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THE MINERALOGICAL RECORD

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Articles

Columns

COVER: PYRITE and quartz, 13.5 cm, from the Spruce Claim, King County, Washington. Joseph Ondraka collection; Jeff Scovil photo.

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Editorial

MINERAL SPECIMEN REPAIR AND RESTORATION: AN ATTITUDE CHECK

Although "mineral specimen preservation" is a goal supported, at least in theory, by all mineral curators, such homage is often tempered by a pervading attitude that repair or (especially) restoration of specimens is somehow less than proper or ethical, that it may be equivalent to fakery, and that repaired or restored specimens have little value. Because of this attitude, many people are unmotivated to repair or restore otherwise excellent specimens, some of which have the potential to be scientifically or aesthetically important pieces. Although some misgivings are sensible in the case of overly extensive restoration, careful and prudent restoration should, in our opinion, be encouraged. The concepts of mineral restoration vs. fakery[1] may require some thoughtful reevaluation in the context of conscientious collecting and preservation of irreplaceable mineral specimens.

Part of the problem in deciding how to view restoration stems from the dual nature of mineral specimens as objects to be appreciated both aesthetically and scientifically. Nevertheless, major restorations of manmade art objects, extensive reconstruction of vertebrate fossils, and even restoration of antique cars or scientific instruments (for example) are readily accepted by professionals in those fields and by the general public. In fact, non-mineral curators who fail to properly restore, reconstruct, and mount important artistic, historic, and scientific objects in their collections are considered remiss by their colleagues. And yet mineral specimens are often considered to have been fatally "tainted" if they have been repaired or restored; this rationale is not always logical.

Certainly a repaired or restored specimen of any kind is rightfully less desirable, to some degree, than its pristine counterpart. But specimens suitable for repair or restoration should never be discarded or left in ruins; to do so is considered an unconscionable waste in other fields, and so also should it be viewed when it comes to minerals. There is a finite number of mineral specimens in and on this planet, and we cannot afford to be throwing away everything that has some kind of defect.

Restoration can be defined as the addition of foreign material in order to achieve close similarity to an earlier state of appearance; **cleaning** might conversely be referred to as the *removal* of material (foreign or non-foreign) for the same purpose; and **repair** as the accurate reassembly of separated original parts for the same purpose, with no significant addition or subtraction of material. **Fakery**, on the other hand, may be considered to result when the outcome varies from an original state of appearance (if known), or when an original appearance cannot be deducted with reasonable certainty. Ralph Mayer, in his authoritative book *The Artist's Handbook of Materials and Techniques* (third edition, 1972), states that:

> Besides the arresting of decay and prevention of further disintegration, the purpose of sincere restoration should be to present an acceptably good appearance to an object so that it may be seen or studied as a whole without the distraction of serious blemishes—not to reproduce what the restorer thinks the lacuna (gap or missing part) or defective element would have looked like, or to attempt a forgery or fake of the original.

Obviously, there is a fine distinction to be made here, and extreme perfection in restoration is not necessarily always the ideal goal. In the case of valuable artistic works as well as large paleontological reconstructions, it is desirable to create an appearance in which, as Mayer says:

> . . . **repairs** are not readily apparent but so that upon close examination all the **restored spots** may be detected without trouble.

The restoration of an "original" appearance is predicated on our ability to know accurately what the original appearance was. For example, the face of Michelangelo's *Pietá*, one of the world's greatest sculptures in marble, was brutally hammered some years ago by a deranged geologist named Lazlo Toth. It was subsequently perfectly restored utilizing rubber molds and photographs that had been made of the face; a marble-like compound was cast onto the damaged areas using the molds, and a priceless masterpiece was rescued. We are not always so lucky. If only we had molds or photos of what the sphinx looked like before its nose was hammered off by a religious fanatic named Saim-el-Dahr in the 15th century. But we don't, so it cannot be legitimately restored.

Criteria followed by the Denver Museum of Natural History for restoration of vertebrate fossils are that (1) the scientific integrity is not compromised; (2) the replacement parts are restored such that they are detectable by an expert in the field, but are not so incongruous as to be obvious to the lay public; and (3) the extent of restoration is less than approximately 50% of the total fossil (Richard Stucky, personal communication, 1995). In other words, the specimen is deliberately restored in a manner that leaves no possibility of its being mistaken as authentic. In fact, fossils or

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[1] The concept of mineral fakery has been dealt with at length by Pete Dunn, Ron Bentley and Wendell Wilson in their 1981 article "Mineral fakes" (*Mineralogical Record*, 12, 197–219).

artifacts that are exposed as fakes at the Denver Museum, which have no historical significance, are destroyed to maintain the integrity of the collection. Some important dinosaur specimens on public exhibit at this museum have been extensively restored; the *Stegosaurus* is composed of about 70% original material, while the *Diplodocus* is 50–60% original, and the *Allosaurus* is 40–50% fossilized bone. Accurate restorations are nonetheless assured by comparisons involving bilateral symmetry and by information gleaned from other, more complete specimens of the same species, and thus artistic latitude is quite limited.

Advocacy of outright fakery[2] (*Lapidary Journal*, 1982, p. 1436, and more recently in *Rock and Gem*, 1992, April, p. 26) and the continuing presence of "enhanced" specimens in prominent gem and mineral shows has only served to further polarize the opinions of those opposed to any form of restoration and repair. However, it is important to recognize that restoration does not constitute fraudulent adulteration of a specimen. Restoration transgresses the line into fakery when insupportable or unprovable guesses, extrapolations and imagination are employed to create a desired appearance that may well have never existed. An evaluation of the extent to which restoration can be prudently justified is more or less a scientific exercise. The difference between imprudent extrapolation and prudent interpolation is critical. Filling in a thin crack with clear resin is interpolation that approximates an original (unfractured) state, as is restoring a part of a missing termination where sufficient crystal faces remain to geometrically constrain artistic latitude. Rebuilding an entire missing termination whose original, exact configuration of faces is lost and unknowable is imprudent extrapolation (i.e. fakery).

The idea of restoring a specimen to an earlier appearance does not necessarily imply that a given specimen has only *one* earlier appearance that may be legitimately recreated. Cleaning, for example, may involve only simple removal of dirt and roots, or it may involve the dissolution of later minerals that have overgrown earlier species (i.e., exposing neptunite from its enclosing natrolite using hydrochloric acid). Repair can involve the reassembly of specimens broken during the collecting process, or specimens broken eons ago by tectonic processes. Actual restoration by addition of foreign material, however, is more rigidly limited by what we are capable of knowing about those early appearance states.

There are many examples on the recent collector market that illustrate restoration and/or enhancement; the difficulty with such examples is that they span a range between prudent restoration to outright fakery (i.e., enhancing luster by leaving excessive lacquer on a surface or adding dye to improve color). Colorado amazonite provides a good example. Crystals showing a high degree of luster and a pronounced blue-green color are quite rare; many crystals either have a thin veneer of late-formed subhedral feldspar or quartz microcrystals that substantially diminish the luster to a chalky or earthy texture, or have been surficially etched following the last stage of crystal growth, giving the same result. Such crystals have little specimen value. With specimen "preservation" (and in many cases, profit) in mind, many collectors and dealers resort to a variety of methods to "enhance" the appearance which may or may not approximate an earlier appearance. Consequently, Colorado amazonite specimens have been sandblasted, treated in hydrofluoric acid, coated with floor wax, coated with other types of lacquer, impregnated with silicone, mineral oils, paraffin, Thompson's Water Seal, and even cooking oil.

Given the premise that restoration is intended to return a specimen to an earlier appearance, careful consideration must be given to procedures such as oiling. Such treatments may not restore a surface to an earlier state, but rather may *enhance* (i.e. fake) the appearance of a specimen, making it better than it ever was. One might assume that a crystal surface had been brighter prior to a stage of alteration or corrosion, and that the application of a coating of some reflective material could "restore" that original luster. The fundamental problems here are that (a) the "original" luster may not be accurately known, any attempt at "restoration" equalling unwarranted extrapolation; and (b) even if it were known, a luster is the result of a microsurface configuration that may not be duplicable by any means (there are many different kinds of "shiny"). And there are additional problems. For example, prudent restoration would dictate that no *irreversible* work be done. (Obviously, sandblasting may irreversibly alter the surface to a state that was never natural or pre-existing.) Proprietary ingredients in Thompson's Water Seal, baby oil, etc., may leave harmful residues that cannot later be removed. And some treatments may render future scientific analyses impossible or unreliable.

In other cases, however, excess sealing materials can be removed from the surface such that intrinsic luster is not altered, but *subsurface* microfactures are sealed, resulting in a uniform transmission of light that consequently improves the overall color (contrast this with artificially coloring or dying a specimen). In this situation, it can be argued that the mineral is reliably restored to an earlier appearance. Unlike treatment with oils which need to be replenished periodically, paraffin impregnation need only be done once, and is reversible.

Unfortunately, fracture-sealing treatments fail one test of proper restoration if they cannot be easily discerned by an expert, even upon close examination. Although this would not constitute a "fake" (because the *original* appearance has not been improved upon), neither would it constitute proper restoration by standards established in other fields.

The important point here is a balance between necessary treatment to salvage (preserve) a specimen, and enhancement beyond a reasonable state, or in a way that somehow compromises scientific value; if the specimen is satisfactory as is, then further treatment must be avoided. In this context, a statement from Donald C. Williams of the Smithsonian Institution's Conservation Analytical Laboratory (*Chemical and Engineering News*, 1988, **66** (46), p. 10) seems fitting: "Do as little as possible but as much as necessary."

Examples of minerals commonly "restored" by surface and subsurface sealing techniques and marketed in major shows include:

(1) **Guerrero, Mexico, amethyst**; may be treated with silicone or other materials to improve luster, possibly including mild hydrofluoric acid treatment to remove surficial impurities.

(2) **Minerva, Illinois, fluorite**; many have been heavily silicone-treated to seal fractures and/or improve luster.

(3) **Fremont County, Colorado, botryoidal fluorite**; impregnated with mineral oil to improve luster or restore color to an "as found" (i.e. wet) appearance.

(4) **Russian fluorite**; some have been treated with proprietary lacquers to seal fractures.

(5) **Okarusu, Namibia, fluorite**; often heavily silicone treated to seal fractures and internal reflections from intergrown crystals.

(6) **Pala, California, tourmaline** (elbaite); surficial quartz is sometimes removed with hydrofluoric acid, then treated with

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[2] The author of both articles, Carl Fischer, advocated drilling holes in matrix and gluing single crystals in the holes, thus creating a matrix specimen that would command a higher price; the author justified this practice for reasons of profit, and because "everyone is doing it"! Unfortunately, the backlash from this attitude results in some collectors believing that legitimately repaired specimens are in themselves unethical.

silicone or other proprietary materials to improve luster and fill internal fractures.

In most cases of restoration on the market today, the minerals are impregnated with silicone or other proprietary compounds either to seal fractures (or interstitial voids between subparallel crystals in the case of botryoidal fluorite) or to fill in subsurface imperfections, with the excess being removed. Small missing corners of franklinite (particularly the larger specimens) are often replaced by material of similar color and luster; restoration is again limited by geometric constraints.

Certainly, for the purposes of mineral commerce, sellers should clearly identify repaired or restored specimens (cleaning is generally presumed). Most dealers are careful to label specimens that have been repaired, but few label specimens as being "restored." In some cases this is because "proprietary" methods have been used, but in many cases such information is withheld in hopes of receiving a higher price, a dishonest practice motivated by the pervasive negative attitude about mineral restoration. The deception is often compounded by restorations which are too difficult to discern. Other people will be dishonest regarding imprudent extrapolation. However, the abuse of trust in some cases in no way de-legitimizes the proper practice of ethical repair and restoration. A person's intent to defraud can seldom be reliably assessed, which leaves a prospective buyer to speculate on the relative merit of specimen restoration as seen in today's collector market. It would be prudent and honest to clearly label restored specimens as such, as well as those having been repaired.

A final consideration regarding mineral preservation and restoration is the necessity of careful and responsible field collecting, predicated not only on the often-stated fact that the collector is only a temporary custodian of irreplaceable specimens, but more importantly that the field collector is often the only person who can make the decision of what to collect and thus what will have the chance to be repaired or restored. The judgment made in the field by the collector as to what is to be saved for possible future repair is usually irrevocable, and allows no hindsight as to what could have or should have been repaired. Consequently, every incomplete crystal, crystal shard and fragment from an important pocket or other find should be saved in order to facilitate future repairs. Such fragments may constitute a critical part of a broken crystal—if they are discarded in the field there is no further opportunity for repair.

In essence, the conscientious collector need not apologize for specimen repair or accurate restorations, so long as the accuracy is logically demonstrable, the method is reversible, the restored part is discernible, the repair/restoration is not passed off as truly natural, and the specimen's scientific value is not damaged. The current climate of disapproval only results in the discarding of specimens that have potential aesthetic (and perhaps also scientific) importance. A continuing rational and open discussion of methods of repair and restoration (see the feature article in this issue) will serve to increase awareness and acceptance of legitimate and ethical repair and restoration techniques, and consequently will enhance specimen preservation by field collectors, dealers, curators, and connoisseurs of minerals.

Daniel E. Kile
333 Salem Street
Aurora, Colorado 80011

Wendell E. Wilson
4631 Paseo Tubutama
Tucson, Arizona 85715

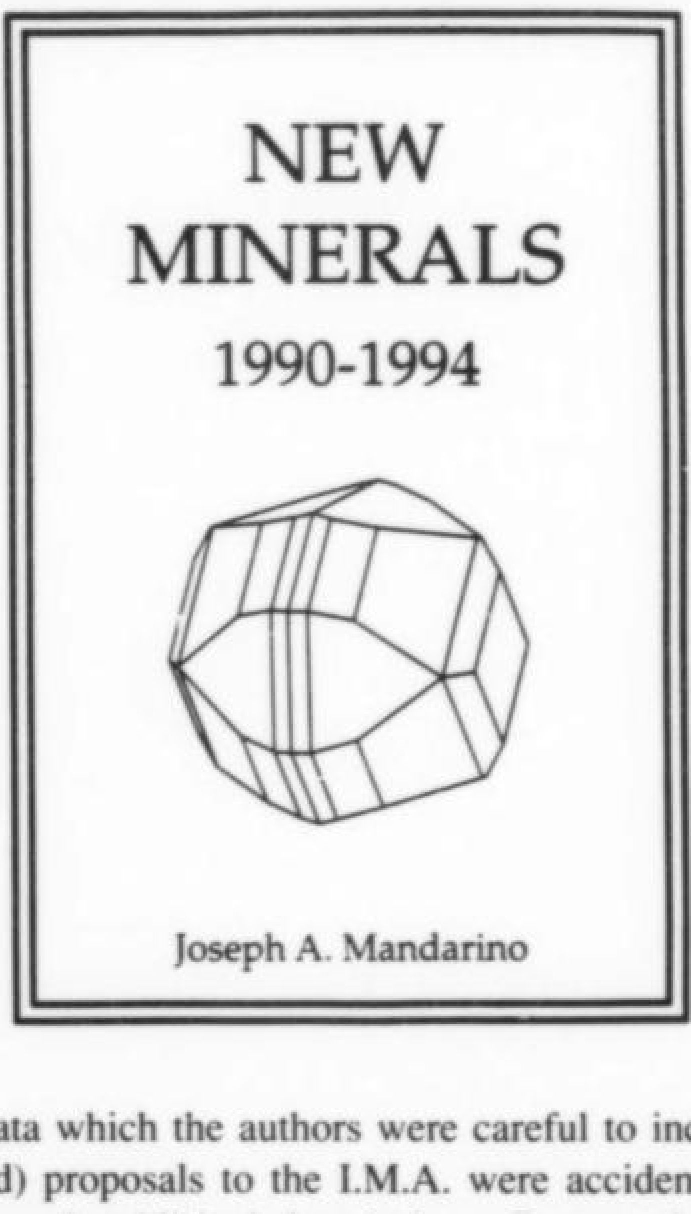
notes from the EDITOR

NEW BOOK on NEW MINERALS!

We are proud to present a new reference work containing detailed abstracts, written by Dr. Joseph A. Mandarino, covering all 219 new minerals described during the years 1990–1994. Most of these have ***not*** appeared previously in the *Mineralogical Record*, or anywhere else, but were written and compiled specifically for this book, the first of a series.

Joe Mandarino's abstracts of newly described mineral species have been appearing in the *Mineralogical Record* since 1995 and have been widely praised. Mandarino, as the former chairman of the I.M.A.'s Committee on New Minerals and Mineral Names, is an eminent authority on new minerals. In fact, some of his abstracts have the unique distinction of being *superior to the original descriptions* as references on the species. The reason is that these are actually "perfected abstracts," in the sense that he has meticulously reviewed, recalculated, corrected and augmented the data presented in each of the original descriptions.

It is surprising how many errors and omissions he has found in new species descriptions. For example, in the majority of cases, important data which the authors were careful to include in their (unpublished) proposals to the I.M.A. were accidentally omitted from the formal published descriptions. Fortunately, Mandarino has a complete file of past proposals and has easy access to newly submitted ones, so he can retrieve the missing data which would otherwise be lost to science (usually such properties as streak, diaphaneity, tenacity, fluorescence, etc.). Sometimes the value for density was nowhere to be found in the body of the original



description, but did appear in the author's own abstract; sometimes, differing values appeared in the main article and the author's abstract; and sometimes both values proved to be wrong!

Many authors are laboratory-oriented and give little thought to practical field identification parameters, even though such features may have provided the first clue that a new species was involved. Consequently, useful information for the field collector, such as streak, might be absent from the original description, from the author's abstract *and* from the initial I.M.A. proposals. Mandarino would then contact the author on the telephone, and a hypothetical conversation might go something like this:

> *What color is the streak?*
> We don't know.
>
> *Why not?*
> Because we didn't have a big enough sample to perform a streak test.
>
> *Didn't you powder a small sample for the X-ray diffraction analysis?*
> Of course.
>
> *What color was the powder?*
> Pale blue.
>
> *Well then, that's the streak.*
> Oh really!?

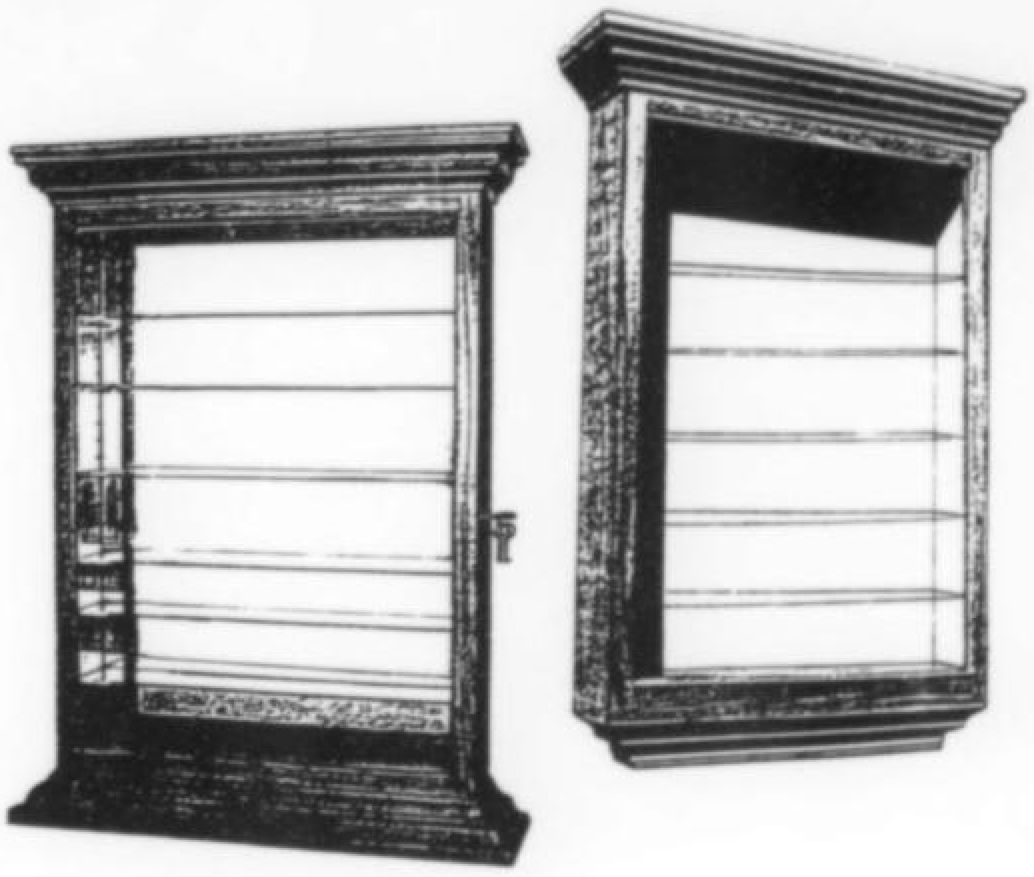
Crystal drawings rarely accompany new species descriptions these days, and often when present prove to be incorrectly done. Mandarino has not only corrected all of these errors (generally with the help and approval of the original authors) but has in many cases generated crystal drawings of his own from the data presented, and has confirmed the habit through correspondence with the original authors.

Some authors have described numerous species, over a span of years, from a single occurrence. The locality may be precisely specified only in the earliest descriptions and not in the later ones. In such cases Mandarino has extracted the maximum amount of locality data from the early descriptions and upgraded the later abstracts accordingly.

Mandarino's scholarly and very demanding approach to completeness is a real service to mineralogy. These abstracts, in the *Mineralogical Record* and in this new book covering 1990–1994, are the *best* references to the new species. Readers specializing in rare minerals no longer need to pay substantial subscription fees for *Mineralogical Abstracts*, *American Mineralogist*, or *Mineralogical Magazine* if their only need is for the best data on new species. Nor would a new edition of *Encyclopedia of Minerals* (1990) be needed some day for the species published since then. Abstracts appearing elsewhere in the collector literature are grossly abbreviated and non-critically compiled.

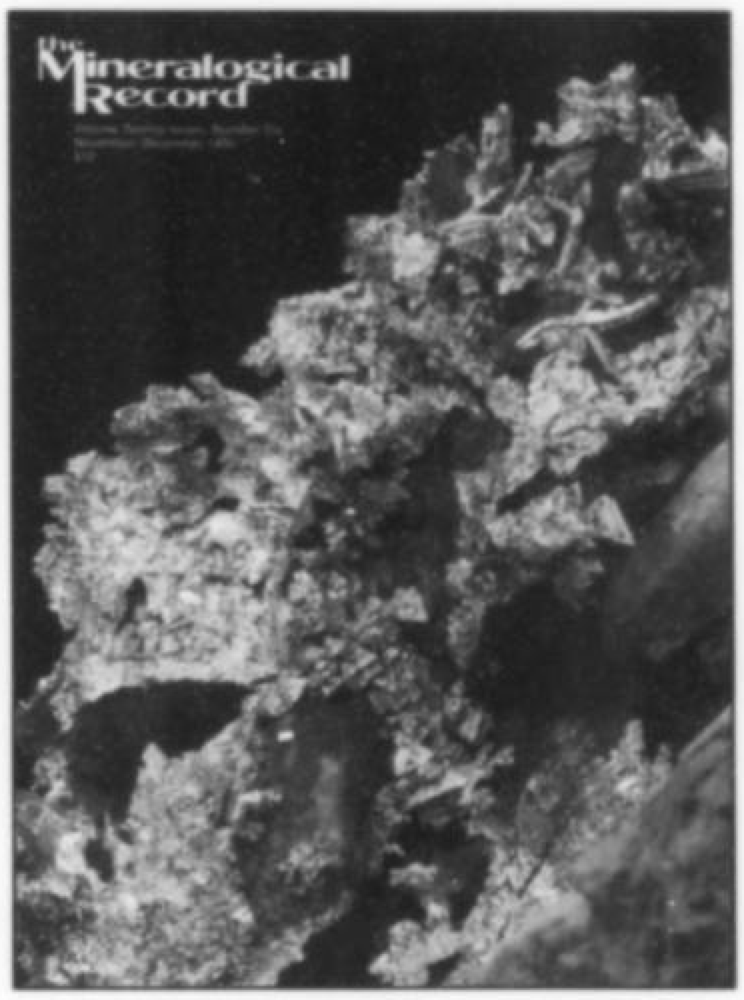
For the future we will issue in due course another book in the series covering 1995–1999, and (if sales indicate sufficient interest) a prequel volume perhaps covering the 1980's. Each volume devotes a full page to each species (like Bideaux *et al.*'s *Handbook of Mineralogy*, but with crystal drawings) and the species are alphabetically arranged. All species in a volume are listed alphabetically on the *outside back cover* so you don't even need to open the book in order to find out if a particular species is included.

To order your copy, send $20 plus $1 postage and shipping (that's less than 10¢ per species!) to the Circulation Manager, Mineralogical Record, P.O. Box 35565, Tucson, AZ 85740, or FAX your credit card order (VISA or Mastercard only) to 520-544-0815. Support this first book of abstracts now, so that we can continue in the future with many volumes that will save you hundreds of dollars while putting up-to-date mineral data at your fingertips.



MINERAL CASES (V)

Our featured case for this issue is a wall-mounted or table-top display case built by James Sheraikis and distributed by William F. Pogue, Pegmatite Mining Specialists, P.O. Box 989, Del Mar, CA 92014 (Tel: 619-566-5902). The specifications are: inside dimensions 4 x 22 x 32 inches; oak or walnut; neon or fluorescent lighting built in; fixed or adjustable glass shelves; tempered glass door with German lever lock and full piano hinge; mirror or felt back, and mirror or wood interior sides. The prices are $800 for the fluorescent-light version and $1,100 for the unique neon-light model, plus shipping. These are very carefully constructed cases, made by a real craftsman. Custom sizes and other woods are also available. Examples may be seen during the Tucson Show each year in the Executive Inn, room 272.



COVER ERRATUM

The beautiful photo of the California gold on our November–December cover was erroneously credited to Jeff Scovil. Actually it was the work of Geoffrey Wheeler, a professional photographer in Boulder, Colorado. Geoffrey has recently been adapting his skills to mineral photography; potential clients are invited to give him a call at 303-449-2137. ☒

MINERAL SPECIMEN REPAIR AND RESTORATION: TECHNIQUES AND MATERIALS

Peter B. Leavens
Department of Geology
University of Delaware
Newark, Delaware 19716

Kory R. Berrett
Berrett Conservation Studio
3053 Reisler Road
Oxford, Pennsylvania 19363

Repair and restoration are honorable concepts in virtually every other major field of museum curation, from fine art to classic cars to paleontology. The philosophy is also defensible for use in mineralogy, but the technology must be carefully selected and skillfully applied for optimum results.

INTRODUCTION

Specimen repair is a subject that evokes strong differences of opinion, and it seems there is enough reticence about it to make it one of mineral collecting's dirty secrets (see accompanying editorial). When we first considered writing this article, the eminent curator of a major museum remarked, "You don't want to do that—you'll become known as the curator with all the repaired specimens." (Of about 475 specimens in the general display of the University of Delaware museum (Leavens, 1983), about 30 have some repair or restoration.) By contrast, another curator of another major museum commented, "I love it when the dealer says the specimen has been repaired. It means we may be able to afford it." Many collectors, especially Europeans, will not knowingly buy a repaired specimen, and therefore such specimens are cheaper than unrepaired pieces of similar quality.

However, in the fields of fine and decorative arts, repairs and restoration of objects are so commonly necessary that they are generally accepted, although the market value of some specific kinds of collectibles can be seriously affected by repairs. There are different opinions in these fields as to what constitutes appropriate treatment, but there is general agreement that the purpose of restoration is to present the object as it was originally, and *not* to supply missing elements without solid evidence supplied by expert knowledge that is supported by research. The *Code of Ethics and Standards of Practice* for museum conservators (AIC, 1994) states that conservators cannot ethically carry compensation (restoration) to a point of modifying the known character of the original. Those restorers willing to "improve" the appearance or the identity of collectible objects, including mineral specimens, are involved in faking.

We feel that the practice of repairing mineral specimens should be recognized openly. In this article we present our opinions as to what constitutes appropriate repair (versus faking); how repairs should be reported in mineral transactions, on display labels, and in catalogs; and what materials and methods are most appropriate for mineral specimen repair treatments. In an era when fine mineral specimens (even repaired ones) may be worth thousands of dollars, it is important that there be some agreement on these issues, and that repairs be done in an honest and ethical way.

PREVIOUS WORK

There are few articles on repair techniques for mineral specimens. Thompson and Richards (1976) wrote an editorial in the *Mineralogical Record*, providing definitions and defending the concept of repair, particularly by analogy to the art world, but they did not discuss methods of repair, or the distinction between repair and faking. Dunn, Bentley and Wilson (1981) wrote an excellent and detailed article on mineral fakes for the same publication. They provided a summary of the literature on faking and on repair which should be read by all collectors. That article is quoted in this paper.

Writings which discuss the care and preservation of mineral collections in museums are also sparse. Waller (1980) compiled a listing of environmentally sensitive mineral species and a review of previous scientific papers, but offered little regarding repair except to acknowledge the fragility of minerals and briefly to discuss consolidation measures. Howie (1992) edited an excellent series of papers on the care of specimens in collections, but the papers do not deal with repairs, except for the list by King of consolidants and adhesives suitable for use on rock and mineral specimens.

DEFINITIONS

Although repair and restoration involve assembling fragments, it is useful to make a clear distinction between them. Following Dunn *et al.* (1981), to **repair** is to secure any portion of a specimen in its original position and orientation without replacement of missing material; to **restore** is to replace damaged or missing portions of a specimen with foreign material intended to duplicate the original appearance (in art conservation this action is called "compensation"). Thompson and Richards (1976) added the category of reinforcement: securing of weakened but not detached areas to prevent future breakage; also, the hardening of unstable clay or mud matrix.

REASONS FOR REPAIR

Specimens for research, study or reference do not usually need repair. Indeed, repairs, no matter how carefully carried out, add foreign materials, adhesives or consolidants, which can alter the results of analyses and may conceal or destroy some information of interest to the mineralogist. Thus, the specimens likely to be repaired are usually for display, the kind that excite collectors and curators, and that are placed into competitive cases and museum displays. Because repairs usually require a significant investment, specimens that get repaired are likely to be larger or more aesthetically pleasing than average for the locality or find.

Why would a person acquire a repaired mineral specimen? There are a number of reasons, including availability, quality, size and price, or any combination of these. It is obvious to anyone involved in the mineral market that repaired specimens sell for less than unrepaired specimens of the same quality. Some collectors, concerned with the investment potential of their collections, will not buy repaired specimens. A prominent and experienced New York dealer estimates that as a rough rule of thumb, a well-repaired specimen is worth about half of what it would be unrepaired, at least for moderate to good specimens up to about $1000 in value. For outstanding or rare specimens, no such estimates can be given, but the differential shrinks, and some of the most valuable mineral specimens in the world, such as the rhodochrosites discussed below, are repaired.

The larger the crystal, the more likely it is to be broken or detached from matrix or pocket walls during formation, as a result of later earth movements, or during collecting. A recent example illustrates this point. In the summer of 1992 Bryan Lees of *Collectors Edge* reopened the Sweet Home mine in Alma, Colorado, with the help of backers and made the greatest recovery of rhodochrosite crystals in history (Moore, 1993). Because of movements during and after pocket formation, almost all the larger specimens were recovered broken and had to be reconstructed, including the largest and most dramatic specimen, the "Alma King." Some fine smaller specimens were recovered intact. Another superb Alma rhodochrosite specimen from a previous find (now at the Houston Museum of Natural Science) is also repaired.

For several reasons museums are more likely than many private collectors to own repaired pieces. Larger pieces, generally more suitable for museum display, are more likely to be recovered broken. A museum generally does not have to be concerned with the investment value of a specimen but display value is paramount. (The late Paul Desautels, Curator of Minerals at the Smithsonian Institution, frequently commented that only the front of a specimen mattered in a museum display.) Since almost all museums are on restricted budgets and must use acquisition money for research specimens as well as display pieces, many curators will buy a fine repaired piece, rather than an untreated specimen, in order to maximize their resources.

REPAIR VERSUS FAKING

It is important that repairs not be carried to the point of faking. Dunn *et al.* (1981) made the following distinctions between repair and faking:

> Specimens which have been repaired and are **clearly marked** as repaired are not deceptive, and are therefore outside the scope of this study, provided that:
>
> (1) The repair has returned the specimen to its original configuration and has not "improved" it.
> (2) The glue or cement is colorless, so as not to alter the apparent color of the specimen.
> (3) No missing portions have been replaced by foreign substitutes.

The first point is the most vital distinction between repair and fake. On the second point, while we agree that the body color of a specimen should not be altered by the adhesive used to repair it, we also believe that colored adhesives have a role in *restoration*, and that missing portions can sometimes be ethically restored, as discussed below.

We agree that repairs must be clearly identified, but we think that how the specimen should be identified as repaired depends on its context. A repaired specimen being offered for sale **must** have the word "repaired" clearly written on the label. The dealer should, additionally, identify the specimen as repaired to any prospective buyer. Ideally, the specimen itself should be marked as repaired, because labels can easily be separated from specimens, but marking the specimen may not be practical. A cataloged specimen should have the repair noted in the catalog entry. However, it is not necessary that the repair be mentioned in every display label or figure caption; the *Mineralogical Record*, for instance, in its photographs and descriptions does not generally note repairs; nor is it done in other mineral displays. This is also true for objects exhibited in the general art and antique world.

Repaired specimens in the University of Delaware Mineralogical Museum are cataloged as such, and if the repair was done after the museum acquired the specimen, a treatment file is kept describing the repair. The file will include a detailed description of the repair procedures and materials, the date of the repair, and the reason for the repair, and may also include "before" and "after" photographs.

RESTORATION

Even mineral collectors who accept *repairs* of mineral specimens may have trouble condoning *restoration*. This is partly because of the difficulty in making a distinction between a restoration and a fake, and partly because in our current culture some collectors feel that restoration falsifies the specimen as it is, even if it restores it accurately to its former appearance. On the first point Dunn *et al.* (1981) commented,

> Only highly accurate photographs, castings, or other firm evidence might form an acceptable basis for restoration. Lacking these, the restorer is only guessing about what the specimen looked like prior to damage, and the "restoration," if incorrect, may actually be a fake. . . . It is not possible to precisely define the distinction between restoration and fake. . . . A specimen should probably be considered a fake when an "important part" of the specimen has been replaced.

Although we respect the position of those who feel that all restoration involves some level of falsification, we feel restoration is appropriate in some cases. Dunn's insistence on firm evidence in support of restoration is consistent with the standards of professional conservation practice. We believe that four factors should be considered in determining whether a restoration is appropriate:

(1) Sufficient evidence should be available to guarantee that the restoration is not an interpretation. Such evidence might include photographs, if the specimen was damaged after collecting, molds of the specimen against enclosing matrix, or careful comparison with other similar specimens from the same find. While comparison provides the least certainty in restoration, it is commonly the only source of information. We believe that comparison may be an acceptable source, particularly if the restoration conforms with the other criteria listed below.

(2) The restoration of terminations has a great chance of being inaccurate and thus becoming faking. Therefore this practice should usually be avoided, even if there is information about the original termination.

(3) Missing pieces of crystals being restored with an appropriate filler must fit together, or register, at least in part; recreating bridging segments of crystals which do not touch almost always involves interpretation with a high degree of uncertainty.

(4) In cases where more than a small percentage of the specimen is missing, the restoration material is likely to become so obtrusive that filling is probably not warranted. Obtrusiveness by virtue of placement is another reason for avoiding restoration of terminations.

Restoration, with or without faking, has long been practiced on opaque minerals such as franklinite, which can be restored with opaque fillers like plaster and paint. In recent years the development of transparent, colorless synthetics such as epoxies and acrylics makes it possible to restore many transparent crystal specimens as well.

MATERIALS

The ideal qualities for adhesives used in repairs and restorations include high bond-strength, long-term stability, controllable setting times, no shrinkage, lasting clarity, and a selection of refractive indices to match the repaired specimen so that glue joints will not refract light and will therefore remain invisible. The adhesive should also wet and bond to mineral surfaces readily, and, importantly, should remain fully reversible, so that it may be removed if it becomes desirable to undo the repair. Unfortunately, no single material currently offers all of these properties.

Historically, a variety of different materials have been used in repairing specimens. Many specimens from Alpine localities have been repaired (or faked) with water-soluble glue, probably the animal-hide glue which was in general use at that time in furniture construction. Epidote specimens from Untersalzbachtal in Austria were repaired with black asphalt (Dunn *et al.*, 1981) which is soluble in organic solvents. Howie's (1984) review of materials used for conserving fossil specimens describes the range of adhesives available for use throughout the 19th and 20th centuries: shellac and other naturally occurring resins like dammar and Canada balsam may have been used to bond minerals; isinglass, fish glue, and after 1900, cellulose nitrate were also likely choices.

The 1930's saw the development of many of the groups of polymers that have generally replaced the natural products for repairing materials such as glasses, ceramics and minerals. These include water and solvent-soluble cements such as white glue, cellulose acetate, nitrocellulose-based adhesives, and other synthetic resins, and catalytic-setting cements including epoxies, polyesters and cyanoacrylates. Each has its advantages and disadvantages.

Commercial solvent-soluble cements, which come in single containers or tubes, are typified by white glue and cellulose acetate. They are inexpensive, readily available, reasonably transparent, and easy to use. They are not as strong as reaction-type adhesives like epoxies, and are not very suitable for repairs which require high bond strength. As they age, they may change from nearly colorless to amber, which is a problem in repairing colorless minerals such as transparent quartz groups. Because commercial cements include various additives, such as plasticizers, extenders and wetting agents, they may cross-link* over time, becoming less reversible. For some small repairs, their availability and convenience makes them attractive.

Various synthetic, thermoplastic, acrylic resins are used in adhesive formulations, including polyvinyl acetate resins and ethyl methacrylate copolymer resins. Most acrylic resins are readily dissolved in organic solvents such as acetone and mineral spirits. They are useful as consolidants and as adhesives for repairs that do not require high strength. Acrylics can also be colored to match a specimen, and they can be altered with the addition of fumed colloidal silica and used as filler in restorations. Enough fumed silica is added to the acrylic to make it thixotropic—so that it has low but definite shear strength and will not flow under its own weight. But since they are solvent-based, acrylics shrink on setting, the amount depending on the proportion of solvent. The key advantage to acrylics is that most do not cross-link over time, so they are more reversible than other adhesives and are also more color-stable. These resins are favored in the restoration of art objects.

Cyanoacrylates seem to offer the possibility of instant repairs—push together the coated surfaces and presto, repaired specimen. Unfortunately, these adhesives require an air-tight seal to cure fully and are incompatible with alkaline substrates. As a result, they may fail without warning after a few years. We cannot recommend cyanoacrylates for any mineral repairs.

A large number of different epoxies are commercially available. They have the advantage of not shrinking during setting, as there is no solvent to be lost, so they can be used for filling gaps. Epoxies also form very strong bonds, even where relatively small bonding surfaces are available. The refractive indices of optical-grade epoxies approach those of quartz, so repairs of many transparent materials can be inconspicuous. Like acrylics, they can be colored and thickened for use in restorations. Unfortunately most epoxies, particularly the fast-setting ones, continue to cross-link over time, becoming more yellow and less reversible.

Optical-grade epoxies, engineered for use in optical instruments such as microscopes, are used in museum conservation to repair art objects made of materials such as glass, that require high bond strength and transparency. These resins exhibit minimal yellowing and are removable, though not truly reversible. Because of their high purity they are more difficult to use, and are more expensive than commercial epoxies. Several optical epoxies are widely used in museum practice, including *Epotek 301-2* (Epoxy Technology, Inc.), *Hxtyl NYL-1* (Hillery Enterprises), and *Ablebond 342-1* (Ablestik Laboratories). Because the working character and batch purity of these products may change at any time, the conservator must evaluate each new purchase of resin for its acceptability.

During the first few days of curing, epoxy can be dissolved in acetone. On some objects, epoxy bonds will fail with exposure to

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*Cross-linking refers to a chemical reaction resulting in a less soluble compound.

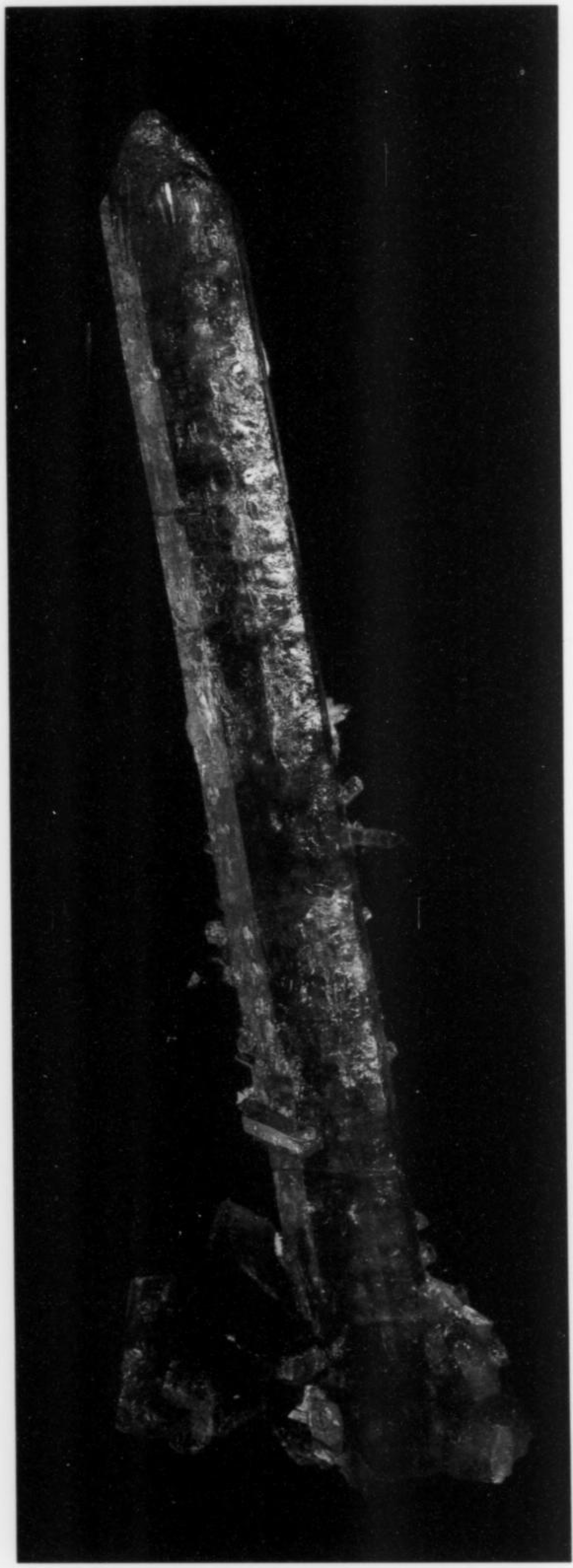

Figure 1. **Vesuvianite crystal; 16.5 cm; from the Thetford mines, Asbestos, Quebec (after treatment).**

live steam, or after prolonged soaking in water. Fully cured epoxy will usually come apart if exposed overnight in a closed container to vapors of methylene chloride. This solvent invades the epoxy network and will cause the resin to swell and soften. Depending on the configuration of the bond, this swelling effect can also cause significant damage to the repaired object. (Methylene chloride, an ingredient in many paint strippers, must be used with appropriate safeguards. In addition to other effects, exposure to methylene chloride depresses the central nervous system, causes stress on the cardiovascular system, and has been identified as an animal carcinogen. Standard MSDS—materials safety data standards, available from manufacturers—should be consulted prior to use. It should always be used with adequate ventilation.)

CASE STUDIES

The following five detailed examples show the range of materials and techniques which can be applied to the repair and restoration of mineral specimens, as well as the choices in both objectives and methods that must be made. All are more complex than simple regluing of a broken specimen or reattachment of a crystal to matrix. In four cases, previous repairs had to be undone, and in the last example an elaborate fake was reconstructed into an authentic but repaired specimen. All the specimens are in the University of Delaware Mineralogical Museum collection.

Vesuvianite from Asbestos, Quebec

This specimen, which measures 16.5 cm, is one of the large crystals recovered in 1990 at the Thetford mines, Asbestos, Quebec (Fig. 1) (Wilson, 1991). It is apparently the largest crystal known from the locality. Like other large crystals from the find, it had been broken into pieces during formation by pocket movements, and the broken surfaces show signs of recrystallization, either etching or minor overgrowth. There are some small chips at the edges of the broken surfaces. The crystal was repaired in three places at the time we acquired it; the two outer joins were well

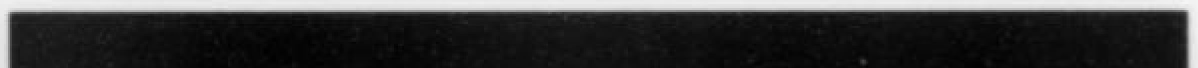

Figure 2. **Hematite with epitaxial rutile, on quartz; 7 x 10 x 10 cm; from Cavradi, Tavetschtal, Switzerland (after treatment).**

Figure 3. Franklinite crystal in franklinite-calcite-willemite-zincite matrix; 10 cm on the leading edge; from the 750-foot level, Sterling Hill mine, Ogdensburg, New Jersey (after treatment).

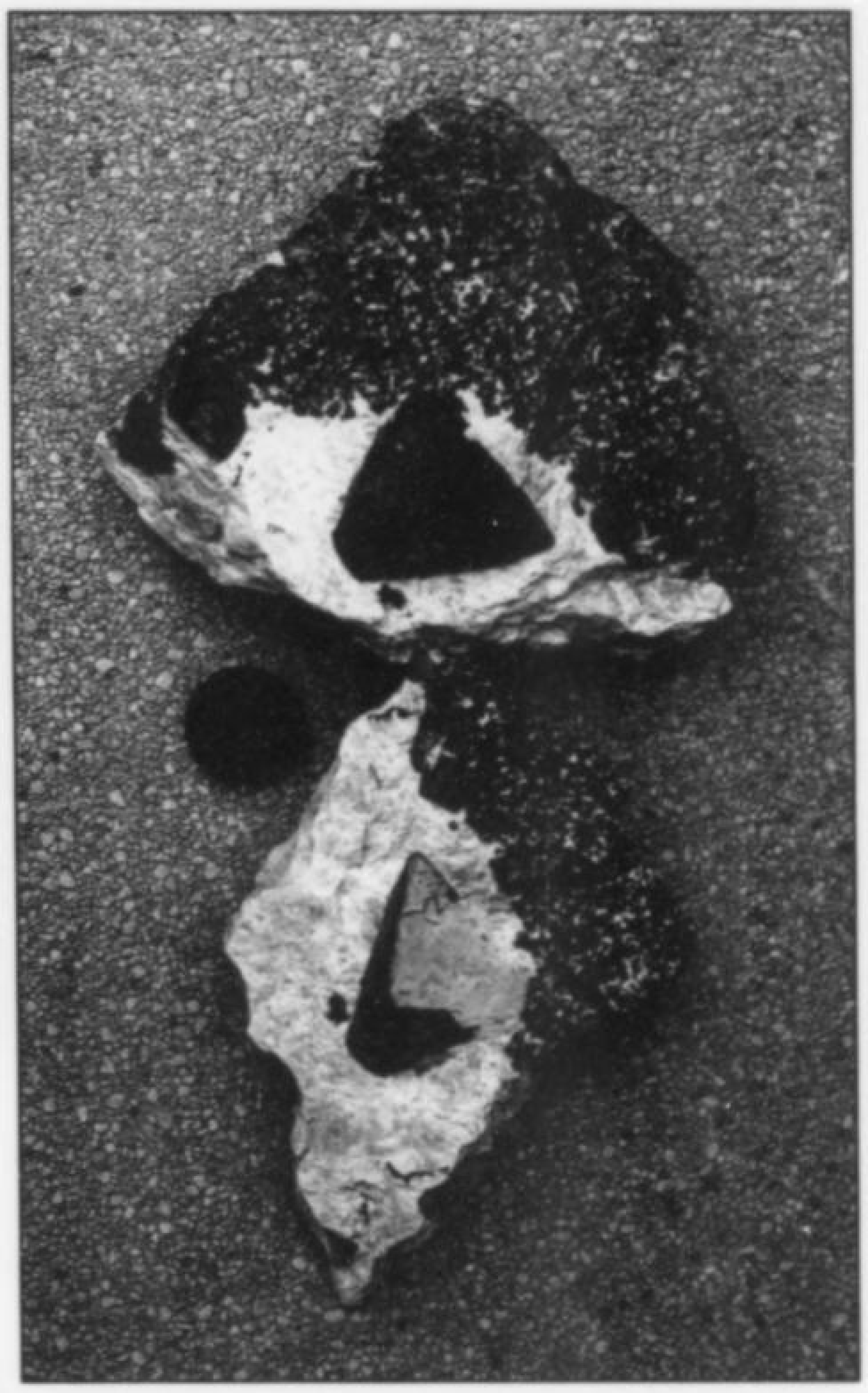

Figure 4. The franklinite specimen shown in Figure 3 (as collected).

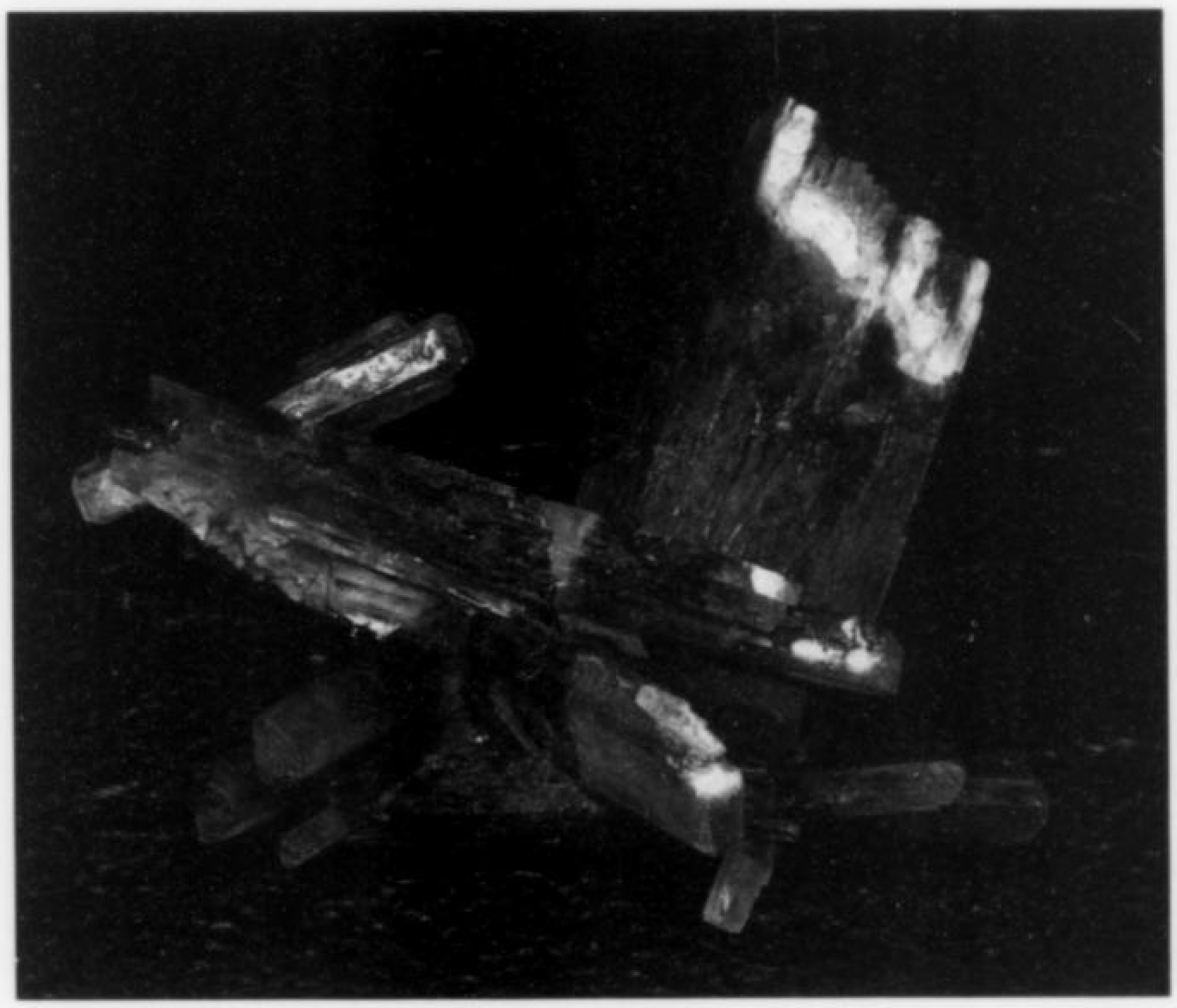

Figure 5. Barite crystal group; 13.8 cm long; from Stoneham, Weld County, Colorado (after treatment). The larger epoxy restoration is clearly visible in the center of the front crystal.

Figure 6. (right, above) Barite crystal group on matrix; about 20 cm tall; from Elk Creek, South Dakota (as purchased).

Figure 7. The barite specimen of Figure 6, correctly reconstructed.

registered, but the center join was not. In long-wave ultraviolet light the joins fluoresced a pale milky white, suggesting that commercial epoxy had been employed in the previous repair. Because we hoped to improve the quality of the central join, and preferred to employ a more stable and reversible adhesive, we decided to dismantle and reglue the specimen.

The specimen was photographed using black-and-white print film to document its condition before treatment. The old bonds were released using methylene chloride in an enclosed vapor chamber. A bedding of surgical cotton batting saturated with liquid solvent was placed in a wide-mouthed jar with lid, and the specimen was nested in the cotton. After standing 48 hours, the joins failed and the crystal separated into four segments of roughly equal length. Residual adhesive was removed under magnification with the aid of ultraviolet light, using wooden picks, micro-tweezers, and scalpels. Where further solvent action was required, a methylene chloride-based paint stripper was applied, allowed to stand, and washed off with acetone.

It was noted during the treatment that two of the joins were made using an epoxy resin and the third employed a cyanoacrylate. This is in line with the story that the dealer had bought portions of the crystal, already partly repaired, from two different miners.

The crystal sections were photographed to document their actual state. The sections were reassembled using an acrylic adhesive, *Acryloid B72* (ethyl methacrylate copolymer) in acetone. The larger chips around the edges were not restored, but four smaller losses were filled with a clear, ultraviolet light-curing acrylic monomer to provide a smooth reflective surface across the eroded edges of one of the joins.

