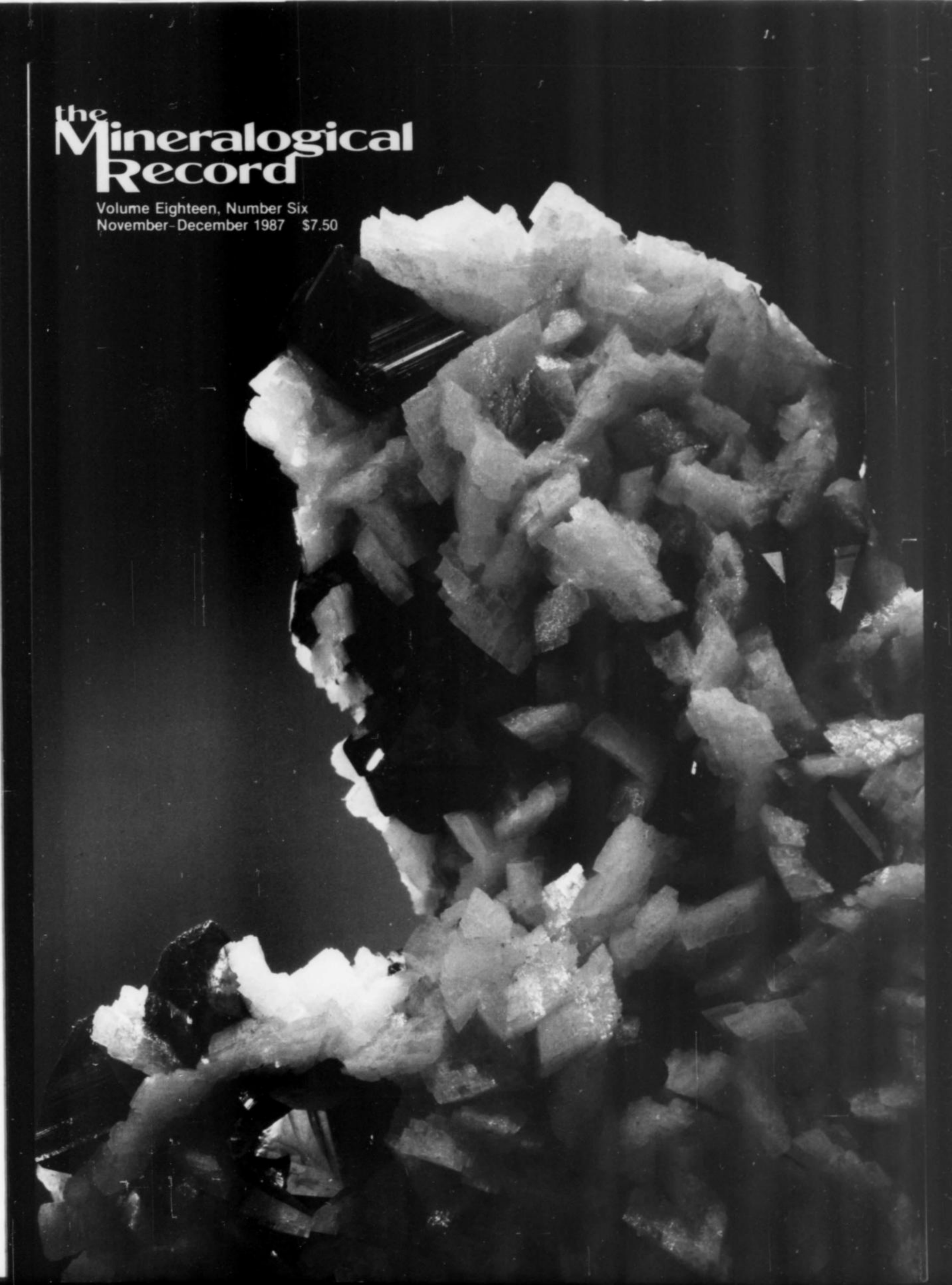
the Mineralogical Record

Volume Eighteen, Number Six
November-December 1987 $7.50



KRISTALLE

Wayne and Dona Leicht, 332 Forest Avenue No. 8,
Laguna Beach, Cal. 92651 (714) 494-7695 ... 494-5155
Open Mon.-Sat. 10-5.

photo by Harold and Erica Van Pelt, Los Angeles • Note our mailing address: P.O. Box 1621, Laguna Beach, CA 92652.

The Mineralogical Record Inc.
is a non-profit organization
The Mineralogical Record magazine is published by the Mineralogical Record Inc., 7413 N. Mowry Place Tucson, Arizona 85741

Editor & Publisher
Wendell E. Wilson

Associate Editors
Pete J. Dunn
Washington, DC
Peter G. Embrey
London, England
Richard C. Erd
U.S. Geological Survey
Menlo Park, CA
Donald R. Peacor
University of Michigan
Ann Arbor, MI
George W. Robinson
Natl. Museums of Canada
Ottawa, Ontario
Abraham Rosenzweig
Tampa, FL
Richard W. Thomssen
Carson City, NV

Associate Photographers
Nelly Barland
Sorbonne
Paris, France
Werner Lieber
Heidelberg, W. Germany
Olaf Medenbach
Ruhr Universitat Bochum
Bochum, W. Germany
Eric Offermann
Arlesheim, Switzerland
Harold and Erica Van Pelt
Los Angeles, CA
Julius Weber
Mamaroneck, NY

Circulation Manager
Mary Lynn Michela
(Subscriptions, back issues, reprints)
P.O. Box 35565
Tucson, Arizona 85740
602-297-6709

Editing, advertising
Wendell E. Wilson
4631 Paseo Tubutama
Tucson, AZ 85715
602-299-5274

Promotions and Book Sales
Gale Thomssen
P.O. Box 1656
Carson City, NV 89702

Design
Wendell E. Wilson

Subscriptions
- **Individuals (U.S.):** $27 for one year, $52 for two years, $750 lifetime. (First-class mailing available; write to circulation manager for rates.)
- **Individuals (outside the U.S.):** $30 for 1 year, $58 for two years, $850 lifetime. (Airmail mailing available; write to circulation manager for rates.)
- **Libraries, Companies and institutions (worldwide):** $45 for one year. (First-class or Airmail mailing available; write to circulation manager for rates.)

Special second class postage
(USPS-887-700)
Paid at Tucson, Arizona, and additional offices. POSTMASTER: send address changes to:
7413 N. Mowry Place
Tucson, AZ 85741

* Continued on cover-3

the Mineralogical Record

November-December 1987
Volume Eighteen, Number Six

Articles

Departments

COVER: CINNABAR with dolomite and quartz, Guizhou Province, China. The cinnabar crystals measure up to 1.4 cm in size. Collection of Charles Leavitt; photo by Harold and Erica Van Pelt.

notes from the EDITOR

STEREO VIEWERS

In this issue is an article by Steven Chamberlain and myself on the subject of stereo or "3-D" mineral photography. Naturally it is illustrated with stereo-pair photos, and these generally require a special viewer in order to achieve the proper effect. We have not published stereo pairs in the *Mineralogical Record* for many years simply because most readers do not have a stereo viewer readily at hand. But, thanks to a grant from associate photographer Eric Offermann, we have been able to enclose a free viewer with every copy of this issue! We will now feel free to publish stereophotography whenever necessary in future issues, knowing that all of our readers have carefully preserved their viewer in a handy place.

Your viewer comes in a clear plastic sleeve with a peel-off adhesive backing so that it may be attached permanently to the inside back cover of this issue where it will always be available for your use. Purists who do not wish to obstruct their view of the inside back cover, and who may rightly be concerned about the longevity and archival quality of the peel-off adhesive, are advised to affix the plastic sleeve (or a paper envelope) to a blank sheet of paper and tip this sheet in over the inside back cover using a little white glue along the gutter. If you plan to have your 1987 issues hardbound, attach the pocket to an inside face of the hardcover binding.

Dr. Offermann has been an enthusiastic practitioner of stereophotography for several years, and has had many beautiful stereo pairs of minerals published in a variety of European magazines. His generous gift of $8000 for the viewers will allow *Mineralogical Record* readers to enjoy this unique approach to specimen photography for many years to come. In fact, the article in this issue on Duff quarry pyrite would probably not otherwise have been published with stereo photos. Readers certainly owe Dr. Offermann a sincere vote of thanks for so kindly sharing his enthusiasm with us.

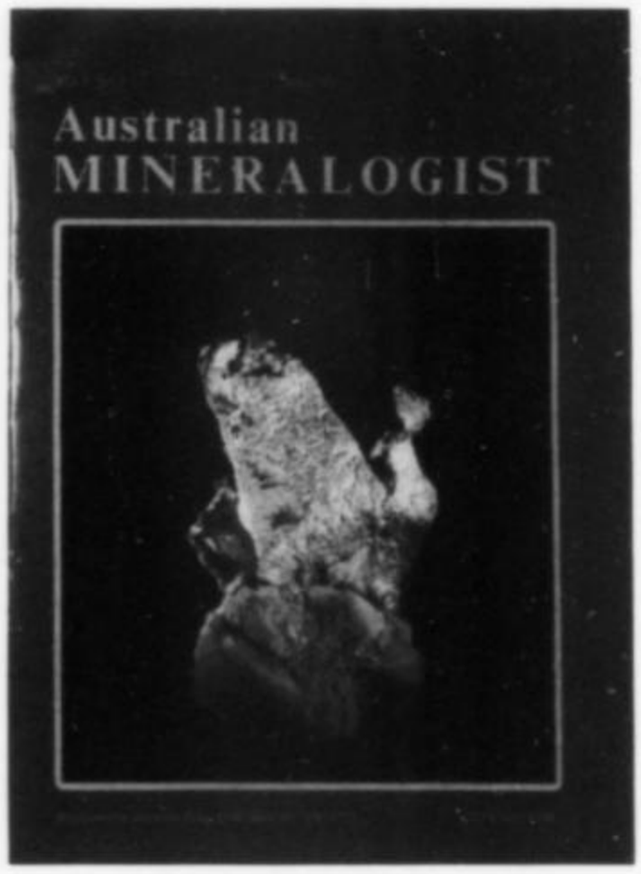
Should you wish to obtain additional stereo viewers, they are available at $2.50 postpaid from Taylor-Merchant Corporation, 212 West 35th Street, New York, NY 10001.

NEW BRITISH MAGAZINE

Mineral publications from England are of potentially great interest, at least to American, Canadian and Australian readers, for two overriding reasons: (1) The Brits have some great, classic localities at hand to write about, and (2) they write in English. Up to now they've been struggling to produce some kind of viable collector's journal. The publications *Gems* and *Mineral Realm,* very modest and somewhat outdated in format, folded up a few years ago. The *Journal of the Russell Society* comes out only very rarely (yearly?). But now there is a new and modern looking entry entitled *Rockbottom, UK Journal of Mines and Minerals.*

Issue no. 2 (Spring 1987) is 36 pages, large format (21 x 30 cm), properly typeset with good B&W photography, and plenty of interesting articles. The journal carries a nice mix of subject matter, from chatty pieces to short show reports (Munich and Brussels), book reviews, locality articles, micromineral articles and dealer ads. Try it; you'll like it. Issue no. 1 is sold out but issues 2 and 3 are available at £3 each plus postage. The equivalent in dollars can be sent to their American agent, Mrs. J. Schmitt, 812 Imperial Court,

Hartland WI 53029. Their British circulation office is c/o Mrs. J. C. Spence, 3 Oak Tree Road, Bawtry, nr. Doncaster, S. Yorkshire.



AUSTRALIAN MINERALOGIST

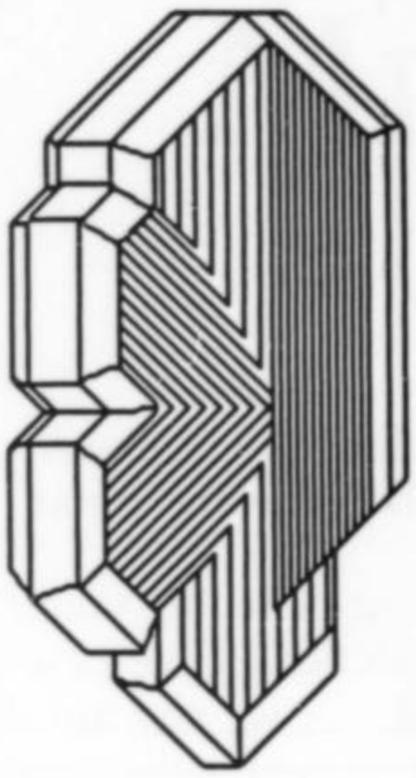
The *Australian Mineralogist,* formerly published as a short supplement to *Australian Gems & Crafts* magazine and its successors from 1976 to 1985, has now been revived as a new, independent publication. The journal plans to carry technical scientific papers and also more general, descriptive reviews of Australian minerals and localities. The first issue, in 17 x 24-cm, 40-page format with full-color cover, was issued in July. Annual subscriptions (4 issues per year) are $24 (Australian), $20 U.S. surface mail and $32 U.S. airmail for all other countries. Write to Gemcraft Pty. Ltd., 1st Floor, 293 Wattletree Road, East Malvern, Victoria 3145 Australia.

AUSTRALIA TOUR PLANNED

A group tour to Australia for the annual Gemboree (their biggest mineral show of the year) is being planned for March 23, 1988—return date open. Interested parties should contact Book Department manager Gale Thomssen (P.O. Box 1656, Carson City, NV 89702).

15th ROCHESTER ACADEMY OF SCIENCE MINERALOGICAL SYMPOSIUM

April 7-10, 1988



Calcocite
Bristol, CT

Join us for a
Celebration
of the
15th ANNIVERSARY
of the
ROCHESTER SYMPOSIUM

>>BENEFIT AUCTION<<

FOR THE
NATIONAL MUSEUMS OF CANADA
TO PURCHASE THE
WILLIAM W. PINCH COLLECTION

Speakers will include:

PIERRE BARIAND
RICHARD GAINES
JOHN GREENE
DICK HAUCK
BOB JONES
TONY MARIANO
FRED POUGH

Also:

What's New in Minerals
Exhibits
Major Dealers
Social Events
RAS Publications
Technical Session
Camaraderie

The Symposium will be held at the Rochester Hilton Inn, 175 Jefferson Road, Rochester, NY — 2 miles west of East Henrietta Road exit of I390.

Continuing this year: CONTRIBUTED SHORT PAPERS IN SPECIMEN MINERALOGY

For further information about REGISTRATION contact:

Dr. Helen H. Chamberlain
P. O. Box 336
Nedrow, New York 13120

To submit a SHORT PAPER contact:

Dr. Steven C. Chamberlain
Department of Bioengineering
Syracuse University
Syracuse, New York 13244-1240

Fine Mineral Specimens
Wholesale and Retail

Thinking of selling your collection? Give us a call . . . we pay top dollar for mineral collections

See us at:
TUCSON * DETROIT

Private Showroom in Tucson
Call for an appointment
No List Available

Gypsum
14 cm as shown
Santa Eulalia,
Mexico

RECENTLY ACQUIRED: several lots of attractive and interesting Mexican minerals, many of them quite inexpensive . . . lustrous Naica galenas 6-12 cm, Adamite with Hemimorphite from the Ojuela mine, pale green and purple Naica fluorites in small cabinet sizes, etc. Native silvers such as the above are a specialty, and we regularly get fine examples from classic localities. Give us a call or stop in (by appointment) to see what's new.

Western Minerals

Fine Mineral Specimens

GENE & JACKIE SCHLEPP • P.O. BOX 43603 • TUCSON, ARIZONA 85733 • 602-325-4534

Mineral Curators

Their Appointment and Duties

Peter G. Embrey
19 Edith Road, Baron's Court
London, W14 OSU England

The International Mineralogical Association is the only international body in the field of mineralogy. It has more than 30 member countries, each represented through its national professional mineralogical organization, in our case the Mineralogical Society of America. Much of the IMA's work is carried out through subject-specific commissions and working groups. In early 1987 the Commission on Museums formally adopted the following statement, "Mineral curators: their appointments and duties." It is the Commission's hope that wide circulation of this statement will positively influence the selection of mineral curators and ultimately benefit the mineral collections of the world.

Carl A. Francis
Curator, Harvard Mineralogical Museum
American Representative to the
IMA Commission on Museums

Curator – distinct from private collector

There is a clear distinction between the private collector and the curator. A curator, by definition, is entrusted with the care and management of a collection that is not his own. He must operate within certain guidelines, determined by the owner and by the nature and purpose of the collection he manages. Unlike the private collector, who may modify the nature of his collection at will, the curator must subordinate his preferences to the needs of the collection.

Curator – position of trust; duty to collection

The curator is usually employed by a corporate body, as the current holder of a position of trust that may have existed for many decades – perhaps one or two centuries. This position may be expected to endure long after his retirement or death. The curator has the immediate personal responsibility; but the ultimate responsibility is corporate and lies with the owning or employing body, through a chain of mangement which may have little familiarity with or appreciation for the nature and needs of the collection. The curator owes a dual allegiance, to the collection as well as to his employer. Generally, there will be no conflict; his personal responsibility means that the curator has a clear moral duty to argue if he feels that the collection is under threat – but the final word will usually lie with his superiors.

Collection management – need for agreed policy

There should always be a clear statement, on paper, defining both the purpose(s) for which the collection exists, and the aims to be pursued by the curator in maintaining, augmenting or altering its nature. Policy should be decided by agreement between management and curator; it should be capable of amendment when the need arises. It should not be too detailed, yet it should leave the curator in no doubt of the extent of his discretion. Curators are usually left to use the professional judgment that they have acquired through training and expertise. However, problems or misunderstandings may arise; and a policy statement will protect the interests of both curator and management, as well as fostering a mutual understanding of responsibilities.

Curator – diverse nature of the task

The curatorial job has so many aspects that no curator, however able, can give equal attention to all of them. (The Appendix gives a brief list of parts of the curator's job, in no special order of priority and certainly not all-inclusive.) No two curators will view their priorities in the same order, and no two – even in the same museum – are expected by their superiors to perform the same tasks. It follows that there must be agreement between management and curator on the nature of the job.

Curator's task – duty of management to agree on job description

Because there are so many aspects of the curatorial task, it is essential that there should be agreement concerning the aspects that may safely be neglected; resources are finite, so some aspects must inevitably receive less attention than others.

Management has a continuing obligation to agree on priorities and guidelines, and particularly when making new appointments or decisions about staffing levels. Any reasonable and competent management, faced with a list of activities that are all relevant to the curatorial job, must either select those jobs which must be done (and relegate the others), or it must provide enough staff to attend to them all.

The only job requirement that ought not to need any policy decision on the part of the management is that the curator shall attend to all internal paperwork required of him; this cannot be avoided, but perhaps needs to be stated.

Curator – specialist and generalist?

The mineral department is usually the smallest in a museum. It may have separate collections, but the mineral curator is expected to be equally familiar with silicates and non-silicates, opaque minerals and transparent ones. Biological departments, by contrast, usually have greater specialization; and in spite of techniques unheard of a few decades ago, the modern biological curator rarely has the working knowledge of physics, chemistry and the associated instrumentation that is expected of the mineralogist. In addition to modern techniques, the mineral curator often must utilize traditional techniques, such as optical goniometry, which are no longer in fashion, yet are both effective and inexpensive to use.

Curation versus research

The conflict between curation and research is familiar and painful. Mineralogy is a specimen-based science, and museums are nothing if not based on their collections. It is destructive for research to be demanded from curators at the expense of neglecting the collections. A collection that is not worked on is an interesting historical record, but it rapidly goes into decline. A competent curator will want to carry out research, from time to time, and should be encouraged to do so; but, if his primary duty is curation, research should not be demanded of him for its own sake. The fiducial responsibility for the collection can only be satisfied by attention to curatorial activities such as preparing catalogues and inventories, which are at least as important as the publication of research papers and the preparation of exhibits.

It is impossible for a single curator to plan ahead in any detail for time to be devoted to research. Unanticipated exigencies and outright emergencies frequently arise. A large collection will also attract a steady flow of visitors and inquiries which cannot be ignored.

Mineralogical research in museum departments should logically be related to some aspect of the collections, including descriptive and systematic topics. It is impossible to draw a clear distinction between research activities and attention to inquiries and identifications. Any attentive curator, in the ordinary course of this duties, will find more problems than he can handle. Current fashions in mineralogical research increasingly demand teamwork and technical resources that are only available in the larger universities.

Curatorial appointments

Appreciation and respect for specimens are rarely taught or inspired in degree courses, but are important qualifications of a curator. A good research man or a good private collector will not necessarily make a good curator; either one may, but the research man may have no talent for assessing specimens or bargaining over an exchange, and the collector may have no taste for cataloging. When candidates are being considered for appointment, someone with recognized experience in mineral curation should be a member of the interviewing or selection board.

Management should bear clearly in mind that a collection needs continuity in its curation, and whenever possible should ensure that a new curator – if he is an external appointee – has a significant period of overlap with his predecessor. There is usually a lot to be learned about the existing system that can only be passed on by word of mouth, because no written statement can cover everything. Established procedures have often evolved for good reasons that are not self-evident; and a newcomer, with the best of motives, if he is not restrained, can easily make changes that he will later regret. There will be plenty of time, when he has gained some experience and is on his own, for him to make changes that will be all the better for his having matured for a while.

If an inexperienced but otherwise suitable appointee cannot be trained "in house," opportunity should be provided for him to spend time visiting and learning from experienced curators in more than one other museum.

●

APPENDIX: SOME ASPECTS OF A CURATOR'S JOB

Care and cataloging of collection:

Maintain the collections in a clean, undamaged, well-labeled and findable state, paying special attention to type specimens.
Attend to specimen conservation, taking note of techniques developed in other fields.
Prepare and maintain registers, indexes and catalogs.
Be aware of progress in cataloging techniques.
Gain a sound knowledge of the history of the collection, and attend to archival problems.
Keep abreast of the professional literature and other relevant journals; be aware of changes in mineral and geographic nomenclature.

Growth of the collection:

Augment the collections by exchange and purchase, by seeking donations and bequests, and by any other means, in the areas of species and locality representation, study and educational (including exhibits) material, and for any other purpose that the agreed nature and scope of the collection make desirable.
Maintain contacts with the specimen market, and visit dealers and shows to that end. Knowledge of prices is essential.
Undertake expeditions or field work in search of specimens.
Build up reserves of exchange material.
Assess and evaluate specimens for scientific and aesthetic merit and for probable market value.

Exhibition and education:

Exhibit specimens from the collections, and related material, in a manner that is educational or artistically attractive, or both.
Work with architects/designers/contractors on new exhibits.
Write guides and other educational matter.
Give lectures and instruction to students and amateur groups.

General duties and public relations:

Prepare reports, budget estimates and other internal management paperwork.
Answer inquiries and deal with correspondence.
Identify specimens, both to verify incoming material and to answer inquiries.
Process loan requests.
Serve on internal and external committees; attend conferences.
Prepare plans and estimates for future development.
Supervise and train subordinate staff and volunteers.
Cooperate with building maintenance staff.
Maintain friendly and constructive contacts with other curators, professional colleagues and collectors, and visit them when possible.
Receive and entertain visiting scientists, collectors and dealers.
Acquire or advise on reference works for the library.
Be aware of security problems, and act on them as instructed.

Research:

Engage in research or investigation, and publish the results. ⚒

Pyrite Crystals from the Duff Quarry

R. Peter Richards
Jones Mineral Museum
Heidelberg College, Tiffin, Ohio 44883

Photographs by **Steven C. Chamberlain**
Department of Bioengineering
Syracuse University, Syracuse, New York 13210

Pyrite crystals of unusual form and complex habits have been collected at the Duff quarry in Logan County, Ohio, for more than ten years. The crystals are challenging to characterize morphologically, but with some practice it can be done by visual inspection alone.

INTRODUCTION

Pyrite is among the most common of minerals, and is the most common sulfide, according to Palache *et al.* (1944). It typically forms brilliantly showy, brassy crystals of pleasingly regular shape, often of large size. Pyrite is readily available from dealers, and is generally not expensive. This and the beauty of its well-formed crystals make it sought after by beginning and advanced collectors alike.

Pyrite crystals from the Duff quarry rarely exceed 5 mm across, and the larger ones are commonly distorted and irregularly developed. However, most of the smaller crystals are regularly formed, and have faces of mirror-like brilliance. Their habits are so complex that the crystals often appear to be faceted rather than the product of natural growth. While the crystals have the same symmetry as other pyrite, their habits are so unusual that one may wonder initially if the crystals are indeed pyrite.

GEOLOGY

The C. E. Duff quarry is located on Route 117 approximately 2 kilometers north of Huntsville, Logan County, in west-central Ohio. The quarry produces crushed stone from the Middle Silurian Tymochtee Formation.

In northwestern Ohio, the Tymochtee Formation is a sequence of about 40 meters of thin to medium bedded dolostones, in part with considerable shale content. Abundant evidence points to a supratidal origin for these beds (Kahle and Floyd, 1971), including a suite a sedimentary structures such as mud cracks and ripple marks, fossils such as stromatolites and Leperditiid ostracodes, and gypsum biscuits and single crystal molds. Evidence of dissolved evaporite minerals is common in some parts of the formation.

The section exposed at the Duff quarry includes stromatolite beds; thin to medium bedded shaly dolostones with cross-laminations and occasional mud cracks and ripple marks; very porous, vuggy, buff dolostone (bird's eye texture); and dense buff dolostone of mottled texture. No gypsum biscuits are found in the exposed strata.

Vugs up to 20 cm across are concentrated at two horizons in the quarry, one about 3 meters and the other about 7 meters above the floor. Some of the vugs appear to be natural pockets between stromatolites, and some may have been formed from the dissolution of the shells of other organisms. But most of them seem to have been left by the dissolution of gypsum biscuits and perhaps other evaporite minerals. Many of these vugs are now mineralized, and it is in them that the best-formed crystals are usually found.

MINERALOGY

Minerals found at the Duff quarry, in order of decreasing abundance, are calcite, pyrite, dolomite, fluorite and sphalerite. The sequence of crystallization within the vugs, as determined by overgrowth relationships, is shown in Figure 1.

Pyrite FeS_2

Pyrite is almost always found attached to the sedimentary walls of the vugs. Rarely, however, small pyrite crystals are found attached to dolomite crystals. Taken together, these two observations indicate that the periods of pyrite and dolomite crystal growth over-

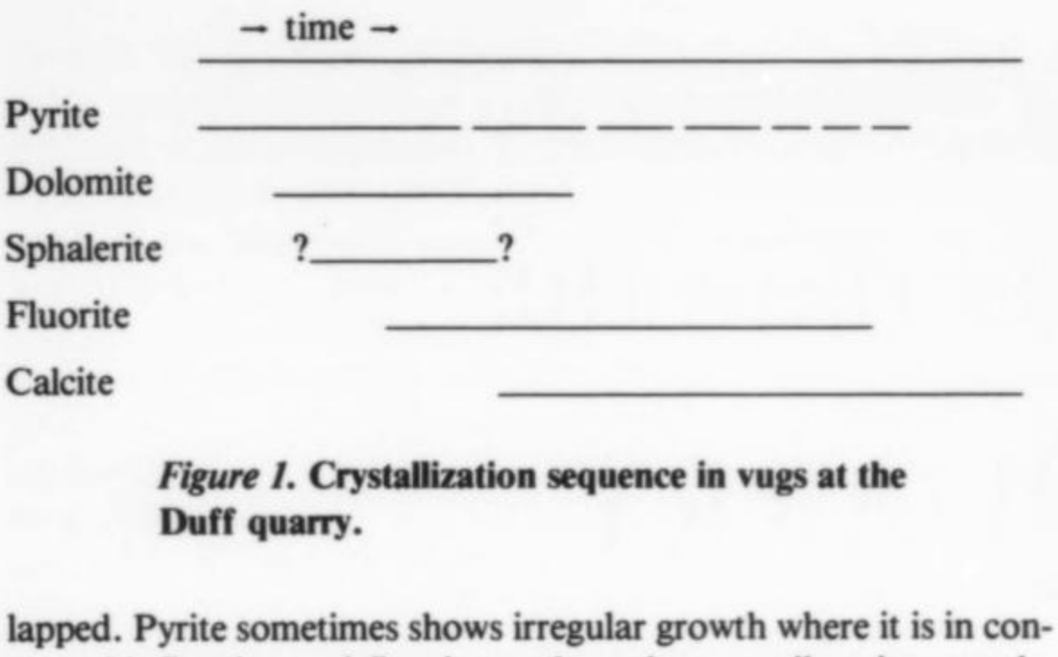


Figure 1. **Crystallization sequence in vugs at the Duff quarry.**

lapped. Pyrite sometimes shows irregular growth where it is in contact with fluorite, and fluorite rarely encloses small pyrite crystals. These observations indicate that the period of pyrite growth also overlapped slightly the period of fluorite growth. Although pyrite is usually capped by calcite, where the pyrite crystals are in contact with calcite they do not show distorted faces; this indicates that the calcite was deposited after pyrite deposition was complete.

Irridescent colors are often seen on Duff pyrite, most commonly gold, deep red and bluish purple. These appear to be due to a very thin surface coating, most likely of goethite. The colors result from diffraction of light reflected from the crystal faces, in much the same way as a thin film of oil on water gives a rainbow of color. Some crystals have a thicker opaque brown coating of goethite, which can be removed by soaking in a hot oxalic acid solution, or more gradually and gently by the Waller method (see Waller, 1980; Chamberlain, 1984). The procedure is often not worth the effort, however, since by the time the goethite coating is thick enough to be opaque, the luster of the faces underneath is usually gone, a casualty of the natural weathering process. (See below for a discussion of pyrite crystal forms.)

Figure 2. **Typical crystals of dolomite from the Duff quarry. The largest in the figure are about 4 mm across. The strong curvature of the crystals is typical. This and all other specimens illustrated are in the author's collection.**

Dolomite $CaMg(CO_3)_2$

Dolomite is common as strongly curved, white, euhedral crystals up to about 1 cm across. The crystals are found in vugs with pyrite or rarely sphalerite, and in other vugs in which they are the only mineral present. Some specimens are quite attractive. When it occurs with pyrite, dolomite always seems to have grown from the original surface of the vug. No examples of dolomite attached only to pyrite have been noted. However, where dolomite and pyrite are in contact, the dolomite is usually wrapped over the pyrite, indicating that pyrite usually crystallized first.

Figure 3. **Typical crystals of sphalerite from the vuggy dolomite at the Duff quarry. The crystals are about 2 mm across. Forms present include the cube and a distorted hextetrahedron.**

Sphalerite (Zn,Fe)S

Sphalerite is the least common of the minerals from the Duff quarry. It occurs as unattractive, small, dark crystals with calcite in thin vein fillings, and rarely in porous, vuggy, brown dolostone from low in the quarry, where it occurs as beautiful druses of crystals commonly associated with white dolomite. These crystals are usually well-formed and transparent, and make fine micromounts. The sphalerite and dolomite appear to have crystallized simultaneously.

Fluorite CaF_2

Fluorite is not common at the Duff quarry. Fluorite which is found in vugs with pyrite is badly crazed and irregularly developed, rarely showing recognizable crystal faces. It is usually clear to yellowish, sometimes with pale purple zones. According to other collectors, good crystals of fluorite showing complex forms have been found in the past in small numbers, apparently from strata lower in the quarry than those which produce the majority of the pyrite specimens.

Calcite $CaCO_3$

Calcite is found filling the interior of most pyrite-bearing vugs. Such vugs are usually completely filled, and no vugs showing euhedral calcite crystals have been found. Vugs which are incompletely filled have probably had some of their calcite dissolved by groundwater made acidic by the oxidation of pyrite. Calcite vug-fillings protect the pyrite from weathering; as a consequence the brightest crystals are usually found in the calcite-filled vugs. Calcite can be removed by careful use of dilute muriatic acid, but with some risk since the dolostone also dissolves, although more slowly.

MEASURING AND INDEXING CRYSTAL FACES

The external form of a mineral reflects the orderly internal geometric arrangement of the atoms which make up the species. There are 32 possible external symmetry combinations, called crystal classes, which can be grouped into 6 crystal systems. It can be shown mathematically that these 32 crystal classes are the only possible ones. Of these, 30 are known to occur as minerals.

The symmetry of a mineral refers to the relationships between the faces on a crystal of that species. All faces which are identically related to each other through symmetry belong to a *form*. For example, in pyrite the six faces of the cube belong to one form, and the twelve faces of the pyritohedron (see later) belong to another.

One of the cornerstones of the science of crystallography is the Law of the Constancy of Interfacial Angles, first described by

Nicolaus Steno in 1669: "In all crystals of the same substance the angles between corresponding faces have the same value." Thus, in pyrite, the angle between a given pair of faces on one crystal will be the same as the angle between the same pair of faces on another crystal. This remains true regardless of the size of the faces involved.

One consequence of this law is that, if one can measure the orientation of the faces on a crystal relative to the crystal's symmetry axes, one can describe the essential aspects of the crystal's external geometry. This is best done with a device called a two-circle reflecting goniometer, which holds the crystal to be measured on a spindle attached to two wheels at right angles to each other. The goniometer is equipped with a light source and an observing scope. By rotating the crystal using both wheels, any face on one half of the crystal can be brought into an orientation where it reflects light from the light source into the viewing source. The unique position at which this happens is described in terms of two angles, read from the vertical and horizontal wheels. These angles are analogous to latitude and longitude on a globe, and can be transformed by appropriate mathematical manipulations into *Miller indices,* which are used to describe the orientation of the plane of the crystal face relative to the crystal symmetry axes.

The Miller indices of a crystal face are related to the points at which the plane of that face cuts through the crystal axes. If a plane intersects the three crystal axes at distances of 1, 2 and 3 units, the Miller indices are found by taking the reciprocals of these distances (1/1, 1/2, 1/3), clearing them of fractions, in this example by multiplying by 6, to get 6, 3, 2. Common factors are removed, so 9, 6, 3 would become 3, 2, 1. The indices are written without commas or spaces, and enclosed in parentheses: (632) (this is read "six three two").[1] Negative indices are indicated by a bar over the number: ($6\bar{3}2$) (read "six bar-three two"). Miller indices with more than one digit are usually separated by periods, for example (22.10.7). The faces are also designated by a letter such as *a* for the cube, or *o* for the octahedron; both the letter and the Miller indices can be given, as *a*(100) or *o*(111).

Planes which are parallel to a crystal axis are taken to intersect it at infinity, and their Miller indices have a zero in the position for that axis. Thus the face (110) is parallel to the third axis, and the face (100) is parallel to both the second and third axes. Miller indices are an appropriate means of describing the faces of a crystal because they describe its angular relationship to the crystal axes, but are independent of the size of the face or its distance from the center of the crystal. Since all faces of a form are related to each other by the symmetry of the crystal class, a form can be adequately described by giving the Miller indices of any face of the form.

Extensive study of minerals has led to the development of a second "law" of crystallography, the law of simple rational intercepts. This law states that the Miller indices of faces found naturally on crystals tend to be small whole numbers: the forms {100} and {210} are common, but {37.24.15} is unlikely. Thus only a few of the infinite number of possible forms are ever represented by faces on a crystal, and these tend to have simple relationships to the crystal axes.

More information on crystal symmetry, Miller indices, and other aspects of crystallography of interest to mineral collectors can be found in most introductory mineralogy textbooks, such as Berry, Mason and Dietrich (1983), Hurlbut and Klein (1977), and Buerger (1956). These presentations are usually elementary enough to be understood by collectors who survived high school math.

The art of crystal measurement enters this seemingly purely mathematical exercise because real crystals are not perfect mathematical entities. Real crystals often have distortions of their internal geometry, or are composed of domains which are slightly out of perfect alignment with each other. One can see this on the cleavage faces of many galena crystals, which should be perfectly flat but are usually seen to have areas that are tipped slightly from adjacent areas. Furthermore, some faces on the crystals of certain minerals are curved, not flat. While they may not be very apparent to the eye, these deviations from perfection introduce errors and uncertainties in the determination of indices. Only the most perfect crystals can be used for measurement, and even with these it is often necessary to do a little "enlightened fudging" to come up with an appropriate determination of a crystal form. When unusual faces with relatively high Miller indices are present, it may not be possible to determine the correct indices with complete certainty. This is the case with some of the forms on Duff quarry pyrite, as Gait (1980) commented in his note on this material.

CRYSTAL FORMS OF DUFF QUARRY PYRITE

Pyrite crystallizes in the diploidal or pyritohedral symmetry class of the isometric crystal system. The geometric forms which are consistent with the symmetry of this class are the cube, dodecahedron, octahedron, positive and negative pyritohedra, trisoctahedron, trapezohedron and positive and negative diploids. These forms are the only ones which can be found on pyrite. The forms are described in Table 1, and examples of each are shown in Figure 4. Further discussion of these forms can be found in Gait (1978).

The indices of all forms listed from the Duff quarry are considered accurate with the exception of those for the diploids. The form *d1*{22.10.7} typically has faces which are not totally flat, leading to uncertainty in its indices. Even when large numbers of faces are measured and averages taken, or when rarely one finds a crystal with flat faces in this form, the indices do not work out to small whole numbers. The best approximation for this form is {22.10.7}, as determined by measurement of a number of carefully chosen crystals.

The diploid *d3*{57.32.10} also rarely has flat faces. In addition, the orientation of the faces seems to vary slightly from crystal to crystal. The indices used here are good approximations. An alternative set of indices for this form would be {22.13.4}, but this plane assymetrically truncates[2] the edges between {210} and {111}, and the diploid in question is not seen to do so.

The diploid *d2*{22.11.7} is uncommon, having been found as four distinct faces on one crystal only. Until more examples can be found, its indices must be considered as approximate.

The diploid *t*{421} is known from other localities, and was measured accurately on Duff pyrite, but is present only as one or

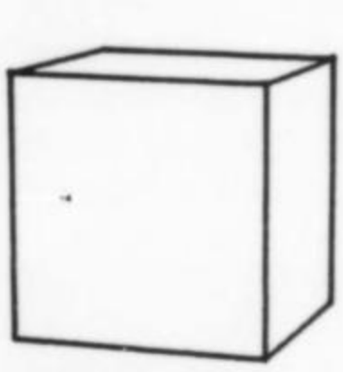
---

[1] By convention, Miller indices are enclosed in parentheses (111) when they refer to a particular face of a form, and pointed brackets {111} when all faces of the form are referred to collectively. Thus ($11\bar{1}$), ($\bar{1}1\bar{1}$) and ($1\bar{1}1$) are all faces of the form {111}. Parentheses can also designate the composition plane of a twin, or a general plane which may not necessarily be represented by a face. Pointed brackets are also used to indicate cleavage planes and twin-law planes. Square brackets [111] refer to an axis or crystal edge.

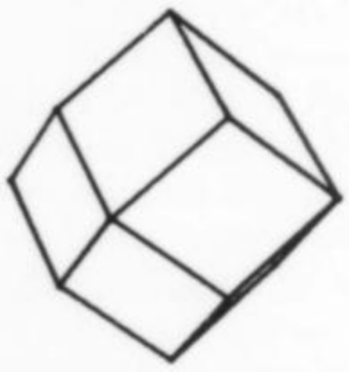
[2] A truncating face replaces an edge between two faces with a new narrow face with parallel sides. If the angles between the truncating face and both truncated faces are equal, the truncation is described as symmetrical, otherwise it is described as assymetrical. Symmetric truncating faces have Miller indices which are the sum of the Miller indices of the truncated faces. Thus {211} truncates {210} and {001}. Assymetric truncating faces have Miller indices which are the sum of multiples of the Miller indices of the truncated faces. In the case above, {22.13.4} is 9 times {210} plus 4 times {111}.

Table 1. **Crystal forms of the isometric pyritohedral class, and the specific forms found on Duff quarry pyrite. The letters h, k and l represent any positive whole numbers for which h › k › l. The letters listed with the Duff forms are the standard letter symbols for those forms unless enclosed in quotation marks.**

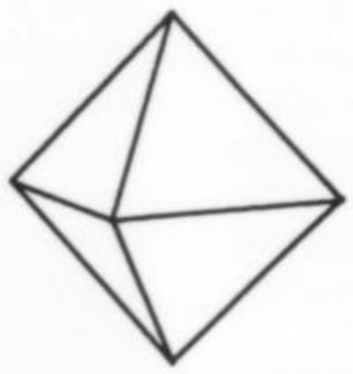
Name of form	Miller indices	Number of faces	Forms known from the Duff quarry
Cube	100	6	*a*{100}
Dodecahedron (rhombic)	110	12	*d*{110}
Octahedron	111	8	*o*{111}
Pyritohedron (+)	hk0	12	*e*{210}
			f{310}
Pyritohedron (−)	kh0	12	*e'*{120}
Trapezohedron	hkk	24	*n*{211}
			m{311}
Trisoctahedron	hhk	24	*p*{221}
			r{332}
Diploid (+)	hkl	24	*s*{321}
			t{421}
			"d1"{22.10.7}
			"d2"{22.11.7}
			"d3"{57.32.10}
Diploid (−)	khl	24	none



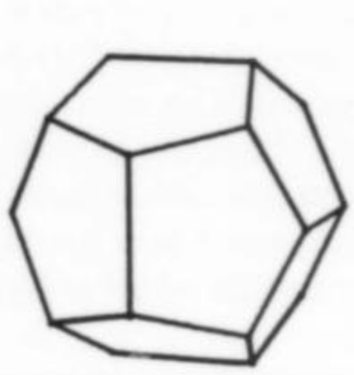
cube *a*{100}



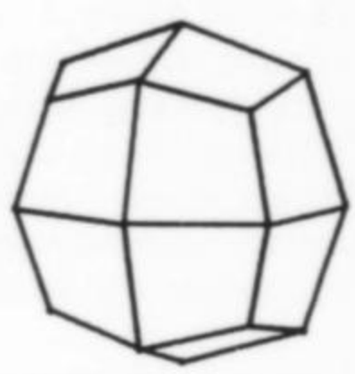
dodecahedron *d*{110}



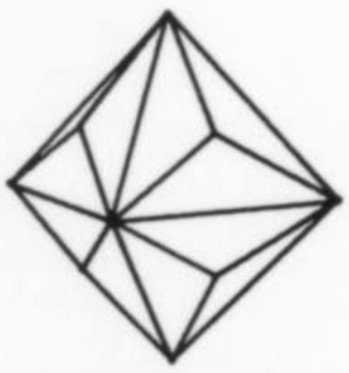
octahedron *o*{111}



pyritohedron *e*{210}



trapezohedron *m*{311}



trisoctahedron *p*{221}

diploid *s*{321}

Figure 4. **The seven geometric forms of the pyritohedral symmetry class ($\frac{2}{m}\bar{3}$). The cube, octahedron, and dodecahedron are of fixed form, whereas each of the others can be represented by several different versions. There are positive and negative versions of pyritohedra and diploids; each positive form (e.g. {210}) has a correspondong negative form ({120} in this example), which is related by a rotation of 90 degrees in the plane of the paper (i.e. about a 2-fold axis of symmetry).**

two small faces on several crystals. In spite of the rareness of this form, its occurrence at the Duff quarry is considered well established.

