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Articles

Columns

COVER: BERYL with muscovite, 14.6 cm, from near Dusso, Gilgit division, Pakistan. (See the article on these deposits in vol. 16, no. 5, p. 393.) This specimen was exhibited at the 1990 Tucson Gem & Mineral Show by Siber + Siber, Zurich; it is now in the Smithsonian collection. Photo by Harold and Erica Van Pelt.

notes from the EDITOR

GOLDSCHMIDT & GOLDSCHMIDT

People who attended the 1989 Photographic Symposium sponsored by the Rochester Mineralogical Symposium had the good fortune to see a rare sight: Steven Chamberlain and Vandall King actually standing side by side. For years these two gentlemen have been mistaken for each other, because (apparently) of rather similar physical appearance and similar beards. In fact, the rumor had been circulating that there really was only one person, going alternately by two names (rather like Clark Kent and Superman, or vice versa). Standing together at last, Steve and Van settled that rumor once and for all . . . although some confusion still remains as to which is which.

So it also has been with two other figures in mineralogy: Victor Goldschmidt (1853–1933) and Victor Moritz Goldschmidt (1888–1947), who not only had nearly identical names but also proud, bushy mustaches. The former, author of the famous *Atlas der Kristallformen* and always without a middle initial, was featured in the previous issue, and the latter, a famous geochemist, is featured in this issue. Perhaps this side-by-side treatment, as with Steve and Van, will help to put an end to the confusion.

PERSONALIZED MINERAL LABELS

Personalized mineral labels are a centuries-old tradition in mineral collecting. They are a source of handy information about each specimen, especially for visitors who may not wish to look every item up in your catalog. They show pride in one's collection, and they can travel with the individual specimens in later years as they become part of future collections, thus helping to preserve provenance.

The only thing preventing many collectors from using personalized labels is the problem of having them made. These days there is a ready-made system all set up and waiting to be used: business-card printers.

Every reasonably large town or city has at least one company specializing in business cards. Often they can be enlisted through a local photocopy store. You simply walk in and say you'd like to order some business cards. The sales person can help select typefaces, and can sketch something out that meets with your approval. Or you can bring in your own sketch, including a crystal drawing, monogram or other logo artwork for them to include. You might even have them duplicate an antique label, inserting your own name. The fact that your mineral label is not a business card is of no significance whatsoever to the printer.

Virtually all the options available for business cards may also prove applicable to mineral labels. You might wish the labels to be printed in two or three colors of ink, or have gold stamping, or be printed on some unusually colored or textured paper. And, although business cards are typically 2 x 3½ inches, even this can be varied. The cards are usually printed "four up," that is, in a strip of four which must be cut apart. They might just as well be sized so that three or eight fit on the same strip.

Business cards are typically ordered in increments of 500, the price generally including typesetting, layout and paste-up. Because the printers specialize in this kind of product, the cost is usually quite reasonable as well, especially on orders of several thousand. And business card paper stock is thicker and more durable than traditional bond-paper labels. Check into it the next time you're having photocopies made.

ARCHIVAL SUPPLIES

Most mineral species are fairly stable, requiring minimal pampering in order to maintain proper conservation and preservation conditions. However, it seems that mineral collectors often end up collecting an array of paper items, books and photographs which are related in some way to minerals and mining. Antique photos, mineral labels, mining stock certificates, early correspondence, various sorts of illustrations, and many other types of "ephemera" all attract interest.

A wide variety of archival supplies can be obtained through the catalog of Light Impressions, 439 Monroe Avenue, Rochester, NY 14607-3717. *Acid-free* portfolio boxes, manuscript boxes, museum-quality carrying cases, drop-front storage boxes, "banker's" boxes, archival shipping boxes, folio folders, scrapbooks, slide storage boxes, photo albums, sheet-protectors, film enclosures, transview mats, interleaving tissues, boxboard and matboard are all stocked, along with other conservation equipment and supplies such as metal filing cabinets designed for photographic slides, thermometer/hygrometers, dessicants, deacidification solutions, plastic sheets and sealing tape for encapsulating documents, dry mounting supplies and presses, and so on . . . good things for protecting the history of mineralogy. Technical assistance and advice is available from Light Impressions by calling 716-271-8960 (Monday-Friday, 9–5 EST).

MINERALOGICAL RECORD INDEX

Several years ago the Friends of Mineralogy undertook a major project: to write and publish a cumulative index to the first 14 years of the *Mineralogical Record*. With the help of many volunteer workers (organized by Mike Groben), contributors and sponsors (notably Barry Yampol, Hazel Radcliffe and long-time *Mineralogical Record* donor Randy Rothschild, among many others), the enormous text was completed, typeset, printed and bound for distribution. Only those people who have actually experienced working on such a project can fully comprehend the vast numbers of man-hours that are required. The completed 14-year index has been a real boon to users of the *Mineralogical Record*, and has significantly increased the scientific utility of the journal by providing easy and quick access to the data it contains.

Happily, the Friends of Mineralogy did not stop there. They have continued each year to supply indexing of subsequently published issues, with the idea in mind of eventually creating a new cumulative index.

With the magazine having recently achieved the ripe old age of twenty years, it seems a good time to gather everything together and issue a 20-year index covering volumes 1–20, cumulatively updating the published 14-year index. Work is now well along toward this goal.

Thanks to the backing of our anonymous donor from Georgia, the Mineralogical Record will be the publisher this time. The 20-year index will be bound hardcover with a sewn binding (rather than a glued binding as per the 14-year index), built to survive long and heavy use. The *next* published index will probably cover only volumes 21–30, so the 20-year index will not be replaced or made obsolete in the future. This will be the one to keep. Consequently it must be constructed to last.

Anyone wishing to make suggestions regarding the 20-year index, or to point out errors in the 14-year index before it is merged with the new entries, should write to the editor, *Mineralogical Record*.

FAMOUS MINERALOGISTS:

VICTOR MORITZ GOLDSCHMIDT

1888–1947

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The final selection* in my small gallery of famous mineralogists is Victor Moritz Goldschmidt, a truly remarkable thinker who, more than anyone, brought mineralogical science into its quantitative and rather precise maturity. In many respects, Goldschmidt is the link from our rich mineralogical heritage—which slowly stagnated—to the dynamic study which so characterizes earth and planetary sciences today. Goldschmidt, in effect, evolved the laws of not only one science, but two: crystal chemistry and geochemistry. A lonely, pessimistic somewhat tragic figure, his *persona* is a delight to study, for he possessed all those qualities of the Romantic figure of a bygone age. Even his dress and manner were classically quaint. Yet Goldschmidt's romanticism was not that of the tragic dreamer but that of the tragic hero, and his legacy, bestowed to Mankind, speaks of a man whose drive, decency, dignity and manner were remarkable.

Berzelius and Penfield married late in life. Goldschmidt didn't marry at all. Once, while at Göttingen, he encountered a colleague, Dr. V. V. Schcherbina from Leningrad, who was not married. Goldschmidt said "This is very good because a married scientist is no longer a real scientist." This encapsulates Goldschmidt's attitudes very nicely. His humor, which occasionally bordered on the pessimistic and sarcastic, also conveyed his tendency toward a bittersweet comment on the human condition, sometimes overinclusive, sometimes opinionated. Jungians could spend much time on this remarkable personality. It is my opinion that most of our creative geniuses simply held a set of *priorities* different than the mainstream. Goldschmidt early on announced his goal: "The basic problem of geochemistry is to determine the quantitative chemical composition of the Earth and to find the laws which underlie the frequency and distribution of the various elements in Nature."

Goldschmidt, or V.M. as he was later nicknamed, was an only child, born in Zürich, Switzerland, on January 27, 1888. His father, Heinrich Jacob, was a distinguished physical chemist. In 1905, the father went to the University of Kristiana (later Oslo) and shortly thereafter, the family received Norwegian citizenship. V.M. studied mineralogy and geology under the great W. C. Brøgger; inorganic chemistry under Th. Hiortdahl; and physical chemistry under his father. Brøgger's monograph on Langesundfjord mineralogy, where he named many new species of rare earth (REE) titano-, zircono- and boro-silicates, came out in 1890. For a short period in 1908, V.M.

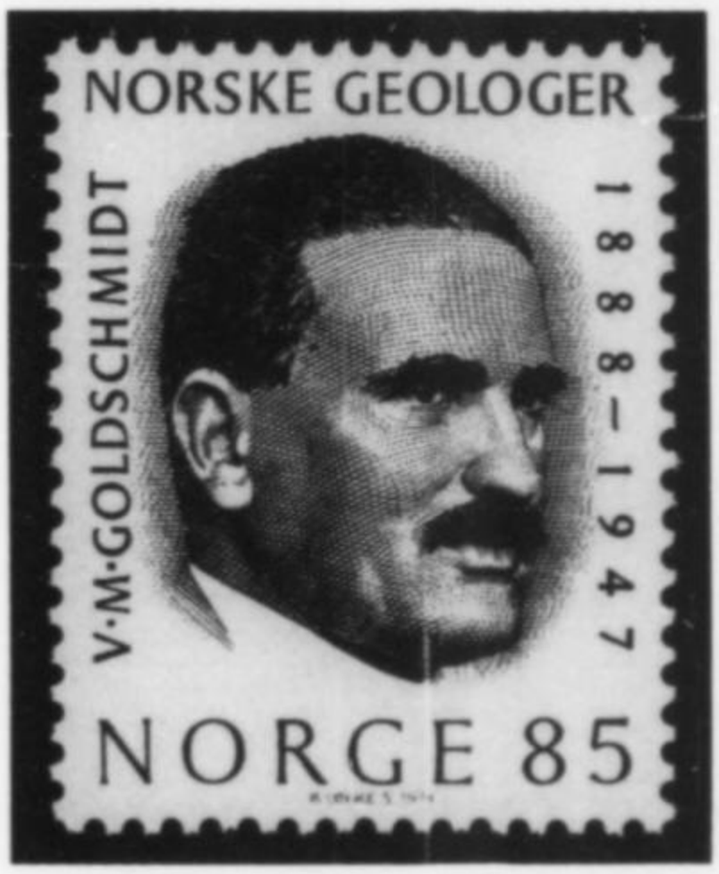

Figure 1. **V. M. Goldschmidt (1888–1947) featured on the 85 øre stamp issued around 1974. This was one of a series of Norwegian geologists thus honored, including Goldschmidt, J. H. L. Vogt, Th. Kjerulf, and W. C. Brøgger.**

studied optical mineralogy under F. Becke in Vienna, and chemical crystallography under P. von Groth in Munich in 1911, receiving his Doctorate in the same year. In 1914, only 26 years old, V.M. was appointed Full Professor and Director of the Mineralogical Institute, University of Oslo. This culminated from his enormous treatise on the contact metamorphism of the Kristiana (Oslo) region, and formed the basis from his years of field study, of his famous "mineralogical phase rule," whose roots are found in the thermochemical phase rule of J. Willard Gibbs.

In this first period of V.M.'s development, several early papers appeared which displayed his wide range of interests, from pyroluminescence in quartz to extensive studies on contact metamorphism in the Oslo region wherein he regarded the entire Earth as a large physicochemical system. Later, the Norwegian government appointed V.M. to appraise Norway's mineral resources, laying the foundation for his later development of geochemistry. Geochemistry was espe-

*This is the third of three parts originally delivered as a lecture. Ed.

cially fertile in Russia; V. I. Vernadskii pioneered in biogeochemistry, or the distribution of elements in plants and animals, and A. E. Fersman pioneered in pegmatite geochemistry, subjects which later were to elicit great interest in V.M. During this period in Oslo, he outlined experiments and observations toward establishing the foundations of geochemistry.

One key problem was the partitioning of elements between coexisting vapor and liquid, and in immiscible liquid phases. From this model could be related partitioning of elements in molten iron, iron sulfides and coexisting fused silicates—a common association in certain meteorites. And from this model, *siderophile* elements (including rare crustal elements such as Au, Ni, Co) associated themselves with the metal melt, *chalcophiles* with the sulfide fraction, and *lithophiles* with the silicate liquid as a logical conclusion. Terms to come later included *atmophile* elements in the primordial atmosphere and *biophile* elements in organisms. In an analogy to steel-making, the shells of the Earth included siderosphere, chalcosphere, lithosphere and atmosphere. He noted that alkalies, alkaline earths, Si, Al and Ti concentrated in the lithosphere, and that the first and second transition series metals appeared in the siderosphere. Some of these conclusions were inferred from meteorite samples, and from the blast furnace industry.

The key principles were ionic size and charge, not weight, in the formation of substitutions and replacements in crystals called *solid solutions*. For example, Mg^{+2}, Ni^{+2} and Fe^{+2} have similar radii, but Ni^{+2} substitutes first in forsterite (Mg_2SiO_4) crystals in a melt, followed by Fe^{+2} because Ni^{+2} more closely matches Mg^{+2} in ionic size than does Fe^{+2}. Regarding ions of nearly the same radius but different charge, say Sc^{+3}, Mg^{+2} and Li^{+1}, scandium substitutes first and later this is followed by Li^{+1}. This he explained by the ion with greater positive charge being more attracted to a negative anion-coordinated site. Other examples of substitutions which V.M. brought to light include (Al^{+3}, Ga^{+3}), (Zr^{+4}, Hf^{+4}) and the familiar REE^{+3} or lanthanides for Na^{+1} and Ca^{+2}. The ions in each combination all have similar radii. When minor ions frequently substitute for more abundant ones, V.M. called this camouflage. It was a valuable contribution to locating ores of common minerals from which minor elements could be extracted, e.g., Ni in olivines and Ga in bauxite. V.M. proposed model structures with desired properties, dictated by interatomic distances in the crystal, ion charges and the structure type. Such properties as optical refraction, melting point, solubility and hardness were predicted in this way. Small cations with high charge form hard oxide crystals, with high melting points. Before this period, Goldschmidt wrote that crystallography was "a purely descriptive auxiliary science which made possible the recognition and distinction of crystalline materials, whether they were minerals or technical products."

In 1929, V.M. received a call from Göttingen to head up the Mineralogical Institute. Göttingen had a magnificent history in science, stretching from Gauss to Hilbert and including his contemporaries James Franck and Max Born, both Nobel prize-winning physicists. The free exchange of ideas was welcome to him since he was relatively isolated in Oslo, and the next four years were perhaps the happiest and most productive in his life. The monumental *Geochemische Verteilungsgesetze der Elemente* (Geochemical Partition Laws of the Elements), volumes I to IX, a total of 600 pages, extended from 1923 to 1937. It was perhaps V.M.'s single greatest achievement; all the fundamental laws of crystal chemistry and geochemistry are found within it.

By nature, V.M. was a pessimist and was often shy and difficult to approach. He was given to an occasionally sarcastic to macabre sense of humor, which explains certain quotations attributed to him, and reflects his lifelong experience as a Jew in non-Jewish ("Aryan") countries. His feelings of persecution took on an almost paranoid quality.

His standards in science were of the highest caliber. In Göttingen, this benevolent autocrat required daily reports on progress by his 10–15 assistants and students. Projects with poor logic were strenuously criticized. An assistant with a hangover was criticized by silence. A man of strong likes and dislikes, he adored animals and had a veritable zoo in his one-story home, with cats, birds, squirrels, a toad and a family of bats. Names were given to each, usually honoring living or deceased persons he disliked. His admiring assistants and collaborators eventually became outstanding scientists and industrial leaders themselves.

His interests in biogeochemistry were amplified by discoveries of high concentrations of Be, B, Ge, Co, Ni, As and Pt in the ash of coals and petroleums. His major tools were carbon arc emission spectrography, X-ray diffraction and X-ray spectroscopy (forerunner of the electron probe). The vast field of biogeochemistry is still a wide-open territory with many questions. V.M. was most reluctant to publish hasty or poorly researched conclusions. He remarked, "Make two thousand experiments, and then you have your theory and can publish both." Always very sensitive about any inadequate citation of his work by others, his standards and desire for conciseness sometimes were overwhelming. He admonished his students, since he loathed writing long-winded papers: "Write as concisely as a Scotsman if the manuscript were to be sent by telegram." The greater effort at Göttingen was devoted to systematic study of the geochemistry of the minor elements such as Ga, Ge, Sc, Be, B investigated one by one. He even began studies on isotopes of certain elements by mass spectroscopy, a key contemporary geochemical instrument.

The Nazi takeover in 1933 almost shattered V.M. His humor took on a grim quality. Surprisingly little protest arose by most intellectuals against the Nazi attacks on science and the arts. Harrassed and belittled, V.M. would reply to a "Heil Hitler" with "Grüss Gott," the South German salutation. In 1935, he resigned and fled back to Oslo, penniless since the Nazis confiscated his belongings and substantial sums of money in the banks. Ironically, V.M. lived on Wagnerstrasse. As an aside, his courageous and bold successor at Göttingen wrote a strong letter to Hjalmar Schacht (who was born Horace Greeley Schacht in the USA), President of the German Reichsbank. In due course his bank accounts were transferred back to Oslo. Time was precious. Helping refugees, avoiding compromise of his non-Jewish friends, building up a laboratory yet again, his health steadily deteriorated. The caustic, bleak humor reached monumental proportions. In addition, his beloved father died. One day, P. Rosbaud accompanied him on a visit to the family crematorium in Oslo. There were urns made of Norwegian olivine, two with ashes of his parents, the third reserved for him. V.M. said bitterly, "Ja, Ja, the whole family in magnesium orthosilicate."

But the worst was to come. After the Nazi seizure of Norway, V.M. was scheduled for the concentration camp and subsequent liquidation, the first because he was a Norwegian intellectual, the second because he was a Jew. Prior to this and during the Nazi takeover while he was in Göttingen, he carried an ampule of KCN just in case. In fact, earlier in Göttingen, he arrived at the Institute with his hair cropped unusually short. When a colleague remarked, he replied, "So dass es ist besser zu rollen" (so that it will roll better). A Norwegian colleague asked for an ampule. More pessimistic than ever, V.M. grimly replied: "this poison is for professors of chemistry only. You, as professor of mechanics, will have to use the rope." [It wasn't until he was in England that he buried the poison for good.] Arrested by the S.S., his property confiscated, V.M. was sent to a concentration camp in Norway. But the effective Norwegian resistance somehow reached him and he was carted in a load of hay to the Swedish border. From there, he went to the Macaulay Institute in Scotland and worked on his "Geochemistry" (published posthumously) where the staff affectionately nicknamed him "Goldie."

After the war, he went back to Oslo, and two all-too-rare delights were in store for him: being greeted by a former prize student, Fredrik

Figure 2. **Collecting specimens on the Oslofjord, June 20, 1920. V. M. Goldschmidt is on the left. The gentleman wearing a frock coat is Albert Einstein. See Levinson and Sclar (1988). The photo was taken by H. Rosendahl. The print is courtesy of J. A. Dons and A. A. Levinson.**

William Houlder Zachariasen (then at the University of Chicago), and his former maid who provided him with an abundant supply of whale meat. Shortly thereafter, a carcinoma appeared on his leg, a discovery which was followed by several separate treatments. On March 20, 1947, as he returned home from hospital, he suffered an intense head pain and died shortly thereafter.

His concluding words almost represent a paean of triumph and transfiguration: ". . . I am fully convinced that it is my duty towards science and decency to stand firm in continuing my work as long as health permits, thus giving an example to at least some of my junior colleagues. . . ."

V.M.'s background in his intellectual development was practically unique; he should not be confused with Victor Goldschmidt of Heidelberg, the great morphological crystallographer and Charles Palache's mentor. V.M. was the first to experimentally establish the Harkins-Oddo even-odd rule for elements, where elements (in a block such as the lanthanides) of even atomic number are more abundant than those of odd number. This was geochemically established through spectrographic analysis of minerals containing the fourteen (La-Lu) lanthanide elements. V.M. was the first investigator to evolve working lists of ionic radii and determine fundamental structure types. For this, he utilized the marvelous development of crystal chemistry after the fundamental X-ray diffraction studies of Laue and the Braggs in 1913. Relative abundances of minor to trace elements were determined by carbon arc emission spectrography. These powerful tools are used to this day in various refinements and modifications. In fact, nearly every aspect of crystal chemistry and geochemistry can be traced back to V.M.'s fundamental discoveries and principles.

Two interesting papers never made it to the printer. The first was evidently not laden with "two thousand experiments" and the second he considered not a particularly dignified subject. One paper concerned the primordial condensation of hydrocarbons and other carbon-bearing molecules, the organic molecules. The second was another foray into biogeochemistry, the study of *album Graecum* or dog feces. Dog feces, rich in phosphates (after all, dogs chew bones), gradually develop a white coating with time as relatively soluble alkali phosphates are converted into more insoluble alkaline earth phosphates.

It appears that V.M. had his early announced goal in mind, and what a labyrinthine goal it turned out to be!

This concludes my submission of personae whom I consider the greatest contributors to mineralogic science. Not one exemplified a common, secure and uninteresting *bourgeois* life. All were quirky. It is this quirkiness which marks the individuals of unusual creativity, the lonely galley slaves of Life whom we have come to call geniuses—and therefore they had to set sail alone.

I offer a small list of references from which most of the factual material can be found (caution! as in all references, contradictions will be found) and I thank Prof. Denis Shaw of McMaster University for so generously providing me with valuable source material. It is all-too-often forgotten that *access* to information is much easier than *retrieval* of that information, and that retrieval often involves other compatriots in the same zealous research.

I trust the National Science Foundation will accept my thanks for the small sums which went into this entire project, which was outside my program of research.

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The ORIGIN *of* FADEN QUARTZ

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Faden crystals are those which contain a milky, string-like zone passing through them. These crystals share a common and unusual origin, and the story of the way they formed provides an interesting view into the complex world of crystal growth.

INTRODUCTION

The defining characteristic of faden quartz crystals is the presence of a white thread-like or string-like zone, which passes through their interior, usually near the center. The term is from the German *Faden* (plural: *Faden,* pronounced "fah-den"), which means "thread."[1] Faden quartz crystals are usually tabular due to uneven development of the prism faces. The faden not only give these crystals their name, but play a central role in their formation.

Faden quartz crystals are typically found in low-grade metamorphic rocks produced by mountain building. The crucial characteristic of the environment of growth is a tectonic setting in which fissures are created and gradually widened. Faden quartz is generally associated with the alpine mineral assemblage, which typically includes albite, adularia, calcite, chlorite minerals and anatase (Campbell, 1927). This assemblage is characteristic of low-temperature metamorphic environments; most of the components of the minerals are leached from the surrounding country rock during metamorphism. Ramsay and Huber (1983) suggest that the temperature of faden formation is not higher than 350° C; it may be considerably lower. Faden quartz is apparently not found in other settings in which more typical quartz may be common, such as pegmatite veins or cavities in sedimentary rock. The localities for faden quartz are numerous, and the list in Table 1 is undoubtedly incomplete. Examples of faden quartz crystals are easily found in dealers' offerings and in older collections, but they have generally been regarded merely as interestingly distorted quartz crystals, and the presence and significance of the faden have been overlooked.

The recognition that faden quartz crystals all have a common mode of growth can be traced back at least to 1864, when Scharff explained the faden (incorrectly) as the traces of a foreign mineral upon which the quartz grew (Stalder-Scherrer, 1972). In 1946, Laemmlein published (in Russian) the first essentially correct and complete interpretation of the origin of faden quartz. However, his interpretation of these crystals has remained largely unknown outside of Russia. For example, it was not included in the third volume of Dana's *System of Mineralogy* (Frondel, 1962), although other works by Laemmlein are cited, and Figure 38 of that volume may be an example of a faden quartz crystal. A German-language translation of Laemmlein's article was published in 1972 in *Schweizer Strahler* (Stalder-Scherrer, 1972), with the comment that the translation would make German-speaking collectors more aware of these crystals. Rykart (1977) added his observations in an excellent article in the same journal, and some information is also to be found in his book *Bergkristall* (Rykart, 1971). However, to date the only mention of faden quartz in English, as far as I have been able to ascertain, has been a couple of notes in *Mineral News* in 1987. Inquiries of people well versed in the mineralogy of quartz indicate that the origin of these interesting crystals is as little known in the English-speaking world today as it was to German-speaking collectors before 1972. This paper summarizes the works of Laemmlein (read in the German translation) and Rykart, and adds some further observations based on my research on faden quartz crystals during the last several years.

ORIGIN OF FADEN STRUCTURE

During episodes of mountain building in which the dominant tectonic forces are those of lateral compression (for example, as two tectonic plates collide), the rocks are folded and metamorphosed. Rocks which are more readily deformed "flow" away from the direction of maximum compression, by a combination of processes which include recrystallization and grain deformation. Cracks or fissures often form, particularly in rocks which are more resistant to deformation. These fissures gradually open in directions perpendicular to the maximum tectonic stresses. They enlarge and become filled with minerals like calcite and quartz (as the fissure opens, or later). In some cases, this process leads to simple veins filled with massive calcite or quartz. Given the right balance between the rates of fissure widening and of mineral growth, however, the minerals can develop as parallel fibers oriented perpendicular or oblique to the vein walls. Several genetic types of fibrous vein fillings can be identified. The

[1]The term "faden" is used here alone to refer to the "thread," either singular or plural, and "faden crystal" to refer to the larger crystal which contains the "thread."

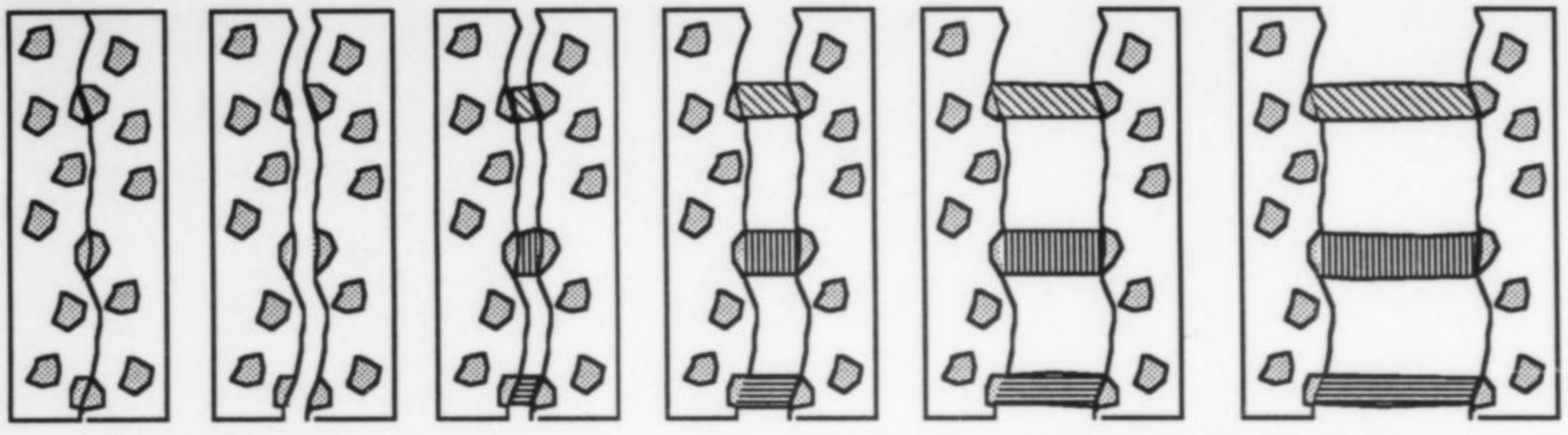


Figure 1. **Faden develop by repeated cracking and healing of grains in the country rock, which are broken and exposed when the fissure gradually widens.**

type known as "stretched crystal fibers" appears to best explain the development of faden. According to the stretched crystal fiber hypothesis, when the rock first fractures, crystal grains are broken, and new material may be deposited to fill the opening. The existing grains control the orientation of new mineral growth, which is deposited in crystallographic continuity with these "host" grains. This process of cracking and healing of the individual grains is repeated many times, with deposition following the crystallographic orientation of the original grains. If the rate of deposition of new mineral material is not exceeded by the rate of fissure widening, the eventual result is a series of fibrous crystals which connect the ends of the original grains and span the vein. The boundaries between these fibers are all parallel to each other, but the crystallographic orientations of the fibers are random. For a more detailed discussion of fibrous vein fillings, see Ramsay and Huber (1983, 1987).