The present repairs are both more durable and more reversible than the original ones. The central join is better than the original, but after disassembly it was noted that minor recrystallization had developed on the break surfaces; this prevented a perfect fit. While it may be argued that the central break is part of the crystal's formation history, as shown by the recrystallization of the break surfaces, we felt that the crystal was best represented as a single unit. In addition to the written and photographic documentation created regarding its actual state, we left most of the gaps between the segments unrestored, to show that the crystal has been fractured.

Hematite on Quartz from Cavradi, Tavetschtal, Switzerland

This specimen, which measures 7 x 10 x 10 cm, contains a large, free-standing cluster of platy, brilliant hematite crystals with epitaxial rutile, on quartz (Fig. 2). Collected in the last few years, it was formerly in the Tom McKee collection. The base of the specimen is sawn. The hematite crystal cluster had been shattered and repaired. The adhesive, which fluoresced amber under longwave ultraviolet illumination, was present in excess along many of the cracks, and formed smears and blobs on some of the crystal surfaces. It had yellowed over time. The joins between various pieces were not well aligned.

Because we felt that reorienting the fragments of the specimen would be difficult after disassembly, the joins were mapped on two drawings using ultraviolet light to show the glue.

Analysis with Fourier-transformed infrared spectroscopy enabled us to identify the adhesive as a nitrocellulose cement with an aromatic plasticizer. The adhesive had apparently cross-linked with time, because it was not soluble in acetone, ethanol or toluene, and only swelled in methylene chloride. After the specimen was exposed to fumes of methylene chloride in an enclosed vapor chamber for two hours, the adhesive loosened and became soft enough to remove with tweezers. Unfortunately, two joins on the back of the specimen did not come apart even after repeated applications of methylene chloride. These had to be left intact, although they provided poor alignment.

After the old adhesive had been removed, the joins were cleaned with ethanol. The separate pieces were reintegrated with *Ablebond 342-1* epoxy, to which *Cabosil* fumed silica was added to prevent flow. The specimen was placed in a trough of glass micro-beads while the epoxy set so that the pieces retained proper alignment by gravity.

After treatment the specimen was more discretely repaired and several errors from the previous treatment were corrected. In a few areas, the resulting alignment was poor because of the poorly aligned joins of the previous repair which could not be reversed. A few previous joins had been cosmetically filled with fragments of hematite which were not in their original locations. The correct locations of many small fragments were found, but some of the fragments could not be correctly reintegrated and were retained separately.

Franklinite on matrix from the Sterling Hill mine

This specimen, a 10-cm crystal of franklinite embedded in calcite with banded ore (Fig. 3), was collected on the 750-foot level of the Sterling Hill mine, Ogdensburg, New Jersey, in 1990 by Richard Hauck. It was recovered in two pieces, since the block of ore containing the crystal broke across a termination, so that most of the crystal was in one large piece, but the termination and a mold of one face of the crystal was in another. Another termination was broken off and not recovered.

Crystals of franklinite of this size and sharpness are very rare, and the associated matrix provides a dramatic contrast and illustrates an interesting geological problem: large crystals of silicates or oxides in marble are commonly found, as here, at the contacts between massive silicate or oxide and pure or nearly pure marble. The massive material may be much finer grained than the isolated crystals; in this case the massive franklinite layer contains grains about 1 cm across, but the big crystal, which contacts that layer but is embedded in the marble, is 10 cm on an octahedral edge, and has a volume about 1000 times as great as one of the massive grains. There is not a good explanation for this extraordinary difference in grain size. The contact between the bands of ore is sharp, with an irregularity of about one grain diameter, suggesting that there was little movement of material across the contact. Movement of atoms within the marble band must have been much greater to allow for the growth of the large crystals in it. Because of the size of the crystal and the interest of the specimen as a whole, it was a good candidate for repair.

Figure 4 shows the specimen as collected. The large block was trimmed and carved with a small hammer and chisels, some made from dental picks, to expose the crystal, a process that took about three hours. The embedded termination was trimmed off the other block and dissolved out of the enclosing marble with dilute nitric acid. It was recovered in several pieces.

As is sometimes the case, especially with crystals of metamorphic minerals embedded in matrix, the break released stresses in the crystal and allowed the pieces to deform slightly, so that they could not be perfectly realigned. The pieces were reattached so as to align most tightly along the front (or display side) of the specimen. Since gap-filling was required, the pieces were reattached using *Ablebond 342-1* epoxy made thixotropic by the addition of fumed colloidal silica (*Cabosil*) and tinted with a mixture of ivory black and titanium white powdered pigments.

There was a loss about 3 cm long and 2–3 mm deep on the lower edge of the crystal, and an area about 5 mm square along one of the top edges. The associated matrix piece showed the molds or imprints of these areas, so their original form was certain, and after discussion with various colleagues (some of it heated) we decided to restore these two areas, but not several other small ones. They were filled using *Liquitex* acrylic emulsion paste tinted with *Liquitex* ivory black emulsion colors. The fills were applied in four steps to develop adequate depth. After drying, the fills were carefully shaped and given surface features with scalpels. Inpainting employed a wash of acrylic resin (*Magna Resin*) paints applied to adjust the color of the fill. An acrylic varnish (*Flecto*, a poly N-butyl methacrylate) was then applied to impart gloss. Finally, powdered graphite was rubbed onto the surface to give a luster and metallic sheen that resembles the mineral's natural surface. This restoration is more stable and more reversible than the traditional plaster and stove black. The acrylic medium used can be dissolved away using acetone, while hardened plaster could not be readily removed without risk to the specimen. The mechanical stress which comes from the expansion of plaster during its setting is also avoided. The restorations are inconspicuous, but can be picked out with careful inspection, and are obvious under ultraviolet light.

The prominent intact termination is sharp and pointed, but the termination on the damaged portion is irregular and rounded. Terminations on some other crystals from the same find also show great variation in sharpness. The back termination of this crystal is missing, but its restoration would be so conjectural that it provides a prime illustration of our rule against restoring terminations. Many older franklinite specimens were restored, and terminations, which are easily broken, are the most commonly restored parts. In some cases, there is more plaster than franklinite in the finished specimen, and as Dunn *et al.* (1981) point out, these so-called "restorations" are clearly fakes. It is possible that our impression of the sharpness of large franklinite crystals is influenced by the prevalence of large crystals "restored" with fake sharp edges and terminations.

Barite from Stoneham, Weld County, Colorado

This specimen (Fig. 5) was collected in July of 1989. Measuring 13.8 cm in maximum dimension, it is reportedly one of the largest crystal clusters recovered, but it had broken in half before being found and suffered additional damage during collecting. The early breaks involved some loss of material, but the pieces still made contact, or registered. There was no sign of recrystallization of these broken surfaces. The collecting damage occurred when crystals broke along the diagonal {210} cleavage without any loss. The cluster had been repaired with epoxy but the lost areas, which comprised only a small part of the interior of the specimen, had not been restored. The terminations of all the crystals are intact, but some are rough and pale in color, apparently from having formed in contact with the pocket walls. The specimen conformed to our requirements for restoration: the nature of the missing area could be accurately inferred from the adjacent portions of the crystal, the pieces made contact and no entire crystal section had to be inferred, the terminations are intact so the restoration would involve only the interior of the cluster, and the area that required restoration was small, especially in proportion to the size of the specimen. Finally, the specimen is aesthetically pleasing and large for the locality.

The previous repair was undone by soaking the specimen for about a week, until the epoxy came apart. The specimen disassembled into two major sections and ten other pieces of various sizes.

The residual adhesive was removed in several steps: first, the bulk of the dry, brittle resin was flaked away mechanically, using tools like those mentioned in the vesuvianite restoration, above. Great care had to be taken because of the soft and brittle nature of the barite. Mechanical removal was finished under longwave ultraviolet light in order to distinguish the fluorescent adhesive more clearly. Those traces which did not yield easily were softened in a commercial paint stripper (methyl cellulose paste as a carrier for methylene chloride) and then swabbed away with acetone.

As a preliminary experiment, two small pieces were attached using *Acryloid B72* acrylic resin dissolved in an organic solvent and bulked with fumed silica, but these repairs were too conspicuous and the use of epoxy was elected; the refractive index of the acrylic is about 1.47, that of the epoxy about 1.56, and the average for barite is about 1.64, so the epoxy is closer to the barite in refractive index, although not very close. The cleaned surfaces were degreased with ethanol, and the sections assembled and restored using *Ablebond 342-1* epoxy resin adhesive thickened with fumed colloidal silica. Epoxy in the restored areas was colored with dry pigments (cerulean blue, cadmium yellow deep, and burnt sienna) to match the specimen.

The same epoxy mixture was employed to fill three areas of loss and to bulk the major sectional join which had suffered considerable wear through repeated treatments. The restored areas can be easily seen because of the difference in index of refraction between the barite and the epoxy, but because of film sensitivity to the color temperature of light sources, are more conspicuous in photographs than to the eye.

For an "invisible" repair, the index of the cement should closely match that of the mineral, but there are currently no adhesive resins which have indices approaching those of barite and other minerals with high values. Epoxy resins make a stronger bond and provide a better match to the refractive index of barite, but their long-term color stability is less certain than that of acrylic resins, and removal of epoxy at a future time may endanger the specimen; as we noted above, there is no perfect cement.

Barite in septarian nodule from Elk Creek, South Dakota

This specimen, a spectacular "starburst" of orange barite crystals on matrix (Fig. 6) from a septarian nodule in the Pierre Shale exposed along Elk Creek near the Black Hills (Campbell *et al.*, 1987), was offered for sale as a "repaired" (it should have been termed "restored") specimen at a very high price at the Tucson Show several years ago. Inspection showed that several of the terminations were attached with large filled areas of amber cement, probably epoxy, between the crystal and the termination. The work was excellent and the cement matched the barite in color, luster, and surface textures. However, the terminations were not perfect matches in proportion to the crystals with which they were paired, and in none of the cases was the termination in observable contact with the crystal. In addition, careful examination of the specimen showed that what appeared to be a broken surface on the side of the matrix was actually a natural fracture surface where another block of the septarian had separated from the specimen. At least one of the repaired terminations would have run into the projected extension of this missing block, suggesting that the repair was incorrect.

A couple of years later the specimen was offered "as is" by another dealer at about 1/3 the original asking price. Assuming that none of the restored terminations were correct, the piece was still a fine barite specimen and was purchased, with the intent of undoing the restoration and starting over.

The restoration was undone by placing the specimen on a stand in a closed jar, with methylene chloride in the bottom of the jar. After exposure overnight, the epoxy gelatinized and the terminations came away. At this point it was clear that all of the restored terminations were false and that the incomplete crystals were not broken, but had formed contacts with other pieces of septarian matrix, now missing. The evidence for these conclusions included the cloudy appearance of the ends of the contacted crystals which contrasted with the clarity of terminated crystals, the irregular surfaces of the contacted crystal ends which contrasted with the cleavage breaks expected, and the pattern of contact marks on the matrix showing where other pieces had touched the specimen. In addition to the false terminations, several correct terminations had also been repaired with epoxy, and these also came apart. These terminations were cleaved off their parent crystals and fit back exactly.

To further complicate matters, there was a thin layer of material, probably smectite clay, between the various pieces of matrix and between the matrix and the crystal cluster. During the disassembly this material absorbed methylene chloride, swelled and weakened, and the specimen came apart into four pieces on handling, with the barite crystal cluster being one of the pieces.

The repair involved sorting the various elements, cleaning the surfaces, and putting the pieces which belonged to the original specimen back together. Traces of adhesive from the previous repair were removed mechanically using ultraviolet light to identify residual adhesive. The crystalline mass was dismounted from the parent rock and reattached using *Acryloid B72*, an ethyl methacrylate copolymer, bulked with fumed silica to reduce its tendency to flow. Other elements with minimal contact surface, and with poor orientation with respect to gravity, were joined with epoxy resin adhesive. It was necessary to reorient the whole specimen with each fragment to be added; each of the crystals was repaired in a separate step to insure correct alignment through balancing while the epoxy cured.

The result (Fig. 7) is considerably less spectacular than the original fake, but is still a fine specimen, and has the advantage of being an honest one. We cannot say with certainty whether the previous restorer intended to make a fake, or whether he was just overenthusiastic in his restoration. But we do feel that the specimen gives clues to show that the previous restoration should not have been done as it was. If the original owner had left the specimen unembellished, and had only repaired the cleaved terminations, this complex treatment could have been avoided.

CONCLUDING REMARKS

It is important that the practice of repairing mineral specimens be recognized openly, and that repairs be executed honestly and carefully. The techniques and materials presented here have proven effective in the repair of various mineral specimens, and we hope that the discussion of the philosophy guiding our treatment decisions will stimulate open dialog. We believe that the ethical and accurate repair and restoration of mineral specimens can enhance their stability, restore their beauty, and promote their preservation.

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v.12/#4 Mineral Fakes, Mineral Fraud, Leadhills-Wanlockhead (England) $10	**v.12/#6** Bu Yat SOLD OUT burg eak (CO) $10	**v.13/#4** Diamond (CO), Quartz (MT), Jeanbandyite. Bancroft (Ont.) $10	**v.14/#1** Celestite (IN), Derbyshire (England), Lotharmeyerite (Mapimi) $10	**v.14/#6** Chuquicamata (Chile), Univ. of Delaware Mineral Museum $10
v.15/#1 Darwin (CA), Pereta Mine (Italy), Cetine Mine (Italy) $10	**v.15/#4** Sterling mine (NY), Burra mine (Australia), Lotharmeyerite, Jack Boyle $10	**v.15/#5** Jacupiranga mine (Brazil), Jensen quarry (CA), Cunha Baixa mine, Paulkerrite $10	**v.15/#6** Bad Ems (Germany), Touissit Vanadinite, Hawleyite (IN), Fluorapatite (SD) $10	**v.16/#1 Nevada Issue!** Comstock Lode, Getchell, Steamboat, Majuba Hill. White Caps $10
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PLATINUM-GROUP MINERALS FROM THE KONDER MASSIF, RUSSIAN FAR EAST

Louis J. Cabri and **J. H. Gilles Laflamme**
Canada Centre for Mineral and Energy Technology
555 Booth Street
Ottawa, Ontario, Canada K1A 0G1

Crystals of platinum-group minerals from the Konder massif, located near Nel'kan in the Russian Far East, were examined by optical microscopy, X-ray diffraction, scanning electron microscopy, and by electron probe microanalysis. They were found to be ferroan platinum (Pt_3Fe) and platinum-bearing zvyagintsevite (ideally Pd_3Pb). Several other species were found in association, including cooperite (PtS), hongshiite (?) (PtCu), palladian-cuprian electrum and gold.

INTRODUCTION

Mr. Brad van Scriver, *Heliodor,* P.O. Box 10, 19900 Prague 9, Czech Republic, approached CANMET with a request for a mineralogical characterization of three "platinum crystals" from the Russian Far East. These crystals are similar to some previously illustrated in mineralogical journals in color photomicrographs (e.g., *Mineralogical Record,* **24**, 225 and **26**, 529). Mr. van Scriver wished to confirm that the crystals he had bought in good faith are genuine minerals. He had been given limited information about the locality and the geology, ". . . a pipe in an old river bed . . . ," which "The Russians claim is an alluvial prospect, but some of the xls are so sharp they seem not to have been moved at all (elluvial?)." The location on a label as given was "Konder (Village), near Nelkan, Ajano-Maiskiv region, Khabarovskiy Kray, Russia, C.I.S." Mr. van Scriver also supplied crystals of a possible palladium mineral from the same locality.

When this investigation was begun, we had little information on the locality or on Russian publications describing the locality and its mineralogy. We have subsequently been fortunate to have not only obtained several relevant Russian publications, but also to have made direct contact with Russian geologists who have worked on the Konder[1] massif.

The Konder massif is a circular, concentrically zoned alkali-ultramafic massif with a diameter of about 7 km, situated in the Ayan-Maya region in the northern part of Khabarovsk Territory, about 200 km west of the Sea of Okhotsk, Far Eastern Russia (Makrushev *et al.*, 1990; Nekrasov *et al.*, 1994). It is one of several concentric ultramafic massifs that intruded the Archean and Proterozoic rocks of the Siberian Platform (Aldan Shield) as shown in Figure 1. It had been classified as an Inagli (Aldan) type of intrusion, a sub-type of forsteritic dunites intruded into stable platforms at shallow depths (Razin, 1976; Cabri and Naldrett, 1984). The Konder intrusive is surrounded by a circular ridge of the same name, the intrusion itself forming a basin in its lowermost part (Kharkevitch and Krot, 1985). The Konder River flows northward from the center of the basin where it is connected to a system of radially dispersed streams (Fig. 2). Placers containing grains and nuggets of platinum-group minerals and gold are found

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[1] EDITOR'S NOTE: There is some disagreement regarding the best transliteration of the name Кондер. Some authorities prefer the standard transliteration *Konder.* Others point out that the name in Russian is not pronounced the way it is spelled, and that *Kondyor* would be closer to describing the correct pronunciation. We shall retain the Russian spelling here (*Konder*) with the stipulation that it is pronounced "Kondyor," and may occasionally be spelled that way.

along the Konder River and its tributaries (Sushkin, 1995). The Konder River emerges through a trough-like gap, changing direction to the northwest until it converges with the Uorgalan River, itself a tributary of the Maya River, which eventually flows into the Aldan River.

The geology and mineralization of the Konder intrusion have been the subjects of numerous studies in the former Soviet Union since the 1960's, and the placers have been the source of several new platinum-group minerals such as cuprorhodsite, cuproiridsite and konderite (Rudashevsky *et al.*, 1984, 1985). According to Sushkin (1995), active mining and geological surveying have been under way since 1984. The bulk of the platinum is found in the form of shapeless, angular grains, grain aggregates, lumpy grains and nuggets. The platinum nuggets weigh up to 3.521 kg, and all are reported to contain chromite phenocrysts measuring 2–7 mm (Shushkin, 1995). Grain-size decreases downstream in the lower Konder to 0.05–0.5 mm, whereas in the upper Konder, Pt-bearing grains finer than 0.1 mm occur in insignificant quantities. Again, according to Sushkin (1995), a remarkable feature of the upper Konder placers is the presence of a considerable quantity of nuggets in addition to well-formed platinum crystals. Euhedral cubic and octahedral crystals, as large as 1.5 cm^3, were initially reported to be the mineral *isoferroplatinum* and were found to be associated with alkaline metasomatites (Nekrasov *et al.*, 1994). These are apparently the largest known crystals of any Pt-Fe alloy; the next closest in size occur in Chukotka, and are less than 5 mm (Dr. Vadim Distler, personal communication, 1996, from Dr. A. D. Genkin). The highest concentrations of placer gold (up to 5 wt.% of the placer platinum) occur along the Anomal'nyi and Treglavyi streams, as tiny nuggets weighing 1–5 g, but rarely more than 10 g (Shuskin, 1995). The gold is thought to have been derived from quartz veins and cupriferous garnet-epidote-magnetite skarns.

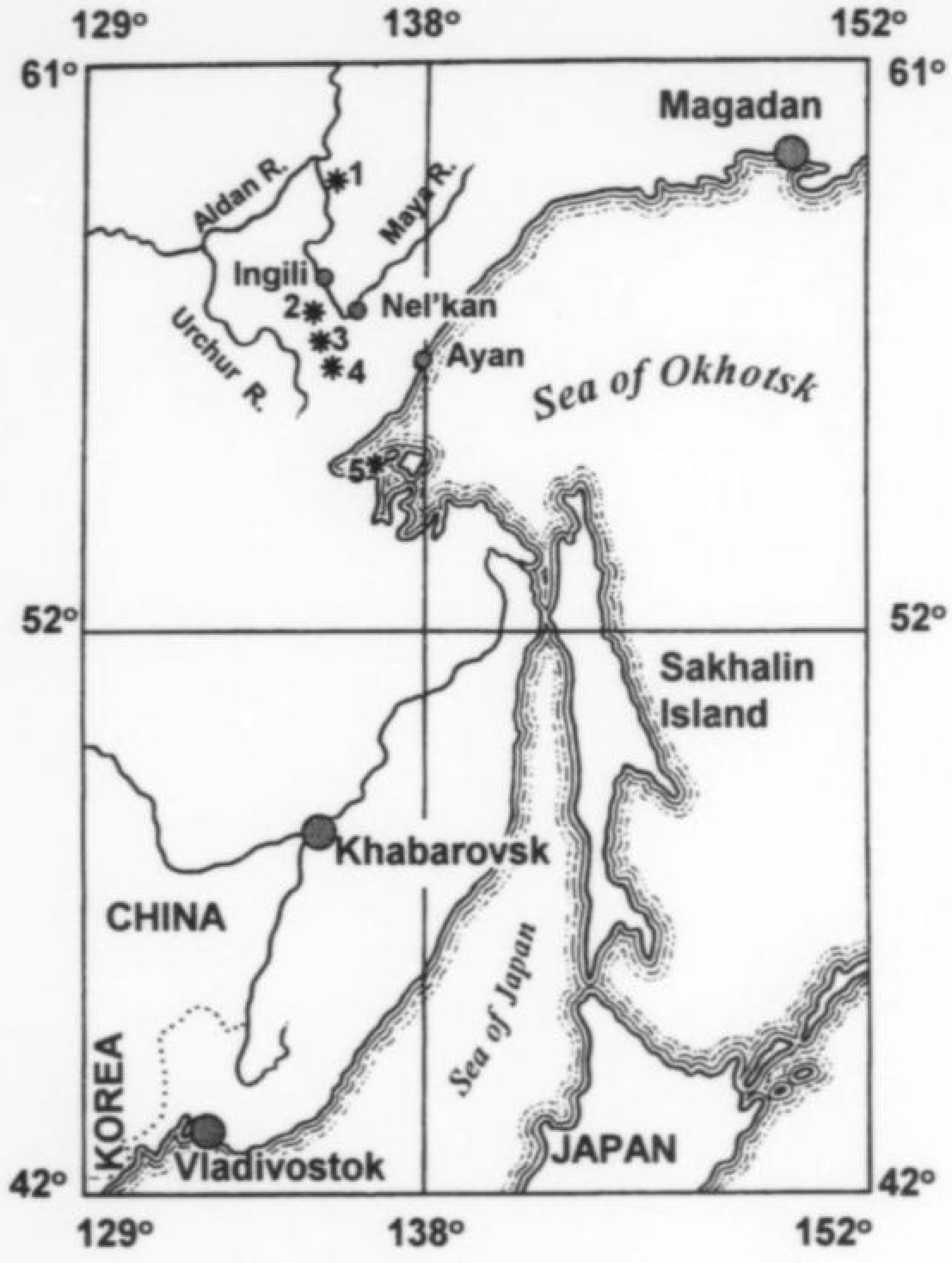

Figure 1. **Location map showing some ultramafic intrusions in the Aldan Shield: (1) Inagli, (2) Konder, (3) Sybah, (4) Chad, (5) Feklistov's Island.**

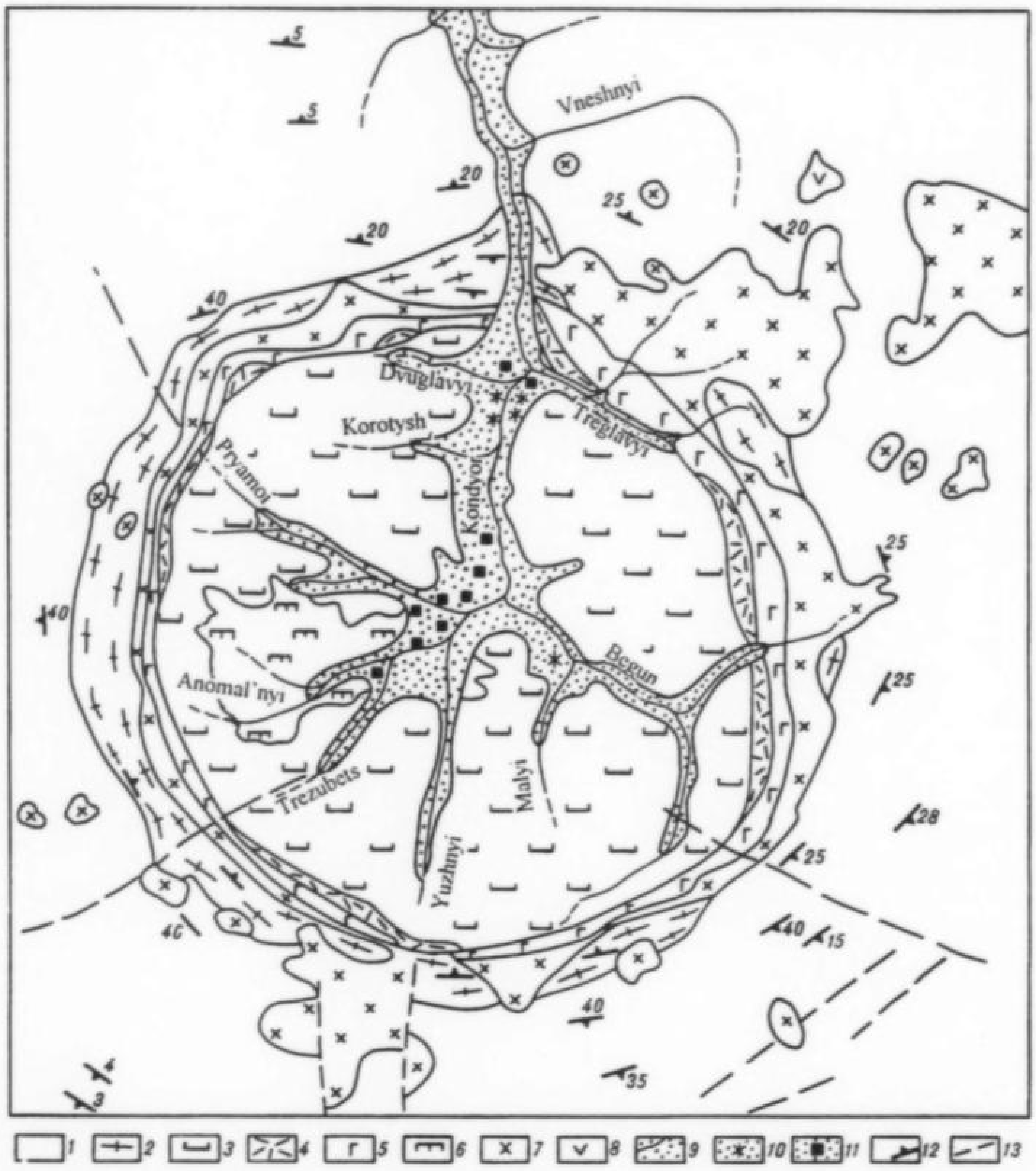

Figure 2. **Geological sketch map of the Konder intrusion (based on data of G. V. Andreev, A. A. El'yanov, A. N. Mil'to, and E. P. Emel'yanenko as given in Sushkin, 1995).** ***Legend for symbols:*** **(1) Platform carbonate-terrigenous Proterozoic sediments, (2) Precambrian gneisses and crystalline schists, (3) Dunites, (4) Peridotites, (5) Pyroxenites, (6) Koswites (i.e., magnetite-rich olivine clinopyroxenites?), (7) Diorites, (8) Volcanogenic rocks, (9) Platinum-bearing placers, (10) Location of discovery of Pt-Fe alloy nuggets weighing more than 1.5 kg, (11) Areas of accumulation of Pt-Fe crystals, (12) Dip and strike of bedding, (13) Faults.**

Lazarenkov and Malich (1989, 1992) reported that the bulk chemistry of the Konder rocks shows very high contents of Pt and Pd in comparison with the concentrically zoned ultramafic intrusions of the Urals' metallogenetic belt (cf., Betekhtin, 1961; Cabri and Genkin, 1991) or the Tulameen (Canada) intrusion (cf., Raicevic and Cabri, 1976; Nixon *et al.*, 1990). They also showed that chondrite-normalized patterns of platinum-group elements in Konder chromitites and the Konder placers are identical, with peaks for Ir and Pt (Fig. 3).

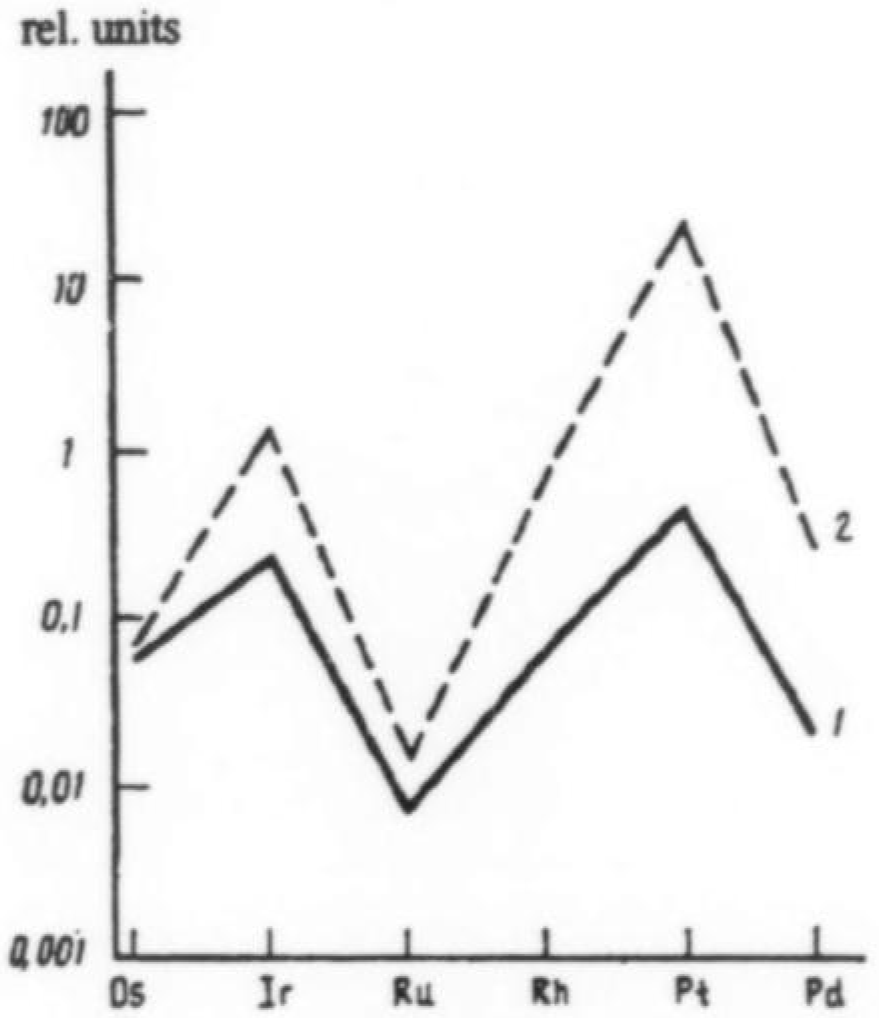

***Figure 3.* Chondrite-normalized diagram of platinum-group elements in chromitite (1) and of placer platinum concentrates (2) for the Konder intrusion (from Lazarenkov and Malich, 1989, 1992).**

SAMPLE PREPARATION and ANALYTICAL TECHNIQUES

Three platinum crystals were first examined by binocular and reflected light microscopy, then by scanning electron microscopy (SEM), with qualitative analyses performed by energy dispersion spectrometry (EDS). The crystals weighed 0.589 g (#1), 0.503 g (#2), and 3.281 g (#3).

A polished section of crystal #3 was prepared, examined by reflected light microscopy and SEM, and analyzed by quantitative electron probe microanalysis (EPMA) using wavelength dispersion spectrometry, on a JEOL 733 electron microanalyzer, operated at 20 kV with a beam current of 20 nA (Faraday cup reading). The following X-ray emission lines and standards were used: PtLα, FeKα (synthetic Pt_3Fe); IrLα, OsMα, RuLα, RhLα, PdLα, NiKα, CuKα, SbLα (metals); SKα (pyrite) and AuLα, AgLα (synthetic $Au_{80}Ag_{20}$). Counting time was of the order of 60 s for the trace elements, and raw data corrections were made using Tracor Northern's ZAF program. Some grains were extracted for further characterization by X-ray diffraction. Fragments dug from the polished surface with a steel needle were analyzed by XRD using a 114.6-mm Debye-Scherrer camera and Fe-filtered Co radiation ($\lambda CoK\alpha_1 = 1.789007$Å).

Two other crystals, selected on the basis of having a lower density (13+ compared to >18 for Pt_3Fe), thought to be either zvyagintsevite or plumbopalladinite, were first examined by binocular and reflected light microscopy, then by SEM with qualitative analyses performed by EDS. These crystals weighed 0.771 g (Crystal A) and 1.240 g (Crystal B). Fragments were removed from a corner of crystal A for analyses by X-ray powder diffraction using a 114.6-mm Debye-Scherrer camera and Fe-filtered Co radiation.

MINERALS

Bornite (?) Cu_5FeS_4

A single rectangular cavity in crystal #3 was filled with a mineral resembling bornite in optical properties, but the grain was unfortunately lost in an attempt to expose more of the specimen's surface.

Cooperite PtS

Small crystals of cooperite (PtS, with minor Pd) and intergrowths of Pt-Cu and Pt-Fe alloys with silica-bearing phases were found lining the cavities and depressions in crystal #3. This intergrowth contains fairly common small inclusions of cooperite and a low-silver gold alloy.

Six grains of cooperite, occurring as small inclusions (<5 µm to a maximum dimension of 50 µm, Figs. 4 and 5) in the ferroan platinum, were quantitatively analyzed and gave average compositions of 81.0 wt.% Pt, 2.63 wt.% Pd, 0.59 wt.% Ni, 0.09 wt.% Fe, 0.25 wt.% Cu and 14.4 wt.% S (Table 1), corresponding to: $(Pt_{.919}Pd_{.055}Ni_{.022}Cu_{.009}Fe_{.004})_{\Sigma = 1.009}S_{.992}$.

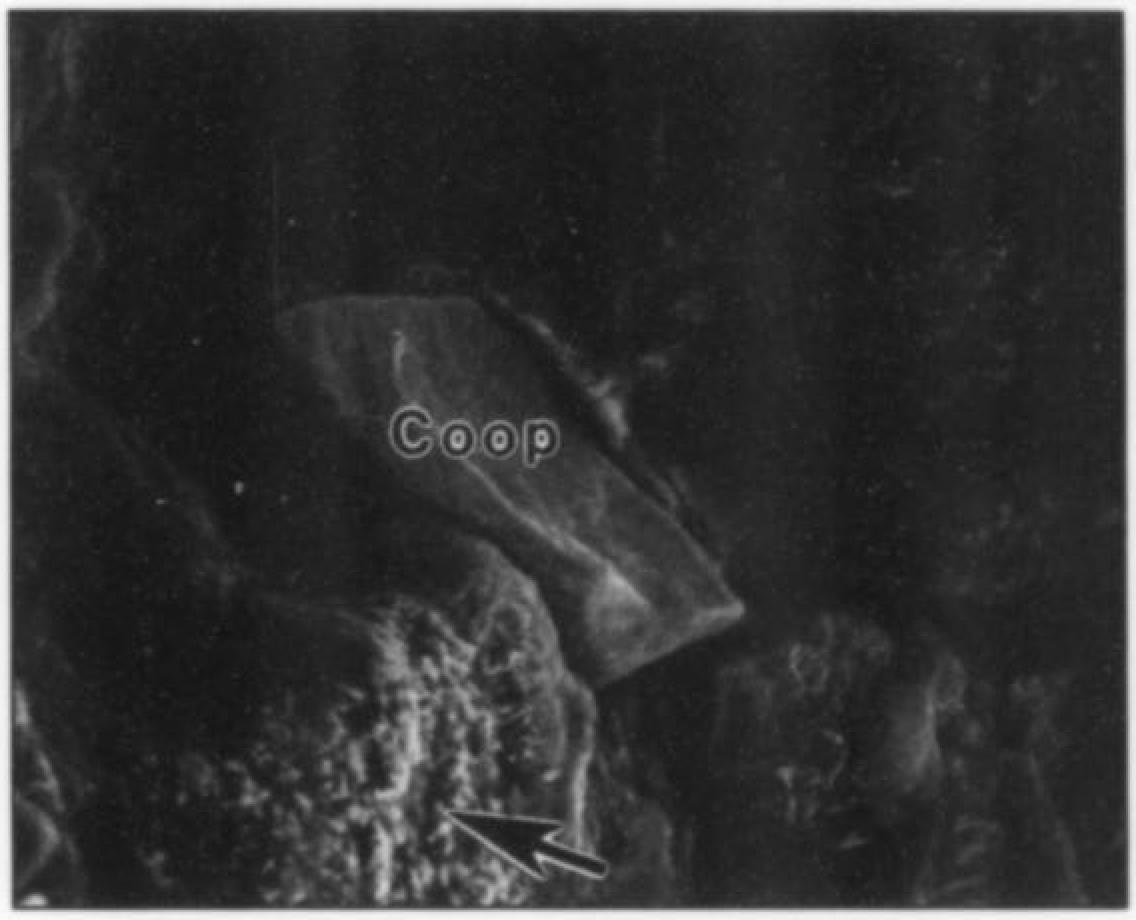

***Figure 4.* Secondary electron image showing a 30-micron grain of cooperite (Coop), Pt-Cu and amorphous siliceous mixture intergrowth (arrow) which line a cavity in the ferroan platinum crystal.**

***Table 1.* Electron microprobe analyses of cooperite from Konder.**

Anal.	*Weight per cent**						
no.	*Pt*	*Pd*	*Ni*	*Fe*	*Cu*	*S*	*Total*
1	80.62	3.29	0.49	0.11	0.31	14.47	99.29
2	80.86	3.11	0.50	0.06	0.14	14.35	99.02
3	81.33	2.88	0.38	0.12	0.08	14.24	99.03
4	80.74	2.75	0.41	0.04	0.30	14.26	98.50
5	81.84	0.93	1.32	0.12	0.17	14.38	98.76
6	80.54	2.84	0.42	0.10	0.49	14.54	98.93
Average	80.99	2.63	0.59	0.09	0.25	14.37	98.92

*Ir, Os, Ru, Rh and Sb were sought but not detected; minimum detection levels of 0.08, 0.14, 0.05, 0.05 and 0.04 wt.%, respectively.

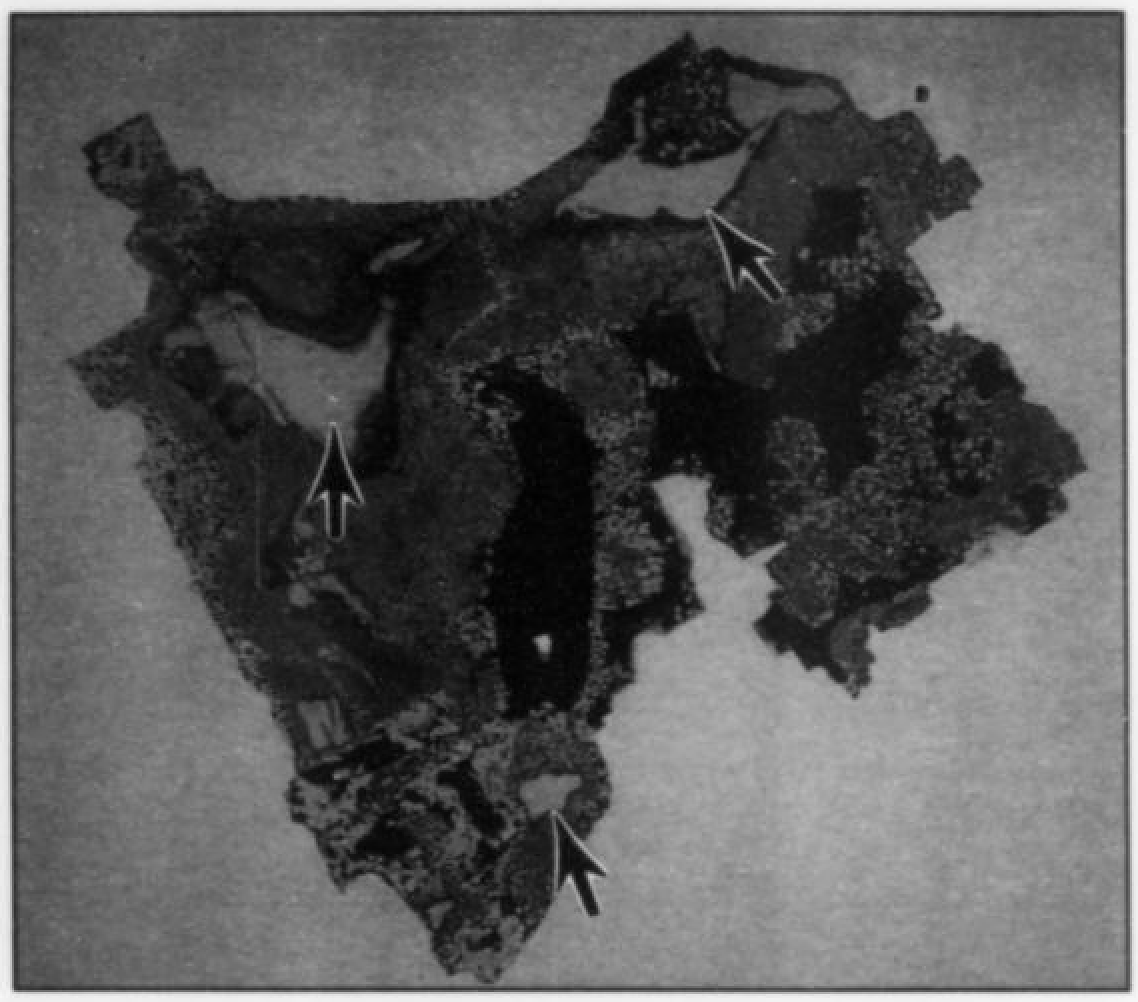

***Figure 5.* Backscattered electron image (BEI) showing a 250-micron multimineralic assemblage in the ferroan platinum crystal, consisting of cooperite (arrows) within a fine-grained mixture of Pt-Cu alloy, Pt-Fe-Cu alloy and an amorphous siliceous phase.**

Gold Alloys

The color of crystal #2 is golden to the naked eye (Fig. 99) and under the binocular microscope it can be seen that the crystal surface is coated with patches of a golden metallic phase, which also lines cavities and depressions. This phase was confirmed to be silver-bearing gold by qualitative SEM-EDS.

Numerous grains of a Au-Ag-Pd alloy (Fig. 6) were also found, ranging from <5 µm to a maximum dimension of 55 µm. Two of these grains were quantitatively analyzed (Table 2) and gave average contents of 72.0 wt.% Au, 26.8 wt.% Ag, 1.35 wt.% Pd and 0.60 wt.% Cu, which corresponds to: $Au_{.574}Ag_{.391}Pd_{.020}Cu_{.015}$.

***Table 2.* Electron microprobe analyses of Au-Ag-Pd alloy (wt.%) from Konder.**

Anal.	*n*	*Au*	*Ag*	*Pd*	*Cu*	*Total*
1	3	74.19	24.48	1.29	0.59	100.55
2	2	69.81	29.16	1.42	0.61	101.00
Average		72.00	26.82	1.35	0.60	100.77

Hongshiite (?) PtCu

A Pt-Cu alloy, possibly hongshiite, has been observed as fine intergrowths (<5 µm to a maximum dimension of 15 µm; Figs. 5 and 6) in a complex mixture with Pt-Fe-Cu alloy (?) and an amorphous siliceous phase, closely associated with cooperite and a Au-Ag-Pd alloy. Because of their small grain-size, only two grains were quantitatively analyzed. These gave average contents of 73.3 wt.% Pt, 24.9 wt.% Cu and 0.10 wt.% Fe (Table 3), which corresponds to: $Pt_{0.976}(Cu_{1.019}Fe_{.005})_{\Sigma=1.024}$.

Platinum Pt_3Fe

Crystals #1 and #2 were only examined qualitatively. Crystal #1 consists of a steel-gray penetration twin (Fig. 9) determined to be a Pt-Fe alloy. Depressions and cavities contained an aluminum silicate phase with Fe>Mg. Both determinations were by qualitative SEM-EDS without sputtering a conductive coating on the crystal.

***Table 3.* Electron microprobe analyses of Pt-Cu (hongshiite?) from Konder.**

Anal.	*Weight per cent**			
no.	*Pt*	*Cu*	*Fe*	*Total*
1	73.20	24.93	0.14	98.27
2	73.44	24.88	0.05	98.37
Average	73.32	24.91	0.10	98.33

*Ir, Os, Ru, Rh, Pd, Ni and Sb were sought but not detected; minimum detection levels of 0.08, 0.14, 0.05, 0.05, 0.05, 0.03 and 0.04 wt.%, respectively.

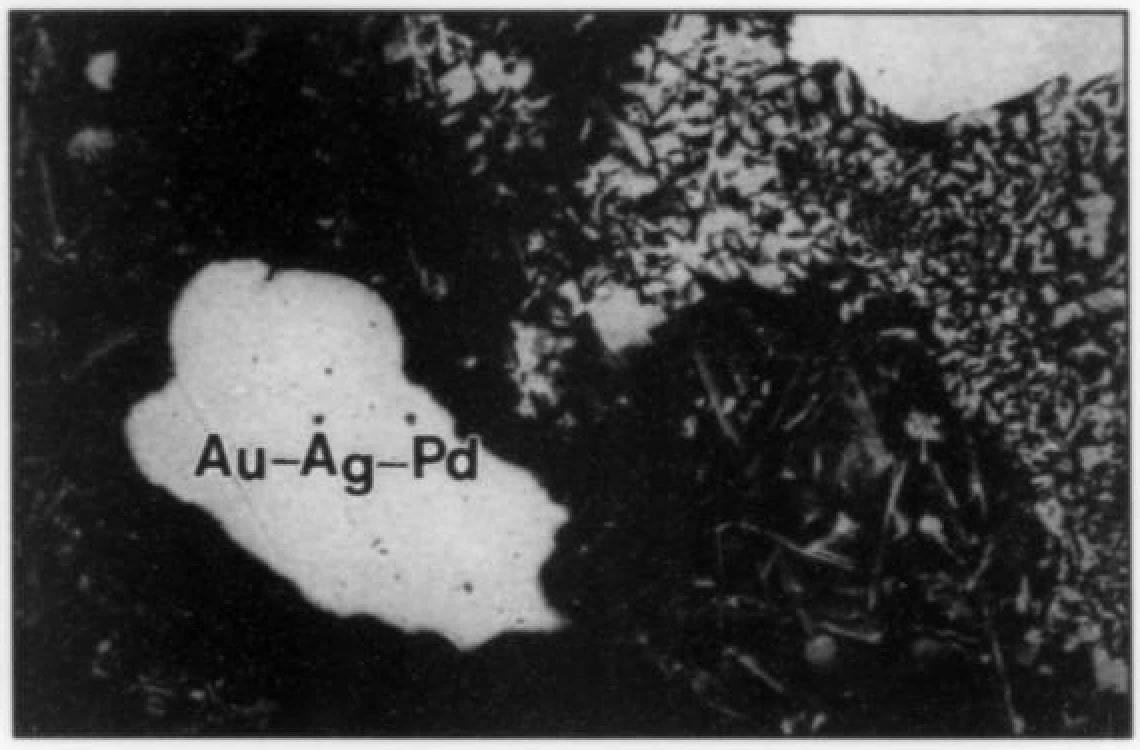

***Figure 6.* BEI showing a 23-µm grain of Au-Ag-Pd alloy surrounded by the complex mixture depicted in Figure 5.**

Crystal #2 (Fig. 9) consists of a more or less perfect cube containing two pronounced lenticular depressions with parallel sides, filled with a siliceous phase similar to that found in crystal #1. The crystal was determined to be a Pt-Fe alloy by qualitative SEM-EDS (done without sputtering a conductive coating on the crystal).

Crystal #3, which is the largest, measures approximately 7.5 mm in length, and consists of a steel-gray penetration twin (Fig. 9). The surface also contains cavities and depressions which are macroscopically lenticular and irregular in shape. This crystal was carbon-coated to improve SEM resolution.

The crystal was then mounted in plastic and a polished surface was studied by reflected light microscopy and by SEM. The crystal consists of an alloy of Pt_3Fe composition containing numerous cavities, often with cubic crystal outlines, which are lined with a complex assemblage of finely-intergrown Pt-Fe-Cu alloy(s).

Examination of crystal #3 by quantitative EPMA shows that the crystal is quite homogeneous (Table 4) with average contents of 89.0 wt.% Pt, 0.05 wt.% Pd, 9.15 wt.% Fe, 0.75 wt.% Cu, 0.04 wt.% Ni, 0.05 wt.% Sb corresponding to: $(Pt_{2.88}Pd_{<.01})_{\Sigma=2.88}(Fe_{1.04}Cu_{.08}Ni_{<.01}Sb_{<.01})_{\Sigma=1.12}$. Analysis by X-ray diffraction showed that it is ferroan platinum (Table 5) using the nomenclature of Cabri and Feather (1975); that is, it has a face-centered cubic structure (isoferroplatinum of the same composition would have a primitive cubic structure).

Siliceous Phase

Identification of the siliceous phase (Fig. 7) was not possible, despite qualitative analysis performed by EDS which shows Si>Al>Fe ~ Mg and trace amounts of Ca and K. The material was extracted for X-ray diffraction analysis but proved to be amorphous, although a pattern was obtained and tentatively identified as

Table 4. **Electron microprobe analyses of ferroan platinum (crystal #3) from Konder.**

Spot no.	*Pt*	*Pd*	*Fe*	*Cu*	*Ni*	*Sb*	*Total*
	*Weight per cent**						
1	89.33	0.04	9.11	0.75	0.03	0.04	99.30
2	89.01	0.03	9.05	0.75	0.05	0.05	98.94
3	88.78	0.04	9.15	0.75	0.04	0.05	98.81
4	88.69	0.04	9.07	0.75	0.04	0.05	98.64
5	88.77	0.04	9.16	0.74	0.04	0.05	98.80
6	88.71	0.04	9.18	0.72	0.04	0.05	98.74
7	89.09	0.04	9.31	0.76	0.04	0.05	99.29
8	89.10	0.04	9.13	0.74	0.04	0.05	99.10
9	88.79	0.04	9.20	0.75	0.04	0.05	98.87
10	88.77	0.06	9.12	0.75	0.04	0.03	98.77
11	88.77	0.06	9.16	0.74	0.04	0.03	98.80
12	89.14	0.06	9.17	0.76	0.04	0.03	99.20
13	89.72	0.08	9.16	0.75	0.05	0.06	99.82
Average	88.97	0.05	9.15	0.75	0.04	0.05	99.01

*Ir, Os, and Rh were sought but not detected; minimum detection levels of 0.08, 0.14, and 0.05 wt.%, respectively.

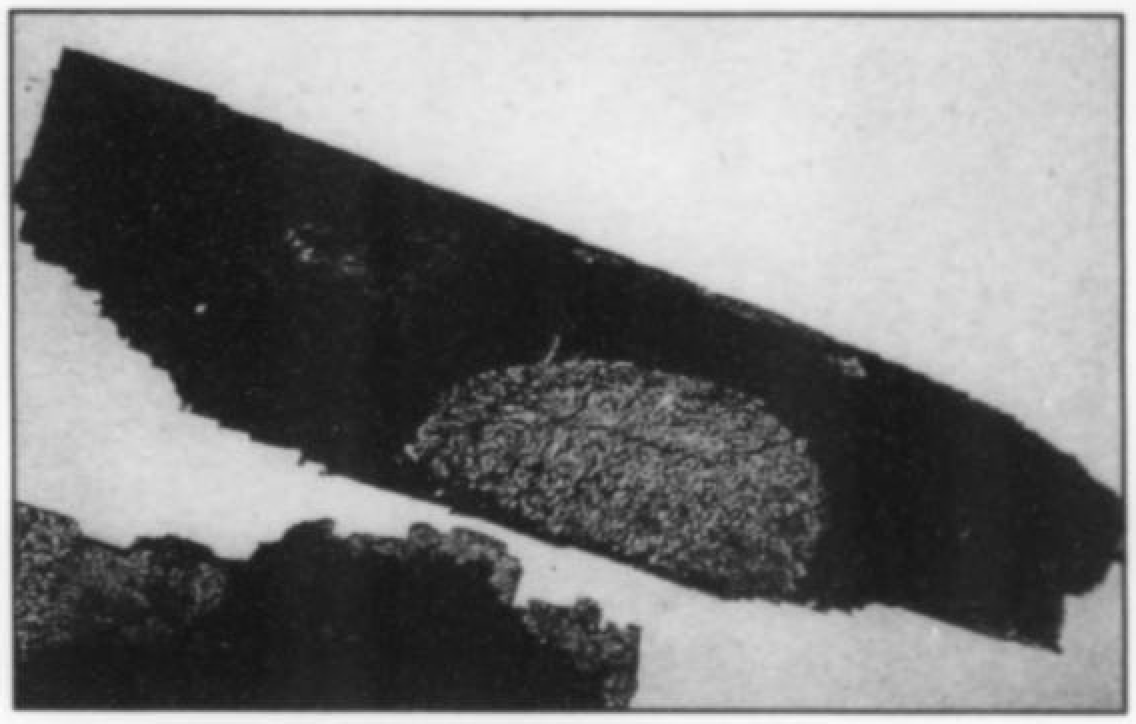

Figure 7. **BEI of a lenticular area in the ferroan platinum crystal which is partly filled with an amorphous siliceous phase and with a 160-micron semi-circular mass consisting of a fine-grained mixture of Pt-Cu and Pt-Fe-Cu alloys.**

Table 5. **X-ray powder diffraction data for three grains of ferroan platinum (crystal #3) from Konder.**

hkl	I(est.)	D(obs)	D(calc)	I(est.)	D(obs)	D(calc)	I(est.)	D(obs)	D(calc)
		a = 3.8645Å			a = 3.8648Å			a = 3.8625Å	
	0.5	7.138		1	7.115				
				0.4	6.162				
111	10	2.231	2.232	10	2.228	2.231	10	2.229	2.23
200	4b	1.932	1.933	5	1.928	1.932	3b	1.932	1.931
220	3vb	1.366	1.367	4b	1.365	1.366	2b	1.365	1.366
311	4vb	1.166	1.166	2b	1.166	1.165	3vb	1.164	1.165
222	1vb	1.116	1.16	1b	1.116	1.116	1vb	1.116	1.115

Abbreviations: b = broad, vb = very broad

platinum. The material was therefore mounted on a stub and re-examined by SEM which showed the amorphous crystal filled with micro-inclusions (<1 μm) of a Pt-Fe-Cu alloy phase (Fig. 8).

Zvyagintsevite Pd_3Pb

The smaller of the two palladian crystals analyzed (A) is of tabular cubic habit with stepped facets in one corner, and with a silver-gray metallic appearance and a faint pinkish cast; approximate dimensions are 3 x 3.5 x 8 mm. One side appears to show conchoidal fracture. There are numerous growth-related cavities, most of which are partly filled with silicates found to contain Si > Fe-Al-Mg-Ca by qualitative SEM/EDS examination. The larger of the two crystals (B) has a similar habit but is better formed (Fig. 10), with dimensions of approximately 2 x 5.5 x 8.5 mm. It also has growth-related cavities which are lined with a fine-grained, rusty-looking material (goethite?).