The diploid *s*{321} is seen as a truncating face on a few crystals from several vugs. The crystals are dominated by the forms *e*{210}, *n*{211} and *o*{111}, and the truncation is between *e*{210} and *o*{111} in one direction, and between two faces of *n*{211} in the other. The indices of the diploid were worked out using zone relationships, and verified by goniometry. Although this form is uncommon at the Duff quarry, and has not been seen except as occasional faces, its occurrence is considered well established.

As can be seen from Table 1, 15 forms are known from crystals of Duff pyrite, one of them only tentatively. Most crystals are composed of several forms, and usually one form is larger than the rest. This dominant form is usually the octahedron *o*{111}, the diploid *d1*{22.10.7} or one of the two trapezohedra *n*{211} or *m*{311}. The cube *a*{100} is usually present, but as very small faces. The pyritohedron *e*{210} and the dodecahedron *d*{110} are usually present, and larger than the cube, but still small. The octahedron is usually present as a small face if it is not the dominant form. The other forms are seen less frequently, and always are subordinate in size. The forms *e'*{120}, *d2*{22.11.7}, *s*{321} and *t*{421} are rare in the materials studied, being represented by small faces on only a few crystals.

The morphological complexity of Duff pyrite is well illustrated by the fact that crystals are commonly composed of 7 or more forms. Such crystals, if completely developed, would have more than 100 faces!

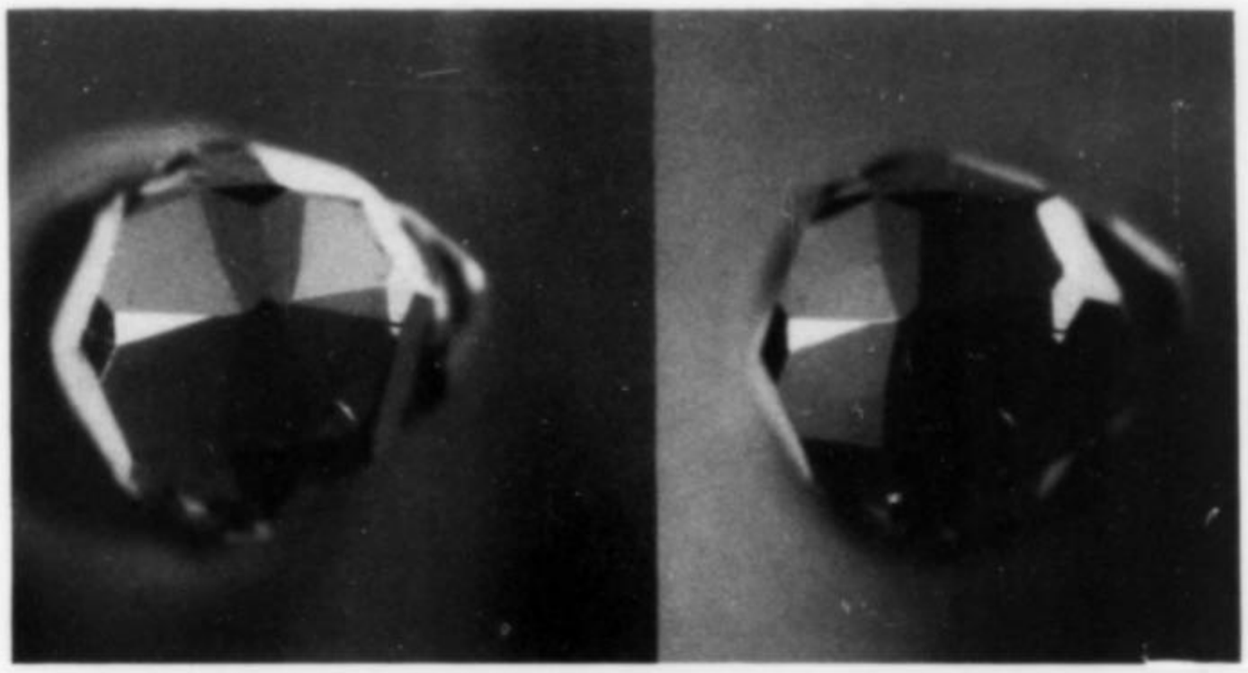
Habits

Certain combinations of forms are seen with varying degrees of frequency on Duff pyrite; other combinations of forms have not been found. Although gradations exist, the range of shapes can be well described by reference to six combinations of forms, shown in Figures 5 through 10. Specific combinations of forms, each having a particular degree of dominance or size relative to the other forms, are called habits. Some of the following habits grade into nearly pure octahedra.

Habit 1, the most typical Duff pyrite crystal habit, comprises roughly 90% of all crystals. It is dominated by the diploid *d1*{22.10.7}, has well developed faces of the trapezohedron *m*{311}, and shows the pyritohedron *e*{210}. Often also present as very small faces are the octahedron *o*{111}, the dodecahedron *d*{110}, and the cube *a*{100} with or without the trapezohedron *n*{211} (listed in decreasing order of size and frequency of occurrence). A crystal of this habit was illustrated by Gait (1980), who also discussed the uncertainty of the Miller indices of the diploid *d1*. This habit is illustrated here as Figure 5.

Occasional vugs reveal crystals having habits quite different from this one. Usually all of the crystals in the vug are of the same habit, so that when a new habit is encountered there are many examples of it. More rarely, only a few crystals in a vug show the unusual habit.

Habit 2 is dominated by the trapezohedron *m*{311}, and has well developed faces of the pyritohedron *e*{210} and the octahedron *o*{111} (Fig. 6a). A more complex variety also shows faces of the



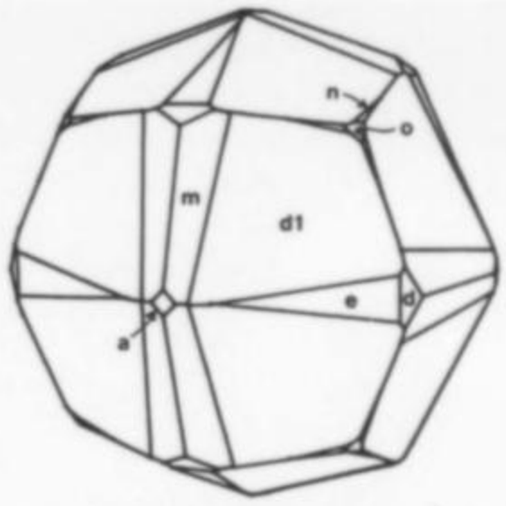
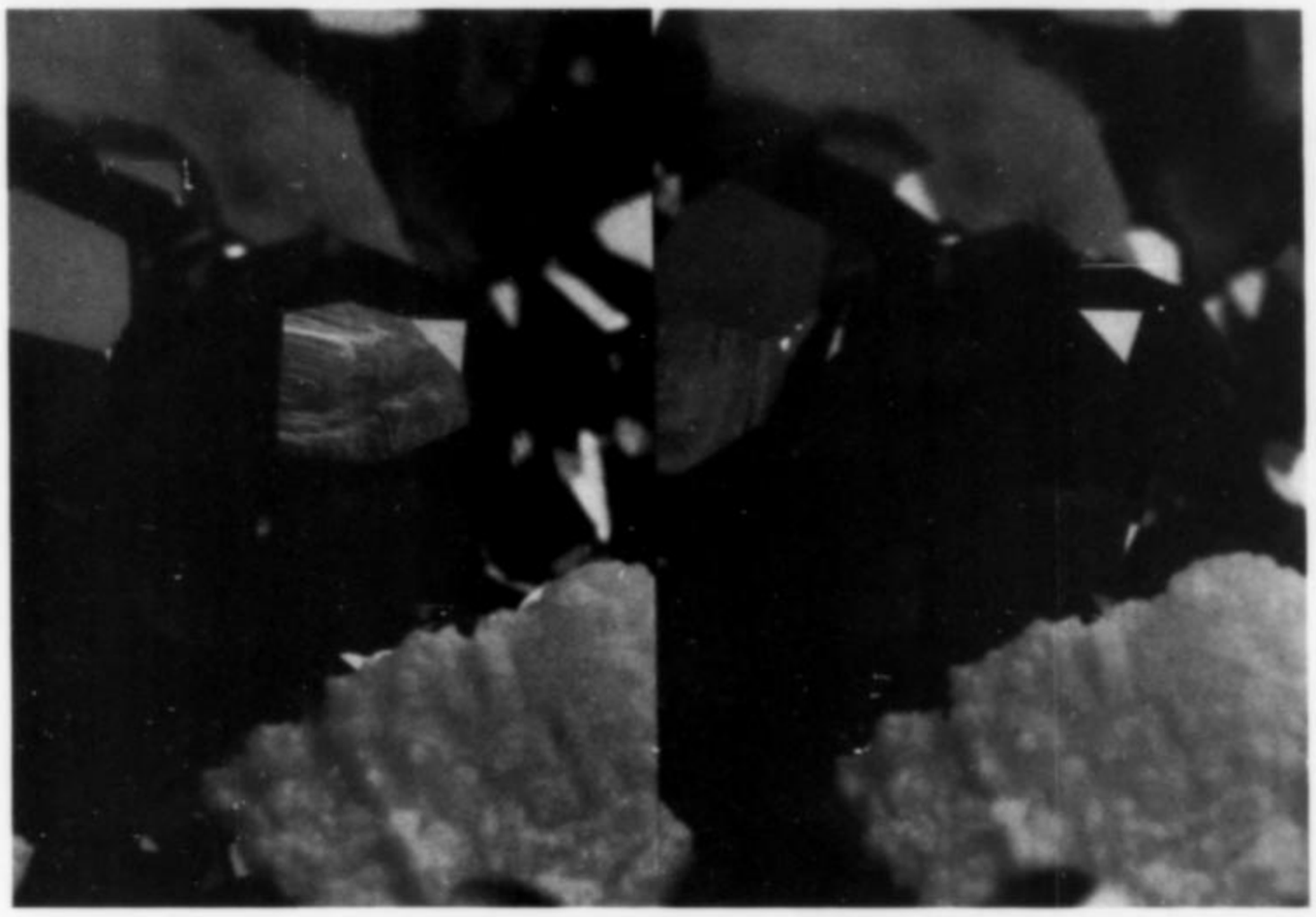


Figure 5. **Stereo photograph and drawing of the typical form of Duff pyrite, habit 1. The faces of the forms other than the diploid *d1* and the pyritohedron *e* are usually smaller than seen on this crystal, or are absent completely. The crystal is 0.8 mm across. See Table 1 for the Miller indices of the forms shown here and in the following figures.**



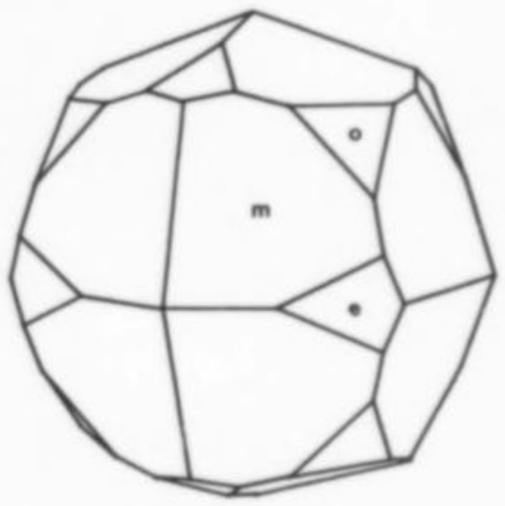
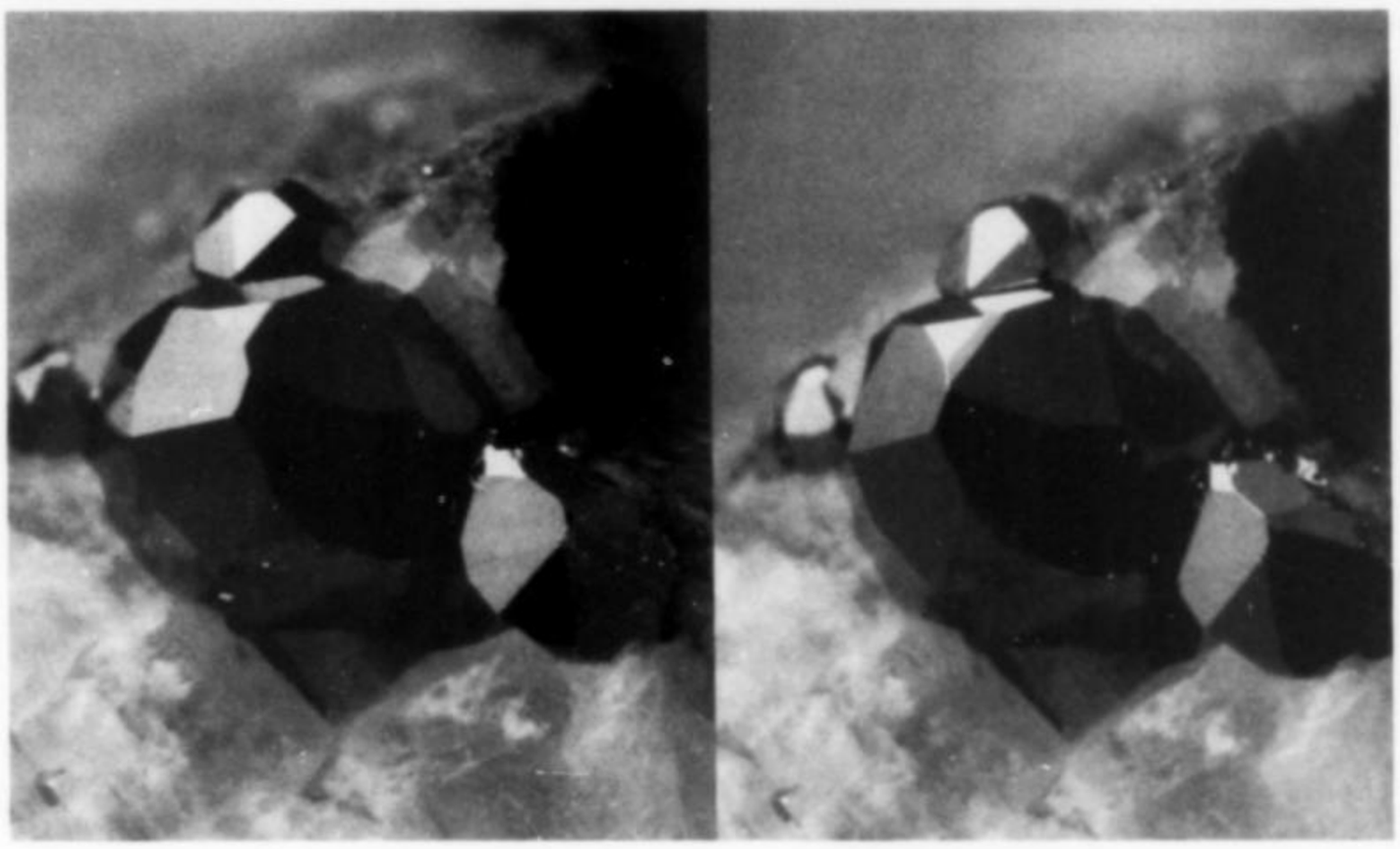
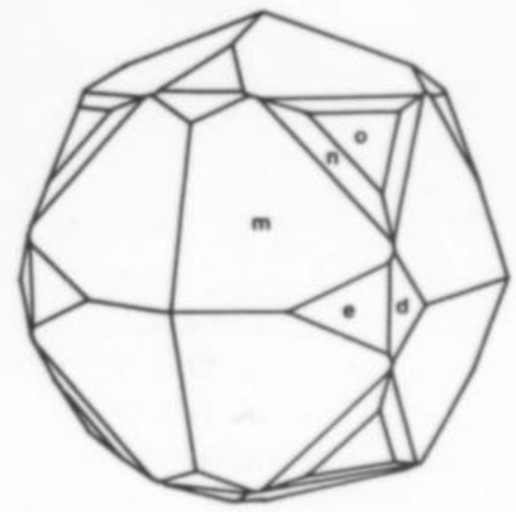


Figure 6. ***(a: upper pair)*** **Stereo photograph and drawing of Duff pyrite, habit 2. This is the simplest version of this habit, showing octahedron, pyritohedron, and trapezohedron *m*{311}. The center crystal is 2.4 mm across.** ***(b: lower pair)*** **Stereo photograph and drawing of Duff pyrite, habit 2. In addition to the faces shown in Figure 6a, this crystal has faces of the dodecahedron *d*{110} and the trapezohedron *n*{211}. The upper crystal is 2.2 mm across.**

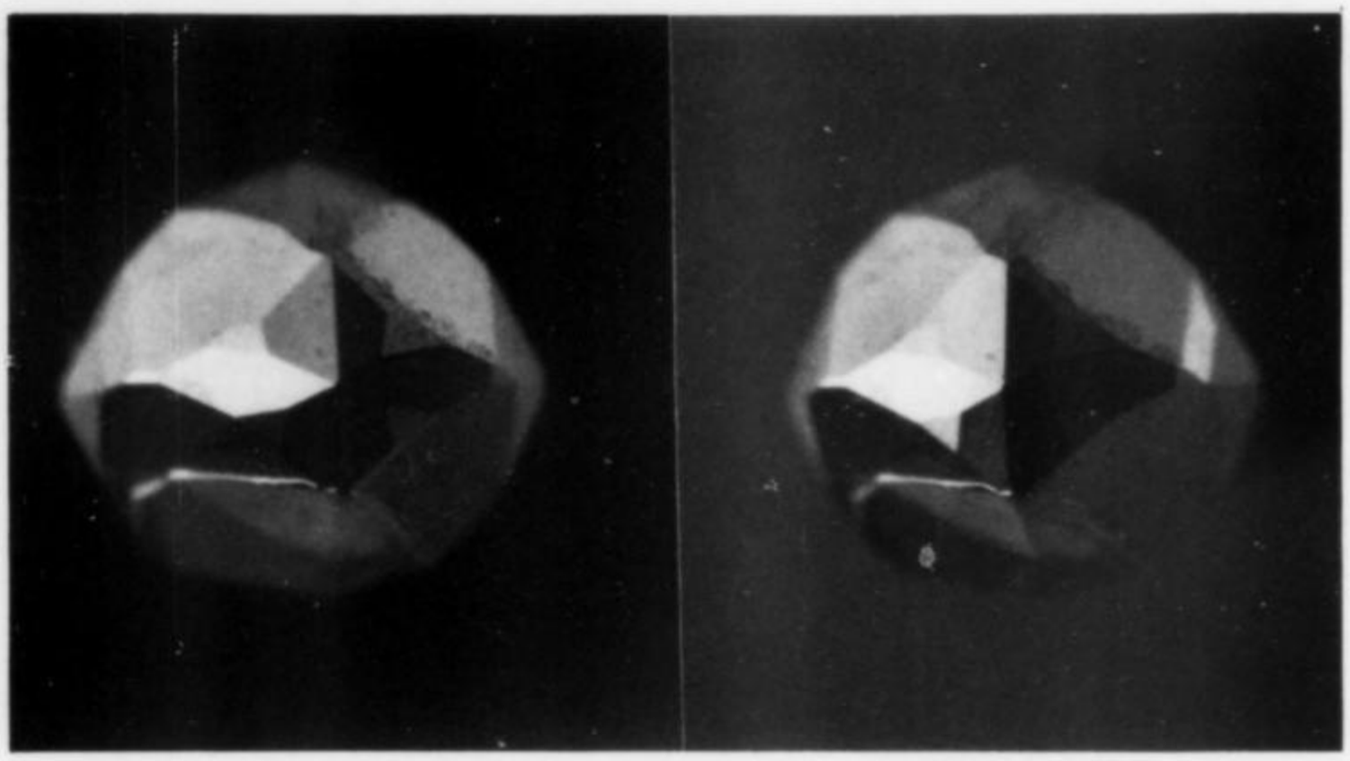




dodecahdron *d*{110} or the trapezohedron *n*{211} or both (Fig. 6b). This habit is fairly common.

Habit 3 differs from habit 2 primarily by including the diploid *d1*{22.10.7}. The octahedron is usually larger, and the trapezohedron *n*{211} is always present. One common variant is shown in Figure 7a. Another variant differs from this one primarily by having almost equal development of *m*{311}, *n*{211} and *d1*{22.10.7}. The faces of these forms have nearly the same angular orientation, and give the impression of single large triangular faces broken into three facets (Fig. 7b). This habit is also fairly common.

Habit 4 is usually dominated by the octahedron, and shows the diploid *d1*{22.10.7}, the pyritohedron *e*{210} and the diploid *d3*{57.32.10}. This habit, less common than those above, is shown in Figure 8. The diploid *d3*{57.32.10}, which helps give this habit its characteristic shape, is also sometimes represented by small faces on crystals of habits 2 and 3. Occasionally, crystals are found on which *d3*{57.32.10} is the dominant form.



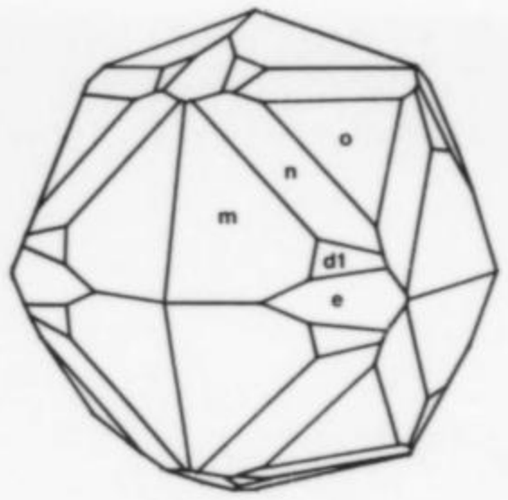
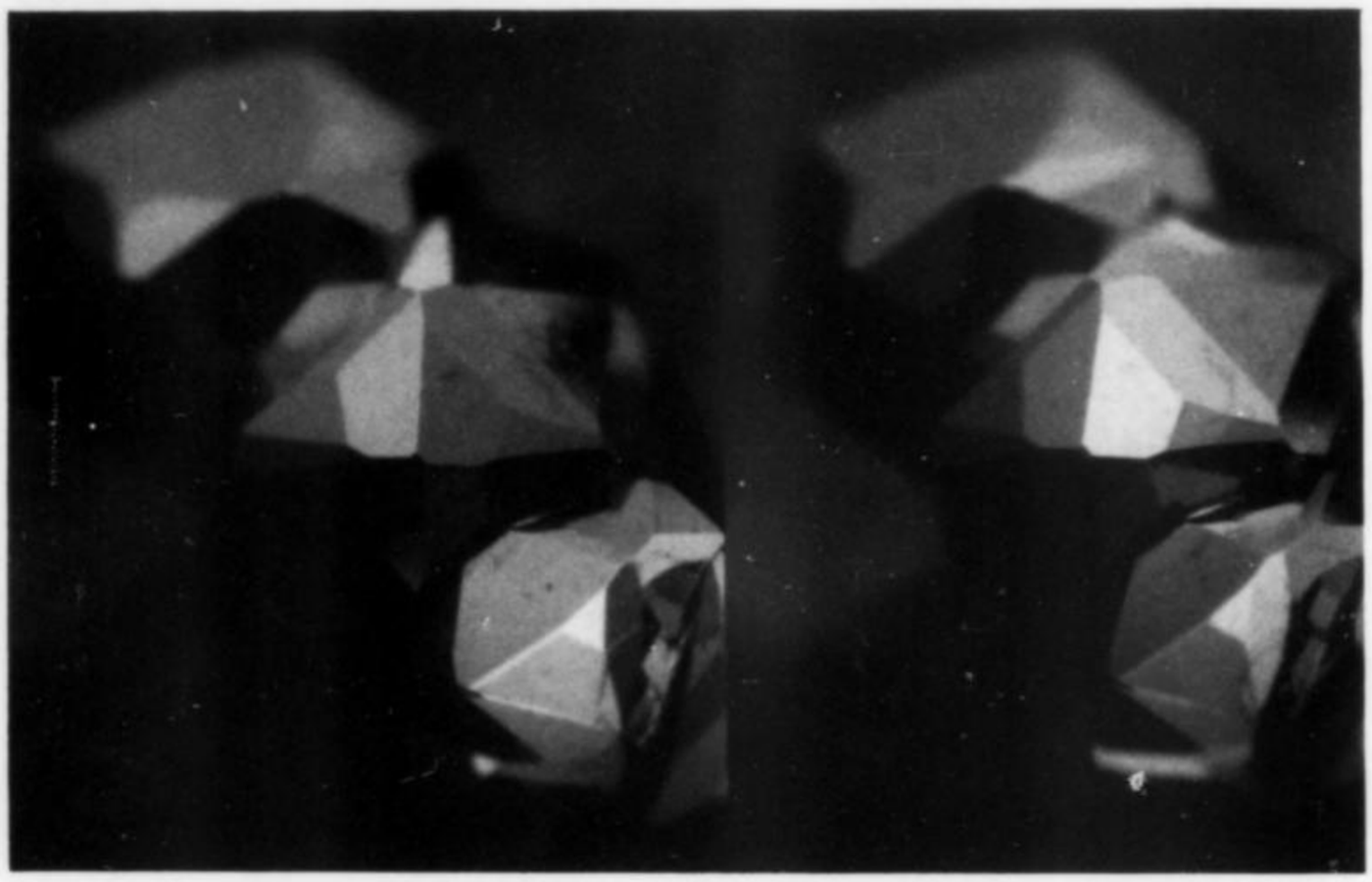
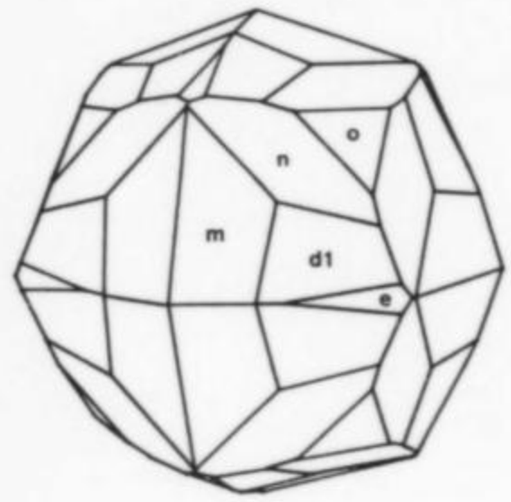
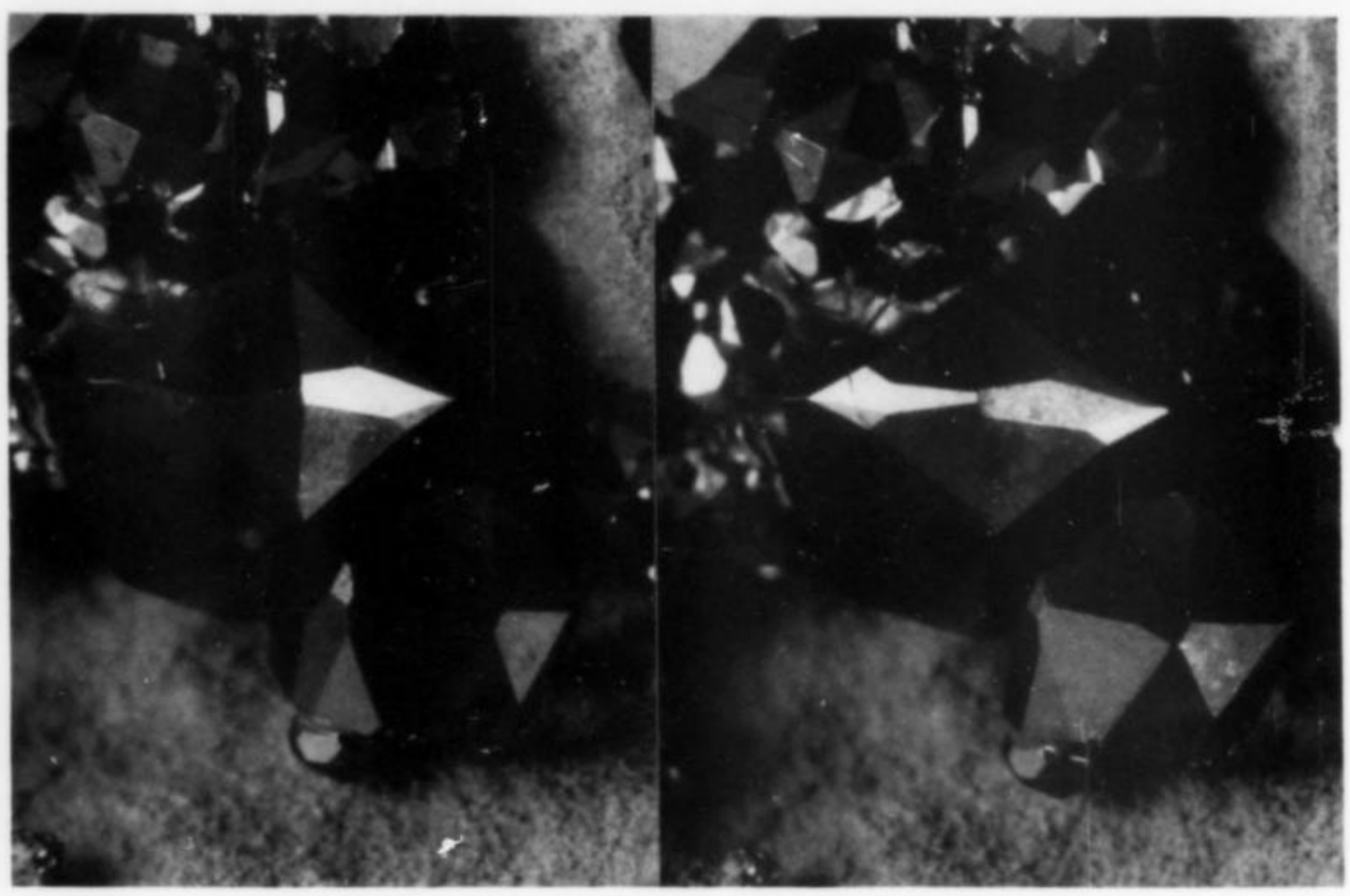


Figure 7. (a: upper pair) **Stereo photograph and drawing of Duff pyrite, habit 3. This habit differs from complex crystals of habit 2 primarily by the presence of the diploid *d1*{22.10.7}. The crystal is 1.6 mm across. *(b: lower pair)* Stereo photograph and drawing of Duff pyrite, habit 3. A common variant in which the faces of *m*, *n* and *d1* are about the same size. The center crystal is 2 mm across.**







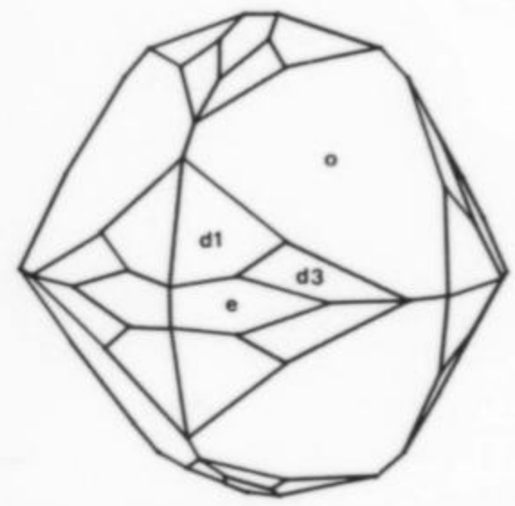
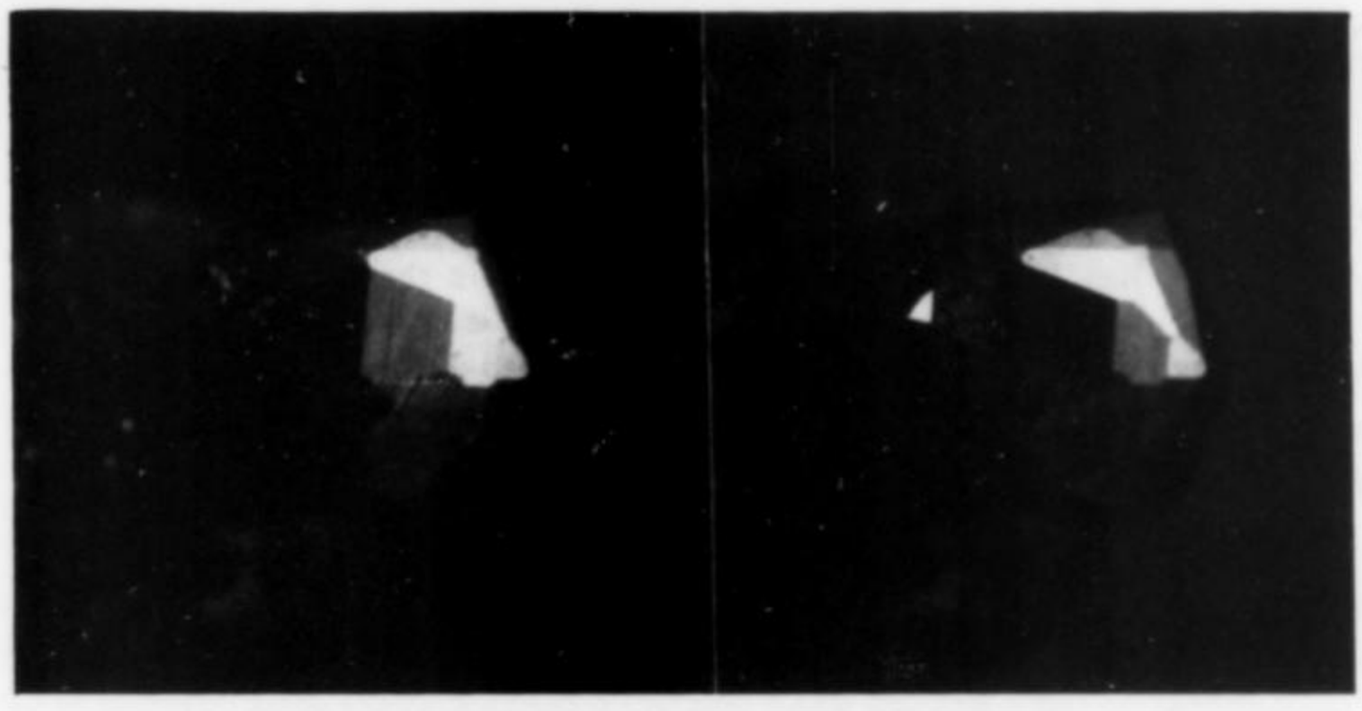


Figure 8. **Stereo photograph and drawing of Duff pyrite, habit 4, characterized by the prominent development of the diploid *d3*{57.32.10}. The center crystal is 2.6 mm across.**

Habit 5 is the least common, having been found to date only in one vug. It is characterized by the presence of the pyritohedron *f*{310}, together with the cube, the pyritohedron *e*{210}, the octahedron, the trapezohedron *n*{211}, and the trisoctahedron *p*{221}. The size of the pyritohedral region compared to the region around the octahedron varies from crystal to crystal; a typical example is shown in Figure 9.

Habit 6 is only slightly more common, being represented so far by crystals from only two vugs. It has large faces of the trapezohedron *n*{211} and the pyritohedron *e*{210}, and is characterized by a three-armed "pinwheel" figure around the octahedral face, composed of the octahedron and the trisoctahedron *p*{221} and usually *r*{332} (Fig. 10).

Gait (1980, Fig. 5) illustrated a crystal of Duff pyrite with sub-



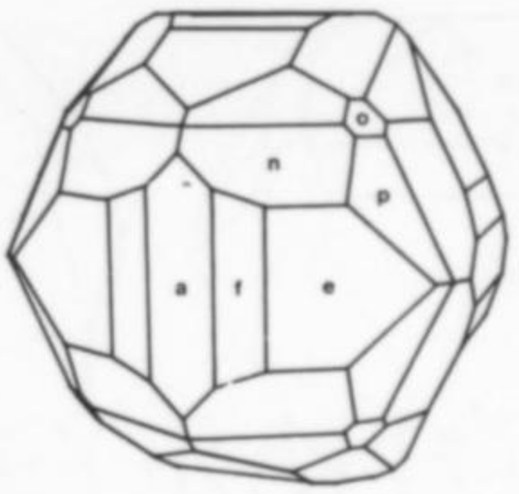
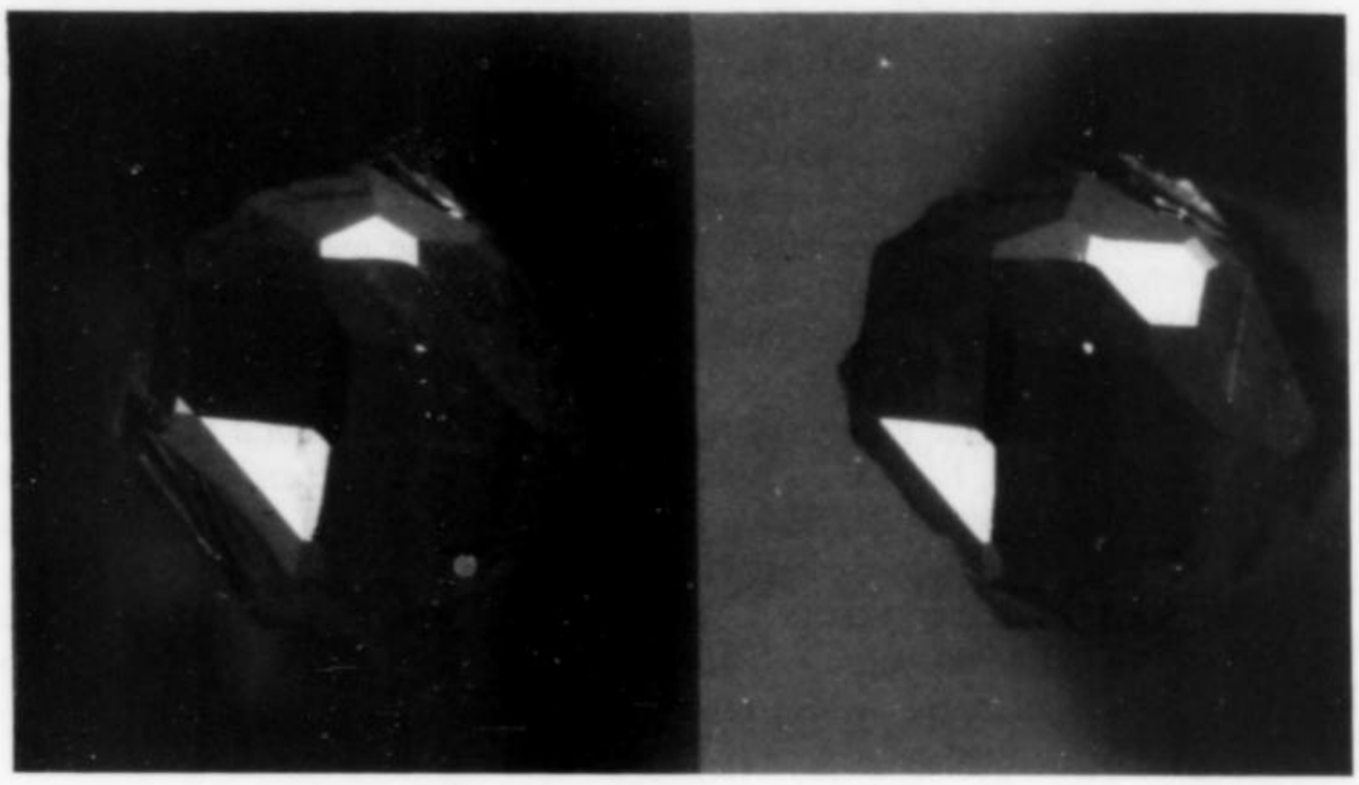


Figure 9. **Stereo photograph and drawing of Duff pyrite, habit 5, showing the pyritohedron *f*{310} and the trisoctahedron *p*{221} in addition to more common forms. The crystal is 0.8 mm across.**



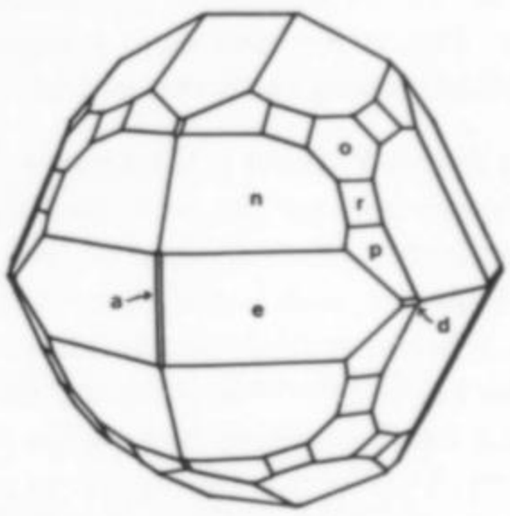


Figure 10. **Stereo photograph and drawing of Duff pyrite, habit 6, characterized by the prominent development of the trisoctahedra *p*{221} and *r*{332} in a three-armed figure centerd on the octahedron. The dominant trapezohedron is *n*{211} rather than *m*{311}. The crystal is 3.8 mm across.**

equal development of *o*{111} and *n*{211} faces and smaller faces of *e*{210} and *p*{221}, which could be considered a variant of this habit. Crystals of this sort seem to have been fairly common five or more years ago, but have not been seen by this author in material collected at the quarry since 1983.