Faden are special examples of fibrous vein fillings, in which the fibers are not in contact with each other. It is unclear whether the space between was originally filled with fluid or with another mineral such as calcite, which later dissolved away. The development of faden by the crack-and-heal process described above is illustrated in Figure 1. Faden may develop because the country rock had only isolated grains of the vein-filling mineral, because many of the grains were too weakly cemented into the country rock to be broken when the vein opened, because growth on some grains was too slow to keep up with vein opening, or perhaps for other reasons. While faden quartz is best known, faden albite, adularia and epidote have also been reported (Martin, 1970, 1971).

DEVELOPMENT OF THE FADEN CRYSTAL

The second and final stage in the development of a faden crystal apparently takes place during a subsequent, tectonically less active period when further growth of the crystal can occur without the frequent fracturing which developed the faden. In what is probably a slower process, more growth occurs on the exposed surfaces of the faden, or crystal fiber. Because the faden is a single crystal fiber, the overgrowth is also a single crystal. However, because the nucleus is

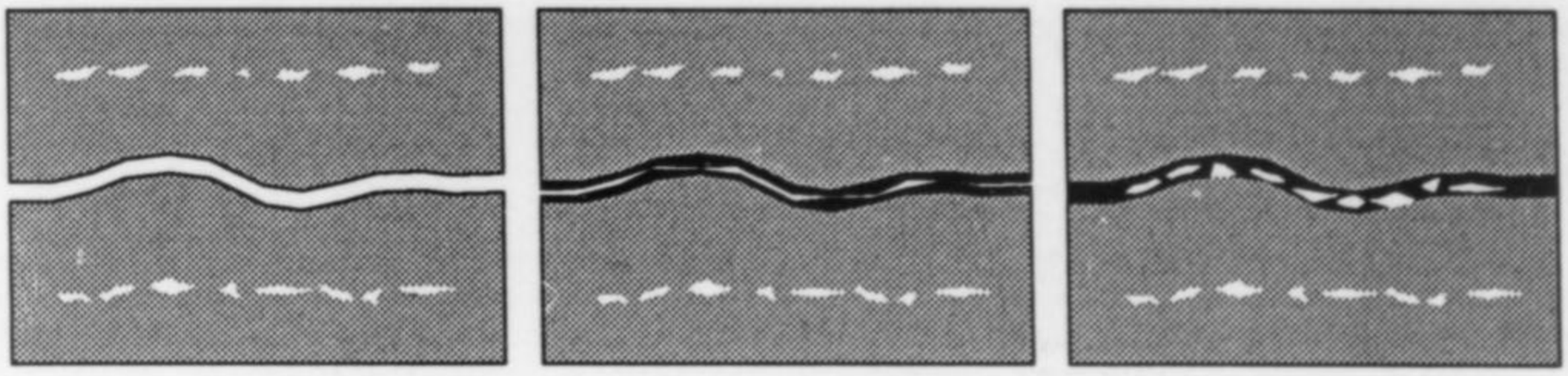


Figure 2. **Cracks in the developing faden heal unevenly, leaving regions of trapped gas and liquid which make the faden visible. Three stages in the healing of a new fracture are shown. New quartz is shown in black, old quartz in grey, and trapped fluid inclusions are shown in white. Two zones of fluid inclusions remaining from earlier cracks are also shown. The direction of vein opening is vertical, and only a small part of the length of the faden is shown.**

a linear feature, the resulting crystal is distorted, "stretched out" in a direction parallel to the faden. During this relatively peaceful period of growth, most of the crystal's volume is deposited.

The faden remains visible as a white "thread" in the middle of the crystal because the fractures do not fully heal as the faden develops. Deposition of new material on a crystal takes place most rapidly at the edges of the crack (Fig. 2), and generally seals the crack before the core of the crystal heals completely with new quartz. As a result, the portion of the crack which transects the crystal core usually remains as a thin zone of fluid-filled inclusions, which typically contain both liquid and gas. The visibility of the faden is due to this parallel series of fluid-filled inclusions, as the thin section shown in Figure 3 demonstrates. It might be noted that the faden type of growth may well have produced countless additional crystals which, due to being turbid throughout, cannot be recognized as faden crystals.

Faden quartz crystals which have formed according to this basic model should have several characteristics: they should contain one (and only one) faden each, they should span the fissure in which they occur, and, while the faden should be parallel to each other, the crystals which contain them may have different degrees of distortion and point in different directions. If the crystals become detached from the fissure walls after growth, there will be a scar at each end of the faden, where the crystals were attached to the faces of the fissure. This simple model is represented in Figure 1, and an example is shown in Figure 4.

Nature is always more complicated than the models we use to explain it, however, and many variations on this basic model are found. Some of these, and their implications for the habit of the resulting faden quartz crystal, are discussed below.

Detached or Interrupted Faden

In a particular fissure, some or all faden may be interrupted, leaving two fibers pointing at each other with a gap between. Each may grow into a larger crystal, but the two crystals may not grow enough to span the gap. These crystals differ from the model in that one end of the faden is exposed, and the crystal will grow over and beyond it. The result is a faden crystal with only one scar and with a faden which does not reach the surface at the other end. Similarly, faden may become detached from both fissure walls before or during the second stage of growth, and may continue to grow as "floaters," suspended in clay or in calcite. Such crystals have no attachment scars. They may at times grow into each other, giving crystal groups with non-parallel faden.

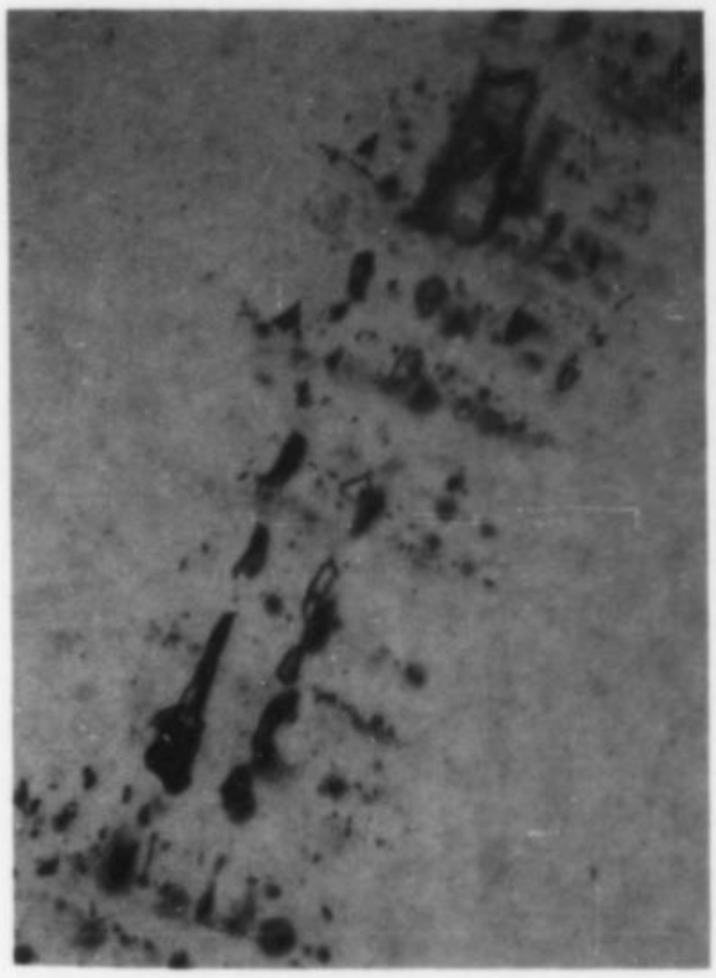


Figure 3. **Microphotograph of a faden, showing the liquid and gas inclusion zones which make the faden visible. The gas bubbles are often extremely small, and are only visible at high magnification.**

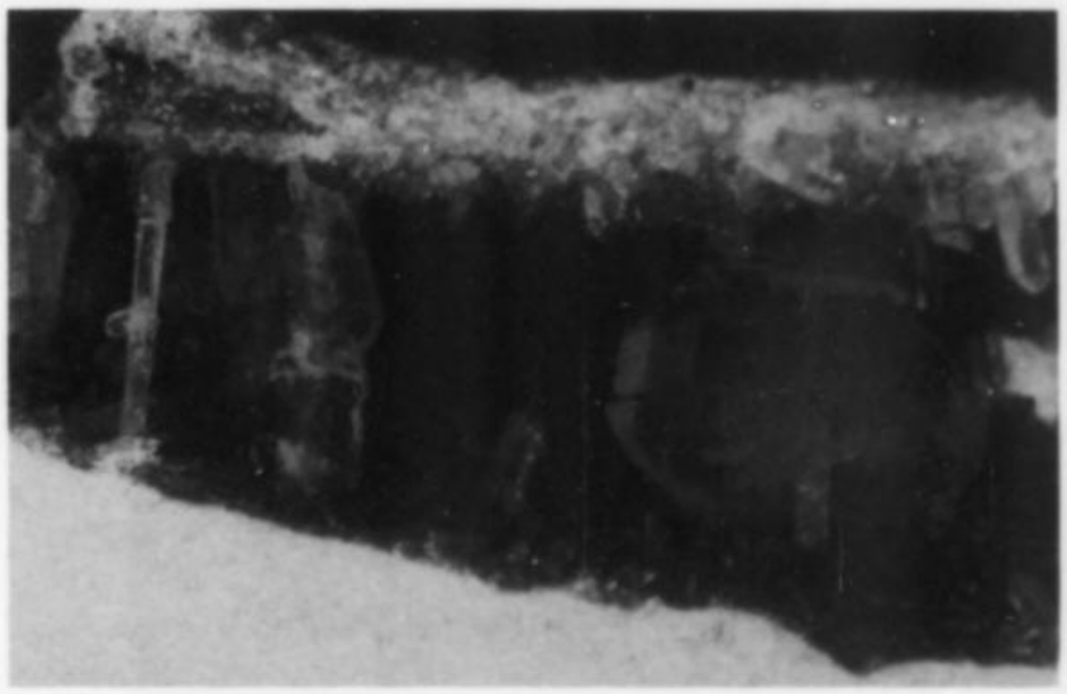


Figure 4. **Faden crystals spanning the vein in which they developed. The specimen is from Piz Sardona, Glarus, Switzerland. Walter Böniger collection; photo by Erich Offermann.**

Rejuvenated Faden

The simple model separates faden quartz development into two stages. However, some overgrowth (stage 2) may form on the faden during a period of quiescence, after which further tectonic activity may cause renewed crack-and-heal development involving the entire crystal. After a final stage of peaceful growth, the resulting crystal will have a well-defined faden, but with occasional zones of cracks

which considerably exceed the dimensions of the faden. Such a crystal is shown in Figure 5.

Polycrystalline Aggregates

Frequently faden crystal groups are found which are composed of intergrown distorted crystals. In some cases these groups result from overgrowths on several faden spaced closely enough that the crystals grew into each other at the overgrowth stage. In other cases, the crystals all meet along a common axis, indicating that they developed from a single, polycrystalline faden, which undoubtedly resulted from a polycrystalline zone broken during the original vein formation. Other mechanisms may also exist.

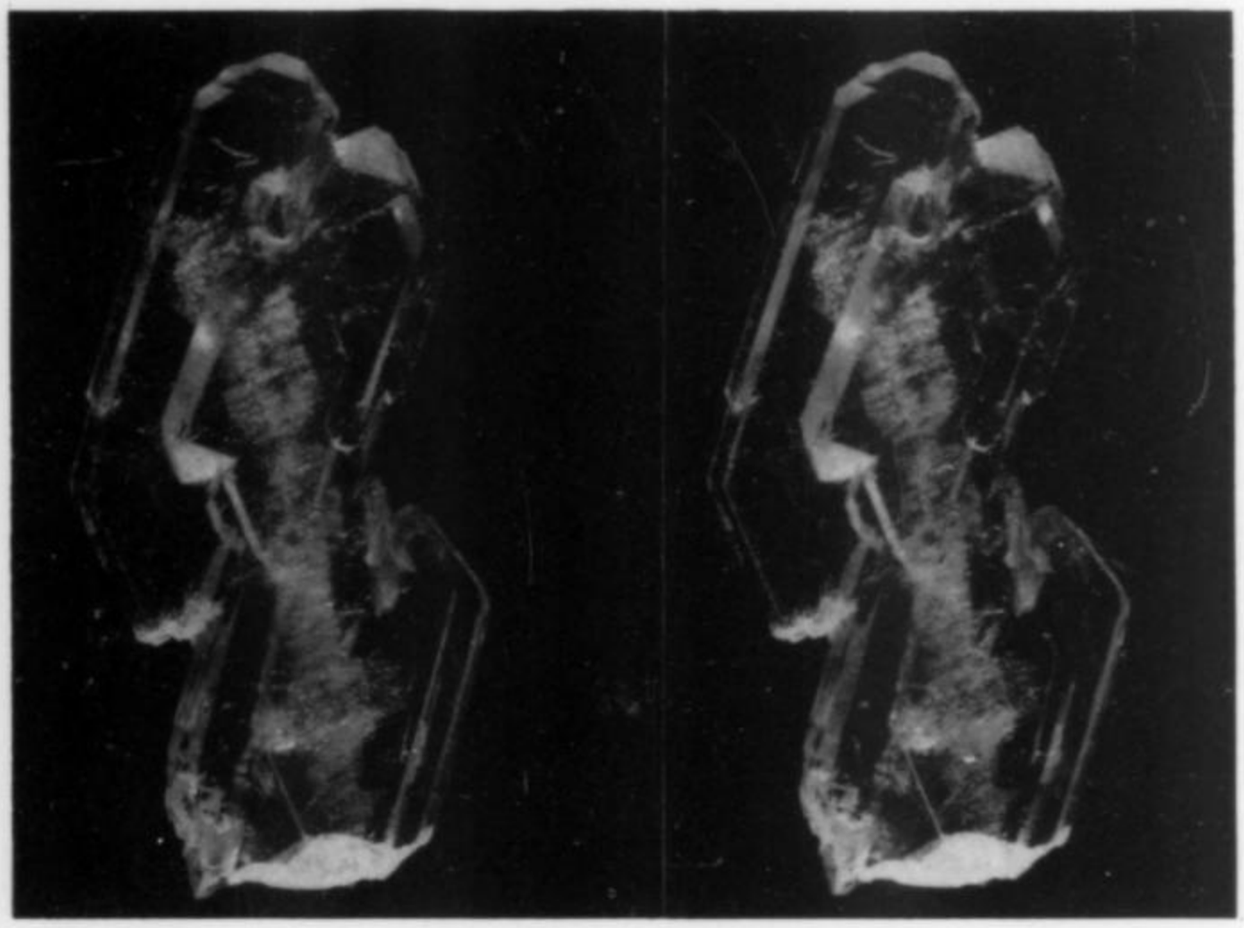


Figure 5. **A faden crystal showing rejuvenated cracking, from Windsor, Quebec. Length of the crystal, 9 mm. Eric Offermann photo; RPR specimen #1619.**

Mosaic Texture and Curved Faden

Development of the fissure can be described in terms of four different types of motion, each of which can have an effect on the shape of the faden and its orientation to the fissure walls. The dominant type of movement is extension, which involves movement perpendicular to the fissure walls (Fig. 6a). Shearing is movement parallel to the fissure walls (Fig. 6b). Rotation is movement about a hinge which lies parallel to the fissure walls (Fig. 6c). Twisting is rotation of the two walls in opposite directions about a line perpendicular to the fissure walls (Fig. 6d). Shearing and rotation can include sustained movement in one direction or about one hinge, as well as many small, random steps with different directions or hinges. Twisting is usually limited to small steps which do not produce a systematic effect.

If the process of fissure widening and faden development takes place by pure extension, the faden and the crystals which grow over them will be internally undistorted, and the faden will be perpendicular to the fissure walls. If shearing is consistently present, the crystals

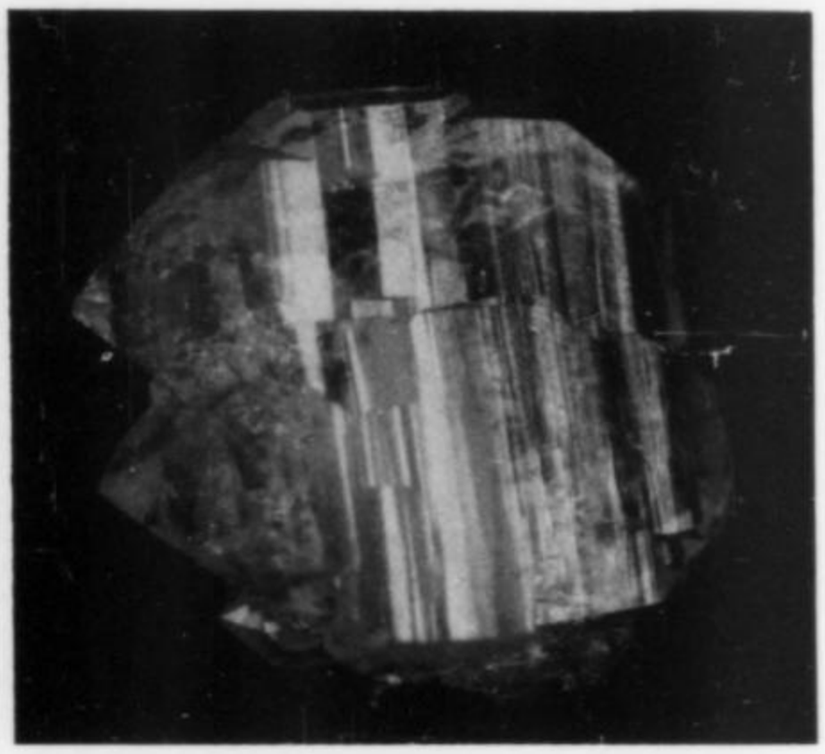
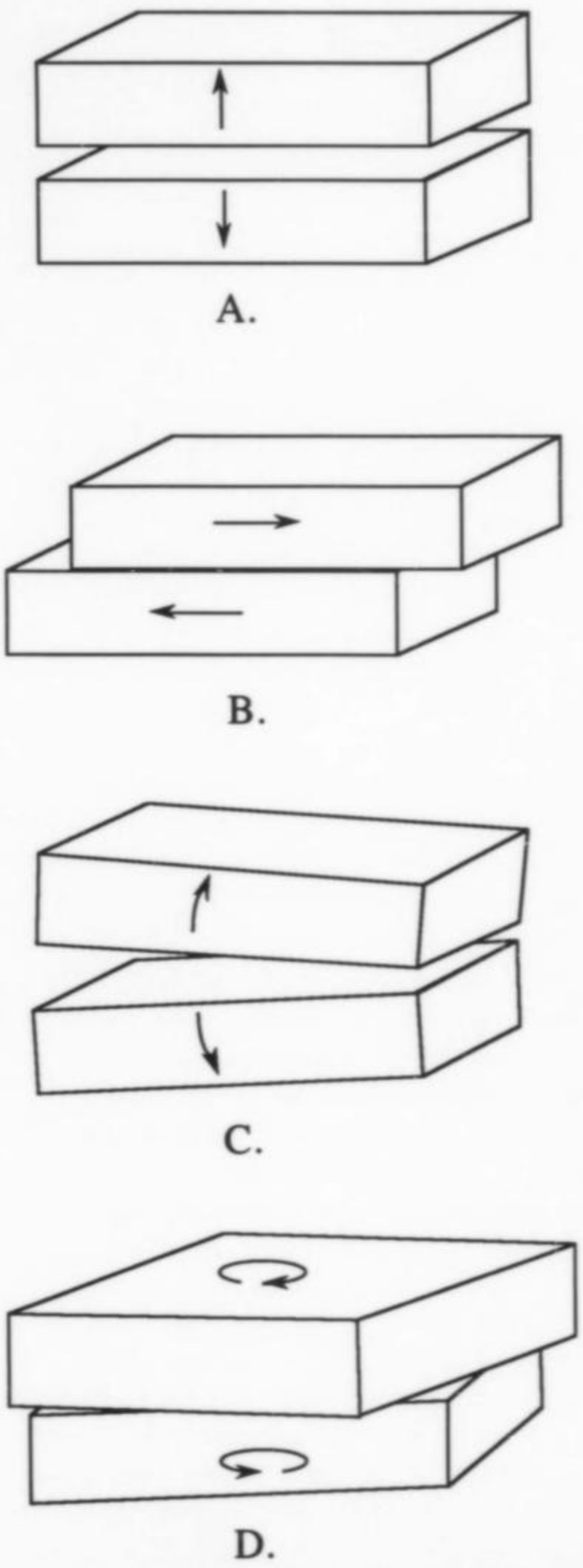


Figure 7. **Mosaic structure seen in light reflected from the surface of a faden crystal from Piz Beverin, Graubünden, Switzerland. The mosaic structure is due to distortions of the faden's crystal structure, which lead to overgrowth on different parts of the faden which are not in precise alignment with each other. The crystal aggregate is 3 cm long. RPR photo and specimen #1444.**

Figure 6. **The four possible modes of movement in a widening fissure. A: extension, B: shearing, C: rotation, D: twisting.**



will still be undistorted, but the faden will be inclined to the fissure walls. More often, however, some episodes of movement during fissure development will include rotational motion as well as extension, and when the faden breaks, the opposing faces of the crack will be left slightly out of crystallographic alignment with each other. If the misfit is not great, the crack can still be healed, but with some strain in the newly deposited quartz. When the distortions introduced in this fashion are minor and random, the result is a crystal which is composed of portions slightly out of alignment with each other. The overgrowths on the various pieces will misfit slightly, often leading to interrupted striations on the prism faces, and segments of near-planar faces which reflect light at slightly different angles. This mosaic structure is extremely common in faden quartz, and can be detected to some degree on nearly every specimen. A pronounced example is shown in Figure 7.

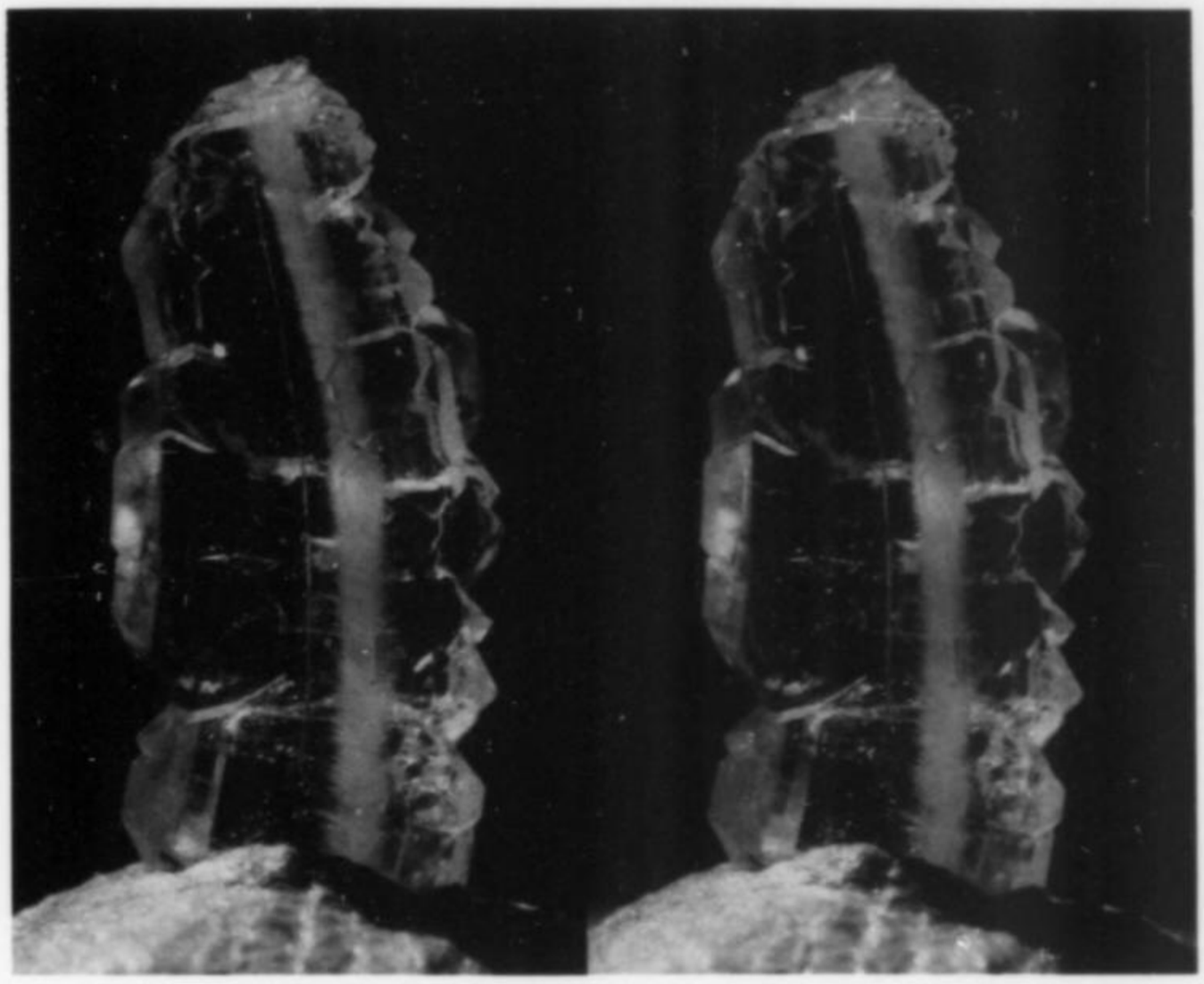
If the widening of the fissure involves pronounced and systematic shearing or rotational movement, or if further movement follows the development of the faden, curved faden can result (Fig. 9). If the widening includes sustained rotation about one hinge, the faden develops as an arc, and the resulting faden crystal will be a mosaic crystal which is distinctly curved (Fig. 8). The direction of cracks in the faden will also change from one end of the faden to the other. Crystallographically bent faden could also result from slight vein compression following faden development, particularly if the faden were supported by surrounding calcite.