Both crystals were qualitatively examined by SEM/EDS and their spectra were compared to that of a CANMET synthetic standard of Pd_3Pb composition. The spectra of both crystals are identical with that of synthetic Pd_3Pb, except for the presence of small amounts of Pt and Fe. The spectra are compared in Figure 12 and correspond in composition to zvyagintsevite, originally found in Noril'sk ores (Cabri and Traill, 1966; Genkin *et al.*, 1966). Some zvyagintsevite from Noril'sk is reported by Genkin *et al.* (1966) to be Pt-bearing (7.5 wt.%), as is also some from the Stillwater Pd-Pt ores, reported to have about 1.2 wt.% Pt (Laflamme, 1976). The powder XRD done on fragments from crystal A shows that they match those of synthetic zvyagintsevite (Table 6). The unit cell of a = 4.036Å for the Konder zvyagintsevite is slightly larger than that of pure synthetic Pd_3Pb (a = 4.024Å), probably because of its Pt content. None of the 70 or so crystals of zvyagintsevite that have since been identified from the Konder massif exhibit penetration twinning (B. van Scriver, personal communication, 1996). The

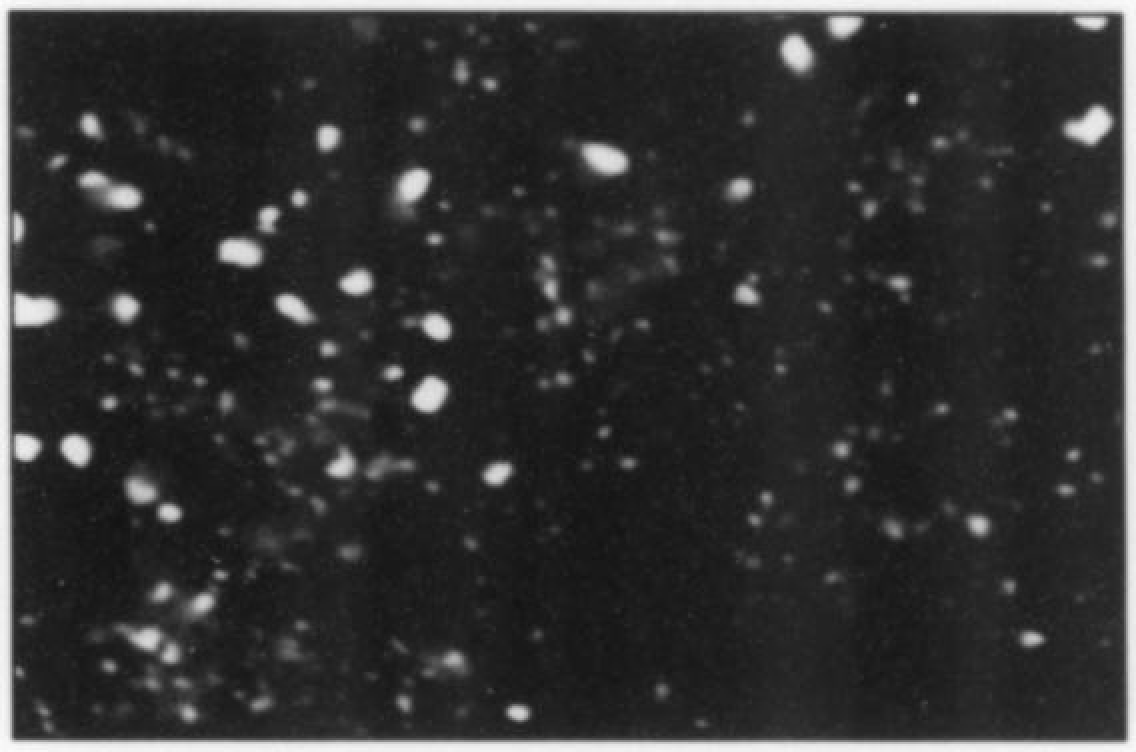

Figure 8. **BEI of an amorphous siliceous phase fragment filled with micro-inclusions of a Pt-Fe-Cu alloy (10-micron field of view.**

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Figure 9. (left) **Pt-Fe alloy cube coated with gold (crystal #2);** ***(center)*** **a ferroan platinum penetration twin (crystal #3);** ***(right)*** **penetration twin of a Pt-Fe alloy (crystal #1). Brad van Scriver specimens.**

prominence of stepped facets as if showing a cubic cleavage, may also assist in visual identification. Skerstupp *et al.* (1996) also point out that Konder zvyagintsevite can be distinguished under magnification by distinct cleavage crevices on {100}, and by minute cubic indentations (5 to 15 µm) in the surface, parallel to the cleavage. While both the ferroan platinum and zvyagintsevite have a metallic luster, high specific gravities (calculated to be 18.4 and 13.4 respectively), and are non-magnetic, the latter mineral can show a faint pinkish cast similar to that of pure elemental bismuth.

A list of the minerals found at Konder and their compositions is given in Table 7.

DISCUSSION

Nekrasov *et al.* (1991, 1994) studied the mineralogy of the Pt-Fe alloys in the Konder intrusion and reported the presence of two generations of Pt-Fe alloys, each with the same iron content (7.5–11.5 wt.% Fe), i.e., equivalent to Pt_3Fe. Nekrasov and co-workers showed that the first-crystallized Pt-Fe alloys are enriched in other platinum-group elements (e.g., 2.5–5.3 wt.% Ir, 0.7–0.9 wt.% Os, 0.2–1.0 wt.% Pd, and 0.7–1.1 wt.% Rh). In contrast, the later generation of Pt-Fe alloys, found in massive chromite lenses and veins in dunites contains (all in wt.%): 0.3–1.0 Os, <0.6 Ir, and up to 0.4 Pd and Rh. In the Pt-Fe alloys of the magnetite pyroxenites, Nekrasov *et al.* (1994) report low Os, Pd and Rh, little Ir and no Ru for four analyses, as well as seven analyses of Pt-Fe alloys from the Konder placers with no measurable Ir, Os, Ru or Rh. The latter grains had Cu contents ranging from 2.41 to 16.62 wt.% and Ni from unmeasurable to 0.96 wt.%. These authors describe the common occurrence of inclusions of osmium and Os-Ir alloys in the Pt-Fe alloys, as well as platinum-group elements, sulfides and sulfarsenides (e.g., laurite, erlichmanite, irarsite, hollingworthite), and cooperite (see also several papers by Rudashevsky and co-workers, e.g., Rudashevsky *et al.*, 1992). Minerals such as tetraferroplatinum, tulameenite, hongshiite, konderite, inaglyite, cuproiridsite, cuprorhodsite, and many other platinum-group minerals are rarer, and occur in the Pt-Fe alloys, both in bedrock and placer samples.

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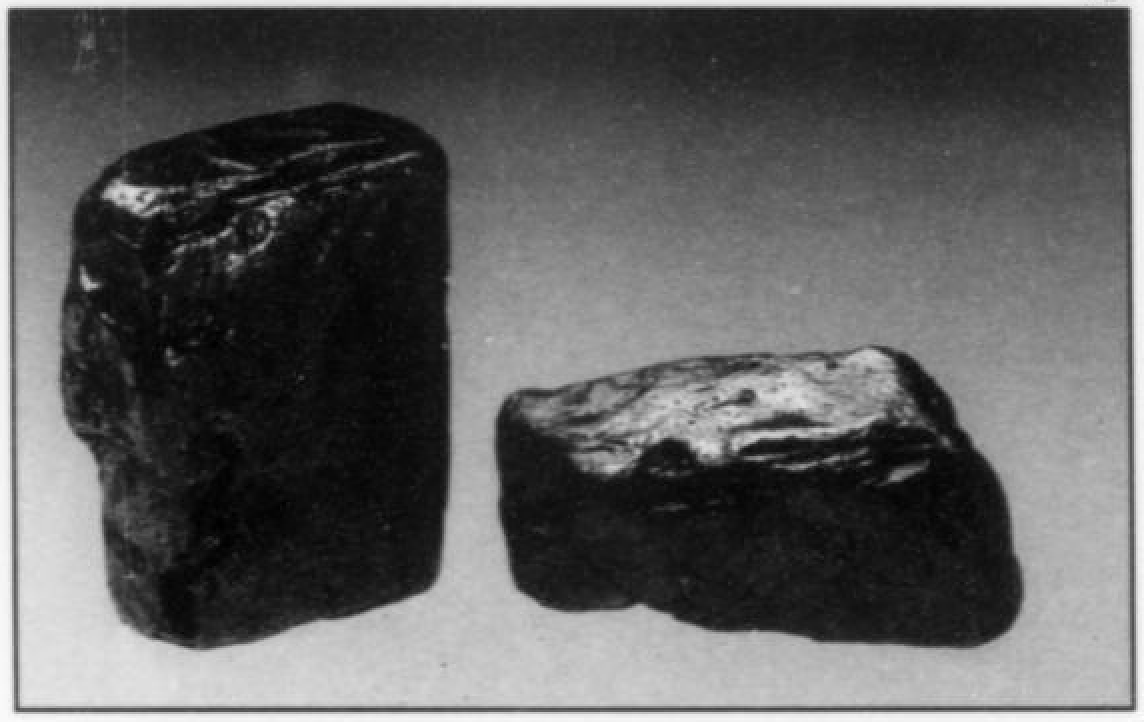

Figure 10. **The two crystals of zvyagintsevite (8 mm and 9 mm) from Konder. Brad van Scriver specimens.**

Nekrasov *et al.* (1994) consider that the largest Pt-Fe alloy crystals were formed later because of their occurrence in association with weathered magnetite-phlogopite-pyroxene rocks (see Fig. 2). They also describe such crystals as often twinned and covered entirely with "a golden shirt" or a golden "rash" (30 to 250 µm thick), the composition of which varies from platinian to palladian to cuprian gold. They postulate that intense mobilization of platinum and platinum-group elements from the chromium-bearing dunites occurred in areas of serpentinization and alkaline metasomatism associated with the formation of dikes and veins of nepheline syenites, ijolites, urtites, alkaline pegmatites, and magnetite-phlogopite-pyroxenites. They propose that these late-stage Pt-Fe crystals grew in a complex system of multicomponent alkaline fluids and hydrothermal solutions. Unlike the case of the large ferroan platinum crystals, there are no published descriptions of large crystals of zvyagintsevite, though the mineral is reported from Konder by Nekrasov *et al.* (1994, in Table 76) as containing minor quantities of Pt, Au and Sn.

Crystal #3 is quite homogeneous (Table 1), with low standard deviations for all elements: Pt ±0.187, Pd ±0.009, Fe ±0.040, Cu ±0.006, Ni ±0.003, Sb ±0.006, all in wt.% at 95% confidence levels. The absence of platinum-group elements such as Ir, Os, Rh and Ru (less so) as determined in these analyses is consistent with some of the analyses reported by Nekrasov and co-workers for Pt-Fe alloys. It is noteworthy that a compilation of 1,709 analyses of

Figure 11. **Platinum crystals (not analyzed) from Konder, the uppermost seven crystals showing obvious penetration twinning. The three crystals at top (each measuring 1 cm) are quite sharp whereas the middle four (1 to 1.1 cm each) show some stream-rounding. The lower three examples (8 to 9 mm each) have thin coatings of gold-rich alloys. Brad van Scriver specimens.**

Pt-Fe alloys from numerous sources worldwide shows that Ir, Os and Rh are present in detectable concentrations in the following respective frequencies: 96.4%, 97.7%, and 98.5% (Cabri *et al.*, 1996). In addition, these three elements have ***never*** all been found to be below minimum detection levels (i.e., Ir 0.08, Os 0.14, and Rh 0.05, all in wt.%) for any of the 1,709 analyses. In only 3 of 1,709 analyses were two of the three elements not detected, i.e., in only 0.17% of the grains analyzed. Thus, the lack of detectable (by EPMA) Ir, Os and Rh in the ferroan platinum crystal from Konder may represent a chemical signature typical of Pt-Fe alloys formed by post-magmatic events, apparently a most uncommon origin.

CONCLUSIONS

The detailed examination of ferroan platinum crystal #3 has shown it to be comparable to similar crystals described by Nekrasov *et al.* (1994). Texturally, the presence of inclusions of other platinum-group minerals (cooperite and hongshiite), Au-Ag-Pd alloys, and possibly bornite, are also consistent with a natural

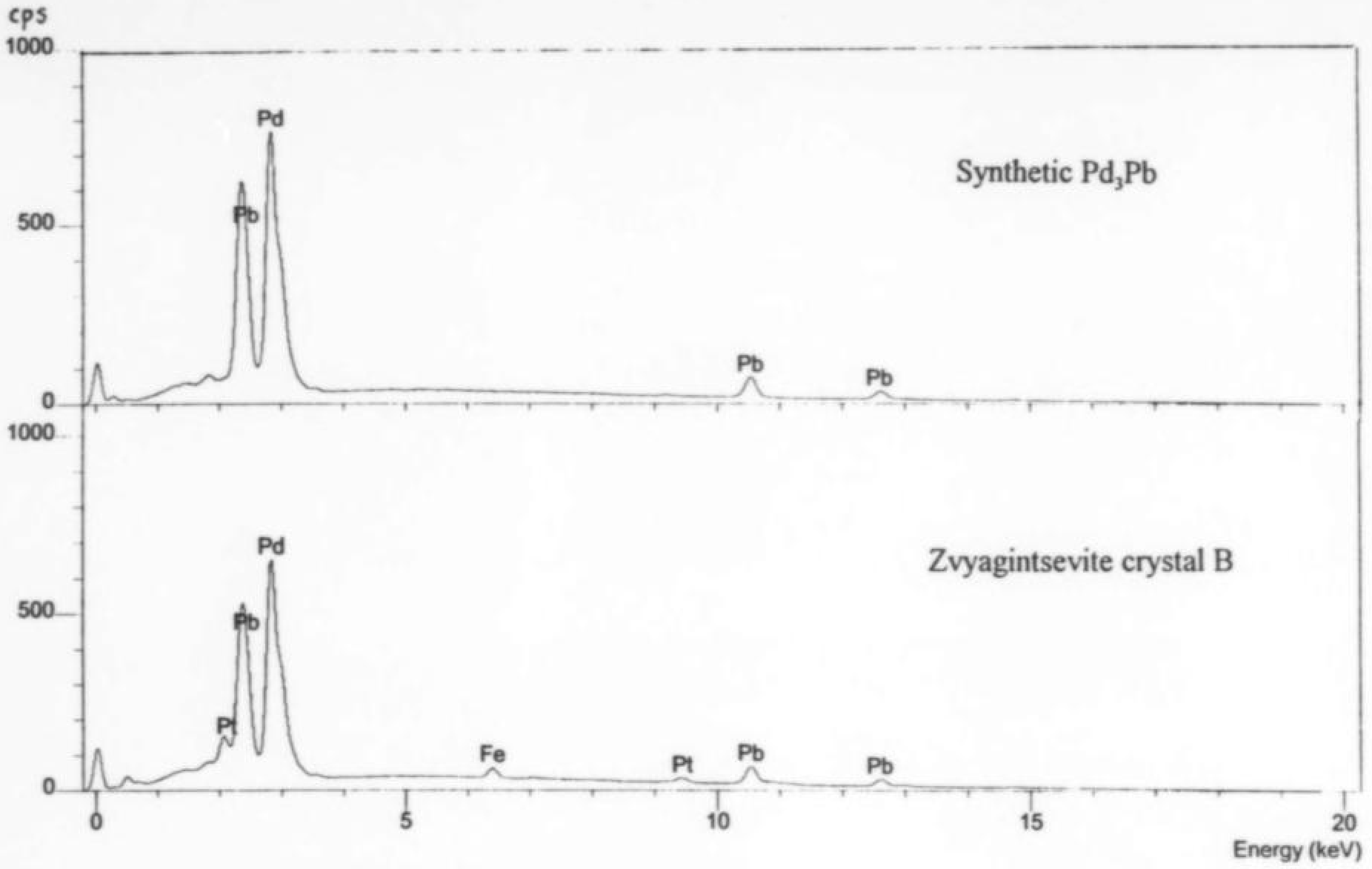

***Figure 12.* EDS spectrum of Pt-Fe-bearing zvyagintsevite compared to that of pure synthetic Pd_3Pb.**

***Table 6.* X-ray powder diffraction data for zvyagintsevite from Konder and synthetic Pd_3Pb.**

Zvyagintsevite			*Synthetic Pd_3Pb*		
D(obs)	D(calc)	I(est.)	*hkl*	D(obs)	I(est.)
7.461		5			
6.449		3			
4.561		2			
4.035	4.036	2	100	4	1
3.886		1b			
2.853	2.854	2	110	2.84	2
2.326	2.330	10b	111	2.32	10
2.017	2.018	8b	200	2.01	8
1.804	1.805	.5b	210	1.80	2
1.646	1.648	.5b	211	1.644	2
1.4259	1.4271	6b	220	1.423	7
			300	1.342	w
			310	1.272	w
1.2160	1.2170	7vb	311	1.215	9
1.1652	1.1652	.2b	222	1.163	4
			320	1.117	w
1.0795	1.0788	.2b	321	1.077	w
1.0095	1.0091	.3vb	400	1.007	3
			410	0.973	w
			330	0.951	w
0.9261	0.9260	5vvb	331	0.923	6b,d

Zvyagintsevite (this study) compared to synthetic Pd_3Pb (Cabri and Traill, 1966)
Abbreviations: b = broad, w = weak, d = diffuse, v = very

occurrence. It should also be noted, however, that the type of inclusions found in the Pt-Fe alloy crystals and their morphology are different from those usually found in Pt-Fe alloys, such as exsolved phases, for example (cf., Cabri *et al.*, 1996). In contrast, the large rounded Pt-Fe alloy nuggets reported from the Konder placers (e.g., Sushkin, 1995) typically contain inclusions of apparently cumulus chromite and represent primary platinum-group minerals derived from the host ultramafic rocks by physical weathering processes. The amorphous siliceous phase found in cavities and depressions of the Pt-Fe alloy crystals, together with intergrown micro-particles (<0.25 µm) of Pt-Fe-Cu alloys (Figs. 7 and 9), has not been previously reported. Its origin is unknown, but it could conceivably represent a siliceous residue from acid-cleaning of the crystal or chemical treatment of the alluvial ore. The zvyagintsevite crystals were not studied in as much detail as the Pt-Fe alloy crystals in order to preserve their pristine characteristics (Fig. 11), but the data obtained are consistent with Konder zvyagintsevite. They represent the largest crystals of zvyagintsevite ever reported (Dr. A. D. Genkin, personal communication, 1996).

It may be concluded from this study that the three "platinum" crystals are natural crystals of ferroan platinum (of Pt_3Fe composition). These originally crystallized within the Konder concentrically zoned alkali-ultramafic intrusion in the southeastern part of the Siberian platform (eastern part of the Aldan shield), probably during post-magmatic events. The gold alloys found as inclusions in the central parts of complex intergrowths, and on the surface of one crystal, were possibly formed during even later post-magmatic events. The good state of preservation of the ferroan platinum and zvyagintsevite crystals, together with the relative lack of abrasion suggests that there was minimal mechanical transport after weathering and disintegration of their host rocks, which fits in well with descriptions of their occurrence (Nekrasov *et al.*, 1994; Sushkin, 1995).

ADDENDUM

After acceptance of our article, Dr. Wilson brought to our attention two recently published articles directly relevant to this study. Ferh *et al.* (1995) describe several mm to nearly cm-size platinum crystals from the same locality. One crystal was analyzed by microprobe and found to contain 9.2 weight % Fe (mean of several analyses), with significant amounts of Ir, Os and Re and trace amounts of Cu and Ta. The Fe content is nearly identical to our results but the trace-element contents are distinctly different. However, no details of analytical conditions (standards, corrections for interferences, computation etc.) are given. The authors also describe qualitative analyses of a thin coating of gold alloys (one

Table 7. **Platinum-group minerals and associated species from the Konder massif identified in this study.**

Mineral	*Composition*	*Remarks*
Bornite	Cu_5FeS_4	Single grain within cavity in ferroan platinum, not confirmed
Cooperite	PtS	Small <50 µm inclusions in ferroan platinum
Gold	Au, Ag	Qualitatively determined partly coating one ferroan platinum crystal and lining cavities and depressions
Electrum (palladian cuprian)	$Au_{0.57}Ag_{0.39}Pd_{0.02}Cu_{0.02}$	Inclusions <55 µm within complex intergrowths in ferroan platinum
Hongshiite?	PtCu	Very small grains <15 µm in complex mixture with Pt-Fe-Cu alloy and an amorphous siliceous phase in ferroan platinum
Platinum (ferroan)	Pt_3Fe	Cubic crystals and penetration twins
Pt-Fe-Cu alloy	not analyzed	Tiny micro-inclusions (<1 µm) in amorphous phase
Siliceous phase	Si>Al>Fe≡Mg	Amorphous unidentified phase in ferroan platinum
Zvyagintsevite	Pd_3Pb	Untwinned cubic crystals

identified as tetra-auricupride, AuCu) found on some of the platinum crystals. A second paper on minerals from the same locality by Gebhard *et al*. (1996) describes two large zvyagintsevite crystals (4 x 5 x 7 and 2 x 3 x 4 mm). Microprobe analysis of one crystal (found to be isotropic in polished section) corresponds to $(Pd_{2.87}Pt_{0.15})_{\Sigma 3.02}(Pb_{0.92}Bi_{0.05})_{\Sigma 0.97}$. This composition is in good agreement with our qualitative analyses.

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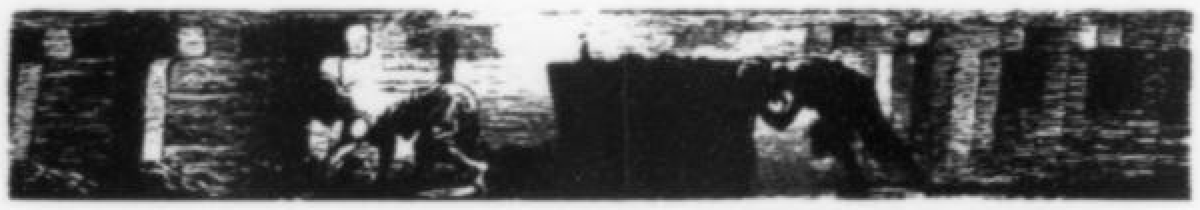

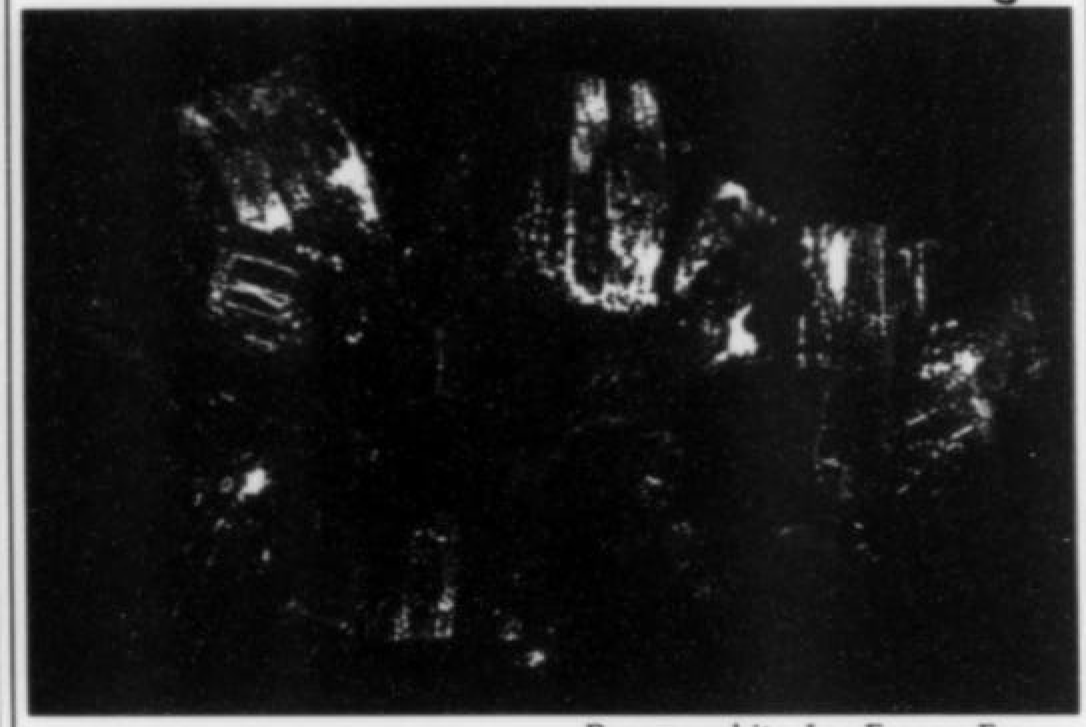

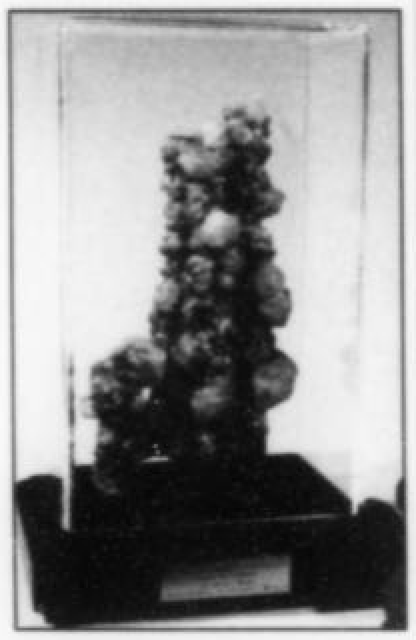

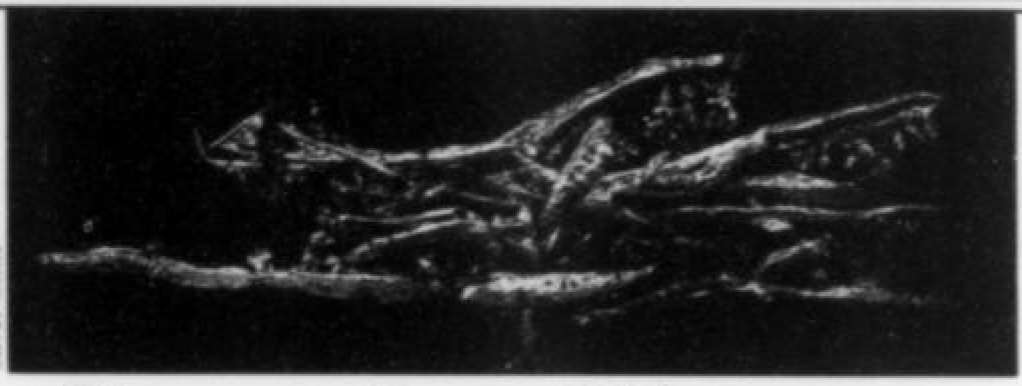

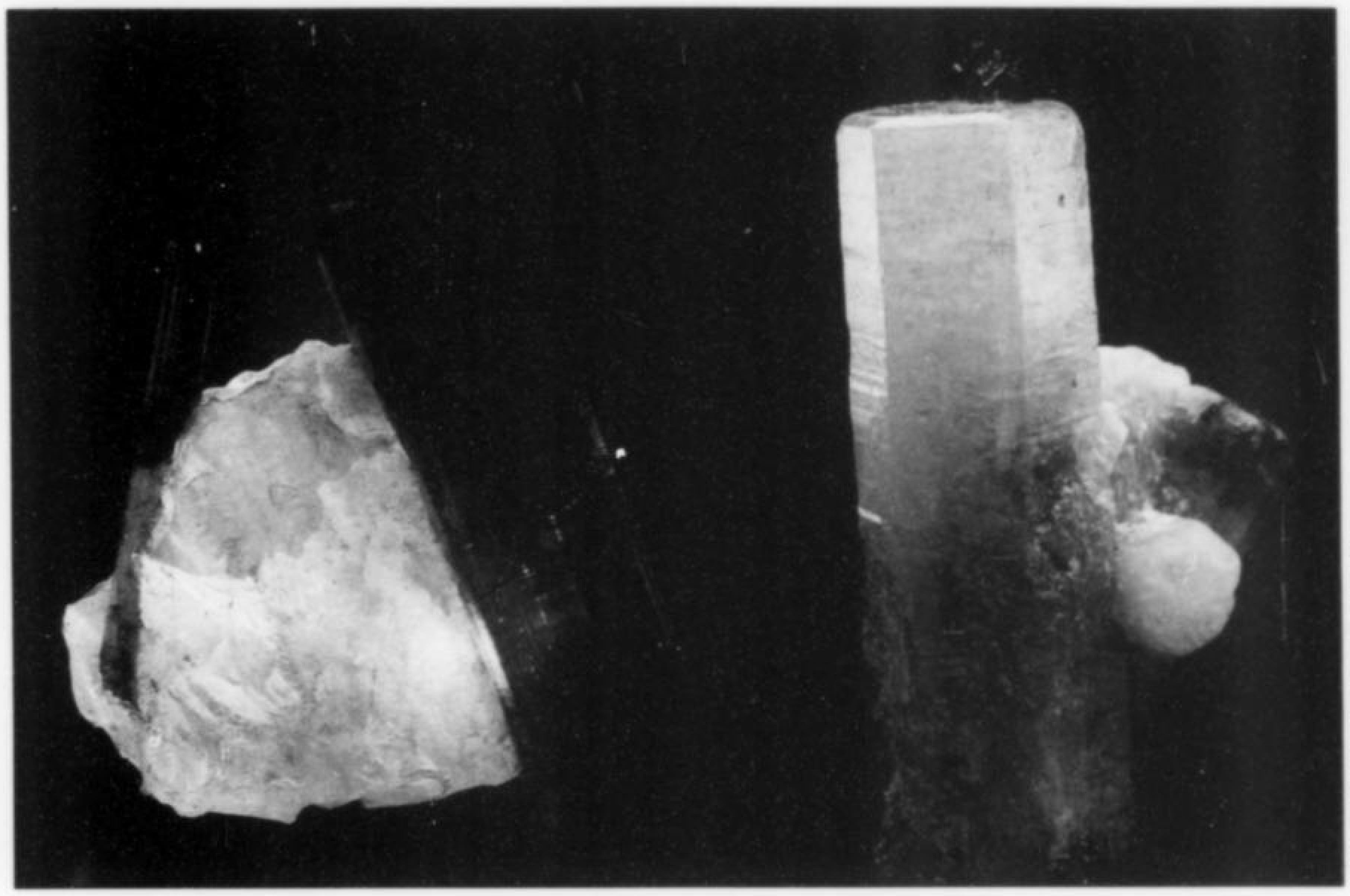

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THE OTAVI MOUNTAIN LAND Cu-Pb-Zn-V DEPOSITS

NAMIBIA

Bruce Cairncross
Department of Geology
Rand Afrikaans University
P.O. Box 524
Auckland Park
Johannesburg 2006
South Africa

The Otavi Mountain Land hosts a wealth of fascinating mineral deposits in addition to the famous Tsumeb and Kombat mines. These include Berg Aukas (Grootfontein), Guchab and Abenab, among others, where world-class descloizite, willemite, dioptase, and the largest known crystals of vanadinite have been found.

INTRODUCTION

The Otavi Mountain Land in northeast Namibia is roughly delineated by the main road that runs from Tsumeb to Grootfontein, through Kombat to Otavi and back up to Tsumeb. The rugged topography of the area is formed by weathered carbonate rocks; the highest mountain lies at an elevation of 1677 meters above sea level. The valleys are characterized by a cover of calcrete (caliche) overgrown by dense thorn bush and scrubby vegetation while the mountain slopes contain even more resilient species of shrubs and cacti, the latter attesting to annual temperatures that commonly exceed 30°C. Yet the rainfall in the Otavi Mountain Land is the highest in Namibia, with Tsumeb recording an average of 520 mm per annum (King, 1994).

The mineral deposits of the Otavi Mountain Land are famous for several reasons. Tsumeb is located here and has been a premier mineral-producing mine for decades. Similarly, although not on as grand a scale, the Kombat mine has also produced superb specimens from time to time and it is also well known for its suite of rare minerals. **The polymetallic Tsumeb and Kombat mines are specifically excluded from this review** as it would be beyond the scope of this article to describe these two major deposits. There is already extensive literature, geologically and mineralogically, for these two mines (see, for example, Wilson, 1977; Lombaard *et al.*, 1986; Hughes, 1987; Innes and Chaplin, 1986; Dunn, 1991; and Gebhard, 1991).

The other well-known locality in the Otavi Mountain Land, situated southeast of Tsumeb, is the Berg Aukas mine, which has produced superb descloizite specimens now in collections around the world. There is a host of other Pb-Zn-V deposits, some relatively well-known such as Abenab and Abenab West, Guchab (Cu) and Gross Otavi, and also a myriad of lesser known localities. Berg Aukas and Abenab have also produced high-quality specimens of smithsonite and willemite. Berg Aukas is believed to have contained the largest single deposit of willemite in the world. Average grades and total tonnages (mined and in reserve) for the three largest mines are shown in Table 1.

HISTORY

"Otavi" is the name given to a spring in the area, and comes from the Ovambo word *tava* which describes the nudging and pushing of a calf when it nurses from its mother (Söhnge, 1967). It appears that the Bergdama tribe introduced copper smelting into Namibia long before the practice was used by either the Herero or the Ovambo people. The evidence obtained from smelting sites at

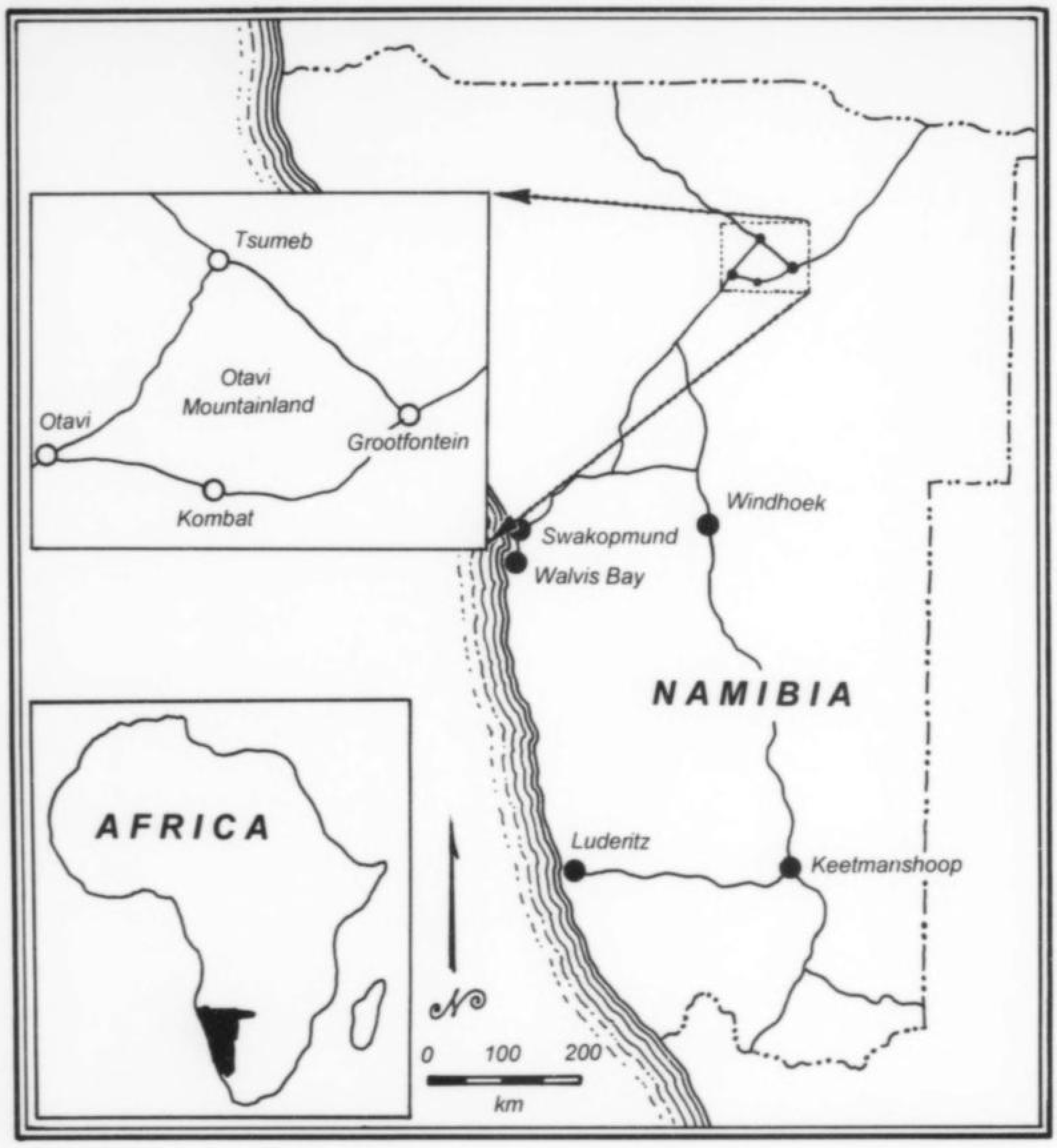


Figure 1. **The Otavi Mountain Land, situated approximately 400 km north of Windhoek, Namibia.**

Gross Otavi and other localities such as Otjikoto suggests that the style and technique of the operations were similar to those used in central Africa, which had previously been introduced from north Africa prior to 500 A.D. (Clark, 1957).

Europeans were first made aware of the presence of copper deposits in the Otavi Mountain Land when Sir Francis Galton published his narrative *Travels in Tropical Africa* in 1852; he described a journey through the Otavi region. Galton, together with Charles Anderson and I. Allen, traveled through Ovamboland in 1851 and camped at Otjikoto Lake, 20 km west of Tsumeb. Here, they met various groups of Bushmen and Ovambos transporting copper ore. Later, in 1857 two Rhenish missionaries, H. Hahn and J. Rath were camped east of Grootfontein where they also encountered Ovambo men transporting copper ore from the Otavi Valley (Söhnge, 1967). The ore was contained in "neatly woven baskets made of palm leaves," with each basket holding approximately 90 pounds of ore. This load, together with adequate supplies of food and water, was being hauled over 250 km! Several years later Hahn undertook a second trip to Ondangwa during which he established that the copper deposits in the Otavi mountains were being excavated by the Bushmen. It is clear from archeological remains that the Bushmen mined copper here and then transported the ore to Ondangwa where it was smelted by the native Omundonga, who specialized in metallurgical work. The copper was then used by these people to barter for various other commodities. Söhnge (1967) relates documented evidence provided by an American trader, Gerald McKiernan, who, together with several British traders including I. Hickey, C. C. Thomas and W. H. C. Wilmer, built a house at Otavi. During a hunting trip, McKiernan and Thomas discovered the site of copper mining at Gross Otavi:

> When the wagon came up, we slaughtered the game, and proceeding onward arrived at sunset at a place which answered the description of that given by Brook's as the vicinity of the copper mine. Old smelting places were plentiful. Calcined stones, charcoal and fragments of copper-ore in heaps. Lion-tracks were very plentiful and a close guard was kept on the bullocks. Soon after dark we heard lions roaring and growling at no great distance. . . . The next morning we began searching for the mine, but were unsuccessful for nearly half the day; and when we finally did find it, it was not more than 200 yards from the wagon. Such is the nature of that part of the country, a dense jungle; and notwithstanding the frequent visits of the natives, no footpaths led to the mine. The mine seemed to be of great richness and pits were dug along the line of the lode for a considerable distance. There were masses of ore of many tons in weight exposed in many places, and seemed to have been left for want of proper tools

Table 1. **Grade and tonnages for the largest mines in the Otavi Mountain Land.**

		Grade			
	Total Tonnage	*Cu%*	*Pb%*	*Zn%*	*V_2O_5%*
Tsumeb	31,700,000	4.13	8.87	3.11	—
Berg Aukas	3,250,000	—	4.52	16.89	0.77
Kombat	13, 300,000	2.76	1.62	—	—

After King, 1994; Misiewicz, 1988

> for breaking it up into portable form. We had a large hammer, and I broke off about 300 lbs for a sample. It was very hot work, the thermometer 106° in the shade.

On 20th January 1876, McKiernan and Wilmer left Otavi for Omaruru because of hostility among the Ovambos and Hereros.

Prior to 1904 (probably during 1903), J. Kuntz had traveled widely throughout the copper districts of the Northern Cape province in South Africa, as well as through most of the main copper-producing regions in Namibia. During his travels through the Otavi Mountain Land he recorded (Kuntz, 1904) a description of the main geological features of the deposits in this area:

> As in all limestone formations, so also here a great number of caves exist in the Otavi Mountains, as a consequence of the action of water. Some of them are empty, some filled with water, and others filled with a sandstone-like mass which contains the copper ore in small and large pieces of different shapes. . . . The enormous copper deposits at Otavi, Guchab and Tschumeb [*sic*], etc, are simply fillings of such cavernous caves.

The Otavi Mountain Land was first occupied by Europeans in 1885 when "trek-boers" under the leadership of Will Worthington Jordan settled in the area. On 21st April 1885, Jordan signed a purchase agreement with one of the Herero Chiefs in which he (Jordan) purchased about 50,000 km^2 of land, which included Tsumeb, Otavi and Grootfontein. For this he paid £300, 25 rifles, an immunized horse and a barrel of brandy. This area he called the Republic of Upingtonia. All the legal rights and ownership in the economic deposits belonged to Jordan. Some of the Hereros resented this arrangement and a plan was made to cancel the deed of sale. This was achieved in brutal fashion by the murder of Jordan, resulting in the partial evacuation of Grootfontein, with the European farmers dispersing into Angola and the Transvaal Republic in South Africa.

In 1890, Germany took possession of the territory and granted a mining concession to the South West Africa Company (SWACO), which was floated in London in 1892 (Misiewicz, 1988). In 1900, a second company, Otavi Minen Und Eisenbahn Gesellschaft (OMEG), was established and an agreement was drawn up in which SWACO ceded mineral rights to OMEG over an area of about 1,200 km^2, which included Tsumeb. This agreement was conditional on a narrow-gauge railroad being constructed from Swakopmund to Tsumeb. This construction took three years to complete, from 1903 to 1906. In 1908, SWACO extended a branch line from Otavi to Grootfontein. This railway proved to be an important transport and communication facility; £400,000 worth of copper and lead ore were transported during 1909 alone (Wagner, 1910). It was always OMEG's intention to resume exploration in the Otavi Mountain Land during the early 1900's following the successful commissioning of the Tsumeb mine. In 1907, the Guchab copper mine was reopened, in 1908 exploration began at Asis (Klein Otavi, now called Kombat) and in 1909 further investigations were conducted at Gross Otavi (Söhnge, 1967). In order to concentrate its efforts on renewed exploration, OMEG formed a subsidiary company in 1909, Otavi Exploration Syndicate Limited, registered in London with starting capital of £63,000. In 1911 the Syndicate opened the copper-lead mine at Asis Ost, close to Kombat, and in 1915 they discovered the Nosib vanadium deposit. The presence of vanadium in the Otavi region was first noticed when mottramite was described from the oxidation zone at the Tsumeb mine (Maucher, 1908) and the mineralogy of the vanadates was first described by Pufahl (1920). The next discovery of vanadium away from Tsumeb was on the Rietfontein farm, 33 km west of Grootfontein, by the prospector J. Sinclair. In the following years, several other deposits were discovered as sand-filled solution karsts formed in the Otavi dolomites (Stahl, 1926; Schneiderhöhn, 1929; Clark, 1931); these were colloquially referred to as sources of "sand-bag" or "sand-sack" ore.

At the end of the First World War, SWACO's mineral rights were lost, but later reinstated by the Union Government. During this period, the Abenab vanadiniferous breccia pipe was discovered in 1921 and mined until 1947. It was reported to be the largest vanadate ore deposit in the world (Verwoerd, 1957). Abenab West mine was operative from 1939 to 1958. Prior to the development of the Abenab mines, in 1913, W. Joubert, a SWACO prospector reported discovering zinc on the crest of a hill, now called Berg Aukas Mine Kopje. During the early 1920's, geological exploration revealed alluvial descloizite deposits scattered around the foot of this hill. In 1924, J. Sinclair started mine development at Berg Aukas for SWACO. Only later, in 1940, was further prospecting undertaken here again, when a fracture-filled descloizite body, now called the Central Ore Body, was discovered by Sinclair. In 1955, following an extensive drilling program, the mine was worked on a small scale. At this particular time, the Northern Ore Body was discovered, and this was accompanied by underground mine development. In 1968, the No. 2 Shaft was sunk and a kiln constructed to treat oxidized ore. Mining operations ceased in 1978 when the price of zinc dropped to less than US$550 per ton, resulting in losses at the mine. Today Berg Aukas belongs to Gold Fields of South Africa Ltd., a company based in Johannesburg. At present, only two mines are operating in the Otavi Mountain Land: Kombat and Khusib (Chamber of Mines of Namibia, 1996; Anonymous, 1996). Underground mining at Tsumeb ceased on 30 June 1996, but open pit operations may still continue adjacent to the Glory Hole. The smelter will still operate at Tsumeb.

GEOLOGY

The Otavi Mountain Land mineral province covers an area of about 10,000 square kilometers and is located on the eastern side of the so-called Northern Carbonate Platform of the Damara Orogen (Martin and Eder, 1983; Miller, 1983). The Damara Orogen is considered to be a late-Proterozoic orogenic belt positioned between the Congo and Kalahari cratons (Pirajno and Joubert, 1993). This geological terrain has undergone a complex geological history that consisted, in general, of an early rifting period followed by a later compressional (convergence-collisional) episode. The rifting began about 1,000 million years ago and resulted in the separation of South America and southern Africa during the late Proterozoic (Porada, 1989).

Stratigraphically, the rocks of the Otavi Mountain Land are subdivided lithologically and chronologically into the Nosib Group, Otavi Group (consisting of the Abenab Subgroup overlain by the Tsumeb Subgroup) and Mulden Group. These sedimentary rocks rest on basement rocks composed of granite, gneiss and a poorly exposed mafic complex. The Nosib Group consists of quartzite, arkose, conglomerate and shale; the Abenab Subgroup is dolomite, limestone and shale; the Tsumeb Group is dolomite, limestone, quartzite, shale, chert and mixtite (the Chuos Tillite); and the Mulden Group is quartzite, greywacke, conglomerate and phyllite (Wartha and Schreuder, 1992; Pirajno and Joubert, 1993). The regional structure of the Otavi Mountain Land consists of east-west-trending folds, overprinted by a second folding phase producing northward verging recumbent folds. In addition, the strata of the Otavi Mountain Land have been subjected to lower greenschist to prehnite-pumpellyite facies metamorphism.

The Otavi Mountain Land is reputed to have approximately 600

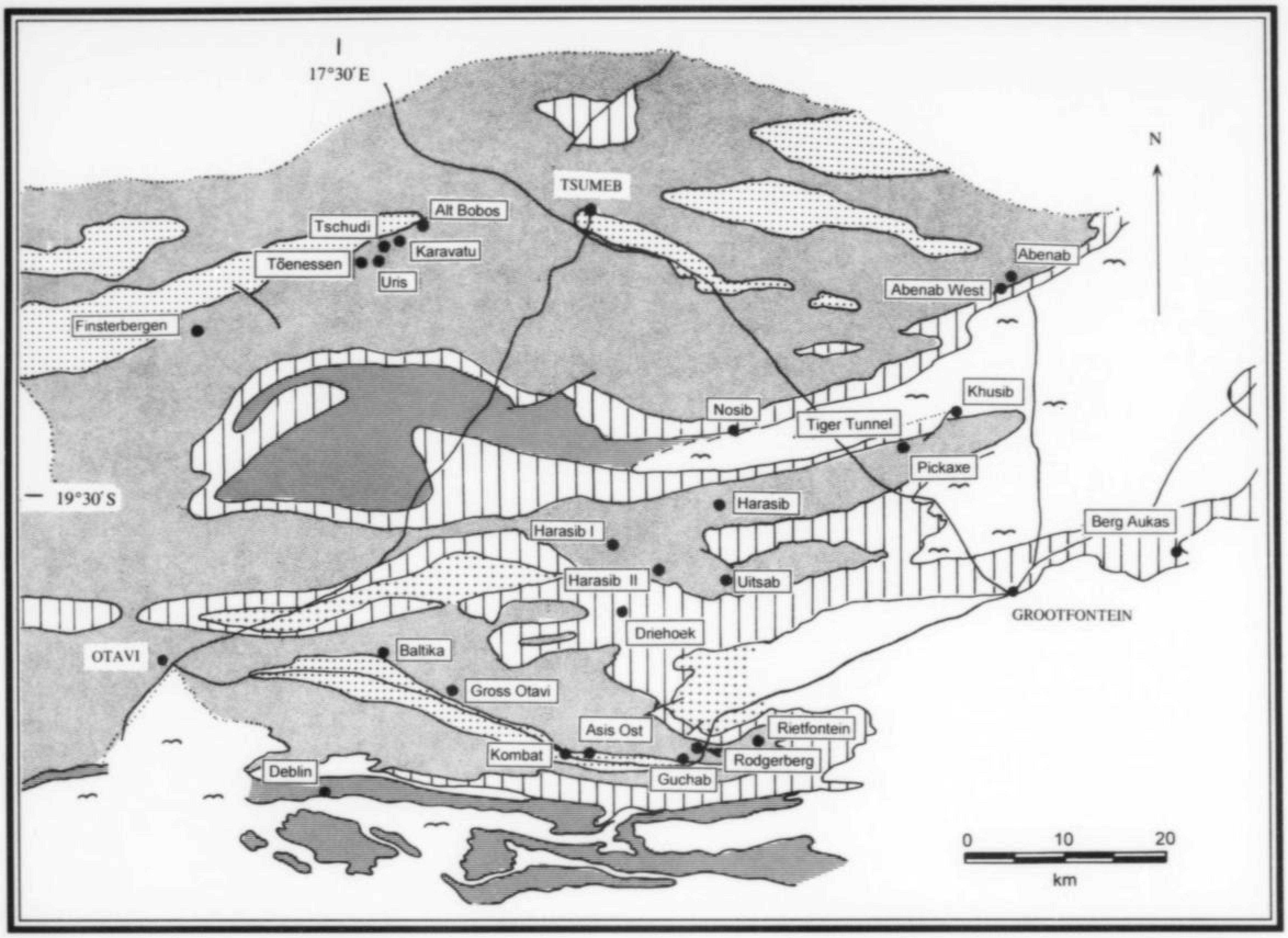


Figure 2. **Simplified geology and stratigraphy of the Otavi Mountain Land. The localities of the deposits described in this article are shown (adapted in part from Wartha and Schreuder, 1992).**

known mineral occurrences, the most well-known being those at Tsumeb, Kombat, Berg Aukas and Abenab. These, and others, are not large occurrences by world standards, but they contain economically rich polymetallic ores with very high metal grades. Apart from producing copper, lead, zinc, vanadium and silver, the Tsumeb deposit has also produced gallium, germanium and cadmium. Some of the other occurrences also contain traces of Ga, Ge and Cd but these have not been exploited.

The carbonate-hosted mineral deposits of the Otavi Mountain Land have traditionally been classified into two main categories of mineralization:

(1) The Tsumeb-type (e.g., Hughes, 1987)

(2) The Berg Aukas-type (e.g., Misiewicz, 1988)

The Tsumeb-type ore deposits are characterized by polymetallic phases of sulfide minerals containing copper, lead, zinc, silver, arsenic, germanium, cadmium and gallium. The ore minerals are usually disseminated in a variety of structures such as solution breccias and pipes, shear zones and fractures (Pirajno and Joubert, 1993). The orebodies usually occur in the upper portions of the Tsumeb Subgroup. In contrast, the Berg Aukas-type ores are composed of sulfides containing lead, zinc and vanadium, resembling ore from the Zn-Pb-rich Mississippi Valley-type deposits. Copper is rare to absent and Ag, Ge, Ga and Cd, although present, are much less abundant than in the Tsumeb-type ores. Furthermore, the Berg Aukas-type deposits are generally confined to the Abenab Subgroup and middle-lower portions of the Tsumeb Subgroup. On the basis of various data, including isotopic and fluid inclusion analyses, the two different types of deposits are considered to have formed during two different mineralizing events, both in time and space (Pirajno and Joubert, 1993). An earlier event produced the Berg Aukas-type deposits and involved fluids derived from compaction and dewatering of sediments. Lead and zinc were scavenged by the fluids which were then deposited as sulfides over structural "highs" in karst breccias and along faults in the Abenab Subgroup carbonates. The vanadium mineralization that accompanies the Berg Aukas deposits resulted from supergene processes,

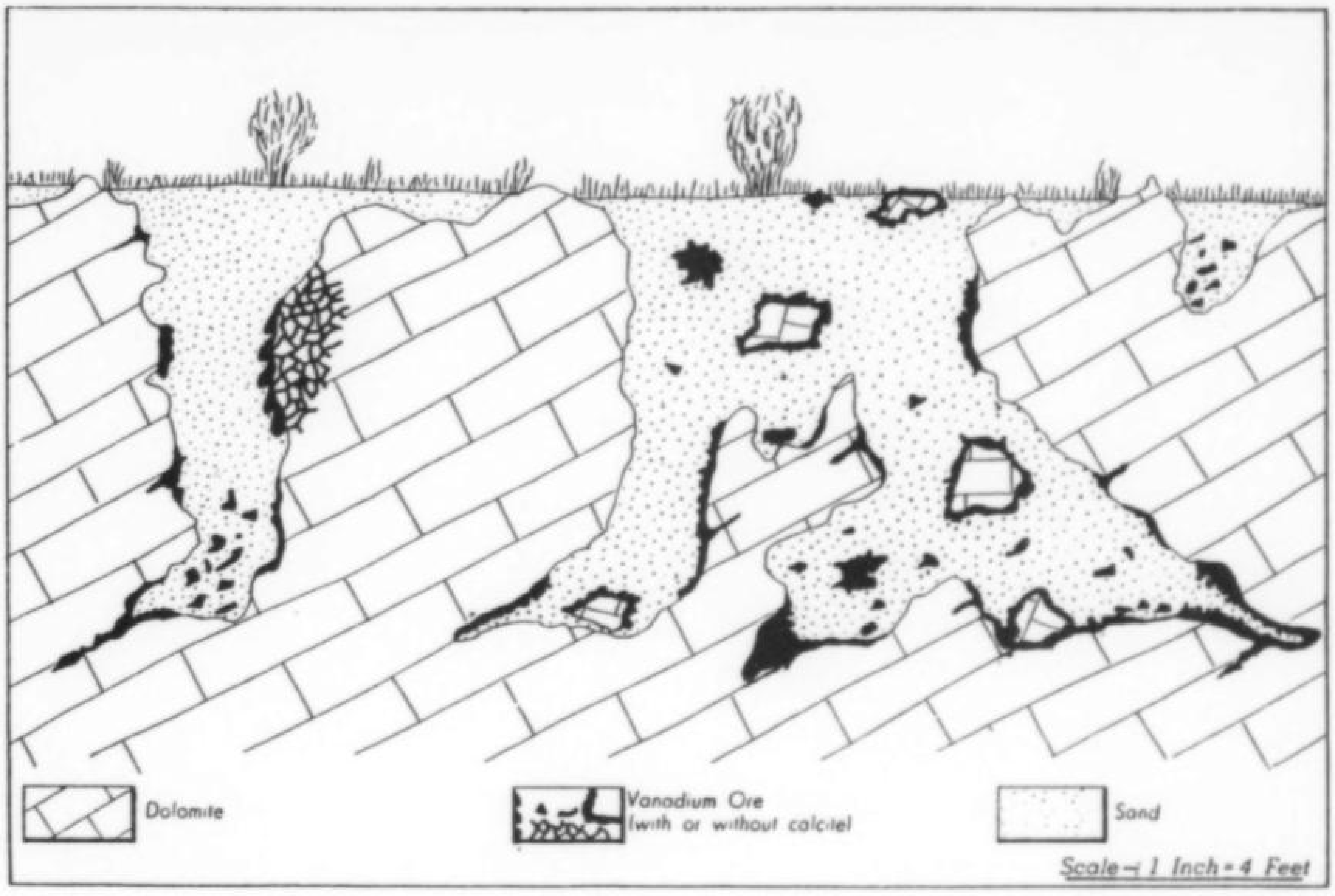


***Figure 3.* An early field sketch showing the general characteristics of the so-called "sand-sack" type of vanadium deposits encountered in several parts of the Otavi Mountain Land. Examples of this type of deposit include those at the Baltika mine, at Gross Otavi and at several mines in the Bobos mining area (Schwellnus, 1945).**

during which vanadium was carried in solution as calcium metavanadate under oxidizing conditions (van der Westhuizen, 1984). When these fluids encountered sulfides, and hence a reducing environment, the solution reacted with the metal ions liberated from the sulfides, thereby forming vanadates such as descloizite. This vanadium event postdates the second or Tsumeb-type deposits which were emplaced after the deposition of the overlying Tsumeb Subgroup carbonates. The vanadium event involved copper-rich, higher temperature/lower salinity fluids.