Other habits could be established, based on crystals which do not fit easily into the six habits mentioned above. I have found crystals for at least four more potential habits, and almost every collecting trip produces material for another. However, beyond a certain point, the proliferation of habit designations reduces their utility as a means of understanding the crystals they represent.

Nonetheless, a tremendous number of crystals have been taken from the quarry over the years, and there is some evidence that different habits may be more common in different parts of the quarry, and therefore may have been available at different times during quarry development. Thus there may well be crystals in the hands of other collectors which are quite different from the ones described here. I would be most interested in seeing examples of such crystals.

The crystal drawn in Figure 11 is a composite of all the forms known from the quarry to date. I suspect that a crystal like this will never be found, because experience shows that some forms occur only in special combinations, and tend not to occur with certain other forms. Perhaps they require slightly different chemical conditions for their formation.

This drawing, though hypothetical, is useful in showing the relationships of the various forms to each other. In particular, note that the pyritohedra occur in a band (called a zone) between faces of the cube and the dodecahedron, along the dashed line *a-f-e-d*. Similarly, the trapezohedra occupy a zone between the cube and the

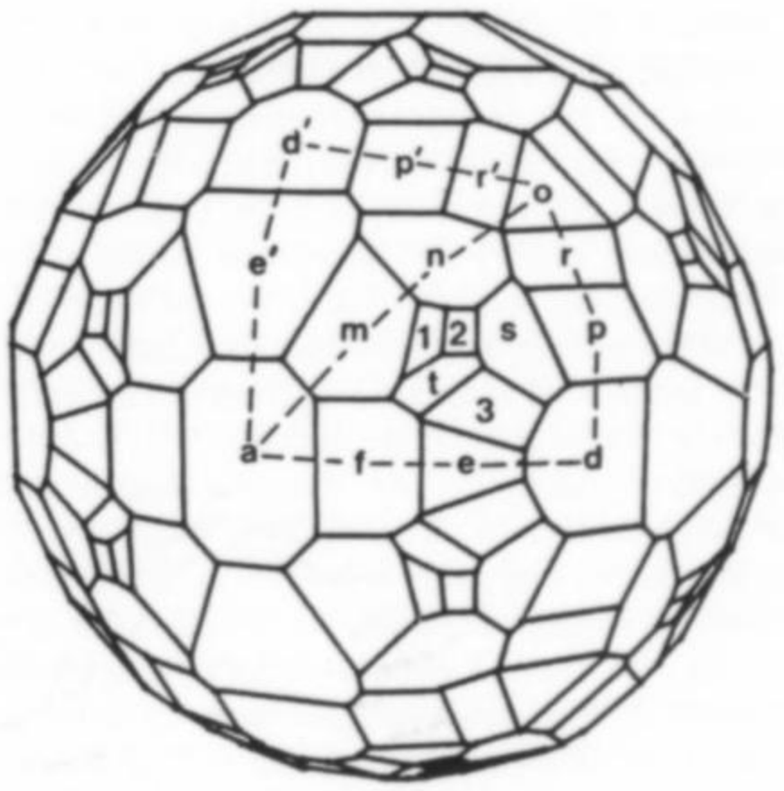


Figure 11. **Drawing of a hypothetical crystal with all forms known to occur on Duff pyrite. See text for discussion. Faces numbered 1 to 3 are the diploids *d1* to *d3* respectively.**

octahedron (dashed line *a-m-n-o*), and the trisoctahedra occupy a zone between the octahedron and the dodecahedron (dotted line *o-r-p-d*). These three zones define a triangular region *a-o-d,* and it

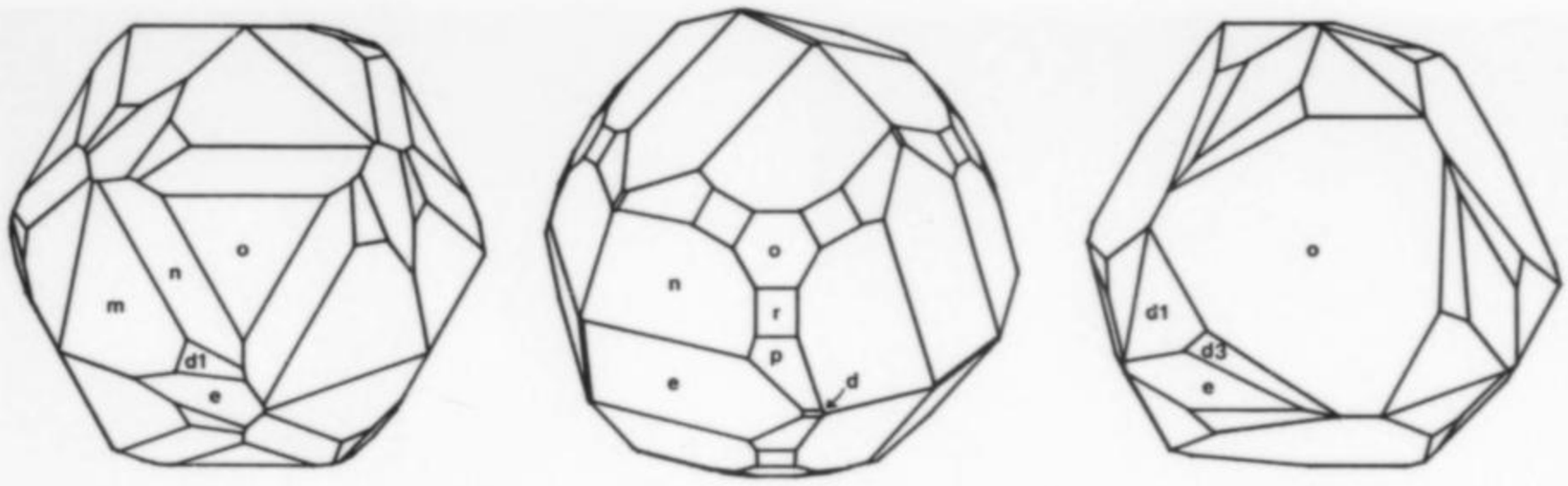


Figure 12. **Drawings of several habits of Duff pyrite, viewed down a three-fold axis. The faces of the crystal are arrayed in a three-fold pattern around the octahedral face. From right to left, the crystals represent habits 3, 6 and 4.**

is within this triangular region (and its equivalent positions elsewhere on the crystal) that the diploids occur.

Note further that there is another set of triangular regions *a-o-d'* which is distinct from the first. While these triangular regions share faces with the first set along their common edges, they have no internal faces. This is the geometric manifestation of the lack of negative diploids among the forms of Duff pyrite listed in Table 1.

Deciphering Forms Without a Goniometer

The first impression one gets when looking at these crystals is one of great complexity, with little sense of how the faces are related to each other. However, with knowledge of what to look for and a little patience, it becomes fairly easy to identify the various forms on a crystal. The key to this lies in orienting the crystal as in the drawings. The best way to being is to look for the faces of the pyritohedron *e*{210}. This form is almost always present on at least some crystals in a vug, and occurs as six pairs of faces which are usually basically triangular with their sharpest angles pointed at each other (see especially Figs. 5 and 6). The octahedral faces should also be looked for. They are equilateral triangles (sometimes with "bent" sides) or hexagons, and when the crystal is examined looking directly down onto one of them, all the other faces on the crystal are located in a three-fold rotational pattern around it (see Fig. 12). With these faces identified and the crystal oriented as in Figures 5 to 11, the other major faces can usually be identified.

If the pyritohedron *e*{210} has faces which are very narrow triangles, as in Figure 5, the faces on either side belong to the diploid *d1*{22.10.7}. If the faces of the pyritohedron form a broader triangle, as in Figure 6, the bounding faces belong to the trapezohedron *m*{311}. If the pyritohedron has parallel edges, it is bounded by the trapezohedron *n*{211}. The trapezohedron *m*{311} lies to the inside of the diploid *d1*{22.10.7} if both are present, and the trapezohedron *n*{211} lies above and to the outside of it. *n*{211} symmetrically truncates the edges between *m*{311} and *o*{111}; *r*{332} symmetrically truncates the edges between *p*{221} and *o*{111}; and *f*{310} symmetrically truncates the edges between *e*{210} and the cube *a*{100}. If the diploid *d3*{57.32.10} is present, the pyritohedral faces will be diamond-shaped rather than triangular. With these observations and the illustrations in this article, it becomes rather easy, after some practice, to recognize nearly all the forms on most Duff pyrite. As bewilderment gives way to understanding, the fun of looking at these crystals increases.

The remarkable little pyrite crystals from the Duff quarry are clearly among Nature's works of art, and their complex geometry can be deciphered when you know how to examine them. Thus understood, they become even more beautiful.

ACKNOWLEDGMENTS

I want to acknowledge the generosity of the owners and operators of the C. E. Duff quarry in giving permission to collect on their property. They are aware of the special nature of the pyrite, and are therefore willing to take the risk of allowing controlled collecting. *Permission to collect must be obtained in advance.* At a time when many quarries in Ohio will not even consider allowing collecting, the generous attitude of the Duff quarry people is a treasure which deserves protection by the good behavior of all who collect there!

The crystals were measured on a goniometer which belongs to the Oberlin College Geology Department. Crystals were drawn using a modified version of Eric Dowty's computer program SHAPE, using the computer facilities of Heidelberg College. I appreciate their sometimes bemused patience during the many hours of intense computer use involved in making the drawings. Without the help of all these people, this project could not have been begun, much less completed.

Peter Embrey of the British Museum of Natural History, London, has been a willing and knowledgeable correspondent about many matters having to do with measuring and drawing crystals. I have learned much from him which has contributed to this effort.

Robert Gait of the Royal Ontario Museum, Toronto, and Steve Chamberlain of Syracuse, New York, read earlier versions of the manuscript with great care, and contributed substantially to its improvement.

Finally, my sincere thanks to Steve Chamberlain for producing the photographs of Duff pyrite which are a central part of this article. The brilliance of the crystals makes photographing them extremely difficult; Steve has done a remarkable job!

REFERENCES

BERRY, L. G., MASON, B., and DIETRICH, R. V. (1983) *Mineralogy,* 2nd edition. W. H. Freeman and Co., San Francisco, 561 p.

BUERGER, M. J. (1956) *Elementary Crystallography.* John Wiley, New York, 528 p.

CHAMBERLAIN, S. C. (1984) Use of the sodium hydrosulfite/citrate/bicarbonate method for removing iron stains from mineral specimens. *Rocks and Minerals,* **59**, 225.

GAIT, R. I. (1978) The crystal forms of pyrite. *Mineralogical Record,* **9**, 219–229.

GAIT, R. I. (1980) Pyrite crystals from Duff's quarry, Huntsville, Ohio, U.S.A. *Mineralogical Record,* **11**, 97–99.

HURLBUT, C., and KLEIN, C. (1977) *Manual of Mineralogy,* 19th Edition. John Wiley and Sons, New York, 532 p.

KAHLE, C. F., and FLOYD, J. C. (1971) Stratigraphic and environmental significance of sedimentary structures in Cayugan (Silurian) tidal flat carbonates, northwestern Ohio. *Geological Society of America Bulletin* **82**, 2071–2098.

PALACHE, C., BERMAN, H., and FRONDEL, C. (1944) *Dana's System of Mineralogy,* seventh edition, volume 1. John Wiley, New York. 834 p.

STENO, N. (1669) *De Solido Intra Solidum Naturaliter Centento Dissertationis Prodromus.* Florence, 78 p.

WALLER, R. (1980) A rust removal method for mineral specimens. *Mineralogical Record,* **11**, 109–110.

MINERAL STEREOPHOTOGRAPHY

Wendell E. Wilson
The Mineralogical Record
4631 Paseo Tubutama
Tucson, Arizona 85715

Steven C. Chamberlain
Department of Bioengineering
Syracuse University
Syracuse, New York 13244

The goal of good mineral photography is to depict the specimen with as much accuracy and realism as possible. The success of a photograph depends in large part on how much of the three-dimensional character of a mineral specimen is shown in the two-dimensional image. Stereophotography permits a two-dimensional medium to reveal much of the three-dimensional nature of a specimen.

INTRODUCTION

Although the 3-D effect of a stereograph is a visual illusion and as such is not consistently realistic, most stereophotographs of minerals specimens are a striking improvement over normal photographs. Both external faces and internal intricacies of transparent crystals are more clearly visible, complicated crystal aggregates are more easily resolved, and the geometries of crystal shapes are more easily discerned. In its simplest form mineral stereophotography is a readily accessible technique and one that merits more widespread use.

Inserted within this issue of the *Mineralogical Record* is a Stereopticon stereo viewer for use in viewing the accompanying photos. Please follow the instructions printed on it in order to fold it into position. When viewing stereographs, be sure that each half of the pair is identically and uniformly illuminated without glare. It may be necessary to rock the viewer back and forth a little to get the images to "merge." If this is difficult at first, do not be discouraged. Perception of stereographs as three-dimensional is a learned skill and requires a bit of practice, like using a stereomicroscope, but the results are certainly worth the effort.

It should be mentioned that not everyone actually sees stereographs as three-dimensional. Studies have shown that roughly 8% of the population as a whole have an impaired perception of depth and may therefore see a stereograph no differently from a single photo. It is very likely, however, that among mineral collectors this percentage is lower since a normal perception of depth is likely to be important to the appreciation of mineral specimens and intrinsic to the allure of specimen mineralogy.

HISTORY

Stereophotography has a long and fascinating history with a voluminous literature, and we will attempt only the briefest summary here. Additional information can be found in references listed in the bibliography.

As early as 280 BC, Euclid had presented the essential information about binocular vision which led to the development of stereophotography. Over 2000 years passed, however, before an actual device, a stereoscope, was invented for viewing stereographs. In 1838, Sir Charles Wheatstone produced a cumbersome reflecting stereoscope for viewing perspective line drawings of solid objects. Wheatstone's stereoscope predated the invention of photography by a mere six months; soon thereafter Henry Fox Talbot produced paper-print "calotype" stereographs of buildings, statues and people utilizing Wheatstone's stereoscope, and Antoine Claudet produced metal-plate "daguerreotype" stereographs using the rival process of Louis Daguerre and the same instrument.

A few years later, in 1849, Sir David Brewster produced a portable lenticular stereoscope of compact design utilizing lenses instead of mirrors. Brewster's viewer and compatible daguerreotype stereographs were manufactured by the Paris optical firm of Duboscq and Soleil and enjoyed commercial success.

It took the enthusiasm of Queen Victoria, however, to transform stereophotography from an interesting curiosity to an international fad. During the World's Fair of 1851, at the opulent Crystal Palace in London, Her Majesty became entranced with the stereoscopes on exhibit in the French section. Her delight at being presented with a set of stereo-daguerreotypes by Jules Duboscq inspired a huge

Figure 1. **The Lothian stereoscope (above) and the stereoscope designed by Sir Oliver Wendell Holmes (right).**

fashionable demand for stereographs.

Even Oliver Wendell Holmes made a contribution to stereoscopy by inventing, in 1859, an inexpensive skeletal contraption for viewing pasteboard-mounted stereographs. Holmes' invention made the stereoscope a household word, and from 1860 to 1880 there was hardly a photographer to be found who was not engaged in cranking out stereophotographs. The Civil War, the driving of the golden spike completing the first transcontinental railroad, the mining camps of the West, remote natural wonders – virtually anything that could be photographed – were recorded as stereographs. Photographers even documented a few mineral specimens (Fig. 2). By 1900 for example, the firm of Underwood & Underwood was selling 300,000 Holmes-type stereoscopes annually and manufacturing 25,000 stereographs per day. By 1920, however, only the Keystone View Company remained as a manufacturer of stereographs. With the advent of 35-mm stereocameras, stereophotography became largely the province of amateur photographers. During the middle of this century stereocameras, viewers and projectors underwent continuous evolution and improvement in design. Then, in recent decades, stereocameras went out of production. Today only the Viewmaster, a children's toy, remains of the once popular stereophotography industry.

Meanwhile, serious uses of stereophotography have been steadily evolving. Stereomicrographs have been used to illustrate biological and paleontological specimens since the last century. The use of aerial photography for mapping has evolved so that quantitative stereophotography or stereophotogrammetry is now extensively utilized for producing contour lines on topographic maps. Computer-generated stereopair drawings of organic molecules and crystal structures are common in modern scientific literature. A recently published undergraduate mineralogy text contains numerous stereopair crystal structures. The *Atlas of Crystal Stereograms* and the *Stereogram Book of Rocks, Minerals, and Gems* are probably already familiar to many readers. Even scanning electron micrographs, though seemingly already quite three-dimensional, are often produced as stereographs to avoid the "crater illusion" problem, i.e. to unambiguously separate "bumps" from "dips" in micrographs.

As an approach to photographing mineral specimens, stereophotography is an accessible, serious technique. Since the subject of such photographs is not likely to move between shots, the use of modern, high-quality equipment to take sequential, rather than simultaneous pairs of photographs is completely satisfactory.

GENERAL APPROACH

To achieve our visual perception of the world as three-dimensional, our brain utilizes a large number of cues. One important source of spatial information is the difference between the image of an object that our left eye sees and the image that our right eye sees. The mind uses these two slightly different views to give us depth vision. Stereophotography works on the principle of providing a separate photo for each eye, in order to more accurately imitate the effect of looking at a real object. It should be remembered, however, that the effect produced by stereophotography is still just a visual illusion rather than the real thing, and perceived depth may depend to some extent on idiosyncracies of each viewer's eyes and brain. Not everyone will obtain the same effect from viewing the same photos. Actually this holds true in the viewing of real objects as well.

To produce a pair of photographs for a stereograph, it is necessary to photograph separately the two images seen by the two eyes. For distant objects, the lines of sight are nearly parallel. We can mimic the views of the two eyes by taking a picture, moving the camera laterally some distance, and taking another picture. This is the "translation" technique and works quite well for long and intermediate lens-to-subject distances. The stereocameras and attachments of the 1950's utilized the translation technique. At the short distances necessary in mineral photography, however, the "rotation" technique is easier to use. At close distances, the two eyes are not at all parallel, but are each pointed at the center of view. To record the two images by the rotation technique, the specimen is first photographed, then the specimen, background and lighting are rotated through some angle, and the specimen is photographed again. In practice, one angle of rotation can successfully be used for all working distances, including photographs taken with a bellows.

PRACTICAL TECHNIQUE

In our suggested procedure, using a standard 35-mm SLR camera, *two* photos are taken of each scene at slightly different angles. One photo is then shown only to the left eye, and the other photo only to the right eye. For most people a difference of about 5° between the two photos is satisfactory, but only personal ex-

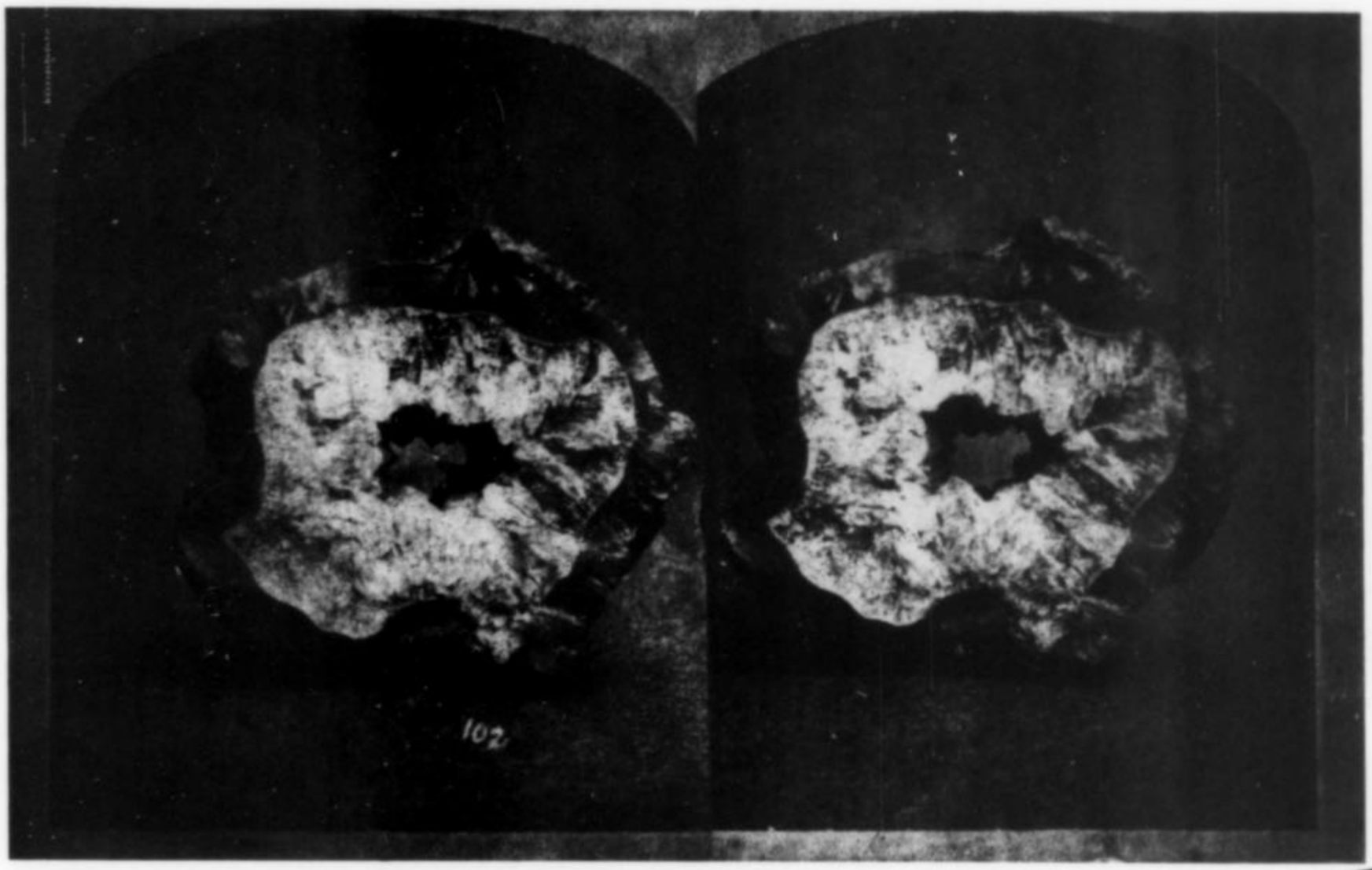


Figure 2. **Calcite-filled concretion from Yellowstone National Park, published around the turn of the century by C. D. Kirkland, Cheyenne, Wyoming.**

perimentation will pinpoint what is best for you. Moyd (1949) recommends 10°.

Most of the stereographs in this article were produced by rotating the specimen through 5° using a platform like a "lazy susan." A platform can be made simply by putting two squares of plywood together and securing them in the center with a small tack or pivot nail. The specimen is placed over the pivot center, photographed, rotated 5°, and photographed again. Lights and reflectors should all be placed on the platform and rotated with the specimen, although rotating just the specimen often works nearly as well. Camera-to-subject distance must be precisely maintained with no adjustment of focus between the two photographs. The specimen should not be otherwise moved during the rotation. The lens axis should be more or less parallel to the platform, but some latitude may be allowed in looking down on the specimen at a small angle without noticeably disturbing the stereo effect.

This technique works for all sizes of specimens, from cabinet pieces down to micromounts photographed at maximum bellows extension. Perhaps the only thing to specifically avoid is a reflection from a particular crystal face which appears only in one of the two photos. Most observers find such reflections awkward to look at in the stereograph; so the light should be arranged to make important reflections appear more or less the same in both shots.

VIEWING STEREOGRAPHS

There are three methods for viewing stereophotos: (1) as hand-held transparencies, (2) as hand-held prints, and (3) as slide-projection programs for an audience. Your Stereopticon viewer will work for the first two, and you have probably already experimented with it on the accompanying prints. The only serious limitation with simple viewers is that the centers of the two photos cannot be separated by more than the distance between your eyes (about 2.5 inches or less). Otherwise you would have to look "cockeyed" to see both prints—a process beyond most people's capabilities and one that is uncomfortable at best. Consequently the prints must be published rather small and therefore cannot show as much sharpness and detail as, for example, a full-page photo.

To view 35-mm transparencies with the Stereopticon, it is helpful to enclose the viewing tunnel so as to block out extraneous reflected

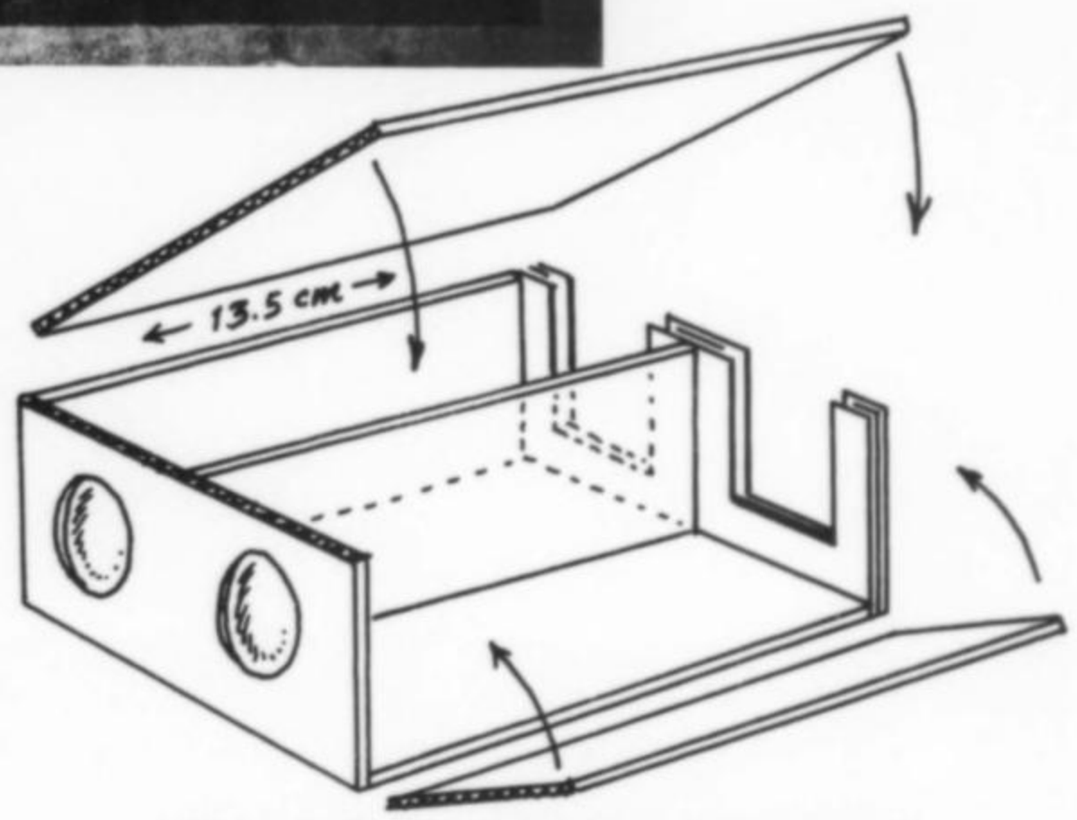


Figure 3. **Sketch showing how to construct an enclosed cardboard stereoscope for viewing 35-mm slide pairs. Interior should be painted black.**

light (see Fig. 3), creating a "Brewster stereoscope." The slides are then inserted into a holder of some sort and held up to a light source. Alternatively the slides can be placed on a horizontal light table and viewed with transillumination in the same manner as prints. Transparent plastic loose-leaf slide holders are excellent for storing stereopair transparencies and keeping them in alignment while viewing them.

With practice, some people can learn to view stereographs without the need of optical apparatus. If you stare at a distance so that the eyes are parallel, but focus closer at hand in the plane of the stereograph, a 3-D image can be observed from two 2-D images. To learn this procedure, hold up a pencil while looking far away. You will see two out-of-focus images of the pencil. If you substitute a stereograph for the pencil, you will see four photos. If you move the stereograph closer and farther, at one position the two middle photos will overlap and become three-dimensional, though still out of focus. Concentrating on bringing the image into focus without losing the 3-D effect will enable you to decouple focusing the eyes from converging them. This procedure causes no eye strain, and once mastered, is much more convenient than using viewers.

Sharing stereophotographs of minerals with an audience requires

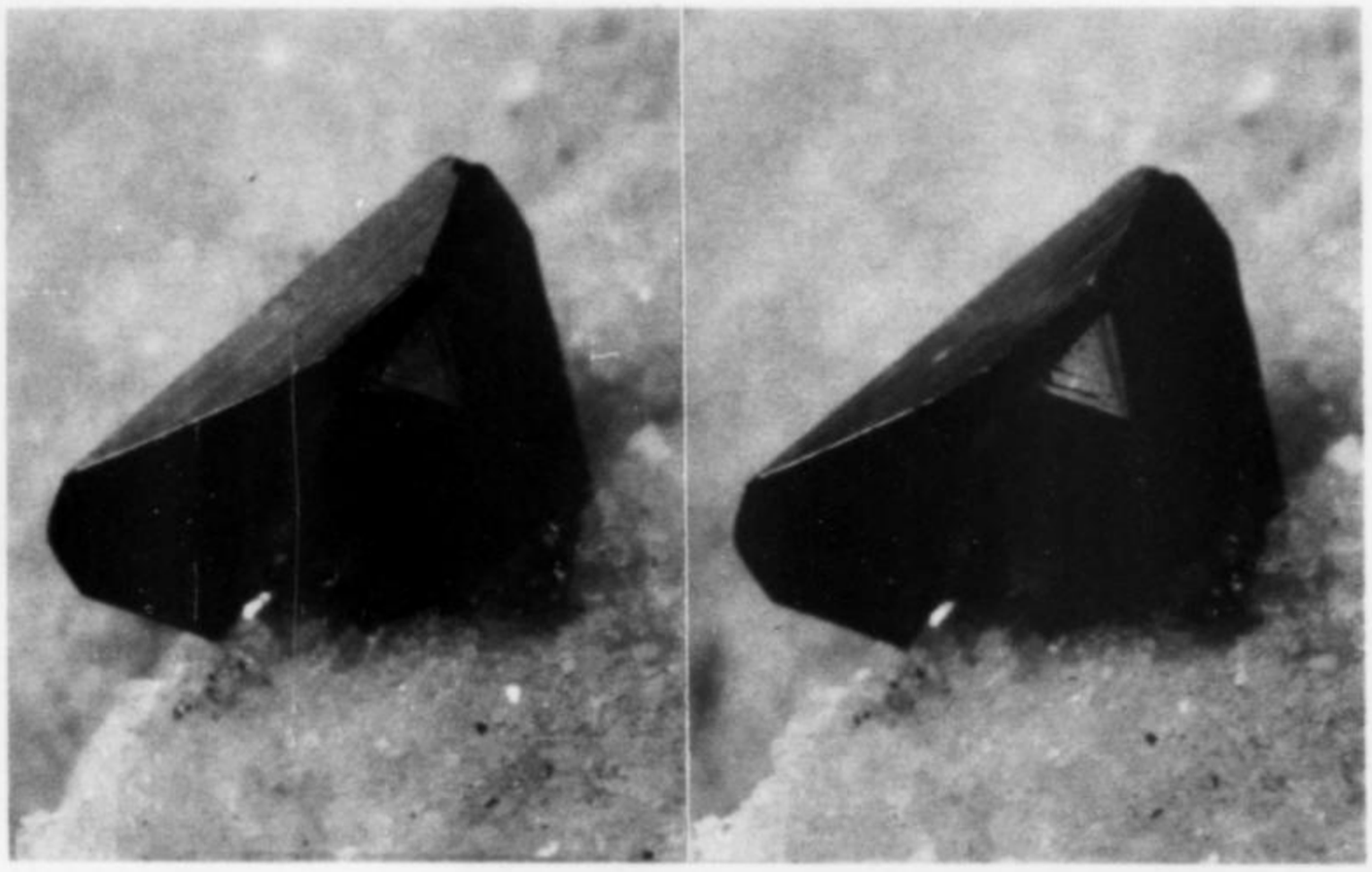


Figure 4. **Sphalerite crystal, 5 mm, from the Lengenbach quarry, Binntal, Valais, Switzerland. Photo by Eric Offermann.**

Figure 5. **Copper crystal, about 5.7 cm, from Michigan. Wayne State University collection.**

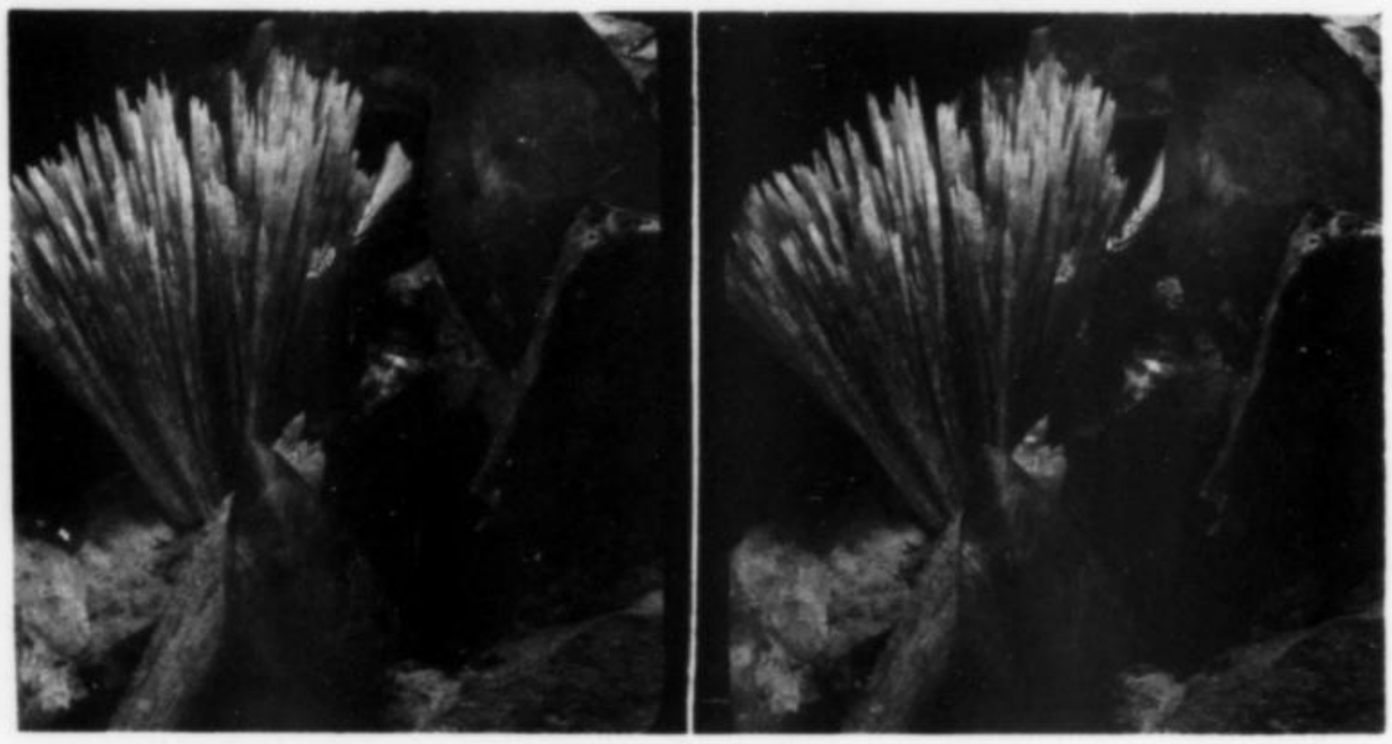


Figure 6. **Celestine and calcite crystals from the Holloway quarry, Berlin Township, Michigan. Photographed by David Huddle and John Medici using a Realistic macro stereo camera. (See Fig. 9.) Collection of John Medici.**

two projectors, a metallized screen (not a plastic or glass-bead screen), a polarizing filter for each projector lens, and polarizing glasses for every member of the audience (available from Polaroid Corporation). Commercial metallized screens are generally adequate, although you can make a marginally effective substitute with a can of aluminum spray paint and any flat surface. To check the effectiveness of a given screen, place a polarizing filter over the projector lens, put on a pair of polarizing glasses, flood the screen with light and adjust the projector polarizer to darken one eye. The better your ability to extinguish reflected light from the screen by rotating the polarizing filter, the better that screen will work for projecting stereopair transparencies.

Adjusting a pair of projectors for showing stereopair slides is straightforward, but requires a bit of precision. First, project suitable full-frame test slides to align the two slide borders to exactly overlap on the screen. Then, while wearing polarizing glasses, turn on only the right projector and adjust its polarizing filter to darken the image in the left eye which will simultaneously make it maximally bright in the right eye. Turn it off and do the same for the left projector so that its image is darkened in the right eye. The two projection polarizing filters are now oriented at 90° and when both projectors are turned on, the left eye will see only the image from the left projector and the right eye will see only the image from the right projector.

