as I read the letter from Rich Kosnar in the last issue of *MR.* Surely Rich and I have known each other long enough so that he could have identified me as one of the "pious" curators who rush around to do a little pre-show buying. I don't mind being accused of pre-show buying, but "pious" about it — good grief!

One of the things I admire about Rich is his ability to pursue and successfully acquire fine specimens. He and I often cross paths and discover we are using the same procedures. Surely, I would be derelict in my duty as curator if I didn't pursue specimens with vim and vigor as long as what I do is moral and legal. I'm pious about that! Aside from that, I'll get the specimens we need anywhere, at any time, from anyone who will part with them.

All of this is not in contradiction with my feelings about the editorial on pre-show selling. Rich and everyone else who cares should know that I was, and still am, 1000% in *dis*agreement with the editorial.

Paul E. Desautels
Smithsonian Institution
Washington, D. C.

WRITE FOR PRICE LIST



LAWRENCE H. CONKLIN
Mineralogist

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ROOM
REET
10036
264

LIST #33

RSENIC, Shimoajimi, Ono-gun, Japan. A very rare xld.
" ½x½x3/8..............................$55.00
LLITE, Poona, India. A superb specimen. This entire piece
ists of two excellent huge stout green xls. on a bit of
rix. Outstanding. 2½x1½x1-3/4..........................0.00
PSIDE, Schwarzenstein, Zillertal, Tyrol, Austria. Very fine
i-colored (green & white) xl. in a very rare large size. From
the Frank W. Hess Collection. 2½x5/8x½..................175.0
CYLINDRITE, Santa Cruz Mine, Poopo, Bolivia. Very well xld. on
matrix. 2½x1½x1..190.0
. AXINITE, Baja California, Mexico. An amazing large mass of xld.
Axinite. Xls. up to ½" and no matrix. 3¼x3x3..............4 .00
6. MALACHITE, Chessy, France. Group of two octahedrons pseudo. after
Cuprite. No matrix. 3/4x½x½.................................6 .00
7. AMETHYST, Deer Hill, Stowe, Maine. A huge loose single term. xl.
Fine color. Old Peter Zodac label. 4½x3x2½..................150.00
8. HEMATITE, Ascension Island. A magnificent old time loose skeletal
xl. 7/8x½x¼..50.00
9. SMITHSONITE, Leadhills, Scotland. Pale blue botryoidal on matrix.
Old label. 3¼x2½x1...45.00
10. AQUAMARINE, Adun-Tschalon, Siberia, U.S.S.R. Superb gem quality
well term. xl. Old label. 2-5/8x3/16x3/16....................150.00
11. ZIRCON, Eganville, Ontario, Canada. Superb brilliant term. 2x5/16
x5/16 On matrix with smaller xl. 3x2½x1......................200.00
12. LINARITE, Mex Tex Mine, Bingham, N.M. Well xld. for the locality
howing a good amount of relief on a nice group of Quartz xls.
From the collections of Ed Over, Raymond Schortmann and Frank W.
Hess. 3 x1¼..125.0
13. POLYBASITE, Las Chispas Mine, Arizpe, Sonora, Mexico. Very fine
xld. mass. x3/4x3/4...75
CAESIUM-BERYL, Mt. Mica, Maine. Superb compound xl. 1x3/4x½.
ZIRCON, Miask, Ural Mts., U.S.S.R. Very fine 1" xl. on matrix.
This fine old-timer was once in the School of Mines of St. Peters
burg collection. Old label. 2½x2x1..............................
GARNET, Garnet Hill, Calaveras Co., Calif. Very fine group of
large xls. (up to 1-7/8" across) 2x2x1-3/4......................
TOPAZ & SMOKY QUARTZ, Klein Spitzkopje, S.W. Africa. This enti
superb specimen consists of one colorless Topaz xl. intergro
with one Smoky Quartz xl. It would be hard to imagine a fine
1x1x5/8...
17. MANGANITE, Ilfeld, Harz Mts., Ger . A magnificent speci
A spray of term. xls. 2¼x1½ on x of xld. Manganit
A beauty. 4x3x3............ rland. A m
18. SCHEELITE, Gutannen, Bernese O in A
translucent to transparent b th
Collected in October 1889.
Frank W. Hess collection.
OOKITE, Magnet Cove, Ark
tered on a mass of g
from the Raymo

Lawrence H. Conklin
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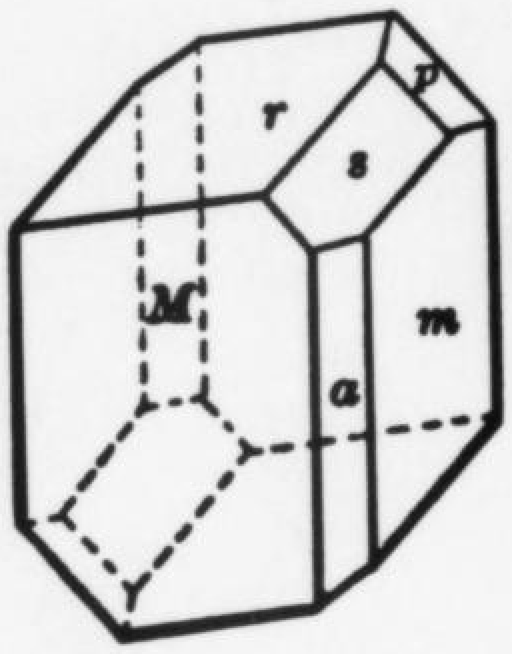