Apart from these two widely recognized styles of mineralization, King (1994) distinguishes an additional three categories in the Otavi Mountain Land. In addition to the Tsumeb-type (Cu-Pb-Zn-Ag) and Berg Aukas-type (V-Zn-Pb), the other three varieties are:

(1) Kombat-type (Cu-Pb-Ag)
(2) Mississippi Valley-type (Zn-Pb)
(3) Sandstone-type (Cu-Ag)

The Kombat-type deposits are restricted to the northern limb of the Otavi Valley Syncline. Separate orebodies occur along the contact between the Tsumeb Subgroup dolomite and the slate of the Mulden Group above. The Mississippi Valley-type deposits are the most abundant in the region. They are usually stratabound with sphalerite and galena-bearing ores concentrated in dolospar cement or quartz veins. The sandstone-type deposits occur in the sandstones of the Nosib and Mulden Groups. The Nosib mine extracted ore from the former, while the Tschudi copper deposits are the only significant ones known (to date) from the Mulden Group sandstone.

It is interesting to note that although vanadium mineralization is far more prevalent in the Tsumeb Subgroup than in the Abenab Subgroup, the latter hosted the two largest vanadium-producing mines, Berg Aukas and Abenab West (Wartha and Schreuder, 1992).

Apart from the various regional geological studies (Stahl, 1926; Martin, 1965; Veldsman, 1977; Hedberg, 1979), there have been several investigations aimed specifically at certain aspects of mineralization and/or specific mines and localities (Schneiderhöhn, 1921 and 1929; Schwellnus, 1945; Verwoerd, 1957; Söhnge, 1957 and 1967; Allsopp and Ferguson, 1970; Wilson, 1977; Emslie, 1979 and 1980; Hughes, 1979 and 1987; Ypma, 1978; Lombaard *et al.*, 1986; Innes and Chaplin, 1986; Misiewicz, 1988; van der Westhuizen, *et al.*, 1986). During the last five years, there have been a number of geological investigations which have focussed on various aspects of the geology and mineralization of the Otavi Mountain Land. This has coincided with renewed exploration in the region together with several local and international congresses being held in Namibia (see Stanistreet *et al.*, 1991; Chadwick, 1993; Deane, 1993; King, 1994; Miller, 1994; Theron, 1994).

BERG AUKAS MINE

> "The technical manager took me out to the Berg Aukas, an old zinc mine, now just filled with bats." (Samuel G. Gordon, 1929)

This quote by the renowned Samuel Gordon, made after a visit to Berg Aukas during December 1929 (Montgomery, 1974), is somewhat disparaging, although it was probably made in a state of disappointment as the mine was inoperative when Gordon visited it. Berg Aukas is *the* premier locality for, and is synonymous with, the lead-zinc vanadate, descloizite, and most mineral collections around the world display specimens from this locality.

The Berg Aukas Zn-Pb-V deposit is located in the eastern region of the Otavi Mountain Land, 20 km northeast of Grootfontein at latitude 19°34′12″ and longitude 18°15′36″. The occurrence is geologically and mineralogically unique because it is probably the world's largest deposit of descloizite and willemite (Misiewicz, 1988). The mine ceased operation in 1978, having typically milled 11,000 tons per month, grading 17% Zn, 5% Pb and 0.6% V_2O_5.

Although there have been several contributions to the regional geology of the Otavi Mountain Land, e.g., Söhnge (1957), Smit (1958) and Hedberg (1979), very little has been published on Berg Aukas *per se*. At least several unpublished company reports describe the geology and ore mineralogy (see Markham 1958a and 1958b; Weilers, 1959; Schreuder, 1969; Gavine, 1979). Two important contributions during the last 10 years have been the research conducted by Misiewicz (1988) and Chadwick (1993).

The ore at Berg Aukas is hosted in dolomite assigned to the Gauss Formation, which forms the central portion of the Abenab Subgroup. Three types of orebodies were mined at Berg Aukas (Weilers, 1959; Misiewicz, 1988):

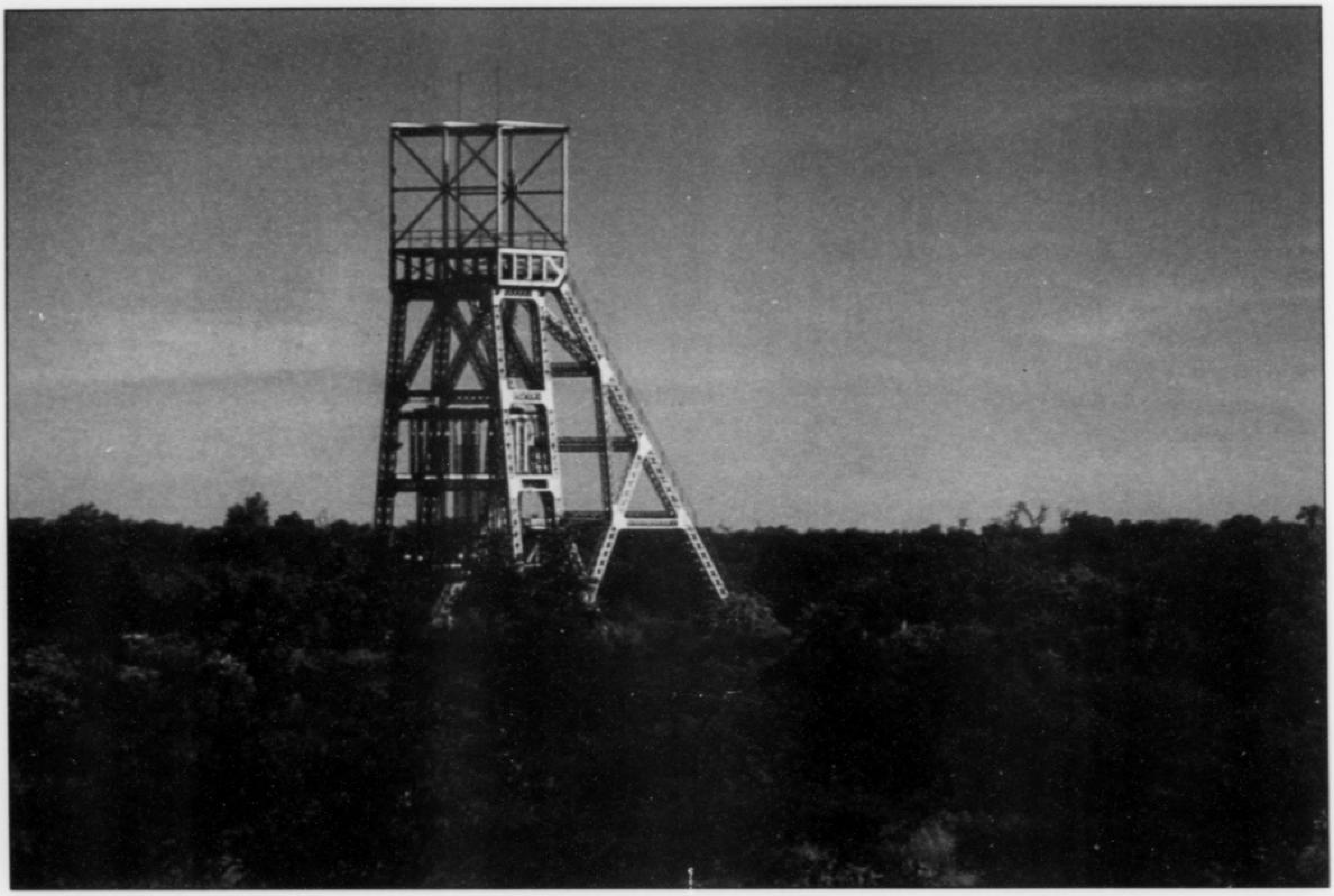
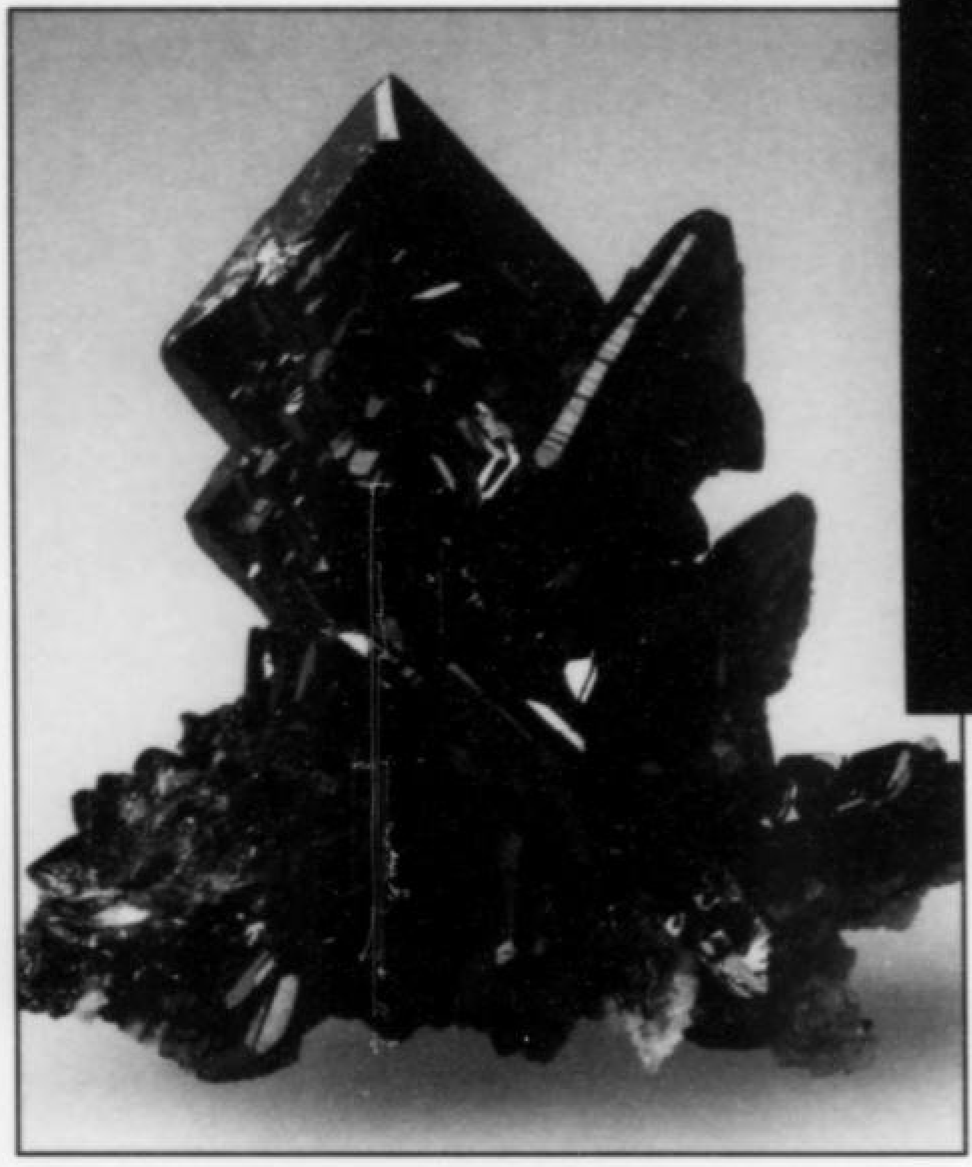


Figure 4. The headframe at the Berg Aukas mine. Photo Roger Dixon.

Figure 6. Metallic gray descloizite with smaller, transparent, orange-red crystals, from Berg Aukas, 9 cm. Desmond Sacco collection; Bruce Cairncross photo.

Figure 5. Descloizite crystal group, 8 cm. Desmond Sacco collection; Carlos Pais photo.



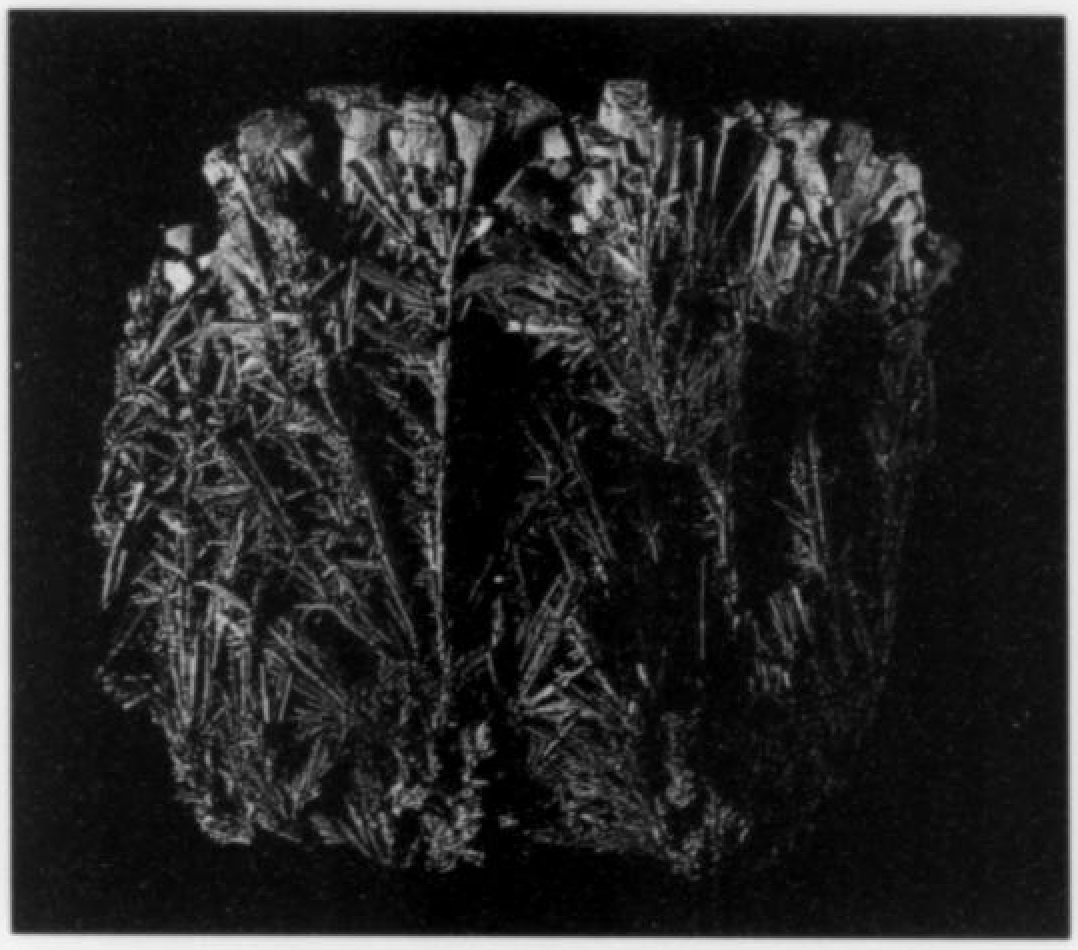


Figure 7. **Dendritic cuprian descloizite, 7 cm, from Berg Aukas mine, collected during the early 1970s. Desmond Sacco collection; Bruce Cairncross photo.**

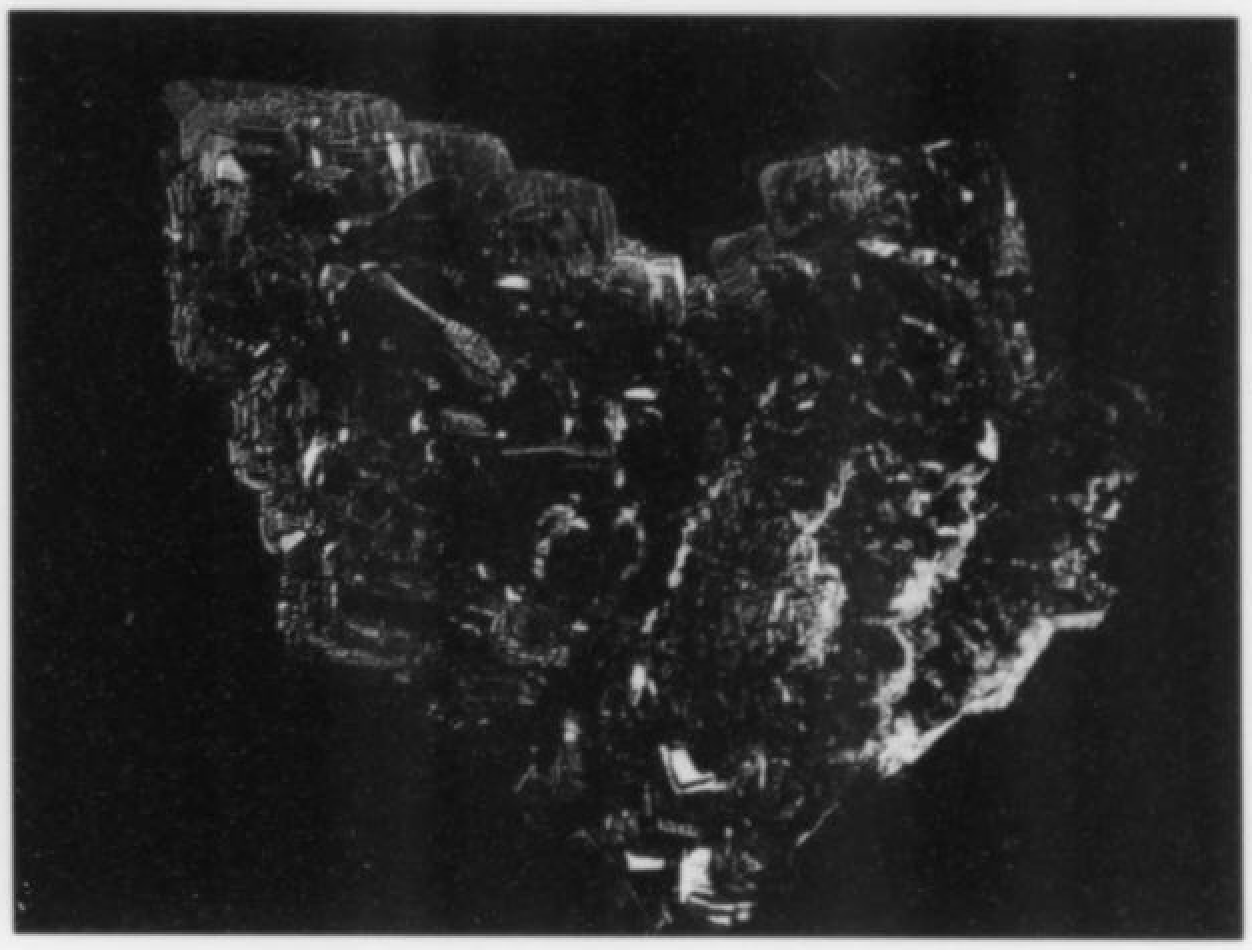


Figure 8. **Partly translucent descloizite, 4.2 cm, from Berg Aukas. Bruce Cairncross specimen and photo.**

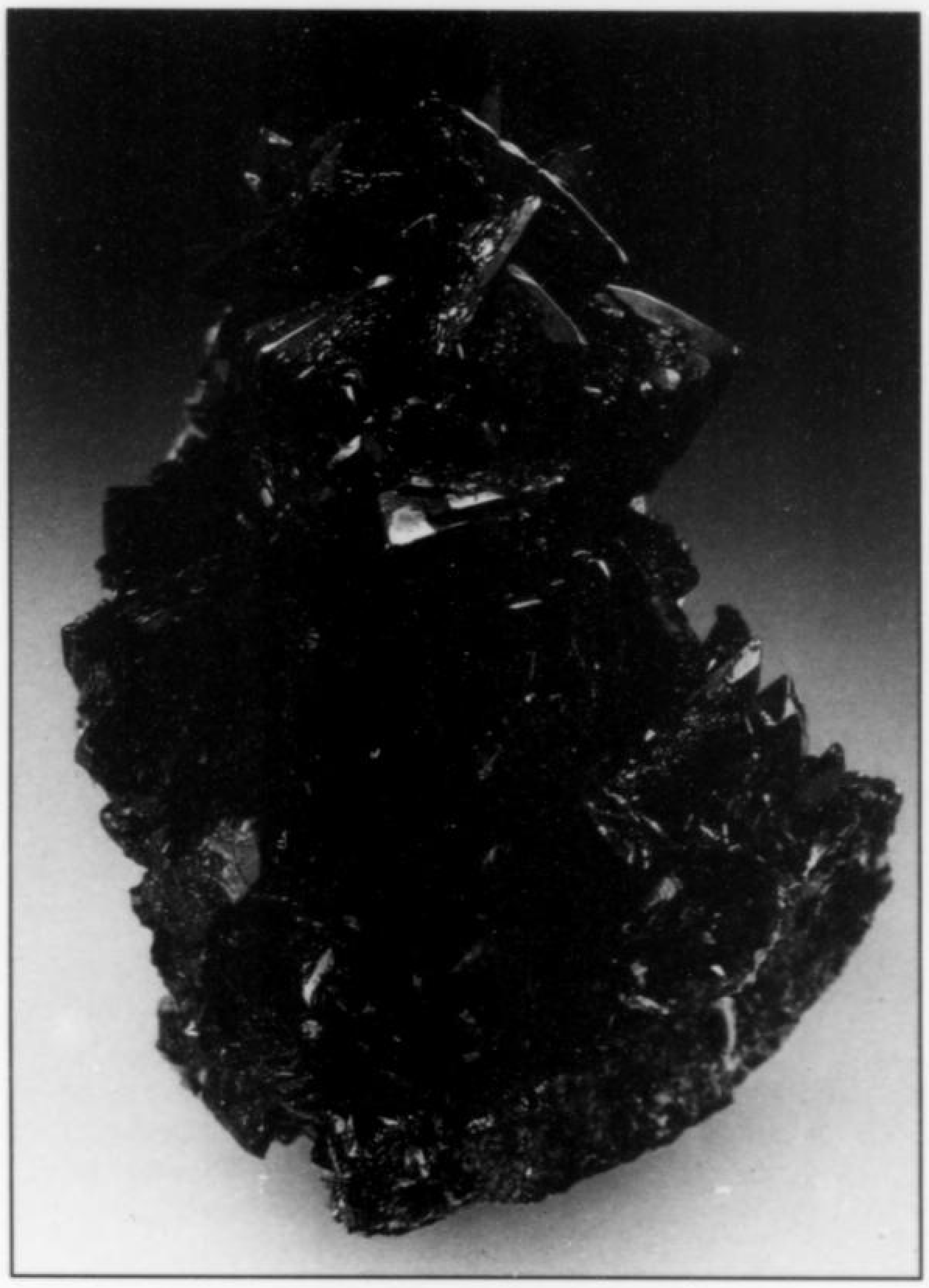


Figure 9. **Descloizite crystal group, 6.2 cm, from Berg Aukas. Gene Schlepp specimen.**

Figure 10. **Descloizite crystal group, 10.4 cm, from Berg Aukas. Bruce Cairncross specimen and photo.**

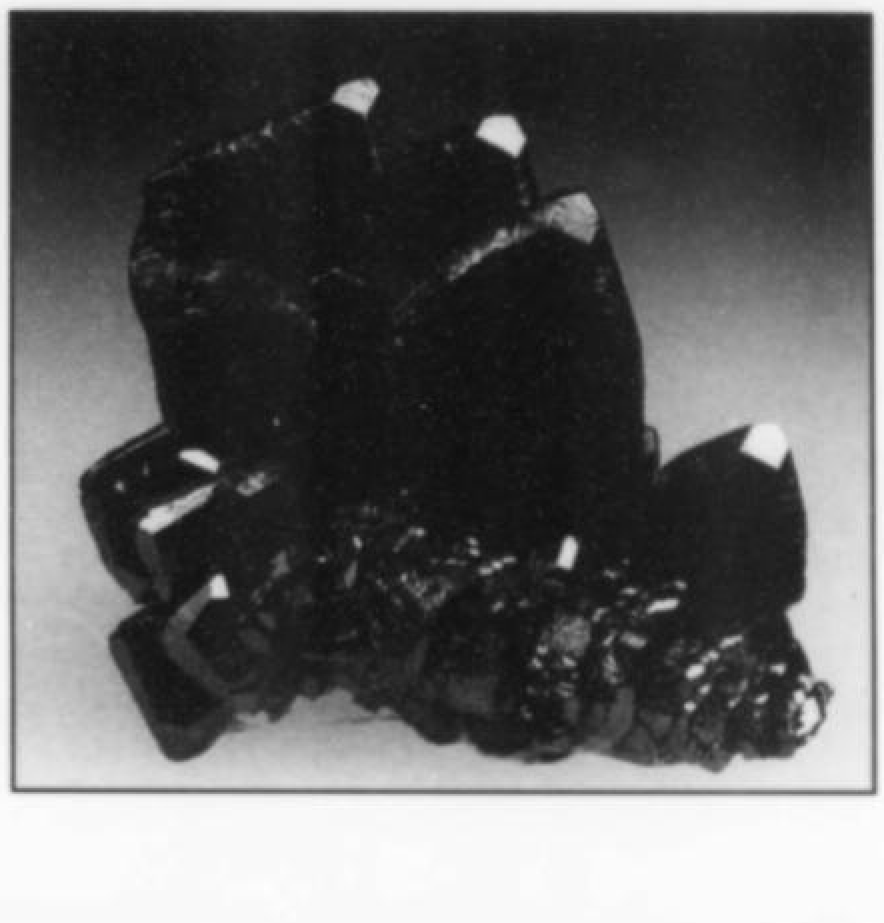


Figure 11. **Descloizite crystal group, 2.7 cm, from Berg Aukas. Frank Melanson specimen.**

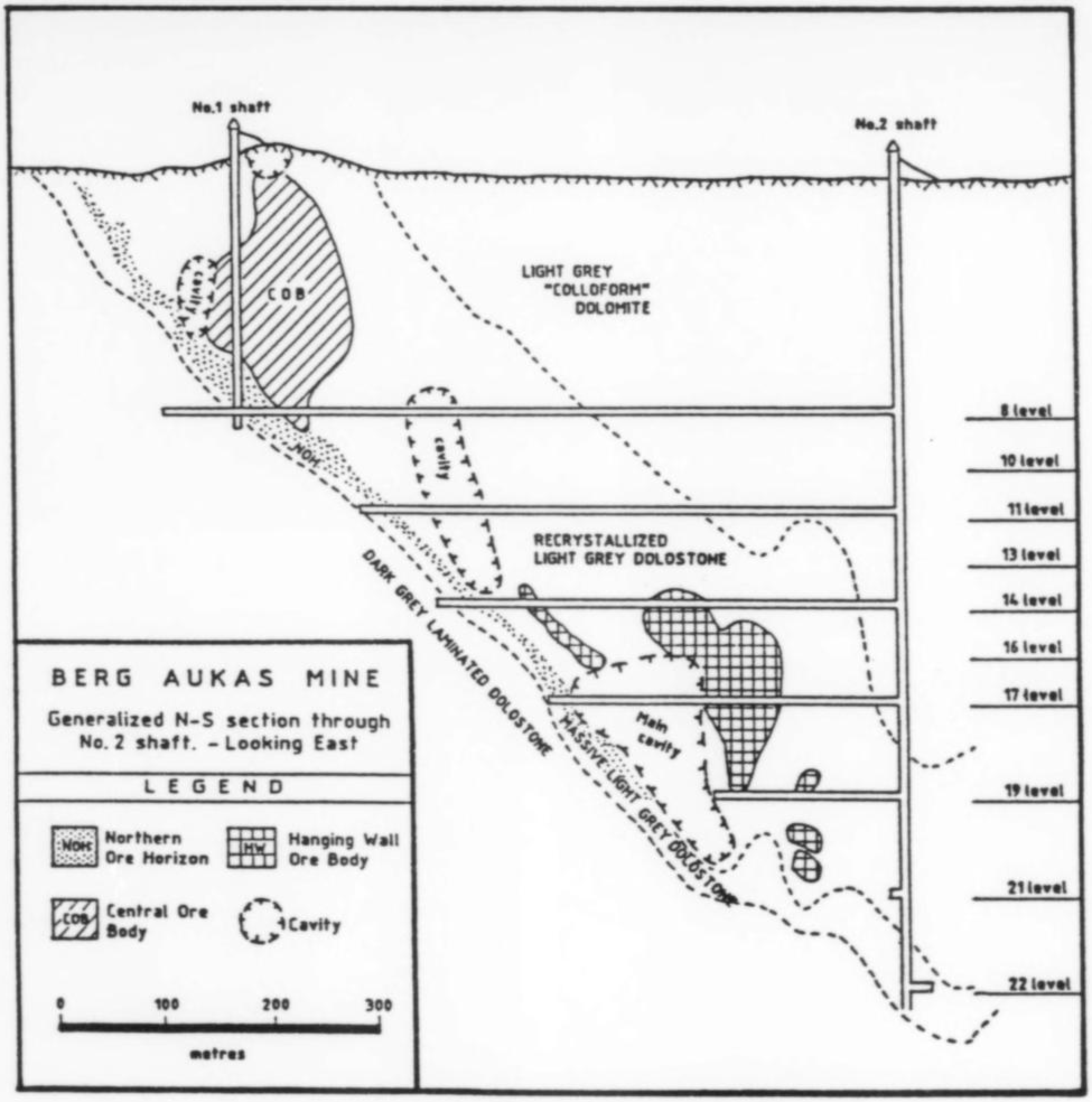


Figure 12. **A generalized north-south section (viewed towards the east) through the Berg Aukas deposit. Note the position of the Central Ore Body, and others, discussed in the text (Chadwick, 1993).**

(1) The stratabound **Northern Ore Horizon**
(2) The discordant **Central Ore Body**
(3) The stratabound **Hanging Ore Horizon**

The spatial distributions of all three of these ore-types are stratigraphically and structurally controlled. The orebodies are known to persist to a depth of 750 m below the surface, but were mined to a limited depth of 600 m (19 level). Mineralization in all three varieties consists of open space filling in karst areas. Massive sulfides consisting of sphalerite and galena are present; Berg Aukas is the only significantly large sphalerite deposit found in the Otavi Mountain Land (Misiewicz, 1988). Oxidation of the primary sulfides formed large deposits of secondary mineralization containing willemite, smithsonite and cerussite. Late-stage descloizite mineralization took place when metavanadate solutions were introduced into the deposit along vertical fractures. The ores are therefore essentially breccia-type deposits and also contain significant amounts of metal-enriched mud and caliche.

Northern Ore Horizon

The Northern Ore Horizon consists of three stratabound lenses. Each mineralized lens has been subjected to oxidation and brecciation, and consists of basal massive coarse-grained galena and sphalerite. Overlying this is oxidized sulfide, composed predominantly of willemite with lesser amounts of smithsonite and cerussite (Misiewicz, 1988). The lens is then usually capped by brecciated dolomite enriched in descloizite. Other features of mineralogical interest include limonite pseudomorphs after pyrite and willemite, and quartz and dolomite associated with the descloizite (Weilers, 1959).

Central Ore Body

The Central Ore Body was a brecciated pipe-like body that extended vertically from dolomite into the hanging wall. The Central Ore Body was exposed at the surface as a series of mud-filled fractures. The ore was oxidized and extensively enriched in vanadiferous muds and breccia. Cavities were usually lined by massive willemite and/or descloizite (Misiewicz, 1988).

Hanging Wall Ore Body

North-south trending lenses of ore-filled fractures characterize the Hanging Wall Ore Body. These steeply dipping lenses are located above the Northern Ore Horizon and are best developed between 14 and 23 level. Erratic grade and different structural fabric made the Hanging Wall Ore body somewhat more difficult to mine; consequently most of the remaining, unmined ore reserve is of this type.

Table 2. **Hypogene minerals from Berg Aukas.**

Calcite	$CaCO_3$
Chalcopyrite*	$CuFeS_2$
Dolomite	$CaMg(CO_3)_2$
Enargite	Cu_3AsS_4
Galena	PbS
Jordanite*	$Pb_{14}(As,Sb)_6S_{23}$
Pyrite*	FeS_2
Quartz	SiO_2
Renierite	$(Cu, Zn)_{11}(Ge,As)_2Fe_4S_{16}$
Sphalerite	ZnS
Tennantite	$(Cu,Ag,Fe,Zn)_{12}As_4S_{13}$
Tetrahedrite	$(Cu,Fe,Ag,Zn)_{12}Sb_4S_{13}$

* = accessory mineral

After van der Westhuizen, 1984; Misiewicz,1988)

Table 3. **Supergene minerals from Berg Aukas.**

Aragonite	$CaCO_3$
Calcite	$CaCO_3$
Cerussite	$PbCO_3$
Chalcocite	Cu_2S
Covellite	CuS
Descloizite	$PbZn(VO_4)(OH)$
Dolomite	$CaMg(CO_3)_2$
Galena	PbS
Goethite	$\alpha\text{-}Fe^{3+}O(OH)$
Greenockite	CdS
Hematite	$\alpha\text{-}Fe_2O_3$
Malachite	$CU_2^{2+}(CO_3)(OH)_2$
Quartz	SiO_2
Smithsonite	$ZnCO_3$
Willemite	Zn_2SiO_4

After Emslie, 1979; van der Westhuizen, 1984; Misiewicz, 1988

Mineralogy

A detailed investigation of the hypogene and supergene minerals found at Berg Aukas (Misiewicz, 1988) revealed the following:

Sphalerite and galena are the main hypogene components. The sphalerite is typically honey-colored and crystals 1 cm in size were common. Berg Aukas sphalerite is very low in iron and contains trace amounts of cadmium and germanium (Markham, 1958a). Galena is enriched in silver. In fact, silver was recovered from the lead concentrate at grades of up to 210 g/ton and averaged 10 g/ton throughout the mine (Lombaard, 1981). Accessory minerals of hypogene origin include tennantite, enargite, renierite and ordanite.

The supergene minerals at Berg Aukas form an important component to the ore assemblages and have been the focus of two unpublished reports (Markham, 1958b; von Rahden, 1963). The hypogene and supergene minerals from Berg Aukas are listed in Tables 2 and 3. Some of these minerals, such as chalcocite, covellite, and greenockite occur as microscopic components; gangue minerals such as calcite, dolomite and quartz are relatively rare as well (Misiewicz, 1988). Secondary quartz and calcite are common, particularly in the breccias, associated with descloizite. Aragonite has a similar association.

Table 4. **Mineral paragenesis for Berg Aukas.**

Deformation	*Alteration*	*Mineralization*		
Basement faulting		Sphalerite I	HYPOGENE	TIME
		Galena I		
Folding	Dolomite I	Tennantite		
	Calcite I	Enargite		
	Quartz I	Pyrite		
		Sphalerite II		
Hydrothermal Karsting		Goethite I		
		Galena II		
		Chalcocite		
		Greenockite	SUPERGENE	
		Covellite		
		Cerussite		
KARSTING	Dolomite II	Willemite I		
	Calcite II	Smithsonite I		
	Quartz II	Willemite II		
		Smithsonite II		
		Hematite		
		Goethite II		
		Descloizite		

After Misiewicz, 1988

Cerussite $PbCO_3$

Cerussite is relatively uncommon at Berg Aukas, forming less than 1 % of the ore minerals (Misiewicz, 1988). Where present, it is found in association with either willemite or smithsonite.

Descloizite $PbZn(VO_4)(OH)$

Descloizite is the mineral for which Berg Aukas is most famous; fine specimens may be seen in most collections worldwide. The mine probably contains the largest deposit of descloizite known. The association of zinc, lead and vanadium is relatively uncommon but not unknown from other African localities, such as at Kabwe (Broken Hill) in Zambia (Spencer, 1908; Pelletier, 1930; Notebaart and Korowski, 1980), at Minas Do Lueca in Angola (Millman, 1960) and in carbonates associated with the Bushveld Complex in South Africa (Willemse *et al.*, 1944).

Berg Aukas descloizite displays a variety of habits including pyramidal, prismatic, pseudocubic and tabular. Typically, many specimens have spear-shaped terminations and are often highly lustrous. Some show an attractive bornite-like iridescence. Spectacular drusy aggregates were often collected, some weighing several kilograms and more. Individual crystals of 1 cm are abundant and larger, 2–3 cm crystals are common. The color is variable, from metallic black to green-black and orange-brown. Some specimens are a vibrant bright red, but this color is usually restricted to small (<5 mm), thin, transparent crystals. Matrix specimens rest on orange-brown, amorphous iron-rich claystone. It is uncommon to find other minerals associated with the descloizite, but sometimes small, euhedral calcite and/or dolomite rhombs form partial coatings. Other associated minerals may include smithsonite and willemite. Some splendid specimens of white smithsonite crystals draped over a matrix of well-crystallized descloizite are also known. Table 4 shows the mineral paragenesis at Berg Aukas.

Figure 13. Metallic gray, multiply twinned descloizite from Berg Aukas. Bruce Cairncross specimen and photo.

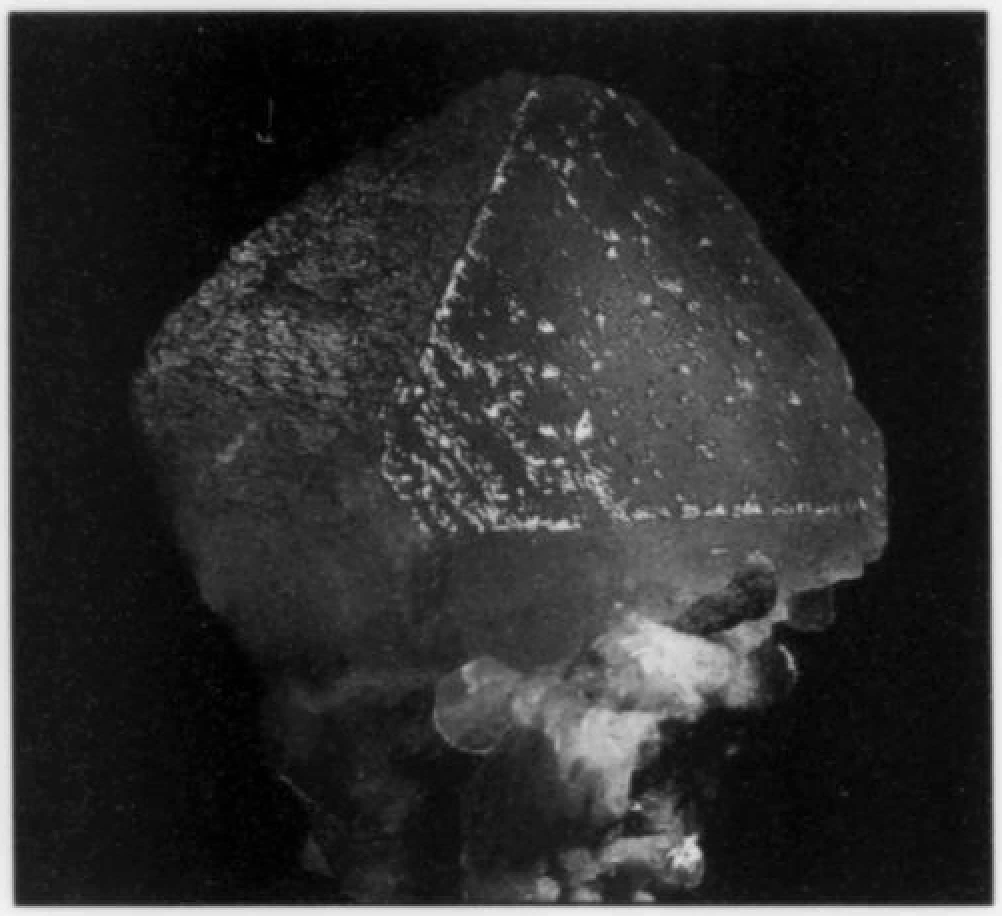


Figure 14. Euhedral smithsonite crystal, 3.8 cm, with minor willemite at the base, from Berg Aukas. Desmond Sacco collection; Bruce Cairncross photo.

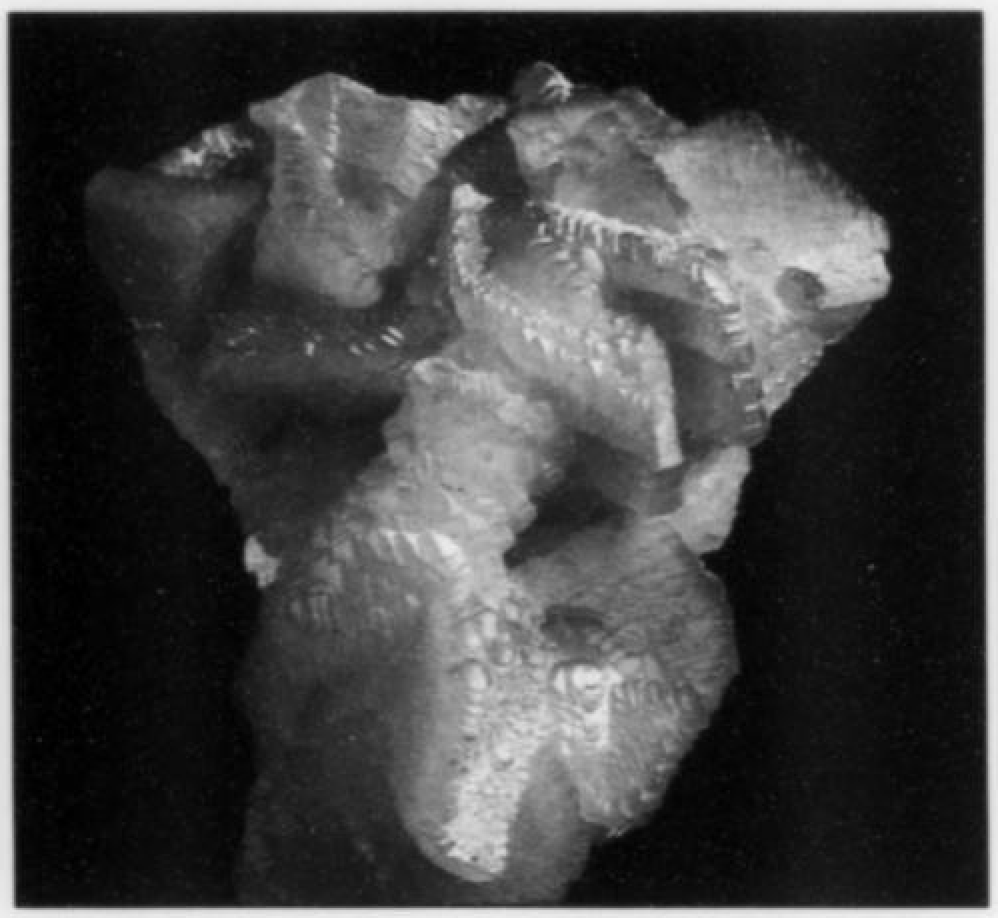


Figure 15. Group of smithsonite crystals, 10.5 cm, from Berg Aukas. Bruce Cairncross specimen and photo.

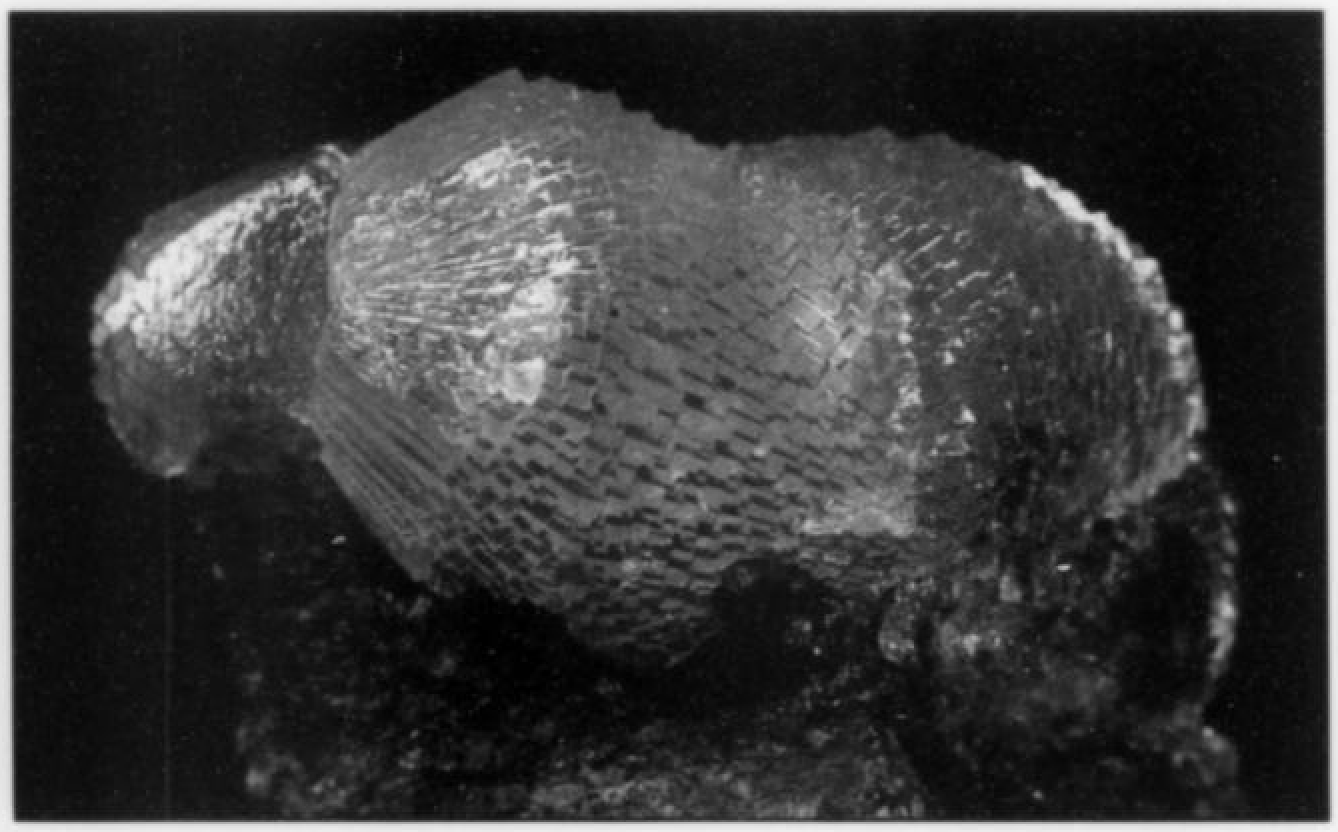


Figure 16. Composite smithsonite crystals, 4.5 cm, from Berg Aukas. Desmond Sacco collection; Bruce Cairncross photo.

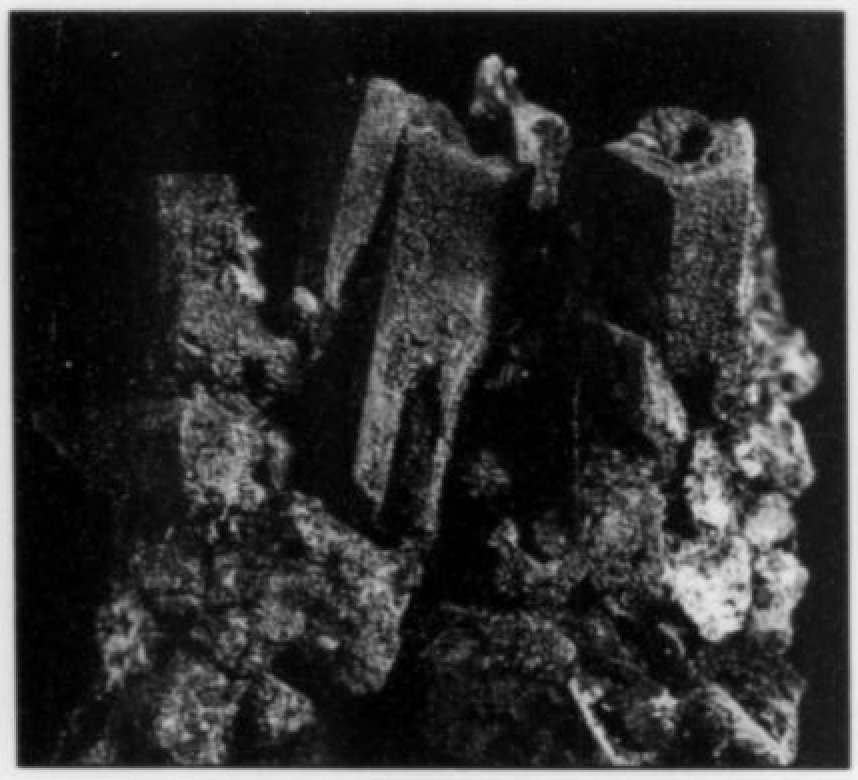


Figure 17. Descloizite pseudomorphs after vanadinite, from Berg Aukas, purchased in 1974 from Sid Pieters. The largest crystal is 4 cm. Karl Messner collection; Bruce Cairncross photo.

Figure 18. Gemmy vanadinite crystals from Berg Aukas. The largest crystal is 4 mm. Bruce Cairncross specimen and photo.

Figure 19. A vug lined with drusy willemite crystals 1 cm long, and also containing a naturally etched cerussite crystal, 9 cm. Collected at Berg Aukas in 1961. Bruce Cairncross specimen and photo.

Smithsonite $ZnCO_3$

Smithsonite is also an important zinc mineral at Berg Aukas, but not as widespread as willemite, being most common in the upper parts of the Central Ore Body (Markham, 1958b). It is always opaque white to tan in color. Botryoidal masses as well as sheaf-like aggregates are common. Composite crystals up to 4 cm also occur.

Willemite Zn_2SiO_4

Willemite is the most important and widespread supergene mineral at Berg Aukas; it is found in all of the orebodies and is reputed to account for 40% of the total zinc. This calculation has lead to suggestions that Berg Aukas has the world's largest accumulation of willemite.

Massive willemite is very common. In vugs, it occurs as needle-like prismatic hexagonal crystals up to 1 cm, usually forming aggregate bundles or radiating rosettes. The crystals are typically white or pale yellow-white to red-brown, the latter related to ferruginization on the crystal surfaces. An interesting aspect of the Berg Aukas willemite, and also that found at Abenab (Verwoerd, 1957), is that, unlike willemite from other world localities (Spencer, 1927), it does not fluoresce in ultraviolet light. The typical yellow-green fluorescence elsewhere is attributed to trace amounts of manganese, so this element is apparently lacking in the Otavi Mountain Land specimens. Willemite is believed to have originated by the direct replacement of sphalerite.