During the slide show, small adjustments may need to be made to the vertical alignment of one of the projectors. Because our eyes are

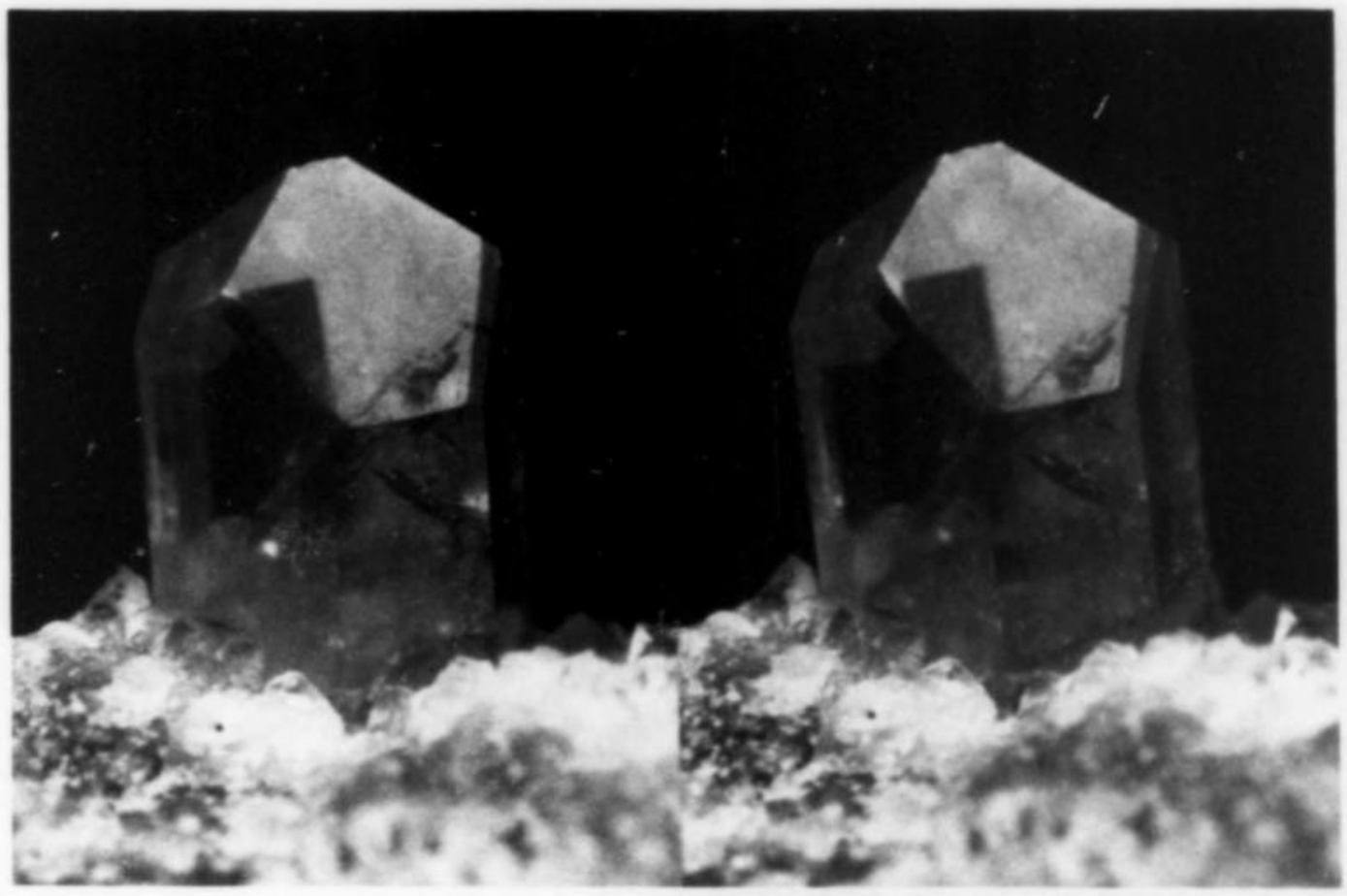


Figure 7. **Celestine crystal, 5 mm, from Balmberg, Solothurner Jura, Switzerland. Eric Offermann photo.**

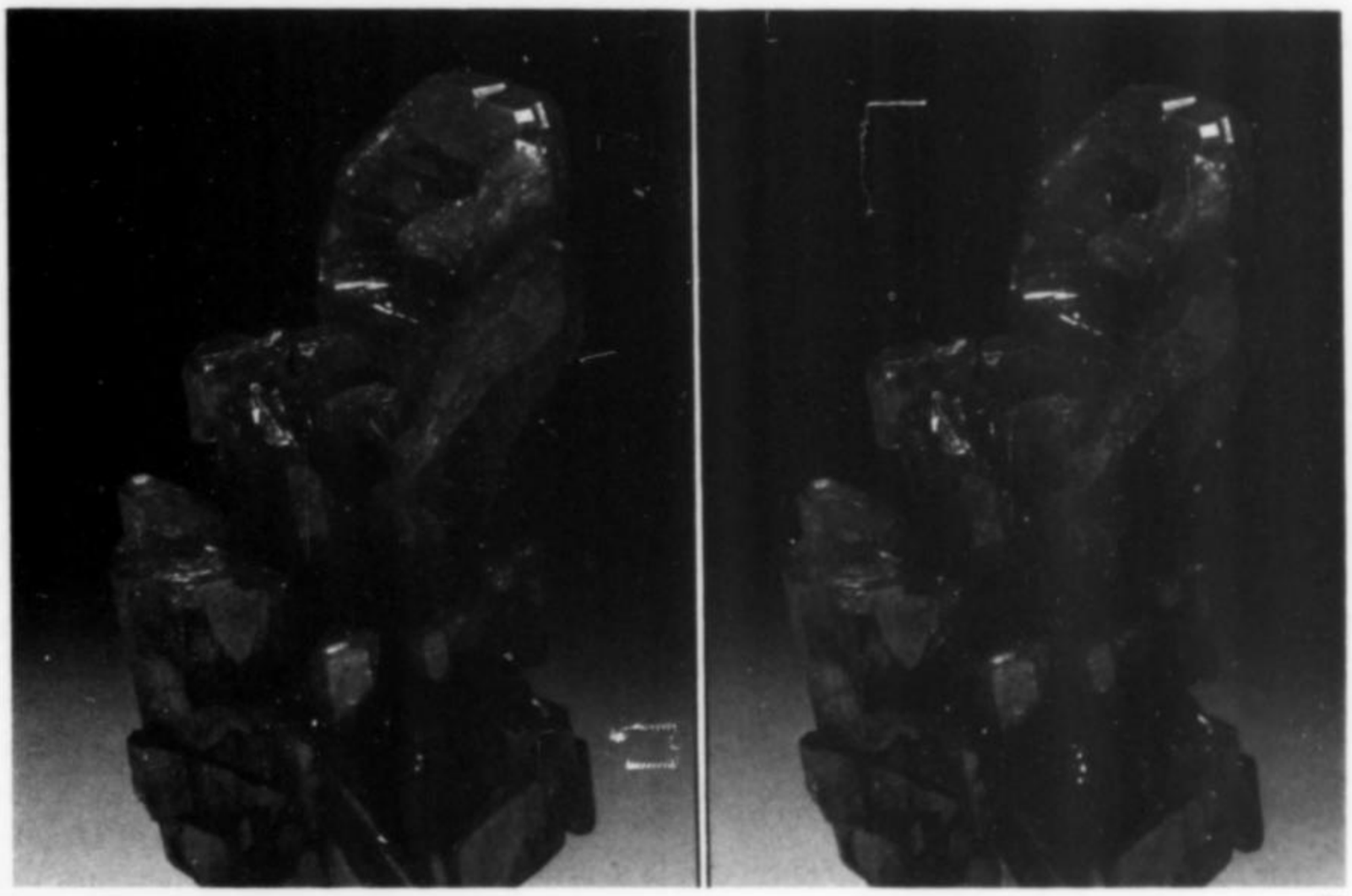


Figure 8. **Vanadinite crystal from the Old Yuma mine, Pima County, Arizona; 3.8 cm. Chris Panczner collection.**

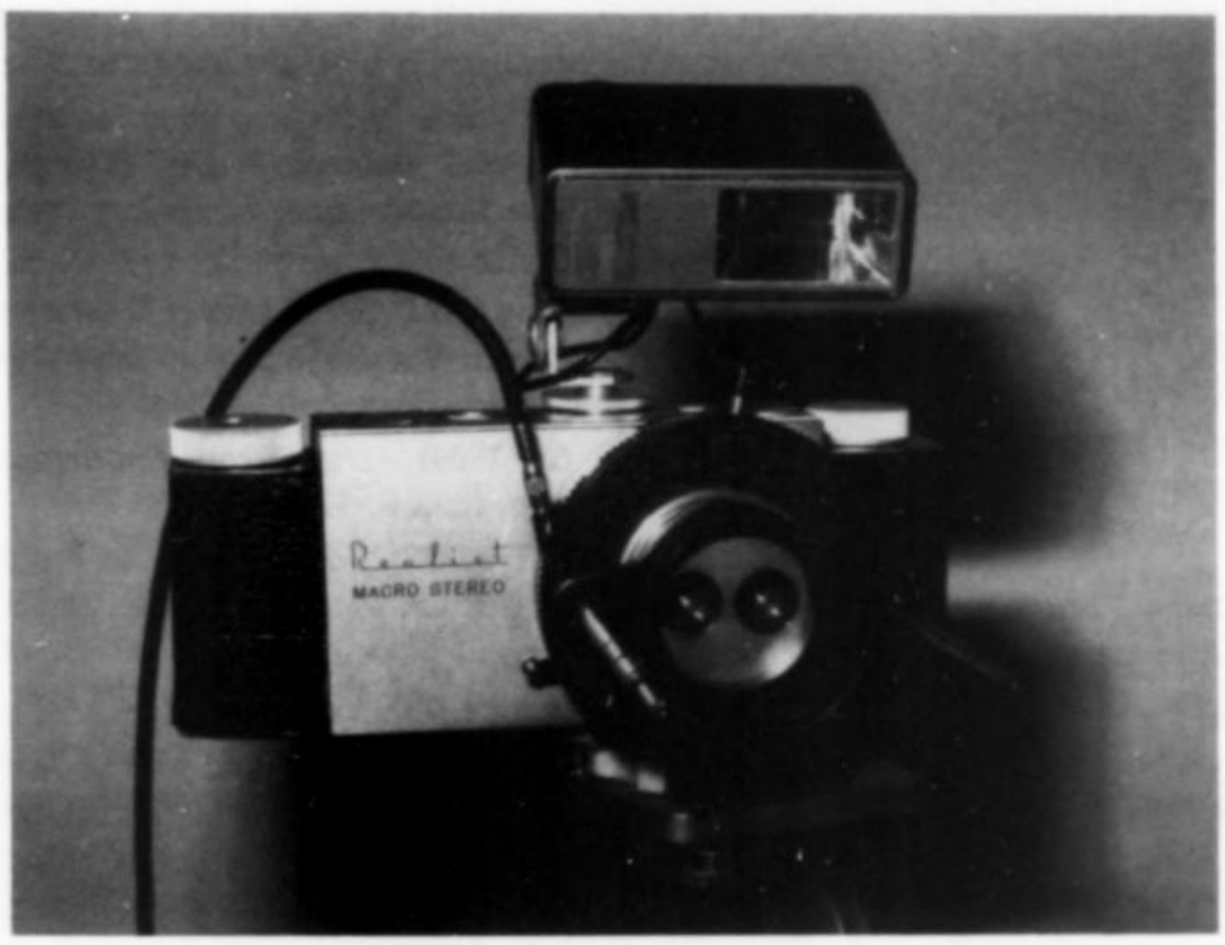


Figure 9. **The Realistic macro stereo camera for close-up work. (Courtesy of David Huddle.) The two photos are taken simultaneously, so that no rotation of the specimen between shots is necessary.**

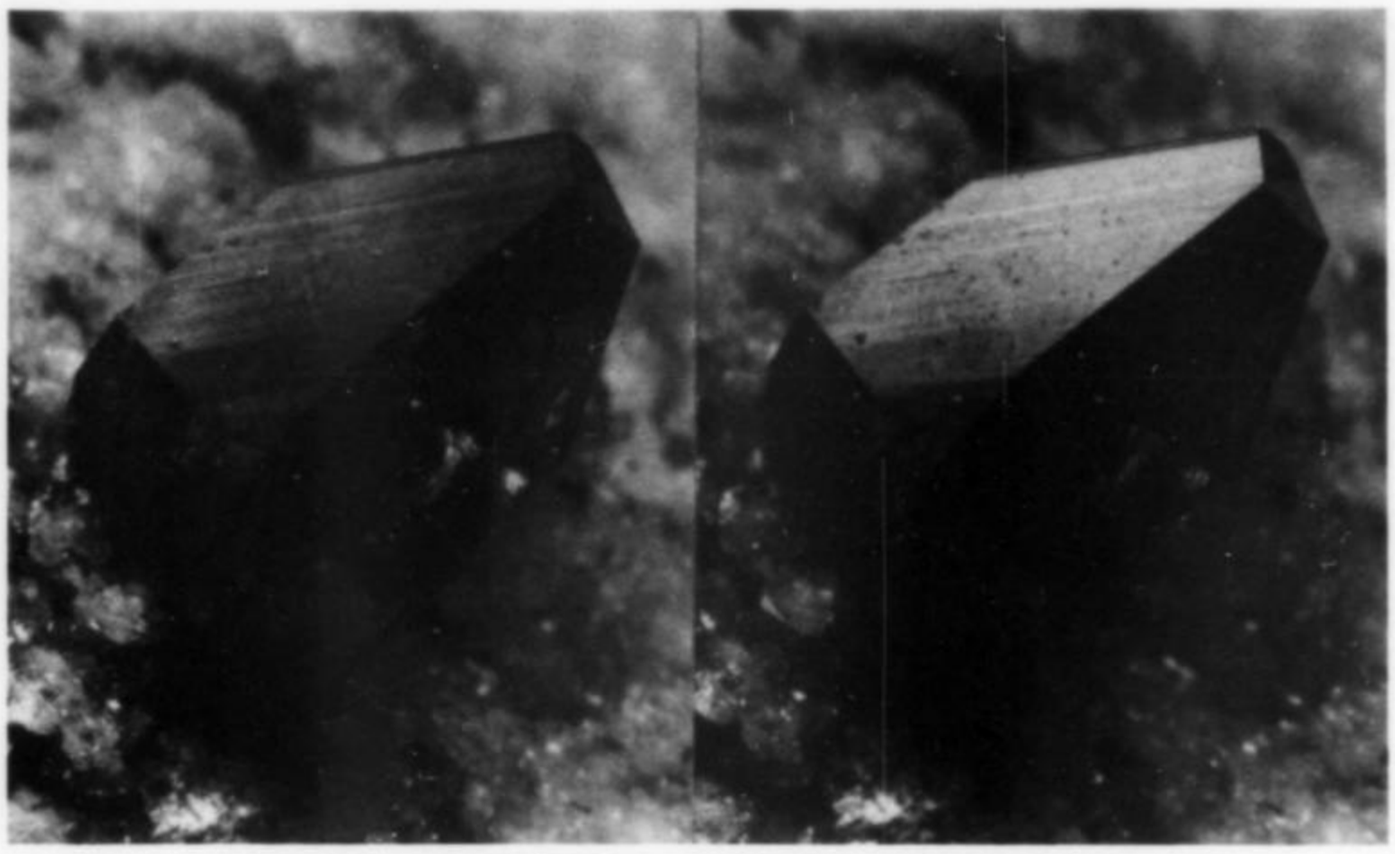


Figure 10. **Titanite crystal, 5 mm, from Val Curnera, Switzerland. Photo by Eric Offermann.**

aligned on a horizontal axis, small horizontal deviations between the two projected images are forgiven, but small vertical deviations are catastrophic, preventing the mind from merging the two images into a 3-D view. It is particularly important to advance the projectors together; a misfire which projects two unrelated images is uncomfortable for the audience. Although stereoprojectors with built-in filters and slide holders are still manufactured, they are extremely expensive and are rarely found in an audio-visual equipment inventory. Using two separate projectors with identical lenses as described above is less convenient, but with care and practice works extremely well.

CONCLUSIONS

In Victorian times it was not uncommon to see a stereoscope prominently displayed on the side table in fashionable sitting rooms. Beside it would be a stack of stereograph cards that visitors could admire through the hand-held stereoscope. There is no reason why this charming tradition could not be revived using mineral prints or slide pairs.

The appropriate use of stereopair photographs in mineralogical publications might be encouraged as well, when three-dimensional aspects of specimens are critical. Despite the limitation in print size, stereographs are a unique and excellent tool for recording mineral specimens.

ACKNOWLEDGMENTS

Our special thanks to Eric Offermann, who has been an enthusiastic practitioner and promoter of mineral stereophotography for many years, and who generously donated the funds to purchase all 8,000 Stereopticon viewers accompanying the press run of this issue.

BIBLIOGRAPHY

BREWSTER, D. (1856) *The Stereoscope, its History, Theory, and Construction.* John Murray: London, 235 p. Also available as a 1971 facsimile edition, Morgan and Morgan: Hastings-on-Hudson, New York.

DALZELL, J. M. (1936) *Practical Stereoscope Photography.* London.

GOWLAND, P. (1954) *The Art and Technique of Stereo Photography.* Crown Publishers, New York, 128 p.

HEDGECOE, J. (1978) *The Photographer's Handbook.* Alfred A. Knopf, New York, p. 299–310.

HOLMES, O. W. (1859) The stereoscope and the stereograph. *Atlantic Monthly,* **3,** 738–748.

HOLMES, O. W. (1869) History of the American stereoscope. *Philadelphia Photographer,* **6,** 1–3.

JONES, J. (1976) *Wonders of the Stereoscope.* Alfred A. Knopf, New York, 125 p.

McKAY, H. C. (1948) *Principles of Stereoscopy.* American Photographic Publishing Company, Boston, 191 p.

MORGAN, W. D., and LESTER, H. M., editors (1954) *Stereo Realist Manual.* Morgan and Lester, New York, 400 p.

MOYD, L. (1949) A simple method for making stereoscopic photographs and micrographs. *Transactions of the A.I.M.E.,* **184,** 383–384.

OFFERMANN, E. (1986) Stereofotografien von Mineralien. *Schweizer Strahler,* **7,** no. 7, 293–303.

PEARL, R. M. (1976) *Atlas of Crystal Stereograms.* Earth Science Publishing Company, Colorado Springs, Colorado, 80 p.

TECHTER, D., and OLSEN, E. (1972) *Stereogram Book of Rocks, Minerals, and Gems.* Hubbard Press, Northbrook, Illinois, 64 p.

TURNER, J. N. (1981) *Methods in Cell Biology, Volume 22: Three dimensional Ultrastructure in Biology.* Academic Press, New York, 363 p.

WADE, N. J., editor (1983) *Brewster and Wheatstone on Vision.* Academic Press, New York, 358 p. (Contains reprints of many of the germinal papers in stereoscopy.)

WANLESS, H. R. (1969) *Aerial Stereo Photographs.* Hubbard Press, Northbrook, Illinois, 92 p.

WHEATSTONE, C. (1838) Contributions to the physiology of vision—Part the first. On some remarkable, and hitherto unobserved, phenomena of binocular vision. *Philosophical Transactions of the Royal Society,* London, **128,** 371–394.

WILSON, W. E. (1987) A photographer's guide to taking mineral specimen photographs for the *Mineralogical Record. Mineralogical Record,* **18,** 229–235.

ZOLTAI, T., and STOUT, J. (1984) *Mineralogy, Concepts and Principles.* Burgess, Minneapolis, 500 p.

The Miller Calcite Collection

Chuck Turley
8650 S 300E
Sandy, Utah 84070

Marshall Koval
P.O. Box 1382
Richland, Washington 99352

Montana has its share of world-class covellite crystals, trout fishing, and friendly little bars situated about ten miles apart on every highway in the state. An addition to this list of excellences is the calcite collection assembled by Mary and Gardner Miller of Missoula.

Mary Brockway Miller is a native of Miles City, Montana; Gardner Miller is originally from Okmulgee, Oklahoma, where his family was involved in ranching and the oil business. Gardner recalls that his father was known as "Dry-Hole Miller" due to his knack for drilling wells just off the margins of major discoveries. The way the story goes, "If he had only moved his drill rig a mile or so, we'd all be filling up at Miller Stations!" The couple married during their senior year at Stanford University, where Mary and Gardner received degrees in psychology and geology, respectively. After graduation Gardner worked in the underground copper mines at Butte, Montana, for several months before he was sent to the Colorado Plateau to spend two years in uranium exploration for the Manhattan Project.

After the war the couple settled on the Miller Ranch in southern Texas, near the town of Falfurrias. Eventually they started looking for somewhere to live where they and their four children could enjoy skiing and other outdoor activities. In 1957 the family moved to Missoula where they operated a photography business for a number of years.

The Millers each had a latent interest in minerals. Mary recalls being exposed to them during a childhood visit to the Field Museum in Chicago; Gardner gained an appreciation for ore minerals while at Butte. Their interest was awakened during a trip to Alaska in 1975 where they ran into a small Ma-and-Pa rock shop that led them to consider opening something similar in Montana. Instead of opening a shop they hit the show circuit as collectors in 1976 and they made their first trip to the Tucson show in 1977. Mary and Gardner tried dealing at Tucson, Rochester, New York, and Washington, D.C. during 1979 but they soon learned that dealing was physically too demanding and found that they both lacked the required sales ability, so they quit dealing to concentrate solely on collecting.

About that time Mary came up with the idea of collecting calcites because of their great variety and relatively low prices. (She is possessive of her calcites, once taking umbrage at one of the authors for referring to them as "Gardner's Collection.") Mary loves calcites that resemble flowers and plants, and she particularly enjoys the comments of small children when they see the collection.

THE COLLECTION

Some 2500 calcites and 700 other display-quality specimens are arranged in custom-built glass cases in the Millers' home. Currently the Millers are acquiring only calcites. Three hundred non-calcite specimens were donated to the Arizona Sonora Desert Museum in order to provide shelf space for new acquisitions. Most of the labeling and handling of new pieces is done by Marlen Tweten, a local collector noted for the fine smoky quartz crystals he has collected near Granite Creek, Lolo Pass, Montana.

Soon after starting the collection the Millers faced the problem of whether to concentrate on acquiring only high-quality calcite specimens or to accumulate calcites from all available localities. In a way, the collection has evolved toward both ends. Highest priority is given to the acquisition of outstanding display pieces. Of course, calcite is such a common mineral that a complete locality collection would be endless, so even locality specimens are required to have some aesthetic character. Forty-eight countries and 37 states are represented. A third function of the collection has been to assemble calcite-related "oddities" such as unusual crystal habits or twinning, uncommon associations, inclusions and pseudomorphs.

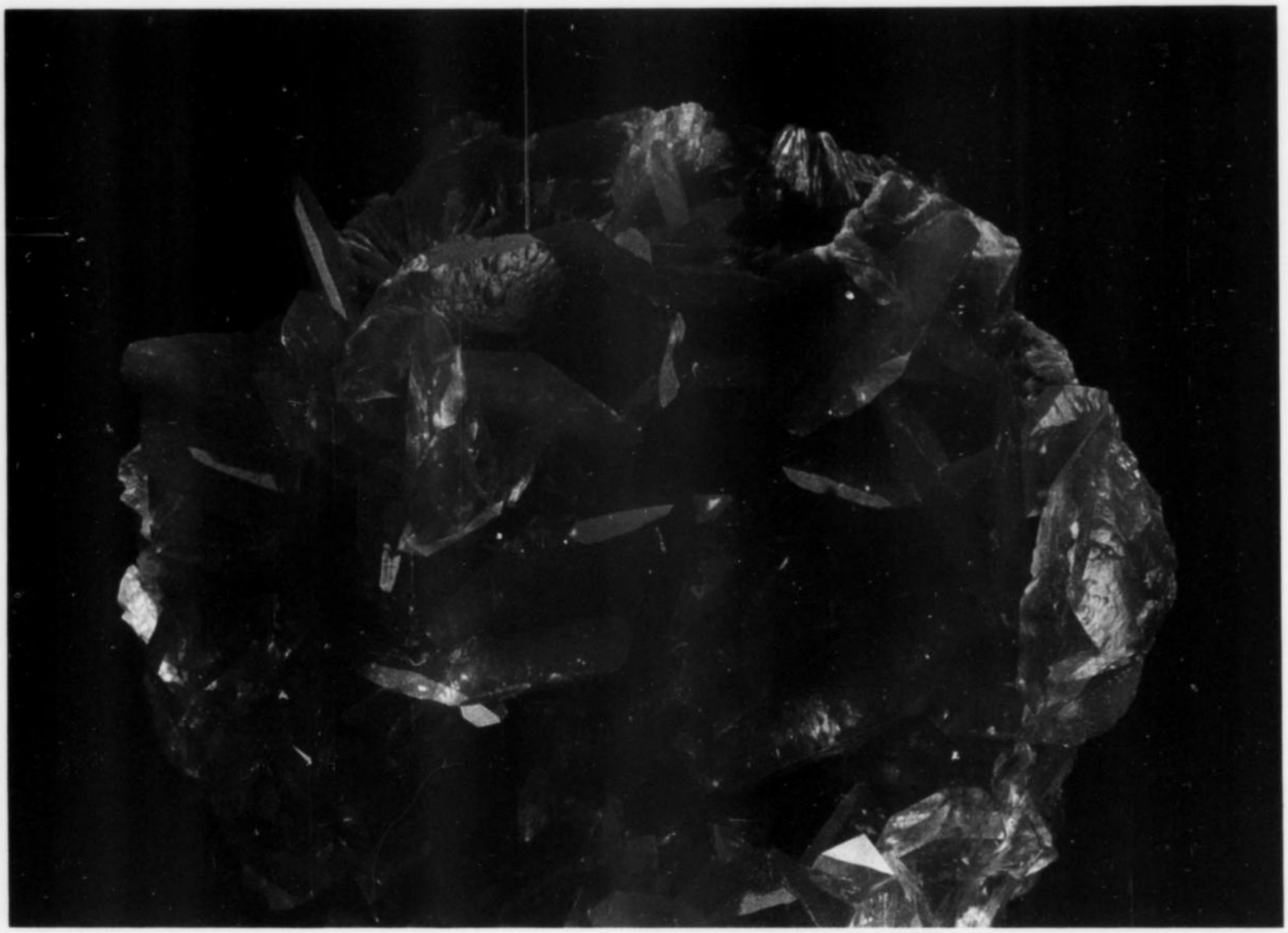


Figure 1. **Calcite with aurichalcite inclusions, from the Ojuela mine, Mapimi, Durango, Mexico. The specimen measures 6 cm across.**

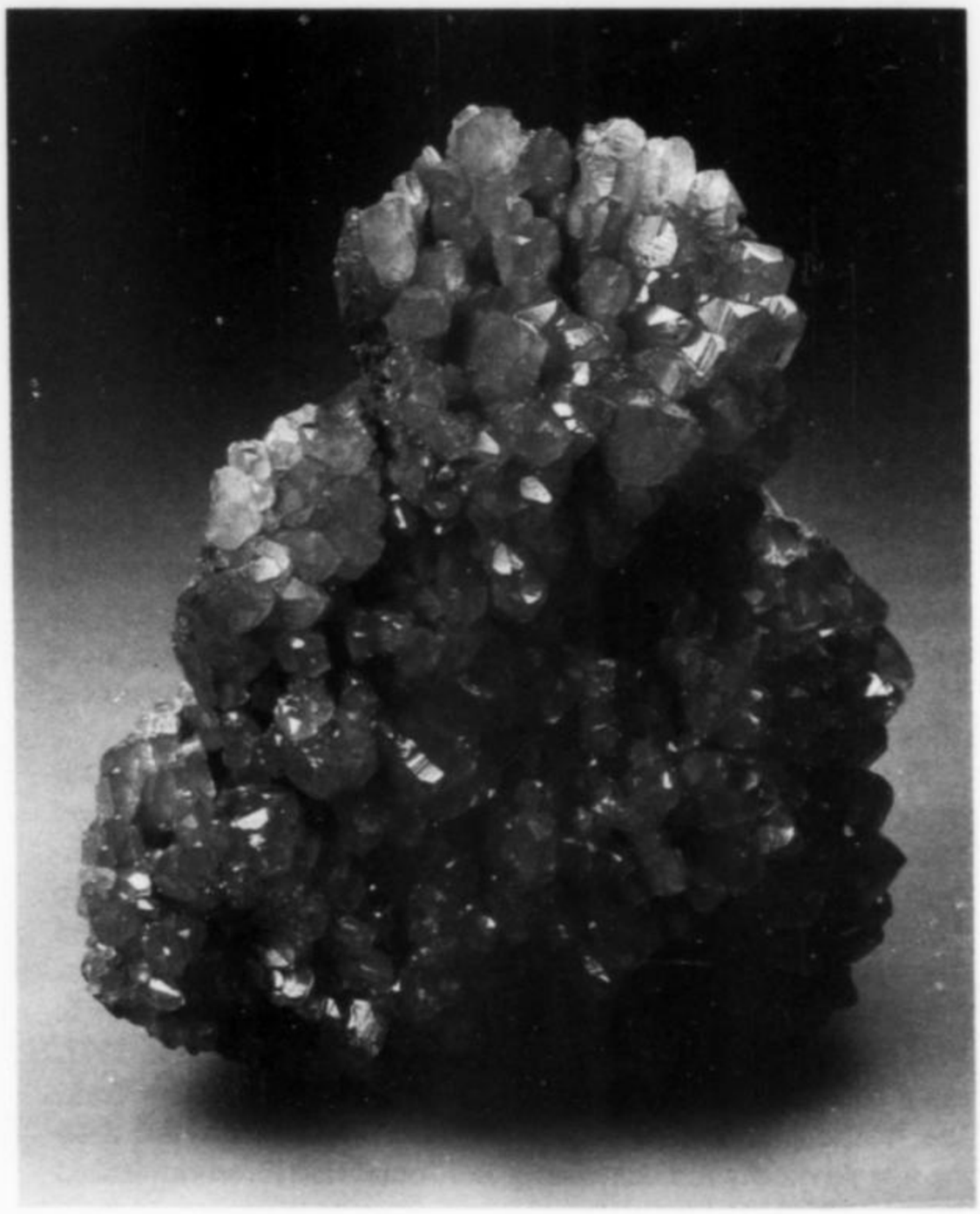


Figure 2. **Calcite colored orange by inclusions of iron oxides (?), from Pribram, Czechoslovakia. The specimen measures 14.2 cm.**

The intent from the start was to build the world's finest calcite collection, and the effort has probably succeeded; there is little doubt that no comparable group of calcites has ever been assembled. Special attention has been given to the acquisition of specimens from old private and museums collections in the U.S. and Europe, along with the best pieces from currently producing localities. The Millers' commitment to acquiring the finest available calcite is exemplified at the Tucson show, where many dealers will give them first shot at the best calcites that have been held back during the year.

One striking feature of the collection is the aesthetics inherent in calcite's enormous range of forms and colors. Even the nontechnical viewer can readily appreciate them as natural "sculptures." By comparison, other common minerals such as quartz and fluorite occur in a much more restricted range of habits, and, at least in the case of quartz, considerably fewer colors.

Another consideration with the collection has been the possibility of making it available for scientific studies related to topics such as calcite genesis, crystals habits and associations.

Highlights of the collection (arranged by locality) include the following:

Figure 3. **Calcite colored red by hematite inclusions, 24 cm (9½ inches) across, from Cumberland, England.**

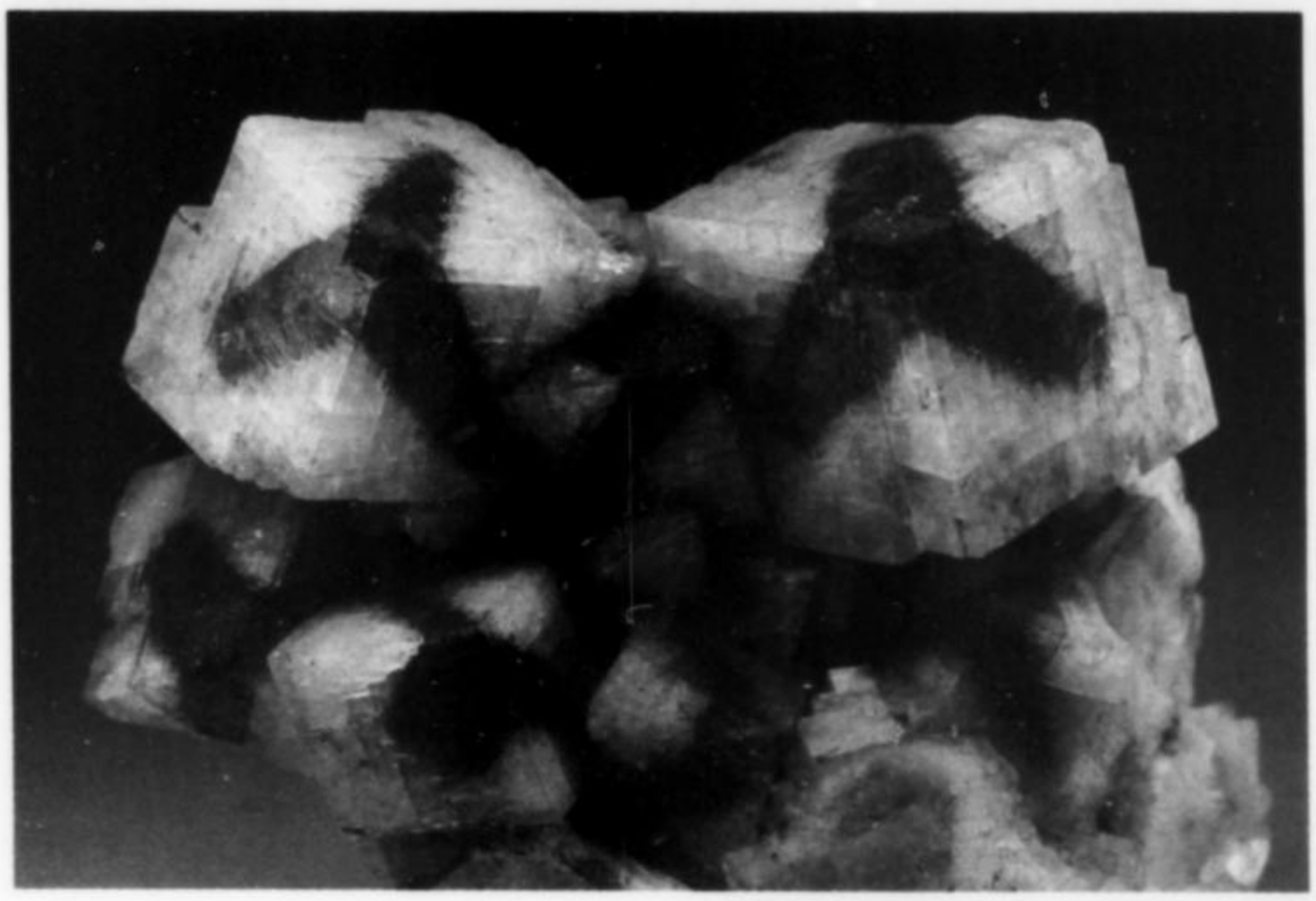


Figure 4. **Calcite with oriented inclusions of duftite, from Tsumeb, Namibia. The calcite crystals measure about 3.2 cm.**

Figure 5. **Calcite with malachite inclusions from Bisbee, Arizona. The group is 9.5 cm across.**

Brazil

Three notable pieces from the amethyst mines at Rio Grande do Sul: a 148-kg portion of an amethyst geode sprinkled with prismatic calcites, a banana-shaped calcite crystal on matrix (colored green by nontronite) and a pseudomorph of chalcedony replacing a calcite scalenohedron.

Canada

Twinned cubanite crystals on a calcite plate, from Chibougamau, Quebec.

China

Calcites with cinnabar and realgar, from Hunan Province.

Colombia

Crystallized calcite with a gem-quality emerald (not a fake) from Muzo.

Czechoslovakia

Pribram calcites, a private collection of 127 pieces assembled between 1950 and 1965. Many have pyrite and marcasite coatings similar to specimens from the Idarado mine in Colorado.

England

The outstanding collection of English calcites, mostly from Cumberland, rivals the British Museum and fills over two cases. Notable pieces include the following:

A pair of large cabinet calcites with green barite.

An L-shaped twin, nearly 90°, colored a light orange by included hematite.

A baseball-sized gemmy twinned angel-wing crystal on a matrix of smaller calcites.

Mary and Gardner Miller

Figure 6. **Subparallel calcite crystal group, 8.4 cm tall, from the Pallaflat mine, Cumberland, England.**

France

Several Fontainbleau "sand" calcites.

Calcite with pyromorphite, from Les Farges.

Germany

A suite from St. Andreasberg, with several white-tipped "gun barrel" prismatic groups.

Hungary

Some 70 choice calcites from the Karoly mine, Gyongyosoroszi; part of the Triebl Collection, these were apparently collected at the mine over a period of years.

India

An amber rhombohedron 10 cm on an edge, possibly the finest calcite ever recovered from the traprock quarries at Poona.

Mexico

The Mexican collection fills more than four cases and includes:

A large manganocalcite with quartz from the recent find at Francisco Portillo, Chihuahua.

Chalky-white rhombohedrons on pale green fluorite, from Naica, Chihuahua.

Scalenohedrons with included stibnite from Somberete, Zacatecas.

Some 40 of the classic Charcas "poker chip," prismatic calcites.

Namibia

The Millers have one of the finest known suites of Tsumeb calcites, some

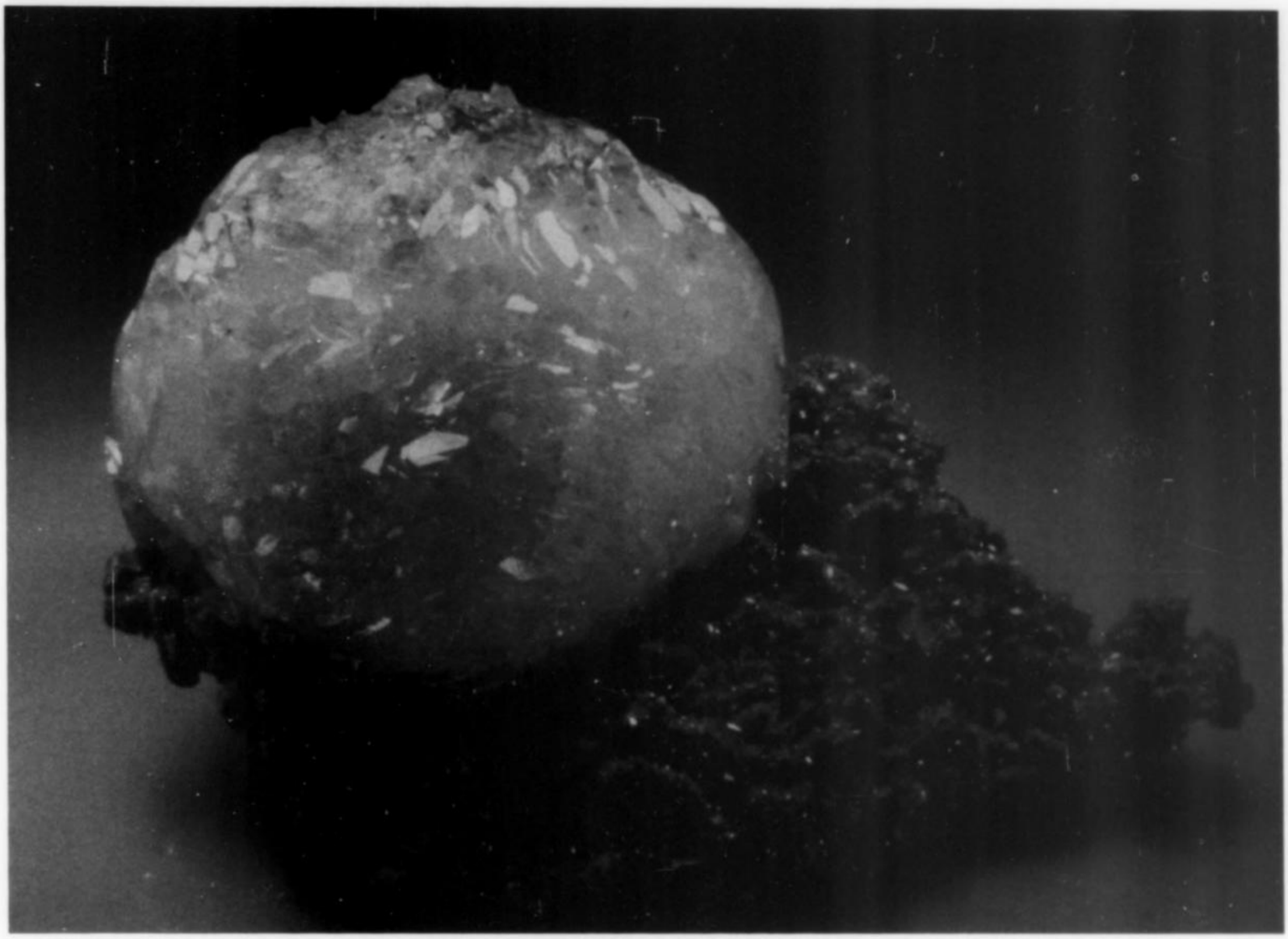


Figure 7. **Spheroidal grouping of calcite crystals with pyrite, 18.5 cm in total length, from the Karoly mine, Gyongyosoroszi, Hungary.**

with dioptase, many colored red or green by secondary minerals. One particularly interesting piece has green duftite oriented trigonally on white rhombohedrons. An amber calcite with faint cuprite inclusions from the Onganja mine closely resembles the Sweetwater calcite from Missouri.

Norway

Tiny "balls" of calcite on a single wire of silver, from Kongsberg.

Peru

Several fine manganocalcites from Casapalca and Pachapaqui.

South Africa

Calcite with sturmanite, from the N'chwaning mine.

Spain

The Millers have an excellent suite of about 30 calcites with fluorite and barite, from Villabona, Asturias; also, calcite on bluish purple, dodecahedrally modified fluorite cubes, from La Collada, Asturias.

United States

Naturally there are many fine American pieces in the collection, including the following.

Several translucent calcites with included copper, from Keweenaw County, Michigan.

Spherical manganocalcite clusters on iron-manganese oxide matrix from Hurley, Wisconsin.

A suite of Bisbee, Arizona, calcites in odd, gnarled forms resembling cave formations.

A pair of gemmy, amber-colored faceted calcites, from Gallatin Canyon, Montana.

Scalenohedrons from the Idarado mine, Telluride, Colorado, with a fine-grained pyrite coating.

A prismatic crystal 8.5 cm long, on matrix, from the Pea Ridge mine, Sullivan, Missouri, that closely resembles some of the classic crystals from Cumberland, England.

A group of small, unusual calcites from the quarries near Pleasant Ridge, Indiana. (One piece could easily be mistaken for a Korean scheelite!)

Some 30 calcites from the old Tri-State lead-zinc district. Few of these have been touched up with acid, as were most of the calcites from this district.

Possibly the best large amber and green phantom calcite combination ever collected at the Sweetwater mine, Ellington, Missouri, along with a matching large calcite and marcasite specimen from the Brushy Creek mine, Bixby, Missouri.

U.S.S.R.

White calcites on citrine quartz with small pyrite crystals, from the Ural Mountains.