If the faden curvature is due to shearing motion, it is possible for the faden to be curved without the crystal having its structure disrupted (Fig. 10). In this case, the cracks in the faden will have a parallel orientation throughout, the overgrowth will not be curved, and the result will be an undistorted crystal surrounding a curved faden. This may seem unlikely to happen, because random breakage would more probably yield an approximately straight faden not perpendicular to the vein walls. One possible model would have the faden fully developed, and surrounded by calcite, then subjected to a shearing episode which breaks the faden in many places simultaneously. Different amounts of movement would have to occur at different points along the faden to produce a curve. Healing and overgrowth could follow later. Alternatively, a curved faden could result if the point of cracking and healing remains the same throughout the faden's development and the shear rate changed over time. Fibrous vein fillings of this sort are common in many rocks and are illustrated in Ramsay and Huber (1983, 1987). Either of these models would explain the systematic shifting of the faden fragments to form the curved faden.

Faden Orientation and Crystal Morphology

In the geometric model of normal crystal growth, a crystal develops from a tiny nucleus, so small that its shape has no effect on the shape of the crystal. Each face grows outward at a rate which is the same as every other crystallographically equivalent face (prism faces all grow at one rate, rhombohedron faces grow at another, etc.). The balance between the different growth rates determines the shape of the crystal. Faden quartz crystals begin the second stage of their growth from the faden, which is nearly a line in a geometric sense. Obviously, the fact that the main crystal growth begins from a line rather than a point will have a significant effect on the final form. Three special habits can be identified. (1) If the faden is developed parallel to the c axis, the resulting crystal is essentially undistorted, but more elongate than a non-faden crystal would be under the same growth conditions. An example is shown in Figure 11A. (2) If the faden is developed perpendicular to the *c* axis and parallel to a prism face, the resulting crystal will be tabular, with two unusually large prism faces. Figure 11N is nearly of this habit, but the faden is not exactly perpendicular to the *c* axis. (3) If the faden is developed perpendicular to the *c* axis and perpendicular to a prism face, and presuming no re-entrant angles developed, a nearly diamond shaped cross section, with two prism faces much smaller than the other four would result. However, since this would require a great deal of deposition on the prism faces not perpendicular to the faden, this idealized form is not often seen, and the four large faces are usually separated into a series of zig-zag alternations of the prism faces, giving a grossly tabular crystal with

Figure 8. **A curved faden crystal, developed from a faden of type B, Figure 9. The crystal is 1.9 cm long, and is from Lenzerheide, Graubünden, Switzerland. Erich Offermann specimen and stereo photograph.**



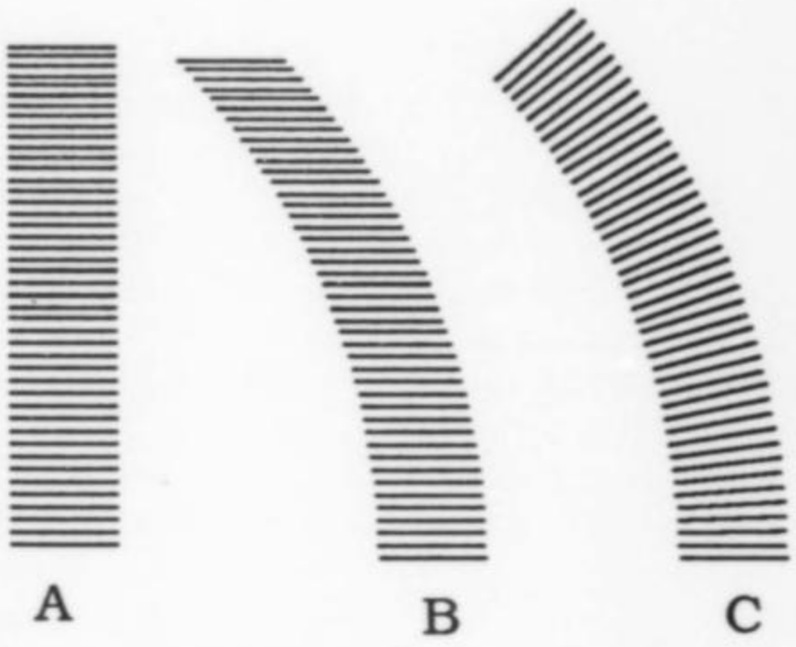


Figure 9. **Three schematic computer-generated faden illustrating two different types of curved faden. A: uncurved faden. B: curved faden created from A by increasing horizontal offsets of each crack in succession, as by a shearing movement. C: curved faden created by successive rotation of the cracks about a common center. The inner edges of both B and C follow the same circular arc. B would give rise to an uncurved crystal, while C would give rise to a curved crystal.**

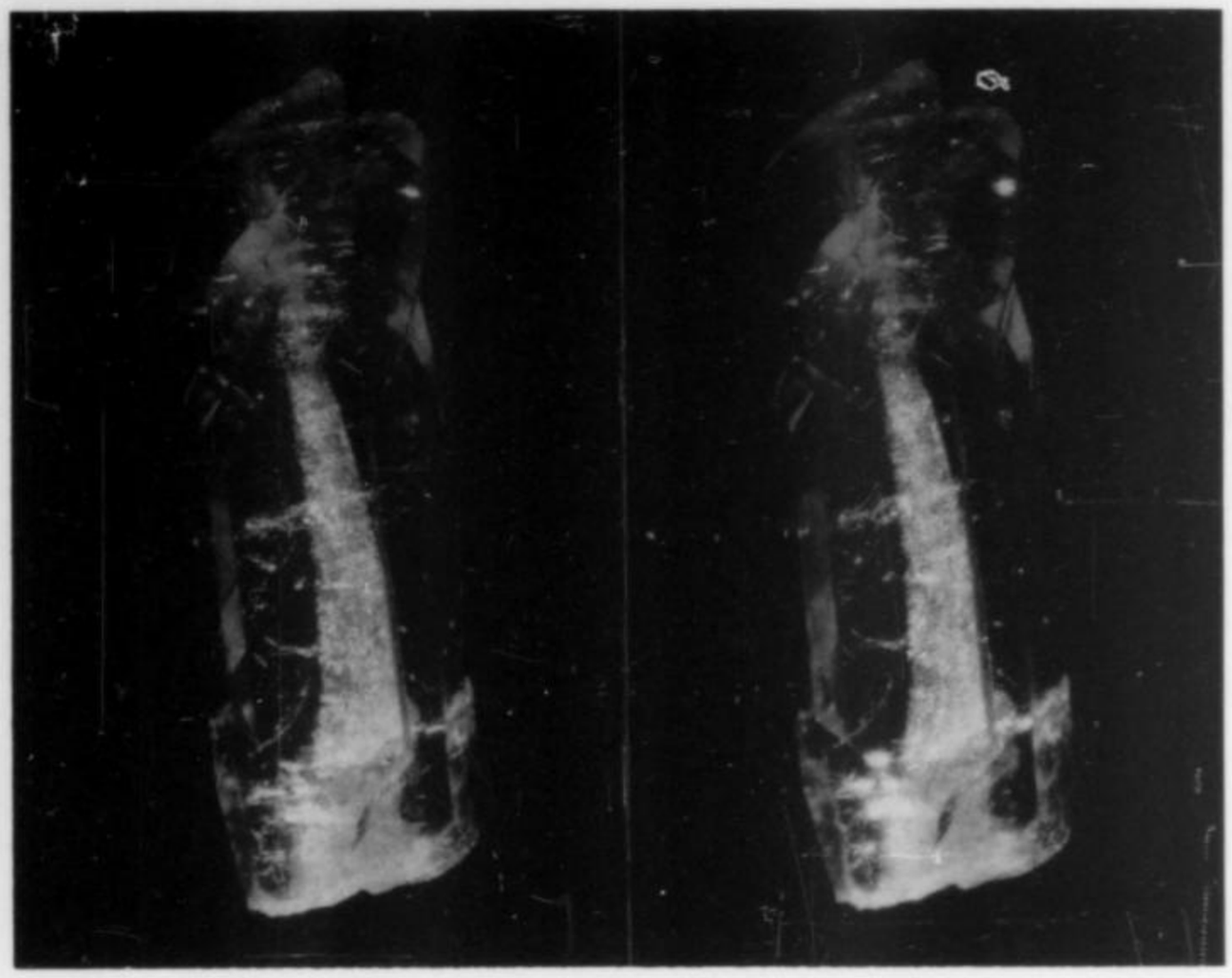


Figure 10. **An unbent faden crystal with a curved faden, from Windsor, Quebec. The crystal is 1.1 cm long. Eric Offermann stereo photograph; RPR specimen #1611.**

two large sets of "washboard" surfaces. Such crystals are not common, but one is shown in Figure 15.

These three orientations are useful for visualizing the effect of the faden on overall crystal morphology. However, there is no reason to expect the faden to be oriented only in these special directions. Faden oriented in directions between these ideal ones result in habits which are compromises between the limiting habit types just discussed (Fig. 11).

Evolution of Faden Habits

Most of the material of the typical faden crystal is deposited in the second, peaceful stage of growth. In this stage, the growth of the crystal gradually accommodates the distortions and irregularities inherited from the stressed growth of the faden, and the crystal evolves toward the typical crystal shape as the size of the overall crystal increases relative to the length of the faden (within the constraints imposed by the size of the vein itself). When second stage growth begins, it is likely to commence at many places along the faden, creating many nearly parallel crystals, each in effect growing from a single point on the faden. If interrupted at this juvenile stage, the faden crystal is characterized by a relatively thin zone of clear second-growth quartz over the faden, and by many reentrant angles where the crystal segments originating at different points along the faden have begun to intersect. In the intermediate stage, further growth tends to fill in reentrant angles and resolve mosaic misfit, producing a faden crystal which looks more like a single crystal, but with some major reentrants. In the mature stage, this smoothing process is complete, and the crystal is typically tabular, but essentially without reentrant angles. If growth were to continue indefinitely, the crystal eventually would become very large compared to the faden, the distortion would become insignificant, and the crystal probably would not be recognized as a faden crystal. This may not happen very frequently, however, since the faden is as large as the fissure opening, and a very much larger crystal would contact both sides of the fissure over much of its surface, and thus not be a well-formed euhedral crystal at all. In Figure 11, crystals H and I are relatively juvenile, crystals G and K are intermediate, and crystals J, L and M are mature in their development. Evolutionary stage accounts for the main difference in the appearance of these crystals, because they all have faden with similar crystallographic orientations.

The evolutionary stages of the faden crystal habit just described are a function not only of the amount of crystal growth, but of the orientation of the faden, the amount of strain in its crystal structure, and the details of the crystal's growth history. Clearly, these many factors can and do combine to produce a vast variety of habits of faden crystals.

Preferred Orientation

Although it has been suggested above that the faden can have any orientation relative to the quartz crystal's structure, there are several ways in which faden with only a narrow range of orientations could occur. Laemmlein (1946) believed that the faden tended to develop perpendicular to certain crystallographic directions, notably $\{11\bar{2}0\}$, $\{11\bar{2}2\}$ and $\{10\bar{1}0\}$, though he gave no reason for this belief.

Rykart (1977) found crystals with faden at nearly every angle to the *c* axis from 0° to 90°, but reported that faden crystals with the "washboard" sides (ideal habit 3 above) were seemingly rare. He suggested this might be because they were not recognized by collectors, but I have also observed them to be uncommon in bulk samples from Windsor, Quebec, in which every quartz fragment was examined microscopically for evidence of faden.

Rykart also reported that the faden in crystals from a given vein or locality sometimes have a preferred orientation, but that the preferred orientation changes from one locality to another. He attributed this to a preferred orientation present in the original grains in the country rock, before the fissure opened. In one fissure at Windsor, Quebec, more than half of the faden crystals had the faden essentially parallel to the *c* axis. In another sample, taken from a vein not 100 meters away, faden parallel to the *c* axis were very uncommon.

Preferred orientation of faden crystals could also occur due to differential growth rates in different crystallographic directions. Figure 12 shows the rate of growth of quartz as a function of crystallographic direction, as determined by laboratory experiments. The lower graph shows the rate of growth on potential crystal surfaces parallel to the *c* axis. It indicates, for example, that growth occurs about 8 times as slowly on the first-order prism faces as it would on a face which bevelled the edge between two first-order prism faces. The upper graph shows the rate of growth on potential rhombohedral crystal surfaces, which have various inclinations from the *c* axis but are all parallel to an *a* axis. The faces of the major rhombohedron *r* grow about 15 times as fast as the prism faces, while those of the minor rhombohedron *z* grow about 20 times as fast. A face perpendicular to the *c* axis would grow about 24 times as fast as the prism face. It should be remembered that growth on a face means adding new crystal layers to that face.

The important point for the development of faden is that there are great differences in growth rates in different crystallographic direc-

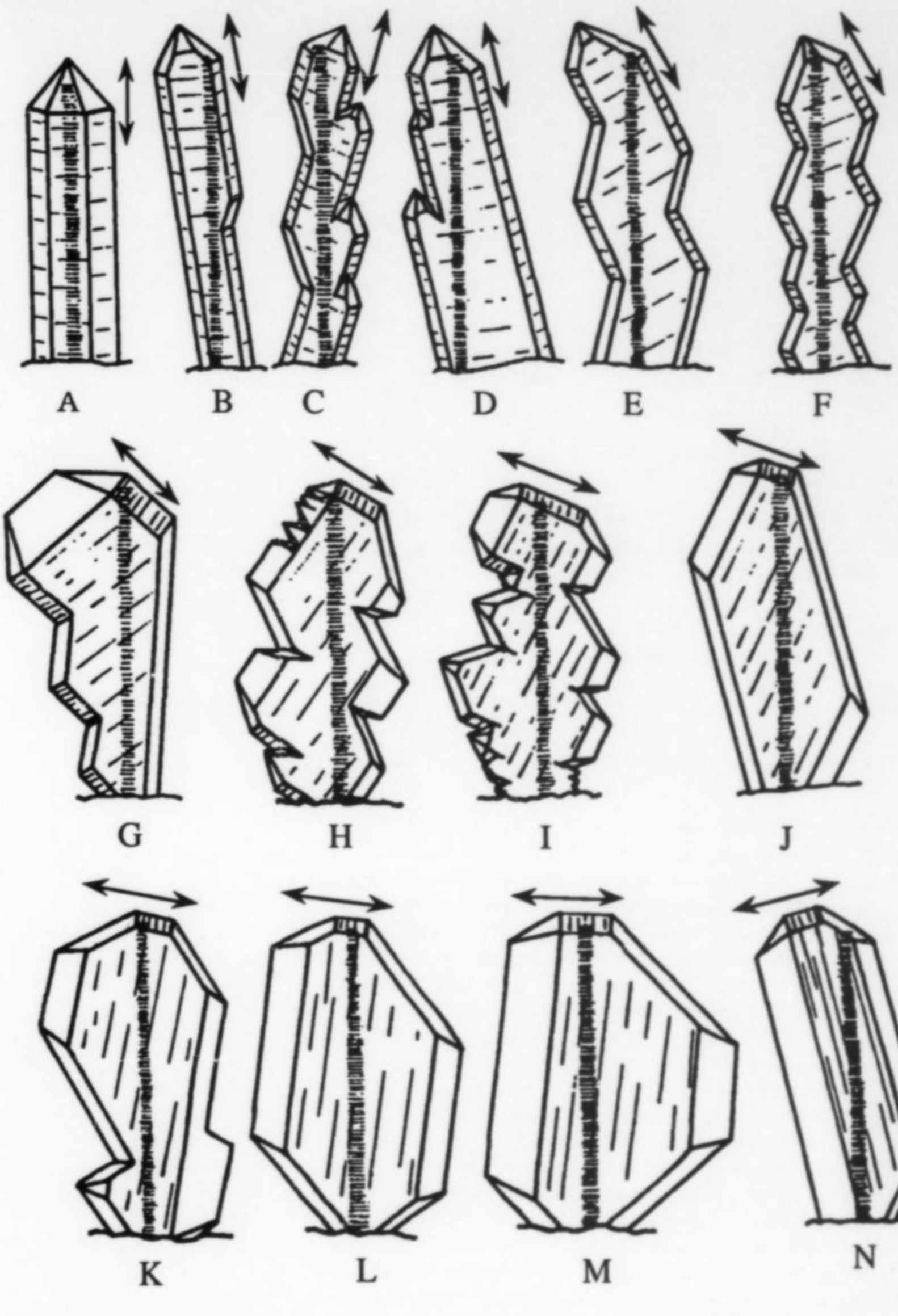


Figure 11. **Drawings of a number of tabular faden quartz crystals from Switzerland, illustrating the range of habit produced by different combinations of faden orientation and habit evolution. The faden is the vertical shaded line in each crystal drawing. Prism faces can be identified by the light parallel lines which signify striations. The arrows indicate the orientation of the *c* axis of each crystal. Slightly modified from Rykart (1977).**

tions. In order for a faden to develop, the cracks which form during fissure widening must grow closed again by addition of new crystal layers. These cracks will have different crystallographic orientations on different faden, and as a result cracks in different faden will grow closed at different rates. If fissure widening occurs too rapidly or precipitously, none of the cracked grains will be able to heal across the gap, and faden crystals will not develop. If fissure widening occurs slowly in comparison with the crystal growth rate even on the prism, faden can develop with any crystallographic orientation. However, if the rate of fissure widening is in the same range as the rate at which faden can heal, faden oriented along faster-growing directions in the crystal might be able to remain intact, while faden oriented along slower-growing directions might become interrupted or fail to form in the first place. This selective process would result, in mild cases, in the failure of faden to develop from grains with cracks approximately parallel to the slow-growing prism directions. These failed faden would have produced crystals of habit 3, which in fact are observed to be uncommon. In more extreme cases, the selective process would allow only the fastest growing faden to survive, and these would be faden which are parallel or nearly parallel to the *c* axis. Some collections of faden crystals from single veins are characterized by a strong predominance of crystals of this type.

TESTING THE HYPOTHESIS

The explanation presented above for the origin of faden crystals is coherent and explains many observed features. However, there has been no convincing evidence that the faden was indeed the center of growth, and a skeptic might reasonably argue that the explanation

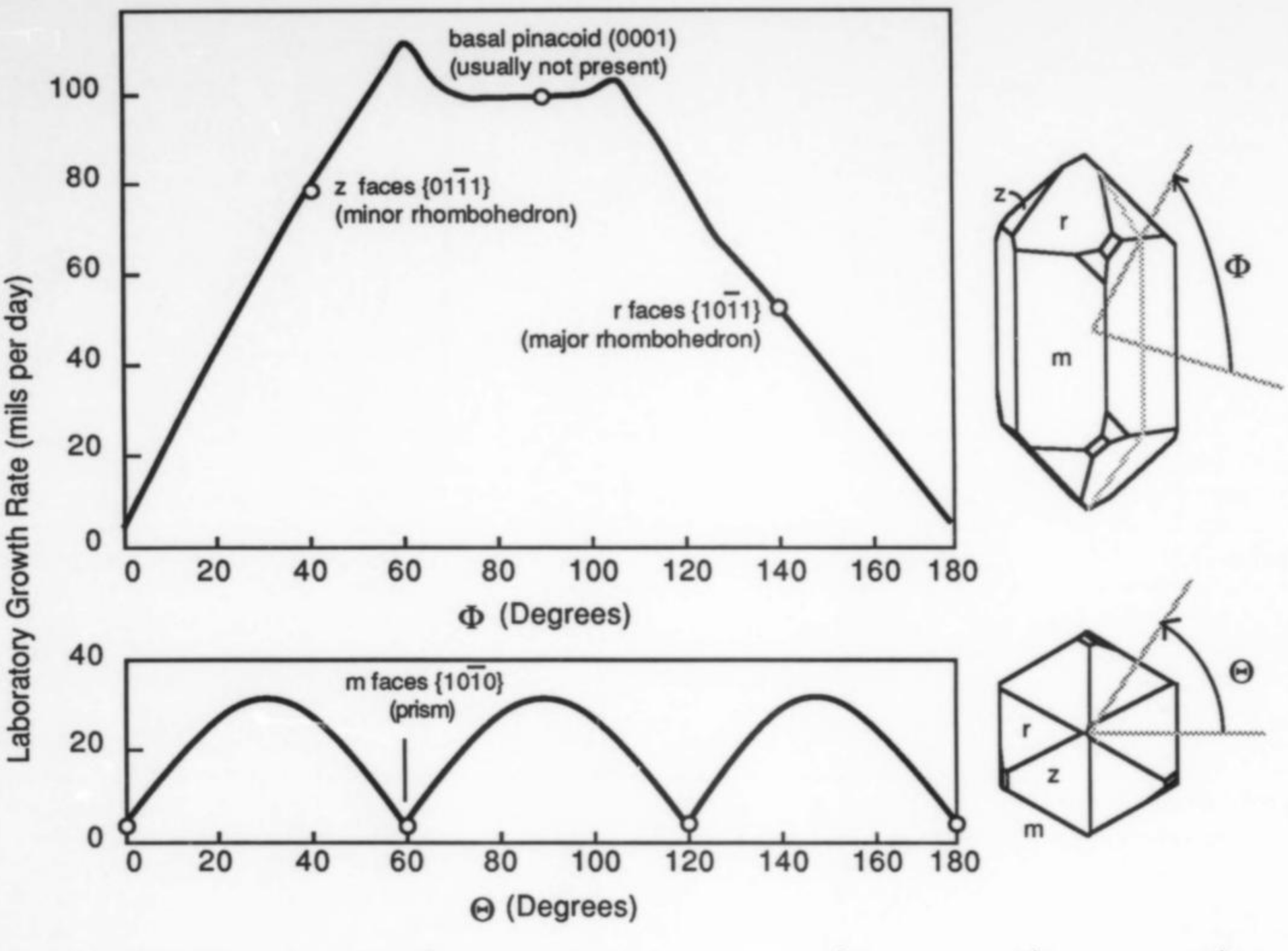


Figure 12. **Growth rate of quartz in different crystallographic directions, after Nassau (1980, p. 124). Open circles mark the positions of special crystallographic planes, mostly common faces of quartz. Upper diagram, variation of growth rate with vertical orientation, in a plane which includes the c axis and is perpendicular to a pair of prism faces. Lower diagram, variation of growth rate with horizontal direction, in the plane perpendicular to the c axis.**

was rather complex and required a lot of cooperation from nature to work. The evidence cited by previous workers includes the fact that faden are generally more or less in the middle of the crystal; observations of faden crystals still in place spanning fissures, and with the faden parallel; faden coated with chlorite, indicating that they grew earlier than the rest of the crystal, and the stages of habit evolution described above. In thin section, the increase in mosaic structure and strain in the vicinity of the faden suggest it was the center of growth, and satellite crystals are sometimes observed attached to the faden, but engulfed by the growth of the main crystal. Furthermore, polycrystal groups often share a single faden, which is located at their intersection, a strange coincidence if it is not the growth origin. Finally, single crystals with multiple faden have not been observed (but would be expected, for example, if Scharff's epitactic hypothesis were valid). While none of these observations directly and unambiguously reflects the growth process, and so cannot prove that the faden was the center of growth, the circumstantial evidence is convincing.

One could detect the growth history of a faden crystal either from a series of concentric shells, or "phantoms," or from the boundaries of regions of the crystal which were deposited on different faces (Fig. 13). In the case of phantoms, oscillations in trace element chemistry might show sequences of growth. At sector boundaries, systematic differences in the incorporation of impurities by different faces (sector

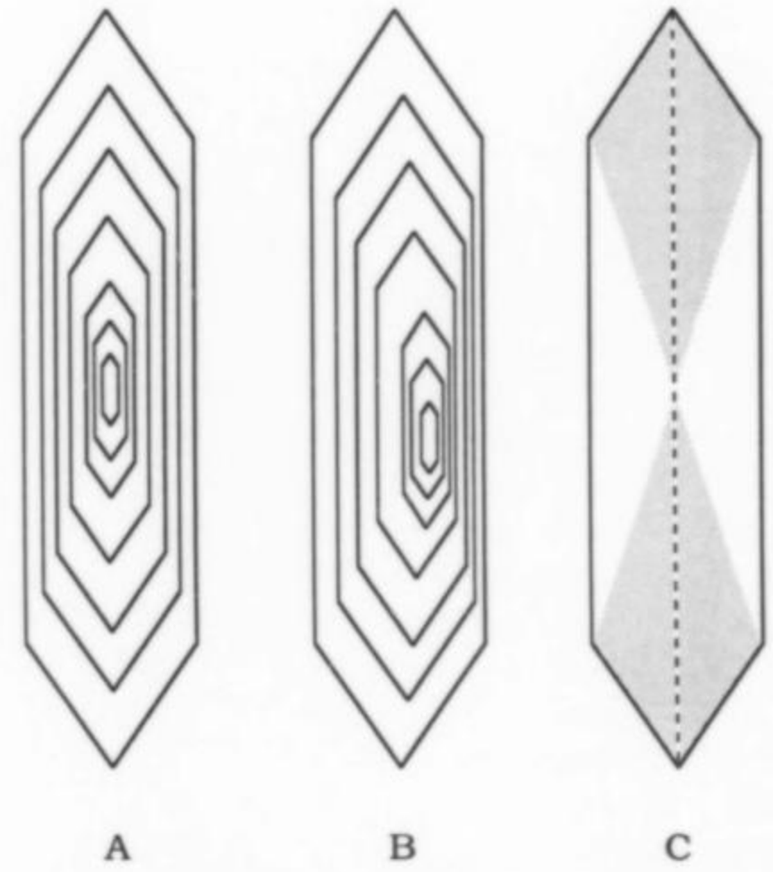


Figure 13. **Either a series of concentric "phantoms" or some form of sectoral zonation would allow the center of growth of the crystal to be located, as shown by these schematic crystals. A: Concentric phantoms converge inward to the center of a symmetrically developed crystal. B: Phantoms converge inward to the growth center of an assymetrically developed crystal. The center of growth is different from the geometric center of the crystal. C. Sectoral zoning, shown here in a symmetrically developed crystal, reveals the growth center as the point at which all sector boundaries meet. Each sector represents crystal material deposited on a different face of the crystal.**

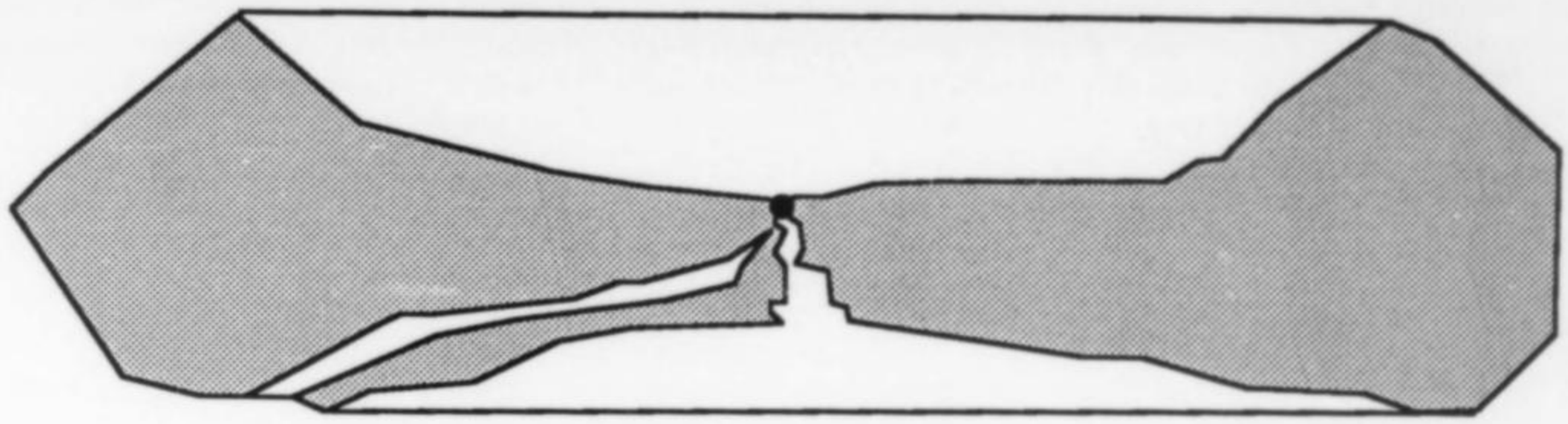


Figure 14. **Artificially irradiated quartz crystal with sectoral zoning converging to the faden, which demonstrates that the faden was the growth center of the crystal. Section perpendicular to the faden, and nearly parallel to the *c* axis, which runs horizontally. The grey zones were deposited on the pyramid faces, and the clear zones were deposited on the prism faces. Several changes in relative growth rates of prism and pyramid are evident as changes in the sector boundaries. The narrow grey zone at the bottom left is due to mosaic growth, which is also expressed as a small secondary pyramidal region part of the way along the prism. This secondary termination is marked in this section by the outward flexure of the crystal at the edge of the narrow grey zone. Drawn from RPR specimen #1616.**

zoning) would show the growth history. In either case, the center of growth would be the point of convergence and would be expected to coincide with the faden.