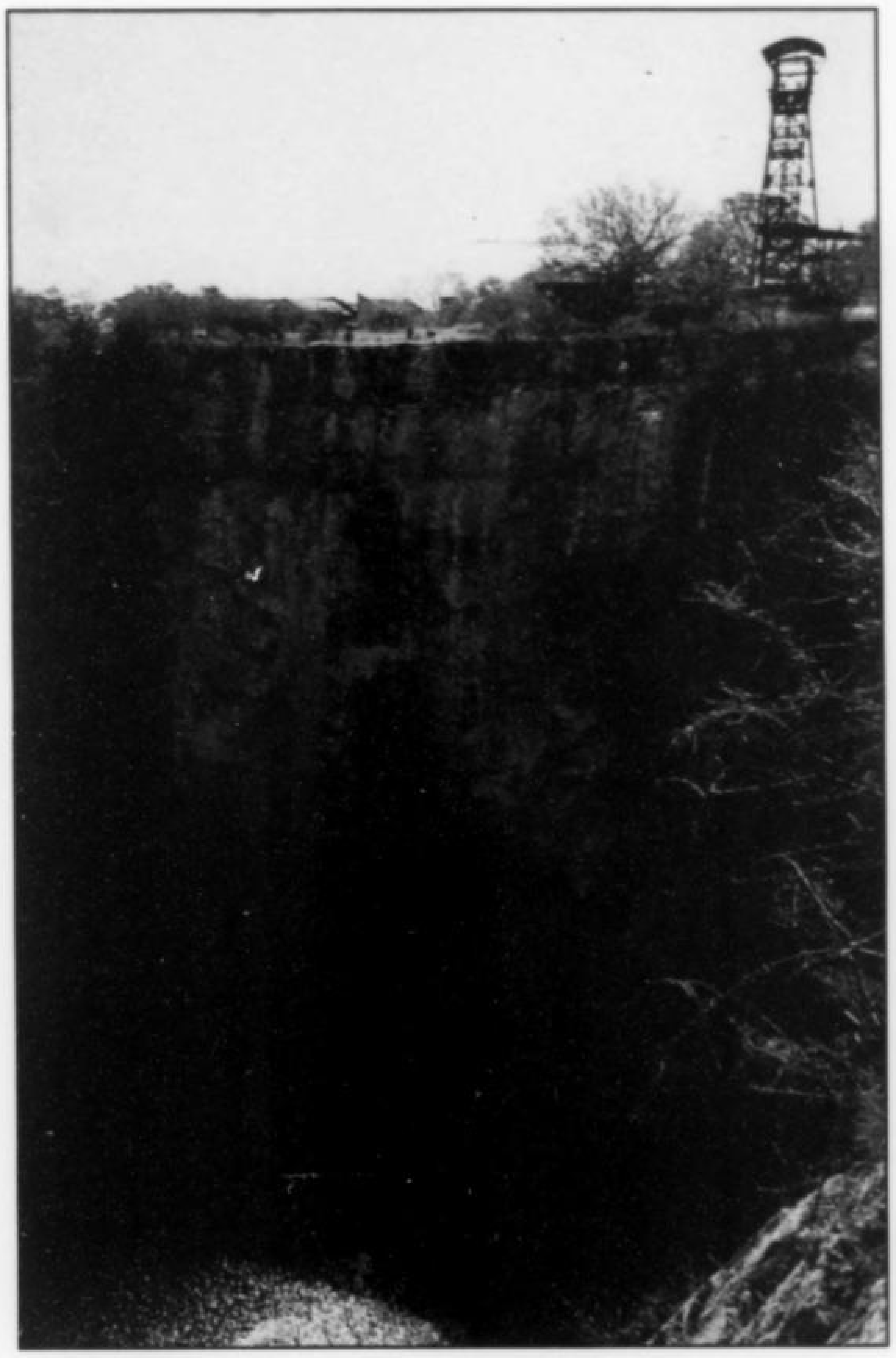


Figure 20. **The pit at the Abenab breccia pipe, now abandoned and partially water-filled. Small tunnels can be seen leading off from the sides of the pit walls. Photo by Julian Misiewicz.**

ABENAB MINE

The ore deposits at Abenab and Abenab West were exploited during the period 1922–1958. The orebody at Abenab consisted of a steeply dipping, crudely cylindrical pipe containing brecciated country rock. The breccia pipe is carrot-shaped and extends to a depth of 250 m. Compact red clay, together with well-crystallized aggregates of descloizite and calcite, cemented the breccia. No sulfide mineralization was ever found associated with the pipe, prompting speculation that a sulfide orebody still exists at depth (Misiewicz, 1988).

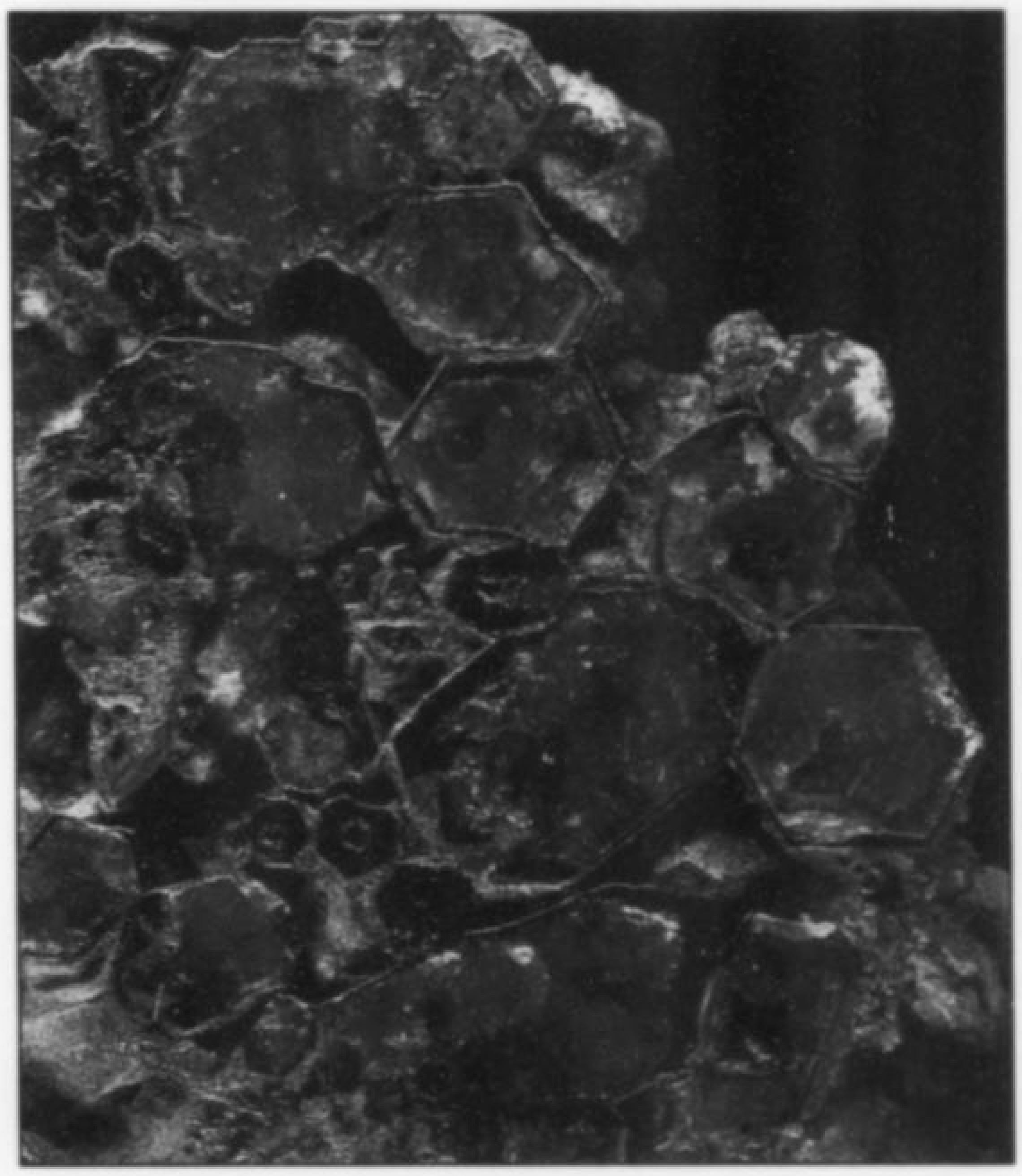


Figure 21. **Sawn and polished specimen of hexagonal vanadanite coated by descloizite from the Abenab mine; the largest crystal is 1.8 cm diameter. Museum of the Council for Geoscience (Pretoria) specimen #MGS 19093; Bruce Cairncross photo.**

Figure 22. **Vanadinite from Abenab; side view of Figure 21. The longest crystal is 4.8 cm, but 12-cm crystals occur on another specimen in the Museum's collection, making these the largest in the world. Bruce Cairncross photo.**

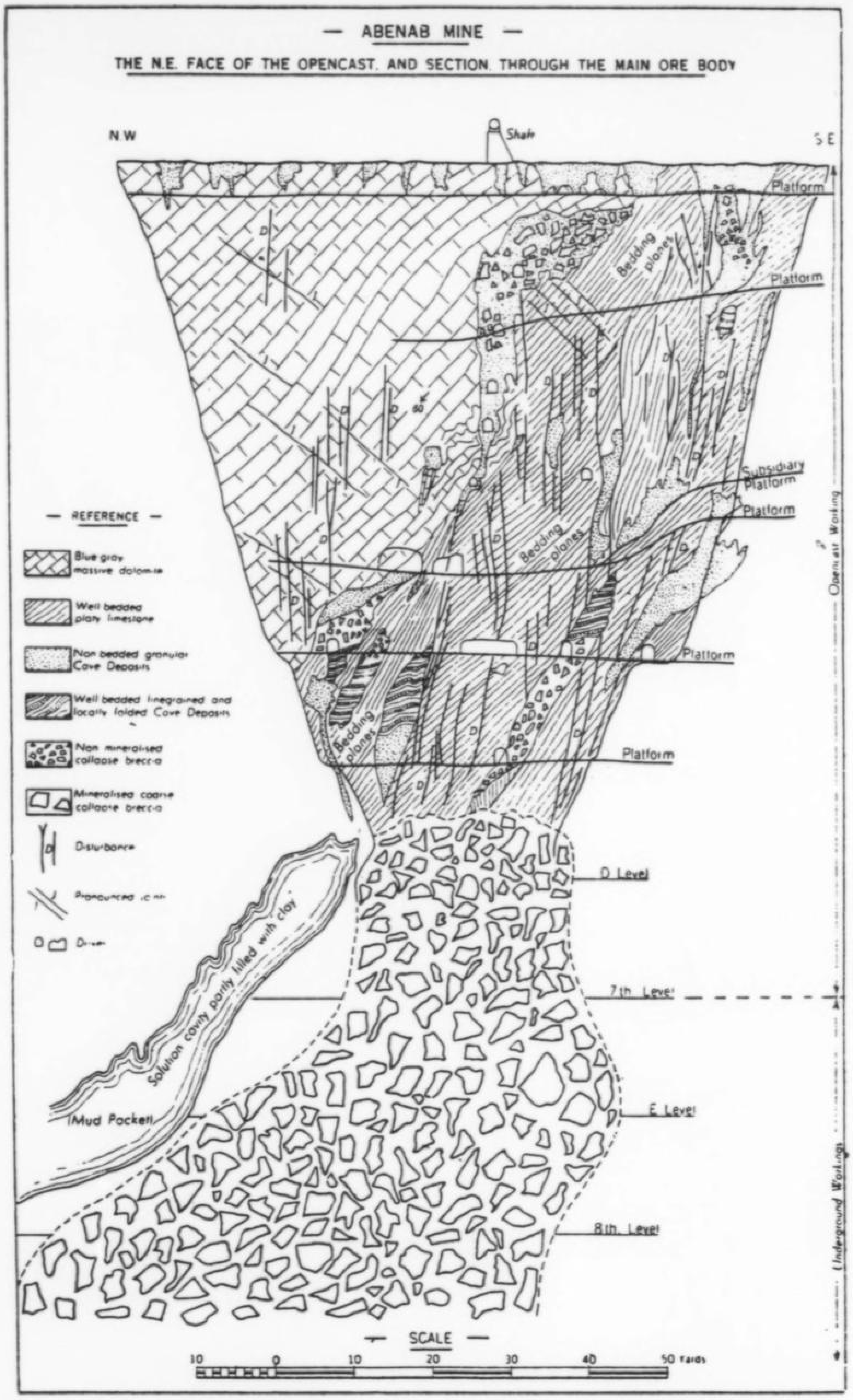


Figure 23. **Northwest-southeast cross-section through the Abenab mine, *circa* 1940 (Schwellnus, 1945).**

Descloizite $PbZn(VO_4)(OH)$

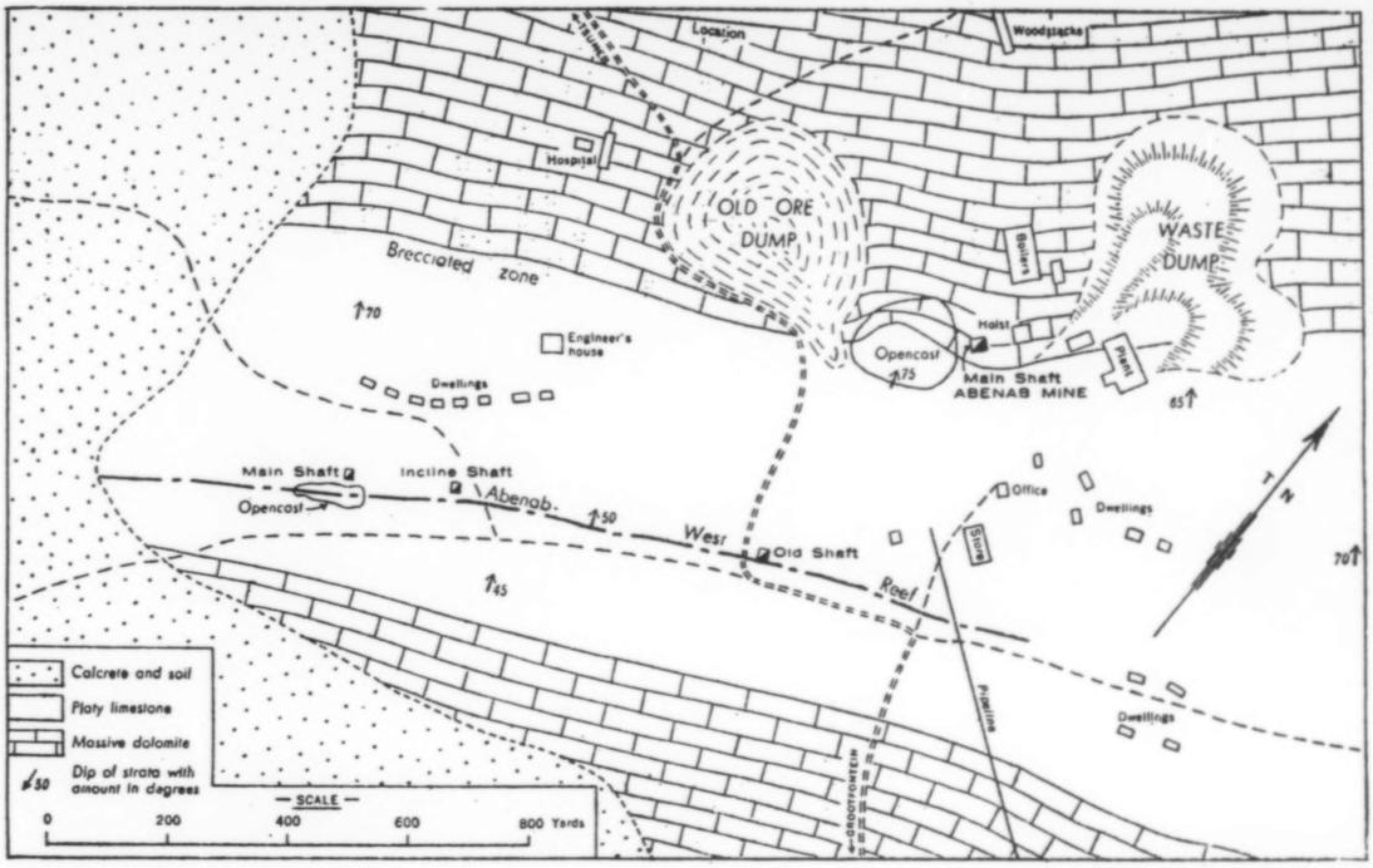
Cavities at Abenab measured up to several meters across and were partially or wholly filled by large groups of descloizite, calcite and vanadinite crystals. Dark green, drusy descloizite is commonly succeeded by aggregates of crystals a few millimeters to several centimeters in length (Verwoerd, 1957), either coated by calcite or projecting freely into open cavities. The descloizite consists of numerous pyramidal crystals with dull black faces, in sub-parallel or branching patterns. In some cavities, pale green, tabular, drusy descloizite crystals encrust calcite or are enclosed in a groundmass of transparent calcite. Several varieties of descloizite were described from the early 1920's mining period. The breccia consisted of angular fragments of pink limestone and red dolomite. According to Wagner (1922), these were:

> . . . encased by crusts of dark green or brown descloizite crystals, the cementing medium being coarsely crystalline white calcite. The latter forms a network of irregular veins up to 2 centimeters, across which are interspersed with vugs lined with crystals of descloizite and colorless calcite.

A variety of forms and colors of descloizite occurred. For example black-green pyramidal crystals; bottle-green varieties up to 2 cm; tabular green-brown crystals; and lustrous brown crystals up to 1.5 cm, arranged in parallel and imbedded in white calcite (Wagner, 1922).

Vanadinite $Pb_5(VO_4)_3Cl$

Vanadinite was found in large quantities below the fourth level (120 feet), in clusters of "large, prismatic crystals up to three or



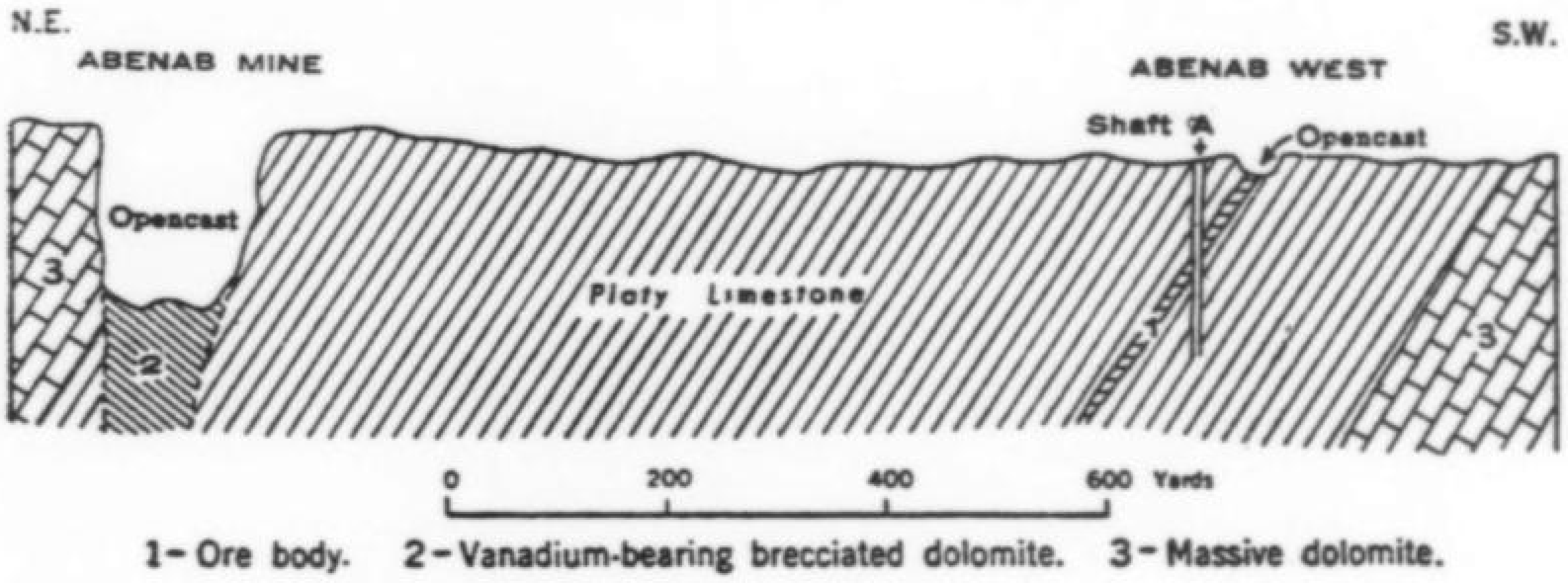


Figure 24. **Plan view of the Abenab and Abenab West mines *circa* 1943 (top). Simplified geological cross-section through the two deposits (bottom). Figure 20 is a view of the pit shown in this cross-section (Willemse *et al.*, 1944).**

four inches long (!), usually coated with a film of descloizite as much as 1/16 inch thick" (Clark, 1931). This vanadinite is brilliant red. What are reputed to be the largest vanadinite crystals in the world came from Abenab (Rickwood, 1981). Specimen 4525 in the collection of the Museum of the Council for Geoscience (housed in the Transvaal Museum, Pretoria), has crystals up to 12 cm long. These consist of hexagonal, red vanadanite that is coated with a crust of dark green descloizite. Rickwood (1981) incorrectly states that the descloizite has formed pseudomorphically after the vanadinite, but actually the crystals are (epitaxially?) coated by descloizite, with the cores still composed of zoned, red vanadinite (see Fig. 21). Calcite occurred as transparent, colorless drusy layers, with individual crystals up to 3 cm.

ABENAB WEST MINE

Prospecting operations at Abenab West began in 1924, but the deposit was not exploited until 1939 when world vanadium prices improved. The mine closed in 1958, by which time the orebody had been largely mined out.

The Abenab West mine is located 100 meters to the southwest of the Abenab mine. Although these two mines are in close proximity to one another, there are obvious differences in the styles of mineralization (Verwoerd, 1957). At Abenab, the orebody consisted of a pipe-like feature filled with brecciated country rock cemented by red claystone and crystalline calcite, descloizite and vanadinite. These minerals commonly lined cavities and vugs as beautiful, euhedral crystals. In contrast, the Abenab West mine contained a "reef" of unconsolidated ferruginous claystone that was mineralized by microscopically disseminated vanadinite and descloizite. Abenab West also contained a significant occurrence of secondary willemite that cropped out on surface.

The suite of minerals identified from the Abenab West mine during the active mining phase are listed in Table 5. Many of these occur as components of the country rock or as microscopic species. Those species that occurred as larger, collectable specimens and that are of collector interest include cerussite, anglesite, willemite, vanadinite and descloizite. The paragenetic sequence is shown in Table 6.

The mineralization of the Abenab West orebody consisted of finely disseminated minerals contained in an unconsolidated red-brown clay. This orebody was known to occur along 700 m of outcrop; the width of the economic zone varied between 0.5 and 7 m, and persisted to a depth of at least 150 m (Verwoerd, 1957). Infilled caves were a common feature of the orebody. These contained horizontally layered sequences of alternating coarse and

Figure 25. **Cerussite crystal, 2.4 cm, on mottramite, from the Abenab mine. Museum of the Council for Geoscience (Pretoria) specimen #NBL 023: Bruce Cairncross photo.**

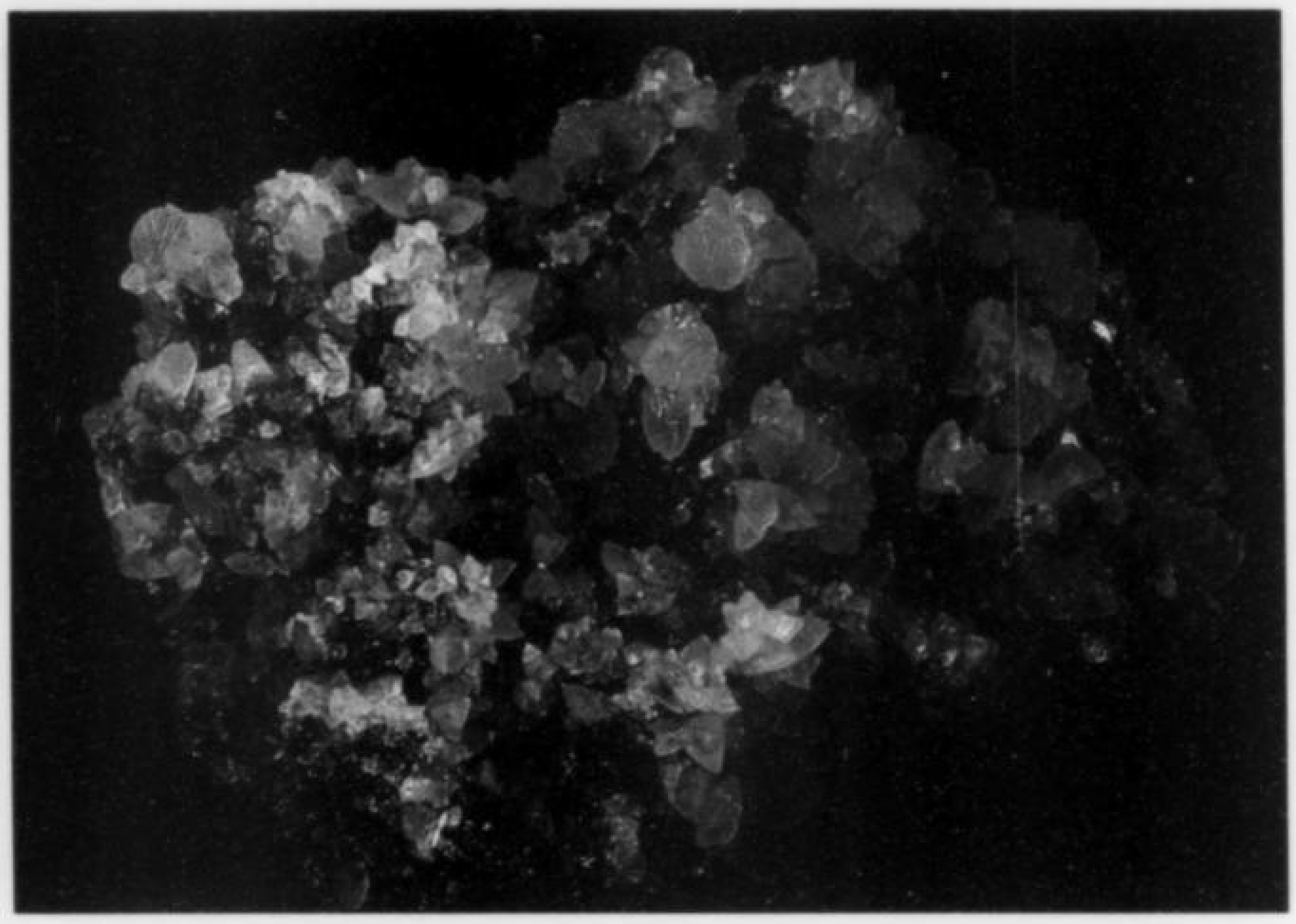


Figure 26. **Smithsonite on descloizite from Abenab mine. This large, 25-cm specimen weighs several kilograms and was collected during the late 1950's. Desmond Sacco specimen; Bruce Cairncross photo.**

Figure 27. **Euhedral vanadanite, 4 cm long and 2.5 wide, from the Abenab mine. Museum of the Council for Geoscience (Pretoria) specimen #NBR 295; Bruce Cairncross photo.**

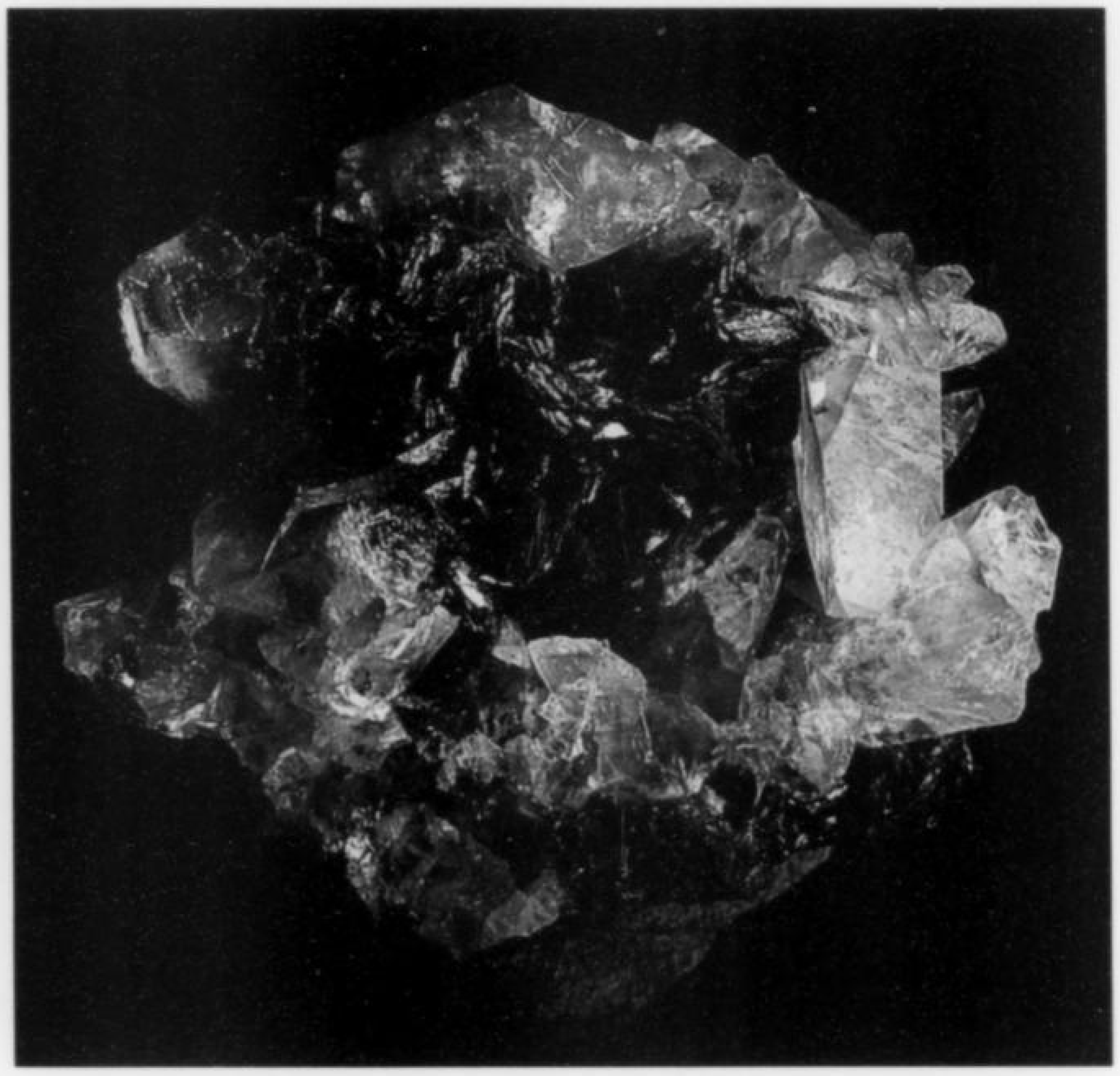


Figure 28. **An unusual group of golden lime-green descloizite surrounded by euhedral calcite crystals, 6.2 cm, from the Abenab mine. Museum of the Council for Geoscience specimen #NBL 023; Bruce Cairncross photo.**

fine sediment. This material contained quartz, zircon, epidote, magnetite, lumps of red-black goethite, and fragments of cerussite, descloizite and vanadinite. The latter two minerals crystallized *in situ* in the bedded ore. In addition to this main body of mineralization, a second zone termed the "Zinc Reef" also contained economic potential. A hard, resistant outcrop of zinc silicate extended along a strike distance of 450 m east of Abenab West. This reef consisted of hard, red rock, "riddled with veins and drusy cavities lined by radiating aggregates of colorless, acicular willemite . . ." (Verwoerd, 1957, p. 265). Noteworthy minerals found in the "Zinc Reef" include:

Anglesite $PbSO_4$

Anglesite was a rare constituent at Abenab West, but one specimen consisted of "oxidized lead ore showing a cavity exclusively occupied by anglesite in the form of transparent equidimensional prisms ranging from 0.5 mm to 5.0 mm in diameter" (Verwoerd, 1957).

Cerussite $PbCO_3$

Cerussite formed by the oxidation of galena was found as a direct replacement and as cavity linings around remnant galena crystals, and as scattered crystals and crystal aggregates. The Abenab West cerussite is colorless or black due to galena inclusions. Discrete cerussite crystals were found as nests or clusters in the orebody. These were a few millimeters in size but tabular crystals up to several centimeters were also found. Colorless cerussite crystals up to 3 mm were found supported by drusy willemite in one particular cavity in the Zinc Reef.

Descloizite $PbZn(VO_4)(OH)$

Descloizite was the main ore mineral at the Abenab West mine. Between the 150-foot and 200-foot levels an extremely rich pocket of several tons of almost pure descloizite was encountered. A variety of habits were recorded (Verwoerd, 1957); including (1) earthy dull green-yellow descloizite as concentrations in the red clay, commonly associated with porous limonite; (2) minute (0.02–0.08 mm) prismatic crystals disseminated in unconsolidated clay; and (3) megascopic, crystalline druses. These letter were found in only three zones in the orebody, with the best specimens coming from W54 on the 340-foot level (Verwoerd, 1957). Pyramidal crystals attained a few centimeters in length. Similar but smaller crystals were removed from W27 on the 340-foot level. These descloizite specimens are similar in habit to the much coarser aggregates from the old Abenab breccia body. However, the Abenab West material has smooth and lustrous crystals, without any dull, black exterior.

A fourth habit consists of descloizite pseudomorphs after vanadinite. Grass-green hexagonal prisms were found near the "Zinc Reef" at E55 on the 50-foot level. These have an average diameter of 5 mm and are grouped in sub-parallel aggregates, similar to the habit of the cherry-red vanadinite from Abenab.

Descloizite was one of the last minerals to form in the Zinc Reef and was a relatively rare constituent there. It occurs only as microscopic (<0.1 mm) crystals encrusting willemite, dolomite, calcite, malachite and country rock.

Dolomite $CaMg(CO_3)_2$

Dolomite crystals with a distinctly pearly luster have been found encrusted by calcite and descloizite.

Goethite $Fe^{3+}O(OH)$

Goethite pseudomorphs after calcite and vanadinite were also recorded.

Malachite $Cu_2(CO_3)(OH)_2$

Malachite, sometimes enclosed in cerussite, occurs as grass-green, prismatic crystals forming radiating tufts.

Vanadinite $Pb_5(VO_4)_3Cl$

Vanadinite was one of the main ore minerals at the mine, but although it occurred as euhedral, transparent yellow-brown hexagonal crystals terminated by steep pyramidal faces, these crystals were minute, the largest recorded 1.3 mm x 0.4 mm.

Willemite Zn_2SiO_4

Willemite, the main component of the Zinc Reef, occurred in several habits. Drusy willemite lined most surfaces, small veins and cavities. The crystals are colorless or white, slender and needle-like. Hexagonal prisms 0.5 to 4 mm occur singly, in diverging groups and in at least three major modes of aggradation: (1) Radial clusters composed of the needle-like crystals in close contact with one another forming continuous layers with a botryoidal outer surface. (2) Carpet-like layers of flattened, tabular crystals. (3) Stalactitic growths displaying radial internal structures.

Willemite was relatively unimportant at Abenab West, except for its presence in the Zinc Reef. Here, it was found predominantly as drusy, mat-like layers lining cavities and fracture surfaces. The crystals are colorless to opaque, white, hexagonal prisms 0.5–4.0 mm long. These occurred either densely packed together, or as

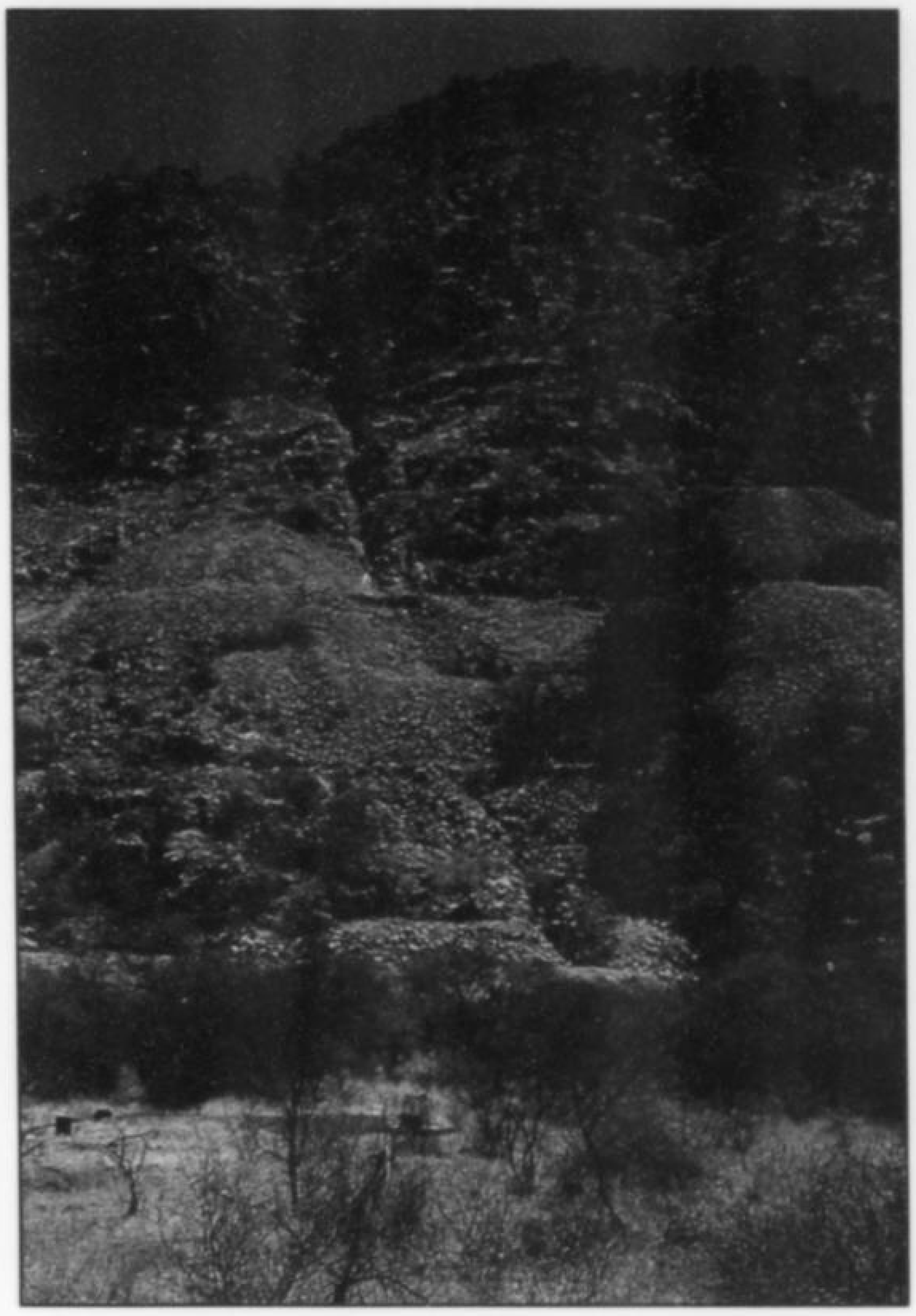


Figure 29. **The mined-out mineralization that occurred along a fracture zone at the defunct Baltika mine. Julian Misiewicz photo.**

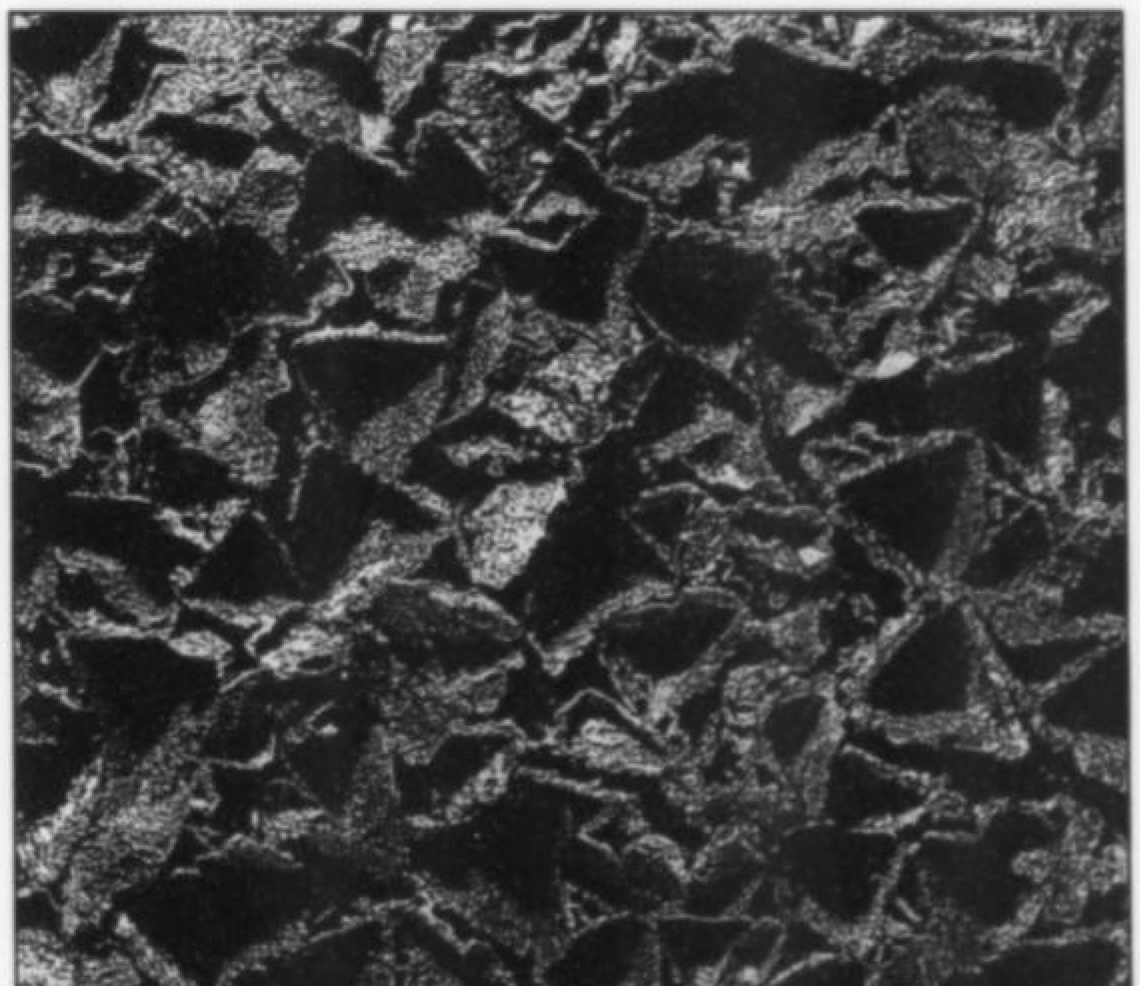


Figure 30. **Plate of green, perimorphic descloizite, 29 cm, from the Baltika mine. The descloizite crystallized on calcite crystals which were subsequently etched away, leaving the cast of descloizite. Museum of the Council for Geoscience (Pretoria) specimen #MGS 18736.**

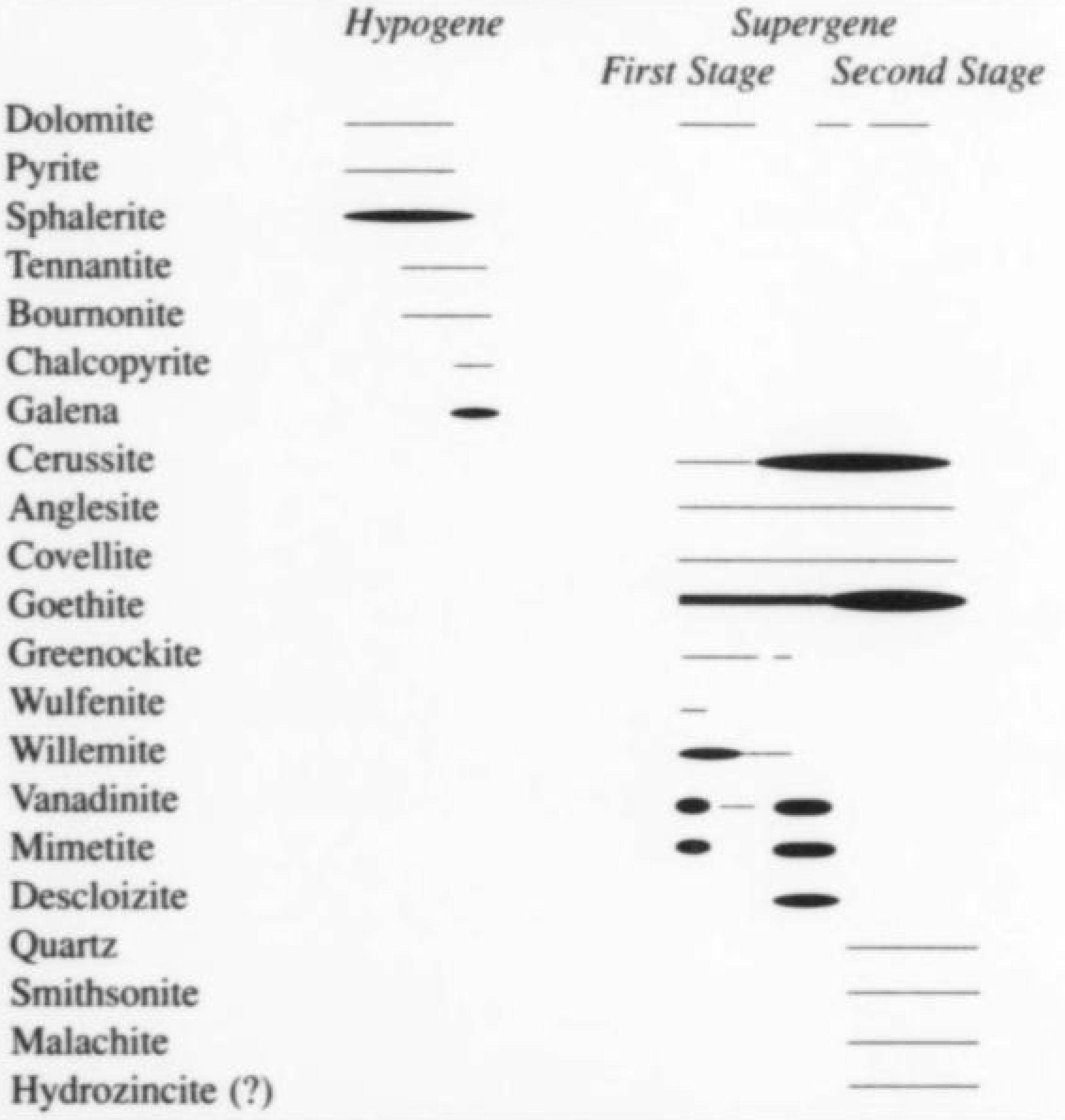
***Table 5.* Minerals reported from Abaneb West.**

Allanite*	$(Ce,Ca,Y)_2(Al,Fe^{2+}Fe^{3+})_3(SiO_4)_3(OH)$
Anatase	TiO_2
Anglesite	$PbSO_4$
Bournonite	$PbCuSbS_3$
Calcite	$CaCO_3$
Cerussite	$PbCO_3$
Covellite	CuS
Descloizite	$PbZn(VO_4)OH$
Dolomite	$CaMg(CO_3)_2$
Epidote	$Ca(Fe^{3+},Al)_3(SiO_4)_3(OH)$
Galena	PbS
Goethite	$\alpha\text{-}Fe^{3+}O(OH)$
Greenockite	CdS
Hematite	$\alpha\text{-}Fe_2O_3$
Kaolinite	$Al_2Si_2O_5(OH)_4$
Kyanite	Al_2SiO_5
Magnetite	$Fe^{2+}Fe_2^{3+}O_4$
Malachite	$Cu^{2+}(CO_3)(OH)_2$
Microcline	$KAlSi_3O_8$
Mimetite	$Pb_5(AsO_4)_3Cl$
Montmorillonite*	$(Na,Ca)_{0.3}(Al,Mg)_2Si_4O_{10}(OH)_2 \cdot nH_2O$
Muscovite*	$KAl_2(Si_3,Al)O_{10}(OH,F)_2$
Quartz	SiO_2
Rutile	TiO_2
Smithsonite	$ZnCO_3$
Sphalerite	$(Zn,Fe)S$
Tennantite	$(Cu,Ag,Fe,Zn)_{12}As_4S_{13}$
Tetrahedrite	$(Cu,Fe,Ag,Zn)_{12}Sb_4S_{13}$
Tourmaline var. schorl	$NaFe_3^{2+}Al_6(BO_3)_3Si_6O_{18}(OH)_4$
Vanadanite	$Pb_5(VO_4)Cl$
Willemite	Zn_2SiO_4
Wulfenite	$PbMoO_4$

* = minor occurrences

After Verwoerd, 1957; Emslie, 1979

***Table 6.* Paragenesis of minerals at Abenab West (after Verwoerd, 1957).**



radiating, stellate aggregates. The matrix to the willemite is usually pink dolomite. Abenab West willemite shows no fluorescence in ultraviolet light.

Wulfenite $PbMoO_4$

Vanadian wulfenite was described as 2-mm, euhedral, prismatic or tabular crystals embedded in drusy white willemite (Verwoerd, 1957). It is reportedly extremely rare.

***Table 7.* Lesser known vanadium deposits in the Otavi Mountain Land.**

Mine/Prospect	*Mineral Description*
Wolkenhaben	Cuprian descloizite crystals on sandstone matrix. Sphalerite, galena, tennantite as primary sulfides.
Auros	Drusy descloizite lining cavities in country rock. Cerussite and smithsonite on outcrop. Sphalerite, galena, tennantite, bornite, tetrahedrite, pyrite as primary sulfides.
Friesenberg	Zincian mottramite encrusting dolomite. Botryoidal masses and crystals up to 4 cm associated with calcite on red dolomite.
Uitsabpad	Cuprian descloizite encrusting dolomite breccia fragments.
Uitsab North	Dark-green to black botryoidal masses of zincian mottramite.
Lucas Post	Cuprian descloizite crystals up to 5 mm.
Rohrers	Cuprian descloizite as coatings on dolomite.
Tsumeb West Vanadium	Mottramite, cerussite. Other minerals reported include malachite, cuprite, native copper, chalcopyrite, bornite, tennantite, chalcocite, germanite and galena.
Kupferberg	Jordanite, in irregular masses up to 1 cm (Markham, 1959).
Okarundu	Vanadanite, yellow to orange "stout" hexagonal prisms up to 1 cm, enclosed in pseudomorphic shells of crystalline descloizite (Verwoerd, 1957).

After van der Westhuizen, 1984; Emslie, 1979

BALTIKA MINE

At the Baltika 215 farm vanadium mineralization occurs along the northern limb of the Otavi Valley Syncline (Korn and Martin, 1937). The Baltika deposit was discovered in 1931 and worked for 11 years (until 1942), during which time 5,820 tons of vanadium concentrate with an average grade of 9% vanadium pentoxide was produced (Söhnge, 1967). Three modes of mineralization occur: (1) Fissure fillings of vanadium ore consisting of regular bands of descloizite and calcite. These fissures sometimes widen considerably into open cavities lined with euhedral descloizite crystals. (2) Cemented solution-collapse breccias containing descloizite, calcite and aragonite. (3) Karst sinkholes ("sand-sack" ore), up to 3 m deep and filled with red-brown dolomitized eolian sand, clay and vanadium ore. Minor amounts of smithsonite and sphalerite accompany the vanadium ores (Wartha and Schreuder, 1992). The descloizite occurred as dark green to olive-green botryoidal masses and small crystals on red sandstone matrix (van der Westhuizen, 1984).

An unusual specimen in the collection of the Museum of the Council for Geoscience, Pretoria, consists of a plate-like cast of green descloizite. The descloizite clearly crystallized as a thin layer on top of calcite crystals, the latter now leached away leaving an epimorphic cast containing euhedral cavities left by the calcite.

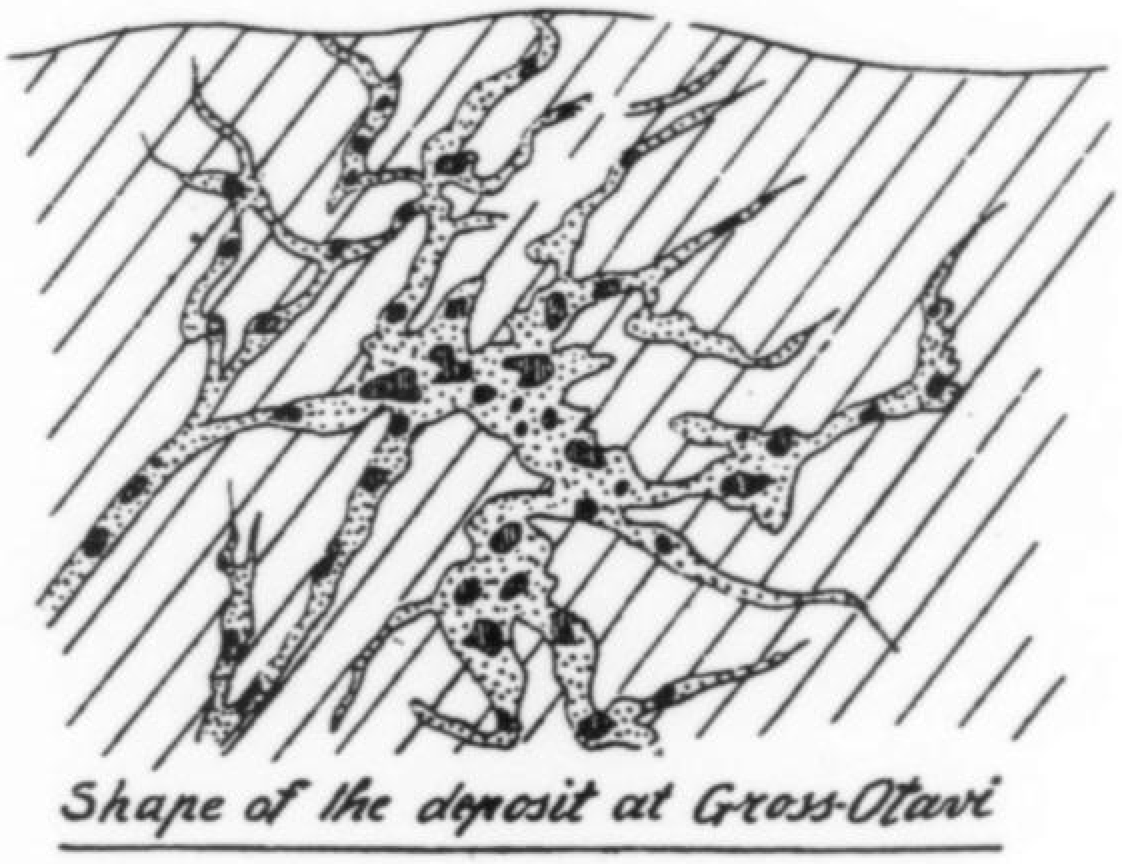


Figure 31. **A 1904 plan view of the Gross Otavi mine (top), and a geological cross-section through the orebody showing its complex, dendritic fracture pattern (Kunz, 1904).**

BOBOS AREA

The Alt Bobos mine is situated on the Uris 481 farm about 15 km west of Tsumeb. It was worked from 1914 until 1918 by the Otavi Exploration Syndicate. The operation consisted of 3 open cast pits and several smaller excavations. The deposit was mined primarily for aggregates of copper sulfides that occurred in calcitic rock (Schneider and Seeger, 1992), together with a 2-km-long stratabound zone of malachite and chalcocite.

In 1919, zincian mottramite was discovered nearby at Karavatu, which was being mined for copper at the time. The Karavatu deposit consisted of descloizite-mottramite mineralization located above hypogene galena and chalcocite (Misiewicz, 1988). The zincian mottramite is sometimes coated by transparent, euhedral calcite crystals (van der Westhuizen, 1984).

Exploration then revealed eluvial vanadium ore at Töenessen in 1920, and the Uris deposit, a mottramite-vanadate-tennantite calcite-dolomite breccia plug 27 km west of Tsumeb, was also discovered around 1920. Collectively, all of the above mines are referred to as the Bobos mining area. These deposits are of the "sand-sack" karst variety, with some depressions up to 25 m deep. These contain dolomitized eolian sand, vanadium-rich clay, wall-rock fragments, and iron and copper concretions (Schneiderhöhn, 1921). Cuprian descloizite was the main ore mineral.