Yugoslavia

Three large cabinet pieces from Trepča, one with calcite draped

Figure 8. **An enormous amber-colored rhombohedron of calcite, 14 cm (5½ inches) across, from Poona, India.**

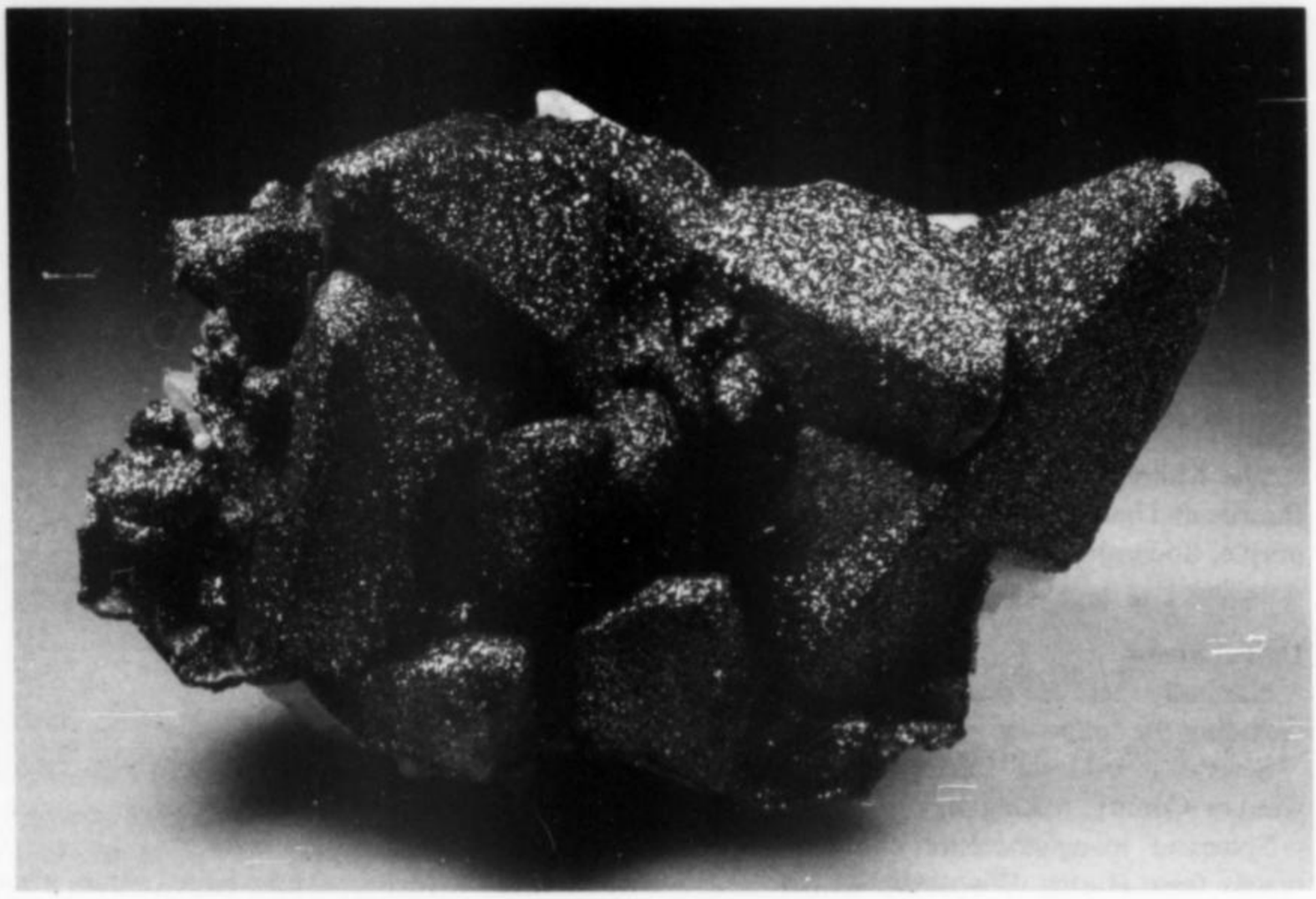


Figure 9. **Pyrite-coated calcite crystal group, 15.5 cm across, from the Idarado mine, Telluride, Colorado.**

Figure 10. **Cobaltian calcite with malachite inclusions, from the Mupine mine, Shaba, Zaire. The largest crystal is nearly 4 cm tall.**

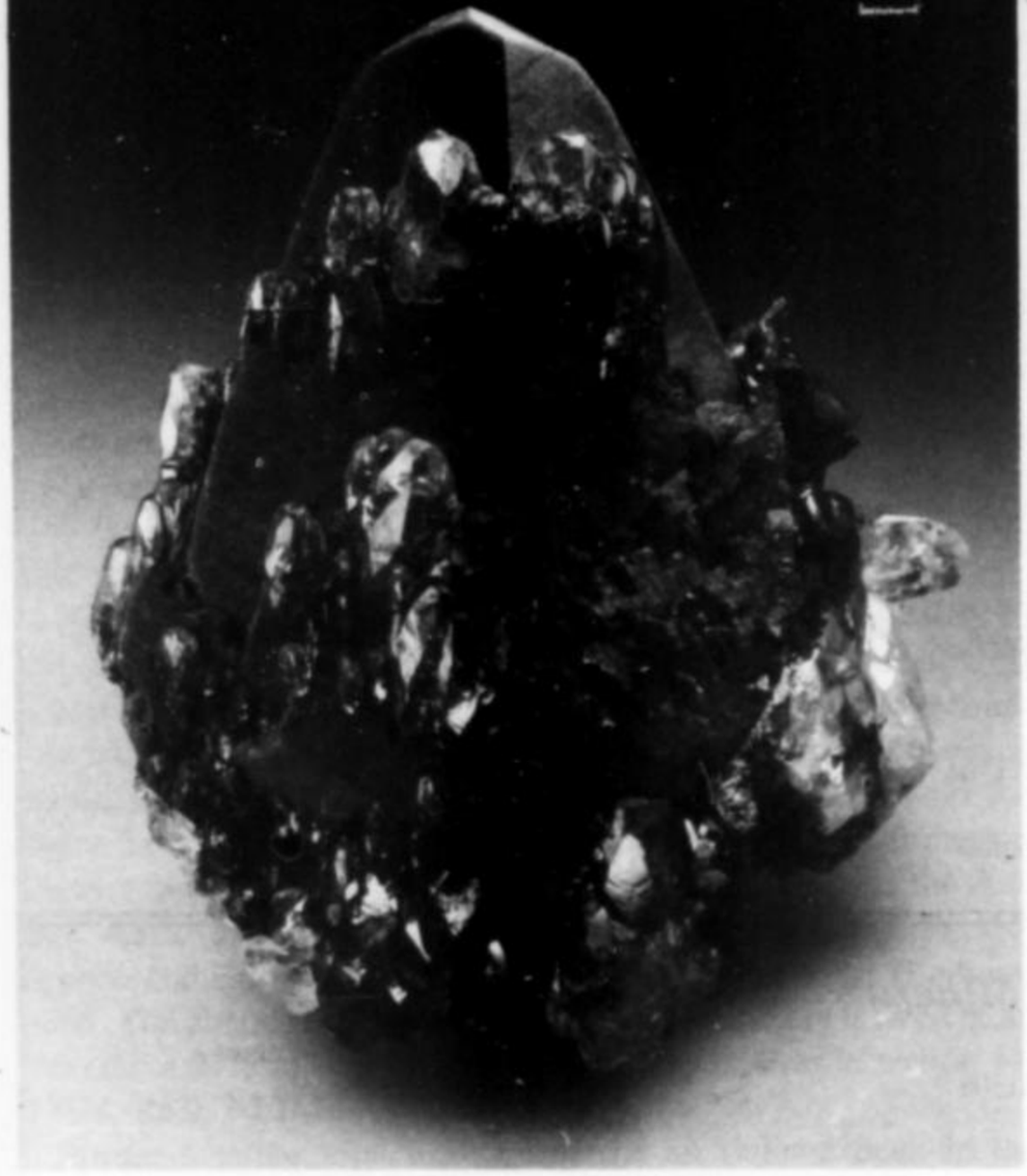


Figure 11. **Dark brown calcite crystal, 14.5 cm tall (probably colored by goethite inclusions), with a second-generation growth of oriented colorless crystals, from Lancashire, England. Formerly in the collection of Clarence Bement.**

on arsenopyrite and sphalerite, another showing calcite on sphalerite and rhodochrosite, and a stunning calcite on pyrite.

Zaire

Cobaltian calcite with malachite and kolwezite, from Shaba Province.

Other Minerals

The Millers also have a case devoted to barites, topped by a spectacular large blue barite from Frizington, Cumberland, England. Other pieces on display include a number of Tsumeb dioptase and cerussite specimens, several Romanian stibnites, and an 8.5-cm classic Kongsberg silver formerly in the Heimat Museum.

CONCLUSION

The bulk of the major calcite acquisitions possible from worldwide localities has surely been accomplished, which is fortunate since space is becoming a problem. It is anticipated that future acquisitions will mostly be upgrades of existing pieces, except for genuinely new discoveries.

Mary and Gardner graciously invite anyone interested to stop by and view the collection. They hope that the calcites can someday be taken over by an institution in order to make them more readily accessible to both professional mineralogists and the public. It is well known that Montana is usually entombed in snowdrifts, so plans to visit should be made during the annual "Three Days of Summer" in July.

Colorado Dealers

Collector's Edge

Bryan & Kathryn Lees
402 Gladiola Street
Golden, CO 80401
303-278-9724
We Buy Collections

Collector's Stope

Jim & Patti McGlasson
7387 S. Flower Street
Littleton, CO 80123
303-972-0376
Fine Minerals, Species, Micromounts

Crystal-Linn International

Martin Zinn
P.O. Box 2433
Evergreen, CO 80439
303-670-1960
Display Quality Minerals

Eldorado Enterprises

Don Belsher
P.O. Box 219
Eldorado Springs, CO 80025
303-494-7785
Fine Minerals, We Buy Collections

Golden Minerals

Don E. Knowles
13030 West 6th Place
Golden, CO 80401
303-233-4188
Largest Stock in Colorado

L & T Creations

Tag & Lee McKinney
6780 S. Logan
Littleton, CO 80122
303-794-7803
Colorado-Utah Minerals

*

Colorado Mineral & Fossil Show

September 14-17, 1988
Holiday Inn-North Denver
Two Great Shows to See!
10 a.m. to 10 p.m. Daily

Micromount Exchange

Dale Denham
P.O. Box 363
Louisville, CO 80027
303-665-3802
Colo., Mex., & West U.S. Micromounts

Mineral Treasures

Dee Belsher
P.O. Box 1204
Broomfield, CO 80020-1204
303-466-4128
Fine Minerals, Collections

Moly B • Caviano

5910 South University
Littleton, CO 80121
303-798-6696
Mon-Sat 10-5:30, Sun call first
Quality Minerals from the
Ray Thompson Collection

Mountain Minerals International

George & Cindy Witters, Dudley Blauwet
P.O. Box 302
Louisville, CO 80027
303-499-2920
Specializing in Asian Minerals

Tavernier

3355 S. Wadsworth, G123
Lakewood, CO 80227
303-985-9646
Fine Minerals & Gems

Topaz Gem & Mineral

David Burchett
942 Pearl Street
Boulder, CO 80302
303-447-0600
Minerals from Around the World,
Including Nepal

Williams Minerals

Keith & Brenda Williams
P.O. Box 1599
Idaho Springs, CO 80452
303-567-4647
Colorado Minerals & Mineral Mounts

Worldwide Resources

Dennis O. Belsher
P.O. Box 636
Golden, CO 80402
303-322-4748
South American Minerals

Columbine Mineral Shop

Benjy & Liz Kuehling
633 Main Street
Ouray, CO 81427
303-325-4345
Open 7 days, May 1-Oct. 31
9 a.m. to 9 p.m.
Off-season by Appointment
Fine Minerals for Collectors

Mike Madson Minerals

3201 Snowberry Court
Grand Junction, CO 81506
303-243-2234
Wholesale Minerals

The Rock Hut

Gus Seppi, Jim & Irene Witmer
706 Harrison Avenue
Leadville, CO 80461
303-486-2313
Specimens, Unique Gifts, Jewelry

Mineralogy of the
KILLIE MINE
Elko County, Nevada

Gail E. Dunning
773 Durshire Way
Sunnyvale, Calfornia 94087

Joseph F. Cooper, Jr.
482 Green Valley Road
Watsonville, California 95076

The oxidized silver-bearing lead ores of Nevada's Spruce Mountain mining district, and in particular those of the Killie mine, contain a number of interesting secondary minerals including bayldonite, carminite, beudantite, fornacite and vauquelinite.

INTRODUCTION

Bayldonite, $PbCu_3(AsO_4)_2(OH)_2 \cdot H_2O$, was a major secondary mineral of the oxidized orebody cap at the Killie mine. Schrader (1931) recognized an unusual yellowish green mineral capping the upper zone of the orebody, but presumed it to be a lead oxychloride rather than bayldonite. In addition, some 25 other secondary minerals, including arsenates, sulfates, phosphates and chromates, occur in this deposit. Most of these minerals occur as massive veins and minute crystals lining cavities in the porous rock. Cerussite, and to a lesser degree bayldonite, occurred as large replacement masses.

LOCATION

The Spruce Mountain mining district is located approximately 73 km south of Wells, Elko County, Nevada, and 11 km east of U.S. Highway 93; it covers about 2.6 square kilometers of Spruce Mountain itself. The deserted mining settlement of Sprucemont, which served the district during its productive years, is located on the lower west slope of the mountain at an altitude of 2170 meters. District mines which were served by Sprucemont include the Ada H., Black Forest, Bullshead, Monarch, Paramount, Parker, Spence and Spruce Standard in addition to the Killie (Latham) mine. The abandoned workings of the Killie mine are located at an altitude of 2713 meters near the saddle of Killie Pass in section 14, T31N, R63E M.D.M.

Spruce Mountain, at 3250 meters, is an isolated peak in the southwestern section of the Pequop Mountains and forms the highest part of the Spruce Mountain Ridge. It rises nearly 1250 meters above the flat valleys surrounding the peak. Banner Hill, a copper-rich area about 2.5 km to the north, is separated from Spruce Mountain by Killie Pass.

HISTORY

Silver-bearing lead ores were first discovered on Spruce Mountain in 1869 at the site of the Latham mine, which was renamed the Killie mine several years later. In 1871 the three original mining districts in the area, the Latham, Johnson and Steptoe, were combined to form what is now known as the Spruce Mountain district (Schrader, 1931). Although oxidized ore was plentiful, little silver production resulted due to inefficient ore processing methods, inadequate water supply and poor ore quality.

The Ingot Mining Company acquired the Killie mine in 1871, built a 1.5-meter Philadelphia-type smelter at Sprucemont to treat the lead carbonate ores, and, for a short time, treated 35 tons of ore daily. However, this plant was not a success and operations soon ceased. From 1910 to 1918 mining was sporadic with only small quantities of ore being produced due primarily to low lead prices. In 1926 the mine was reopened by the Spruce Consolidated Mines Company which operated it for about a year before being acquired by the Nevada Lead and Zinc Company, which then operated the mine until 1930.

During the years from 1926 to 1930, the mine shipped about 100 tons of ore a month for a total approximating 4800 tons containing on the average 22% lead, 13% zinc, 5% iron, 6% manganese, 4 ounces silver and 0.005 ounces of gold to the ton. Reported net profit was $3.40 per ton.

The Killie camp consisted of a number of buildings adequate to winter 20 men during normal mining activity, and included an ore storage bin and shaft hoist building containing mechanical power and air compression equipment. A 25-horsepower gasoline engine hoist was used to lift ore buckets from the underground workings; compressed air was supplied by a 65-horsepower Premier oil-burning automatic engine. Ore was conveyed 1300 meters by aerial

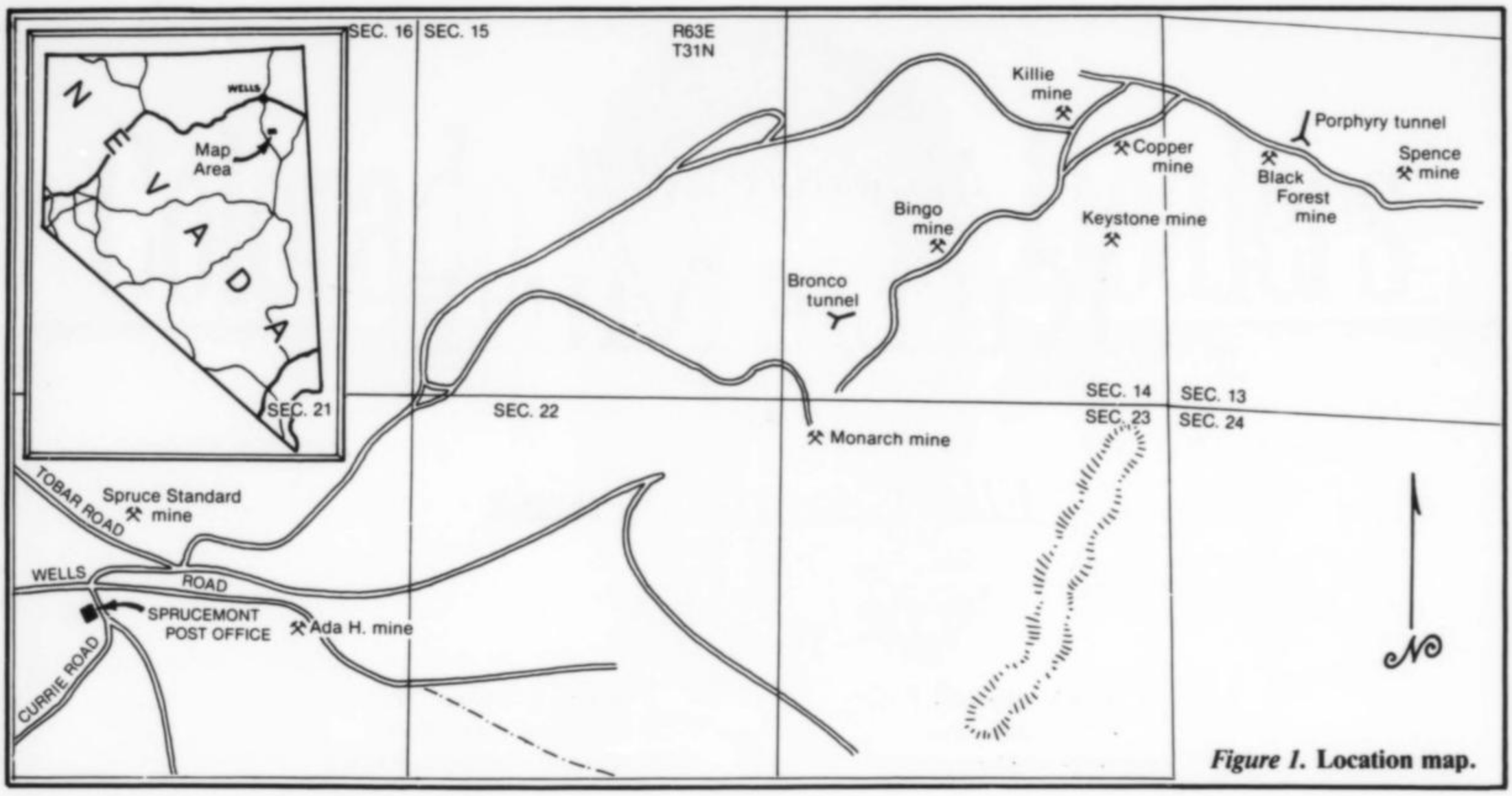


Figure 1. **Location map.**

tram to an ore bin at the lower tunnel of the Black Forest mine, and from there another tram relayed ore 1400 meters to a truck loading station. The tram capacity was about 50 tons of ore per eight-hour shift with each bucket holding 340 kg. Ore was then trucked to the railhead at Tobar, about 40 km to the north.

The workings of the Killie mine were developed to a vertical depth of 76 meters, 136 meters on the dip of the lode, by more than 1000 meters of workings on six main levels: 23, 28, 40, 53, 70 and 73-meter. The 23-meter and 53-meter levels were the most extensively developed. Mining during the earlier periods of operations took place between the surface and the 23-meter level; most of the stoping was above the 40-meter level. The Killie glory hole, where mining first started, was roughly 24 meters long, 18 meters wide and 18 meters deep in 1930.

GEOLOGIC SETTING

The first geological reconnaissance of the region was performed in 1877 by geologists of the Fortieth Parallel Survey (Hill, 1916). The geology has since been revised or summarized by Hill (1916), Schrader (1931), and Granger *et al.* (1957).

The oldest sedimentary rocks of the area consist of lower to upper Paleozoic limestones and dolomites ranging in color from a pale to dark gray to pale buff. The sedimentary sequence exceeds 2300 meters in thickness and consists in the lower units of limestones containing Ordovician fossils. Above these lower units is a series of gray limestones interbedded with chert overlain by argillite, quartzite and quartzitic conglomerate. Next in the sequence is another gray limestone containing Mississippian fossils with a few thin beds of shale. The youngest limestone strata in the area contain Upper Pennsylvanian or Lower Permian fossils with a 67-meter sandstone unit, as well as some sandy limestones.

These sedimentary units have been intruded by igneous rocks composed of granite porphyry, diorite porphyry and lamprophyre. These igneous rocks are highly altered and not well exposed, except for a granite porphyry dike about 160 meters wide which extends across the district. It is light gray in color and medium-grained in texture with abundant phenocrysts of quartz and orthoclase. Some pyrite, biotite and traces of hornblende are also present. The granite porphyry has been highly weathered and hydrothermally altered. The feldspar is largely kaolinized, and the biotite has been altered to chlorite and iron oxides.

The diorite porphyry is a fine-grained, dark brownish gray rock which occurs as small, irregular bodies and dikes. It is composed mainly of plagioclase and hornblende, both of which have been altered to kaolin, sericite, chlorite and epidote.

A lamprophyric dike in the upper tunnel of the Black Forest mine is a dark greenish gray, speckled, medium to fine-grained, porphyritic rock characterized by abundant small phenocrysts of biotite together with hornblende and olivine. Considerable orthoclase and plagioclase are also present. Most of the biotite has been altered to greenish chlorite, the hornblende to actinolite and other products, and the feldspars to epidote, sericite and kaolin.

In general, these porphyry dikes have had only a minor metamorphic effect on the intruded rocks. Metamorphism of the sedimentary rocks in most places extends about 10 meters from the contact with the dikes.

The structure of Spruce Mountain has been described as an anticlinal fold which has been highly modified in the vicinity of the mines by normal faulting and igneous intrusion. Two prominent faults in the district strike about N20°E. Both faults have steep dips with the eastern fault dipping to the east and the western fault dipping to the west. The granite porphyry dikes are localized near the fault zones.

The faults provided channels for ore-bearing solutions that followed the emplacement of the intrusive rocks. Ore formed as replacement deposits in the limestone and was controlled by fissures and fractures, in addition to following bedding planes between favorable limestone beds.

MINERALOGY

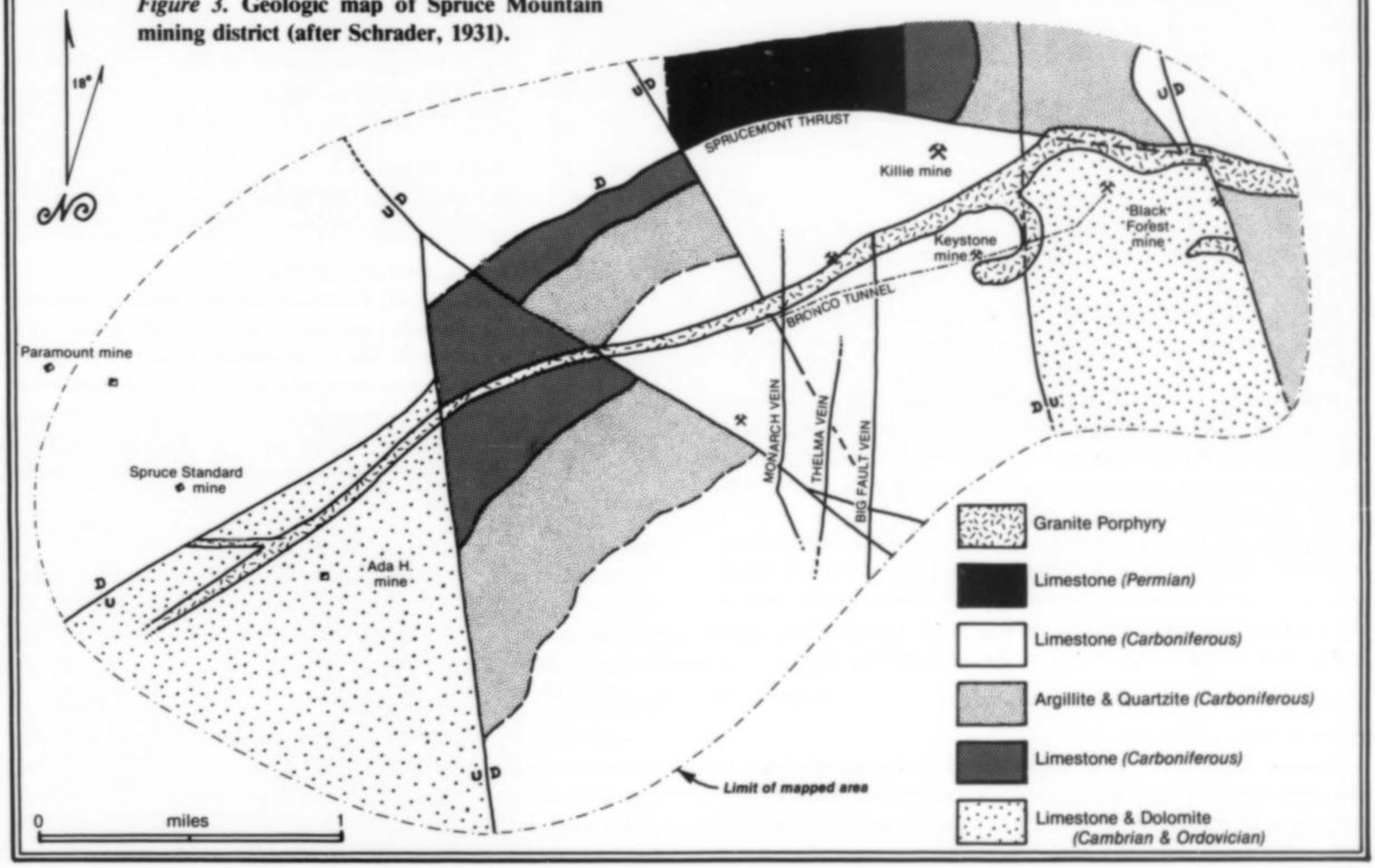
Ore Description

Both Hill (1916) and Schrader (1931) described the ores recovered from Spruce Mountain. The present authors obtained a selection of ore samples during 1967 and again in 1983 from the large dumps at the mine site.

With minor exceptions, the ore deposits are replacements of limestone and are closely associated with fractures, faults and the

Figure 2. **Surface workings and dumps of Killie mine, 1983. G. E. Moss photo.**

Figure 3. **Geologic map of Spruce Mountain mining district (after Schrader, 1931).**



intrusive igneous rocks. The copper ores are generally associated with calc-silicate minerals of contact metamorphic origin and are found north of the saddle between Spruce Mountain and Banner Hill. They are generally smaller in extent than the lead ores south of the saddle and consist of malachite, chrysocolla and chalcopyrite. Minor amounts of bornite and chalcocite were noted in the deeper ores from Banner Hill, whereas tenorite, malachite and chrysocolla were more common near the surface (Hill, 1916).

A typical hand sample of oxidized ore varies from light to dark brown and has a specific gravity between 3.5 and 5.5, depending on the amount of lead mineralization present. The principal ore mineral, silver-bearing cerussite, ranges in color from a dirty white to dark gray. Minor replacement by fornacite has occurred as rims on small cerussite masses. However, in ore from the capping zone, small cerussite masses are rimmed by bayldonite. Veins of crystalline hemimorphite cut this ore and carry occasional pockets of sharp, clear crystals. Both the hemimorphite and, to some degree, the cerussite contain inclusions of bluish green rosasite spheres.

Ore from the Jackson Lode of the Killie mine is roughly banded and consists mainly of brownish gray cerussite with malachite staining. The sandy lead-silver ore from the footwall of this lode consists of brownish green, fine-grained, very finely banded cerussite preserving in detail the structure of the limestone it has replaced. In addition, the brown limonitic ore which occurs in this zone is composed of a mixture of partially oxidized sphalerite and cerussite traversed by seams of smithsonite and hemimorphite.

The upper part of the orebody is highly oxidized with abundant solution cavities and was capped by several centimeters or more of a yellowish green mineral referred to by Schrader (1931) as a "possible lead oxy-chloride."

Schrader's Unknown

The authors first became interested in the Killie mine after reading the ore descriptions by Schrader (1931) and Granger *et al.* (1957). In 1967 the Killie mine was visited for the purpose of locating and positively identifying Schrader's "possible lead oxy-chloride." During this visit the mine dumps and surface workings were explored, and a number of highly oxidized ore samples containing a pale green, massive to crystalline mineral with a moderate specific gravity were collected. In addition, samples of a massive yellowish green mineral were also collected along fault surfaces in the limestone.

Both X-ray diffraction and energy dispersive analysis proved the moderately heavy, light green, massive mineral to be bayldonite and the yellowish green mineral as vauquelinite. Since only small amounts of vauquelinite were found, it was concluded that Schrader's unknown mineral was bayldonite, as it was found in masses weighing a kilogram or more in association with oxidized ore.

Because of the unusual quantity of bayldonite in the oxidized orebody, in addition to the relatively rare phosphate-chromate vauquelinite, a study of the oxidized zone mineral assemblage was made by means of the scanning electron microscope (SEM) with energy dispersive spectrometry (EDS).

The oxidized ore is a complex assemblage of about 25 secondary minerals which have been derived wholly or in part from the oxidation of about six primary sulfide minerals. Although small, most of the secondary minerals show some degree of crystallization, especially when found lining cavities in the more porous rock.

Primary Minerals

Arsenopyrite FeAsS

Massive arsenopyrite associated with pyrite occurs sparingly in the unoxidized portions of the limestone replacement veins and was the source of arsenic for the many arsenates found in the oxidized ore.

Bornite Cu_5FeS_4

Small amounts of bornite were reported by Schrader (1931) from the lower unoxidized ores in association with chalcopyrite.

Chalcopyrite $CuFeS_2$

Massive chalcopyrite, with some bornite, was the major copper ore mineral of the original sulfide vein, but has generally been oxidized to malachite, azurite, rosasite, chrysocolla and tenorite.

Galena PbS

Galena was the major constituent of the original sulfide replacement orebody. Samples containing isolated cores and veins of galena surrounded by anglesite and cerussite can still be found on the dumps. Polished ore sections show only galena with no evidence of any silver-bearing mineral. An EDS area scan of the polished surfaces gave only a very small peak for silver. Minute grains of chalcopyrite were observed associated with the galena, but were nearly always replaced by covellite.

Gold Au

Small amounts of gold were recovered from smelting the ore as noted by Schrader (1931). The gold was probably associated with pyrite.

Pyrite FeS_2

Massive pyrite associated with galena and chalcopyrite was reported by Schrader (1931) from the unoxidized ores.

Sphalerite ZnS

Veins of sphalerite were reported in masses of pyrite, galena and chalcopyrite mined from the unoxidized sections of the orebody. The sphalerite has been oxidized primarily to smithsonite and hemimorphite.

Secondary Minerals

Anglesite $PbSO_4$

Anglesite is usually the first product of galena oxidation, commonly forming concentric rims around it. Samples of galena with anglesite from the orebody were reported by Hill (1916). Anglesite has also been identified in the gossan as small, yellow, subhedral crystals lining small cavities in the porous rock.

Azurite $Cu_3(CO_3)_2(OH)_2$

Minor azurite occurs as thin coatings and crystals associated with malachite and cerussite along fractures in the oxidized ore.

Bayldonite $PbCu_3(AsO_4)(OH)_2 \cdot H_2O$

The supposed lead oxy-chloride mineral described by Schrader (1931) as capping the oxidizing zone is actually bayldonite which has replaced cerussite *in situ*. Bayldonite masses, commonly granular in texture and intermixed with iron oxides and occasionally carminite, are irregular in shape and pale green to apple-green in color. When these masses are viewed with the SEM, their surfaces show complex arrangements of rough-surfaced, subhedral crystals less than 0.1 mm in size.

Beudantite $PbFe_3^{+3}(AsO_4)(SO_4)(OH)_6$

Minute pseudocubic crystals of beudantite were identified lining cavities in the iron-rich gossan ore associated with jarosite and plumbojarosite. Crystals are normally less than 0.05 mm in size and form complex intergrowths.

Carminite $PbFe_2^{+3}(AsO_4)_2(OH)_2$

Aggregates of fine needles, typically in bundles, occur in cavities within massive bayldonite which has been partially leached. Small carminite groups commonly show a fibrous, spherical habit. Some of the individual needles exhibit the crystal forms *e*{001}, with the most common form being *o*{010}.

Figure 4. **Subhedral apple-green bayldonite crystals, 0.1 mm, comprising spheroidal crusts in gossan cavities. Dunning SEM photo and specimen.**

Figure 5. **Bundles of acicular, carmine-red carminite crystals filling cavities in gossan, average size 0.01 x 1.5 mm. Dunning SEM photo and specimen.**

Figure 6. **Drusy coating of minute pseudocubic corkite crystals lining a cavity in gossan associated with rounded hematite. Field of view: 0.25 x 0.3 mm. Dunning SEM photo and specimen.**

Figure 7. **Thin, interpenetrating, brownish green fornacite crystals, 0.002 x 0.025 mm, filling a cavity in cerussite. Dunning SEM photo and specimen.**

Figure 8. **Thin fornacite crystals on subhedral bayldonite. Field of view: 0.6 x 0.75 mm. Dunning SEM photo and specimen.**

Cerussite $PbCO_3$

Massive cerussite replacements of galena comprise the silver-bearing ore of the Killie mine; it has been estimated to exceed several thousand tons (Schrader, 1931). Cerussite crystals, however, are uncommon, being found only in small cavities surrounding unoxidized galena cores. From the relatively small amount of silver found in the sulfide ore, Schrader (1931) inferred that the silver in the oxidized ore has been concentrated by leaching and reprecipitation.

Chalcocite Cu_2S

Massive chalcocite was reported in the copper-rich ores by Schrader (1931). Since no samples were available for examination, this reference could not be confirmed. Any chalcocite was probably of supergene origin and may have been associated with more than one of the several minerals in the copper-sulfur system.

Chrysocolla $(Cu,Al)_2H_2Si_2O_5(OH)_4 \cdot nH_2O$

Chrysocolla was common in the oxidized copper ore where it has replaced malachite and rosasite during the weathering process (Schrader, 1931).

Corkite $PbFe^{+3}_3(PO_4)(SO_4)(OH)_6$

Small pseudocubic crystals of corkite were identified coating cavities in ore rich in iron oxides, particularly hematite. However, this mineral is quite rare in the oxidized ore.

Covellite CuS

Small masses of chalcopyrite were found rimmed with covellite in polished sections of unoxidized galena samples.

Fornacite $(Pb,Cu)_3[(Cr,As)O_4]_2(OH)$

Fornacite, containing appreciable phosphorus, occurs in masses of fan-shaped crystals within veins of cerussite where it has been observed as a replacement. The fornacite crystals are pale brown to dark yellow with a saffron-yellow streak. Cavities containing interpenetrating crystals are common, and such crystals are typically attached to small bayldonite and hemimorphite crystals.

Goethite α-FeO(OH)

Very abundant, finely disseminated grains of goethite make up most of the brown gossan ore. When mixed with silica, the goethite forms a very hard, compact rock containing plentiful small cavities. It is within these cavities that many of the secondary minerals have formed.

Hematite Fe_2O_3

Very small, spheroidal masses of hematite were noted associated with corkite coatings in the oxidized ore.

Hemimorphite $Zn_4Si_2O_7(OH)_2 \cdot H_2O$

Veins composed of crystalline hemimorphite, commonly containing cavities of sharp crystals, cut the highly friable to compact gossan. Within the veins can be found small spheres of bluish green rosasite which appear to have formed before the hemimorphite. Hemimorphite crystals are also present on limestone and often form small but attractive specimens.

Jarosite $KFe^{+3}_3(SO_4)_2(OH)_6$

Plumbojarosite $PbFe^{+3}_6(SO_4)_2(OH)_{12}$

Both plumbian jarosite and plumbojarosite in very small crystals with a trigonal outline were identified under the SEM associated with bayldonite and fornacite crystals. Dark red carminite crystals are commonly found in association with both plumbojarosite and beudantite lining cavities in the leached iron-rich gossan.

Malachite $Cu_2(CO_3)(OH)_2$

Malachite was abundant in the upper levels of the oxidized orebody where it occurred coating limestone fractures and as veins with cerussite (Hill, 1916; Schrader, 1931).

Mimetite $Pb_5(AsO_4)_3Cl$

A single sample of oxidized ore collected in 1967 contained several small, subhedral crystals of pale orange mimetite.

Pyromorphite $Pb_5(PO_4)_3Cl$

Rare pyromorphite containing some calcium was identified under the SEM as small hexagonal prisms associated with bayldonite in cavities of gossan rock.

Rosasite $(Cu,Zn)_2(CO_3)(OH)_2$

Rosasite occurs closely associated with hemimorphite in the iron-rich gossan ore as bluish green botryoidal crusts with a fibrous to spherulitic structure.

Smithsonite $ZnCO_3$

White veins of smithsonite with cerussite were reported by Schrader (1931) as cutting the partially oxidized sulfide veins rich in sphalerite.

Stibiconite $Sb^{+3}Sb^{+5}_2O_6(OH)$

Hill (1916) reported that the ores of the Killie (Latham) mine contained an oxidized antimony mineral in addition to cerussite, anglesite and residual galena. This antimony mineral may have been stibiconite or possibly bindheimite; some stibnite, tetrahedrite or jamesonite was probably present in the original ores. Neither Schrader (1931) nor Granger *et al.* (1957) mentioned any antimony mineral. No antimony mineral was found during our examination of the oxidized ores.

Tenorite CuO

Massive tenorite was reported by Schrader (1931) as occurring in the copper-rich mineralized zone near the surface. Samples collected in 1983 contain small masses of black tenorite associated with chrysocolla.

Vauquelinite $Pb_2Cu(CrO_4)(PO_4)(OH)$

Isolated coatings of vauquelinite, containing appreciable arsenic, occur on limestone fracture surfaces in several of the surface

Figure 9. **Pseudocubic rhombohedral crystals of plumbojarosite coating compact, iron-rich gossan. Maximum size: 0.06 mm. Dunning SEM photo and specimen.**

trenches in the western part of the mine. The mineral is typically yellowish green in color with no evidence of crystallization. Occasional hemimorphite crystals were found covered by massive vauquelinite in the limestone. No vauquelinite has been found associated with any of the other arsenates or sulfates in the iron-rich gossan. Stability of vauquelinite is generally favored in zones of higher pH approaching 8.0 instead of the lower pH conditions more favorable to the arsenates and sulfates.

Wulfenite $PbMoO_4$

Schrader (1931) reported wulfenite from the Killie mine, but without any reference to associated minerals or location. No wulfenite was observed on our samples.

PARAGENESIS

A realistic paragenetic sequence for the Killie gossan deposit was difficult to formulate because of the complex mineral assemblage in the gossan samples, in addition to the spotty nature of the rarer phosphates and complex chromates.

Both orebody physical conditions (such as rock density and degree of fracturing) and chemical composition of descending meteoric waters passing through the deposit can change with time and position within the deposit. In addition, factors such as solution concentration, pH (acid ion activity), Eh (oxidation-reduction potential), temperature and dissolved oxygen can affect the stablity of gossan mineral assemblages.

Despite the complex nature of the gossan mineral assemblage, a number of mineral associations were observed using either the optical microscope or the scanning electron microscope (SEM) with energy dispersive capabilities, the latter combination being quite useful in mineral composition, crystal habit observation, and associations of the more minute crystals lining cavities in the gossan. Nickel (1981) describes the use of the SEM in gossan research.

Based on the secondary mineral associations observed in the Killie gossan samples, a complex set of solution condition must have existed during gossan development. Observations of both Hill (1916) and Schrader (1931), in addition to our own, show that the upper portion of the deposit was the most highly oxidized, with only small residual cores of galena remaining. The middle to lower portion of the deposit, however, showed a much higher amount of unoxidized sulfides with fewer secondary minerals. At the lowest depth, only unoxidized sulfides were encountered (Schrader, 1931), suggesting a typical descending gossan development. Samples from the upper oxidized zone show the effects of late-stage chemical leaching by solutions of lower pH. This effect is evident from a distinct color change in the dark brown, compact gossan rock to a pale yellow-brown, pulverant rock, with the addition of minerals stable at lower pH conditions.

In the partially leached gossan samples jarosite, plumbojarosite, anglesite and beudantite, which form at lower pH values, have been observed attached to both fornacite and bayldonite, stable at higher pH values. Also, both carminite and calcian pyromorphite have been observed on bayldonite.

Both vauquelinite and fornacite, which are stable at a pH of about 8, would be expected to be found along fractures in unreplaced limestone. Vauquelinite has been only observed as fracture coatings along shear zones in the limestone. Fornacite, however, has been only observed replacing cerussite in dark brown gossan cut by narrow hemimorphite veins associated with small rosasite spheroids. Peripheral leaching of this dark brown gossan has removed most of the cerussite and fornacite.

The following general paragenetic sequence, although not in exact order, represents an overall picture of the Killie sulfide ore deposit development and its subsequentual oxidation, resulting in the present gossan deposit.

Table 1. **Secondary mineral assemblage arranged in order of abundance by class and mineral.**

Carbonates	
Cerussite	$PbCO_3$
Smithsonite	$ZnCO_3$
Malachite	$Cu_2(CO_3)(OH)_2$
Rosasite	$(Cu,Zn)_2(CO_3)(OH)_2$
Azurite	$Cu_3(CO_3)_2(OH)_2$
Oxides	
Goethite	α-FeO(OH)
Tenorite	CuO
Hematite	Fe_2O_3
Stibiconite (?)	$Sb^{+3}Sb_2^{+5}O_6(OH)$
Silicates	
Hemimorphite	$Zn_4Si_2O_7(OH)_2 \cdot H_2O$
Chrysocolla	$(Cu,Al)_2H_2Si_2O_5(OH)_4 \cdot nH_2O$
Arsenates	
Bayldonite	$PbCu_3(AsO_4)(OH)_2 \cdot H_2O$
Carminite	$PbFe_2^{+3}(AsO_4)_2(OH)_2$
Mimetite	$Pb_5(AsO_4)_3Cl$
Sulfates	
Anglesite	$PbSO_4$
Plumbojarosite	$PbFe_6^{+3}(SO_4)_2(OH)_{12}$
Jarosite	$KFe_3^{+3}(SO_4)_2(OH)_6$
Complex Arsenates	
Beudantite	$PbFe_3^{+3}(AsO_4)(SO_4)(OH)_6$
Complex Chromates	
Fornacite	$(Pb,Cu)_3[(Cr,As)O_4]_2(OH)$
Vauquelinite	$Pb_2Cu(CrO_4)(PO_4)(OH)$
Complex Phosphates	
Corkite	$PbFe_3^{+3}(PO_4)(SO_4)(OH)_6$
Molybdates	
Wulfenite	$PbMoO_4$
Phosphates	
Pyromorphite	$Pb_5(PO_4)_3Cl$

1. Replacement of Paleozoic limestone along fractures, faults and bedding planes by sulfide and arsenide-rich solutions containing lead, copper, zinc, and iron with some silver and gold.
2. Oxidation of the sulfides, probably by descending solutions, forming iron oxide, copper carbonates (?) and anglesite, moderated by the buffer effects of the limestone.
3. Replacement of anglesite, in part, by cerussite, with the formation of smithsonite, malachite and azurite.
4. Local replacement of cerussite and malachite, possibly by leaching and redeposition in the upper section (cap) of the deposit, forming bayldonite.
5. Formation of hemimorphite veins cutting the dark brown gossan associated with rosasite; also possible formation of vauquelinite along limestone shear zones.
6. Minor replacement of cerussite by fornacite.
7. Local leaching of cerussite, fornacite and bayldonite to form a friable, pale yellow-brown rock.
8. Formation of plumbian jarosite, plumbojarosite, beaudantite, carminite and pyromorphite (?) in the upper oxidized zone.
9. Formation of late anglesite on beudantite and fornacite in the leached rock.
10. Replacement of rosasite (and malachite?) by chrysocolla; formation of tenorite (?).

Figure 10. **View of Spruce Mountain from the Killie mine, G. E. Moss photo.**

DISCUSSION

The majority of secondary minerals identified in the Killie gossan ore were formed locally from the oxidation of the primary sulfides and sulfide-arsenide mineralization. Notable exceptions, in part, are vauquelinite (phosphate-chromate), fornacite (arsenate-chromate), pyromorphite (phosphate) and corkite (phosphate-sulfate), which derived their anions from either the host limestone or intruded dikes (phosphate) or from the oxidation of chromium-bearing minerals, as yet unidentified, in the basic intrusive rocks of Spruce Mountain (chromate).

