the Mineralogical Record

Volume Twenty, Number Two
March–April 1989
$8.50

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THE TOURMALINE

the Mineralogical Record

March–April 1989
Volume Twenty, Number Two

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

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Subscriptions
- **Individuals (U.S.):** $30 for one year; $58 for two years. (First-class mailing available; write to circulation manager for rates.)
- **Individuals (outside the U.S.):** $33 for one year, $64 for two years. (Airmail mailing available; write to circulation manager for rates.)
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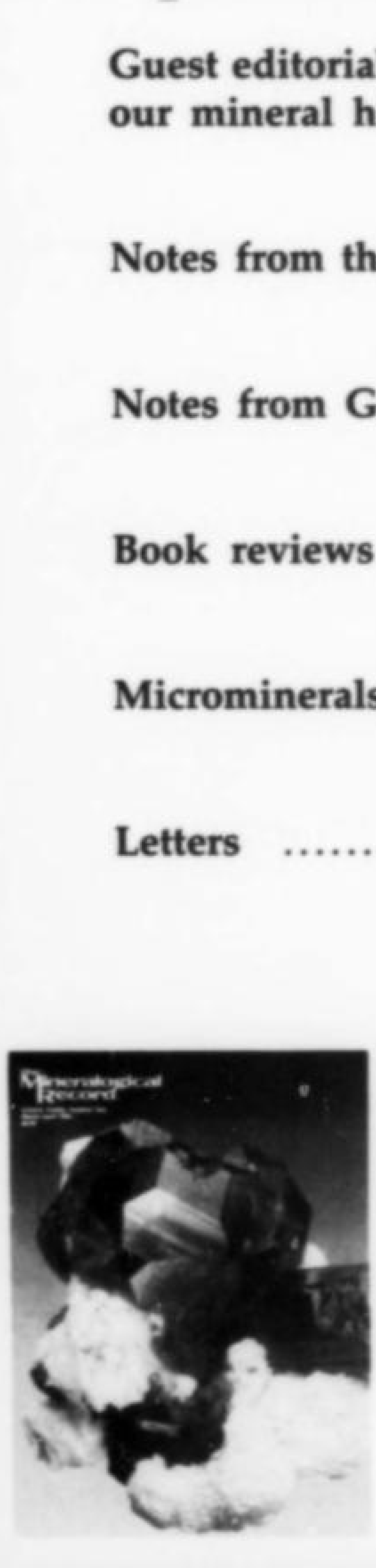

COVER: SPESSARTINE, a fine unetched crystal (4 cm) associated with albite and schorl from the Hercules-Spessartine dike, Little Three mine, San Diego County, California. Los Angeles County Museum of Natural History specimen; photo by Donald Meyer L.A.C.M.N.H. See the article beginning on page 101 of this issue.

Guest Editorial:

PRESERVING AND UTILIZING OUR MINERALOGICAL HERITAGE

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In recent decades the science of mineralogy has gradually been allowing its rich heritage of practical technique to slip away. New students are not being taught old and useful techniques along with new ones; they view their education as more complete than it really is and could be.

A quality education is one of the most important things that anyone can receive. But, a good education is not automatic; it requires effort on the part of both teacher and student. In the field of geology as well as mineralogy, there have been sweeping changes and advancements in the last 25 years or so. Many new instrumental techniques have been introduced to all scientific disciplines. Mineralogy has also been greatly influenced by the advent of the "computer age." Most, but not all, of the new influences have been beneficial. Minerals can now be more completely studied than ever before. EPR (electron paramagnetic resonance), EPSR (electron paramagnetic spin resonance), HRTEM (high-resolution transmission electron microscopy), SIMS (secondary ion mass spectroscopy), ESCA (electron spectroscopy for chemical analysis), EXAFS (extended X-ray absorption fine structure), AES (Auger electron spectroscopy), neutron-diffraction, Rietveld analysis and others are only some of the techniques which have been introduced and applied. Crystal structure determinations, which used to be difficult and time-consuming, and sometimes satisfied the thesis requirements for a Ph.D. degree in crystallography-mineralogy, are now quickly and often easily done. Mastering these new techniques is no small task, and the high level of sophistication tends to make the older, simpler techniques seem archaic by comparison.

The advent of computers has been a bane as well as a boon. Many students today would be lost without either a hand calculator or a PC (personal computer) to do mathematical computations or a data-bank search. There is no question that the speed and ease of calculation are wonderful but not everyone understands how the answer is arrived at. One has a better perspective of the problem and appreciation of possible sources of error if he or she understands fully the path from A to B. A very simple example is the execution of the square root of a number. An increasing number of people have no idea how to do it by hand. You may not always have your PC handy, or your calculator batteries may go dead, and then you are helpless to do that operation unless you have a textbook handy. A mineralogical example is that of crystal drawing. Several commercially available computer programs (e.g., SHAPE) exist for generating crystal drawings from different perspectives. While these programs work well, the user should (if possible) understand how a crystal drawing projection is made. Computer programs may also have 'bugs' in them, resulting in erroneous answers. I have reviewed several papers for professional journals and found errors of various sorts which appear to have been computer generated and that were uncritically accepted.

To complicate the situation even further, we now live in a "use and throw away society." Turnover of equipment is rapid. This is somewhat unavoidable because of the continuing improvement and new developments that constantly are being made. Nevertheless, it causes mineralogists and educators to become ever more preoccupied with keeping abreast of the newest, most sophisticated techniques, and they have less time to devote to perpetuating the older though still very useful approaches.

The increasing emphasis on exotic technology and highly specialized studies has caused many mineralogists to devote less time to field collecting and study of hand specimens. Many mineralogists today are not proficient at sight identifications. This is most unfortunate. One should know how to identify a large number of minerals from hand specimen only. Granted, it takes years of work and the handling of thousands of different specimens to become proficient. But this is a worthy goal and one to be strived for. If you are good at identifying minerals in hand specimen, you save yourself all kinds of work later on. You may be able to make an important decision on the spot or be able to help someone immediately.

One of the most distressing things that I see happening more and more is the identification of unknown minerals by expensive equipment first rather than later. If a mineral cannot be identified with a high degree of certainty by visual inspection using either the naked eye, a hand-lens, or a binocular microscope, then it should be examined under a petrographic microscope (if it is a non-opaque mineral). No sample preparation other than making crushed fragments is necessary. Many people however, immediately go to X-ray diffraction, SEM (scanning electron microscope) with EDS, or electron microprobe techniques. I agree that in many cases XRD or electron probe methods will give a definitive identification. However, in many other cases, even they will not do so. XRD patterns of minerals in the same group are frequently similar and careful work is necessary to determine which species is being examined. On the other hand, some mineral families (e.g., amphiboles) are very difficult to sort out at the species level by optical methods but can be identified by chemical means. A knowledge of all available identification techniques is essential as well as the knowledge of when to use each technique.

Classical techniques of mineralogy such as blow-pipe, flame-tests, morphological crystallography, and crystal drawing are rarely or no longer taught. Blow-pipe and flame-test analyses have been replaced by EDS (energy-dispersive spectrometry), NAA (neutron activation analysis), WDS (wavelength-dispersive spectrometry) and other techniques. Wet chemical analytical methods have been replaced by ion- and electron-microprobe, XRF (X-ray fluorescence), and others. The Penfield method of determining water has been replaced by micro-coulometric moisture analysis. There is no question that we have the capability of making better and more complete chemical analyses of minerals than we did in the past. However, some classical analytical methods, such as those for FeO-Fe_2O_3 and MnO-Mn_2O_3 differentiation, must still be used in many cases. Modern instrumentation is generally extremely expensive and only major universities, corporations and government agencies can afford to purchase and maintain such equipment. Where does that leave everyone else who is also interested in mineralogy? They, fortunately, still have access to the simple classical techniques, if they have managed to learn them. The classical techniques should be at least touched upon briefly to give students some background in their mineralogical heritage.

Morphological crystallography and crystal drawing are in the process of becoming a lost art. Part of the description of a new mineral, if the crystals are large enough for morphological studies, should be the determination of the forms present, degree of development, and their abundances. New forms on presently known minerals should also be described. Morphological data are now being obtained principally by SEM techniques. Studies, such as those by Ivan Kostov (1968, *Mineralogy*, Oliver and Boyd, Edinburgh and London, 587 pp.), of the relationship between morphology and conditions of formation should be continued and elaborated upon.

Optical crystallography, while still a very much-used and respected part of mineralogy as a whole, is not being taught at some schools as commonly or in as great a detail as in the past. Identification of a mineral by optical methods is one of the most powerful and simple tools that we have. A non-opaque mineral can usually be identified in a matter of minutes by a skilled microscopist. At least all but a handful of possibilities will be readily eliminated.

A true and useful appreciation for historical approaches must extend beyond one's college training. There are a great many things not listed in books that need to be learned by actual doing or by observation (being shown by another person). When a mineralogist or geologist completes his formal education (particularly at the graduate level), and obtains employment, he or she in many cases begins work on an independent level or a minimally supervised level. Employers assume that graduate school has prepared their new employees for independent work. as is probably true in many cases. If the student is particularly capable and his/her education has been reasonably complete, then there will be a minimum of problems, but this certainly is not always true. In many cases, mineralogical training is now so narrow and specialized that a conscious effort must be made to broaden one's knowledge of the field. Consequently, working with or under an "old master" is more often than not an extremely rewarding process for both parties. It makes possible the orderly transfer of knowledge from one generation to another.

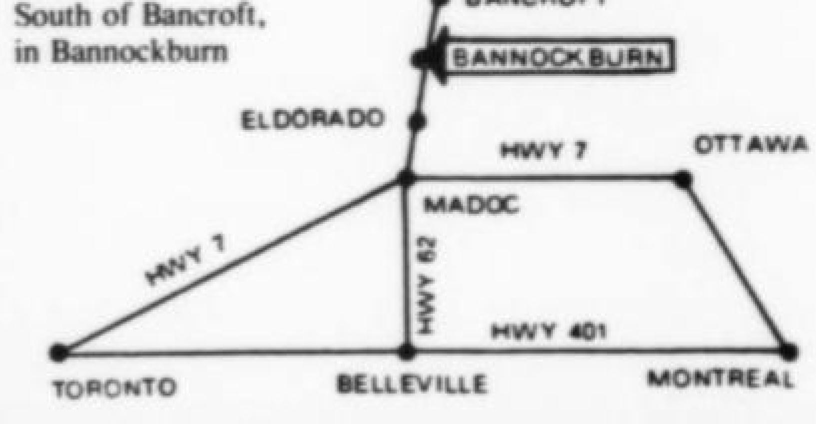
Until recently, the USGS had an unofficial apprenticeship program for its new geologists. One might be in such a program for several years or only one year. One such geologist I know was hired from a major eastern college and assigned to work in one of the western states with one of the best geologists on the Survey. He initially balked and said, "I have my Ph.D. degree; I have been teaching for a number of years, and should be doing independent fieldwork and evaluation." After one summer with the "old master," he came back from the field and said "I didn't realize how much I didn't know." I consider myself very fortunate to have had the opportunity to work under some excellent field geologists and hope that when I retire I will know half as much as they do. It is unfortunate that the apprenticeship program appears to be dying out. However, those people who initially realize what they do not know and seek help from an experienced "oldtimer" will still be able to benefit.

Just as the experience of our senior scientists is a major and vital resource, so are their archival materials and specimen collections. These need to be conserved and maintained for future generations. All too often, upon the retirement or death of a mineralogist or geologist, all or much of his/her research materials are discarded. In many cases, these materials are irreplaceable.

A certain eminent mineralogist, who had more than 60 years of government service before he died, asked to be allowed to teach a course in mineralogical techniques to his junior colleagues. He was told that such a course was not needed and that modern techniques were superior to his classical methods. The real truth of course, is that a judicious blending of the two is necessary, drawing from the good points of both. Exclusion of one at the expense of the other is detrimental to the science. Another mineralogist with the U.S. Geological Survey served 'as an amanuensis' to the eminent mineralogist mentioned above for a several month period. He considers the experience to have been very worthwhile to him in all respects. The inevitable changes in mineralogy that have taken place allow us to characterize and study minerals in more detail than previously. However, it is unfortunate that much of our mineralogical heritage may be lost except by those specifically interested in the historical techniques of mineralogy.

In summary, the science of mineralogy is alive and well, but the patient could be in even better health if the points mentioned above, as well as others, were properly addressed. There are innumerable problems waiting to be solved; new minerals that have yet to be described; as well as chemical, structural, and physical properties of minerals that need to be determined. With a good, complete education and some training under "an old-timer" as well as study of the latest developments and concepts, we can all advance the science of mineralogy and our knowledge of minerals.

I wish to acknowledge the comments and constructive criticism of J. S. White, Jr., R. C. Erd, R. R. Cobban, P. J. Modreski, and two anonymous reviewers.



notes from the EDITOR

UNDERGROUND PHOTOGRAPHY

Field collectors who work underground often end up wishing they had photographed their discoveries *in situ*, before breaking up the pockets into portable sizes and packing them out. For one thing, such photos preserve mineralogical data regarding the arrangement and overall appearance of zones of mineralization. The collector may well be the first and last person to see these occurrences intact, and without some photos, important information is lost forever. (The Mineralogical Record maintains a file of photographs of pockets in place, before removal of the contents; we welcome documented contributions of such photos or photo duplicates from our readers.) Furthermore, the photos will later make an entertaining slide show, and the older they become the more historic they are.

Unfortunately there are some serious hindrances which have prevented many, if not most collectors from doing much underground photography. Good 35-mm cameras have traditionally been rather heavy and bulky; this has led to some understandable reluctance in trying to pack them underground when already overloaded with heavy collecting tools, boxes, batteries, packing material, water and lunch. They also tend to be expensive and delicate . . . not well suited to use under rugged, dirty and sometimes wet working conditions. Manual focussing can be extremely difficult in the dark, especially when the viewfinder fogs up. And electronic flash is essential; flash attachments can be bulky and awkward to work with in the dark. (I can remember, in the "old days," using flash bulbs underground . . . now *that* was inconvenient.)

All of these difficulties no longer apply, thanks to the introduction in recent years of compact 35-mm cameras. These are typically small enough to fit in a jacket pocket, weigh only 250 to 500 grams, are priced between $100 and $200, have automatic focus (some will shoot a field of view as small as 18 cm across), and have small but powerful built-in flashes. Some models are even waterproof (and thus presumably dust-proof). Dozens of makes and models are available; a survey was recently published by *Consumer Reports* (Box 53009, Boulder, CO 80321-3009; $18 per year) in their November 1988 issue. The highest rated models tested were the *Fuji DL-400 Tele* and the *Nikon Tele-Touch Deluxe*, both about $200 at typical discounts, with built-in flashes good up to about 6 meters. Thirty-two models were tested, and for $8 *Consumer Reports* will send you a much lengthier guide and computer print-out of *all* current models and their features. (Send your order to Consumer Reports Feature Finder, Box 17003, Hauppauge, NY 11788.)

The only barrier now to good pocket shots is becoming so excited about the discovery that you forget you even brought a camera!

ABOUT THOSE TYPOS . . .

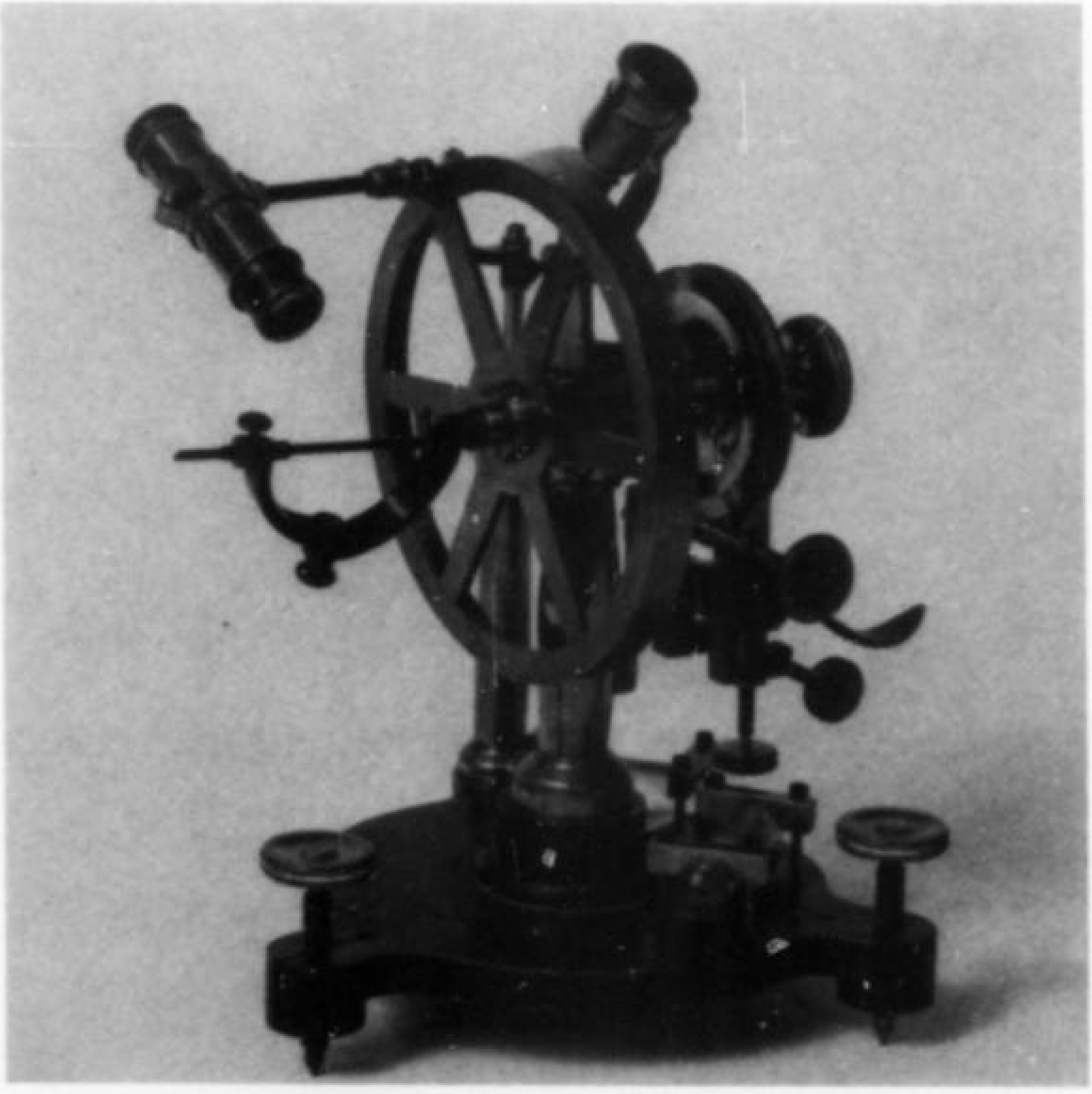
Typographical errors are a thorn in the side of every editor. Years ago, when I first took this job, then-publisher John White offered to buy me a steak dinner if I ever managed to produce an issue completely free of typos. He was confident it could not be done, no matter how carefully the issue was proofread before printing. Eventually I was forced to agree with him. And he's never withdrawn the offer.

Of course, the problem is not new; it's as old as the printing press, and older. The first book having a printed errata (list of errors and corresponding corrections) is the 1478 edition of works by the Roman satirist Juvenal. Prior to that, errors were corrected *by pen* in every printed copy of a book. My favorite typo story concerns an edition of the classics published by the Foulis brothers (founded 1741) in Glasgow. The publishers were determined to issue a book which would be a prime specimen of typographical perfection. Six experienced proofreaders spent hours scrutinizing each page of proofs. When they felt they had rooted out every error, the proof pages were posted on a wall at the University of Glasgow for two weeks, and a reward of 50 pounds (an enormous sum then) was offered to any person who could find another error. At last, confident of perfection, they went to press. Despite all their efforts, several errors were indeed found in the printed edition, including one on the first line of the first page.

Many kind souls have attempted to console the publishing community with regard to the inevitable typos. Oliver Goldsmith (1728–1774) wrote: "A book may be amusing [despite] numerous errors, or it may be very dull [though lacking] a single absurdity." An anonymous printer in 1610 wrote: "When points and letters doe containe the sence, the wise may halt, yet doe no great offence." An author, horrified at seeing his 72-page booklet (*Missae ac Missalis Anatomia*, 1561) published along with *15 pages* of errata, charitably proclaimed that the devil must have caused the printer to misread his manuscript.

Here at *Mineralogical Record* we have a system whereby no less than nine people (and sometimes considerably more) read each issue before it goes to press. The vast majority of errors are caught before publication . . . but perfection is elusive. An "absurdity" in point: check the figure caption on the ouside-back-cover of the recent Australia Issue—it *should* have been dropped, but somehow lingered on from the previous issue. (The specimen is obviously a superb Tasmanian crocoite; we've made our apologies to Bill Larson of Pala International who, thank goodness, has a good sense of humor.)

So the next time you spot some letters gone awry, please don't assume we were all out on coffee break when the issue was printed. We tried . . . honest, we did. Just say to yourself: "Well, there goes another steak dinner."



MORE GONIOMETERS

Uli Burchard's first project involving the limited-edition production of new classic-design goniometers having been such a success (see vol. 19, p. 2), he is now planning to produce 22 examples of a considerably more complex optical goniometer. The photo shows an original 1880 model by Böhm & Wiedemann; the new ones will be identical, and made by the original manufacturer. They will be priced at DM 4000 (about $2300); Uli plans to have them available for sale at the Denver Show in September.

W.E.W.

Mineralogy and Paragenesis of the

LITTLE THREE MINE PEGMATITES

Ramona District, San Diego County, California

●

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The Little Three pegmatites have yielded superb orange spessartine, large blue topaz crystals, multicolored elbaite and well-formed crystals of lepidolite, plus an interesting range of rare species. The mine, first opened in 1903, continues to produce fine specimens.

INTRODUCTION

The Little Three mine is one of several mines located on the Little Three property in the Ramona district, San Diego County, California. This mine, strictly speaking, is developed in the Little Three main dike, one of five major pegmatite dikes on the property. All five dikes have been mined for gem-quality and specimen-quality pegmatite minerals. The Little Three property is world-famous for its production of fine gem-quality and specimen-quality orange spessartine garnet, and blue topaz equalling or surpassing material produced from the Mursinka-Alabashka District, Urals, and the Volyn pegmatites in the Ukraine, U.S.S.R. Little Three topaz also rivals much of the topaz produced from pegmatites in the state of Minas Gerais, Brazil, and St. Anne's mine, Karoi district, Zimbabwe. Fine specimens of dark green elbaite, some pink and red elbaite, K-feldspar and *cleavelandite* (albite) have also been produced. Some especially fine large, euhedral crystals of lepidolite were produced from one large pocket known as the "New Spaulding" pocket in 1976. (Details concerning this pocket are given in Stern *et al.*, 1986.) Other rare minerals such as manganaxinite, hambergite and a new stibiocolumbite-stibiotantalite polymorph have also been found on the property. The Little Three mine is currently owned and operated by the second author, and permission to visit and collect at the property must be obtained in advance.

HISTORY

The Little Three pegmatites were discovered in May of 1903 by H. W. Robb of Escondido, who took two partners, Dan MacIntosh of Ramona and Charles F. Schnack of Escondido. The partnership purchased the 40-acre plot from John Ferguson, who owned a ranch of several hundred acres. The name "Little Three" refers to the three original owners. Litigation and disagreement among the owners resulted in little production for 1906 (Sterrett, 1907). The bulk of the mining activity prior to World War I was done in the Little Three main dike and, to a lesser extent, in the Hercules-Spessartine dike. Kunz (1905) described the initial mining activity at the Little Three mine, and additional production information was given by Sterrett (1911). Two other small mines, the Black Panther and the ABC (formerly known as the Sunrise and Daggett group, respectively; Sterrett, 1908), both west of the Little Three property, also were discovered prior to World War I. The Surprise mine, located about 450 meters southeast of the main Little Three mine, was worked prior to World War I but is now obliterated by fill (Sinkankas, 1959). The Lookout mine, further up the hill from the Hercules mine, produced some excellent spessartine garnet (Sterrett, 1908) but has not been worked for many years. Figure 1 shows the locations and names of the mining claims and patented ground in the principal part of the

Ramona district (compiled by the F. H. Weber, California Division of Mines and Geology). Figure 2 shows the Little Three property in 1978.

As was true for the other pegmatite gem mines in San Diego County, the collapse of the Chinese tourmaline market in 1912 halted mining activity. Only sporadic highgrading occurred until the acquisition of the property for $2000 from Charles Turner (a San Diego real estate speculator) by Louis B. Spaulding, Sr. and his son (the second author) in 1951. No intensive mining was undertaken until 1955. Several dikes on the property were mined by Mr. and Mrs. Spaulding until her death in 1964, after which he continued mining alone until his death in 1973. He confined most of his work to the Spaulding dike (for spessartine and schorl), and to the Little Three main dike (for elbaite and topaz).

Simpson (1962, 1965) examined the structure and petrology of the dikes, particularly the graphic granite, but no detailed mineralogical work was done.

John Sinkankas was granted permission in 1956 to work the Sinkankas and Hatfield Creek dikes (Sinkankas, 1957). In 1960, J. F. Scripps and several others reworked the Hercules mine dump, which is actually on the Little Three mining claim rather than the Hercules claim. One cash lease was obtained by J. F. Scripps and W. F. Larson in 1972 to work a portion of the Little Three main dike, with the actual mining activity carried out by William McGee (now deceased). In 1965–1966, J. Sinkankas mined a portion of the Hercules dike near the original tunnel opening (Sinkankas, 1967).

Since resumption in March 1975 of nearly full-time mining activity by the second author, an extensive amount of work has been done, and approximately 100 meters of underground tunnel have been driven. Efforts have primarily been devoted to the Little Three main dike and to the Hercules-Spessartine dike. Both surface and underground min-

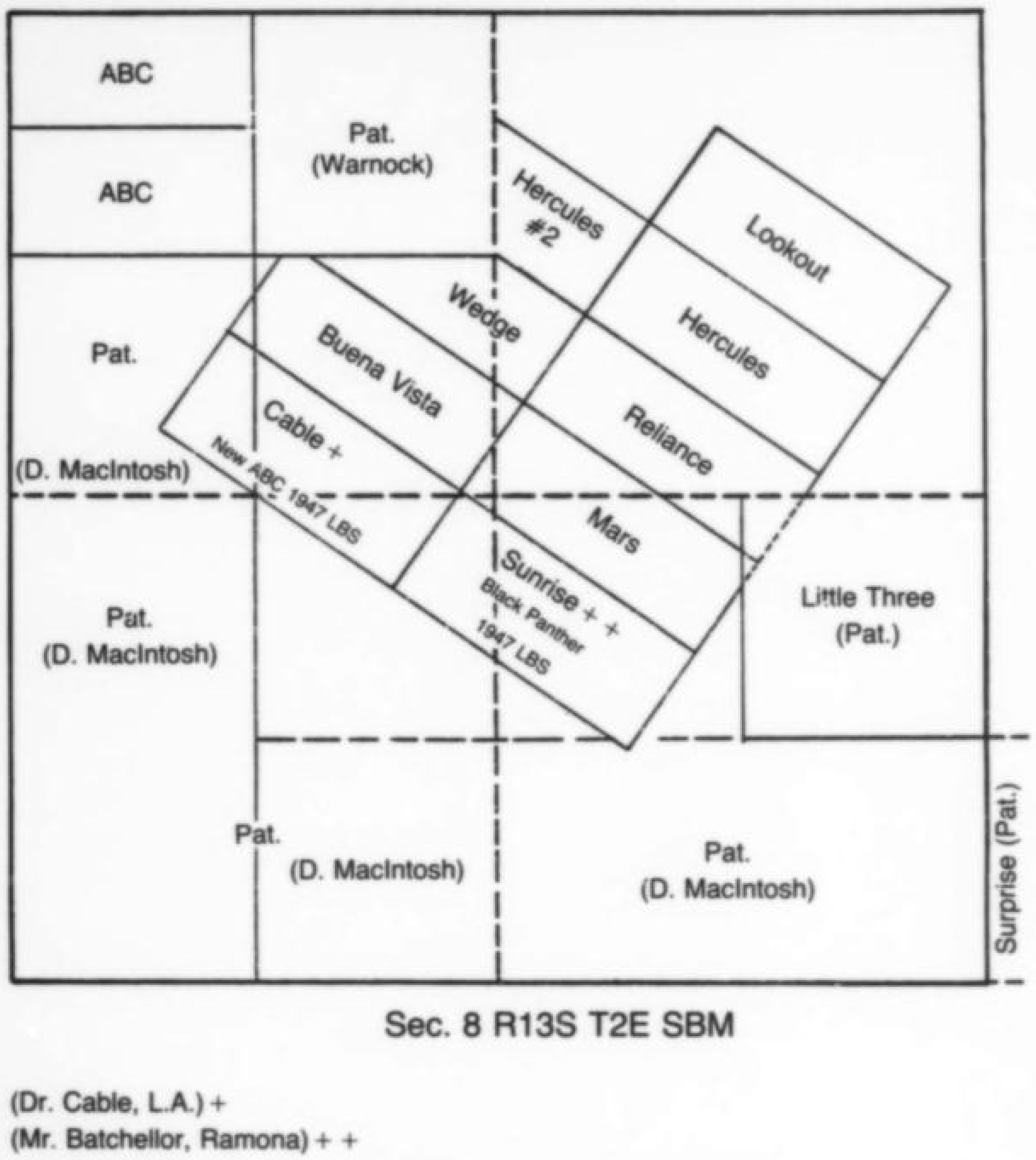

***Figure 1.* Mining claim map of the Little Three mine area.**

***Figure 2.* View of the Little Three mining property taken in 1978.**

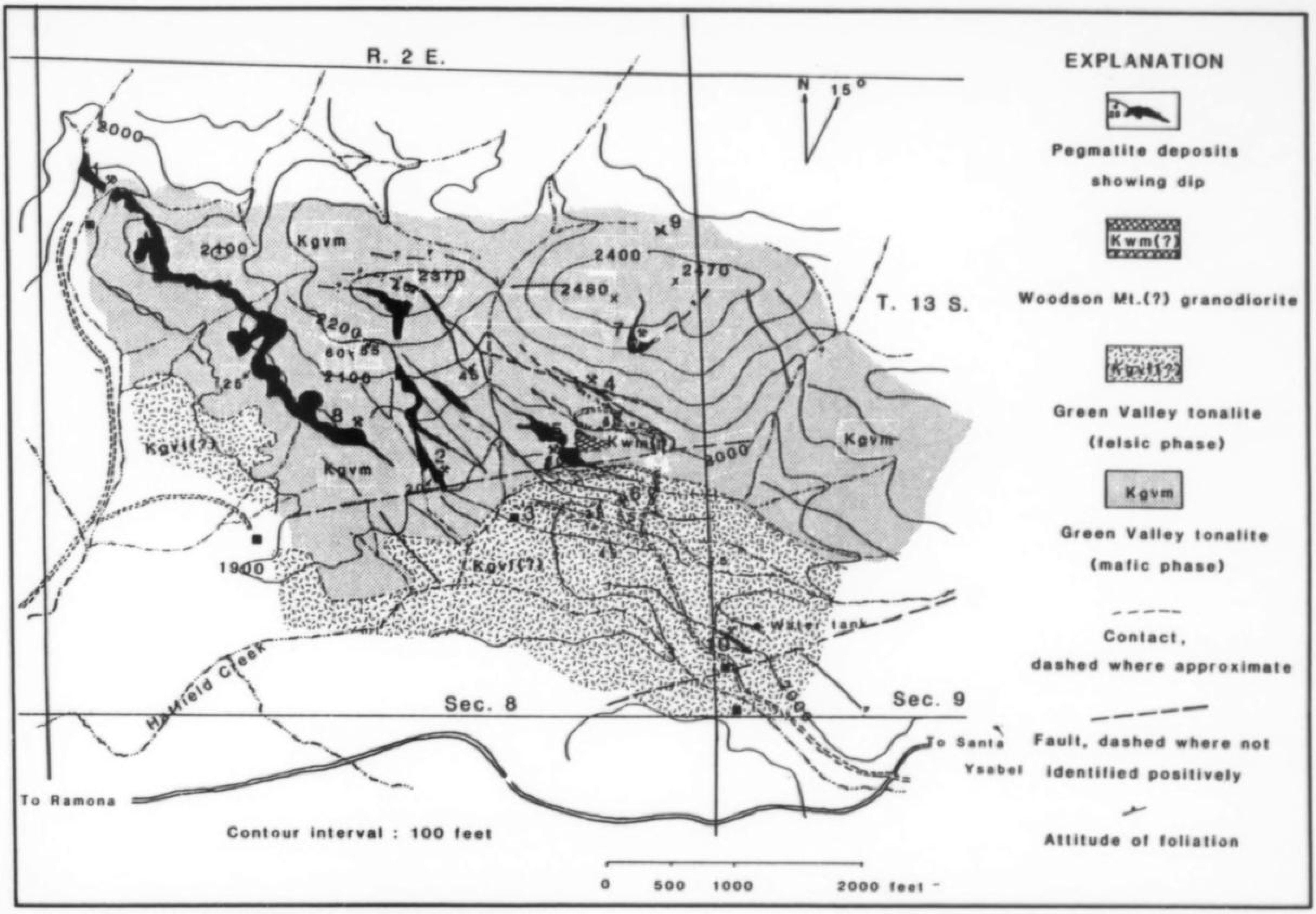

Figure 3. **Simplified topographic and geologic map of the central portion of the Ramona pegmatite district. Modified from Weber (1963). Mine and prospect locations are given by nos. 1–10. 1 = A.B.C. mine, 2 = Black Panther prospect, 3 = Fraction claim, 4 = Hercules-Spessartine mine, 5 = Little Three mine, 6 = Hatfield Creek-Sinkankas-Spaulding dikes, 7 = Lookout prospect, 8 = New A.B.C. prospect, 9 = Sonny Boy claim, 10 = Surprise mine.**

ing have been and are currently being carried out. To date (1988), the scientifically and economically most significant discoveries, for perhaps the entire history of the mine, have been made within the upper parts of the Little Three main dike, and in particular within the large New Spaulding pocket (Stern *et al.*, 1986). The New Spaulding pocket was discovered in June, 1976; the excavation and removal of contained material took about a month. The senior author was very fortunate in being able to participate in the discovery and subsequent excavation of that pocket. A pocket containing fine-quality manganaxinite and spessartine garnet was found at the end of 1986.

GEOLOGY and GENERAL FEATURES

The Little Three main dike is one of five principal dikes of granitic pegmatite (with or without associated aplite) on the Little Three property. The dikes are hosted by a mafic phase of the Green Valley Tonalite and by the Bonsall Tonalite, both of which are units of the Southern California batholith of mid-Cretaceous age (120 to 100 million years (m.y.); Krumenacher *et al.*, 1975). The pegmatites themselves are believed to be about 100 m.y. old, based on radiometric age data from the Himalaya pegmatite-aplite dike system at Mesa Grande (Foord, 1976) and the Pala district (Leon T. Silver, personal communication, 1975). At the Little Three property, the dikes include the Little Three main dike, the Hercules-Spessartine dike, the Spaulding dike, the Sinkankas dike, and the axinite-bearing Hatfield Creek dike. All apparently formed as locally anastomosing but essentially separate intrusive bodies derived from the same magma source. Figure 3 is a simplified geological map of the property showing the location of each of the principal dikes.

All of the dikes strike northwest and dip southwest at 10–65°. Thicknesses vary from essentially 0 to more than 2 meters, but 50 cm to 1 meter is most common. Most of the dikes crop out along hillside exposures, where they are folded on dip-slope orientation (resembling a slightly crumpled sheet of paper) and run perpendicular to the hillside, presenting irregularly rolling surfaces in cross-sectional view (Fig. 4).

The Little Three main dike displays marked variation in texture, composition, patterns of textural and compositional zonation, and mineralogy. In these aspects, it is similar to layered pegmatite-aplite intrusive bodies exposed in neighboring districts (e.g., Pala, Rincon, Mesa Grande; Jahns and Tuttle, 1963). An aplitic footwall, 50 cm to 1 meter thick, comprises one-third to (locally) one-half of the zoned body. The lowermost massive albite-rich aplite or pegmatitic aplite contains major quartz and albite, with less abundant K-feldspar and schorl. Muscovite and almandine-spessartine garnet are sparsely distributed.

The lower massive section compositionally and texturally grades upward to banded aplite or "line-rock," which contains somewhat more schorl, muscovite and garnet; this section ranges from 10 to 36 cm in maximum composite thickness. The banded aplite consists of 0.1-cm to 4-cm-thick layers of varying shades of white, gray and orange-brown. Figure 5 is a view of the Little Three main dike adjacent to the large New Spaulding pocket, and Figure 6 is a closer view of

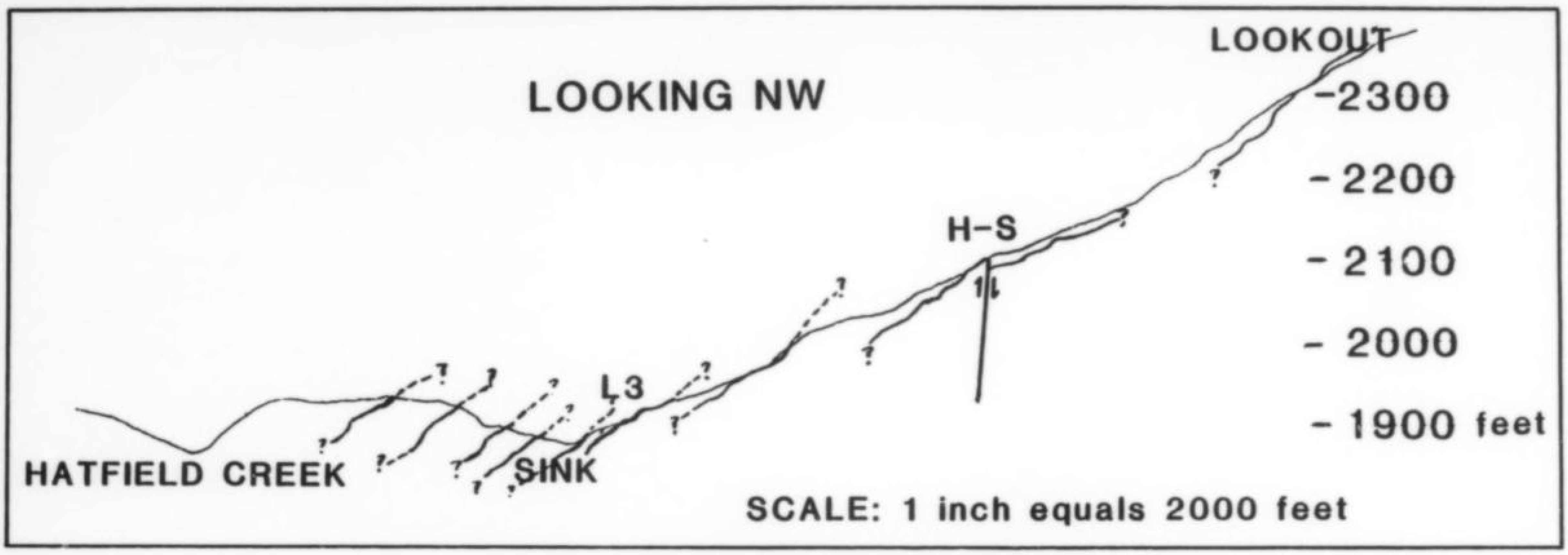

Figure 4. **Cross section looking northwest through the Lookout, Hercules-Spessartine, Little Three and Sinkankas dikes.**

the layered aplite portion of that dike.

The layered aplite grades upward to a zone of increasingly coarse-grained quartz-perthite-albite pegmatite. Coarse-grained albite and intermediate microcline-hosted perthite (Stern *et al.*, 1986, Table 1) make up the bulk of this zone, along with subordinate and widespread schorl and lesser amounts of muscovite and garnet. K-feldspar megacrysts as much as 10 cm long flare outward toward the pocket zone. A change from a light to dark color in the quartz-perthite-albite pegmatite was found to be coincident with a change from intermediate microcline perthite to orthoclase perthite (Stern *et al.*, 1986). Schorl, muscovite, and spessartine garnet increase in size and concentration as the pocket zone is approached.

Graphic quartz-perthite pegmatite is the predominant unit in the hanging wall of the dike. The perthite is composed of a maximum microcline host containing exsolved low albite lamellae. Simpson (1962) has documented the three-dimensional continuity of the quartz and feldspar individuals in the graphic intergrowths. The distribution of schorl, spessartine and muscovite is similar to that in the underlying pegmatite; they increase in grain size and abundance toward the approximately centrally located line of pockets.

The pocket zone is characterized by the presence of large, euhedral crystals of quartz, microcline or orthoclase, albite, tourmaline, topaz and other minerals. These crystals either occur in open or clay-filled miarolitic cavities (pockets) or mutually enclose one another in what are known as "frozen pockets." Larger pockets commonly extend up into the graphic granite pegmatite hanging wall, and the floors of such

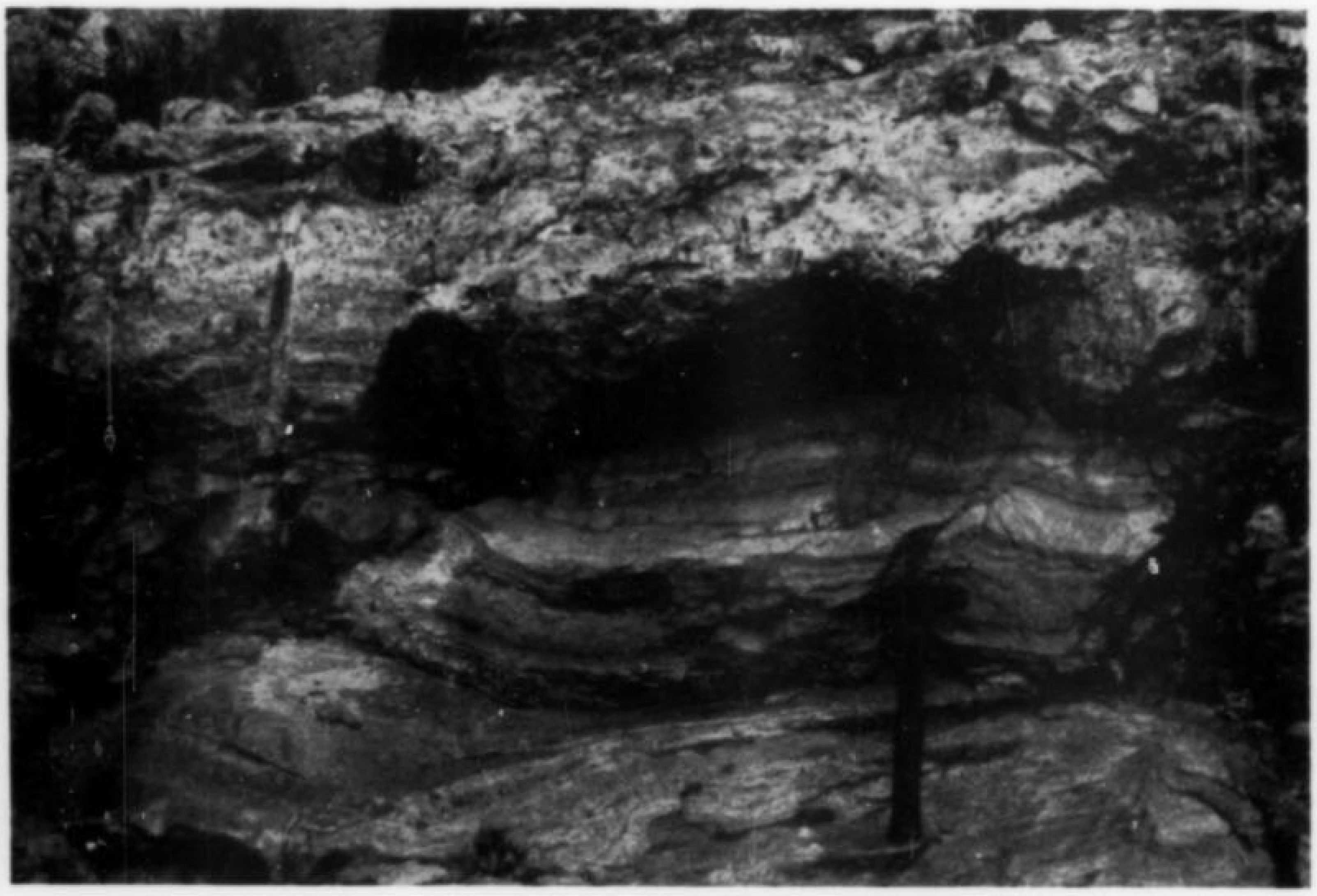

Figure 5. **Exposed partial section through the Little Three main dike showing graphic schorl-bearing pegmatite above albite-schorl-quartz-muscovite layered aplite. Upper and lower contacts of the pegmatite are not shown. Section is immediately to the east of the New Spaulding pocket. Photo by E. E. Foord.**

Figure 6. **Closer view of the central portion of layered aplite in the basal part of the Little Three main dike as shown in Figure 5. Note the presence of albite-rich (or poor) and schorl-poor (or rich) layers. Note the presence of a megacryst of alkali feldspar draped over with successive layers of aplite. Photo by E. E. Foord.**

pockets may extend down into the layered aplite. The dimensions of the New Spaulding pocket were about 0.3 × 3 × 3 meters, and those of the "mud" pocket in the Spessartine dike were about 0.2 × 2.5 × 3 meters. The pockets usually contain broken fragments (many or all of which show subsequent growth) of all of the primary minerals, as well as intact and undamaged crystals. In the case of the New Spaulding pocket, a strong vertical zonation in mineral assemblages was noted. Quartz, lepidolite, albite (variety *cleavelandite*), K-feldspar and topaz grew from the floor of the pocket, whereas quartz, elbaite, cleavelandite, and some K-feldspar grew downward from the roof.

Chemical corrosion of pocket minerals and minerals adjacent to pockets is sometimes shown by the presence of etched and boxwork-type K-feldspar crystals in which interstitial graphic quartz and exsolved albite lamellae have been removed. Other chemically corroded minerals such as spessartine garnet, beryl and schorl also have been found. This chemical dissolution is particularly prominent in the Hercules-Spessartine and Spaulding dikes. This phenomenon was noted by Simpson (1965) and Sinkankas (1967). In some cases, the graphic intergrowth of cleavelandite and quartz that forms pocket walls is extensively etched, to the point that the rock resembles a sponge. In such material, the quartz rods are selectively removed and are considered in some cases to be deposited as a secondary generation of quartz along concentric fractures (onion-skin-like) and radial fractures surrounding pockets as well as in the pockets themselves.

The cavities and fractures contain variable amounts of a second generation of fine-grained to medium-grained tourmaline and spessartine, as well as quartz. The quartz may have been removed from the graphic quartz-feldspar intergrowths by late-stage pocket fluids rich in F, perhaps as SiF_4. However, alkaline solutions also may have been responsible for the selective etching. Pockets may be partly filled with clay minerals that enclose the primary minerals and fragments thereof. Rarely, some pockets contain fragments of primary minerals (quartz, schorl, feldspars and others) that have been physically abraded and rounded, and resemble stream-tumbled pebbles. Evidence of fluid flow carrying scouring material is also seen in the form of abraded attached primary minerals in channels and low areas at the bottom of pockets.

The other pegmatite dikes on the property are grossly similar to the main Little Three dike, but each has its own distinct textural features and mineralogical characteristics. This is particularly true of the pocket pegmatite portions of the dikes. Basal aplite is best developed in the Little Three main dike. Other pegmatite dikes with or without associated aplite are exposed along strike to the northwest and to the southeast from the Little Three mine (Fig. 3).

MINING and PRODUCTION

Most of the mining on the Little Three property has been surficial in nature. Two 18-meter drifts on the Hercules-Spessartine dike, one on the Hercules claim and one about 30 meters south of the north property line of the Little Three claim, date from prior to World War I. In the 1970's, the latter drift was extended approximately 5 meters by the second author. Since 1975, an aggregate of approximately 150 meters of underground and surface work has been done in the Little Three main dike and the Hercules-Spessartine workings. The dip-slope configuration of large parts of many of the dikes has made surface stripping with a bulldozer and front-end loader very effective.

Production of gem-quality and specimen-quality material from the Little Three property has been sporadic; boom-or-bust cycles have predominated. Production records for the Little Three property are extremely scanty, and adequate records have been kept for about the past 30 years only. Production from the large New Spaulding pocket consisted of approximately 90 kilograms of elbaite, more than 28 kg of topaz, in excess of 225 kg of large, euhedral "books" of lepidolite, and still larger amounts of quartz and feldspar. Approximately 1 kg of a new bismuth-bearing and tungsten-bearing stibiocolumbite-stibiotantalite polymorph was also recovered. Total production of elbaite to date is estimated to be 900 kg, and topaz production is estimated to be 115 kg. A total of about 25 kg of beryl (goshenite-morganite), with about 16 kg being produced within the last two years, has been produced from the Hercules-Spessartine dike and, to a lesser extent, from the Little Three main dike. A minimum of 545 kg of lepidolite has been produced to date. The total production of faceting-grade spessartine garnet from the Hercules-Spessartine workings and the Spaulding dike remains uncertain but is estimated to be about 40,000 carats. About 10 kg of specimen-grade and faceting-grade manganaxinite has been produced from the Spaulding, Hatfield Creek and Hercules-Spessartine dikes.

A very fine topaz-elbaite matrix specimen weighing about 60 kg was mined in 1905 from the Little Three main dike. It was on display for many years at the San Diego Chamber of Commerce until moved to the then newly opened Natural History Museum. During World War II, the Navy took over the museum, and the displays were crated and stored for the duration. The specimen was never seen again; it is probable that it was hauled out to sea with a barge of junk and dumped!

MINERALOGY

Aspects of the mineralogy of the Little Three property have been treated by Eakle (1907), Ford (1906), Schaller (1910, 1913, 1916) and, more recently, by Foord (1982a,b), Foord *et al.* (1986) and Stern *et al.* (1986). Despite similar bulk-compositions and features of asymmetrical zoning, each dike has its own characteristic pocket mineralogy, suggesting at least some degree of independence during formation. The Hercules-Spessartine dike yields muscovite, microcline, albite, spessartine, schorl-elbaite, beryl (*goshenite-morganite*), fluorapatite and quartz, plus minor yellow to dark purplish brown manganaxinite, topaz and rare columbite, as principal primary pocket minerals. In contrast, pockets from the Little Three main dike have produced elbaite (principally dark green), muscovite or fluorine-rich lepidolite, quartz, microcline, albite, and topaz (blue to colorless), plus minor fluorapatite, microlite-uranmicrolite, a new bismuth-bearing and tungsten-bearing stibiocolumbite-stibiotantalite polymorph, beryl (*goshenite-morganite*), hambergite, native bismuth, pucherite, bismite and bismutite. The Little Three main dike also has produced perhaps the best-quality lepidolite crystals of all of the pegmatite dikes in San Diego County. Sharp, well-formed crystals as large as 8 cm or more in diameter and 2.5 cm thick were recovered (Figs. 14, 15 and 16). Hambergite was recovered by John Sinkankas from pockets in the upper part of the open cut in the Little Three main dike. Dark, purplish red-brown crystals of manganaxinite were also mined from the Spaulding and Hatfield Creek dikes. Gem-quality spessartine garnet was also recovered from the Spaulding dike.

Table 1 includes a list of minerals identified from the several dikes on the Little Three property. All minerals, except for cassiterite, have been observed and identified by the authors. Two of the minerals, the stibiocolumbite-stibiotantalite polymorph and a boron-substituted (borian) muscovite, are unique to the Little Three mine.

The mineral assemblages within the dikes on the Little Three property may be considered typical of complex rare-element pegmatites. Each of the principal dikes on the property has its own characteristic mineralogy. This is particularly true of the pocket pegmatite portions of the dikes. Each dike appears to have developed separately from its neighbors, but all were likely derived from the same magma source.

Principal Minerals

Quartz SiO_2

Quartz is a ubiquitous mineral within all of the dikes examined. Aplite (layered and non-layered) contains gray to colorless quartz, which is anhedral to subhedral. Quartz within graphic granite (quartz-

***Table 1.* List of minerals found at the Little Three mine, Ramona district, San Diego County, California.**

Mineral or mineral group	main Little Three, Sinkankas, Hatfield Creek, and Spaulding dikes	Spessartine-Hercules dike
Albite (inc. var. cleavelandite)	A	A
Axinite (Manganaxinite)	C-R#	C-R#
Beryl (var. aquamarine, goshenite and morganite)	R*	R*
Biotite (inclusions of altered wallrock)	R	R
Bismite[2]	VR#	—
Bismuth[2]	VR#	—
Bismutite	VR#	—
Cassiterite[1]	VR#	—
Cerussite[2]	VR#	—
Clay minerals:		
Ca-Mg Montmorillonite	R#	R#
Kaolinite (ordered and disordered)	R	R
Columbite-Tantalite:		
Ferrocolumbite-Manganocolumbite	—	VR#
Cookeite	VR#	VR#
Epidote (including Clinozoisite)	R*	R#
Fersmite[2]	VR#	—
Fluorapatite	R*	R*
Garnet:		
Almandine-Spessartine	C	C
Spessartine	C*	C*
Goethite[2]	R	R
Hambergite	VR#	—
Lepidolite	C*	—
Microcline (including maximum and intermediate)	A	A
Microlite-Uranmicrolite[2]	VR#	—
Monazite[2]	VR#	—
Muscovite	A	A
Borian Muscovite[2]	C#!	—
Orthoclase	R#	R#
Pucherite[2]	VR#	—
Quartz	A	A
Stibiocolumbite-Stibiotantalite polymorph	R#+!	—
Todorokite[2]	R#	—
Topaz	C#	ER#
Tourmaline:		
Schorl	C	C
Elbaite	C	C
Vermiculite (alteration of Biotite)	R	R
Zeolites:		
Laumontite	R*	R*
Stilbite[2]	R#	R#
Zircon (including var. cyrtolite)	VR*	—
Unidentified Pb-Bi-Ag Sulfosalt[2]	VR	—

+ bismuthian and tungstenian variety of stibiocolumbite polymorph
A abundant and widespread
C common or locally abundant
R uncommon or rare
VR very rare
ER extremely rare, only a few specimens known
— not known or reported
* chiefly or wholly in pocket pegmatite

only from pocket pegmatite (open cavities or 'frozen' cavities)
! minerals of unique composition known only from the Little Three mine.
[1] Reported by Schaller (1916) and Sinkankas (personal communication, 1987)
[2] new occurrence for this locality (total of 12 found in this work). Sinkankas (1967) reported the presence of bismuthinite associated with bismutite from the Hercules workings. Examination of this material by E. E. Foord showed an unidentified Pb-Bi-Ag sulfosalt and cerussite to be present.

feldspar intergrowth) is also anhedral, but crudely elongated along *a*. Simpson (1962) has documented the three-dimensional continuity of the quartz-feldspar intergrowths. Within the pocket zone, quartz may be colorless, various shades of smoky color, or distinctly yellowish. The crystals of α-quartz are euhedral where unconfined, and generally exhibit compromise growth-surfaces where in contact with other pocket minerals. Solid inclusions (e.g., schorl) are locally present, but are usually minimal. Fluid inclusions (milky appearance) may be prevalent throughout pocket quartz crystals, and of several generations. Terminations of pocket quartz crystals generally are free of any types of inclusions. Some pockets peripheral to the New Spaulding pocket have produced optical-grade smoky quartz. Quartz from the Spessartine dike generally is not of the quality found in the Little Three main dike. Growth spirals and layer edges are very well shown on many pocket crystals of quartz (Fig. 7).