The Uris mine consisted of a pipe-shaped deposit measuring 20 m on surface and pinching out at a depth of 75 m, ringed by high-grade eluvial ore. Zincian mottramite (Lamming, 1969) occurs here, associated with botryoidal, drusy mats of pale green descloizite. The mottramite also forms drusy mats, with individual crystals ranging from microscopic to 4 mm (van der Westhuizen, 1984). Recent detailed mapping and exploration drilling has revealed a steeply plunging breccia pipe below the old mine workings. Here, beneath the supergene vanadate zone, ore minerals consist of tennantite, chalcocite, chalcopyrite, pyrite, covellite, Cu-Pb arsenates, sphalerite and native copper (King, 1994). The Uris pipe is considered to be a Tsumeb-type deposit. The Karavatu and Uris mines operated between 1919–1924, 1931–1932 and 1928–1943 during which time 5,234 tons of 11.87% V_2O_5 were produced.

FINSTERBERGEN PROSPECT

This copper-lead-zinc prospect approximately 80 km west of Tsumeb was discovered from a surface geochemical anomaly (Ferreira and Zwanziger, 1971). Veins and scattered patches of surface mineralization contain malachite, plancheite, chrysocolla, cuprite, hematite, vanadinite and smithsonite, together with Cu-Pb-Zn sulfides.

GROSS OTAVI MINE

The Gross Otavi mine was mined intermittently from 1909 until 1941. During 1939 to 1941, 70 tons of 17% vanadium pentoxide concentrate were mined (Söhnge, 1967). The lead-copper-vanadium ores occurred in calcitized and brecciated zones in dolomite and sericitic shale.

The outcrop at Gross Otavi contained impressive copper mineralization. Oxidized copper ores occurred in "sand-sack" karst holes that were 20–70 m wide and extended 150 m along strike. One of these karst holes contained a solid 24 m^3 block of chalcocite imbedded in karstic fill 4 m below surface (Schneiderhöhn, 1929). The descloizite from Gross Otavi was characteristically "a pistachio-green mineral, probably . . . a cupriferous descloizite, which is often found in fern-like and arborescent aggregates" (Schwellnus, 1945). Dark green mottramite coats dolomite and calcite and crystals, and clusters of mottramite occur embedded in calcite (van der Westhuizen, 1984).

GUCHAB-RODGERBERG AREA

The South West Africa Company, via one of their employees, Mathew Rogers, investigated various copper deposits in the Guchab mining area in 1893 (Schneider and Seeger, 1992). Seven years later, in 1900, several exploration adits were excavated by Christopher James for the OMEG. However, nothing further happened until 1908 when the Grootfontein railway line was completed and the Guchab mine was brought into production, yielding 1,800 tons of ore at 33% copper. Sporadic development continued, but by 1911 production was down to 646 tons. Prospecting in the vicinity revealed another copper orebody to the east, on the Rodgerberg (named after Mathew Rogers), but development only began there in 1924.

The mineralized zone in the Guchab-Rodgerberg area consists of shallow orebodies pinching out at about 50 m below surface. Copper mineralization is associated with either calcitization and/or silicification. The minerals found include malachite, plancheite, chalcocite and dioptase.

A willemite specimen, reported to have come from Guchab in 1924 consists of "stout, hexagonal prisms 2.5 to 5 mm across with botryoidal malachite on massive chalcosine. The crystals are sulfur yellow on the exterior, and somewhat resemble the crystals of mimetite from this locality; but in the interior the material is white and gray in patches" (Spencer, 1927). There is, however, a strong possibility that this specimen came from the adjacent Rodgerberg mine and not Guchab.

Figure 32. **The Guchab mine as seen from the road between Kombat and Grootfontein. The red bougainvillea plants are growing at the site of the old buildings. Roger Dixon photo.**

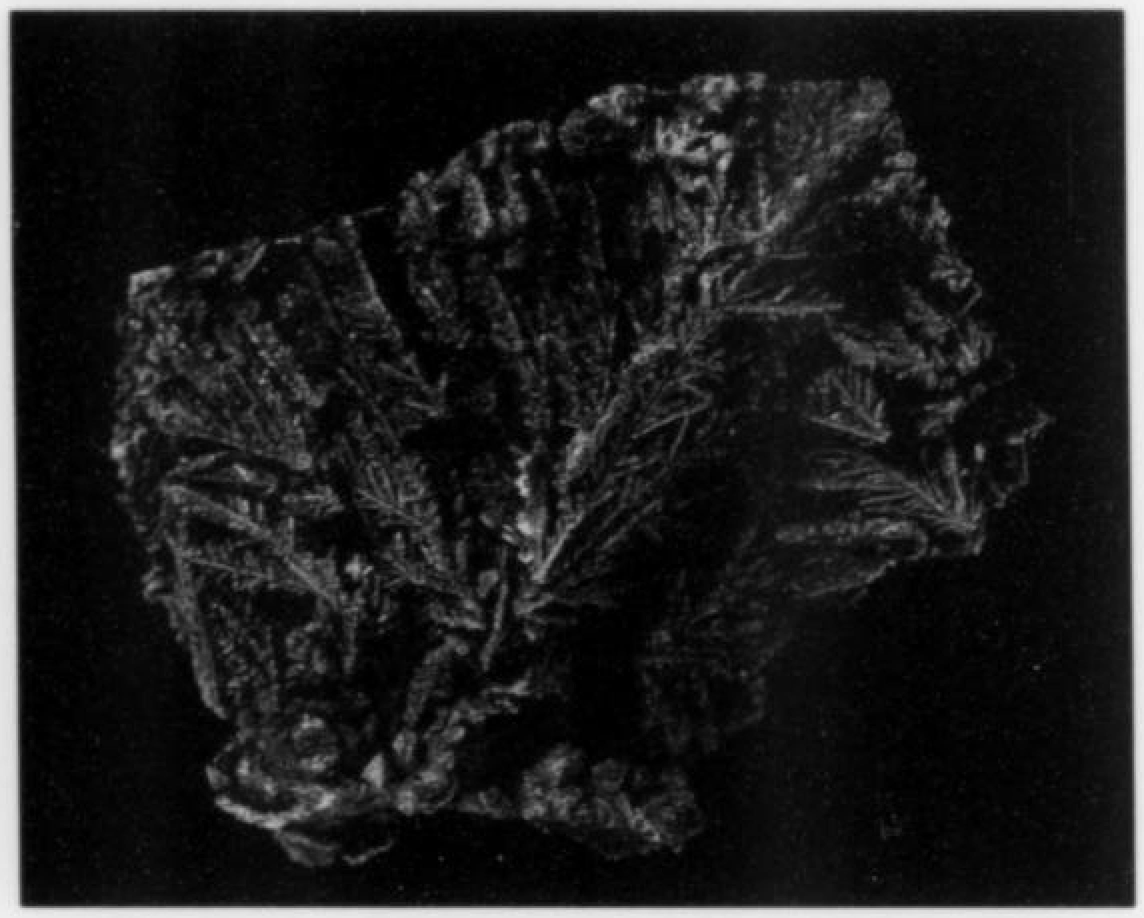


Figure 33. **Dendritic mottramite, 6.2 cm, from the Gross Otavi mine. Museum of the Council for Geoscience (Pretoria) specimen #MGS 28595; Bruce Cairncross photo.**

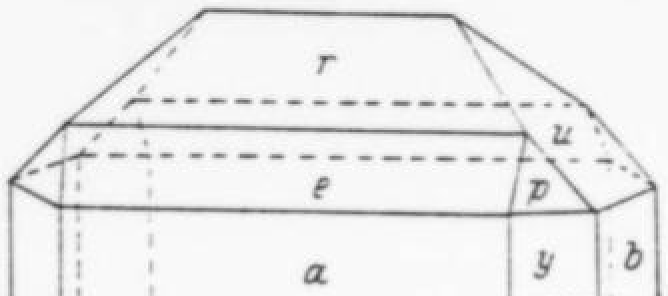


Figure 34. **Crystal drawing of descloizite from the Uitsab mine (Diefenbach, 1930).**

Figure 35. **Wulfenite crystal group (field of view is 2 cm) from the Khusib mine. Demetrius Pohl collection; Bruce Cairncross photo.**

The Rodgerberg mine is located about a kilometer east of the Guchab mine, and was productive from 1919 until 1931. It is important to note that it was this deposit that made the Otavi Mountain Land and Guchab famous for the highly desired clusters of green dioptase (referred to in mineralogy text books, for example, Dana, 1966) found in the upper part of the orebody (Söhnge, 1967) There is evidence in support of this from dioptase mineralization prevalent on the dumps at the mine (Tsumeb Corporation Limited, 1978). The ore pinched out at a depth of 27 m below the original adit, and the mine was finally closed in 1931.

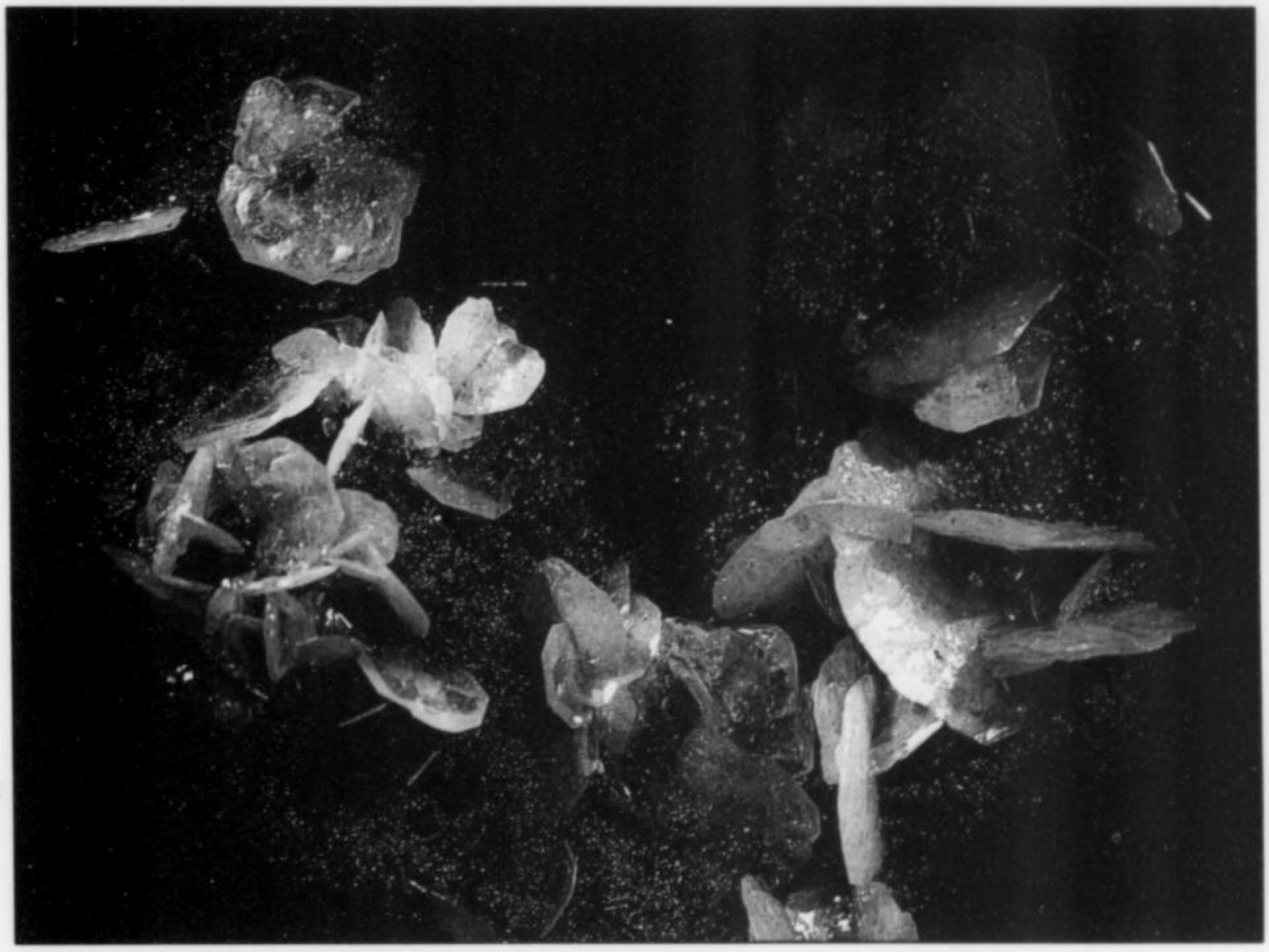


Figure 36. **Wulfenite crystals to 1 cm, on cuprian descloizite, from Guchab. Smithsonian specimen.**

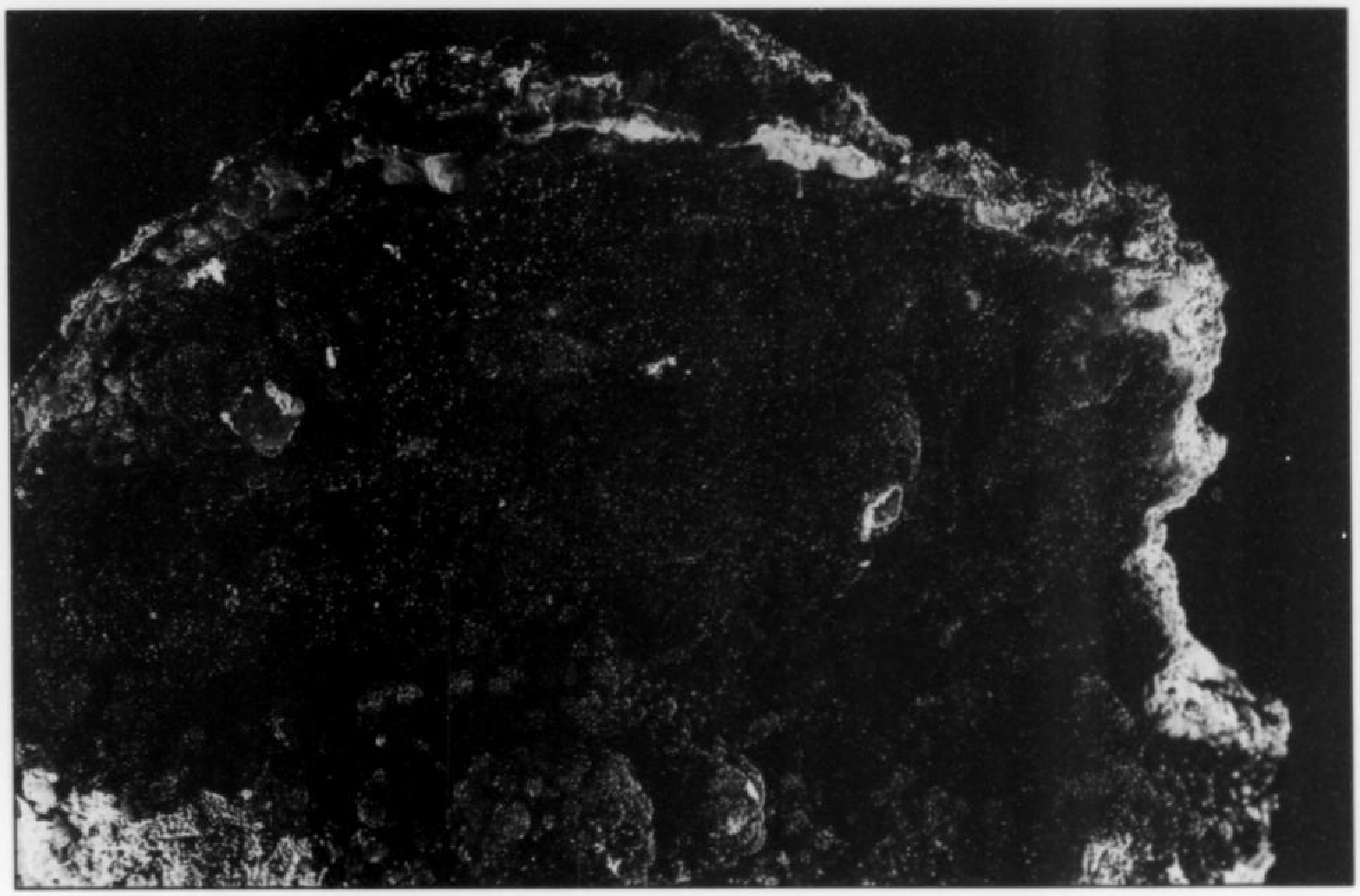


Figure 37. **Azurite from the Tschudi mine, 18 cm. Only a handful of azurite specimens were collected from Tschudi, this one being one of the largest and most aesthetic. Desmond Sacco collection; Bruce Cairncross photo.**

HARASIB PROSPECTS

Approximately a dozen mineralized deposits are known from the central Otavi Mountain Land. Most of these deposits are found not only in the Harasib-Olifantsfontein syncline but also in the Toggenburg syncline to the south. These are Berg Aukas-type deposits, with simple Zn-Pb mineralization, associated with descloizite (Weilers, 1962). Ore minerals include galena, sphalerite, descloizite, vanadinite and pyromorphite. Descloizite from the Harasib I mine consists of dark green to black cuprian descloizite (van der Westhuizen, 1984) coating red sandstone breccia fragments. Opencast mining of the Harasib I, II and III deposits has produced 800 tons of vanadium concentrate (Wartha and Schreuder, 1992). Other deposits in the area include the Harasib Sinkhole (Emslie, 1979), Uitsab North and Uitsab East (Vickers, 1975a and 1975b), and the Pickaxe, Driehoek, Border and Tiger Tunnel mines (Ypma, 1978).

KHUSIB MINE

With the closure of the Tsumeb mine in June 1996, Gold Fields Namibia began short-term development of a small, high-grade copper-silver deposit at Khusib (Anonymous, 1996). The objective of this operation is to partially compensate for the expected loss of ore production from Tsumeb. Although only recently opened, Khusib has already produced a handful of interesting specimens. These include euhedral tennantite crystals up to 1 cm, associated with small, gray-white dolomite crystals. These would be indistinguishable from Tsumeb specimens, were it not for a second, associated species, enargite. Unlike Tsumeb enargite, which tends to be highly corroded and altered, these crystals are very lustrous and bright silver. The largest enargite crystal so far obtained is 8 mm. Finely crystalline, granular pyrite partially coats some of the specimens. A few specimens of wulfenite (X-ray diffraction identified) have also been found. These are pale yellow and consist of flattened sheaf-like aggregates on massive tennantite matrix.

NOSIB MINE

The Nosib mine is located close to the Tsumeb-Kombat gravel road. The deposit was discovered in 1915 and worked during German colonial times by the Otavi Exploration Syndicate Ltd., a SWACO subsidiary, until the mine was closed in 1920, when it was at a depth of 120 m (Söhnge, 1967). The vanadium-bearing ore was located along the contact between the Nosib and Otavi Groups. Below this contact, disseminated galena, chalcocite, descloizite and sphalerite occurred in a sheared breccia. Four small orebodies contain high-grade secondary copper carbonates, lead oxides and lead-copper vanadates in a highly ferruginous mud. On the surface, mineralization is characterized by the presence of malachite, azurite and mottramite. Galena, cerussite and anglesite are rare constituents; it is believed that the main lead minerals are plumboferrite and massicot (Vickers, 1975c).

RIETFONTEIN MINE

Diamond drilling revealed an orebody composed of vanadate ore coating dolomite boulders that occur in a local depression east of Guchab. Some of this descloizite was seen to be coating fossilized mammalian bone fragments, suggesting late stage remobilization (Schwellnus, 1945). Lead and zinc mineralization is accessory to the vanadium ore. Zincian mottramite occurs as small, dark brown to black crystals on limonitic matrix (van der Westhuizen, 1984).

TSCHUDI MINE

The Tschudi deposit, discovered in 1968, is situated about 20 km west of Tsumeb. Copper-silver mineralization occurs along a 3-km strike zone at the contact between the Otavi and Mulden Group rocks (King, 1994). Diamond drilling has revealed further mineralization consisting of disseminated stratiform copper at the base of the Mulden sandstone. The deposit is tabular and dips 30° to the northwest (Misiewicz, 1988). By 1980 underground development had begun; further feasibility studies are pending. The deposit is oxidized to a depth of 80 m, and this oxide zone contains malachite, cuprite, azurite and lesser amounts of chalcocite and covellite. Additional copper minerals in the sulfide zone are bornite and chalcopyrite. Several display-quality azurite specimens were collected at Tschudi during the early 1990's. These consist of a myriad of platelets of intense blue azurite crystals forming flat mat-like aggregates and stalactitic protruberences on matrix.

UITSAB MINE

Vanadate ore was mined between 1920 and 1940 from an opencast pit at Uitsab, 25 km west of Grootfontein. Vanadium-copper-lead mineralization occurs in a shear zone in dolomite (Wartha and Schreuder, 1992). The main ore minerals were descloizite, vanadinite and pyromorphite, the former two minerals occurring in "large cavities lined with beautiful crystals" (Schwellnus, 1945). In the northern section of the pit, galena, cerussite and pyromorphite occurred associated with a breccia zone (Willemse *et al.*, 1944). The descloizite mined at Uitsab varies from olive-green to dark green and black. Primary sulfide minerals are galena and tennantite (van der Westhuizen, 1984).

SUMMARY

There is a commonality to the style of mineralization at the various vanadium prospects in the Otavi Mountain Land, and descloizite is a species found at many of the prospects. One suspects that, prior to the late 1950's, some (perhaps a great deal) of descloizite specimens simply labeled "Berg Aukas" may have come from other mines such as Abenab, Abenab West, Baltika and Gross Otavi. Specimens labeled "Grootfontein" are generally assumed to originate from Berg Aukas, as *no occurrence ever existed at Grootfontein per se*. For these older specimens, there is no easy way to determine their exact locality. The matrix of most pieces consists of similar red, oxidized claystone or sandstone, or gray dolomite, and there are usually no diagnostic, associated mineral species. Similarly, willemite has been collected from the dump at Berg Aukas and most willemite specimens bear this label, but undoubtedly other willemite specimens came from Abenab West as well. During the 1970's, Berg Aukas was the only vanadium mine operating, so most of the specimens entering the collector market during this period must have come specifically from Berg Aukas. Details of some of the other smaller or lesser known deposits are listed in Table 7.

The prospect of the older mines such as Berg Aukas and Abenab being re-opened in the foreseeable future appears to be uncertain. However, geological exploration is continuing in the Otavi Mountain Land so there is always the potential of new prospects being brought on-line, such as the newly opened Khusib mine. Perhaps a new Berg Aukas or Tsumeb still waits to be discovered!

COLLECTING STATUS

Most of the mines and prospects described above belong to Gold Fields Namibia. Active geological exploration is taking place in the region, and several old prospects are being re-examined to ascertain their economic potential. For this reason, trespassing and mineral collecting is strictly prohibited at all of these localities, and the Company does not readily entertain requests for collecting to take place. The author does not have any specimens for trade or sale.

ACKNOWLEDGMENTS

I would like to thank Desmond Sacco, Karl Messner and Demetrius Pohl for allowing some of their specimens to be photographed for this article. Thanks in this regard are also due to Patrick Bender, Curator of the Museum of the Council for Geoscience, Pretoria, who helped locate many old Otavi Mountain Land specimens in the Museum's collection. Wendell Wilson kindly provided photos of specimens from the Gene Schlepp, Frank Melanson and U.S. National Museum collections. Julian Misiewicz and Roger Dixon provided scenic slides from the Otavi Mountain Land. My thanks also to Clive King and Julian Misiewicz for reviewing the manuscript and for their constructive criticism which helped to improve the text.

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(continued on p. 157)

What's New

in Minerals

Franklin, New Jersey, Show 1996

by Joe Polityka

[September 27–29]

Finally, the much-anticipated weekend had arrived! The Franklin, New Jersey, show was about to commence and I, hopefully, was going to be a part of it. The Weather Lady had predicted rain for portions of Saturday and Sunday and I was determined to prove her wrong! I pulled out of my driveway at 6:00 a.m. with Johnny Horton's "North to Alaska" blasting on my tape deck. My daughter Renee got tired of the "Oldies" and soon we were listening to "Macarena." After a short discussion, we reached a compromise: one "Oldie" for me and one song for her. So it went for an hour and a half: "Walk—Don't Run" . . . "Macarena"; "Runaround Sue" . . . "Macarena"; "Respect" . . . "Macarena." When we got to Franklin, I was certain my car was doing a line dance.

We arrived at 7:15 a.m. on Saturday, and over 40 tailgaters had already set up their tables. No more trying to beat this group! In the future I'll have to be content with placing within the top 50 early arrivals! In actuality, many of the "early birds" spent Friday night in the Franklin area, which gave them the jump on other tailgaters. Some looked like they had slept in the parking lot.

By 8:30 about 120 tailgaters had set up at the athletic field adjacent to the schoolhouse. I met folks from New England, the Mid-Atlantic states and Georgia, and renewed friendships with a lot of old buddies. Several groups chartered buses in Long Island and Springfield, Massachusetts, just so they could enjoy the Franklin experience. There was a lot of minerals to see so I hurried from table to table trying to stay one step ahead of mineral dealers from the main show, while I kept one eye on the rain clouds.

Rocko (Margaretville, New York) had a variety of choice, singular specimens including pale purple **calcite** twins to 3 cm on drusy calcite matrix from the Zinc Corporation of America mine, Edwards, New York. Each specimen has a single calcite perched attractively on the matrix. **Aegerine** on feldspar with smoky quartz from Mt. Malosa, Malawi, was offered at attractive prices. They also had a flat of old-time English classics in small cabinet sizes. **Mimetite** from Roughten Gill, Cumbria, and **barite** from Frizington, Cumbria, caught my eye.

Robert Rybnicky (Edison, New Jersey), whose business card states that he is a "mineral collector," had an attractive large cabinet specimen of botryoidal **pyrite/chalcopyrite** from Bound Brook, New Jersey. The sulfides are associated with drusy calcite and sit like golden metallic gum drops on the matrix. The specimen reminds me of the antique blister-copper specimens from England which are quite attractive after cleaning. The Hauck brothers have

Figure 1. **Franklin Show, 1996 (tailgating area).**

some specimens of this material for sale at the mine gift shop in Ogdensburg, New Jersey.

Zhou Zhou Minerals (140-10 29 Avenue, Flushing, New York 11354) had a large selection of minerals from China. **Beryl**, **scheelite**, **cassiterite**, **fluorite** and **calcite** were offered in all sizes and levels of quality.

John Betts (215 West 98th St., Apt. 2F, New York, NY 10025), an energetic young dealer, had something new: single **quartz** crystals to 3 cm with inclusions of **rutile** (?) from Rhinebeck, New York. About 1:00 p.m. a young woman showed up and caused quite a stir: she had traveled by bus from New York City, and had taken a cab from Sparta, New Jersey, so she could sell her **vivianite** crystals on matrix from the Huanuni mine, Oruro, Bolivia. There she was, sitting on her blanket, encircled by eager, wide-eyed, perspiration-doused collectors who knew this was their chance to get a specimen at a reasonable price. Most crystals are in the 3-cm range, on miniature to cabinet-size matrix. Several specimens have clean and transparent single crystals to 4 cm. When it comes to minerals, you can never predict "where, what or when." Later in the day, my daughter and I drove her to the bus station. She told us her name is Carola and that she is a student from Bolivia studying in New York.

At the indoor portion of the show 19 mineral, fossil, gem and jewelry dealers were set up. *Mohawk Enterprises* (Johnstown, New York) had "Herkimer diamond" **quartz** scepters from Fall Ridge, Little Falls, New York. The crystals, up to 5 cm in length, are found in a weathered dolostone. Several doubly terminated crystals were found with skeletal terminations. Also found were some elongated, bent crystals and one Japan-law twin. Quartz scepters have also been found at the Bench Mark quarry, St. Johnsville, New York. These crystals are similar to those found at Fall Ridge but are rarely double terminated or skeletal. The specimens are found in a hard dolostone matrix.

Val "Sugar Bear" Collins and his son Jeff also had **sphalerite** crystals on white, drusy dolomite crystals from Walworth, New York. The crystals are translucent, reddish brown singles and twins which range from 8 mm to 1 cm in size and sit isolated and in groups on a gray rock matrix.

The Rocksmiths had a nice selection of minerals from the Soviet Union, including ruby **corundum** from Khit Ostrov (island), Northern Karelia. The crystals are found in a white, massive quartz matrix and reach about 2 cm in size. I have, in the past, seen several specimens for sale which were incorrectly labeled Khitrov (sic) Island, obviously a contraction of Khit Ostrov. Refer to the *Mineralogical Record*, vol. 26, no. 6, if you need to clear up locality data on your specimens from Russia.

Willis' Earth Treasures had recently received a lot of about 200 specimens of **azurite**, **malachite**, **smithsonite**, **cerussite** and **calcite** from Tsumeb, Namibia. The entire lot was acquired from Demetrius Pohl, who currently lives in Africa. Most specimens are in miniature to small cabinet sizes, with average-size crystals for each species. They were, in my opinion, reasonable priced.

Coisas Preciosas (Newark, Delaware) had a large selection of **pegmatite** species from Brazil, especially Brumado and the Golconda mine.

The Mineral Cabinet (New Providence, New Jersey) had a large selection of Millington, New Jersey, **zeolites** and associate minerals. Bill Butkowski received permission from the quarry management to collect, or at least inspect, the quarry on a weekly basis. This is good news for local collectors. One important point to keep in mind, though, is that mineralization is found in one zone at the quarry and, as is often the case, the operators try to avoid this zone because they are in the crushed rock business, not the mineral business. Therefore, specimens only appear when they have to cut through the mineralized zone to get at the good rock. Zeolites from Millington generally are found in small pockets no bigger than grapefruit size; as a result, most specimens will be in the miniature to small cabinet sizes. Also, the small size of the pockets makes it difficult to find clean, undamaged specimens. Bill had **pectolite** in hemispherical aggregates of acicular crystals having a pleasing pale pink color; **prehnite**, botryoidal, pale green, in hemispheres up to 1 cm; and **natrolite** sprays of white acicular crystals up to 2 cm, some in radiating groups. All specimens are miniature to small cabinet size. I was told that the quarry will operate for about another 15 years. Then, the property will be graded and divided into expensive homesites. Therefore, you still have time to see Bill at his next show.

Howard Minerals (Brooklyn, New York) had several nice cabinet specimens of **sulfur** crystals, to 2 cm, on matrix from Agrigento, Sicily. They purchased these specimens in Italy in 1996.

P&H Fluorescent Minerals (37F Deerwood Manor, Norwalk, CT 06851) had an extensive inventory of **fluorescent mineral species** from worldwide locations. They were set up in the fluorescent exhibit room, with overhead, longwave and shortwave ultraviolet lighting. Their display, combined with the rainbow of colors from the other exhibits, created quite a spectacle.

At the nearby Sterling mine in Ogdensburg the Hauck brothers had just completed a new section of tunnel which will shortly be added to the mine tour. The tunnel, at several points, cuts through willemite, zincite and franklinite veins and is an impressive sight. The new tunnel slopes down to a lower level and will have a "rainbow room" of fluorescent minerals large enough to impress even the most jaded collector.

In spite of its popularity, Franklin has maintained its rural character. The town is only 65 miles from New York City but, because it is out of reasonable commuting range of the "Big Apple," it has been spared the development of closer-in suburbs. Farms, cows and roadside markets dominate the landscape, not people.

As the day wore on, gray skies persisted (this kept the temperature down). Gone were the soaring hawks from last year, replaced by one lonely turkey vulture who, in spite of his ungainly look, had soaring down pat.

The sun popped out every now and then but eventually the rains came. By 5:00 p.m. everyone in the swap area was running for cover. Sharp gusts of wind blew tarps in all directions, scattered newspapers and blew hats off of heads. Sheets of rain soaked books, magazines and cotton-filled mineral boxes, punishing the stragglers who did not heed the cold front which had passed through minutes before. In spite of the rain, I was happy, as usual. Now it was time to dance the "Macarena" and head over to the annual Franklin Mineral Club banquet and auction—master of ceremonies: Vandall King. Lots of good, clean fun and bland food. Unfortunately, I had to leave before the auction and the lecture (Graphite from Franklin and beyond!), but as I drove back to Staten Island, the rain finally stopped. Maybe they're still partying in Franklin; in any case, if you have a chance to visit this great little show next year, don't pass it up.

Munich Show 1996

by Michael P. Cooper

[November 1–3]

My feet hurt! Walking the Munich show for four days has taken its toll on feet, voice, and wallet: so much to see, so many people to talk to, so many minerals I want!

Munich is more than just a buyer's paradise each year; it's also a temporary museum. This year's special theme was "Dukes, Kings, and Pebbles—Minerals as Symbols of Power." The fascinating exhibits covered everything from common beach pebbles to very uncommon wire silver, huge nuggets of gold and platinum, emeralds on matrix, and exquisite lapidary work. Among numerous art works hung on the walls were some remarkable paintings of pebbles and mineral specimens by Susan Robinson (wife of *Mineralogical Record* author, associate editor and director George Robinson). The "inner sanctum" of the show featured, among other priceless things, mineral specimens from the Hermitage Museum in St. Petersburg, and rings and lapidary work from the Vatican Collections at the University of Rome (including some exquisite *Chrysomelid* beetles rendered in semi-precious stones—as if the real things aren't amazing enough).

The show exhibits included several of the most famous silver specimens of all times, such as the circular Kongsberg wire given to Louis XV of France by King Christian VII of Denmark and Norway in 1770 (now in the Natural History Museum, Paris), the huge 3.5-cm twin from the "God's Help in Distress" mine at Kongsberg (in the Norwegian Mining Museum), the "Silver Cross" from Widersberg near Schneeberg, Saxony, and the sole surviving chunk from the famous "Silver Table" discovered in the St. Georg mine at Schneeberg in 1477 (preserved today in the State Museum of Mineralogy and Geology in Dresden). Also in the core display was the best pebble in the show: a lustrous, rounded gold nugget weighing over a pound (507 g) from Peru, which was involved in a famous case of attempted bribery in 1806 (exhibited by the Natural History Museum, Paris).

Moving on from the special exhibits, the visitor's boggled eyes were treated to the stand of *Superb Minerals* (Nasik, India). Living up to the name, proprietor K. C. Pandey offered some of the finest Indian minerals at the show, including large **powellite** crystals, excellent, recently collected, deep emerald-green **apophyllite** and optical-quality **calcite** from Jalgaon; and also some beautiful pale custard-yellow fans of **stellerite** from Aurangabad. Prices for the best pieces were in the "If-you-have-to-ask-you-can't-afford-it" category, a good green apophyllite demanding $3,500.

In Hall 2, where most of the world's top mineral dealers were concentrated, it was hard to know where to start. Consequently I just dived in, visiting stands in no particular order.

Mine 21 at Dzhezkazgan, Kazakhstan, has recently yielded still more superb **bornite** in rather rough but very large (to 5 cm!), iridescent crystals scattered on quartz matrix. At least ten high-quality pieces were found, good ones bringing $1,000 to $2,000; smaller examples were more reasonable but still not exactly cheap. *KARP* (P.O. Box 51, CZ-272 80 Kladno, Bulharská 2210, Czech Republic) and *Joachim Karl* (Gutzkowstr. 77, D-60594 Frankfurt/Main, Germany) had a number of fine pieces.

New and different pockets of **galena** continued to be found at Dal'negorsk, Russia, including skeletal cubes and cuboctahedra to 1 cm (unusual habits for the locality), as single crystals on calcite and as sharp and clean spinel-law twins to 10 cm. Some of these are on matrix with bright black **sphalerite** and lustrous **chalcopyrite**, better than any I have seen before. The mineralogical cooperative *KARP* had the best pieces, but several other dealers including *Min-Geo* (Pardubická 734, CZ-50002 Hradec Králové, Czech Republic) and *András Lelkes* (Hercegprímás v. 11, H-1051 Budapest, Hungary) had fine examples too. András also had the best of a small lot of water-clear **fluorite** from Dal'negorsk, sharp and flawless octahedra(!) to 2 cm on edge, scattered and intergrown on matrix. The best small cabinet pieces sold out quickly at around $250, although larger cabinet specimens were still available from *KARP* and others. András also had a second lot of Dal'negorsk **fluorite** consisting of loose clusters and matrix pieces having cubic crystals with well-developed trisoctahedron and dodecahedron modifications. I also saw my first butterfly twin of Dal'negorsk **calcite**, a good-quality "floater." (They call them *schwimmern*, "swimmers," in Germany.) It is about 9 cm across. Coincidentally, there was a similar twin available from Dashkezan, Azerbaijan, measuring 6 cm across and partially imbedded in sprays of olive-green **epidote**. Simon Harrison found this one somewhere at the show and let me have a look at it over a lunchtime beer. Other **calcite** from Dal'negorsk included lustrous, 5 to 7 cm scalenohedra on matrix, perhaps the nicest one appearing at the *Min-Geo* stand. (It ended up with Jean-François Astier of Grenoble.)

Calcite and **stellerite** from the Sarbayskiy mine at Rudnyy, Kustanay, Russia, were still everywhere in fine specimens, along with stilbite and gmelenite at the *KARP* stand.

Andreas Weerth's (Hochfeldstr. 37, D-83684 Tegernsee, Germany) colorful and spectacular display included a showpiece **elbaite** from a new find at Paprock, Nuristan, Afghanistan. This fine specimen, discovered along with a few others about two weeks before the show, consists of white albite studded with short, pink prisms about 3 cm across that have green terminations (reminiscent of the old "blue cap" tourmalines from California). Associated species include smoky quartz and small, brown crystals of what may be eosphorite. My favorite piece at Weerth's stand, however, was a large (9 cm) doubly terminated, translucent, pale brown **apatite** prism with two smaller attached crystals from the aquamarine mine at Nagar in the Hunza Valley, Pakistan. Andreas also had one of the most aesthetic groups of Chinese **fluorite** and **calcite** from the Xuanghualin mine at Chenzou in Hunan Province. These specimens were widespread at the show, two of the most abundant sources being *Frédéric Escaut* (route des Huitres, F-17550 Dolus, France) and *Budil & Budil* (Sendlingerstr. 24, D-80331 Munich, Germany). Two types are available: groups of frosty green octahedra up to 5 cm on edge, and lustrous, glassy, flawless, intergrown cubes having a distinctive olive-green color, with or without lenticular calcite crystals to 5 cm. A 15-cm specimen with 3.5-cm crystals could be had for about $450. The calcite was also available in groups lacking associated fluorite. The good ones are quite attractive and sculptural, with a high luster and dull gray color; a nice 12-cm piece could be purchased for around $120. Andreas's prime specimen consists of two calcite "ears" perched on a mound of fluorite, but it was pushed into second place by Frédéric Escaut's elongated group of calcite crystals tipped with a green fluorite cube. There was also an interesting fluorite at the stand of *François Lietard* (Au Bourg, F-42800 Tartaras, France), a pretty, bright green octahedron about 2 cm across, perched neatly below a superb aquamarine crystal on a mica-encrusted matrix, from Nagar.

The green color of the Chinese fluorites may not be very stable. During the course of the show I observed some bright olive-green examples slowly change to a paler, dirtier gray-green, probably in response to intense display lighting. Incidentally, the same locality (the Xuanghualin or Hsianghualin mine) is the type locality for another interesting fluoride, **hsianghualite** ($Ca_3Li_2Be_3(SiO_4)_3F_2$). Frédéric Escaut had a few specimens of this very rare mineral in crystals to 1.5 cm (much bigger than those originally described), and also some white **scheelite** on calcite from the same occurrence.

Deserving of special mention is the large lot of new **sphalerite** from Shuikoushan, Hunan, China, that Frédéric Escaut acquired recently. The showy crystals are a deep chestnut-red "ruby blende" of exceptional size for this variety. Gemmy red sphalerite usually seems to occur in crystals just a few millimeters in size, but the new Chinese crystals measure approximately 1 cm. They occur on a contrasting matrix of small, pale gray quartz crystals and colorless lenticular calcite. A curious aspect of these specimens is the presence of water-filled cavities in the matrix which may contain

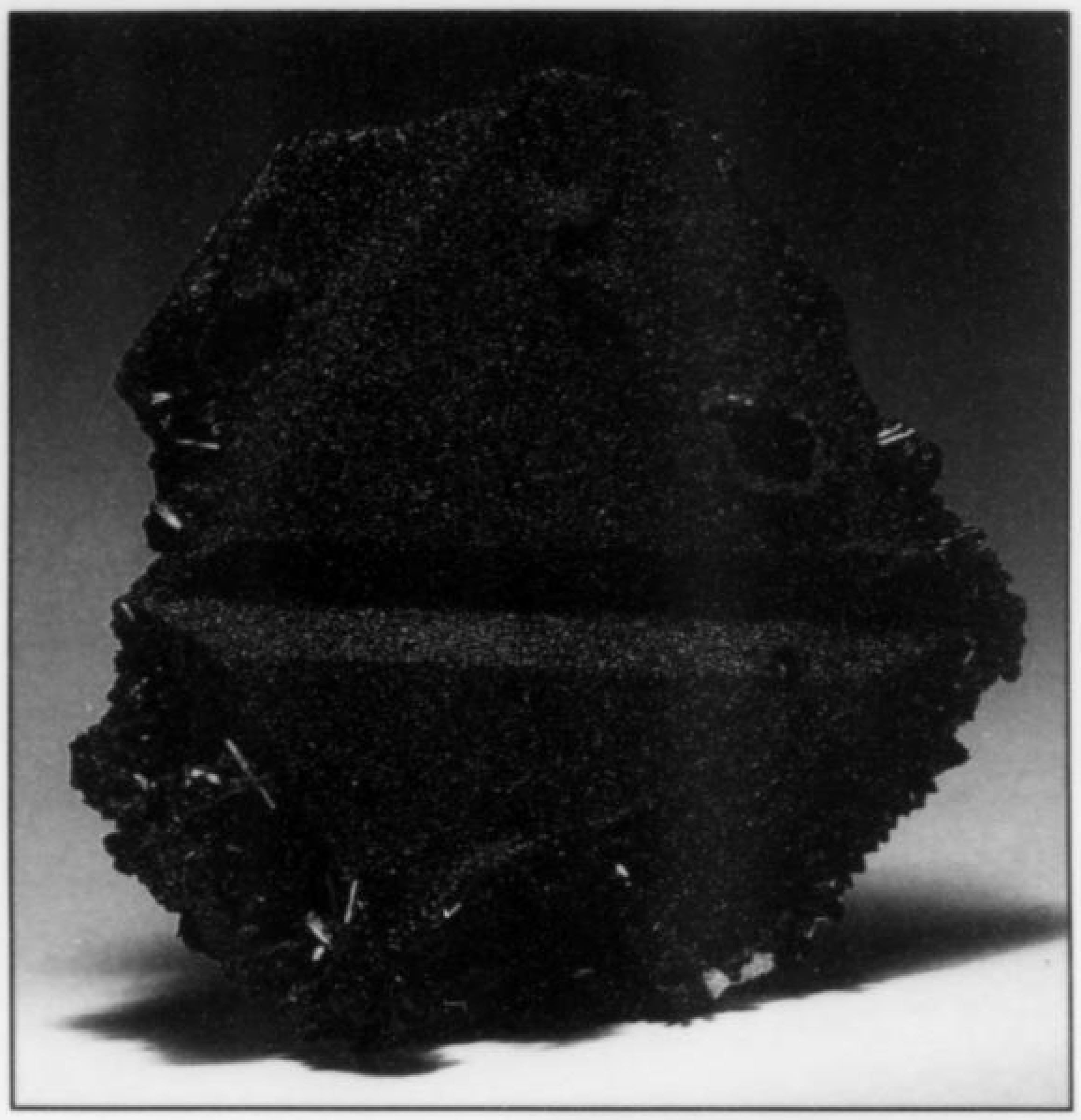

Figure 2. Andradite pseudomorph after a twin, 9 cm, with g audofroyite from the N'Chwaning mine, Kuruman, Cape Province, South Africa. *Miner K* specimen; M. P. Cooper photo.

Figure 4. Hematite crystals to 3.5 cm on matrix from the Black Rock mine, Hotazel, Cape Province, South Africa. *Miner K* specimen; M. P. Cooper photo.

Figure 3. Gaudefroyite crystals to 1 cm with blood-red andradite from the N'Chwaning mine, Kuruman, Cape Province, South Africa. *Miner K* specimen; M. P. Cooper photo.

Figure 5. Brown-red sphalerite crystal, 1.5 cm, on matrix from Shuikoushan, Hunan, China. Frédéric Escaut specimen; M. P. Cooper photo.

Figure 6. Superb whewellite crystal (twin), 6.9 cm, from the Boldut mine, Cavnic, Maramures, Romania. René Treibl specimen; M. P. Cooper photo.

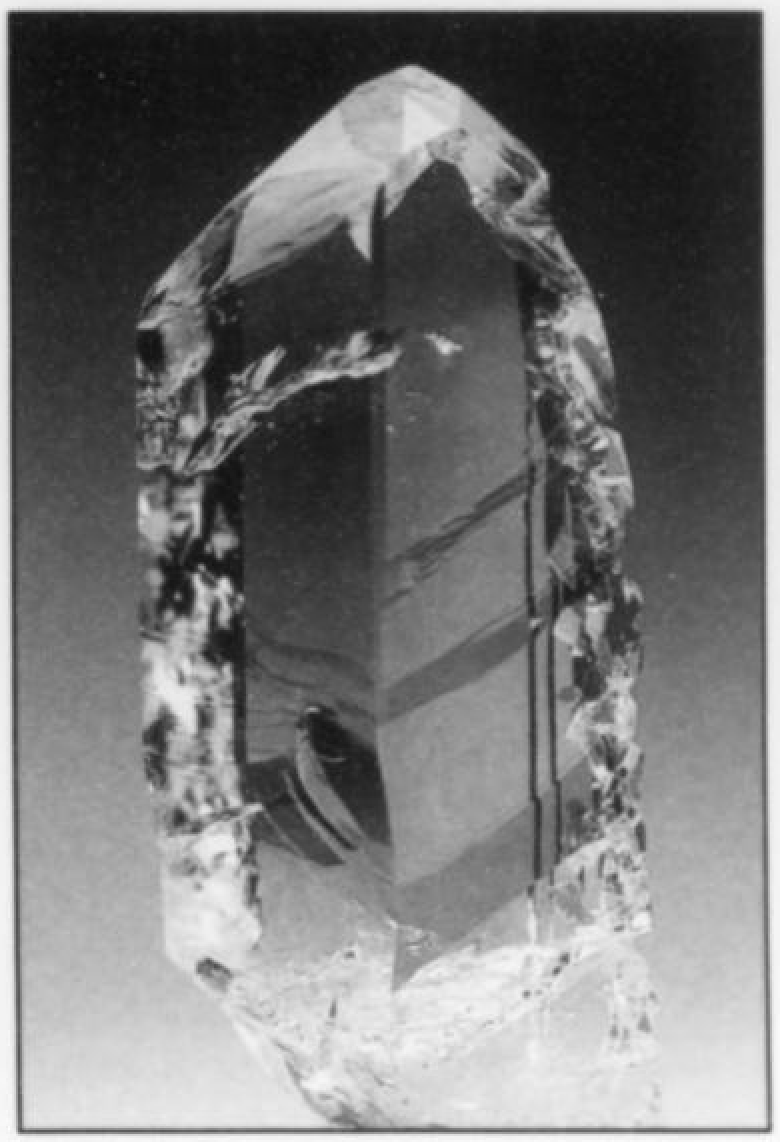

Figure 7. Quartz crystal, 5 cm, from Sigoyer, Haute Provence, France. Jordi Fabri specimen, now in the John S. White collection; M. P. Cooper photo.

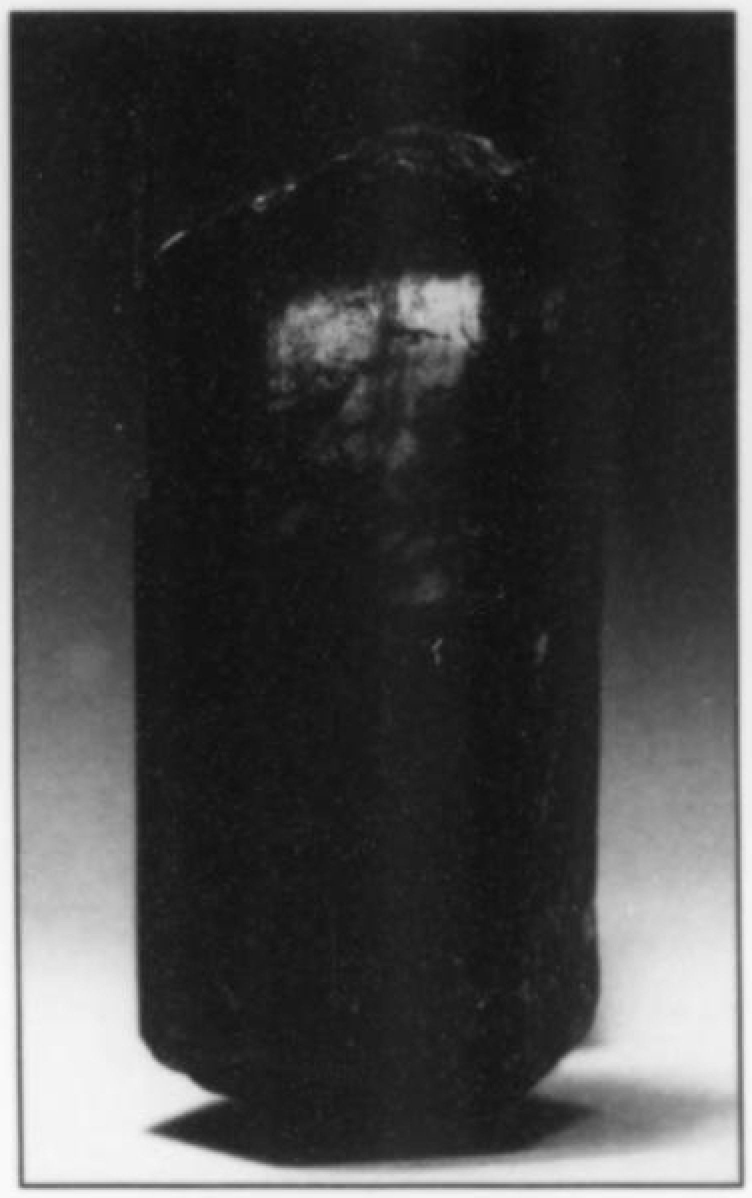

Figure 8. Thick, doubly terminated dravite crystal, 5 cm, from Ganesh Himal, Nepal. Gilbert Gauthier specimen; M. P. Cooper photo.

Figure 9. Magnetite dodecahedrons to 1 cm with fibrous epidote from Dashkesan, Azerbaijan. Eric Schmidt specimen; M. P. Cooper photo.

Figure 10. (below) A sharp magnetite dodecahedron, 1.5 cm.

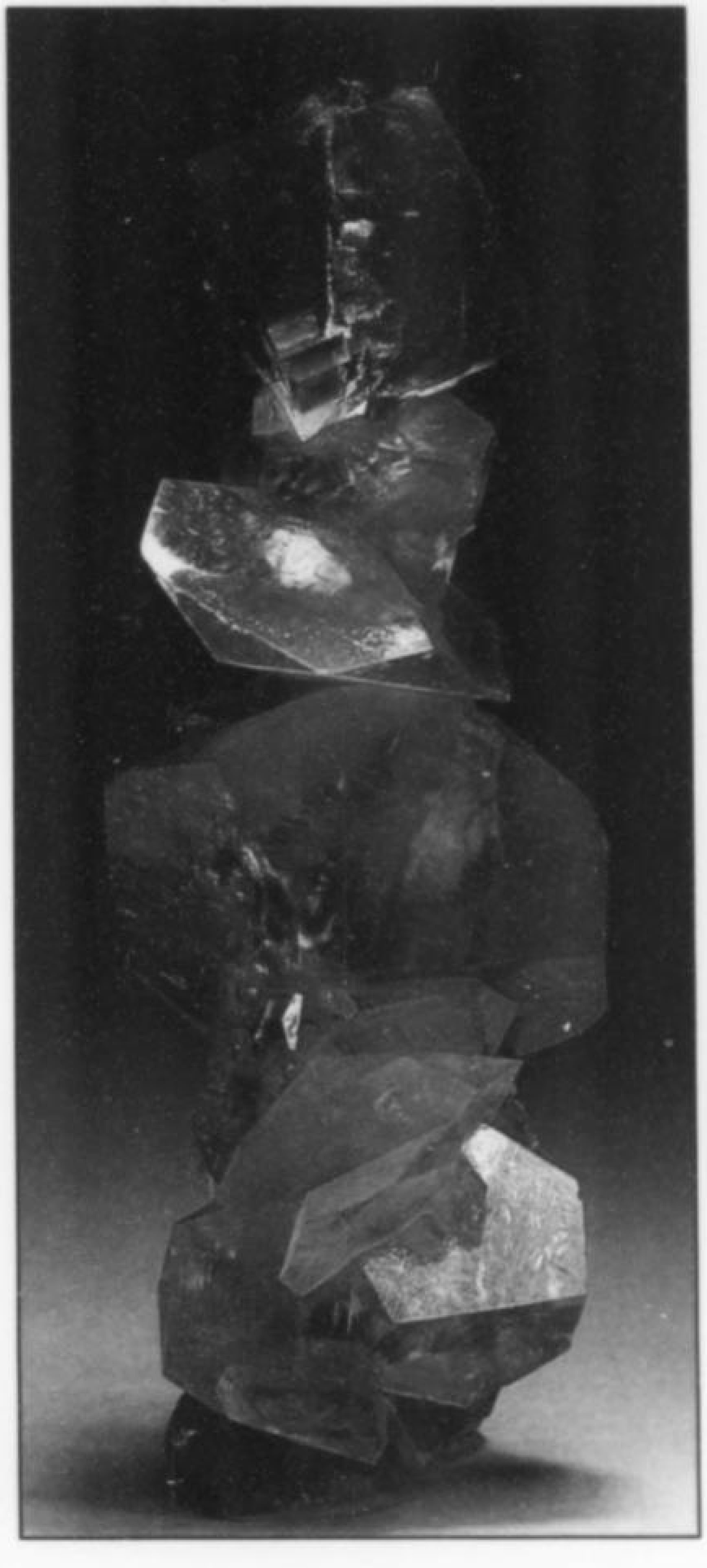

Figure 11. Fluorite crystal, 2 cm, perched on rhombic calcite crystals from the Xuanghualin mine, Chenzou, Hunan, China. Frédéric Escaut specimen; M. P. Cooper photo.

several milliliters of liquid. Specimens, available in a range of sizes from small cabinet on up, sold well in Munich.