Attempts to use variations in trace element chemistry to reveal growth history have been made using three techniques: cathodoluminescence, boron mapping using alpha particles from a nuclear research reactor, and irradiation to develop zonal color changes. Of these, the first two methods proved unsuccessful in revealing any zonation in the crystals examined. The third method proved more fruitful. Faden crystals from four localities were irradiated for this study using a 50-megarad dose of gamma rays from radioactive cobalt-60. Crystals from Windsor, Quebec, and Savoie, France, developed an overall light smoky shade, and one from Saline County, Arkansas, failed to turn color at all. Crystals from a fourth but unknown locality, however, developed smoky coloration under the rhombohedron faces but no coloration under the prism faces. The boundaries between the smoky and clear regions thus define the growth center of the crystal. The zones converge to their origin exactly at the faden (Fig. 14). This is the first direct demonstration that faden crystals do indeed develop from the faden, and puts the detailed hypothesis developed by Laemmlein and extended by Rykart and this paper on firmer ground.

GWINDELS, ETC.

It is always tempting to overextend an explanation. I wish to avoid doing so, and this section is included to discourage others from doing so either. In this case the temptation might be to use the faden model to try to explain the twisted crystals called gwindels, and perhaps other distorted crystals which have other causes, known and unknown.

There is a limited similarity between gwindels and faden quartz crystals, in that both are clearly distorted. Gwindels are tabular, due to elongation along an axis parallel to a prism face, as many faden quartzes are. Gwindels are curved and have a pronounced mosaic structure, as do many faden crystals, especially the curved ones. However, there are many important differences as well.

Some gwindels are rumored to contain faden, but I am not aware of any examples. Rudolph Rykart, on the basis of his extensive personal experience with both faden quartz crystals and gwindels, asserts absolutely that gwindels do not contain faden (personal communication, 1988). Gwindels are often smoky; faden crystals are usually clear. Gwindels are found in clefts in igneous intrusive rocks (granites, syenites, etc.), according to my Swiss friends, whereas faden quartz crystals are found in metamorphic rocks. The higher natural radioactivity level of igneous rocks probably explains the greater tendency of gwindels to be smoky. Just as the association of faden quartzes with metamorphic rocks reflects their origin in the metamorphic event, the association of gwindels with igneous rocks (and their apparent absence from metamorphic rocks) suggests that they grew during the final stages of the crystallization process of the igneous body. Finally the mechanics of faden formation are not suited to producing the gwindel morphology. In order for a faden to lead to the formation of a gwindel, the faden itself would have to be twisted about its axis as it formed. It is easy to envision tectonic movements causing elongation, shearing, and even rotation of a scissoring sort, but it is difficult to see how they could cause rotation of a twisting sort. Thus there is abundant reason to conclude that gwindels and faden crystals are two totally separate phenomena.

There are also untwisted tabular crystals which lack faden. There are several ways in which tabular crystals may form without faden. Quartz has cleavage directions parallel to the major faces, and crystals may cleave in response to pressure. During vein collapse, flat cleavage plates can be broken from crystals, and with a little healing of the broken surface become tabular floaters. Crystals of this sort are also common in alpine veins. Tabular crystals can also result when shells of incomplete growth form, separated from the main crystal by a thin layer of clay. If these overgrowth crystals become detached, they also form tabular crystals. Finally, a strongly directional source of quartz-bearing solution can lead to the uneven development of faces on the crystal, producing a tabular morphology which is usually not as pronounced as that resulting from these other processes. There are probably other causes as well.

Thus, not all tabular crystals are faden crystals, and, as we have seen, not all faden crystals are tabular. The visible presence of a faden should remain the defining feature of faden quartz crystals.

SUMMARY

Faden quartz crystals form in tectonic environments by a two-stage growth process. In the first stage, tectonic stresses open fissures, splitting grains of quartz in the country rock, and by a gradual crack-and-heal process cause them to elongate into single-crystal fibers which span the fissure. Deposition of the main bulk of the crystal occurs after this period of fissure widening ceases.

The faden remains visible because healing of the cracks in the crystals is incomplete, and leaves a series of zones of liquid and gas-filled inclusions. The tabular nature of typical faden crystals, and other aspects of their unusual form, are directly attributable to development of the crystal around the faden as a linear seed, often possessing some crystallographic strain.

The direction of the faden can bear almost any relationship to the

Table 1. **Localities known to have produced faden quartz. References are literature citations, catalog numbers for examples (HC: Heidelberg College collection, now part of Cleveland Museum of Natural History collections; OC: Oberlin College collection; RPR: author's collection), and/or names of people who have provided site information and/or specimens. No attempt has been made to search exhaustively for indications of other localities; there are probably many.**

Locality	Province or state	Country	Mountain range	Reference
Kozhim-Ner		Russia	Subpolar Urals	Laemmlein (1946)
Sura-Is Mountain		Russia	Subpolar Urals	Laemmlein (1946)
Chus-Oika Mountain		Russia	Subpolar Urals	Laemmlein (1946)
St. Gotthard		Switzerland	Alps	RPR #1492, 1398
Kiental	Bern	Switzerland	Alps	E. Offermann photo
Ganzenlouwina	Bern	Switzerland	Alps	H. A. Stalder, RPR #1444
Piz Sardona	Glarus	Switzerland	Alps	E. Offermann photo
Lenzerheide	Graubünden	Switzerland	Alps	E. Offermann photo
Piz Beverin	Graubünden	Switzerland	Alps	H. A. Stalder, RPR #1443
Schons	Graubünden	Switzerland	Alps	Rykart (1971)
Charstelenbach bei Amsteg	Uri	Switzerland	Alps	E. Offermann photo
Intschialpbachtobel	Uri	Switzerland	Alps	Rykart (1971)
Val d'Illiez	Valais	Switzerland	Alps	H. P. Klinger, RPR #1565
Leukerberge	Valais	Switzerland	Alps	Rykart (1977)
Rotenberg bei Goppenstein	Valais	Switzerland	Alps	Rykart (1971)
La Table	Savoie	France	Alps	H. A. Stalder, RPR #1445
Mt. Blanc, Chamonix	Haute-Savoie	France	Alps	RPR #1792
Stand-on-your-head claim*	Arkansas	U.S.	Ouachitas	RPR #1517
Royal*	Arkansas	U.S.	Ouachitas	RPR #1425
"Hot Springs area"*	Arkansas	U.S.	Ouachitas	HC #1153
"Hot Springs area"	Arkansas	U.S.	Ouachitas	OC #4956
Lincoln County	New Mexico	U.S.	?	S. Frazier
Veta Grande Claim, Yuma Co.	Arizona	U.S.	Dome Rock	RPR #1608
Windsor	Quebec	Canada	Appalachians	Chamberlain *et al.* (1989)

*Some Arkansas localities may be listed more than once under different descriptions.

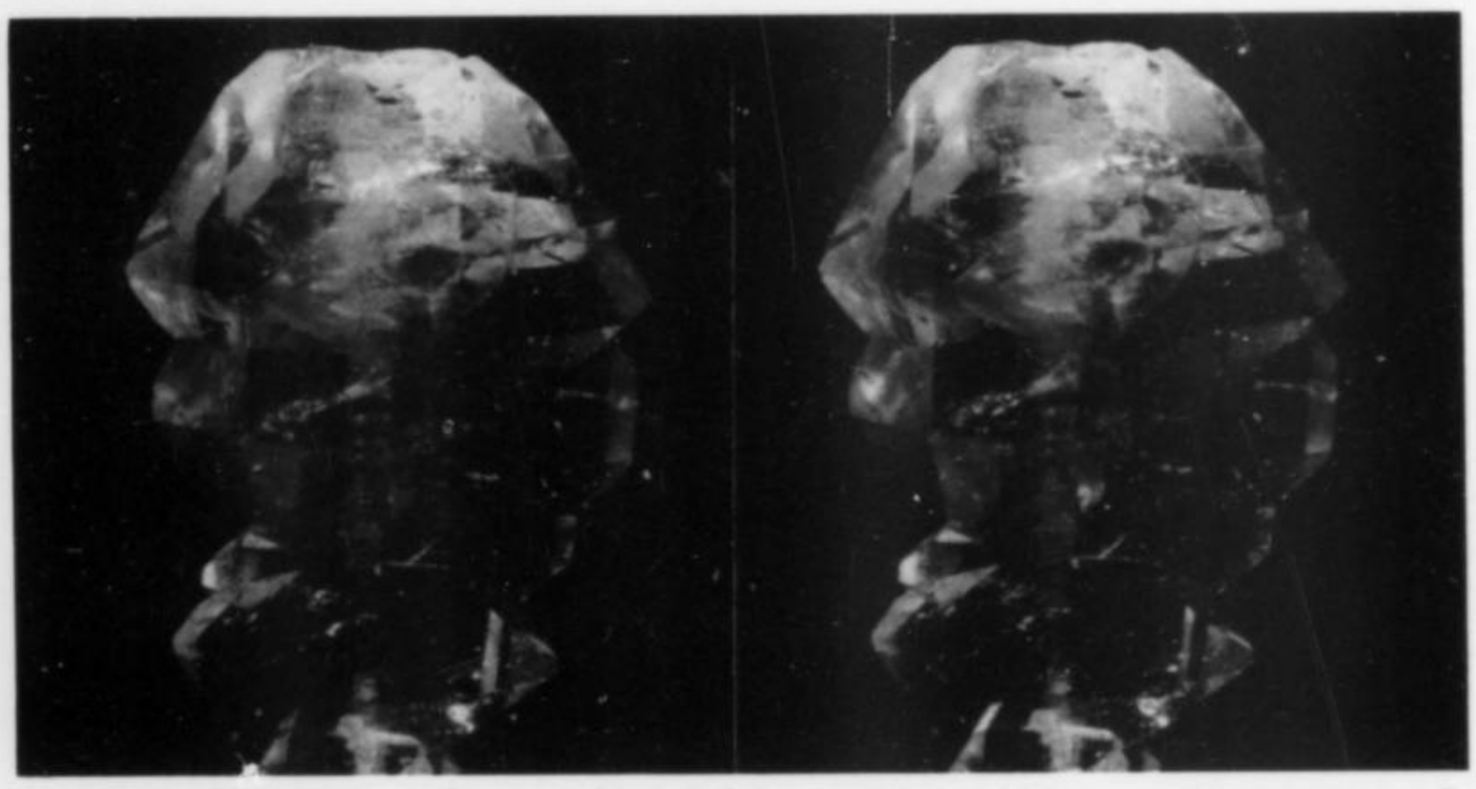


Figure 15. **A faden crystal of the uncommon habit 3, in which the faden is perpendicular to a pair of prism faces. The crystal is from Windsor, Quebec, and is 0.9 cm long. RPR specimen #1611; Eric Offermann stereo photograph.**

crystallographic directions of quartz, although faden crystals in which the faden is elongate perpendicular to a prism face appear to be relatively uncommon. Preferred orientations may be locally present if the original grains in the rock have a preferred orientation, or if rates of vein opening are too great to permit development of faden with certain crystallographic orientations.

Radiation-induced color zoning has successfully revealed the growth history of faden crystals and demonstrated directly that they grew from the faden as a nucleus.

ACKNOWLEDGMENTS

Many people have offered help and encouragement during this project, and I thank all those who have discussed ideas or suggested others to contact. Steve Chamberlain of Syracuse University took me collecting at Windsor, Quebec, where I found the faden crystals which were the seed of this paper. Frank Melanson of *Hawthorneden* first introduced me to the term faden quartz, and puzzled with me about the origin of these crystals. John White of the Smithsonian Institution led me to H. A. Stalder of the Naturhistorisches Museum Bern, who sent me reprints of the two papers on faden quartz from *Schweizer Strahler*, and specimens of faden quartz from several European localities. The Oberlin College Geology Department provided access to preparatory and research equipment, including a cathodoluminescence device, and provided the faden quartz which developed sector zoning when irradiated. M. Truscott of Hamilton University examined thin sections for zonation using boron tracking techniques. Dr. Kurt

Nassau of Lebanon, New Jersey, irradiated the specimens which documented growth around the faden. Erich Offermann provided photographs of faden specimens. Erich Offermann also read an early draft of this paper, obtained copies of articles for me, and shared his personal observations and those of his Swiss colleagues. Expenses involved in the work were defrayed by a faculty research grant from Heidelberg College.

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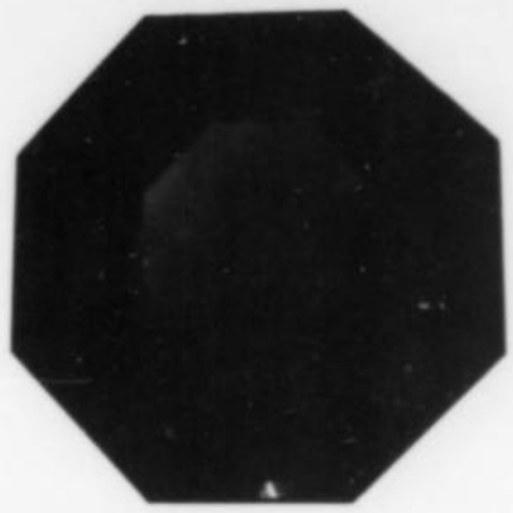

Amethyst Occurrences of the Eastern United States

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Gem and specimen amethyst has been known from exceptional occurrences in the eastern United States for more than a century. These occurrences represent no more than four distinct types of geological environments, each producing material of characteristic appearance.

INTRODUCTION

Only rarely do mineral deposits of the eastern United States produce large quantities of fine-quality amethyst specimens. Even less common is the discovery of material suitable for the fashioning of significant gemstones. But, in addition to the classic occurrences that are represented by exquisite material, there are dozens of other, similar amethyst localities that have sporadically produced good to excellent specimens which have gained wide acceptance among collectors. The purpose of this paper is to present a summary and tabulation of all eastern United States amethyst occurrences described in the literature or represented in private or public collections to which we have access.

GENERAL CHARACTERISTICS

Amethyst specimens from localities within the eastern United States exhibit a number of significant features with respect to crystal habit and size, inclusions and coloration. Unlike most other types of crystalline quartz, amethyst occurs only rarely in massive form. Crystals are typically rather stubby with an unusually low prism length to crystal length ratio; amethyst crystals with long prism faces characteristic of colorless, milky and many smoky quartz locations are very unusual in the eastern United States. Flattened crystals are similarly uncommon. A relatively high percentage of better-quality amethyst crystals are doubly terminated. Amethyst crystals may reach exceptionally large sizes, up to 20 cm in diameter, and may occur in groups up to a meter in diameter; however, extremely small crystals or crystal druses are unknown in the eastern United States. Special habits such as scepters seem to be characteristic of some occurrences while totally absent at others.

Amethyst from many eastern locations is characterized by inclusions of other minerals or fluids. Several locations produce rutilated amethyst in which the rutile needles are oriented perpendicular to both prism and rhombohedron faces, forming a network of minute red needles pointing inward toward the centers of the crystals. More than a few fine southeastern amethyst specimens have been lost due to expansion of water inclusions during hard winter freezes. A number of North Carolina locations are noted for smoky amethyst crystals containing large fluid inclusions with moveable bubbles. Other minerals occa-

Figure 1. ***(top)*** **Faceted amethyst from Upper Providence, Delaware County, Pennsylvania; 36.2 carats, NMNH #G1283. Photo by Chip Clark.**

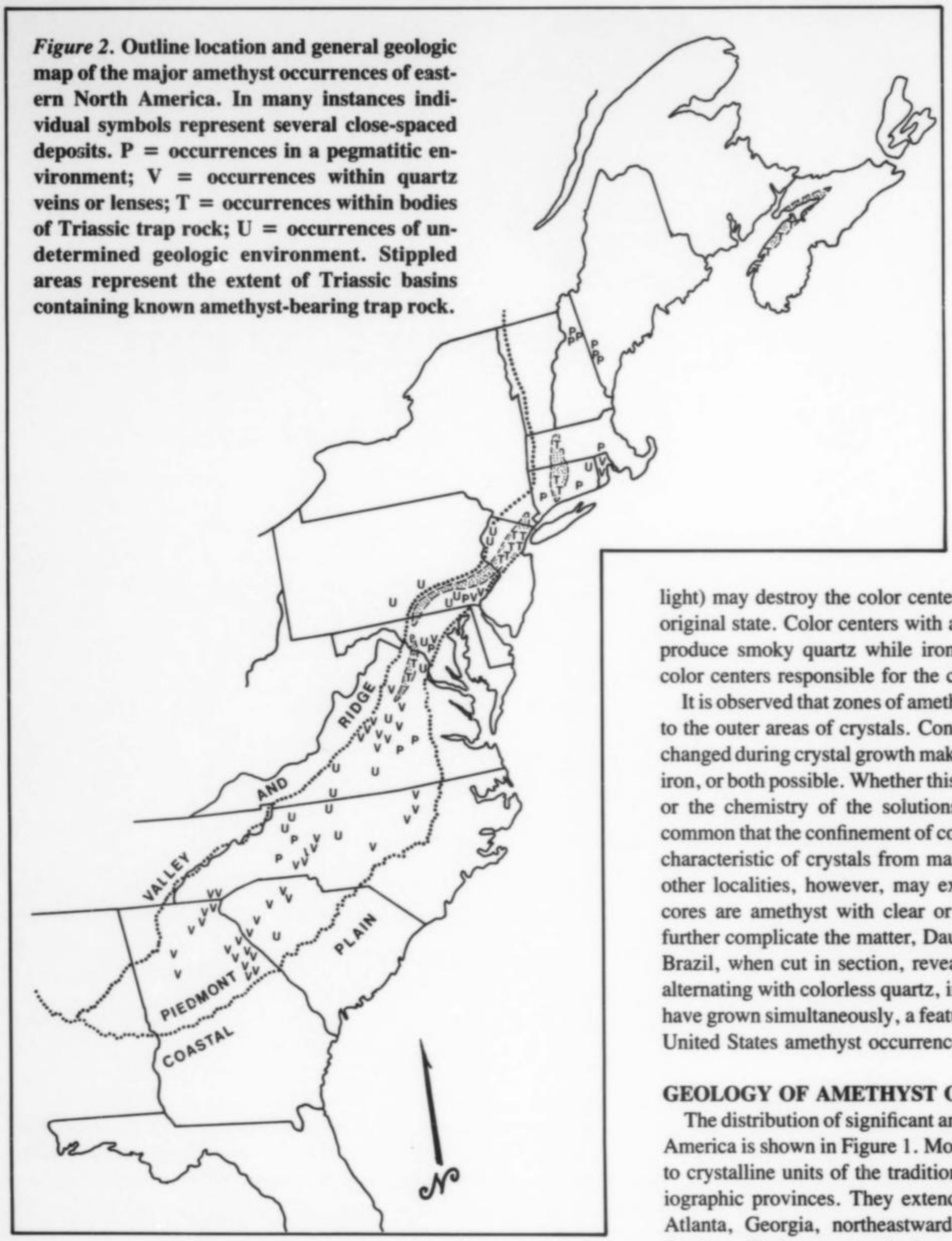


Figure 2. **Outline location and general geologic map of the major amethyst occurrences of eastern North America. In many instances individual symbols represent several close-spaced deposits. P = occurrences in a pegmatitic environment; V = occurrences within quartz veins or lenses; T = occurrences within bodies of Triassic trap rock; U = occurrences of undetermined geologic environment. Stippled areas represent the extent of Triassic basins containing known amethyst-bearing trap rock.**

sionally seen as inclusions are specular hematite and clay minerals. In rare instances, inclusions occupy zones parallel to rhombohedron faces, giving the appearance of phantoms.

Color variations in quartz from amethyst occurrences of the eastern United States are characteristic of important deposits throughout the world and are directly related to the prevailing physical and chemical conditions at the time of formation. The color of amethyst and the brownish gray to black of commonly associated smoky quartz are both due to the presence of color centers in the quartz crystal structure. Color centers are atoms or groups of atoms within crystalline materials that have been altered through the displacement of electrons by energetic radiation. These electrons are "trapped" by hydrogen atoms within the crystal lattice so that they cannot return to the atoms that gave them up. Color centers have the effect of selectively absorbing light, thus imparting color. There are some exceptions to this definition of color centers, and the reader is referred to Nassau (1983) for a more detailed explanation of the phenomenon. Heat (and sometimes light) may destroy the color center by restoring the electrons to their original state. Color centers with aluminum in substitution for silicon produce smoky quartz while iron substituting for silicon forms the color centers responsible for the color of amethyst.

It is observed that zones of amethyst and also smokiness are confined to the outer areas of crystals. Conditions of crystallization must have changed during crystal growth making substitution of either aluminum, iron, or both possible. Whether this is related to changes of temperature or the chemistry of the solutions, or both, the phenomenon is so common that the confinement of color to the outer zones is a distinctive characteristic of crystals from many different localities. Quartz from other localities, however, may exhibit just the reverse, wherein the cores are amethyst with clear or white quartz the last to form. To further complicate the matter, Dauphiné-twinned quartz crystals from Brazil, when cut in section, reveal pie-shaped segments of amethyst alternating with colorless quartz, indicating that the two varieties must have grown simultaneously, a feature yet to be identified in any eastern United States amethyst occurrence.

GEOLOGY OF AMETHYST OCCURRENCES

The distribution of significant amethyst occurrences in eastern North America is shown in Figure 1. Most of these occurrences are restricted to crystalline units of the traditional Piedmont and Blue Ridge physiographic provinces. They extend from the Northern Piedmont near Atlanta, Georgia, northeastward through the Northern, Inner and Southern Piedmont or equivalent geologic provinces of the Carolinas, Virginia, Maryland and Pennsylvania, to the high-grade metamorphic and intrusive province of New England at least as far as southwestern Maine. An additional set of important though quite different occurrences is contained in Triassic trap rock dikes and sills from northern Virginia through Nova Scotia.

Within the southeastern United States amethyst occurrences can be classified as occurring either north or south of the Brevard Zone, a major zone of faulting that forms the traditional boundary between rocks of the Northern Piedmont, and those of the Inner Piedmont and Southern Piedmont. Amethyst within the Northern Piedmont is generally restricted to pocket zones within quartz veins or lenses or, more rarely, to small pegmatites. A direct connection with proximal granitic plutons or felsic gneisses of possible igneous origin usually cannot be demonstrated. Pockets within these occurrences are small, seldom containing more than 100 kg of amethyst. Deposits of this class that have produced commercial quantities of gem amethyst are limited to those along Charlies Creek in Towns County, Georgia, and those of

the Tessentee Creek area of Macon County, North Carolina.

Amethyst deposits south of the Brevard Zone in the southeastern United States are typically associated with major granitic plutons such as the Elberton Granite in eastern Georgia and the Bald Rock Granite in west-central South Carolina. Occurrences may be found within the granite body itself and in veins or pegmatites within adjacent host units. Amethyst occurrences within the plutons occur in zones of clay-filled pockets that may or may not be connected by narrow white quartz stringers. Magnificent groups of royal-purple amethyst, rutilated amethyst, and amethyst-smoky quartz phantoms are found in this type of occurrence. Individual pockets or pocket zones are known to have produced as much as 1000 kg of amethyst. Veins adjacent to these fertile plutons are typically composed of milky quartz that in places contains small lenticular openings lined with colorless transparent quartz crystals upon which rest a later generation of amethyst. Occurrences of this type produce amethyst scepters and associated amethyst specimens of great beauty, in part a result of the contrasting deep purple amethyst against the white quartz matrix. Amethyst from these occurrences typically is not of exceptional gem quality, is characterized by only partial transparency, and exhibits prism faces that are almost invariably short relative to those of accompanying non-amethystine crystalline quartz. Amethyst within associated pegmatites is typically found with more abundant crystalline smoky quartz. Individual crystals of smoky quartz containing centers of gem amethyst have been reported from a number of locations of this type.

Piedmont amethyst occurrences of the east-central states, such as the well-known Virginia and Pennsylvania localities, are similar to those of the southeastern Appalachian orogenic belt in that they are generally small, consisting of isolated or interconnected pockets or pocket zones within or near a granitic intrusion or its metamorphosed equivalent. Many of the deposits have produced only float specimens, so detailed geologic relationships have yet to be determined. Several are related to pegmatites, and these occurrences are characterized by a predominance of smoky quartz with only minor amethyst.

