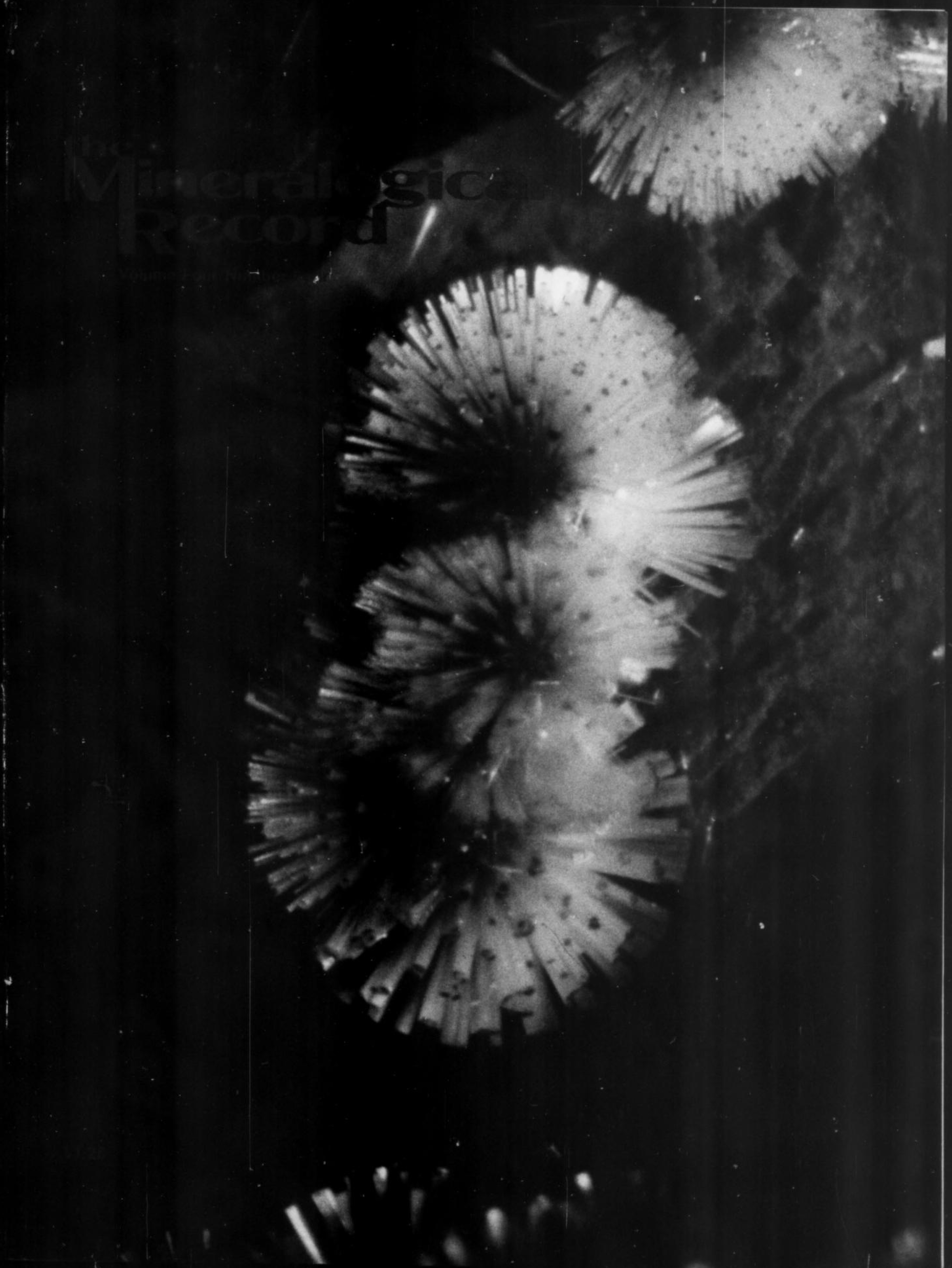
the
Mineralogical
Record

Volume Four, Number [illegible]



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Volume Four/Number Four

affiliated with the Friends of Mineralogy

editor & publisher

John S. White, Jr.
Division of Mineralogy
The Smithsonian Institution

circulation manager

Mary Lynn White

design & composition

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Crofton, Maryland

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editorial matter

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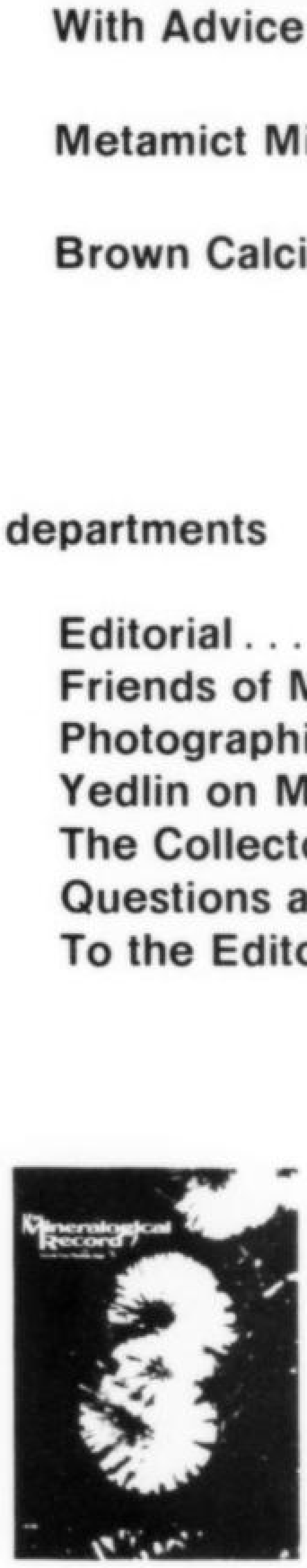

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Editorial

Locality Preservation

With disturbing frequency we hear of prime mineral localities being closed to collectors — and usually it is irresponsible collectors who are to blame. A classic recent example is the De Mix quarry at Mont St. Hilaire, Quebec. Most of us are aware by now that a careless collector left his mineral hammer in the quarry. It was scooped up with the rock and it caused more than $3,000 worth of damage in passing through the crusher. This was particularly distressing for several reasons. Not only is the locality one of the prolific producers of exceptional specimens of numerous species, many quite rare, it is also the only specimen-rich alkali syenite being mined today. Its life expectancy is limited and we must do all we can to see that we are not deprived of the opportunity to rescue its minerals as long as the quarry is being worked. But what makes this tragedy even more poignant is that St. Hilaire is one locality where a strong liaison had been established between a local mineral club and the owner of the property. At one time the Montreal Gem and Mineral Society was permitted to act as the official agent for approving visits by collectors and scheduling these visits. The Montreal group screened those seeking admission and, to some degree, policed them while on the premises. Unfortunately this alliance worked so well that the owner became lax and began to open the gate to everyone. In short order stories were circulating of extremely dangerous practices by overzealous and foolish collectors culminating, of course, in the "hammer in the crusher" event. We all almost literally held our breath while waiting to learn if the incident would close St. Hilaire to legitimate collecting forever. Fortunately the owner is still allowing entry but now on a fee basis only, presumably in the expectation of recovering his losses from the damage to the crusher. It is likely that the owner's earlier successful collaboration with the Montreal Society was a major influence in his decision to allow continued collecting.

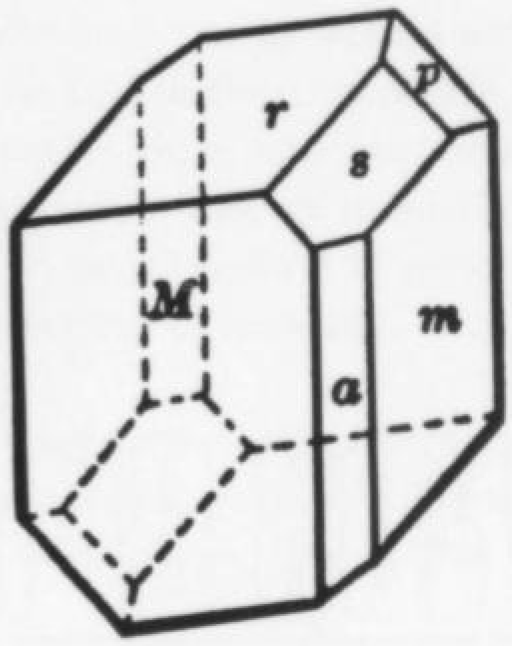
It is evident, from this story, that any attempt by mineral clubs to serve in a similar capacity with mines and quarries in their vicinity will enhance the prospects of keeping the locality "open". Certainly a formal approach toward establishing a liaison should always be tried.

Too often we hear of a good locality that is absolutely closed to collectors. Should we simply regretfully accept this or should we make a concerted effort, through our mineral clubs, to persuade the owner that worthwhile collecting is possible under controls which will minimize the risks? I fear that in most instances the collectors give in without a struggle. Surely the acquisition and preservation of fine mineral specimens is worth a dedicated effort to win the privilege to collect. If we put our energies and ingenuity to the task I am sure we can think of many ways to persuade the owners to be co-operative. Clubs could, for example, explore the possibility of negotiating liability insurance to cover those on sanctioned collecting trips, charging fees or using club funds to pay for it. The efforts of clubs to promote safety during mine and quarry visits should be stressed. As a good will gesture, local collectors might also assemble a suite of properly labelled specimens for the mine or quarry office. Many of us know of localities which have been closed because of vandalism. Perhaps if it can be established that the culprits were not mineral collectors, the owner can then be convinced that collectors shouldn't be unfairly penalized by being kept out of the locality. Possibly the offer of favorable publicity for the manager or owner in the local media might also be effective. Surely any effort to placate the owner can do no harm.

Although certainly not an exhaustive list, these are some of the ways we can work toward keeping our too few collecting areas accessible. As the hobby continues to grow, the ratio of good sites to collectors worsens. It is for this very reason that we cannot afford to be indifferent to any threat to the most precious commodity of mineral collectors — the source of the specimens.

John S. White, Jr.

CRYSTAL SHOWCASE



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QUALITY MINERALS BY MAIL

As you know by now, Crystal Showcase is set up primarily as a mail order house to supply collectors with quality specimens for their collections. However, if you are going to be in our area we invite you to stop to visit and go through our stock. Please call or write first to be sure that we'll be here. You will also see us wandering around some of the major shows such as Charlotte, Detroit, and of course Tucson. When you see us stop and say Hi. We usually have a few nice things with us.

Paul Otto

4-1. **STIBNITE** xls. Bejutz, Romania. We were fortunate to be given first selection from a collection of these fine stibnites from this new mine near Felsobanya. The xls on these are much larger, more isolated, and sturdier than the usual Romanian material. The twelve specimens that we selected are all attractive with large blocky terminated xls and a minimum of damage. There is only one of each so please give a second choice if possible.

A) Most of the xls on this, the largest specimen, are about 2.5 cm long and 4-5 mm across. The specimen is 5 cm x 9 cm. **$260.00**

B) This specimen is a mixture of stout and slender xls with the largest xl being obout 4 cm x 7 mm. Specimen size is 5 cm x 8 cm. **$250.00**

C) Nice sprays of very blocky xls with small white barite xls on the back side. Xls 2.5 cm x 5 mm. Specimen size 4 cm x 8 cm. **$165.00**

D) A radiating cluster of very large blocky xls up to 3.5 cm x 6 mm. Specimen size 4 cm x 5 cm. **$140.00**

E) Hundreds of terminated xls about 1 cm x 2 mm are attractively arranged to make this a fine specimen. 5.5 cm x 7 cm. **$75.00**

F) This specimen is much like E only the xls are a little larger. Most are about 2 cm x 3 mm. Specimen size 5 cm x 5 cm. **$75.00**

G) Like F. 4 cm x 5 cm. **$65.00**

H) Like F. 4 cm x 5 cm. **$65.00**

I) Attractive white barite xls cling to Stibnite xls up to 3 cm x 6 mm making an attractive association specimen. 3.5 cm x 5.2 cm. **$55.00**

J) A spray of xls up to 2.5 cm x 5 mm. Specimen size 3 cm x 4 cm. **$35.00**

K) Same as J only with very small xls in between the larger ones. **$35.00**

L) Same as J only with a little matrix at the base. **$30.00**

4-2. **OLIVENITE** xls. Devonshire, England. A large vug of lustrous terminated xls 3-4 mm long. Specimen size 4 cm x 5 cm. U.S.N.M. label. **$40.00**

4-3. **MILLERITE** xls on Dolomite xls. Kladno, Bohemia. Many attractive sprays of millerite xls up to 1 cm long. Specimen size 6 cm x 7 cm. **$25.00**

4-4. **SERANDITE** xls. Mt. St. Hilaire, Quebec, Canada. Two specimens. Fine flesh-pink single terminated xls. Miniatures. Each has been expertly repaired in one place. **$45.00** ea.

4-5. **HEMATITE** xls. Yuma Co., Arizona. A nice thumbnail of these lustrous black hematites. **$3.00**

4-6. **AZURITE** xl. Ajo, Arizona. A nice thumbnail from the new find. A little malachite. Single xl. **$6.00**

4-7. **ARTINITE** xls. Clear Creek, San Benito Co., Calif. A recent purchase from an advanced collector in California yielded these superb artinites. Solid tufts of snow white xls with a minimum of damage.

A) 9 cm x 12 cm. **$22.50**

B) 8 cm x 11 cm. **$20.00**

C) 7 cm x 8 cm. **$12.50**

D) 7 cm x 4 cm. **$9.00**

E) 6 cm x 4 cm. **$6.00**

F) 4 cm x 4 cm. **$4.00**

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FRIENDS OF MINERALOGY

Mineral Conservation *by Arthur Montgomery*

Dr. Judith Frondel reminded us at the last annual meeting in Tucson that mineral conservation, rather than mineral preservation, is the primary goal of Friends of Mineralogy. Conservation is a larger concept than preservation, because a moral imperative is added. Preserving minerals can safeguard them for any purpose; conserving them implies that the purpose will be good, beneficial to man. It is the responsibility of each one of us in FM to work toward conservation of minerals in this higher sense.

If the term *preserve* predominates in our stated FM goals, it is because FM's forerunner was called the *Mineral Preservation Society*. Yet I can testify that the ideal of mineral conservation permeated the ideas which led to that parent MPS group. Ray Grant and I developed those ideas through our concern that minerals were being increasingly downgraded and misused. The results could only prove profoundly harmful to all of mineralogy and everyone interested in minerals. Three trends we especially deplored were commercialism, hoarding and specialization. Minerals were being chiefly prized, it seemed to us, in Shows, books and collections, for their spectacular features and dollar value; were being too much added to collections, private and institutional, in a selfish competitive spirit rather than being put to improved cultural-educational use and made more accessible to the interests of others; and were being studied in mineralogy courses and research in an ever narrower and more highly specialized way. Entirely opposed to those trends, we felt that minerals above all need to be preserved and appreciated for what they are in themselves, culturally, educationally and scientifically; to be shared more generously and usefully between collectors and institutions; and to be valued in mineralogical science as much for their descriptive specimen interest, geological occurrence and origin, and vital significance in the world of nature, as for their data-yielding research potentialities. We determined to start a group dedicated to those ideals, and were joined by our two other co-founders Joel Arem and Dick Bideaux. We realized such a society might only appeal to a small number of idealists — but at least it would be a beginning and set an example. Since we saw mineral amateurs and professionals as equally responsible for what is done with minerals to give them broader cultural meaning — yet are separated from each other by a wide gap of interest and understanding — another major aim was to have members equally drawn from both groups in order to be partners in a greater unifying cause.

After a year the Mineral Preservation Society was metamorphosed into our Friends of Mineralogy. MPS was meant to remain small, informal and purely idealistic. The present organization has expanded rapidly, perhaps over-ambitiously, in various directions, some of which I consider to be somewhat removed from the founding philosophy. As long as FM works for the greater cause of a stronger and more public-spirited mineralogy, and sticks to its ideals, its contributions will be beneficial. The kind of helpful role it can play has been best exemplified in developing educational display awards at Mineral Shows, acting as an intermediary to encourage closer relations between mineral amateurs and professionals, and bringing closer together numerous clubs, societies and institutional groups in certain areas and states in the cause of mineral locality conservation. Here we see clearly why FM must never compete with other mineral groups, small or large; but should endeavor always to act as a coordinating agent aimed at strengthening what is already there and promoting a unifying common cause. One of the most beneficial developments we have aided, in behalf of all of mineralogy, has been FM's strong support of and close affiliation with the *Mineralogical Record,* whose educational aims are very much like our own.

I conclude with some personal newly-discovered thoughts on mineral conservation which reflect no one else's thinking in FM, so far as I know. We must first see minerals in their full stature as nature's third kingdom, in all their fascination, marvel and creative meaning for man, before we can understand why we should conserve them. Only then may they become for us precious parts of the planet Earth and the whole world of Nature. Life also only becomes precious to man when glimpsed in this higher sense. Minerals are not mere bits of inert matter. They hold within their being, clues to their own creation and the pages of earth history; and they symbolize, as nothing else in the universe ever can, the marvelous architectural perfection of the atomic world hidden within a crystal. The minerals which form the great ore deposits are no less wonderful, for Nature's alchemy has created these vast creations of metallic and other elements out of incredibly scarce trace amounts dispersed throughout the earth's rocky crust. Some see these deposits as gifts of chance belonging to the finder for wealth and power; others regard them as essential to fire the furnaces and forge the tools and girders of industry. In both cases their value is in terms of material wealth; and their mining and exploitation lead inexorably to over-production, depletion, waste, gaping holes in the earth, and evil scars on the landscape. A nobler conservational viewpoint — and one may we find FM upholding some day! — envisions such economic mineral deposits as a trust provided by a beneficent Creator who meant them to be conserved for their tremendous potentialities for good: to be mined by nations having them only when needed for self-sufficiency; to be shared with the poorer nations and those lacking them; to thus help unite nations, rather than to separate them and encourage wars; and, finally, to be dedicated, whenever industrially and financially productive, to the alleviation of poverty throughout the world and betterment of mankind.

All news and material relating to FM, for Record *publication, should be sent to Dr. Arthur Montgomery at: Dept. of Geology, Lafayette College, Easton, Penna. 18042.*

WINTER JOINT MINERALOGICAL MEETING AND SYMPOSIUM

Sunday, Feb. 10, 1974, and Monday, Feb. 11, 1974

Meetings to be held in the Tucson Community Center Meeting Rooms (in the same building as the Tucson Gem & Mineral Show), 350 S. Church St., Tucson, Arizona

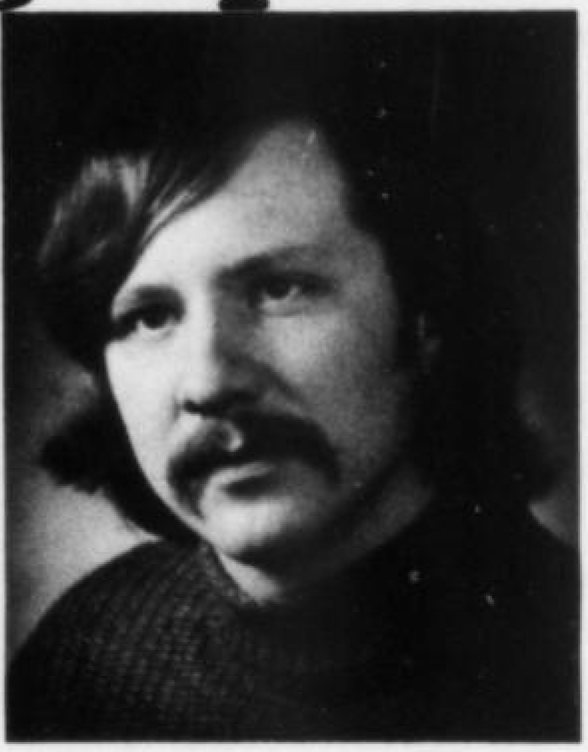
Sponsoring organizations are: University of Arizona, Mineralogical Society of America, Friends of Mineralogy, Mineral Museums Advisory Council, Tucson Gem & Mineral Society

Two major themes will be discussed: Mineral nomenclature, terminology and sytematics; and the mineralogy and paragenesis of porphyry copper deposits; with additional time for a session containing general papers. Readers are invited to offer papers for consideration for use in the symposium to Dr. Spencer Titley, Dept. of Geosciences, University of Arizona, Tucson, Arizona 85721

There will be a registration fee for this meeting, and information, registration forms, program information, and motel/hotel reservation forms will be available about the first of September from:

Dr. John W. Anthony, Chairman
Winter Joint Mineralogical Meeting and Symposium
Department of Geology
University of Arizona
Tucson, Arizona 85721

The Photographic Record



by Wendell E. Wilson

In order to lay a foundation for further discussions in this column I will go over a few fundamental concepts in photography. It is my goal that even collectors with no experience at all in photography be able to understand the ideas in future columns. This installment can be referred to whenever a reminder is needed on the definition of some term or concept.

Exposure refers to the amount of light striking the film. The amount of light can be varied by two separate means: the aperture or *f/stop* and the *shutter speed*. The *f/stop* refers to the size of hole which admits light to the film when the shutter is opened, and the shutter speed refers to how long the shutter remains open. *F*/stops are designated by the numbers 16, 11, 8, 5.6, 4, 2.8, and sometimes others on either end. *F*/16 is the SMALLER of the holes (a sometimes confusing idea since the designating number is the largest of the numbers), and *f*/2.8 is the larger hole. The sizes of holes are arranged such that each step represents twice (or one-half) the amount of light admitted by a neighboring *f*/stop. For example *f*/11 admits twice as much light as *f*/16, but only half as much as *f*/8. Exposure times are indicated on your camera by numbers such as 250, 125, 60, 30, 15, 8, 4, 2, etc. Here again the largest numbers actually represent the SHORTEST time of exposure. The number 250 means "1/250 second". The "1/" portion is apparently omitted on camera bodies for conservation of space. In books and articles the full form "1/250" is used, as will be the convention in this column. But keep in mind the omission of "1/" on your camera. As with *f*/stops the shutter speeds are in approximate multiples of two. Remember that you can double or cut in half the amount of light reaching the film by a change of one step in either the *f*/stop or the shutter speed. An exposure of 1/30 sec. and *f*/11 admits exactly as much light as an exposure of 1/15 sec. and *f*/16; 1/15 sec. obviously lets in light for twice as long as 1/30 sec., but an aperture of *f*/16 is only half as large as *f*/11. This ability to juggle *f*/stops and shutter speeds comes in handy. The light meter in (or on) your camera will tell you what combination of aperture and shutter speed will yield a good exposure.

If juggling *f*/stops and shutter speeds had no effect on the finished picture there would be no point. But the significant difference is in *depth of field*, which is defined as the zone (in distance from the camera) in which some object will be in sharp focus. This zone is *larger* for *small apertures* such as *f*/16. Therefore *f*/16 is used almost exclusively in mineral photography to maximize depth of field. The shutter speed is then adjusted for proper exposure.

There is a third factor which (with *f*/stop and shutter speed) determines what settings will constitute a proper exposure: the *film speed*. Depending on the chemistry of a particular film type, a certain amount of light is necessary for a good exposure. When relatively little light is required the film is called "fast" because you can use a faster (shorter) shutter speed. On the other hand, a "slow" film requires more light. It is a fact of life that slow films, whether color or black and white, produce sharper, less "grainy" pictures. But they require longer exposures.

Film speeds are designated by a number called the *ASA rating*. A high ASA means a fast film; a low ASA means a slow film. *Kodachrome II*, for instance, (ASA of 25), is much slower than, say *Kodachrome-X* (ASA 64). The highest film speed attainable with commercial color films is about 500, but black and white films, with their simpler chemistry, can achieve speeds in the thousands. I still usually use relatively slow black and white (referred to after this as B&W) films to maximize sharpness. My favorite color film is *Kodachrome II Professional Film, Type A* (ASA 40), and for B&W I usually use *Kodak Plus-X* (ASA 125) or *Kodak Panatomic-X* (ASA 32). All three have superior sharpness, resolving power, enlargement capability, and a very fine grain.

The human eye and brain seem to compensate automatically for the kind of lighting encountered. Incandescent light bulbs, for instance, give off a light which is distinctly yellower than sunlight. Although colors look fine to *us* under either kind of light, color film will record the color difference faithfully. In a print or slide this difference would be all too obvious to us, whereas we didn't notice it at the time we took the shot. Because of this, a variety of films are available which are "balanced" chemically to produce a picture with accurate (or at least identical) color rendition under particular kinds of lighting.

When metals (or anything) get very hot they glow; the hotter they are, the bluer the light is which they emit. For color photography all light sources are classified according to the *temperature* at which tungsten would emit an essentially identical light. Many, but not all, light sources *are* tungsten. A 100-watt bulb produces a light corresponding

(continued on page 196)

Fig. 1. **Photomicrograph depicting general appearance of tennantite overgrowths on pyrite. Light lines traversing tennantite (gray) rhombuses are (011) of pyrite.** ***Photograph by Julius Weber.***

Epitaxial Overgrowths of Tennantite on Octahedral Pyrite from Quiruvilca, Peru

by John W. Anthony
and W. John McLean

Department of Geosciences,
University of Arizona, Tucson, Arizona 85721

INTRODUCTION

In the mid-nineteen sixties Mr. Joy Merz, at that time geologist at the ASARCO underground mine at Quiruvilca, Peru, presented to the Mineralogical Museum of the University of Arizona a suite of specimens he had collected at the property. Notable in the collection are several spectacular, large, brilliant octahedral pyrite crystals possessed of mirror-like faces. Abundant, large enargite crystals are represented, as are brilliant, complex tennantites. A few pieces consist of massive granular pyrite and enargite with octahedral pyrite crystals overgrown by tennantite which is in parallel crystallographic orientation with the underlying pyrite. The occurrence of oriented overgrowths of tetrahedrite on pyrite is documented (Dana, 7th ed.), but we had not seen examples as strikingly developed as these from Quiruvilca. The highly selective nature of the overgrowth, the remarkable consistency and, to our knowledge, uniqueness of habit, and the persistence of the unusual (for tennantite) large, habit-controlling dodecahedron prompted us to examine the specimens closely.

MORPHOLOGY AND HABIT

The overgrowths were studied on the reflecting goniometer. The dominant forms on pyrite are the octahedron and dodecahedron, both of which yielded good goniometrical reflections. The pyritohedra of pyrite and all tennantite faces with very few exceptions exhibited very poor reflectivity. One multicrystal fragment was vacuum coated with platinum-palladium alloy to increase the reflectivity of the dull, strongly etched faces of pyrite and tennantite. This technique proved effective and the reflectivity of faces was improved to the extent that interfacial angles could be measured. Because pyrite and tennantite are both isometric, zonal relations were useful in confirming specific crystal forms.

In the idealized case, the octahedron faces of a pyrite crystal apparently served as substrates for nucleation and growth of eight individual tennantite crystals whose dominant form is the dodecahedron {011}. Each octahedral face of pyrite is coincident with a tetrahedral plane of an epitaxial tennantite crystal. The dodecahedral faces of tennantite having a common pyrite substrate are often so uniform in size and shape that the composite of eight overgrowths mimics the shape of a larger dodecahedron. As can be seen in Figures 1 and 2, each "face" of this pseudododecahedron is a composite of two dodecahedral planes on distinct tennantites perched on contiguous pyrite octahedral faces. The "slots" through which a pyrite dodecahedron face is exposed traverse the long axes of the rhombic faces of the large pseudododecahedra formed by the tennantites. Pyrite dodecahedra are, of course, parallel to the {011} faces of the epitaxial tennantite.

In all instances observed the tennantites abutting the pyrite dodecahedra are modified by elongate tetrahedral faces which parallel the slots. The breadth of these tetrahedral faces provides a visual measure of the thickness of the overgrowths.

At the extremities of the pyrite exposed in the slot, the dodecahedra are invariably modified by pyritohedral faces which are always dull and of inferior reflectivity. The indices of the most prominant and abundant form are {203}. The {506} and {102} forms are sometimes present but they are of minor importance. Characteristically the tennantite flares outward and away from the exposed pyritohedron and, although the faces of the bounding form of tennantite are sometimes curved and usually etched and dull, the tristetrahedron { 112} was identified on several specimens. Figures 2 and 3 illustrate this habit development which is remarkably persistent and uniform in shape on the overgrowths.

An intriguing aspect of the specimens is that the tennantite growing on (111) of pyrite usually extends only to the line marking the intersection of (111) and (203) of pyrite. The line of this face intersection has zonal indices $[\bar{3}12]$ and only certain rational faces of tennantite, i.e. those parallel to the line $[\bar{3}12]$, could terminate along this specific crystallographic direction. Calculation shows that the tristetrahedron {112} satisfies the condition of parallelism to this family of lines and its presence controls the conformation of the overgrowths at the distal ends of the slots.

The width of the slot is primarily influenced by the width of the pyrite dodecahedron exposed in it. The width of this form is exaggerated for clarity in Figure 3. On some overgrowths pyrite is not exposed and the position of the slot is occupied by a V-shaped groove formed by two intersecting tetrahedral faces on adjacent tennantite crystals. On these specimens the underlying pyrite dodecahedron is narrow or absent. Similarly, the pyritohedron {203} limits the extent of tennantite growth on {111} of pyrite at the line of their intersection. These observations suggest a structural antipathy between pyrite and tennantite in directions other than {111}.

Fig. 2. **Tennantite-pyrite overgrowth viewed approximately normal to (110) of tennantite (gray) and pyrite (white). Divergent flaring at top extremity is delineated by (112) of tennantite terminating at (203) of pyrite. Walls of the V-shaped depression running top to bottom are (111) faces of tennantite.** ***Photograph by Julius Weber.***

Our explanation of the persistence of the tristetrahedron {112} on tennantite is that it represents the attempt by tennantite to provide a crystallographic termination that will limit growth on {111} of pyrite just at the boundary formed by the intersection of {111} and {203} of pyrite. Similarly, the tetrahedral faces limit tennantite growth on {111} of pyrite at the intersection of {111} and {011} of pyrite along the line common to the two forms.

TENNANTITE-PYRITE EPITAXY

It is generally believed, on the basis of observation and experiment, especially with the epitaxy of thin films, that the primary factors governing epitaxial growth are similarity and closeness of match of the patterns displayed by the substrate and the deposit at the common interface, as well as the similarity of type of chemical bonding of the two crystalline solids (Pashley, 1956, 1965); the more similar these factors the higher will be the probability that epitaxy will occur.