Quartz crystallized virtually throughout the entire history of the dikes. Within the New Spaulding pocket and in smaller pockets peripheral to it, excellent overgrowths of quartz on a quartz substrate were developed. Fractured and broken pieces of quartz were healed and overgrown in many cases; broken surfaces were reterminated to form doubly terminated crystals. The "snow-on-the-roof" texture (minerals covered with a usually fine-grained coating on the "roof," but not the "eaves," and deposited from a stagnant solution) was found to be prevalent in the large New Spaulding pocket: quartz, K-feldspar, cleavelandite, topaz and elbaite crystals are covered with a white coating of borian muscovite. Simultaneous regrowth of primary pocket minerals and the muscovite coating is indicated by interlaying of these minerals. However, final crystallization consisted of only the borian muscovite.

Microcline and Orthoclase $(K,Na)AlSi_3O_8$

Potassium-rich feldspar is also a ubiquitous mineral within the dikes on the Little Three property. K-feldspar is present within all zones of the dikes but is most abundant within the upper graphic quartz-feldspar

Figure 7. **Trigonal-shaped growth hillock and growth spirals on one of the pyramidal faces of a nearly flawless smoky quartz crystal from the Little Three main dike. Specimen and photo, E. E. Foord. Width of field = 10 cm.**

pegmatite and in the pocket zone. Very pale tan, graphic microcline perthite is present within the basal layered aplite. Much of the feldspar is present as oriented megacrysts, some of them tapered; the direction of elongation is *a*, which is oriented normal to the plane of the aplite layering and the aplite-tonalite contact. Within the grapic pegmatite portions of the dikes, much of the microcline is subhedral to anhedral. The pocket zone may contain pale to dark buff-tan euhedra of single-phase orthoclase, orthoclase perthite, single-phase microcline, or microcline perthite. Cleavage surfaces commonly show mottled and patchy variations in color. The absence of albite lamellae in some of these euhedral crystals is considered the result of its removal by post-exsolution corrosion. The overgrowth developed on these euhedra in some pockets is clear and colorless to milky white to tan, and consists of orthoclase, although a maximum microcline overgrowth characterizes some pocket crystals. The overgrowth generally was deposited as a single phase from the fluid medium.

Within the New Spaulding pocket, the microcline occasionally has a readily visible overgrowth. Selected crystal surfaces of much of the microcline from that pocket are characterized by a rough, sawtooth-like texture. The sawtooth-like surfaces predate the deposition of the white to cream porcelain-like "snow-on-the-roof" covering of boron-rich (7.0 wt. % B_2O_3) muscovite. An ion-microprobe traverse across one of these crystals for seven elements shows evidence of compositional zoning (Table 2). Data for included laths of albite are also given. An approximately 1-mm thick outer layer shows more Rb, and less P and Ba than the substrate. Values for Li, B, Cs and Pb show erratic variations. In another euhedral crystal of microcline from the same portion of the main dike, the distinct textural and compositional zoning are not apparent, but the elemental concentrations are similar to those found in the first crystal. Values determined by ion-microprobe for seven elements (averages of 11 data points over a 5.3-mm traverse) are as follows: Li 1.5 ppm, Be 6.1 ppm, B 5.7 ppm, Rb 1.01%, Sr 4.2 ppm, Cs 608 ppm, and Ba 4.2 ppm. Results of semiquantitative emission spectrographic analysis are as follows: Fe 0.07 wt. %, Mg 0.003%, Ca 0.03%, Na 3.0%, Mn 700 ppm, B 70 ppm, Ba 60 ppm, Be 17 ppm, Cr 15 ppm, Pb 50 ppm, Ga 100 ppm, Cs 470 ppm, Rb 0.58%, Li 5 ppm. All other elements were not detected at respective limits of detection. Figure 8 shows a euhedral Baveno-twinned microcline crystal with selectively etched(?) faces from this pocket. Terminations of the crystals are generally more corroded than the other portions. Randomly oriented blades and sheaves of albite (var. *cleavelandite*) commonly are present within and on the K-feldspar crystals (Fig. 9). The sawtooth-like faces are probably a feature of primary growth because some of them show evidence of later chemical corrosion and deposition and overgrowth material.

X-ray diffraction studies on the K-feldspar lead to an estimate of the degree of Al-Si order achieved during the subsolidus evolution of the Little Three pegmatite. Data on the cell dimensions of the pocket orthoclase and microcline are provided in Table 3, and supplement the information given by Foord *et al.* (1979) and Stern *et al.* (1986).

There is an amazing diversity in the structural state of the K-feldspar found in the Little Three pegmatitic system. The following interpretation accounts for the prevalence of microcline away from the pockets, and of orthoclase in the pocket environment. At the solidus, the K-feldspar that formed from the magma was sanidine solid-solution (i.e., an intermediate member of the series high sanidine-high albite); nowhere is this high-temperature material preserved in the pegmatite. This bulk composition began to unmix (i.e., to form the perthitic intergrowth of K-feldspar and albite) when the solvus was intersected, close to 600°C. At this temperature, limited Al-Si ordering of the

Table 2. **Ion-microprobe traverse data for one crystal of microcline and included laths of albite from the New Spaulding pocket.**

	MICROCLINE				
	Rim (overgrowth)		**Substrate**		**included albite laths**
Element	**Ion-probe**[1]	**E-spec**	**Ion-probe**[2]	**E-spec**	**Ion-probe**[3]
Li	1.3 ppm	4 ppm	0.7^+	3	0.07
B	5.4	290	4.5	50	7.3
P	52	<1000	323	<1000	436
Rb	1.08%	n.d.	0.50%	n.d.	18
Cs	780	n.d.	811	n.d.	0.8*
Ba	10.6	<10	15.4	<10	0.09*
Pb	4	<15	11	<15	3
Sr	ND	<10	ND	<10	ND
Be	ND	<5	ND	7	ND
	[1]Average of 6 points (over a distance of 1 mm)		[2]Average of 10 points (over a distance of 10.5 mm)		[3]Average of 6 points

\+ excluding one value of 8.7 Li (inclusion?)

* excluding one point

ND not determined

Notes—Sample is a euhedral crystal of buff-cream microcline with included randomly-oriented laths of albite (cleavelandite). There is a one-mm thick rim of overgrowth material which has a crenulated sawtooth-like texture on the outer surface. This material has been called the rim above, and the remaining portion of the traverse (1.05 cm) has been called the substrate. The crystal was cut parallel to the *a-b* plane. The K-feldspar is full of microscopic inclusions (both fluid and solid) while the included albite laths are free of inclusions.

Semiquantitative emission-spectrographic analyses of the microcline overgrowth-substrate pair also showed: (overgrowth) Fe 0.015%, Mg 0.003%, Ca 0.0015%, Na 0.7%, Mn 15 ppm, Cr 15 ppm, V 5 ppm, Ga 150 ppm, (substrate) Fe 0.015%, Mg < 0.001%, Ca 0.002%, Na 3%, Mn 30 ppm, Cr 15 ppm, V <5 ppm, Ga 150 ppm. All other elements below respective limits of detection.

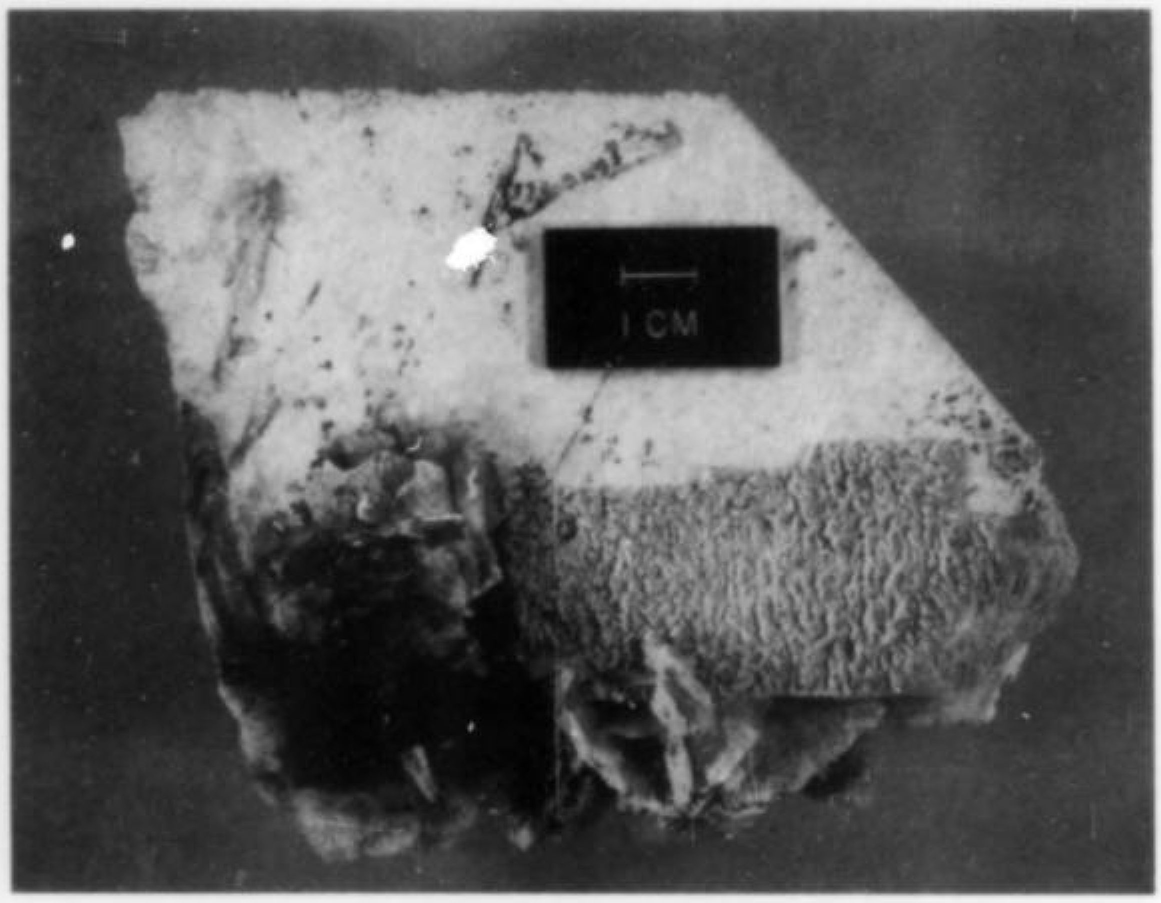

Figure 8. **Euhedral Baveno-twinned crystal of K-feldspar from the New Spaulding pocket showing selective growth and etching. Associated minerals are cleavelandite and elbaite. Sharp contact on feldspar crystal is the trace of the twin plane. Specimen and photo, E. E. Foord.**

monoclinic K-feldspar is expected, and the degree of order increases progressively down to roughly 400°C. Two factors contribute to efficient ordering of the K-feldspar: (1) availability of an aqueous fluid, and (2) slow rate of cooling. In the parts of the system that cooled most rapidly near the hanging wall and footwall, the sanidine ordered to orthoclase, probably characterized by approximately 70% of the aluminum in the T_1O + T_1m positions in the structure. There are no indications that this material was preserved in the Little Three system.

Over the same interval down to 400°C, the pocket area is dominated by a fluid phase, and the rate of heat loss probably was slower there than near the contacts. As long as there is efficient interchange between the monoclinic K-feldspar and the fluid, ordering will continue. The result is well-ordered orthoclase, characterized by 92% of the aluminum in the T_1O + T_1m structural positions (Table 3). As the temperature falls below 400°C in the pegmatite body, the monoclinic K-feldspar *should* give way to triclinic K-feldspar (microcline). The partly ordered orthoclase near the contacts inverts readily, and appears today as well-ordered microcline (i.e., virtually 100% of the aluminum is in the T_1O position). Closer to the pocket zone, where the orthoclase had become better ordered, the inversion was less efficient in the time available, probably because the difference in free energy between the (metastable) better-ordered orthoclase and the microcline was smaller than between the more poorly ordered orthoclase and microcline near the contacts. As a result, intermediate microcline is found, in which only 65% of the aluminum is in the T_1O structural position (Stern *et al.*, 1986, Table 1). Finally, in the pockets themselves, the difference in free energy between very well-ordered orthoclase and microcline was so small that the inversion did not occur in some cases. Table 3

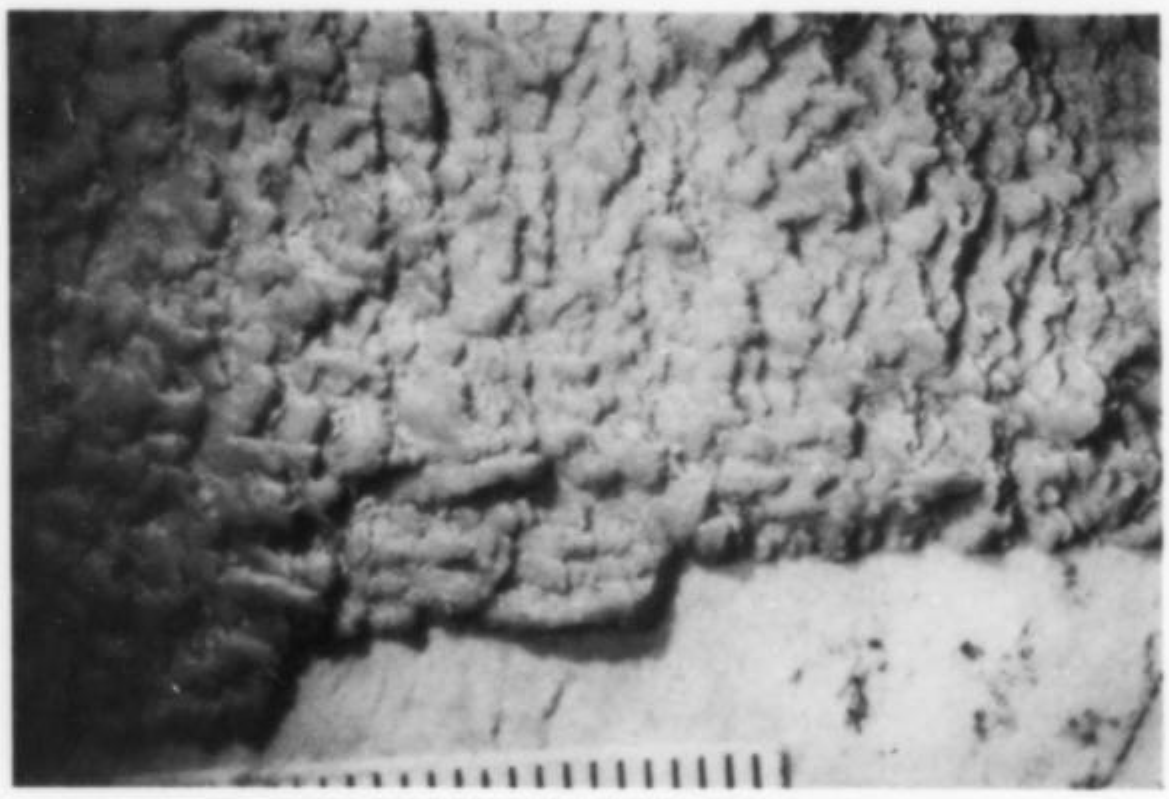

Figure 9. **Close-up view of twin boundary in crystal of microcline from the New Spaulding pocket. One twin individual shows sawtooth-like growth features. Specimen and photo, E. E. Foord.**

Table 3. **Cell parameters and indicators of composition and degree of Al-Si Order, K-feldspar from the Little Three pegmatite.**

	a (Å)	*b* (Å)	*c* (Å)	α (°)	β (°)	γ (°)	*V* (Å³)	α* (°)	β* (°)	γ* (°)	N_{Or}	t_1O	B
Substrate*	8.5892	12.9632	7.2186	90.628	115.943	87.750	722.18	90.396	64.061	92.196	0.99	0.97 LM	50
1976 pocket	0.0007	0.0009	0.0006	0.006	0.006	0.006	0.06	0.006	0.006	0.006			
Overgrowth	8.5910	12.9657	7.2226	90.628	115.969	87.736	722.70	90.404	64.035	92.213	1.00	0.98 LM	290
(milky)	0.0005	0.0006	0.0004	0.005	0.005	0.005	0.05	0.006	0.005	0.005			
Main dike*	8.5921	12.9652	7.2233	90.611	115.970	87.720	722.82	90.431	64.033	92.239	1.01	0.99 LM	70
1977	0.0006	0.0008	0.0005	0.008	0.006	0.006	0.06	0.008	0.006	0.007			
Host*	8.5717	12.9717	7.2130	90	116.051	90	720.53	90	63.949	90	0.93	0.46 OR	
SU 7368	0.0018	0.0031	0.0014		0.016		0.21		0.016				
Overgrowth	8.5585	12.9619	7.2100	90	116.015	90	718.79	90	63.985	90	0.89	0.46 OR	
	0.0013	0.0021	0.0018		0.014		0.17		0.014				
Host	8.5614	12.9699	7.2105	90	116.037	90	719.40	90	63.963	90	0.90	0.45 OR	
(leached)	0.0010	0.0012	0.0007		0.008		0.09		0.008				
Overgrowth	8.5651	12.9669	7.2129	90	116.035	90	719.79	90	63.965	90	0.91	0.46 OR	
	0.0014	0.0016	0.0010		0.010		0.13		0.010				

Note: LM low (or maximum) microcline, OR orthoclase, * albite is present (perthitic intergrowth). The cell dimensions were calculated using the least-squares program of Appleman & Evans (1973). Composition N_{Or} is calculated from cell volume using the equations of Kroll & Ribbe (1983). N_{Or} is expressed as a mole fraction (in end-member K-feldspar, N_{Or} = 1). The degree of Al-Si order is expressed as t_1O (for microcline; maximum value 1.0) and t_1 (for orthoclase; maximum value 0.50), and calculated using the expressions of Blasi (1977). Also shown is the concentration of boron (B) in ppm. SU: Stanford University Reference Collection.

contains data for two pairs of pocket K-feldspar euhedra and overgrowth, one in which both are well-ordered microcline, presumably from a pocket that cooled through the field of stability of orthoclase quickly, and the other in which both are "stuck" metastably in the well-ordered orthoclase state. Sudden evacuation of the fluid medium from the pocket environment after formation of the overgrowth could also prevent nucleation of the low-temperature polymorph. This phenomenon could give rise to compositions containing 88 to 92% $KAlSi_3O_8$ (Table 3), whereas uninterrupted contact with the fluid medium down to 200°C or so would lead to K-feldspar containing 98 to 100% $KAlSi_3O_8$ (Table 3; Stern *el al.*, 1986, Table 4).

Albite $NaAlSi_3O_8$

Albite (all structurally low albite) is a major constituent of the basal layered aplite portion of the Little Three main dike. Some dikes on the Little Three property do not appear to have aplite developed, and in such dikes most of the albite is present in the pocket zone. Within the aplite and pegmatitic aplite portions of the main dike, the albite is subhedral to anhedral, and the grain size is less than 0.5 mm. Within the pegmatite and pocket portions the grain size is larger by an order of magnitude or more. Some of the cleavelandite from the New Spaulding pocket is very coarse grained, in crystals as much as 2 cm across and 0.5 cm thick. Color ranges from white or colorless to a distinct pale blue. No discernible overgrowths are present on pocket-zone albite. Compositions of the coarse New Spaulding pocket cleavelandite and albite lamellae included within maximum microcline megacrysts are essentially the same. Ion-microprobe data for two points on one sample of bladed cleavelandite from a pocket immediately adjacent to the New Spaulding pocket are as follows (values in ppm): Li 0.08, 0.13, Be 11, 20; B 1.6, 2.2; P 336, 141; Cs 5, 1.7; Ba 0.3, 0.0; Pb 26, 55. Results of semiquantitative emission-spectrographic analysis for albite (var. cleavelandite) from the New Spaulding pocket are as follows: Fe 0.03%, Mg 0.0015%, Ca <70 ppm, Mn 3 ppm, B 70

***Table 4.* Results of semiquantitative emission-spectrographic and ICP analyses of muscovite and lepidolite from the Little Three mine.**

Element	large, light purple lepidolite 'books' from floor of New Spaulding pocket	deep purple lepidolite from peripheral pocket to New Spaulding pocket (east)	green outer part of zoned muscovite 'books' adjacent to New Spaulding pocket	pale yellow cores of zoned muscovite 'books', adjacent to New Spaulding pocket	pale yellow muscovite coated with laumontite H-S dike	pale purple Li-muscovite from beryl pocket in H-S dike	white-cream borian-muscovite coating on lepidolite, New Spaulding pocket (1976)	
Analytical method	**e-spec**	**e-spec**	**e-spec**	**ICP**	**ICP**	**ICP**	**e-spec**	**ICP**
Si (%)	major	major	major	22.0	21.3	21.0	major	24.2
Al (%)	major	major	major	19	19.5	18	major	16
Ca (%)	0.003	0.005	0.002	0.09	0.14	0.13	0.03	0.36
Fe (%)	0.2	0.07	7.0	0.53	0.43	0.38	0.1	0.13
K (%)	7.0	7.0	7.0	7.7	8.9	7.5	7.	11.0
Mg (%)	0.005	0.003	0.03	<0.02	<0.02	<0.02	0.07	0.08
Na (%)	0.3	0.3	0.7	—	—	—	0.3	—
Ti (%)	0.03	0.015	0.05	0.05	0.05	0.05	0.01	<0.04
Mn (%)	1.5	1.0	0.1	0.11	0.2	0.21	0.15	.07
B (ppm)	150	150	100	660	450	460	>2.0%	2.2%
Ba	N2	2	5	7	4	6	15	30
Be	70	50	10	25	16	17	5	<9
Cr	N	N	N	10	27	7	<2	14
Cu	N1	15	N1	20	10	21	1	18
Ga	150	70	150	290	300	290	200	120
Li	3%	3%	100	43	120	140	300	240
Nb	N10	N10	70	60	80	90	<10	<40
Ni	N	N	N	9	23	<8	<10	<20
Pb	N	N	N	<20	40	20	15	<40
Sc	10	7	7	<8	8	<8	<10	<20
Sn	30	15	30	520	440	550	<50	<90
Sr	7	7	N5	<8	10	10	7	40
Zn	200	N200	N200	55	110	120	<10	<20
Rb	1.5%	1.5%	700	2000	1700	1600	5000	4800
Cs	0.3%	0.5%	70	190	200	140	300	450

Note—The borian muscovite also contains 30 ppm Bi, 7 ppm V, 15 ppm Zr, 30 ppm Ge, and 50 ppm T1 as determined by semi-quantitative emission spectrographic methods. 660 ppm As, as determined by ICP, is also present in the borian muscovite.

N not detected at value shown

— not determined

ppm, Be 1 ppm, Cr 1.5 ppm, V 7 ppm, Ga 300 ppm. All other elements were not detected at respective limits of detection. Additional data for cleavelandite and albite from the New Spaulding pocket are given in Stern *et al.* (1986).

Results of a complete wet chemical analysis and full optical data are available for a sample (USNM no. 89,192, collected by W. T. Schaller) of pocket cleavelandite from the Little Three mine (Emmons, 1953). The composition ($Or_{1.0}Ab_{98.5}An_{0.5}$) is similar to that of other samples of cleavelandite examined in this study. A two-dimensional refinement of the crystal structure was performed on this sample of structurally low albite by Ferguson *et al.* (1958). Subsequently, a three-dimensional structure refinement by Ribbe *et al.* (1969) confirmed the highly ordered distribution of Al and Si in the albite.

Micas

Micas are abundant within the pegmatite dikes on the Little Three property, and consist of three major species: biotite (including lithian biotite), muscovite (including lithian muscovite) and lepidolite. Within the Little Three main dike and the Sinkankas dike, all three micas occur. Only two micas, biotite and muscovite, are present within the Spaulding, Hatfield Creek and Hercules-Spessartine dikes. Minerals on the floor of the New Spaulding pocket were covered with a fine-grained coating of borian muscovite.

Biotite $K(Mg,Fe^{+2})_3(Al,Fe^{+3})Si_3O_{10}(OH,F)_2$

Biotite and lithian biotite are sporadically developed in the upper contact zone of the dikes and the host mafic tonalite. The flakes of biotite reach several mm in size. Biotite has not been found within the central portions of the dikes.

Muscovite $KAl_2(AlSi_3)O_{10}(OH,F)_2$

The amount of muscovite in the basal layered aplite is low, 5 volume percent or less, and the grain size is less than 0.5 mm. Within the pegmatite and pocket pegmatite portions of the dikes, the grain size is characteristically several orders of magnitude larger. The absolute amount and proportion of mica are not that much greater in the graphic pegmatite portions of the dikes, but are significantly larger within the pocket cavities. The muscovite in the aplite and in areas away from most pockets is yellowish or greenish (apple-green). However, in the pocket zone it is very pale green or yellow-green, colorless, or slightly pink. Some of the pocket-zone muscovite peripheral to the New Spaulding pocket is strongly color-zoned, ranging from colorless to pale medium purple to medium yellow-green. The color zonation correlates well with that shown in the pocket tourmaline, e.g., green Fe-rich muscovite crystallized contemporaneously with dark olive-green Fe-bearing elbaite; colorless Fe-poor muscovite crystallized with pale green, low Fe-bearing elbaite. The zonation may be sharp to graduational. Figure 10 shows an example of a distinctly color-zoned (and compositionally zoned) book of muscovite taken from an area peripheral to the New Spaulding pocket. Results of emission-spectrographic and induction-coupled plasma (ICP) analyses for two samples of muscovite from the main dike and for one muscovite from the Hercules-Spessartine dike are given in Table 4.

Some pale purple lithian muscovite occurs in pockets within the Hercules-Spessartine dike. Results of an ICP analysis of a sample of this mica are given in Table 4.

Lepidolite $K(Li,Al)_3(Al,Si)_4O_{10}(F,OH)_2$

Pale to medium lavender-colored lepidolite is confined to the pocket zone. Within the New Spaulding pocket and in some smaller pockets adjacent and mostly up-dip from it, the only mica present is lepidolite. Coarsely intergrown flat books of lepidolite covered much of the floor of the big pocket but were absent from the roof of the pocket. Lepidolite books in the New Spaulding pocket grew to a maximum of 10 cm in diameter and 2 cm thick; they occasionally exhibit multiple growth-fronts defined by minute inclusions of stibio-bismuto-colum-

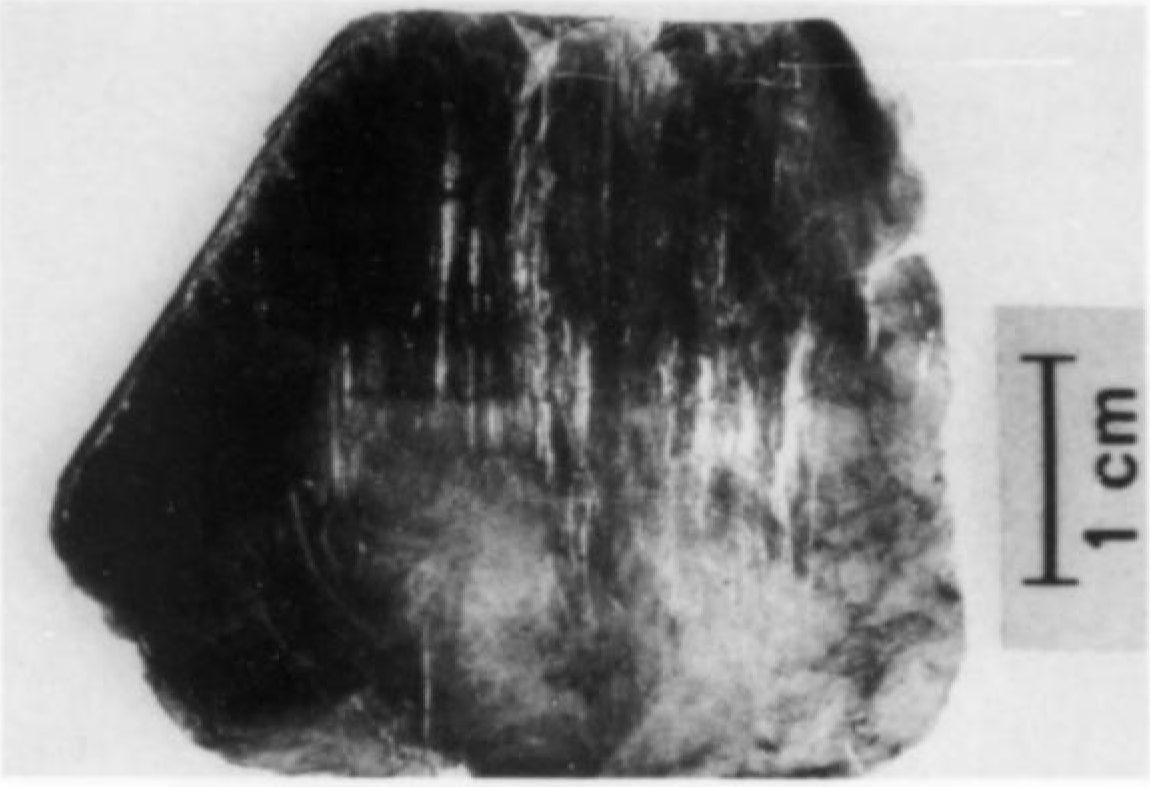

***Figure 10*. Color-zoned book of muscovite (colorless-green) from immediately east of the New Spaulding pocket. Analyses of this material are given in Table 4. Specimen and photo, E. E. Foord.**

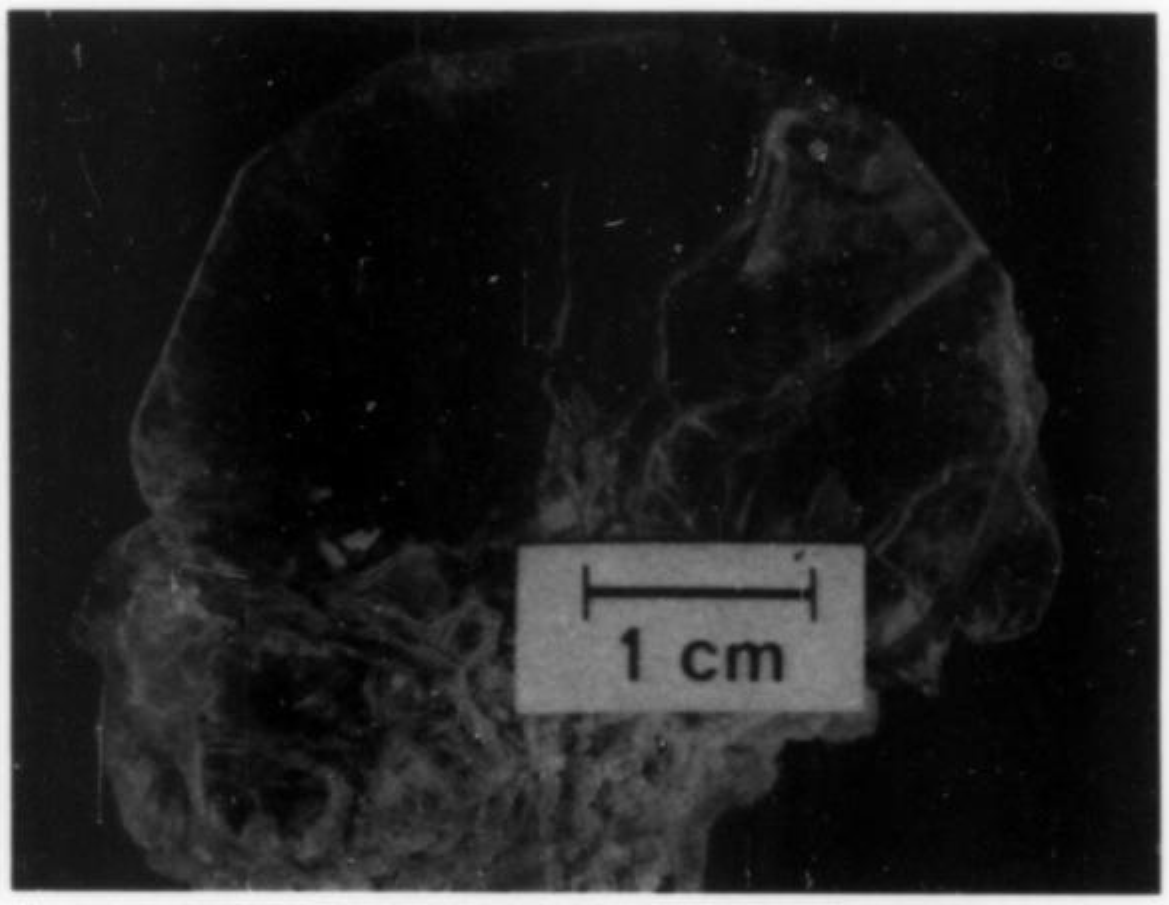

***Figure 11*. Fossil growth-zoning in a lepidolite crystal from the New Spaulding pocket. Zoning is defined by inclusions of stibiocolumbite-stibiotantalite polymorph. Specimen and photo, E. E. Foord.**

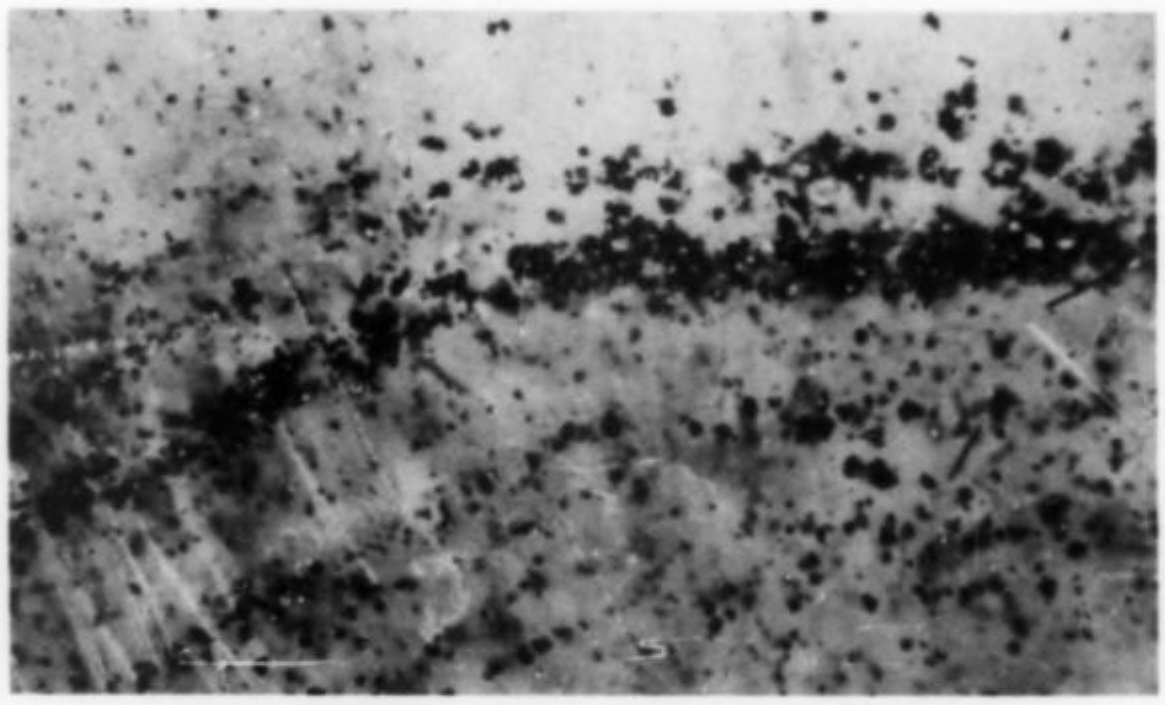

***Figure 12*. Closer view of a cleavage surface of the zoned lepidolite crystal from the New Spaulding pocket. Note the black inclusions of stibiocolumbite-stibiotantalite polymorph. Specimen and photo, E. E. Foord. Width of field of view = 6 mm.**

bite-tantalite, as well as coatings of this mineral. Figures 11, 12 and 14 show these features. Euhedral crystals of lepidolite of this size have not been found anywhere in San Diego County for nearly 70 years. Several specimens of lepidolite housed in the British Museum of Natural History, which predate World War I, are of comparable appearance to the material from the New Spaulding pocket, indicating that other very large pockets were found within the main dike in the early days of mining activity. Results of emission spectrographic analyses for two samples of lepidolite from the main dike and the New Spaulding pocket are given in Table 4. Pocket lepidolite from the New Spaulding pocket shows evidence of nearly complete F substitution for (OH). Additional details concerning the lepidolite from the New Spaulding pocket are given in Stern *et al.* (1986).

Several smaller pockets immediately up-dip from the New Spaulding pocket contained sharp, well-formed and lustrous crystals of deep purple ("Tyre purple") lepidolite as much as 1 cm thick and 2–3 cm across. This particular variety of lepidolite is a striking deep lavender-purple when viewed in the *a*—*b* plane, compared to a pale gray-purple in the same orientation for the large crystals from the New Spaulding pocket. Optical-absorption spectra for both varieties (Fig. 13) were obtained through the courtesy of Dr. P. G. Manning (personal communication, 1976). The principal difference in the E ‖ (001) and E⊥ (001) spectra of the deep violet-purple lepidolite lies in the polarized band at 22500 cm^{-1} (445 nm), which is probably due to intervalence charge-transfer processes, possibly involving Fe^{+2} and Ti^{+4} ions in adjacent octahedral positions. The other features at 18000 cm^{-1} and 19500 cm^{-1} probably belong to Mn^{+3}. Note that the polarized 22500 cm^{-1} band is absent in the pale purple lepidolite, even though it contains more total manganese than the deep purple lepidolite (Table 4). This lepidolite also shows nearly complete replacement of (OH) by F.

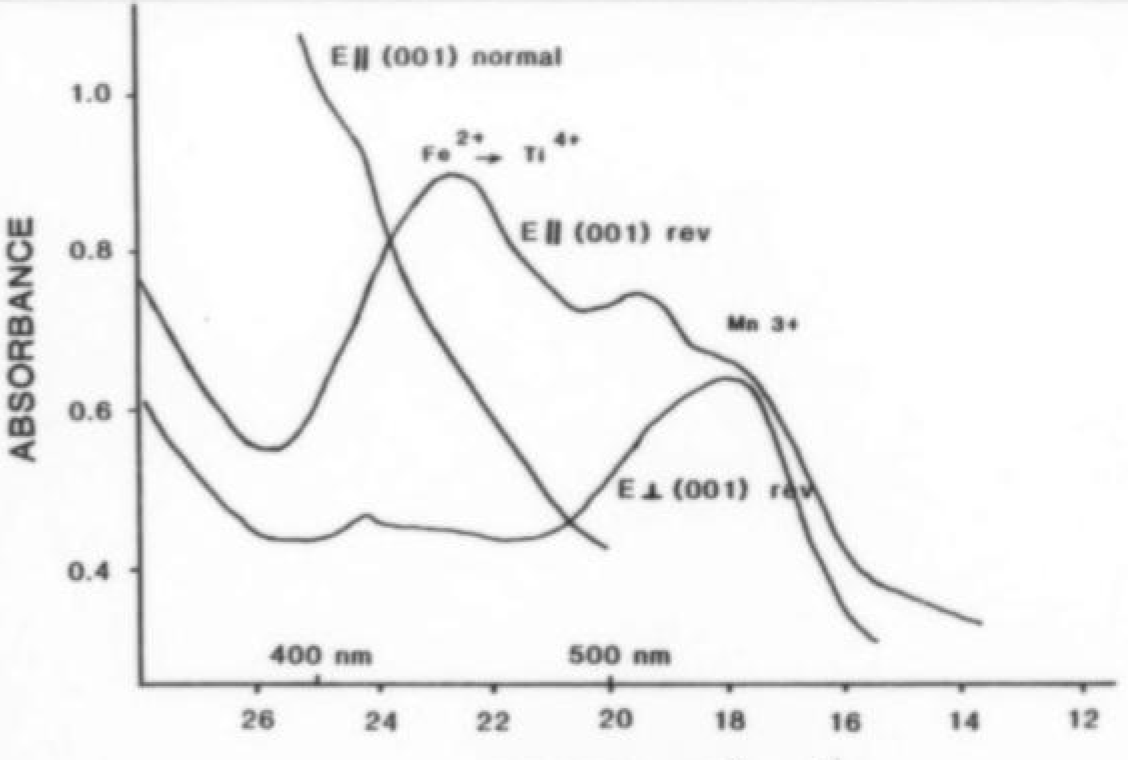

Figure 13. **Optical absorption spectra parallel to and normal to *c* of lepidolite from the Little Three main dike. See text for details.**

Some of the lepidolite crystals from pockets west of the large New Spaulding pocket differ in their striking bow-tie habit, red-violet color and color zonation (intensely red-violet rim).

Lepidolite has not been found in the Hercules-Spessartine dike, the Hatfield Creek dike, or the Spaulding dike, but it does occur sporadically in the Sinkankas dike.

Boron-substituted (borian) muscovite

$K_2[Al_4(Si,B,Al)_8O_{20}(OH,F)_4]$

In the large New Spaulding pocket, the floor, its constituent minerals and the fragments of minerals that had fallen at the time of (or subsequent to) pocket rupture are covered with a veneer of white to cream-colored, relatively hard, porcellaneous material. This material superficially resembles the normal white to cream colored pocket clays, such as found in the Himalaya dike system (Foord *et al.*, 1986), but is harder. It is extremely fine-grained, having an average grain size of less than 1–2 micrometers. Figure 16 shows a specimen of lepidolite-albite-quartz from the floor of the New Spaulding pocket coated with this material. Included in the coating, which is as much as 1 cm thick, are fragments of topaz, albite, elbaite and other pocket minerals. The material is clearly a result of precipitation from a late-stage pocket fluid, as it occurs only as a "snow-on-the-roof" coating. Based on depositional textures, final deposition of the borian muscovite took place from a stagnant fluid. Subsequent to deposition of this coating, and after a further period of fluid flow through the pocket, red-brown montmorillonite and kaolinite were deposited from groundwater. These minerals coat all pocket minerals and all fractures and cracks within the pocket.

Microprobe and X-ray fluorescence (XRF) analyses of the white material agree very closely, and results of a composite analysis are given in Table 5. Results of emission-spectrographic and ICP analyses of the same material are given in Table 4. The combination of X-ray diffraction and chemical studies of the coating shows that it is a mixture of about equal parts of 2*M*$_1$ and 1*M* muscovite with part of the tetrahedrally coordinated aluminum replaced by boron! This type of material has never been found before. A structural formula for the material based on 22 oxygen atoms is given below.

$$(K_{1.90}Rb_{0.05}Ca_{0.02})_{\Sigma 1.97}[(Al_{3.79}Mg_{0.03}Li_{0.03}Fe_{0.01}Mn_{0.01})_{\Sigma 3.87}$$
$$(Si_{6.50}B_{0.82}Al_{0.68})_{\Sigma 8.00}O_{20}(OH,F)_{\Sigma 4}]$$

X-ray cell data and powder diffraction data for both polytypes are given in Table 6. Refined unit-cell parameters for both the 2*M*$_1$ and 1*M* polytypes of borian muscovite are significantly smaller than those for regular muscovite. The volumes of both polytypes are only about 93–94% of regular muscovite.

This material is significant and interesting for several reasons. We still do not know the exact composition of the late-stage pocket fluid from which the elbaite, topaz, lepidolite, quartz and feldspars crystallized. The white, extremely fine-grained coating of borian muscovite formed at the time of pocket-rupture of the New Spaulding pocket;

***Table 5.* Chemical analysis of borian muscovite from the New Spaulding pocket.**

oxide	Wt. %
Al_2O_3	28.1
SiO_2	48.1
B_2O_3	7.0
CaO	0.1
MgO	0.15
Fe_2O_3	0.1
MnO	0.08
P_2O_5	none
TiO_2	none
K_2O	11.0
Na_2O	none
Li_2O	0.05
Rb_2O	0.52
Cs_2O	0.05
F	0.76
H_2O^+	4.55
H_2O^-	0.22
O for F	0.32
Total	100.46

Notes—Analysis done by X-ray fluorescence spectroscopy, electron microprobe, induction-coupled plasma-AAS, specific ion-electrode, and microcoulometric moisture analysis.

***Table 6.* Indexed X-ray power-diffraction and unit-cell data for borian muscovite from the New Spaulding pocket.**

hk*l*	d_{calc}(Å)	d_{obs}(Å)	I/I_o	polytype
002	9.860	9.861	60	$2M_1$
001	9.865	9.862		1M
004	4.930	4.929	20	$2M_1$
002	4.933	4.929		1M
110	4.379	4.391	80	$2M_1$
$\bar{1}11$	4.354	4.350	<10	$2M_1$
$\bar{1}11$	4.240	4.239	40	1M
111	4.201	4.194	<10	$2M_1$
022	4.014	4.007	40	$2M_1$
$\bar{1}13$	3.796	3.799	10	$2M_1$
023	3.654	3.652	10	$2M_1$
$\bar{1}12$	3.570	3.569	100	1M
$\bar{1}14$	3.421	3.418	10	$2M_1$
006	3.287	3.287	40	$2M_1$
003	3.288	3.287		1M
024	3.281	3.280	20	$2M_1$
114	3.145	3.142	10	$2M_1$
112,121	3.010	3.008	80	1M
025	2.935	2.930	<10	$2M_1$
$\bar{1}13$	2.865	2.865	20	1M
201	2.534	2.533	30	1M
200	2.525	2.524	40	$2M_1$
$\bar{1}31$	2.504	2.505	80	1M
200	2.489	2.489	40	1M
$\bar{1}17$	2.466	2.467	<10	$2M_1$
113	2.427	2.427	10	1M
$\bar{2}02$	2.422	2.421	10	1M
131	2.387	2.388	20	1M
$\bar{2}04$	2.342	2.341	30	$2M_1$
201	2.309	2.309	20	1M
$\bar{2}21$,040	2.195(2.194)	2.195	40	1M
204	2.164	2.165	20	$2M_1$
041	2.142	2.141	10	1M
$\bar{2}22$	2.120	2.119	10	1M
$\bar{2}06$	2.104	2.104	30	$2M_1$
135	2.086	2.087	10	$2M_1$
202	2.065	2.066	10	1M
221	2.043	2.043	10	1M
00*10*	1.972	1.972	30	$2M_1$
005	1.973	1.972		1M
$\bar{2}04$	1.954	1.954	10	1M
113	1.912	1.910	10	1M
$\bar{2}08$	1.857	1.857	<10	$2M_1$
$\bar{2}24$	1.785	1.786	10	1M
$\bar{3}11$, $\bar{1}06$	1.661	1.661	10	1M
20*10*	1.633	1.633	10	$2M_1$
204, $\bar{1}52$	1.601	1.601	10	1M
$\bar{1}54$	1.589	1.590	10	$2M_1$
$\bar{3}13$	1.588	1.588	<10	1M
$\bar{2}43$	1.555	1.555	<10	1M
02*12*	1.539	1.539	<10	$2M_1$
$\bar{2}06$, $\bar{3}23$	1.515	1.515	<10	1M
135	1.484	1.485	<10	1M
060	1.465	1.465	40	$2M_1$

Cell data

$2M_1$	MPDF no. 6–263	1*M* muscovite	MPDF no. 7–25
a — 5.075(1)Å	5.190Å	5.077(1)Å	5.208Å
b — 8.794(4)Å	9.030Å	8.775(3)Å	8.995Å
c — 19.815(25)Å	20.050Å	10.061(2)Å	10.275Å
β — 95.59(3)°	95.77°	101.31(2)°	101.6°
V — 879.68(150)Å^3	934.90Å^3	439.525(139)Å^3	471.5Å^3

Note: Operating conditions—Haag-Guinier camera, Cu Kα_1 radiation, 12 hour exposure, 40 KV, 30 Ma. Si internal standard (NBS). Refinements done using computer program of Appleman and Evans (1973).

it was found in the New Spaulding pocket itself, and may constitute part or all of similar coatings found in pockets peripheral to the New Spaulding pocket. Had crystallization been allowed to continue unhampered, more elbaite, lepidolite, topaz, quartz and K-feldspar would have formed, and at still lower temperatures and pressures, some or all of these minerals would have become unstable in the Li-rich and F-rich residual fluid and would have been partially or completely etched or altered (as for example in the case of the pocket minerals in the Hercules-Spessartine dikes and the Spaulding dike). The boron-bearing muscovite is considered to represent a quenched time-capsule of the late-stage pocket fluid present during the most important stage of chemical fractionation of crystals and aqueous fluid. At the time of the pressure quench, the fluid would appear to have become decidedly aluminous, and enriched in K and F. Deposition of the boron-substituted muscovite predated later movements of lower-temperature fluids through the New Spaulding pocket, which produced the physical abrasion in flow channels on the floor of the pocket. The abrasion by material carried in solution scoured away the borian muscovite and underlying lepidolite, quartz, albite and topaz.

[Ed. note: Borian muscovite is currently under consideration by the I.M.A. to determine whether it should be considered as a variety of muscovite or as an independent species.]

Schorl-Elbaite $NaFe_3^{+2}Al_6(BO_3)_3Si_6O_{18}(OH)_4$—$Na(Li,Al)_3Al_6(BO_3Si_6O_{18}(OH,F)_4$

Tourmaline is present in major amounts (constituting several weight % or more of the pegmatite-aplite) within the dikes on the Little Three property. A composition of schorl from the Surprise mine was reported by Schaller (1910, 1913). Schorl is developed within the aplite portions of the dikes and within the pocket zone of the Spessartine-Hercules dike. Boron metasomatism of the host rocks appears to have been much less important here than adjacent to the Himalaya dike system in the Mesa Grande district (see Foord, 1976; Shigley *et al.*, 1986): also the host tonalite contains less magnesium. Thus, schorl with an appreciable dravite component is uncommon to the dikes on the Little Three mine property (Table 7). Schorl-elbaite is developed within the pocket zone of the Little Three main dike and the Sinkankas dike.

Figure 14. **Euhedral crystals of lavender lepidolite coated with black stibiocolumbite-stibiotantalite polymorph. Cream-colored borian muscovite coating is also present. Width of field is 7 cm. Specimen and photo by E. E. Foord.**

Figure 15. **Matrix specimen of lepidolite from the New Spaulding pocket showing well-formed lavender crystals. Specimen is 10 cm across. Cal and Kerith Graeber collection.**

WEW

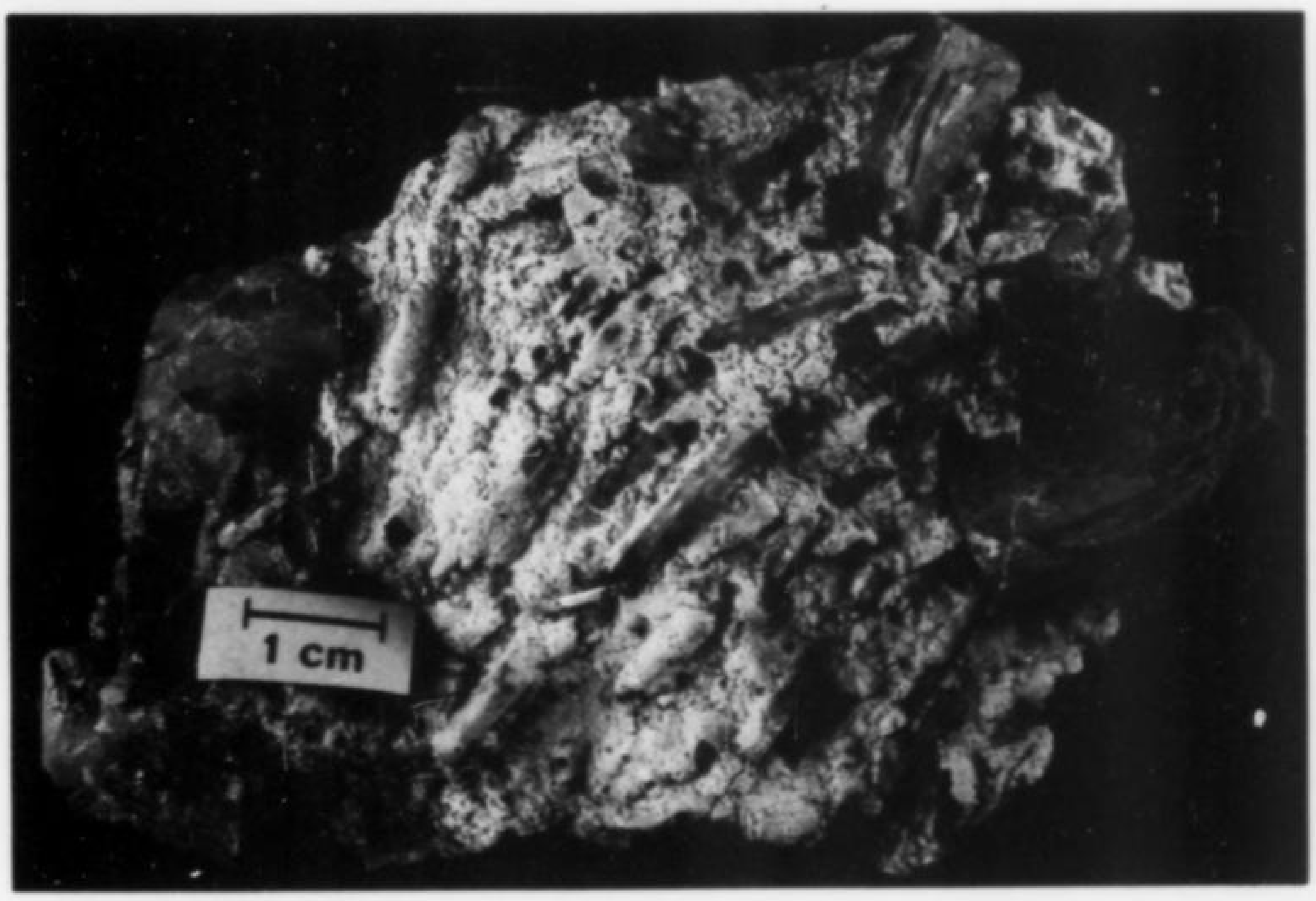

Figure 16. **Lepidolite-cleavelandite matrix specimen from the floor of the New Spaulding pocket, coated with fine-grained boron-substituted (borian) muscovite. Specimen and photo, E. E. Foord.**

Table 7. **Results of semiquantitative emission-spectrographic and ICP analyses of schorl-elbaite from the Little Three mine.**

Element	olive-green elbaite New Spaulding pocket	green core elbaite main dike	black schorl (early) H-S dike	black schorl non-corroded H-S dike	black schorl corroded H-S dike	burgundy pencil elbaite New Spaulding pocket		nailhead elbaite Sinkankas dike
Analytical method	**ICP**	**ICP**	**e-spec**	**ICP**	**ICP**	**ICP**	**e-spec**	**ICP**
Al (%)	21.0	20.4	major	20.3	20.7	20.8	major	19.7
Si (%)	17.4	16.7	major	16.9	16.9	17.3	major	17.1
Ca (%)	0.25	0.20	0.15	0.27	0.22	0.17	0.03	0.25
Fe (%)	1.1	0.24	7.0	5.83	5.81	0.09	0.3	1.65
Mg (%)	<0.03	<0.03	1.5	0.04	<0.03	<0.04	L0.001	<0.03
Na (%)	—	—	1.0	—	—		1.5	—
Ti (%)	0.08	0.05	0.03	0.07	0.05	0.04	0.07	0.05
Mn (%)	4.4	5.3	0.1	2.7	2.9	5.4	7.0	4.3
B (%)	3.1	3.0	major	3.0	3.0	3.1	major	3.0
Ba (ppm)	6	<5	N2	9	<7	<8	<2	6
Be	6	6	N3	8	130	<8	3	100
Cr	65	58	L2	47	70	<8	N2	71
Cu	<6	<5	<1	<6	11	<8	7	<5
Ga	410	330	70	280	270	350	300	180
Li	4900	4700	N100	1500	1200	4700	3000	6300
Nb	<20	<20	N10	<30	<30	<30	N10	40
Ni	<10	10	2	10	<10	<20	3	<10
Pb	<20	<20	N10	<30	<30	<30	N10	30
Sc	<10	<10	N5	<10	<10	<20	N5	40
Sn	100	80	N100	80	90	80	N100	<50
Sr	20	10	50	20	20	<20	N5	10
Th	<20	20	N20	<30	<30	<30	N20	<20
Zn	230	1700	500	6900	6300	90	N300	130

Note—The early black schorl from the H-S dike also contains 7 ppm Co, 7 ppm Sc, and 30 ppm V.