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Paul Otto

3-1. **AMAZONITE** xls and **SMOKY QUARTZ** xls with xline **ALBITE.** Florissant, Colo. A very attractive group of xls that displays well. Not damaged. One of the Quartz xls has a contact but complete termination. Xls up to 8.0 cm long. **$50.00.**

3-2. **AMETHYST** xls. Vera Cruz, Mexico. *A.* A very choice miniature that came out of Mexico many years ago. Color deepest at the terminations. **$20.00.**
B. Several very nice small miniatures that are bascially single sceptered Amethysts about 3.5 to 5.0 cm long. **$5.00** each.

3-3. **ANGLESITE** xls. Monte Poni, Sardinia. *A.* Xls micro to 6 mm cover one surface of this 4.0 x 6.0 cm matrix specimen. **$16.00.** *B.* A single blocky xl almost 1 cm in Galena matrix. A nice thumbnail. **$18.00.**

3-4. **AZURITE** xls. Chessy, France. A nice group of tightly packed blocky xls with good color and luster. 2.5 x 2.0 cm. **$30.00.**

3-5. Golden **BARITE** xls. Badlands of South Dakota. A matrix specimen of Barite xls on Calcite xls. The largest Barite is 2.5 cm long. 4.0 x 7.0 cm. **$30.00.**

3-6. **BOURNONITE.** Herodsfoot Mine, Lonreath, Cornwall, England. Massive to xline with Quartz and Chalcopyrite xls. 4.0 x 5.0 cm. **$10.00.**

3-7. **CABRERITE** xls. Laurium, Greece. Magnesian Annabergite. A matrix specimen 3.0 x 3.0 cm. An old F. W. Cassirer, Prague, CSR. label. **$10.00.**

3-8. **CALCITE** xls. Tsumeb, S. W. A. A long doubly terminated xl 5.0 cm long is a major part of this group of clear xls. A super miniature with no damage. **$35.00.**

3-9. **CALCITE** xls on and enclosing **COPPER.** Keweenaw Peninsula, Mich. xls up to 1.3 cm. A nice miniature 3.0 x 4.5 cm. **$20.00.**

3-10. **CELESTINE** xl. Clay Center, Ohio. A large single xl 4.5 cm long. An old specimen. Dinged. **$6.00.**

3-11. **CINNABAR** xls. Upper Kuskowin River Dist., Alaska. A couple of fine twins up to 4 mm on a white Quartz xl vein in matrix. Very sharp and bright red. 4.0 x 6.0 cm. **$20.00.**

3-12. **CUBANITE** xls. Minas Gerais, Brazil. Three sharp xls of this rare mineral on a matrix of Pyrrhotite, Quartz, and Siderite xls. Cubanites 1 mm to 3 mm. 3.5 x 5.5 cm. **$20.00.**

3-13. **CUPRO-ADAMITE** xls. Tsumeb, S. W. A. Very rare. *A.* Massive and xls up to 5 mm. Rich. 2.0 x 2.0 cm. **$20.00.** *B.* A vug of very nice sharp xls up to 3 mm. 1.6 x 3.5 cm. **$45.00.**

3-14. **DIOPTASE** xls. Tsumeb, S. W. A. Bright green xls 2-3 mm on matrix. Some white Calcite sets them off. Attractive. *A.* 4.0 x 4.0 cm. **$15.00.** *B.* 1.5 x 2.0 cm. a nice thumbnail. **$7.50.**

3-15. **ELECTRUM.** Altai Mts., Russia. A nice small rich vein running through matrix 2.5 x 2.0 cm. **$15.00.**

3-16. **LEGRANDITE** xls. Mapimi, Durango, Mexico. A vug with xls up to 5 mm. Not a showy specimen. 2.0 x 4.0 cm. **$15.00.**

3-17. **MANGANOCALCITE** xls. Telluride, Colo. A superb specimen with xls of a delicate pink up to 3.5 cm long. Very fluorescent. 7.0 x 8.0 cm. **$40.00.**

3-18. **PYROMORPHITE** xls. Mt. Isa, Queensland, Australia. A nice thumbnail group of xls in parallel growth. Yellow-green. **$10.00.**

3-19. **REDLEDGEITE.** Redledge Mine, Nevada Co., Calif. A 3.0 x 3.0 cm specimen of this very rare species. Massive with Chromite. See *Amer. Min.,* **46,** 1201. **$37.50.**

3-20. **TITANITE** xls. Minas Gerais, Brazil. A fine matrix specimen consisting of two green twinned xls 3.5 and 5.0 cm on a matrix of smaller xls. Xls sharp and lustrous. 6.0 x 8.0 cm. **$110.00.**

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