The morphological study of the Quiruvilca material shows that the crystallographic direction common to the pyrite substrate and the epitaxially overgrown tennantite is {111}, and that the two sets of crystal axes are parallel. It is also clear that the later-formed tennantite systematically avoids deposition on {011} and {203} (or other pyritohedra) of octahedral pyrite. Further, pyrite in the samples examined, which is of pyritohedral {102} rather than octahedral habit, shows no tennantite overgrowth.*

In order to recognize similarities which may exist between the structures of the two minerals we have constructed projections of selected atomic layers of each onto the crystallographic planes (111) and (011). All projections are to identical scales so that similarity between equivalent projections of the two structures can be examined. Circles representing atomic species in the diagrams are also to scale (Dickinson, 1970) and are modified according to the covalent-ionic contributions suggested by the differences between the electro-negativities of neighboring atoms. Data for the structural projections of tennantite are from Wuensch (1964); those for pyrite are from Bragg, Claringbull, and Taylor (1965). We determined the unit cell par-

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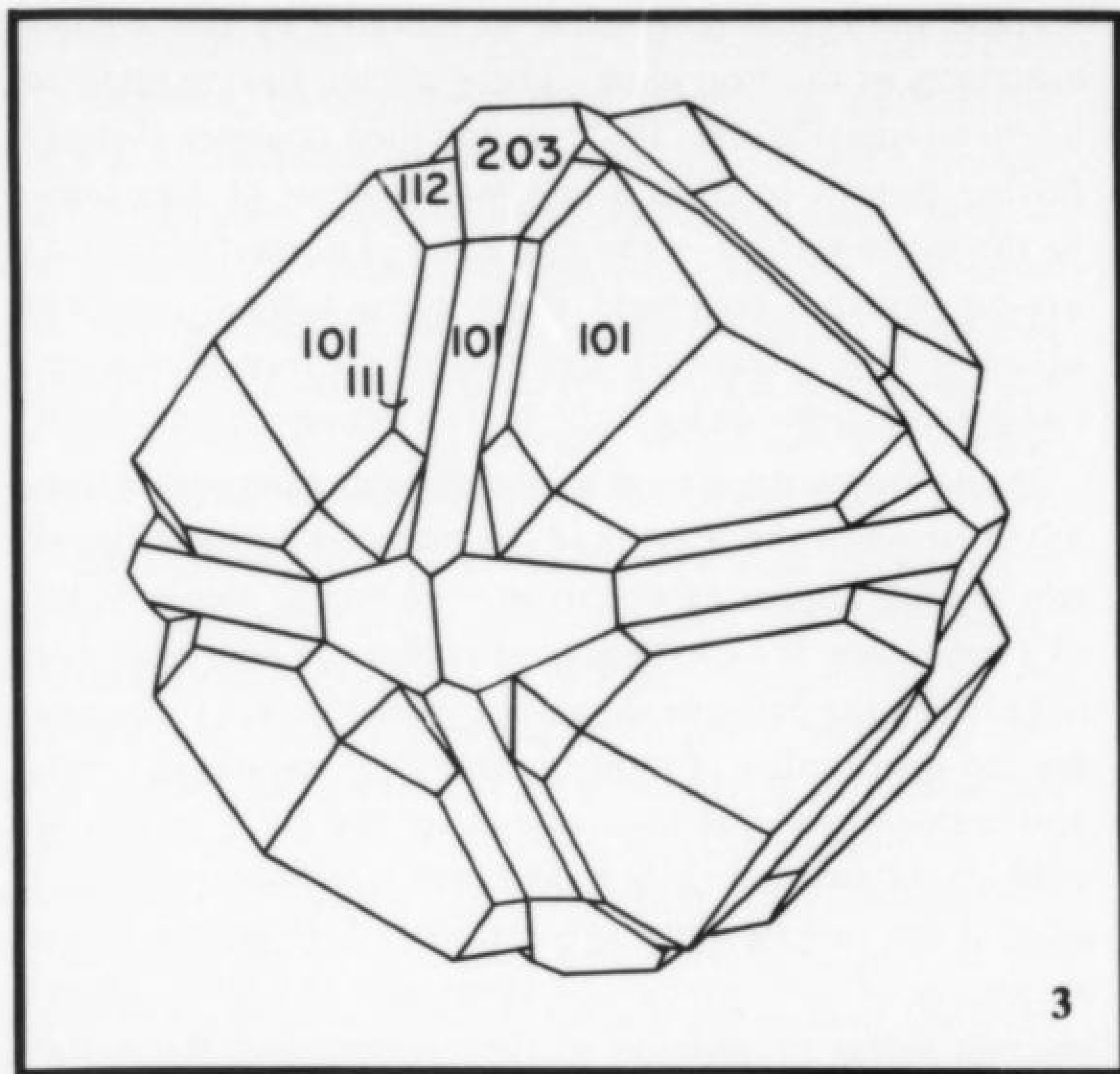
* The work of Spangenberg and Neuhaus (1930), cited in Dana's System of Mineralogy (v. 2, p. 384, 1944), appears not to consider the controls governing oriented overgrowth of tennantite on pyrite as implied, but rather speculates as to the nature of structural aspects of replacement of tennantite by pyrite.



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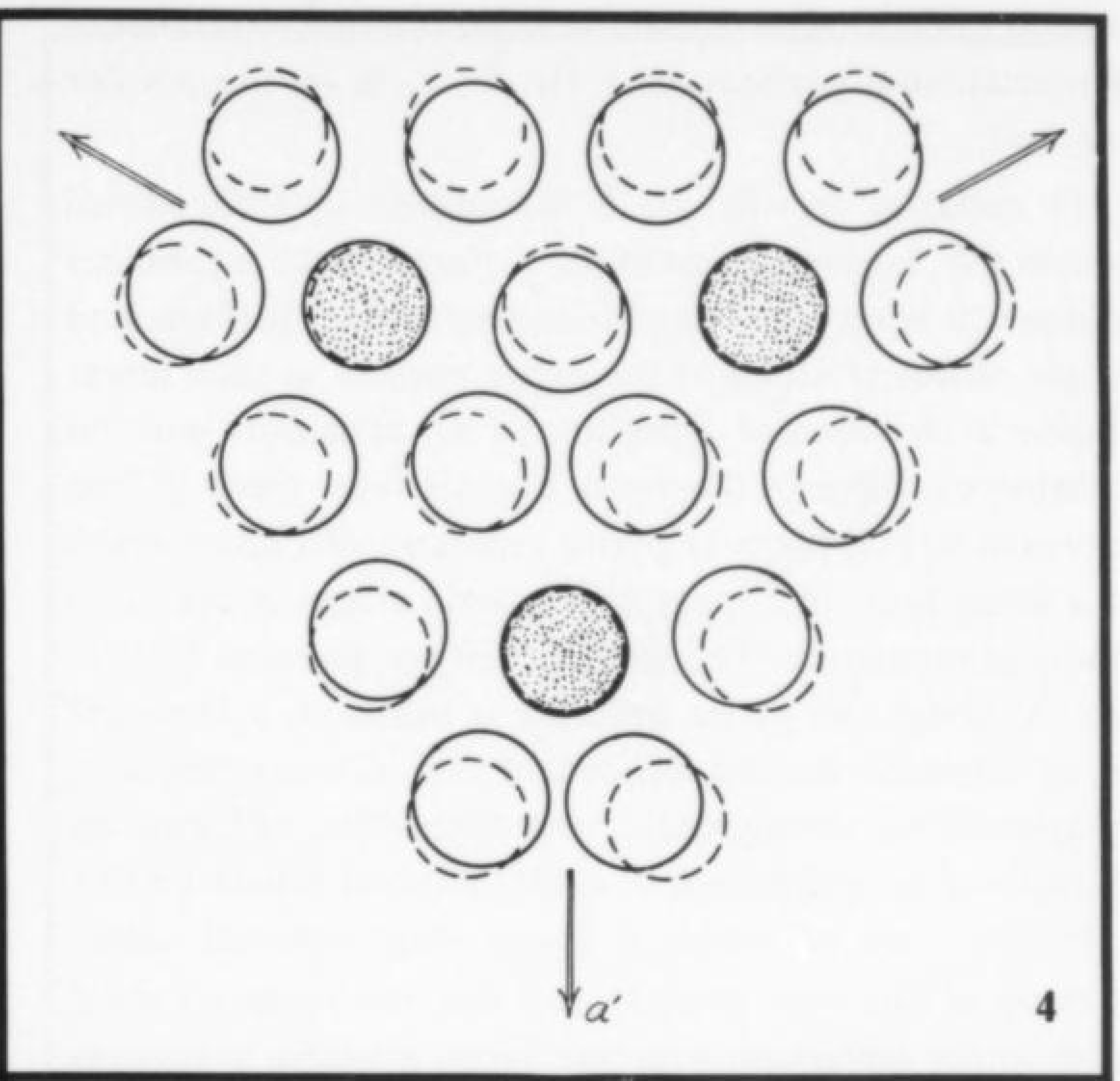

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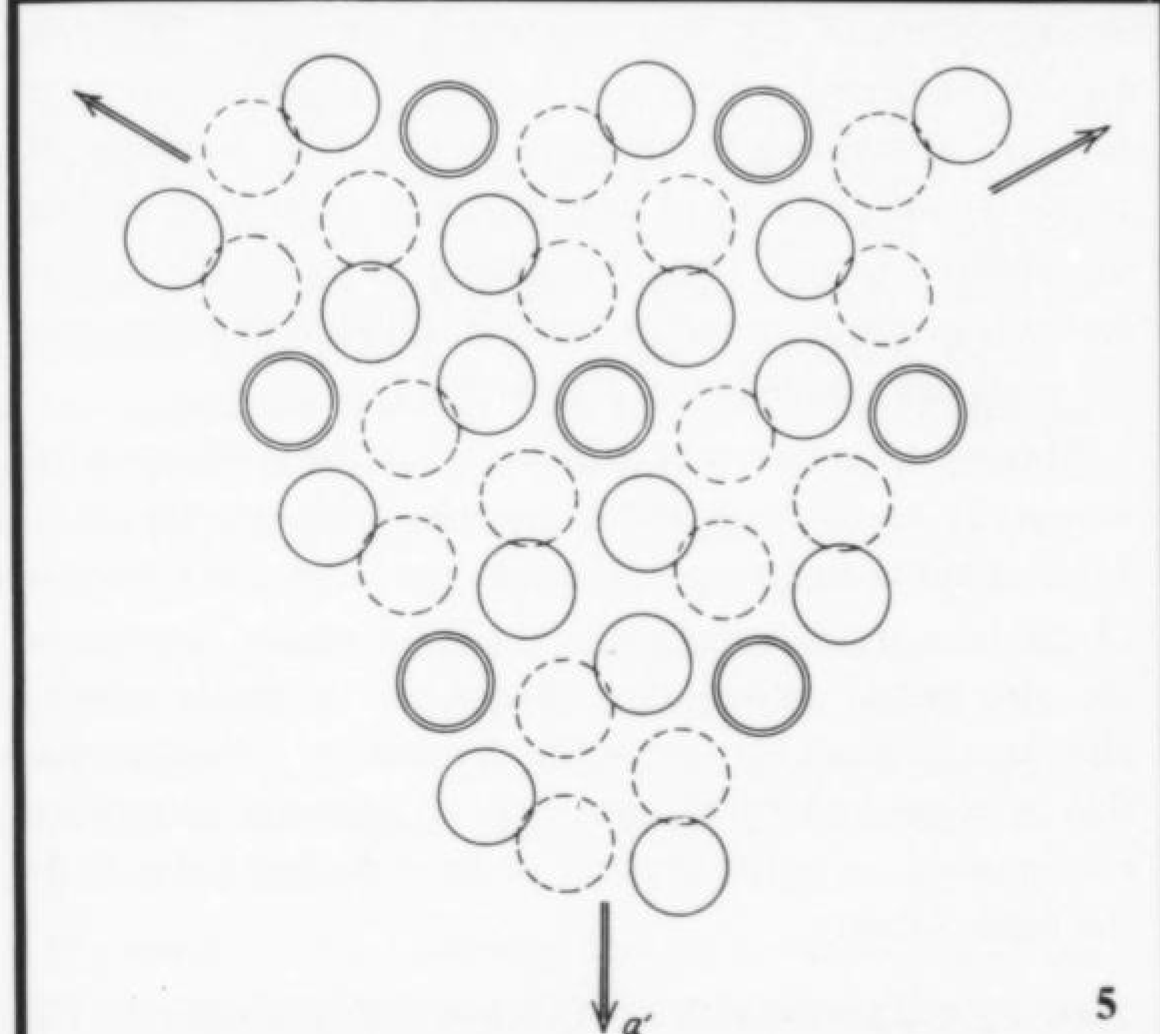

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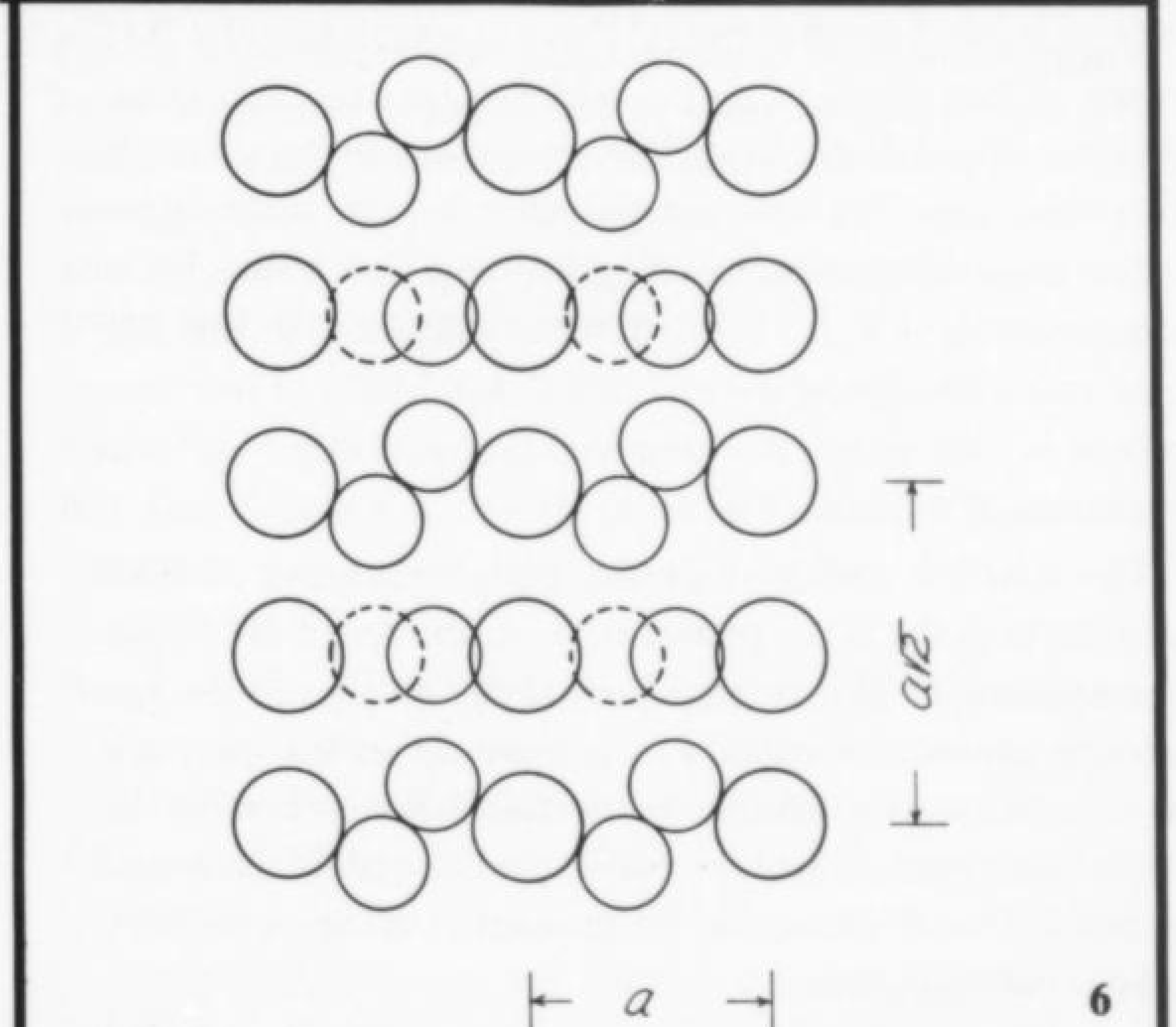

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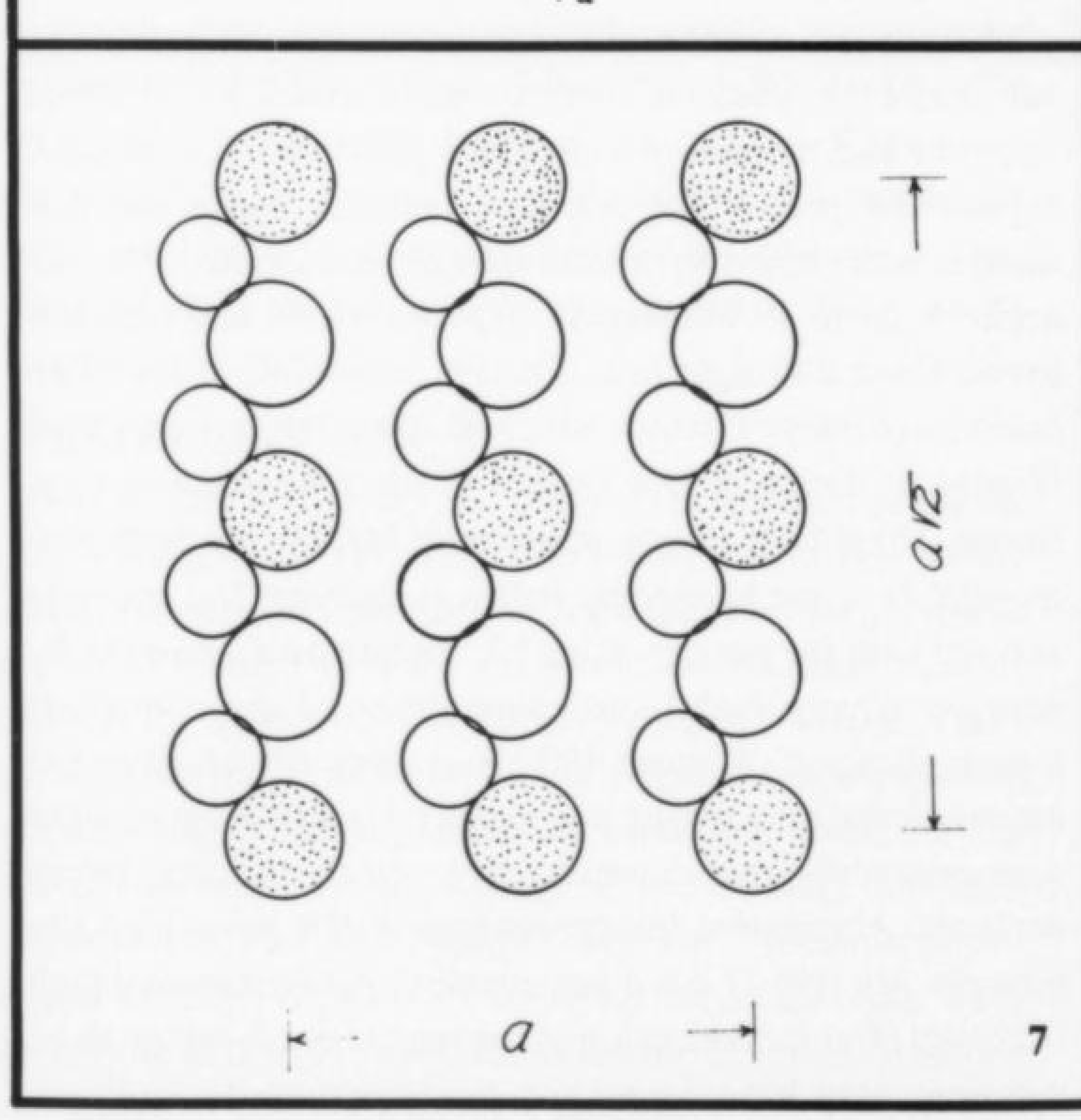

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Fig. 3. **Axonometric projection of tennantite-pyrite overgrowth. Width of pyrite exposure is exaggerated. Compare Figure 2.**

Fig. 4. **Projections of cation planes of (111) of pyrite and of tennantite superimposed. Dashed circles represent iron of pyrite; large circles and stippled circles are copper and arsenic of tennantite. The degree of misfit is 6 percent. Arrows indicate traces of the directions of the three crystallographic axes.**

Fig. 5. **Sulfur plane of pyrite projected into (111). Solid circles are slightly above and dashed circles slightly below reference plane; concentric circles are S_2 units oriented normal to plane of projection.**

Fig. 6. **Projection of the cation-anion plane of pyrite onto (110). Large circles represent iron atoms, small full and dashed circles, sulfur. Rows containing dashed circles are like the alternate rows but are rotated 90 degrees about the row axis.**

Fig. 7. **Projection of the cation-anion plane of tennantite onto (110). Large circles represent copper; stippled circles, arsenic; small circles, sulfur.**

ameter of Quiruvilca tennantite to be 10.170 Å and that of the octahedral pyrite to be 5.416 Å, both by the powder method.

In epitaxial growth one is concerned with the detail within the planes of atoms at the surfaces of the substances which will bond together to form the contact surface, and single planes of atoms at the pyrite surface as they might appear at the onset of deposition of the tennantite must be considered. Figure 4 illustrates a single layer mesh of iron atoms in a (111) plane of pyrite superimposed upon which is a single layer of copper and arsenic atoms in the (111) plane of tennantite. The similarity of the patterns is striking. Although the pyrite structure is based on a face-centered isometric Bravais lattice and that of tennantite on a body-centered arrangement, the tennantite cell can be thought of as constructed of eight modified sphalerite-like sub-cells, each of which is pseudo-face-centered cubic. Viewed in this way, one can see that the copper-arsenic layer in the tennantite structure forms a nearly hexagonal closest packed mesh in the (111) plane, much like the (111) plane of iron atoms in pyrite, which is an exact hexagonal pattern. In addition to differences in detail between the two structures, the factor responsible for the misfit apparent in Figure 4 is that the length of the unit cell edge of tennantite (10.170 Å) is 6.1 percent smaller than the doubled unit cell edge of pyrite (10.832 Å). Misfit of this magnitude is well within the observed limits of other epitaxial situations (Pashley, 1956).

The marked similarity of the cation patterns of these structures in the {111} planes is, then, the result of two circumstances: 1) The arrangement of the cations in the tennantite structure is pseudo-face-centered so that they are, as a consequence, similar in spatial arrangement to the truly face-centered iron atoms in pyrite, and 2) the length of the unit cell parameter of tennantite is approximately twice that of pyrite.

If we imagine that the surface of a (111) face of an octahedral pyrite crystal, at the inception of tennantite deposition, consists of the hexagonal mesh of positively charged iron ions, nuclei whose bases are (111) layers of negatively charged sulfur ions would collect at the positive pyrite surface and orient themselves as dictated by the trigonal symmetry of the iron mesh. These nuclei, having attained a critical size (Pashley, 1965), would then coalesce through further growth to form a continuous layer of tennantite on the pyrite surface — the precursor of normal tennantite crystal growth. Conversely, if the pyrite surface consisted of sulfur ions (Figure 5), the contact surface of the tennantite nuclei would logically by the copper-arsenic layer.

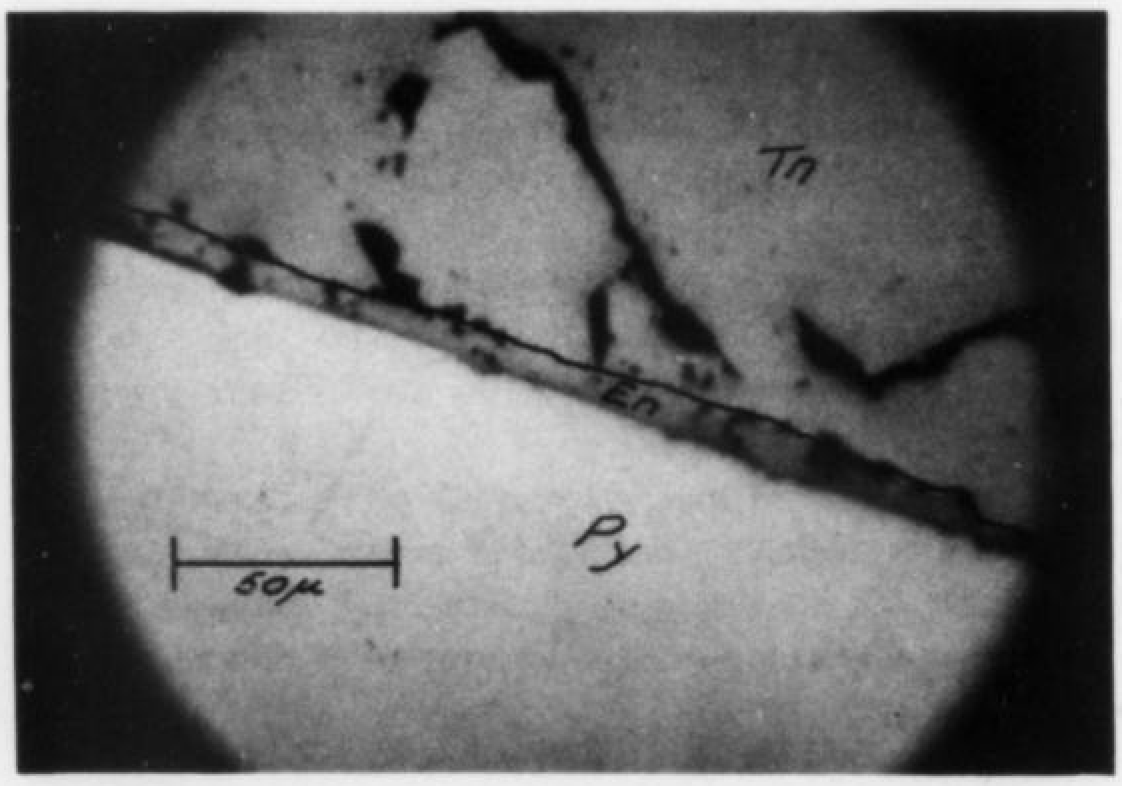

Fig. 8. **Photomicrograph showing enargite selvage between pyrite and tennantite.**

In the isometric system a percentage difference established between the lengths of the unit cell periodicities of two crystals applies as well to any equivalent planes in the two structures. We can then predict that the degree of misfit between the patterns shown in Figures 6 and 7 representing the distribution of atoms in the {011} planes of pyrite and tennantite will be the same as for the {111} planes already compared in Figure 4. The match appears to be very good if the cations alone are considered. However, in the structures of both pyrite and tennantite the {011} planes contain sulfur in addition to the cations, and the sulfur arrangements of the two substances are quite different. Unlike the situation described for the {111} planes, tennantite ions attempting to nucleate on the {011} surfaces of pyrite would find ions of like charge in apposition setting up repulsive forces. The {011} planes of pyrite would presumably prove to be energetically unsuitable as a substrate for epitaxial nucleation of tennantite.

This model offers an explanation for the preference of tennantite to nucleate and grow selectively on the {111} faces of pyrite and to avoid the {011} surfaces. Examination of the structures reveals that the {0kl} planar directions are also mixed cation-anion planes and probably unsuitable as substrates for tennantite deposition. This supposition is supported by the absence of epitaxial tennantite overgrowths on pyrite crystals of pyritohedral habit from the same locality.

THE PYRITE-ENARGITE-TENNANTITE CONTACTS

Microscopic examination in reflected light of a polished surface of the oriented overgrowth, in which {011} planes of pyrite and tennantite were made parallel to the surface, reveals that part of the interface between pyrite and tennantite is occupied by a thin selvage of enargite. This enargite is up to 10 microns in exposed width and contacts pyrite along a straight line. Against tennantite, it forms an essentially linear contact which is irregular in fine detail (Figure 8). Enargite also occurs in the tennantite as tiny, sparse, irregular patches, apparently intergrown with tennantite. In some instances, stringers connect the enargite selvage with the patchy material. Embayment of pyrite by enargite is very slight, and examination of the contact at a magnification of about 1000 diameters reveals that the embayments into pyrite are usually bounded by straight segments which may represent steps on the original pyrite surfaces. Alternative interpretations of the genesis of the enargite are that 1) it is a replacement phenomenon which occurred after the formation of the tennantite overgrowth — solutions may have found the pyrite-tennantite interface an easy channelway of access; 2) the enargite was epitaxially deposited on octahedral faces of pyrite before tennantite was precipitated and continued to form while tennantite crystals grew. Neither interpretation is strongly supported by textural relations, but tenuous evidence that enargite may be oriented with respect to the pyrite surface is provided by the microscopical observation of what appear to be cleavage traces in enargite which are very nearly parallel to the exposed edge of the pyrite {111} planes.

Additional support for epitaxy comes from the nature of the structure of enargite projected onto its basal plane. Interpretation of examples of oriented overgrowths of tetrahedrite on {001} of enargite from Butte, Montana (Bideaux, 1960), has pointed to the similarity of pattern of this plane to that of {111} of tetrahedrite. Although enargite is orthorhombic, Pauling and Weinbaum (1934) showed the structure to be wurtzite-like, and demonstrated that the pattern of the basal plane is pseudo-hexagonal. Data for these reconstructions were taken from a recent refinement of the enargite structure by McLean (1968). The structure is such that planes parallel to {001} contain only cations (copper and arsenic) or only anions (sulfur), so that comparisons are feasible between pyrite-enargite and enargite-tennantite that are analagous to those already made between the {111} planes of pyrite and tennantite. Figure 9 is a superposition of the {001} sulfur atom plane of enargite and the {111} iron atom plane of pyrite (Figure 4). Calculation shows that the misfits are: pyrite-enargite, (-)3 percent; enargite-tennantite, (-)3 percent; and pyrite-tennantite, (-)6 percent. Enargite, then occupies a position midway between the misfit of pyrite and tennantite, and would be more likely to grow epitaxially upon pyrite than would tennantite if the concept of degree of misfit is effective in controlling epitaxy.

We estimate that somewhat less than one-fourth of the total observed pyrite-tennantite contact length is occupied by visually detectable enargite. It is possible that enargite may occupy the entire area of the contact but be too thin for visual detection over much of the surface. If the enargite is epitaxially deposited on the octahedral pyrite surfaces, we have the unusual situation of sequential, two-stage epitaxial growth — enargite on pyrite followed by tennantite on enargite.

ACKNOWLEDGEMENTS

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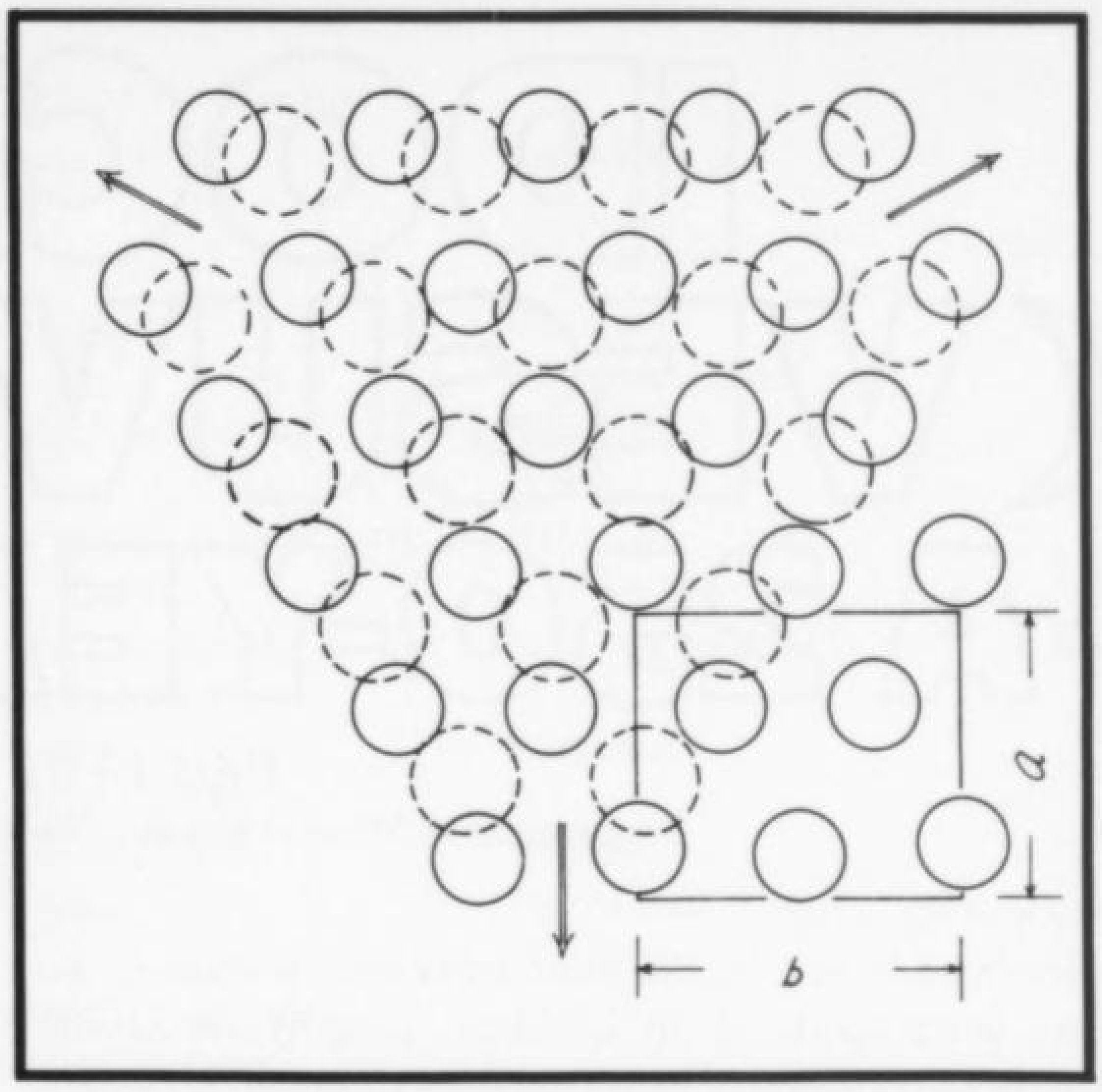

***Fig. 9.* Superimposition of projections of selected planes in the structures of pyrite and of enargite onto (111) pyrite and (001) enargite. Small circles represent sulfur atoms of enargite; dashed circles are iron atoms of pyrite. The degree of misfit is 3 percent. The orthorhombic unit cell projection of enargite is shown.**

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IDOCRASE (VESUVIANITE) -A 250-YEAR PUZZLE

Part I—*by Joel E. Arem*

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INTRODUCTION

Idocrase is one of the most exhaustively studied, yet least understood, of all minerals. Lengthy tabulations have been compiled of its crystal forms, optical properties, chemical variations and mineral associations. In spite of this wealth of data the true symmetry of idocrase is still uncertain, its general optical behavior cannot be unambiguously determined, an adequate general formula has only recently been proposed, and even contemporary structural work leaves several critical questions unanswered. These uncertainties are still further complicated by the diverse range of conditions in which the mineral forms in nature, with consequent variation in habit, chemistry and occurrence.