L less than value shown
N not detected at value shown
— not determined

The bulk of the material shows diverse shades of green, olive-green, and yellow-green, but some pink elbaite also is present. Schorl is also present within the graphic pegmatite portions of the dikes. Within the layered aplite in the Little Three main dike, the schorl is concentrated within specific tourmaline-rich layers and nearly absent elsewhere. Within the basal non-layered pegmatitic aplite, it is distributed randomly in clot-like fashion.

Pocket schorl-elbaite crystals from the Hercules-Spessartine dike, on average, attain 1–2 cm in diameter and 5 cm in length. Crystals have a simple habit, showing (in decreasing order of prominence) the forms $m_1\{01\bar{1}0\}$, $a\{11\bar{2}0\}$, $m\{10\bar{1}0\}$, $c'\{000\bar{1}\}$, $r\{10\bar{1}1\}$, and $e\{01\bar{1}2\}$. Most terminated crystals show only the pedion $c'\{000\bar{1}\}$. Some pockets in the Hercules-Spessartine dike (e.g., the "mud" pocket found in 1975) contain crystals showing signs of rapid cellular and dendritic growth that results in rough and fibrous terminations. Some crystals show cat's-eye schorl-elbaite that is 3–4 mm thick or more on the terminations. This very chatoyant material has sharp contacts with the substrate. Other pockets in the same dike contain schorl-elbaite crystals that are lustrous on all faces.

Most tourmaline crystals in pockets within the Hercules-Spessartine dike are black to deep blue-violet, but at least one pocket did contain green elbaite along with some fine topaz crystals.

Results of an emission-spectrographic analysis of one sample of Mg-bearing schorl, collected from near the base of a tapered crystal in the footwall portion of the Hercules-Spessartine dike, are given in Table 7.

Results of two ICP analyses of different terminated crystals from pockets within the Hercules-Spessartine dike are given in Table 7. These schorl-elbaite crystals, which contain essentially no dravite component (Mg), are about midway in composition between schorl and elbaite. The zinc content (6300 to 6900 ppm) is noteworthy.

Doubly terminated crystals were not found within some areas in the Hercules-Spessartine dike, and evidence for physical disruption of pockets in these areas is virtually nil. Many of the pocket minerals are in nearly perfect condition. Muscovite crystals are sharp, with no bent edges or deformation, and quartz is clear and unabraded. On the other hand, spessartine, beryl and K-feldspar show evidence of chemical dissolution by late-stage pocket fluids. Some schorl-elbaite crystals also show significant chemical corrosion. Results of analyses of unetched and etched crystals from different pockets are similar (Table 7). We consider the corrosion to be due to the presence and action of late-stage pocket-filling fluids, prior to their escape. Pockets in the Little Three main dike show substantial evidence for rupture and sudden expulsion of the contained fluids. Removal of the fluorine-rich corrosive fluids allowed better preservation of the primary pocket minerals. Fluorine and lithium, as well as some aluminum and silicon, were removed from the New Spaulding pocket upon pocket rupture and resulted in sudden and rapid crystallization of a boron-rich, lithium-poor muscovite that coats all pocket minerals. A very compact, unctuous, brownish green clay (montmorillonite) that had its origin outside the dike filled one particular pocket (the "mud" pocket) (see Foord *et al.*, 1986). Areas of the pocket covered by this clay were preserved perfectly. Pocket crystals in areas not covered were found to be slightly corroded, and cloudy surfaces were developed on the quartz crystals. The slight corrosion is presumably due to groundwaters containing humic acids. One large pocket in the Hercules-Spessartine dike contained abundant, well-rounded and physically abraded crystals and crystal fragments of all the contained pocket minerals (chiefly quartz, microcline, albite and schorl) (Fig. 17). Discrete zones and channelways on the heavily abraded floor of the pocket contained the scouring crystals and crystal fragments.

The tourmaline from the New Spaulding pocket and pockets directly up-dip from it, within the Little Three main dike, differs in many ways from the schorl described above. Schorl roots enclosed in surrounding silicate minerals grade compositionally to elbaite terminations. Of all the tourmaline crystals removed from the New Spaulding pocket, more than 90% were growing downward from the roof, and only 10% or less upward from the floor. Those that did project up from the floor are very small (2 cm maximum diameter) compared to those that projected downward from the roof (in excess of 7 cm in diameter). Somewhat more than 90 kilograms of elbaite were removed from the New Spaulding pocket. The physical condition of the crystals removed ranges from excellent to poor. Some crystals are badly fractured and incipiently altered, and crumble to pieces when removed. Others, however, are smooth and lustrous on the prism faces, and nearly free of flaws. Approximately 30% of the crystals within the

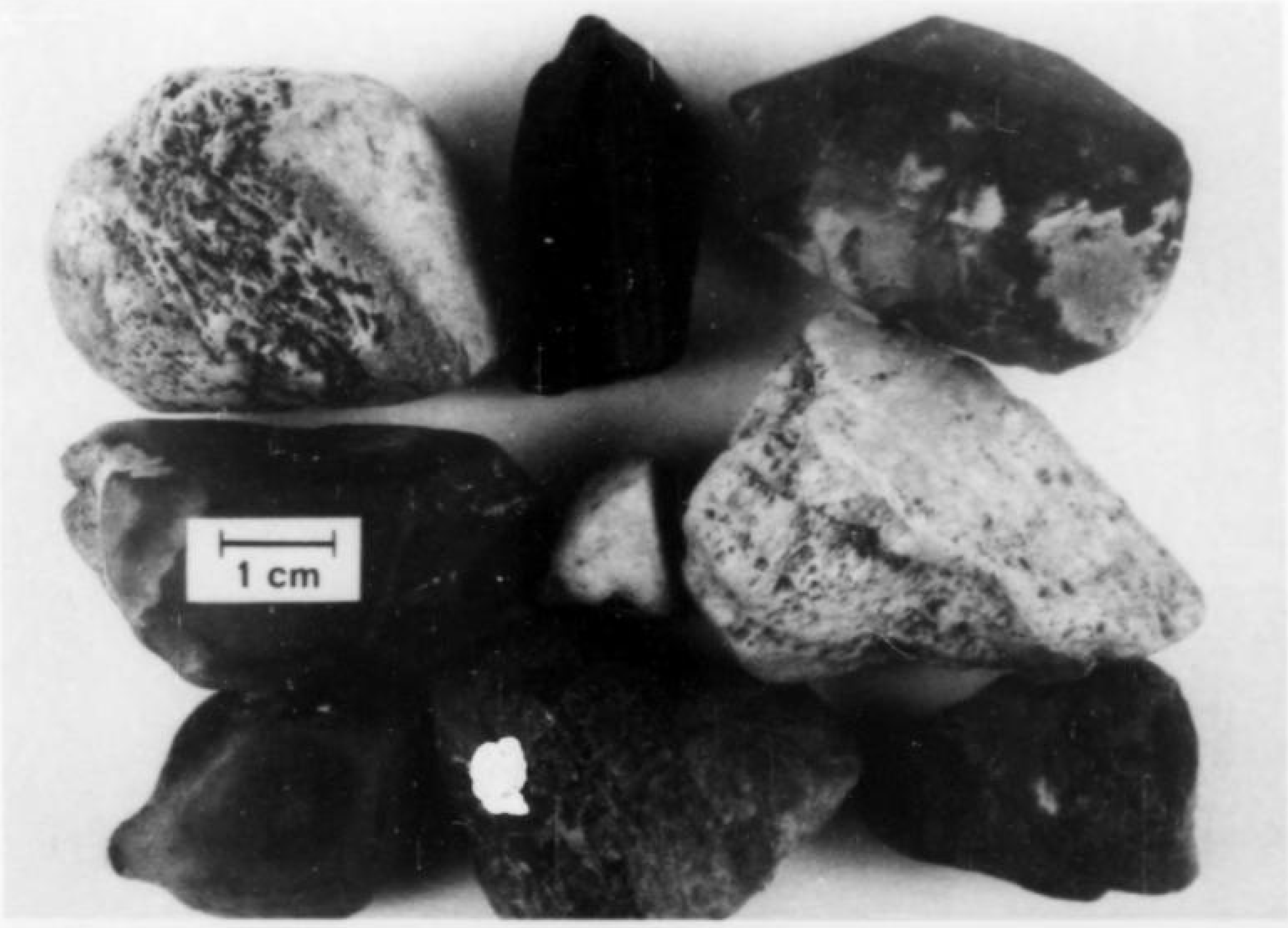

***Figure 17.* Physically abraded pocket crystals of quartz, potassium feldspar and schorl from a large pocket in the Hercules-Spessartine dike. Abrasion in an aqueous medium occurred after pocket rupture. Specimens and photo by E. E. Foord.**

***Figure 18.* A fine matrix specimen of dark-green elbaite associated with bladed cleavelandite, quartz and topaz from the New Spaulding pocket. Owner: L. B. Spaulding, Jr.; now in the Carnegie Museum collection, Pittsburgh. Specimen is 25 cm across.**

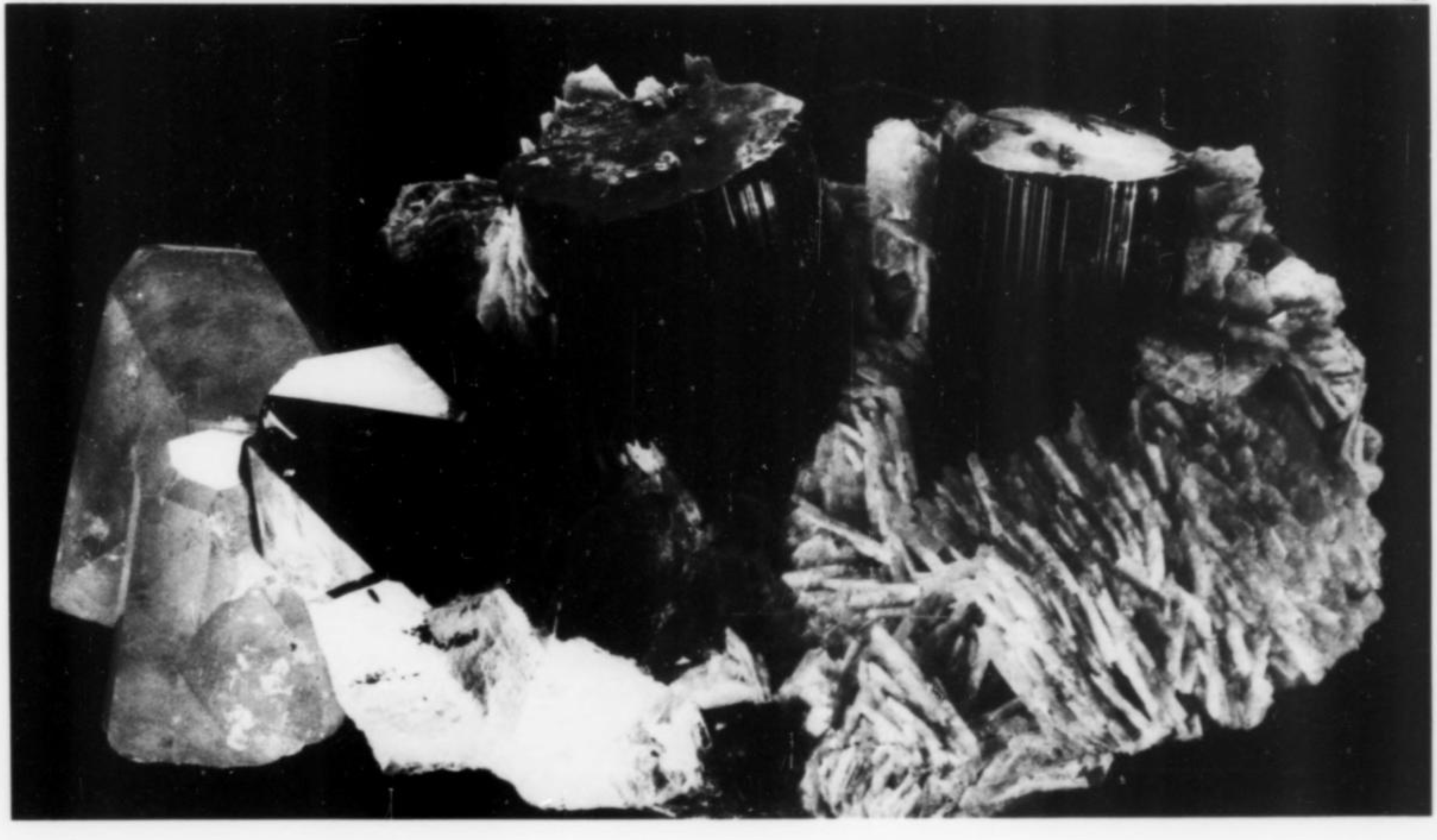

Figure 19. **Two "pencil" elbaite crystals from the Little Three main dike. Collections of William Larson and Cal and Kerith Graeber. Crystals are 6 cm long.**

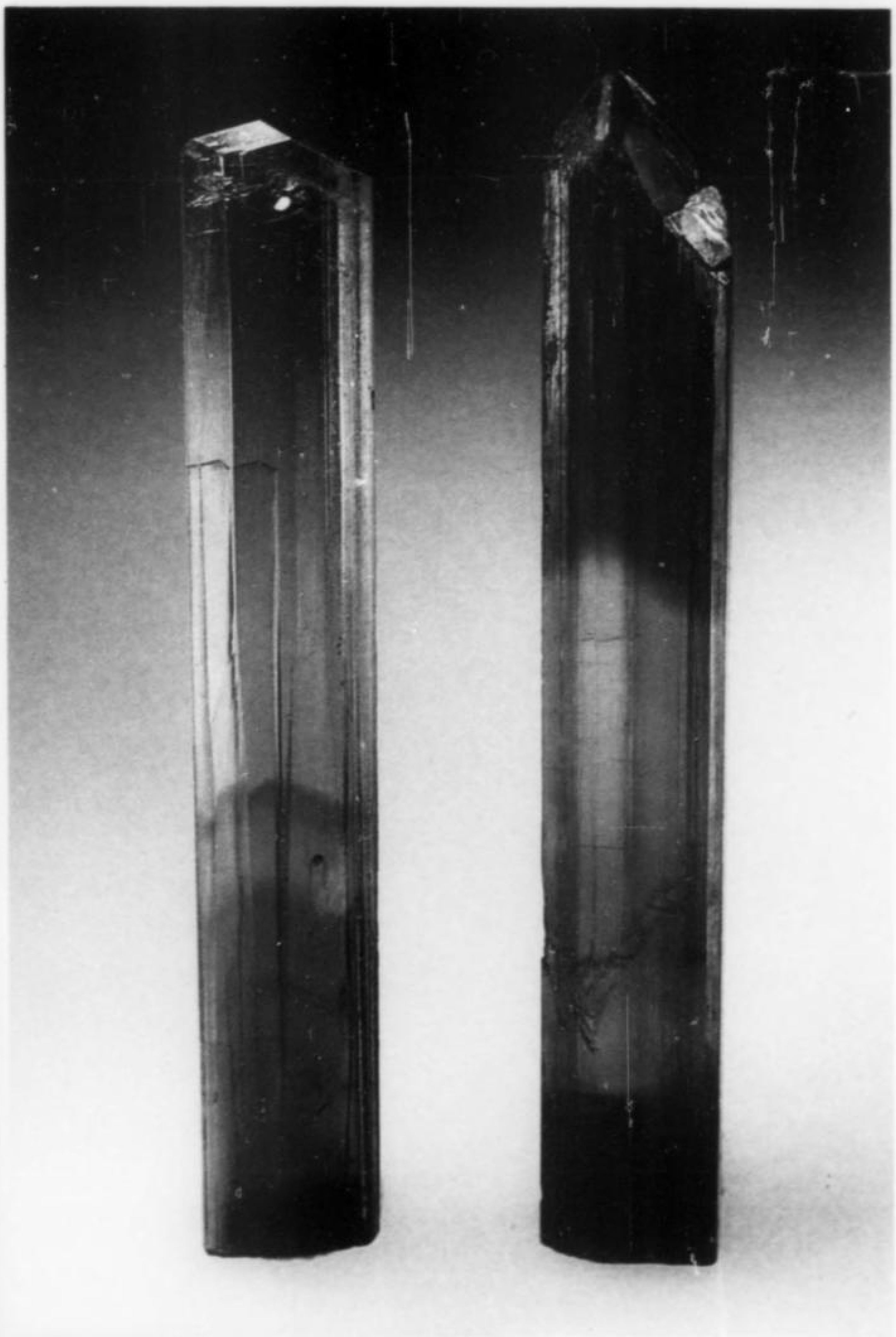
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Figure 20. **Set of 26 slices of a doubly terminated elbaite crystal from the same pocket as the specimen shown in Figure 21. Sequence is from upper left to lower right (top to bottom). Note the presence of phantom trigonal pyramid faces. Specimen and photo, E. E. Foord. Each slice is 12 mm across.**

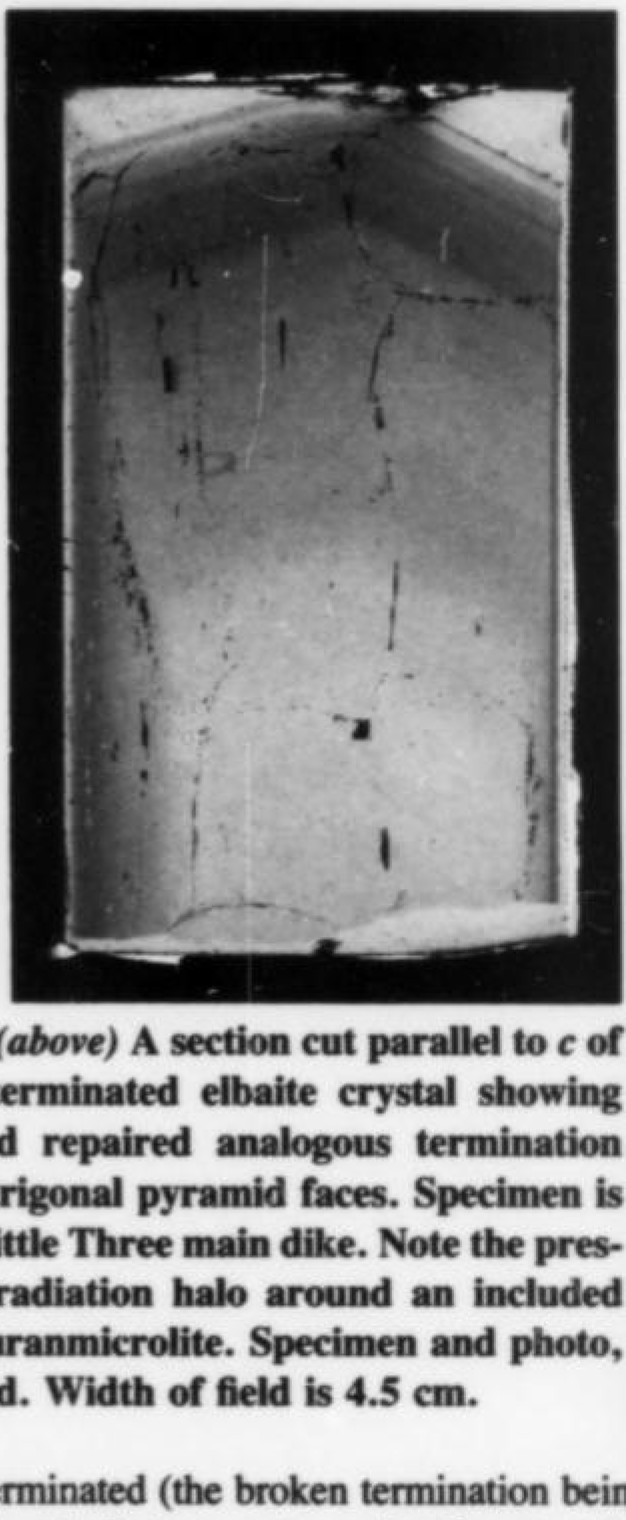

Figure 21. *(above)* **A section cut parallel to *c* of a doubly terminated elbaite crystal showing broken and repaired analogous termination and fossil trigonal pyramid faces. Specimen is from the Little Three main dike. Note the presence of a radiation halo around an included crystal of uranmicrolite. Specimen and photo, E. E. Foord. Width of field is 4.5 cm.**

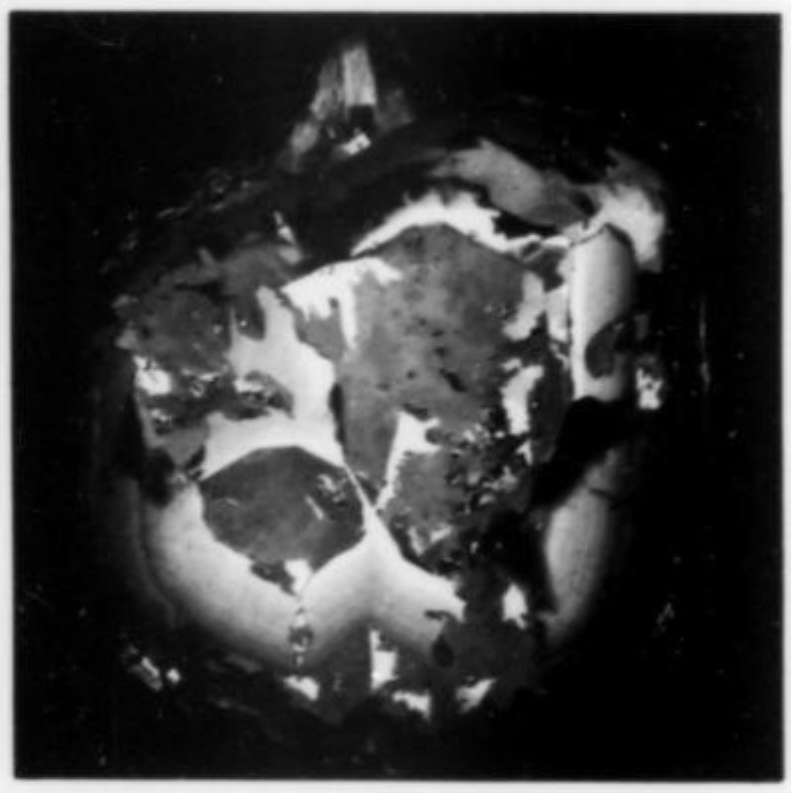

Figure 22. **One cut section of an elbaite crystal showing a complex multiple-stage growth history. Tubular voids now filled with another generation of elbaite. Specimen is from the Little Three main dike. Specimen and photo, E. E. Foord. Width of crystal is 1.5 cm.**

pocket are doubly terminated (the broken termination being naturally overgrown by additional elbaite) or show significant addition of material on the broken end. Figure 18 shows one of the fine matrix specimens of dark green elbaite associated with bladed cleavelandite from this pocket. Most of the material from the New Spaulding pocket has been broken or has spalled off from its original location of growth. This breakage occurred during pocket rupture in the latest stages of pocket formation. Only about 5% of the tourmaline crystals were still in place at the time of pocket excavation.

Crystals of elbaite from a variety of pockets in the Little Three main dike grew toward their analogous ends $(\bar{c})$, and virtually all crystals recovered show only the pedion $c'\{000\bar{1}\}$. However, sectioning of some crystals and visual examination of uncut crystals show that at one or more times in the growth history, as revealed by changes

Figure 23. **Two large crystals of topaz from the New Spaulding pocket showing the two typical habits of Little Three mine topaz. Owner: L. B. Spaulding, Jr.; now in the collection of the Natural History Museum of Los Angeles County. Photo by E. E. Foord. The right crystal measures 11 cm.**

Figure 24. **Corroded crystal of aquamarine (7.8 cm) and terminated crystal of pale pink morganite. Owner: B. Harris.**

in color zonation, the analogous termination was more complex, showing development of $r'\{10\bar{1}\bar{1}\}$ in addition to the pedion $c'\{000\bar{1}\}$. In all of these crystals, the trigonal pyramid grew itself out of existence, leaving only the pedion $\{000\bar{1}\}$. Figure 21 shows a section of a doubly terminated crystal of elbaite (cut parallel to the *c* axis) taken from the same pocket as the multiply sectioned crystal, shown in Figure 20.

The forms observed on singly terminated elbaite crystals from the New Spaulding pocket and other pockets in the Little Three main dike include (in decreasing order of prominence): $m\{10\bar{1}0\}$, $a\{11\bar{2}0\}$, $c'\{000\bar{1}\}$, $e\{01\bar{1}2\}$, and $r'\{10\bar{1}\bar{1}\}$. Pyramid forms are rarely present, perhaps on 1–2% of all crystals. Doubly terminated crystals show the development of $r\{10\bar{1}1\}$ on the antilogous end as well as $c\{0001\}$. Some of the broken crystals of elbaite show more complex forms on the antilogous end, such as $o\{02\bar{2}1\}$ and $t\{21\bar{3}1\}$, but these are not common.

The color zonation in the tourmalines from the smaller pockets updip from the New Spaulding pocket, which contain the deep purple lepidolite, is very similar to that in elbaite from the New Spaulding pocket. A doubly terminated crystal, measuring 3.7 cm long and 1.5 cm in diameter, from one of these upper pockets was cut into 26 slices, each about 1 mm thick, all normal to *c*. The end plates were left a bit thicker to preserve contact relationships. Figures 20 and 21 show the progressive zoning observed in the crystal. A core of achroite (Mn-rich, Fe-poor) was mantled by successive growth zones of yellowish brown and yellowish green elbaite (Mn-bearing and Fe-bearing). The broken bottom end was naturally repaired and covered with a green to pink (no Fe and moderate Mn) termination.

Some crystals of elbaite from the New Spaulding pocket or peripheral pockets show inclusions of uranmicrolite. Such crystals show radiation haloes around these inclusions. A reddish color was imparted to the host elbaite regardless of the initial color. The uranmicrolite was found only within the outermost zone, formed after pocket rupture, or within the latest-formed pre-rupture material (Fig. 21). The final material to crystallize in the New Spaulding pocket and peripheral pockets prior to pocket rupture was pink to red in color. This is indicative of the earlier removal of iron into crystallizing tourmaline and other minerals in these closed-system pockets. This is clearly evident on broken crystals and gem-quality "pencil" elbaite crystals. Two "pencils" are shown in Figure 19. Both show strong color zonation and phantom pyramidal crystal faces, and are from near the New Spaulding pocket in the Little Three main dike. Results of an emission spectrographic and ICP analysis (of the same sample) of one of the pink-red elbaite pencils is given in Table 7. Note the high (5 to 7 weight %) Mn content (tsilaisite component). A majority of fragments of primary elbaite crystals that were formed at the time of pocket rupture were then repaired to varying degrees. These fragments generally show very well the presence of overgrowth material and the partitioning of chromophores between ends, as discussed by Foord (1976). One crystal of elbaite appears to have had a topaz crystal growing adjacent to it; upon pocket rupture, the topaz crystal was jarred loose, leaving a v-shaped slot in the tourmaline crystal that was filled in by pink elbaite. The largest crystal recovered from the New Spaulding pocket is about 5.5 cm in diameter and 7 cm long (600 grams). However, according to Kunz (1905), a single crystal weighing 7 kg was recovered. The smallest crystal recovered is 1.5 × 3 cm (60 grams), and the average for the entire lot is about 4.5 cm × 5 cm (220 grams).

The elbaite crystals within the New Spaulding pocket could be further separated into two categories: (1) those with small crystals of colorless topaz growing on the $\{000\bar{1}\}$ face and, in some cases, other faces, and (2) those with no topaz crystals present. Those with the topaz growing on the elbaite crystals (some topaz being doubly terminated) have a black, velvety, sooty surface, whereas those without the topaz are quite lustrous. Growth spirals can be seen readily on the terminations of the elbaite crystals without topaz crystals growing on them, but not at all on those that had topaz present. The deposition of topaz on the terminations was evidently controlled by position in the pocket. After pocket rupture, the tourmaline crystals still in place were covered with tiny crystals of topaz on the terminations and prism faces. Those that had been broken off and fallen to the bottom of the pocket were not. Subsequent tectonic activity resulted in some additional disruption of the pocket; thus when the pocket was excavated, those crystals not broken off the roof were found to have topaz crystals on them, and all other broken material was piled in a random arrangement at the lowest part of the pocket, with some concentration of material around the scattered K-feldspar "pillars" growing upward from the floor. Continued tectonic (seismic) activity may have contributed to the piling up of pocket crystals in the lowest part. A total of about 75 crystals with topaz present on the $\{000\bar{1}\}$ and prism faces were recovered in good condition. About 10 crystals devoid of topaz crystals were found.

The large crystals from the New Spaulding pocket were also sectioned normal to *c*. They show mainly concentric growth zoning in the outer parts, with relatively unzoned material in the core. Details on the chemistry and zoning are given by Stern *et al.* (1986). One unusual feature is the high bulk content of manganese (6.1 weight % average MnO). Results of ICP analyses of one green crystal from the New Spaulding pocket and another crystal adjacent to the New Spaulding pocket are given in Table 7.

All of the elbaite from the New Spaulding pocket contains tubular voids and negative crystal cavities parallel to *c*. Such material appears to have formed at one major period of crystal growth. The initial growth of the pocket crystals led to good-quality material; the absence of tubular voids indicates conditions of slow growth. This stage was followed by a period of presumably rapid cellular and dendritic growth, which produced cavity-filled material. This was followed by a final period of growth, which resulted in material of high quality and imparted the fine final appearance of the crystals. The tubular voids are clearly seen in crystals that have been broken normal to *c* across the direction of elongation. If a break occurred in a crystal where the voids were present, the voids were then filled partly or wholly by light-colored green to pink elbaite. This same phenomenon has been observed in other pockets in the main dike. Figure 22 shows a crystal section oriented to show numerous tubular voids that are present.

Elbaite from one noteworthy pocket (Sinkankas, 1957) in the Sinkankas dike is olive-green with purplish gray-violet terminations. The crystals have a very slender and pointed habit. Trigonal and ditrigonal pyramidal faces, particularly $r\{10\bar{1}1\}$ and $u\{32\bar{5}1\}$, are well developed on these crystals. Several hundred crystals ranging from 8 cm long and 5 mm across to needle-like crystals were recovered. Results of an ICP analysis of one of these crystals are given in Table 7. This particular elbaite contains the maximum amount of Li (6300 ppm) determined for elbaite from the Little Three property.

Topaz $Al_2SiO_4(F,OH)_2$

The Little Three mine is one of only two major producers of topaz in San Diego County. The other, the J. W. Ware mine (also known as the Emeralite no. 2 or the Mountain Lily mine) on Aguanga Mountain, has been inactive for many years. The topaz from the Little Three main dike is of excellent quality and resembles material from the Mursinka-Alabashka region, Urals, and from the Volyn pegmatites, Ukraine, U.S.S.R. On the Little Three property, topaz has been found chiefly within the pocket pegmatite portions of the Little Three main dike and the Sinkankas dike. One pocket within the Hercules-Spessartine dike also contained topaz, associated with green elbaite. The mineral has also been reported from the New ABC and Surprise mines (Pemberton, 1983).

The topaz from the main dike is of at least two generations. More than 28 kilograms of topaz were removed from the New Spaulding pocket in the form of about 75 nearly complete and additional fragmented crystals. The earliest topaz crystals, which are the largest (many in excess of 450 grams each), are a pale to medium blue or sea-green. These crystals were found attached or loose on the floor of the pocket. A second generation of much smaller (several mm in diameter), colorless and nearly flawless crystals are found perched on most pocket minerals, particularly crystals of dark green elbaite. Fluid inclusions as much as 0.5 mm in maximum dimension are present in the first generation of crystals and generally occur as tubular voids parallel to the *c* axis.

Two general types of topaz are present (Fig. 23), based on terminations. The first type is characterized by well-developed *c*{001} basal pinacoid terminations typical of the Murskina-Alabashka topaz (Chukhrov, 1972). Crystals of the first type are bound by large *m*{110} and *l*{120} third-order prism faces, and the majority also have large *y*{021} first-order prism faces. The second type, also typical of Mursinka-type topaz, has steep roof-shaped terminations made up of intersecting *y*{021} and *f*{011} first-order prism faces, bounded by *m*{110} and *l*{120} third-order prism faces. Additional, less prominent, forms present on both generations of topaz are: *i*{113}, *u*{112}, *X*{023}, *o*{111}, and *h*{103}. Many of the smaller crystals of second-generation topaz are flattened on *l*{120} so as to resemble andalusite crystals. No differences in major-element chemistry between the early- and late-stage topaz were found.

A few small (less than 1 cm in maximum dimension), doubly terminated crystals of clear colorless topaz were found in 1976 in the New Spaulding pocket and in 1985 in pockets to the west and down-dip from the New Spaulding pocket. The forms present {*m*, *l*, *c*, *y*, *i*, *u* and *h*} on the doubly terminated crystals appear to be consistent with the centrosymmetric space-group *Pbnm*, a subset of point group *mmm* (orthorhombic) found for most topaz. Triclinic topaz from North Queensland, Australia, space group *P1*, was reported by Parise *et al.* (1980). Topaz that is triclinic contains appreciable H_2O^+ (OH), generally more than about 2 weight % H_2O^+. The decrease in symmetry is due to ordering of OH for F. Results of emission-spectrographic and ICP analyses of a pale blue crystal from the New Spaulding pocket and similar material are given in Table 8. The content of Ge (300 ppm) is noteworthy; levels of X00 ppm have been reported for other examples (El-Hinnawi and Hofmann, 1966; Černý and Hawthorne, 1982). A maximum content of about 700 ppm Ge for topaz was reported by Bernstein (1985). The distribution of Ge between topaz and coexisting quartz from the Little Three mine and other localities has been examined by A. Cohen (Univ. of Pittsburgh, personal communication, 1987).

One pale blue crystal from the New Spaulding pocket was analyzed for all major constituents and the following results obtained (in weight %): SiO_2 32.3, Al_2O_3 55.6, F 19.0, H_2O^+ 0.54, total 99.44. A structural formula based on 2(F,OH) is: $Al_{2.06}Si_{1.01}(F_{1.89}OH_{0.11})$.

Much topaz, regardless of environment of deposition, is not fluorescent under either shortwave or longwave ultraviolet radiation. However, most, if not all, of the topaz from the Little Three mine is moderately to strongly fluorescent under both shortwave and longwave ultraviolet light. All first-generation crystals from the New Spaulding pocket and other pockets in the Little Three main dike fluoresce a bright lemon-yellow and show growth zones, which are evident in all orientations. The core zone is only weakly fluorescent; one or several intermediate zones are strongly fluorescent, and then an outer zone shows moderate to strong fluorescence. Many of the second-generation colorless crystals from the New Spaulding pocket show very little or no fluorescence under either shortwave or longwave ultraviolet light. Some of the primary crystals show little or no apparent zoning in degree of fluorescence, and are a uniform orange-yellow. Under longwave ultraviolet light, all first-generation topaz fluoresces yellow-orange. A few crystal fragments were observed to show yellow to yellow-orange fluorescence under shortwave ultraviolet light but showed no response to longwave radiation. A few other crystal fragments which show yellow to yellow-orange fluorescence under shortwave light fluoresce even more strongly (bright yellow) under longwave light. One crystal of pale blue topaz from Sakangei, Burma, shows nearly identical fluorescence behavior (shortwave only, not fluorescent under longwave) to those from the Little Three mine. Topaz from Ouro Preto, Minas Gerais, Brazil, is also fluorescent under shortwave and longwave light, but different areas fluoresce under each wavelength. Under shortwave light, the fluorescence is bright blue-white, whereas under longwave light, the fluorescence is yellow-orange. The chromium-bearing topaz from Katlang, Pakistan, is also locally fluorescent bright blue-white under shortwave light. Additional work needs to be done on fluorescent topaz to determine the activator(s) and cause of fluorescence.

One additional unusual feature of Little Three topaz is that some of the material deepens in color (shades of blue or blue-green) after being removed from pocket cavities. Crystals excavated in 1976 were very pale blue and have darkened noticeably since then, without exposure to direct sunlight. This same phenomenon has been observed for some crystals of topaz from the Tarryall region, Pikes Peak batholith, Colorado. Crystals that were initially colorless or orange brown are now distinctly blue. One large crystal of brown topaz from Glen Cove, El Paso County, Colorado, cut by John Sinkankas and now in the U.S. National Museum, turned blue after being put on display. The fine sherry to orange-brown crystals of topaz from the Thomas Range, Utah, fade rapidly and become colorless upon exposure to sunlight. Usually, any color change taking place in pegmatite minerals involves bleaching of the original color or a change from one color to another upon exposure to sunlight. More work needs to be done on this phenomenon.

Worm-like etch cavities and evidence of chemical corrosion are present on some crystals of topaz from the Little Three main dike, but not on topaz from the New Spaulding pocket. Many of these crystals have the first-order prism forms *X*{023} and *f*{011} well developed, with no *y*{021} form present at all. Topaz crystals from a pocket west of the "Pasadena" pocket, in the Little Three main dike, are either unetched or etched. The etching is usually preferentially developed, particularly on *X*{023}. This same phenomenon was observed on topaz crystals from Devil's Head, Colorado, (Peacock, 1935) and has been observed by the senior author on virtually all topaz crystals from pegmatites in the Pikes Peak batholith. Crystals on top of the pile of rubble in the pocket have escaped etching, whereas material deeper in the pile shows progressive etching with depth. Many of the latter crystals were found embedded in clay and pink montmorillonite. The etching is most prominent on the {001} and prism faces. This type of etching has been ascribed to an increase in the alkalinity of the fluid phase, and in particular to its content of K (Černý and Hawthorne, 1982).

Beryl $Be_3Al_2Si_6O_{18}$

Beryl is not common on the Little Three property. Different varieties of this mineral have been found at the ABC, Black Panther, and Surprise mines to the northwest and southeast of the Little Three mine (Sinkankas, 1959; Weber, 1963). Locally it is relatively common in the Spessartine-Hercules dike and occurs as sporadic crystals within the Little Three main dike. No beryl was found in the New Spaulding pocket, however. Beryl is found only in the pocket zones of the dikes. All crystals are elongate along *c*; elongation ratios *c*/*a* range from about 1:1 to 10:1. Recently (1985) some beryl crystals of three varieties (aquamarine, goshenite and morganite), in many cases doubly terminated, were found in the Spessartine-Hercules workings (Fig. 24). The largest morganite (pink) crystal found is about 8 cm long and about 2.5 cm in diameter, and occurs on a matrix of quartz and cleavelandite. Specimens of beryl with attached crystals of spessartine were also found.

Forms determined to be present are (in decreasing order of prominence): $m\{10\bar{1}0\}$, $c\{0001\}$, $s\{11\bar{2}1\}$, $v\{21\bar{3}1\}$ and $p\{10\bar{1}1\}$. Similar morphological data on beryl from the Ramona district are given by Eakle (1907) and Ford (1906). A few small (2–5 mm across) pale pink crystals of "cat's-eye" beryl and intergrown clusters of beryl crystals were found in the Hercules dike in 1978. The "cat's-eye" beryl is a late-stage second generation of material formed on clear to slightly cloudy beryl. Foord and Mills (1978) found strong compositional zoning, expressed mainly in the alkalis, in goshenite-morganite from the Little Three mine. Data for Na and Cs along a microprobe traverse across a 6.7-mm wide crystal of pale pink morganite show as much as 2.85 weight % Na_2O and 1.85% Cs_2O in the outer portion. The core of the crystal contains about 1.6 weight % Na_2O and 0.7% Cs_2O. Results of an ICP analysis for a crystal of the pale pink morganite, found in 1985, are given in Table 8.

Like topaz from the Little Three main dike, the beryl from the Hercules-Spessartine dike also deepens in color upon removal from the host pockets. Whereas months or years are necessary for the color change to take place in topaz, only weeks are required for beryl.

Many of the beryl crystals found associated with orange spessartine, white cleavelandite, quartz, muscovite and etched schorl are doubly terminated, with mirror-finish terminations. A few crystals show pale blue or blue-green terminations on both ends, with a colorless to pink center. All of the crystals show variable chemical etching and corrosion on both the prism and pedion faces, but the corrosion is most severe on the prism faces. Some crystals are extremely cavernous, and as little as 10% of the original crystals may remain. The feldspars and quartz do not appear to show any noticeable resorption effects, but the spessartine garnet shows some resorption, and some of the associated schorl shows strong resorption. The resorption of the rounded tourmaline prisms results in trigonal planar relics, nearly all with mirror-quality surfaces in the prism zone.

Almandine-spessartine $Fe_3Al_2Si_3O_{12}$—$Mn_3Al_2Si_3O_{12}$

Garnet, invariably of the almandine-spessartine series, is a widespread mineral within the Little Three and other pegmatite dikes in the Ramona district. In the layered basal aplite portion of the Little Three main dike, the garnet is about Alm_{50}-$Spess_{50}$. There, it is subhedral to euhedral and has a grain size of less than 0.5 mm. Garnet constitutes only as much as 1 to 2% of the aplite portion of the main dike, but individual layers within the layered aplite contain 40% or

Figure 25. **A corroded crystal of spessartine from the Hercules-Spessartine dike showing step-like etch faces. Specimen and photo, E. E. Foord. Crystal is 1.5 cm across.**

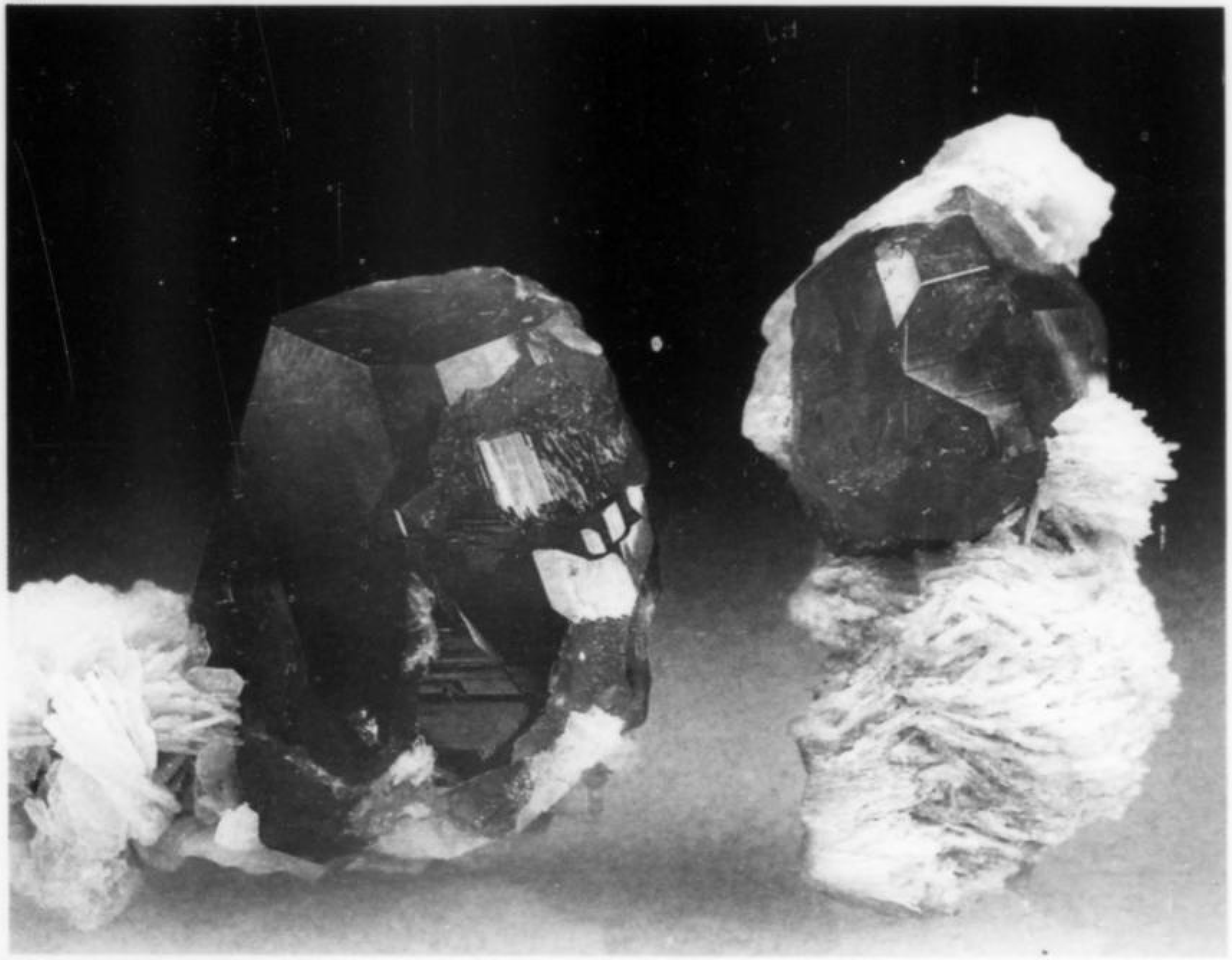
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Figure 26. **Spessartine crystals to 2 cm on albite matrix, from the Hercules-Spessartine dike. Tim Sherburn collection.**

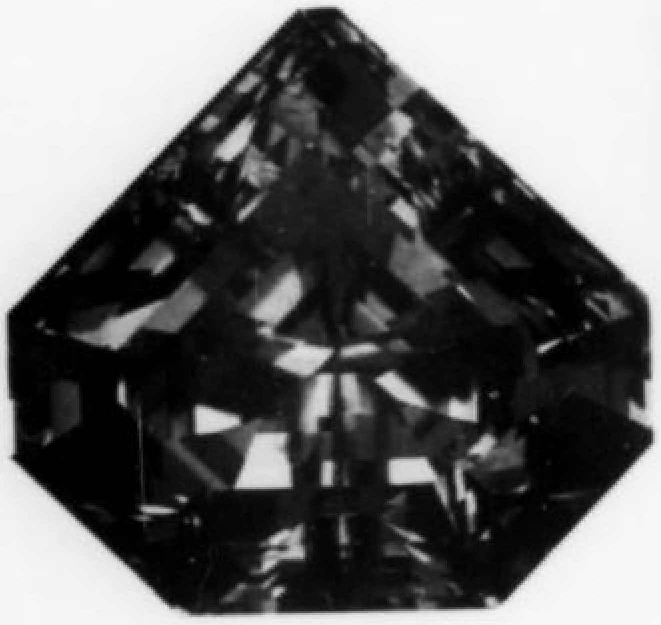

Figure 27. **A 10.4-carat cut spessartine from the Hercules-Spessartine dike. Owner: Kerith Graeber. Photo by Michael Havestad.**

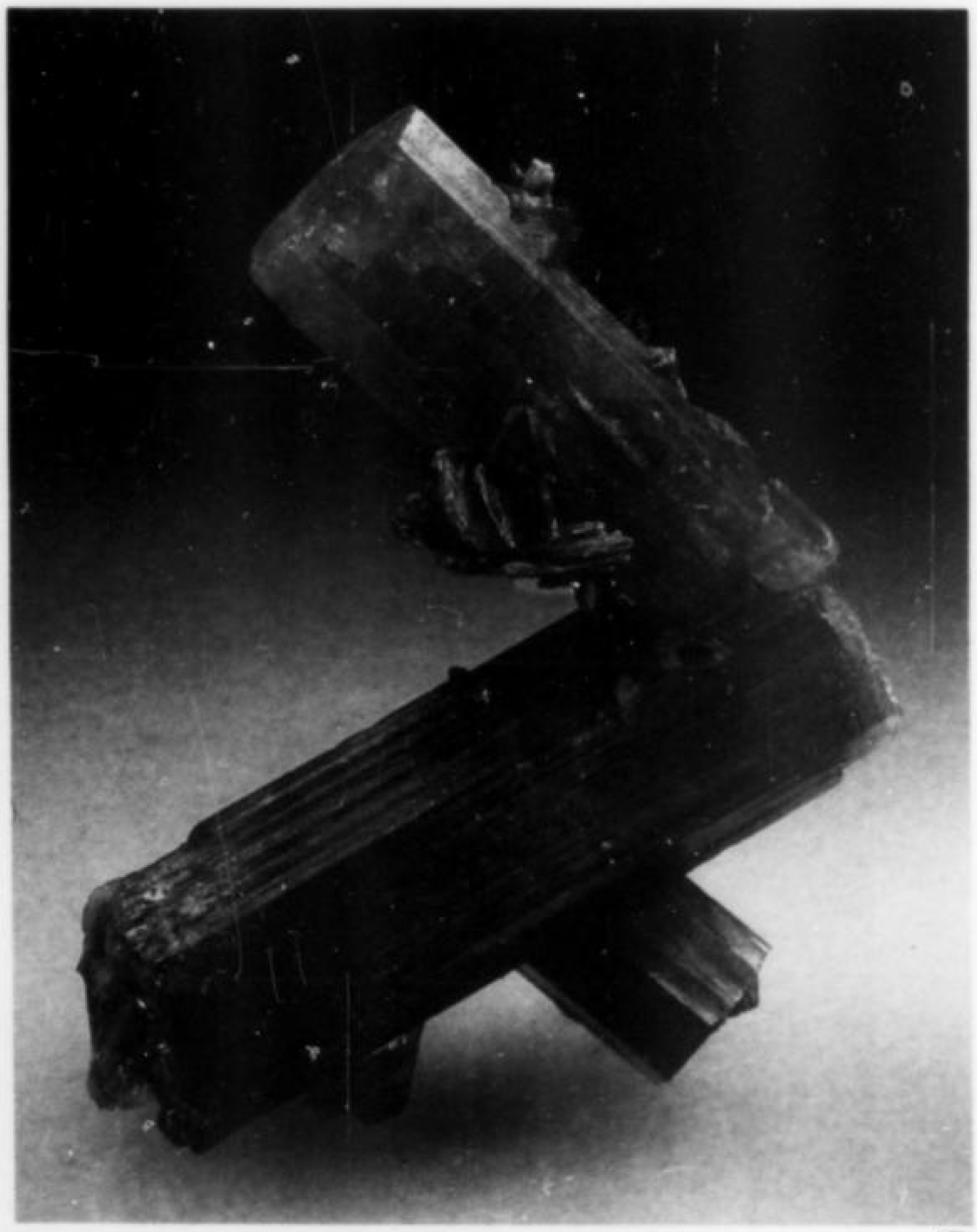
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Figure 28. **Group of fluorapatite crystals with muscovite from the Hercules-Spessartine dike. Largest crystal is 4.6 cm long. Owner: Cal Graeber.**

more. Almandine-spessartine is present within the graphic pegmatite portions of the dikes as well, but in isolated grains as much as 1 cm or more across. The garnet rapidly becomes enriched in the spessartine component as the pocket zone is approached. Spessartine garnet was and is the principal mineral of economic interest in the Spaulding and Hercules-Spessartine dikes. Whereas spessartine does occur in the pocket zone of the Little Three main dike, it is sparsely distributed and generally fractured, and does not form in open pockets. Most of the pocket spessartine within the Hercules-Spessartine dike is about Spess$_{95}$Alm$_{05}$, but some material is more or less Mn-rich. Results of an emission-spectrographic analysis of an orange-red spessartine garnet crystal from the Hercules-Spessartine dike are shown in Table 8. The color of the spessartine is a very diagnostic indicator of the Fe:Mn ratio (Sinkankas, 1968, 1976; Foord, 1976). Bright orange spessartine is nearly of end-member composition. Such pure or nearly pure spessartine, as is found in the Spessartine-Hercules workings, is relatively rare; it is found at only a few other localities worldwide in crystals large enough for gem-cutting purposes (e.g., Brazil, East Africa, Virginia and Idaho).