Amethyst within the northeastern states, with the exception of the trap rock occurrences, is restricted to areas of abundant granitic plutons. Many occurrences, such as those of northern New Hampshire and southwestern Maine, are almost entirely related to pegmatites hosted by biotite granites of Late Paleozoic age. At many of these locations, amethyst is less common than crystalline smoky quartz or may occur rhythmically with smoky quartz in a manner which suggests alternating periods of Fe^{+3} and Al^{+3} substitution during deposition. Unlike pegmatitic amethyst occurrences in the east-central and southeastern states, these pegmatites are characterized locally by giant pockets that reach dimensions of up to 6 x 6 x 3 meters (as at Deer Hill, Oxford County, Maine), and are commonly associated with topaz, potassium feldspar and fluorite. Only a small amount of gem amethyst has been produced from these occurrences.

Basalt or trap rock sills within Triassic basins that extend from northern Virginia northeastward through Maryland, southeastern Pennsylvania, New Jersey, extreme southeastern New York, central Connecticut, Massachusetts and Nova Scotia have produced exceptional amethyst specimens. In urban areas where many quarries have been opened in these rocks, pockets lined with pale to dark purple amethyst are encountered frequently. In areas characterized by the weathered residuum of these units, chalcedony geodes lined with small amethyst crystals are locally abundant. In general, the many amethyst occurrences in the Triassic basalts of the northeastern United States do not afford notable gems. Most individual crystals are too small to supply stones of more than a few carats in weight.

With the exception of the Triassic basalt-hosted occurrences, major amethyst localities of the eastern United States generally define zones of plutonism and high-grade regional metamorphism related to Paleozoic orogenic activity. Although amethyst is, of course, relatively abundant within these zones, occurrences of colorless or smoky quartz are more common and widespread. The occurrence of amethyst may well be related to the local availability of iron in a residual melt, coupled with crystallization near to or within an anomalously radioactive host, such as a granitic pegmatite, under the general conditions suggested by Nassau (1983).

EXCEPTIONAL OCCURRENCES

The nature and quality of amethyst found throughout the crystalline rocks of the Piedmont vary widely, even though certain features, such as smokiness and a tendency for the color to be concentrated under alternating rhombohedron faces, are common to much of it. Although we have attempted to list all of the amethyst localities known to us irrespective of the quantity and/or quality of the specimens (Table 1), we feel it is worthwhile to describe the characteristics of the more notable specimens that have come from some of the most important occurrences.

Sweden, Maine

In the fall of 1987 a major amethyst discovery was made at Sweden, Oxford County, Maine. A small gravel pit in decomposed schist and gneiss intersected a large quartz vein containing a number of amethyst crystal pockets. The vein is vertical and of unknown depth and lateral extent. There are no associated species, but pink feldspar (orthoclase?) and large crystals of muscovite are found as float in the vicinity. The quality of the amethyst appears to worsen with depth.

There are three distinct generations of quartz crystal growth. The first consists of white crystals covering virtually all surfaces. This was followed by the deposition of amethyst in much larger crystals of somewhat irregular distribution. Much of the first-generation quartz never became covered by amethyst. Finally, there was yet another period of white quartz crystal growth of relatively minor extent. The amethyst varies from very dark in color to the lightest tints of purple and there is virtually no smoky quartz.

Several very large plates (up to 37 x 60 cm) have been removed, five or six of which are quite exceptional. One is in the Maine State Museum in Augusta (Fig. 5) while another is the property of Cross Jewelers in Portland (Fig. 3). By late fall of 1988 nearly a half ton of good to excellent amethyst had been removed from this pit, a location now referred to as the Saltman amethyst prospect. Additional mining during much of the summer of 1989 resulted in the removal of an even larger quantity of amethyst. The vein is currently being mined by Plumbago Mining Corporation under the direction of Phillip McCrillis and Irving "Duddy" Groves. Only a few hundred carats of very good to superb gem amethyst have been cut from this material thus far. Plumbago and others feel that the Saltman amethyst occurrence will become widely known as a major domestic source of both gem and specimen amethyst.

New Hampshire

In the course of making road cuts in New Hampshire, a number of fine amethyst occurrences have been discovered in recent years. In the 1970's during construction of Interstate 89 at New London, Merrimack County, a series of ledges were uncovered which produced thousands of individual amethyst crystals of good color, many of gem quality. Occurrences at Hurricane and Blackcap Mountains, Carroll County, have produced scepters consisting of smoky crystals with amethyst caps. In the winter of 1987/1988 crystals up to 34 kg of the highly desirable Siberian color were mined near Stark, Coos County (R. W. Whitmore, 1989, personal communication).

Bellingham, Massachusetts

One of the finest amethysts ever faceted from New England material is the 52.8-carat "Star of Bellingham," a medium purple antique cushion cut gem measuring 27 x 24 x 16 mm. The rough was collected by John H. Marshall, Jr., at an undeveloped house lot on Rose Street, Bellingham, Norfolk County, Massachusetts, in 1976 (W. Metropolis, 1989, personal communication).

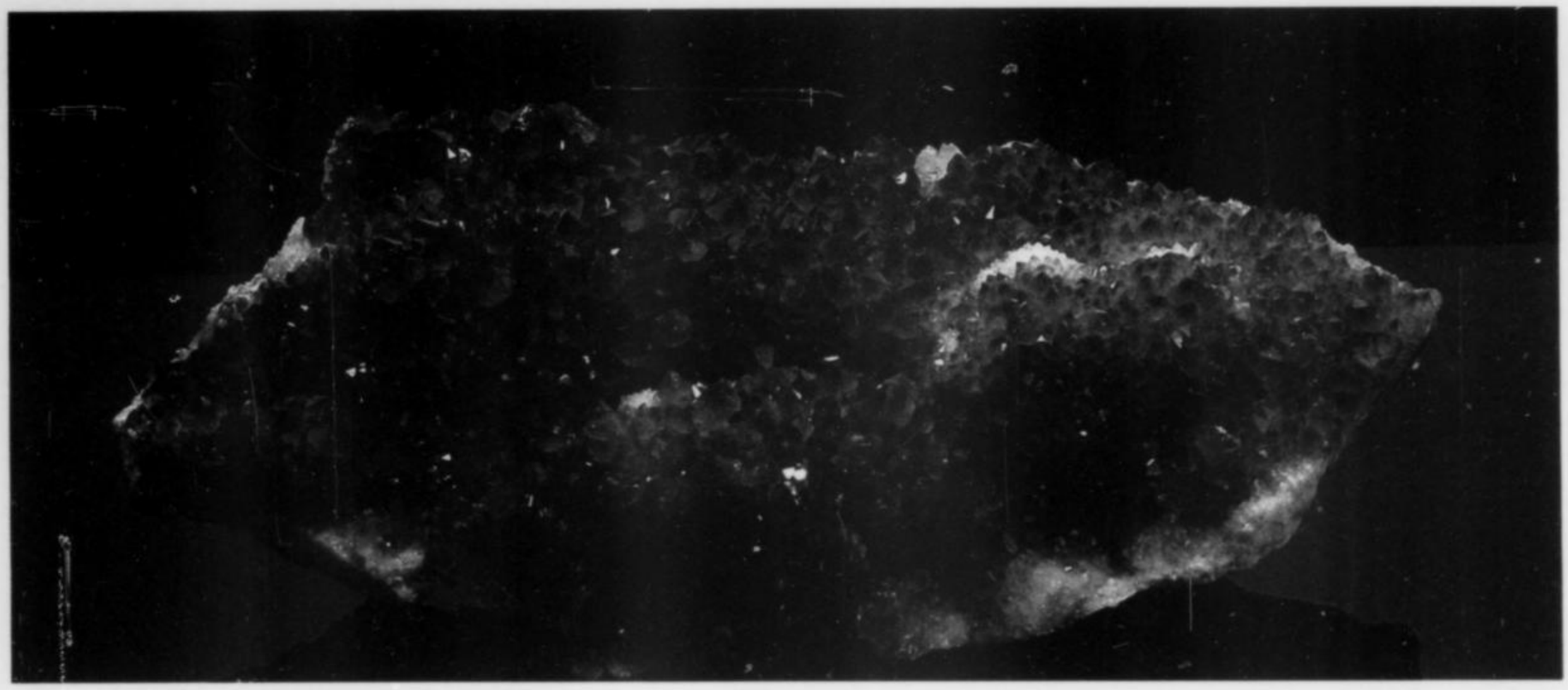
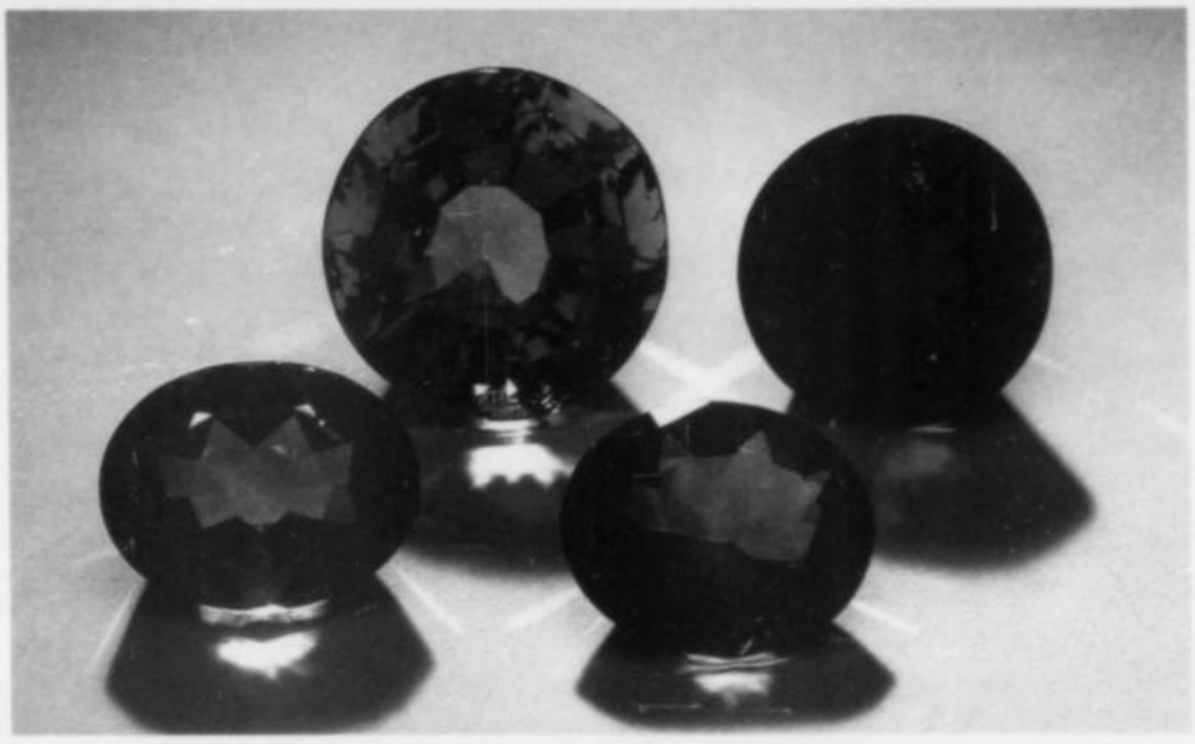


Figure 3. **Amethyst from the Saltman amethyst prospect, Sweden, Maine. The plate is 61 x 36 cm and contains 1,076 amethyst crystals. Cross Jewelers specimen, Portland, Maine. Photo by D. C. Sinclair.**

Figure 4. **Four faceted amethysts, clockwise from upper left: from near Statesville, Alexander County, North Carolina, 27.5 carats, NMNH #G1289; Nelson County, Virginia, 18.7 carats, NMNH #G1301; Warren County, North Carolina, 9.5 carats, NMNH #G1522; Stow, Oxford County, Maine, 13.1 carats, NMNH #G1270. Photo by Chip Clark.**

Figure 5. **Amethyst from the Saltman amethyst prospect, Sweden, Maine. The plate is 62 x 36 x 22 cm. Maine State Museum specimen #88.108.1. Photo by Greg Hart.**



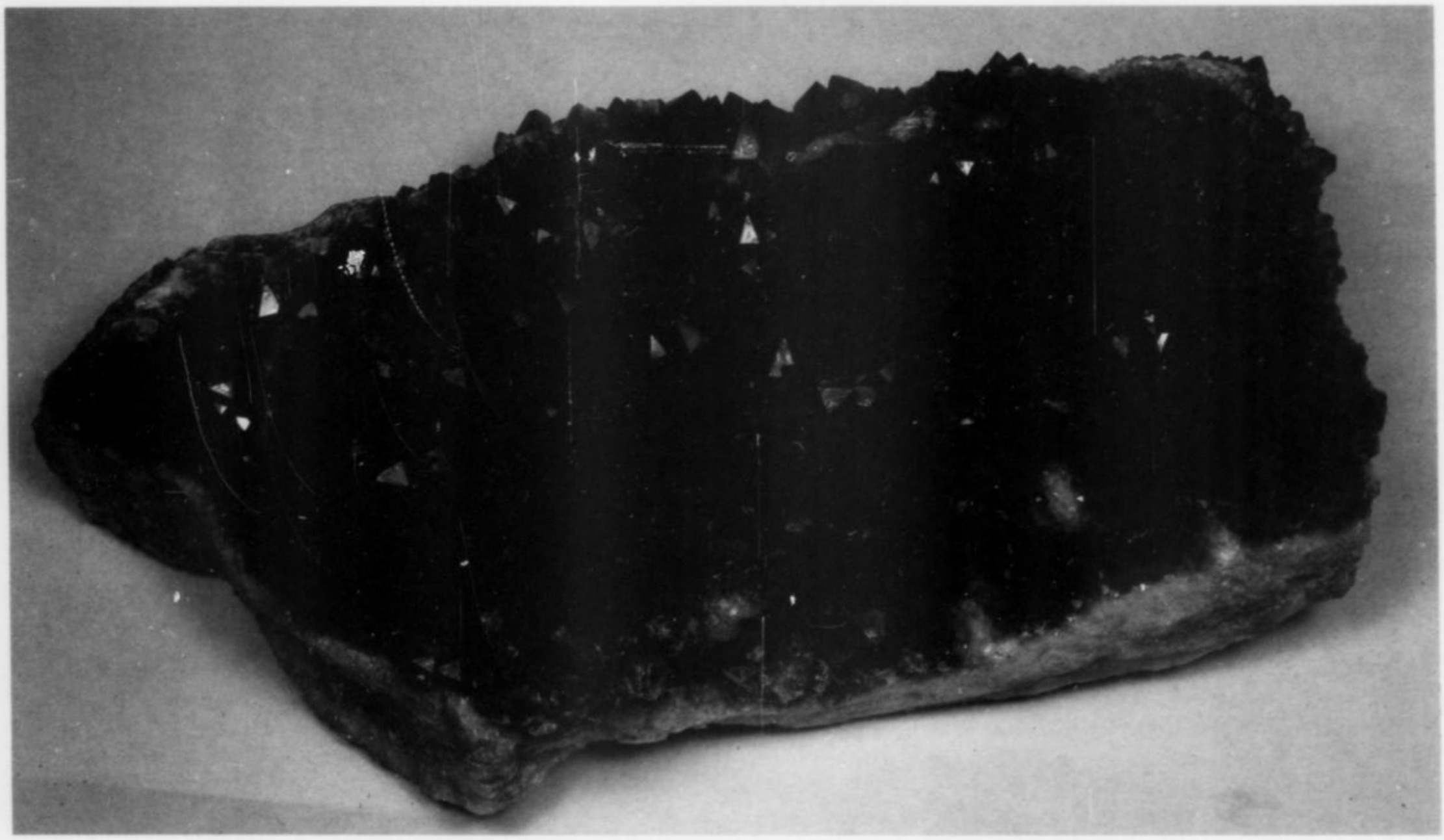


Figure 6. **Amethyst from Ashaway Village, Hopkinton, Rhode Island. The specimen measures 23 x 15 x 12 cm and the iargest scepter is 2.5 cm across. Smithsonian specimen, NMNH #R18877. Photo by Victor E. Krantz.**

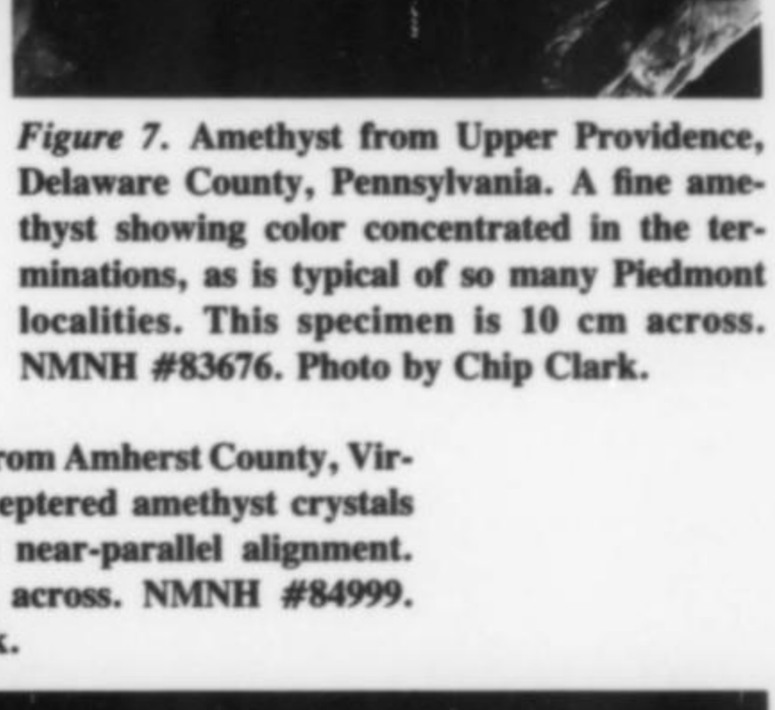


Figure 7. **Amethyst from Upper Providence, Delaware County, Pennsylvania. A fine amethyst showing color concentrated in the terminations, as is typical of so many Piedmont localities. This specimen is 10 cm across. NMNH #83676. Photo by Chip Clark.**

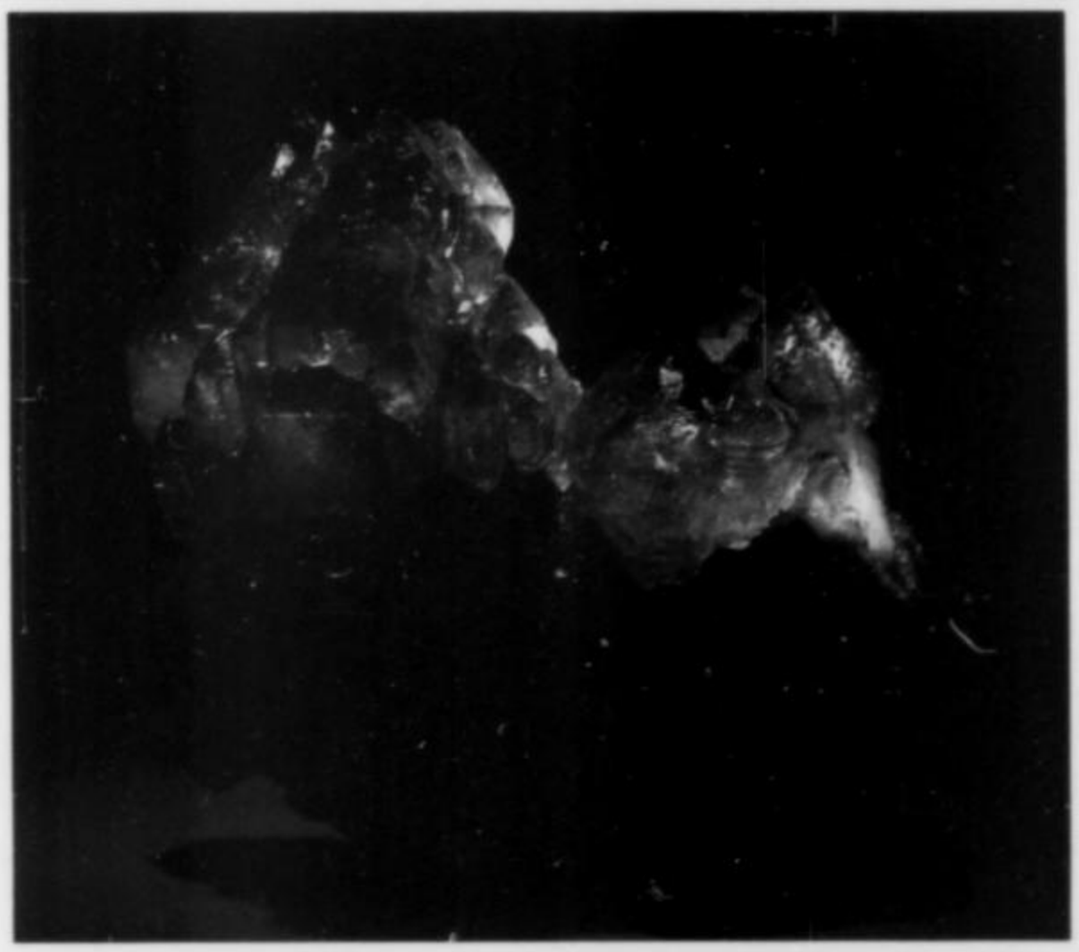


Figure 8. **Amethyst from Amherst County, Virginia. A group of sceptered amethyst crystals that have grown in near-parallel alignment. The group is 9 cm across. NMNH #84999. Photo by Chip Clark.**

Figure 9. **Amethyst from near Minnieville, Prince William County, Virginia. Scepter growth in parallel arrangement on white quartz. The specimen is 15 cm across. NMNH #87511. Photo by Chip Clark.**

Figure 10. **Amethyst from the Goodson farm, Iron Station, Lincoln County, North Carolina. Large group of smoky amethyst crystals 13 cm across. NMNH #113709. Photo by Chip Clark.**

Hopkinton, Rhode Island

The scepter amethyst locality in Ashaway Village, Hopkinton, Washington County, Rhode Island, has been described by Metropolis *et al.* (1986). One thing that makes this locality unique is that a reliable estimate of the total recovery of specimens has been made. Metropolis *et al.* (1986) reported that about 500 single amethyst scepters and 25 matrix groups were removed from the three pits dug during 1981 and 1982. The largest group measures 35 x 20 cm. The character of the amethyst scepters is remarkably uniform. All are perched on white or milky quartz crystals that tend to be about 1.5 cm in diameter and about twice as long as they are wide. The amethyst tips range from those that are similar in diameter to the stems to those that are twice as thick as the stems. They are also usually no longer than they are wide. The crystals are bright and pale colored with a high degree of transparency and only the slightest tint of smokiness, so that the specimens, in which the amethyst sharply contrasts with the white quartz, are strikingly beautiful. The matrix specimens are quite possibly the most beautiful of all from the Piedmont occurrences. In spite of their beauty as specimens, however, this amethyst offers very little if any faceting potential, largely because the crystals tend to be sharply color-zoned. The Smithsonian has a fine Hopkinton scepter amethyst specimen which measures 23 x 15 x 10 cm (Fig. 6).

Providence, Pennsylvania

Probably the most exceptionally beautiful faceted gems have come from Upper Providence Township, Delaware County, Pennsylvania. The Smithsonian displays a superb 36.2-carat gem (Fig. 1) from here as well as a huge crystal group (Fig. 7) of a very deep color highlighted with the desired reddish hues typical of the best Siberian and Brazilian amethyst. The fine amethyst color in the crystals is limited to the zones associated with the rhombohedral terminations, while the smokiness is found in zones defined by the growth of prism faces. The amethyst color stops abruptly at the juncture of the prism and rhombohedral forms.

Virginia

Virginia is not often associated with high-quality amethyst specimens, but Amherst County has produced some lovely ones (Fig. 8). They tend to show the scepter habit with the caps arranged in parallel fashion on milky quartz. They are of a pleasing color with virtually no hint of smokiness. Even though the most attractive crystal specimens do not appear to contain gem-grade domains, the Smithsonian's 18.7-carat gem (Fig. 4) from Nelson County (which borders Amherst County) is quite possibly the most beautiful domestic amethyst in the collection.

North Carolina

The state that has almost certainly out-produced all the others is North Carolina. There are many amethyst localities in North Carolina, and most have been producing specimens for decades. For this reason no meaningful estimate of total production is possible, but the quantity of very good to excellent specimens seen by the authors is prodigious. As far as is known, this production does not include significant gems. On display at the Smithsonian are three faceted amethysts from North Carolina, 44.5 carats, 33.2 carats and 27.5 carats, but the color of the biggest one is very pale and the other two are only fair. They are all probably from the same locality which is near Amity Hill, Iredell County.

There are many North Carolina localities that have enjoyed significant amethyst specimen production. Attractive specimens consisting of sparkling, equant, medium purple crystals on prismatic white quartz crystals have been produced from a prospect on Leepers Creek, Lincoln County. Some crystals are sceptered and closely resemble those from Rhode Island. Iredell County localities have been the source of other very good sceptered amethysts (Fig. 11), but not of the quality of those from Rhode Island. Some of the most aesthetically pleasing North American amethyst specimens were once found on the Minor Lentz farm in Iredell County. The specimens consist of individual amethyst crystal aggregates up to 5 cm in diameter, randomly grouped on plates of dark gray gneissic matrix. Crystal groups of wonderfully sculptural forms have been recovered in abundance from other Iredell County sites, especially Reel's Farm near Iron Station. The amethyst color of these, however, is usually pale and smoky, and the crystal's prism zones are actually white rather than gray or smoky, a feature which may be regarded as fairly distinctive for this locality. An amethyst specimen from this locality in the collection of James McKinney, Jr., of Spruce Pine, North Carolina, ranks with the finest in the world. The specimen weighs approximately 80 kg and is a dome-shaped, equidimensional crystal aggregate 60 cm in diameter. Individual crystals are up to 15 cm in diameter and are of medium to deep purple color. Many crystals contain significantly large gemmy areas.

Due West, South Carolina

From Due West, Abbeville County, South Carolina, has come one of the most famous amethyst specimens in the world (Fig. 16). The specimen is an 11 x 8 x 7-cm group of crystals that was depicted on one of a set of four "Mineral Heritage" U.S. postage stamps issued February 8, 1974. This Smithsonian specimen consists of crystals in a parallel grouping. The color is excellent at the points, although the prism areas are quite smoky. The Smithsonian has another large group of South Carolina crystals labeled "near Moffatsville, Anderson County," a locality that is near Due West and actually may be the same site. The specimen is 25 x 18 x 15 cm in size, of good color with large crystals of high transparency but slightly smoky. Individual crystals in this group are as large as 10 x 6 cm. In spite of the quality of the color, these pieces seem to have limited gem potential due to numerous internal imperfections. Additionally, nearly everything that has been recovered is a good mineral specimen, much too fine to be subjected to faceting.