Even the name of the mineral is debated. Werner (1795) applies the name *vesuvianite* to material found on the slopes of Mt. Vesuvius, Italy. Hauy (1797) coined the term *idocrase* in allusion to the complex habit of the mineral. "Idocrase" comes from Greek words loosely translated as "mixed-appearing", since forms on the mineral resemble those seen commonly on a variety of other species. Vesuvianite thus has priority, but idocrase is a popular name and remains in very widespread use. The Commission on New Mineral Names of the IMA voted on a preferred nomenclature, but the vote deadlocked. The problem remains unresolved.

The extreme complexity of idocrase crystal forms has led to frequent misidentification. Although the mineral often resembles zircon or melilite it is most easily mistaken for garnet, as in the case of "colophonite" from Arendal, Norway (Widman, 1890). Large variations in appearance have also led to a plethora of names (Table 1). Some of these are meaningful varietal names referring to composition, as in the case of manganidocrase and titanvesuvianite. Other names are based on color, as in xanthite (yellow) and cyprine (blue). Its color variation is so great that idocrase may justly be called one of the true "chameleons" of the mineral world. Many shades of green and blue have been observed. Beryllian-idocrase is pink, manganidocrase is lilac-colored and xanthite is golden yellow. Brown crystals are frequently zoned. Colorless idocrase exists, and some crystals are so deeply colored as to appear almost black.

Color has, in some cases, been correlated with optical properites and specific gravity. Even though idocrase is a tetragonal mineral (and therefore optically uniaxial) there exists a substantial amount of literature on "anomalous" or "abnormal" types. In addition, while most idocrase is optically negative, optically positive varieties seem to be common and even biaxial idocrase is known from many localities. Some of these optical features can be related to chemistry, yet chemical variations in idocrase generally defy simple correlation.

Numerous "working formulas" have appeared in the literature. Some fit specific groups of analyses better than others, but none can be applied to all published analyses. The search for a better chemical formula led to numerous attempts at idocrase syntheses. Only recently (Ito and Arem, 1970) has this type of investigation been able to provide details on idocrase phase relations.

Idocrase occurs in hundreds of localities throughout the world (Table 2) and is represented in many types of geological environments. At first glance there seems to be no correlation between occurrence type and the physical and chemical properties of idocrase. Yet consideration of all information available in the literature reveals distinct trends in both the composition and X-ray properties of idocrase, trends that clearly relate to occurrence (discussed in Part II of this paper). Crystal habit is likewise related to occurrence.

The structure of idocrase was solved by Warren and Modell in 1931. Since this initial work two attempts have been made to refine the structure (Arem, 1970; Coda *et al.* 1970). Although a refined model has been published (Coda), this model is inconsistent with variations in other observed X-ray characteristics of idocrase. Thus, virtually all aspects of the study of the mineral remain unresolved. This paper presents a summary of the problems and observations, and some possible answers.

OCCURRENCE

Idocrase occurs in a diversity of environments, including tactites (skarns), regionally metamorphosed limestones,

Table 1. Names proposed for idocrase

Date	Name	Origin of Name	Named by ...
1723	Hyacinthus dictus octodecahedricus		Cappeller
1799	Hyacinthe volcanique	Probably Vesuvius	Demeste
1783	Hyacinthe de Vesuve	Vesuvius	Rome de L'Isle
1784	Leucite	Greek: "leukos" (white)	Kirwan
1795	Vesuvian	Vesuvius	Werner
1799	Idocrase	From Greek words: "mixed form"	Hauy
1800	Wiluite	Wilui River, Siberia	
1810	Gahnite	Gahn (chemist); material from Gokum, Sweden	Lobo da Silveira
1812	Loboite	Lobo da Silveira; material from Gokum	Berzelius
1817	Egeran	Eger, Czechoslovakia	Werner
1820	Frugardite	Frugard, Finland	Nordanskjold
1820	Jewreinowite		Nordanskjold
1821	Cyprine	Greek: "kypros" (blue color) Material from Norway	Berzelius
1828	Xanthite	Greek: "xanthos" (Yellow) Material from Amity, N. Y.	Thomson
1828	Gokumite	Gokum, Sweden	Thomson
1845	Heteromerite	Greek: "heteros" +"meros" (different part)	Hermann
1880	Manganidocrase	Contains Mn; Material from Jordansmuhl, Silesia	von Lasaulx
1903	Californite	State name	Kunz
1927	Genevite	Proper name (Genev); material from Morocco	Duparc and Gysin
1933	Duparcite	Proper name (Duparc); material from Morocco	Duparc and Gysin
Varietal names relating to composition:			
1930	Beryllian idocrase	Be	Palache and Bauer
1940	Titan-vesuvianite	Ti	Shilin
1966	Cerian idocrase	Ce	Murdoch and Ingram

veins associated with mafic and ultramafic rocks, nepheline syenites and other alkalic rocks, and in rodingite (a type of garnetized gabbro). The classic occurrence at Vesuvius, Italy (hence the name vesuvianite) is essentially a case of limestone alteration. The most common types of occurrence can be broadly described as rodingites and metamorphosed limestones.

Calcsilicate bodies in carbonates are abundant and widespread, and idocrase occurs in many of them. Calcium in the silicates was derived from surrounding carbonates, in which migration of chemical components takes place primarily by diffusion and movement along grain boundaries. Temperature gradients result in a concentration of calcsilicates near the igneous intrusive in a contact zone, although veins may also contain these minerals in areas further from the heat source.

Minerals within calcsilicate masses may be anhedral, but well formed crystals entirely surrounded by carbonate also commonly form. Open spaces in tactites are rare. Crystals can reach large size due to slow, continued growth and great mobility of components.

Rodingite is a gabbro (although sometimes the term is applied to other rocks as well) that has been altered to calcsilicate assemblages, typically prehnite, grossular, idocrase, zoisite and clinozoisite, diopside and chlorite. Rodingites are massive rocks, and minerals within them tend to be complexly intergrown. They apparently form as a result of *in situ* alteration of dikes that cut through serpentinites.

Idocrase associated with serpentinite also occurs in veins and cavities due to late-stage filling of fissures. Here the mineral is in free-growing euhedral, terminated crystals and druses. Interstices between crystals may be filled with other minerals, such as calcite, diopside and grossular. The physical features of such occurrences suggest that iodcrase was deposited from freely moving solutions, probably at rather low temperatures (approximately 400°C.) Low temperature deposition is also suggested by the presence of prehnite in the assemblage.

The assemblage of minerals associated with low temperature veins in serpentinites is well known to collectors. A good example is the occurrence at the Jeffrey mine, Asbestos, Quebec. Grossular of exceptional size and trans-

Table 2.

Localities where idocrase has been found; localities are given according to geographical boundaries at time of literature.

Argentina: Casa la Platte
Australia: Eulaminna (Mt. Margaret Goldfield)
Austria: Klopfberge; Waldenstein; Pinzgaus; Rauris valley; Staubach valley; Hollersbach valley; Kamp valley
Canada: Calumet Falls; Litchfield; Grenville; Asbestos; Black Lake; Laurel; Chrome pits of SE Quebec (Montreal, Southwark, Dominion, American, Caribou, Union Hall); Templeton; Wakefield; Clarendon; Mt. Royal; Mt. St. Hilaire; Turnback Lake (NWT); Dungannon Twp.
Czechoslovakia: Friedeberg; Kaltenstein (was Silesia at time described)
France: Pie d'Arbizon; Pie d'Aulon; Cauterets; St. Marcel; Gressoney
Finland: Lupikko; Pitkaranta; Toija; Nordsundsvik; Frugard
Germany:
  (Prussia) Auerbach; Grossherzogsthum; Oberschauffhausen;
  (Bavaria) Gopfersgrun; Wurlitz; Passau; Wusstuben; Keitersberge; Gossweinstein; Wunsiedel; Goringsreuth; Hauxdorf; Pleystein; Muhlbuhl; Tirschenreuth; Wildenau; Fuchsberg; Pleistein; Ebendorf; Pfaffenreuth
  (Saxony) Breitenbrunn; Schwartzenberg; Schneeburg; Militz; Grunstadtel; Hohendorf
  (Silesia) Strehlen; Kupferberg; Jordansmuhl; Rudelstadt; Dominsel; Potsdam; Gleinitz; Altkemnitz; Rothenzechau; Schmiedeberg
  (Bohemia) Haslau; Eger; Kunicek; Klementinov
  (Moravia) Blauda; Nedwieditz; Strutz; Popuwek; Wiesenberg; Froschau
Hungary: (Rumania) Rezbanya; Banat; Cziklova; Oravicza; Dognacska
Ireland: Derryloaghan (Donegal); Barnes Gap; Kilmacrenan; Bumbeg; Gweedore; Lettermacherwald; Lough Anure (Donegal)
Italy (Piedmont): Ala Valley; Ciamarella; Testa Ciarva; Corbassera; Valle Grande (Cantoria); Ceresole Valley (Locana); Monte Lovanna; Monte Rosa; Almeza; Elba; Pitigliano; Bracciano Lake; Albano; Gallori; Ponza; Vesuvius; Monte Somma; Calabria (Cantazaro); Bric Camula; Tiriolo
Japan: Miho (Kanagawa pref.); Ogurazawa (Saitama pref.); Fukushima pref.; Kiura (Bungo province)
Korea: Fukushinzan
Mexico: Conception del Oro; Morelos; Chiapas
Morocco: Azegour
New Zealand: Roding River; Waimea
Norway: Kristiansand; Egg; Eie; Arendal; Eker Vand; Hamrefjeld; Drammen; Sauland; Telemark; Stromshein; Setesdal; Rostoy; Kongsgardskogen; Hortvaer; Nordland; Oslo Region (Sata; Myrseter; Dalstjern; Viksbergene; Arvoll Valley)
Pakistan: Hindubagh; Zhob Valley
Poland: Strzelin
Romania: Paringu-Massif
Spain: San Lorenzo; Buitrago; Escorial
South Africa: Magnet Heights; Avontuur (Bushveld)
Sweden: Gokum; Lindbo; Fahlun; Pajsberg; Jakobsberg; Tennberget; Dalarne; Sala
Switzerland: Ordlegna; La Canaletta; Piz Longhin; Davos; Rympfischwang; Zermatt; Strahlhorn; Mittagshorn; Feegelgletscher; Campo Longo; Fibia
U. S. S. R.: Uzbek SSR (Turkistan); Kazakhstan; Uzun Tashty; Norilsk Region; Talnakh intrusive; Rila Mtns. (Bulgaria); S. W. Tuva; Yakutia; Donets Basin; W. Uzbekistan
  Siberia: Wilui River (Yakutsk)
  Urals: Achmatowsk (Slatoust District); Nikolai Maximilien Mine (So. Urals); Medwediewa; Schischimsker Mtn.; Beresowaja Gora; Kumatschink Mtn.; Poljakow Mine (Slatoust); Ekaterinberg; Catherineberg; Kossulina; Kyschtym District; Kedabek (Caucasus); Tyrdanov Ulus
United States:
  Arkansas: Magnet Cove
  California: Georgetown; Happy Camp; Tulare County; San Benito County (Crestmore, Dallas Gem Mine)
  Connecticut: Salisbury
  Colorado: Iron Hill
  Maine: Robinson Mtn.; Philippsburg; Poland; Parsonfield; Rumford; Auburn; Sanford
  Massachusetts: Worcester; Newbury
  Nevada: Silver Peak Quadrangle
  New Jersey: Franklin
  New York: Long Pond; Moriah; Olmsteadville; Antwerp; Amity; Gouverneur
  New Mexico: Iron Mountain
  Tennessee: Polk County

parency (Fig. 1) has been encountered in asbestos mining operations. The garnet occurs in "acidic dikes" that cut through the deposit and are visible in the open pit. Other minerals found in the mine include prehnite (in crystals up to an inch in length — some of the world's largest), diopside (both stubby prismatic and "balls" of acicular crystals — Fig. 2), pectolite (see *Min. Record*, 2, 188), wollastonite, albite and chlorite.

Growth zones are commonly observed in idocrase from such occurrences. Bands of varying color may reflect chemical fluctuations in the solutions from which the crystals were deposited. Some doubly-terminated crystals from the Jeffrey mine are deep emerald-green at one end and a deep lilac color at the other. The cause of this coloration was verified (probe analysis) by the writer as due to chromium and manganese, respectively. The difference in coloration developed at opposite ends of the same crystals may actually indicate a lack of a symmetry center in the mineral. Additional evidence for this conclusion will be presented in Parts 2 and 3 of this paper.

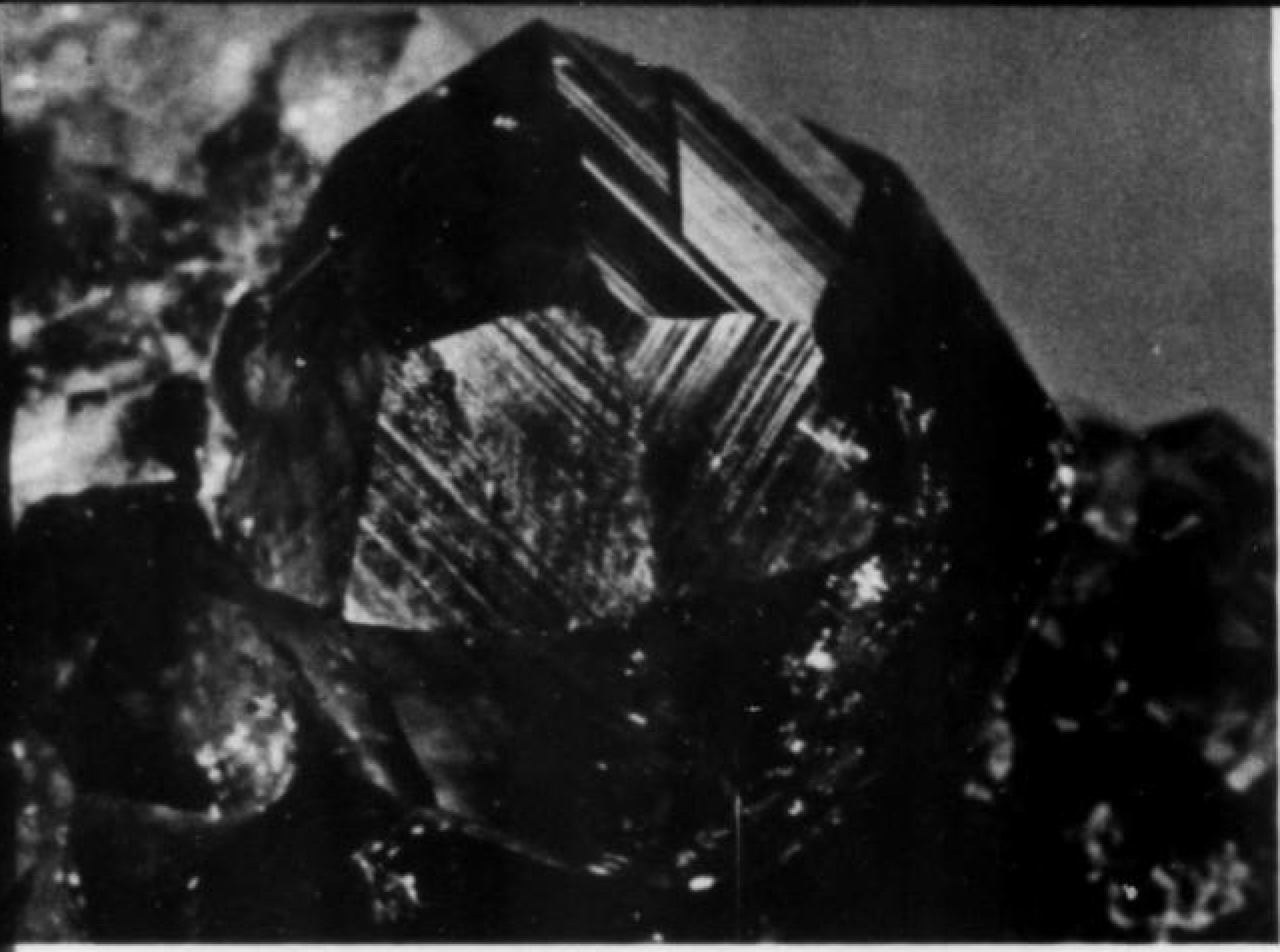

Fig. 1. **Grossular from Asbestos, Quebec. The crystals are a pale sherry color.**

Occurrences of idocrase in altered mafic rocks include Dundas, Tasmania (Ward, 1911); Hindubagh, Pakistan (Bilgrami, 1960); Georgetown, California (Pabst, 1951); San Benito County, California (Murdoch and Ingram, 1966) and the Paringu-Massif, Bulgaria (Munteanu-Murgoci, 1900). The deposits at Asbestos, Quebec have also been described in detail (De, 1961; Olsen, 1961) as have similar occurrences in Quebec (Poitevin and Graham, 1918).

The occurrence of idocrase in alkalic rocks is uncommon, but has been reported at Iron Hill, Colorado (Larsen and Goranson, 1917); Dungannon Township, Ontario (Osborne, 1930); Almunge, Sweden (Quensel, 1915); Southwest Tuva, U. S. S. R. (Kononova, 1961); Seiland, Norway (Barth, 1927) and Fukushinzan, Korea (Inoue and Miyashiro, 1951). Brown, massive idocrase embedded in rock as well as sprays of fine, acicular yellow-green crystals occur at Mt. St. Hilaire, Quebec (Fig. 3). Idocrase in alkalic rocks is often associated with melilite. This is in exact accord with the results of synthesis experiments (Ito and Arem, 1970) which demonstrate that idocrase forms from the breakdown products of melilite. Mineral textures verifying this reaction were actually observed in the field (Larsen and Goranson, 1917) in rocks known as uncompahgrite.

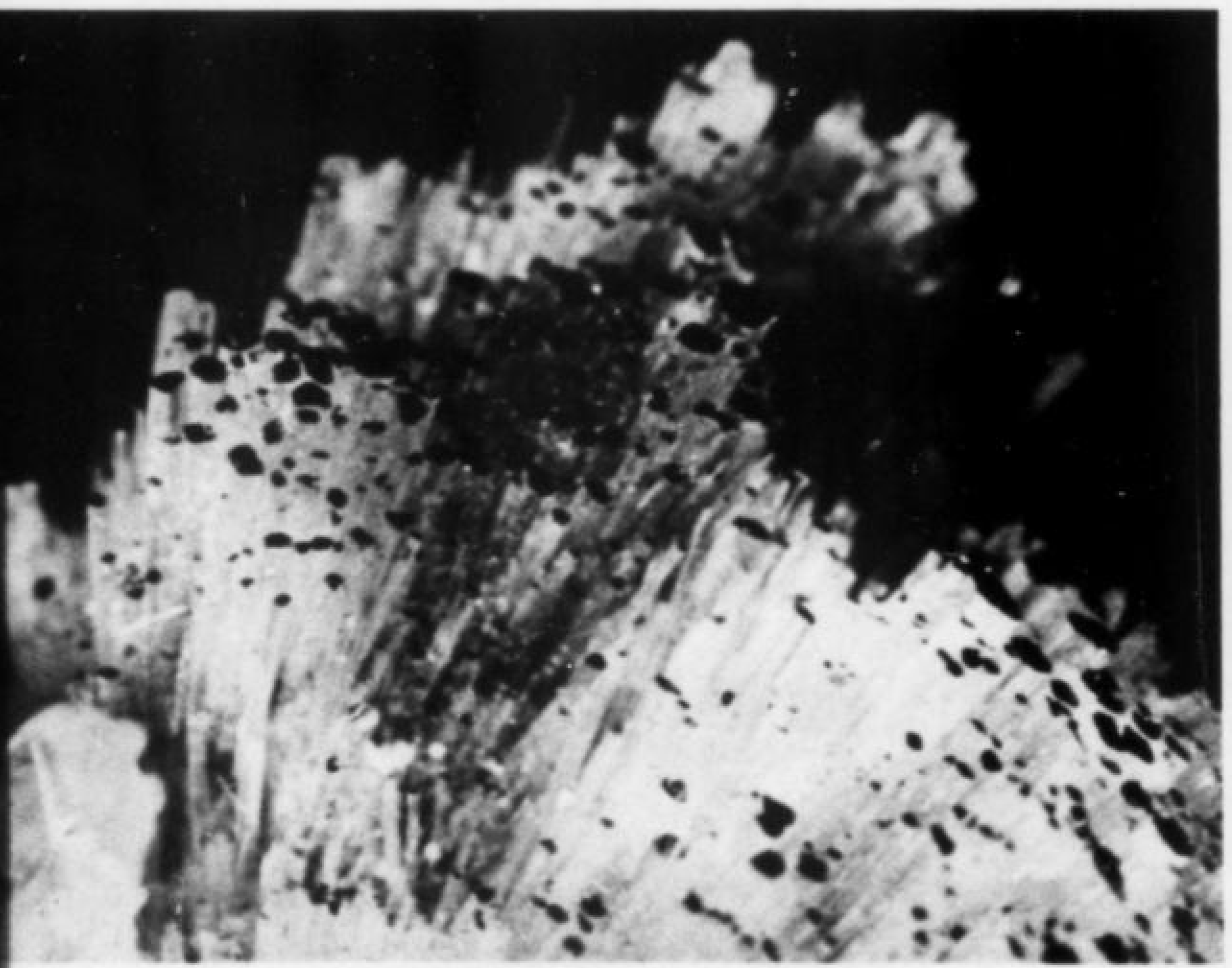

Fig. 3. **Idocrase from Mt. St. Hilaire, Quebec. The crystals are extremely elongated on *c* and have pyramidal terminations. The color is pale green.**

Idocrase occurs in regionally metamorphosed rocks in a wide range of metamorphic grades. In all of these occurrences, however, the host material for the idocrase is a limestone or marble bed. If not for the lack of a nearby intrusive body and the obvious association with schist, gneiss and other metamorphic rocks, these assemblages would be easily mistaken for those found in tactites at igneous contacts. The idocrase crystals from both regionally and contact metamorphosed limestones have similar characteristics.

Fig. 2. **Diopside from Asbestos, Quebec, in acicular, pale green crystals.**

In virtually all of its occurrences idocrase is associated with grossular. This persistent association is one of the most striking in mineralogical literature, and its explanation lies primarily in very similar thermodynamic stability fields for the two minerals. The ramifications of the association, however, extend to the optical, chemical, structural and physical properties of both minerals. This will be discussed in Part 3 of this paper.

HABIT OF IDOCRASE

Idocrase has long been the subject of detailed morphological study, and considerable literature on the subject exists. Crystals may contain as few as two forms (such as *m* and *p*) or as many as 30 (in the case of idocrase from Vesuvius, Italy). The many observations reported before 1900 have been summarized by Hintze (1897) and Dana (1892). Goldschmidt's *Atlas der Krystallformen* (1918) illustrates 249 idocrase crystals from scores of localities. Holzberg (1934), working in Goldschmidt's laboratory in Heidelberg, reviewed all previous literature on idocrase morphology and determined the frequency of occurrence of various forms; a similar compilation was made by Trem-

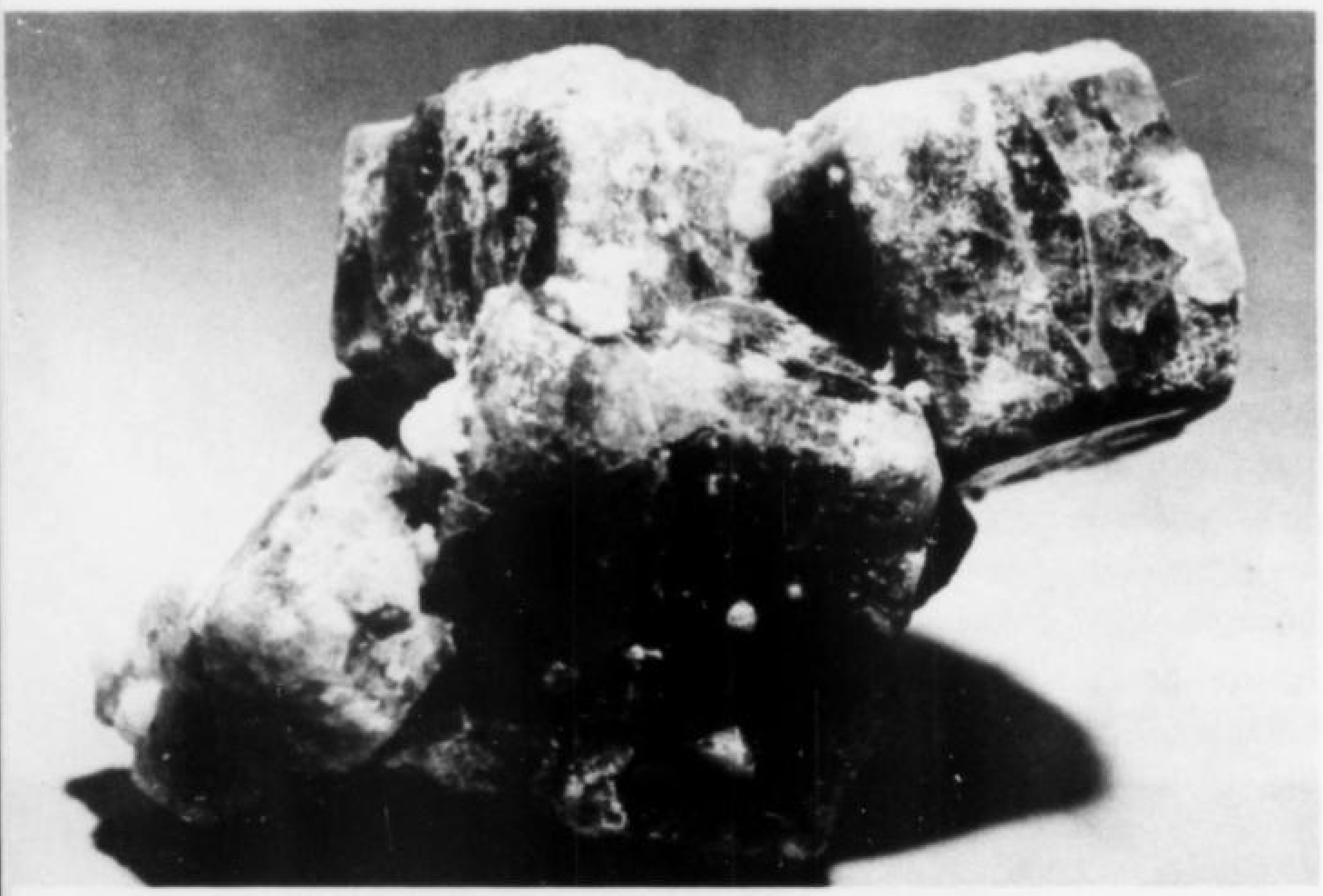

Fig. 4. **Idocrase from Lake Jaco, Mexico, associated with white grossular.**

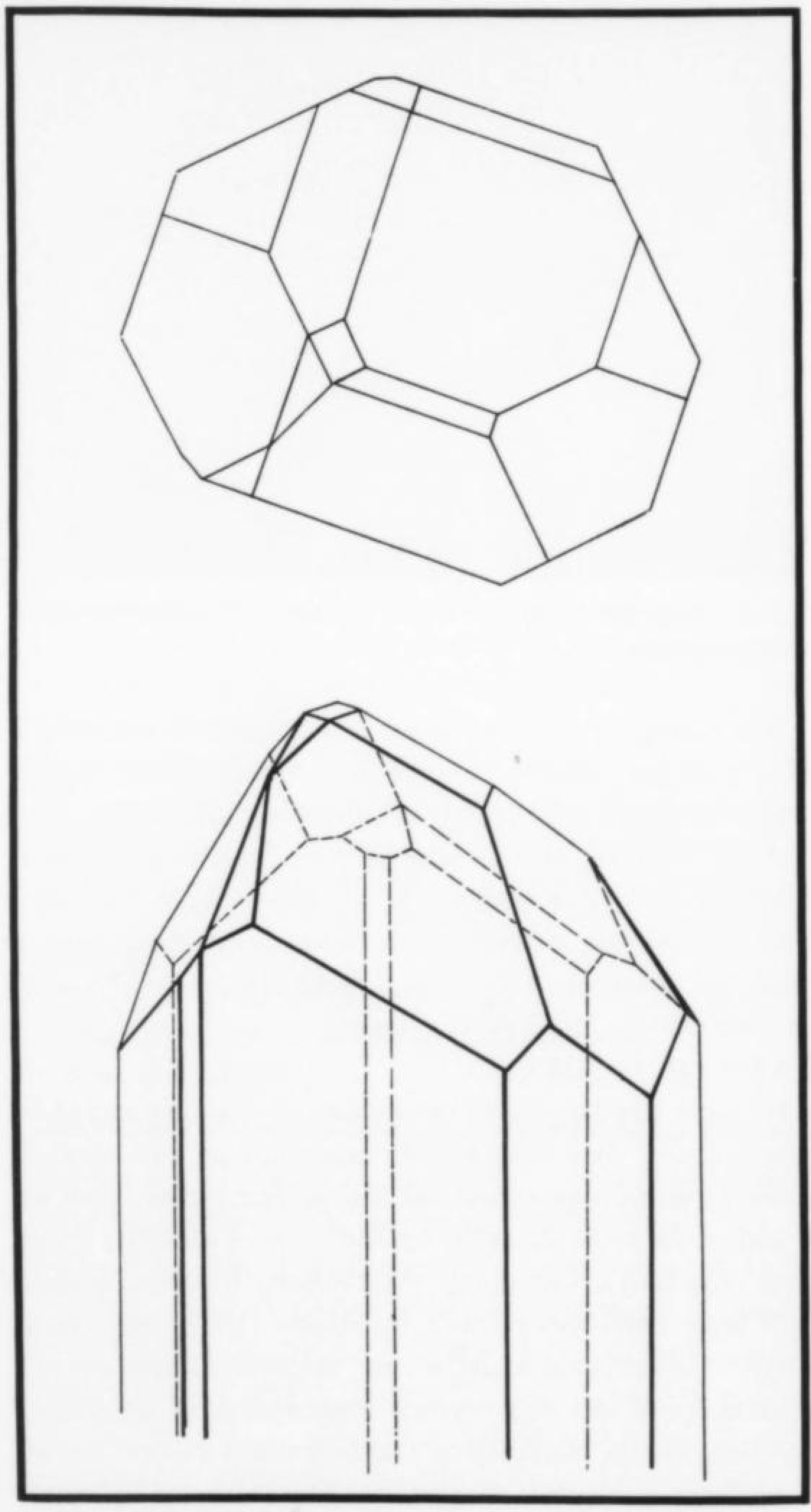

Fig. 5. **Idocrase from Asbestos, Quebec.** ***Drawing by the author.***

blay (1942). Both Holzberg and Tremblay found that idocrase crystals most frequently exhibit the forms *c* {001}, *m* {110}, *a* {100} and *p* {111}.