Much of the spessartine exposed in pockets is chemically etched and corroded. Some crystals may show a thin overgrowth of the same mineral, but such material is uncommon. Individual pockets usually

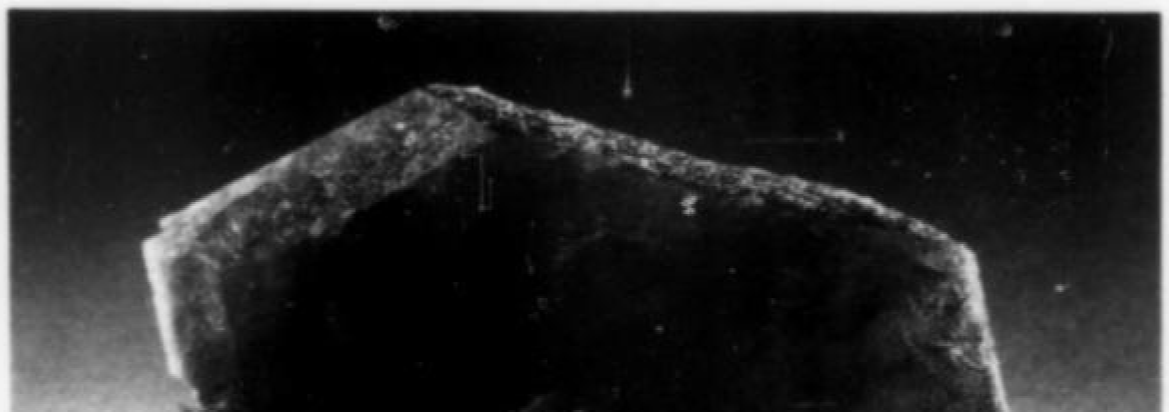
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Figure 29. **Doubly terminated crystal (4.5 cm) of manganaxinite from the Hercules-Spessartine dike. Owner: Cal Graeber.**

contain both corroded (etched) and lustrous garnet crystals. Beryl crystals from pockets free of garnet are lustrous and unetched, whereas beryl from pockets containing spessartine garnet is variably corroded and etched. Spessartine garnet that shows smooth and lustrous faces is either covered with other silicate minerals and hence was protected from reaction with late-stage pocket fluids, or represents a second generation of flawless or nearly-flawless, virtually end-member spessartine garnet, formed after pocket rupture. Most of the garnet crystals show dodecahedral {110} or trapezohedral {211} faces dominant. Many crystals also show hexoctahedral {321} faces (Sinkankas, 1976).

About 6000 carats of spessartine were removed prior to February, 1976, from one area in the Spessartine workings. About half that amount could be used for gem-cutting purposes. Much of the material was found loose at the bottom of the pocket seam; it shows chemically etched hopper and step faces. In late 1985 to early 1986, another area in the Spessartine workings produced fine matrix specimens of spessartine and associated beryl. Several matrix specimens of spessartine show clearly that the original size of the garnet crystals was perhaps several times that of the relict fragments, some of which are extremely cavernous and cellular. Some crystals of garnet were completely dissolved. An example of one of the corroded crystals of spessartine garnet in matrix is shown in Figure 25. The cover of this issue shows a fine unetched example of spessartine garnet, and Figure 27 shows a fine 10-carat faceted stone of spessartine.

Other Minerals

Axinite group: Manganaxinite $A_3Al_2BSi_4O_{15}OH$
where A = Ca, Fe^{+2}, Mg, Mn^{+2}

Manganaxinite, a Ca-Fe-Mn-Mg-bearing borosilicate, has been found in pockets in three dikes on the Little Three property. The second author found manganaxinite in one pocket in the Spaulding dike. The crystals reach 1.3 × 2.5 cm (Sinkankas, 1967). The Hatfield Creek dike contains dark violet-brown to purplish brown crystals 1 cm or more across. Complete crystals are rare, and most of the manganaxinite occurs as broken and naturally repaired fragments. Results of an ICP analysis of such a sample of manganaxinite are given in Table 8. A crystal of manganaxinite from the Spaulding dike contains minor amounts of Na and P. The Hercules-Spessartine dike also contains manganaxinite, but only locally. Small amounts of pale straw-yellow crystals coating cleavelandite and other pocket minerals were found in 1976. The crystals are small, 0.5 mm or less in maximum dimension. Based on optical and partial chemical data, this straw-yellow axinite should be considered a manganaxinite with small amounts (<1%) of P and Fe.

In late 1986, a pocket area in the Hercules-Spessartine dike was found that contains relatively abundant, large (individual crystals as much as 2.5 × 5 cm), yellowish brown to purplish brown crystals of manganaxinite (Fig. 29). Results of an ICP analysis of this manganaxinite are given in Table 8. Associated minerals are quartz, microcline, perthite, schorl, spessartine, and albite. The schorl, mircocline and spessartine are all corroded and etched to varying degrees. The manganaxinite is a late-stage pocket mineral, coexisting with schorl; it continued to grow after pocket rupture, as indicated by textural relationships.

Bismite Bi_2O_3

Fine-grained gray bismite was found associated with native bismuth and bismutite within the "Pasadena pocket" west of the New Spaulding pocket in the Little Three main dike.

Bismuth Bi

Native bismuth has been found rarely in the Little Three main dike. The "Pasadena pocket" to the west of the New Spaulding pocket, contained some masses of bright metallic native Bi, with alteration rinds of gray bismite and bright yellow bismutite. The masses of native Bi attain 1 cm across, and combined masses of all three bismuth-bearing minerals may be as much as 2 to 3 cm across.

Bismutite $Bi_2(CO_3)O_2$

Bismutite was found at several locations in the Little Three main dike. It is readily noticeable by its distinct yellow color (bismuth ocher). It may occur singly or associated with other bismuth-bearing mineral species such as native Bi, bismite and pucherite. It usually occurs as a thin film coating other pocket minerals or as earthy yellow masses pseudomorphous after native bismuth. In some cases, the original mineral may have been bismuthinite, but no fresh material has been found.

Cassiterite SnO_2

Cassiterite was found with topaz in the Little Three pegmatite (Schaller, 1916). A mass of cassiterite 5 cm in diameter was found in the Sinkankas dike and identified by X-ray diffraction (J. Sinkankas, personal communication, 1987).

Cerussite $PbCO_3$

Microprobe analyses of quartz containing an unidentified Ag-Bi-Pb sulfosalt showed the presence of cerussite. It is extremely fine-grained and gray in color.

Cookeite $LiAl_4(Si_3Al)O_{10}(OH)_8$

Sparse amounts of pearly cookeite have been found coating pocket minerals in the Spessartine-Hercules dike. It has been observed on quartz, K-feldspar, albite, schorl-elbaite and other minerals. Individual flakes of cookeite are less than 0.25 mm across.

This mineral was also reported from the Sinkankas dike, associated with hambergite, quartz, lepidolite and topaz (Switzer *et al.*, 1965). Weber (1963) also reported cookeite from the Little Three mine and the New ABC mine.

Epidote-Clinozoisite $Ca_2(Al,Fe^{+3})_3(SiO_4)_3(OH)$—
$Ca_2Al_3(SiO_4)_3(OH)$

Some scattered crystals of zoned epidote-clinozoisite were found coating K-feldspar crystals from pockets in an unnamed dike near Hatfield Creek. The associated pocket minerals are cleavelandite, quartz, muscovite and schorl. Crystals of epidote-clinozoisite attain 2 mm in length and are medium pistachio-green in color. The tips of the crystals are nearly colorless. This material contains essentially no iron, whereas the green material contains 4 weight % or more of iron. Single-crystal X-ray diffraction studies (EEF, unpublished data) confirm the identity of the material as zoned epidote-clinozoisite.

Sprays of dark green, partly altered crystals of epidote were reported from the district (upper end of the Hercules dike) by Sinkankas (1967). The crystals attain 10 cm in length, but are less than 3 mm wide.

Ferrocolumbite-Manganocolumbite $FeNb_2O_6$—$MnNb_2O_6$

Specimens of columbite are rare from the Little Three property. Morphological data (13 forms) were reported by Eakle (1907) for one crystal from the Little Three mine. Some crystals have been collected at the neighboring Black Panther mine to the northwest. Emission spectrographic data for one 0.75 × 1 × 3 cm crystal of columbite from the Hercules-Spessartine dike are given in Table 8. Quantitative electron-microprobe results for the same crystal indicate strong compositional zonation involving Fe and Mn. The core portion of the crystal has the following composition: Ta_2O_5 4.0, Nb_2O_5 73.6, WO_3 0.2, ZrO_2 0.5, TiO_2 1.4, FeO 10.8, MnO 9.8, total 100.3; and the outer portion of the crystal has the composition: Ta_2O_5 4.3, Nb_2O_5 75.2 WO_3 0.2, TiO_2 0.4, FeO 2.6, MnO 17.6, total 100.3. Structural formulae (based on 6 oxygen atoms) for these two average compositions are:

$(Fe_{0.51}Mn_{0.47})_{\Sigma 0.98}(Nb_{1.88}Ta_{0.06}Ti_{0.06}Zr_{0.01})_{\Sigma 2.01}O_6$ and
$(Mn_{0.85}Fe_{0.12})_{\Sigma 0.97}Nb_{1.93}Ta_{0.07}Ti_{0.02})_{\Sigma 2.02}O_6$.

Fluorapatite $Ca_5(PO_4)_3(F,OH)$

Fluorapatite is a sparse but locally abundant constituent of some of the dikes on the Little Three property. Some pink to reddish violet crystals and crystal fragments were found in the Hercules-Spessartine dike (Fig. 28) and some pale blue and pale pink material was found

Table 8. **Results of semiquantitative emission-spectrographic and ICP analyses of selected minerals from the Little Three mine.**

Element	**Topaz 1**		**Topaz 2**	**Mangan-axinite**	**Beryl**	**Spessartine**	**Mangan-axinite**	**Apatite**	**Goethite pseudo-morphous after pyrite**	**Columbite**
	Little Three main dike (New Spaulding pocket)			**Hatfield Creek dike**	**Hercules-Spessartine dike**		**Hercules-Spessartine dike**		**Little Three main dike**	**Hercules-Spessartine dike**
analytical method	**e-spec**	**ICP**	**ICP**	**ICP**	**ICP**	**e-spec**	**ICP**	**ICP**	**ICP**	**e-spec**
Si (%)	M	16.1	15.	20.1	30.4	M	21.0%	0.26%	1.9%	0.07%
Al (%)	M	30.5	28.	9.7	10.0	M	9.8	0.17	0.39	N0.01
Ca (%)	0.07	0.23	0.12	13.4	0.14	0.07	14.0	40.2	0.29	0.015
Fe (%)	0.007	0.05	<0.03	2.6	0.09	3.0	2.3	0.10	62.0	7.
Mg (%)	<0.0015	<0.03	<0.03	0.07	0.04	0.0015	0.27	0.02	0.16	0.002
P (%)	N	<0.03	<0.03	<0.03	<0.03	N	<0.03	21.0	<0.04	N
Ti (%)	0.002	<0.03	<0.03	<0.03	<0.03	0.05	<0.03	<0.02	<0.04	0.3
Mn (ppm)	2	<30	<30	7.8%	150	M	7.0%	0.81%	0.2%	major
As (ppm)	N	<70	<70	130	<50	N	<60	120	460	N
B (ppm)	N	<30	40	1.7%	<20	N	1.8%	20	100	N
Ba	2	<7	<7	<6	<5	N	20	4	130	N
Be	N	<7	<7	180	3.4%	N	440	6	55	N
Bi	N	<70	—	<60	<50	N	—	<40	100	N
Cd	N	<10	—	<10	<10	N	—	<8	80	N
Ce	N	<30	<30	<20	<20	N	<30	300	<30	N
Co	N	<7	<7	6	<5	N	<6	5	28	N
Cr	N	47	27	26	42	N	22	14	9	N
Cu	N	10	<7	<6	7	N	<6	<4	290	N
Ga	N	<30	<30	70	50	N	90	<20	<30	N
Ge	300	—	—	—	—	70	—	—	—	N
Ho	N	<30	<30	40	<20	N	<30	30	<30	N
La	N	<10	<10	<10	<10	N	<10	74	<20	N
Li	N	<10	<10	<10	680	N	<10	64	<20	N
Nb	N	<30	<30	<20	<20	30	<30	20	130	major
Nd	N	<30	<30	<20	<20	N	<30	370	<30	N
Ta	—	—	—	—	—	—	—	—	—	1.5%
Ni	N	<10	<10	10	<10	N	<10	<8	20	N
Pb	N	<30	<30	<20	<20	N	<30	<20	220	50
Sc	N	<10	<10	40	<10	70	30	<8	<20	70
Sn	N	<70	<70	90	80	N	150	<40	<80	interference
Sr	N	20	<10	<20	<10	N	30	96	50	N
Th	N	<30	<30	30	<20	N	<30	30	<30	N
Zr	N	—	—	—	—	—	—	—	—	1500
V	N	<10	<10	<10	<10	N	30	<8	110	N
Y	N	<10	<10	1500	<10	150	220	1200	<20	N
Yb	N	<7	<7	100	<5	3	22	30	<8	N
Zn	N	<10	<10	160	80	N	190	17	4200	N

Notes: Beryl (morganite) also contains <10 ppm Rb, and 2900 ppm Cs as determined by AAS. The spessartine garnet also contains 70 ppm Gd, 50 ppm Dy and 50 ppm Zr.

M major

N not detected at value shown or limit of detection

— not determined

in the Little Three main dike. Euhedral crystals of dull, gray-green apatite were reported from the Sinkankas dike (J. Sinkankas, personal communication, 1987). Fluorapatite is found only within the pocket zone and in open pockets. The crystals attain several cm in maximum dimension but are rare. Their habit varies from squat and tabular to slightly elongate prismatic. Results of an ICP analysis of one sample of pale pink fluorapatite from the Hercules-Spessartine dike are given in Table 8.

All of the pink or reddish violet fluorapatite found is cloudy or opaque, whereas the minor proportion of pale blue fluorapatite is clear and transparent. The pink to lavender fluorapatite from all of the dikes fades to white after a few hours of exposure to sunlight. This phenomenon has been noted for fluorapatite from other localities as well. Some fluorapatite crystals and crystal fragments show evidence of secondary growth analogous to that in pocket tourmaline, garnet, quartz and other minerals. In such cases, clear blue material coats variably cloudy pink to reddish pink fluorapatite. Clear, pale blue crystals of fluorapatite also occur as a coating on other pocket minerals and are clearly very late (post-pocket rupture). All of the primary fluorapatite is fluorescent yellow to orange under shortwave and longwave ultraviolet light, but clear gem-quality material is only weakly so. Secondary fine-grained apatite and primary colorless crystals included within topaz crystals from the New Spaulding pocket fluoresce bright orange. Fluids in fluid inclusions in the fluorapatite may contribute to the intensity of fluorescence.

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

Pseudomorphs of red-brown to tan-yellow goethite after pyrite were found in one pocket in the Hercules dike, and four or five crystals of similar material were collected from the Little Three main dike to the east of the New Spaulding pocket. Results of an ICP analysis of one pseudomorph are given in Table 8. Pseudomorphs faithfully preserve the growth striations and growth distortions of the original cubes of pyrite, and attain 1 cm or more across.

Hambergite $Be_2BO_3(OH,F)$

The first discovery of hambergite in California was made by John Sinkankas in 1956 at the Little Three mine (Switzer *et al.*, 1965). Several hundred corroded and etched crystals of hambergite were found in the upper portions of the Little Three main dike. Only about a dozen crystals from the Little Three dike exceed 1.5 cm in length. Only one piece of hambergite was found during recent work in the Little Three main dike, near the "Pasadena" pocket. None, however, has been found in the Hercules-Spessartine dike. It occurs as a pocket mineral only, and is very difficult to spot or recognize readily. It resembles fragments of feldspar or altered spodumene and is often colored by Fe-oxides and pocket clays. Undoubtedly some material has been thrown out on the dumps. Where perfectly clean, the hambergite is white. Individual crystals and masses of crystals in excess of 5.5 cm across have been found. The hambergite is F-rich (6.0 weight % F); Switzer *et al.* (1965) provided data on this and other examples of hambergite. The Little Three hambergite shows development of two new forms {340} and {341}, and is noteworthy in containing the highest fluorine content yet reported for the mineral. Many crystals are multiply twinned; the twin and composition plane is (110).

Laumontite $CaAl_2Si_4O_{12}\cdot 4H_2O$

Euhedral crystals of white laumontite were apparently first positively identified from the Ramona district (Hercules dike) by Sinkankas (1967). Additional crystals were recently (1986) found coating all primary pocket minerals in a series of interconnected pockets in the Hercules-Spessartine dike. The laumontite was in turn covered by dark red-brown, sticky, disordered kaolinite which is of surficial origin. Laumontite crystals attain 5 mm in length and several mm in width, and have the typical habit with wedge-shaped terminations. The laumontite is a product of deposition of an aqueous fluid that interacted with both the pegmatite dike and the host tonalite.

Microlite-Uranmicrolite (general formula is:
$A_{2-m}B_2O_6(O,OH,F)_{1-n}\cdot pH_2O$, where m = 0 to 1,
n = 0 to 1, and p = 0 to ?)

Microlite has Ca and Na dominant in the A site, and uranmicrolite has U dominant in the A site. Both contain dominant Ta in the B site, and Nb + Ta invariably exceeds 2 Ti. Specimens of this mineral series are rare and have not been found larger than approximately 1 mm in diameter. Crystals are deep honey-brown to dark brown. All specimens found have come from the Little Three main dike. It is a very late-stage pocket mineral coeval with pink tourmaline, topaz, the stibiocolumbite-stibiotantalite polymorph and lepidolite. A spectral scan by wavelength dispersion for one crystal included within a doubly terminated elbaite crystal (Fig. 21) from a pocket adjacent to the New Spaulding pocket showed: Ta, Nb, Ti, Bi, Ca, U, Na and F as major constituents, and Mn, Ce, La, Pb, Sn and Sb as minor constituents.

Montmorillonite $(Na,Ca)_{0.33}(Al,Mg)_2Si_4O_{10}(OH)_2\cdot nH_2O$

Montmorillonite has been found in all of the dikes on the Little Three property. Unstained and clean montmorillonite, which is either white or shades of pink, has been found in the Little Three main dike, and in lesser amounts in the Hercules-Spessartine dikes. All of the dikes on the property, particularly those that are thinner and less competent, contain pockets that have been filled with tan, buff, greenish brown, or reddish brown clays. These clays are a mixture of montmorillonite and kaolinite. Within the Little Three main dike, several pseudomorphs of pink montmorillonite after topaz were found. The montmorillonite is a Ca-Mg variety, details of which are given in Foord *et al.* (1986).

Pucherite $BiVO_4$

Sparse amounts of powdery yellow-orange pucherite associated with bismutite were found in a pocket adjacent to the New Spaulding pocket in the Little Three main dike. Pucherite is a relatively rare mineral and has been reported from only one other locality in San Diego County (the Tourmaline King mine; Jahns and Wright, 1951).

Stibiocolumbite-Stibiotantalite polymorph
(bismuthian and tungstenian $(Sb,Bi,W)NbO_4$—$(Sb,Bi,W)TaO_4$

Crystals of stibiotantalite were reported from the New ABC mine adjacent to the Little Three property by Weber (1963). No member of the stibiocolumbite-stibiotantalite series was definitively identified from the Little Three property until material examined by Foord (1982a,b) and Stern *et al.* (1986) was shown to be bismuthian and tungstenian stibiocolumbite-stibiotantalite. Material of this composition had never been reported previously. Additional studies on stibiocolumbite-stibiotantalite and bismutotantalite, which have different space groups, are under way (EEF and T. S. Ercit, National Museum of Natural Sciences, Ottawa, Canada). The material from the Little Three mine is in fact a new species because compositionally it is stibiocolumbite-stibiotantalite, but it has the space-group of bismutotantalite. Crystals are black in hand specimen and yellow brown to red brown in thin section. Details are given in the above three references. The material occurs in the New Spaulding pocket within the Little Three main dike. The largest crystal found is about 1 × 1 × 2 cm and was attached to a large crystal of K-feldspar. Many of the crystals are polysynthetically twinned. Figure 14 shows crystals coating euhedral "books" of lepidolite from the New Spaulding pocket.

Stilbite $NaCa_2Al_5Si_{13}O_{36}\cdot 14H_2O$

Stilbite sheaves and bow-tie-shaped aggregates have been found in pockets in the Little Three main dike. The crystals are euhedral, 1 to 10 mm long, and are gray to gray-white. This mineral has not previously been reported from the Little Three mine.

Todorokite $(Mn^{+2},Ca,Ba)Mn_3^{+4}O_7\cdot H_2O$

Locally abundant dark brownish black crusts of todorokite are present on quartz, the feldspars and other pocket minerals in the New Spaulding pocket. The todorokite forms a very late and discontinuous coating on broken fragments of crystals and naturally repaired crystals. It postdates the "snow-on-the-roof" coating of borian muscovite but predates the very late, surficially derived pocket-filling clays.

X-ray analysis of several different samples of todorokite from the Little Three property (using energy dispersion) shows the presence of major Mn and minor amounts of Ca, Ba, Zn and K.

Unidentified Ag-Bi-Pb Sulfosalt

A mass of fractured quartz containing a dark gray powdery material was found by John Sinkankas within the Hercules-Spessartine dike (J. Sinkankas, personal communication, 1976). About half a kilogram of this material was collected. The gray material was initially identified by X-ray diffraction (XRD) studies (Sinkankas, 1967) as a mixture of bismuthinite and bismutite. A subsequent XRD pattern (also by Sinkankas) was interpreted to show bismutite and beyerite. In 1976, some of this gray powdery material was given to EEF for additional study. Electron microprobe WDS spectral scans of the material showed the presence of major amounts of Bi, Pb, Ag and S, with minor amounts of Sb and Te. The WDS scans also showed the presence of a major proportion of oxygen. SEM examination of one sample of the fine-grained powder showed intergrown sheaves and aggregates of 1-micrometer plates of a Pb-Bi-Ag sulfosalt mixed with other minerals. XRD studies of the material yielded patterns similar to those obtained by Sinkankas. Whereas most of the peaks fit bismutite and cerussite fairly well, there are additional peaks that do not. The XRD studies at the moment are inconclusive as to the identity of all of the minerals present.

PEGMATITE GENESIS

Miners, gem cutters, professional geologists and mineralogists have been asking questions about the petrogenesis and conditions of formation of the complex granitic pegmatites in San Diego County since the turn of the century. Schaller (1925) made one of the first attempts to explain the genesis of lithium pegmatites, and drew upon 22 years of observation and studies of the San Diego County pegmatites. Richard H. (Dick) Jahns spent more than 40 years studying the San Diego County pegmatites. He was intensively interested in the mineralogy and the genesis of these pegmatites, and succeeded admirably in involving his students (for example EEF and RFM) and colleagues in relevant studies. The Jahns-Burnham model for the origin and crystallization of granitic pegmatites (Jahns and Burnham, 1969) is now a classic study; it has been added to and refined by more recent work (e.g. Chorlton and Martin, 1978; Stewart, 1978; Taylor *et al.*, 1979; Jahns, 1982; Černý, 1982; Pichavant, 1981, 1983; London, 1984, 1986a,b; London *et al.*, 1987).

Following emplacement of the sheet-like dikes on the Little Three property, crystallization from a vapor-saturated, geochemically evolved, hydrous silicate melt containing dissolved fluxing agents (mineralizers), and volatiles took place mainly under closed-system conditions. The ensuing crystallization of the bubble-laden silicate melt resulted in a highly asymmetrical pattern of mineral distribution and textural development (e.g., Figures 2 and 1b; Foord, 1977; Jahns, 1982). Sodic, non-layered aplite and layered aplite formed on the lower portions of many of the dikes, and relatively K-rich graphic pegmatite containing large tapered crystals of K-feldspar characterizes the upper portions (Jahns and Tuttle, 1963). The K-feldspar crystals grew from the melt relatively quickly downward from the hanging wall, as inferred from the presence of a graphic intergrowth with quartz (Fenn, 1986). As the rate of crystallization decreases, the amount of discrete quartz crystals increases, so that by the time the pocket stage is reached, the K-feldspar is virtually quartz-free.

The rhythmic layering of the aplite in the lower portions of the dikes is believed to be influenced at least in part by minor fluctuations in confining pressure on the system. "Miarolitic pockets provide incontrovertible evidence for the exsolution of a comparatively low-density aqueous fluid from silicate melt during the late stages of pegmatite consolidation" (Shigley *et al.*, 1986). The elements that are incompatible (rare alkalis, rare elements) in the structure of the silicate minerals became progressively concentrated in the supercritical fluid medium at the pocket stage. Concentrations of these elements became sufficient to allow crystallization of exotic minerals containing these same elements as major constituents. These minerals include topaz, lepidolite, elbaite, columbite-tantalite, and the stibiocolumbite-bismutocolumbite polymorph as well as others. We consider that the crystallization of the pocket minerals occurred from the residual aqueous vapor phase under subsolidus conditions.

The pressure and temperature of formulation of pockets in the San Diego County pegmatites have recently been elucidated on the basis of data on fluid inclusions, stable isotopes, field observations and phase equilibria; the pockets formed in the range of 425–475°C and 2.4 to 2.8 kbars pressure (London, 1986a). The dramatic (and, to a large extent, additive) fluxing effects of B, Li, F and water on depressing solidus temperatures have been shown by various investigators (e.g., Chorlton and Martin, 1978; Manning, 1981; Pichavant, 1981, 1983; London, 1986a,b; Weidner and Martin, 1987).

The crystallization of tourmaline, which is the only important sink for boron in these systems, remove boron from the fluid phase; as a result, the crystallization of tourmaline (and fluorine-rich minerals) leads to (1) a rise in the solidus temperature, (2) forced precipitation of alkali aluminosilicates and oxide-forming minerals, and (3) consequent exsolution of copious amounts of aqueous fluid (Shigley *et al.*, 1986; London, 1986a).

The formation of large and highly fractioned pockets such as the New Spaulding pocket was likely controlled by the F-rich, B-rich and Li-rich aqueous vapor. Experimentally determined effects of B and F concentrations may account for the floorward distribution and K-rich and F-rich minerals (lepidolite, K-feldspar and topaz), whereas Na-rich, B-rich and Si-rich minerals (cleavelandite, elbaite and quartz) are preferentially distributed roofward. This zonation (of K) is the opposite of that observed in the early-formed, Na-rich, basal aplite and coeval, K-rich graphic pegmatite on the hanging wall. The reasons for this are not yet clear but may reflect different patterns of diffusion in a silicate melt vs. an aqueous vapor phase. Crystallization in pockets containing substantial amounts of F, B and Li (e.g., New Spaulding pocket) persisted to considerably lower temperatures than those pockets deficient in these elements (e.g., "mud" pocket) (Stern *et al.*, 1986).

Rupture of individual or interconnected pockets and evacuation of a portion of the contents are believed to occur when the internal pressure of the pockets greatly exceeds the confining strength of the surrounding dike and host rocks. A degree of overstepping of the internal vapor pressure (P_{int}) relative to that of the external confining pressure (P_{ext}) is necessary to activate the rupture process. The continued increase in the proportion of aqueous vapor phase exsolved from the silicate melt in a nearly constant volume causes the internal pressure to increase. Depending on the geometry of a given pocket and the rate of escape of the contained fluid, the rupture event may be minor to major in disruptive capacity with respect to the contained crystalline minerals. Thus, in the case of the Hercules-Spessartine dike, a violent or sudden decrease in pressure does not appear to have occurred. As mentioned previously, the pocket minerals there are generally in excellent condition, with almost no breakage. The content of Li and of F, in particular, as represented by the pocket minerals, is low. The observed chemical corrosion of the quartz, spessartine garnet, K-feldspar, schorl-elbaite and beryl but not cleavelandite cannot be fully explained at present. Hydrolysis of K-feldspar and production of KOH, producing a mildly alkaline medium, could account for the etching of these minerals. If HF (hydrofluoric acid) were the agent responsible for the corrosion, then all of the exposed pocket minerals should show evidence of etching. The pegmatite pockets found in the Sawtooth batholith, Idaho, which contain extensively corroded gem-quality aquamarine, pristine quartz and pristine spessartine garnet, may have contained alkaline solutions at the end stages of crystallization rather than the expected mildly acidic solutions (R. A. Kosnar, personal communication, 1986). As an alternative, corrosion of the pocket minerals listed may have occurred because the pocket fluid continued to react with the silicate minerals and was not immediately evacuated as a result of a rupture. In thin dikes such as the Hercules-Spessartine, internal pressures may not have reached the levels attained in pockets in thicker dikes, such as in the Little Three main dike. The chemistry of the pocket contents must also play a role in their development. Earlier(?), less-fractionated pockets such as those in the Hercules-Spessartine dike did not evolve fluids having the same characteristics as those fluids evolved from highly fractionated pockets, such as the New Spaulding pocket.

Conversely, in the case of the New Spaulding pocket, a very disruptive rupturing event clearly took place. Primary pocket minerals (e.g., quartz, feldspars, elbaite, topaz) were broken off, shattered and fractured extensively. Doubly terminated crystals and repaired fragments of crystals were then formed. Depending upon location in the pocket and degree of fluid flow, some crystals were not noticeably disrupted, and these crystals form the matrix specimens that are so prized by mineral collectors. Overgrowths on the various minerals are of the same species as the substrate (e.g., quartz growing on quartz, elbaite growing on elbaite, and K-feldspar growing on K-feldspar). More than one rupturing event may occur, as is very evident in pockets in the Himalaya dike system (Foord, 1976; Foord *et al.*, 1986). The elbaite crystals in the New Spaulding pocket are unusual in that they show a sharp contact between (1) dark olive-green-brown and (2) pale green and pink zones. Usually, pocket elbaite crystals show a sharp transition from pale green, colorless or pink to a dark or medium green or even blue, reflecting a resetting of the "chemical clock" during pocket rupture. Deposition of the borian muscovite occurred subsequent to the initial rupturing event in the New Spaulding pocket, and after another period of growth of the primary pocket minerals and repair of broken surfaces and fragments of crystals. Still later movement of a lower-temperature hydrothermal aqueous solution through the pocket resulted in abrasion of the muscovite coating and the underlying minerals. Pockets that were not reopened to migrating solutions, such as some pockets peripheral to the New Spaulding pocket, remained as "dry pockets," which contain only the "snow-on-the-roof" coating of borian muscovite, regular muscovite or cookeite.

Pockets that were opened to circulating hydrothermal solutions contain secondary minerals such as laumontite, stilbite and montmorillonite. These minerals are the result of interaction between the host tonalite and the circulating fluid. This phenomenon has been well documented by Foord *et al.* (1986).

Very late, low-temperature groundwater solutions moving through the dikes resulted in deposition of another generation of montmorillonite or kaolinite of near-surface and surficial origin. Agitation and transport of the rounded and abraded "stream pebbles" of pocket minerals, such as those found in the Hercules dike, occurred prior to the establishment of the slow percolation of groundwater (Fig. 17). High velocities of flow were necessary to move the pebble-sized fragments around in the pockets; stratification of later clays and fine-grained material occurred when flow velocities decreased substantially.

CONCLUSIONS

The Little Three property is somewhat unusual in having a variety of pegmatite dikes containing varied mineral assemblages in close proximity to one another. Pegmatite dikes in other districts (e.g., Pala and Mesa Grande) are more similar to one another in terms of their mineralogy and chemistry. The cause for this is not yet known. The Little Three mine is also unique for San Diego County in being the only producer of major amounts of gem-quality and specimen-quality crystals of nearly pure spessartine garnet. It is in fact the only current producer in the United States. Two minerals of unusual composition are unique to the Little Three main dike: a bismuthian and tungstenian stibiocolumbite-stibiotantalite polymorph and borian muscovite. It is one of only a few localities worldwide for pucherite. The exceptionally fine lepidolite specimens produced from the Little Three main dike are also noteworthy.

The Little Three property will continue to be a producer of fine pegmatite minerals for years to come. We trust that through continued mineralogical and geochemical investigations, the property will become established as one of the best-understood pegmatitic systems.

ACKNOWLEDGMENTS

The authors gratefully acknowledge the emission-spectrographic analyses done by Nancy M. Conklin of the U. S. Geological Survey. ICP analyses of the borian muscovite and other minerals were done by James G. Crock of the U. S. Geological Survey. X-ray-fluorescence analyses of topaz and borian muscovite were done by Joseph E. Taggart (U.S.G.S.). Fluorine and water determinations were done by L. A. Jackson (U.S.G.S.). The optical spectra for two samples of lepidolite were provided by Dr. P. G. Manning (Canada Centre for Inland Waters, Burlington, Ontario). Thanks are also due to the following individuals for providing photographs used in this article: Cal Graeber, Dr. A. R. Kampf, Dr. Wendell E. Wilson, and Michael Havestad. Unpublished information and a careful review of the manuscript provided by John Sinkankas are gratefully acknowledged. Reviews by Thomas C. Michalski and Peter J. Modreski, both of the U.S.G.S., are also acknowledged.

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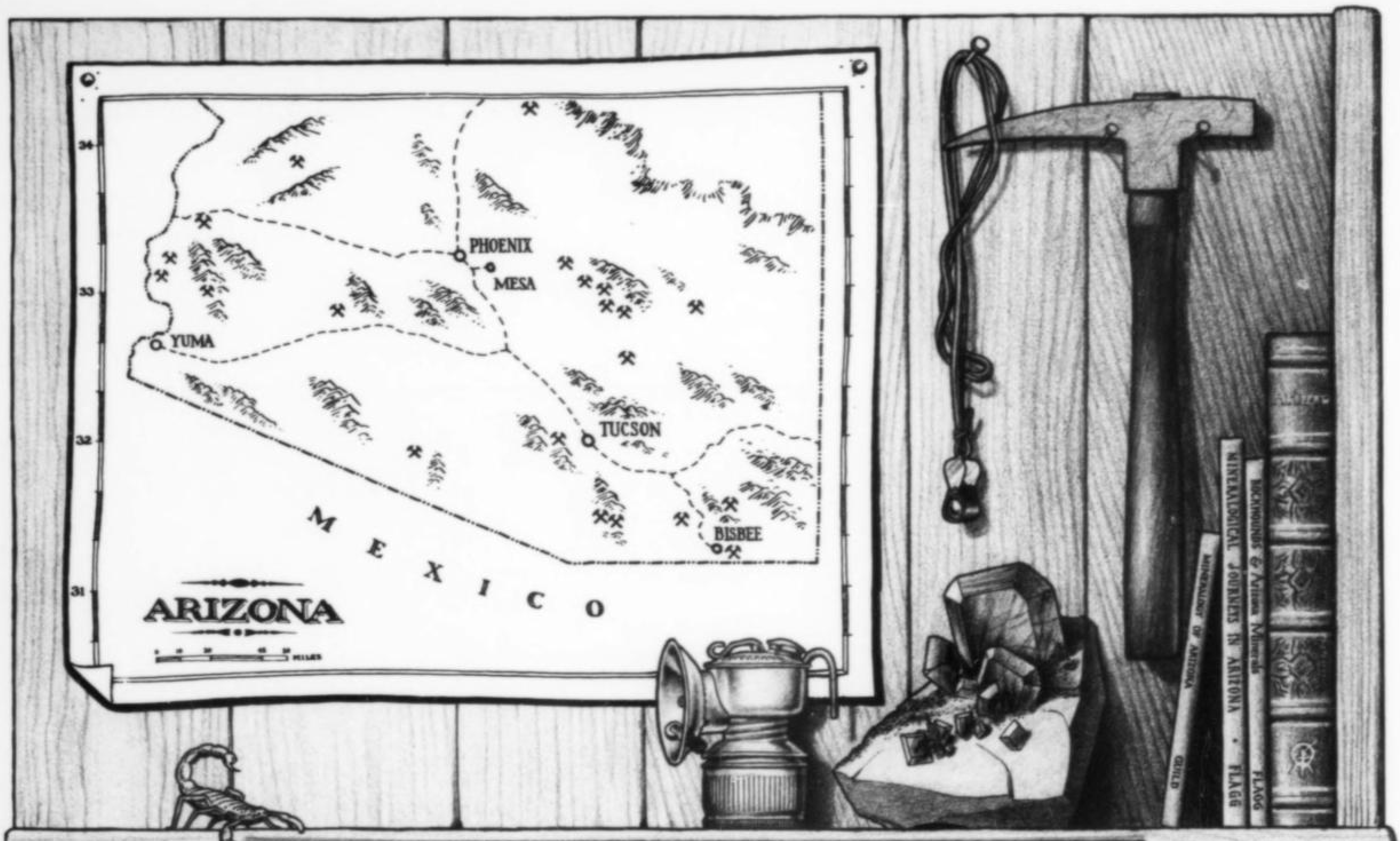
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CALIFORNIA LOCALITY INDEX

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California is one of the most geologically and mineralogically diverse regions in the world. The state has been blessed with a remarkable number of mineral deposits, which have yielded in excess of 800 different mineral species. Eighty-nine minerals were first discovered and described from California.

INTRODUCTION

The California Locality Index was undertaken in conjunction with the "Locality Index Project" of the Friends of Mineralogy. The intent is to provide locality names, approximate locations, and important minerals for the best known and most significant mineral occurrences in California. These include deposits which have produced a notable quantity and/or quality of specimens for museum and private collections. This is not intended to be used as a collecting guide—many of the localities are not open to collecting and some are effectively extinct.

The localities are grouped by county and are arranged alphabetically within counties. Most entries represent discrete deposits. However, where several deposits or mines are closely related in proximity, mineralization and significance, they have been grouped as a single entry. In these cases one of two approaches is followed: (1) if one of the localities is particularly important, it is listed first followed by the names of less important localities, (2) if no single locality stands out, all are grouped under a general locality name, such as a district name. If a deposit has no "official" name, a common or descriptive name has been applied. Synonymous mine or locality names have also been included. To help in finding specific locality names (including synonyms), an alphabetical index has been provided.

Not all minerals known from the localities have been listed; however, those of particular mineralogical and/or collector significance are included as well as certain commonly associated species. No effort has been made to indicate which minerals are most important; the minerals are simply listed in alphabetical order. Where two or more mines have been grouped and a certain mineral is specific to one of the mines, the mineral is listed followed by the initial(s) or name of that mine in parentheses. Varietal names or descriptive information, where of particular significance, are also provided in parentheses following the species name.

Readers who are particularly interested in type localities should refer to the separate listing which follows the locality index. This listing is in alphabetical order by mineral. Some, but not all, of these localities are included in the main locality index, depending on the significance of their specimen production.

The single most important reference to the mineral localities of California is the *Minerals of California* series. The first six editions were published in 1914, 1923, 1938, 1948, 1956 and 1966 as Bulletins of the California Division of Mines and Geology. The latest update, compiled by H. Earl Pemberton, was published by Van Nostrand Reinhold in 1983. The localities listed in these compendia consist, for the most part, of all those which had been recorded in previous literature. As such, the most recent *Minerals of California* provides (along with references) many more localities than are listed in this locality index. Nevertheless, this locality index should be of use for several reasons. (1) It is organized by locality rather than by mineral species. (2) It includes mineral localities of importance to collectors which have not been recorded in mineralogical literature. (3) Its information is more current than that in the earlier compendia. (4) It is more concise and consistent in its coverage of locality information. (5) It does not require reference to publications which are sometimes difficult to obtain.

No matter how carefully a listing such as this is compiled, a certain number of errors and omissions are inevitable. For a state which boasts tens of thousands of deposits, mines, claims and prospects, it is impossible to be completely consistent and unbiased in choosing which localities to include. As important new discoveries are made every year, this locality index will in a sense be out-of-date even before it is published. We are anxious to improve, correct and update this locality index. In that context, please send any comments to the address provided above.

In addition to the members of the Locality Index Committee, the assistance of the following persons is gratefully acknowledged: Juanita Curtis, Fred DeVito, Ralph Dietz, Vi Frazier, Margaret Gross, Walter Lombardo, Al McGuinness, Al Ordway, William Reifel, Kay Robertson, Richard Thomssen and William Wise.

Finally, the late H. Earl Pemberton (1907–1987) is to be commended for his many years of intense, dedicated, productive and selfless work in documenting the mineral localities of California. It is to his memory that this publication is dedicated.

I.—LOCALITIES BY COUNTY

ALAMEDA COUNTY

Alma mine, [and Leona mine]—Leona Heights, Oakland.
Alunogen, boothite, chalcanthite, copiapite, copper, halotrichite, hexahydrite, kroehnkite, pyrite, roemerite.

Cedar Mountain Ridge chromite deposits [includes Clark claim, Douglas mine, Newman deposit]—Cedar Mountain Ridge, 12 miles SE of Livermore.
Albite(N), clinochlore (kämmererite), magnesiochromite, quartz(N), uvarovite.

Corral Hollow selenite locality—Corral Hollow, 11 miles ESE of Livermore.
Calcite, gypsum.

ALPINE COUNTY

Exchequer mine, [and I. X. L. mine]—I. X. L. Canyon, Silver Mountain district, 4-5 miles south of Markleeville.
Arsenolite, barite, gold, proustite, pyrargyrite, silver, stibnite, tetrahedrite.

Leviathan mine—on Leviathan Creek, Monitor-Mogul district, 6.5 miles east of Markleeville.
Chalcanthite, greigite, halotrichite, melanterite, pyrite, roemerite, sulfur (selenian).

Morning Star mine—west of Mogul Peak, Monitor-Mogul district, 5 miles ESE of Markleeville.
Arsenopyrite, barite, enargite, famatinite, galena, polybasite, pyrargyrite, realgar, stephanite, tetrahedrite.

Zaca mine [also known as Advance mine, Colorado mine, Tarshish mine]—Colorado Hill, Monitor-Mogul district, 5.5 miles ESE of Markleeville.
Argentite, arsenopyrite, freibergite, galena, huebnerite, polybasite, pyrite, quartz, rhodochrosite, sphalerite, stromeyerite, tetrahedrite.

BUTTE COUNTY

Cherokee mine—Cherokee, 12 miles north of Oroville.
Diamond, gold.

Feather River axinite locality—Feather River.
Axinite, quartz, tremolite.

Pulga deposit, [and Jade mine, Mar-Bon claims]—1 mile north of Pulga along North Fork of Feather River.
Nephrite, vesuvianite (californite).

Sawmill Peak quartz locality—Sawmill Peak area, NE of Magalia.
Quartz.

CALAVERAS COUNTY

Calaveras Crystal mine [also known as Green Mountain mine, Rough Diamond Crystal mine]—Chili Gulch, 2.5 miles SE of Mokelumne Hill.
Gold, quartz.

Carson Hill mines [includes Melones mine, Stanislaus mine, Morgan mine]—Carson Hill, 4 miles SE of Angels Camp.
Altaite, calaverite, coloradoite, gold, hessite, melonite, millerite, molybdenite, petzite, sylvanite, tellurium, tetradymite.

Garnet Hill deposits [includes Garnet Hill mine (also known as Miracle Mountain claim), Moore Creek mine]—Garnet Hill, 2 miles west of Salt Springs Reservoir on North Fork of Mokelumne River.
Andradite, axinite, epidote, molybdenite(MC), quartz, scheelite, tremolite (mountain leather).

New Melones Dam spillway—6.5 miles south of Angels Camp.
Actinolite, albite, calcite, epidote, ferroaxinite, palygorskite, quartz.

Penn mine—1 mile WNW of Campo Seco.
Antlerite, bornite, chalcocite, copper, covellite, tetrahedrite.

CONTRA COSTA COUNTY

Mount Diablo mine, [and Ryne mine]—NE side of Mount Diablo, 4 miles SE of Clayton.
Alunogen, cinnabar, copiapite, coquimbite, hypercinnabar, metacinnabar, morenosite, siderotil, stibiconite, stibnite, valentinite, voltaite.

DEL NORTE COUNTY

Alta mine—5 miles NE of Smith River.
Chalcocite, cobaltite, erythrite, starkeyite, tenorite, troilite.

High Plateau mine—NW side of High Plateau Mountain, 5.5 miles north of Gasquet.
Magnesiochromite, uvarovite.

EL DORADO COUNTY

Cosumnes mine—3 miles ENE of Fairplay, 13 miles SE of Placerville.

Azurite, bornite, epidote, ferrimolybdite, gold, grossular, hornblende, malachite, manganaxinite, molybdenite, powellite, stibnite.

Georgetown district [includes Grit mine (also known as Spanish Dry Diggins Seam mine), Georgia Slide mine, French mine]—1 mile north of Georgetown.

Gold.

Josephine mine—near Volcanoville, 6 miles NE of Georgetown.

Quartz.

Old Pino Grande prospect—Old Pino Grande, 10 miles NE of Placerville.

Quartz (smoky), rutile.

Shingle Springs quartz locality—Shingle Springs, 8 miles SW of Placerville.

Quartz (w/chlorite).

Slate Mountain mine—west slope of Slate Mountain, 7.5 miles SE of Georgetown.

Cacoxenite, crandallite, quartz (smoky), rutile, strengite, variscite, wavellite.

Smith's Flat—3 miles east of Placerville.

Diamond, gold.

Stifle Memorial claim—Traverse Creek, 2.5 miles SE of Georgetown.

Clinochlore, diopside, grossular, prehnite, vesuvianite.

FRESNO COUNTY

Atlas Asbestos mine—1.5 miles ENE of Condon Peak, New Idria district.

Artinite, brucite.

Big Creek - Rush Creek sanbornite deposit [includes Esquire No. 1 claim, Esquire No. 7 claim, Esquire No. 8 claim, Lucky Strike claim]—along Big Creek & Rush Creek, 5 miles NE of Trimmer.

Alforsite, anandite, bazirite, benitoite, fresnoite, gillespite, krauskopfite, macdonaldite, muirite, sanbornite, titantaramellite, traskite, verplankite, walstromite.

Christi mine—0.5 mile NW of Wright Mountain, New Idria district.

Dolomite, magnetite.

Coalinga asbestos mine—10 miles SE of Idria, New Idria district.

Analcime, artinite, coalingite, desautelsite, dolomite.

Dinkey Creek pluton—Dinkey Lakes area, 8 miles SE of Huntington Lake.

Feldspar, hematite, quartz (smoky), spessartine.

Shaver Lake amethyst locality—NE shoreline of Shaver Lake.

Quartz (amethyst).

Twin Lakes deposit—Twin Lakes, 3 miles north of east end of Huntington Lake.

Clinohumite, clintonite, diaspore, diopside, epidote, lillianite, ludwigite, pargasite, scheelite, spinel, titanite, vesuvianite, wightmanite.

HUMBOLDT COUNTY

Coyote Peak diatreme—Coyote Peak, 16 miles SW of Orick.

Bartonite, breithauptite, coyoteite, djerfisherite, erdite, greigite, kaersutite, orickite, rasvumite, schloromite, sodalite, taeniolite.

IMPERIAL COUNTY

Bertram mine [also known as Bertram Siding]—1 mile east of Bertram Siding, near east shore of Salton Sea.

Glauberite.

Bluebird kyanite deposit [also known as Ogilby kyanite deposit, Vitrefrax mine]—Vitrefrax Hill, west side of Cargo Muchacho Mountains, 2.5 miles NE of Ogilby.

Andalusite, barite, carnotite, fluorapatite, kyanite, lazulite, pyrophyllite, schorl, scorzalite, staurolite, svanbergite.

Hauser beds—8 miles SW of Wileys Well.

Apatite, calcite, quartz (agate & amethyst in geodes).

INYO COUNTY

Billie No. 1 mine—1.5 miles NW of Ryan, Furnace Creek district, Death Valley.

Celestite, colemanite, veatchite.

Bird Springs garnet claim [also known as Nelson Range deposit]—north end of Nelson Range.

Epidote, grossular, quartz (Japan twins).

Boraxo mine [also known as Thompson mine, Tenneco mine]—3.5 miles NW of Ryan, Furnace Creek district, Death Valley.

Celestite, colemanite, hydroboracite, probertite, tunellite.

Buttermilk Country—eastern Sierra Nevada, 10 miles west of Bishop.

Ilmenorutile, quartz (smoky).

Cerro Gordo mine, [and Morning Star mine]—1 mile west of Cerro Gordo Pt, 6 miles NE of Keeler, Inyo Mountains.

Aurichalcite, caledonite, galena, greenockite, hemimorphite, hydrozincite, leadhillite, linarite, malachite, pyromorphite, smithsonite, tetradymite, wulfenite.

Corkscrew mine—Corkscrew Canyon, Black Mountains, Furnace Creek district, Death Valley.

Bakerite, colemanite, nobleite, ulexite.

Coso Hot Springs deposit [also known as Obsidian Ridge]—5 miles WSW of Coso Hot Springs, Sugar Loaf Mountains.

Clinoferrosilite, cristobalite, fayalite, tridymite.

Coyote garnet deposit—Coyote Front Range, 5.5 miles SW of Bishop.

Calcite, grossular, scheelite, vesuvianite.

Darwin mines [includes a great many mines and prospects]—north & east of Darwin.

Andorite, aurichalcite, bismuthinite, caledonite, crocoite, galena, gypsum, leadhillite, linarite, paraspurrite, pyrite, pyromorphite, scheelite, selenium, stannite, tetradymite, vanadinite, wulfenite.

Devil's Kitchen—near Coso Hot Springs.

Alunite, butlerite, chalcanthite, cinnabar, copiapite, coquimbite, covellite, halotrichite, jarosite, kornelite, metacinnabar, opal, parabutlerite, pyrite, quartz, sulfur, voltaite.

Gower Gulch mine—Gower Gulch, Black Mountains, Furnace Creek district, Death Valley.

Celestite, colemanite, gowerite, howlite, meyerhofferite.

Granite Hill—Deep Springs Valley, 12 miles NE of Westguard Pass, south end of White Mountains.

Quartz.

Green Monster mine—5 miles ENE of Independence.

Brochantite, chrysocolla, dioptase, volborthite.

Hard Scramble claim [also known as Hardscrabble claim]—east side of Black Mountains, Furnace Creek district, Death Valley.

Colemanite, ginorite, gowerite, hungchaoite, inderite, kurnakovite, nobleite, priceite, rivadavite, ulexite, wardsmithite.

Hunter Mountain—10 miles SSE of Ubehebe Peak, 20 miles north of Darwin.

Schorl.

Lippincott mine—4 miles south of Ubehebe Peak, Ubehebe district.

Aragonite, calcite, cerussite, galena, hemimorphite, sphalerite, wulfenite.

Lost John mine—Gem Valley on Haystack Mountain [also known as Boulder Mountain], 6 miles east of Lone Pine.
Andradite, beryl (aquamarine), fluorite, microcline (amazonite), quartz (smoky).

Mount Blanco mine—Mount Blanco, Black Mountains, Furnace Creek district, Death Valley.
Colemanite, hydroboracite, inyoite, meyerhofferite, ulexite.

Pine Creek mine—18 miles west of Bishop, south slope of Mount Morgan.
Bismuthinite, bornite, calcite, chalcopyrite, ferrimolybdite, laumontite, molybdenite, powellite, scheelite.

Ryan borax deposits [includes Played Out mine, Biddy McCarthy mine, Grandview mine, Lizzie V. Oakley mine]—near Ryan, Furnace Creek district, Death Valley.
Colemanite.

Saline Valley quartz locality—NW Saline Valley, east side of Inyo Mountains.
Quartz (smoky).

Terry mine—4.5 miles west of Death Valley Junction, Furnace Creek district, Death Valley.
Analcime, calcite, chabazite, colemanite, heulandite, hydroboracite, phillipsite.

Ubehebe mine—north end of Death Valley, Ubehebe district.
Cerussite, hydrozincite, vanadinite, wulfenite.

Zinc Hill mine—4 miles NE of Darwin, west slope of Argus Range.
Anglesite, aurichalcite, azurite, brochantite, cerussite, hemimorphite, hydrozincite, malachite, rosasite, smithsonite, sphalerite, wulfenite.

KERN COUNTY

Antimony Peak mine [also known as San Emigdio mine]—north & east slopes of Antimony Peak, 8 miles NW of Frazier Park.
Antimony, kermesite, senarmontite, stibiconite, stibnite, sulfur, valentinite.

Boron borate deposit [also known as Kramer borate deposit] [includes U. S. Borax open pit (also known as Kramer open pit, Boron mine), Jenifer mine, Baker mine, West Baker mine]—14 miles NW of Boron, Kramer district.
Borax, colemanite, garrelsite, gerstleyite, greigite, howlite, hydroboracite, inderite, inyoite, kernite, kurnakovite, mackinawite, meyerhofferite, pararealgar, probertite, searlesite, smythite, tincalconite, tunellite, ulexite, zeolite minerals.

Cinco orthoclase locality—Water Canyon, 1.5 miles NNW of Cinco.
Orthoclase (Carlsbad twins).

El Paso Mountains deposits—north side of El Paso Mountains.
Opal (fire), quartz (fire agate & petrified wood).

Golden Queen mine—north slope of Soledad Mountain, 5 miles SW of Mojave.
Halotrichite.

Greenhorn Mountains scheelite deposits [includes Black Mountain King mine (also known as Huckabay mine), Little Acorn mine (also known as Aldridge mine, Old Zelner mine), Total Wreck Crystal claim]—1.5 miles SE of Greenhorn Summit, Greenhorn Summit district, Greenhorn Mountains.
Andradite, epidote, humboldtine(BMK), orthoclase, quartz, scheelite.

Red Rock Canyon zeolite locality—west edge of El Paso Mountains, near Ricardo.
Analcime, mesolite, natrolite, thomsonite.

Saltdale works—Koehn Dry Lake, 1 mile south of Saltdale.
Halite, thermonatrite.

Tejon Ranch garnet deposit—0.5 mile south of Tejon Ranch headquarters, 12 NE of Lebec.
Almandine.

LAKE COUNTY

Abbott mine—2 miles SW of Wilbur Springs, Wilbur Springs district.
Cinnabar (after marcasite), marcasite, tiemannite (after marcasite).

Borax Lake—SE edge of Clear Lake.
Borax, gaylussite, glauberite, halite, northrupite, pirssonite, teepleite, thermonatrite, trona.

Eastern Mayacmas district [includes Helen mine group, Great Western mine, Mirabel mine, Baker mine]—west and east of Middletown.
Ankerite(M), aragonite(H), cinnabar, idrialite(GW), marcasite(H), mercury, metacinnabar, pyrite(H), tiemannite(GW).

Middletown pectolite locality—1.5 miles NW of Middletown.
Calcite, pectolite.

Sulphur Bank mine—end of east arm of Clear Lake.
Buddingtonite, cinnabar, copiapite, coquimbite, epsomite, jarosite, melanterite, metacinnabar, metastibnite, rosickyite, schuettite, stibnite, sulfur.

LASSEN COUNTY

Hallelujah Junction quartz locality—west of Petersen Peak (Nevada), 8 miles north of Hallelujah Junction.
Quartz (amethyst & smoky).

LOS ANGELES COUNTY

Felix mine—Azusa, 0.5 mile east of north end of Azusa Avenue, San Gabriel Mountains.
Fluorite, minium.

Kanan Road zeolite localities—roadcuts along Kanan Road, Agoura, Santa Monica Mountains.
Barite, calcite, dachiardite, ferrierite, heulandite, sphalerite.

Pacoima Canyon pegmatite—Pacoima Canyon, 10 miles NE of San Fernando, San Gabriel Mountains.
Allanite, apatite, zircon.