Georgia

Georgia has received only local notoriety for its amethyst specimens, which probably deserve more attention because they are often very lovely. From Wilkes County come small groups of large crystals which have a rich amethyst color in zones at the rhombohedrons, and whitish body colors. They are not smoky, which greatly enhances their beauty. The Smithsonian has a large individual crystal (6 x 4.5 x 3.5 cm) from Tate City, Towns County, that is similar to the Wilkes County material but is much more transparent. The National Collection also contains a good scepter labeled only "Milton County" (now Fulton County), Georgia, an old-timer from the Roebling collection that must have been acquired in the very early 1900's. The crystals are very similar to those from Rhode Island, but not as showy because the amethystine color is less intense and the stems are transparent rather than white. Exceptional medium to deep royal-purple, somewhat equant amethyst crystals were once mined along Charlies Creek in Towns County. A number of fine gems exhibiting red internal reflections have been cut from this material. An excellent suite of Charlies Creek amethysts is on display in the Weinman Mineral Museum at Cartersville, Georgia.

Thus it can be seen that not only have the crystalline rocks of the eastern United States produced amethyst throughout their extent, but states in this region have localities that are justly famous for superb amethyst crystal groups, localities which, with few exceptions, retain the potential for redevelopment and future production. Furthermore, the wide distribution of amethyst suggests that it is entirely possible that numerous as-yet undiscovered sources exist elsewhere within the region. The great Rhode Island locality and the Maine occurrence currently under exploitation were recent discoveries. Where will the next ones be?

Table 1. **Amethyst localities of eastern North America.**
T and P refer to traprock and pegmatite occurrences as indicated in the references cited.

ALABAMA

Cherokee County
Lowe farm, north of Leesburg (19)

CONNECTICUT

Hartford County
Canton (Pb mine) (9)(18), Farmington (T)(18)(19), Meriden (T)(7)(19)

Middlesex County
Haddam (P)(18)

New Haven County
Southbury (9), Wallingford (9)

Windham County
Dayville (near Killingly (18)

GEORGIA

Cobb County
300 yards north of Adamsville Bridge (4)

Elbert County
Chapman Mica mine (4), 2 miles west of Dewy Rose (Deweyrose (19))(4)

Fayette County
1 mile north of Fayetteville (4)

Forsyth County
6 miles east of Cumming (4)

Fulton County
5.5 miles northwest, 0.5 mile northeast, and 7.5 miles north of Alpharetta (4)

Hall County
Near Lula and near Clermont (4)

McDuffie County
1500 feet northeast of junction of Little Germany Creek with Germany Creek (4)

Morgan County
Ben Ray property (Benny Ray (19)), 2.6 miles east of Buckhead (4)

Oglethorpe County
2 miles north of Lexington (4)

Rabun County
Ledbetter mine, 1 mile north of Rabun Gap (4)(19), North Georgia mine, 4 miles northwest of Clayton (4)(19), John A. Wilson prospect, 4 miles southeast of Clayton (4)(19), near Mountain City Water Works (4), Kelly Mica mine, 9 miles east of Clayton (P)(4), W. T. Smith property, Mocassin district (4)

Taliaferro County
Rt. 1, Crawfordville (4)

Towns County
4 miles from Titus (4), 0.9 mile south of Hightower Bald (4), Charlie's Creek, near Hiawassee (20)

Union County
Garrett mine, 1 mile south of Hightower Bald (19)

Warren County
5 miles southwest of Warrenton (4), 0.3 mile north of Union Church (4)

Wilkes County
1 mile north of Tignall and 6 miles east of Tignall (4), 0.6 mile south of Tyrone (4), near Clifford Grove Church (4), 2.5 miles northwest of Newtown(4)

MAINE

Oxford County
Little Deer Hill, near Stow (P)(20)(25), Eastmine mine (P)(19), Saltman amethyst prospect, Sweden, near Bridgton (1-B) (D. A. McCrillis, 1988, personal communication)

MARYLAND

Howard County
Vicinity of Columbia (2), Old Maryland Mica mine, near Simpsonville, about 6 miles from Laurel (16)

MASSACHUSETTS

Franklin County
Cheapside quarry, East Deerfield (19)

Hampden County
Lane quarry, Westfield (C. A. Francis, 1988, pers. comm.)

Hampshire County
Hotch quarry, Amherst (C. A. Francis, 1988, pers. comm.)

Norfolk County
Needham (C. A. Francis, 1988, pers. comm.), Rose Street, Bellingham (ibid.), Simeone quarry, Wrentham (ibid.)

Suffolk County
Center Street quarry, Roslindale section, Boston (C. A. Francis, 1988, pers. comm.)

NEW HAMPSHIRE

Carroll County
Hurricane Mountain (R. W. Whitmore, 1989, pers. comm.), Blackcap Mountain (ibid.), Table Mountain (ibid.), Ossipee Mountains (ibid.)

Coos County
Green's Ledge, western Milan Township (P)(19), Diamond Ledges, Long Mountain, northern Stark Township (P)(19), between North Peak and Square Mountain, Kilkenny Township (P)(19), south peak of Percy Peak (P)(19), western slopes of Hutchins Mountain, Stark Township (P)(19), Mount Crawford (19), Surry Township (19), Waterville Township (19), and Westmoreland Township (19)

Cheshire County
William Wise mine, Westmoreland (R. W. Whitmore, 1989, pers. comm.)

Hillsborough County
Roadcuts for Route 101, Raymond (R. W. Whitmore, 1989, pers. comm.), roadcuts for Route 101, Chester (ibid.)

Merrimack County
Roadcuts for Route 89, New London (R. W. Whitmore, 1989, pers. comm.)

NEW JERSEY

Bergen County
Edgewater (T)(12)

(Table continued on p. 212)

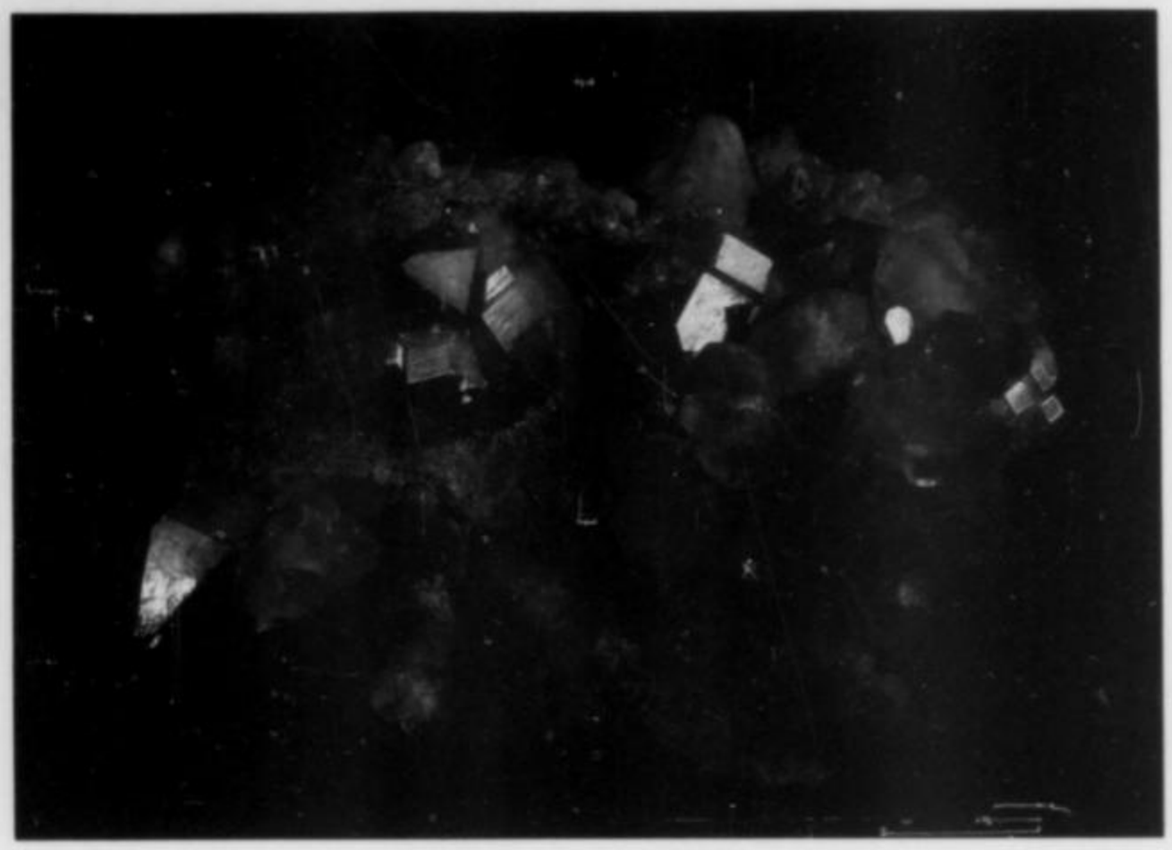


Figure 11. **Amethyst from the Minor Lentz farm near Statesville, Iredell County, North Carolina. The specimen is 25.5 cm across. Grandfather Mountain Nature Museum (N.C.) specimen. Photo by Hugh Morton.**

Figure 13. **Amethyst from Leepers Creek, Lincoln County, North Carolina. The amethyst is 9 cm across. Grandfather Mountain Nature Museum (N.C.) specimen. Photo by Hugh Morton.**

Figure 14. **Amethyst from Fulton (originally Milton) County, Georgia. Close-up of part of the specimen shown in the previous figure; 4 cm across. NMNH #R1650. Photo by Chip Clark.**

Figure 15. **Amethyst from Vail, Lincoln County, North Carolina. Although pale, the amethyst scepters from this locality are locally famous. This specimen is 4.5 cm high. NMNH #102858. Photo by Chip Clark.**

Figure 12. **Amethyst from Reel's farm, Iron Station, Lincoln County, North Carolina. Smoky amethyst crystal group 11.5 cm high. NMNH #121687. Photo by Chip Clark.**

Figure 16. (left) **Amethyst from Due West, Abbeville County, South Carolina. A beautiful group of amethyst measuring 8 cm across. NMNH #122441. Photo by Chip Clark.**

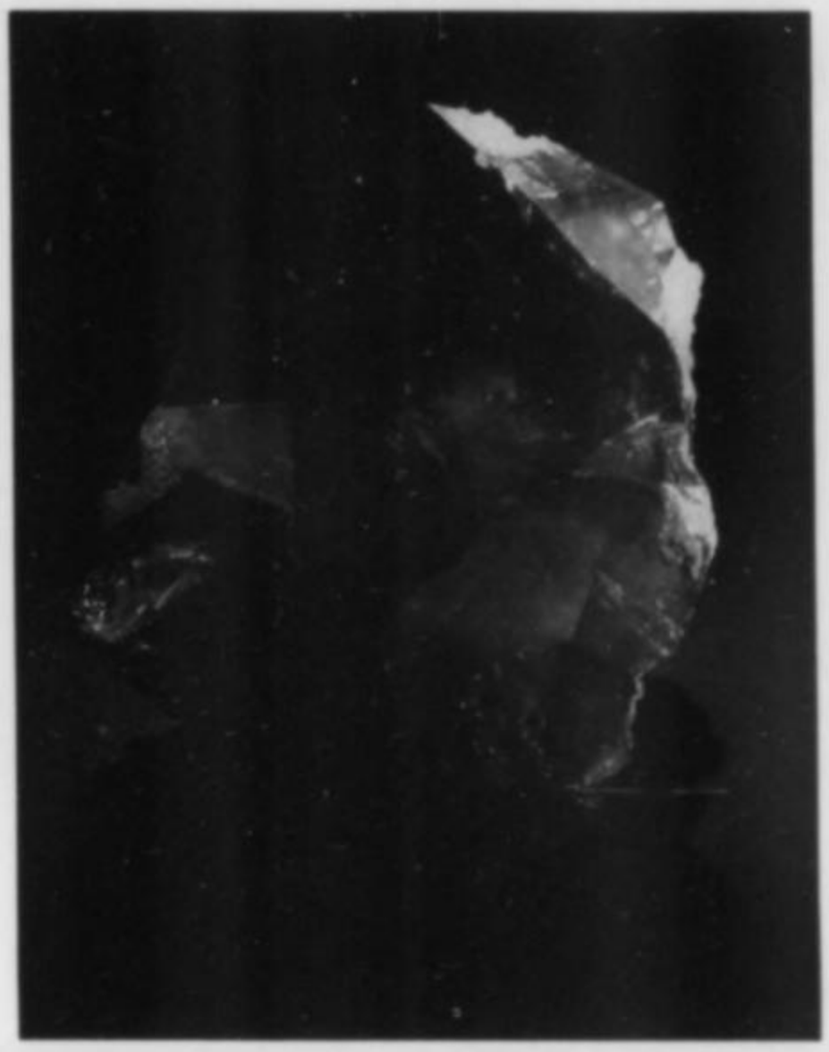


Figure 17. (right) **Amethyst from Wilkes County, Georgia, of excellent color, 6 cm across. NMNH #123167. Photo by Chip Clark.**

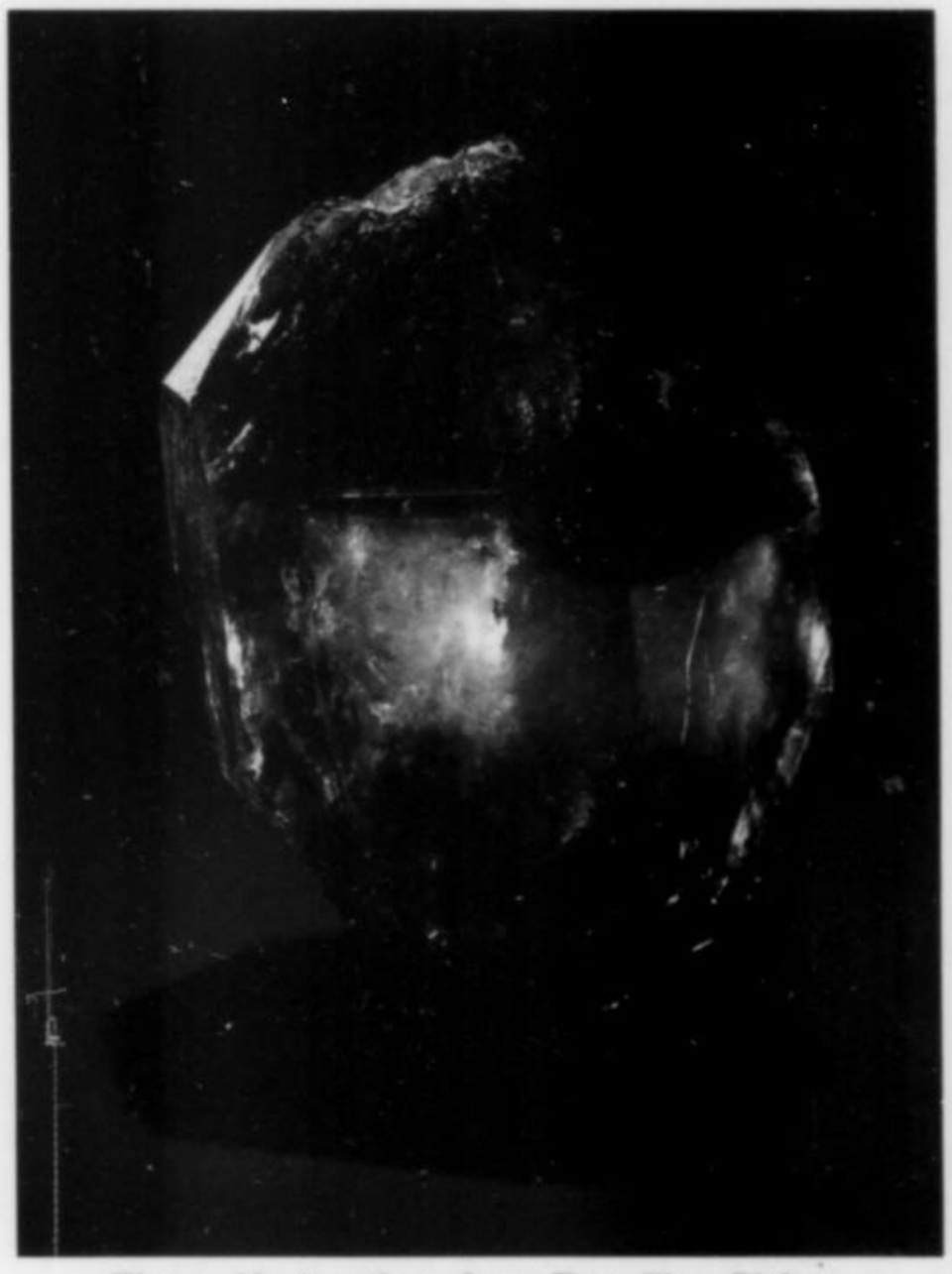


Figure 18. **Amethyst from Tate City, Pickens County, Georgia. A wonderful example of a crystal with amethyst confined to the rhombohedral zones with white prisms. This superb single crystal is 6 cm high. NMNH #116420. Photo by Chip Clark.**

Figure 19. (above) **Amethyst from the Blackwelder farm near Concord, Cabarrus County, North Carolina. Specimen is 28 cm across. Grandfather Mountain Nature Museum (N.C.) specimen. Photo by Hugh Morton.**

Figure 20. **Amethyst from Wilkes County, Georgia. Beautiful crystals showing amethyst terminations with white prism zones; 5 cm across. NMNH #127720. Photo by Chip Clark.**

Essex County
Upper Montclair (T)(12)

Hudson County
Bergen Hill (12), Bull's Ferry (12), Weehawken and Union Hill (12)

Morris County
Long Hill (and in Somerset Co.) (12), Millington (T)(12)

Passaic County
Quarry at end of Planter Avenue, Prospect Park (T)(19), quarry on McBride Avenue, just above Passaic Falls (T)(19), New Street Trap Rock quarry, West Paterson (T)(12), Little Falls (T)(12), Paterson (12), Great Notch (T)(12)

Somerset County
Bound Brook (12), Liberty Corner (12), Lyons Station (T)(12)

Sussex County
Franklin (12), Hamburg (12), Newton (12)

Union County
Summit (T)(12)

NEW YORK

New York City (12)

Bronx County
Dodgewood Road and Independence Avenue (10)

Lewis County
Carbola talc mine, near Natural Bridge (10)

NORTH CAROLINA

Burke County
Silver Creek, Brindletown (3)(21)

Franklin County
Near Centerville (3)(21)

Iredell County
Nine miles southeast of Statesville (19), near Amity Hill (3)(21), 4.5 miles westnorthwest of Mooresville (19), 6 miles westnorthwest of Mooresville (19), 3 miles south of Statesville (19)

Lincoln County
About 2 miles northeast of Iron Station (which certainly includes the Reel farm or Reel mine) (3)(11)(19)(20)(21)(22), 1.3 miles south of Denver (3)(19)

Macon County
Waggoner mine, 6 miles southwest of Highlands, on Abes Creek (3), Tessente Creek (21), Rhodes mine, Tessente Creek (21), Ammons mine, 4.5 miles southeast of Highlands (3)

Moore County
Southwest of Robbins (21)

Stokes County
Copper Gap (21)

Wake County
Northeast of Wilders Groove (3)(21)

Warren County
Near Inez, 11 miles south of Warrenton (19)(21)

Wilkes County
Head of Honey Creek (19)

PENNSYLVANIA

Bedford County
East Bedford (8), Morrison Cove Valley between New Enterprise and Waterside (8)

Chester County
Brinton's quarry, Westtown Twp. (8)(19), Charlestown Twp. (8), East Caln (8), East Marlboro (8), Entrikin's farm (8), Glenhall, Newlin Twp. (8)(19), Jug Hollow mine (8), Lenape (8), Parkesburg, Sadsbury Twp. (8)(19), Sadsburyville, Sadsbury Twp. (8)(19), Pocopson, Pocopson Twp. (8)(19), ¼ mile east of Pocopson Station, Birmingham Twp. (19), south and southwest of Sconneltown, East Bradford Twp. (19), 2 miles south of West Chester, East Bradford Twp. (19), northwest of Coatesville, Valley Twp. (19)

Cumberland County
1.5 miles northwest of Carlisle (19)

Delaware County
West of Morgan Station, Aston Twp. (8)(19), ½ mile west of Crozierville, Aston Twp. (8)(19), 1.5 miles south of Chadd's Ford, Birmingham Twp. (8)(19), ¼ mile east of Chester Station, Chester Twp. (19), Henvi's quarry, north of Chester Creek, Chester Twp. (19), ¼ mile west of Upland Station, Chester Twp. (19), near Bridgewater Station, Chester Twp. (19), along Crum Creek, near Worrell, Marple Twp. (19), ½ mile south of Sycamore Mills, Middletown Twp. (P)(19), 2 miles north of Boothwyn, Upper Chichester Twp. (P)(8)(19), ½ mile north of Boothwyn, Upper Chichester Twp. (19), Blue Hill, 2.5 miles north of Media, Upper Providence Twp. (19), Crum Creek, 1.5 miles northeast of Media, Upper Providence Twp. (19), Hunter's farm, Upper Providence Twp. (8)(19), Copple farm, ½ mile east of Media reservoir, Upper Providence Twp. (8)(19), Concord Twp. (8), Edgemont (8), Randolph's farm (8), Sharpless' farm, Nether Providence Twp. (8), Shaw and Esray's quarry, Chester (8), Wawa (8)

Lancaster County
1 mile northwest of Mt. Pleasant, Bart Twp. (1)(8)(19), Strasburg (8)

Philadelphia (city)
Falls of Schuylkill River (8), Tacony Creek (8)

York County
New Salem (8)

RHODE ISLAND

Bristol County
Two miles south of Bristol (7)(14), Bristol Neck, near Mount Hope Bridge by old ferry slip (13)(19)

Kent County
Rockland (14)

Providence County
Old Batty farm, Harrisville (14), Blackstone River (14), Iron Mine Hill (14), road cut, Rts. 195 and 295 (14), Winsor Heights (14), Old River Road quarry, Lonsdale (14), Old Scythe-stone quarry, Forestdale (14), Union Village (14), Waterford (14), Providence (14)

Washington County
Ashaway, Hopkinton (13)(14)(19)(24), granite quarries, Westerly Twp. (14)

SOUTH CAROLINA

Abbeville County
Due West, 18 miles northwest of Greenwood (20)(23)

Greenwood County
1.5 miles southeast of Shoals Junction (19), 1 mile southwest of Shoals Junction (19), 4 miles southeast of Donalds (19)

Laurens County
Near Cross Hill (20)

VIRGINIA

Albemarle County
Ash Lawn, about 3.5 miles south of Charlottesville (6)(20), Sunny Fields area, east of Charlottesville (6), 1 mile southeast of Massies Mill (6), 1 mile south of Covesville (6)

Amelia County
Rutherford mines (P)(6), Duncan farm on county road 638, southeast of Amelia (6)

Amherst County
Fancy Hill, 1/3 mile north of Sandidges Post Office (6)(19), near Amherst (20)(26), Buffalo Ridge (6), 2.5 miles northeast of Lowesville (6)

Appomattox County
Northeast side of county road 616, 0.7 mile northwest of intersection with state road 24 (6), 50 yds west of county road 161, 1.2 miles from intersection with state road 24 (6)

Bedford County
Near Moneta (6)

Buckingham County
Near New Store (6), near Willis Mountain (6)

Campbell County
Near Brookneal (6)(19), 1/3 mile northeast of Brookneal (19), 10 miles northeast of Brookneal (6)

Charlotte County
2 1/4 miles westnorthwest and 4 miles south of Charlotte Court House (19), 4.5 miles southwest and 2.6 miles west of Charlotte Court House (6)

Culpeper County
Quarry east of Culpeper (6)

Fairfax County
Vicinity of Centreville (6)

Fluvanna County
1 mile eastnortheast of Yanceys Store (6)

Henry County
1.5 miles northnortheast of intersection of county road 687 and state route 58 (6)

Louisa County
At and near Trevilians (6), 4 miles south of Trevilians (19)

Nelson County
2.5 miles northeast of Lowesville (6)

Prince Edward County
0.5 miles east of Rice (6), 3 miles north of Rice (19)

Prince William County
Minnieville (6)(19)

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The authors are indebted to George Robinson, Donald Peacor and Richard Thomssen for very helpful technical reviews of the original manuscript. The photographic expertise of Roy E. "Chip" Clark, Jr., and Victor E. Krantz of the Smithsonian Institution, Hugh Morton of the Grandfather Mountain Nature Museum, D. C. Sinclair and Greg Hart are gratefully acknowledged.

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EDGARBAILEYITE
THE FIRST KNOWN SILICATE OF MERCURY, FROM CALIFORNIA AND TEXAS

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ABSTRACT

Edgarbaileyite, idealized as $Hg_6^{+1}Si_2O_7$, is monoclinic, space group $C2/m(12)$, with refined unit-cell parameters a = 11.725(4), b = 7.698(2), c = 5.967(2) Å, β = 112.07(3)°, V = 499.2(2) Å^3, $a:b:c$ = 1.5231:1:0.7751, Z = 2. The strongest eight lines in the X-ray powder pattern are [*d (I) (hkl)*]:6.28 *(20)* (110); 3.160 *(100)* (021); 3.027 *(27)* ($\bar{2}$21); 2.952 *(34)* ($\bar{2}$02); 2.765 *(20)* (002); 2.715 *(63)* (400); 2.321 *(24)* ($\bar{4}$21); 1.872 *(36)* ($\bar{6}$02). The mineral is rare, but rather widespread. At the Socrates mine, Sonoma County, California, it has been identified as thin crusts on fracture surfaces, as disseminated rounded to mammillary masses in small cavities, and as hollow mammillary nodules; it is most closely associated with chalcedonic quartz, native mercury, cinnabar and montroydite in a host rock composed principally of magnesite and quartz. At the Clear Creek claim, San Benito County, California, the habit is identical to that at the Socrates mine; it is most closely associated with native mercury and montroydite

[1]Geological Survey of Canada contribution number 12989.