In general, idocrase crystals from tactites exhibit simple morphology as, for example, in crystals from Lake Jaco, Morelos, Mexico (Fig. 4). These crystals display *a*, *m*, *c* and *p* and seldom show additional modifying forms. Crystals from serpentines, on the other hand, are usually highly complex and tend to be well-formed. Figure 5 is a drawing of a crystal from Asbestos, Quebec; Figure 6 illustrates a crystal from the Montreal chrome pit, Quebec (Poitevin and Graham, 1918). Figure 7 shows crystals from Hindubagh, Pakistan and Fig. 8 is a typically complex crystal from Ala, Piedmont, Italy.

Idocrase crystals from serpentines are frequently deformed and may appear distinctly monoclinic, as demonstrated by Figure 9. The non-tetragonality in idocrase forms may be more than an accident of crystal growth. It may actually indicate a lower internal symmetry than previously supposed (this argument is elaborated in Part III). The slight angular deviations found in careful measurements of crystals by early workers led to great speculation as to the true symmetry of idocrase, but nothing conclusive was established.

OPTICAL PROPERTIES

The published literature on optical properties of idocrase is vast and abounds in contradictions. Accurate

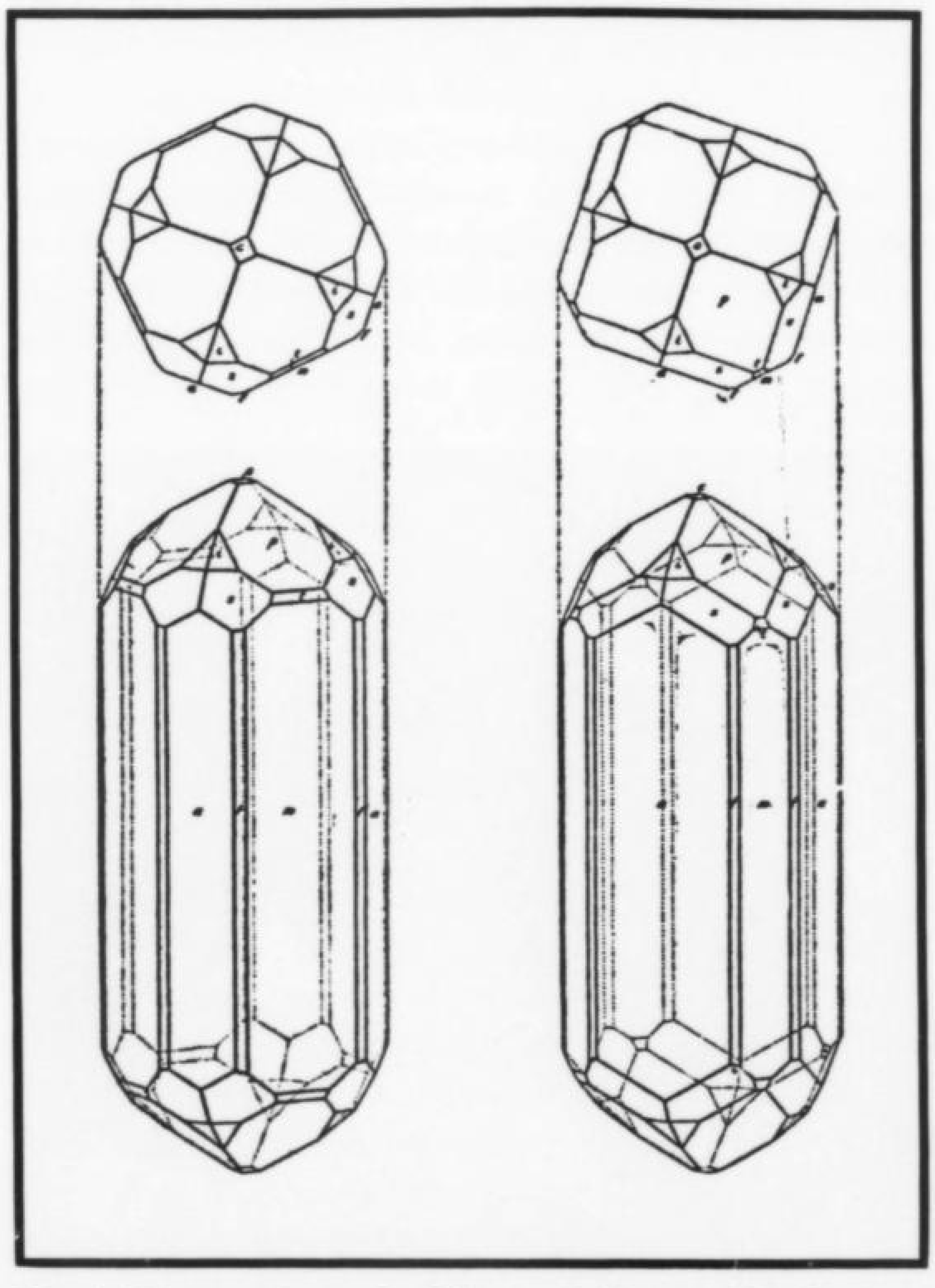

Fig. 6. **Idocrase from the Montreal Chrome Pit, Quebec, a classic locality now under water. From Poitevin and Graham, p. 53.**

Fig. 7. **Idocrase from Hindubagh, Pakistan. This is a serpentine occurrence.**

measurements were reported by numerous early workers, but no two idocrase specimens seemed to give the same results. The conclusions reached by many researchers (regarding the causes of observed optical anomalies in idocrase) vary widely. In retrospect, and in light of recent findings, it seems likely that much or even most of the literature is factually correct. The observed inconsistencies are due to real variations in the optic nature of idocrase.

Earlier observations had raised doubts (as early as 1880) as to the true symmetry of idocrase. In spite of the unequal form development frequently observed, goniometry (excluding a few dubious measurements) seemed always to indicate tetragonal symmetry. But optical data were sometimes difficult to explain without assuming that idocrase has a lower symmetry. Some workers concluded that optical anomalies had to be the result of twinning. Others decided that idocrase was composed of two substances (call them A and B) combined in a way that would produce the observed optical anomalies (and still give a reasonable chemical composition).

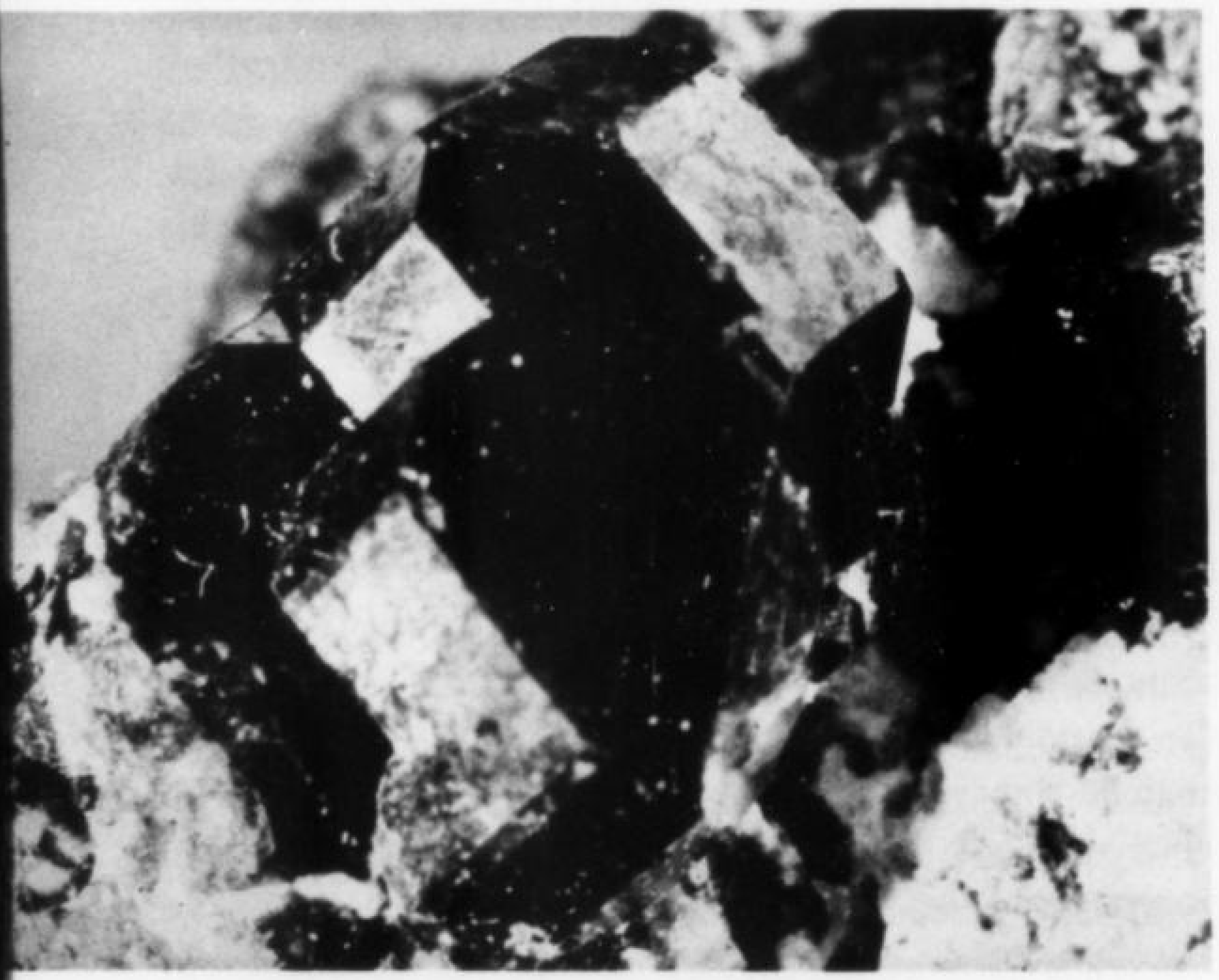

Fig. 8. **Idocrase from Ala, Piedmont, Italy.**

Mallard (1876) was one of the earliest workers to note anomalies in idocrase optics. A tetragonal crystal should be uniaxial and therefore (in crossed polarized light) a section normal to the *c*-axis should be extinct (dark) in all orientations. Mallard found, however, that crystals from Ala, Italy displayed four sectors separated by diagonals of the square outline of the crystal. Each sector was biaxial, indicating orthorhombic, monoclinic or triclinic symmetry. Around the edge of the section, however, the crystal appeared uniaxial.

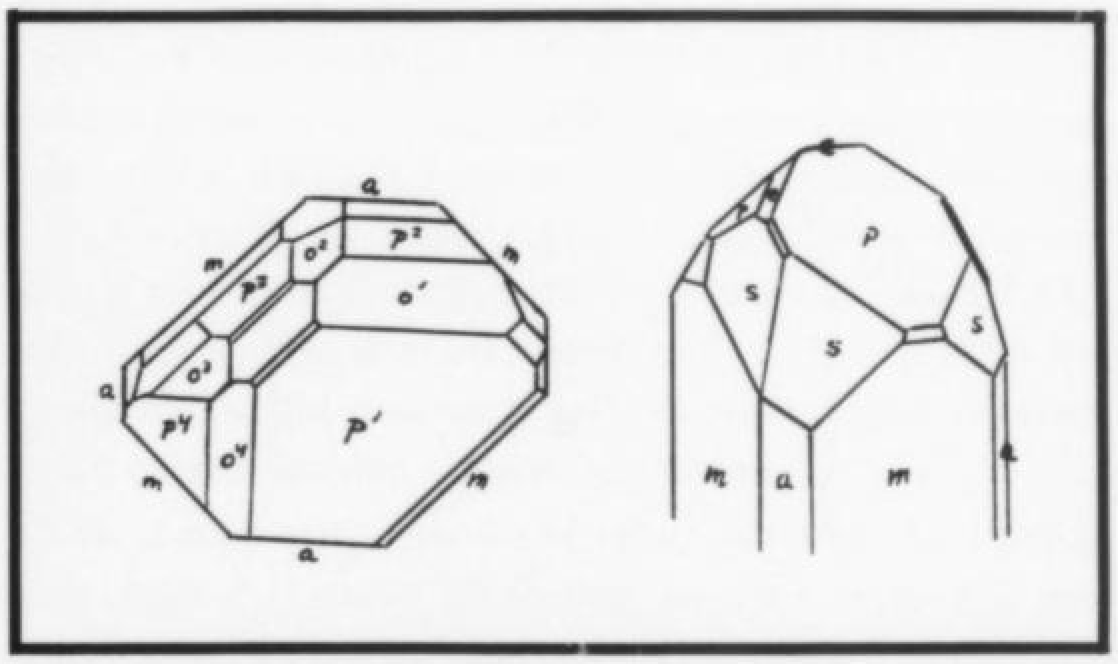

Fig. 9. **Idocrase crystals with a monoclinic appearance. From Goldschmidt, Plates 119 and 128 (Figs. 101, 228) respectively.**

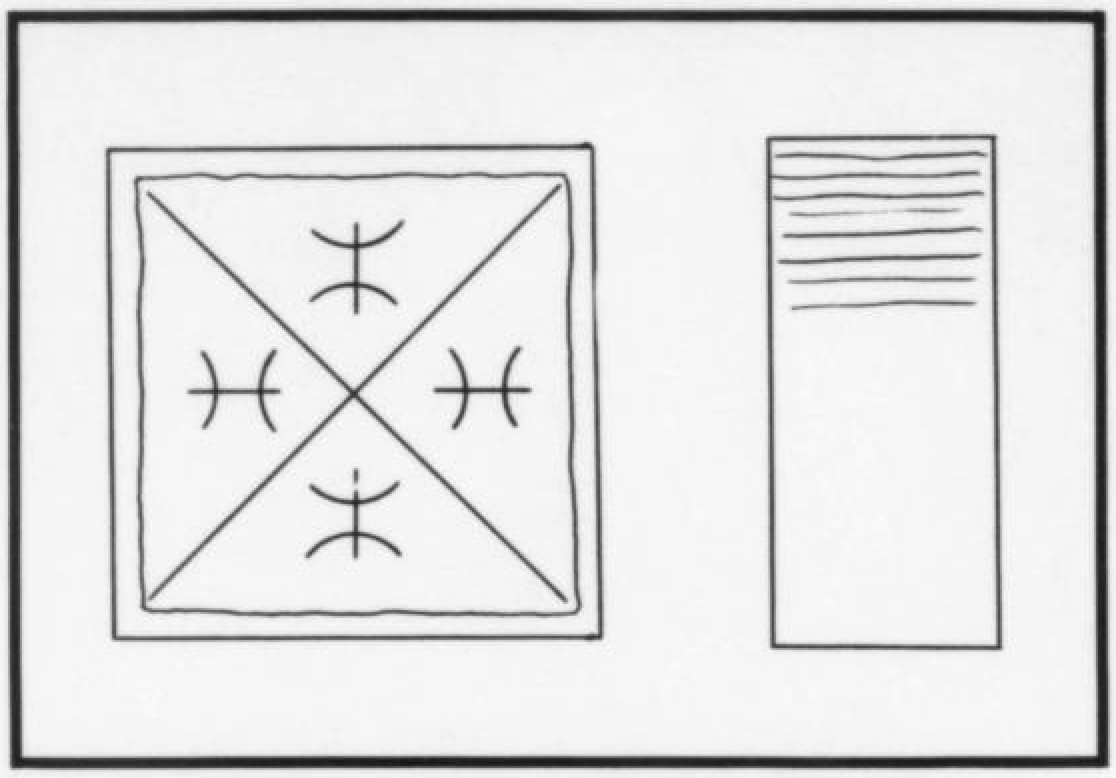

Fig. 10. **Idocrase optics as sketched by Mallard.**

Klocke (1881) noted sectors also, but the *centers* of the crystals he examined were uniaxial. Klocke maintained that the biaxial properties were due to structural anomalies in a "normally uniaxial" mineral. He tried to duplicate these effects in plates of synthetic colloidal materials. Such plates, when stressed, gave optical effects similar to those seen in sections of the natural minerals.

The optic angle 2E (which is zero in uniaxial minerals) varies in idocrase from zero to as much as 62°47' (Brezina, 1877) in idocrase from Ala, Italy. Brezina concluded that the highest possible symmetry for idocrase could only be monoclinic. Mallard defied this claim and asserted that Brezina's observations were best explained by strain in the mineral.

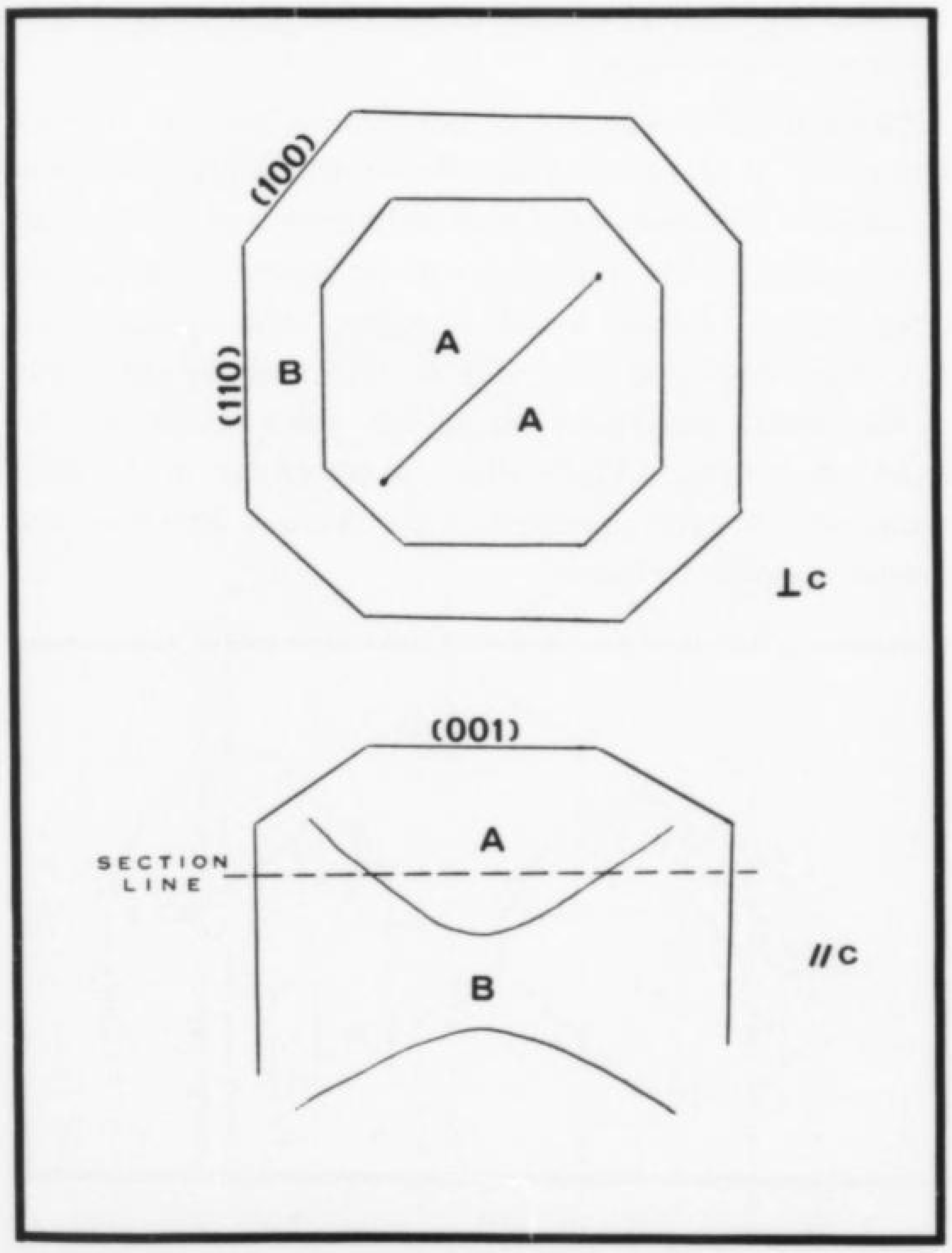

Fig. 11. **Wiluite crystal showing sectors seen in polarized light.**

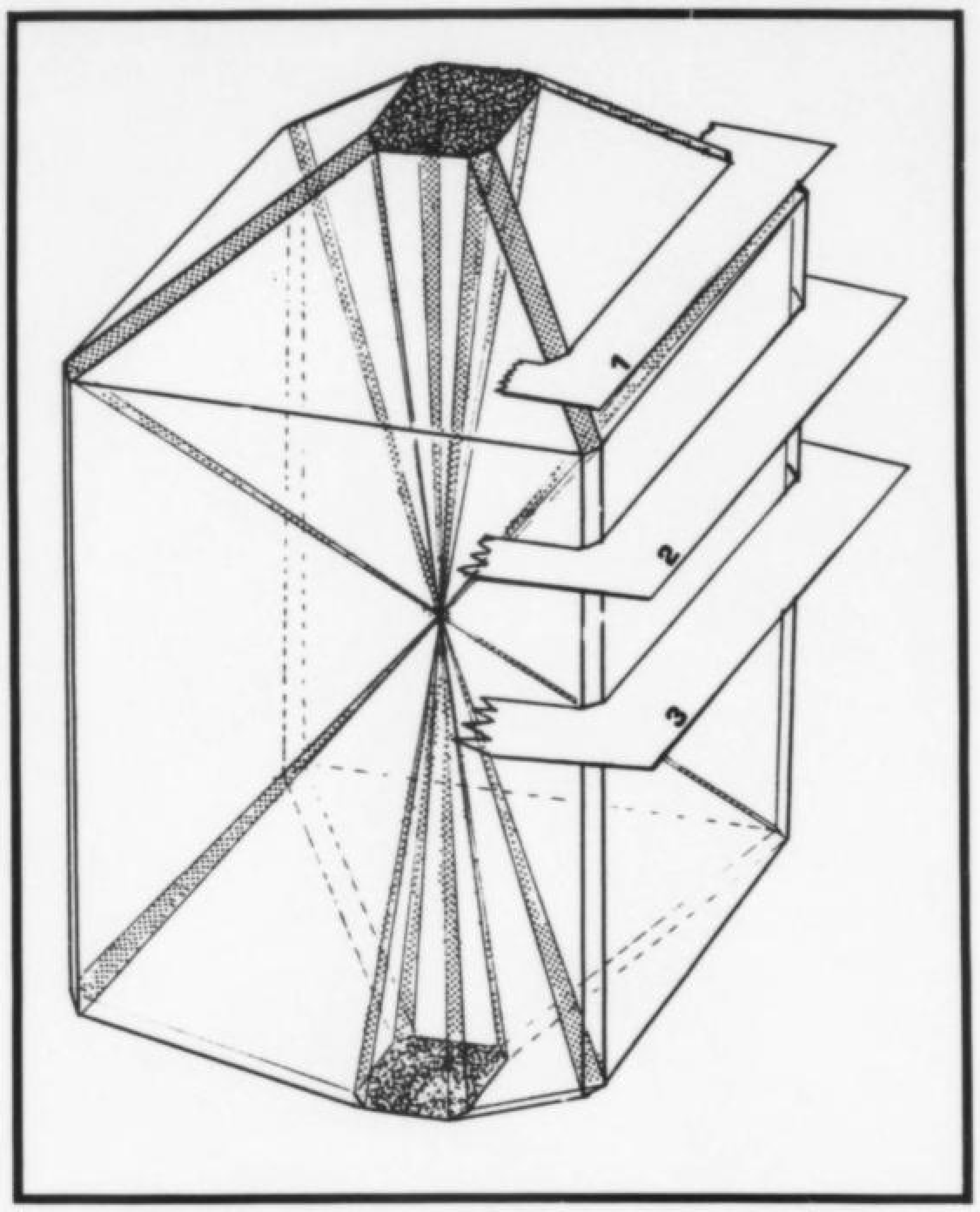

Fig. 12. **Face loci in idocrase, which may concentrate trace impurities and thus modify crystal habit and effect optical properties.**

Von Lasaulx (1880, 1882) described even more striking optical features. Idocrase from Gleinitz and Johnsburge (= Johannisburg, now Pisz) in Silesia occurs with prehnite, natrolite, pectolite and hyalite; the idocrase forms colorless druses that grade to amethyst color at the crystal terminations. Water-clear crystals cut normal to the *c*-axis gave uniaxial interference figures, but still showed the sectors described by Mallard. Between these sectors and along the diagonals of the basal plate lay dark, diverging wedges. The four sectors became extinct simultaneously when an edge of the crystal lay parallel to one of the polarizers; in the 45° position a bright field was seen, with color stripes running parallel to the sides of the plate. Von Lasaulx noted zoning in sections cut parallel to *c*, but he regarded these as due to irregularities in crystal growth.

Doelter (1884) found that the optic angle could be changed merely by heating. Crystals that (at room temperature) had a small axial angle showed an increase in this angle on heating. Vesuvius idocrase showed a change of 14°. Surprisingly, however, crystals with large optic angles at room temperature showed a *decrease* in angle after heating. A brownish crystal from Ala gave 2E of 24° at room temperature, 15° at red heat, and 9° just below the melting point. Doelter concluded that the variations in 2E he observed were due to the role of water in idocrase, since variations in water content could be related to the properties of the various samples.

Work by Brauns (1891) and Klein (1894) established the existence of both optically positive and optically negative

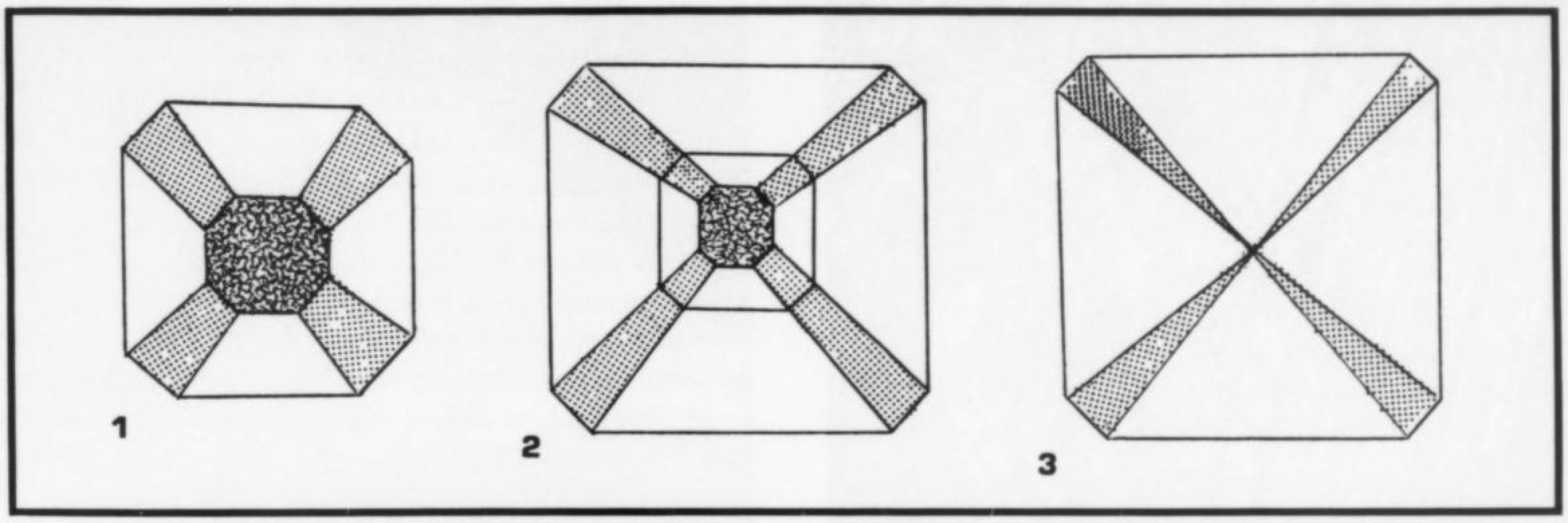

Fig. 13. **Sections through crystal shown in Fig. 12, center section inclined. Trace elements concentrated on face loci may explain some of the optical features seen by early workers.**

idocrase. Crystals from Ala, for example, were consistently negative while those from Wilui River, Siberia were always found to be positive. Brauns explained anomalous optical properties in idocrase as due to admixture of positive and negative types (recall the A + B argument mentioned previously). Klein found it difficult to imagine that the observed effects could be due to distortions of a "normal" substance of some kind. A mixed-phase theory seemed satisfactory, but Klein thought the "individuals" in the mixture (i.e., A or B) possessed a *lower* symmetry than tetragonal, perhaps orthorhombic.

Prendel (1890) wrote extensively on a variety of idocrase called "wiluite" (from the Wilui River, Yakutsk, East Siberia). Wiluite crystals invariably contain small inclusions of birefringent grossular. The idocrase is optically positive, strongly birefringent in some sections, zoned, and rather rich in boron. The most distinctive feature of "wiluite", however, is a clearly-defined zonal arrangement seen in polarized light (Fig. 11). The regions labeled *A* are homogeneous and nearly uniaxial; regions *B*, however, are "scaly" with birefringence that varies between layers, and are distinctly biaxial. Prendel found that heating of such crystals caused the centers to become uniaxial, and extended heating made the changes permanent. The optical features of wiluite were attributed to boron, since this material is quite rich in boron (up to 6% B_2O_3). Idocrase crystals from Cziklowa and Monzoni, however, are optically positive and contain *no* boron. The long debated question as to the cause of the optic sign in idocrase could therefore not simply be attributed to the presence of this element.

Gadecke (1938) tried to correlate optical properties of idocrase with chemical composition, and considered refractive index, specific gravity, dispersion and optical anomalies. All his tests were performed on very carefully purified material. A structural model for idocrase was available by this time (Warren and Modell, 1931) and Gadecke tried to fit his observations to the known structure. A difference in refractive indices of Mg-rich and Mg-poor parts of idocrase crystals was discovered. Gadecke therefore proposed the existence of two distinct chemical types: $A = Ca_9Al_4Mg_3Si_9(O,OH,F)_{38}$ and $B = Ca_9Al_6Si_9(O,OH,F)_{38}$. The *B* component is almost identical in composition to grossular (not surprising, since Warren and Modell's model had shown idocrase to contain structural units of grossular). Analyses (from old and new literature) of natural idocrase indicate a range of $A_{30}B_{70}$ to $A_{60}B_{40}$; this matches closely an idocrase formula proposed by Machatschki (1930). Gadecke used his "bipartite" idocrase theory to explain chemical variations and optical anomalies in the mineral. Chemical variations in idocrase are so extreme, however, that these correlations are, at best, uncertain. A two-component idocrase model also has not proved to be widely acceptable.

There is little doubt that many of the observed "anomalous" features of idocrase optics can be rather simply and adequately explained. Compositional heterogeneity in crystals has been the subject of a great deal of research, well-summarized by Frondel *et al* (1942), Buckley (1951), and others. Crystals, while growing, may selectively adsorb components from the surrounding medium, concentrating them on specific growth loci (edges, faces and corners). Even the presence of trace amounts of certain elements in a crystal may significantly alter the optical or physical properties of the host material. The powerful chromophores[1] discussed by Buckley are excellent examples of this.