Palos Verdes barite locality—sea cliffs at Point Vicente, Palos Verdes Hills.
Barite, dolomite, epsomite.

Sterling Borax mine—Tick Canyon, 3.5 miles NNE of Lang, San Gabriel Mountains.
Bakerite, celestite, colemanite, howlite, priceite, probertite, veachite.

MADERA COUNTY

Beasore claims—head of Iron Creek, Minarets district, 6 miles west of Devil's Postpile.
Pyrite, quartz, wolframite.

Coarsegold axinite locality—5 miles NE of Coarsegold.
Actinolite, albite, ferroaxinite, titanite.

Daulton deposit—1 mile SE of Daulton, 11 miles NNE of Madera.
Andalusite (chiastolite), copper.

I. X. L. claim—9 miles NNE of Raymond.
Andalusite, quartz, wolframite.

Strawberry mine—Minarets district, 31 miles NE of Bass Lake.
Andradite, epidote, molybdenite, scheelite.

MARIN COUNTY

Reed Station lawsonite locality—0.5 mile east of Reed Station, Tiburon Peninsula.
Actinolite, albite, almandine, glaucophane, lawsonite, omphacite.

Stinson Beach szaibelyite locality—0.5 mile east of Stinson Beach.

Ferroaxinite, prehnite, szaibelyite.

MARIPOSA COUNTY

Colorado Quartz mine, [and Artru mine, Mockingbird mine, Schroeder mine, Diltz mine]—WNW of Midpines, Whitlock district.

Gold, quartz.

El Portal deposit, [and Devil's Gulch deposit]—south of El Portal.

Barite, witherite.

Incline sanbornite deposit, north side of Trumbull Peak, 4 miles WNW of Incline.

Alforsite, celsian, gillespite, sanbornite, taramellite, witherite.

Three Buttes deposit—Three Buttes [also known as Tres Cerritos], 6 miles south of Hornitos.

Andalusite, pyrophyllite.

White Rock mine—White Rock, 7 miles south of Catheys Valley.

Aragonite, calcite, copper, goethite, quartz.

MENDOCINO COUNTY

Ash Creek edingtonite locality—on Ash Creek, 3.5 miles north of Cloverdale.

Apophyllite, brewsterite, edingtonite.

Laytonville quarry [also known as Shamrock Ranch quarry]—5 miles south of Laytonville.

Deerite, howieite, lawsonite, stilpnomelane, zussmanite.

Miners Ridge—Red Mountain, 15 miles SE of Ukiah.

Chalcocite, chlorite, copper, cuprite, hydrogrossular, vesuvianite, magnesiochromite, mcguinnessite, vuagnatite.

Russian River jadeite locality—5 miles NNW of Cloverdale on Russian River.

Actinolite, apophyllite, datolite, hydrogrossular, jadeite, laumontite, pectolite, pumpellyite, rosenhahnite, xonotlite.

MERCED COUNTY

Stayton district [includes Blue Wing mine, Stayton mine, Yellow Jacket mine]—11 miles ENE of Hollister, near San Benito Co. line.

Cinnabar, jarosite, stibiconite, stibnite.

MONO COUNTY

Champion mine [also known as Champion Sillimanite mine, Champion Sparkplug mine, Mono County andalusite mine, Jeffrey mine]—4 miles WSW of White Mountain Peak, west slope of the White Mountains, north of Laws.

Andalusite, apatite, augelite, barite, corundum, diaspore, hematite, jarosite, lazulite, pyrophyllite, quartz, rutile, schorl, natroalunite (strontian), svanbergite, topaz, trolleite, viseite, woodhouseite.

Paoha Island—Mono Lake.

Brushite, monetite, newberryite (after struvite), struvite.

MONTEREY COUNTY

Jade Cove, [and Willow Creek Beach]—0 to 3 miles north of Cape San Martin, Big Sur.

Actinolite (nephrite), jadeite, serpentine.

NAPA COUNTY

Aetna mine—1 mile NW of Aetna Springs, Mayacmas district.

Cinnabar, mercury, metacinnabar.

Calistoga silver mines [includes Palisade mine, Silverado mine]—3 to 6 miles north of Calistoga.

Acanthite, chlorargyrite, silver.

Redington mine [also known as Knoxville mine, Boston mine], and Manhattan mine—north & south of Knoxville, Knoxville district.

Botryogen, calomel, cinnabar, coquimbite, epsomite, fibroferrite, hohmannite, magnesiocopiapite, marcasite, melanterite, metacinnabar, redingtonite, siderite, stibnite, voltaite.

NEVADA COUNTY

Grass Valley district [includes Idaho-Maryland mine, Pennsylvania mine, Empire mine, North Star mine]—Grass Valley.

Arsenic(E), gold, hessite(I-M), naumannite(I-M), petzite(I-M), pyrite.

Nevada City district [includes Nevada City mine, Providence mine, Queen mine]—west of Nevada City.

Altaite(P), arsenopyrite(Q), gold, hessite(NC).

Red Ledge mine—south of Washington, Washington district.

Clinochlore (kämmererite), copper, galena, gold, magnesiochromite, pyrite, quartz, redledgeite, stibnite, uvarovite.

PLACER COUNTY

Michigan Bluff district [includes Eagle's Nest mine, Michigan Bluff mine, Pioneer mine, Rawhide mine]—5 miles ENE of Foresthill.

Gold.

PLUMAS COUNTY

Clio vesuvianite locality—2.5 miles NE of Clio.

Vesuvianite.

Engle mine [also known as Engles mine, Empire mine]—10 miles NNE of Taylorsville.

Analcime, azurite, bornite, carbonate-cyanotrichite, chabazite, chalcocite, chalcopyrite, chrysocolla, covellite, enargite, heulandite, ilmenite, laumontite, magnetite, natrolite, prehnite, scolecite, stilbite, thomsonite.

Greystone claim—5 miles NE of Genesee.

Clinozoisite, manganaxinite.

Grizzly Ridge quartz locality, Grizzly Ridge [also known as Grizzly Mountains], SE of Grizzly Peak, east of Quincy, north of Sloat.

Quartz (w/chlorite & actinolite).

Poison Creek epidote locality—on Poison Creek, south of Thompson Peak, 10 miles SW of Milford.

Epidote, quartz.

Thompson Peak mine—0.5 miles SSE of Thompson Peak, 3.5 miles SSW of Janesville.

Fluorapatite, muscovite, quartz, schorl.

Tobin—Feather River Canyon.

Feldspar, muscovite.

RIVERSIDE COUNTY

Blue Chihauhau mine [also known as Blue Dog mine]—near San Diego Co. line and Cooper Cienega Truck Road, Chihuahua Valley district.

Herderite, muscovite, quartz, schorl, topaz.

Cahuilla Mountain district [includes Fano mine (also known as Fano-Simmons mine), Lithia Dyke, Schindler claims]—Cahuilla Mountain, San Jacinto Mountains.

Albite, amblygonite, beryl (aquamarine(F) & morganite(LD)), elbaite, lepidolite, quartz, schorl, spodumene (kunzite).

Cajalco tin mine—1.5 miles west of Lake Matthews, 5 miles ESE of Corona.

Cassiterite.

Coon Hollow—3 miles south of Wiley Well, Mule Mountains.
Apatite, dachiardite, quartz.

Crestmore quarry [includes Commercial, Wet Weather, Lone Star, and Chino quarries]—Sky Blue Hill and Chino Hill, SW of Crestmore, east of Jurupa Mountains, 5 miles NW of Riverside.
Afwillite, andradite, axinite, brucite, bulfonteinite, calcite, chondrodite, clinohumite, clinozoisite, cuspidine, danburite, datolite, diopside, ellestadite, epidote, fluoborite, forsterite, foshagite, ganomalite, gonnardite, graphite, grossular, hawleyite, hemimorphite, hillebrandite, huntite, jennite, ludwigite, merwinite, monticellite, nasonite, nekoite, parawollastonite, periclase, plombierite, riversideite, scapolite, scawtite, schorl, serendibite, spurrite, szaibelyite, tilleyite, titanite, tobermorite, vesuvianite, wightmanite, wollastonite, xanthophyllite, xonotlite, zoisite, . . .

Eagle Mountain mine [also known as Iron Chief mine and Black Eagle mine]—Eagle Mountain (town), Eagle Mountains.
Acanthite, actinolite, chalcopyrite, diopside, dolomite, epidote, feldspar, galena, goethite, gold, gypsum, hematite, magnetite, pyrite, quartz, serpentine.

Jensen quarry—SW of Crestmore, Jurupa Mountains, 5 miles NW of Riverside.
Danburite, elbaite, epidote, ferroaxinite, goosecreekite, hambergite, schorl, spinel, stibiotantalite, xenotime.

North Hill quarry—North Hill (E of Evans Lake), City of Riverside.
Arsenopyrite, chalcopyrite, chrysocolla, epidote, garnet, hornblende, molybdenite, opal, scheelite, schorl, titanite, wollastonite.

Southern Pacific silica quarry—2 miles SE of Nuevo, Lakeview Mountains.
Allanite, almandite, biotite, elbaite, microcline, monazite, quartz, schorl, spessartine, titanite, xenotime, zircon.

SAN BENITO COUNTY

Alpine mine, [and Auroro mine, Molina No. 1 mine, San Carlos mine]—2 miles south & SE of Idria, New Idria district.
Cinnabar, mercury, montroydite (Alpine), quartz (amethyst(SC) & chrysoprase(Aurora)).

Artinite locality, [and Old talc prospect]—1 mile NE of Picacho Peak, New Idria district.
Artinite, calcite, desautelsite, dypingite, hydromagnesite.

Benitoite Gem mine [also known as Dallas Gem mine, Gem mine]—headwaters of the San Benito River, 1 mile south of Santa Rita Peak, New Idria district.
Albite, baotite, bario-orthojoaquinite, benitoite, digenite, djurleite, fresnoite, joaquinite, jonesite, natrolite, neptunite, serandite.

Clear Creek deposits—on Clear Creek, New Idria district.
Analcime, apatite, coalingite, copper, datolite, dolomite, epsomite, hydromagnesite, jadeite, magnesiochromite, natrolite, reevesite, uvarovite.

Garnet prospect—ridge 1 to 1.3 miles west of Aurora mine, New Idria district.
Andradite (melanite & topazolite), clinochlore, diopside, vesuvianite.

Green Fire mine—north of Sawmill Creek, New Idria district.
Andradite (demantoid).

Junilla mine—0.5 mile SE of Benitoite Gem mine, New Idria district.
Andradite (demantoid, melanite, & topazolite).

Juniper mine—3 miles south of Panoche, Panoche district.
Aluminite, alunogen, cinnabar, metacinnabar, millerite.

KCAC mine [also known as Union Carbide asbestos mine]—0.5 mile west of Benitoite Gem mine, New Idria district.
Aragonite, brucite, coalingite, ilmenite, magnetite, talc.

Llanada copper mine—4 miles NNE of Llanada, Panoche Valley.
Chrysocolla, glaucophane, libethenite, nissonite, turquoise, volborthite.

Mina Numero Uno—near San Benito Mountain, New Idria district.
Albite, benitoite, joaquinite, neptunite, strontiojoaquinite.

New Idria mine—south of Idria, New Idria district.
Cinnabar, diachochite, idrialite, koninckite, mercury, metacinnabar, millerite, onofrite, schuettite, tiemannite, voltaite.

Perovskite Peak [also known as Schist Knob, Chorite Knob]—1.5 miles south of Santa Rita Peak, New Idria district.
Agardite-La, andradite (melanite), baddeleyite, beidellite, clinochlore, diopside, fluorapatite, ilmenite, perovskite, pseudomalachite, rutile, vesuvianite (cerian).

Picacho mine [also known as Fourth of July mine]—3 miles WSW of San Benito Mountain, New Idria district.
Cinnabar, karpatite.

Stayton district [includes Ambrose mine, Lone Tree mine, Quien Sabe mine]—10 miles ENE of Hollister.
Stibiconite, stibnite.

Victor claim—2.5 miles west of San Benito Mountain, New Idria district.
Benitoite, fresnoite, pectolite, titantaramellite.

Windy Mountain claim—1 mile SSE of Santa Rita Peak, New Idria district.
Apatite, perovskite, spinel, titanite.

SAN BERNARDINO COUNTY

Atolia mine—4.5 miles SE of Randsburg, Atolia district.
Ankerite, cinnabar, dolomite, pyrite, quartz, scheelite, siderite, stibnite.

Bar & Grill claim—ridge east of Caruthers Canyon, New York Mountains.
Beryl, lepidolite, microcline (amazonite), muscovite (fuchsite), quartz, topaz.

Black Butte mine [also known as Big Reef mine]—12 miles WNW of Ludlow.
Calcite, psilomelane, pyrolusite.

Blue Bell mine [also known as Hard Luck claims, Atkinson claim]—6.5 miles west of Baker, Soda Mountains.
Bromargyrite, caledonite, chlorargyrite, dioptase, fluorite, jarosite, kettnerite, linarite, mimetite, murdochite, perite, pyromorphite, tsumebite, vauquelinite, wulfenite.

Bristol Dry Lake—SE of Amboy.
Antarcticite, celestite, gypsum, halite.

Calico district [includes Silver King mine, Oriental mine, Waterloo mine, Langtry mine, Burcham mine (also known as Total Wreck mine), & others]—north & NW of Calico.
Anglesite, barite, bromargyrite, cerussite, chlorargyrite, galena, gold, pyrite, quartz (amethyst), silver, sphalerite, stromeyerite.

Cascade Canyon lapis locality—Cascade Canyon, 2 miles south of Camp Baldy, San Gabriel Mountains.
Corundum (ruby), forsterite, lazurite, muscovite (fuchsite), pyrite.

Copper World mine—2.5 miles SW of Clark Mountain, Clark Mountain district.
Azurite, brochantite, chrysocolla, dioptase, hemimorphite, linarite, malachite, opal, serpentine, smithsonite, tenorite, turquoise.

Coupon mine [also known as Coupon Ledge]—1 mile NW of Ord Mountain, 12 miles SSE of Daggett, Ord Mountains district.

Azurite, creedite, cyanotrichite, gold, malachite, spangolite.

Danby Dry Lake.

Gypsum (selenite).

Evening Star mine—West foothills of Ivanpah Mountains, 8 miles north of Cima.

Andradite, azurite, bornite, cassiterite, chalcocite, chalcopyrite, covellite, cummingtonite, gold, malachite, scheelite, tenorite.

Faujasite locality—7 miles west of Valley Wells.

Faujasite, phillipsite.

Imperial Lode [and Tip Top mine]—NW of Sunshine Peak, Lava Beds district, 10 miles SSE of Hector.

Anglesite, cerussite, chlorargyrite, fornacite, hemimorphite, mimetite, willemite, wulfenite.

Kingston Peak amethyst deposits [includes Amethyst Queen claim, Mile-Hi claim]—north of Kingston Peak, Kingston Range, 13 miles ESE of Tecopa.

Quartz (amethyst).

Lead Mountain deposit [includes Lead Mountain mine, Barite claim]—4 miles east of Barstow.

Alunite, barite, bayldonite, calcite, chlorargyrite, fibroferrite, hemimorphite, malachite, murdochite(?), plattnerite, rosasite, sulfur(?).

Leiser Ray mine [also known as Vanadium King mine, California Comstock mine, Louisiana-California Co. mine]—Signal Hill, Camp Signal district, 8 miles NE of Goffs.

Cerussite, chlorargyrite, descloizite, ferberite, heubnerite, mimetite, mottramite, vanadinite, wulfenite.

Mohawk mine—Mohawk Ridge, Clark Mountain district, south edge of Clark Mountains.

Adamite, aragonite, arsenbrackebuschite, arseniosiderite, arsenopyrite, austinite, azurite, beudantite, brochantite, carminite, cerussite, chalcophanite, chlorargyrite, conichalcite, cuprite, dioptase, duftite, fraipontite, hemimorphite, hetaerolite, hidalgoite, hydrozincite, jarosite, malachite, massicot, mimetite, mixite, olivenite, sauconite, scorodite, smithsonite, tsumcorite.

New Method mine [also known as Hope mine, Benson mine]—SE edge of Bristol Mountains, 6 miles ENE of Amboy.

Boltwoodite, fluoborite, fluorite, sepiolite.

Pacific Coast Borax Co. mine [also known as Borate mines]—Borate Camp, Mule Canyon, Calico Mountains.

Bakerite, celestite, colemanite, gypsum, howlite, priceite, strontianite, tincalconite, ulexite.

Randsburg district [includes Kelly mine (also known as California Rand mine, Rand mine), Coyote mine, Santa Fe mine]—SW of Red Mountain.

Cervantite, chlorargyrite, gold, miargyrite, proustite, pyrargyrite, pyrostilpnite, silver, stibnite, freibergite.

Searles Lake deposit [also known as Trona deposit] [includes West End Chemical mine, McGee mine]—Searles Lake near Trona.

Aphthitalite, borax, burkeite, galeite, gaylussite, halite, hanksite, mirabilite, nahcolite, northupite, pirssonite, schairerite, searlesite, sulphohalite, teepleite, thenardite, tincalconite, trona, tychite.

Sulfide Queen mines [also known as Mountain Pass mine, Rare Earth mine, Birthday claim]—Mountain Pass, Clark Mountain district, south edge of Clark Mountains.

Allanite, bastnaesite, cerite, monazite, parisite, sahamalite, vanadinite, wulfenite.

Sulfur Hole [also known as Sulfateria]—near Borate Camp, Mule Canyon, Calico Mountains.

Copiapite, coquimbite, halotrichite, krausite, quenstedite, roemerite, voltaite.

Turquoise Mountains deposits [includes East Camp, Middle Camp, Himalaya, Toltec]—near Halloran Summit, Turquoise Mountains.

Turquoise (after apatite, orthoclase, pyrite).

Wrightwood actinolite locality—Lone Pine Canyon, San Gabriel Mountains.

Actinolite, dravite, rhodonite.

SAN DIEGO COUNTY

Aguanga Mountain district [includes Ware mine (also known as Mountain Lily mine, Emeralite No. 2 mine, Gem Mine No. 1), Maple Lode]—Aguanga Mountain, 4 miles SSE of Oak Grove.

Albite, beryl, elbaite, lepidolite, microcline, muscovite, quartz, topaz.

Blue Lady mine [also known as Blue Bell mine]—east end of Chihuahua Valley, Chihuahua Valley district.

Beryl (morganite), cassiterite, columbite, elbaite (indicolite), lepidolite, muscovite, quartz, schorl, spessartine.

Dehesa deposit—near Dehesa, 2.5 miles SSW of Alpine.

Dumortierite, quartz, rutile, sillimanite, titanite.

Fallbrook axinite locality—Fallbrook.

Axinite, epidote, quartz (smoky).

Jacumba district [includes Beebe Hole mine, Pack Rat mine]—Tule Mountain, NW of Jacumba.

Albite, beryl (aquamarine), helvite(PR), herderite(PR), lithiophilite, microcline, muscovite, quartz, secondary Mn-phosphates, spessartine(PR), spodumene (kunzite(BH)).

Mesa Grande district [includes Himalaya mine, San Diego mine, Esmeralda mine, Mesa Grande mine, Cota mine]—NW of Mesa Grande.

Albite, beryl, elbaite, fluorapatite, hambergite(H), lepidolite, microcline, quartz, rynersonite(SD), spessartine, stibiotantalite(H).

Pala district, Hiriart Hill [includes White Queen mine, Katerina mine, Vanderburg mine, San Pedro mine, Anita mine, and others]—ENE of Pala.

Albite, albite, beryl (morganite), elbaite, lepidolite, lithiophilite, microcline, muscovite, petalite, quartz, secondary Mn-phosphates, spodumene (kunzite).

Pala district, Chief Mountain [includes Pala Chief mine, Elizabeth R mine (also known as Oceanview mine), Margarita mine]—NE of Pala.

Albite, apatite(ER), beryl (morganite), elbaite (rubellite), lepidolite, lithiophilite(ER), microcline, muscovite, quartz, schorl, secondary Mn-phosphates(ER), spodumene (kunzite).

Pala district, Queen Mountain [includes Stewart mine, Tourmaline Queen mine, Tourmaline King mine, Ed Fletcher mine, Pala View mine]—north of Pala.

Albite, apatite, beryl, elbaite, lepidolite, lithiophilite, microcline, muscovite, quartz, schorl, secondary Mn-phosphates, spessartine, spodumene.

Palm Wash calcite deposit [also known as Hilton deposit, Calcite Operators, Inc. mine]—Palm Wash, 9 miles west of Salton City, east edge of Santa Rosa Mountains.

Calcite (optical).

Ramona district [includes Little Three mine, Hercules mine, ABC mine, Surprise mine]—4 miles ENE of Ramona.

Albite, apatite, axinite, beryl, elbaite, lepidolite, microcline, quartz, schorl, spessartine, topaz.

Rincon district [includes Mack mine, Victor mine, Clark mine]—Rincon Mountain, 1 to 2 miles SE of Rincon.

Albite, apatite, beryl (aquamarine), elbaite (indicolite), lithiophilite, microcline, quartz, spodumene (kunzite).

Whaley mine [also known as De Luz quartz deposit]—2 miles north of De Luz, 7 miles NW of Fallbrook.

Goethite (after pyrite), quartz (w/adularia, arsenopyrite, chlorite, muscovite, spodumene).

SAN FRANCISCO COUNTY

Fort Point—south end of Golden Gate Bridge.

Apophyllite, aragonite, barite, coalingite, datolite, desautelsite, gyrolite, hydromagnesite, nesquehonite, pectolite, pyroaurite, sjogrenite, wollastonite.

SAN LUIS OBISPO COUNTY

Adelaida district [includes Oceanic mine, Cambria mines, Klau mines, Buena Vista mine, La Libertad mine (also known as Thompson mine)]—west of Paso Robles, Santa Lucia Range.

Bieberite(K), cinnabar, linnaeite(K), marcasite(K), mercury(O), metacinnabar(K), millerite(K,L), morenosite(K), schuetteite(O), siegenite(K).

Morro Bay aragonite locality [also known as Sweetwater mine]—7 miles by road NE of Morro Bay, CA 41 roadcut.

Aragonite.

Soda Lake—Carrizo Plain, 9 miles SE of California Valley.

Bloedite, mirabilite, thenardite.

SAN MATEO COUNTY

Challenge deposit—0.5 mile SE of Upper Emerald Lake, south of Redwood City.

Calomel, cinnabar, eglestonite, mercury, metacinnabar, montroydite.

San Bruno Mountain—north of South San Francisco.

Quartz (amethyst).

SANTA BARBARA COUNTY

Point Sal zeolite locality—south end of Point Sal State Beach, 1.8 miles ESE of Point Sal.

Analcime, natrolite, thomsonite.

SANTA CLARA COUNTY

Alum Rock Park—7 miles NE of San Jose.

Alabandite, alleghanyite, barite, ganophyllite, hausmannite, kempite, pyrochroite, tephroite.

Mount Hamilton deposit—4 miles ENE of Mount Hamilton in roadcut.

Melanophlogite, alumohydrocalcite.

New Almaden district [includes New Almaden mine, Guadalupe mine]—9 miles south of San Jose.

Apophyllite(NA), cinnabar, gyrolite(NA), mercury, metacinnabar, millerite(NA), pyrite, stibnite(NA), zaratite(NA).

Pacheco Pass lawsonite locality—2.5 miles west of Pacheco Pass.

Albite, cymrite, glaucophane, jadeite, lawsonite, pumpellyite, stilpnomelane.

Paradise Valley jasper locality [also known as Morgan Hill jasper locality]—near Morgan Hill.

Quartz (orbicular jasper).

Pennsylvania mine—SW side of San Antonio Valley, 4 miles ENE of Mount Hamilton.

Barite, braunite, cristobalite, franciscanite, harmotome, kutnohorite, rhodonite, santaclaraite, taneyamalite.

Westvaco mine [also known as Western mines, Sherlock mine]—Red Mountain district.

Magnesite, siderite.

SANTA CRUZ COUNTY

Kalkar quarry [also known as Pacific Limestone Products quarry]—north of Santa Cruz.

Annabergite, arsenopyrite, bismuth, cerussite, frankeite, gersdorffite, kermesite, loellingite, meneghinite, pabstite, rozenite, stannite, taramellite, . . .

SIERRA COUNTY

Alleghany district [includes 16-to-1 mine, Oriental mine, & others]—near Alleghany.

Arsenopyrite, beidellite, gold, muscovite, palygorskite, uvarovite.

Quartz Knob [also known as Crystal Peak]—7 miles NW of Verdi, NV.

Cuprotungstite, muscovite, quartz, scheelite.

SISKIYOU COUNTY

Cougar Butte cristobalite locality—east of Cougar Butte.

Cristobalite, fayalite.

Happy Camp deposit [also known as Indian Creek deposit, Chan claim]—7 miles NNW Happy Camp, along South Fork of Indian Creek.

Rhodonite, vesuvianite (californite).

Yreka axinite locality—7 miles NNE of Yreka, roadcut near CA 263 crossing of Klamath River.

Axinite.

SONOMA COUNTY

Camp Meeker lawsonite locality—2 miles north of Occidental.

Glaucophane, lawsonite, pumpellyite.

Cazadero quarry—0.5 mile north of Cazadero.

Albite, antigorite, apatite, chlorite, clinozoisite, diopside, glaucophane, hornblende, lawsonite, muscovite, pumpellyite, rutile, talc, titanite, tremolite, zoisite.

Porter Creek lawsonite locality—6 miles south of Healdsburg.

Glaucophane, lawsonite, pumpellyite.

Skaggs Spring mine—west of Skaggs Springs, 10 miles NW of Healdsburg.

Cinnabar, idrialite, metacinnabar, opal, orpiment, realgar.

Sonoma mine [also known as Great Western mine & Mount Jackson mine]—4 miles NE of Guerneville, Guerneville district.

Bravoite, cinnabar, mercury, metacinnabar, vaesite.

The Geysers—12 miles east of Cloverdale, Western Mayacmas district.

Alunogen, boussingaultite, cinnabar, letovicite, mascagnite, pentahydrite, pickeringite, stellerite, sulfur, tschermigite, voltaite, wairakite.

Valley Ford lawsonite locality—2 miles north of Valley Ford.

Glaucophane, lawsonite.

Western Mayacmas district [includes Culver-Baer mine, Socrates mine (also known as Pioneer mine), Rattlesnake mine, Cloverdale mine]—8 to 14 miles west of Cloverdale.

Barite, cinnabar, mercury, metacinnabar, montroydite.

STANISLAUS COUNTY

Del Puerto Canyon calcite locality—Del Puerto Canyon.

Calcite, quartz.

Del Puerto Canyon hydromagnesite locality—Del Puerto Canyon, 0.3 mile NE of Adobe Canyon.

Aragonite, hydromagnesite.

TRINITY COUNTY

Altoona mine—14 miles WSW of Dunsmuir, East Fork of Trinity River.

Ankerite, barite, cinnabar, mercury, pyrite, quartz.

Hale Creek mine—Mad River Ridge, 1 mile west of north end of Ruth Reservoir, 7 miles west of Forest Glen.
Barite, bementite, calcite, hausmannite, inesite, julgoldite, rhodochrosite, wellsite.

Trinity County magadiite locality—6 miles east of Trinity Center.
Kenyaite, magadiite, montmorillonite, mountainite, rhodesite, silhydrite.

Trinity River placers—Trinity River near Junction City.
Iridosmine, platinum.

TULARE COUNTY

Drum Valley tungsten deposits [includes Bill Waley Indian Allotment mine (also known as J. H. B. mine, Tom Cat mine), Consolidated Tungsten mine (also known as Drum Valley mine, Harrel Hill mine)]—east end of Drum Valley, 6 miles west of Badger.
Apatite(C), axinite(C), calcite, epidote, grossular, loellingite(BW), scheelite, vesuvianite(BW), wollastonite(C).

Tyler Creek mine—2 miles west of California Hot Springs.
Laumontite, phlogopite, scheelite.

TUOLUMNE COUNTY

Jacksonville uvarovite locality [includes Bluepoint claim, Buckhorn claim]—2.5 miles south of Jacksonville (site), Marsh's Flat district, west of Don Pedro Reservoir.
Clinochlore (kämmererite), magnesiochromite, uvarovite.

VENTURA COUNTY

Circle X Boy Scout Camp zeolite locality—east side of Sandstone Peak, Boney Mountain, Santa Monica Mountains Conservancy, Santa Monica Mountains.
Analcime, chabazite, epistilbite, heulandite, mordenite, natrolite, quartz, saponite, stilbite.

Rincon Point rosickyite locality—Rincon Point, 3 miles ESE of Carpinteria.
Rosickyite, sulfur.

II.—ALPHABETICAL LOCALITY LISTING

Abbott mine (Lake Co.)
ABC mine (see Ramona district, San Diego Co.)
Adelaida district (San Luis Obispo Co.)
Advance mine (= Zaca mine, Alpine Co.)
Aetna mine (Napa Co.)
Aldrige mine (= Little Acorn mine, see Greenhorn Mountains scheelite deposits, Kern Co.)
Alleghany district (Sierra Co.)
Alma mine (Alameda Co.)
Alpine mine (San Benito Co.)
Alta claim (Del Norte Co.)
Altoona mine (Trinity Co.)
Alum Rock Park (Santa Clara Co.)
Aguanga Mountain district (San Diego Co.)
Ambrose mine (see Stayton district, San Benito Co.)
Amethyst Queen claim (see Kingston Peak amethyst deposits, San Bernardino Co.)
Anita mine (see Pala district, Hiriart Hill, San Diego Co.)
Antimony Peak mine (Kern Co.)
Artinite locality (San Benito Co.)
Artru mine (see Colorado Quartz mine, Mariposa Co.)
Ash Creek edingtonite locality (Mendocino Co.)
Atkinson claim (= Blue Bell mine, San Bernardino Co.)
Atlas Asbestos mine (Fresno Co.)
Atolia mine (San Bernardino Co.)
Aurora mine (see Alpine mine, San Benito Co.)
Baker mine (see Boron borate deposit, Kern Co.)
Baker mine (see Eastern Mayacmas district, Lake Co.)
Bar and Grill claim (San Bernardino Co.)
Barite claim (see Lead Mountain deposit, San Bernardino Co.)
Beasore claims (Madera Co.)
Beebe Hole mine (see Jacumba district, San Diego Co.)
Benitoite Gem mine (San Benito Co.)
Benson mine (= New Method mine, San Bernardino Co.)
Bertram mine (Imperial Co.)
Biddy McCarthy mine (see Ryan borax deposits, Inyo Co.)
Big Creek - Rush Creek sanbornite deposit (Fresno Co.)
Big Reef mine (= Black Butte mine, San Bernardino Co.)
Bill Waley Indian Allotment mine (see Drum Valley tungsten deposits, Tulare Co.)
Billie No. 1 mine (Inyo Co.)
Birthday claim (= Sulfide Queen mine, San Bernardino Co.)
Black Butte mine (San Bernardino Co.)
Black Eagle mine (= Eagle Mountain mine, Riverside Co.)
Black Mountain King mine (see Greenhorn Mountains scheelite deposits, Kern Co.)
Blue Bell mine (San Bernardino Co.)
Blue Bell mine (= Blue Lady mine, San Diego Co.)
Blue Chihuahua mine (Riverside Co.)
Blue Dog mine (San Diego Co.)
Blue Wing mine (see Stayton district, Merced Co.)
Bluebird kyanite deposit (Imperial Co.)
Bluepoint claim (see Jacksonville uvarovite locality, Tuolumne Co.)
Borate mines (= Pacific Coast Borax Co. mine, San Bernardino Co.)
Borax Lake (Lake Co.)
Boraxo mine (Inyo Co.)
Boron borate deposit (Kern Co.)
Boron mine (= U. S. Borax open opit, see Boron borate deposit, Kern Co.)
Boston mine (= Redington mine, Napa Co.)
Bristol Dry Lake (San Bernardino Co.)
Buckhorn claim (see Jacksonville uvarovite locality, Tuolumne Co.)
Buena Vista mine (see Adelaida district, San Luis Obispo Co.)
Burcham mine (see Calico district, San Bernardino Co.)
Buttermilk Country (Inyo Co.)
Cahuilla Mountain district (Riverside Co.)
Cajalco tin mine (Riverside Co.)
Calaveras Crystal mine (Calaveras Co.)
Calcite Operators, Inc. mine (= Hilton deposit, San Diego Co.)
Calico district (San Bernardino Co.)
California Comstock mine (= Leiser Ray mine, San Bernardino Co.)
California Rand mine (= Kelly mine, see Randsburg district, San Bernardino Co.)
Cambria mines (see Adelaida district, San Luis Obispo Co.)
Camp Meeker lawsonite locality (Sonoma Co.)
Carson Hill mines (Calaveras Co.)
Cascade Canyon lapis locality (San Bernardino Co.)
Cazadero quarry (Sonoma Co.)
Cedar Mountain chromite deposits (Alameda Co.)
Cerro Gordo mine (Inyo Co.)
Challenge deposit (San Mateo Co.)
Champion mine (Mono Co.)

Champion Sillimanite mine (= Champion mine, Inyo Co.)
Champion Sparkplug mine (= Champion mine, Inyo Co.)
Chan claim (= Happy Camp deposit, Siskiyou Co.)
Cherokee mine (Butte Co.)
Chino quarry (see Crestmore quarry, Riverside Co.)
Chlorite Knob (= Perovskite Peak, San Benito Co.)
Christi mine (Fresno Co.)
Cinco orthoclase locality (Kern Co.)
Circle X Boy Scout Camp zeolite locality (Ventura Co.)
Clark claim (see Cedar Mountain chromite deposits, Alameda Co.)
Clark mine (see Rincon district, San Diego Co.)
Clear Creek deposits (San Benito Co.)
Clio vesuvianite locality (Plumas Co.)
Cloverdale mine (see Western mayacmas district, Sonoma Co.)
Coalinga Asbestos mine (Fresno Co.)
Coarsegold axinite locality (Madera Co.)
Colorado mine (= Zaca mine, Alpine Co.)
Colorado Quartz mine (Mariposa Co.)
Commercial quarry (= Crestmore quarry, Riverside Co.)
Consolidated Tungsten mine (see Drum Valley tungsten deposits, Tulare Co.)
Coon Hollow (Riverside Co.)
Copper World mine (San Bernardino Co.)
Corkscrew mine (Inyo Co.)
Corral Hollow selenite locality (Alameda Co.)
Coso Hot Springs deposit (Inyo Co.)
Consumnes mine (El Dorado Co.)
Cota mine (see Mesa Grande district, San Diego Co.)
Cougar Butte cristobalite locality (Siskiyou Co.)
Coupon Ledge (= Coupon mine, San Bernardino Co.)
Coupon mine (San Bernardino Co.)
Coyote garnet deposit (Inyo Co.)
Coyote mine (see Randsburg district, San Bernardino Co.)
Coyote Peak (Humboldt Co.)
Crestmore quarry (Riverside Co.)
Crystal Peak (= Quartz Knob, Sierra Co.)
Culver-Baer mine (see Western Mayacmas district, Sonoma Co.)
Dallas Gem mine (= Benitoite Gem mine, San Benito Co.)
Danby Dry Lake (San Bernardino Co.)
Darwin mines (Inyo Co.)
Daulton deposit (Madera Co.)
Dehesa deposit (San Diego Co.)
Del Puerto Canyon calcite locality (Stanislaus Co.)
Del Puerto Canyon hydromagnesite locality (Stanislaus Co.)
Devil's Gulch deposit (see El Portal deposit, Mariposa Co.)
Diltz mine (see Colorado Quartz mine, Mariposa Co.)
Dinkey Creek pluton (Fresno Co.)
Douglas mine (see Cedar Mountain chromite deposits, Alameda Co.)
Drum Valley mine (= Consolidated Tungsten mine, see Drum Valley tungsten deposits, Tulare Co.)
Drum Valley tungsten deposits (Tulare Co.)
Eagle Mountain mine (Riverside Co.)
East Camp (see Turquoise Mountains deposits, San Bernardino Co.)
Eastern Mayacmas district (Lake Co.)
Ed Fletcher mine (see Pala district, Queen Mountain, San Diego Co.)
El Paso Mountains deposits (Kern Co.)
El Portal deposit (Mariposa Co.)
Elizabeth R. mine (see Pala district, Chief Mountain, San Deigo Co.)
Emeralite No. 2 mine (= Ware mine, see Aguanga district, San Diego Co.)
Empire mine (= Engle mine, Plumas Co.)
Empire mine (see Grass Valley district, Sierra Co.)
Engle mine (Plumas Co.)
Engles mine (= Engle mine, Plumas Co.)
Esmerelda mine (see Mesa Grande district, San Diego Co.)
Esquire No. 1 claim (see Big Creek - Rush Creek sanbornite deposit, Fresno Co.)
Esquire No. 7 claim (see Big Creek - Rush Creek sanbornite deposit, Fresno Co.)
Esquire No. 8 claim (see Big Creek - Rush Creek sanbornite deposit, Fresno Co.)
Evening Star mine (San Bernardino Co.)
Exchequer mine (Alpine Co.)
Fallbrook axinite locality (San Diego Co.)
Fano mine (see Cahuilla Mountain district, Riverside Co.)
Fano-Simmons mine (= Fano mine, see Cahuilla Mountain district, Riverside Co.)
Faujasite locality (San Bernardino Co.)
Feather River axinite locality (Butte Co.)
Felix mine (Los Angeles Co.)
Folsom (Sacramento Co.)
Fort Point (San Francisco Co.)
Fourth of July mine (= Picacho mine, San Benito Co.)
French mine (see Georgetown district, El Dorado Co.)
Garnet Hill mine (see Garnet Hill deposits, Calavaras Co.)
Garnet prospect (San Benito Co.)
Gem mine (= Benitoite Gem mine, San Benito Co.)
Gem Mine No. 1 (= Ware mine, see Aguanga district, San Diego Co.)
Georgetown district (El Dorado Co.)
Georgia Slide mine (see Georgetown district, El Dorado Co.)
Golden Queen mine (Kern Co.)
Gower Gulch mine (Inyo Co.)
Grandview mine (see Ryan borax deposits, Inyo Co.)
Granite Hill (Inyo Co.)
Great Western mine & Mount Jackson mine (= Sonoma mine, Sonoma Co.)
Great Western mine (see Eastern Mayacmas district, Lake Co.)
Green Fire mine (San Benito Co.)
Green Monster mine (Inyo Co.)
Green Mountain mine (= Calaveras Crystal mine, Calaveras Co.)
Greenhorn Mountains scheelite deposits (Kern Co.)
Greystone claim (Plumas Co.)
Grit mine (see Georgetown district, El Dorado Co.)
Grizzly Mountains (= Grizzly Ridge, Plumas Co.)
Grizzly Ridge quartz locality (Plumas Co.)
Guadalupe mine (see New Almaden district, Santa Clara Co.)
Hale Creek mine (Trinity Co.)
Hallelujah Junction quartz locality (Lassen Co.)
Happy Camp deposit (Siskiyou Co.)
Hard Luck claims (= Blue Bell mine, San Bernardino Co.)
Hard Scramble claim (Inyo Co.)
Hardscrabble claim (= Hard Scramble claim, Inyo Co.)
Harrel Hill mine (= Consolidated Tungsten mine, see Drum Valley tungsten deposits, Tulare Co.)
Hauser beds (Imperial Co.)
Helen mine group (see Eastern Mayacmas district, Lake Co.)
Hercules mine (see Ramona district, San Diego Co.)
High Plateau mine (Del Norte Co.)
Hilton deposit (see Palm Wash calcite deposit, San Diego Co.)
Himalaya (Turquoise Mountains deposits, San Bernardino Co.)
Himalaya mine (see Mesa Grande district, San Diego Co.)
Hope mine (= New Method mine, San Bernardino Co.)
Huckabay mine (= Black Mountain King mine, see Greenhorn Mountains scheelite deposits, Kern Co.)
Hunter Mountain (Inyo Co.)

I. X. L. claim (Madera Co.)
I. X. L. mine (see Exchequer mine, Alpine Co.)
Idaho-Maryland mine (see Grass Valley district, Sierra Co.)
Imperial Lode (San Bernardino Co.)
Incline sanbornite deposit (Mariposa Co.)
Indian Creek deposit (= Happy Camp deposit, Siskiyou Co.)
Iron Chief mine (= Eagle Mountain mine, Riverside Co.)
J. H. B. mine (= Bill Waley Indian Allotment mine, see Drum Valley tungsten deposits, Tulare Co.)
Jacksonville uvarovite locality (Tuolomne Co.)
Jacumba district (San Diego Co.)
Jade Cove (Monterey Co.)
Jade mine (see Pulga deposit, Butte Co.)
Jeffrey mine (Mono Co.)
Jenifer mine (see Boron borate deposit, Kern Co.)
Jensen quarry (Riverside Co.)
Josephine mine (El Dorado Co.)
Junilla mine (San Benito Co.)
Juniper mine (San Benito Co.)
Kalkar quarry (Santa Cruz Co.)
Kanan Road zeolite deposites (Los Angeles Co.)
Katerina mine (see Pala district, Hiriart Hill, San Diego Co.)
KCAC mine (San Benito Co.)
Kelly mine (see Randsburg district, San Bernardino Co.)
Klau mines (see Adelaida district, San Luis Obispo Co.)
Knoxville mine (= Redington mine, Napa Co.)
Kramer open pit (= U. S. Borax open pit, see Boron borate deposits, Kern Co.)
LaLibertad mine (see Adelaida district, San Luis Obispo Co.)
Langtry mine (see Calico district, San Bernardino Co.)
Laytonville quarry (Mendocino Co.)
Lead Mountain deposit (San Bernardino Co.)
Lead Mountain mine (see Lead Mountain deposit, San Bernardino Co.)
Leiser Ray mine (San Bernardino Co.)
Leona mine (see Alma pyrite mine, Alameda Co.)
Leviathan mine (Alpine Co.)
Lippincott lead mine (Inyo Co.)
Lithia Dyke (see Cahuilla Mountain district, Riverside Co.)
Little Acorn mine (see Greenhorn Mountains scheelite deposits, Kern Co.)
Little Three mine (see Ramona district, San Diego Co.)
Lizzie V. Oakley mine (see Ryan borax deposits, Inyo Co.)
Llanada copper mine (San Benito Co.)
Lone Star quarry (= Crestmore quarry, Riverside Co.)
Lone Tree mine (see Stayton district, San Benito Co.)
Lost John mine (Inyo Co.)
Louisiana-California Co. mine (= Leiser Ray mine, San Bernardino Co.)
Lucky Strike claim (see Big Creek - Rusk Creek sanbornite deposit, Fresno Co.)
Mack mine (see Rincon district, San Diego Co.)
Manhattan mine (Napa Co.)
Maple Lode (see Aguanga Mountain district, San Diego Co.)
Mar-Bon claims (see Pulga deposit, Butte Co.)
McGee mine (see Searles Lake deposit, San Bernardino Co.)
Melones mine (see Carson Hill mines, Calaveras Co.)
Mesa Grande district (San Diego Co.)
Mesa Grande mine (see Mesa Grande district, San Diego Co.)
Michigan Bluff district (Placer Co.)
Michigan Bluff mine (see Michigan Bluff district, Placer Co.)
Middle Camp (see Turquoise Mountains deposits, San Bernardino Co.)
Middletown pectolite locality (Lake Co.)
Mile-Hi claim (see Kingston Peak amethyst deposits, San Bernardino Co.)
Mina Numero Uno (San Benito Co.)
Miners Ridge (Mendocino Co.)
Mirabel mine (see Eastern Mayacmas district, Lake Co.)
Miracle Mountain claim (= Garnet Hill mine, Calaveras Co.)
Mockingbird mine (see Colorado Quartz mine, Mariposa Co.)
Mohawk mine (San Bernardino Co.)
Molina No. 1 mine (see Alpine mine, San Benito Co.)
Mono County Andalusite mine (= Champion mine, Mono Co.)
Mono Lake (see Paoha Island, Mono Co.)
Moore Creek mine (see Garnet Hill deposits, Calaveras Co.)
Morgan Hill jasper locality (see Paradise Valley jasper locality, Santa Clara Co.)
Morgan mine (see Carson mines, Calaveras Co.)
Morning Star mine (Alpine Co.)
Morning Star mine (see Cerro Gordo mine, Inyo Co.)
Morro Bay aragonite locality (San Luis Obispo Co.)
Mount Blanco mine (Inyo Co.)
Mount Diablo mine (Contra Costa Co.)
Mount Hamilton deposit (Santa Clara Co.)
Mountain Lily mine (= Ware mine, see Aguanga district, San Diego Co.)
Mountain Pass mine (= Sulfide Queen mine, San Bernardino Co.)
Nevada City mine (see Nevada City district, Sierra Co.)
New Almaden district (Santa Clara Co.)
New Almaden mine (see New Almaden district, Santa Clara Co.)
New Idria mine (San Benito Co.)
New Melones Dam spillway (Calaveras Co.)
New Method mine (San Bernardino Co.)
Newman deposit (see Cedar Mountain chromite deposits, Alameda Co.)
North Hill quarry (Riverside Co.)
North Star mine (see Grass Valley district, Sierra Co.)
Obsidian Ridge (= Coso Hot Springs deposit, Inyo Co.)
Oceanic mine (see Adelaida district, San Luis Obispo Co.)
Oceanview mine (= Elizabeth R mine, see pala district, Chief Mountain, San Diego Co.)
Ogilby Kyanite deposit (= Bluebird Kyanite deposit, Imperial Co.)
Old Pino Grande prospect (El Dorado Co.)
Old talc prospect (see Artinite locality, San Benito Co.)
Old Zelner mine (= Little Acorn mine, see Greenhorn Mountains scheelite deposits, Kern Co.)
Oriental mine (see Calico distirct, San Bernardino Co.)
Oriental mine (see Alleghany district, Sierra Co.)
Pacheco Pass lawsonite locality (Santa Clara Co.)
Pacific Coast Borax Co. mine (San Bernardino Co.)
Pacific Limestone Products quarry (= Kalkar quarry, Santa Cruz Co.)
Pack Rat mine (see Jacumba district, San Diego Co.)
Pacoima Canyon pegmatite (Los Angeles Co.)
Pala Chief mine (see Pala district, Chief Mountain, San Diego Co.)
Pala district, Hiriart Hill (San Diego Co.)
Pala district, Chief Mountain (San Diego Co.)
Pala district, Queen Mountain (San Diego Co.)
Palisade mine (Napa Co.)
Palm Wash calcite deposit (San Deigo Co.)
Palos Verdes barite locality (Los Angeles Co.)
Paoha Island (Mono Co.)
Paradise Valley jasper locality (Santa Clara Co.)
Penn mine (Calaveras Co.)
Pennsylvania mine (see Grass Valley district, Sierra Co.)
Pennsylvania mine (Santa Clara Co.)
Perovskite Peak (San Benito Co.)
Picacho mine (San Benito Co.)
Pine Creek tungsten mine (Inyo Co.)

Pioneer mine (= Socrates mine, see Western Mayacmas district, Sonoma Co.)
Pioneer mine (see Michigan Bluff district, Placer Co.)
Played Out mine (see Ryan borax deposits, Inyo Co.)
Point Sal zeolite locality (Santa Barbara Co.)
Poison Creek epidote locality (Plumas Co.)
Porter Creek lawsonite locality (Sonoma Co.)
Providence mine (see Nevada City district, Sierra Co.)
Pulga deposit (Butte Co.)
Quartz Knob (Sierra Co.)
Quien Sabe mine (see Stayton district, San Benito Co.)
Ramona district (San Diego Co.)
Rand mine (= Kelly mine, see Randsburg district, San Bernardino Co.)
Randsburg district (San Bernardino Co.)
Rare Earth mine(= Sulfide Queen mine, San Bernardino Co.)
Rattlesnake mine (see Western Mayacmas district, Sonoma Co.)
Rawhide mine (see Michigan Bluff district, Placer Co.)
Red Ledge mine (Nevada Co.)
Red Rock Canyon zeolite locality (Kern Co.)
Redington mine (Napa Co.)
Reed Station lawsonite locality (Marin Co.)
Rincon district (San Diego Co.)
Rincon Point rosickyite locality (Ventura Co.)
Rough Diamond Crystal mine (= Calaveras Crystal mine, Calaveras Co.)
Russian River jadeite locality (Mendocino Co.)
Ryne mine (see Mount Diablo mine, Contra Costa Co.)
Saline Valley quartz locality (Inyo Co.)
Saltdale works (Kern Co.)
San Bruno Mountain (San Mateo Co.)
San Carlos mine (see Alpine mine, San Benito Co.)
San Diego mine (see Mesa Grande district, San Diego Co.)
San Emigdio mine (= Antimony Peak mine, Kern Co.)
San Pedro mine (see Pala district, Hiriart Hill, San Diego Co.)
Santa Fe mine (see Randsburg district, San Bernardino Co.)
Sawmill Peak quartz locality (Butte Co.)
Schindler claims (see Cahuilla Mountain district, Riverside Co.)
Schist Knob (= Perovskite Peak, San Benito Co.)
Schroeder mine (see Colorado Quartz mine, Mariposa Co.)
Searles Lake deposit (San Bernardino Co.)
Shamrock Ranch quarry (= Laytonville quarry, Mendocino Co.)
Shaver Lake amethyst locality (Fresno Co.)
Sherlock mine (= Westvaco mine, Santa Clara Co.)
Shingle Springs quartz locality (El Dorado Co.)
Silver King mine (see Calico district, San Bernardino Co.)
Silverado mine (Napa Co.)
16-to-1 mine (see Alleghany district, Sierra Co.)
Skaggs Spring mine (Sonoma Co.)
Slate Mountain mine (El Dorado Co.)
Slayton mine (see Stayton district, Merced Co.)
Smith's Flat (El Dorado Co.)
Socrates mine (see Western Mayacmas district, Sonoma Co.)
Soda Lake (San Luis Obispo Co.)
Sonoma mine (Sonoma Co.)
Southern Pacific silica quarry (Riverside Co.)
Spanish Dry Diggins Seam mine (= Grit mine, see Georgetown district, El Dorado Co.)
Stanislaus mine (see Carson Hill mines, Calaveras Co.)
Stayton district (Merced Co. & San Benito Co.)
Sterling Borax mine (Los Angeles Co.)
Stewart mine (see Pala district, Queen Mountain, San Diego Co.)
Stifle Memorial claim (El Dorado Co.)
Stinson Beach szaibelyite locality (Marin Co.)
Strawberry mine (Madera Co.)
Sulfateria (= Sulfur Hole, San Bernardino Co.)
Sulfide Queen mine (San Bernardino Co.)
Sulfur Hole (San Bernardino Co.)
Sulphur Bank mine (Lake Co.)
Surcease mine (Butte Co.)
Surprise mine (see Ramona district, San Diego Co.)
Sweetwater mine (= Morro Bay aragonite locality, San Luis Obispo Co.)
Tarshish mine (= Zaca mine, Alpine Co.)
Tejon Ranch garnet deposit (Kern Co.)
Tenneco mine (= Boraxo mine, Inyo Co.)
Terry mine (Inyo Co.)
The Geysers (Sonoma Co.)
Thompson mine (= Boraxo mine, Inyo Co.)
Thompson mine (= LaLibertad mine, see Adelaida district, San Luis Obispo Co.)
Thompson Peak mine (Plumas Co.)
Three Buttes deposit (Mariposa Co.)
Tip Top mine (see Imperial Lode, San Bernardino Co.)
Tobin (Plumas Co.)
Toltec (see Turquoise Mountains deposits, San Bernardino Co.)
Tom Cat mine (= Bill Waley Indian Allotment mine, see Drum Valley tungsten deposits, Tulare Co.)
Total Wreck Crystal claim (see Greenhorn Mountains scheelite deposits, Kern Co.)
Total Wreck mine (= Burcham mine, see Calico district, San Bernardino Co.)
Tourmaline King mine (see Pala district, Queen Mountain, San Diego Co.)
Tourmaline Queen mine (see Pala district, Queen Mountain, San Diego Co.)
Trinity County magadiite locality (Trinity Co.)
Trinity River placers (Trinity Co.)
Turquoise Mountains deposits (San Bernardino Co.)
Twin Lakes deposit (Fresno Co.)
Tyler Creek mine (Tulare Co.)
U. S. Borax open pit (see Boron borate deposit, Kern Co.)
Ubehebe mine (Inyo Co.)
Union Carbide Asbestos mine (= KCAC mine, San Benito Co.)
Valley Ford lawsonite locality (Sonoma Co.)
Vanadium King mine (= Leiser Ray mine, San Bernardino Co.)
Vanderburg mine (see Pala district, Hiriart Hill, San Diego Co.)
Victor mine (see Rincon district, San Diego Co.)
Victor mine (San Benito Co.)
Vitrefrax mine (= Bluebird Kyanite deposit, Imperial Co.)
Ware mine (see Aguanga Mountain district, San Diego Co.)
Waterloo mine (see Calico district, San Bernardino Co.)
West Baker mine (see Boron borate deposit, Kern Co.)
West End Chemical mine (see Searles Lake deposit, San Bernardino Co.)
Western Mayacmas district (Sonoma Co.)
Western mines (= Westvaco mine, Santa Clara Co.)
Westvaco mine (Santa Clara Co.)
Wet Weather quarry (= Crestmore quarry, Riverside Co.)
White Queen mine (see Pala district, Hiriart Hill, San Diego Co.)
White Rock mine (Mariposa Co.)
Willow Creek Beach (see Jade Cove, Monterey Co.)
Windy Mountain claim (San Benito Co.)
Wrightwood actinolite locality (San Bernardino Co.)
Yellow Jacket mine (see Stayton district, Merced Co.)
Yreka axinite locality (Siskiyou Co.)
Zaca mine (Alpine Co.)
Zinc Hill mine (Inyo Co.)

III.—CALIFORNIA TYPE LOCATIONS

Alforsite: Big Creek - Rush Creek sanbornite deposit, 5 miles NE of Trimmer, Fresno Co.; Incline sanbornite deposit, Trumbull Peak, 4 miles WNW of Incline, Mariposa Co.

Arcanite: Santa Ana mine, Trabuco Canyon, Orange Co.

Bakerite: Corkscrew mine, Corkscrew Canyon, Death Valley, Inyo Co.

Bario-orthojoaquinite: Benitoite Gem mine, head waters of the San Benito River, 1 mile south of Santa Rita Peak, San Benito Co.

Bartonite: Coyote Peak diatreme, 16 miles SW of Orick, Humboldt Co.

Benitoite: Benitoite Gem mine, head waters of the San Benito River, 1 mile south of Santa Rita Peak, San Benito Co.

Boothite: Alma pyrite mine, Leona Heights, Alameda Co.

Buddingtonite: Sulfur Bank mine, end of east arm of Clear Lake, Lake Co.

Burkeite: Searles Lake, San Bernardino Co.