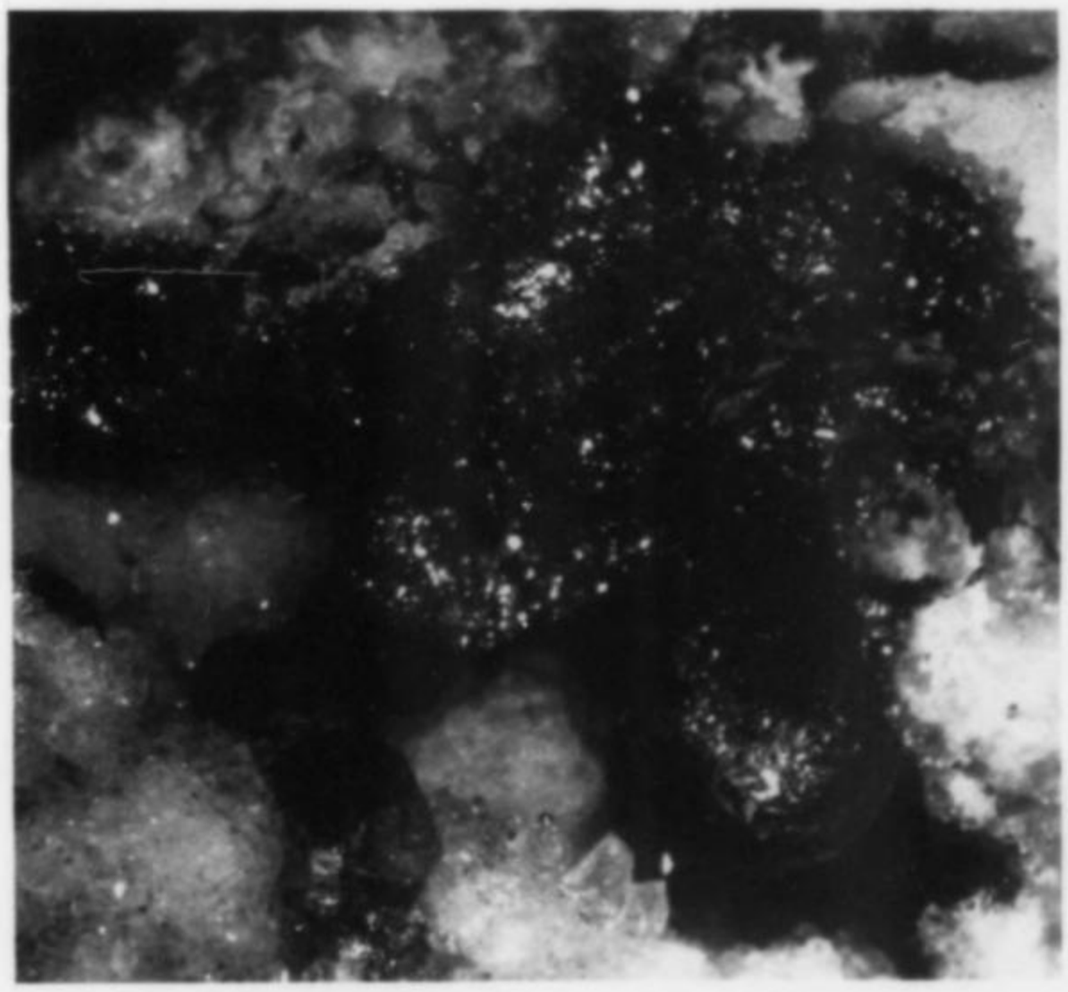

Figure 1. **Nodular masses of edgarbaileyite in a quartz-lined cavity. Field of view is 17 mm (Socrates mine).**

in a host rock composed principally of quartz, magnesite and chalcedony. Edgarbaileyite has also been identified on a museum specimen from Terlingua, Brewster County, Texas, as ill-formed tabular aggregates and sheaves of crystals in cavities and fractures; it is most closely associated with montroydite, terlinguaite, eglestonite and native mercury in a matrix of calcite, quartz and barite. Crystals range from cryptocrystalline and anhedral up to 0.2-mm platy crystal aggregates with dominant {100} form. Crystals are polysynthetically twinned on {100}. Edgarbaileyite is photosensitive and is varicolored; freshly exposed material is lemon-yellow to orangish yellow; exposed surfaces range from dark olive-green to a lighter yellowish green to dark green-brown. Physical properties include: pale green streak with a yellow tinge; vitreous (crystals) to resinous (masses) luster; translucent (crystals) to opaque (masses); non-fluorescent; VHN_{100} 192 (range 153–217); calculated Mohs' hardness 4; brittle; irregular to subconchoidal fracture; density 9.4(3) g/cm^3 (9.11 calc. for empirical formula). The mineral is optically biaxial with all refractive indices greater than 2; it has weak pleochroism and strong absorption. In polished section, edgarbaileyite is weakly to strongly bireflectant and is not pleochroic. In plane-polarized light it is gray to slightly lighter gray with pale lemon-yellow internal reflections. Measured reflectance values for 2 grains in air and in oil are tabulated. Maximum and minimum calculated refractive indices (at 590 *nm*) are 2.58 and 2.10. Electron microprobe analyses (from the Socrates mine) yielded Hg_2O = 89.6, SiO_2 = 8.6, sum = 98.2 weight %, corresponding to $Hg^{+1}_{6.00}Si_{2.00}O_7$, based on O = 7. Virtually identical results were obtained from microprobe analyses of Terlingua material. The mineral is named for Dr. Edgar Herbert Bailey (1914–1983), distinguished geologist and mercury commodity specialist for the U.S. Geological Survey.

INTRODUCTION

The new mineral species described here, edgarbaileyite, was first brought to the attention of one of us (RCE) by Dr. Edgar Bailey. He had received a specimen containing an unidentified yellow mercury-bearing mineral from Leo Rosenhahn, who had originally collected the material at the Socrates mine, Sonoma County, California in 1963. The first X-ray powder pattern was run in March, 1968, and could not be identified with any known inorganic phase listed in the Powder Diffraction File. Somewhat later, in 1972, Edward H. Oyler collected some specimens at the Clear Creek claim, San Benito County, California, and submitted a massive yellow-orange phase to RCE for X-ray identification. Oyler's unknown was found to be identical to Rosenhahn's previously unidentified mineral. However, a lack of sufficient pure material prevented a more detailed mineralogical study at that time. In 1987, Mr. Oyler and John Parnau brought RCE some additional specimens from the Socrates mine, which Parnau had collected in 1963. Megascopic examination and X-ray powder diffraction study confirmed the presence of the same mineral previously identified in 1968 and in 1972. In addition, the same mineral from Terlingua, Brewster County, Texas, was found by AJC during the acquisition of optical reflectance and chemical data for a range of oxide minerals for eventual inclusion in the QDF (*The Quantitative Data File for Ore Minerals,* Criddle and Stanley, 1986). The identity of the Terlingua material with that from the Socrates mine was confirmed by comparison of its X-ray powder data with the unpublished X-ray powder data previously submitted to the Commission on New Minerals and Mineral Names, I.M.A. Subsequently, AJC wrote to the senior author, and it was agreed that the chemical, optical and crystallographic data for the Terlingua material should be included in the present paper. Sufficient material was then available from both California and Texas for a comprehensive mineralogical study and full characterization; the results are reported here.

We take great pleasure in naming this new mineral *edgarbaileyite* after Dr. Edgar Herbert Bailey (1914–1983), a distinguished geologist who worked for the United States Geological Survey as a mercury commodity specialist, and who studied and described mercury deposits both in the U.S. and in Turkey. Two of the occurrences within the continental U.S. on which he reported were the Socrates mine (Bailey 1946) and the deposits at Terlingua (Yates and Thompson, 1959). The mineral and name have been approved by the Commission on New Minerals and Mineral Names, I.M.A. The type locality is hereby designated the Socrates mine for two reasons: (1) chronologically, it was the first verified occurrence, and (2) most of the megascopically identifiable edgarbaileyite comes from this locality. The holotype specimen, which has been broken into two hand specimens, several mineral fragments, two polished grain mounts and two SEM stubs, is preserved within the Systematic Reference Series of the National Mineral Collection at the Geological Survey of Canada, Ottawa, under catalog number NMC 65531. The hand specimen containing edgarbaileyite from Terlingua, Texas, is housed within the mineral collections of the British Museum (Natural History), London, under catalog number BM 1906, 190.

OCCURRENCE

Edgarbaileyite has been identified at two widely separated localities in California and in a museum specimen labeled as originating from Texas. The localities are: the upper workings of the abandoned Socrates mercury mine, Sonoma County, California (latitude 38°45′47″N, longitude 122°45′30″W); a small prospect pit near the long-abandoned Clear Creek mercury mine, New Idria District, San Benito County, California (latitude 36°22′59″N, longitude 120°45′58″W); and the Terlingua deposit, Brewster County, Texas (latitude 29°20′N, longitude 103°39′W). The mineral is rare, but is rather widespread at both occurrences in California. Its spatial distribution at Terlingua is unknown, but we assume it to be very rare.

At the Socrates mine, edgarbaileyite is most closely associated with quartz, native mercury, cinnabar and montroydite in host rock principally composed of magnesite and quartz. Other minerals identified are chalcedonic quartz, opal and chromite. For more information regarding the mercury deposits found within Sonoma County and, specifically, the Socrates mine, the reader is referred to the report by Bailey (1946). Collectors should be advised that the Socrates mine has been bulldozed and that there are no remnants nor dump from which specimens may be obtained.

At the Clear Creek locality, edgarbaileyite is closely associated with native mercury, montroydite and minor cinnabar. The host rock is predominantly quartz, magnesite, chalcedony with minor pecoraite, opal, goethite, chromite, montmorillonite, huntite, dolomite, gypsum and chlorite. Mercury-bearing minerals identified by X-ray diffraction analysis include edoylerite (Erd *et al.*, in preparation, IMA approved), wattersite (Erd *et al.*, in preparation, IMA approved), metacinnabar, eglestonite, calomel, terlinguaite, mosesite, gianellaite and five unnamed mercury-bearing phases that are currently under investigation. A description of the geology of the Clear Creek mercury mine is given by Eckel and Myers (1946).

At both Californian localities, edgarbaileyite has been identified in several different varietal forms: as thin crusts on fracture surfaces, generally coating cinnabar or quartz; as disseminated rounded to mammillary masses in small cavities that are usually lined with quartz or chalcedony; and as hollow mammillary nodules as much as 3.4 mm in diameter with a wall thickness of 1.2 mm (Fig. 1).

The Terlingua specimen, which was purchased from Dr. F. Krantz, Bonn, Federal Republic of Germany, in 1906 by the British Museum (Natural History), consists of intergrown crystals of montroydite, terlinguaite, eglestonite and edgarbaileyite in cavities and fractures in a matrix of crystalline calcite, quartz and barite. Native mercury is also abundant within the cavities. For more information and references on the Terlingua deposit, the reader is referred to Hill (1903), Yates and Thompson (1959), Crook (1977), Roberts *et al.* (1981) and Origlieri (1990).

MORPHOLOGY

Most edgarbaileyite at the Californian localities occurs as cryptocrystalline anhedral masses without obvious crystal form. Rarely, crystalline masses composed of aggregates as much as 50 μm in size (Fig. 2) were observed in small vugs. Individual crystals have a platy micaceous habit with average dimensions of 0.1 x 5 x 5 μm. The dominant face, based on single-crystal examination, is {100} (Fig. 3).

At Terlingua, edgarbaileyite is characteristically intergrown with montroydite, where ill-formed tabular crystals of edgarbaileyite aggregate, and sometimes form sheaves of crystals as much as 2 x 2 mm. Only two discrete single-crystals, as much as 200 μm in size, were found. These have a pronounced platy habit with {100} face (Fig. 4)—identical to those from the Socrates mine. Crystal-structure studies indicate that these crystals are polysynthetically twinned on {100}.

Figure 2. **Scanning electron photomicrograph of a vug containing edgarbaileyite crystal aggregates (Socrates mine).**

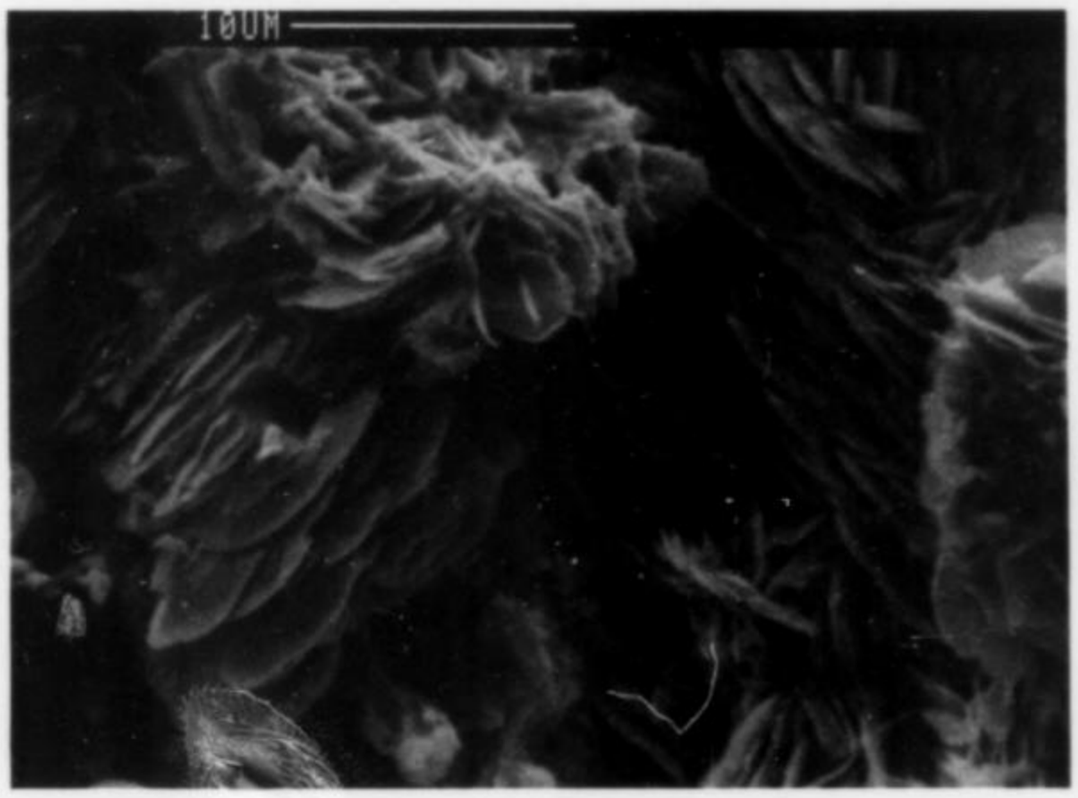

Figure 3. **Scanning electron photomicrograph showing the typical morphology of edgarbaileyite crystals (Socrates mine).**

PHYSICAL AND OPTICAL PROPERTIES

Edgarbaileyite is variable in color; freshly exposed material is lemon-yellow to orangish yellow; exposed surfaces are varicolored from dark olive-green, to a lighter yellowish green, to a dark green-brown. The mineral is photosensitive and darkens with exposure to ultraviolet, infrared, X-radiation, and the visible light spectrum. The streak is pale green with a definite tinge of yellow. Crystal aggregates are translucent with a vitreous luster; nodular masses are opaque with a resinous luster. The mineral is brittle, possesses an irregular to subconchoidal fracture, and is nonfluorescent under both longwave and shortwave ultraviolet light. The measured density of the Socrates mine material, determined by Berman balance on 11.65 mg of hand-picked sample containing approximately 1% native-mercury contamination, is 9.4(3) g/cm^3; the calculated density, based on the empirical formula, is 9.11 g/cm^3.

Microhardness measurements were made with a Leitz Miniload 2 tester. The range for VHN_{100} from three badly fractured but measurable indentations is 153 to 217, the average is 192. This corresponds very approximately to a Mohs' hardness of 4.

Optically, edgarbaileyite is biaxial with all refractive indices greater than 2. The lowest refractive index (X′) is greater than 2, with low to medium relief; the highest refractive index (Z′) is much greater

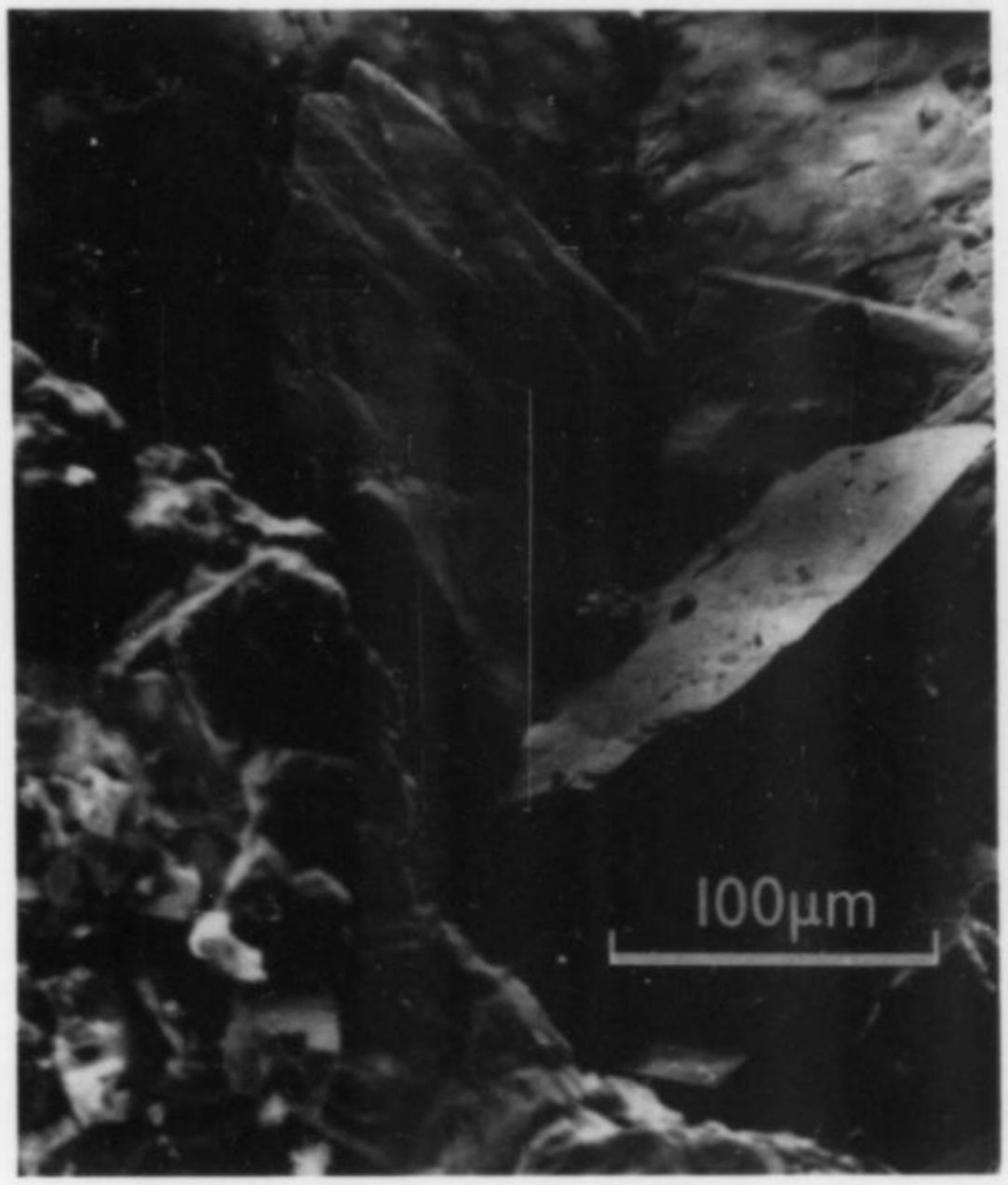

Figure 4. **Electron-photomicrograph of three crystals of edgarbaileyite on calcite/dolomite. Note the platy habit of the crystal in the foreground (Terlingua).**

than 2 with high relief. The color of the mineral under oils is lemon-yellow. The pleochroism is weak, from lemon-yellow to a deeper shade of yellow; it is partially obscured by the strong change in relief. There is also strong absorption, especially for the higher index. Grain-size limitations made it impossible to determine the optical sign, orientation or extinction angles. Edgarbaileyite is slowly attacked by high-index immersion media.

In polished section, in reflected light, edgarbaileyite from Terlingua (depending on orientation) is weakly to strongly bireflectant and is not pleochroic. In plane-polarized light (at a color temperature of about 3300°K) it is gray to a slightly lighter gray. The surface properties are, however, generally masked by the pale lemon-yellow internal reflections. Reflectance measurements on four grains were made rel-

ative to a Zeiss Si reflectance standard (no. 472) using the equipment and procedures described by Criddle *et al.* (1983). The areas measured are virtually free from internal reflections (*cf.* Dunn *et al.* (1988), on ingersonite). Representative reflectance spectra are shown in Figure 5, and minimum (R_1) and maximum (R_2) reflectance for the least and most bireflectant grains are given in Table 1. A characteristic feature, observed between crossed polars, of all of these grains is that they are finely twinned, or compound and finely fibrous. The five measurements on the four grains were taken on areas that are apparently untwinned and monocrystalline. The reflectance spectra in Figure 5 confirm that edgarbaileyite is strongly bireflectant (hence, strongly birefringent), they also demonstrate that its biaxial character is more pronounced below 500 *nm*. Refractive indices calculated from the R and ^{im}R data are all greater than 2, and their dispersion follows the same trend as the R spectra; with $r<v$. The same is true for the absorption, and, as was noted above, the absorption for R_2 (approximating to Z′ for the most extreme values of R) is higher throughout the visible spectrum than for R_1 (X′). The maximum and minimum refractive indices (taken from all of those calculated from the five sets of R data) at 590 *nm* are 2.58 and 2.10. Gladstone-Dale calculations for the mean refractive index of 2.34 (mean of the ten R-derived values), using the constants reported by Mandarino (1981), the idealized formula, and the calculated density, gave the following values for the compatibility index: +0.017 for the Hg_2O constant $k = 0.144$, and −0.047 for the Hg_2O constant $k = 0.134$ ("superior" and "good," respectively, in the terminology of Mandarino, 1981).

CHEMISTRY

Edgarbaileyite from the Socrates mine was analyzed chemically by means of a CAMEBAX electron microprobe, utilizing a 20-kV operating voltage, a 30-nA beam current, a 10-second count rate, and a 6-micron beam diameter. The standards employed were natural quartz (Si) and natural cinnabar (Hg). A wavelength dispersive microprobe scan indicated the absence of any other elements with atomic number greater than 9 except those reported here. The average of five analyses, calculated after the crystal structure was determined, gave Hg_2O = 89.6(1.0), SiO_2 = 8.6(6), total = 98.2 weight %. With O = 7, the empirical formula is $Hg_{6.00}^{+1}Si_{2.00}O_7$, or ideally, $Hg_6^{+1}Si_2O_7$ with Z = 2. This idealized formula requires Hg_2O = 91.24, SiO_2 = 8.77, total = 100.01 weight %. An infrared absorption spectrum (Fig. 6) indicates the absence of both (OH) and H_2O vibration bands and confirms the anhydrous nature of the mineral.

Edgarbaileyite from Terlingua was chemically analyzed by means of a Cambridge Instruments Microscan IX electron microprobe utilizing a 20-kV operating voltage, a 25-nA beam current and a defocussed 20-micron beam diameter. The standards employed were wollastonite (Si) and cinnabar (Hg). The average of three analyses gave Hg = 87.5, Si = 3.7, O(calc.) = 7.8, total = 99.0 weight %. The empirical formula, assuming 15 atoms for the formula unit, is $Hg_{6.2}Si_{1.9}O_{6.9}$. These data are very similar to those reported above for the edgarbaileyite from the Socrates mine.

Edgarbaileyite is the first reported mercury-bearing silicate to occur naturally or to be synthetically prepared. Röpke and Eysel (1978) investigated the HgO-GeO_2-SiO_2 system in the presence of water up to 600°C and 4 kb. They found that no mercury silicate compound, and only one mercury germanate compound (Hg_2GeO_4) exists in that system under those conditions. To our knowledge, the system Hg_2O-SiO_2 has not yet been investigated.

The mineral is easily soluble in cold 1:10 HCl; it quickly turns white, appears to "bloom" somewhat, and then disintegrates to a powdery residue. In cold 1:1 HNO_3 the mineral dissolves rather rapidly and leaves a transparent shell that is both isotropic and gelatinous.

HEATING EXPERIMENTS

Gentle heating to low red heat in a closed tube destroys the structure.

***Table 1.* Reflectance values for two grains of edgarbaileyite: for ^{im}R, $n_D = 1.515$.**

Grain:	1		2		1		2	
λ*nm*	R_1	R_2	R_1	R_2	$^{im}R_1$	$^{im}R_2$	$^{im}R_1$	$^{im}R_2$
400	16.7	20.2	20.0	24.9	5.32	7.42	7.42	11.25
10	16.9	19.85	20.25	24.6	5.43	7.20	7.64	10.9
20	17.1	19.5	20.45	24.4	5.53	7.02	7.48	10.5
30	17.2	19.3	20.1	24.2	5.53	6.93	7.14	10.2
40	17.0	19.2	19.4	23.9	5.38	6.83	6.63	9.91
450	16.75	19.0	18.75	23.5	5.18	6.83	6.16	9.63
60	16.4	18.8	18.1	23.2	4.91	6.48	5.73	9.33
70	16.1	18.5	17.5	22.8	4.69	6.24	5.38	9.12
80	15.8	18.2	17.0	22.5	4.50	6.03	5.08	8.88
90	15.5	18.0	16.6	22.2	4.34	5.85	4.82	8.67
500	15.3	17.7	16.2	21.9	4.21	5.70	4.63	8.49
10	15.1	17.5	15.9	21.7	4.13	5.57	4.49	8.37
20	14.9	17.3	15.7	21.5	4.07	5.47	4.38	8.25
30	14.7	17.0	15.4	21.25	4.00	5.37	4.26	8.12
40	14.6	16.8	15.2	21.1	3.93	5.26	4.16	8.00
550	14.5	16.65	15.0	20.9	3.87	5.15	4.07	7.88
60	14.3	16.5	14.9	20.7	3.81	5.05	3.98	7.77
70	14.2	16.4	14.7	20.6	3.75	4.97	3.90	7.67
80	14.2	16.2	14.6	20.5	3.71	4.90	3.84	7.59
90	14.1	16.1	14.5	20.3	3.65	4.83	3.78	7.50
600	14.0	16.0	14.4	20.2	3.61	4.77	3.73	7.43
10	14.0	15.95	14.3	20.1	3.58	4.72	3.70	7.37
20	13.95	15.9	14.2	20.0	3.54	4.68	3.66	7.30
30	13.9	15.8	14.2	19.9	3.52	4.65	3.62	7.25
40	13.85	15.8	14.1	19.8	3.50	4.60	3.59	7.21
650	13.8	15.7	14.0	19.75	3.48	4.57	3.57	7.16
60	13.75	15.6	14.0	19.65	3.46	4.53	3.54	7.12
70	13.7	15.55	13.9	19.6	3.41	4.48	3.51	7.06
80	13.7	15.5	13.9	19.5	3.39	4.44	3.49	7.03
90	13.6	15.5	13.8	19.4	3.38	4.41	3.45	6.99
700	13.6	15.4	13.7	19.4	3.34	4.39	3.43	6.95
Color values relative to CIE illuminant C:								
x	0.297	0.296	0.290	0.298	0.283	0.284	0.272	0.289
y	0.300	0.302	0.291	0.303	0.283	0.287	0.265	0.293
Y%	14.5	16.7	15.1	20.9	3.87	5.15	4.10	7.87
λ*d*	474	477	473	476	473	473	471	475
P_e%	6.8	6.7	10.5	6.1	13.8	13.0	20.1	10.4

Mercury is liberated almost immediately and is deposited on the sides of the tube. Edgarbaileyite turns white and remains that color. The reaction product was subjected to X-ray diffraction and yielded only the characteristic X-ray powder lines of a poorly crystallized opal-cT. Prolonged heating at 1000–1100°C for a period of 14 hours yielded a product that when X-rayed was found to be composed of major amounts of tridymite and minor amounts of cristobalite.