A new find of excellent **magnetite** from Dashkesan, Azerbaijan, was featured by *Erich Schmidt* (Friedhofstr. 3, D-95709 Tröstau, Germany). Most of these sharp, greasy-lustered black crystals are dodecahedra measuring about 2 cm on the average and set off nicely by associated sprays and beds of epidote. One odd piece consists of a loose octahedron with strange, bulbous overgrowths of what appears to be a second generation of magnetite. Grayish prisms of **apatite** to several cm in length are found here as well. Some people were confusing the location with Dzhezkazghan in Kazakhstan, so beware labeling errors.

Another iron oxide available in superb crystals was **hematite**. *Miner K* (Patrick de Koenigswarter, En Berou, St. Julia de Gras Capou, F-31540 France) had a fine lot of ten specimens from the Black Rock mine, Hotazel, in the Kalahari Manganese Field, South Africa. They are very lustrous and clean, the single crystals measuring up to 7 cm and the groups consisting of 3 to 4-cm crystals. Patrick displayed these alongside some excellent **gaudefroyite** in small, black prisms on blood-red drusy andradite matrix from the N'Chwaning mine. These included a remarkable 9-cm garnet pseudomorph after a tabular twin of some unknown mineral (perhaps calcite or rhodochrosite). A scattering of gaudefroyite crystals around the edge makes it particularly attractive, and it sold quickly.

Last year's interesting finds of **cassiterite** at Merek and **anatase** at Lapcha in the Ural Mountains were surpassed during this year's short collecting season at these obscure localities. *Andras Lelkes* had some of the former in excellent, smoky brown, semi-transparent crystals to 3 cm, and some of the anatase crystals to 1.5 cm in groups on terminated quartz crystals. Excellent matrix thumbnails and loose crystals of **anatase** from Valdres, Norway, were available from *Budil & Budil*. These doubly terminated crystals reach 2 cm, and were priced at $90 to $130.

Wurtzite is a mineral rarely seen at shows, and then only as rather unremarkable specimens. However, from under the table of *Dr. Jaroslav Hyrsl* (Heverova 222, CZ-28000 Kolin 4, Czech Republic) came what must be the finest known example of the species. This stunning piece, from the Animas Vein in the Chocaya District at Potosí, Bolivia, surpasses the remarkable specimen from the same occurrence owned by the Carnegie Museum in Pittsburgh (see vol. 21, no. 5, 1990). Held back by a local Bolivian collector for several years, Jaroslav's specimen measures 11 x 15 cm and is richly studded with wurtzite crystal aggregates to 7 cm across.

Jaroslav's table also bore some other interesting material from Bolivia (his colleague lives and works there). Being a long-time pseudomorph enthusiast, I noticed first of all some classic Corocoro **copper** after aragonite, an old and unique occurrence. Though not as sharp as some I've seen, these are very respectable specimens and quite large (to 5 cm). Next, from an unusual metamorphosed evaporite deposit at Alta Chapare he had some unique **danburite** crystals, doubly terminated gray floaters to 4.5 cm, and crude **boracite** cubes to 2.5 cm (1 inch!); these latter are huge for the species, but not very attractive. There was also some microcrystalline **povondraite**, a rare member of the tourmaline group which appears to have formed through the reaction of xenoliths with igneous rocks included in the metamorphosed evaporite. **Ericaite** has also been found there but is extremely rare. These various minerals occur mostly as fine-grained masses with gypsum, talc, magnesite and dolomite. And finally, just to keep the collector confused, Jaroslav had some **bertrandite** pseudomorphs after fluorite octahedra from "Zabytoe, Primorsky Kray, Russia" that look exactly like the examples from Kounrad, Kazakhstan, right down to the associated lenticular crystals of rhodochrosite. The "Zabytoe" listed in Smith and Smith's *Guide to Mineral Localities in the Former Soviet Union* (vol. 26, no. 6) is near Irkutsk, a long way from Primorsky.

The ever-cheerful *Gilbert Gauthier* (7, Avenue Alexandre III, F-78600 Maisons-Lafitte, France) had some remarkable **dravite** specimens: well-formed, doubly terminated, semi-transparent crystals to 5 cm! The locality was given as Ganesh Himal, Dhading, Nepal, which is north of Kathmandu. A few of the crystals are on matrix but most are loose singles, priced at $60 to $120. They were said to have been found about two months before the show.

Epidote from the fantastic find at the Rosario Mabel mine near Castrovirreyna, Peru, was everywhere at the Munich Show this year, but nowhere in such great profusion as at the stand of Maurice Eyraud (*Minerama*, 49 rue de la Republique, F-42800 Rive de Gier, France). He had *the* killer specimen from the occurrence, over half a meter across with big brushes of epidote sprouting all over it. Although these don't quite have the bright color and nice transparency of the Austrian and Pakistani specimens, they do have excellent and distinctive form and they contrast attractively with the associated quartz crystals. Many great single fans of epidote, with or without attached quartz crystals, were also available and would grace any collector's cabinet.

In an earlier report, I noted the disappearance from the market of the new, unnamed **rhenium sulfide** mineral found lining the fumaroles at the Kudriavy volcano, Iturup Island, Kurily, Russia, which were first reported from the 1994 Tucson Show (see vol. 26, no. 3). Specimens were once again available at Munich. This chemically surprising mineral reminds me of a couple of superb crystals of lime-green **praseodymium sulfate** and a magenta-red **neodymium salt** of some kind; Jorgen Langhof of the Swedish Museum of Natural History purchased them from a dealer at the show. These are surely synthetic, since natural geochemical processes are incapable of separating praseodymium from neodymium.

Many interesting rarities were in abundance on the tables of Victor Yakovenchuk's *Laplandia Minerals* (14 Fersman Street, Apatity, GUS-Murmansk, RU-184200 Russia . . . great address for a mineral dealer, eh?). Victor, who specializes in Kola Peninsula specimens, had dozens of fine **kovdorskite** specimens from the "Iron quarry," Kovdor Massif; these consist of encrustations of glassy, pale pink blades to 2.5 cm on pieces of matrix up to 8 cm or so. Small specimens were priced at $25 to $160, and larger ones could be had for about $800, but there were none of the extraordinary *blue* crystals reported from Tucson last year (see vol. 27, no. 3). **Villiaumite** was available in blood-red lumps from Karnasurt, Lovozero Massif (at $30 for a 5-cm fragment), and **osmium** in minute nuggets from Nevjansk in the Urals for $63/gram.

Gunnar Färber (Bornschestr. 9, D-39326 Samswegen, Germany) recently made an extensive collecting trip to the Polaris mine on Little Cornwallis Island, Canada, the world's northernmost lead-zinc mine, way up above the Arctic Circle a mere 80 km southeast of the Magnetic North Pole. This was a unique opportunity, the envy of Canadian mineralogists, which yielded a good selection of specimens from the Polaris mine and also the nearby Nanisivik mine on Baffin Island (see the article in vol. 21, no. 6). From Polaris he had **galena** cubes to 3 cm, golden **calcite** rhombs and scalenohedra to 5 cm, curved gray **dolomite** rhombs to 5 cm on edge, and polished slices of banded **sphalerite** *schalenblende* ore. Nanisivik **pyrite** is famous for its high luster and variety of habits; Gunnar's specimens showed a wide range including distorted, complex, flattened habits and some very attractive small crystals on dolomite. The tiny, iridescent crystals show well-developed octahedron and trisoctahedron faces, and are particularly stunning under magnification. The Nanisivik mine also produces some fairly large **pyrrhotite** crystals.

From the other end of the earth Gunnar had Antarctic **prehnite** from (naturally) Prehnite Hill, Litell Rocks on the Rennick Glacier, North Victoria Land. The occurrence was discovered by a German geologist back in 1981 during an unplanned stop-over when his helicopter made a forced landing there. While waiting for rescue he, being a geologist, prospected the place. Admittedly the specimens are not real exciting to look at—battered, pale green botryoidal crusts with quartz—but what a locality to put on the label! There was also **stilbite** from Brimstone Peak in the Prince Albert Range, Victoria Land, though again just lumps for the locality collector.

Seekers after more aesthetic **prehnite** found their way to the stand of *Manfred Grimmel* (Gewerbeschulstr. 36, D-42289 Wuppertal, Germany), who had some of the famous prehnite-lined geodes from Brandberg, South Africa. The apple-green prehnite is associated with colorless quartz prisms, an attractive combination I hadn't seen before. He also had one of the finest selections I've ever seen of deep purple/green **fluorite** from Okaruso, Namibia.

Quartz collectors had much to choose from at Munich this year. There was new amethyst from Amatitlan, Guerrero, Mexico, in spindle-shaped prisms to 10 cm or so, lightly dusted with citrine microcrystals, in attractive sprays on matrix. *Joachin Karl* had some fine examples, and also some unusual, 25-cm, doubly terminated, part smoky floaters from Yushnee in the southern Ural Mountains. There was some classic, doubly terminated "window quartz" from San Carlos, Coahuila, Mexico, in crystals to 8 cm (a good value at $15 to $25), from *Joop and Willy Jansen* (Achterveld 30, NL-8334 TUK Steenwijk, Netherlands). *Andreas Weerth* had small but fantastically high-quality quartz crystals from the Shigar region, Pakistan. The luster and fire of these crystals are quite remarkable, especially interesting because good quartz is rare there. *Jordi Fabre** also had a couple of interesting finds. The first is some long (to 12 cm) prismatic quartz crystals collected last year at the Brumado mine in Bahia, Brazil; the pretty crystals carry encrustations and inclusions of lustrous red hematite and yellow goethite, making them resemble exotic, contemporary oxidized glasswork.

The second is a find of quartz crystals (some of them distorted) from Sigoyer, Haute Provence, France, the best of which resembles a blade of flawless gypsum about 6 cm long. Widespread at the show were specimens labeled "prase" from "Sinya Rechka," Russia—I take this to be Sinerechenskoe, Primorskiy Kray, Siberia. The spindle-shaped crystals are heavily included with **actinolite**, giving them a dark olive-green color. *Erich Schmidt* and *Joachim Karl*, among others, had good pieces. And lastly (for quartz, at least), from Nanchan, Jansee, China, have come some curious hematite-coated quartz crystals with overgrowths of second-generation colorless quartz; the result is good phantoms and complex "windows." These were carried by several dealers.

Andrea Znojemszky (Glotzbergstr. 42, D-77815 Bühl, Germany) recently brought back some interesting quartz with a possible pinacoid face, which she found on a mine dump at Aktas, Kazakhstan. Another trip to the site is planned in order to confirm the occurrence of the rare crystal form. Andrea was also very proud of her **creedite** from Akchatau, Kazakhstan. The small cabinet piece is encrusted with deep blue drusy crystals resembling Bolivian vauxite. A few more of these wouldn't hurt either!

Christophe Dubois (Königsbergerstr. 20, D-38302 Wolfenbüttel, Germany) always has interesting odd French things. This year he brought a good lot of attractive, blue **chalcophyllite** in crystals to 1 cm with blue **cyanotrichite** from the Salsigne gold mine, Aude in southern France—a nice association and a rare chance to acquire good chalcophyllite from *anywhere*. The occurrence is the gossan of an open-pit operation, in a very localized area which could disappear overnight. The pit itself is due to close sometime in 1997. The underground workings of the mine have also yielded interesting material including **cronstedtite** in brilliant, well-formed crystals to 4 mm, associated with **vivianite** and **ludlamite**.

Gypsum is unexciting to many collectors, but Helmut and Gisela Brückner (*Brückner Exclusive Mineralien*, Postfach 1342, D-79373 Müllheim, Germany) had some specimens that really turned heads. Their lavish stand, more like a miniature museum constructed within the show hall, had excellent textbook-perfect, totally flawless, 15-cm crystals from the Maravillas mine at Naica, Chihuahua, Mexico. The single crystals occur on a fine-grained brown matrix, and are extraordinarily aesthetic even by Naica standards; the prices started at $650 and went up from there. The Brückners also exhibited a superb, red Burmese **spinel**, a lustrous octahedron about 1.2 cm on edge, perched on a snow-white marble matrix. Some excitement was also caused by Inge-Maria Sieber (*Cristallina*, Dahlienweg 18/11, D-73760 Ostfildern, Germany) who had some large, new spinels from Sri Lanka. The milky lavender octahedra reach 8 cm (!) on edge.

Who cannot fail to be stunned by the huge variety, high quality and seemingly unending quantity of zeolitic specimens which continue to pour forth from India? In the face of such mind-numbing abundance it is good to see zeolites and associated species from elsewhere receive some attention as well. This year at Munich I was particularly taken with some intriguing **apophyllite** from the platinum mine at Talnach, Noril'sk, Russia. Famed for sperrylite, Talnach is relatively unknown as a source for anything other than precious metals, but in fact produces a fine array of apophyllite in various colors and habits, associated with **thaumasite**, **natrolite**, **pectolite** balls, pseudo-cubic **calcite** and other species. The apophyllite forms thin, square 1-cm plates of pale pink color encrusting matrix; it was collected around 1990. The specimen I photographed fooled everyone who saw it . . . most thought it was barite.

Romanian minerals were as abundant as ever at Munich. No new species were in evidence, but new finds of well-known minerals came to light, including some of the best-ever **fizelyite** and **semseyite** from Herja, found on the sixth level last winter. The fizelyite crystals reach an enormous 3 cm, and occur associated with **jamesonite**, **freibergite** and pseudomorphs of **pyrite** and **galena** after pyrrhotite. The Boldut mine at Cavnic recently produced many fine specimens of yellow **barite** in intergrown masses of simple rhombic plates; these are the best barites found at Cavnic in over 30 years. Individual crystals reach 15 cm and some contain reddish phantoms. Several dealers had good pieces, including René Treibl (*Top Minerals*, Rudolf-Hawel-Gasse 21, A-2700 Wiener Neustadt, Austria) and *Jordi Fabre*. René also had some new **realgar** in small crystals on native **arsenic** from Mine No. 6 at Baia Sprie, one of two relatively new mines there, opened about 10 years ago. Apparently, these two mines are the source of much recent material that has been labeled simply "Baia Sprie." **Barite** crystals to 2.5 cm, colored orange by realgar inclusions, also come from here. The tail-end of an attractive lot of **calcite** found at the Boldut mine in 1996 was also available; the hedgehog-like clusters of spiky crystals are palest yellow in color, and have a "trigonal wheat-sheaf" habit (rather like the N'Chwaning mine rhodochrosite shown in vol. 9, no. 2, but somewhat more extreme in its development). The groups, about 3 cm across, some with associated **quartz** (some of it amethystine) and **pyrite** on an attractively contrasting matrix of pale peach-pink **dolomite.**

Oftentimes the best specimens are hidden *under* tables, and from

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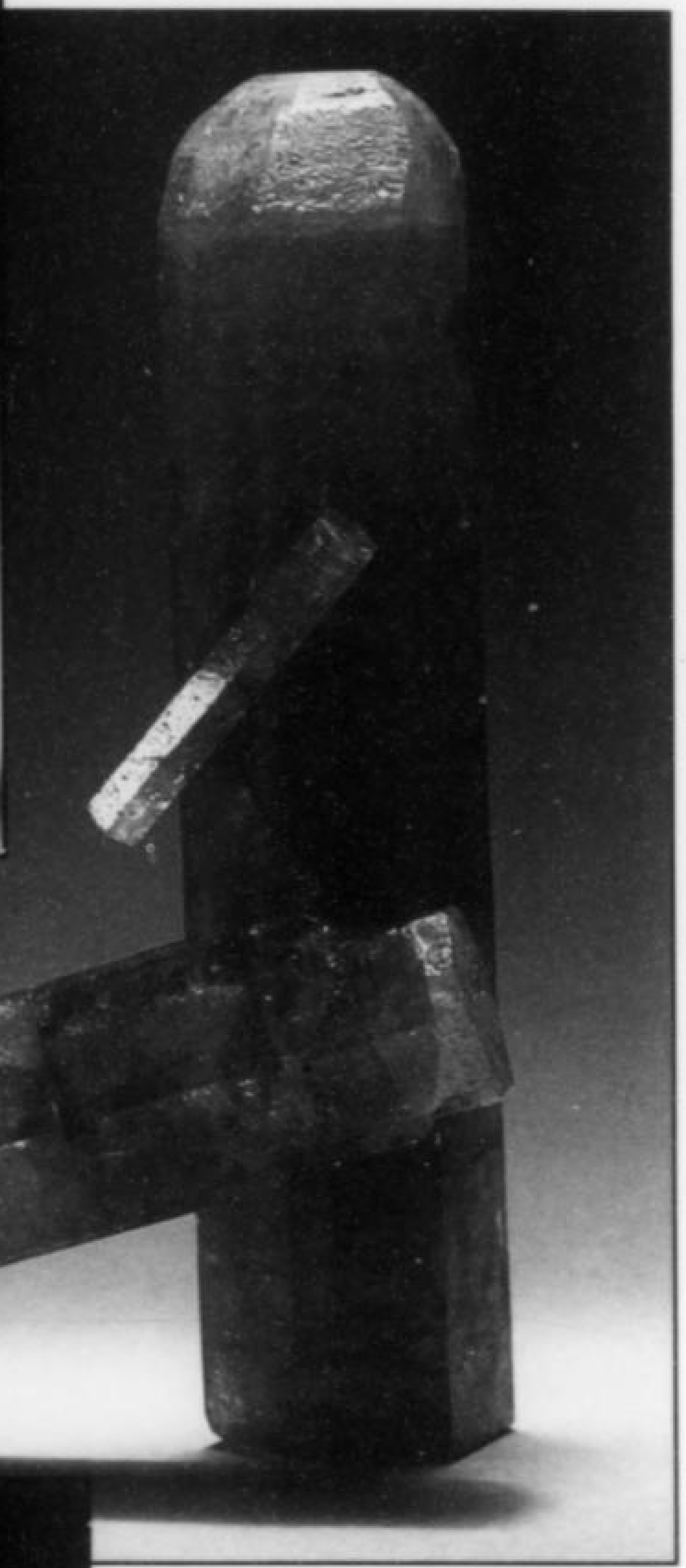
*Jordi is one of the first European dealers to offer minerals for sale on the Internet. He can be contacted at www.fabre-minerals.com.

Figure 12. **Barite crystal group, 12 cm, from the Roata mine, Cavnic, Romania. Jordi Fabre specimen; M. P. Cooper photo.**

Figure 13. **Apatite crystals to 9 cm from Nagar, Hunza Valley, Pakistan. Andreas Weerth specimen; M. P. Cooper photo.**



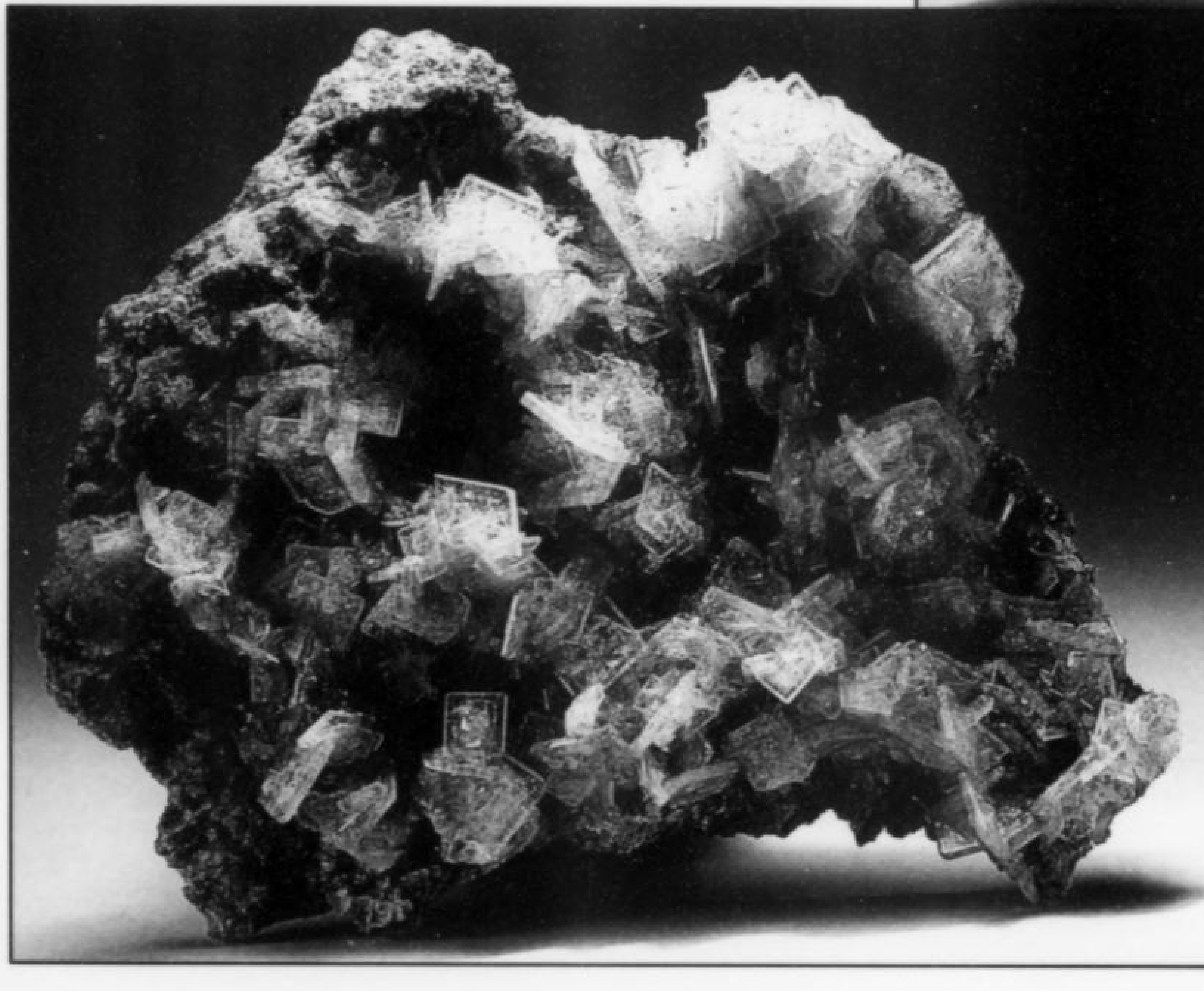


Figure 14. **Tabular apophyllite crystals on matrix, 10 cm, from Noril'sk, Russia.** ***KARP*** **specimen; M. P. Cooper photo.**

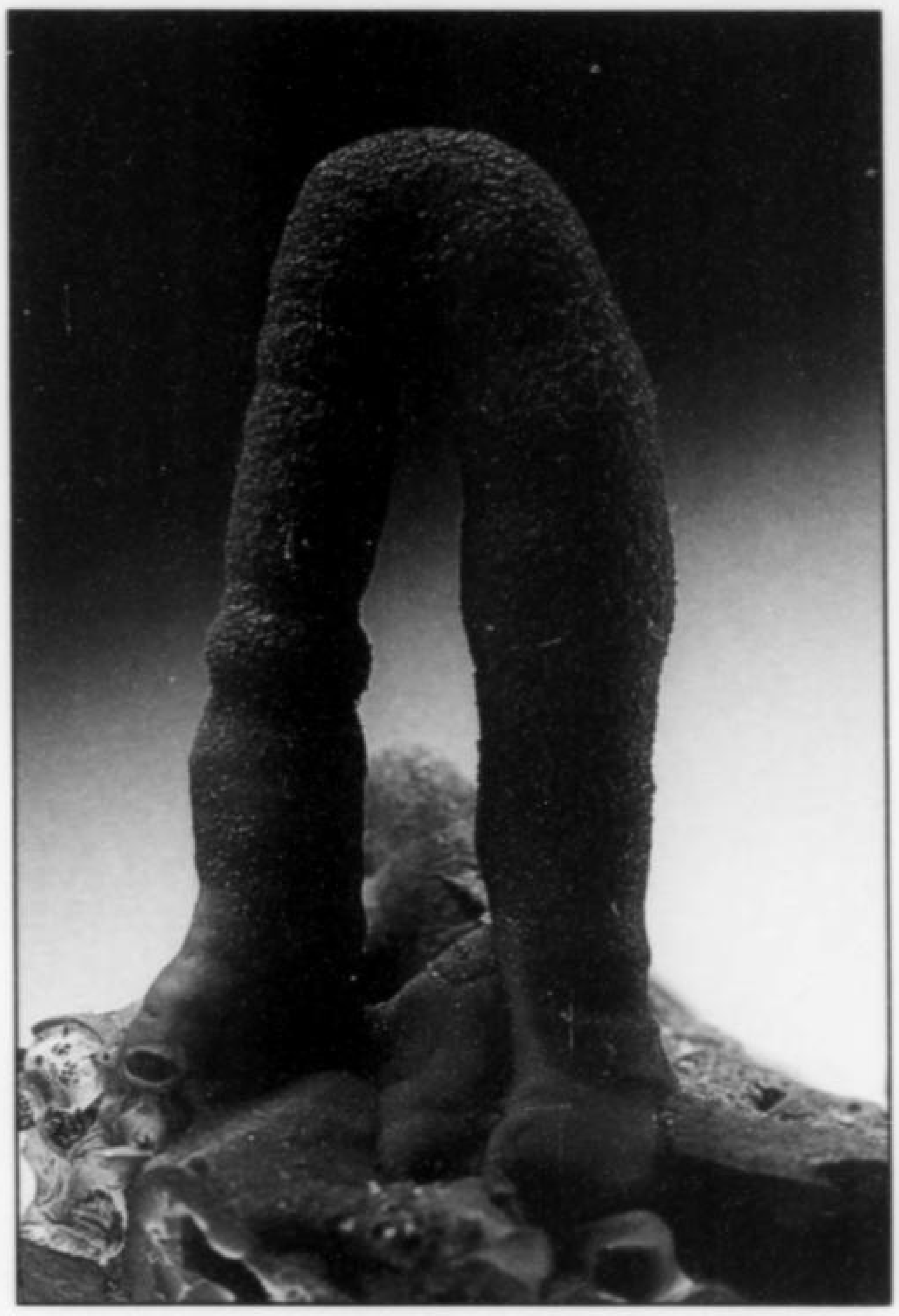


Figure 15. **Malachite stalactite loop, 2.5 cm, from the Miguel Vacas mine, Altentejana, Portugal.** ***Crystal Classics*** **specimen; M. P. Cooper photo.**

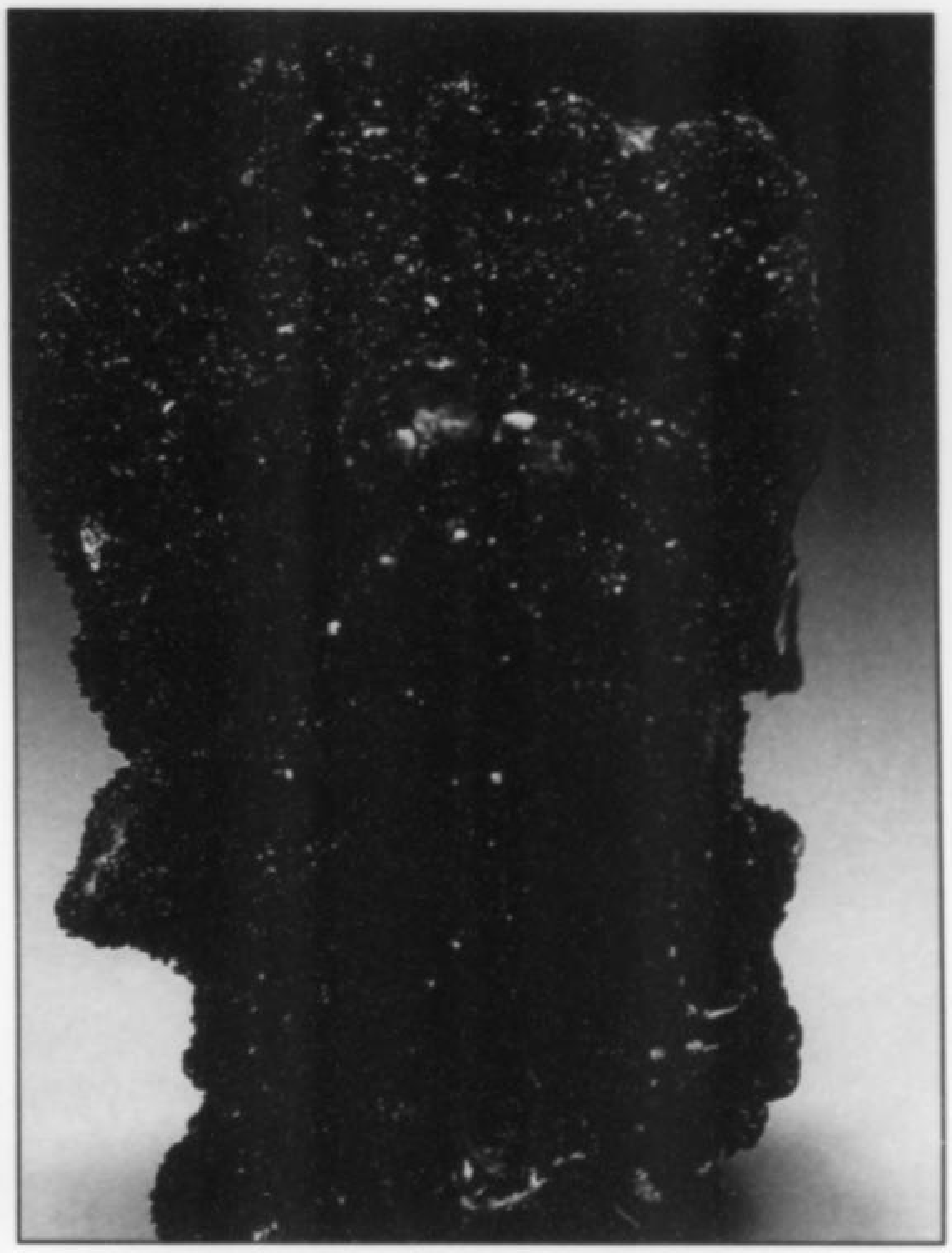


Figure 16. **Dark blue creedite druse, 7 cm, from Akchatau, Kazakhstan. Andrea Znojemsky specimen; M. P. Cooper photo.**

beneath his René Treible treated me to the sight of a superb **whewellite** twin from the Boldut mine. This transparent, well-formed, doubly terminated beauty is 6.9 cm (nearly 3 inches!) tall. It was acquired misidentified as a calcite from a Romanian miner in April, and only later identified as a whewellite; by then it was too late to find the miner again and learn more about the details surrounding its discovery. It could well be the world's best specimen of the species.

Incidentally, it may be worth noting that continental European collectors pronounce the mineral "vevellite" (sounding to my ears more like "wavellite") and Americans often say "we-willite," but in England it is properly pronounced "hewellite," having been named after the English naturalist William Whewell (1794–1866) who dropped the first "W" in pronouncing his own family name.

Pyromorphite collectors were also fortunate at Munich this year, having the opportunity to catch up on material found at the well-known Les Farges mine, Ussell, France. *Jordi Fabre* had secured an old collection of excellent pieces from the late 1970's, mostly small cabinet specimens exhibiting the typical colors and habits that have made Les Farges famous. Brown crystal groups started at only $30, and green ones began at $60. (The green-tipped brown crystals are my favorite.) And don't forget the lovely, bright green pyromorphite from Chaillac, Indre, France, which is still trickling onto the market. Although small, the lustrous, glittering crystals make for beautiful specimens. Some fine examples were offered by aesthetica specialists *Giles and Françoise Barras-Gautier* (Le Besset, F-63880 Olliergues, France).

Finally, first prize for the most unusual **malachite** at Munich must go to Ian Bruce (*Crystal Classics*, 59 Exeter Road, Okehampton, Devon EX20 1QF England), for a piece from the Miguel Vacas mine, Altentejana, Portugal. It consists of a stalactite forming a perfect loop or arch 2.5 cm high, connected on both ends to the same piece of matrix. How such a thing could form is a mystery.

I had a great time at Munich, but the fun was tempered by sadness over the death of long-time Munich Show dealer Christian Gobin (see the notice in the previous issue). Christian's taste was always impeccable, and the visitor to his booth could never find a poor specimen. Even for the lower-priced pieces good taste prevailed, and his booths were always among the most eye-catching at any European show. It was good to see his stand at the Munich Show as usual, still with its hallmark display of Zaire malachite. I wish his sons well.

Mick Cooper

E-mail: *minerals@mpcooper.demon.co.uk*

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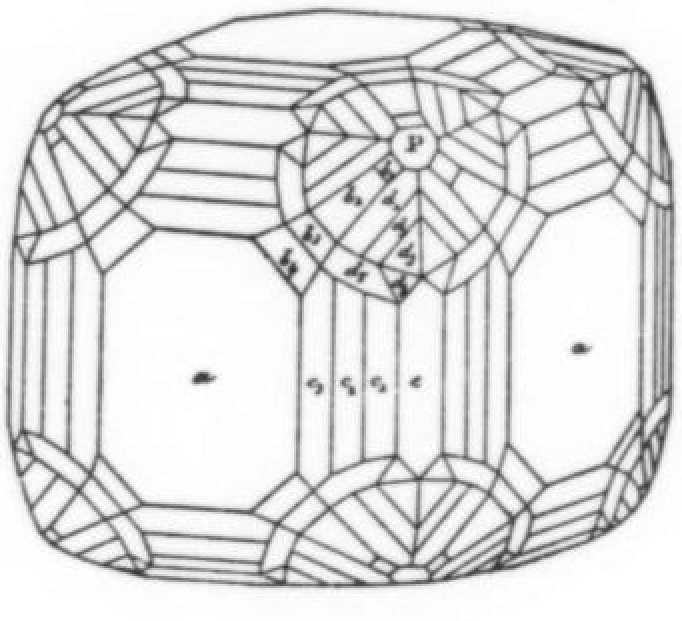


J. A. Mandarino
Chairman Emeritus of the Commission on
New Minerals and Mineral Names
of the International Mineralogical Association
and
Curator Emeritus
Department of Mineralogy
Royal Ontario Museum
100 Queen's Park
Toronto, Ontario, Canada M5S 2C6

Benauite Hexagonal (trigonal)

$HSrFe_3^{3+}(PO_4)_2(OH)_6$

Locality: The Clara mine, near Oberwolfach, Central Black Forest, Germany.

Occurrence: Associated minerals are: goethite, fluorite, and kidwellite.

General appearance: Radial aggregates (up to 3 mm in diameter) of scaly crystals more than 1 mm long.

Physical, chemical and crystallographic properties: *Luster:* vitreous to resinous, but the indices of refraction indicate that it should be adamantine. *Diaphaneity:* transparent to translucent. *Color:* yellow to brown. *Streak:* yellowish. *Luminescence:* nonfluorescent. *Hardness:* about 3½. *Tenacity:* brittle. *Cleavage:* {001} rather perfect. *Fracture:* conchoidal. *Density:* 3.65 g/cm^3 (meas.), 3.48 g/cm^3 (calc.). ***Crystallography:*** Hexagonal (trigonal), probably $R\bar{3}m$, a 7.28, c 16.85 Å, V 773.6 Å^3, Z 3, c:a = 2.315. Morphology: forms, only {001} was observed. Twinning: none observed. ***X-ray powder diffraction data:*** 5.88 (10), 3.65 (6), 3.06 (9), 2.96 (5), 2.81 (5), 2.53 (5), 2.25 (6), 1.969 (5), 1.820 (5). ***Optical data:*** Uniaxial (-), ω 1.872, ε 1.862, but with 2V up to 20°, pleochroism O = yellow, E = nearly colorless. ***Chemical analytical data:*** Means of six sets of electron microprobe data: K_2O 0.07, CaO 0.07, CuO 0.03, ZnO 0.07, SrO 12.35, BaO 4.32, PbO 2.79, Al_2O_3 0.26, Fe_2O_3 40.85, SO_3 6.79, P_2O_5 18.53, As_2O_5 0.78, H_2O (13.09), Total (100.00) wt.%. H_2O by difference. Empirical formula: $(Sr_{0.64}Ba_{0.15}Pb_{0.07}K_{0.01}Ca_{0.01})_{\Sigma 0.88}(Fe_{2.77}Al_{0.03})_{\Sigma 2.80}(PO_4)_{1.41}(AsO_4)_{0.04}(SO_4)_{0.46}O_{6.36}H_{7.86}$. ***Relationship to other species:*** A member of the crandallite group.

Name: For "a locality in the vicinity of the Clara Mine." ***Comments:*** IMA No. 95-001. This mineral replaces "lusungite" which has been discredited. The calculated density given here is significantly different from that given in the paper (3.648 g/cm^3), as are the subscripts of the empirical formula. These are caused by different derivations of the formula; here, the formula is based on O = 14, whereas the authors' formula is based on P+As+S = 2.

WALENTA, K., BIRCH, W. D., and DUNN, P. J. (1996) Benauite, a new mineral of the crandallite group from the Clara mine in the Central Black Forest, Germany. *Chemie der Erde* **56**, 171–176.

Fettelite Hexagonal (trigonal)

$Ag_{24}HgAs_5S_{20}$

Locality: The Nieder-Beerbach mine, 10 km south of Darmstadt, Odenwald, Germany.

Occurrence: In hydrothermal veins, which cut gabbro-diorite intrusives. Associated minerals are: proustite, pearceite, xanthoconite, and safflorite.

General appearance: Clusters of hexagonal flakes (up to 0.2 mm across and usually 5 to 10 μm thick); also as somewhat larger, subparallel aggregates of more compact hexagonal tablets up to 0.05 mm thick.

Physical, chemical and crystallographic properties: *Luster:* submetallic to adamantine. *Diaphaneity:* opaque. *Color:* dark violet to scarlet. *Streak:* dark vermilion. *Hardness:* VHN_{20} 158 kg/mm^2, Mohs about 4. *Tenacity:* brittle. *Cleavage:* {001} perfect. *Fracture:* irregular. *Density:* could not be determined, 6.30 g/cm^3 (calc.). ***Crystallography:*** Hexagonal (trigonal), P312, P321, P3m1, P31m, $P\bar{3}m1$, or $P\bar{3}1m$, a 15.00, c 15.46 Å, V 3014 Å^3, Z 3, c:a = 1.0307. Morphology: forms, only {001} was observed. Twinning: none observed. ***X-ray powder diffraction data:*** 3.175 (6), 3.091 (10), 2.998 (4), 2.755 (3), 1.878 (8). ***Optical data:*** In reflected light: grey with a greenish tint, weak anisotropism with bright greenish grey to dark bluish grey tints, weak bireflectance, weak pleochroism. $R_{max.}$, $R_{min.}$; $^{im}R_{max.}$, $^{im}R_{min.}$: (31.0, 30.3; 14.2, 13.8 %) 470nm, (29.2, 27.6; 13.1, 12.0 %) 546nm, (27.6, 26.0; 11.7, 10.8 %) 589nm, (24.8, 23.9; 10.3, 9.6 %) 650nm. ***Chemical analytical data:*** Means of twenty-eight sets of electron microprobe data: Cu 0.07, Pb 0.07, Fe 0.04, Sb 0.23, Ag 67.55, As 9.80, Hg 5.21, Tl 0.13, S 16.79, Total 99.89 (given as 99.88) wt.%. Empirical formula: $(Ag_{23.88}Cu_{0.04}Fe_{0.03})_{\Sigma 23.95}Hg_{0.99}Tl_{0.02}Pb_{0.01}(As_{4.99}Sb_{0.07})_{\Sigma 5.06}S_{19.97}$. ***Relationship to other species:*** None apparent.

Name: For Mr. M. Fettel (1943–), an experienced field worker and collector in the area, who found the mineral. ***Comments:*** IMA No. 94-056.

WANG, N. and PANIAGUA, A. (1996) Fettelite, a new Hg-sulfosalt mineral from Odenwald. *Neues Jahrbuch für Mineralogie, Monatshefte* **1996**, 313–320.

Fluor-cannilloite

Monoclinic

$\mathrm{CaCa_2(Mg_4Al)(Si_5Al_3)O_{22}F_2}$

Locality: Pargas, Finland.

Occurrence: In a marble. Associated minerals are: muscovite, anorthite, "aluminous diopside" (i.e., aluminian diopside), pyrope, and fluorite. "Cannilloite" is also mentioned, but this probably is a typographic error for fluor-cannilloite.

General appearance: Isolated anhedral grains and granular aggregates (up to 0.15 x 0.15 x 0.20 mm).

Physical, chemical and crystallographic properties: *Luster:* vitreous. *Diaphaneity:* semi-translucent. *Color:* grey-green. *Streak:* greyish-white. *Luminescence:* non-fluorescent. *Hardness:* ~ 6. *Tenacity:* brittle. *Cleavage:* {110} perfect. *Fracture:* splintery. *Density:* 3.05 g/cm^3 (meas.), 3.18 g/cm^3 (calc.). ***Crystallography:*** Monoclinic, C2/m, a 9.826, b 17.906, c 5.301 Å, β 105.41°, V 899.2 Å^3, Z 2, a:b:c = 0.5488:1:0.2960. Morphology: no forms observed. Twinning: none mentioned. ***X-ray powder diffraction data:*** 3.107 (10), 2.686 (10), 2.578 (10), 2.165 (6), 2.036 (5), 1.434 (9). ***Optical data:*** Biaxial (+), α 1.611, β 1.616, γ 1.633, 2V(meas.) 49°, 2V(calc.) 57°; dispersion r > v, weak; nonpleochroic; orientation not given, but the IMA proposal gives X ^ a = 9° (in acute angle β), Y = b, Z ^ c = 24° (in obtuse angle β). ***Chemical analytical data:*** Three sets of electron microprobe data are given; the one with the highest fluorine content has: $\mathrm{Na_2O}$ 1.22, $\mathrm{K_2O}$ 0.66, MgO 17.54, CaO 15.73, MnO 0.41, FeO 3.19, $\mathrm{Al_2O_3}$ 18.74, $\mathrm{SiO_2}$ 38.78, $\mathrm{TiO_2}$ 0.18, $\mathrm{H_2O}$ (0.33), F 3.66, sum 100.44, less O = F 1.54, Total (98.90) wt.% (given as 98.79 wt.%). $\mathrm{H_2O}$ was calculated to give F+OH = 2, the value given for $\mathrm{H_2O}$ in the paper (0.48) gives F+OH = 2.13. Empirical formula: $\mathrm{(Ca_{0.51}Na_{0.34}K_{0.12})_{\Sigma 0.97}(Ca_{1.93}Mn_{0.05}Fe_{0.02})_{\Sigma 2.00}(Mg_{3.79}Al_{0.82}Fe_{0.37}Ti_{0.02})_{\Sigma 5.00}(Si_{5.62}Al_{2.38})_{\Sigma 8.00}O_{22}[F_{1.68}(OH)_{0.32}]_{\Sigma 2.00}}$. ***Relationship to other species:*** It is a member of the amphibole group.

Name: For Dr. Elio Cannillo (1938–), Pavia, Italy, in recognition of his work on the crystal chemistry of rock-forming minerals, particularly pyroxenes and amphiboles. ***Comments:*** IMA No. 93-033. As noted above, some of the data in this abstract were taken from the IMA proposal.

HAWTHORNE, F. C., OBERTI, R., UNGARETTI, L, and GRICE, J. D. (1996) A new hyper-calcic amphibole with Ca at the A site: Fluor-cannilloite from Pargas, Finland. *American Mineralogist* **81**, 995–1002.

Gottardiite

Orthorhombic

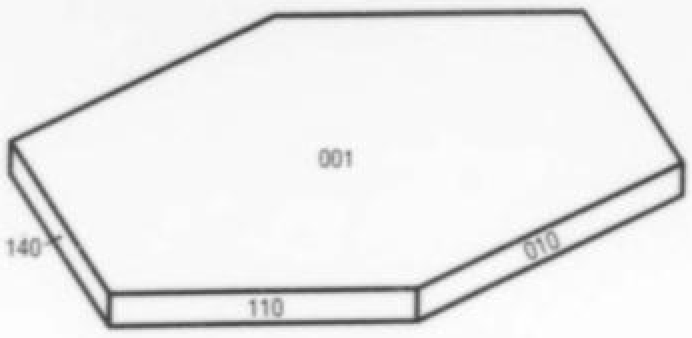
$\mathrm{Na_3Mg_3Ca_5Al_{19}Si_{117}O_{272}\cdot 93H_2O}$

Locality: On the SW crest of Mt. Adamson, just under the summit, Northern Victoria Land, Antarctica (Lat. 73°56′ S, Long. 162°56′ E).

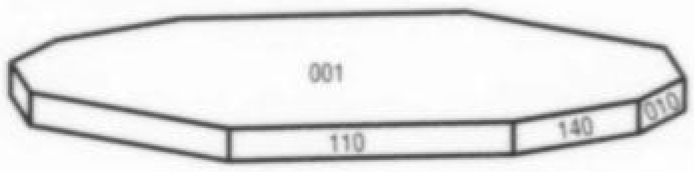
Occurrence: In vesicles in basalts. Associated minerals are: "Fe-smectite," mordenite, heulandite, erionite, phillipsite, stilbite, levyne, epistilbite, tschernichite, boggsite, cowlesite, quartz, cristobalite, apophyllite, gypsum, and calcite.

General appearance: Thin lamellae, pseudo-hexagonal (see comment) or elongated along [100] (up to 0.3 x 0.2 x 0.02 mm). Isolated crystals are rare; more commonly the mineral occurs as subparallel or wedge-shaped aggregates.

Physical, chemical and crystallographic properties: *Luster:* vitreous. *Diaphaneity:* transparent. *Color:* colorless. *Streak:* white. *Luminescence:* non-fluorescent. *Hardness:* could not be determined. *Tenacity:* brittle. *Cleavage:* {001} perfect. *Fracture:* conchoidal to irregular. *Density:* 2.14 g/cm^3 (meas.), 2.16 g/cm^3 (calc.). ***Crystallography:*** Orthorhombic, Cmca, a 13.698, b 25.213, c 22.660 Å, V 7827 Å^3, Z 1, a:b:c = 0.5433:1:0.8987. Morphology: forms, {001}, {010}, {140}, {110} (see comments). Twinning: none observed. ***X-ray powder diffraction data:*** 11.34 (100), 10.64 (31), 4.64 (35), 4.37 (79), 4.01 (57), 3.938 (36), 3.428 (29), 3.282 (68). ***Optical data:*** Biaxial (-), α 1.480, β 1.485, γ 1.486, 2V(meas.) < 60°, 2V(calc.) 48°; dispersion not given; nonpleochroic; orientation, X = b, Y = a, Z = c. ***Chemical analytical data:*** Means of thirteen sets of electron microprobe data: $\mathrm{Na_2O}$ 0.77, $\mathrm{K_2O}$ 0.08, MgO 1.24, CaO 2.67, SrO 0.04, BaO 0.03, $\mathrm{Al_2O_3}$ 9.40, $\mathrm{Fe_2O_3}$ 0.10, $\mathrm{SiO_2}$ 69.23, $\mathrm{H_2O}$ 16.44, Total (100.00) wt.%. $\mathrm{H_2O}$ was determined by TGA. The values of the other constituents were "normalized" (i.e., reduced) to give a sum of 83.56 wt.%; this, with the $\mathrm{H_2O}$ value gives a total of 100.00 wt.%. Empirical formula: $\mathrm{Na_{2.53}K_{0.17}Mg_{3.13}Ca_{4.84}Sr_{0.04}Ba_{0.02}Al_{18.76}Fe_{0.13}Si_{117.23}O_{272.18}\cdot 92.82H_2O}$. ***Relationship to other species:*** A member of the zeolite group.



Gottardiite



Name: For Prof. Glauco Gottardi (1928–1988), Università di Modena, Modena, Italy, in recognition of his pioneering work on the structure and crystal chemistry of natural zeolites. ***Comments:*** IMA No. 94-054. The forms are given in the paper as {001}, {0$\bar{1}$0}, {1$\bar{4}$0}, and {110}. However, {0$\bar{1}$0} and {1$\bar{4}$0} are faces which belong to the forms {010} and {140}, respectively. The crystal drawing given in the paper is not in the standard orientation and shows only some of the faces of each form. Two crystal drawings have been produced for this abstract. The drawing on the left, which approximates the drawing in the paper, represents a crystal with only half of the faces of {110} and {140}; the drawing on the right is an idealized version showing all of the faces. Neither of these crystals can be considered pseudo-hexagonal, although the figure on the left is six-sided; only the angle between the faces (110) and (010) is close to 60° (61.49°), other angles are close to 90° and 25°.

ALBERTI, A., VEZZALINI, G., GALLI, E., and QUARTIERI, S. (1996) The crystal structure of gottardiite, a new natural zeolite. *European Journal of Mineralogy* **8**, 69–75. GALLI, E., QUARTIERI, S., VEZZALINI, G., and ALBERTI, A. (1996) Gottardiite, a new high-silica zeolite from Antarctica: the natural counterpart of synthetic NU-87. *European Journal of Mineralogy* **8**, 687–693.

Jáchymovite

Monoclinic

$\mathrm{(UO_2)_8(SO_4)(OH)_{14}\cdot 13H_2O}$

Locality: The Jáchymov (formerly Joachimsthal) uranium deposit, 20 km NNE of Karlovy Vary, the Krušné hory Mts., Western Bohemia, Czech Republic.

Occurrence: In dolomite-uraninite veins. Associated minerals are: gypsum, uranopilite, and uraninite.

General appearance: Acicular crystals (up to 0.1 mm long) forming crystalline coatings up to "some cm^2."

Physical, chemical and crystallographic properties: *Luster:* vitreous. *Diaphaneity:* translucent. *Color:* yellow. *Streak:* pale yellow. *Luminescence:* fluoresces yellow in UV (254 and 366 nm). *Hardness:* could not be determined. *Tenacity:* brittle. *Cleavage:* {010} very good. *Fracture:* conchoidal. *Density:* could not be determined, 4.79 g/cm^3 (calc.). ***Crystallography:*** Monoclinic, P2$_1$ or P2$_1$/m, a 18.553, b 9.276, c 13.532 Å, β 125.56°, V 1894 Å^3, Z 2, a:b:c = 2.0001:1:1.4588. Morphology: no forms were identified. Twinning: none mentioned. ***X-ray powder diffraction data:*** 7.56 (100), 7.13 (48), 3.771 (34), 3.554 (20), 3.234 (10), 3.206 (13), 2.052 (8). ***Optical data:*** Biaxial (-), α 1.715, β 1.718, γ 1.720, 2V(meas.) not given, 2V(calc.) 78°; dispersion not given; pleochroism Y = pale yellow, Z = yellow; orientation not given. ***Chemical analytical data:*** Means of two sets of wet chemical analytical data: UO_3 84.20, SO_3 2.79, H_2O 13.32, Total 100.31 wt.%. Empirical formula: $(UO_2)_{8.01}(SO_4)_{0.95}(OH)_{14.12}\cdot 13.06H_2O$. ***Relationship to other species:*** It is chemically similar to uranopilite and metauranopilite.

Name: For the locality. ***Comments:*** IMA No. 94-025. The name was given to a hydrated copper uranium silicate in 1935, but this was later discredited as being the same as cuprosklodowskite. Because the name has not been in use for over 50 years, the Commission on New Minerals and Mineral Names of the International Mineralogical Association allowed it to be assigned to this new mineral.

ČEJKA, J., SEJKORA, J., MRÁZEK, Z., URBANEC, Z., and JARCHOVSKÝ (1996) Jáchymovite, $(UO_2)_8(SO_4)(OH)_{14}\cdot 13H_2O$, a new uranyl mineral from Jáchymov, the Krušné hory Mts., Czech Republic, and its comparison with uranopilite. *Neues Jahrbuch für Mineralogie, Abhand–lungen* **170**, 155–170.

Meurigite

Monoclinic

$KFe^{3+}_7(PO_4)_5(OH)_7\cdot 8H_2O$

Locality: The Santa Rita mine, near Silver City in southwestern New Mexico, U.S.A. (Type Locality). Also found at the following three localities: the Hagendorf-Sud pegmatite, Bavaria, Germany; granite pegmatite veins at Wycheproof, Victoria, Australia; and the Gold Quarry mine, northeast Nevada, U.S.A. Most of the data given here are for material from the type locality.

Occurrence: In hematitic fault gouge in the oxidized zone above copper sulfides. Associated minerals are: dufrenite, beraunite, and leucophosphite.

General appearance: Hemispheres and globular aggregates (up to about 2 mm across).

Physical, chemical and crystallographic properties: *Luster:* given as vitreous to waxy, but the indices of refraction indicate it should be adamantine. *Diaphaneity:* translucent. *Color:* yellowish brown. *Streak:* very pale yellow to cream. *Luminescence:* fluorescence not observed. *Hardness:* about 3. *Tenacity:* not given. *Cleavage:* {001} perfect. *Fracture:* not given. *Density:* 2.96 g/cm^3 (meas.), 2.92 g/cm^3 (calc.). ***Crystallography:*** Monoclinic, C2, Cm or C2/m, a 29.52, b 5.294, c 18.26 Å, β 109.27°, V 2672 Å^3, Z 4, a:b:c = 5.6239:1:3.4788. Morphology: forms, only {001} was observed. Twinning: none mentioned. ***X-ray powder diffraction data:*** 9.41 (60), 4.84 (90), 4.32 (70), 4.25 (50), 3.470 (60), 3.216 (100), 3.116 (80). ***Optical data:*** Biaxial (+), α 1.780, β 1.785, γ 1.800, 2V could not be measured, 2V(calc.) 60°; dispersion not given; no pleochroism observed; orientation not given. ***Chemical analytical data:*** Means of five sets of electron microprobe data: Na_2O 0.07, K_2O 3.37, CuO 0.16, Al_2O_3 0.70, Fe_2O_3 47.40, P_2O_5 30.71, As_2O_5 0.03, H_2O 16.20, Total 99.37 wt.%. Empirical formula: $(K_{0.84}Na_{0.03})_{\Sigma 0.87}(Fe^{3+}_{7.01}Al_{0.16}Cu_{0.02})_{\Sigma 7.19}(PO_4)_{5.11}(CO_3)_{0.20}(OH)_{6.69}\cdot 7.27H_2O$. ***Relationship to other species:*** None definite, although there are similarities with kidwellite and phosphofibrite.

Name: For Prof. Sir John *Meurig* Thomas KB FRS (1932–) eminent British crystal chemist at the University of Cambridge. ***Comments:*** IMA No. 95-022.

BIRCH, W. D., PRING, A., SELF, P. G., GIBBS, R. B., KECK, E., JENSEN, M. C., and FOORD, E. E. (1996) Meurigite, a new fibrous iron phosphate resembling kidwellite. *Mineralogical Magazine* **60**, 787–793.