Fig. 12 shows the outline of an idealized idocrase crystal, exhibiting prisms, pyramids and a pinacoid. Within the outline can be seen the growth locus characteristic of each of these forms, assuming growth from a very small nucleus at the center. The zonal features to be expected in sections of such a crystal are diagrammed in Fig. 13. These figures offer a simple explanation for the observations of Klein and other early workers. Impurities concentrated on growth loci might thus seem to be a panacea for explaining all optical anomalies seen in idocrase.

This complacent view is shattered, however, by certain other optical features (including lamellar twins and extremely complex zoning) that cannot be so simply explained.

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[1] A chromophore is a substance whose presence in minute quantities causes a distinct coloration of a host material.

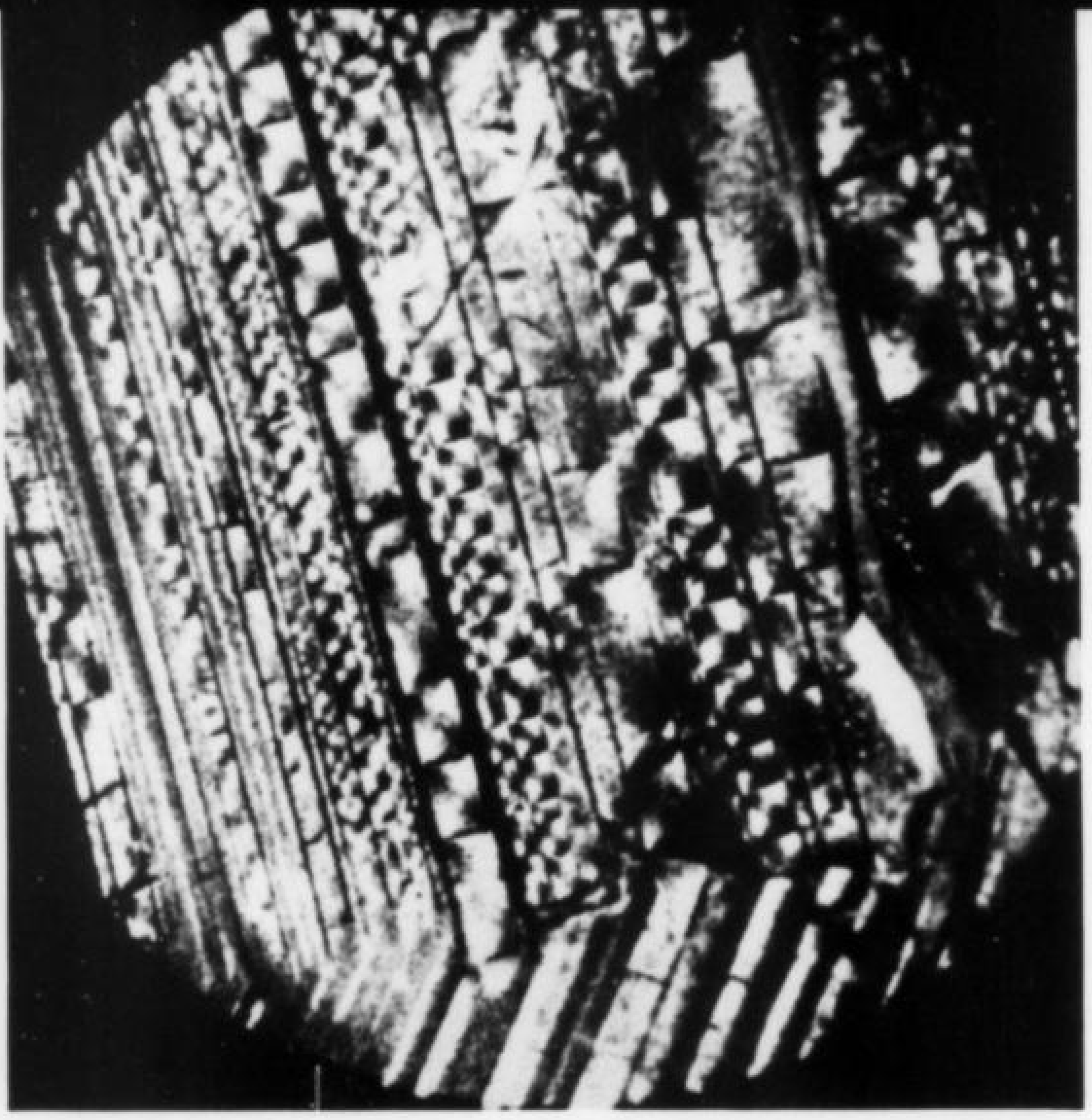

***Fig. 14.* Idocrase from Lupikko, Finland, showing a "chessboard" structure.**

Figure 14 shows a thin section of idocrase from Lupikko, Finland, reported by Eskola (1951). Eskola termed the observed feature "chessboard structure" and careful analysis showed that thin chlorite layers are interleaved between layers of idocrase. The composition and optical properties of idocrase vary markedly within such crystals, and exhibit both optically positive and negative areas.

The writer has observed other unusual effects in thin sections of idocrase crystals from various localities. Crystals from Asbestos, Quebec display (in sections cut normal to the *c*-axis) remarkable and distinct zonal patterns that vary in extinction position (Fig. 15). Electron microprobe scans across such crystals show complete homogeneity in all major elements (Ca, Si, Al, Mg, Si and Fe), and wet chemical analysis shows the only other components present to be water (2.9%) and MnO (0.19%) with a trace of Na. In plane polarized light the crystals are completely uniform in appearance. Asbestos idocrase is variable in optic character: it can be either uniaxial or biaxial.

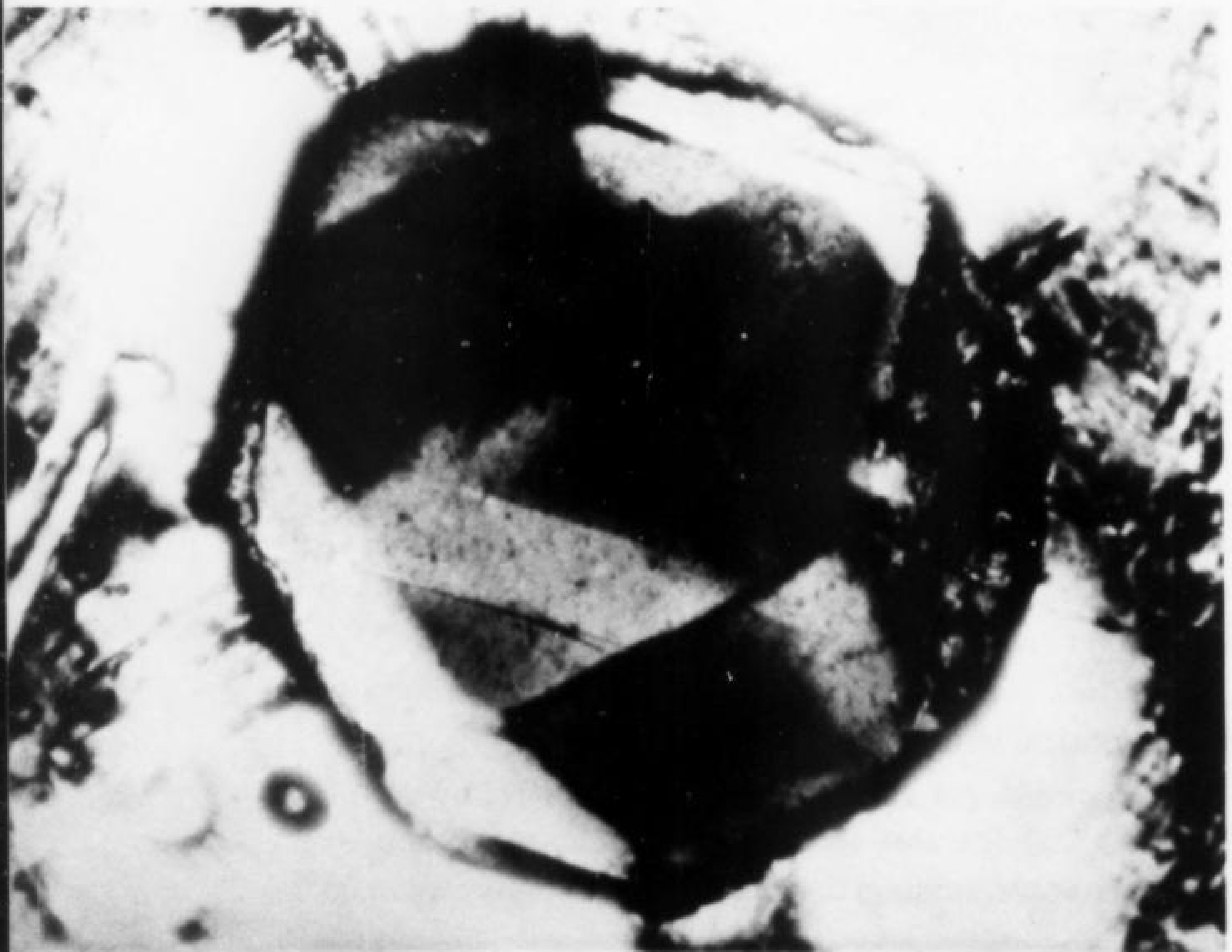

***Fig. 15.* Idocrase from Asbestos, Quebec. Single crystal in crossed polars, section cut perpendicular to the *c* axis.**

Idocrase from Black Lake, Quebec shows (Fig. 16) similar distinct zones, while idocrase from Franklin, New Jersey (beryllian variety, Fig. 17) displays lamellae that resemble nothing so much as twin bands in plagioclase feldspar. Such lamellae are almost impossible to explain on the basis of growth loci impurity concentrations, but are good evidence for true twinning in idocrase. In sections of idocrase from Sanford, Maine the observed lamellae are extremely fine. It is a logical conclusion that twinning may be occurring on a submicroscopic scale. This conclusion is supported by evidence from various other analytical approaches, and will be discussed in parts II and III of this paper.

No unified theory has yet been proposed to account for the huge diversity of optical effects seen in idocrase for nearly a century. Uniaxial and biaxial, optically positive and negative types all exist; zonal structures are common in thin sections. Heating and pressure produce marked changes in observed optical characteristics. Birefringent colors are frequently "abnormal". Fine scale intergrowths with other minerals are observed, and twinning may be present both macroscopically and microscopically.

Anomalous optical properties have been noted in many minerals, including grossular. Such observations point out a gap in our understanding of the true structural characteristics of many of these minerals. Birefringence in grossular (an isometric mineral that should exhibit isotropic optical properties) is well known. Its cause may be related to the anomalous optical properties of idocrase. Structural work does not help in the case of grossular, X-ray and neutron diffraction both yield isometric structures.

A structure for idocrase was presented in 1931. It has since been modified (Coda *et al*, 1970) but the basic features of the original model remain unchanged. How does this model help explain idocrase properties? What is the nature and significance of chemical variation in the mineral, and how is this related to observed optical, physical and paragenetic features? These problems will be discussed in Part II of this paper. Part III will present new data and a theory that may explain and unify optical, chemical, X-ray and morphological features of idocrase and relate these to the origin and occurrence of the mineral.

ACKNOWLEDGEMENTS

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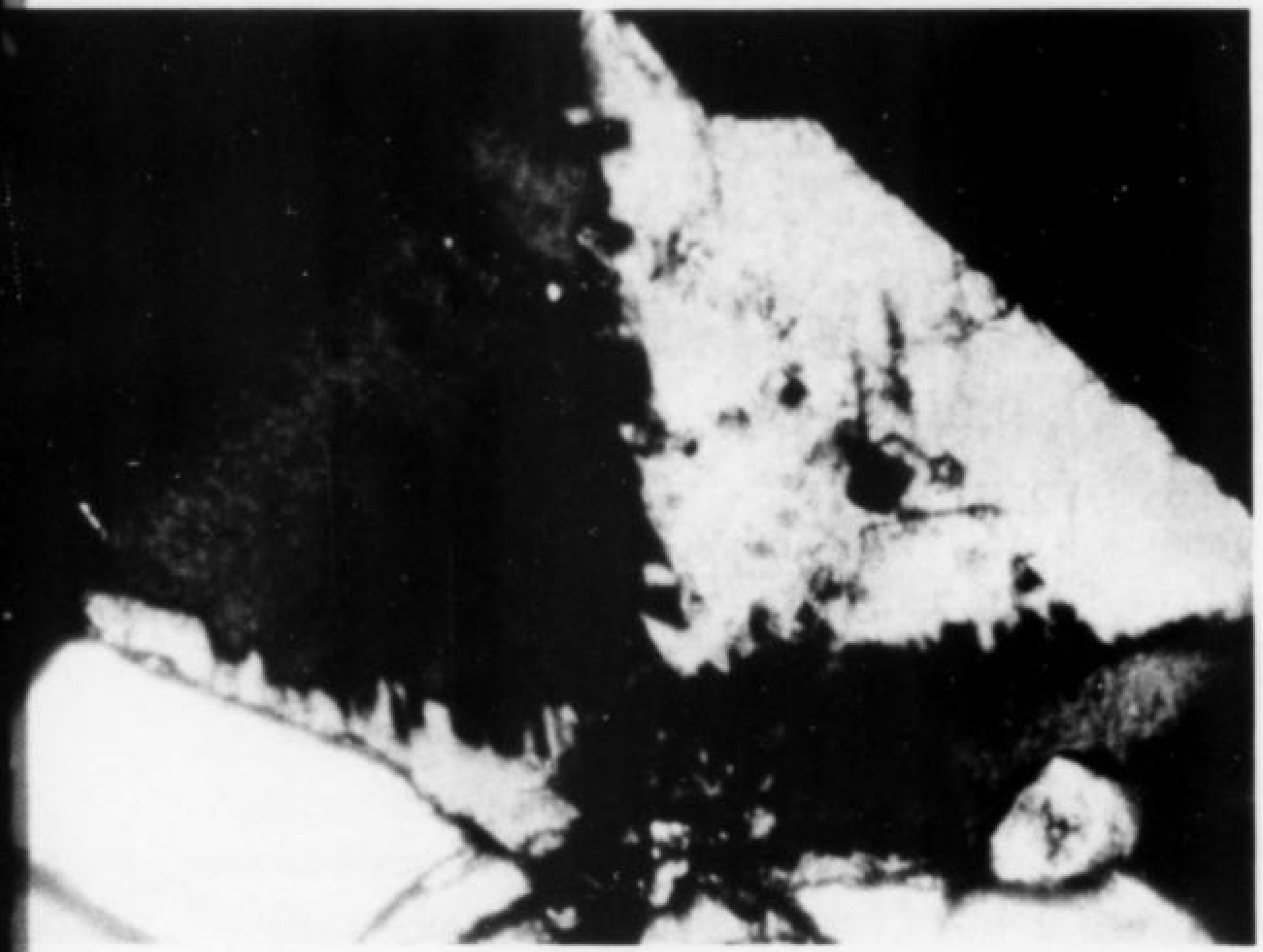

Fig. 16. **Idocrase from Black Lake Quebec, crossed polars, section cut perpendicular to the *c* axis.**

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Fig. 17. **Beryllian idocrase from Franklin, New Jersey, showing (crossed polars) what appears to be lamellar or polysynthetic twinning.**

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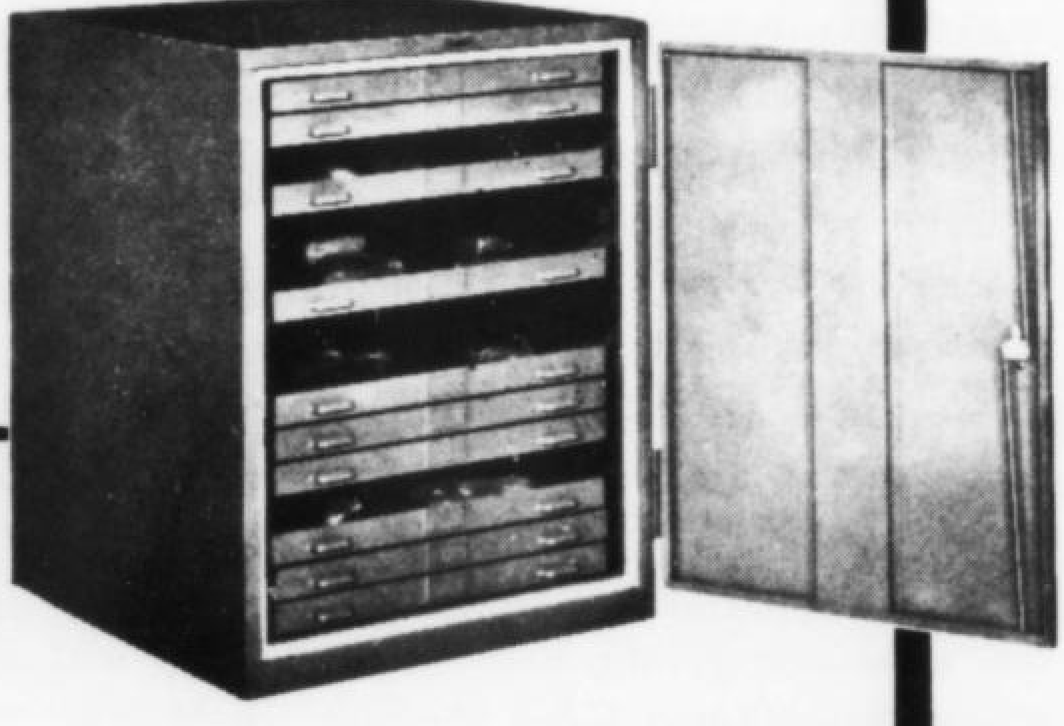

Dot Projection Method of Reproducing Crystal Drawings

With Advice on Crystal Drawing in General

by John Sinkankas

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Crystal drawings are constantly needed for articles and books, and no doubt more would be freely used if it were not for the trouble involved in preparing them. Conventional methods sometimes fail to produce good results as evidenced by obviously inaccurate drawings that have appeared in some recent books. In making the illustrations for *Mineralogy for Amateurs* a simple and direct solution to the problem was struck upon which is described herein. It is not claimed to be a new method, but at the same time no one appears to be using it, and thus for future authors and illustrators it may become a useful technique.

In essence, the method uses the projection upon drawing paper of a network of illuminated dots from a corresponding network of perforations in a heavy paper slide inserted in a conventional 35 mm slide projector. The perforations are made at the intersections of the lines in a crystal drawing pasted to the paper slide. The illuminated dots are marked with pencil, the paper taken to the drafting board, and the dots connected to accurately reproduce the original crystal drawing. The original crystal representations are obtained by simply cutting out suitable text figures in any book of mineralogy or crystallography.

Compared to this uncomplicated method all others such as tracing, scaling up from a grid of parallel lines, photography, etc., are cumbersome and time-consuming, not to mention being inaccurate at times. A very strong point in favor of the dot projection method is the ability to easily obtain any desired degree of magnification. In order for a crystal drawing to appear at its best when printed, and at the same time allow ease of inking and lettering, it should be about three or four times as large as the final size depicted in the textbook. In most textbook illustrations where the crystal figure measures about one to two inches (25 to 50 mm) diameter, the enlargement should be from three to four inches (75 to 100 mm). From practical experience this has been shown to be convenient for easy inking, variable thickness of line inking, and for inserting lettering.

The original drawings are obtainable from any standard textbook. A copy that is beyond repair is excellent for the purpose and lessens the pain caused by cutting it up. However, in order to project the text drawing in its entirety it should not exceed a diameter of about 1.5 inches (c. 40 mm) inasmuch as most slide projectors accept square slides of only two inches (c. 50 mm) on edge. A list of textbooks containing figures of suitable size is appended at the end of this article.

Larger drawings may be projected in segments but care must be used in adjusting the enlargement and orientation. It is usually best to project one portion of the drawing, lay in the dots, and then pencil in the connecting lines. Return the drawing to beneath the projector and repeat for the second portion making sure the projected dots coincide with appropriate lines of the first portion. This procedure is commonly necessary when drawing calcite scalenohedra for example. Alternatively, only one end of the elongated crystal drawing need be pierced, and the other end "mirror-imaged" by turning around the slide in the projector. A final possibility and one that has generally worked well is to mount elongated crystal drawings diagonally upon the heavy paper square.

After a series of textbook cut-outs are assembled they are fixed to the heavy paper square by brushing quickly with any convenient glue such as thinned "white" or polyvinyl chloride water-emulsion glue. It is important to coat the back of the drawings quickly and completely to avoid cockling. Center upon the paper square and adjust positions; gently rub down with a clean cloth to insure flatness and removal of air bubbles. Avoid sliding or shifting because this may cause wrinkles or stretching and subsequent inaccuracies in projection. Let dry between several sheets of blotting paper or other soft paper; use a flat weight to apply pressure.

Mounting stock for making squares should be at least as heavy as file card stock. Library file card stock is excellent because of its somewhat greater thickness, stiffness and ability to produce clean holes when pierced by the needle.

After the squares are dry, lay each in turn upon a piece of corrugated cardboard or other soft yet flat surface and holding the needle as vertically as possible, pierce a hole completely through the crystal figure and paper at each line intersection. Use a no. 5 sewing needle which measures approximately 1.25 inches (c. 30 mm) long and is about 1/32 inch (c. 1 mm) thick. Insert the eye end of the needle into a small piece of wooden dowel to form a convenient handle. A magnifier helps to accurately start the holes.

While any projector can be made to serve it has been found most convenient to use an older model designed to take one (or two) slides at a time. The projector can be used horizontally but it is better to mount it vertically with clamps to a table edge and place the drafting board and paper below on the floor. This enables the drawing board to be easily shifted in position and its height adjusted by use of blocks. It is also easier to reach and dot the projected spots of light.

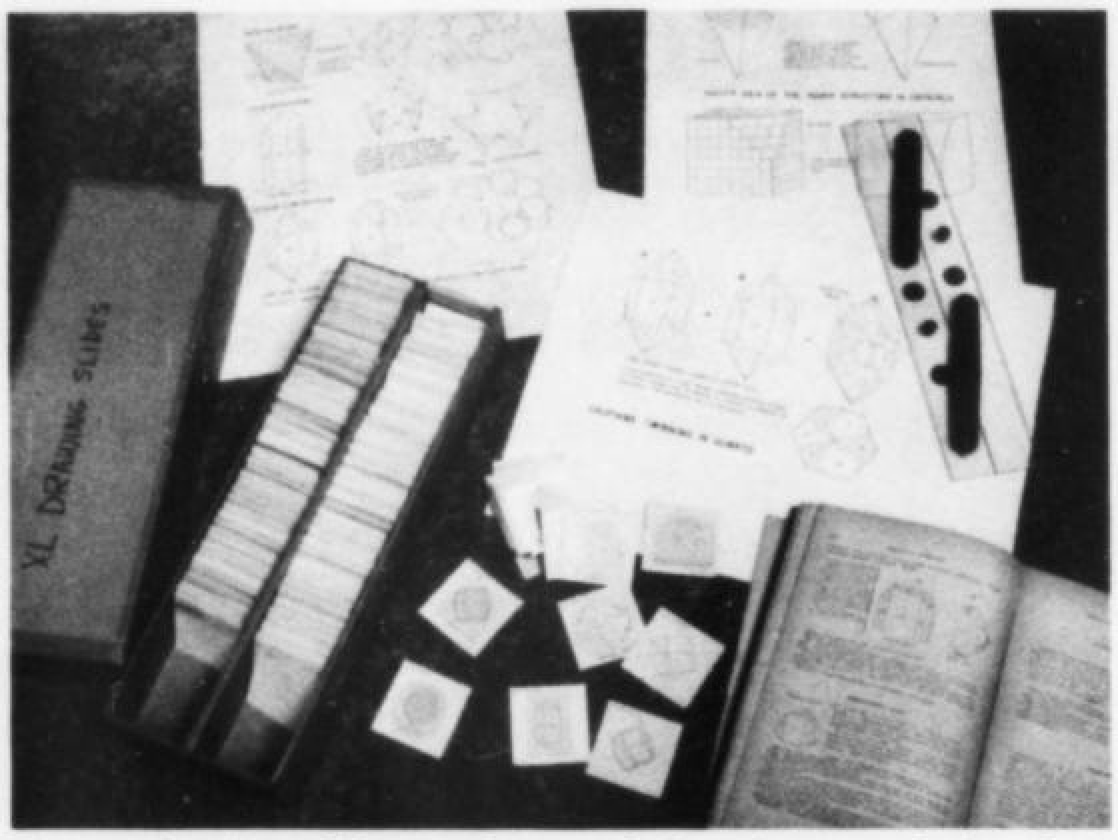
When the height is appropriate for the enlargement desired, focus the light spots sharply and mark their centers with a soft pencil, no. 1 or no. 2. Do not press hard and cause dimpling of the paper.

The dotted paper is now removed to the drafting table and the lines ruled in pencil to connect appropriate sets of dots. To promote accuracy at this stage rule in all lines in any given zone by using parallel rules or establish the direction of one of the lines in a zone and lock the head of the drafting machine if such is being used. In very short order an accurate reproduction of the crystal drawing of the textbook will be made except magnified to a desirable diameter.

In inking, consider using thinner and thicker lines to promote the illusion of depth. In general, fronting lines should be inked about twice as thick as those dotted lines at the back which indicate edges of the crystal not visible from the front. Axes may be indicated by lines composed of alternating dashes and dots but in any case should be inked in very lightly. Fronting lines in the drawing may also be inked in tapered fashion so that the thickest portion is that closest to the eye and the thinnest portion that farthest away. This technique creates an unusually elegant drawing with considerable realism.

In drawing models of close-packed spheres representing ions it helps a great deal to apply the laws of perspective to promote the illusion of depth. In this technique the lines in the vertical zone are allowed to remain parallel but those in the horizontal zone (*a*-axis) converge on a "vanishing point" placed somewhere behind the drawing along the extension of the *a*-axis, that is, somewhere to the right of the drawing.

Where it is desired to make dot projection drawings from figures in textbooks or reprints without harming same, use the following method. Place a piece of file card stock underneath the page containing the drawing; adjust the paper until one edge is aligned exactly with the page edge or parallel to the *c*-axis; secure in position with a small but powerful steel spring clamp of the kind sold in stationery stores; paper clips are unsatisfactory. Underneath the paper place a piece of corrugated cardboard and proceed to pierce the intersections as before. Remove the heavy paper beneath the drawing and sketch in the connecting lines using the text figure as a guide. Label all faces, axes, etc., as needed and identify. Trim the heavy paper to the size that will fit in the projector. The small holes left in the textbook or reprint paper can be burnished closed with the back of a fingernail after first placing a hard smooth surface beneath the page.



Dot projection slides and several drawings made by their use. Slides (2 x 2 in.) in storage box and in lower center.

The following slides are useful: all forms of the crystal systems, system axial crosses, twins, distortions, typical habits, epitaxies, lattice arrays, atomic structures, views along axial ends, symmetry diagrams, axial intercept diagrams, and in fact almost any kind of small text drawing.

Non-geometrical text figures, for example, sketches or photographs of mineral specimens, complex crystals, or others, can also be reproduced with a fair degree of precision by using many dots along the lines. If these are spaced closely enough the light spots cast upon the drafting paper will at least establish the basic lines in correct proportions.

The following references contain text figures suitable for the dot projection method but do not represent all useful texts by any means.

Bragg, W. S. (1932) *The structure of silicates.* Leipzig: Akad. Verlagsgesellschaft. Fine structural drawings but most are too large.

Dana, E. D. (various) The *Text-Books,* all editions, from 1877 onward. Some earlier editions display greater variety. Used 3rd and 4th editions are commonly available secondhand.

Linck, G. (1896) *Grundriss der Krystallographie.* Jena: Gustav Fischer. Many good drawings.

Miers, H. A. (1902) *Mineralogy.* London: Macmillan. Splendid drawings but many are somewhat large.

Naumann, C. F. (various) *Elemente der Mineralogie.* All editions provide exceptionally large numbers of drawings, especially those showing changes in habit for a given species.

Phillips, A. H. (1928) *Mineralogy.* New York: Macmillan. Many fine drawings but most are too large.

Raaz, F. & Tertsch, H. (1939) *Geometrische Kristallographie.* Wien: Julius Springer. Many fine drawings.

Rinne, F. (1922) *De Feinbauliche Wesen der Materie.* Berlin: Gebr. Borntraeger. Many structural models.

Tschermak, G. (various) *Lehrbuch der Mineralogie.* The various editions contain numerous fine drawings.

One note of caution — when using copyrighted materital, please obtain permission to reproduce crystal drawings for publication.

METAMICT MINERALS: A REVIEW

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PART I. CHEMICAL AND PHYSICAL CHARACTERISTICS, OCCURRENCE.

INTRODUCTION

The term metamict has been used frequently in recent years to denote an unusual noncrystalline condition observed in at least fifty minerals. The purpose of this paper is to review various aspects of the metamict state, and to discuss the more important of these aspects in some detail. The term is applied to certain minerals of complex composition containing U and/or Th which, in the course of time, have passed from a truly crystalline state to an amorphous state. These noncrystalline pseudomorphs often retain their crystal faces (Fig. 1) and have essentially the same chemical composition as the original mineral. With their change from a crystalline to an amorphous state there are accompanying changes in some of their physical and chemical properties, for example, they become x-ray amorphous, optically isotropic, more susceptible to chemical change, etc. In some cases the minerals are in a partially amorphous state, the structure being only partially destroyed. For these, changes in the properties just mentioned are incomplete. The metamict state results from radiation damage to the structure from bombardment by alpha particles arising from the disintegration of U, Th, and their decay products, usually contained by the mineral. That metamict minerals are not formed directly by chemical alteration is indicated by the fact that they are usually pitchy to glassy, they break with clean conchoidal fractures, their cores and borders are equally amorphous, and they usually occur in fresh rocks.

The term metamict was introduced by Broegger (1893) and is derived from a combination of the Greek terms *meta* + *miktos,* meaning *after* + *mixed,* implying the rearrangement of the original structure to a new amorphous structure. In recent years the term metamictization has been used to refer to the process whereby a mineral becomes metamict, and the term metamictness, to the amount of change.

Some minerals in the metamict state have presented nearly insurmountable problems with respect to the determination of their original mineral type, ideal chemical composition, crystal structure, classification, and quantitative data for their physical properties. Barsanov (1964) has considered some of these problems in detail. Generally metamict minerals are chemically complex. They characteristically show large-scale heterovalent isomorphism in both the cation and anion parts of their structures. Furthermore metamictization is usually accompanied by an increase of nonessential water, by oxidation of some cations (especially Fe^2 and U^4), and perhaps even by absorption of impurity elements. This complex and variable chemistry has left the chemical formulas for some of the metamict species in considerable doubt even to the present time.

Chemistry alone is not the major problem. Usually a satisfactory chemical formula can be determined, providing the crystal structure is known, even if the chemistry is exceedingly complex. Unless a nonmetamict or poorly metamict specimen is available, the only crystal data determinable for the mineral is from the external morphology. Often even the morphological data are not accurate, because many crystals are large and have rough faces which only can be measured with contact goniometers. In recent years the difficulty of determining the crystal structure for some species has been overcome by growing synthetic crystals, or by recrystallizing metamict specimens by heat treatment. For example, samarskite, first named in 1847, and since that time considered to be orthorhombic, was synthesized and shown to be monoclinic by Komkov in 1965. He also established the basic formula, $(Y,U,Fe)NbO_4$, which had not been determined accurately up to that time.

After a chemical formula and structure are known for certain, there is no difficulty in classifying the mineral on the basis of physical-chemical considerations. Special attempts to classify metamict minerals have been made by Van Wambeke (1960) and Barsanov (1964).

When the minerals are classified problems still exist in determining quantitative data for physical properties, e.g., specific gravity, hardness, optical constants, structural parameters. Quantitative data vary according to variations in the chemical composition for an individual specimen as well as the degree of metamictization for that specimen. A knowledge of the ideal composition and crystal structure at least helps define limits to these data.