Calaverite: Stanislaus mine, Carson Hill, Calaveras Co.

Coalingite: New Idria district, Fresno Co. and San Benito Co.

Colemanite: Furnace Creek district, Death Valley, Inyo Co.

Coyoteite: Coyote Peak diatreme, 16 miles SW of Orick, Humboldt Co.

Deerite: Laytonville quarry, 5 miles south of Laytonville, Mendocino Co.

Desautelsite: Artinite locality and old talc prospect, 1 mile NE of Picacho Peak, San Benito Co.; Coalinga asbestos mine, 10 miles south of Idria, Fresno Co.

Ellestadite: Crestmore quarry, 5 miles NW of Riverside, Riverside Co.

Erdite: Coyote Peak diatreme, 16 miles SW of Orick, Humboldt Co.

Erlichmannite: MacIntosh mine, Willow Creek, Humboldt Co.

Foshagite: Crestmore quarry, 5 miles NW of Riverside, Riverside Co.

Franciscanite: Pennsylvania mine, SW side of San Antonio Valley, 4 miles ENE of Mount Hamilton, Santa Clara Co.

Fresnoite: Big Creek - Rush Creek sanbornite deposit, 5 miles NE of Trimmer, Fresno Co.

Galeite: Searles Lake, San Bernardino Co.

Gerstleyite: Baker mine, Boron, Kern Co.

Gowerite: Mott open cut, head of 20 Mule Team Canyon, Death Valley, Inyo Co.

Greigite: Kramer - Four Corners area (drill cores), San Bernardino Co.

Haiweeite: Haiwee Reservoir, Inyo Co.

Hanksite: Searles Lake, San Bernardino Co.

Hectorite: Company No. 1 mine, 3 miles south of Hector, San Bernardino Co.

Howieite: Laytonville quarry, 5 miles south of Laytonville, Mendocino Co.

Inyoite: Mount Blanco mine, Mount Blanco, Black Mountains, Death Valley, Inyo Co.

Jennite: Crestmore quarry, 5 miles NW of Riverside, Riverside Co.

Joaquinite: Benitoite Gem mine, head waters of the San Benito River, 1 mile south of Santa Rita Peak, San Benito Co.

Jonesite: Benitoite Gem mine, head waters of the San Benito River, 1 mile south of Santa Rita Peak, San Benito Co.

Kempite: Alum Rock Park, 7 miles NE of San Jose, Santa Clara Co.

Kernite: Boron, Kern Co.

Krausite: Sulfur Hole, near Borate Camp, Mule Canyon, Calico Mountains, San Bernardino Co.

Krauskopfite: Big Creek - Rush Creek sanbornite deposit, 5 miles NE of Trimmer, Fresno Co.

Lawsonite: Reed Station, Tiburon Peninsula, Marin Co.

Macdonaldite: Big Creek - Rush Creek sanbornite deposit, 5 miles NE of Trimmer, Fresno Co.

Maghemite: Iron Mountain mine, 9.5 miles NW of Redding, Shasta Co.

Mcallisterite: Mott open cut, head of 20 Mule Team Canyon, Death Valley, Inyo Co.

Mcguinnessite: Miners Ridge, Red Mountain, 15 miles SE of Ukiah, Mendocino Co.

Melonite: Stanislaus mine, Carson Hill, Calaveras Co.

Merwinite: Crestmore quarry, 5 miles NW of Riverside, Riverside Co.

Metacinnabar: Redington mine, Knoxville, Napa Co.

Meyerhofferite: Mount Blanco mine, Mount Blanco, Black Mountains, Death Valley, Inyo Co.

Muirite: Big Creek - Rush Creek sanbornite deposit, 5 miles NE of Trimmer, Fresno Co.

Nekoite: Crestmore quarry, 5 miles NW of Riverside, Riverside Co.

Nissonite: Llanada copper mine, 4 miles NNE of Llanada, San Benito Co.

Nobleite: Corkscrew mine, Corkscrew Canyon, Death Valley, Inyo Co.

Northupite: Searles Lake, San Bernardino Co.

Orickite: Coyote Peak diatreme, 16 miles SW of Orick, Humboldt Co.

Osarsite: Gold Bluff, 3 to 6 miles north of Orick, Humboldt Co.

Pabstite: Kalkar quarry, north of Santa Cruz, Santa Cruz Co.

Paraspurrite: Darwin mines, Darwin, Inyo Co.

Partzite: Blind Spring Hill district, 2 miles SE of Benton, Mono Co.

Pirssonite: Searles Lake, San Bernardino Co.

Probertite: Boron, Kern Co.

Redingtonite: Redington mine, Knoxville, Napa Co.

Redledgeite: Red Ledge mine, south of Washington, Nevada Co.

Riversideite: Crestmore quarry, 5 miles NW of Riverside, Riverside Co.

Roscoelite: Stuckslacker mine, 2 miles SW of Coloma, El Dorado Co.

Rosenhahnite: Russian River, 5 miles NNW of Cloverdale, Mendocino Co.

Rynersonite: San Diego mine, Mesa Grande, San Diego Co.

Sahamalite: Sulfide Queen mine, Mountain Pass, San Bernardino Co.

Sanbornite: Incline sanbornite deposit, Trumball Peak, 4 miles WNW of Incline, Mariposa Co.

Santaclaraite: Pennsylvania mine, SW side of San Antonio Valley, 4 miles ENE of Mount Hamilton, Santa Clara Co.

Schairerite: Searles Lake, San Bernardino Co.

Schuettite: Sulphur Bank mine, end of east arm of Clear Lake, Clear Lake, Lake Co.

Searlesite: Searles Lake, San Bernardino Co.

Sicklerite: Stewart mine, Queen Mountain, Pala, San Diego Co.

Silhydrite: Trinity County magadiite locality, 6 miles east of Trinity Center, Trinity Co.

Stewartite: Stewart mine, Queen Mountain, Pala, San Diego Co.

Strontiojoaquinite: Mina Numero Uno, near San Benito Mountain, San Benito Co.

Sulphohalite: Searles Lake, San Bernardino Co.

Teepleite: Borax Lake, SE edge of Clear Lake, Lake Co.

Tilleyite: Crestmore quarry, 5 miles NW of Riverside, Riverside Co.

Tincalconite: Searles Lake, San Bernardino Co.

Traskite: Big Creek - Rush Creek sanbornite deposit, 5 miles NE of Trimmer, Fresno Co.

Tunellite: U. S. Borax open pit, Boron, Kern Co.

Tychite: Searles Lake, San Bernardino Co.

Veachite: Sterling Borax mine, Tick Canyon, 3.5 miles NNE of Lang, Los Angeles Co.

Verplankite: Big Creek - Rush Creek sanbornite deposit, 5 miles NE of Trimmer, Fresno Co.

Vonsenite: Old City Quarry, Riverside, Riverside Co.

Walstromite: Big Creek - Rush Creek sanbornite deposit, 5 miles NE of Trimmer, Fresno Co.

Wardsmithite: Hard Scramble claim and Oliver Consolidated claim, Furnace Creek district, Death Valley, Inyo Co.

Wightmanite: Crestmore quarry, 5 miles NW of Riverside, Riverside Co.

Woodhouseite: Champion mine, 4 miles WSW of White Mountain Peak, north of Laws, Mono Co.

Zussmanite: Laytonville quarry, 5 miles south of Laytonville, Mendocino Co.

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GYPSUM CRYSTALS FROM NEAR ZARAGOZA, SPAIN

Miguel Calvo
Fernando El Católico, 24 dup.6. ªdch.
50009 Zaragoza, Spain

Recently some very fine crystals of gypsum have appeared on the mineral market, labeled as having come from "near Zaragoza, Spain." The exact locality for most of these specimens is a series of alabaster quarries 2 to 5 km south and southwest of the small town of Fuentes de Ebro, which is about 27 km southeast of the city of Zaragoza in the province of the same name. Similar crystals have also come from quarries in the neighboring towns of Rodén, Mediana, La Zaida and others.

The alabaster deposits are part of a large, gypsum-rich sedimentary formation, Tertiary in age, extending over hundreds of square kilometers. It consists of massive, spherical bodies of alabaster (fine-grained marble-like gypsum) up to about a meter in diameter, separated by clays and marl, and forming beds between layers of marl and shale. Percolating groundwater has dissolved cavities between and within the spheroids, providing open spaces where crystals have formed. Generally there are no associated species, except for rare fibrous to earthy epsomite.

The gypsum crystals have been found up to 10 cm in size, with many in the 2–3 cm range. They are colorless to very pale yellow, waterclear, and have almost an adamantine luster. The habit is thin and bladed, sometimes twinned. All crystals exhibit a yellow fluorescence and phosphorescence under longwave ultraviolet light. Many specimens have been recovered, from fine thumbnails to cabinet specimens containing vugs with dozens of crystals. In order to safeguard the crystals from shock damage, specimens are commonly trimmed by saw rather than hammer or rock-splitter.

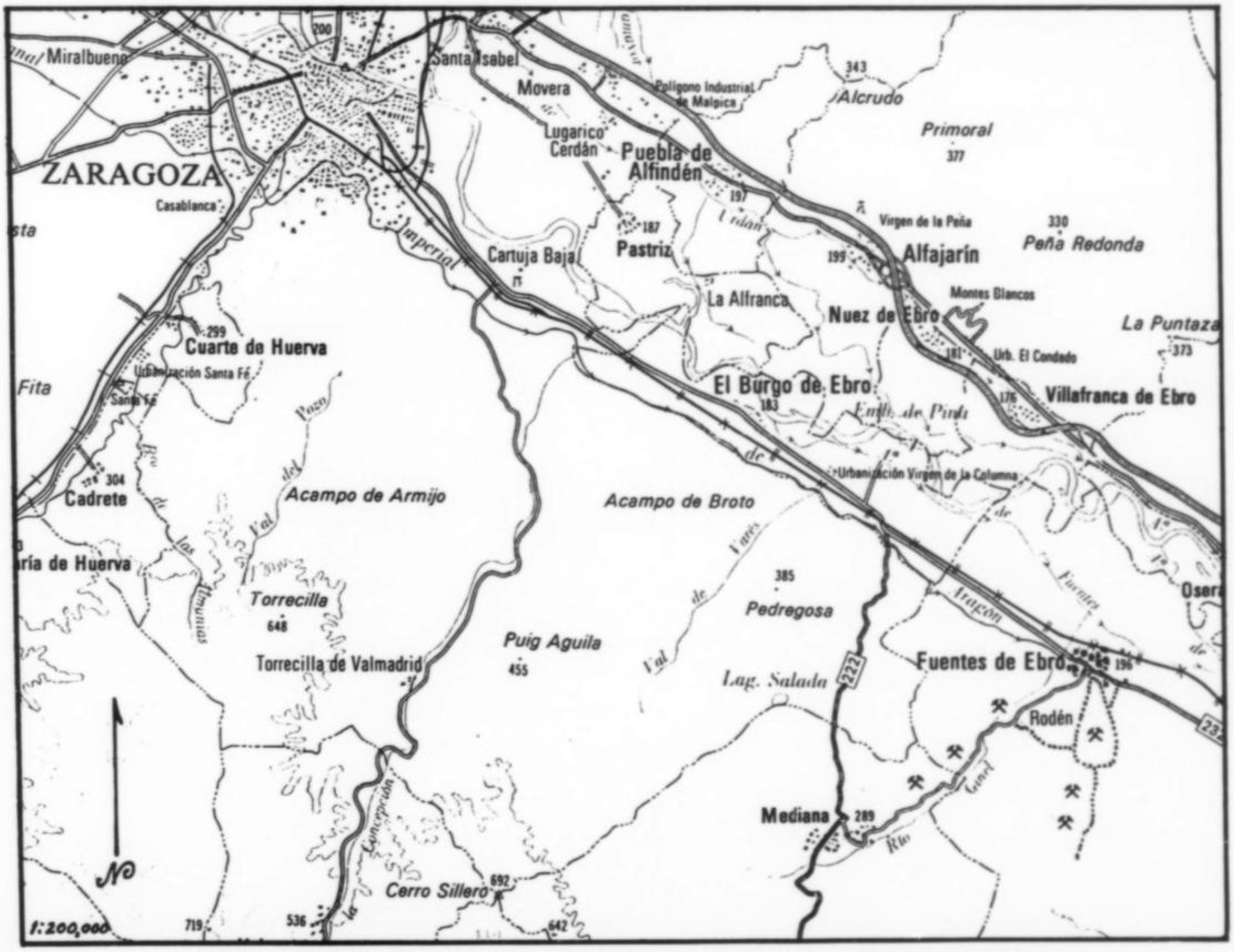

Figure 1. **Location map. The two southeastern-most quarries are the most productive.**

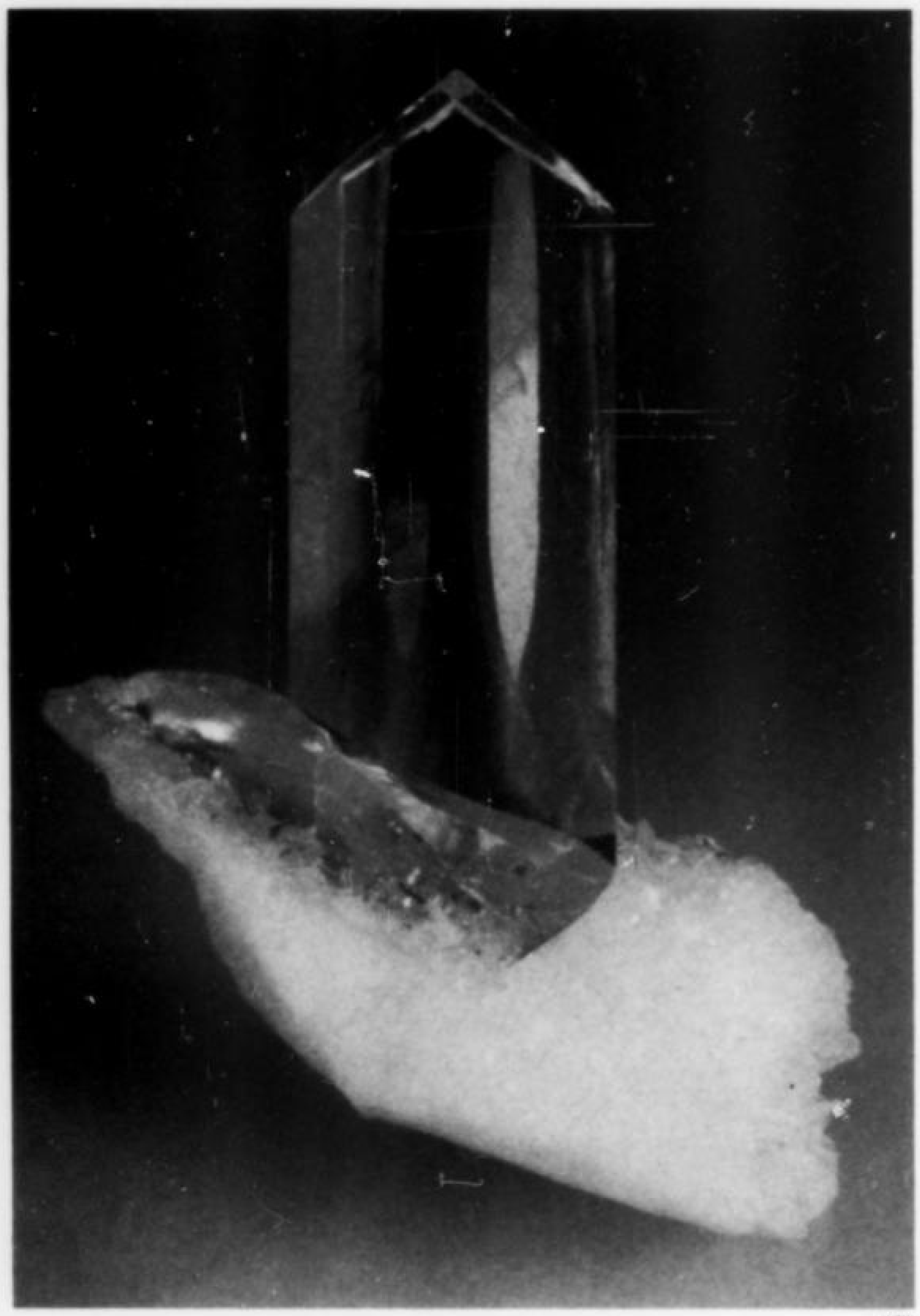

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Figure 2. **Gypsum crystals, 2.5 cm, from near Zaragoza. Andrew Gressman collection.**

Despite the fact that the crystal-containing vugs are rather sparsely distributed in the alabaster, the large size of the formation and the great number of quarries suggest that specimens should be forthcoming for many years.

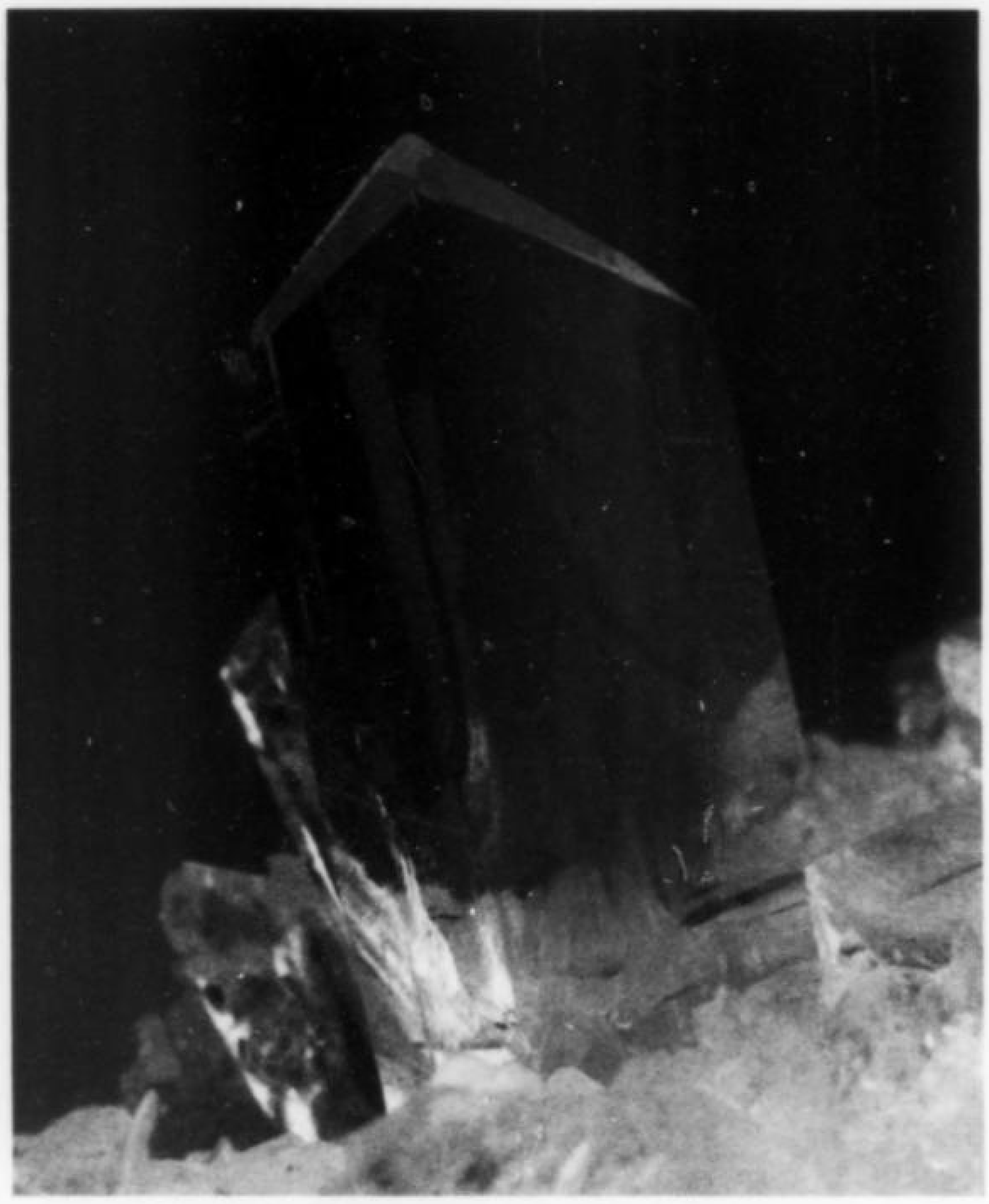

Figure 3. **Gypsum crystal, about 2 cm, from near Zaragoza. Evan Jones collection; photo by Jeff Scovil.**

The status of the individual quarries varies. Abandoned quarries have unrestricted access, but the likelihood of finding good specimens there is small unless commercial quarrying is resumed and large volumes of rock are again exploited. The owners of some of the operating quarries have made arrangements with mineral dealers for controlled recovery and sale of mineral specimens.

Notes from Germany

Ste.-Marie-aux-Mines Show 1988

For those faithful who have subscribed to the *Mineralogical Record* since its beginning in 1970, the last issue of 1986 (vol. 17, no. 6) might seem merely an "eyeblink" ago (*ein Augenblick*, a brief moment: perfectly picturesque German noun). But to me it seems a very long time ago when, in that issue, my clumsy first "Note From Germany," in truth a note from France, appeared, describing in glowing purple that year's Ste.-Marie-aux-Mines show. Since this is still my favorite mineral show in all Europe, it's time for a revisit to Ste.-Marie, in the beautiful Vosges hills, in Alsace, in early July.

The show itself was thriving, healthy, full of surprises as ever, both inside the Opera Building where the higher-powered dealers hang out, and outside, in the sunny tailgaters' lot and in the long blue-and-white-striped tent (for some account of the split personality of this show, see vol. 17, no. 6)—and prices this year were down for the excellent "Steacky Porcs" at the grill area just outside the main entrance.

There are now three days of the Ste.-Marie show; the first one, Friday (as at Munich), is reserved for wholesalers and other insiders to the trade. This means that the aisles on insiders' day are relatively uncongested, and the kinds of questions that dealers get asked, and the ways in which specimens get handled, are knowing, decorous, threatless; it's nice to feel insulated in this way form the hamhock-handed souvenir shoppers, with wild children running in the aisles, who are tomorrow's troubles for the show administrators.

Now, I know that I've gone on before, maybe too much already, about the general abundance of orange to yellow to colorless anglesites from the Touissit mine, Morocco—but nowhere previously had I seen such incredible quantities of them as I saw at this show, where there must have been thousands of pieces in all, in every conceivable size and in qualities ranging from negligible to unbelievably fine. These are, of course, sharp blades rising singly or in jumbled groups off granular galena matrixes, and despite the very high average quality one almost gets too much after awhile; it hardly seems decent that an occurrence should keep excelling itself (and all others) for the species in question. Oddly, though, there was a distinct decline in availabilities of other Touissit species: I saw only a few really good cerussites and wulfenites, only a couple of flats of small specimens of the distinctive silvery brown-yellow vanadinites once so common, and no azurite/malachites at all.

It is pleasant enough to record that really good lazurite crystals from the classic Badakhshan, Afghanistan, locality are—as I reported from Hamburg—becoming what might be called a reliable presence among the more serious dealers; I saw a few matrix pieces with good rounded euhedra up to 3 cm across. To continue to list interesting miscellanies, I saw also some scattered small specimens of the native silver coatings over quartz crystals from Taxco, Mexico, reported by Wendell Wilson (vol. 19, no. 3) and, from the same locality, one exquisite small thumbnail with two lightly striated, blocky silver crystals nestling against a quartz prism. Gilbert Gauthier had four 1-cm, loose, hexagonal prisms, two of them doubly terminated, of very pale yellow-green thaumasite, from the N'Chwaning mine, South Africa. Another top French dealer I've mentioned before, Michel Jouty, had Myr Pipe diamonds, huge Minas Gerais muscovite groups, and much other exotica. And Eric Asselborn had his usual array of old classics lying casually out, unlabeled for the most part, but modestly including some pale orange gem scapolites from Arusha, Tanzania, the longest one 4 x 6 cm; Erzgebirge argentite and pyrargyrite miniatures of top quality; a 5 x 7-cm English "butterfly" twin of calcite; and two loose boleite cubes from Mexico, each 1.5 cm on edge.

Most surprising to me among the "new" occurrences at Ste.-Marie were some very good wire silver thumbnails whose locality was given as the Sidi Ayad mine near Mibladen, Morocco. Morocco experts of course will know better (and I'd welcome hearing from them), but I had never before heard of native silver from any Moroccan source, and these, though small, were just about the peers of the best wire specimens from, say, Freiberg or Colorado. Five thumbnails were available, the best of them for only $50: a very attractive nest of thick curls with no associations. Christian Mondeilh (15 Allee de Roulerens, 33170 Gradignan, France) says that one or two kilograms of such specimens were taken out of the mine between 1950 and 1960.

At one of the tables outside, where breezes were cool, I had the pleasure of learning about some recent Spanish localities from the co-author of a note on this subject (vol. 18, no. 4, p. 301), Jordi Fabre i Fornaguera (C/Sant Joan de Malta, n. 5, baixos dª, 08018 Barcelona, Spain). First, and like many other dealers at the show, Fornaguera had much Panasqueira, Portugal, material . . . and some of the magnificent new gypsum-in-alabaster specimens from Pina de Ebro, Zaragoza, Aragon . . . and a few (not the show's best) of the brilliant new pyromorphites from Villaviciosa de Cordoba, Andalucia. This last is surely an occurrence to watch, since the best pieces are fully as colorful as Bunker Hill, Idaho, pyromorphites, though differing from them in being composed mostly of straightforward hexagonal prisms and tablets *not* barrel-convex on the sides or cavernous at the tops. Perhaps five other dealers had some of these specimens, and none was willing to say much about the source; whether we have here a new world-class pyromorphite locality in the making or just an isolated pocket occurrence seems impossible to know at this point. But meanwhile, for whatever it's worth (precisely the mystery, Watson!), I'll admit that I paid $55 for a 2.7-cm specimen with crystals to 5 mm in a loose, brilliantly apple-green cluster.

Señor Fornaguera also had some very nice sphalerites from a new, as yet unnamed mine near San Sebastian in the Basque country—these not to be confused with the orange gem sphalerites long known from Picos de Europa near Santander. In the case of these new ones, the white dolomite matrix and dustings of tiny chalcopyrite crystals evoke Tri-State specimens, but the presence of large, sharp, brown siderite rhombs de-evokes them again, while the yellow-brown, part-gemmy sphalerite crystals to 1 cm glisten brightly, dominating the mostly small-cabinet-sized pieces. Finally, from the Cala mine, Huelva, there was magnetite in clusters of simple 5-mm octahedra, and, far more interesting, in rosette arrangements of flattened parallel crystals on matrix. Associations for these rosettes include epidote, rose calcite, ferropargasite, quartz and garnet: clearly a skarn assemblage, and much like that of Prince of Wales Island, Alaska, a place renowned for epidote but hardly known at all for its magnetite rosettes, which are indeed much like these Spanish ones. Mineralogically Spain is still, it seems, very much a developing country, a fact which, when I think of it, helps me indulge my pet feeling of being sorry to have moved away as soon as I did (in 1982, after living for less than a year in lovely though largely mineralless Andalucia).

Inside the Opera House again, a lot of impressive glass-shelved distance along a side wall was taken up, as usual, by an impressive bunch of contemporary material offered by Francois Lietard of *Mi-*

nerive (Au Bois, Roisey, 42410 Pélussin, France). Much of this was a Pakistan plethora: e.g. from the Gilgit region, gem-quality sherry topaz in blocky forms to 6 cm on matrix, and doubly terminated gem elbaite with good watermelon banding, a topnotch thumbnail of which could be had for about $60. There were also small rubies, large schorls, brilliant epidotes to 8 cm long, and, with a label that said only "Pakistan," very sharp glassy floaters of *red*-brown (mostly red) zircon in prisms + bipyramids to 5 cm long, average price about $30. And from Hanuchal (see vol. 18, no. 5, p. 368), there were ten spectacular green twinned titanites, the best one 4 cm long and selling for $500. At the same stand, it was fun to spot six thumbnails and small miniatures of Red Cloud mine, Arizona, wulfenite, red-orange and gaudy, like neon from home, among all the pale Pakistani pastels. In 1985 (vol. 16, no. 6) Wendell Wilson reported on new pocket finds at the Red Cloud, yielding somewhat over 300 small specimens. Aware of the charisma of this particular mineral occurrence, I was relieved to see prices here in Alsace keeping to a moderate enough range of $65 for a fine thumbnail to $250 for a 6-cm matrix group.

A few things stood out spectacularly at the stand of Lino Caserini (Via Dal Pozzo Toscanelli n 5/1, 20132 Milano, Italy). Five specimens of the new anatase from Lavrinha, Minas Gerais, Brazil, of which I had only read before, featured sleek blue-black bipyramids to 2.5 cm long on brown quartz crystal matrixes; a 3.5 x 3.5-cm matrix with 2+ cm anatase crystals sold for $220. There were also good, tightly packed scheelite crystals on matrix from the East Camp Bird mine, Ouray, Colorado, and, more familiar to me, eight large matrix pieces (to 15 cm across) of granite from Ziggenstock, Grimsel, Switzerland, on which huddled—you guessed it—pink fluorite octahedra in tight groups, some of the crystals very deeply colored, these at $350-$500 for medium-sized cabinet specimens.

At the rear of the interior of the Opera House is a raised platform area, also jammed with dealers during the show; being somewhat out-of-the-way-looking and thus especially enticing, it is fun to check out. In one corner, at the stand of the Belgian dealer Francis Coune (Rue de Laveu 166, 4000 Liége), was a great number of colorful uranium species from the Shaba mining region of Zaire. The chemistry of these minerals, and even their Rube Goldberg names, I've always found rather intimidating, and the crystals are always micro-sized where they lie in their open seams, but the colors of course are gorgeous: here in hot-orange, yellow and green were studtite, cuprosklodowskite, metatorbernite, vesigneite, soddyite, kasolite, and a new (1986) mineral, *kipushite*, from (naturally) Kipushi, Zaire, in tufts of dark blue microcrystals in vugs in earthy limonite. From the Mashamba mine, some specimens with thin chrysocolla streakings in a hard gray rock matrix showed cuprite crystals to 1 cm on edge, many bashed, but one piece with fine octahedra in a group 7 cm across; these are not, I'm assured, the same as the Mupine mine cuprites I reported on from Munich, but they do look similar, and both localities are clearly capable of producing champion cuprite aesthetics. [*Ed. note:* a prophetic remark, written just before the big load of great Mashamba cuprites hit the market in September at the Denver Show!]

And something new from the Mashamba mine, first found two years ago: sprinkled glitteringly along shallow open seams in that same gray rock (a copper-impregnated quartzite?), many brilliant little (1 mm or so) metallic dodecahedra of carrollite, along with distorted, iridescent cubes of bornite of about the same size. The crystals of the metallic minerals are quite impressively sharp under slight magnification; a good micromounter could produce excellent specimens if he could surmount the trimming problems that such hard matrix poses. Finally, enormous conversation-piece botryoidal malachites, drusy bright pink crusts of cobaltian calcite, and blue acicular radiating plancheites in aggregates to several centimeters, complete the Zaire bazaar.

My special apologies now to Jean-Benoit Denarié, for *not* decorating this Note, as I'd planned, with a photo of the specimen he was packing around at the show: the best one I've yet seen of the new orange barites from the Pöhla mine in the East German Erzgebirge. My friend Gary must have shot two-thirds of a roll on that specimen, but technical malfunctions mean that M. Denarié will *not* have, after all, the admiring/envious psychic vibrations of thousands of collectors to cope with, coming in on him along the crystal wavelengths all through the night. Maybe eventually I'll be able to get more of a photographic act together.

The 1989 Sainte-Marie-aux-Mines Show is scheduled for July 7–9. For more information contact Michel Schwab, 32 rue de Baldersheim, 68110 Illzach, France.

The Nürnberg Show 1988

Readers who dote (if such a thing can be imagined) on this column's every casual remark, will recall that two years ago I almost attended my first Nürnberg show, but at the last moment a defective something-or-other in my aged Mitsubishi prevented the trip. Well, this September, since Mitzi (as she likes to be called) is in general no less defective than ever, I rented a car, and thus *did* make it, with my wife and a covey of friends, for a most pleasant weekend in the second largest and most historical of Bavaria's old brown cities. The still largely intact medieval wall of Nürnberg encloses one of the finest Old Towns in Europe, within which, for example, are the spacious square where Germany's greatest Christmas bazaar, the *Christkindlmarkt,* is held; the restored 15th-century house of Albrecht Dürer; quiet, dark, swan-bedecked old canals; and long shrugging rows of ancient house-fronts along hilly streets. Just beyond the wall, squatting along a ridge overlooking the Old Town, is a huge Castle complex with ruins of all ages scumbling together—10th-century watchtowers guarding Renaissance courtyards, gap-toothed stone walls form which fine city views may be seen, and stone stairsteps that climb over a cross-section of many fossilized strata of elite Nürnbergers' wealth, paranoia and pride.

None of the friends who were with me, indeed not even my wife, chose to accompany me to the mineral show—seeming somehow to think that this would have amounted to "humoring" me. So, at the site, the Hotel Tiergarten ("animal garden"), I went my way, into the large squarish room uncomfortably overfilled with dealers' stands (though a balcony helpfully added an encircling upper level), and *they* went next door to explore the Nürnberg zoo, Germany's largest. Adjoining the show chamber was the hotel's buffet-restaurant, so that one could step past the last straggling dealer stand in the lobby, and into a line for a quick bad food fix, then outside (the weather being fine) into a drowsy, prosaic domain of picnic tables, small lawns, flower beds, and a decomposing asphalt track for a battery-powered toy-car ride for kids. But saving exotica came in the form of occasional glimpses through the shrubbery along a wire fence at the zoo's boundary, of hallucinatory blue plumage-flashes from strolling peacocks.

For the Nürnberg show this was a landmark year, since it is now under new management: U. & R. Buchner of *Kristallkeller Nürnberg* (Hefnersplatz 8, D-8500 Nürnberg), whom I have mentioned before as the first-class specimen dealers they are. The Buchners were determined to reduce the show's size while elevating its concept: no lapidary merchants below a certain horizon of taste allowed, and good mineral dealers to be encouraged. In short, this was an attempt to, as one dealer put it, "stop the flea market approach." Many regular show dealers of dubious *Schmuck* (the German term for lapidary items) are reportedly angry at the change; but the serious mineral people who should be pleased *are* pleased, and the show's total attendance of 1700 people over two days certainly suggests that opting for quality over quantity does not necessarily mean opting for martyred commercial extinction. The Buchners are to be wished every success at holding the line, in their corner of the Earth Science lobbyist's world, against the locust-swarm pushers of both lapidary and mineral specimen *Dreck*.

Besides, they were thoughtful enough to grace this show with a couple of mineral-oriented special features—one of which was a display of their very own fluorite collection, the result of 15 years of collecting effort, and soon to be sold. The quality of the fluorites varied, of course, but dominating the cases was a good number of those enormous knock-your-block-off specimens that Europeans so love: dramatic two-foot groups of (mostly) cubes of all colors from, oh, Cumberland, Cave-in-Rock, Elmwood, Fort Wayne, Ribadisella, etc. I enjoyed guessing localities before checking the labels and was fooled on several, including a group of yellow-brown cubes from Ehrenfriedersdorf in the Erzgebirge, a rich orange and very shiny cluster from Wölsendorf in Bavaria, and a Swiss-like pink octahedron from Mont Blanc, France.

The Buchners also revived at Nürnberg a show tradition lately abandoned at Munich: a special display of "competitive" pieces put in by dealers for judging (and, discreetly, for selling). The token cash prizes awarded to the three winning specimens were collectively called the *Betty Dannapfel Preis*, after an enthusiastic Nürnberg collector who died last year. The judges were from the VFMG, which is to say (for who can resist these German organizational names?) the *Vereinigung der Freunde der Mineralogie und Geologie*, Nürnberg. My favorites among the gorgeous specimens here displayed tended to be conventional things, e.g. a gemmy 10 x 10-cm Hotazel rhodochrosite and a Prince of Wales Island, Alaska, epidote group 40 cm across with a single brilliant blocky twinned crystal 10 cm on edge. However, the judges went for oddity, awarding first prize to Hans Maurer for his huge matrix specimen showing 2-cm emerald-green fluorite octahedra from the Jucken quarry, Fischbachtal, near Idar-Oberstein; second prize to Rudi Geibel for an immense yellow fluorite from Sicily; third prize to Helmut Brückner for his 30-cm single terminated stibnite prism covered with sharp gemmy calcite rhombs, from the Kuangshan mine, Hunan, China. I should note parenthetically that the green fluorite octahedra have only lately been coming out; they occur at isolated collecting sites here and there in the traprocks of the central Pfalz, until now noted chiefly for calcite and goethite geodes, oldtime Idar-Obersteiner agate concretions, and an occasional spectacular harmotome or phillipsite. The new green fluorites, however, are marvelously vivid, very attractive and unusual, and *deserve* wider fame—I'll try to learn more about them, and keep you posted.

One couldn't say that much really exciting *new* material was around at the show—but trust Helmut Brückner (Bugginerstr. 19, 7840 D-Müllheim-Britzingen) to have, if anyone does, a contemporary peculiarity or two. At Nürnberg he was offering two specimens (out of a total of twelve collected) of orange creedite, found within the year at Mina Navidad, Rodeo, Durango, Mexico. The pieces are pale peach-orange, very sparkly aggregates of spherical crystal sprays with individual well-terminated creedites to 2 mm. At 5 x 7 cm and 4 x 4 cm, $275 and $140 respectively, these were interesting and not *too* pricey examples of creedite in a manifestation entirely different from the groups of pale purple blades from Mexico (or, as seen on the recent *Mineralogical Record* cover, Kazakhstan). Brückner had also his usual discriminating offering of one-of-a-kinders of old and new classics—from Ilfeld manganite and Ems pyromorphite to Peruvian chalcopyrite and rhodochrosite—in exquisite specimens, in what was probably the most dazzling dealer stand at the show, save possibly the Buchners' next door to it.

R. Meyer (Lärchenweg 9, D-5603 Wülfrath) had large, spectacular Pakistan schorls in matrix; a few of the "new" and chemically controversial dyscrasites to almost 20 cm across (that one for $2400); Victoria, Australia, gold nuggets; giant green Indian apophyllites and a loose (bashed) 3-cm orange powellite; and even, for a reasonable $175, a 10-cm matrix of Franklin calcite with several very sharp franklinite octahedra to 2.5 cm on edge—it's extremely rare in Europe, I must say, to see anything this good from any of the old classic eastern U.S. localities.

Similarly impressive was the stand of Siegbert Zeche (Windecker Pfad 1, D-6369 Schöneck 2), with another mixture of old and new. Fine thumbnails of edingtonite from the recently developed locality in British Columbia competed for my attention with a nearby razor-sharp cluster of hexagonal plates of galena pseudomorphous after pyromorphite from the old Kautenbach mine near Bernkastel-Kues, Rhineland—this one about 4 x 7 cm for $300. Here also were very respectable matrix miniatures of microcrystallized, ferny gray dyscrasite from Wenzel in the Schwarzwald (Black Forest); good English yellow barite and green fluorite; four good miniatures of Mexican creedite of the purple kind; a few American miners' carbide lamps; and, accompanying everything, Zech's trademark flamboyant labels with beautiful hand-inked Gothic script.

A third German dealership which put on an excellent show this time was a new partnership: Robert Jakob (a Munich dealer I've visited many times) and Markus Klein; the address of their headquarters is very near Munich's famed Hofbräuhaus, a tantalizingly yeasty Brauhausstr. 10, D-8900 München. Here I admired a 3-cm Cornwall cassiterite pseudomorph after orthoclase for $190; a few small but beautiful, *iridescent* pyrargyrite/stephanite groups from the Pöhla mine in the Erzgebirge, better known for its orange barite; and many interesting oldies from the old collections Herr Jakob has always liked to buy up—Ehrenfriedersdorf purple apatite, nagyagite from Nagyag, Cornwall native copper, and numerous others, mostly miniature and small cabinet size.

Out in the lobby a dealer new to me, Marco Schreier (Rosengartenstr. 1, D-7250 Leonberg 7), had a few fine, recently collected "iron rose" hematite thumbnails, the shapely roses nestled or semi-impaled on transparent quartz prisms; most were somewhat damaged but the luster on all was bright, and the prices right—only $30-$40. Herr Schreier also had three enormous Mexican anhydrites (these are getting almost common now), with subparallel pale blue blades edged with drusy quartz, great spectacular beasts for $140, $200 and $800.

Finally, another update on finds at the famous St. Anne's blue topaz mine near Miami, Zimbabwe (see Peter Bancroft's description in chapter 67 of his *Gem and Crystal Treasures*). I have reported before on things that the mine's present owner, Rüdiger Hesse (Beethovenstr. 41, D-7921 Heidenheim) is getting in return for his energetic collecting trips there at least twice a year. This time it was more and better blue topazes than before (though still nothing like the one pictured in Bancroft). These are loose singles of good form and fair color to 2 cm and $35. More very dark green elbaite prisms were available, some reasonably good blue euclase, and even a handful of small, odd-looking, semitransparent, medium-brown floaters of chrysoberyl (somewhat generously designated "cat's eye") which may amount to a harbinger of dramatic things to come. But I was most taken by Hesse's spread of—I know this will sound mundane—orthoclase crystal groups from St. Anne's. They are off-white to very pale pink, with jumbled blocky crystals, mostly untwinned, from thumbnail size to one 5 x 5-cm cluster, very handsome somehow, and very likable. On many of the groups, black tourmaline needles mat surfaces or plunge into, as if to try to impale, the impassive-looking white orthoclase. And on the real elite among the groups (and with prices to match) tiny gemmy blue topaz crystals are sported like an evening's dress-up jewelry; of these topaz-bearing specimens a 2.5-cm thumbnail with a bright 3-mm topaz perched fetchingly on a prism face went (yes, to me) for $28.

So another show, my first in Nürnberg, is as they say history, and so is the U.S. election, and the post-electoral U.S. dollar is sinking anew against the Deutschmark, and that, I suppose, is History too. Perhaps, come to think of it, I'll get a better rate of exchange against the Belgian franc if I go, also for the first time, to the show in Liége this coming Thanksgiving weekend.

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Book Reviews

EN VISITANT
LES GRANDES COLLECTIONS
MINERALOGIQUES MONDIALES

Claude GUILLEMIN
Jean MANTIENNE

En Visitant les Grandes Collections Mineralogiques Mondiales

"On visiting the Great Mineralogical Collections of the World," by Claude Guillemin and Jean Mantienne. Published (1988) by Editions du B.R.G.M., Avenue de Concyr, 45060 Orleans Cedex 2, France; softcover, 21 x 29.5 cm, 248 p.; Price: 100 French Francs (about $16), excluding shipping.

Although titled in French, this book presents no problem to English-speaking readers; it has a duplicate Foreword in English, and the rest of the text is a lengthy list of specimens, their sizes and localities which are easily intelligible.

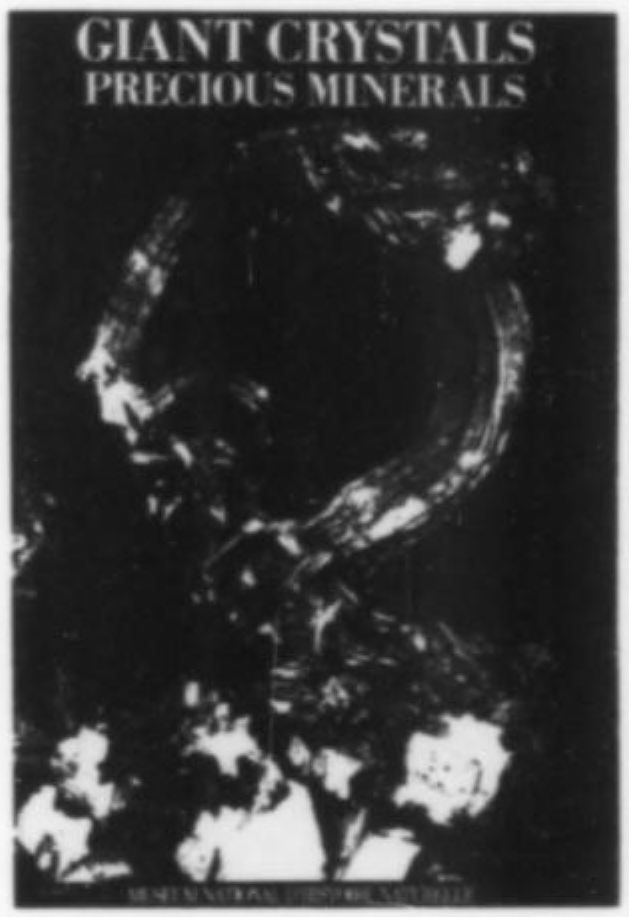
Prof. Claude Guillemin is the long-time Keeper of Minerals at the Museum of Mineralogy, National School of Mines, Paris. For 35 years he has traveled the world, studying the great mineral collections in detail and making notes on the best specimens. He published some of these notes in 1964 and 1972; this 1988 work of the same title incorporates those earlier notes and completes the survey. As the author states in his Foreword, "It is neither a catalog nor a guide in the true sense, since personal opinion plays a large part. These are rather notes for visitors, intended to draw the attention of amateurs and professionals to the best samples in the collections we have had occasion to visit . . ."

The author admits to some unavoidable weaknesses: the large number of (generally lesser) collections not reported on, personal ideosyncrasies of taste and judgment, the lack of simultaneity in the observations, and the lack of up-to-date data on those collections not recently visited. The reader can forgive all these in exchange for the opportunity to share the personal impressions of one of the world's leading mineral curators.

A much greater shortcoming in the eyes of most readers will be the illustrations, which are nothing more than simplified pencil sketches. In this day of the magnificently photographed and printed full-color "coffee-table" book, a book about beautiful minerals illustrated by mere sketches seems like a throw-back to the seventeenth century. It is useful if one has already seen the specimens in person and wishes only to stimulate recall. It is useful when visiting the museums and attempting to search out and see the best pieces. But it is rather less useful to the reader who has had no opportunity to visit the great museums. Even in that case, however, it does give some potentially useful data on which localities have produced great specimens, and the size of crystals they yielded.

Some short lists of best specimens in five of the top ten institutions discussed by Guillemin and Mantienne are also given in Burchard and Bode's *Mineral Museums of [Western] Europe*. But Guillemin and Mantienne's listings are much longer, more comprehensive and more authoritative. This is a notable reference work for the serious collector and, at $16, a bargain. Extensive use of color photography might well have put it into the $75–100 range. So one can hardly complain too loudly about that omission; the book deserves to be judged on its own terms, and on those terms it is a truly unique, desirable and affordable work.

W. E. W.



GIANT CRYSTALS
PRECIOUS MINERALS

Giant Crystals, Precious Minerals

by Henri-Jean Schubnel. Published (1987) by Hachette for the Museum National d'Histoire Naturelle de Paris; hardcover, 20 x 28.5 cm, 64 pages; price: about $20.

Here is a book that the lover of mineral museums will find irresistible. The author, long-time Curator of Minerals at the famous Natural History Museum in Paris, writes eloquently (in this English edition) about that great collection, its history, its remarkable contents, and mineral collecting in general. Thirty-four excellent color photos are included.

Schubnel considers that there are eleven great mineral collections in the world: Freiberg, Harvard, Leningrad, London, Moscow, New York, Paris (the School of Mines museum and the Natural History Museum), Prague, Vienna and Washington. This is, incidentally, identical to the list of Guillemin and Mantienne (see previous review) but for the addition of Leningrad. Short descriptions of all of these except the two American museums can be found either in Burchard's *Mineral Museums of [Western] Europe* (1986), or Bancroft's *Mineral Museums of Eastern Europe* (*Mineralogical Record*, vol. 19, no. 1). Only one of these great museums dates back as far as the 1600's: that housed in the Natural History Museum in Paris.

It began as a section of King Louis XIII's pharmacy, where minerals were stored along with medicinal plants and synthetic medicinal compounds. The oldest specimen label is dated 1628. The Royal Pharmacy was reorganized into the Cabinet of Natural History in 1715, based on the organization of contemporary Italian collections. The first methodical classification of the collection was prepared by Bernard de Jussieu in 1722, and the collection was opened to the public in 1745. It was thus the first museum in Paris, opened five years before the Louvre.

Schubnel relates the museum's long and distinguished history in detail, giving many short but fascinating descriptions and discussions of the famous mineral collections it assimilated over time, including those of Balthazar-Georges Sage (1740–1824), Romé de l'Isle (1736–1790), R. J. Haüy (1743–1822), Gillet de Laumont (1751–1834), Count de Bournon (1751–1825), Alexandre Brongniart (1770–1847) and many others. The history of the collection, to a great extent, reflects the early history of French mineralogy.

A chapter is devoted to short discussions of some famous occurrences represented by world-class specimens in the museum. And a chapter is also devoted to the Deleff collection of giant crystals from Brazil, including several pages of interesting reading on how this collection was assembled. Finally, there are several historical appendices regarding what are considered to be early type and cotype specimens in the collection, followed by a short bibliography.

Many books on mineralogy are fine references to be called on when needed for data. Others are primarily collections of beautiful mineral photography. Schubnel's book, in addition to being beautifully illustrated, is simply fun to read, and is priced very inexpensively. I recommend it to all mineral collectors and mineral historians.

W. E. W.

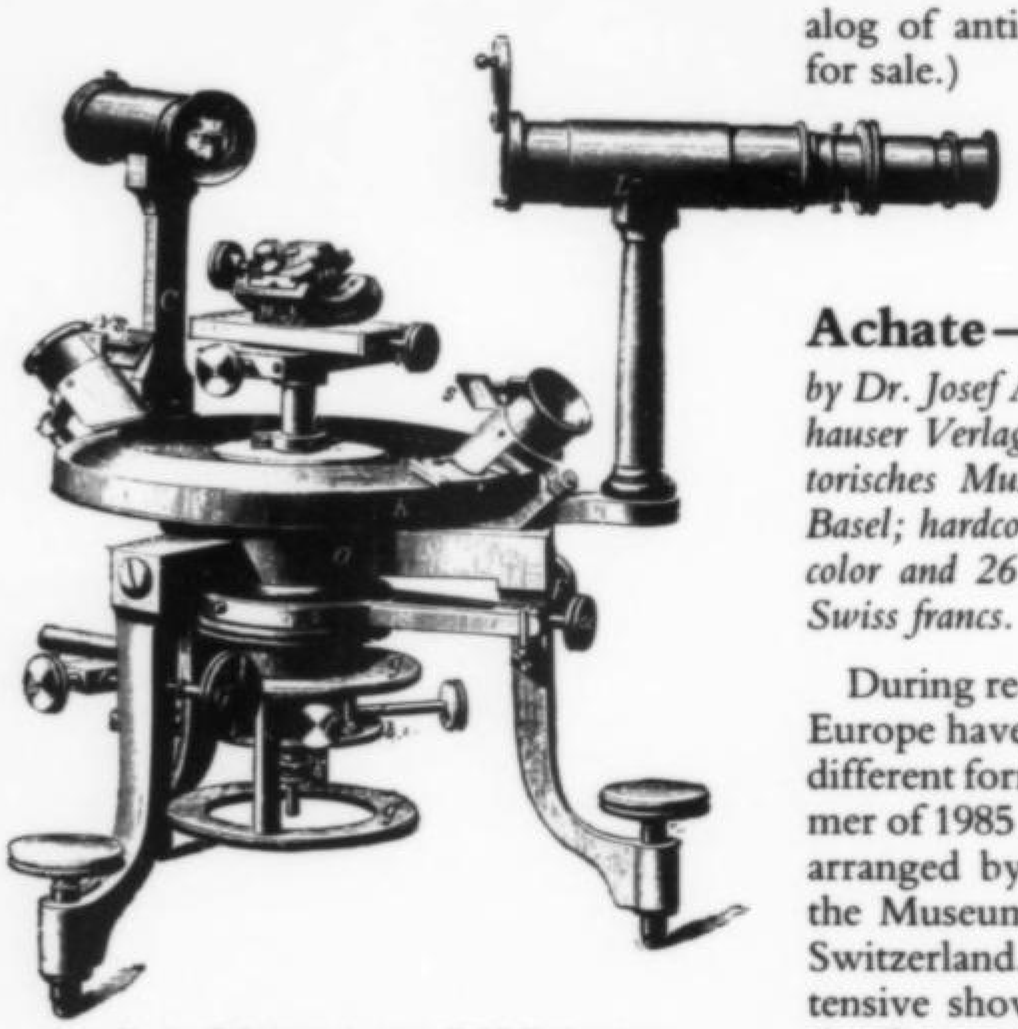


Fig. 59. Reflexionsgoniometer. Modell IIa ($^1/_4$ nat. Gr.).

Die Optischen Instrumente der Firma R. Fuess

by C. Leiss. Facsimile reprint (1988) by The Gemmary, P.O. Box 816, Redondo Beach, CA 90277; hardcover, 14 x 22 cm, 403 p., $57 postpaid.

Good references for the collector of optical goniometers are virtually non-existent. This is particularly frustrating when trying to figure out how a particular model was originally intended to work. Now, Rick Blankenhorn of *the Gemmary* (a dealer in rare mineralogical books and antique mineralogical instruments) has reprinted a work, first published in 1899, which was so rare that it was essentially unknown until Rick came across a copy by accident. It is a textbook-style catalog of one of the nineteenth century's principal instrument makers, the firm of R. Fuess, Steglitz and Berlin.

Included in this catalog are over 230 extremely detailed woodcuts depicting various scientific instruments made by the firm, including nine spectrometers, three reflectometers, two refractometers, two quartz spectrographs, a vacuum spectrograph, four contact goniometers, and 14 optical goniometers, not to mention two polarimeters, eight mineralogical microscopes, several lantern-slide projectors and a camera for use through the microscope. Each is accompanied by highly detailed descriptions and instructions (in German) aided by cut-away diagrams and detailed illustrations of the critical components.

The reproduction quality is so perfect that it's difficult to believe the book is a facsimile reprint; the finest detail in the engravings is faithfully preserved. The hardcover binding is an attractive dark blue cloth with gold stamping—a first rate job. The press run is only 250 copies.

Anyone who collects antique mineralogical instruments must have this book.

(While making out your order, better include $5 for Blankenhorn's just-issued catalog of antique mineralogical instruments for sale.)

W. E. W.

Achate—Bilder im Stein

by Dr. Josef Arnoth (1986). Published by Birkhauser Verlag, Basle; available from Naturhistorisches Museum Basel, Postfach, CH-4001 Basel; hardcover, 23 x 29 cm, 103 pages, 100 color and 26 black-and-white illustrations, 54 Swiss francs.