Nafertisite

Monoclinic

$Na_3(Fe^{2+},Fe^{3+})_6(Ti_2Si_{12}O_{34})(O,OH)_7\cdot 2H_2O$

Locality: Mount Kukisvumchorr, SW part of the Khibina massif, Kola Peninsula, Russia.

Occurrence: In a hyperagpaitic pegmatite. Associated minerals are: potassium feldspar, sodalite, aegirine, calcite, ewaldite, eudialyte, mosandrite, and molybdenite.

General appearance: Aggregates (up to 5–10 cm across) of fine fibers (about 10 µm wide).

Physical, chemical and crystallographic properties: *Luster:* vitreous to silky. *Diaphaneity:* translucent. *Color:* light green. *Streak:* white. *Luminescence:* non-fluorescent. *Hardness:* 2 to 3. *Tenacity:* sectile. *Cleavage:* {010} and {001} perfect. *Fracture:* fibrous. *Density:* 2.7 g/cm^3 (meas.), 2.83 g/cm^3 (calc.). ***Crystallography:*** Monoclinic, A2/m, a 5.353, b 16.18, c 21.95 Å, β 94.6°, V 1895 Å^3, Z 2, a:b:c = 0.3308:1:1.3566. Morphology: forms, {001} lamellae elongated parallel to [100]. Twinning: none mentioned. ***X-ray powder diffraction data:*** 13.00 (30), 10.94 (100), 4.44 (15), 2.728 (25), 2.641 (20), 2.547 (15), 2.480 (15). ***Optical data:*** Biaxial (-), α 1.627, β 1.667, γ 1.693, 2V(meas.) 75°, 2V(calc.) 76°; dispersion r < v, medium; pleochroism X = red brown, Y = green, Z = dark green; $X \wedge c$ = 5° (in obtuse angle β), Y = b, Z ≈ a. ***Chemical analytical data:*** Means of five sets of electron microprobe data: Na_2O 4.78, K_2O 1.64, MgO 1.28, MnO 0.79, FeO 21.04, Al_2O_3 1.32, Fe_2O_3 14.53, SiO_2 38.92, TiO_2 8.32, Nb_2O_5 0.33, H_2O 7.85, Total 100.80 wt.%. H_2O was determined by the Penfield method. Empirical formula: $(Na_{2.47}K_{0.56})_{\Sigma 3.03}(Fe^{2+}_{4.68}Fe^{3+}_{1.27}Mg_{0.51}Mn_{0.18})_{\Sigma 6.64}(Ti_{1.67}Al_{0.41}Nb_{0.04})_{\Sigma 2.12}(Si_{10.36}Fe^{3+}_{1.64})_{\Sigma 12.00}O_{31.06}(OH)_{9.94}\cdot 2H_2O$. ***Relationship to other species:*** It is related structurally to bafertisite and astrophyllite.

Name: For the chemical composition (Na-Fe-Ti-Si) and the analogy with bafertisite. ***Comments:*** IMA No. 94-007. This abstract contains some data taken from the original IMA proposal.

KHOMYAKOV, A. P., FERRARIS, G., IVALDI, G., NECHELYUSTOV, G. N., and SOBOLEVA, S. V. (1995) Nafertisite $Na_3(Fe^{2+},Fe^{3+})_6[Ti_2Si_{12}O_{34}](O,OH)_7\cdot 2H_2O$, a new mineral with a new type of banded silicate radical. *Zapiski Vserossuskogo mineralogicheskogo obshchestva* **124(6)**, 101–107.

Penobsquisite

Monoclinic

$Ca_2Fe^{2+}[B_9O_{13}(OH)_6]Cl\cdot 4H_2O$

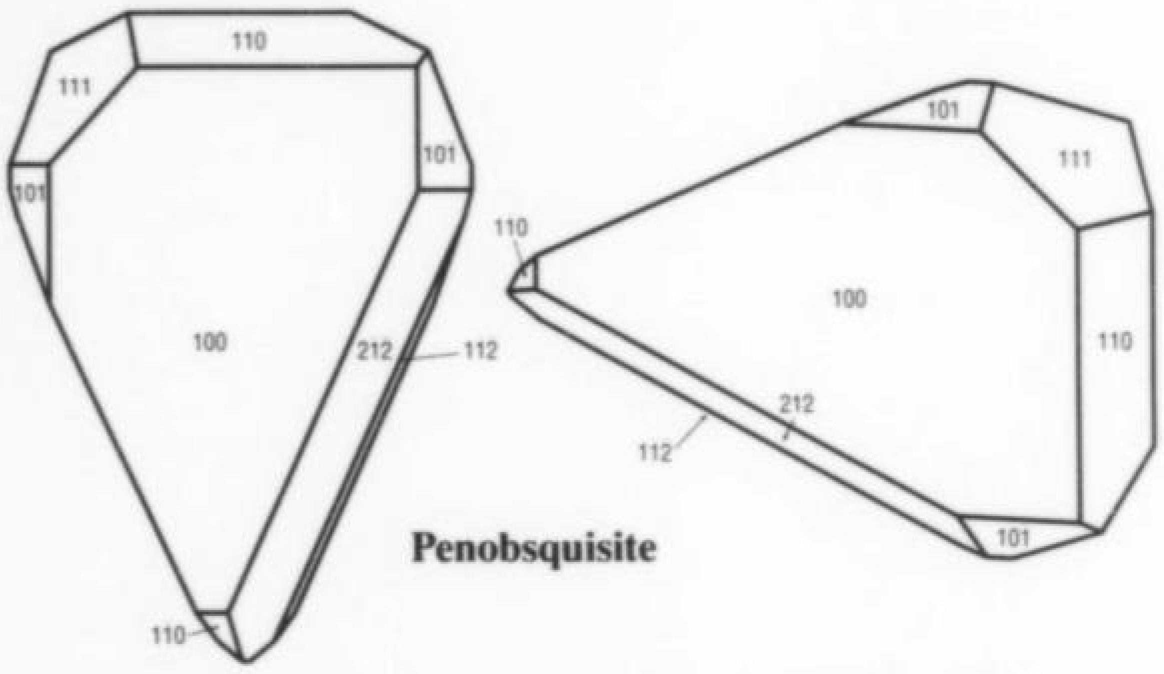
Locality: The mine operated by the Potash Corporation of Saskatchewan (New Brunswick Division), Penobsquis, Cardwell Parish, Kings County, New Brunswick, Canada.

Occurrence: In the lower third of the Upper Halite member in the

Windsor Group. Associated minerals are: halite, boracite, hilgardite, pringleite, trembathite, sellaite, fluorite, hematite, and malachite.

General appearance: Euhedral crystals (0.5 to 1.5 mm).

Physical, chemical and crystallographic properties: *Luster:* vitreous. *Diaphaneity:* transparent to translucent. *Color:* pale yellow. *Streak:* white. *Luminescence:* non-fluorescent. *Hardness:* approximately 3. *Tenacity:* brittle. *Cleavage:* none. *Fracture:* conchoidal. *Density:* 2.26 g/cm^3 (meas.), 2.26 g/cm^3 (calc.).



Penobsquisite

Crystallography: Monoclinic, $P2_1$, a 11.63, b 9.38, c 8.735 Å, β 98.40°, V 942.7 Å^3, Z 2, a:b:c = 1.2399:1:0.9312. Morphology: forms, $\{100\}$, $\{101\}$, $\{10\bar{1}\}$, $\{111\}$, $\{110\}$, $\{1\bar{1}0\}$, $\{2\bar{1}\bar{2}\}$, $\{1\bar{1}\bar{2}\}$. Twinning: none observed. ***X-ray powder diffraction data:*** 8.65 (3), 7.29 (10), 5.32 (2), 4.50 (2), 2.958 (3), 2.744 (2), 2.113 (3). ***Optical data:*** Biaxial (+), α 1.550, β 1.554, γ 1.592, 2V(meas.) 33°, 2V(calc.) 37°; dispersion none; nonpleochroic; Y = b, Z ∧ c = 16.6° (in obtuse angle β). ***Chemical analytical data:*** Means of three sets of electron microprobe data: MgO 1.82, CaO 17.27, MnO 0.23, FeO 7.48, B_2O_3 (48.50), H_2O (19.52), Cl 5.77, sum 100.59, less O = Cl 1.30, Total (99.29) wt.%. H_2O and B_2O_3 were calculated from the crystal structure analysis. Empirical formula: $Ca_{1.99}(Fe^{2+}_{0.67}Mg_{0.29}Mn_{0.02})_{\Sigma 0.98}$-$[B_{9.00}O_{12.95}(OH)_{5.99}]Cl_{1.05}\cdot 4.01H_2O$. ***Relationship to other species:*** None apparent.

Name: For the locality. ***Comments:*** IMA No. 95-014. The crystal drawing in the paper is not in the standard orientation; it is a projection on (100) with [010] vertical and is shown on the left. The crystal in the standard clinographic projection is shown on the right. The forms $\{\bar{2}\bar{1}2\}$ and $\{\bar{1}\bar{1}2\}$ given in the paper have been changed, respectively, to their equivalents, $\{2\bar{1}\bar{2}\}$ and $\{1\bar{1}\bar{2}\}$.

GRICE, J. D., GAULT, R. A., and VAN VELTHUIZEN, J. (1996) Penobsquisite: a new borate mineral with a complex framework structure. *Canadian Mineralogist* **34**, 657–665.

Rosiaite

Hexagonal (trigonal)

$PbSb_2O_6$

Locality: The Cetine di Cotorniano mine, near Rosia, central Tuscany, Italy.

Occurrence: In small cavities in silicified dolomitic limestone. Associated minerals are: valentinite, tripuhyite, bindheimite, and a phase corresponding to synthetic β-Sb_2O_4.

General appearance: Aggregates (up to 2 mm) of crystals (up to 0.3 mm).

Physical, chemical and crystallographic properties: *Luster:* resinous. *Diaphaneity:* transparent. *Color:* colorless to pale yellow. *Streak:* white. *Luminescence:* non-fluorescent. *Hardness:* could not be measured. *Tenacity:* brittle. *Cleavage:* none, but a possible $\{001\}$ parting was observed. *Fracture:* conchoidal. *Density:* could not be measured, 6.96 g/cm^3 (calc.). ***Crystallography:*** Hexagonal (trigonal), $P\bar{3}1m$, a 5.301, c 5.375 Å, V 130.4 Å^3, Z 1, c:a = 1.0140. Morphology: forms, $\{100\}$, $\{101\}$, $\{001\}$, and an unindexed scalenohedron. Twinning: none mentioned. ***X-ray powder diffraction data:*** 3.49 (VS), 2.648 (M), 2.110 (W), 1.887 (W), 1.651 (W), 1.531 (W). ***Optical data:*** Uniaxial (-), ω 2.092, ε 1.920, nonpleochroic. ***Chemical analytical data:*** Means of three sets of electron microprobe data: PbO 40.88, Sb_2O_5 58.67, Total 99.55 wt.%. Empirical formula: $Pb_{1.01}Sb_{2.00}O_{6.00}$. ***Relationship to other species:*** The natural analog of synthetic $PbSb_2O_6$.

Name: For the town of Rosia. ***Comments:*** IMA No. 95-021.

BASSO, R., LUCCHETTI, G., ZEFIRO, L., and PALENZONA, A. (1996) Rosiaite, $PbSb_2O_6$, a new mineral from the Cetine mine, Siena, Italy. *European Journal of Mineralogy* **8**, 487–492.

Smrkovecite

Monoclinic

$Bi_2O(OH)(PO_4)$

Locality: In the old dumps of a small silver-bismuth-arsenic-uranium deposit near Smrkovecý in the Slavkovsky Les Mountains, about 10 km NNE of Mariánské Lázně, Czech Republic.

Occurrence: As a weathering product of bismuth ore segregations in silicified veins. Other secondary minerals found at the locality include: apatite, atelestite, bismutite, bismutoferrite, metatorbernite, eulytite, pucherite, retgersite, petitjeanite, preisingerite, and sillenite.

General appearance: Crusts and small mammillary or spherically shaped aggregates (up to 0.2 mm) of very small intergrown crystals (up to 0.1 mm).

Physical, chemical and crystallographic properties: *Luster:* given as vitreous to adamantine, but the indices of refraction preclude a vitreous luster. *Diaphaneity:* transparent to translucent. *Color:* white to yellow. *Streak:* white. *Luminescence:* non-fluorescent. *Hardness:* 4 to 5. *Tenacity:* brittle. *Cleavage:* $\{010\}$, but given as $\{001\}$ indistinct in the original IMA proposal. *Fracture:* subconchoidal. *Density:* could not be measured, 6.72 g/cm^3 (calc.). ***Crystallography:*** Monoclinic, $P2_1/c$, a 6.954, b 7.494, c 10.869 Å, β 107.00°, V 541.7 Å^3, Z 4, a:b:c = 0.9279:1:1.4504. Morphology: forms, none mentioned. Twinning: present, but not defined. ***X-ray powder diffraction data:*** 4.268 (17), 3.271 (51), 3.254 (100), 3.145 (34), 2.727 (29), 1.885 (16). ***Optical data:*** Biaxial (+), α 2.05, β 2.06, γ 2.09, 2V(meas.) 58°, 2V(calc.) 61°; dispersion r > v, distinct; nonpleochroic; orientation not given. ***Chemical analytical data:*** Means of five sets of electron microprobe data: Bi_2O_3 85.16, SiO_2 0.02, P_2O_5 12.74, As_2O_5 0.17, V_2O_5 0.03, H_2O (1.62) Total (99.74) wt.% (given as 99.77). H_2O was calculated to give one (OH) by analogy with atelestite. Empirical formula: $Bi_{2.01}O_{1.01}(OH)_{0.99}(P_{0.99}As_{0.01})_{\Sigma 1.00}$-$O_{4.00}$. ***Relationship to other species:*** It is the phosphate-dominant analogue of atelestite.

Name: For the locality. ***Comments:*** IMA No. 93-040. Some of the data given in this abstract were taken from the original IMA proposal. The paper contains a number of typographic or editorial errors: the calculated density is given as 4.75 g/cm^3 in the abstract and 2.45 g/cm^3 in the text (the correct value, 6.72 g/cm^3, is given above); the a:b:c ratio is given as 1.235:1:3.352 instead of 0.9279:1:1.4504; the cleavage is noted as indistinct on $\{001\}$ in the abstract, but in the text it is given as $\{010\}$ with no mention of perfection; hardness is given as 4–5 in the abstract but is not mentioned in the text. Two letters to Dr. Řídkošil failed to elicit clarification of these problems.

ŘÍDKOŠIL, T., SEJKORA, J., and ŠREIN, VL. (1996) Smrkovecite, monoclinic $Bi_2O(OH)(PO_4)$, a new mineral of the atelestite group. *Neues Jahrbuch für Mineralogie, Monatshefte* **1996**, 97–102.

Wesselsite — Tetragonal

$SrCu^{2+}(Si_4O_{10})$

Locality: The central-eastern ore body of the Wessels mine, northwest of Kuruman Hill, Kalahari manganese field, northwestern Cape Province, Republic of South Africa.

Occurrence: Associated minerals are: sugilite, xonotlite, quartz, pectolite, and hennomartinite.

General appearance: Subhedral plates (up to 50 x 50 x 5 µm) in clusters with diameters up to 200 µm.

Physical, chemical and crystallographic properties: *Luster:* vitreous. *Diaphaneity:* transparent. *Color:* blue. *Streak:* white to light blue. *Luminescence:* non-fluorescent. *Hardness:* could not be determined. *Tenacity:* brittle. *Cleavage:* {001} perfect. *Fracture:* not observed. *Density:* 3.2 g/cm³ (meas.), 3.32 g/cm³ (calc.). ***Crystallography:*** Tetragonal, P4/ncc, a 7.366, c 15.574 Å, V 845.01 Å³, Z 4, c:a = 2.1143. Morphology: no forms were observed. Twinning: none observed. ***X-ray powder diffraction data:*** 7.79 (35), 3.444 (40), 3.330 (100), 3.119 (55), 3.033 (50), 2.605 (30), 2.322 (30). ***Optical data:*** Uniaxial (-), ω 1.630, ε 1.590, strong pleochroism O = blue, E = pale blue to pale pink. ***Chemical analytical data:*** Means of three sets of EDX analyses carried out on a scanning electron microprobe gave the following data: CuO 18.8, SrO 24.0, SiO_2 56.9, Total 99.7 wt.%. Empirical formula: $Sr_{0.98}Cu_{1.00}Si_{4.01}O_{10.00}$. ***Relationship to other species:*** A member of the gillespite group; specifically, the strontium-dominant analog of cuprorivaite and effenbergerite.

Name: For the name of the mine, which was named for Hendrik Wessels (1875–1941). ***Comments:*** IMA No. 94-055. The authors point out that the trade-name "wesselite" exists for a purple variety of sugilite.

GIESTER, G. and RIECK, B. (1996) Wesselsite, $SrCu[Si_4O_{10}]$, a further new gillespite-group mineral from the Kalahari Manganese Field, South Africa. *Mineralogical Magazine* **60**, 795–798.

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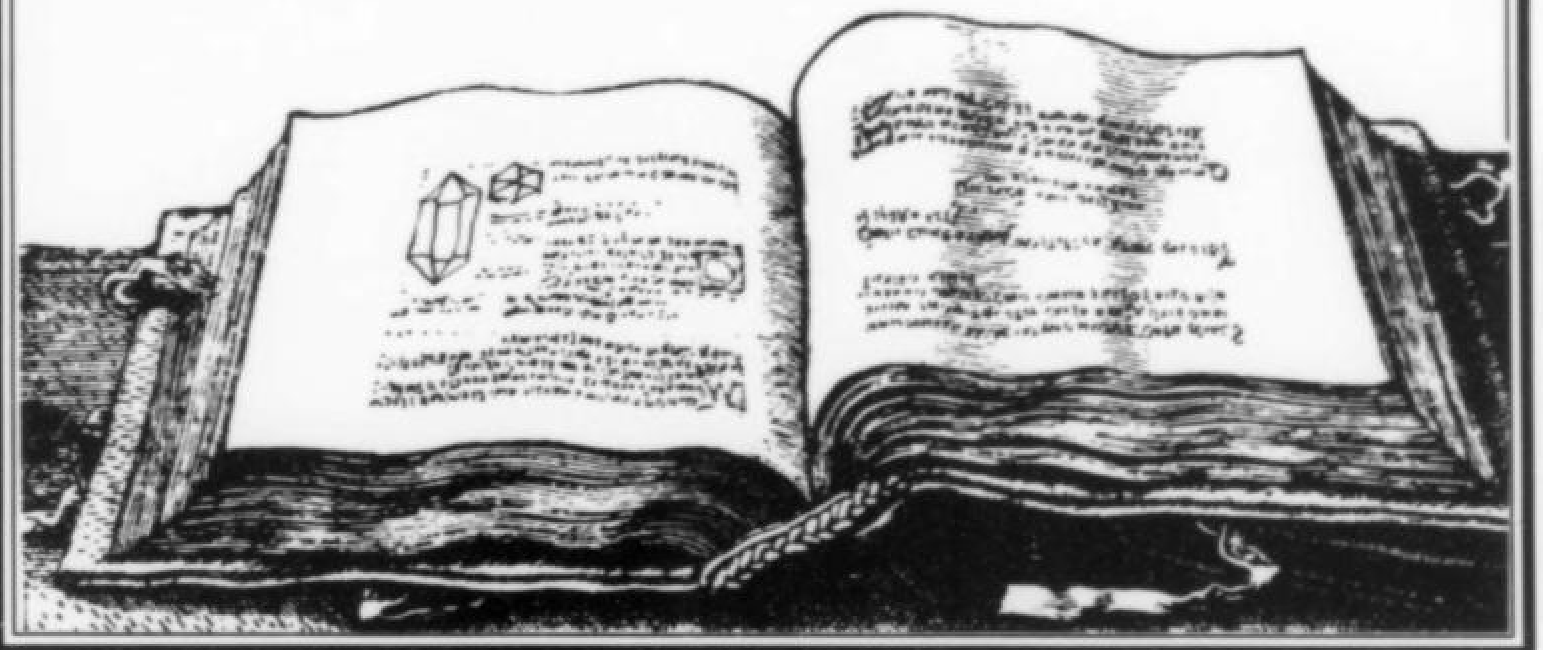
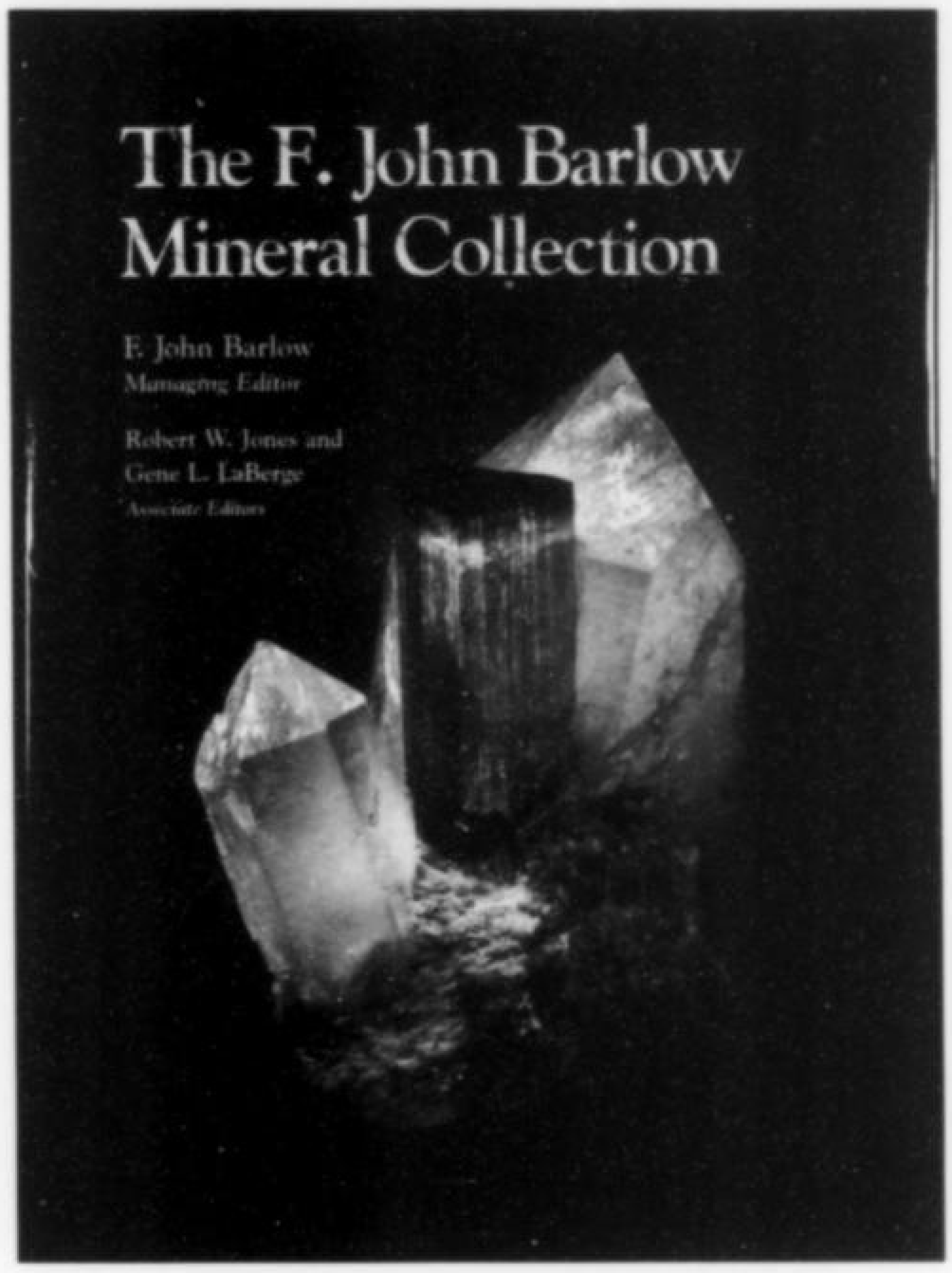
Book Reviews





The F. John Barlow Mineral Collection

F. John Barlow
Managing Editor

Robert W. Jones and
Gene L. LaBerge
Associate Editors

The F. John Barlow Mineral Collection

by F. John Barlow, Robert W. Jones and Gene L. LaBerge (editors), with additional text by Joel A. Bartsch, Martin V. Jensen, Peter J. Juneau, Charles L. Key, Vandall T. King, Peter K. M. Megaw, Bill Smith, Richard W. Thomssen, Terry C. Wallace, David P. Wilber and Marc L. Wilson. Published (1996) by Sanco Publishing, P.O. Box 177, Appleton, WI 54912-0177. Hardcover, 9 x 12 inches, 408 pages, 570 color photos by various photographers; price: clothbound edition $170 + $6 shipping in the U.S.; signed and numbered leatherbound limited edition (500 copies) $250 + $6 shipping in the U.S., ISBN: 0-9653510-0-9.

Here is a book with the rare capacity to reduce the vocabulary of otherwise jaded and articulate mineral folk to a single word: "Wow!" As a reviewer I had to set this book aside after the first page-through and let the enormity of the accomplishment sink in. (And as a mineral collector, it took me a few minutes to stop hyperventilating anyway.)

This book is basically a documentation of the best specimens in the mineral collection of F. John Barlow, an Appleton, Wisconsin, businessman. That's a simple enough statement, but it requires qualification in two important ways: The Barlow collection is among the finest private mineral collections *ever assembled* in America, and this book, with 570 color photographs, is the finest documentation of a mineral collection ever published.

Conceived, designed, organized and published entirely by Barlow himself, the book is telling in its own right (minerals aside), as the product of a truly extraordinary person. I have known John since shortly after he began collecting over 25 years ago. He was a high-energy entrepreneur then, the founder and owner of several successful corporations, and so bursting with energy that he needed hobbies as intense as his business life. For some years previous he had been an active (and, naturally, very successful) big-game hunter, but as that sport gradually became less socially acceptable, he decided to switch to hunting of a different kind. He turned to the pursuit of world-class mineral specimens, and brought to bear the full intensity of his energy and tight focus.

Within a mere four years, Barlow progressed from rank beginner, knowing virtually nothing of mineralogy and the mineral market, to a sophisticated top-rank collector with plenty of moxie and a fine connoisseur's eye for aesthetics and rarity. He became a regular fixture at mineral shows in America and Europe, and was always on the lookout for new contacts as close to the sources as possible. With the financial resources to capitalize on opportunities, and a businessman's knack for reselling acquisitions as they were upgraded, he built an amazing collection of such size and depth that really no one (until now) was fully aware of its true extent and significance. Pegged as a collector of showy aesthetic specimens by many (thanks in part to his fabulous exhibits of a few chosen specimens at the Tucson Shows over the years), he was also a shrewd species collector in special areas such as silver-containing minerals. In fact, he indulged his interests in a number of specialties, each sub-collection being given a chapter in his book.

The book is divided into six major sections consisting of a total of 18 chapters. A different author having special knowledge of each chapter's subject was commissioned to write the text, so that each chapter is not just a documentation but an authoritative review and analysis.

Chapter 1 is an interesting essay by Bob

Jones on "The Collector Instinct," leading directly into a formal biography of Barlow in Chapter 2, written by Gene LaBerge. Here you really get to know the man, and can't help liking him just for his sheer energy (which, by the way, is still undiminished at the age of 82!).

Part II begins the real description of the 5,000-specimen collection with a chapter on the "Worldwide Classics" by Dave Wilber and Joel Bartsch. Each major piece is shown in a superb, high-quality color photograph accompanied by a discussion ranging in length from a long paragraph to more than half a page. One hundred and four world-class specimens are illustrated in this chapter alone, and the exposition has barely gotten started! These were just a few highlights to whet the appetite.

Part III on "The Gem Crystal Species" begins with Chapter 4 on "Tourmaline" by Vandall King; introductory text covers Barlow's involvement at the Tourmaline Queen mine, his reconstructed pocket, and the famous "Postage Stamp Tourmaline" (which graces the front cover of the dust jacket). Seventy-seven exquisite tourmalines are then described—with 31 shown in color photographs—from localities in California, Afghanistan, Brazil, China, Mozambique, Namibia, Nepal, Nigeria, Pakistan, Russia, Madagascar, South Dakota, Connecticut and Maine.

Chapter 5 covers "Beryl and Pegmatite Minerals" (also written by King), with 35 illustrated in color. Chapter 6 (written by Barlow and Peter Juneau) covers a mix of gemstone species and non-gem rare minerals. The selection of specimens here is conceptually a little awkward, but who cares? We get to see Barlow's collection of uncut diamond crystals, a fabulous purple creedite from Mexico, a gemmy red-orange bustamite on matrix from Broken Hill (Australia), a wonderful Cornish torbernite, a rare crystallized stannite from Bolivia, and many other treasures (52 of them shown in full color, including a few faceted stones).

Part IV covers the native elements, beginning with "Gold" (Chapter 7) by Richard Thomssen. A few pages of interesting introductory text lead right into a truly stunning collection of worldwide gold specimens and artifacts, 77 of them shown in color. It is difficult to find words to characterize this gold suite in a brief review, but it probably surpasses the holdings of most major museums in the world. Chapter 8 on platinum and the other native metals is almost as impressive, covering 27 specimens of platinum minerals (21 shown in color) plus rare crystal specimens of native antimony, bismuth, lead and tellurium.

Chapter 9 on "Silver" (by Terry Wallace and Bob Jones) covers another of Barlow's favorite specialties; 46 superb native silvers are pictured in color, from all of the famous localities worldwide. At the end is a tally list of the 125 known silver-containing species, of which 113 are represented in the Barlow collection. Many of these rarer minerals are shown in the following chapter on "Gold- and Silver-bearing Minerals," with text by prominent species collector Bill Smith. Fifty-six specimens are pictured, including beautiful nagyagite, superbly twinned acanthite, bright aguilarite, big crystal clusters of argyrodite, wonderful boleite and cumengeite, an extraordinary Australian chlorargyrite, ruby-red proustite, big and lustrous pyrargyrite and stephanite, great sternbergite crystals groups . . . well, you get the idea.

Chapter 11 on "Copper" was written by Carnegie curator (and Michigan expert) Marc L. Wilson, with photos of over 30 fine specimens, mostly from Michigan but also from Namibia, Arizona, Nevada, Zambia and Zaire. Included is a startling specimen of bright magenta-colored cobaltian calcite crystals on big copper crystals from Zaire.

Part V approaches the other various subcollections geographically, beginning with Chapter 12 on "Africa" (by Charles L. Key). Here, of course, there are pages upon pages of beautiful Tsumeb specimens (including a unique crocoite-red cerussite and an extremely rare and beautiful legrandite crystal group), Kalahari rhodochrosites, Touissit anglesite, Nigerian beryl, Madagascar betafite and orthoclase, Onganja copper, Zaire cuprite, Moroccan erythrite, and many others. The Moroccan paralaurionite (world's finest example of the species, in crystals to 6 cm!), a Madagascar zircon resembling a Red Cloud wulfenite, and several superb tanzanite crystals on matrix are show-stoppers.

Chapter 13 on "Mexico," by Peter Megaw, opens with some pages of background on Mexican mining and on Barlow's activities in Mexico, followed by discussions of some of the most famous Mexican mineral localities. Then we get into the specimens themselves. As an example of the abundance in the collection, there are 46 Mapimi adamite specimens (most of them purple or purple and yellow), of which only five could be pictured. The wonderful legrandites, ludlamites, vivianite, purple creedites, rhodochrosites, azurites, amethysts, topaz and other species are a pleasure to see (oddly enough, no wulfenite here, or anywhere else in the book).

An entire chapter is devoted to the red beryl locality in Utah (Chapter 14) and to the phosphates of the Tip Top mine in South Dakota (Chapter 15, written by Martin Jensen). Red beryl has been one of Barlow's long-time favorites, and he tells the story in his own words. The 11 specimens shown, most of them big, doubly terminated crystals over an inch long, surely represent the finest suite in any collection. The Tip Top specimens are a surprise, but Barlow had managed to have a contact at the mine who sold him many of the best specimens as they came out in the early 1980's.

Finally there is Barlow's "Wisconsin Collection" (Chapter 16, by Gene LaBerge), including especially a substantial suite of the fantastic blue chalcocites from the Flambeau mine. Here again, Barlow had developed contacts at the source and acquired many major pieces (15 are pictured!) before anyone else saw them. Also prominent are his Montreal mine specimens (barites, goethites, manganocalcites, hematites, manganite, psilomelane, rhodochrosite) and a miscellany of other Wisconsin pieces including a superb millerite spray from Milwaukee.

The book concludes with more interesting reminiscences on collecting, philosophy, special experiences and the process of selling one's own specimens (by Barlow), and an amusing little dream-based fantasy piece at the end to justify the inclusion of seven more beautiful specimen photos on no particular theme. A two-page index of species follows the final chapter.

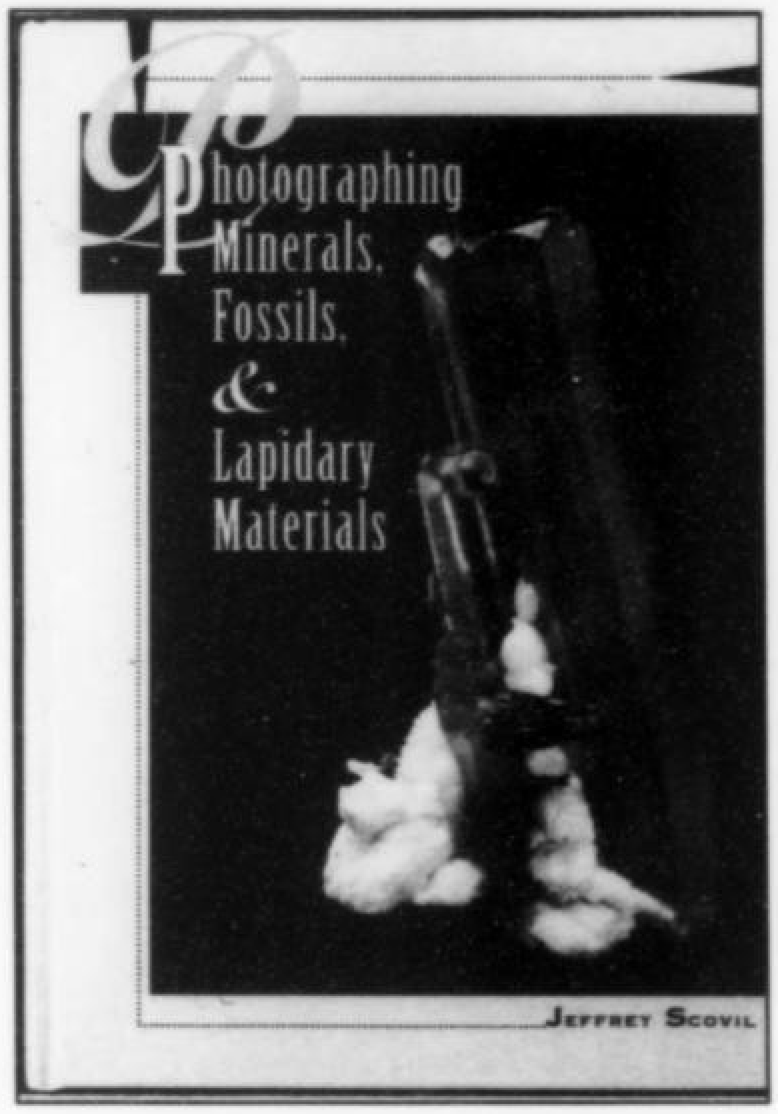
What started years ago as an idea for an article in the *Mineralogical Record* on Barlow's collection grew steadily into this phenomenal book, an important piece of our mineral culture. Being in publishing, I know what this involved, and the accomplishment is remarkable. We should all be grateful that Barlow has put down in this book so many fascinating things for us to see and read. Yes, $170 is a lot of money, but a normal publisher would have had to charge even more for such a lavish book targeted at such a relatively small audience. Be happy. Pay the man his money; you won't regret it.

W.E.W.

Photographing Minerals, Fossils and Lapidary Materials

by Jeffrey Scovil. Published (1996) by Geoscience Press and distributed by Mountain Press Publishing Company, P.O. Box 2399, Missoula, MT 59806. Hardcover only, 7 x 10 inches, 224 pages with 44 color photos. Price: $40 plus $3 shipping in the U.S., ISBN: 0-945005-21-0.

Jeff Scovil's photography is well-known to readers of the *Mineralogical Record*; as an associate photographer he has contrib-



uted many exciting cover photos and probably hundreds of specimen photos published with articles and show reports. He is one of a handful of photographers internationally who have spent years polishing the special skills necessary to master mineral and gem photography. Here at last he presents an accounting of some of the arcane knowledge and personal techniques which he and other masters have accumulated to deal with their beautiful but often difficult subject.

The book is divided into 19 chapters which cover everything the beginning to intermediate photographer might want to know. Discussions of aesthetics, orientation and background materials are followed by advice on preparation and handling, specimen supports, cameras and lenses, medium- and large-format photography, film types, light sources, lighting techniques and applications, metering, filters, magnification and photomicrography, stereophotography and fluorescence photography. There are also chapters on the special problems associated with photographing fossils and lapidary items, with traveling to do photography, and with improving your slide presentations. Appendices listing a variety of gadgets, gizmos and supply sources are followed by a glossary, a bibliography and an index.

Scovil has produced a very useful and comprehensible guide, well illustrated with clear diagrams and examples of good photographic technique, which should give anyone the information they need to learn mineral photography and refine their personal style. This is not a master-level text in subtleties (which would have doubled the size of the book!), but rather a good, basic text designed to serve as the core of one's education in the subject.

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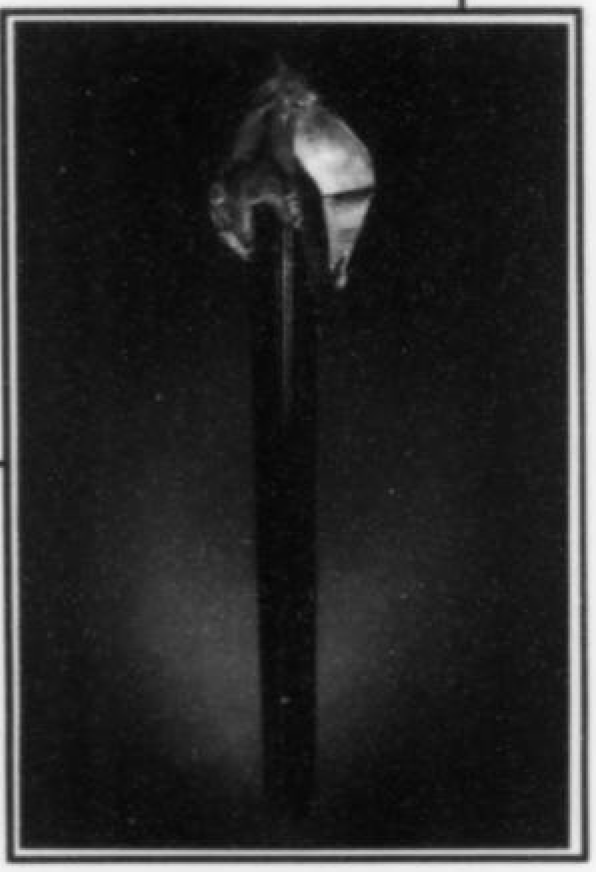

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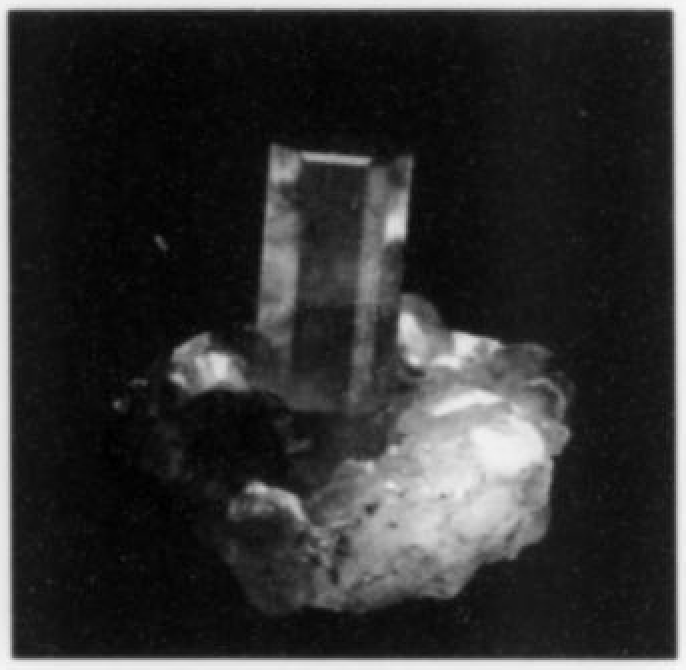

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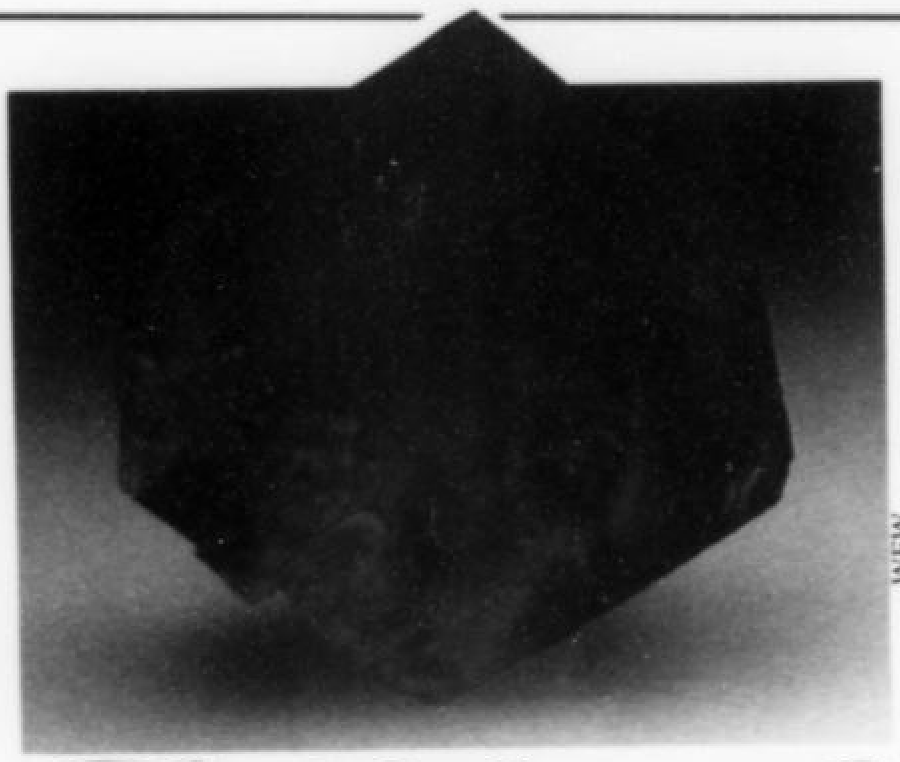

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Letters

SPURIOUS SPECIFICITY

Recently I have twice encountered a particularly egregious form of mineralogical pedantry.

(1) I asked my favorite photographer to take a picture of a green herderite from Pakistan. The slide was returned to me, carefully labeled (as is his custom) but captioned "Hydroxylherderite." I doubt that my friend had determined the relative proportions of OH versus F, and I also doubt that this determination has been published for any Pakistani herderite/hydroxylherderite. My friend has used this spurious specificity because it has become a mineralogical habit, prompted by the great finds of hydroxylherderite in Brazil.

(2) We recently submitted a competitive display of miniatures that contained an apophyllite from Centreville, Virginia. Two points were deducted from the score for "improper labeling," with the note that the specimen should have been labeled "fluorapophyllite." The reason that we did not label the specimen so was because both fluorapophyllite and hydroxylapophyllite are found at this locality, frequently in the same crystal (Dunn and Wilson, 1978, *Mineralogical Record*, vol. 9, p. 95–98). By this application of the rules, one could not competitively display an apophyllite from this locality unless it had first been destroyed for wet chemical analysis.

The point of this letter is not to pick a fight with my photographer, nor embarrass my judges, but to squelch this trend toward spurious precision. In an effort to force displays to conform to Fleischer, the term "apatite" is disappearing, to be replaced by "fluorapatite." But I have in my collection entirely valid specimens of chlorapatite and hydroxylapatite. Suddenly a new find of apatites is located in China, or Tadjikistan, or Afghanistan, and they are promptly labeled "fluorapatites"; what is the basis for the speedy certitude?

Dunn and Wilson said "The IMA Commission ruling clearly states that all unknown material should be called apophyllite." Let's bring this common sense approach to other group names. It's okay to call that platy feldspar in the pegmatitic pocket "albite," as opposed to "plagioclase," since innumerable analyses have shown that the cleavelandite variety is indeed albite. And transparent green olivine is almost surely on the Mg side of the forsterite/fayalite divide. But there are plenty of huebnerites and ferberites that would be more safely labeled by the good old name of wolframite. The boundary between elbaite and liddicoatite is notoriously resistant to sight determination; is it a sin to call a specimen near that boundary a tourmaline?

Bill Smith
Broomfield, Colorado

Your point is well taken, although there was indeed an analysis published for a Pakistani hydroxylherderite (Mineralogical Record, *vol. 16, no. 5, p. 406). Of course, a single analysis is slim evidence on which to name every crystal from an occurrence (or country!) but people will often use it as the only existing precedent until disproved by more comprehensive analysis. For one's own records it would be smarter to withhold judgment, though collectors hate having incompletely identified specimens, and are often more comfortable making a guess, however poorly substantiated.*

For formal competition the rules usually specify that a specimen must be identified down to species (not group). So even if you won the argument on protest that your specimen could not reliably be called "fluorapophyllite," you might still lose the two points for not having a precisely identified specimen. You need to see exactly how your federation's rules are phrased, and lobby for a change if necessary. In any case, it is always wise to check with a local or regional federation official about problematic specimens before *the show in which you will compete, and get verbal approval or advice which could be cited later if judges try to penalize you. You are quite correct that making a baseless guess which could easily be wrong is bad science. Ed.*

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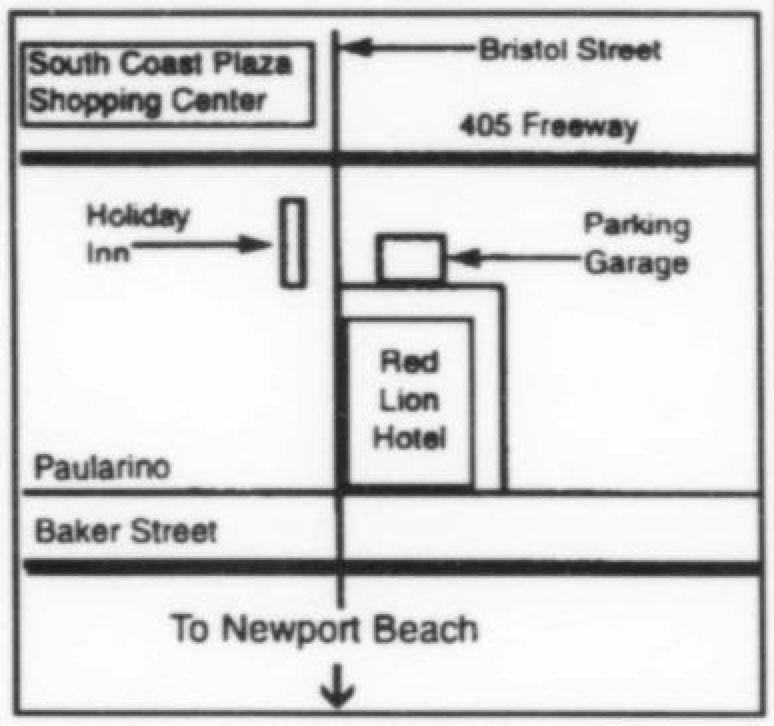

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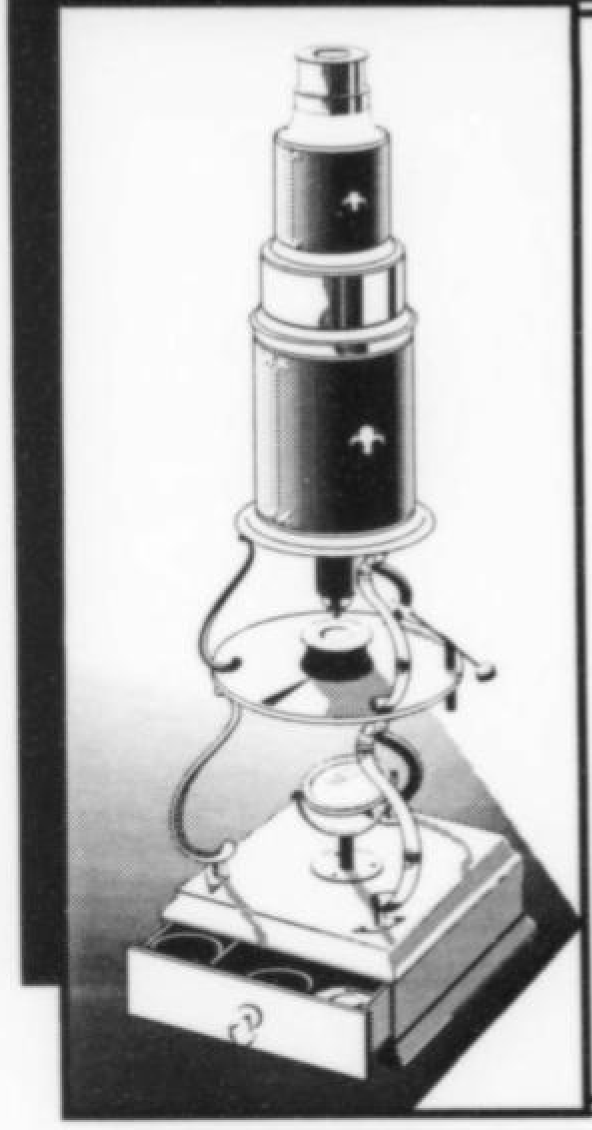

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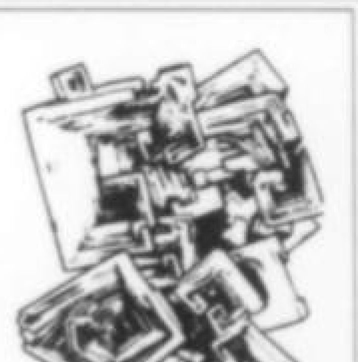

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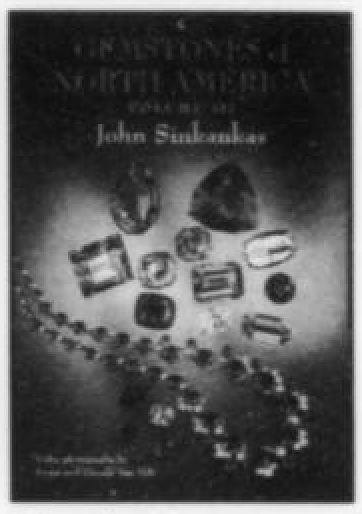

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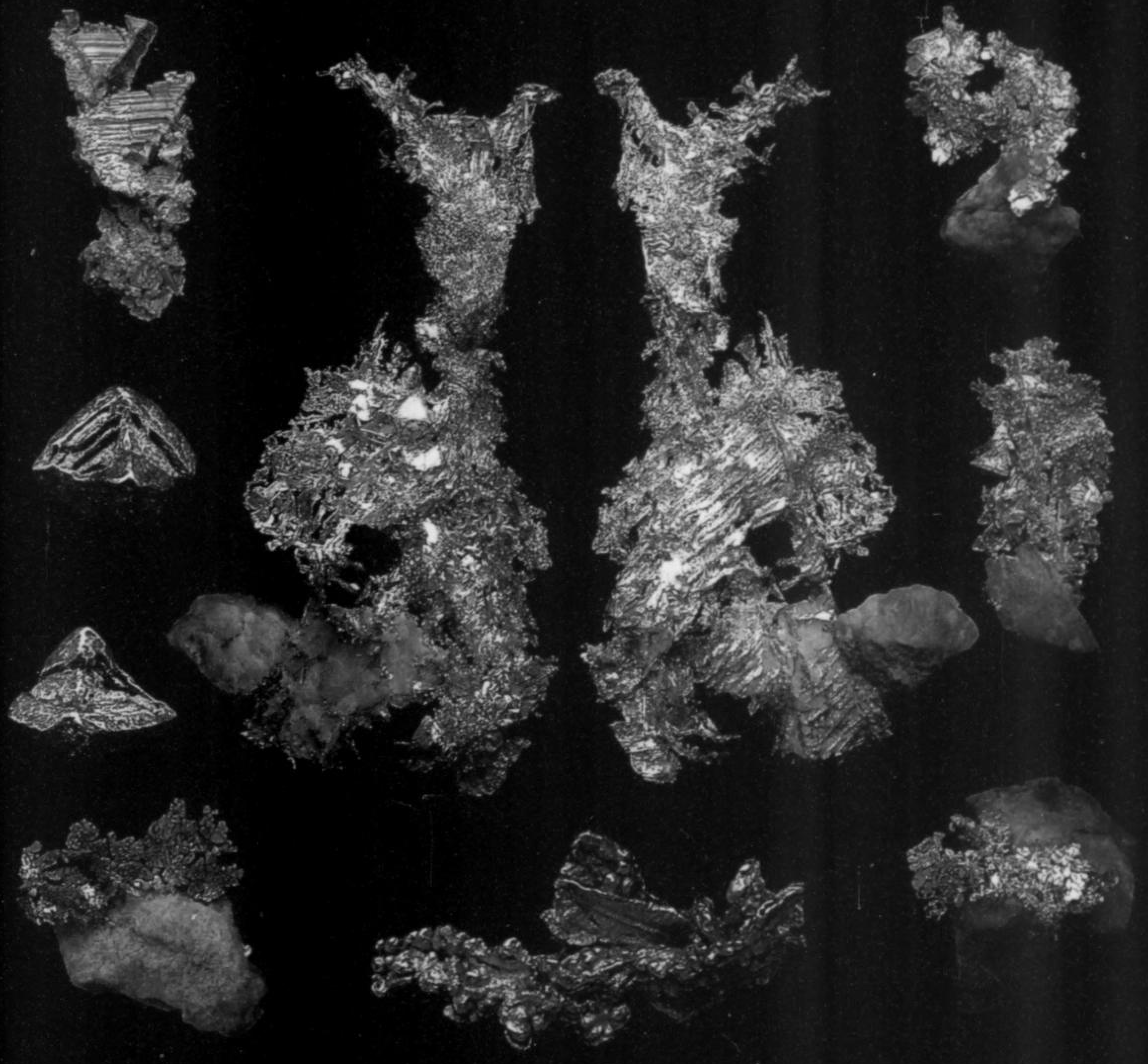

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