THE CHEMISTRY OF METAMICT MINERALS

Metamict minerals occur in three chemical classes, namely, oxides, phosphates, and silicates (Table 1). The largest number are isodesmic multiple oxides containing niobium, tantalum, and/or titanium. Chemically these can be represented by the general formula AxByCz in which A = rare earths (especially Ce, Y, Er, La), U, Th, Ca, Na Fe^{2} , Mn, Pb, etc., B = Nb, Ta, Ti, Zr, Fe^{3}, etc., and C = O, OH, F, etc. The complexity of the chemical composition of these minerals is due to large-scale heterovalent isomorphism within the various parts of the structure. The role of water is not known for certain, but it is generally considered to be introduced during metamictization. Most of these multiple oxides are typically metamict, although rarely nonmetamict, or poorly metamict, specimens of some of them have been reported, especially those varieties which are free of U or Th.

Metamict phosphates are scarce. Even those phosphate minerals known to be metamict show this condition only rarely. Griphite and britholite are metamict more commonly and to a greater degree than monazite and xenotime whose compositions are not as variable.

Numerous silicates show the metamict condition. However, for most of these cases nonmetamict specimens of each species are also well-known. So far only minerals with relatively simple silicate structures are known to be metamict. The number of examples drastically decreases from the simple nesosilicates $(SiO_4)^{-4}$, through the sorosilicates $(Si_2O_7)^{-6}$, to the cyclosilicates $(Si_3O_9)^{-6}$ and $(Si_8O_{20})^{-8}$. The metamict nesosilicates range from simple minerals of the form $ASiO_4$(A = Zr, Th, and/or U), to more complex silicates, borosilicates, and phosphosilicates involving cations of rare earths (especially Y, Ce, La), Ca, Na, Fe, Mn, Th, U, etc., often with F, (OH). Likewise the sorosilicates range from relatively simple $Y_2Si_2O_7$ to more complex silicates of rare earths (especially Y, Ce, La, Yb), Ca, Na, Fe, Ti, Nb, etc., often with F, (OH). Two metamict cyclosilicates are known. These are varieties of eudialyte and ekanite.

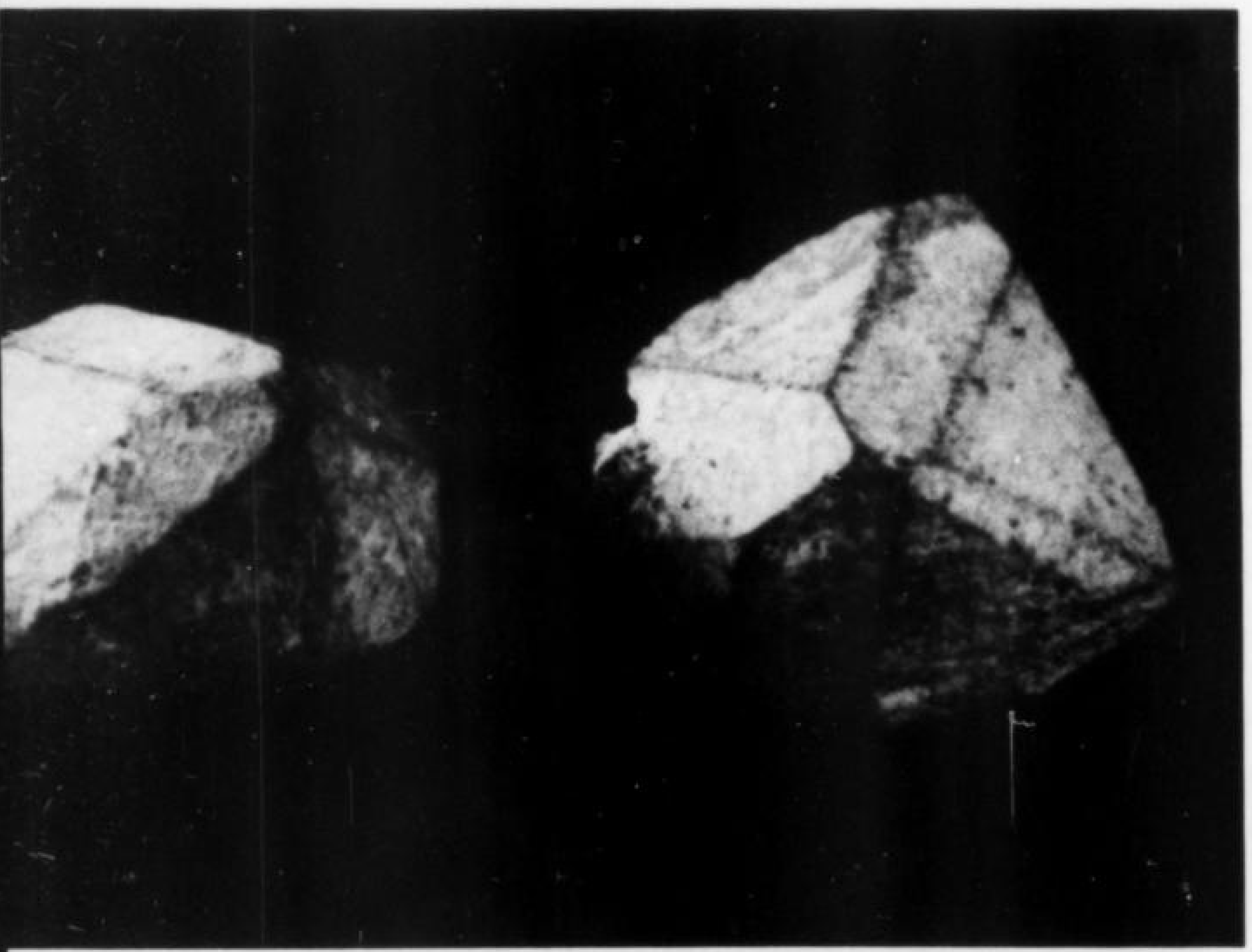

***Fig. 1.* Metamict betafite showing original crystal forms (largest 18 mm across). Antanifotsy, Malagasy.**

CHARACTERISTICS OF METAMICT MINERALS

As a whole metamict minerals have certain properties which tend to set them apart from other minerals. Brief summaries of some of these properties have been given by Goldschmidt (1924), Faessler (1942), Pabst (1952), and Berman (1955). Other characteristics have been added in the discussion which follows.

1. Weakly to strongly radioactive. Apparently all metamict minerals contain either U or Th or both. The radioactivity may be very low as in some gadolinite (e. g., 0.41% ThO_2 in Ytterby gadolinite), zircon, and allanite, or it may be very high as in thorite, brannerite, davidite, and samarskite. Hamberg (1914), who studied the radioactivity of of many geological materials, first suggested a relationship between radioactivity and the metamict state. For some years metamict griphite was believed to be an exception to this relationship, but recently Peacor and Simmons (1972) showed the mineral is metamict because of uranium. Ramdohr (1957) has suggested that nonradioactive minerals might become metamict in zones directly surrounding radioactive inclusions within them. The fact that all metamict minerals are radioactive does not mean that all radioactive minerals are metamict. The relationship between radioactivity and the metamict state is treated later in this paper.

2. Originally weakly bonded structures with a low degree of chemical stability. Metamict minerals characteristically have weak ionic bonding and sufficiently open structures to allow for rearrangements and hydrolysis. Such minerals can be typified as having formed by the combination of weak bases with weak acids. Goldschmidt (1924) initially pointed out these factors, and he and others further observed that metamict minerals have extensive isomorphous replacements, often in more than one structural position. These factors are discussed in detail in a later section of this paper.

3. They contain abnormal amounts of nonessential water which is lost upon heating. As a rule metamict minerals show a higher water content than corresponding nonmetamict compounds. The water content fluctuates and does not appear to correspond to a stoichiometric formula. Generally the water is considered to have been introduced during the process of metamictization.

4. Nonmetamict equivalents of many metamict minerals are known. Des Cloizeaux and Damour (1860), in their study of the optical properties of some metamict minerals, observed that both gadolinite and allanite have anisotropic (nonmetamict) and isotropic (metamict) varieties. Petersson (1890) showed that isotropic and anisotropic gadolinite essentially have the same chemical composition. Now it is clear, however, that the metamict varieties often contain more radioactive elements and usually nonessential water with oxidized iron and uranium. The crystal morphologies of the nonmetamict and metamict varieties of a mineral are essentially the same. This fact was supported by Nefedov (1956) from studies of very rare crystals of nonmetamict fergusonite and euxenite, and is well-known for other minerals like allanite, gadolinite, and zircon. Of course chemical differences, resulting from different isomorphous substitutions in specimens from different localities and environments, might affect interfacial angles slightly, and the attending habits can vary.

5. Amorphous or nearly amorphous to x-ray diffraction. That metamict minerals are either without crystal structures, or at best have poor structures, when studied by x-ray diffraction, was first noticed by Rinne (1915) for gadolinite and by Vegard (1916) for thorite. In the process of metamictization a well-crystallized specimen changes with time to give weak and diffuse x-ray diffraction reflections, and finally with increased metamictness gives no diffraction at all. Therefore, the resulting x-ray diffraction pattern depends upon the degree of metamictness of the specific specimen. Many of the well-known metamict minerals, especially the complex oxides, are completely x-ray amorphous.

6. Partially metamict crystals have unit cell dimensions somewhat larger than nonmetamict crystals. Hurley and Fairbairn (1953) observed that interplanar spacings in a crystal structure increase with increasing metamictness, and suggested that the degree of metamictness of zircon can be measured from the x-ray diffraction angle of the (112) plane. Ueda and Korekawa (1954) reported a similar situation for allanite, and later Ueda (1957) commented that as the metamict state arises the disordering of the allanite structure is accompanied by lattice distensions until the structure is disrupted. Holland and Gottfried (1955) determined quantitatively the increase in the unit cell parameters of Ceylon zircon with increasing metamictness. Similar quantitative data for allanite were subsequently determined by Pellas (1962).

7. Heating forms a crystalline structure below the fusion or sintering temperature. This conclusion was drawn from optical changes noted by Des Cloizeaux and Damour (1860). Crystalline structures for heated metamict specimens are detected most easily by x-ray diffraction analyses, as first shown by Küstner (1922). Crystallization is a very complex situation usually forming an aggregate crystalline pseudomorph, which very often is not composed of the same crystalline phase as the original nonmetamict mineral. This subject is considered in detail later in this paper.

8. They often become thermoluminescent on heating, i. e., they are pyrognomic. The term pyrognomic was introduced by Scheerer (1840) for what he considered to be a remarkable phenomenon of glowing shown by some minerals, especially allanite and gadolinite, when they are heated. The phenomenon already had been observed by several researchers, most notably Wollaston and Berzelius (Berzelius, 1815). Numerous others referred to the property in subsequent years. Considerable importance was attached to the property at first, because it seemed to indicate the temperature at which other changes in physical properties occurred during heat treatment. Specimens which did not show the property generally were considered to be nonmetamict varieties of the specific mineral. Later studies showed a great variability in these relationships, with even a lack of thermoluminescence in some cases (Liebisch, 1910). Faessler (1942) showed that even strongly pyrognomic gadolinite could be annealed below the temperature of glowing with a complete loss of the pyrognomic property. Berman (1955) crystallized metamict minerals for x-ray diffraction study at temperatures appreciably below that required for thermoluminescence.

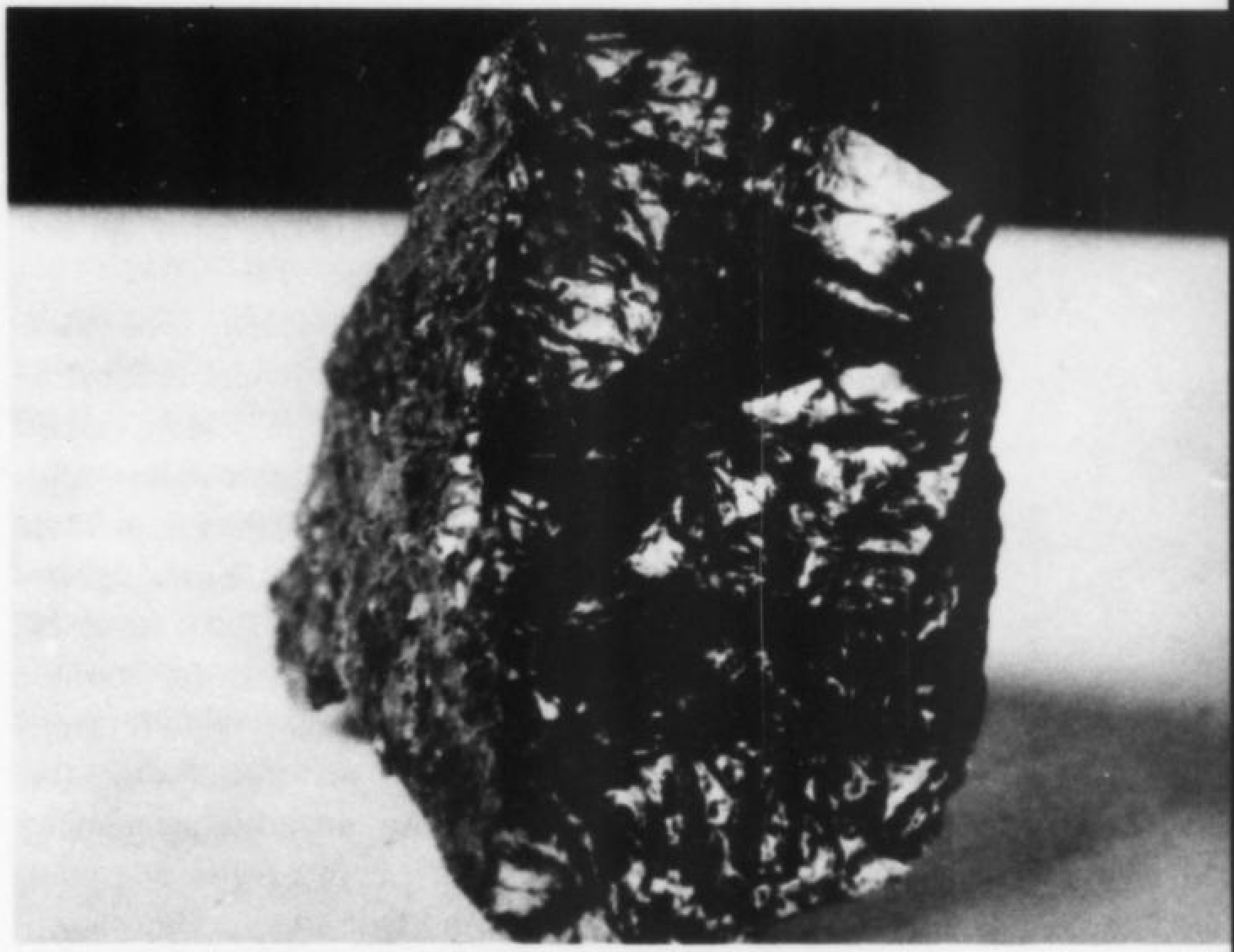

***Fig. 2.* Pitchy allanite fracture surface (45 by 28 mm). Shepherd farm, Roanoke County, Virginia.**

9. Often optically isotropic. In spite of the fact that the external morphology of many metamict minerals indicates the minerals are not isometric and should be anisotropic, they are still isotropic. The isotropic behavior of these minerals has been known and studied for well over a century, a long time before the term metamict was introduced. In their study of the optical properties of several metamict minerals, Des Cloizeaux and Damour (1860) not only reported isotropic varieties of gadolinite and allanite, but observed that these became anisotropic when heat treated. Mügge (1922) verified this for gadolinite. Holland and Gottfried (1955) have shown how the two indices of refraction for Ceylon zircon vary quantitatively with increasing metamictness and finally approach a single isotropic index. Similar data for allanite were determined by Pellas (1962). Numerous metamict minerals are optically heterogeneous, being partially isotropic and partially anisotropic, sometimes in a zonal arrangement. This suggests different degrees of metamictness within a single specimen. Being isotropic does not prove the metamict condition of minerals which occur in the isometric system, since all isometric minerals are optically isotropic.

10. The isotropic index of refraction is usually lower than the indices of refraction for the nonmetamict equivalent mineral. Not only has it been observed that heating causes many isotropic metamict minerals to become anisotropic, but that heating also increases the refractive index. Data showing this for several minerals (e. g., euxenite, aeschynite, priorite) have been summarized by Palache *et al.* (1944). Pabst (1952) verified the relationship for thorite. Refractive indices determined by Nefedov (1956) for nonmetamict fergusonite and euxenite are higher than the isotropic index ranges reported for metamict specimens of these minerals. In making such comparisons one must keep in mind that variations in chemistry (isomorphism) will also cause variations in refractive indices. In studies of Ceylon zircon Holland and Gottfried (1955) graphed variations in refractive index with increasing metamictness and showed that both e (= 1.974) and o (= 1.920) decrease and approach n = 1.810 asymptotically. Somewhat earlier Morgan and Auer (1941) showed that the indices of refraction and birefringence for zircon are inversely proportional to internal radioactivity.

11. The luster is usually pitchlike. Most metamict minerals have a pitchy to glassy luster (fig. 2). Other terms commonly used are resinous, waxy, vitreous, and sub-metallic. The pitchy appearance is further augmented by a conchoidal fracture and the common black to brownish-black colors of the minerals.

12. They are usually black or dark brown in color. Although these colors dominate all metamict minerals, there are some minor differences depending upon chemical class. The multiple oxide minerals are usually black, brownish-black, brown, or, in a few cases, yellow. The metamict phosphates are brown, reddish-brown, and yellowish-brown. There are more variations in the metamict silicates, but again black and various shades of brown dominate. Less commonly observed are shades of green, red, orange, yellow, and colorless. Although a relationship may occur between color and degree of metamictness, apparently no studies of this have been made. At an early date Scheerer (1840) observed that metamict minerals change color when heated. Heating usually causes metamict minerals to become lighter in color.

13. Pleochroism diminishes with metamictness. With increased metamictness, minerals normally showing pleochroism lose this property to become uniform in color. Pellas (1962) studied this phenomenon in allanite and evaluated its use as a method for the determination of the geological age of rocks.

14. Become less transparent when metamict. Ramdohr and Strunz (1967) have observed that with metamictization most minerals decrease in transparency. Explanations for this have not been given, but it might be related to the inhomogeneity of the structure of the mineral which forms during the course of metamictization, or it might be due to chemical factors involving oxidation of constituent cations, like iron, and hydration. Most metamict minerals, especially the multiple oxides, look opaque, but in thin splinters they are translucent to transparent.

15. Conchoidal fracture without cleavage; brittle. In the truly amorphous metamict state any potential cleavage which the mineral originally might have possessed is completely lost. Typical unweathered metamict specimens break with fresh conchoidal fractures resembling glass (Fig. 2). Many specimens are filled with closely spaced fractures. Likewise metamict minerals are usually brittle.

16. Hardness decreases and becomes nonvectorial. With the disruption and weakening of the crystal structure, which accompanies metamictization, the hardness of the mineral decreases. Povarennykh (1964) believes this is facilitated by the removal of components and by hydration. Heating a metamict specimen increases its hardness according to Soboleva and Pudovkina (1961). Ramdohr and Strunz (1967) pointed out that if the original mineral showed hardness variation in different crystal directions, metamictization would cause the hardness to become uniform in all directions. The subject of hardness of metamict minerals is open to considerable research. It is interesting to note that for the metamict multiple oxides and phosphates the hardness is from 5 to 6.5, with only a couple as low as 4. The majority of silicates also fall in this range, with only zircon and gadolinite being harder.

17. Have an abnormally low specific gravity. Commonly the specific gravity is abnormally low for metamict minerals, and can be increased by heating the specimen. Scheerer (1840) made careful measurements of the specific gravity of gadolinite and allanite before and after heating and calculated the volume decrease. From his observations he proposed an explanation based upon "interatomic change, involving change of relative position of atoms and decrease of interatomic distances," an idea which was ingenious for his day. A summary of this explanation was given by Levy (1924). Although most studies of changes in specific gravity with heating of metamict minerals show an increase in the value, some earlier reports indicated the changes are negligible, or the value is even decreased. Reports on some of these early data may be misleading on account of difficulty of making accurate measurements. Some of these exceptions have been summarized by Levy (1924). Faessler (1942) tabulated specific gravities for several metamict minerals, and showed that heating normally increases the value. In a study of Ceylon zircon Holland and Gottfried (1955) graphed specific gravity against metamictness. The specific gravity was about 4.7 for nonmetamict zircon, and with increasing metamictness the value dropped at first slowly, then more rapidly, and finally approached asymptotically a value near 3.96. Earlier von Stackelberg and Chudoba (1937) also found that heating increases the specific grav-

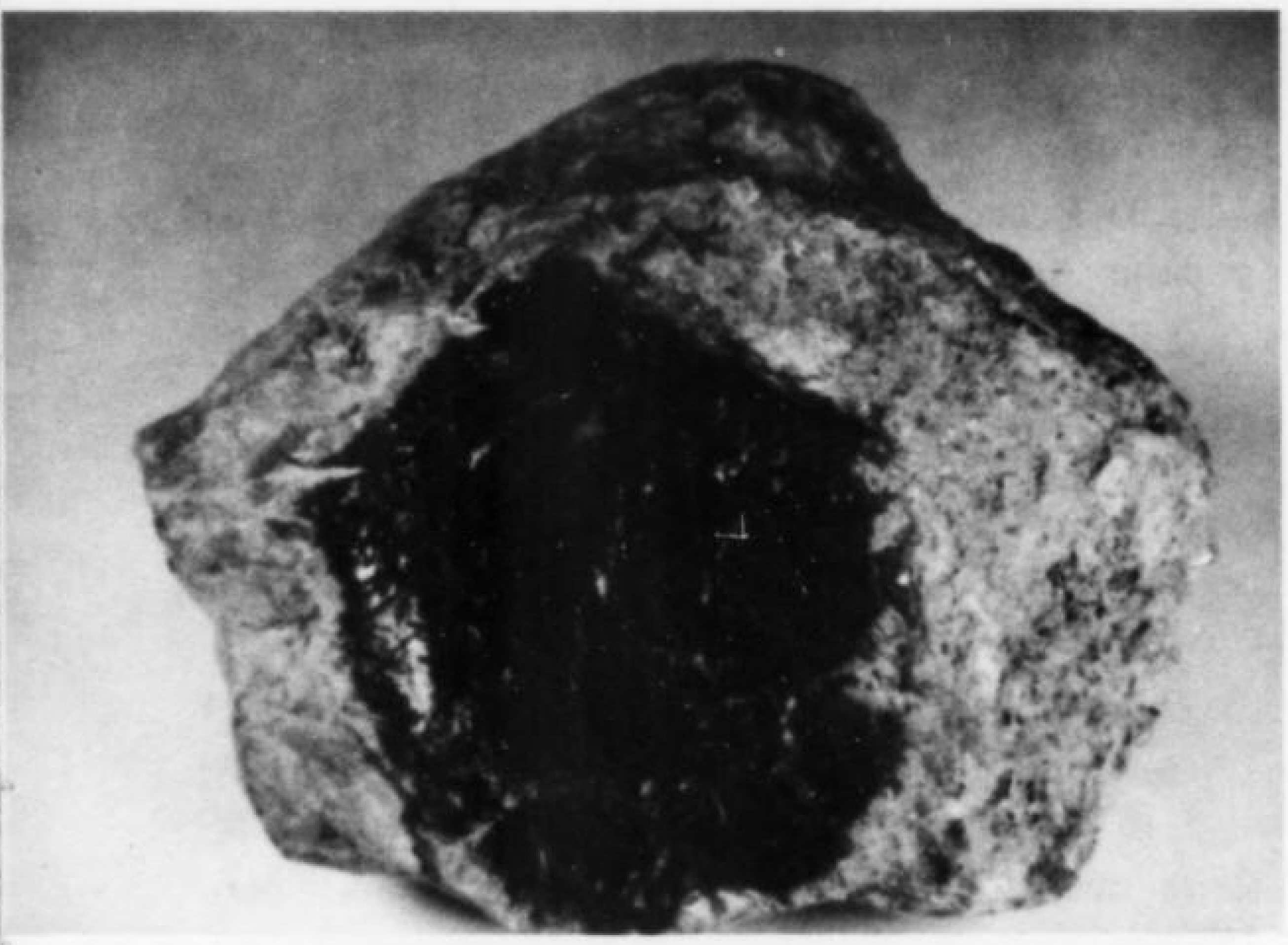

Fig. 3. **Perrierite mass (13 cm wide) with anatase-rich alteration rind. Dooley farm, Bedford County, Virginia.**

ity of metamict zircon. Pabst (1952) reported similar results for thorite.

18. Decreased resistance to chemical attack, especially attack by acids. The resistance to attack by acid is increased by heating. This unusual effect of heating, just the opposite of heating to fusion in many instances, has been known since the early studies by Berzelius (1815), Scheerer (1840), Rose (1841), and Petersson (1890). This phenomenon has been studied primarily for silicates. Allanite and gadolinite were among the first minerals known to show the property. Bauer (1939), who investigated the properties of metamict zircon, concluded that solubility in certain acids is the best way to measure the degree of metamictness of the mineral. A low resistance to chemical attack and weathering is often exemplified by thick yellow, brown, or tan alteration rinds which form on metamict minerals in nature (Fig. 3). Often adjacent feldspars and other neighboring minerals are completely unaffected. The rate of weathering of some metamict minerals has been studied by Van Wambeke (1970).

19. They may be the foci of fractures radiating into the minerals of the surrounding rocks. As a result of metamictization, in which the structure is disordered and oxidation and hydration may occur, the mineral occupies a larger volume. The resulting outward pressure often produces radial fractures in surrounding brittle minerals (fig. 4), e. g., quartz and feldspars. Sometimes these fractures are stained with iron oxides and other secondary minerals derived from the chemical breakdown of the metamict specimen. These features are especially common in allanite-bearing pegmatites (Deer *et al.,* 1962).

OCCURRENCE OF METAMICT MINERALS

By far the largest number of metamict minerals occur in pegmatite deposits. Although most of them are found in granite pegmatites, many also have been found in syenite pegmatites, and feldspathoidal syenite pegmatites. In addition to occurring in the pegmatite phases of these rocks a few also occur as minor accessory minerals in granite, syenite, feldspathoidal syenite, and other rare feldspathoidal rocks. Some metamict minerals (e. g., some davidite and some brannerite) occur with quartz in hydrothermal veins, but the number of such examples is small.

Metamorphic occurrences of metamict minerals are known. These are usually minor accessory minerals (e. g., zircon, monazite, allanite) in gneiss and schist. More rarely some occur in high-temperature metamorphic calcareous rocks (e. g., some davidite and some allanite).

Approximately a dozen metamict minerals have been found in stream gravels and other detrital deposits. These usually are from weathered pegmatite deposits or were minor accessories in igneous or metamorphic rocks. An important occurrence of brannerite is in a Precambrian quartz-pebble conglomerate, in Ontario, where it is a detrital constituent.

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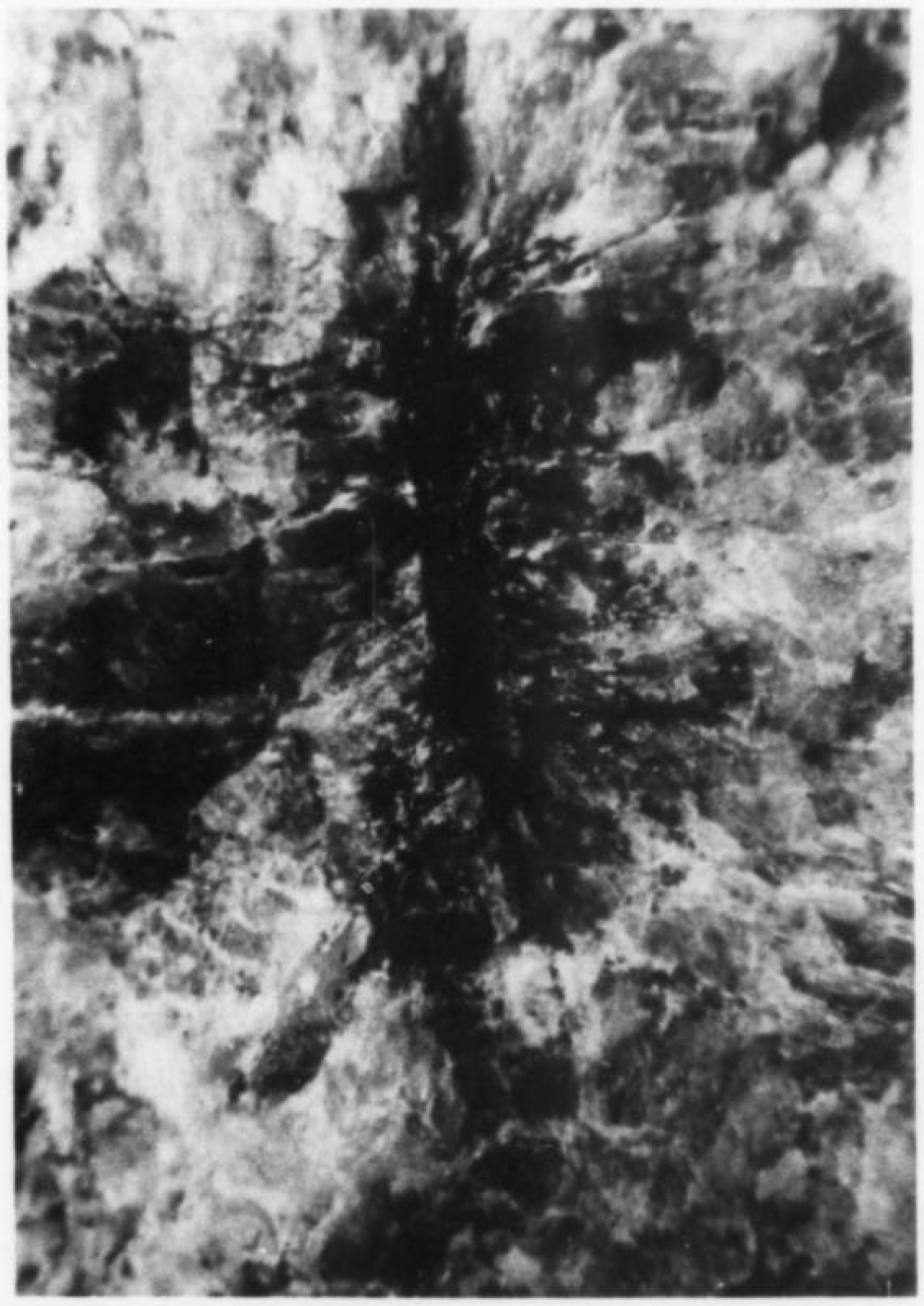

Fig. 4. **Radial cracks, stained with dark oxides, in pegmatite rock surrounding allanite prism (12 mm long). North Carolina.**

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Yedlin on Micromounting

We met an old friend, Harold Arndt, the other day. Reasenberg, Krotki and Goldstein, of the New York Mineralogical Club, had accepted invitations to address the Philadelphia Mineralogical Society on the mineralogy and geology of Kenya and Tanzania, and we tagged along to renew old acquaintances and breathe the special air of the territory where micromounting first began in America — Philadelphia, Pennsylvania, home of Rakestraw, Fiss, Bement, Brinton, Wills and others.

We had arranged to arrive early in the afternoon to view the mineral collection at Bryn Mawr College, and there we found that Harold Arndt was curator of the collections. In 1942 we were stationed at Media, at the Williamson School, an installation of the Army Air Corps. Arndt wrangled permission for a day off for us, and he introduced us to the famous Falls of French Creek, the Wheatley mine at Phoenixville, and Pennsylvania Dutch cooking (from which we've never recovered).

French Creek is famous for its superb and unusual pyrite, chalcopyrite, magnetite, byssolite, calcite and others. The mine has not been in operation for some seventy-five years or so, yet the dumps still offer fine specimens with earnest endeavor.