The Paleozoic limestone units of the district could certainly be a source of phosphate in the form of collophane, a massive fine-grained member of the apatite group, usually carbonate-fluorapatite or carbonate-hydroxylapatite. Hill (1916) records the presence of abundant apatite in the dike northwest of the Killie shaft. Also, EDS of selected limestone samples indicated small but distinct peaks for phosphorus. Although no analysis was available for the intruded basic rocks near the summit of Spruce Mountain, first identified by geologists of the Fortieth Parallel Survey (Hill, 1916), these rocks, or similar rocks at greater depth, could possibly have provided the necessary chromium.

Of particular mineralogical interest at the Killie mine is the formation of bayldonite as a capping mineral in the upper oxidized zone. No mineral associations of the bayldonite cap were made by Schrader (1931). Optical examinations of a number of ore samples containing bayldonite suggest that it resulted from replacement of cerussite lenses *in situ* along slips and fractures in the limestone. A number of bayldonite-rich samples contain small cores of cerussite and, in some samples, malachite.

A deposit with a similar oxidation assemblage, resembling the Killie, has been described by Williams (1978) at Granite Gap, Hildalgo County, New Mexico. At this deposit the ore mineral is silver-bearing cerussite associated with various amounts of beudantite, mimetite, anglesite, duftite, malachite, conichalcite, adamite, hemimorphite and rosasite. Duftite was found to have partially replaced the cerussite, resembling the replacement of cerussite by bayldonite at the Killie mine.

Sumin de Portilla *et al.* (1981) observed that bayldonite can be synthesized at 180°C and between pH 5 and 8 from a solution of arsenic acid (H_3AsO_4), malachite and cerussite. Both malachite and cerussite were certainly prominent minerals at the Killie mine, especially in the upper zone, and a scenario of this type seems quite possible for the formation of bayldonite.

Significant quantities of bayldonite are known in nature. Sumin de Portilla *et al.* (1981) refer to a metasomatic lead-zinc deposit in Kayrakty, central Kazahkstan, U.S.S.R., where bayldonite was found in the upper layers of barite lenses embedded in sandstone. At Kayrakty, bayldonite formed by pseudomorphic substitution for cerussite resulting in irregular accumulations in fine-grained malachite and azurite. Also at Kayrakty, concentric masses of pure bayldonite up to 7 cm have been observed in association with intergrowths of beudantite and inclusions of anglesite.

ACKNOWLEDGMENTS

The authors wish to express their sincere thanks to Dr. S. A. Williams for reviewing an early draft of this paper, for helpful information on chromate mineral stability and reference to a similar deposit in New Mexico. Thanks are also extended to John S. White of the Smithsonian Institution for X-ray confirmation of vauquelinite, and to John Lewis of General Electric for the X-ray identification of bayldonite. Gary E. Moss provided numerous additional ore samples collected at the Killie mine, in addition to current site photographs and review of an intermediate draft of this paper. His help and interest are gratefully appreciated.

REFERENCES

GRANGER, A. E., BELL, M. M., SIMMONS, G. C., and LEE, F. (1957) Geology and mineral resources of Elko County, Nevada. *University of Nevada Bulletin* **54**, 142–144.

HILL, J. F. (1916) Notes on some mining districts in eastern Nevada. *United States Geological Survey Bulletin* **648**.

NICKEL, E. H. (1981) The application of the scanning electron microscope in gossan research. *Bulletin de Mineralogie,* **104**, 292–297.

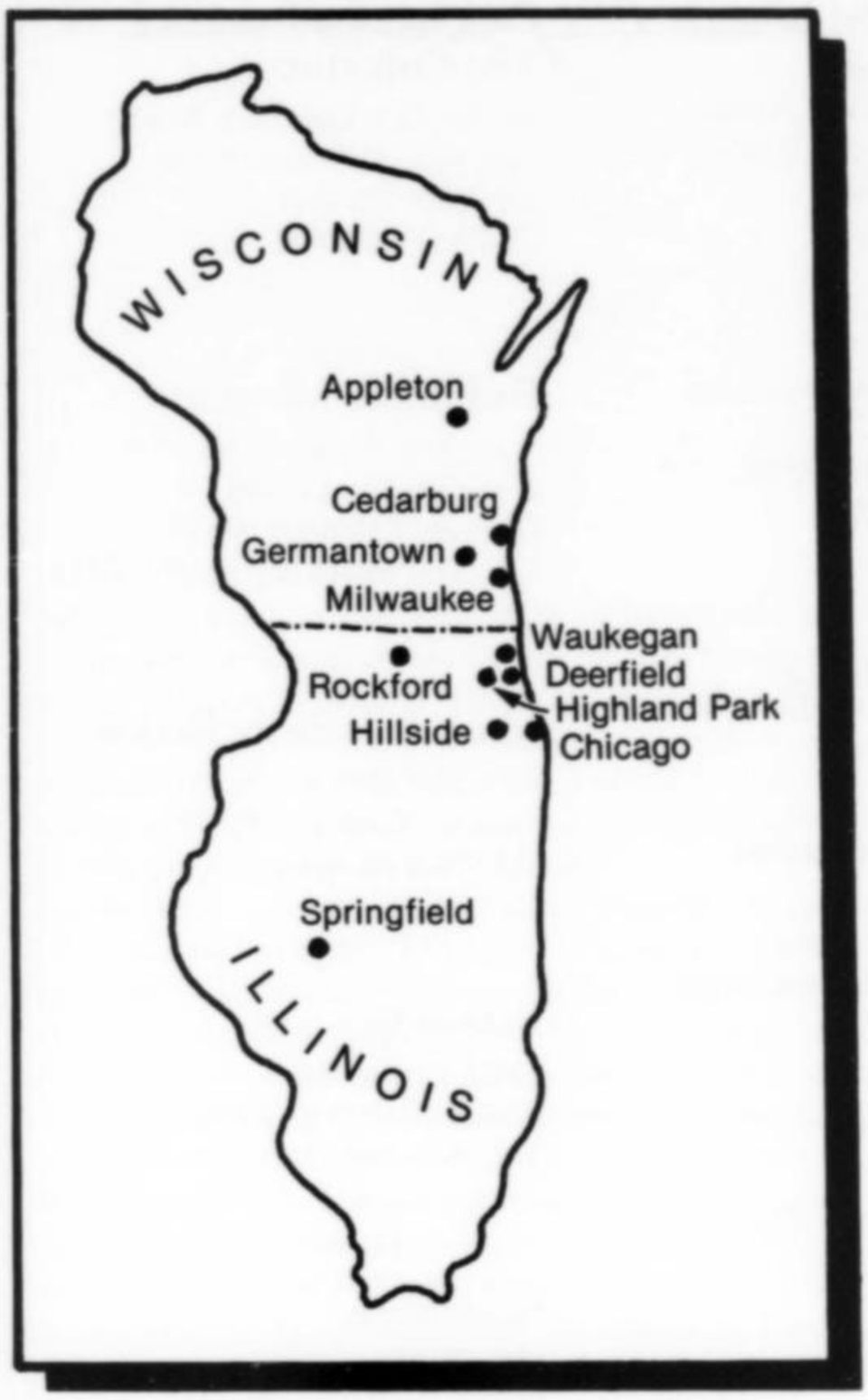
SCHRADER, F. C. (1931) Spruce Mountain district, Elko County and Cherry Creek (Egan Canyon) district, White Pine County, Nevada. *University of Nevada Bulletin* **25**, pt. 7, 39 p.

SUMIN DE PORTILLA, V., QUEVEDO, M. P., and STEPANOV, V. E. (1981) The structure of bayldonite: chemical analysis, differential thermal analysis, and IR spectroscopy. *American Mineralogist,* **66**, 148–153.

WILLIAMS, S. A. (1978) Mineralization at Granite Cap, Hidalgo County, New Mexico. *New Mexico Geological Society Guidebook, 29th Field Conference, "Land of Cochise."*

Illinois-Wisconsin

mineral dealers



MAKE CONTACT!

. . . with a great source for fine mineral specimens from Midwestern and Worldwide sources. We have everything from top-quality display pieces to affordable beginner specimens, thumbnails to cabinets. Give us a call! Many of us have lists, others are open by appointment or attend shows where you can see our stock. You'll enjoy seeing our material, and we'll enjoy meeting another collector!

Mineral Miner
Henry Schmidt
177 Blackhawk Rd.
Highland Park, Illinois 60035
(312) 433-2413
Worldwide Minerals, Appt. only

Mike Bergmann
919 Northwoods Dr.
Deerfield, Illinois 60015
(312) 945-0772
Fine Mineral Specimens

Earth Resources
F. John Barlow
P.O. Box 576
Appleton, Wisconsin 54912
(414) 739-1313

The Outcrop
Pete & Nancy Olson
P.O. Box 2171
Springfield, Illinois 62705
(217) 787-6149
By Appt.; List Available

David M. Crawford
1808 Harlem Blvd.
Rockford, Illinois 61103
(815) 962-5286
Quality Mineral Specimens

Grayson Lapidary, Inc.
Roy Grayson
5135 Washington
Hillside, Illinois 60162
(312) 449-1399
Wholesale & Retail, Appt. only

Reo N. Pickens
610 N. Martin Ave.
Waukegan, Illinois 60085
(312) 623-2823

Dave's "Down to Earth" Rock Shop
1312 Chicago Ave.
Evanston, Illinois 60201
(312) 866-7374
Fine Minerals & Fossils

Donald K. Olson Gemstones & Minerals
P.O. Box 766
Cedarburg, Wisconsin 53012
(414) 377-5844
See us at Major Shows

Precious Earth Co.
Lance T. Hampel
in The Gold Mine Shops
W156 N9666 Pilgrim Rd.
Germantown, Wisconsin 53022
(414) 255-4540
Fine Minerals; Open Daily

California Dealers

Bourget Bros.
1636 11th Street
Santa Monica, California 90404
Tel: (213) 450-6556

California Rock and Mineral Co.
P.O. Box 86
Brea, California 92622
Tel: (714) 990-5073

Frazier's Minerals and Lapidary
Si and Ann Frazier
Suite 306, 6331 Fairmont Ave.
El Cerrito, California 94530
Tel: (415) 848-9541

Galas Minerals
Chris and Agatha Galas
1419 N. Commons Road
Turlock, California 95380
Tel: (209) 632-6222

Cal Graeber
P.O. Box 47
Fallbrook, California 92028
Tel: (619) 723-9292

Hamel Minerals
6451 West 84th Place
Los Angeles, California 90045
Tel: (213) 645-1175

Ikon Mining & Exploration
Jim Walker & Mary Fong/Walker
2030 Shipway Avenue
Long Beach, California 90815
Tel: (213) 430-0080

Jewel Tunnel Imports
Rock H. Currier
1212 S. Mayflower Avenue
Arcadia, California 91006
Tel: (818) 357-6338
Wholesale Only

Kassionas
John and Dolores Kassionas
P.O. Box 578
Alviso, California 95002
Tel: (408) 263-7784

Kristalle
332 Forest Avenue, #8
Laguna Beach, California 92651
Tel: (714) 494-7695

A. L. McGuinness
Al McGuinness
4305 Camden Avenue
San Mateo, California 94403
Tel: (415) 345-2068

James Minette
25918 Cherryhill
Boron, California 93516
Tel: (619) 762-5308

Nature's Treasures
P.O. Box 10136
Torrance, California 90505
Tel: (213) 373-3601

Oxcart Minerals
Hollis & Priscilla Oxley
989 Leo Drive
San Jose, California 95129
Tel: (408) 255-1495

Pala International & The Collector
912 So. Live Oak Park Road
Fallbrook, California 92028
Tel: (619) 728-9121
US Wats 1-(800)-854-1598

Pathfinder Minerals
Mary Jean & Larry Cull
41942 Via San Gabriel
Fremont, California 94538
Tel: (415) 657-5174

Mark & Jeanette Rogers
P.O. Box 1093
Yucaipa, California 92399
Tel: (714) 797-8034

Schneider's
13021 Poway Road
Poway, California 92064
Tel: (619) 748-3719

Silverhorn
Mike Ridding
1155 Coast Village Road
Montecito, California 93108
Tel: (805) 969-0442

Weber's Minerals
605 San Dieguito Drive
Encinitas, California 92024
Tel: (619) 436-4350

Whatever you're looking for in the way of fine display specimens, rare species material, moderately priced specimens for beginning and intermediate collectors, bulk material for research and study, wholesale or retail, you'll find it in California. Plan to stop in when you're in our area. Many of us do shows, so it's always best to call first.

HISTORICAL NOTES ON MINERALOGY

Lawrence H. Conklin

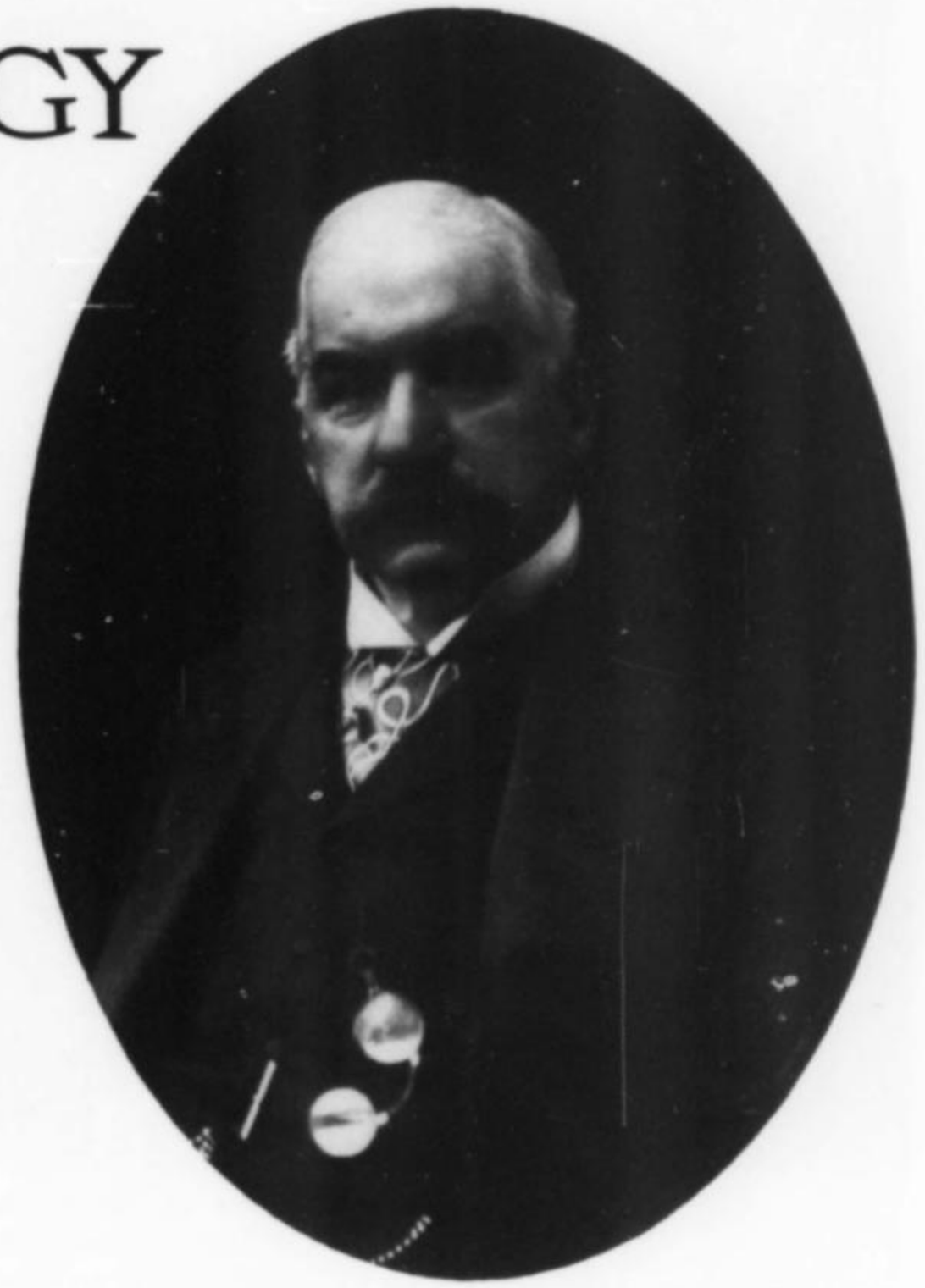


Figure 1. **John Pierpont Morgan (1837–1913).**

On the Old Morgan Hall

As a young boy I lived on East 75th Street in New York City. Whenever I managed to scrape up a nickel for bus fare I could get to the American Museum of Natural History at Central Park West and 79th Street in a few minutes; otherwise the trip on foot took about an hour. In either case, when I arrived I would find myself walking past the stuffed lions, the elephants and even the dinosaurs to enter the Morgan Memorial Hall of Minerals.

This mineral hall was named for John Pierpont Morgan (1837–1913), better known in his day as J. P. Morgan. He was one of America's great financiers and bankers, the third richest man in the country (only John D. Rockefeller and Andrew Carnegie surpassed him), and he was a philanthropist on a grand scale. It is said that, at their peak, the Morgan and Rockefeller interests controlled some $20 billion in corporate assets, about one-fifth of the total national wealth! So, when Mr. Morgan purchased the mineral collection of Clarence Sweet Bement (1843–1923) in 1900 for the sum of $100,000 (a huge amount for ordinary people of those days) it was "small change" for *him*. He then, through the efforts of George Frederick Kunz (1856–1932), another friend of the museum, donated "the finest collection of minerals ever made"[1] to the American Museum of Natural History; and this, it must be remembered, all happened before the days of income tax and tax deductible gifts! It is interesting to note that there was then no department of mineralogy at the museum; minerals were under the care of the Department of Geology. A new Department of Mineralogy was immediately set up and Louis Pope Gratacap (1851–1917) was named curator. Gratacap announced in a paper read before the New York Mineralogical Club on April 26, 1902, that all former collection pieces had been placed in storage and that all specimens on display, some 12,300 items, were from the Bement collection. It was essentially this collection, virtually undisturbed from its original display setting, that I spent so much time admiring some 40 years later.

The displays were full of wonder for a young boy, and he could learn so much from them too! One day I would concentrate on the study of pyrite and perhaps another day on galena (still labeled galenite). If I were studying quartz I could look down on perhaps a *hundred* or more specimens in those old, flat, glazed-top cases, lean over and, with my breath hot on the glass, get my nose to within inches of each piece. I could then study them and make comparisons as to varieties, localities, crystallizations, colors, etc., etc., learning much in the process. Today, of course, this cannot be done. I do not intend a criticism of the new display in any way; it serves these times well, these times of high-tech and microprobe analysis, but one simply cannot learn visual, comparative, sight mineralogy by viewing it; of course, it was not designed for that purpose. Neither, of course, was the old hall, but with thousands of specimens on display, all arranged according to "Dana's System,"[2] the magnificent alongside the ordinary, it was a natural setting for serious study. One thing the new hall (perhaps gallery is a better term) is designed to do, is to bring in casual traffic and introduce

[1] From *The Final Disposition of some American Collections of Minerals,* by Frederick A. Canfield (1922).

[2] The system, a chemical one, was invented by James Dwight Dana (1813–1895), and later refined by his son, Edward Salisbury Dana (1849–1935). Every mineral species known at the time (less than 1000) was assigned a "Dana number." Diamond was originally number one. This system was the natural result of the preoccupation by mineralogists of the nineteenth century for order in their science, and "systems" were published frequently. Needless to say, a "system" with numbers became incomplete upon the discovery of just one new species. Nevertheless, some collectors even up to the present time have used these Dana numbers to help them organize their collections.

Figure 2. **South facade of the American Museum of Natural History in New York, early 1940's. Photo by Dwight Bentle.**

the general public to the world of minerals. With that as a goal, it is eminently successful.

From its early beginnings in 1900 the collection has grown to a staggering number that exceeds 130,000 specimens, and is one of the largest such holdings in the world. Indeed, the American Museum of Natural History with its 19 interconnected buildings and 23 acres of floor space is, according to *The Guiness Book of World Records* (1983), the largest single museum in the world! In 1986 the mineral hall had more than 700,000 visitors; quite an increase over 1945.

Today the serious student of mineralogy must be content with studying only 6,000 specimens on public exhibit,[3] and this includes gemstones. However, each specimen is displayed to its maximum visual potential, and each is beautifully lighted. (There were times in my youth when I needed a small flashlight to really observe the minerals clearly, especially on cloudy days.) Nevertheless, it should not be thought that aesthetics were ignored in those early days; they were not. One curator (presumably Gratacap) had a small black arrow painstakingly painted on the bottom of every specimen. This was to show his successors the correct orientation, in his opinion, for the proper display of each piece!

In a recent conversation with an old friend and fellow mineral-enthusiast, Louis D'Alonzo, a collector from Nutley, New Jersey, I asked him about *his* early visits to the Morgan Hall. He first viewed the mineral collection as a boy of ten in 1932, a year before I was born. When pressed for his recollections, the first thing he mentioned was the elegantly handwritten labels that accompanied each specimen. I had completely forgotten about them, and I wonder if the new labels (typed or engraved on plastic) are really an improvement. Lou visited the Morgan Hall for the first time in the company of his 5th grade class, and soon found himself returning to the hall on his own. Was this a typical percentage of those infected with the passion to collect minerals, one in 30 or so? I fear not as the percentage seems too high. The round trip cost *him* 54¢. His favorite case for comparative study was the case of calcites, and calcites are still his favorite today. He recalls once meeting the mineral dealer John Albanese at the museum. Albanese was about 30 years old at the time. Although he was especially smitten with the mineral and gem carvings, Lou never tried to start a collection of them. He remembers that the chemical arrangement of the collection was of particular importance to him.

Peter Schneirla, senior gemologist and vice-president of Tiffany & Company, particularly remembers seeing, as a boy, a very large, faceted, oval-shaped aquamarine that sat on a custom-made mirrored base. (That stone from Minas Gerais, Brazil, weighing 737 carats, was on long-term loan from David Impastato, and was the largest faceted aquamarine in the collection at the time. It became a gift to the collection in 1959.) Peter proceeded with his education

[3] The actual breakdown is as follows: 4300 minerals, 1700 gems, 125 meteorites and 100 rocks.

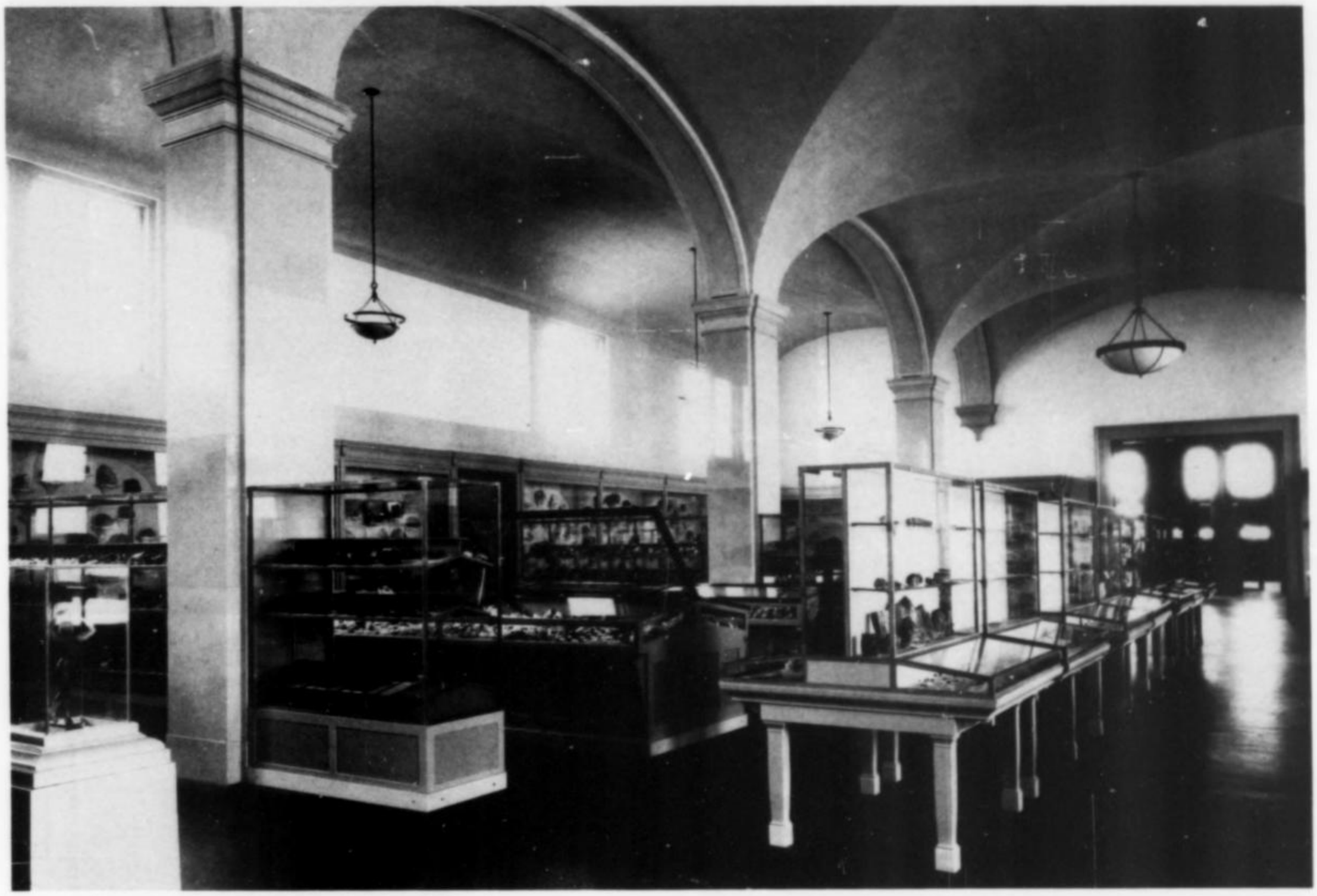


Figure 3. **Interior of the old Morgan Hall at the American Museum. Photo by Julius Kirschner.**

Figure 4. **One of the wall-cases in the old Morgan Hall. Photo by Rota.**

and went on to get a degree in physiological psychology and another degree in anthropology, but he is certain that it was the influence of the gem collection of the American Museum of Natural History, and especially the Impastato aquamarine impressed in his memory as a child, that led him ultimately to his career in gemology and to his present position.

There were times when I would put in a "full day" at the American, arriving around 10 a.m. and leaving by 4 or 5 p.m. I knew the security guards always observed me out of the corners of their eyes, and I am sure they got used to seeing me, but not once did a gesture of recognition pass between us. Perhaps I, who was often the sole occupant of the hall, kept them at attention so they could not sit down and relax.

One of my long-term favorite specimens, one that I made sure to see on *every* visit to the hall, is a very large blue crystal of topaz from Alabaschka in the Ural Mountains, Russia (Fig. 5). It measures approximately 8 x 8 x 10 cm, and, with its excellent basal cleavage, sits up perfectly. Its museum number is G(em)42236 and it presently resides in the vault, although it is scheduled to be put back on display in the near future. Bement purchased it in Berlin from the dealer C. F. Pech, during one of his European trips in the 1870's or 1880's, for 1500 marks or about $375.00. If I apply my well researched and well documented rule of thumb for the dollar of those days, and multiply the price by a factor of one hundred, the price now should be $37,500. I believe that most who know this piece, myself included, would consider that price to be low. So, perhaps Clarence Bement got one of his rare bargains. It is my opinion that mineral specimens were tremendously more expensive in Bement's time, on an absolute basis, than they are today, but that is another story. In his original cataloging of the Bement collection, Gratacap wrote on the index card of this specimen: "A colossus." Not much more need be said.

Another old favorite was a very large Chinese cinnabar matrix

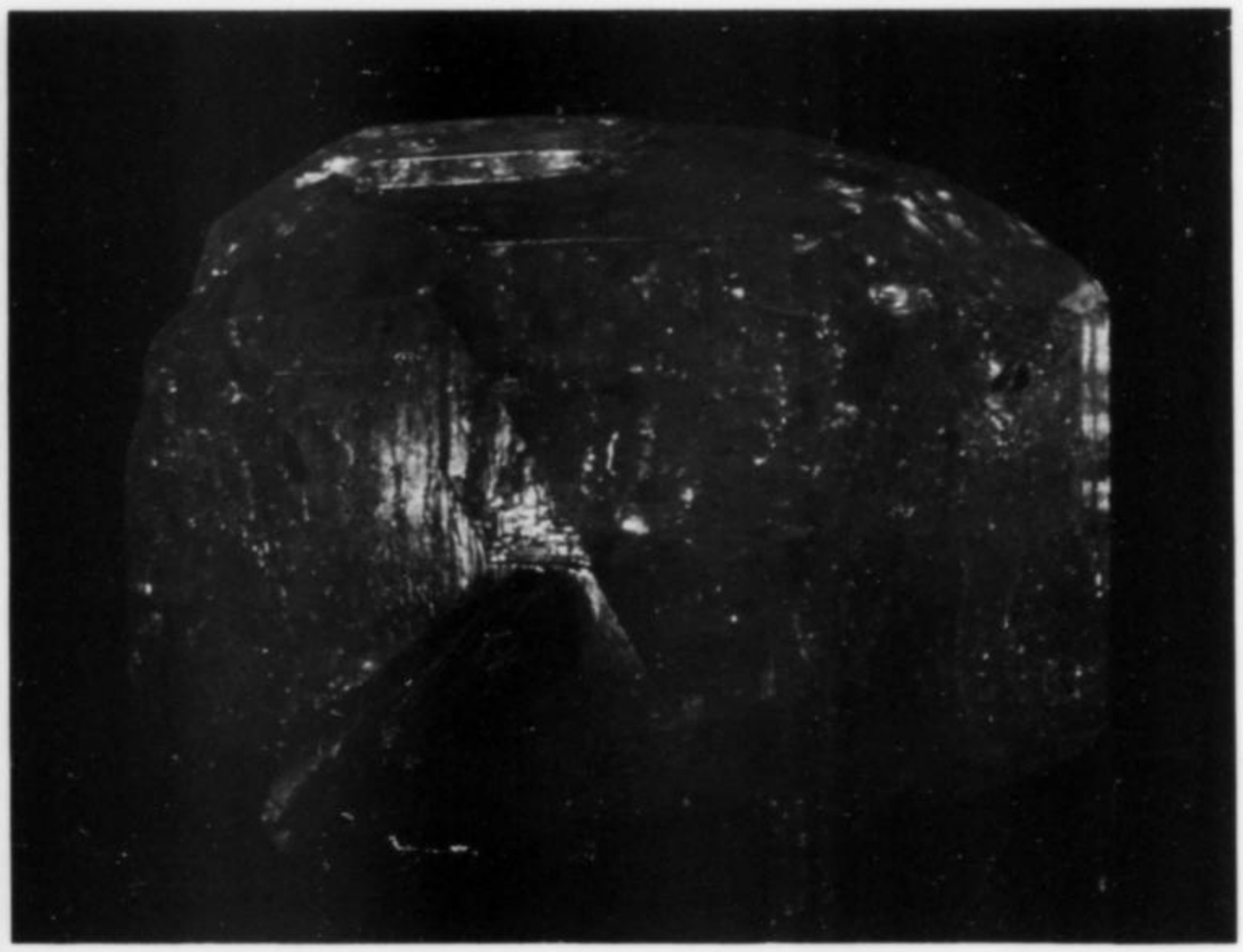


Figure 5. (above) **Topaz crystal, 10 cm, from Alabaschka in the Ural Mountains, Soviet Union.**

Figure 6. (left) **A youthful J. P. Morgan.**

Figure 7. (right) **Commemorative bronze plaque in the American Museum of Natural History.**

piece with many huge twinned crystals on it, a treasure of the collection of William Boyce Thompson (1869–1930). I wonder what I would have thought had I known (as was later discovered) that this great object of my attention and affection was actually a fake! It was eventually, and properly, reduced to several very fine small cabinet-sized matrix specimens that had been joined with the help of plaster of paris! Thompson, who founded The Newmont Mining Corporation in 1921, had a special fondness for very large specimens, and one suspects that this piece was "custom made" for him!

The curator of the collection in the 1940's was Frederick H. Pough, but I never had the good fortune to meet him in those days. What would I have thought of the idea that in the future our paths would have crossed numerous times, and that I would consider him, ultimately, a dear friend? I had cut my mineralogical teeth on his *Field Guide to the Rocks and Minerals,* and I suspect that countless mineral collectors and mineralogists can say the same. Perhaps many would never have entered the world of minerals had Fred Pough not taken the time and effort to write his classic book.

One old display at the museum that is sorely missed by me, and, I am told, by others too, is the collection of minerals found on Manhattan Island. How many visitors to the museum today are aware of the wealth of minerals found, literally, under their feet! In some instances world-class specimens were dug up in the excavations for building foundations and subways!

The mineral display of today that comes closest to the feeling of the old Morgan Hall, that I have seen, is at Harvard. I really enjoy my visits there, and walking on the creaky old wood floors is a special treat for me.

Strangely enough, although there were a few really great, large specimens in the wall cases of the Morgan Hall, such as the superb Japanese Stibnite (see Gratacap,[4] opposite page 22), I spent almost no time studying them. Perhaps it was because I lived in a small

[4] The full title is *A Popular Guide to Minerals, With Chapters on the Bement Collection of Minerals in the American Museum of Natural History,* by Louis Pope Gratacap (1912). Incidentally, I heartily recommend this book even though copies are hard to find. It is one of my favorite books, and the favorite of others too. Former Smithsonian curator Paul Desautels wrote me recently that, "it is one of my favorite historical books. The back section particularly is packed full of thought-provoking tidbits including Gratacap's opinions on things mineralogical plus his early 1900's attitude toward minerals, etc. (much of which I find myself attuned to)." In addition to his philosophy, Gratacap has added 120 very good photographs of specimens from the Bement Collection, including one in color. There are also numerous fine quality crystal drawings.

apartment and could not personally relate to very large specimens, or perhaps it was because the few really good things were surrounded mostly by pieces of indifferent quality.

Another thing I recall is that in all the hundreds, perhaps thousands of hours that I spent in the Hall, I never once met or spoke to a fellow mineral enthusiast. Although there were many times when I was completely alone, there were other times when I certainly was not. Perhaps mineral collectors in those days were too reserved to speak to strangers. And yet it's much the same today, even at mineral shows having fine exhibits. Too few people take the rare opportunity to introduce themselves and get to know others who are quite obviously interested in the same thing.

There were some special occasions, perhaps Christmas, or my birthday, when I would have two or perhaps three dollars to spend on a mineral specimen at the museum's gift shop. Unlike today, there certainly wasn't much of a selection of fine things for sale. And all suffered from the inevitable invidious comparisons made to the "great stuff" upstairs, but things like a 5 x 5 cm polished slab of "tiger-eye" (silicified asbestos) could be had. It certainly was not a great Chinese cinnabar, but it would save the day.

ACKNOWLEDGMENTS

Special thanks to George Harlow, Joseph Peters, Charles Pearson, Louis D'Alonzo and Peter Schneirla. All photographs were provided courtesy of the Department of Library Services, American Museum of Natural History.

Lawrence H. Conklin
17 St. John Place
New Canaan, CT 06840

If you enjoy this column on mineral history, you may wish to subscribe to *Matrix, A Journal of the History of Minerals* (Lawrence Conklin, editor, Jay Lininger, publisher). This new bimonthly publication will cover all aspects of the history of minerals and mineral people, including anecdotes, antique photographs, excerpts from early correspondence and so on. A complete, annotated reproduction of the Edwin Over–Arthur Montgomery correspondence (issued serially and suitable for eventual binding) is a planned feature. A subscription is $12/year. Order from Matrix, P.O.B. 129, Dillsburg, PA 17019.

Bitner's, Inc.
42 West Hatcher
Phoenix, Arizona 85021
(602) 870-0075

De Natura
Les & Paula Presmyk
P.O. Box 2512
Mesa, Arizona 85204
(602) 892-0779

Fosters
Wayne & Sarah Foster
1511 E. Edgemont Ave.
Phoenix, Arizona 85006
(602) 265-1567

Kino Rocks & Minerals
6756 S. Nogales Highway
Tucson, Arizona 85706
9-11:15/Noon-5:30 (Closed Sun.)
(602) 294-0143

Michels Minerals
Harold & Wilma Michel
1030 W. Tenth Street
Mesa, Arizona 85201
(602) 969-0105

David Riley Minerals
529 W. Pepper Place
Mesa, Arizona 85201-7209
(602) 898-0740

David Shannon Minerals
David, Colleen & Mike
1727 W. Drake Circle
Mesa, Arizona 85202
(602) 962-6485

Maudine & Bob Sullivan
Geological Specimens Int'l.
3202 Saguaro West Trail
Tucson, Arizona 85745
(602) 743-0081

SOUTHERN ARIZONA DEALERS

What's New in Minerals?

by Wendell E. Wilson

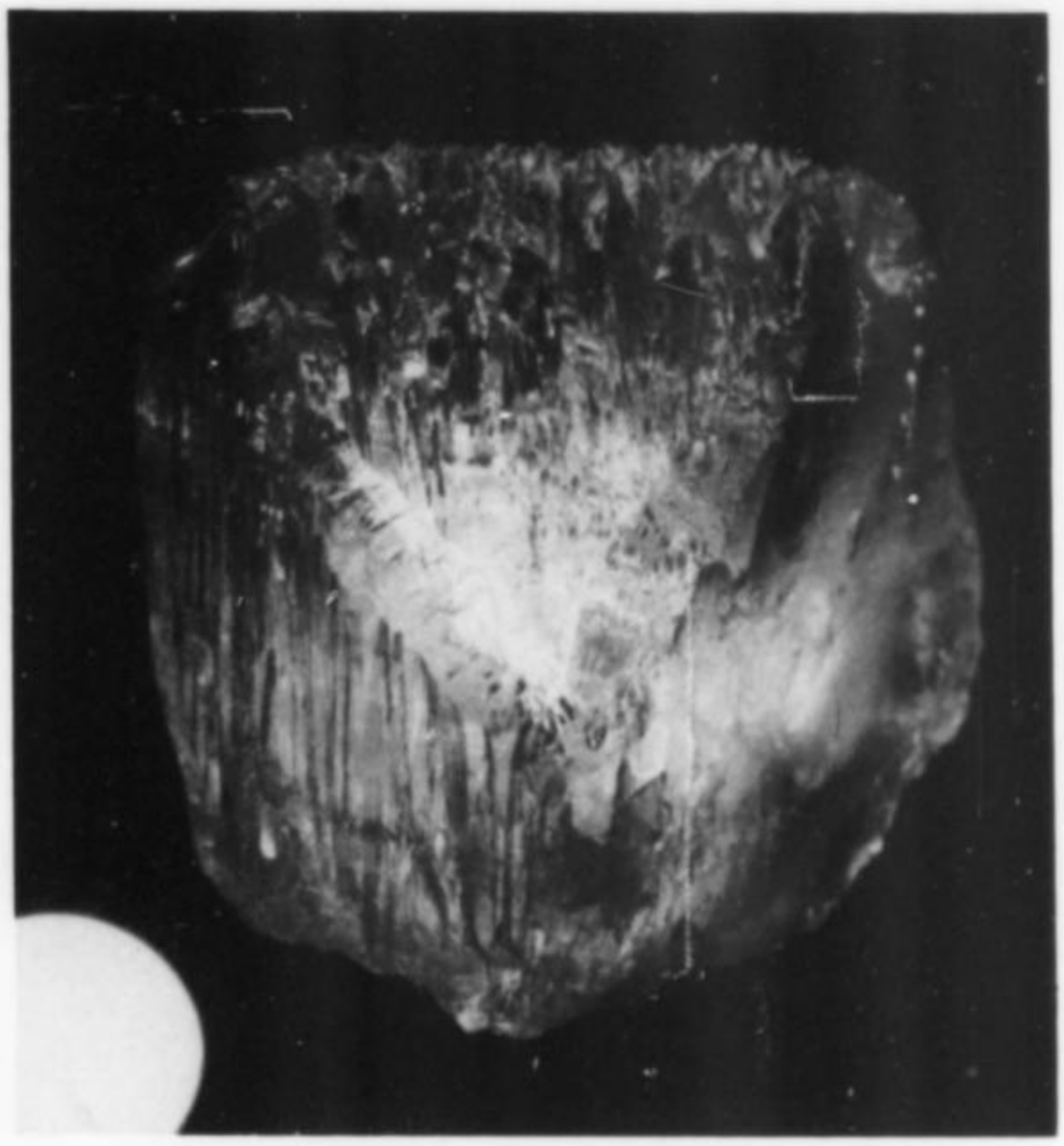


Figure 1. **Brown topaz crystal, 5.5 cm, from Coos County, New Hampshire. Collected by Peter Samuelson and Carlton Holt; photo by Carlton Holt.**

NEW MEXICO SMOKY QUARTZ

Bob Thompson (Renowned Mining and Minerals, 1925 Juan Tabo NE, Suite B-261, Albuquerque, NM 87112) has recently struck it big in Lincoln County, New Mexico, where he has been prospecting for quartz. In late July he came across an extensive sequence of pockets yielding thousands of very beautiful, highly lustrous to frosty, elongated, transparent and phantom-filled smoky quartz crystals up to 20 cm in length. In only one day 227 kg (500 pounds) of crystals and crystal groups were removed! The occurrence promises to rival Brazilian smoky quartz in esthetics if not quite in volume. There are few associated minerals other than feldspar. Bob is not yet divulging the precise location, but has named it the Smokey Bear prospect. The color is reminiscent of the exquisite Japan-law twins of smoky quartz that came from El Capitan Mountain in the same county a few years ago (see vol. 8, p. 58–60, vol. 14, p. 330). Wayne Thompson (1723 E. Winter Drive, Phoenix, AZ 85020) is the distributor for most of these specimens.

NEW HAMPSHIRE TOPAZ

Peter Samuelson (R.F.D. #1, Box 11, Intervale, NH 03845) and Carlton Holt have uncovered some of the finest topaz crystals ever found in the U.S., at a small pegmatite located in Coos County, New Hampshire.