During recent years several exhibitions in Europe have been dedicated to agates, their different forms and occurrences. In the summer of 1985 a large exhibition of agates was arranged by Dr. Josef Arnoth, curator of the Museum of Natural History in Basle, Switzerland. As a selection from this extensive show, Arnoth has pictured 100 of the finest specimens in a superb full-color book entitled *Achate—Bilder im Stein* ("Agates—Pictures in Stone").

There are many fine picture books these days dealing with the mineral world as a whole, with certain localities or with groups of minerals; here is one which is dedicated to one species, even to one variety only, but a variety which shows a wide range of different types and habits. Though dealing only with agates, the book nevertheless supplies much mineralogical knowledge in a clear and impressive manner.

Types of Agates

Agate is defined here as a chalcedony with pictorial design. Arnoth gives a system of more than 20 types of agates based on the patterns they show. According to this system one may define all kinds of agates and understand their genesis. Agates characterized by bands of different color and transparency constitute the first groups in Arnoth's agate iconography. These include banded agates, layered agates and eye agates. Remarkably multiform structures originate from different intergrown phases within the matrix of the agate and form such types as moss agate, dendritic agate and landscape agate. Paragenesis with other varieties or species of quartz and calcite creates types such as fortification agate and moon agate. Other types correspond to different kinds of genesis: chalcedony is known to fill all kinds of vugs and cavities within rock, causing polygonal agates and the filled concretions called "thundereggs," while crazy lace agates or membrane agates show breccia structures. Even the way of cutting the geodes may produce quite different impressions and designs. The book describes all the different types in detail and excellently demonstrates their genesis and fascinating beauty.

Names of Agates

The almost endless variety of impressions can only be classified, defined and described by first forming adequate concepts and terms. There are groups of agates characterized directly by the term used, such as banded and layered agate; other names come from the viewer's imagination, e.g. landscape agate and fortification agate. As agate is characterized by its pictorial design, metaphorical names are especially appropriate. The typology of agates demonstrates the need for numerous trivial names in order to distinguish the more delicate features of any particular habit. Nevertheless not all of those popular names have been chosen appropriately. "Sagemite" agate, for example, is a misleading term if used for each kind of latticed inclusions, and "glass-agate" is an old misleading name for obsidian. After such great efforts have been expended to precisely define mineral species names, any new confusion of names should be avoided, even among lapidary-oriented varietal terms.

The Photographs

The 100 color prints in this book, all photographs by Marcel Treboux, are of exceptional quality. They show agates of outstanding beauty, surprising pictorial character and high significance. The samples come from locations all over the world, many of them from the U.S. The photographs excellently illustrate the different agate types described, proceeding from the simpler to the more complex kinds. The figure captions give short comments on structure and genesis of the agates. By these comments the process of growth, the petrified history of the rock, becomes evident. The black and white photos and the drawings within the text show the same intense effort at elucidation, as, for example, where the typical runs of banded agates are illustrated by the different possible cuts through the layers of an onion.

The figure captions mostly suggest the impressions caused by the agate structures within our imagination: plants, architectures, flames and fountains, land and ocean beneath stars and clouds. In this way Arnoth attempts to initiate the aesthetic experience of the patterns in rock, counterbalancing the merely scientific view, which is often the only one to be accepted. Very often appearing in the pictures, but being ignored in the text of other books, the aesthetic dimension of the mineral world is indeed the main topic of Arnoth's book. He works to create a complete experience of the mineral, "with eyes, mind and heart." For this same purpose we even find some poems and prose texts, dedicated to different rocks, which shall lead to an artistic experience complementing the scientific knowledge. This is an unusual picture book which combines the scientific, aesthetic and philosophical view, a work of art in itself, a book for every open-minded individual but not for the narrow specialist.

Margot Dietrich

Microminerals

Bill Henderson

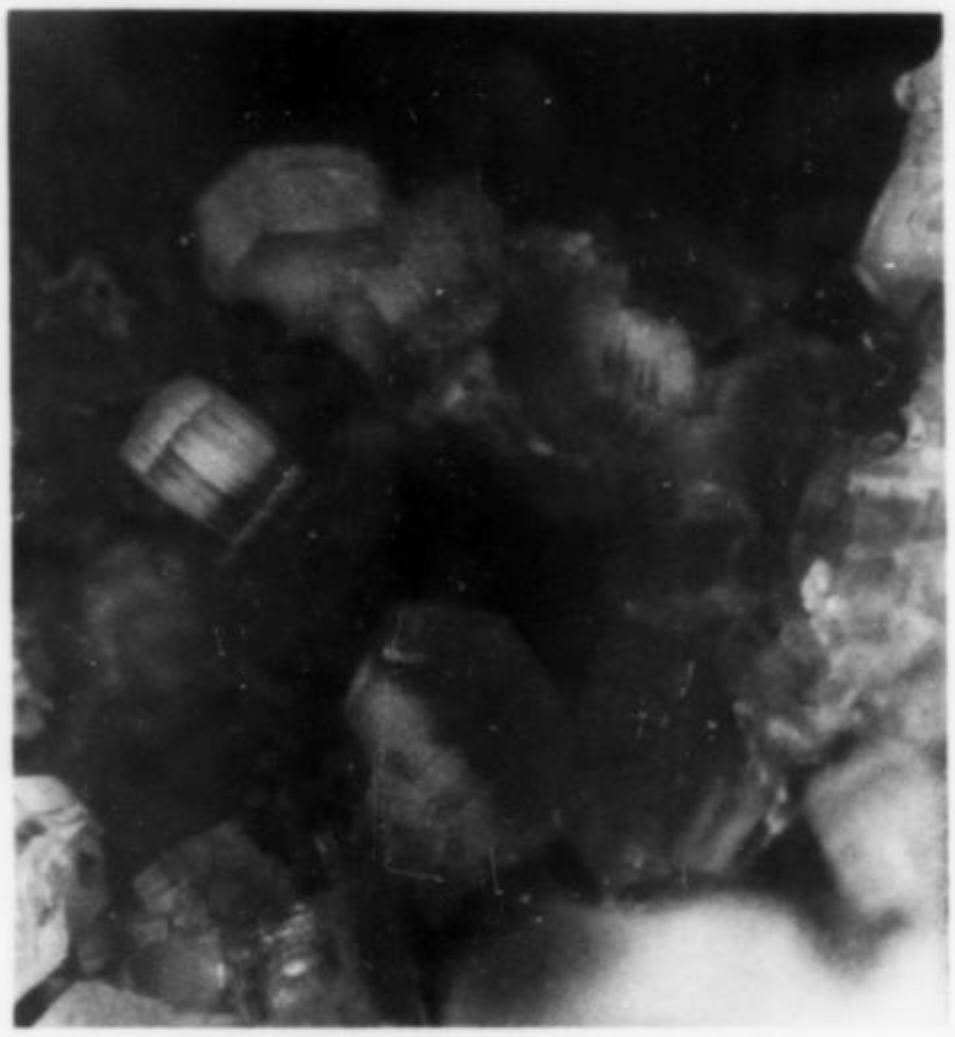


Figure 1. **Herschellite in transparent, colorless, 0.5-mm hexagonal crystals from Aci Castello, 8 km north of Catania, Sicily.**

Visits from fellow mineral collectors, whether they be old acquaintances or complete strangers, can be very enjoyable. Whereas meeting people at shows, symposia or club meetings is all right, in one's home there is ample time to talk about and look at specimens without distraction. I'd like to describe two such recent visits.

Renato Pagano (Via S. Anna 1B, I-54074 Monfalcone, Italy) and I have been writing and exchanging for many years. Hence, it was a real pleasure to hear that he and his wife, Adriana, would visit us not long ago. Italian collectors are amazingly active these days, and many fantastically rare or beautifully crystallized micro species are being found there. Consequently, we had lots to talk about and many fine things to admire. Among other gifts, Renato had excellent pale green, hexagonal plates of the rare mineral namuwite from the Trentini mine, Vicenza, Italy; boulangerite in and on very nicely crystallized calcite from Trepča, Jugoslavia; and superb anglesite and cerussite crystals from Monteponi, Iglesias, Sardinia. A couple of things he has sent in the past are shown in Figures 1–3. The first and second show superb herschellite from the type locality at Aci Castello, 8 km north of Catania, Sicily, at the foot of Mt. Etna. Renato wrote at the time that the mineral was collected from the cliffs on which the Castello (castle) was built and, in 1924, taken by Sir John Herschel to London, where it was studied by Wollaston and Levy. They named it for the famous astronomer. Perhaps the finest thing Renato has sent me is a specimen with some two dozen lemon-yellow crystals of the extremely rare mineral chernovite, associated with muscovite, dravite and adularia (Fig. 3). The chernovite, from Monte Cervandone, Val d'Ossola, Italy, was identified by Prof. Stefan Graeser. Just to name a few other species received from Renato, I mention cafarsite, apuanite, sodium dachiardite, microsommite and saneroite. Renato is a very discerning and painstaking collector/dealer, as well as being the *Mineralogical Record*'s subscription representative in Italy.

Two other recent house guests were Bob and Elsie Boggs from Seattle, Washington. We enjoyed a pleasant evening talking about and exchanging micros. Bob had for exchange tiny, orthorhombic crystals of georgechaoite from the type locality at Wind Mountain, Otero County, New Mexico; and very nice zektzerite, calciohilairite and beta-fergusonite, all from Washington Pass, Okanogan County, Washington. Also from Washington Pass are the very sharp crystals of arfvedsonite in equant and columnar habits shown in Figures 4 and

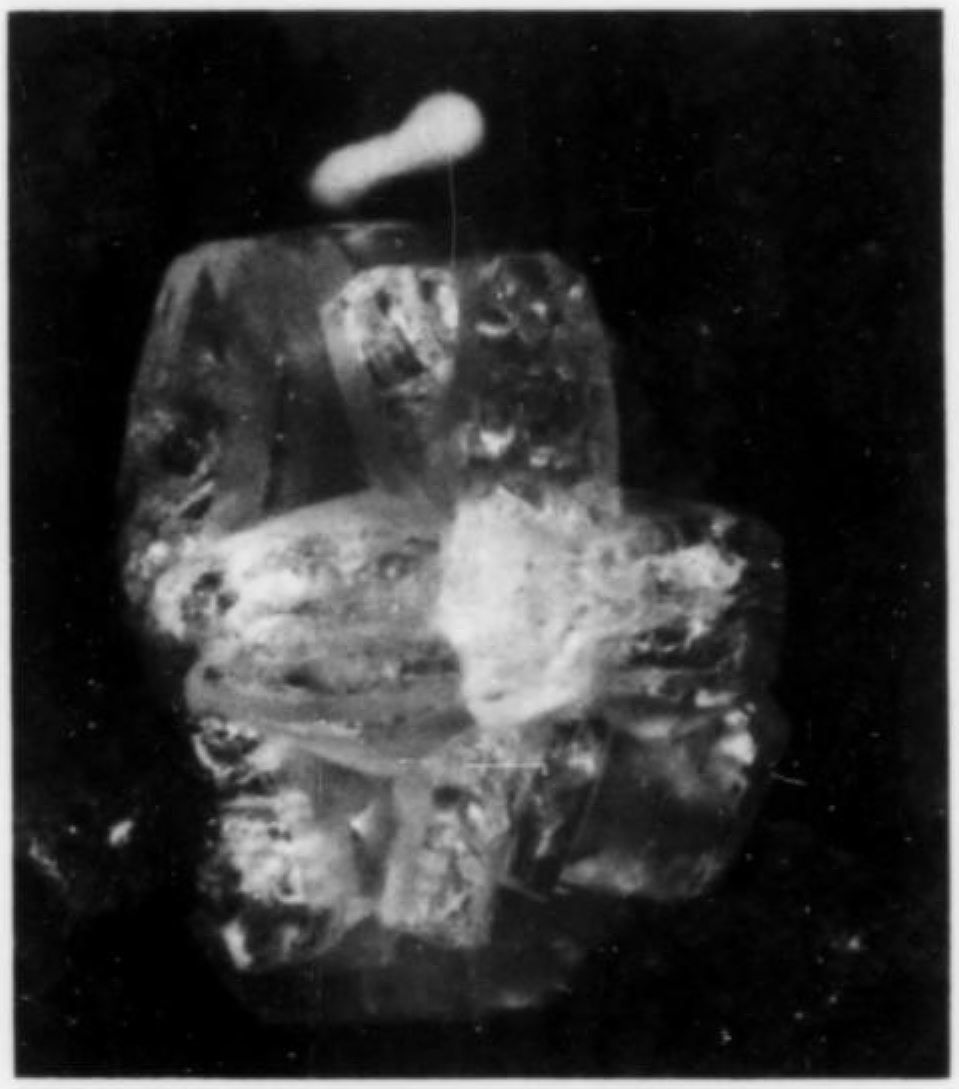


Figure 2. **A 1.5-mm group of translucent, colorless, tabular crystals of herschellite from Aci Castello.**

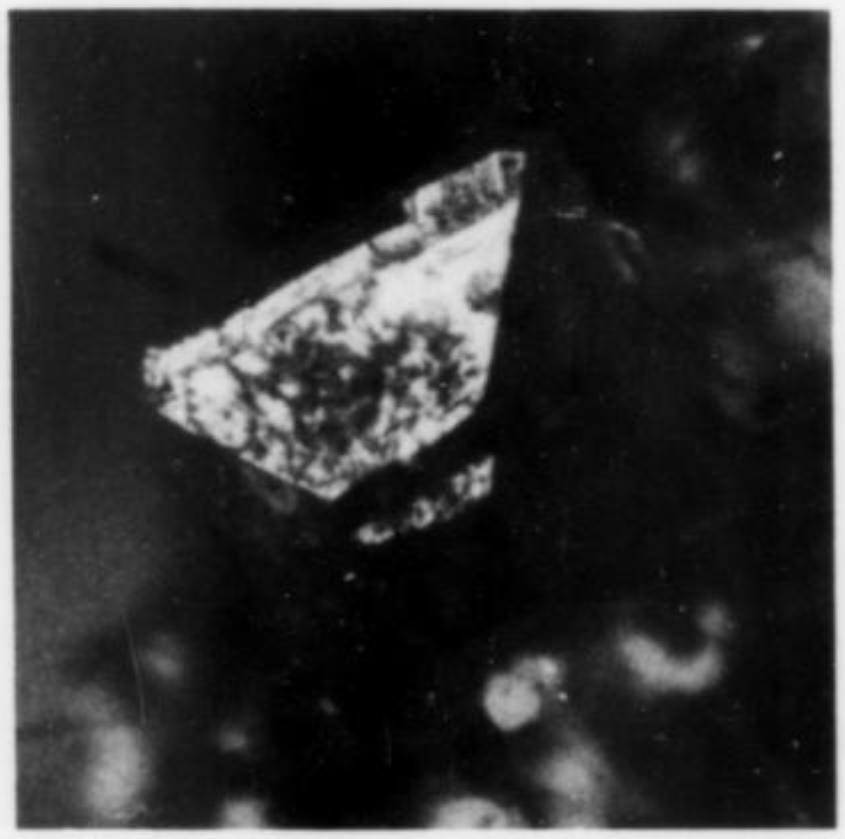


Figure 3. **A canary-yellow, tetragonal dipyramid of chernovite with dravite, "adularia" and muscovite from Monte Cervandone, Ossola, Italy; size, 0.4 mm.**

(continued overleaf)

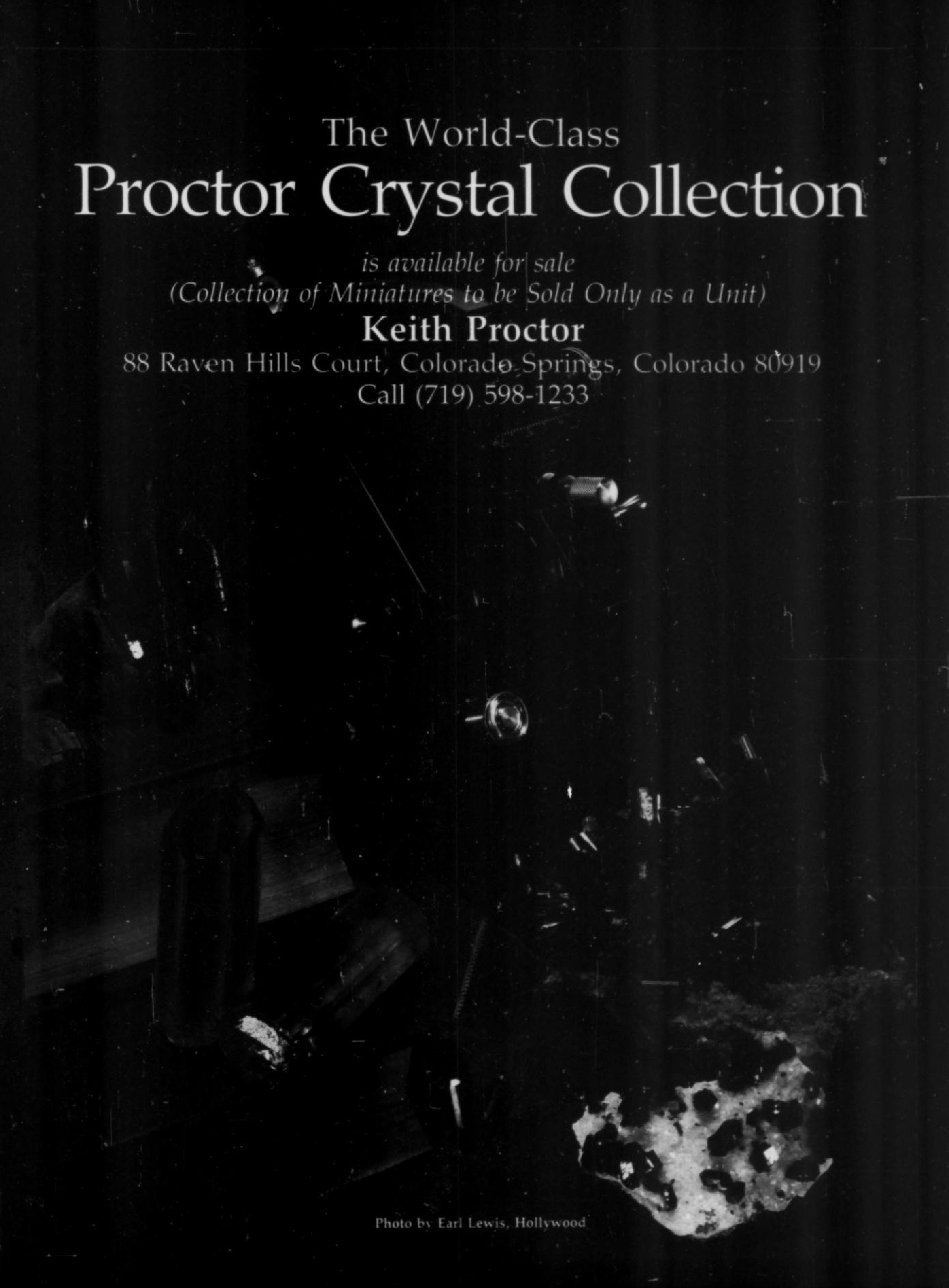


Photo by Earl Lewis, Hollywood

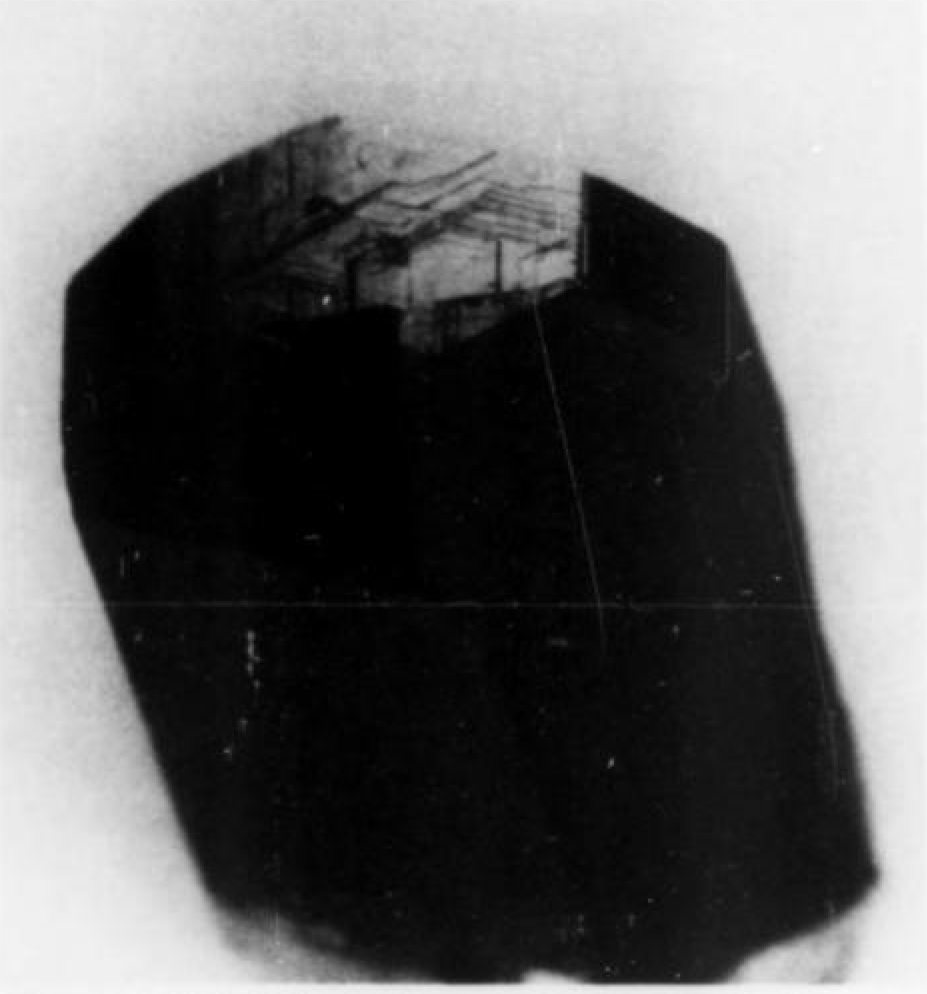


Figure 4. **A jet-black, 3-mm crystal of arfvedsonite from Washington Pass, Okanogan County, Washington.**

5. As if their mineral collecting were not enough, the Boggs are also superb bird photographers; several of their photos have been published.

Of course, some micromineral collectors, even though they live in a mineral collector's paradise, have few if any fellows to visit. A case in point is the South African Micromount Society. This hardy group, whose mainstay and founder is Horst Windish (another national representative of the *Record* and the publisher of the S.A.M.S. bulletin), meets bimonthly and holds annual workshops. Club membership is about 50, of which perhaps a quarter are overseas. Their bulletin is excellent, and contains many well written articles by members, chief of which are Hugh Heron and Andre de Ruijter. One of their most interesting activities is what they term Mass Swops. They exchange packages containing ten lots of ten different minerals (100 specimens in all) with clubs all over the world, each member contributing one or more lots of ten specimens each. This is a great way to swap minerals wholesale! I've swapped with several members of their club, and have never been disappointed. Those wishing to join their club or exchange should write to Horst Windisch (30 van Wouw Street, Groenkloof, Pretoria, South Africa, 0181). They run offers to exchange in their club bulletin.

Even though in my last column, I dwelt on some superb, currently available South African minerals, I can't resist doing so again. So many fine species in micro size are to be acquired that it would be easy to collect nothing else! In Figures 6 and 7 are shown extremely sharp and brilliant, black, monoclinic crystals which occur in close association with sturmanite at the N'Chwaning mine, Kuruman, Cape Province, South Africa. Although there have been some statements made that these crystals are marokite, current opinion is that they are manganite.* The prismatic and striated faces usually predominant in manganite are greatly suppressed.

In the November-December, 1987, issue of the *Mineralogical Record*, Wendell Wilson described in his "What's New in Minerals" column a find of thaumasite crystals, also at the N'Chwaning II mine. These transparent, colorless to pale lemon-yellow crystals, up to 2 cm and more in size, *have* to be the finest ever found. Usually, the species occurs in massive form or in acicular crystals, very rarely with a thickness such that the crystal form can be made out. As shown in Figure 8, the N'Chwaning mine crystals are thick columnar, and show beautifully their hexagonal symmetry. The terminal faces are often etched, and dipyramidal modifications are sometimes seen. Some of the crystals are doubly terminated, as is the smaller one in Figure 9.

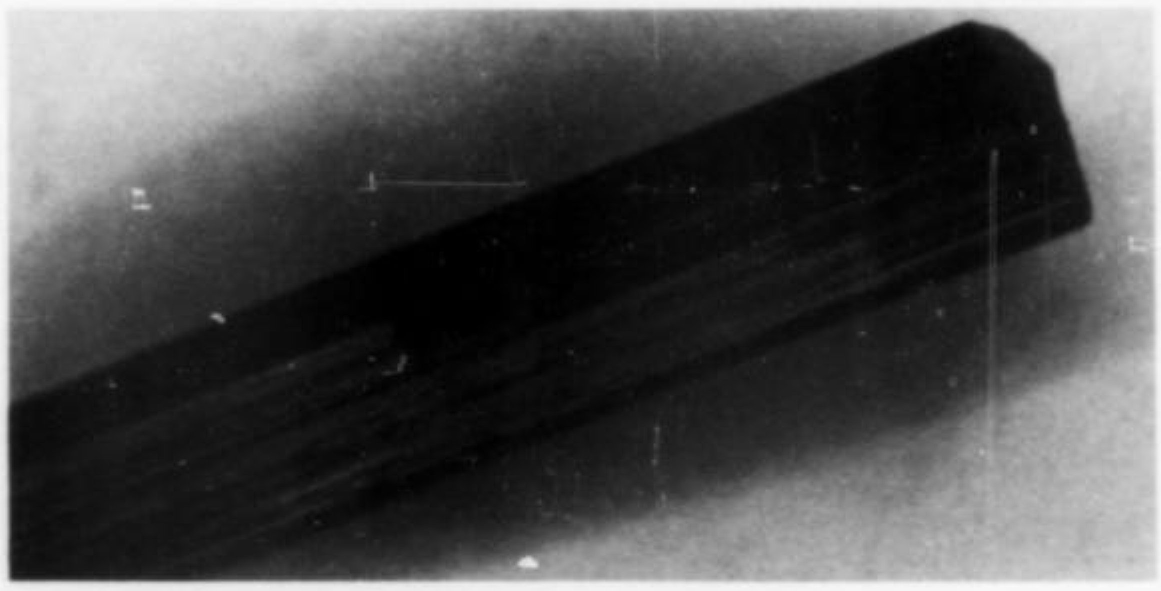


Figure 5. **Crystal of arfvedsonite, 1 cm long, from Washington Pass.**

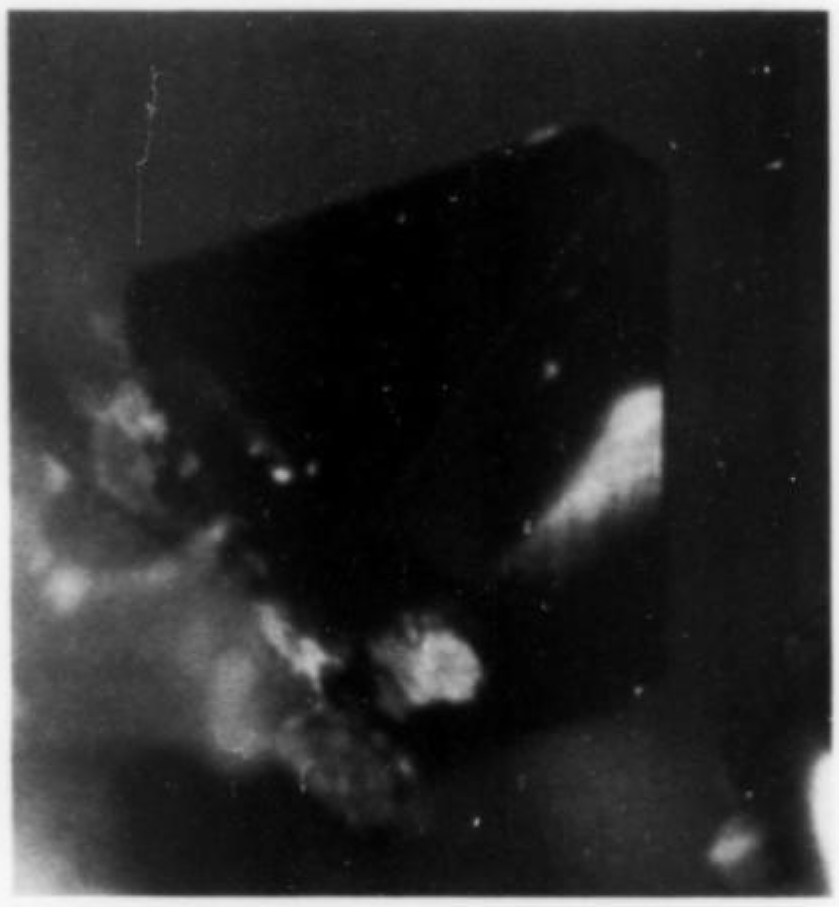


Figure 6. **Manganite, a jet-black, dypyramidal, 0.4-mm crystal associated with bright yellow sturmanite. From the N'Chwaning II mine, near Kuruman, Kalahari manganese district, Cape Province, South Africa.**

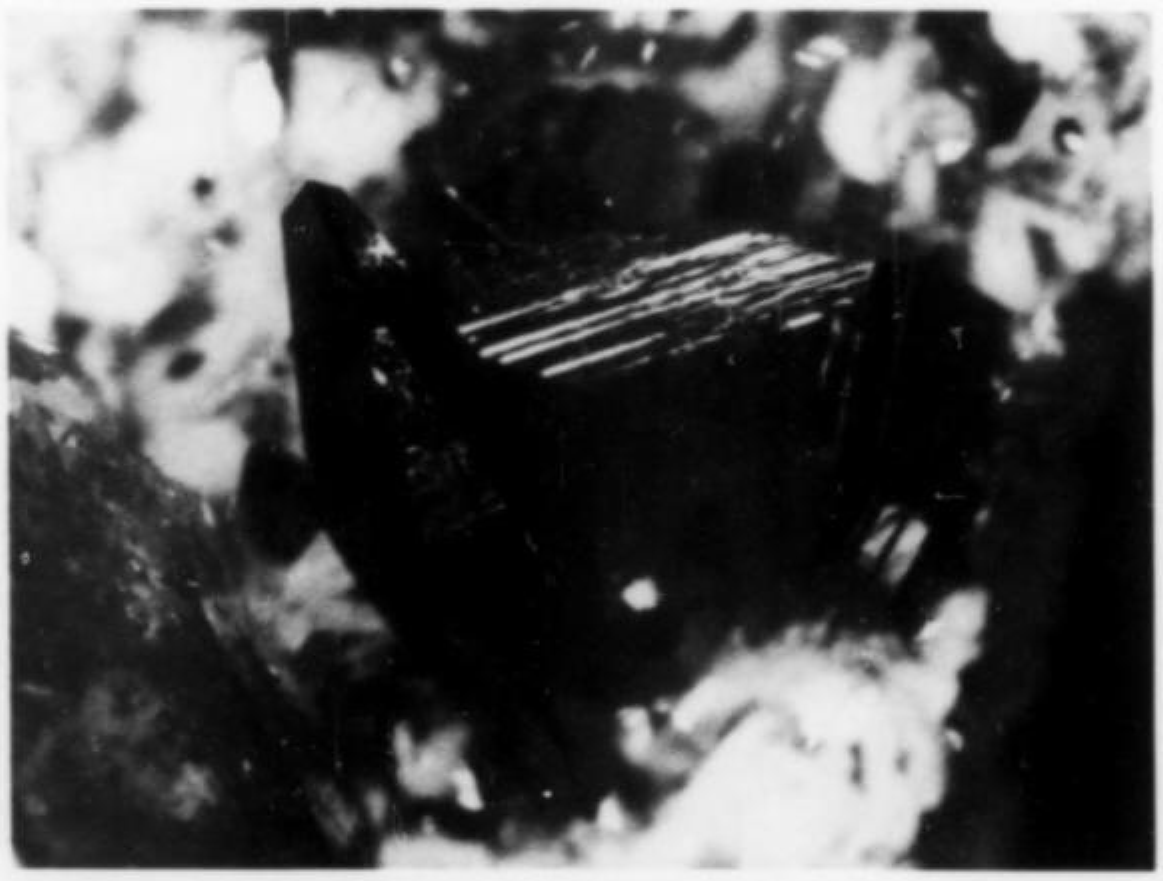


Figure 7. **A pair of 0.8-mm, black crystals of manganite with yellow sturmanite, from the N'Chwaning II mine, South Africa.**

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*Ed. Note: This has been independently verified by x-ray diffraction analysis.

Figure 8. **A transparent, colorless, hexagonal crystal of thaumasite, 1.1 cm long. The crystal shows complex striations or etch pits on the terminal and prism faces. From the N'Chwaning II mine, near Kuruman, South Africa.**

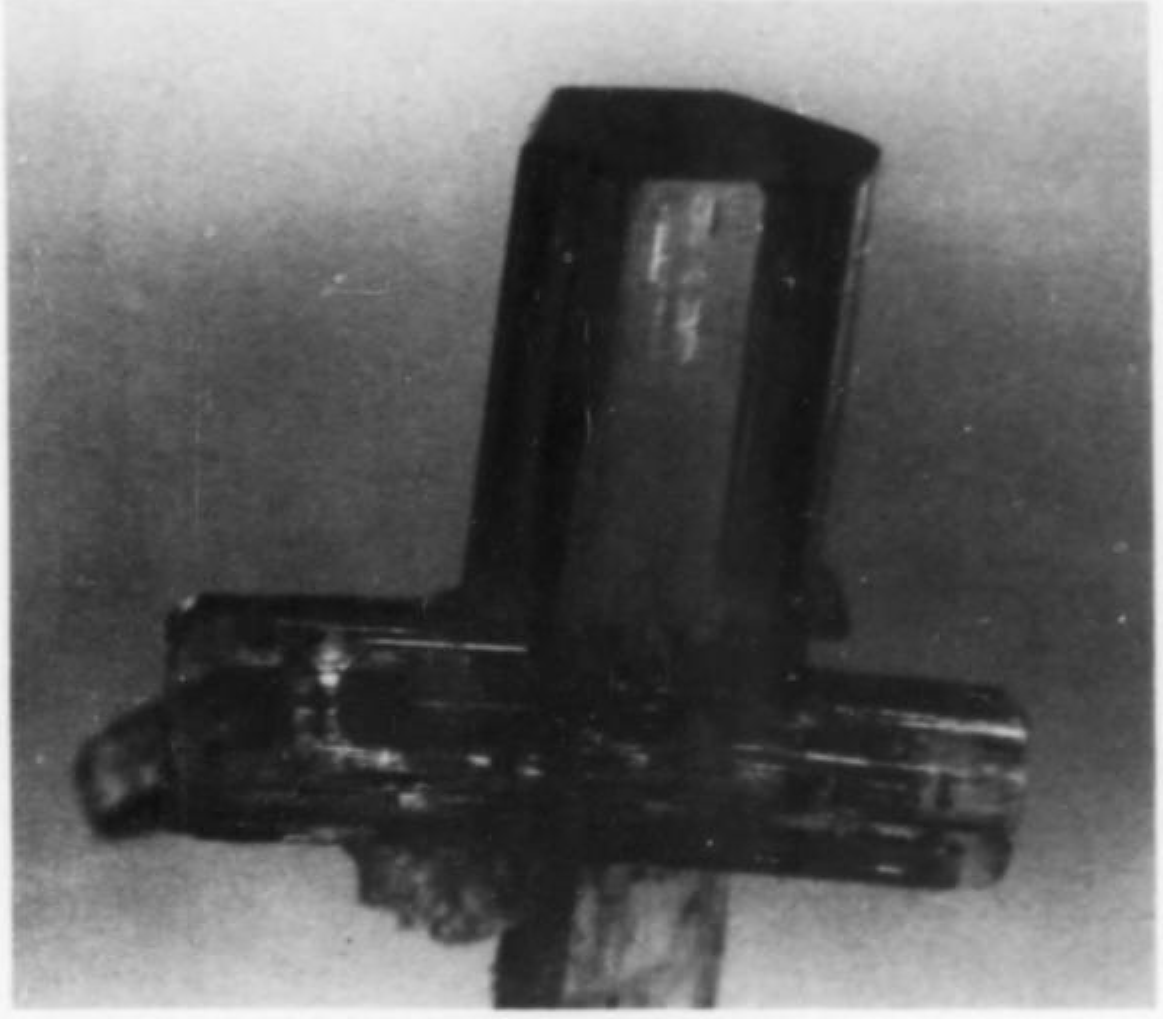


Figure 9. **Two colorless crystals of thaumasite, the larger one 9 mm in length, and the smaller one doubly terminated. From the N'Chwaning II mine, near Kuruman, South Africa.**

Much more common but in very sharp crystals is the native copper shown in Figure 10. This specimen is from Tsumeb, Namibia. All these specimens were obtained from Mike Haritos (*S. T. D. Minerals*, 22 Spring Hill Road, Hyde Park, MA 02136). He has ample supplies at very reasonable prices.

Only recently have I gotten around to mounting specimens acquired at the 1986 Tucson Show. How's that for procrastination? Among them were some nice little bow ties of calcite from the Monte Cristo mine, Rush, Arkansas (Fig. 11). These are a bright yellow, and are perched on a quartz matrix. What makes them more interesting, however, is the shape of the crystal cross-section, which is shown in Figure 12. The three-lobed appearance is a reflection of the fact that calcite is rhombohedral, and thus has three-fold rather than six-fold symmetry about its *c* axis. The same tri-lobed cross section is sometimes seen in siderite bow ties as well.

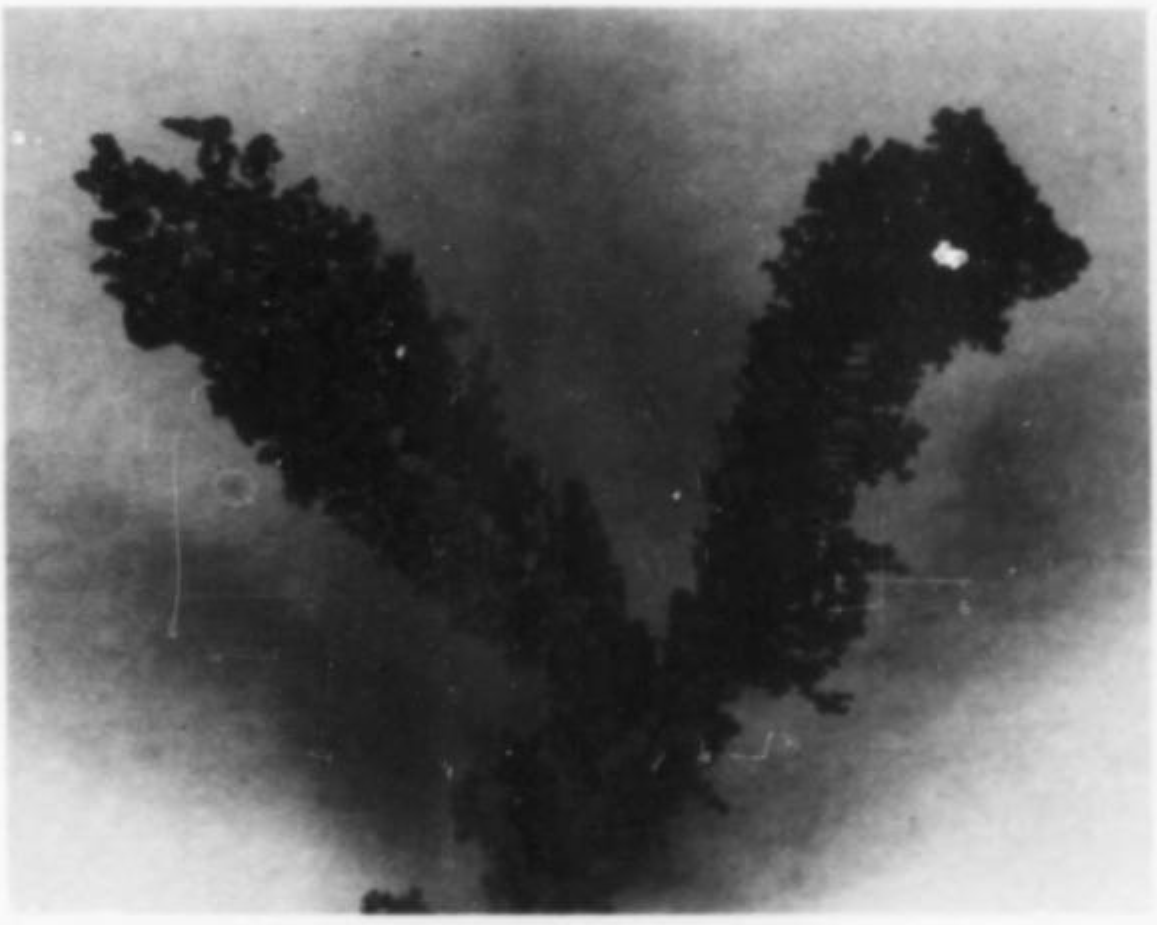


Figure 10. **Bright, reddish brown, arborescent copper from the Tsumeb mine, Namibia. The group is 1.4 cm across.**

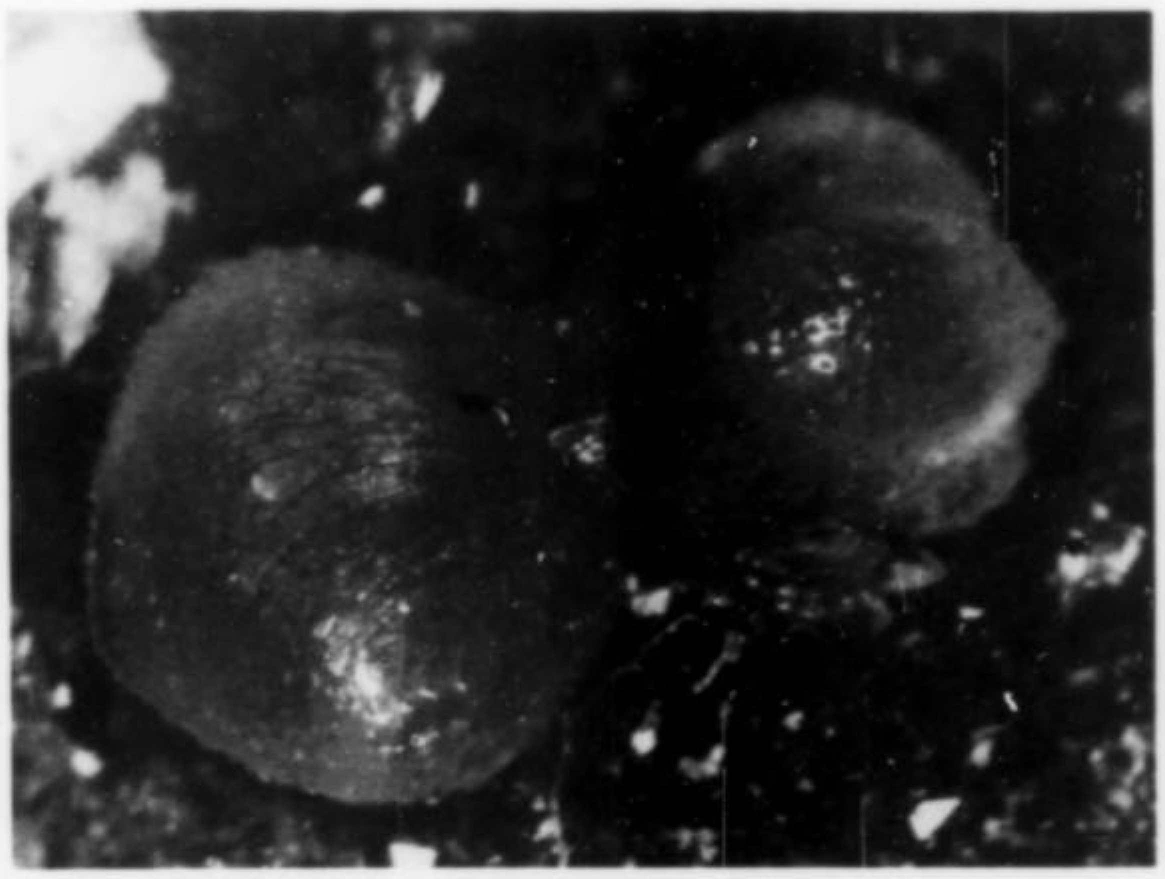


Figure 11. **A bright yellow bow tie of calcite, 2 mm long, from the Monte Cristo mine, Rush, Marion County, Arkansas.**

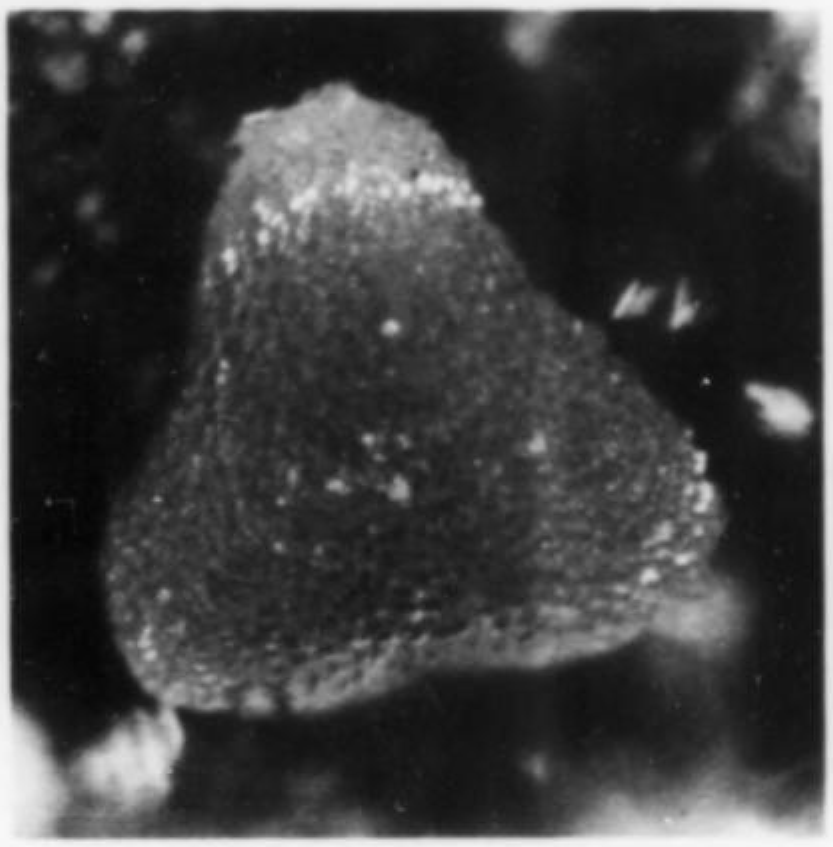


Figure 12. **Bow tie of bright yellow calcite viewed end-on and showing typical three-fold symmetry. Cross-section of the crystal aggregate, 0.4 mm. From the Monte Cristo mine, Rush, Arkansas.**

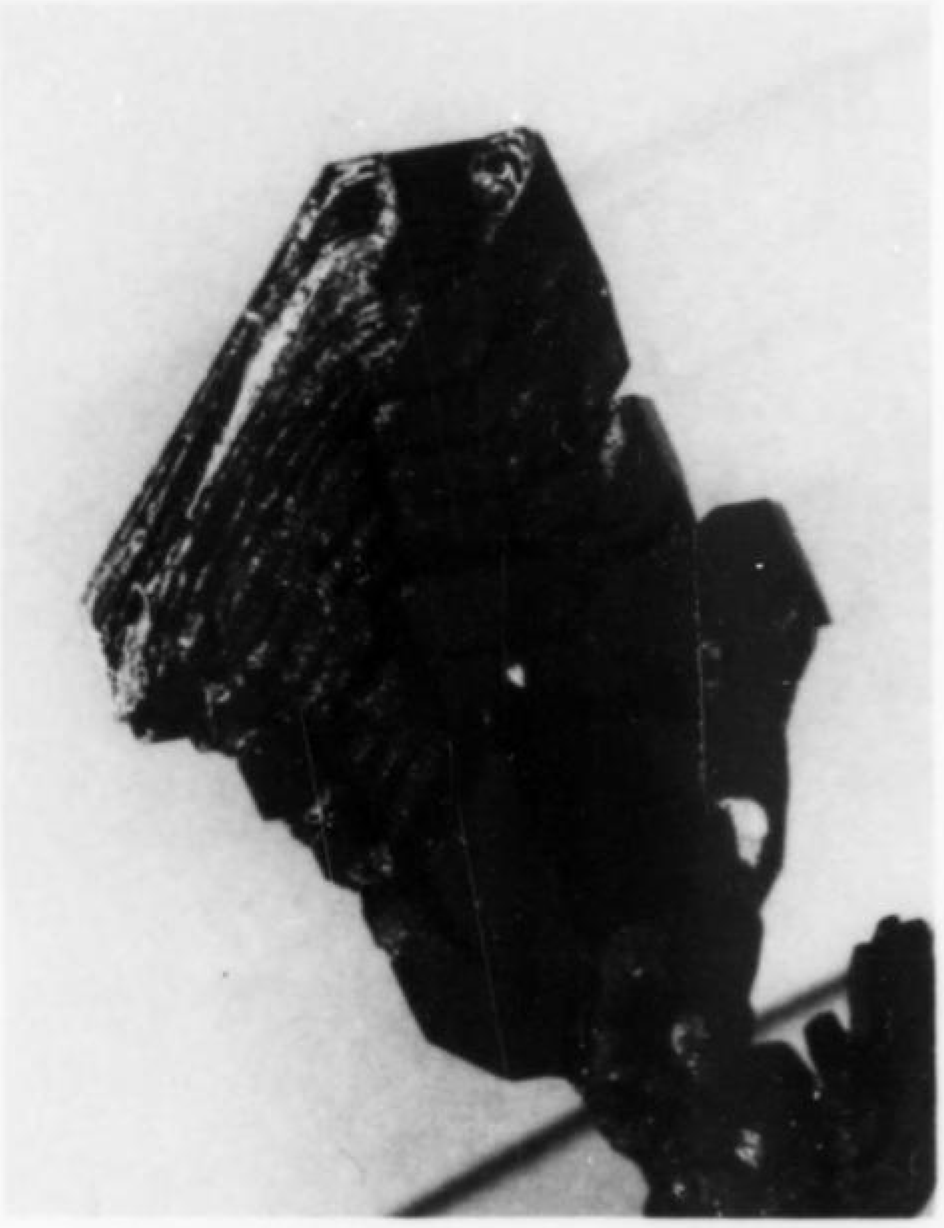


Figure 13. **Black, cavernous crystal of hematite, 9 mm high, from Nickenicher Sattel, Eifel district, West Germany.**

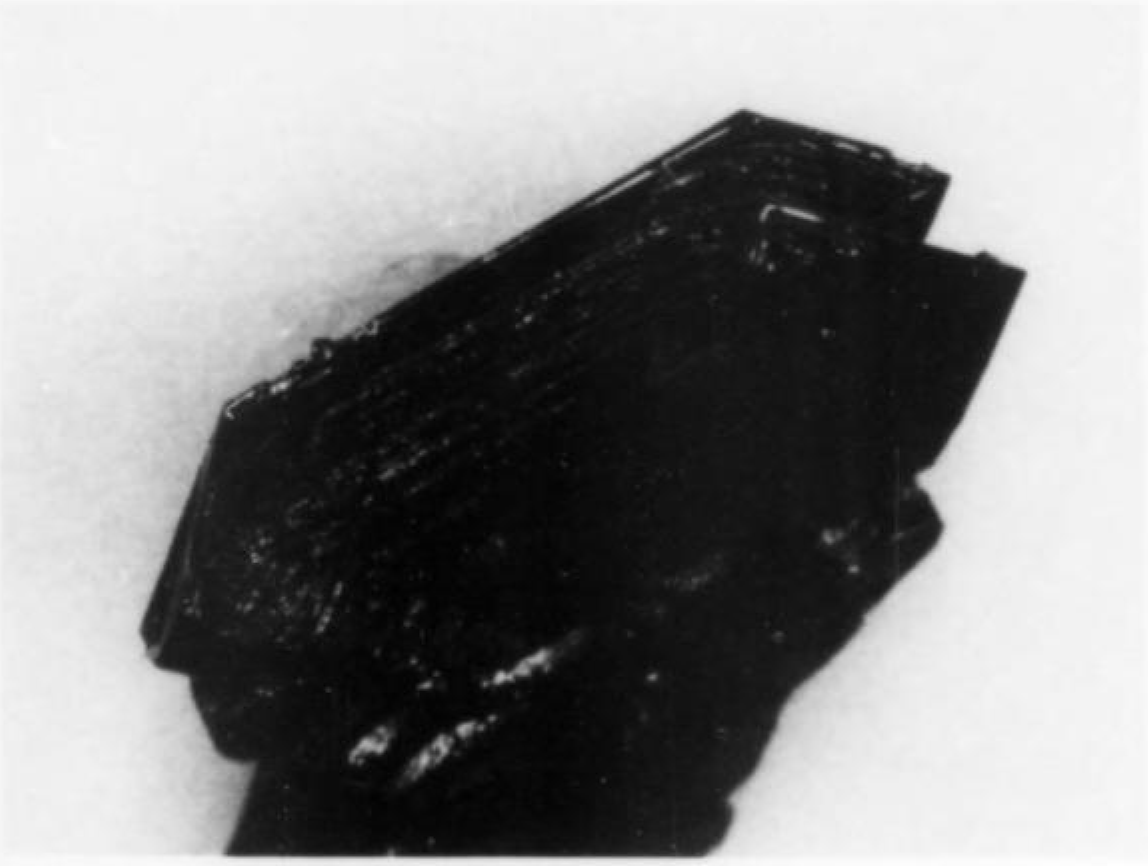


Figure 14. **An end-on, close-up view of the crystal shown in Figure 13, emphasizing the cavernous nature of the crystal.**

Figure 15. **Parallel, 1.2-mm, whisker-like crystals of brick red hematite growing from the *c* face of a larger, equant, black crystal of the same mineral. From Sattelberg, near Kruft, Eifel district, West Germany.**

Also obtained at the 1986 Tucson show were micros from the Eifel district in Germany, the source of a great variety of excellent micro species. The first of these was the tabular and cavernous hematite crystal shown in Figures 13 and 14. This and many of the other crystallized species found in the vesicles in volcanic rocks such as those found in the Eifel area are formed from the vapor phase. On decompression when lava reaches the earth's surface, dissolved gases are released and form the small gas bubbles which are later frozen to become the vesicles we see now. The same gases which form the vesicles are also quite capable of transporting heavy elements such as iron, calcium, magnesium, silicon, and others, things which are not normally thought of as volatile. While water is often present in such systems, elements such as chlorine, fluorine and boron form volatile compounds which greatly assist in transport of other elements at high temperatures. For instance, ferric chloride ($FeCl_3$) or silicon fluoride (SiF_4) are easily transported as vapors. When these later encounter atmospheric oxygen diffusing into the rock or, perhaps, react with water, they form minerals such as the hematite shown here or one of the quartz family polymorphs. Other common pneumatolytic minerals (ones formed from the vapor phase) are chondrodite, vesuvianite, scapolite, phlogopite, tourmaline, topaz and fluorite, most or all of which are found in the Eifel volcanics. The cavernous appearance of the hematite crystals also bears comment. Skeletal, hopper or whisker-type crystals are believed to be formed under conditions of very rapid growth (although, paradoxically, very slow growth will also on occasion form whisker crystals). The reason for this is that under non-equilibrium conditions (conditions of very high supersaturation, where atoms are being literally jammed into the crystals wherever they hit), projections such as corners, edges and ends of crystals capture atoms from larger volumes of the liquid or vapor phase surrounding them than do the faces of the crystals. Hence, corners, edges and ends grow more rapidly than faces, which are left behind. It is also believed that energy lost as atoms are immobilized on the crystal surface, energy which is converted to heat, is more easily radiated from the corners, edges and ends, thus preventing the growing crystal from warming as much in these regions as on the faces themselves. Since hot crystals grow less rapidly (or even dissolve!), heat dissipation also encourages growth at projecting parts of the crystal.