Phoenixville's Wheatley mine (C. W. Wheatley was its operator and manager. His mineral collection was given to Union College, Schenectedy, New York, where another old friend, Elmer Rowley, of Glens Falls, New York, is curator) began serious operation about 1850, and produced such fabulous pyromorphite, wulfenite, anglesite, cerussite, galena, and other minerals, that every major museum in the world has representative specimens from this locality, with special emphasis on Union College and the Philadelphia Academy of Natural Sciences.

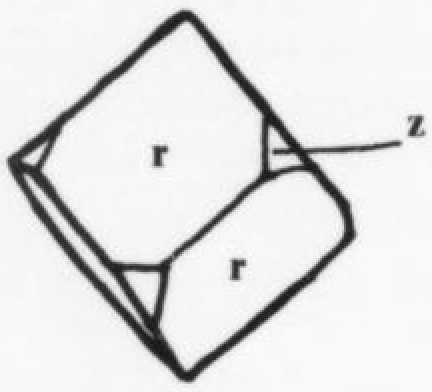
That material from this locality is yet available after more than half a century of inactivity is evidenced by the fact that the New Haven (Connecticut) Mineral Society, under the auspices of Marcelle and Charles Weber, recently visited the area and came away with a plethora of fine micromount material, both from Wheatley and from the almost adjoining dumps of the Chester County Lead Company mine. Pyromorphites, exhibiting several crystal habits and various shades of green, were the rule. Red-orange minute wulfenites turned up as did, but rarely, anglesite and cerussite. We suggest you go there. Please communicate with Mrs. Charles (Marcelle) Weber, 39 Benson Place, Fairfield, Connecticut 06430. She is regional director for Friends of Mineralogy, and will be glad to supply information.

Getting back to Bryn Mawr, the major collections are tastefully exhibited along the hallways of the science building. The George Vaux, Jr. collection provides the major assemblage, and other local groupings can be seen. Minerals are arranged by localities (New England, Pennsylvania, etc.), by collectors (Vaux, T. D. Rand, et al.), and some according to *Dana's System,* with the result that azurite from Tsumeb (as an example) may be seen in 3 or 4 places, — confusing, perhaps, but logical, and easily forgivable, considering the history of the specimens. Early finds are exhibited. We were astounded to see Orange County, New York, spinels two inches on an edge; Haddam, Connecticut, tourmalines, green, transparent, eight inches long; Tilly Foster, New York, chondrodites, striated magnetites, clinochlores (crystals up to three inches across) and titanites; Mount Mica, Maine, tourmalines; and a host of long since unavailables in the mineral field.

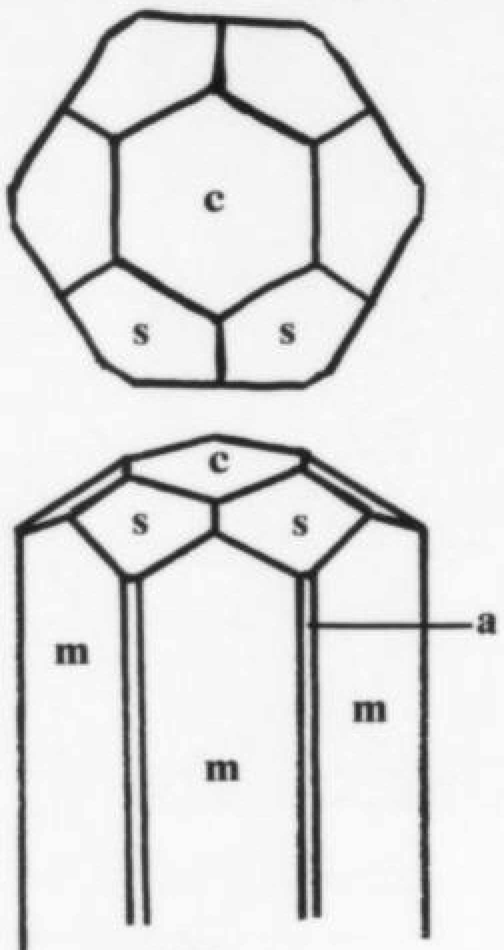
Historic micromount material came to light. In the curator's office, awaiting cataloguing, were a number of mounts about which we'd never heard. W. S. Rand had a collection, as did T. Chalkley Palmer. There were mounts of Van Sinderan (1918), and the entire melange of the old-timers. Rand's mounts were in white cardboard boxes 1 1/16 inch square and 1/2 inch deep, with the covers edged in green, black, and red. Palmer's were of the standard oblong cardboard type used by most of the collectors in the area. His mounts were part of Rand's collection. Van Sinderan's technique was unique, though not recommended. He filled the cardboard box with plaster of Paris, set the specimen into the partially firm plaster, let it harden, and then painted the dried gypsum-anhydrite dull black. (Ed. note — Ugh!)

Arndt's personal collection is at the Delaware County Institute of Science at Media, Pennsylvania. The specimens are in cardboard boxes, oblong, and do not have the typical red-edged covers of the boxes of the original group of devotees. No printed labels are attached, but the face of the cover, in addition to the pertinent mineral data, bears the rubber stamped "Arndt Coll."

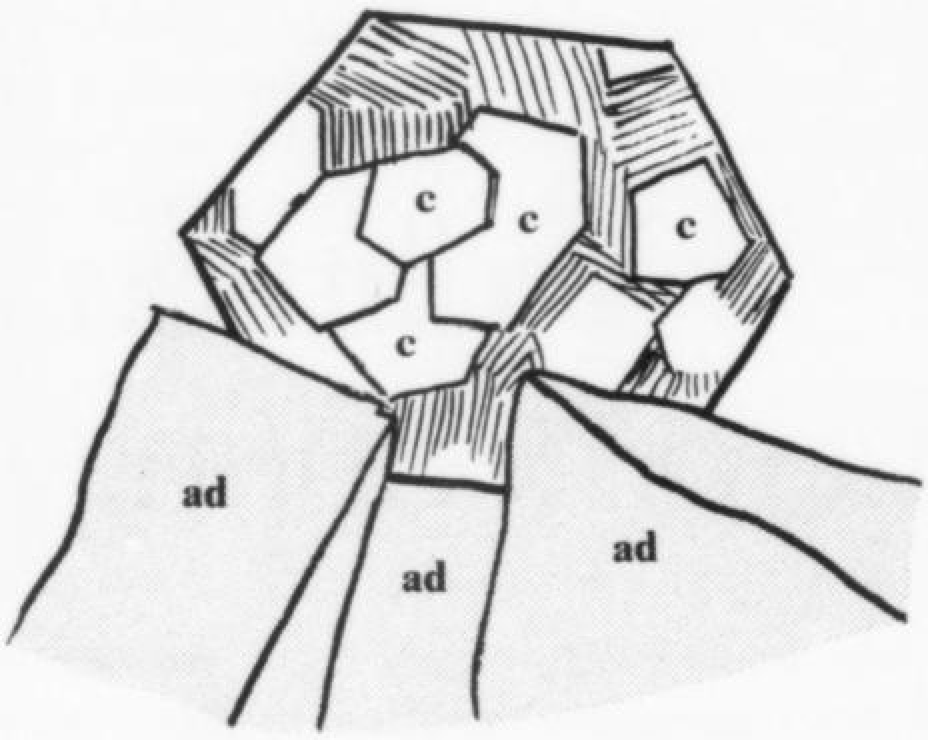
At the Academy were other things to warm the sensitivities of the historic minded. Keeley's collection of old brass microscopes and magnifiers were there, including



Quartz, showing positive rhombohedron (r) and negative rhombohedron (z). No prism evident. Idealized sketch from specimens from Arnprior, Ontario, and Sundwig, Westphalia, Germany.



Milarite
Typical crystal, sketched from a specimen from Swakopmund, S. W. Africa.



Milarite, Guanajuato, Mexico
Compound crystal as evidenced by striations and multiple "c" faces. Associated with adularia (ad).

three Zentmayers, beautiful brass binoculars, coupled to a single ocular, made in Philadelphia, and these are truly treasures. We have one, No. 1313. Yale has one, acquired when it received the Lazard Cahn micromount collection. Paul Seel has one. Here were three of them, in current use!

A letter and package arrived from Wilfred Nicholas, Hi-way 29, Box 135, Arnprior, Ontario, Canada. The missive tells of a roadcut and the resulting specimens that turned up. The crystals are ferruginous quartz, in masses, showing yellow and red variations, doubly terminated, some with phantoms of quartz within a clear crystal. Some of the individuals have one rhomb predominating, with no prism, and when these are properly oriented show the "pseudo-cubic" habit.

Now quartz is common, even ferruginous quartz, but for the collectors who own old-time specimens of almost identical material from Sundwig, Westphalia, Germany, supplied years ago by English, Foote and George Simmons of Brooklyn, New York, a micromount of this new find should be welcome. Nicholas has an adequate supply.

On June 16th and 17th we attended the show of The North Shore Rock and Mineral Club of Massachusetts, Inc. at the fairgrounds at Topsfield, just north of Boston. It was a fine event, and the governors of the club are to be congratulated. The affair was held in three buildings — exhibits, sales and exchanges. There were no admittance fees for the public; people came and went at will, and those who were but curious and who probably would not have attended otherwise, came, saw, and were fascinated, and perhaps converted to mineral and gem collecting. Pete Dunn of the Smithsonian was there, gave several talks, and was in evidence whenever mineralogical questions arose.

For us it was a good weekend. We obtained milarite, minute, clear, prismatic, with basal termination, from Moat Mountain, Conway, New Hampshire. We first saw specimens of this material last fall at Boston when Paul Desautels addressed the mineral club there. They were, as we recall, over an inch long, clear and prismatic, and were the first ever from the locality. They are now where they belong — at the Smithsonian. Milarite — $K_2Ca_4Be_4Al_2Si_{24}O_{60}{\bullet}H_2O$ — is not a common mineral. Dana (System and Textbook) lists two localities, in Switzerland. Since 1932 the list has expanded. We boast milarite from Rozna, Czechoslovakia, in clear prismatic crystals; from the Valencia mine, Guanajuato, Mexico, in green crystals scattered throughout the interstices in the feldspar adularia; from Val Giuv, Grissons, Switzerland, in jackstraw arrangement in a seam, with chlorite, quartz and other fissure minerals, terminated by a shallow pyramid rather than basal pinacoid, and with angular striations on the prism faces, easily distinguishing the species from associated quartz, which has striations on the prism at right angles to the *c* axis; and from Rőssing, near Swakopmund, Southwest Africa, in fine yellow green crystals, which exhibit the base, first and second order prism, and second order pyramid. These latter milarites appeared some nine years ago, when a dealer was selling them as chrysoberyl! They were spotted by an amateur, Edge Goldstein, not as being milarite, but as not being chrysoberyl. Identified at the Smithsonian the entire lot was purchased by that institution. Some of it was disseminated before this event, and a few specimens are in cabinets, misnamed.

Additionally, at Topsfield, we were able to purchase and obtain in trade specimens of babingtonite, from the intersection of Routes 93 and 128 in Reading, Massachusetts; pale blue apatite on albite, Alexandria, New Hampshire; brazilianite on quartz, Smith quarry, Newport, also New Hampshire; clear colorless garnet, and stubby crystals of pectolite, from Asbestos, Quebec; tabular wulfenites in quartz, Loudville, Massachusetts; eosphorite with rose quartz, Newry, Maine; and an eosphorite-wardite, from Brazil. All these were available at the dealers or in the exchanges building.

We saw, too, an exhibit of the tourmaline from the Dunton mine, Newry, Maine, discovered last year. The colors were superb, a light apple-green and a cranberry-red. A few immense crystals were but fair in form, and did not come up to some of the Pala, California, tourmalines in quality of morphology. But two cut stones that we'd viewed previously were as beautiful and glowing as any we'd ever encountered.

We have some minute prisms supplied by John Marshall, 173 Orchard Street, Millis, Massachusetts 02054. They're pale green, clear, long prisms, of excellent micromount quality. They may be available this autumn. We'll keep you posted. Right now with the great quantities of specimen and gem material being gathered at the mine, there is no time to sift the residues for the minutae.

We got some surprises from Hatfield Goudey, whose advertisements for micromount material have appeared in this publication. His letter, dated June 11, 1973, follows: "Dear Neal: I put aside for you micromounts of kammererite and of uvarovite showing a vicinal hexoctahedron. Recently, going over a special collection, I found four more that may be of interest, and am sending them to you, as follows: aurichalcite-hemimorphite-brochantite, Wellington, Nevada; descloizite-cerussite, Chalk Mountain, Nevada; uvarovite with 1.63.64, Jacksonville, California; kammererite, vermiform with uvarovite, same locality; mosesite, Terlingua, Texas; high quartz, Lane County, Oregon."

We wish that everyone had as good taste and judgment as "Hat" does. The specimens were terrific!

There are very few dealers who know enough, or care enough, to devote time to micromount material. From time to time we've listed a few, and shall continue to do so. We've just received a circular from David New, P. O. Box 7, Providence, Utah 84332. He calls his list a "Micro-Gram", and itemizes 32 specimens, every one of which is worthy of being in a collection. A partial summary: antlerite, argentite, boulangerite, carminite, cornetite, fornacite, kasolite, melanophlogite, proustite, pyrargyrite, sklodowskite, sperrylite, stolzite, tarbuttite, tsumebite, xanthaconite. Good enough? Send a stamp for his list, and for a list, too, of cabinet specimens.

Buy and use a good mineral book, check out your microscope, get a good light, and affix a label to each of your specimens.

Neal Yedlin
129 Englewood Drive
New Haven, Connecticut 06515

THE 1974 EDITION OF THE TUCSON SHOW

The members of the Tucson Gem & Mineral Society most cordially invite all readers of the *Record* to attend the 1974 Tucson Gem & Mineral Show. The location will again be the Tucson Community Center Exhibition Hall at 350 S. Church St. in downtown Tucson, Arizona. Dates and hours for the show are as follows:

Thursday, Feb. 7, 1974 — Wholesale Dealer Space open from 10:00 AM to 7:00 PM
Friday, Feb. 8, 1974 — Show opens at 9:00 AM and closes at 9:00 PM
Saturday, Feb. 9, 1974 — Show opens at 10:00 AM and closes at 9:00 PM
Sunday, Feb. 10, 1974 — Show opens at 10:00 AM and closes at 6:00 PM

We expect to again offer high quality mineral exhibits from museums and noted collectors, as well as a lesser number of other exhibits from most areas of the earth science hobby. Most of the same selected dealers will be with us again, and in addition we are offering small size dealer space to some of the foreign dealers who are asking to join us. Programs are being scheduled with eminent mineralogists as speakers, and we expect to again bring one museum curator-mineralogist from a foreign country who will bring examples of the specimens from his collection and who will speak during the show.

The Show Chairman, Mr. A. C. Thompson, and Special Exhibits Chairmen, Mr. & Mrs. Clayton Gibson, are looking for unusual and excellent quality exhibits that have not been previously shown in Tucson, and would like to hear from persons who have such material. We have limited funds for bringing in exhibits and these are usually used in bringing museum exhibits that aren't available otherwise. For very special exhibits that are offered by persons without sufficient financial resources to attend otherwise, the Special Exhibits Chairman may be able to offer some assistance with shipping and insurance costs. Any exhibitor offering an exhibit under these circumstances should give an estimate of funds required to bring the exhibit.

Collectors are invited to enter competitive exhibits in the following categories:

1. The Ed McDole Memorial Trophy Competition is open to any individual — not institutions, clubs, museums, etc. To honor the memory of Ed, collector and lover of fine minerals, a group of his friends annually at the Tucson Show present an "Ed McDole Trophy" to the individual display of the finest specimens.
2. Best-of-Species Competition — The TGMS Show Committee each year designates a species for special competition, and for the 1974 show have chosen fluorite. Anyone — individuals, museums, dealers, clubs — may enter one specimen in each of three sizes (cabinet, miniature, thumbnail), or one lapidary or faceted piece, making a total of four possible.
3. Friends of Mineralogy Educational Mineral Exhibit Competition — sponsored by Friends of Mineralogy and TGMS Show Committee; this offers individuals or societies an opportunity to develop an educational mineral theme with the possibility of winning a mineral specimen award and plaque, in adult and junior divisions.
4. Bob Roots Memorial Junior Trophy Competition — to honor the memory of Bob Roots, collector and pioneer mineral dealer from Denver, Colorado, his family, Mr. & Mrs. Jack Roots, J & M Minerals, Solvang, Calif., will present annually at the Tucson Show a trophy to the junior exhibitor with the best exhibit of thumbnail size mineral specimens. Competition is open to individual juniors who are at least 8 years of age and who shall not have attained their 18th birthday by the opening day of the show.

Information and applications forms for the above competitions are available from Mildred Schupp, TGMS Entries Chairman, P. O. Box 6363, Tucson, Arizona 85716, and deadline for receipt of entries will be Jan. 1, 1974.

Motel and hotel reservation sheets are also available this year, and offer reduced rates on rooms in several of the nearest facilities to the show building. The deadline for making reservations at the reduced rates is Jan. 18, 1974, but we strongly advise interested persons to act immediately because February is a busy time in Tucson and all motels are crowded at that time.

Admission to the show is $1.00 per day, with children 14 and under admitted free when with an adult. There is a charge for parking in the Community Center lot, but many of the motels and hotels offer free transportation to and from the Community Center — ask about this when you make your reservation. In and out privileges are available, and the daily admission also admits persons to the programs and lectures offered by the Show Committee.

For further information, write to Mr. A. C. Thompson, TGMS Show Chairman, P. O. Box 6363, Tucson, Arizona 85716.

GOLD ON QUARTZ – CALIFORNIA

Mineralogical Research Company has recently obtained several hundred first class Gold on quartz specimens from one of the old mines in the California "Mother Lode" area. The recent raise in the price of Gold has enabled many of the old mines, originally worked *circa* 1849, to re-open. Micromounts, thumbnails, and miniature specimens are available. For a descriptive list of the Gold specimens, as well as comprehensive lists of other specimens from worldwide locales, send your name and address to Mineralogical Research Company, 14770 Whipple Ct., San Jose, California 95127.

The Society welcomes as members individuals who are interested in mineralogy, crystallography, petrology, or related sciences. Membership applications can be obtained from the business office at the address below. Membership is for the calendar year, and the annual dues are $20 for all except students, who pay only $6. All members receive two journals, **The American Mineralogist,** and **Geotimes,** and are also entitled to a reduced rate for subscription to **Mineralogical Abstracts. The American Mineralogist** is a bimonthly, technical publication of the Society and emphasizes the latest scientific aspects of modern mineralogy, crystallography, and petrology. **Geotimes** is the monthly news magazine for earth sciences published by the American Geological Institute. A price list for other publications of the Society may be obtained from the business office.

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NEW from Hamel's

SILVER from above the Arctic Circle in Canada's Northwest Territory. Beautiful crystallized native silver specimens of various habits — arborescent sprays, fine dendritic growths, tiny cubic crystals and some specimens which will exhibit several habits. T/N to museum size priced from $2.50 to $1,000.00

HYDROBORACITE from the Thompson mine, Death Valley, Calif. Some specimens with colemanite. Mostly T/N to small miniature size. $2.00 to $50.00

COLEMANITE — we still have some of the world's finest colemanite crystals from Death Valley, Calif. Up to 8" on a crystal face. Brilliant blocky crystals T/N to museum size. $1.50 to $1,000.00

Fig. 1. **Specimen of Iowa brown calcite with a crystal of white barite. Note dark color and curved nature of the crystals.**

BROWN CALCITE FROM IOWA

by George R. McCormick and G. Bryan Bailey

Department of Geology, The University of Iowa

ABSTRACT

Brown-iridescent calcite from South Central Iowa which occurs as curved rhombohedral crystals was examined by optical and x-ray diffraction methods, by a scanning electron microscope with an x-ray multichannel analyzer, and analyzed chemically by atomic absorption methods. The results show the coloration is due to minute inclusions of Fe-MnO_X along growth lines in a nearly pure $CaCO_3$. Curvature of the crystals is caused by Fe + MnO_X inclusions along the growth lines. The two phase assemblage of Fe + MnO_X and $CaCO_3$ indicates the conditions of formation were $pH > 7.8$ and $Eh > -0.1$.

INTRODUCTION

Beer-bottle brown iridescent calcite, often associated with white to pink barite, has been a favorite trading specimen among midwest mineral collectors (fig. 1) and a petrologic and mineralogical challenge of considerable interest. Routine optical and x-ray analyses indicate that the specimens are calcite. Many argue that the specimens cannot be calcite because of the color and curved nature of the crystals, in fact several local museums and private collections have labeled the specimens dolomite or ankerite.

The brown calcite is found in fractures in black carbonaceous limestone or in desiccation cracks in septarian nodules. Both occurrences are present in the Pennsylvanian coal measures of South Central Iowa.

The brown calcite grows as curved rhombohedrons ranging in size from <1 to 5 mm. on a face (fig. 1). The surface of the crystals is iridescent in shades of brown-red-green-lavendar. Calcite in thinsection, cut perpendicular to the fracture filling, exhibits a comb structure (fig. 2). Numerous crystals started to grow at the fracture wall and, as growth proceeded, some crystals interfered with each other and actually stopped the growth of the smaller crystals in some directions. The larger crystals are not perfect single crystals as they exhibit numerous zones or domains of slightly different optical orientation (fig. 2).

Under 450x magnification the calcite appears clear with numerous, very small (<1mu), brown spots distributed in the grains. If a portion of a crystal containing the iridescent coating is examined under uncrossed polarizers, it is seen that the surface is opaque brown and less than 2 mu in thickness. Some specimens have grey translucent overgrowths of calcite which contain particles of iron sulfides (<3mu).

ANALYSES AND CONCLUSIONS

Optical and x-ray analyses indicate the calcite is nearly pure $CaCO_3$ with minor Mg, Fe, or Mn in the structure (Chave, 1952; Rosenberg, 1963; Kennedy, 1947). Analysis of cations by the atomic absorption method indicates the major cation present is Ca (Table 1). Backscatter electron microscopy reveals small (<1 mu) particles along growth lines and on the surface of the crystals (fig. 3). Analysis of the calcite by an x-ray multichannel analyzer on the scanning electron microscope indicated the Fe and Mn were in the small inclusions and the Ca and Mg were in the calcite. The elemental analysis (Table 1) was recalculated on the basis of Ca and Mg as carbonate and Fe + Mn as oxides; the calcite contains 0.76-1.1% $MgCO_3$ and the Fe + Mn oxides make up only 0.7-1.0% of the sample by weight. The brown color of the calcite must be due to the minute inclusions of $Fe + MnO_X$ along the growth lines.

Table 1
Elemental Chemical Analysis

Wt. %	1	2	3	4	5	6
Ca	38.70	39.30	39.50	39.80	39.62	38.95
Mg	0.22	0.22	0.26	0.26	0.32	0.22
Fe	0.53	0.54	0.49	0.48	0.59	0.52
Mn	0.11	0.13	0.21	0.19	0.17	0.20

1) Mich mine, Rose Hill, Iowa SW quarter S10, R15W, T75N

2) Mich mine, Rose Hill, Iowa SW quarter S10, R14W, T75N

3) Lost Creek mine #1, Oskaloosa, Iowa SW quarter S7, R15W, T74N

4) Lost Creek mine #1, Oskaloosa, Iowa SW quarter S7, R15W, T74 N

5) Lost Creek mine #2, Oskaloosa, Iowa SW quarter S3, R16W, T74N

6) Lost Creek mine #3, Oskaloosa, Iowa SW quarter S3, R16W, T74N

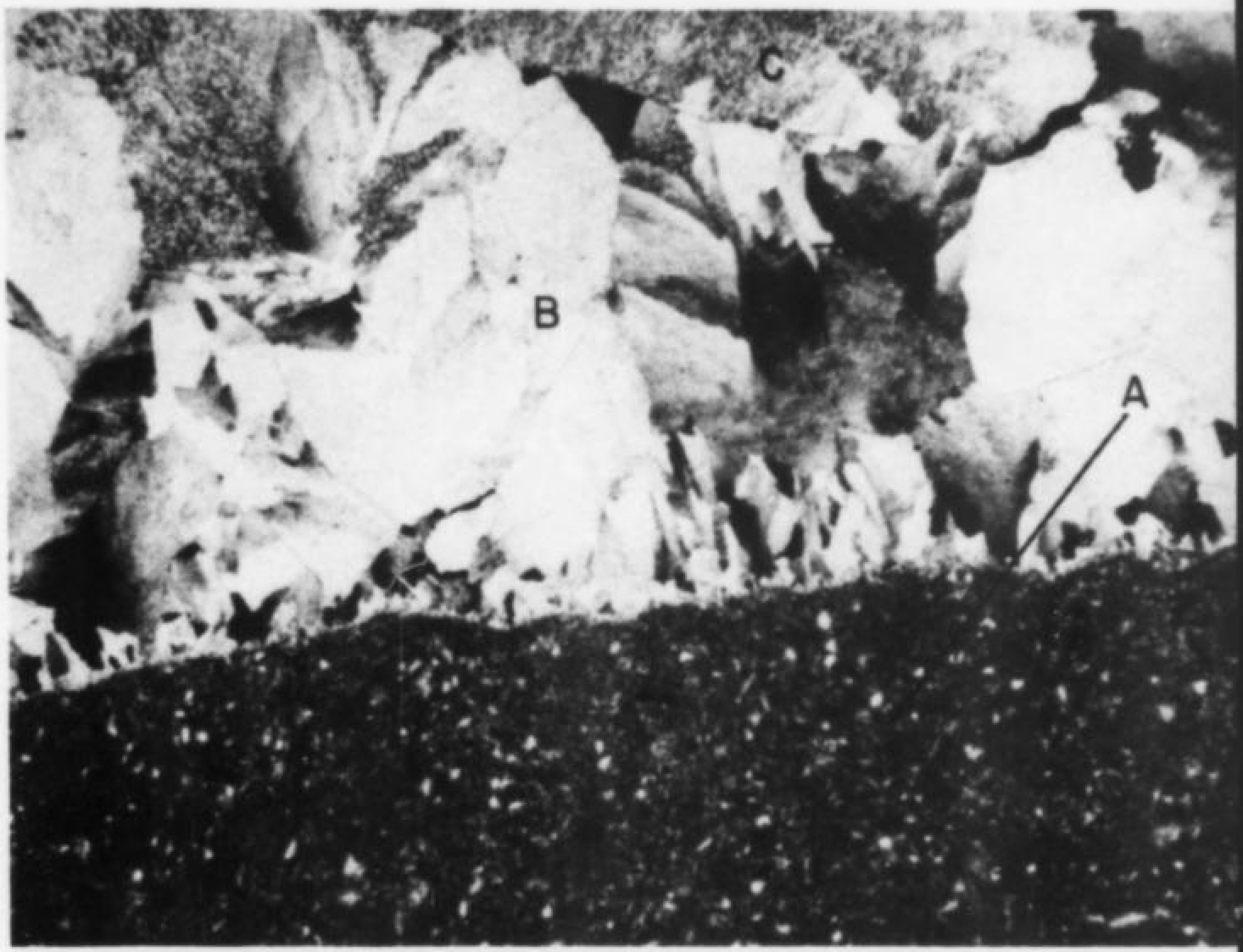

Fig. 2. **Micrograph of Iowa brown calcite under crossed nicols at 35X. *(a)* black, siliceous, carbonaceous limestone, *(b)* brown calcite, *(c)* gray-translucent overgrowth of calcite with included sulfides.**

The thin iridescent $Fe + MnO_X$ coating on the surface is probably a lag of $Fe + MnO_X$ inclusions left as the carbonates are dissolved. The edges of the calcite crystals under the iridescent coating appear rounded when examined optically.

The curvature of the crystals is due to distortions of the lattice caused by formation of $Fe + MnO_X$ particles along the growth lines. Optical examination indicates that the curved crystals contain numerous domains of varying optical orientation. There does not seem to be a continuous extinction pattern along the length of any of the crystals. The development of small aggregates of $Fe + MnO_X$ along a growth surface of the calcite (fig. 3) would cause the next domain of calcite deposited to be slightly disoriented crystallographically to that domain below the growth surface. As the calcite crystal continues to grow and more particles of $Fe + MnO_X$ are added to growth surfaces the effect is multiplied to the point where the megascopic crystal is visibly curved.

The brown calcite in fact is a two-phase assemblage of $Fe + MnO_X$ with $CaCO_3$ containing a small amount of $MgCO_3$ (1.1 to 0.7%). This assemblage indicates conditions of formation were $pH > 7.8$ and $Eh < -0.1$ (Krumbein and Garrels, p. 26). On some specimens the brown calcite is covered with an overgrowth containing grey-translucent calcite with minute inclusions of pyrite or marcasite. This two-phase assemblage indicates conditions of formation to be pH> 7.8 and Eh<-0.2.

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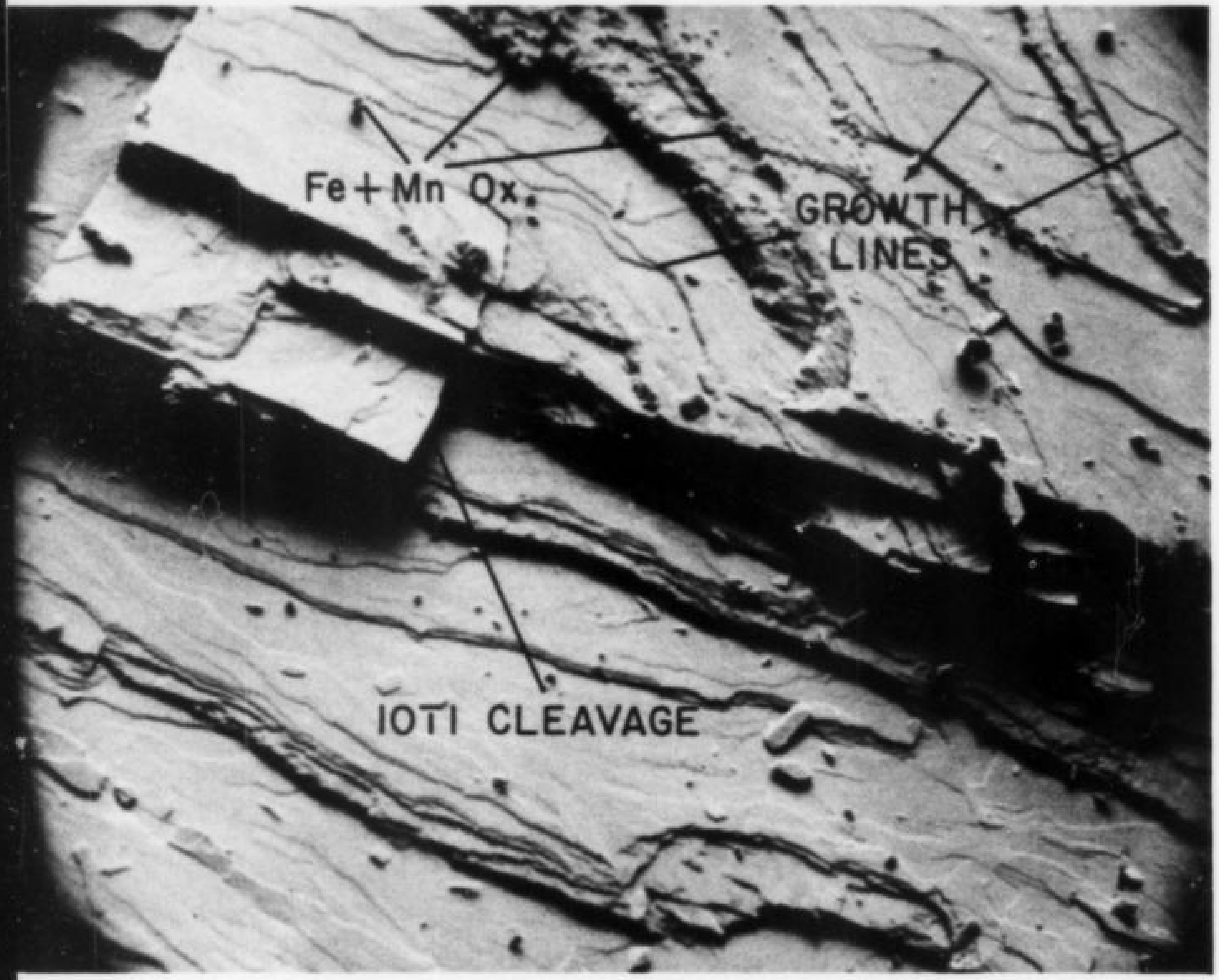


Fig. 3. **Backscattered electron image at 1800 x and 10KV. Inclusions of Fe + MnO_X along growth lines are apparent as is the 10$\bar{1}$1 cleavage.**

MINERALS ON POSTAGE STAMPS

An interesting and unique exhibit of minerals on postage stamps was presented to the public at the Dallas Gem and Mineral Show on October 28-29, 1972. As far as we know this was a first. A large frame contained stamps from Russia, Switzerland, China, etc.