Samuelson began exploring for topaz in the northern New Hampshire Conway Granite after having read an old article in *Rocks and Minerals* magazine ("Amethyst-smoky quartz-topaz in Northern New Hampshire," by Harold J. Verrow, *R&M,* vol. 20 (1945), p. 255), and having been given a tip by a friend who had hiked the area. In October of 1986 he found a collapsed pocket area which he estimates originally measured nearly 3 meters long and roughly 1 meter wide and deep. Samuelson and Holt have been quietly excavating it since that time, and recently displayed all of the material at the Sunapee, New Hampshire, show last August.

The find, which they have named "the Rainbow pocket," has yielded about 150 kg of fine specimens. Over 120 excellent topaz crystals (none on matrix) measuring from 2 to 13 cm have been found, the largest weighing about 2 kg (4½ pounds). The crystals are very sharp and lustrous, equant to somewhat elongated, and a good blue to blue-green or bicolored blue and golden brown. Many of the crystals are flawless or nearly so.

Also found in the pocket was a large quantity of smoky quartz crystals, about 100 kg, plus another 30 kg of high quality gem rough. One crystal weighs over 9 kg (20 pounds) and measures about 18 x 38 cm. All of the crystals are very gemmy and a rich gray-brown coffee color, sometimes showing orange internal reflections. None have been found on matrix, however, and the luster tends to be dull.

Citrine quartz; sharp microcline crystals to 6 cm; several excellent siderite crystals to 6 cm, in rhombohedral to modified rhombohedral habit and opaque brown to black color; small astrophyllite needles penetrating smoky quartz crystals; and muscovite have also been found in the pocket.

MEXICAN MINERALS

Wayne Thompson (1723 E. Winter Drive, Phoenix, AZ 85020) is back into mineral dealing after a hiatus of several years, and reports several interesting discoveries from Mexico. Santa Eulalia has yielded several hundred specimens of coarsely crystalline, yellowish to greenish brown botryoidal mimetite in knobby groups to 25 cm. From the same locality: a small lot of 25 to 30 specimens of nicely colored rhodochrosite in highly elongated "pencil" scalenohedrons to about 4 cm. Naica has recently produced 75–100 pieces of excellent blue anhydrite on matrix, better looking that what people remember from previous finds. Single crystals reach 10 cm and more. Specimens have been available through Bitner's in Phoenix and Rock Shop of El Paso. The Las Vigas amethyst locality in Veracruz has been yielding a fair amount of mediocre material and also some unusual sceptered specimens, 23 groups and about 40 good single crystals. One hundred specimens of botryoidal yellow mimetite from San Pedro Corrallitos recently surfaced, not from a new find of this classic material but from a supply that had remained in storage since the late 1960's. And finally, a few nice proustites, stephanites and pyrargyrites have emerged, probably from Guanajuato but the locality is, at the moment, uncertain.

Gene Schlepp (*Western Minerals*) reported seeing about 60 specimens of stibnite from Taxco. There are a few cabinet pieces, 10–15 cm in size, and the rest are in the 2–7 cm range. Crystals are nicely formed but small, rarely exceeding 5 mm or so, and occur in interesting hemispherical bunches on matrix. Most of these went to a dealer in Spain, although Gene retained a couple of the cabinet specimens.

Figure 2. **Smoky quartz crystal group, 5 cm, from the Smokey Bear prospect, Lincoln County, New Mexico. Bob Thompson specimen.**

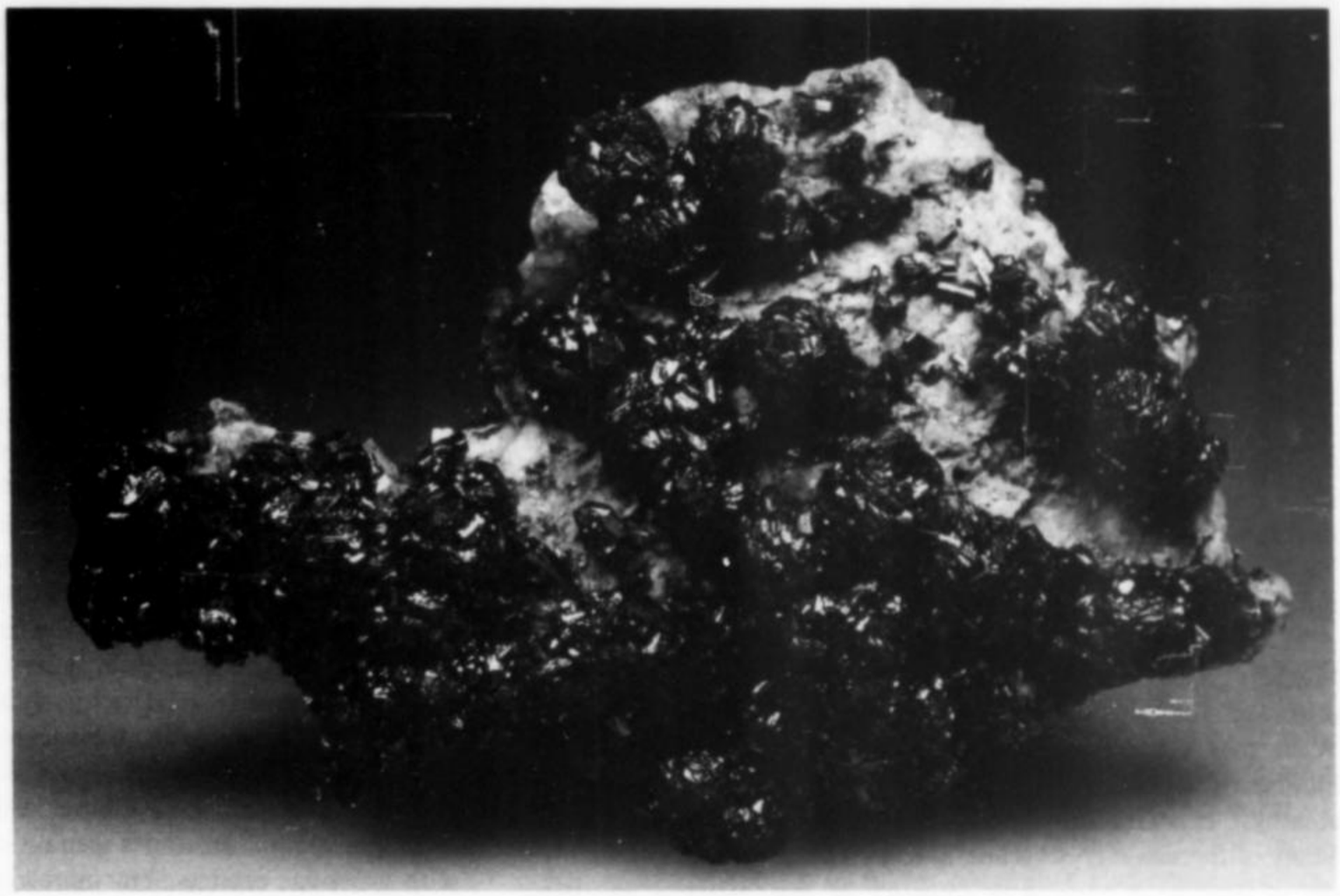
Figure 3. **Topaz crystals from Coos County, New Hampshire, collected by Peter Samuelson and Carlton Holt. Left to right: 5.5 cm; 13.5 cm; 9.6 cm; and 8 cm. Photo by Carlton Holt.**

MOROCCAN PHOSGENITE

Victor Yount reports that more phosgenite crystals have been recovered at the Touissit mine near Oujda, Morocco. Phosgenites have been found there intermittently for a number of years, but never in large quantity. Often they are mistaken for cerussite, but can be distinguished by their basal cleavage. Crystals up to 10 cm long and 4 cm wide, chocolate-brown, transparent and on matrix are known but are very rare. A number of crystals up to 5 cm in size, well terminated and in some cases doubly terminated have been seen on the market just recently. These specimens are some of the finest phosgenites known from anywhere in the world; some have been cut as collector gems, and Victor currently has a 34-carat facetted stone in his collection.

Figure 4. **Amethyst from Amherst, Virginia; 4 cm and 3.5 cm. Victor Yount specimens.**

Figure 5. **Stibnite on matrix, 12 cm, from Taxco, Mexico. Gene Schlepp specimen.**



OTHER DISCOVERIES

Victor Yount also reports obtaining an excellent lot of cubanites from the Chibougamau district, Quebec (see vol. 14, p. 151). The crystals reach up to about 4 cm in size and are very lustrous. There are good cyclic twins in the lot, and a number of matrix pieces.

Also from Vic comes word of an amethyst discovery at Amherst, Virginia. These specimens are the brightest and most deeply colored examples ever recovered from the locality. The crystals occur as individuals to about 4 cm, in tightly packed groups showing very little prism face and mostly terminal rhombohedrons like the well-known Uruguayan material. Some specimens are a bit more prismatic, similar to crystals from Due West. About 40 specimens comprised the lot.

Chris Wright *(Wright's Rock Shop)* reports the discovery of some remarkable marcasite in lustrous, bladed crystals to 7 cm, from Bell County, Texas. About 100 pieces were recovered, thumbnail size to 35 cm.

Peter Hall, writing in the first issue of the new *Australian Mineralogist,* makes note of some other recent discoveries.

Crystals of turquoise to 1 mm in size, lustrous and transparent to translucent, have been found in association with 1 to 2-mm libenthenite crystals at the Mt. Oxide mine, Cloncurry, Queensland, Australia. Turquoise crystals have previously been found only in Virginia, Belgium and Cornwall, England (see vol. 12, no. 6, p. 349).

A pocket of thaumasite crystals has been uncovered at the N'Chwaning mine No. 2, Kuruman, South Africa, yielding about 200 crystals up to 2.5 cm in size. Most are singles, pale lemon-yellow to colorless, transparent and, in some cases, doubly terminated.

Gem-quality crystals of pale green titanite, well terminated and measuring up to 2.5 cm in size, have been recovered in the Dusso area, Gilgit, Pakistan (see vol. 16, no. 5, p. 398). Only a few specimens have turned up.

RECENT COLORADO DISCOVERIES

[The following notes were provided by Barbara Muntyan.]

Just when one thinks that all the minerals have already been found, dug, trimmed, cleaned, catalogued and put away, another

new find is made. 1987 has been a bonanza year in Colorado; four important new occurrences have been discovered. One is in Ouray County, one in San Juan County, one in Fremont County, and one in Larimer County – in other words, in all parts of the state.

In Ouray County, at the famous Camp Bird mine, a very important vug of scheelite has been produced in the King Stope, 5 Level, of the East Camp Bird. Not only is scheelite a rare species for the state, but this is the first reported occurrence of scheelite in the San Juan Mountains. Moreover, these are not mere specks. The crystals are up to 2 cm on edge, with the largest crystal found measuring almost 5 cm across. The crystals are generally a dark cinnamon-brown with a high luster. They occur on a matrix of granular, white fluorite; small sprays of calcite, an occasional quartz crystal, and a few very small chalcopyrites are associated. While most specimens are composed of single crystals scattered in a pleasing manner across the matrix, several excellent plates have been recovered consisting of little matrix and intergrown groups of sharp, dark, cinnamon-color crystals. Although such claims usually raise eyebrows (including mine), these are without dispute the best scheelites to come from Colorado.

In San Juan County, an old working near Eureka has yielded some wonderful waterclear, palest green, complex fluorites on stout quartz plates. The fluorites are generally cuboctahedrons. Included within the fluorite crystals are very small chalcopyrite crystals. The crystals are up to 5 cm across, although most are much smaller. While many people would say that the dark green fluorites from the American Tunnel represent the finest examples of fluorite from Colorado, for gem-clear specimens these are certainly the best I have seen.

As if these discoveries weren't enough, there is yet another find of new material, this time near Canon City in Fremont County. The species is gahnite, the zinc spinel, a quite uncommon species in Colorado. These crystals are found in a narrow quartz seam near the Royal Gorge area, in Grape Creek. The crystals are very sharp, blackish green octahedrons, some exceeding 2 cm on edge. Most are much smaller, but the largest reported crystal, although not quite perfect, is nearly 5 cm on edge.

In Larimer County, the End-of-the-Rainbow claim at Red Feather Lakes has recently been leased and is currently being reworked for amethyst (for which this locality is well-known). What makes the new material noteworthy is that a significant number of the specimens consist of matrix pieces with one or more amethyst crystals on rough plates of hematite-included quartz. Many of the single crystals are doubly terminated and approach 10 cm in length. A very large quantity of this material has been recovered, but as is often the case, the really top specimens are quite limited in number.

Each of these new occurrences deserves a more detailed article. It seems that whenever you think they're all dug, someone comes up with new material. As of this writing (early August, 1987) it is expected that each of these finds will make their official "debut" at the Denver Show in September.

NOTES FROM EUROPE

[Our Dutch correspondent, Dr. Jan Stobbe (Sportlaan 35, 1782 NS Den Helder, Netherlands), sends the following summary of some recent European discoveries. Ed.]

Netherlands

Probably very few people are familiar with the minerals of Holland. It's difficult to believe that any minerals can be found in the Low Countries. Nevertheless, some noteworthy occurrences do exist there.

Agates and chalcedony are locally abundant in old deposits along the Ijssel River, in the province of Gelderland. Of course these did not originate in Holland, but were transported downriver from the Idar-Oberstein region of West Germany during the last ice age. Though waterworn when found, cut and polished specimens are spectacular, showing all the color varieties for which Idar-Oberstein is famous. Sizes range from 1 to 25 cm and reach as much as 6 kg (13 pounds). Nice specimens of black petrified wood occur there too.

In the southern part of Limburg province some fine, large crystals of pyrite, quartz and calcite have been found in the course of mining coal, and nice specimens have also been found on the old dumps.

A spectacular find of gemmy celestine crystals to 2 cm was made at a locality near Winterswijk in the 1970's. The crystals occur in geode-like concretions, in association with scalenohedral calcite and also pyrite crystals to 1.5 cm.

Mineral shows in Holland and elsewhere in Western Europe have had some interesting new things to offer during the last year or two, including the following:

Soviet Union

Old specimens dating back to Czarist times are occasionally offered, but quality is mediocre. From the famous Berezovsk gold mines I saw a large matrix specimen of crocoite crystals, measuring about 15 x 25 cm and having reasonable coverage (price: $150).

A matrix specimen of crystalline gold in quartz, 3 x 4 cm, was reasonably priced at $65. The locality was given only as "Caucasus" on the old label, referring to a mountainous region near the Turkish border.

A nice, translucent, terminated, 3-cm crystal of phenakite on matrix from Takowaja in the Ural Mountains was cheap at $70. Matrix specimens of this mineral are quite rare.

Andradite in attractive, lustrous, dark brown crystals on matrix has been appearing at shows since 1985. The locality is Czegujewa near Tetjuche, Vladivostok area, eastern Siberia. The crystals reach several centimeters. From the same locality, nice datolite, prehnite and ilvaite crystals have been reported.

Lovely sea-green or oil-green grossular crystals from the classic Wilui River district appear on the market from time to time. The locality is near Chernyshevsk. From the same area have come some large, sharp, well formed "achtaragdite" crystals; these are actually pseudomorphs, probably feldspar after helvite, found near the Achtarand River. Also from the Wilui area, some sharp, euhedral, lustrous crystals of "wiluite" have been collected; "wiluite" is a variety of vesuvianite sometimes seen on old labels. It occurs associated with grossular crystals, but matrix specimens are extremely area (I've seen only two such specimens in 18 years).

Finally, from Primorski Kraj, eastern Siberia, have come some interesting aragonite crystal specimens. The crystals are opaque, sharply terminated and in some cases doubly terminated, in radially concentric groups.

Great Britain

Compound or complexly terminated groups of calcite crystals have been reported from Tafts Well, near Cardiff, Wales. The scalenohedral-rhombohedral crystals are large (to 15 x 20 cm), translucent, sometimes with disseminated limonitic inclusions, and free of matrix.

Switzerland

This famous mineral-collecting country still produces excellent mineral specimens. In 1985 a cavity was opened at Cavradi-Schlucht, Graubünden, which yielded interesting, twinned and terminated djurleite-digenite crystals to 4 mm. Pseudomorphs of brochantite and malachite after chalcocite (?) crystals to 3 cm were also found. The original mineral might also have been stromeyerite; the twins are very similar in habit to Cornish chalcocite illustrated

by Greg and Lettsom (1858) *Mineralogy of Great Britain and Ireland*. (These identifications were made by Prof. Oberholzer, ETH, Zürich.)

THE QUARRYVILLE SHOW

[Thomas Moore, our indefatigable columnist on events Germanic, found himself in America for a few days this summer and took the opportunity to file the following show report. Ed.]

Because I'd decided to sit out the St.-Marie Bourse this year, I had been pretty well resigned to a showless midsummer in Europe (in fact, a summerless midsummer: we are now wearing sweaters and wondering about turning on radiators in this, the first week of August in the Rheinpfalz). But some family affairs unexpectedly intervened in late July to take me for a week's visit to Lancaster, Pennsylvania, my hometown – and I spotted an ad in a Lancaster newspaper which was to lead to my rescue from a barren summer mineral-shoppingwise. For obvious reasons, I was at first dubious about going at all to something called the *First Annual Lost Dutchman Gemboree* in the village of Quarryville, deep in southeastern Lancaster County. But a mineral-show experience improbably beyond all my cynical expectations, and moreover of a much different stripe from the ones I've become used to in Europe, redeemed the day.

So come with me to Quarryville, with its Amish or "Pennsylvania Dutch" ambiance ("Dutch" being the common corruption, among tourists and locals alike, of "Deutsch"; the original Amish and Mennonite settlers were driven here from Germany and German-speaking Switzerland by seventeenth-century Protestant turmoils). Eastern American collectors may also be aware that Quarryville is the town nearest to the old Gap Nickel mine, which produced very fine millerite specimens in the earlier nineteenth century, but which now offers only a few small dumps.

So, dodging around the ubiquitous traffic-hazard Amish buggies, stroking these varied memories and associations of youth, I enjoyed the drive through summery landscapes of cornfields and weathered farmhouses, expecting to spend perhaps a token half hour looking around at the Gemboree, and then, duty done, to leave shrugging. You may imagine my surprised delight to find, instead, enough good and interesting minerals to keep me browsing contentedly for three hours, this even after passing by the predictable 70% or so of the dealerships devoted to lapidary items, fossils, "Indian" jewelry, etc.

Nor was I prepared to rediscover how many more sideshows of a lovable sort and how much paraphernalia of every frivolous and instructive variety are apt to characterize American shows. Here, inside the Hofmann Community Building which housed part of the show, was a cafeteria-style setup offering breakfasts, lunches and "full-course dinners"; outside, surrounding the open-sided livestock sheds where the bulk of the dealers' stands were, snack concessions offered Pennsylvania Dutch mysteries like "funnel cakes" (don't ask: I didn't try any). Also outside were charcoal-pit areas for cookouts; game booths; a bandstand where later a country music concert would happen; and booths selling Lost Dutchman Gemboree T-shirts and tankards. In addition, posters inside the Community Building's main door gave departure times for organized field trips; and other posters announced a program of lectures on subjects including "Fantastic Minerals from Cornog, Pa.," "How to Buy Minerals and Gems," "Diamonds," and "The Metaphysical Use of Crystals and Gems." The central attraction among the sideshows was Sam Redman's display of the "Santa Terra" emerald, originally a 175-carat crystal, now a 49.6-carat faceted gem, found about a year ago near the village of Santa Terra, state of Goias, Brazil. Appraised at about $1.2 million, it is "said to be among the largest Brazilian emeralds in North America." But, I think, what finally won my heart for this show was the painted circus clown who went around kicking people in the derrieres and then offering to take their pictures: how German and staid I've become, I thought, in all these years of haunting the singlemindedly businesslike European show scene. So I do hope that this First Annual razzle-dazzlement at Quarryville will prove successful enough to spawn a second, third, etc. Be sure to include it in your next summer's itinerary if you happen to find yourself in Pennsylvania Deutsch country around late July.

The mineral dealers, nearly all from the eastern U.S., had stocks which offered me a rare chance to catch up on what's doing in the eastern U.S. market and at collecting sites within a latitude line or two of my ancestral homeland. For example, Hans van Brindbergen of *Classic Minerals* (Township Line Rd., Uwchland, PA 19480) had a small stand with unremarkable miscellaneous things among which was a flat of indeed remarkable thumbnail, miniature and small cabinet specimens of turquoise crystals from the old locality of Lynch Station, Campbell County, Virginia. This old copper prospect once produced what are probably the world's best crystallized turquoise specimens, and van Brindbergen's selection was a newly released hoard. At their largest the crystals are still barely above micro-size but are very bright sky-blue, forming sparkling coatings on white quartz or phyllitic matrixes. The star piece here was a gorgeous thumbnail (for $100) with 5-mm rosettes of sharp crystals standing up most attractively from a seam.

Arnold and Michele Goldstein of *The Showcase* (103 Kenner Road, Minoa, New York 13116) had five flats of variously sized, really quite impressive (for the species) specimens of graphite crystals in a dark green augite matrix from Lead Hill (or "Chilson Hill"), Ticonderoga, New York (see the article in vol. 14, no. 1), recently collected. The specimens had been prepared with great care, so that the delicately flexible, metallic gray plates, some showing hexagonal profiles, stood up nicely on many pieces. All were priced quite low, from $2 for a small thumbnail to $10 for a 5 x 8-cm piece thickly strewn with subhedral graphite plates.

Some busy field collectors from *Prospectors Pick* (147 Elm Street, E. Bridgewater, MA 02333) had some very nice zeolites which they had gathered by rapelling from sheer cliffs above crashing seas at Wassons Bluff, near Parrsboro, Nova Scotia – rather than by foraging, as do the peons at this popular collecting site, among the alluvia at the base of the cliffs where only dinged specimens may be found. The result was a large number of very handsome and undamaged groups of orange chabazite rhombohedra, and stilbite in clean, yellow-orange clusters of sheaves, with individual crystal (or sheaf) sizes for both species about 1.5 cm. Groups ranged from thumbnail to large miniature in size and from a dollar or two to $10 in price.

As I say, the bulk of the show was held outside in the livestock sheds, but one very noteworthy dealer inside the show building (*F & L Minerals,* 9735 Seavitt, Allen Park, MI 48101) offered a plethora of sharp, stacked-cube groups of the well-known argentite-acanthites from the Reyes mine, Guanajuato, Mexico. These were rather pricey, as befits well crystallized argentite, but still, I think, smart buys at from $50 to about $200 for thumbnail to small cabinet sizes.

But unquestionably the show's best overall selection of minerals – even with my personally skewed taste and addled judgment accounted for (since most of them were thumbnails) – was at the stand of Thelma Kirsch of the unpromisingly named *Mineral & Needle Craft Creations* (P.O. Box 614, Oceanside, NY 11572). Ms. Kirsch, a nice and knowledgeable lady bedecked all over with lavish lapidary creations, had her very best thumbnails in a special glass-topped case, and these included some real wonders, e.g. a lush purple-blue Tsumeb scorodite ($500); a whole row of the new

California gold; veszelyites from the Black Pine mine, Phillipsburg, Montana; three Chinese cinnabars; a magnificent Moroccan anglesite, and other such top-class stuff. But I spent most of my time there gleefully pawing through the eight of ten large flats of Perky-boxed thumbnails stacked casually at the end of her stand. One normally expects such irreverently treated, marginal stock to prove mediocre upon close inspection; but no, here were some outstanding Bunker Hill, Idaho, pyromorphites; Melones Lake, California, ferroaxinites in gemmy brown singles and groups; sharp tetrahedrites from the Black Pine mine, Montana; Minas Gerais apatites in gemmy pale yellow groups; Glove mine, Arizona, wulfenites; brilliant Italian vesuvianites . . . a serendipity or a dozen in every flat. Ms. Kirsch's prices I would describe as "full," though there were a few real bargains to be had – and if I'd expected more from this show in general and had brought more money along I'd have "had" more of them myself.

Microminerals

Bill Henderson

From time to time, kind readers write to me with helpful and insightful comments on past columns or with interesting literature references of which I was not aware. Other readers have pointed out the occasional error which has slipped by. The time has come to convey their messages to readers of this column.

The Micromounting column in vol. 17, no. 4, p. 271, featured acicular crystals from Rock Creek, Washington, labeled mesolite. They were sent to me as such and described as being like the ones shown in the *Encyclopedia of Minerals* by Roberts, Rapp and Weber (1974). Sure enough, there they were in the *Encyclopedia,* labeled mesolite, and I assumed everything was fine. Not two weeks after publication, I was going over my zeolite minerals preparatory to giving a talk on that interesting group, and I found specimens in my collection of the same mineral from the same locality but labeled mordenite. A quick check showed the crystals described in the *Mineralogical Record* to have indices of refraction less than 1.502 and to have parallel extinction, thus fitting mordenite but not mesolite. Hence, the *Encyclopedia* and I were wrong. A few days later, my sharp-eyed and long-time friend Mike Groben wrote to inform me of my error. (See, by the way, the Notes from the Editor

In the Micromounting column on magnetic minerals (vol. 17, no. 2, p. 138) peculiar spheres of Australian siderite were pictured which I referred to as basket-weave siderite. Frank Robinson of Parkdale, Victoria, Australia, wrote that these are not what the folks "down under" consider basket-weave siderite, and he sent me photos of the real thing (Figs. 1 and 2). These he describes as "botryoidal forms [of siderite] coated with brown or blue clay which is superimposed with a criss-cross pattern of secondary siderite." It's easy to see the difference.

Anent the column on magnetic minerals, Bryon Brookmeyer of Harrisburg, Pennsylvania, sent a fascinating and truly rare specimen. While many of us have liquid inclusions in quartz, how many have specimens of liquid inclusions in quartz but containing movable crystals of pyrrhotite? These (see Figs. 3 and 4) contain minute, tabular pyrrhotite crystals, many of them with a hole through the center, and a few of them which can be moved using a magnet!

In a Micromounting column on flat twins (vol. 14, no. 6, p. 363) it was proposed that flat twins form because growth in the reentrant angle of the twins is faster than growth elsewhere. At the time, I could find no such theory in the literature. However, Keith Harshbarger of Altadena, California, wrote to tell me that such a theory has been propounded in a Russian text, *The Ontogeny of Minerals*

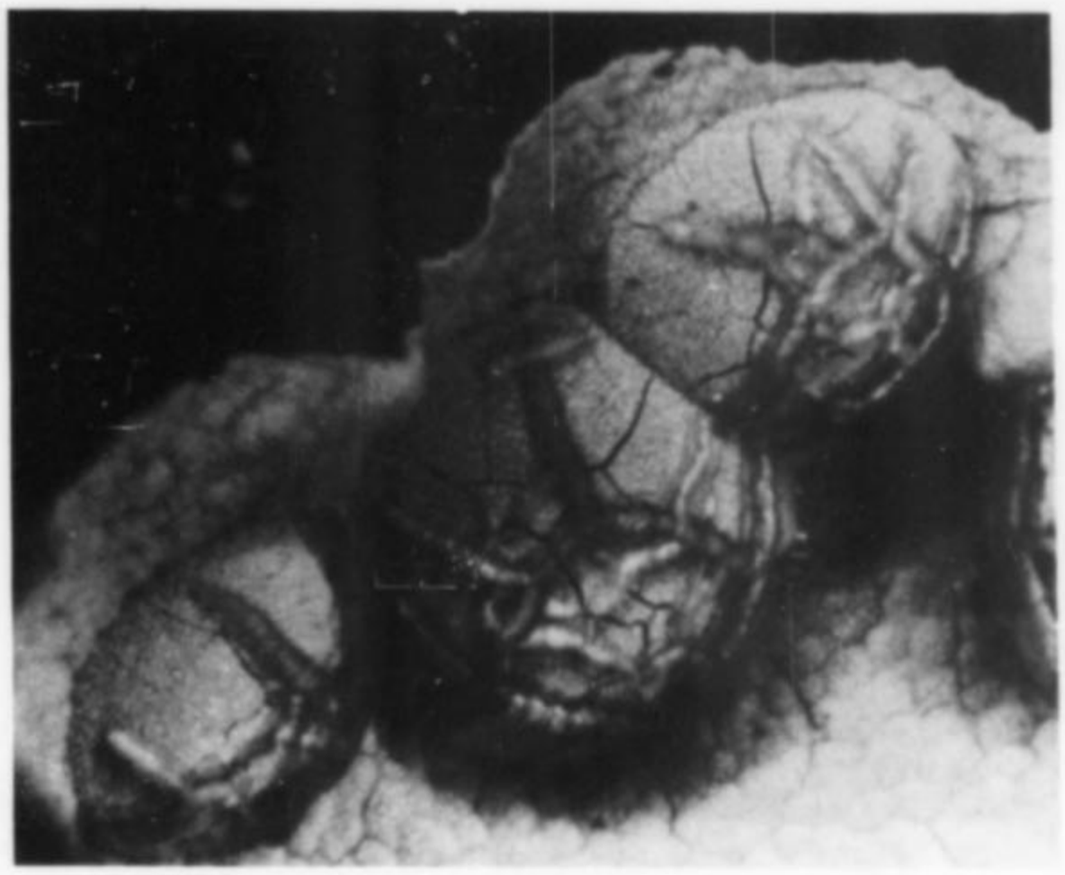


Figure 1. **Spheres of siderite from the Narre Warren quarry, Berwick, Victoria, Australia, coated with a clay mineral and then with "fingers" of secondary siderite with a "basket-weave" pattern. Field of view, 6 mm.**

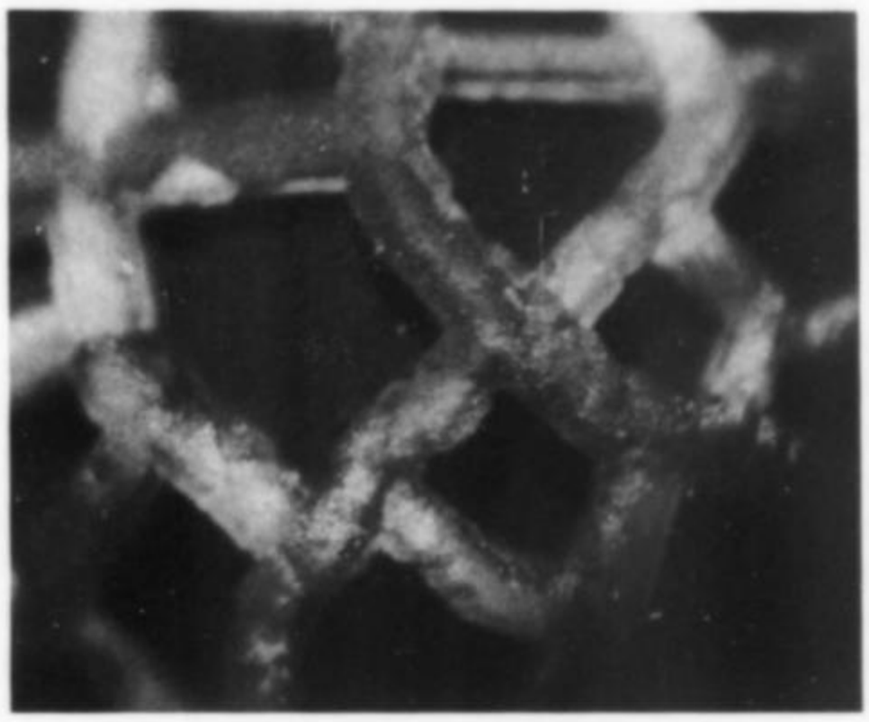


Figure 2. **Closeup view of light tan, basket-weave siderite on blue clay coating over earlier siderite, as in Figure 1. Size of sphere, 2 mm. F. Robinson photo.**

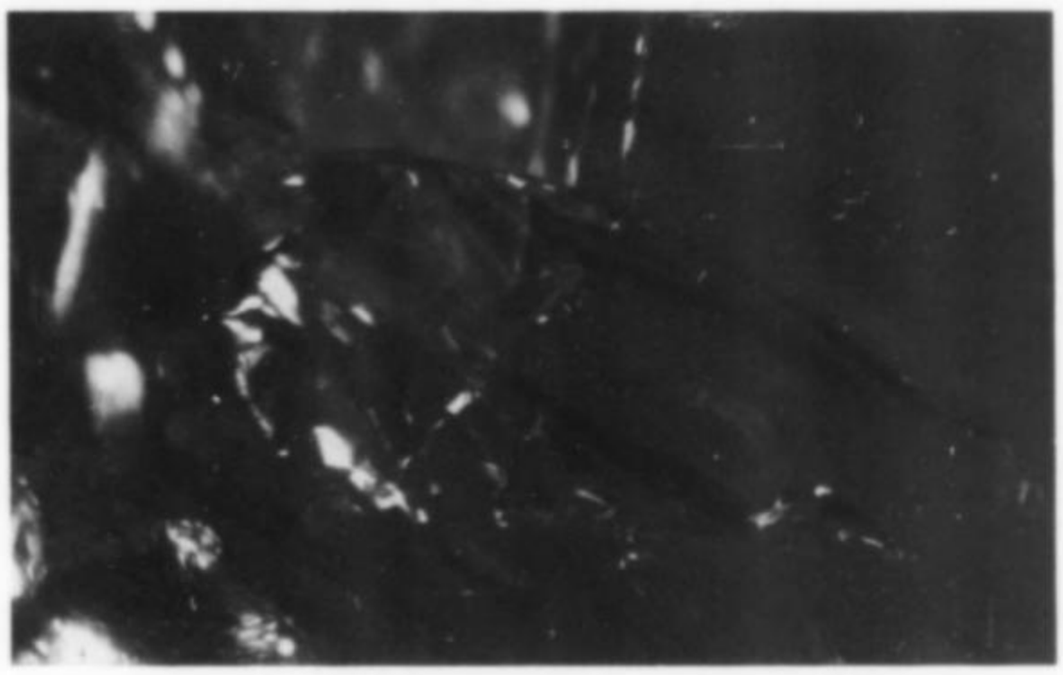


Figure 3. **Dark bronze to almost black, tabular crystal of pyrrhotite, which can be moved with a magnet, in a liquid-filled inclusion in quartz. From a railroad cut west of Newton-Hamilton, Mifflin County, Pennsylvania. The crystal is 0.8 mm in diameter.**

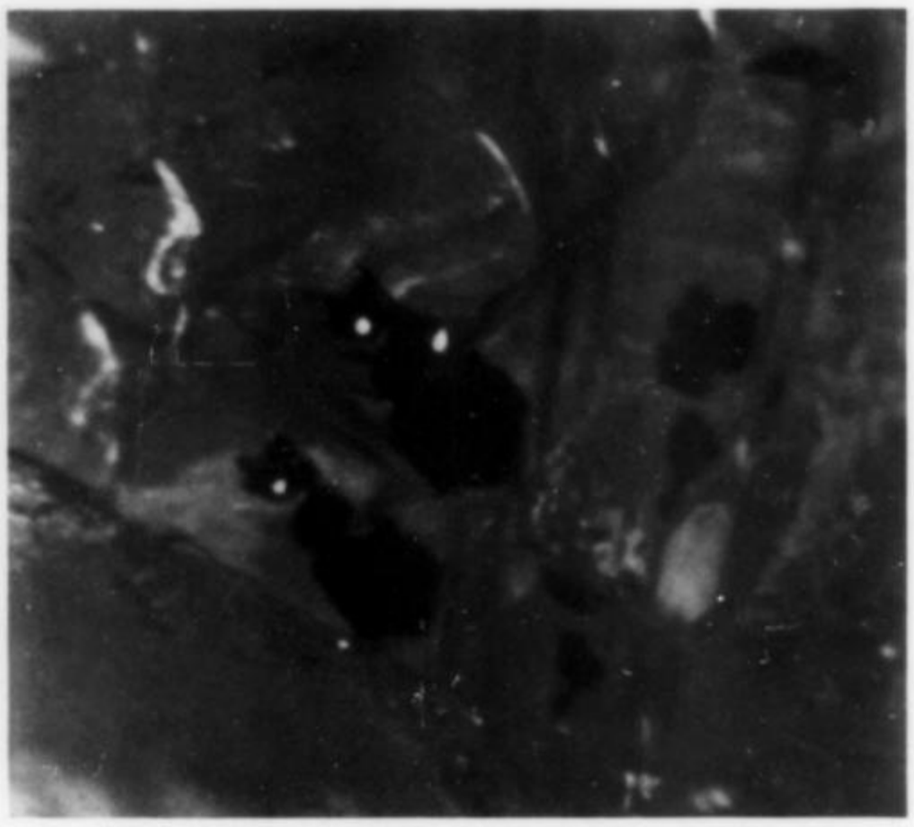


Figure 4. **Bronze-colored, movable crystals of pyrrhotite as in Figure 3. The larger crystal, 1 mm in size, is seen doubled as it was photographed through two adjacent faces of the enclosing quartz crystal.**

by D. P. Grigor'ev. Although not something to be found in one's local library, the text is always available on interlibrary loan. Luckily, one need not be able to read Russian, as the book has been translated into English by the Israel Program for Scientific Translations, and published in the United States by Daniel Davey and Co., New York. The book is a little gem, discussing the origin of many interesting curiosities such as bow ties, the growth of spherical aggregates and flat twins. Sure enough, Grigor'ev does indeed postulate faster growth in a twin reentrant as the cause of flat or large twin crystals.

Interestingly, Grigor'ev also suggests a plausible explanation for the basket-weave siderite pictured earlier. He described the growth of spherical aggregates such as the spheres of siderite on which the basket-weave pattern appears in the usual way, i.e., myriad acicular crystals grow from a point source to form each sphere. He also pictured the result when such a growing sphere reaches a barrier with holes in it. The crystals from the primary sphere which reach the holes grow through them, and begin new, secondary spheres of radiating crystals on the far side (Fig. 5). Taking another look at the basket-weave siderite, I found that many of the secondary siderite ridges follow major shrinkage cracks in the clay coating on the

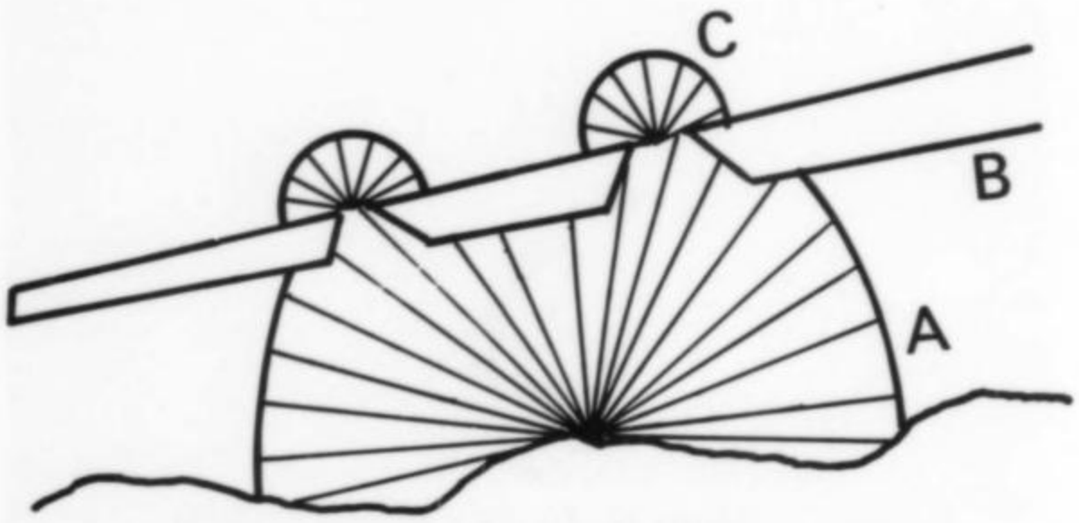


Figure 5. **Mechanism of growth of a second generation of radiating crystals. A large, primary sphere of radiating crystals, A, on reaching a barrier, B, grows through small pinholes or cracks in the barrier and continues growing as radiating crystals to form secondary spherules or ridges, C.**

primary siderite balls. Further, when I broke off a few of the siderite ridges making up the basket-weave pattern, I found a tiny, continuous thread of siderite running through the clay layer from the primary to the secondary siderite. Apparently, this material formed just as described by Grigor'ev.

Pete Richards of Oberlin, Ohio, wrote about the same flat twin column, and asked why I wrote that "At first" I believed in the explanation invoking fast growth in the twin reentrant? He wondered whether I had reservations. Indeed I had, and still do. I'm very concerned that fast growth in the twin reentrant will lead to the disappearance of the reentrant, and thus to the reason for the faster growth. Inspection of the twins shown in Figures 8, 9, 15 and 16 of that column and a little playing around with solid twin models will convince one that fast growth in the twin reentrant should indeed lead to its disappearance and the concomitant expansion of adjacent faces, just as occurs in untwinned crystals such as that shown in Figure 18 of that column. Still it's a fact that such reentrants persist, and that many such crystals are flat, so we have a conundrum.