Also from the Eifel area are the whisker-like crystals of hematite shown in Figure 15. These, interestingly, are parallel because they are growing from the surface of an equant, much thicker crystal of hematite, one showing what looks like a hexagonal prism and base. Is this, perhaps, a case where a "normal" hematite crystal grew first, and then the whiskers grew at a faster rate? Possibly, but there are other explanations as well.

Similar hematites grown in volcanic rocks are found in many places as, for example, at a large number of localities in the western United States. Closer to the Eifel area, though, are some Italian localities such as those at Monte Somma, Vesuvius, Italy. Many of the hematites at Monte Somma are very attractive, brilliant of luster, very sharp,

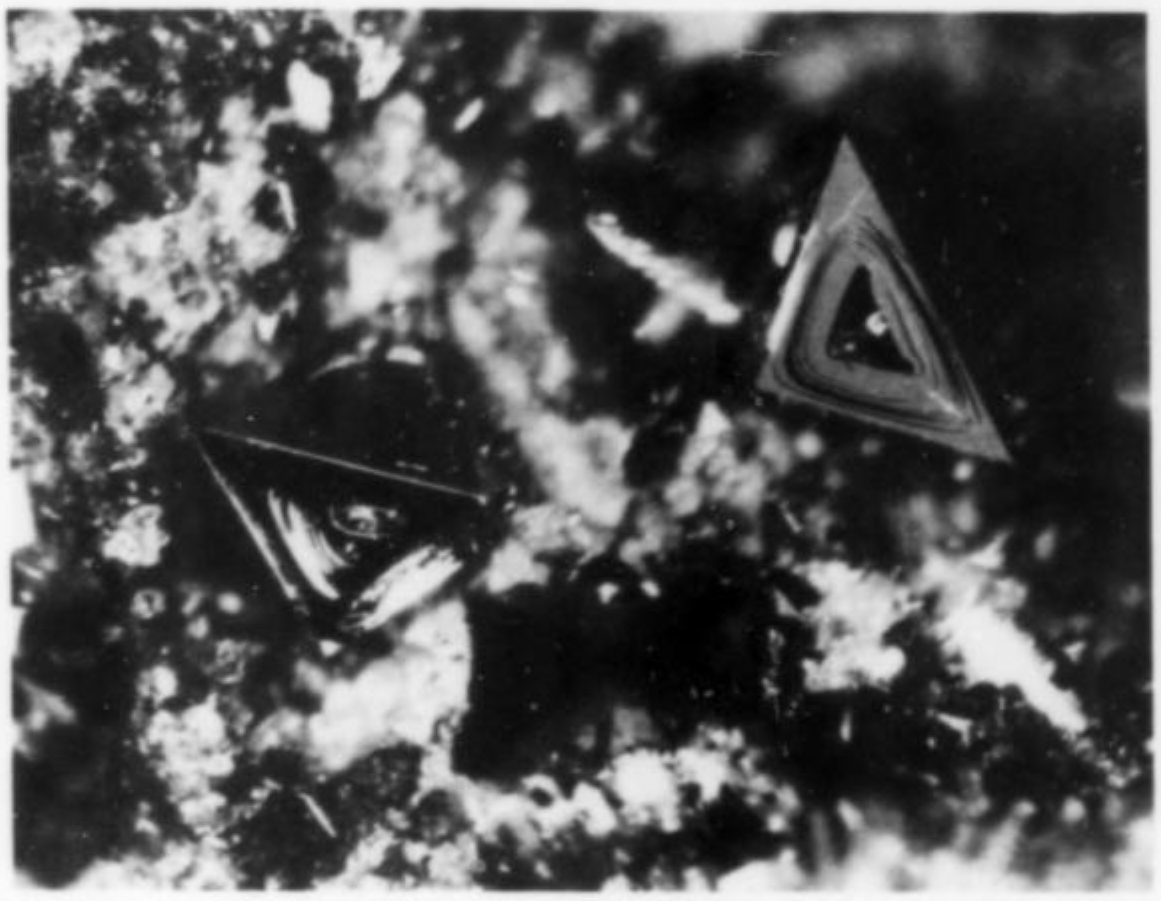


Figure 16. **Jet-black, 0.6-mm crystals of hematite with cavernous rhombohedron faces and smooth *c* faces. From Monte Somma, Vesuvius, Italy.**

Figure 17. **A 0.4-mm, pseudocubic crystal of black hematite from Monte Somma, Vesuvius, Italy.**

and with cavernous faces such as those in Figure 16. Note that only the rhombohedron faces are cavernous, while the *c* faces are quite smooth. Much less common are the pseudo-cubic crystals of hematite (Fig. 17) which show only a rhombohedron with interfacial angles close to 90°. All the rhombohedron faces of the crystal shown are cavernous.

Also obtained at the Tucson show were micros of dendritic perovskite (Fig. 18). These are crystallized in one of two dendritic habits of the mineral shown as crystal drawings in Gerhard Hentschel's excellent article on minerals of the Laacher See, Eifel district, Germany. See *Mineralogical Record*, **8**, 313 (1977). A photograph of the other arborescent habit of perovskite is shown in Harold Esser's photographic essay on the Laacher See minerals in the *Mineralogical Record*, **10**, 91 (1979). Formation of arborescent crystals such as these may also be caused by rapid growth from the vapor phase.

Perovskite, $CaTiO_3$, is an interesting mineral which forms in a number of environments. One such is in the late stages of crystallization of igneous ultrabasic or basic alkaline rocks. An example of these is the perovskite discussed above, which is found at Hannebacher Ley in a melilite-nepheline-leucitite rock. More commonly, it is found in metamorphosed limestone or calcareous rock at the contact with alkalic or basic rocks such as serpentines. The beautiful perovskite crystal shown in Figure 19 is from such an occurrence near the Benitoite Gem mine, San Benito County, California. Transparent and variously honey-color and brown, it shows striae in the "cube" face

Figure 18. **Black, arborescent aggregate of iridescent perovskite with melilite and pyroxene, from Hannebacher Ley, Eifel district, West Germany. Field of view, 1.4 mm.**

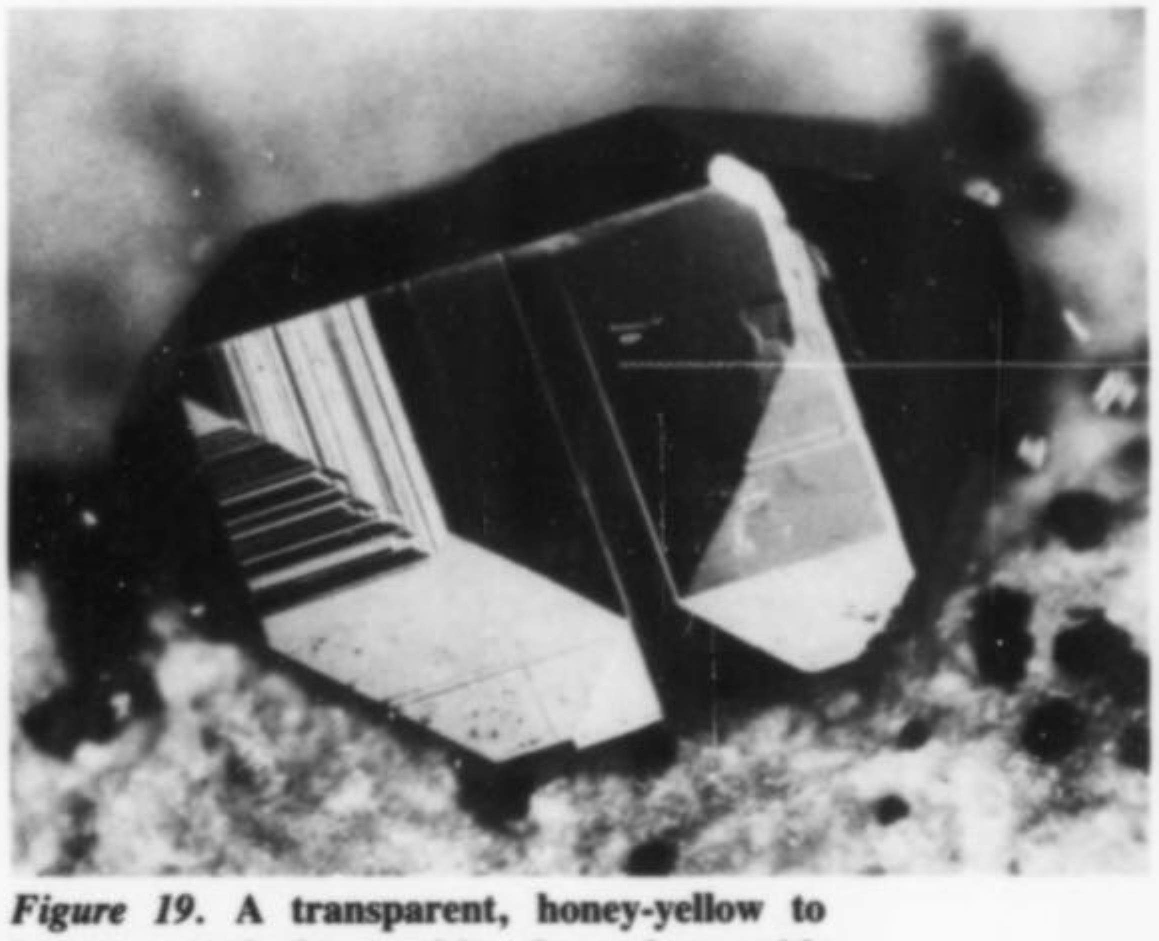


Figure 19. **A transparent, honey-yellow to brown crystal of perovskite, 2 mm long, with dark brown crystals of andradite. From near the Benitoite Gem mine, San Benito County, California.**

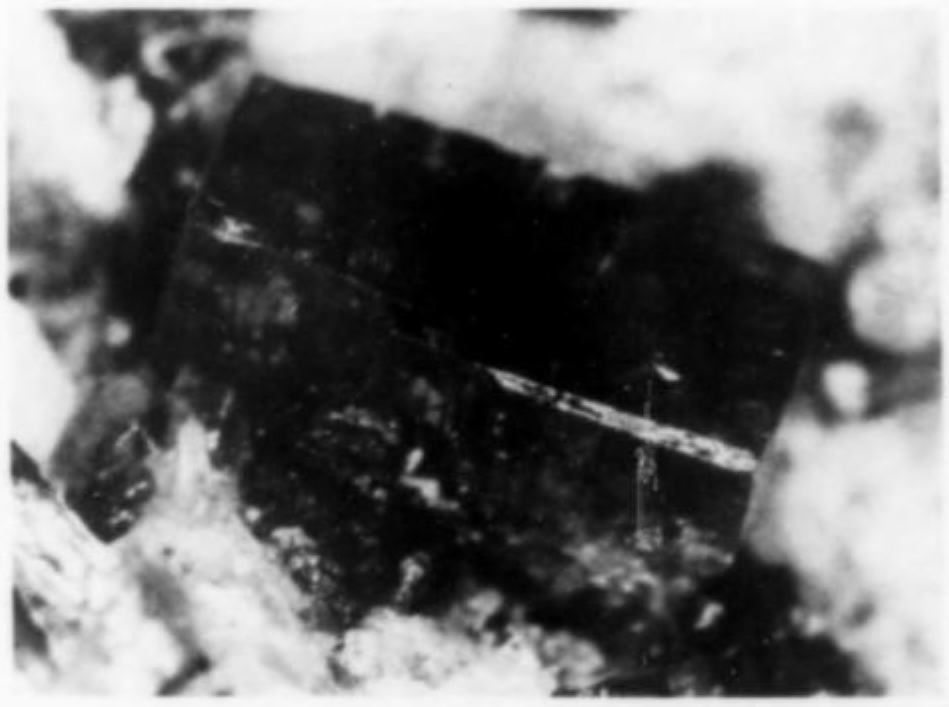


Figure 20. **A 1.4-mm, honey-yellow crystal of perovskite with chlorite in calcite, from Rocca di Castellaccio, Val Malenco, Italy.**

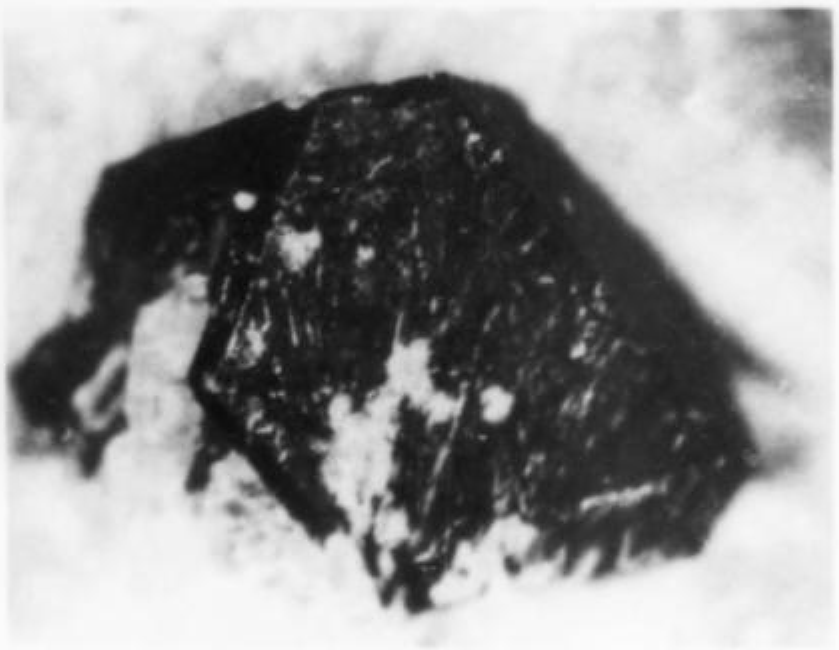


Figure 21. **Niobian perovskite, a 0.8-mm black cuboctahedron, from the Kimzey calcite quarry, Magnet Cove, Hot Springs County, Arkansas.**

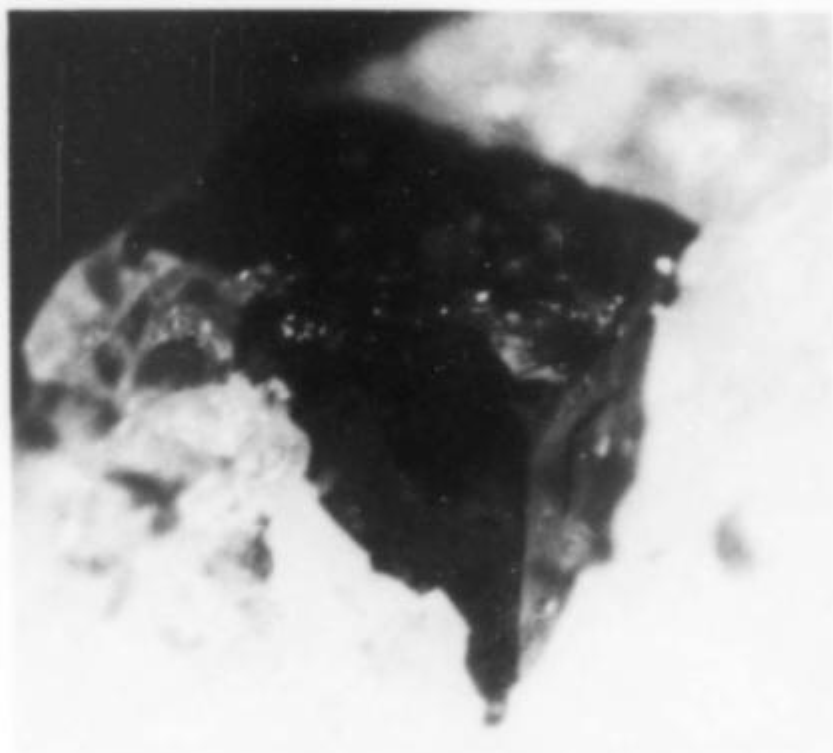


Figure 22. **Cubic crystal of black latrappite, 0.5 mm across, from the Oka Rare Metals mine, Oka, Quebec, Canada.**

which hint at perovskite's less-than-isometric symmetry, the species actually being orthorhombic. Another crystal from a similar occurrence is shown in Figure 20. Honey-yellow, it is associated with clinochlore, and is from one of the notable Italian localities for the mineral, Rocca di Castellaccio.

Still a third mode of occurrence is in carbonatites. The cuboctahedron of niobian perovskite in Figure 21 is from carbonatite (igneous carbonate) rock at Magnet Cove in Arkansas. Dana states that niobian perovskite tends to be octahedral in form, and sure enough, the octahedron is the major form on this crystal.

The last crystal shown (Fig. 22) is of latrappite, $CaNbO_3$, from another carbonatite at Oka, Quebec. Latrappite is also a member of the perovskite group, and seems to occur in similar associations. There are three more members in the group (loparite, tausonite and lueshite), but they are not represented in the author's collection. It is interesting that, of the perovskites shown, only the last two, found in carbonatites, seem to have abundant inclusions. These inclusions of carbonate material suggest the crystals had a relatively hard time growing. A question might be asked: if niobian perovskite tends to occur in octahedrons, why is this crystal of latrappite, the niobian end-member in the perovskite group, a cube? It is mysteries such as this that make mineralogy so fascinating.

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

Letters

NORTH KOREAN MINERAL STAMPS

The three mineral stamps pictured above were issued in 1986 by the government of North Korea. Imagine the surprise of *Mineralogical Record* Associate Photographers Eric Offermann and Olaf Medanbach when they recognized *their own photos* on the stamps! The photos were originally published in Rupert Hochleitner's book, *Fotoatlas der Mineralien und Gesteine*; apparently they were lifted directly from that book for use on the stamps. The North Korean government, it would seem, is not familiar with international copyright conventions and did not seek the permission of the photographers. It's difficult to feel very sorry for Drs. Offermann and Medenbach, though. They now share a rare distinction among mineral photographers.

Ed.

COLLECTING IN NATIONAL FORESTS

I am an amateur mineralogist and collector interested in minerals from granitic plutons. On a recent vacation/collecting trip to the Sawtooth Mountains of Idaho, my collecting partner and I were issued citations and our specimens were confiscated by Forest Service personnel. This occurred when we returned to our car after two weeks of collecting.

The legal basis for the citation is CFR Title 36, 269.9b, which prohibits the removal of "natural features of the land." This [presumably] applies to all National Forest lands; the implications are disastrous for amateur mineralogists and mineral collectors. Please let your readers know that this law is now being enforced.

Kevin Cole
Dept. of Geosciences
University of Arizona, Tucson

First of all, it is important to know whether you are in a National Forest or a National Wilderness Area . . . regulations differ. John C. Nichols, Forest Minerals Geologist for Arkansas's National Forest, writes as follows in a letter published recently in ***Mineral News.***

We encourage valid exploration and development of the mineral resources [in the Ouachita National Forest] and we encourage recreational use of the Forest through "rockhounding" activities. "Rockhounding" is typically considered to be the occasional removal of small amounts of mineral material for personal use. If a person intends to sell . . . the minerals . . . then their interest is considered to be other than "rockhounding" and they must . . . abide by the appropriate laws [regarding] a permit, lease or mining claim. The true "rockhounder" on the Ouachita National Forest has never been considered as subject to arrest, prosecution or a fine for conducting "rockhounding" activities. We prefer instead, to encourage free access to unclaimed/unleased minerals on the Ouachita National Forest by the "rockhounder" for recreational purposes.

This sounds positive, but the catch is that there is no precise definition of what constitutes a "small amount." According to Lanny Ream (Editor of ***Mineral News****), who has spoken to Forest Service personnel in several states, each Forest Ranger is currently establishing his own standards, without formal guidance from the Forest Service or the courts. The cut-off between a legal and an illegal amount of specimens varies with the whim of the local Ranger, and could be as low as two or three small specimens. This is clearly unfair to collectors; some sort of consistent, easily determinable limit must be established for National Forest areas throughout the United States. Until this is done, most collectors will be unable to determine whether they will be found in compliance with the law. Ed.*

NO SMOKING PLEASE

Smoking may be hazardous to your sphalerite! In the March-April issue of *Geology Today*, R. J. King of the National Museum of Wales offers this important logic for smoke-free mineral collections:

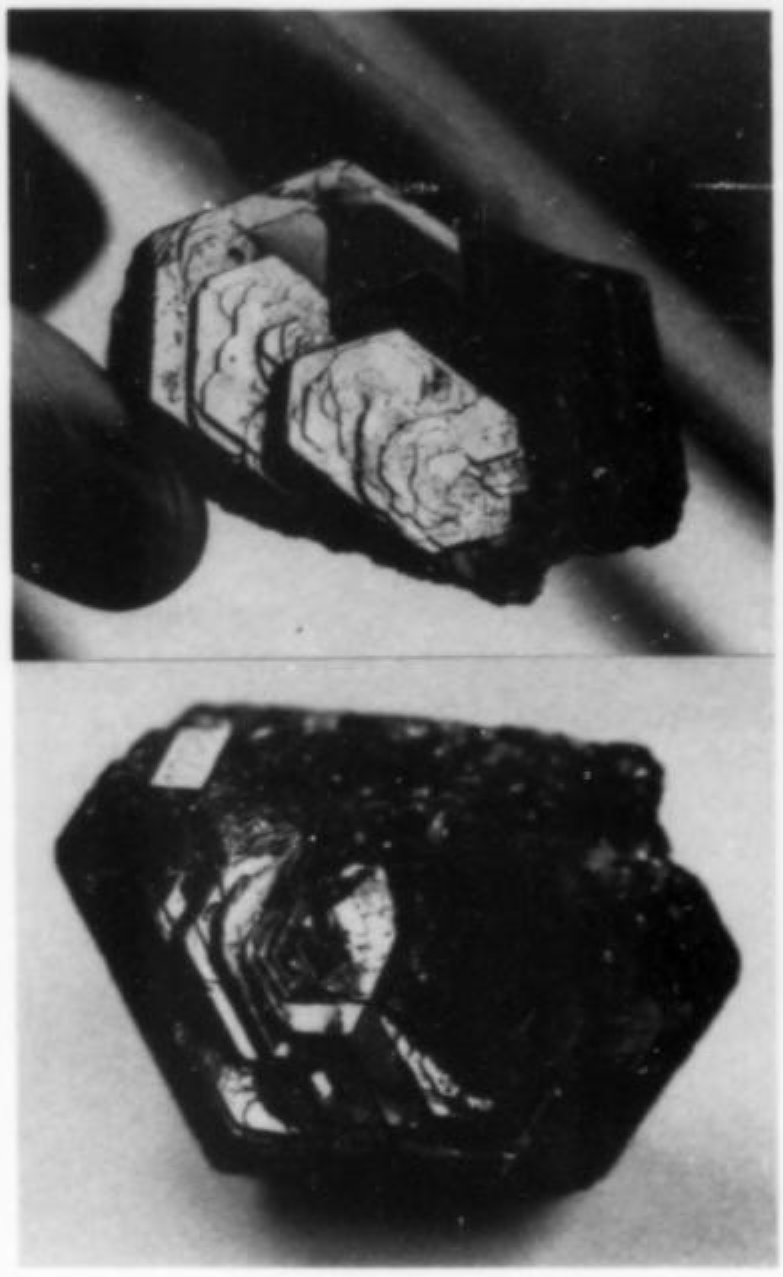
"Sphalerite is a sulfide, and collectors should assume that they have some degree of metastability to deal with. One of sphalerite's chief beauties is its high luster. This is easily lost, often within hours, should a specimen be subjected to attack by airborne noxious gases such as sulfur dioxide, hydrogen sulfide from a nearby industrial plant, or *tobacco smoke*."

Walter A. Gibbins
Yellowknife, N.W.T., Canada

IRON ROSES

While rereading some back issues of the *Mineralogical Record* (a favorite occupation) I came across references to "iron roses" of hematite found near Quartzsite, Arizona. Bob Sullivan refers to these and also the classic examples from Switzerland (vol. 11, p. 315), and wonders whether the Arizona specimens could be the world's first double-sided iron roses.

For a number of years I have had in my collection a double-sided floater hematite rosette reputed to come from a locality called Congonhas do Campo, Minas Gerais, Brazil (see photos). It measures 7 cm across and a little over 4 cm in maximum thickness. Curious about the locality, I wrote to Demetrius Pohl at the American Museum of Natural History in New York. According to Demetrius, the iron

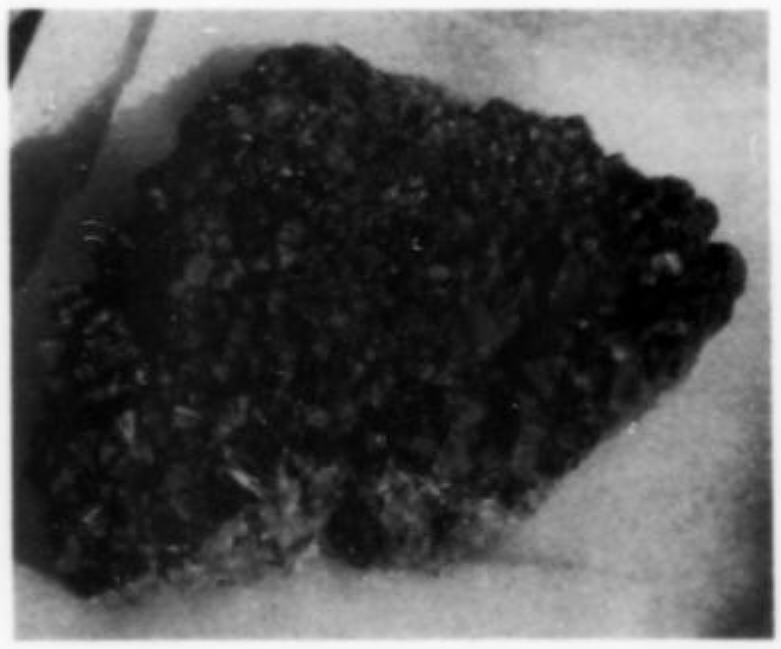


roses are still coming out of Brazil, in a sort of steady trickle. They actually come from a topaz deposit between Congonhas and Ouro Preto about 40 km to the east. Sizes range up to 15 cm (!), so they rank with the world's finest.

David Prince
Hamilton, NSW, Australia

AUTUNITE AVAILABLE

I have a large (13 x 18 cm) autunite specimen from the Daybreak mine in Washington which is available for trade (see photo). Lanny Ream, editor of *Mineral News*, described it in 1986 as "one of the finest I've ever seen."



Due to space limitations, I prefer not to collect specimens of this size. I would be interested in specimens 8 x 8 cm or smaller, and could meet for the exchange at the 1989 Denver, Cincinnati or Detroit shows. I am primarily interested in showing specimens of native elements, gem materials, azurite and fluorite.

Stanley J. Perry
751 Eunice Ave., Webster Groves, MO 63119

TORBERNITE WATER

Considering your expressed interest in the article, *The relationship between sake and radioactive minerals in brewing* (vol. 19, p. 138), I thought you might be interested in the enclosed photos. The "Torbena" jug was found in a local antique shop, and was part of the estate of a local couple who both died at an early age of rectal cancer. The jug looks like it holds about 1½ gallons, and still contains a charge of radioactive torbernite. The charge is quite oxidized, and "hot as a firecracker." This device was in service around 1919.

Prosit!

George F. Melloy
Bethlehem, PA

KOMBAT MINE DISASTER

The Kombat mine, located a few kilometers from Tsumeb, between Otavi and Grootfontein in Namibia, is famous for a suite of rare manganese silicates (e.g. the world's finest nambulite) and also for secondary minerals including superb cerussite twins and groups.

Namibian newspapers reported last November that a disaster had occurred underground at the Kombat mine. The problem dates back to a year ago, when mining operations opened a "geological leak" on the 15th level, about 550 meters below the surface; an enormous body of underground water had been found. Two thousand tons of quick-drying cement were quickly poured into the exploration drift, sealing it off. The problem was thought to have been controlled.

I was recently in Namibia on a buying trip when a disaster occurred which has closed the mine: On November (according to the Windhoek *Observer*) blasting took place on the 15th level as usual. The "all clear" was sounded shortly thereafter, at 4:30, by which time the massive ventilators had presumably cleared the air of toxic fumes from the explosives. A mining crew of seven men then entered the mine, driving their Landcruiser down the truck-sized ramps all the way to the sump station 1,200 meters below the surface. They immediately telephoned to report an unusual inflow of water. Following the call, the hoist driver received an emergency signal, one short ring. That was the last ever heard from the crew; they were apparently inundated with water at that moment.

Estimates indicated that water inflow had suddenly risen from about 30,000 cubic meters per day to over 120,000 cubic meters (about 32 million gallons) per day, far above the mine's pumping capacity. (The water consumption of the entire city of Windhoek is less than 70,000 cubic meters per day.)

As the water level rose steadily, volunteer crews worked to remove as much expensive mining equipment as possible, and to seal off rich stopes with water-tight steel doors. Water was expected to flood the upper levels within two days.

Robert Meiring, chief executive of Tsumeb Corporation which operates the Kombat mine, anticipates the eventual recovery of the mine but would not speculate on how many years that might take. Recovery is considered worthwhile because, whereas the Tsumeb mine has a life expectancy of only seven to ten years, the productive life of the Kombat was thought to be at least 20 more years.

A reporter for the Windhoek *Observer* described the Kombat mine as having been a model of modern mining efficiency: It had an underground crushing plant; "huge workshops, with not a spot of oil on the green-painted floors which were shining like mirrors; first aid stations, telecommunications centers, hoisting chambers, mess rooms and every conceivable facility a small town has. Below the fifteenth level it sometimes rained softly . . . one always heard the thunder of compressed air-driven equipment and in the background the subdued humming of the pumps, fighting water."

Don Olson
Milwaukee, WI

Mineralogical Record BACK ISSUES!

v.8/#6 California Issue Benitoite, Gold, L.A. County Museum, Himalaya mine **$7**

v.9/#3 Kalahari rhodochrosite, Paterson-NJ, Brumado district-Brazil, Bosch Coll. **$7**

v.9/#5 Turkish Kämmererite, Afghan pegmatites, Chuquicamata-Chile **$7**

v.10/#5 Thomas & Wah Wah Ranges-Utah (famous for Topaz, Red Beryl, etc.) **$7**

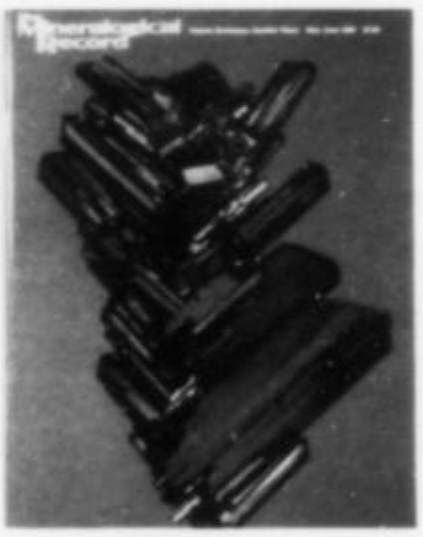
v.10/#6 Colorado-II Issue Locality Index, Amazonite, Mt. Antero, Sweet Home **$7**

v.12/#4 Mineral Fakes, Mineral Fraud, Leadhills-Wanlockhead England **$7**

v.16/#1 Nevada Issue Getchell, Comstock, White Caps, Steamboat, etc. **$9**

v.16/#3 Colorado-III Issue Leadville, Rico, Pikes Peak Cresson Vug, CSM Museum **$9**

v.16/#5 Tourmaline Issue History, Mineralogy, Calif., Elba, Nepal, Pakistan, ME **$12**



v.17/#3 Knappenwand, Laurium, Tucson Show, Senaite-Brazil, New Zealand, Italy **$9**

v.17/#4 Tip Top-Black Hills, Stoneham-Colorado Barite, Tuscany-Italy **$9**

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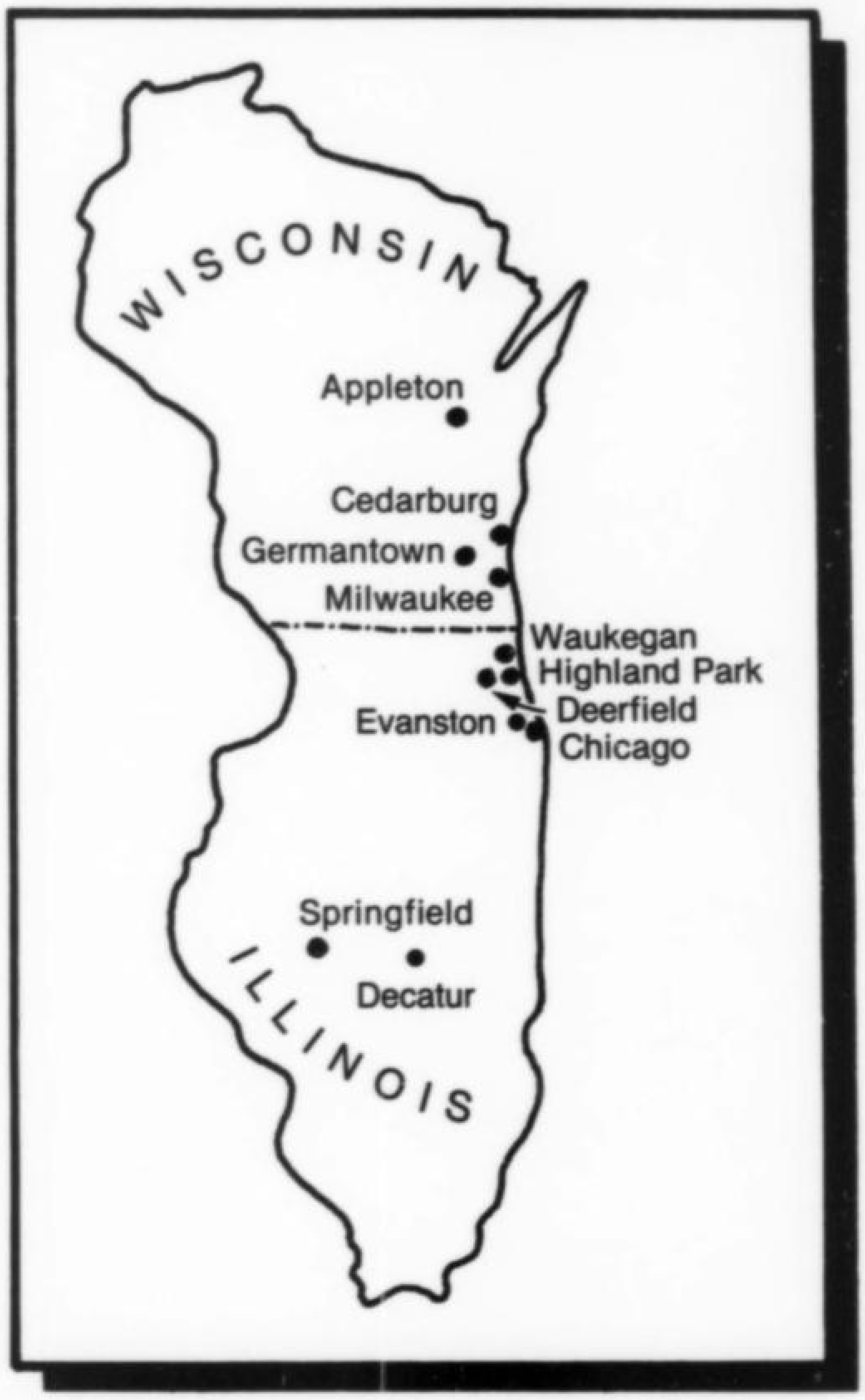

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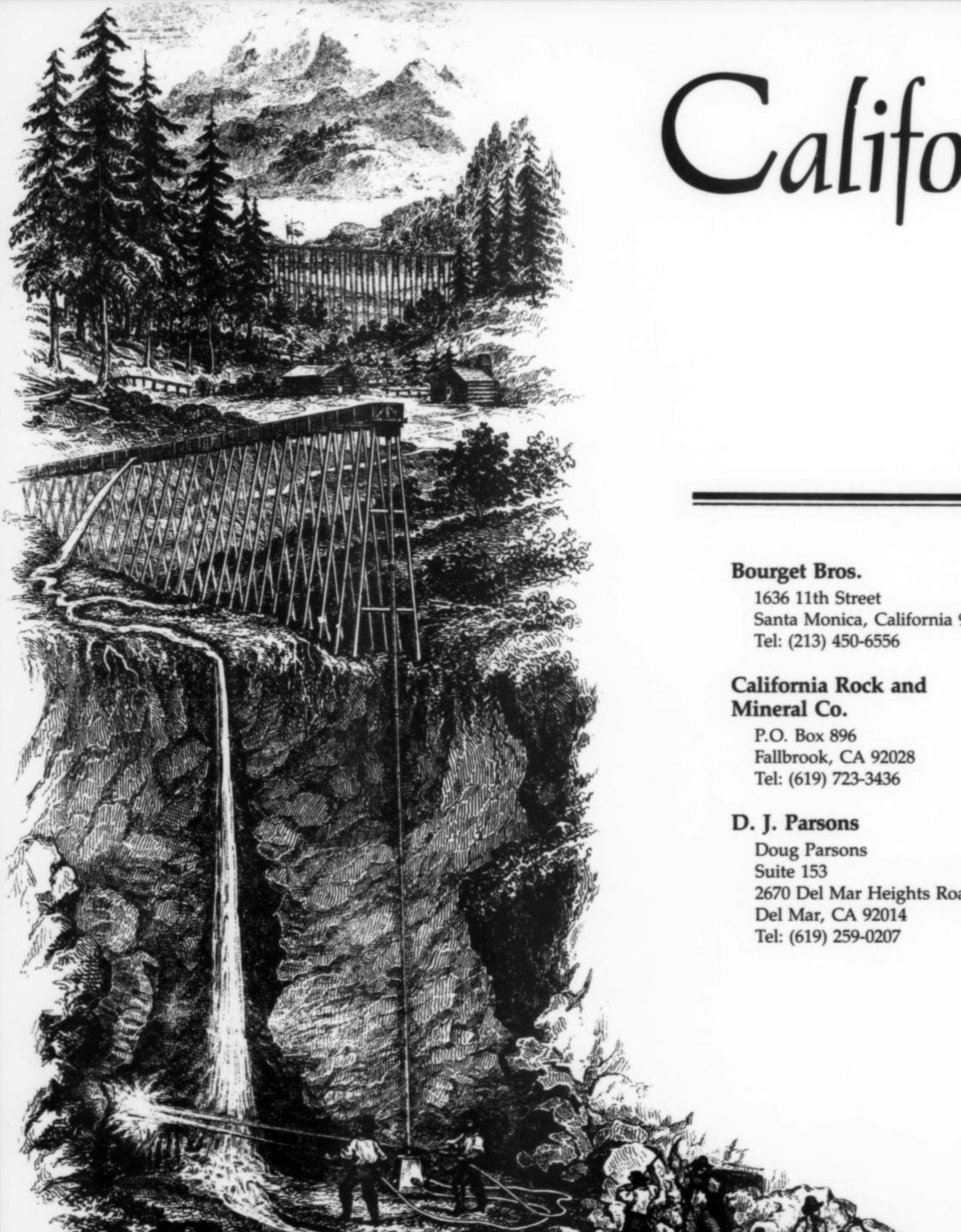

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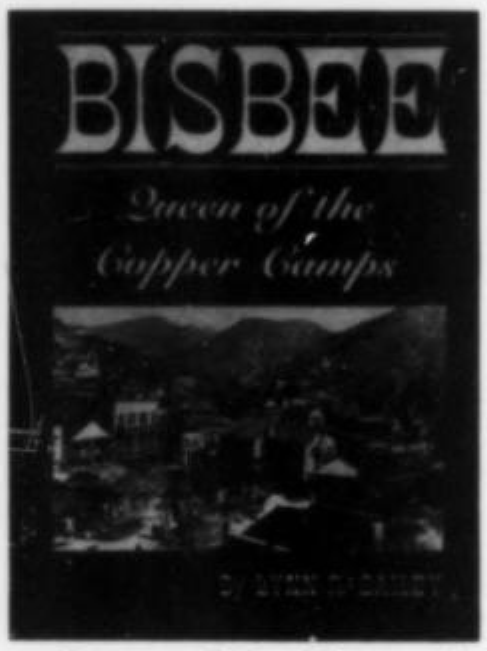

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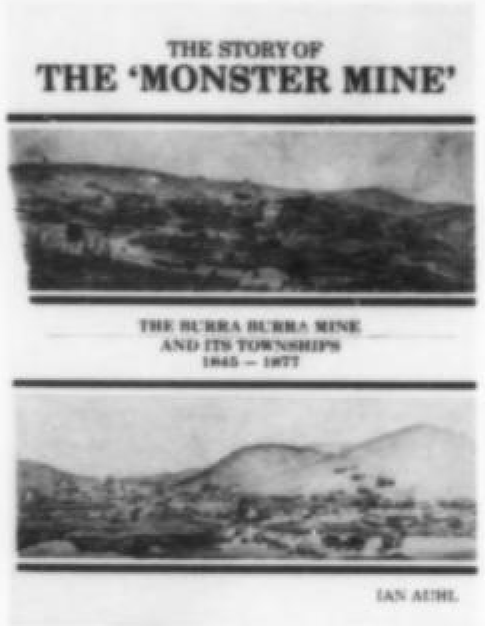

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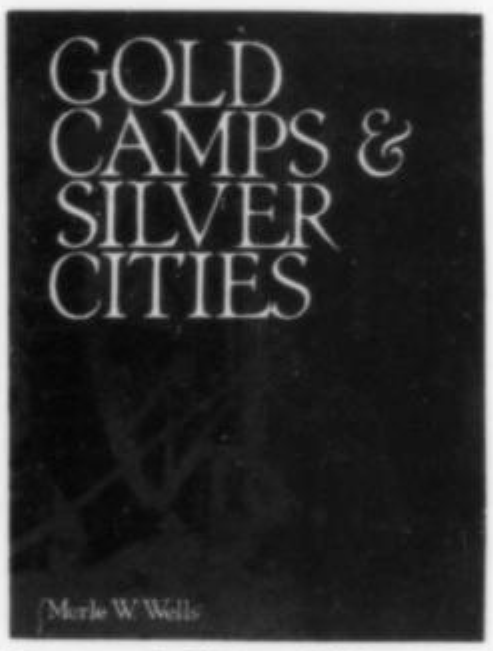

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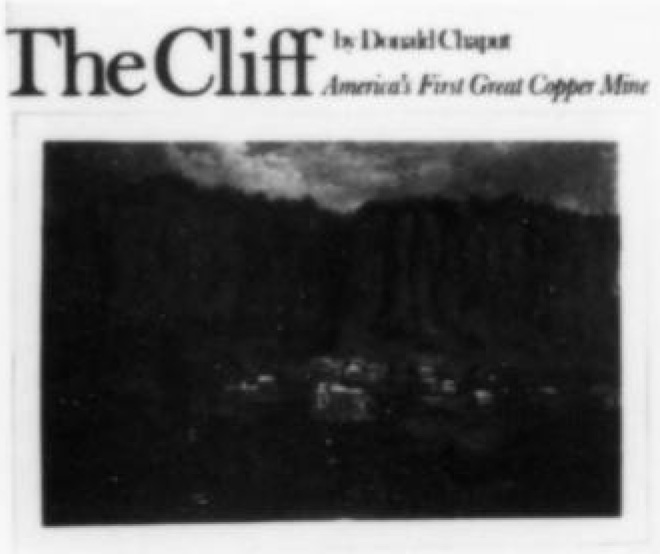

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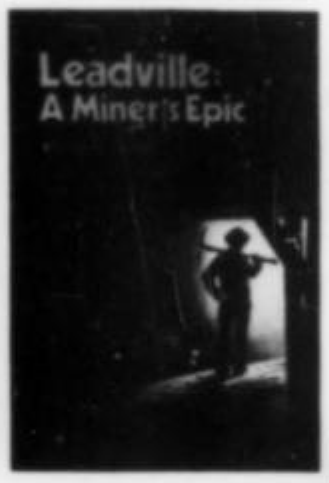

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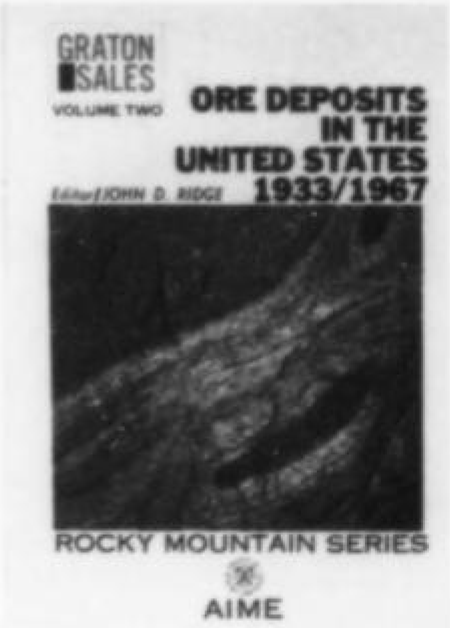

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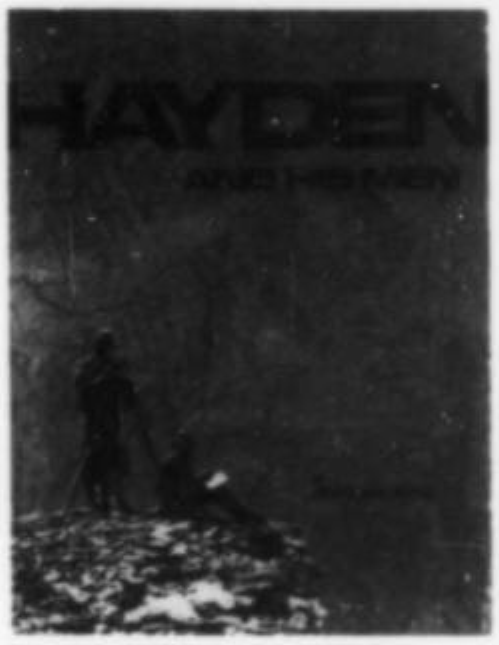

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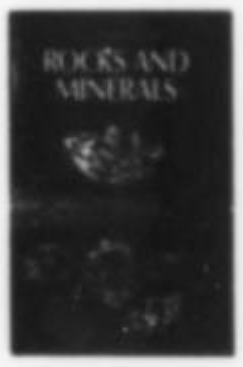

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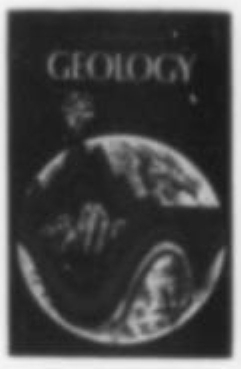

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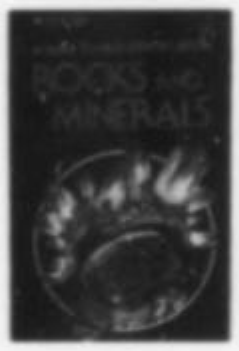

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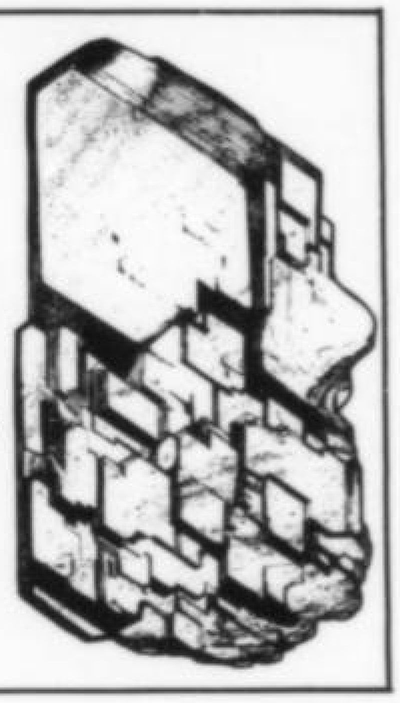

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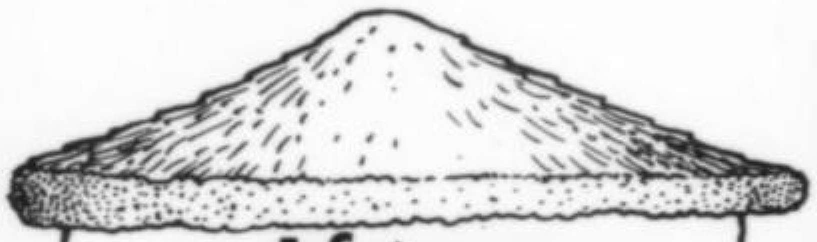

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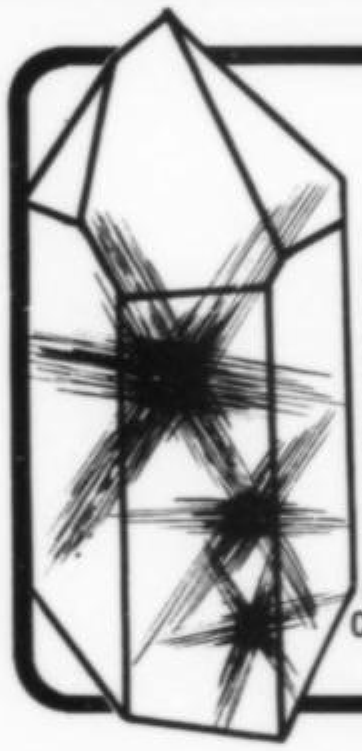

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Affiliated with the Friends of Mineralogy, an independent, non-profit organization devoted to furthering amateur and professional interests in mineralogy. For membership information contact Don Zowader, 97 Leamington Rd., Somerville, NJ 08876.

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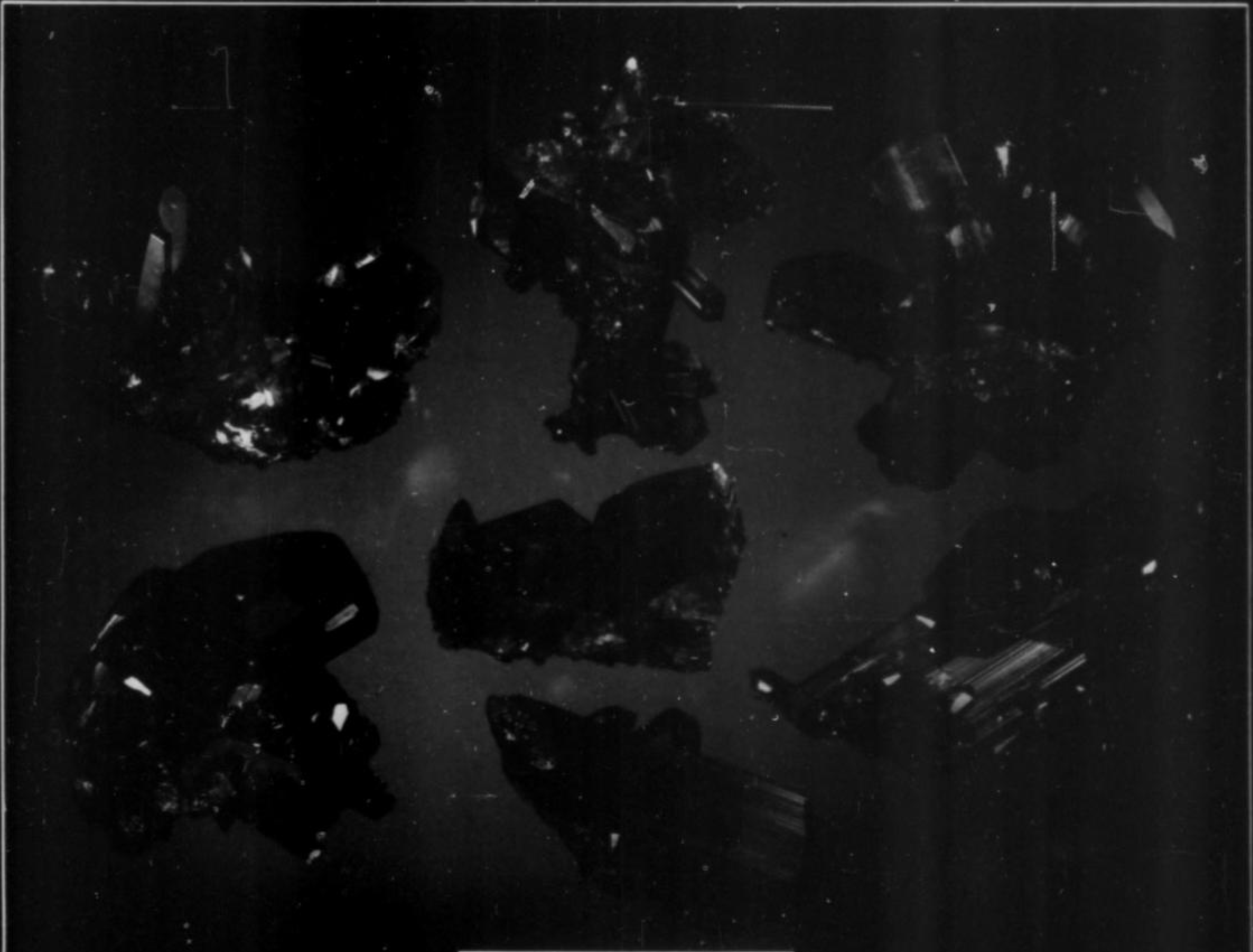


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