The stamp collectors and dealers of Dallas were interested in this topical exhibit and helpful in getting the collection together. By sheer coincidence the December *Gems & Minerals* magazine featured minerals on stamps on their cover and published an article by M. W. Martin on the subject. These stamps are very beautiful. They picture not only mineral specimens such as malachite and amethyst but also carvings, mining, panning for gold, cut stones and jewelry.

MINERAL COLLECTION PRESENTED TO BERKSHIRE COMMUNITY COLLEGE

On May 13, 1973, during the dedication ceremonies of the new $12,500,000 campus of the Berkshire Community College in Pittsfield, Massachusetts, the Greylock and Northern Berkshire Mineral Clubs presented over 600 mineral and 100 fossil specimens. It is anticipated that this will be the start of a fine museum, not only of minerals and fossils, but other natural science specimens. Most of the minerals and fossils in the collection are of cabinet quality with the remainder useable as study specimens.

A high percentage of the specimens were given by members of the two clubs at great sacrifice, as exemplified when a teenager said, in giving a very fine specimen of margarite "This is the best specimen in my collection but I feel the college should have it." The rest of the collection was obtained by personal solicitation from museums, companies and individuals and through items in the *Mineralogical Record* and elsewhere.

As Chairman of the College Mineral Collection Committee for both clubs, and for the members of the clubs, I personally wish to thank all of those who so generously assisted us with this project. The quality of the specimens received was high. Donor's names will appear on the labels of the specimens. We are sure this will bring enjoyment, inspiration and help to many students and members of our community for many years to come. Some may become interested in mineralogy as an avocation and perhaps even be challenged into a vocation.

The two clubs will continue to add to the collection. Just this past Memorial Day weekend as two of us chiseled a specimen from the freshly blasted wall at the Palermo mine in New Hampshire, a member said, "This is for the college." It is a splendid large autunite-uranophane-uraninite-gummite specimen. Each member on the field trip had paid to work the area for his or her own collection but the college came first. Anyone who might wish to add to the collection can do so by sending specimens to: Mineral Collection, c/o G. Fred Lincks, Berkshire Community College, West Street, Pittsfield, Massachusetts 01201.

G. Fred Lincks

The Gem and Mineral Museum of the Southwest

A new museum of the gem, mineral, and lapidary arts has been established at the Carlsbad Zoological-Botanical State Park of the Southwest located at Carlsbad, New Mexico.

The museum is under the auspices of the New Mexico State Park and Recreation Commission. The purpose of the museum is to acquaint our citizens and visitors to the Southwest with various facets of the mineralogical and lapidary arts and to serve as a reference source for students of geology and earth science. Contributions to the museum will be gratefully received and acknowledged.

For further information, write: Bill McMillan, Curator, 1804 Manzana, Carlsbad, New Mexico 88220.

THE COLLECTOR

by Richard A. Bideaux

Hugh A. Ford, the eminent New York City dealer, introduced me to the legend of Dr. A. E. Foote in about 1950. Ford had for sale a delightful series of small but choice specimens which he told me came from a “Foote trunk collection” that he had just purchased. I was pleased to select several varieties of wulfenite from the Stevenson-Bennett mine in New Mexico, with extraordinarily complete labels marked “Dr. A. E. Foote, Philadelphia.”

Fully printed dealer's labels? Quality minerals sold by the trunkful? Who was A. E. Foote? Not too long after, a remarkable issue of *Rocks and Minerals* magazine was published (3). Edited by Clifford Frondel and Arthur Montgomery, this was the 25th Anniversary issue, dedicated to its founder and publisher, Peter Zodac. Among the many outstanding articles written by prominent collectors and professional mineralogists was one by Charles Toothaker, an early associate in the Foote Mineral Company. This provided a wealth of information on this early American mineral dealer.

Here I learned that Foote first put together an exhibit for the Philadelphia Centennial Exposition of 1876, storing excess material from the exhibit in “a cheap building on N. 44th Street just outside the Exposition grounds.” Visitors, wanting specimens, were taken there to buy in such numbers that Foote soon decided to stay on in business.

He suffered terribly from tuberculosis, and was forced to travel yearly to save his life. On these trips, primarily to the western U. S. and Europe, were acquired many of the fine pieces now to be seen in the museum collections donated by such as Clarence S. Bement, George Vaux, Jr., W. W. Jeffris, Col. Washington A. Roebling, and others. Professors E. S. Dana and George W. Koenig were frequent visitors and provided authentication of new materials, finding more than a few new minerals in the process.

Foote was an inveterate collector; Toothaker says “he gathered not only what he really wanted, but could not leave specimens behind him for fear they would be forever lost and wasted, so he brought back barrels and boxes full of everything that looked like a mineral specimen.” Trips to such localities as Joplin, Missouri; Pike's Peak, Colorado; Thomas Mts., Utah; Organ Mts., New Mexico; the Red Cloud mine, Canyon Diablo and Bisbee, Arizona; Guanajuato, Zacetecas and Queretaro, Mexico, resulted in an average of a box a day of specimens being shipped back to Philadelphia. Foote even sent along “which boxes were to be opened first and gave us instructions to offer certain specimens to Bement, others to Vaux, and he indicated prices on the finest.”

Eventually, in alternate years, Foote would go to Europe. “We started out by picking off a lot of top-quality specimens, which we selected very carefully and shipped to the British Museum on approval ... The shipment contained, first of all, half a dozen specimens we felt sure the British Museum would buy. Then we added perhaps a dozen or twenty which we thought they would not purchase. That saved us the ocean freight on some good stuff that could be sold to other European museums or private collectors ...”

“Twice he visited Sicily and I think no one else ever brought away such a quantity of both magnificent and common specimens. There were the most wonderful specimens I have ever seen of sulfur, aragonite, calcite after aragonite, selenite, etc., not to speak of rarer things like melanophlogite.”

“Twice he went to Elba and we had pyrites and hematites — so many and such wonderful specimens as no one else has ever brought to America.”

“Albert E. Foote, M.D. 1857”

780
Ozocerite.
Borysław,
Galacia.
10¢
A. E. FOOTE,
1223 Belmont Avenue, Philadelphia, Pa.

79.J
JAMESONITE
VAR : HETEROMORPHITE
2PbS. Sb^2S^3. Orthorhombique
BOTTINO, TOSCANE, ITALIE
FOOTE MINERAL C°
PHILADELPHIE. PARIS.

DANA
775.1 ALUNOGEN.
Hyd. aluminium sulphate, $Al_2(SO_4)_3+18H_2O$.
Monoclinic.
HEADWATERS OF THE GILA RIVER,
SOCORRO CO., NEW MEXICO.
FOOTE MINERAL CO.,
PHILADELPHIA AND PARIS

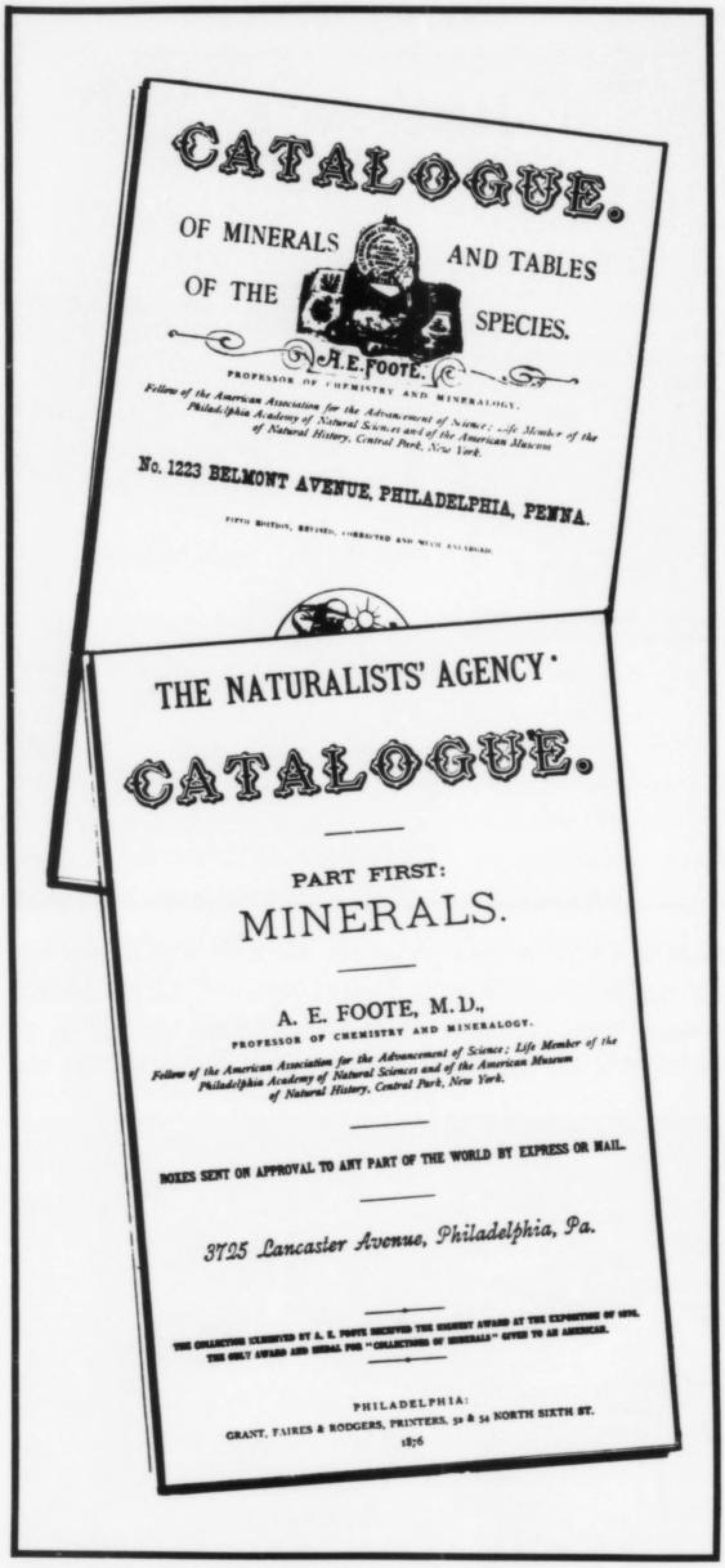
678.
DANA
289. AZURITE.
Basic cupric carbonate, $3CuO.2CO_2.H_2O$.
Monoclinic.
BROKEN HILL MINES, N. S. W.
DR. A. E. FOOTE, PHILADELPHIA.

DANA
443. STILBITE
438. HEULANDITE
THEIGARHORN,
ICELAND
DR. A. E. FOOTE, PHILADELPHIA.

193. Rutile, TiO_2,
Alexander Co., N. C.
A. E. FOOTE, M. D.,
Philadelphia, Pa.

"Once he went to Sardinia and obtained magnificent anglesites and phosgenites — plenty of them. On his way back home he met in Paris his friend and business rival, Ward. Each of them carefully told the other where he had been and what he had gathered. Ward wanted to see the specimens from Sardinia. Foote let himself be persuaded to show some of them. Ward saw anglesites and phosgenites such as we later sold for fifty cents. Foote did not lie

Dr. Albert E. Foote and his son Warren at the New Orleans Exposition of 1885. Like several other Foote exhibits of minerals, this comprehensive display won an award.



CATALOGUE.

OF MINERALS AND TABLES OF THE SPECIES.

A. E. FOOTE.

PROFESSOR OF CHEMISTRY AND MINERALOGY.

Fellow of the American Association for the Advancement of Science; Life Member of the Philadelphia Academy of Natural Sciences and of the American Museum of Natural History, Central Park, New York.

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THE NATURALISTS' AGENCY

CATALOGUE.

PART FIRST:

MINERALS.

A. E. FOOTE, M.D.,

PROFESSOR OF CHEMISTRY AND MINERALOGY.

Fellow of the American Association for the Advancement of Science; Life Member of the Philadelphia Academy of Natural Sciences and of the American Museum of Natural History, Central Park, New York.

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1876

to Ward but let him think that these were good. With great seeming reluctance, and as a personal favor, Foote sold some of these to Ward. Six months later, when Ward came to our store and saw what we really had, he called Foote an old scoundrel. Foote laughed and then Ward laughed too."

For this article I have dug a little more deeply. Neal Yedlin sent me a couple of Foote's Monthly Journals, which make fascinating reading (1). As these are generally unavailable, I will quote some of the specimens listings in full in a future column. Occasionally Foote interjects himself into these Bulletins: " ... The influence that the *mere collecting* of minerals has on the progress of Mineralogy and Chemistry is shown by the following statistics ... In 1875 I visited the Magnet Cove locality, and the number of papers (on titanium) was twice as great in '75 as in '74. The mineralogical papers of 1876 were four times as great as in '74, and the papers of '77 were far more numerous than those of '75 or '76. Such is the record, and yet how often some pseudo-scientist says of a gentleman of taste and means who has satisfied his love for the beautiful with works of absolute perfection instead of copies on canvas *"Oh! he is a mere collector!"* True scientific men appreciate the value of such collections, and even if poor manage to have them at their command ..."

After Dr. Foote's early death in 1895, at the age of 49, his son Warren continued the business. Up until 1910 or so, specimens were a large part (2), but gradually rarer industrial minerals provided the mainstay. Toothaker (3) says: "I know that in the end they threw hundreds of good specimens into barrels which went to the dump." A major supplier of lithium from spodumene (North Carolina) and brine (Utah), the Foote Mineral Company lately lost its autonomy when sold for several tens of millions of dollars.

Along with this column are reproduced a number of Foote specimen labels; probably the earliest is that without the M.D. after his name, although he received the M.D. at age 21. Another pair, one in French, indicates the existence of a Paris store, but the articles available to me make no mention of this. Two others, fully printed, are from the collections typically sold in lots of 100 specimens for $10.00. The smallest label is one of those affixed directly to specimens. Kraus (4) says: "The Foote label on mineral specimens was famous for two sterling virtues — the data it gave was correct; and the glue Dr. Foote used to fix it to the mineral never seemed to loose its grip"!

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1. *The Naturalist's Leisure Hour and Monthly Bulletin,* A. E. Foote, Nos. 128, 1891, and 132, 1892, 32 pp. each. (Neal Yedlin, courtesy of Joe Pollack)
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5. Albert E. Foote, the Naturalist — a Michigan Alumnus; E. H. Kraus, *Mich. Alumnus Quart. Rev.,* **64,** 21, 1959, p. 342-347. (Charles Towle)

The Photographic Record, continued from page 158

to about 2860° Kelvin. Fluorescent lights correspond to about 4500°K, and sunlight about 6000°K. Five-hundred-watt "Photoflood" lights are about 3400°K, and 500-watt "studio lights" are about 3200°K. For color there are three basic *film types*; they are "balanced" for 6000°K, 3400°K, and 3200°K. These are daylight film, type A, and type B, respectively. For any other type of light than these three you (theoretically) need a compensating filter. Kodak's booklet, *Kodak Filters for Scientific and Technical Uses (B-3),* about $2.00, contains a chart called a "mired nomograph" which quickly and easily shows you which filters, lights, and films will work together. Fortunately you can often fudge on light temperatures and still obtain good results on most minerals without a filter. Other good data books include Kodak's booklets on films and on existing-light photography.

In mineral photography the basic objectives are sharpness, depth of field, and accurate color rendition (besides artistic considerations). To achieve these objectives we must use appropriate lighting with a slow film, and yet still use a small *f*/stop, such as *f*/16. Therefore rather long exposures are often required. The color response of some films changes slightly with exposures of longer than about 1/10 sec., but I have made unfiltered exposures of up to three minutes, and have not noticed a color shift. If it becomes too noticeable to you, however, the data sheet you get with each roll of film tells which filter to use to correct it. So the long exposures are really no problem.

The only real problem is just remembering to DO everything before tripping the shutter. You have to set the *f*/stop, the shutter speed, the film speed (on the light meter), and the focus, as well as remembering to use the right light and advance the film before each exposure.

Wendell E. Wilson
8042 Bryant Ave. So.
Bloomington, Minn. 55420

QA column

Q. I offer this question at the risk of showing my ignorance. Beyond the appreciation of a crystal's beauty and an interest in how the crystal formed, where is the study of crystals taking us? What, for example, is the importance of the discovery that wickmanite is isometric, while tetrawickmanite is tetragonal? Okay, so we have a new mineral. What does the recognition of a new mineral mean to future research or the future chemist?

Howard Kraus
Huntsville, Alabama

A. The question of Mr. Howard Kraus is an important and prescient one. It may sound surprising that we scientists often ask similar questions ourselves!

First of all, I submit the statement that knowledge of a mineral's crystal structure (atomic arrangement) is the most valuable information we can have, at least at the level of low-budget research. It places the *species* concept on firm ground and permits us to write an unambiguous formula. Crystal system, point symmetry or crystal class, space group and the powder pattern all immediately derive from knowledge of a mineral's atomic structure. In addition, the structure explains crystal habit and many of the physical properties such as cleavage, hardness, luster, specific gravity, and to some extent, conductivity, optical properties, magnetic properties and color.

The existence of modifications or polymorphs (such as wickmanite and tetrawickmanite) also provides us with valuable information and some sobering questions. A paragenesis (including polymorphic transition) reflects the temperature, pressure, crystal growth rate, oxidation potential and ionic concentrations in the fluid from which the crystals grew. Distortion of an 'ideal' structure to one of lower symmetry often provides us with some basic knowledge of chemical bonding and may lead to fundamental insights into some of the basic laws and phenomena of chemistry. Any lack of serious attempt toward reasonable precision in description of *species,* any casual reference with ignorance of the finer details, is compromise. It leads to 'sloppy science': incorrect deductions about chemical and physical behavior of the material world. Worse yet, it may prohibit the blossoming of a fundamental discovery such as some new principle or effect since anomalous behavior would be overlooked. Tetrawickmanite is an exciting compound because according to present-day canonical (or accepted) knowledge, we don't know why or where the cubic wickmanite structure would distort to lower symmetry. Is it due to the anisotropic behavior of the Sn^{4+} cation, is some form of electronic coupling present, is it a size effect, is it a lattice vibration effect, or combinations of these? We really don't know. These questions are truly fundamental.

Imagine the surprise of Prof. Gregori Aminoff when he discovered that magnetoplumbite, ideally $PbFe^{3+}_{12}O_{19}$, was magnetic and crystals of it would attract iron filings. Canonical knowledge at that time required oxide magnets to have Fe^{2+} present yet it contained none! This discovery, in 1925, anticipated by a decade the phenomenon of oxide ferrimagnetism. Technologically, it led to the development of magnetic tapes, so important in computer science. The rare zeolite, faujasite, possesses a crystal structure which is the basis of a large family of synthetic molecular sieves — and the basis of a half-billion dollar a year industry. To this day, the fine details of the mechanism of zeolitic catalysis, so vital in the catalytic cracking of petroleum, are not known despite some one hundred papers a year devoted to the subject. Studies have even attempted to locate the electronic and proton distributions in the crystal!

Let me remark finally that what may seem almost an obsession with fine details in contemporary mineralogical research is a reflection of our broad knowledge about atomic structure. Such "fine structure" effects as witnessed in laser technology, Mossbauer resonance, neutron scattering and in the entire fields of quantum mechanics and general relativity were not realized until the 20th Century.

Newton's laws still serve faithfully for large-scale systems but as we peel away the layers of this onion-skin universe, yet new worlds continually emerge. The great mathematician David Hilbert felt that the ultimate goal of science is the search for structure, pattern and symmetry. This is what we call *consistency*. To the public at large, such pursuits may not seem obvious or even a worthwhile way to spend one's life. But Nature is still very elusive and She guards Her secrets well. Curiosity is Man's supreme gift of the gods, with its dual Prometheus-Pandora role. If mineralogy were to remain "classical" and frozen in the 19th Century, it would be dead. Growth always requires change: the world of ideas is *dynamic*, not static.

Paul Brian Moore
The University of Chicago

Q. **I recently obtained a mineral specimen that is labeled valencionite — Valencione mine, Guanajuato, Mexico. I have consulted all the reference material I can find but I cannot find any listing on this name. Do you have any information on it?**

Harry A. Wagoner
Earlham, Iowa

A. Valencianite is just another name for adularia, a variety of orthoclase. The name has no special significance and probably should be forgotten. It derives from the locality, the Valencia mine, Guanajuato, Mexico. Reference to valencianite may be found in *Dana's Textbook of Mineralogy*, and other widely used mineral books.

Q. **The place name "Mies" is often seen on old European specimen labels. In which country is it located today?**

Peter Keller
Austin, Texas

A. Mies is a mess. There are two modern equivalents, both mineral localities of some fame. One is in Northern Slovenia, Yugoslavia, about 10 km from Bleiberg on the Austrian side of the border. It is now known as Mezica (or Mezice). The other Mies is now Stribo (Stribno?) and it is in Western Bohemia, Czechoslovakia.

Some of our leading references only compound the difficulties of straightening out these locality name snarls. One of the most prestigious atlases had no listing for Mezica, another had Bleiberg spelled Bleiburg, and there is no general agreement on Stribo vs. Stribno.

Q. **What is the relationship between laumontite and leonhardite? Are laumontite specimens in collections likely to be leonhardite?**

Mrs. C. H. Weber, Jr.
Fairfield, Connecticut

A. Laumontite readily loses about 1/8th of its water when exposed to the atmosphere and it forms what is known variously as leonhardite, beta-leonhardite, or caporcianite. The water loss is accompanied by a marked change in optical properties and cell size; the latter is clearly reflected is distinct differences in the x-ray diffraction powder patterns of leonhardite and the fully hydrated laumontite. It is also reflected in the structural instability which usually results in the disintegration of the crystals. Leonhardite changes back to laumontite when immersed in water but large crystals of laumontite, destroyed through dehydration, cannot be reconstituted.

Yes, laumontite specimens in collections are likely to be leonhardite. For many years knowledgeable collectors have been preserving laumontite by immersing it in or spraying it with a thin medium such as shellac, clear nail polish, or a water soluble glue. Elmer's Glue appears to work very well.

To the Editor

EDUCATIONAL EXHIBITS

Dear Sir:

I would like to comment on the editorial which appeared in the latest issue of the Mineralogical Record entitled "Educational Exhibits". To compile an educational exhibit within the confines of a regulation display case, keep it simple, clear, and most important interesting to *all* who attend the shows is at best a difficult task. I say difficult because many of us are not professionals in the educational field. Certainly there is always room for improvement, but I feel that this can be accomplished more discreetly by the show judges and their comments. Although some of your observations are valid, constructive criticism can be made without mentioning specific displays in your editorials. This type of reporting is only harmful to our hobby. It will simply discourage members from compiling educational displays and substitute cases of a less controversial nature. This would be very sad because we have so few educational cases in our shows now.

I cannot speak for the first display mentioned in the editorial, but I would like to make a comment in defense of the second. This display showing metals and their ores has produced many good comments. One that comes to mind is the frequency of the expression "Gee, I didn't know that". A simple statement, but it implies that something was learned through acquaintance. Acquaintance is one of the definitions for knowledge and certainly knowledge and education have some connection. This educational exhibit, at various shows with over a dozen judges, has earned two "best in show" awards, one "best in division" award and five first place ribbons. Twice its exhibitor has been invited to display the case as an honored exhibit. Additionally, the editor, in his capacity as a judge, awarded a second and a third place ribbon to this display. Evidently, he felt the exhibit had no, or very little, educational value.

Now if all the judges were using the same criteria, I wonder if the so-called problems are really with the educational exhibits, as the editor implies,

COLEMANITE

or do they exist only in the mind and opinion of the editor.

Martin Hamasian
Potomac, Maryland

STANDARDIZED LOCALITY LISTINGS

Dear Sir:

Mr. Silsby's recent suggestion that a standardized locality listing be compiled is one of the most constructive to appear in the pages of the *MR*. The task seems formidable, indeed, but as Mr. Silsby observed, much of the work is already done.

To wit: In the same issue, notice of the reprinting of Gordon's *The Mineralogy of Pennsylvania* appeared. It reads, in part, "Locations are listed alphabetically by counties and townships." Similarly, locality guides to Maine, New Hampshire and Vermont by Philip Morill exhaustively list localities by town. All that's left to do is the numbering. Surely, this situation exists for many other areas.

The project is ideal for an organized effort by a group of enthusiastic mineral collectors — the Friends of Mineralogy. Attacked through the regions, the greatest amount of interest and expertise can be brought to bear on the task. Completion and publication of these compilations will be a substantial contribution to our hobby and that is the stated purpose of the Friends of Mineralogy.

Carl A. Francis
Blacksburg, Virginia

READING LIST DESIRED

Dear Sir:

The gap between the beginning amateur and the professional mineralogist can be bridged by the exchange of information. The *Mineralogical Record* is an important part of the bridge, mineral books are another. Neal Yedlin urges us to "buy and use a good mineral book". It might be a good idea for the *Record* to suggest a list of good mineral reference books for people at all stages of the game, particularly those who are trying to make the transition from rockhound to mineral collector.

If the advanced collector gets a simple book, it may just bore him. But if a novice buys a book that is too complex, he will get discouraged and may seek solace by turning out a few more cabochons. So, please suggest some good reference books for beginning and intermediate collectors. The ultimate result may be more enthusiastic readers of the *Record.*

Henry Truebe
Crested Butte, Colorado

A superb idea, we'll do it. Ed.

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Native copper — Santa Rita, Grant County, New Mexico. 4-1/2" x 2-1/2" **$12.00**

Barite rose — Great Salt Plains, Oklahoma. 2" x 1-1/2" **$6.00**

Calcite — San Carlos, State of Chihuahua, Mexico. Bright red color. 2-1/2" x 2-1/2" **$40.00**

Apatite — Panasqueira, Portugal. 2" x 1-1/2" **$30.00**

Calcite — Tsumeb, Southwest Africa. 5" x 3" **$40.00**

Descloizite — Berg Aukus, Southwest Africa. Unusual wedge-shaped crystals. 2" x 1-1/2" **$40.00**

Arsenopyrite with Wolframite, Siderite and Quartz — Panasqueira, Portugal. 2-1/2" x 2" **$75.00**

Calcite — Silverton, Colorado. 2" x 1-1/2" **$20.00**

Autunite — Daybreak mine, Spokane County, Washington. 1-1/4" x 3/4" **$10.00**

Calcite — San Sebastian mine, near Charcas, State of San Luis Potosi, Mexico. 5" x 4" **$40.00**

Wolframite — Panasqueira, Portugal. 2" x 1" **$12.00**

Copper — near Kolwezi, Katanga, Zaire (Congo). 1-1/2" x 1" **$8.00**

Gold — Sarcomb Hill, Breckenridge, Colorado. 1" x 1/2" **$40.00**

Halite — Herring-Werra, Thuringia, W. Germany. 2" x 7/8" **$18.00**

Black Tourmaline — Yinnietharra, Australia. 2" x 1" **$12.00**

Sulfur — Racalmuto, Sicily, Italy. 1-1/4" x 1-1/4" **$15.00**

Vanadinite on Barite — Mibladen, Morocco. 2" x 2" **$60.00**

Quartz — Mt. Ida, Garland County, Arkansas. 3-1/2" x 2" **$20.00**

Pyrite "dollar" — Sparta, Randolph County, Illinois. 3" across **$40.00**

Amethyst — Las Vigas, State of Vera Cruz, Mexico. 2-1/2" x 2" **$40.00**

Neptunite on Natrolite — Dallas Gem Mine, near New Idria, San Benito County, California. 1-1/2" x 1" **$75.00**

Pyrite — Quiruvilca, Peru. 1-1/2" x 1-1/2" **$10.00**

Galena — Magmont mine, Bixby, Missouri. 2" x 1-1/2" **$25.00**

Pyrite — Ambassaguas, Spain. 1-1/2" x 1-1/2" **$25.00**

Malachite in Calcite — Zacatecas district, State of Zacatecas, Mexico, 4" x 3", **$25.00**

Pyrite — near Gilman, Eagle County, Colorado. 4-1/2" x 2-1/2" **$45.00**

Amethyst — Las Vigas, State of Vera Cruz, Mexico. 2-1/2" x 2" **$105.00**

Beryl, var. Aquamarine — Tres Barras, Minas Gerais, Brazil. 1" x 1/2" **$35.00**

Torbernite — near Shinkolobwe, Province of Shaba, Zaire. 1-1/2" x 1-1/2" **$100.00**

Dioptase with Calcite — Tsumeb, Southwest Africa. 2" x 1" **$95.00**

FOSSILS

***Milesia quadrata* Scudder.** Sweat bee. Eocene Green River formation shale, near Meeker, Rio Blanco County, Colorado. 1/2" x 1/2" **$15.00**

***Plecia pealei* Scudder.** A fly. Eocene Green River formation shale, near Meeker, Rio Blanco County, Colorado. 1/2" x 1/2" **$15.00**

***Cryptocephalus vetustus* Scudder.** Beetle. Eocene Green River formation shale, near Meeker, Rio Blanco County, Colorado. 1/4" x 1/4" **$20.00**

Bird feather on shale. Eocene Green River formation shale, near Meeker, Rio Blanco County, Colorado. 1/2" x 1/2" **$7.00**

***Phacops rana milleri.* Trilobite** in a coiled position. Middle Devonian silica shale formation, near Silvania, Lucas County, Ohio. 1/4" x 1/4" **$25.00**

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THIS (MYSTERIOUS) MINERAL BUSINESS

Many people believe that the mineral specimen business is enveloped in mystery and that the mineral dealer is the most fortunate man alive because he can promote any rock (which he purchased for a pittance) into a valuable specimen. They maintain and honestly feel that since every mineral is different and there is no set value on them, there are no laws governing their price and classification as in other commodities.

This legend has been fostered by romantic stories of hidden collections long widespread in the folk lore of collectors. According to this belief it is ridiculous to buy specimens through ordinary channels; all you have to do (armed with a copy of The Final Disposition ...) is find the descendant of an early collector, hopefully a poor unsuspecting widow, and buy her collection for a song. If you must buy from a dealer, find some obscure, uninformed fellow who has not studied as much as you and discover some great "sleeper" which he overlooks and you buy for a fraction of its value.

I have been actively engaged in the buying and selling of mineral specimens for almost 20 years and have certainly had ample opportunity to capitalize on these windfalls. It is my observation that with few exceptions they are illusions.

From the pioneer days of collecting, when fine minerals were hardly understood and little appreciated, the truly fine things found a ready market and did not wait to be discovered by some bargain hunter. That is why, when Washington Roebling was offered the famous purple Apatite now in the National Museum, for $1000.00, he knew that no price is too high for something superlative. While that was a fantastic price for those days, that piece would bring many times that amount if it ever came on the market again.

The principles governing the purchase of minerals are the same as those employed by intelligent buyers in the purchase of any other commodity.

There is no secret method by which a dealer or collector assembles a fine collection; the only way is to pay a premium for premium pieces.

* * *

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