Leaving the past, let's look at some exceptionally nice and limpidly clear calcites from two different locations. In both cases, the crystals are beautifully transparent, colorless, and show extremely well developed faces. The first (Figs. 6 and 7) are from a roadcut in Kansas, and were sent me by Frank Miller, 916 West 29th Street, Lawrence, Kansas 66046. The second group of crystals (Figs. 8 and 9) are specimens in my collection from the days when I did not record the names of their donors. They are from the Eagle mine, Ottawa, Kansas. All are from cavities in limestone. Their crystallography is so interesting that I sent them to Pete Richards (mentioned earlier), as he styles himself a pocket crystallographer. Pete returned to me some beautiful crystal drawings of the specimens, as shown in Figures 10 and 11, all done by computer. Pete uses a crystal drawing program called SHAPE, developed by Eric Dowty (see vol. 18, no. 2, p. 116). This Pete modified to run on a VAX 11/750 computer. The first step, he says, is to determine the Miller indices of the crystal faces from angular relationships determined using a two-circle goniometer. The input to the computer is the unit cell dimensions of the mineral and its appropriate symmetry parameters, the Miller index of a single face of each crystal form present, and an estimate of the distance from the center of the crystal to each face. The computer then automatically does the calculations, and drives a printer to draw the crystal. The program also allows one to rotate the crystal to any desired orientation. Thus, the crystal drawings shown here were drawn in plan and in clinographic projection according to established conventions. Anyone who has attempted to draw a crystal by hand using the laborious procedures described in Dana's *Textbook of Mineralogy* (1932) will appreciate the tremendous value of this computer program. Pete has said that, in certain circumstances (such as the donation of an excellent specimen of the crystal(s) to be drawn), he might be persuaded to do drawings for readers. Remember, however, that a great deal of work still goes into such an undertaking, and be sure you are dealing with something significant before you write. His address is:

Mr. R. Peter Richards
154 Morgan Street
Oberlin, Ohio 44074

Quite a few babingtonites are being offered from the Indian zeolite localities these days. Among them are some sleepers—specimens of ilvaite, a much rarer mineral with the same black color and brilliant luster. I found three such specimens at the last Tucson Show, crystals from two of which are shown in Figures 12 and 13. Smaller crystals of ilvaite are also being found with zeolites at a second occurrence in Iceland (Fig. 14) along with excellent crystals of the rare zeolite, yugawaralite (Fig. 15). Specimens of these minerals have been sent me by Ernie Schlichter of Sudbury, Massachusetts,

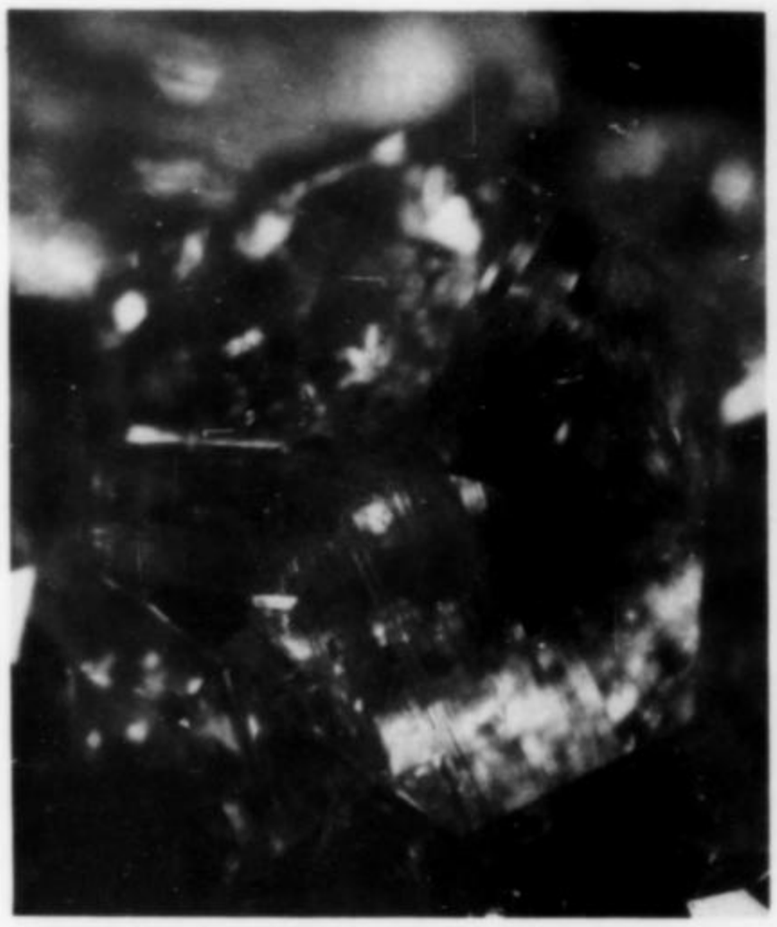


Figure 6. **A colorless, 2.3-mm crystal of calcite from a roadcut on Highway 10, East Johnson County, Kansas, viewed down the *c*-axis.**

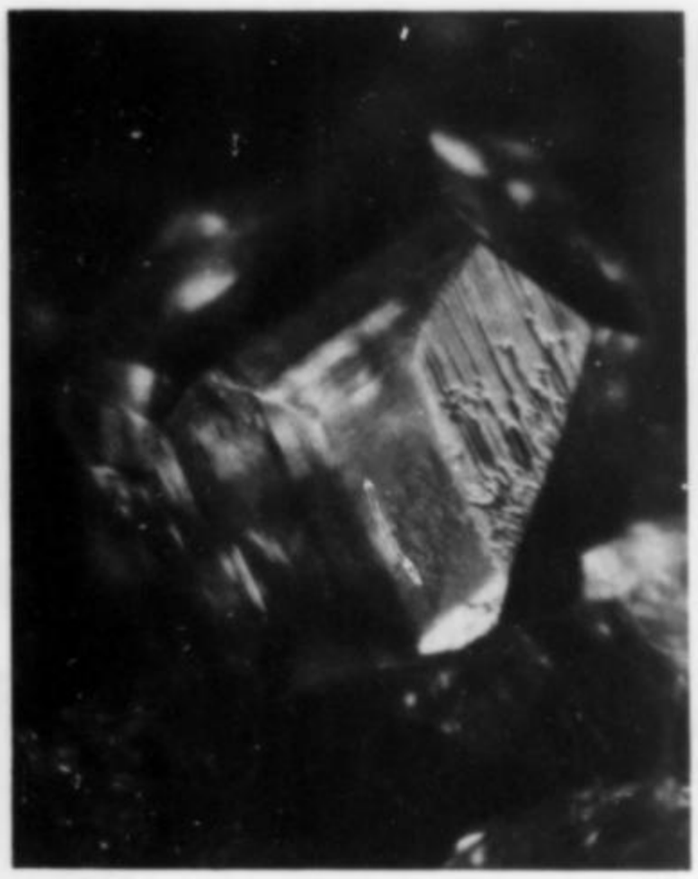


Figure 7. **A crystal as in Figure 6, 2 mm across, viewed obliquely and showing interesting growth marks.**

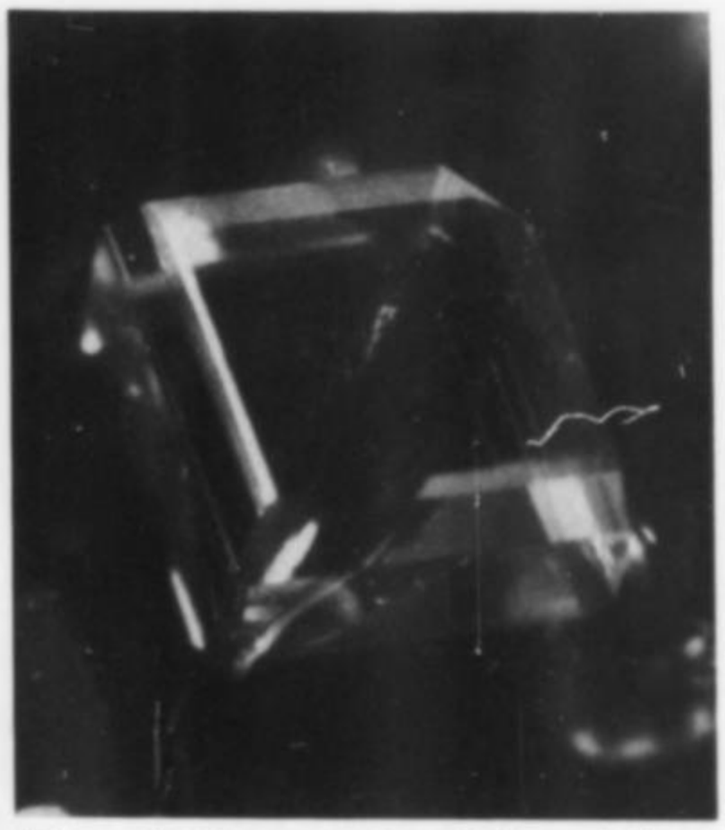


Figure 8. **Transparent, colorless, 1.8-mm crystal of calcite from the Eagle mine, Ottawa, Franklin County, Kansas.**

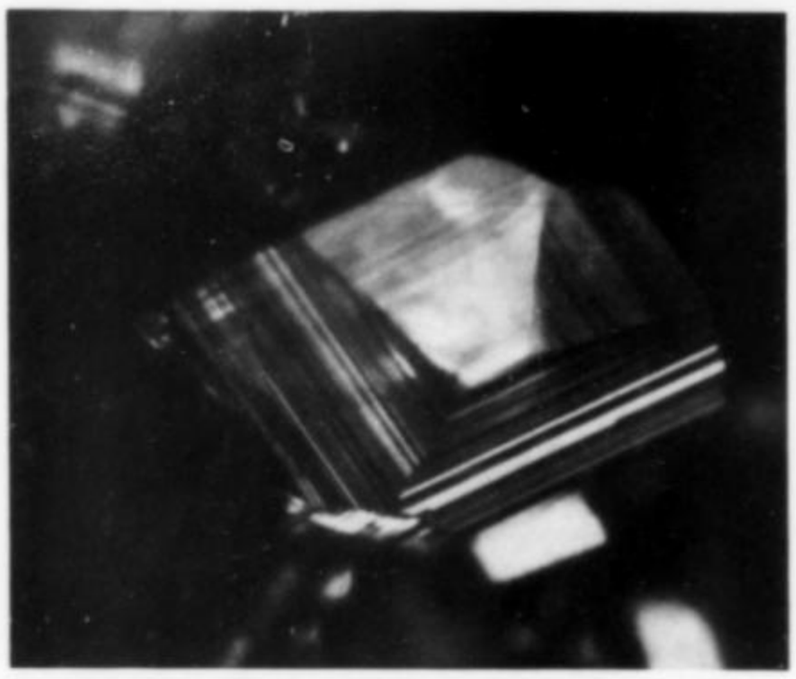


Figure 9. **Heavily striated, colorless, 1.2-mm crystal of calcite from Ottawa, Kansas.**

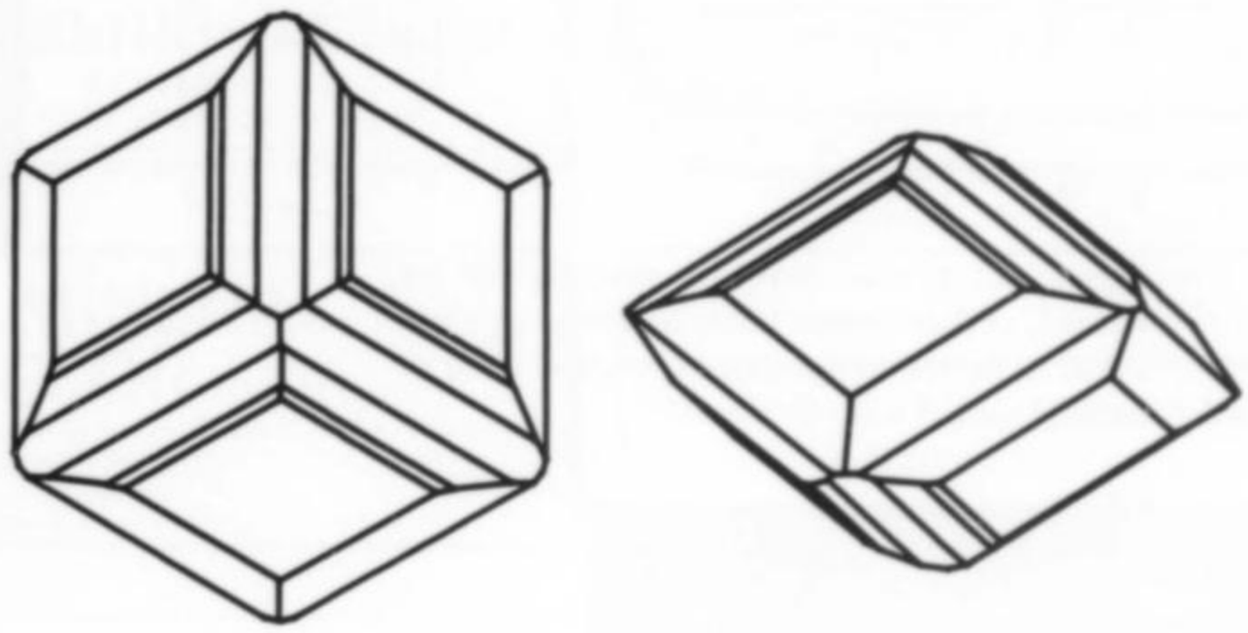


Figure 10. **Plan and oblique views of calcite crystals from East Johnson County, Kansas, computer-generated by Pete Richards.**

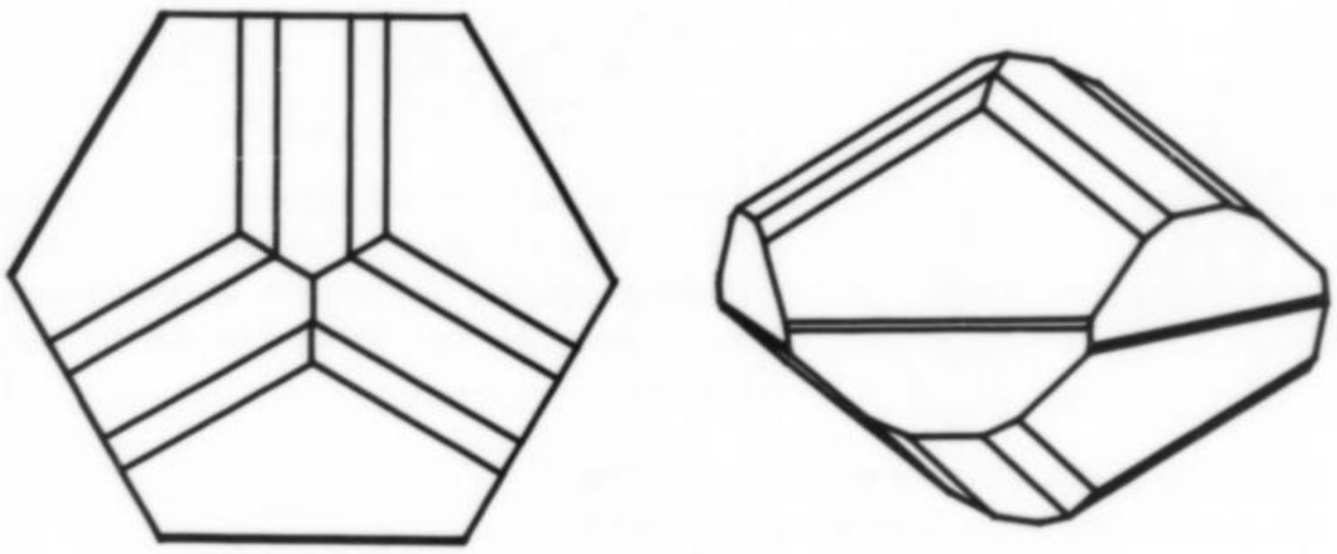


Figure 11. **Plan and oblique views of calcite crystals from Ottawa, Kansas, computer-generated by Pete Richards.**

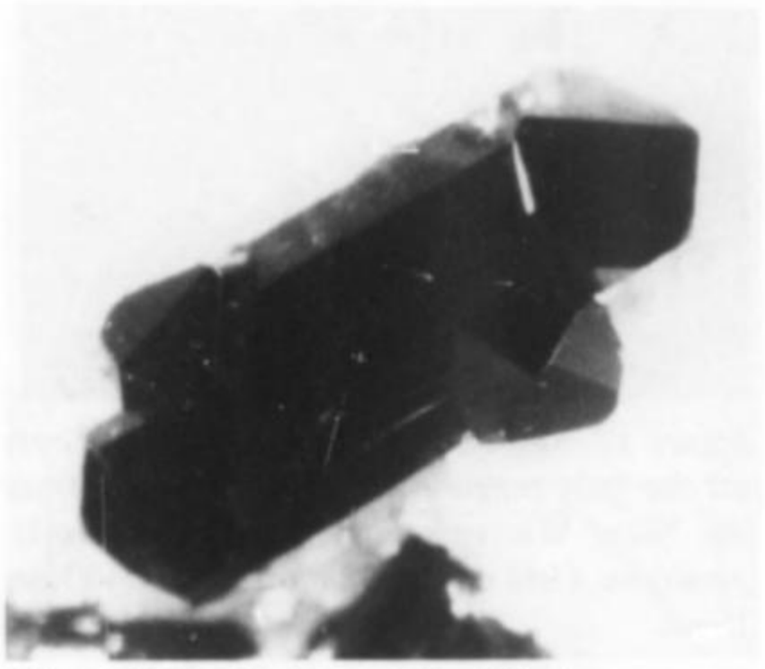


Figure 12. **Jet-black crystals of ilvaite on quartz from the Bombay or Malad quarry, near Kandivli, India. Field of view, 5.5 mm.**

and Sigurdur Jonsson of Reykjavik, Iceland. It's really not at all difficult to distinguish the blockier, orthorhombic habit of ilvaite from the less symmetric, triclinic and wedge-shape habit of babingtonite. The photos and a moment's study of the crystal drawings in Figure 16 should make it possible for readers (and dealers, too) to easily tell one from the other. Incidentally, I had not until recently thought of ilvaite as a mineral occurring in basalts, but a quick check of the literature shows it is found in one or two such parageneses.

Speaking of zeolites and zeolite associates, Jon Mommers, of

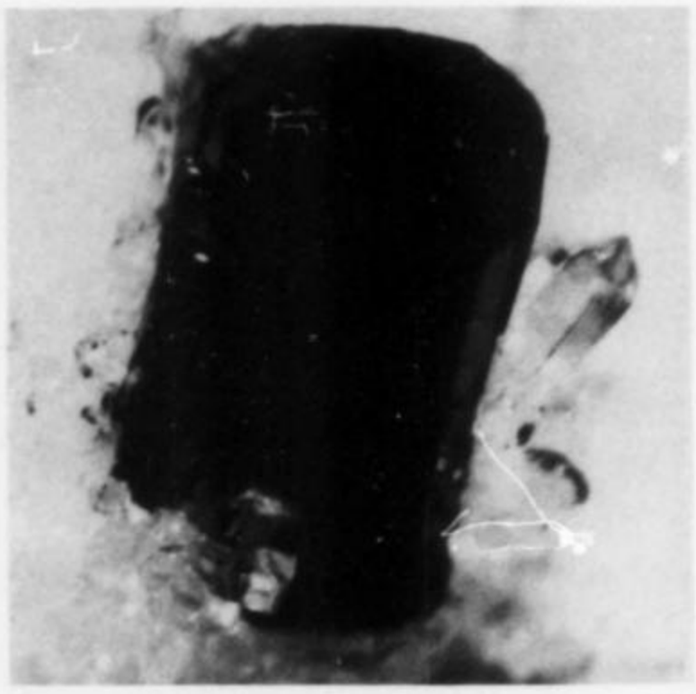


Figure 13. **Brilliant, black ilvaite crystal showing blocky character and orthorhombic symmetry, from the Bombay quarry, India. Size of crystal, 2.3 mm.**

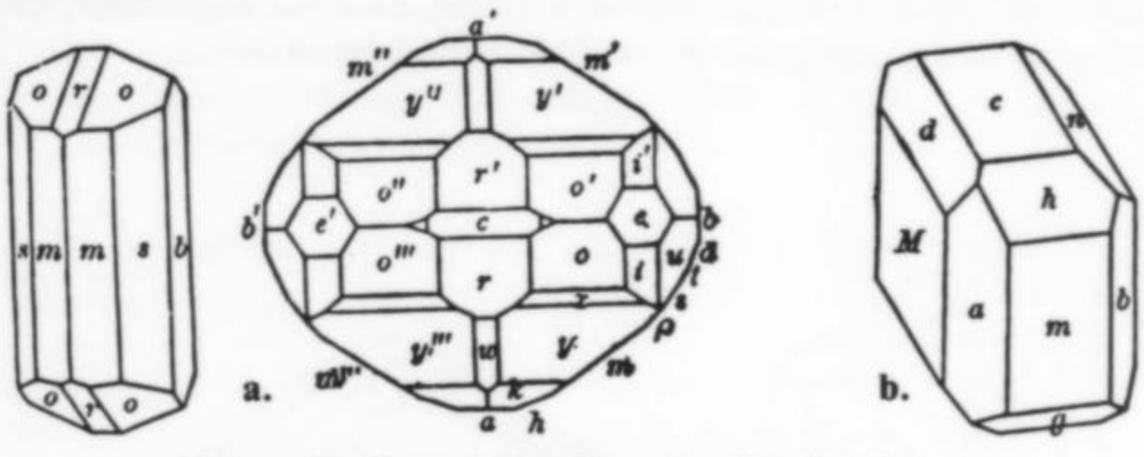


Figure 16. **Crystal drawings showing (a) the equant, orthorhombic habit of ilvaite as compared to (b) the wedge-shaped, triclinic habit of babingtonite.**

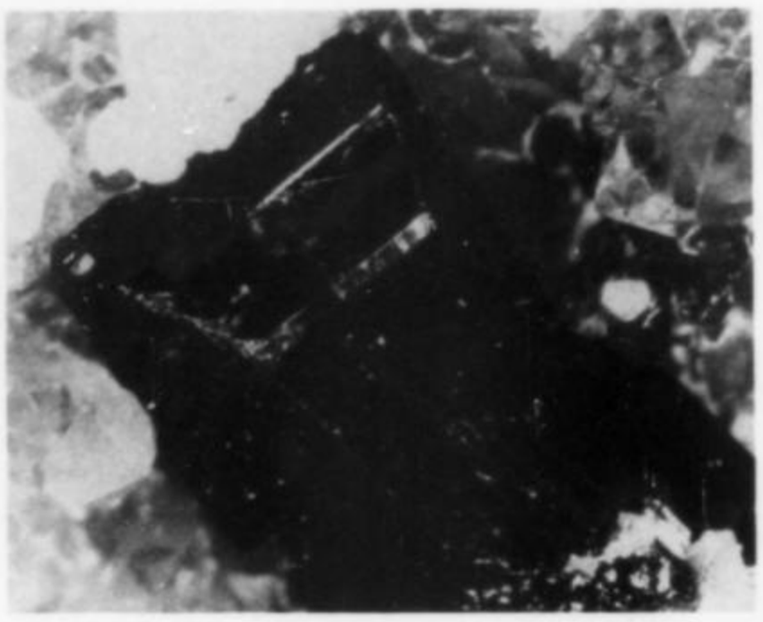


Figure 14. **Black ilvaite crystals 0.8 mm across, from Hvalfjördur, Iceland.**

Figure 15. **Colorless, tabular crystals of yugawaralite from Hvalfjördur, Iceland. Size of group, 4.5 mm.**

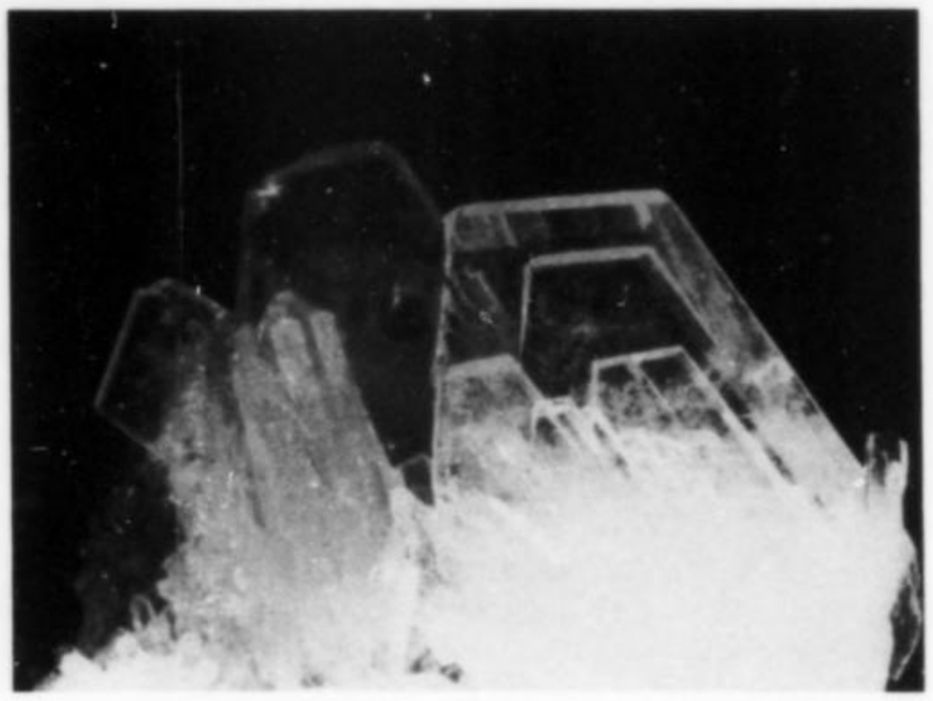


Figure 17. **Montmorillonite growing selectively on the twin junction lines of phillipsite, from the Narre Warren quarry, Berwick, Victoria, Australia. Field of view, 8 mm. Photo by Omer Dean.**

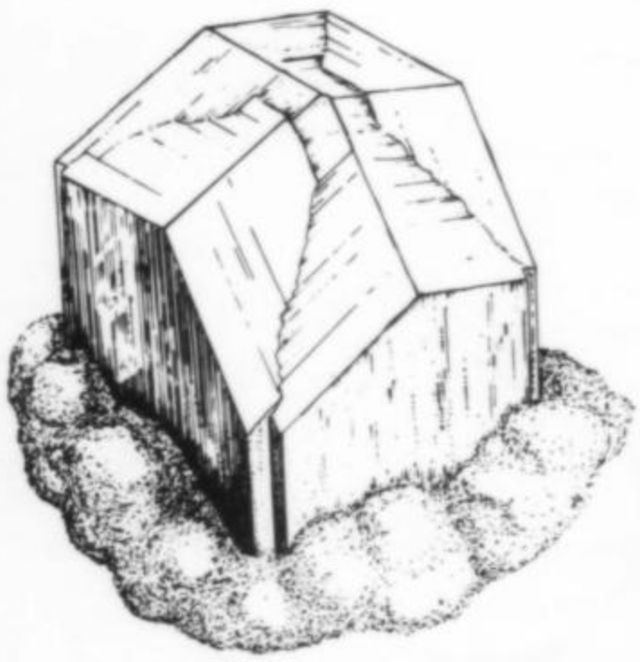


Figure 18. **Sketch of cruciform twin of phillipsite showing twin suture lines in the reentrants in the prism zone and as irregular lines on the terminal faces. Sketch by Bart Cannon.**

Figure 19. **Sketch of phillipsite crystals from the Narre Warren quarry, Victoria, Australia, showing selective overgrowth of montmorillonite along the twin sutures. Sketch by Bart Cannon.**

Sunshine, Victoria, Australia, has sent some remarkable crystals of phillipsite selectively overgrown by montmorillonite (Fig. 17). These are from the Narre Warren quarry in Victoria, Australia. As the sketches in Figures 18 and 19 make clear, the montmorillonite forms selectively along the twin junction lines of the phillipsite, something I have not previously seen.

Yesterday, on my 54th birthday, I committed a mortal sin. I spent the whole day collecting macro, not micro mineral specimens. Today, perhaps as punishment, I am afflicted with assorted aches and pains without which this column might be longer.

Happy hunting!

Wm. A. Henderson, Jr.
174 East Hunting Ridge Road
Stamford, CT 06903

Don Pearce

Michigan Copper Country Minerals!
Copper, Silver & Associated Species

No Lists • Send phone no.
and we'll contact you
with information

P.O. Box 198
Mohawk, Michigan 49950
Tel: (906) 289-4860

David & Celia Lare

Jeffrey Mining Co.
Inc.

See us at
Marietta, GA;
Montgomery, AL;
Murfreesboro, TN

P.O. Box 11506
Memphis, TN 38111
(901) 358-1600

BOB & VERA TURNER

Natural Connection

WHOLESALE Mexican MINERALS

BY APPOINTMENT ONLY
520 MARTHMONT WAY
EL PASO, TEXAS 79912
(915) 581-1926

ARNOLD FISHER MINERALS

fine British & Worldwide Specimens
Mineral Photographs - Devon Gold

Trewellard Cottage, Lower Trewellard
Penzance, Cornwall TR19 7SU, England
Tel: 0736-788305

Geary Murdock

Specializing
in Idaho Aquamarine,
and Fine Worldwide
Mineral Specimens

628 Whittier Street
Idaho Falls, Idaho
83401

MICROMOUNTS, THUMBNAILS, MINIATURES & CABINETS

Specializing in Arsenates,
Benitoite & Associated Minerals.
Micromount List, $2, refundable.

Bruce & Jo Runner

13526 South Ave., Delhi, CA 95315
Showroom by Appt. (209) 634-6470

Exquisite Crystals of

QUARTZ

8 cm to 100 cm
Single crystals up to 17,500 lbs.
from the
JAN COETZZE MINE, NABABEEP,
NAMAQUALAND, SOUTH AFRICA

Contact: Zee's, 2990 E. Michigan,
Tucson, AZ 85714 · (602) 625-2373
or Wayne Thompson (602) 861-1830

Book Dealers

BOOKS OUT—OF PRINT

Send $1.00 for latest catalog listing 100's on minerals, mining, geology, fossils, gems.

Tel.: 619-488-6904
PERI LITHON BOOKS
P.O. Box 9996
5372 Van Nuys Court
San Diego, Calif. 92109

Fine Rare Books

Geology, Mineralogy, Paleontology,
Mining, Gemology, and Jewelry
Send $1.00 for Catalog
THE GEMMARY, INC.
P.O. Box 816, Redondo Beach, Ca. 90277

Books

ANTIQUARIAN
& SECOND-HAND
Catalogs-$1

Geology
Mineralogy, Natural History
R.V. Merritt, 174 Old Bath Rd.
Cheltenham, GL53 7DR, England

In FLORIDA
see the

Gallery of Gems

Fine gems & minerals

2291 N. Federal Hwy.
Boca Raton, FL 33431

SCHNEIDER'S rocks & minerals

13021 Poway Road
Poway, California 92064
619-748-3719

California benitoite,
tourmaline, spessartine,
morganite & minerals
from worldwide localities

NOW BY APPOINTMENT ONLY
OR SEE US AT THE SHOWS

Sam Weller Minerals

Mineral Dealer & Mine Agent

WILLIS' EARTH TREASURES

Fine Mineral Specimens
Wholesale & Retail
Rock Trimmers & Hardwood
Thumbnail Cabinets
Send want list or by appointment
Prospect St., Box 393, Stewartsville, N.J.
201-859-0643

DIAMONDS

fine selected specimens

Cubes, Octahedrons, Twins

Interesting surface features

GEMAURA

JACK & ELAINE GREENSPAN
P.O. BOX 4162 • W. SEDONA, AZ 86340
602-282-7828

NATURE'S WINDOW

- *Minerals*
- *Fossils*
- *Rare Species*
- *Micromounts*
- *Books*

No. Adams, MA-Sep. 12-13
Detroit, MI-Oct. 8-10
Quarryville, PA-Oct. 17-18
Garden City, NY-Nov. 21-22
Lindenhurst, NY-Jan. 23-24

SHOW DEALERS • RON & EMILIE KENDIG
P.O. BOX 6049, WYOMISSING, PA 19610

COMMMING "DOWN UNDER"?

PIERS & ROBYN FOA

of

KOVAC'S GEMS & MINERALS

291-293 WATTLETREE ROAD
EAST MALVERN VIC. 3145

PHONE (03) 509 1611
TELEX 30625/ME1087

TRY AUSSIE SOUTHERN HOSPITALITY
WITH THE MIN. RECORD REPRESENTATIVES
IN THE *LAND OF THE BROKEN HILL!!!*

GREGORY, BOTTLEY & LLOYD

MINERALOGISTS & GEOLOGISTS - ESTABLISHED 1850

8-12 RICKETT STREET, LONDON SW6 1RU
TELEPHONE 01-381 5522: TELEGRAMS METEORITES LONDON SW6

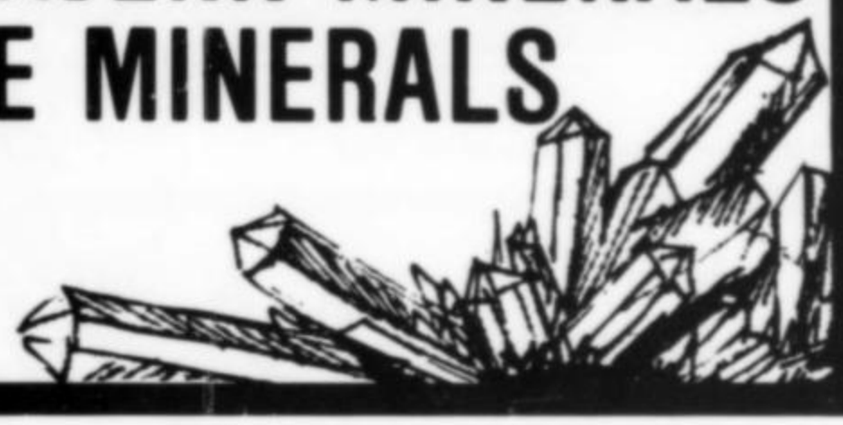
Brian Lloyd looks forward to seeing you when you are next in London. We are open weekdays 9:30 to 5 pm—evenings and weekends by appointment.

Mineral News

Monthly Newsletter

Current news on minerals, localities, dealers, major shows, book reviews, new minerals, and everything else of interest to mineral collectors. Published monthly with a short lead time so all the news and information is still news.
only $12/yr.
If you like minerals you should read the MINERAL NEWS
P.O. Box 2043, Coeur d'Alene, ID 83814 (208) 667-0453

CRYSTAL CAVERN MINERALS
WHOLESALE MINERALS



Tom Palmer
1800 Arnold Palmer Dr.
El Paso, Texas 79935
915-593-1800

Zeolites India

SPECIALIZING in GREEN APOPHYLLITE, MESOLITE sprays, NATROLITE in vugs, CALCITE varieties, STILBITE bowties, OKENITE geodes, PREHNITE stalactites, colorful GYROLITE balls, HEULANDITE, SCOLECITE.
RARITIES: POWELLITE, YUGAWARALITE, GOOSECREEKITE, BABINGTONITE.

Send us your requirements or visit us in Bombay for the largest and finest stock of Indian Minerals

ZEOLITES INDIA, D-311 Manju Mahal, 35, Nargis Dutt Road, nr. Dilipkumar's Bunglow, Bandra (West) Bombay 400 050 India. Tel: 532284

Tysons'

fine mineral specimens

Rod & Helen Tyson
10549 133rd Street
Edmonton, Alberta
Canada T5N 2A4
(403) 452-5357

INDEX TO VOLUME EIGHTEEN (1987)

Articles

Departments

Authors

Localities

Minerals

STATEMENT OF OWNERSHIP, MANAGEMENT AND CIRCULATION
(Required by 39 U.S.C. 3685)

1. *Title of publication:* Mineralogical Record
2. *Date of filing:* September 29, 1987.
3. *Frequency of issue:* Bimonthly
   a. *Number of issues published annually:* Six.
   b. *Annual subscription price:* Twenty-seven dollars.
4. *Location of known office of publication:* 7413 N. Mowry Place, Tucson, Arizona 85741.
5. *Location of the headquarters or general business offices of the publishers:* 7413 N. Mowry Place, Tucson, Arizona 85741.
6. *Names and complete addresses of publisher, editor, and managing editor: Publisher:* Wendell Wilson, 4631 Paseo Tubutama, Tucson, AZ 85715. *Editor:* Wendell E. Wilson, 4631 Paseo Tubutama, Tucson, Arizona 85715. *Managing editor:* none.
7. *Owner:* The Mineralogical Record Incorporated, 7413 N. Mowry Place, Tucson, Arizona 85741. No stockholders.
8. *Known bondholders, mortgagees, and other security holders owning or holding 1 percent or more of total amount of bonds, mortgages or other securities:* none.
9. *For completion by nonprofit organizations authorized to mail at special rates (Section 132.122, PSM).* The purpose, function, and nonprofit status of this organization and the exempt status for Federal income tax purposes have not changed during the preceding 12 months.
10. *Extent and nature of circulation:*

	Average no. copies each issue during preceding 12 months	Actual no. copies of single issue published nearest to filing date
A. Total no. copies printed	9362	8356
B. Paid circulation		
1. Sales through dealers and carriers, street vendors and counter sales	430	542
2. Mail subscriptions	6176	6413
C. Total paid circulation	6606	6955
D. Free distribution by mail, carrier or other means, samples, complimentary and other free copies	100	106
E. Total distribution	6706	7061
F. Copies not distributed		
1. Office use, left over, unaccounted, spoiled after printing	2653	1295
2. Returns from news agents	0	0
G. Total	9362	8356

11. I certify that the statements made by me above are correct and complete. Mary Lynn Michela, treasurer.
12. In accordance with the provisions of this statute, I hereby request permission to mail the publication named in item 1 at the phased postage rates presently authorized by 39 U.S.C. 3626. Mary Lynn Michela, treasurer.

Advertisers Index

Affiliated with the Friends of Mineralogy, an independent, non-profit organization devoted to furthering amateur and professional interests in mineralogy. For membership information contact Don Zowader, 97 Leamington Rd., Somerville, NJ 08876.

Subscriptions
- **Individuals (U.S.):** $27 for one year, $52 for two years. (First-class mailing available; write to circulation manager for rates.)
- **Individuals (outside the U.S.):** $30 for one year, $58 for two years. (Airmail mailing available; write to circulation manager for rates.)
- **Libraries, Companies and institutions (worldwide):** $45 for one year. (First-class or Airmail mailing available; write to circulation manager for rates.)

Replacement copies
Availability of replacement copies usually extends for several months following publication, but is not guaranteed. Requests for replacements should be made as soon as possible.

The Mineralogical Record accepts specimens on loan for photography and study, but can accept no responsibility for loss or damage.

Design
Wendell E. Wilson

Graphic Production
Capitol Communications
Crofton, MD

Printing
Waverly Press, Easton, MD

Color Separations
Hollis Phototechnics
Tucson, AZ

Book sales
P.O. Box 1656
Carson City, NV 89702
702-883-2598

Foreign Payments
Remittance may be made in local currency, at *prevailing exchange rates,* without surcharge, to the following people:

Arab Countries
Abdulla Mohammed Al-Khulaifi
P.O. Box 3454
13035 Safat, Kuwait

Australia
Piers Foa, Kovac's G. & M.
291-293 Wattletree Rd.
East Malvern, Victoria 3145

Belgium:
Paul Van Hee
Marialei 43
B-2120 Schoten

Canada:
Mrs. J. W. Peat
36 Deepwood Crescent
Don Mills, Ontario M3C 1N8

France:
ADIDOM
32, rue Servan
75011 - Paris

Great Britain
Simon Harrison
15 Queenwood Avenue
Fairfield Park
Bath, Avon BA1 6EU

Italy:
Renato Pagano
Via S. Anna 1/B
I-34074 Monfalcone

Japan:
Tsukasa Kikuchi
P.O. Box 18, Hongo
Tokyo 113-91

Netherlands:
W. J. R. Kwak
Kabeljauwallee 23
6865 BL Doorwerth (Gld)

Scandinavia
Claus Hedegaard
Storgade 71
DK-8882 Faarvang, Denmark

South Africa:
Horst Windisch
30 Van Wouw Street
Groenkloof, Pretoria

Spain & Portugal:
Bailey Minerals
Paseo de la Castellana, 171
28046 Madrid, Spain

West Germany:
Christian Weise Verlag
Oberanger 6
D-8000 München 2

Advertising Information
All advertising in the Mineralogical Record must be paid in advance of the closing date. Discounts apply when more than two ads are paid for at a time. Telephone orders not accepted. Write to the editor for rates.

Closing dates:

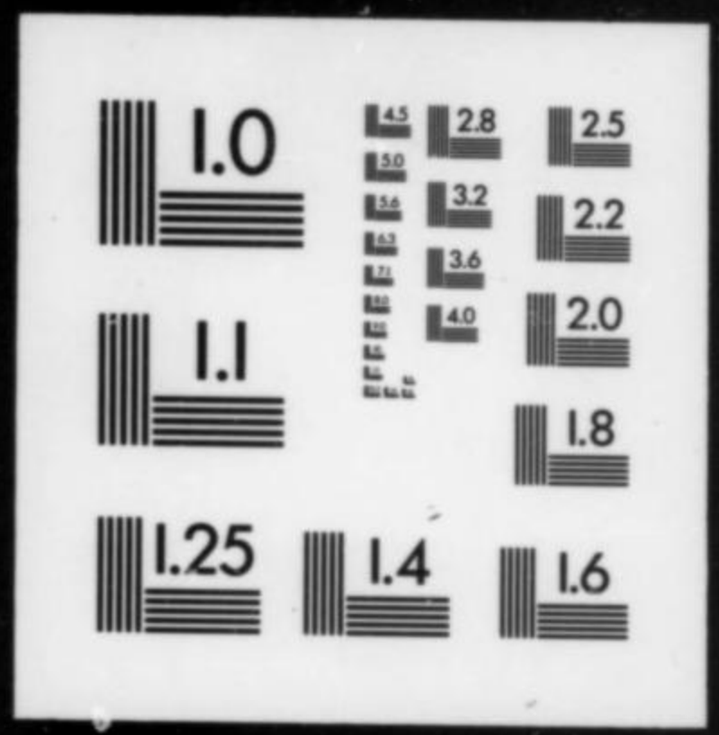
Jan.-Feb. issue	Oct. 15
March-April issue	Dec. 15
May-June issue	Feb. 15
July-Aug. issue	April 15
Sept.-Oct. issue	June 15
Nov.-Dec. issue	Aug. 15

An additional 30 days past the closing date are allowed in which advertisers may make changes (excluding size changes) in ads already paid for.

* Take advantage of our free typesetting and layout service!

* Write for our free 24-page brochure on how to advertise minerals!

Editing, advertising
Wendell E. Wilson
Mineralogical Record
4631 Paseo Tubutama
Tucson, AZ 85715
602-299-5274


1.0
1.1
1.25
1.4
1.6
1.8
2.0
2.2
2.5
2.8
3.2
3.6
4.0
4.5
5.0
5.6
6.3