X-RAY DIFFRACTION

Despite repeated attempts to isolate suitable material from the Socrates mine for a single-crystal precession study, only two crystalline fragments, each less than 0.1 mm in longest dimension, were found that produced diffraction nodes on zero-level films. One fragment was mounted with b^* parallel to the dial axis, and the other fragment was mounted with c^* parallel to the dial axis. The levels collected using Zr-filtered Mo radiation were *hOl*, *Okl* and *hkO*. All final photographs were of extremely poor quality; nodal streaking produced by crystal

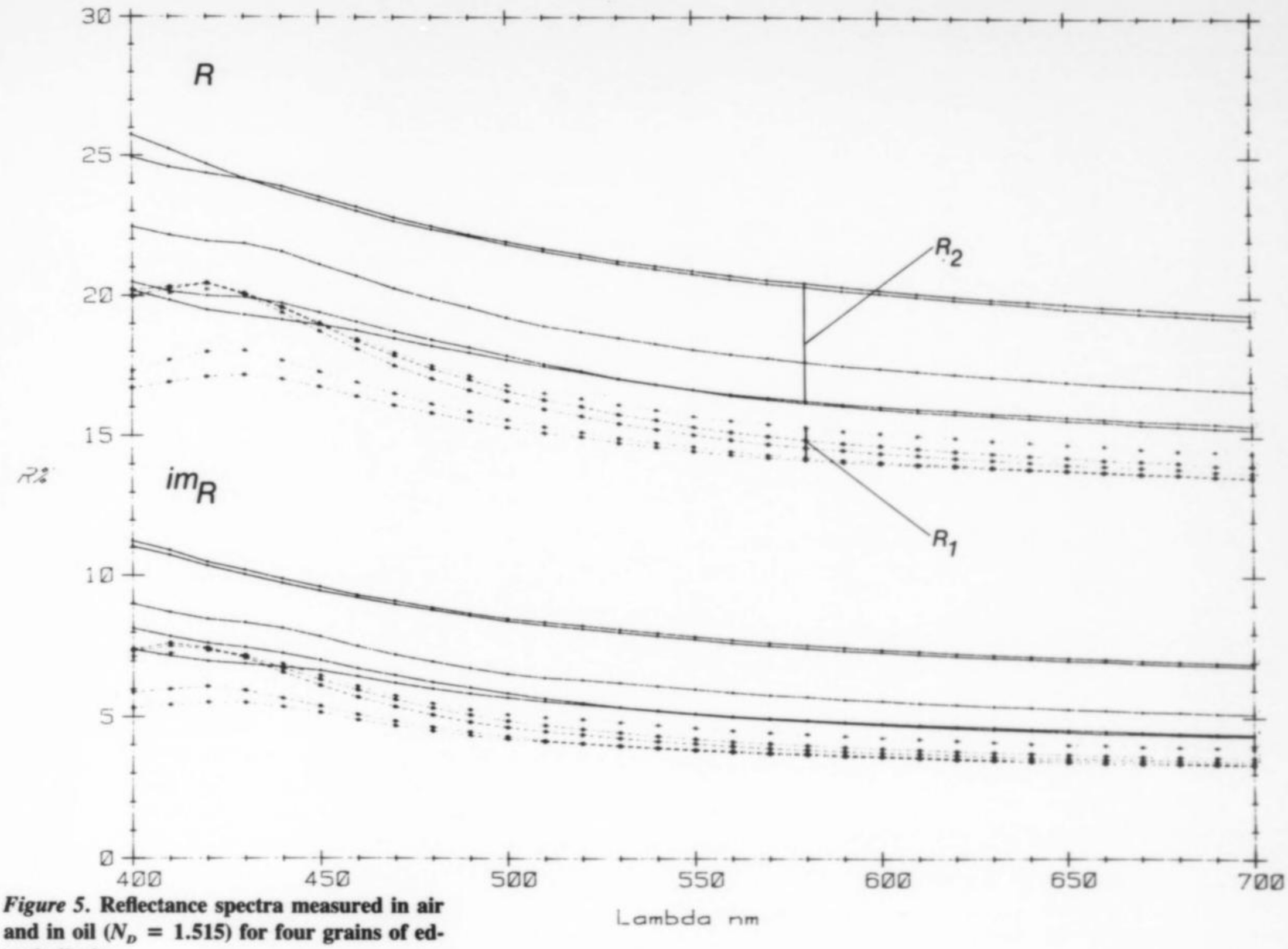

Figure 5. **Reflectance spectra measured in air and in oil (N_D = 1.515) for four grains of edgarbaileyite.**

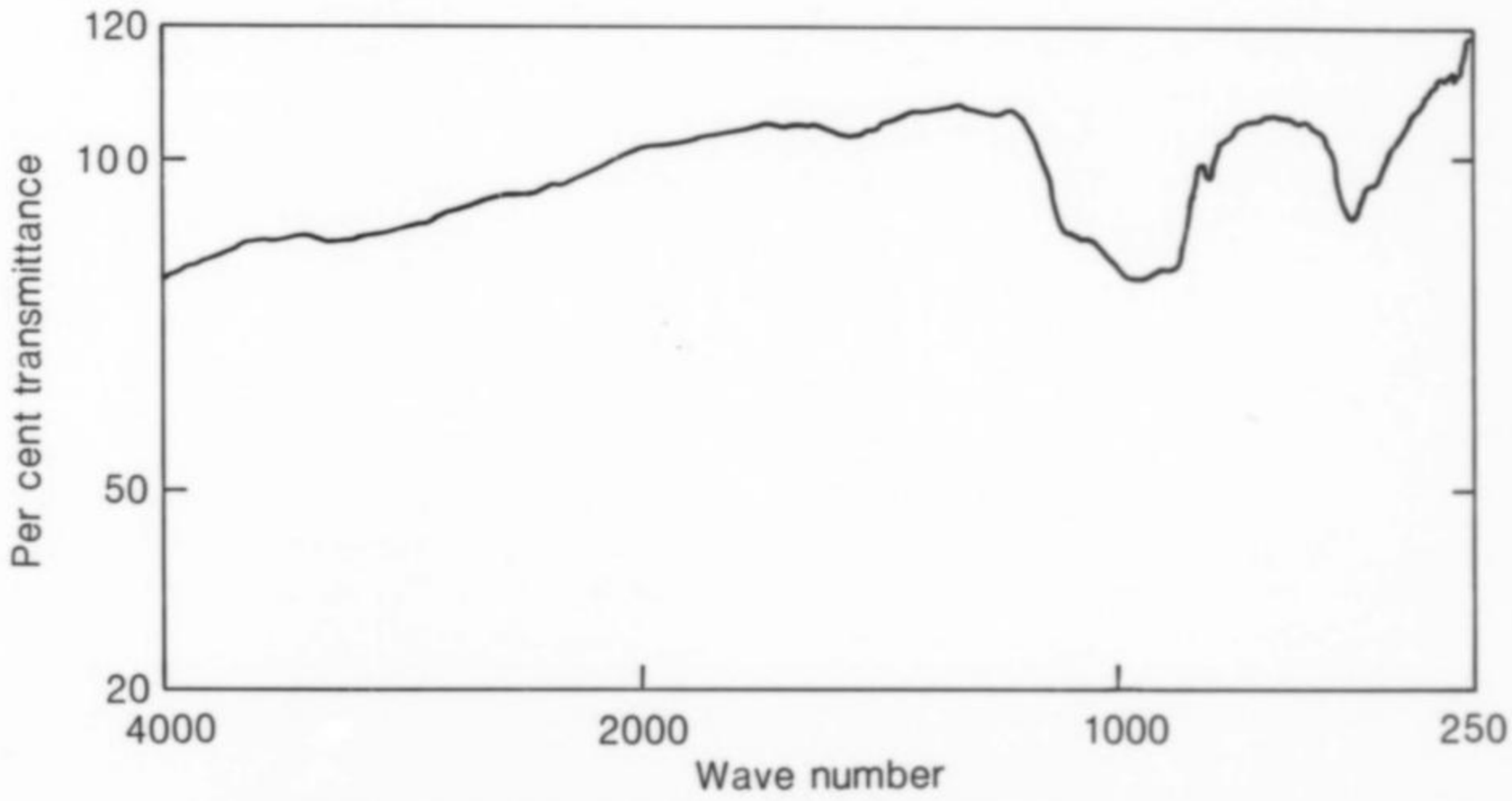

Figure 6. **Infrared absorption spectrum for edgarbaileyite.**

multiplicity was clearly evident on all films. Upper-level zones were also photographed, but the films were either blank or were uninterpretable. Inspection of the zero-level films showed that edgarbaileyite has monoclinic symmetry with measured and calculated unit-cell parameters: a = 10.98, b = 7.70, c = 5.94Å, β = 98.53°. The only observable systematic absence, OkO with k = 2n, dictated that the space-group choices were $P2_1/m$ (11) or $P2_1$ (4). However, crystallographic studies of the coarser Terlingua material have shown that the true space-group choices are $C2/m$(12), Cm(8) or $C2$(5). Polysynthetic twinning on {100} causes the apparent C-lattice violations noted above on the precession films of Socrates mine crystallites. The structure of edgarbaileyite from Terlingua was refined in space group $C2/m$(12) and gave the following unit-cell parameters: a = 11.755(3), b = 7.678(2), c = 5.991(2)Å, β = 111.73(3)°. A full description

Table 2. **X-ray powder data for edgarbaileyite.**

$I_{(meas)}$	dÅ$_{(meas)}$	dÅ$_{(calc)}$	*hkl*	$I_{(meas)}$	dÅ$_{(meas.)}$	dÅ$_{(calc.)}$	*hkl*
20	6.28	6.28	110	7	2.222	2.219	420
10	5.53	5.53	001	5	2.161	2.158	202
2	5.43	5.43	200	3	2.144	2.141	401
7	4.90	4.91	$\bar{2}01$	10	2.094	2.094	330
14	4.68	4.69	$\bar{1}11$	3	2.068	2.068	$\bar{4}22$
8	3.85	3.85	020			2.066	$\bar{5}12$
5	3.76	3.76	111	3	1.954	1.952	$\bar{6}01$
3	3.28	3.28	310	12	1.927	1.925	040
100	3.160	3.159	021	36	1.872	1.871	$\bar{6}02$
27	3.027	3.028	$\bar{2}21$	3	1.834	1.831	331
34	2.952	2.953	$\bar{2}02$	3	1.813	1.811	600
20	2.765	2.765	002	17	1.766	1.766	$\bar{2}23$
63	2.715	2.717	400	14	1.743	1.741	$\bar{6}21$
7	2.509	2.507	221	3	1.685	1.683	$\bar{6}22$
2	2.480	2.474	311	8*b*	1.657	1.658	530
6	2.454	2.452	$\bar{4}02$	9	1.613	1.612	$\bar{2}42$
17	2.353	2.353	$\bar{1}31$	5	1.580	1.580	042
24	2.321	2.321	$\bar{4}21$	12	1.572	1.575	203
7	2.245	2.246	022			1.570	440

Gunier-DeWolff camera; Co radiation, Fe filter ($\lambda CoK\alpha_1$ = 1.78892Å)
b = broad line
Intensities measured from diffractometer trace.
Indexed on a = 11.725, b = 7.698, c = 5.967Å, β = 112.07°

of the structure will be published elsewhere, but it should be noted that the structure refinement clearly shows that all the Hg present must be in the 1+ oxidation state.

Fully indexed Guiner-De Wolff powder data are presented for Socrates mine material in Table 2. The data have been indexed on the *C*-lattice determined from the Terlingua study. Refined unit-cell parameters, based on 34 diffraction lines between 6.28 and 1.572Å, gave: a = 11.725(4), b = 7.698(2), c = 5.967(2)Å, β = 112.07(3)°, V = 499.2(2)Å^3, $a:b:c$ = 1.5231:1:0.7751. It should be mentioned that the mineral is very stable. Except for the color change due to photosensitivity, the X-ray powder patterns remain unchanged for material that was originally collected over 25 years ago.

PARAGENESIS

The mineral is a secondary product formed, most probably, by the reaction of mercury and quartz. The conditions of formation are unknown. Edgarbaileyite from the Socrates mine has been found replacing quartz crystals *in situ*. The crystals morphologically and physically resemble quartz except that the color is opaque dark green. X-ray powder and single-crystal studies of one of these pseudomorphs showed no evidence of residual quartz lines in the powder pattern, and also showed that the pseudomorphs are composed of cryptocrystalline edgarbaileyite aggregates. At the Socrates mine and at the Clear Creek claim, edgarbaileyite is one of the latest minerals in the paragenetic sequence and is found near the center of the quartz veins that transect the host rock. At the Socrates mine some veinlets of edgarbaileyite have been found that were altered to a homogeneous mixture of montroydite and quartz.

ACKNOWLEDGMENTS

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FAMOUS MINERAL LOCALITIES:

TERLINGUA, TEXAS

Marcus Origlieri
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Vista, California 92084

The Terlingua, Texas, mercury deposits, known at least since 1850 and possibly earlier, have yielded a unique assemblage of rare mercury minerals, including several new species.

INTRODUCTION

Only a few mineral localities in Texas are widely known among mineral collectors. One of these is the Terlingua, Texas, mercury district in Brewster County, just west of Big Bend National Park. Unfortunately, few specimens have been produced from the area since the major mines closed in the 1940's. During their lifetime, these deposits produced approximately 150,000 flasks of mercury. Today the mines stand deserted and the town of Terlingua is being promoted as a tourist attraction. Specimens of the various mercury minerals are seen only rarely on the mineral market.

HISTORY

According to local legend, the mercury deposits were first noticed by Indians passing through the area on their way to Mexico. The cinnabar was supposedly mined on a very small scale for making red paint. Other legends suggest that the deposits were originally worked by the Spanish in the late 1700's or early 1800's. Unfortunately there is no evidence to substantiate this early history.

Reports of mercury deposits in the area began to circulate as early as 1850, shortly after that portion of southern Texas was acquired from Mexico in 1848 (Phillips, 1905). The first American claims were not staked until 1884, and mining had commenced at least by 1894 (Blake, 1896) in the vicinity of California Mountain. Thomas Golby (1924) reports having personally found ore there in 1896, and by then other miners were moving in as well.

Jack Dawson, J. A. Davies and Louis Lindheim began mining in the late 1890's and constructed a battery of adobe retorts for distilling mercury from the ores.

Around 1898 a post office was opened at California Mountain. The mining settlement and post office were named "Terlingua," but the exact origin of this name has been lost. Local residents suppose it is a corruption of some Spanish term such as *Tres Lenguas* ("Three Tongues") by which a camp or some local feature may have been known.

By 1900 Golby and his partners (two Norman brothers and Montroyd Sharpe, after whom montroydite was later named) had built a 10-ton furnace for refining mercury ores taken mostly from the Mariposa mine. They were known as the Marfa and Mariposa Mining Company, which operated until about 1910.

According to Hill (1902) the Chisos mine began operations in 1902 and soon became the principal producer in the district. By 1903 the population of Terlingua had grown to about 3000 people. New discoveries to the east caused much of this population to move, along with the post office and the town name, to the settlement surrounding the highly productive Chisos mine. The original settlement of Terlin-

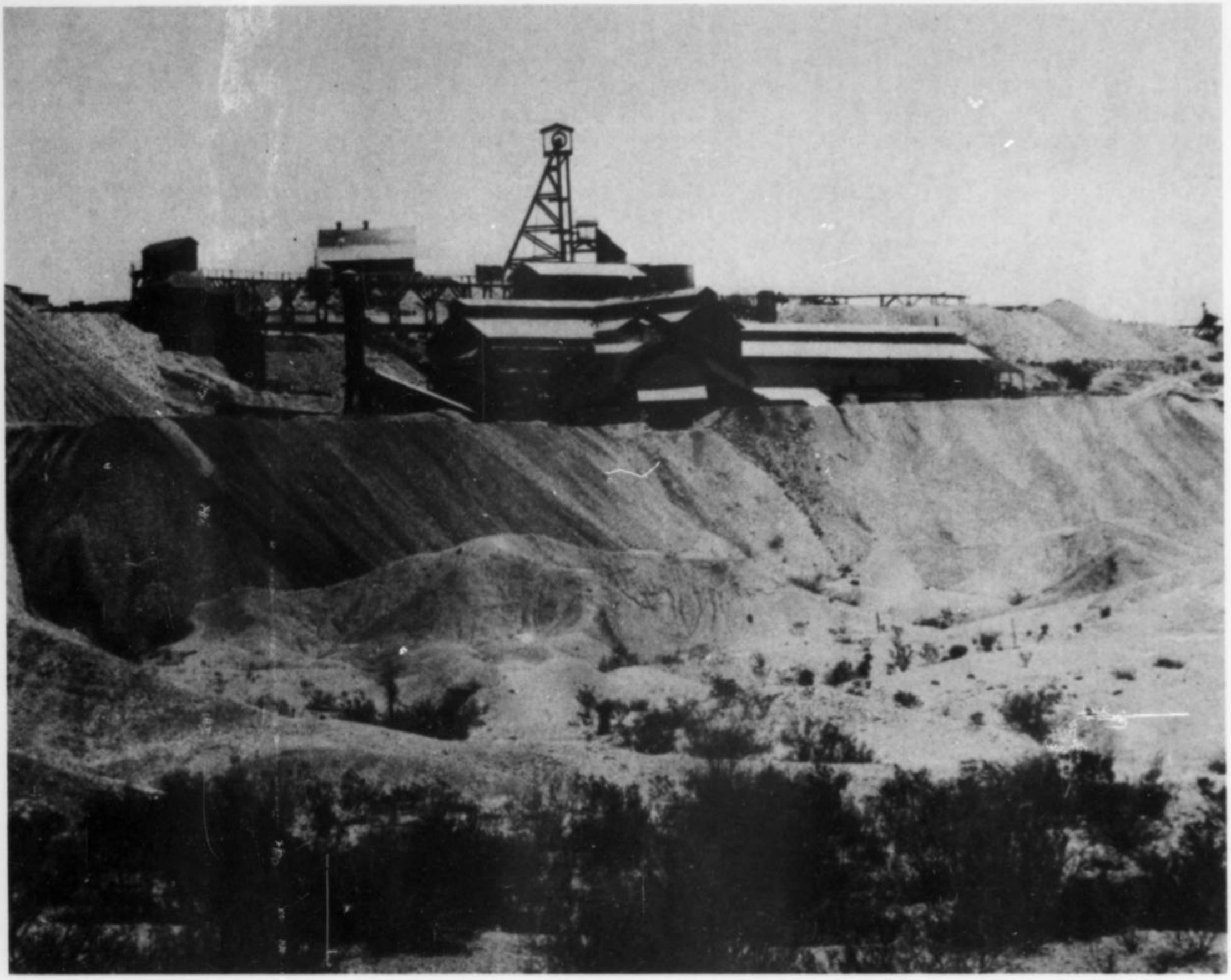


Figure 1. **Chisos mine, ca. 1925. (Photo courtesy of the Smithers Collection, University of Texas at Austin.)**

gua, having lost its name and post office, was renamed Mariposa. It is important in reading early reports on Terlingua to remember this name change in order to understand which area is being discussed.

The Chisos mine was owned and operated by Howard E. Perry of Chicago for most of its forty-plus years of its productive life. He was very conservative and secretive in his operations. In 1906 he built a mansion over-looking the mine and town which still stands today (Ragsdale, 1976).

A 20-ton furnace was installed at the Chisos mine in 1904. At about the same time, mercury was discovered at Study Butte to the east. The Big Bend Mining Company, and the Texas-Almaden Company, were formed and built furnaces, but they ceased operations in 1905 and 1906, leaving the Chisos mine as the only operating property in the district for several years prior to World War I.

The increase in the price of mercury which came as a result of the war revived several of the old mines, and particularly benefitted the Chisos mine. The company had just discovered the largest orebody in their history (called the "Pipe" body) which was mined from 1915 to 1918. The Mariposa and the Colquitt-Tigner mines reopened, the new Rainbow mine was opened in 1916, and the Study Butte mines were reopened until about 1920. Lower mercury prices and an increased flow of water on the lower levels caused most of these mines to close within a few years.

Once again, in the early 1920's, only the Chisos mine remained in operation. F. W. Oakes, Jr. acquired many dormant properties in the district and built a 30-ton furnace, but suspended his activities in 1930. The following year the Tarrant Mining Company acquired most of his leases, and produced mercury from the Monte Cristo mine in 1933.

When it was suspected that the Chisos miners had crossed their boundary line and were stealing ore, the Rainbow mine resumed operations in 1927. Obviously caught, Perry made a settlement and

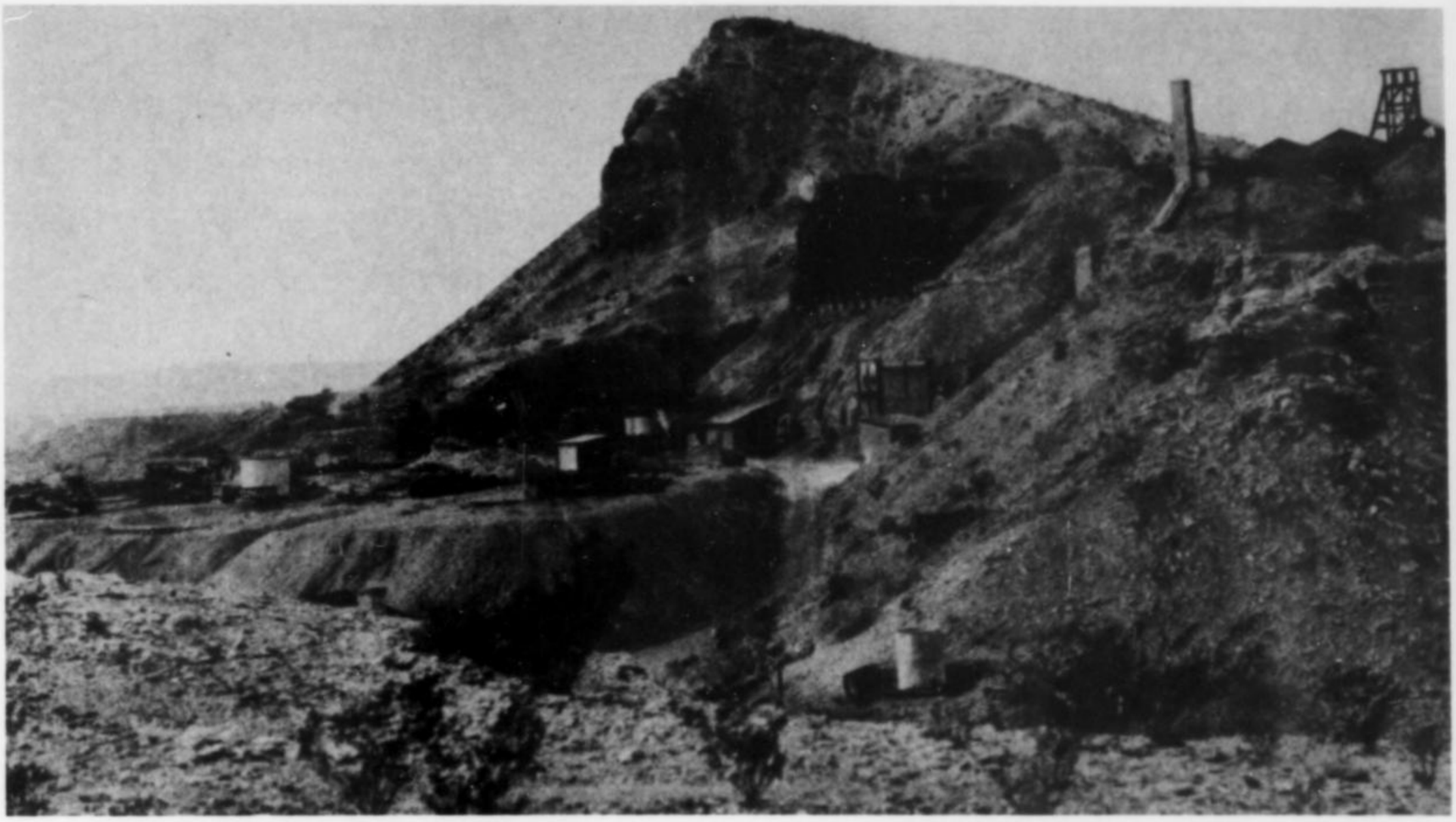


Figure 2. **Study Butte mine, ca. 1923. (Photo courtesy of the Smithers Collection, University of Texas at Austin.)**

the Rainbow was soon mining the rich ore. Ragsdale (1976) quotes C. T. Matthews and W. L. Armstrong from interviews. They were given the right to enter the Chisos mine on behalf of the Rainbow mine during litigation:

> Matthews said that his first impressions of the long-forbidden workings of the Chisos mine, when they finally bumped to an abrupt stop at the base of the shaft, remain graphic in his memory. "The heat in the shaft was intense," he recalls, "and the sweating semi-nude bodies of the Mexican miners appeared like gleaming savages in the subdued light of the carbide lanterns." Armstrong, long accustomed to the underground workings of a mine, was equally impressed by the spectacular showing of rich ore. He recalls: "[William D.] Burcham was there when I arrived. He was sitting on a pile of ore. He said to me, 'I've never seen such ore as this.' It looked like you had killed a cow. Red everywhere. In the artificial light it looked like a room full of rubies. Worth a helluva lot more." Armstrong added that the geological reports state that the ore found in the area of the Chisos-Rainbow contact was some of the richest in the district.

The Study Butte mine opened again in 1928 under a company called Brewster Quicksilver Consolidated, and yielded $400,000 in mercury up until 1936 when it was reorganized as Southwest Mines.

Although World War II brought a renewed demand for mercury the Chisos had depleted its ore reserves and bankruptcy proceedings in 1942 took the mine away from Perry, who was old and too tired of it to fight (Ragsdale, 1976). It was reopened by the Esperado Mining Company but operated uneconomically until the end of the war primarily from dump material and ore shipped in from the Perry open-pit of the Mariposa mine (Sharpe, 1980). Production for the war effort was stepped-up at the Two-Forty Eight, Study Butte and particularly at the Fresno mine. A considerable quantity of mercury is said to have been recovered when the aging furnace at the Chisos mine was dis-

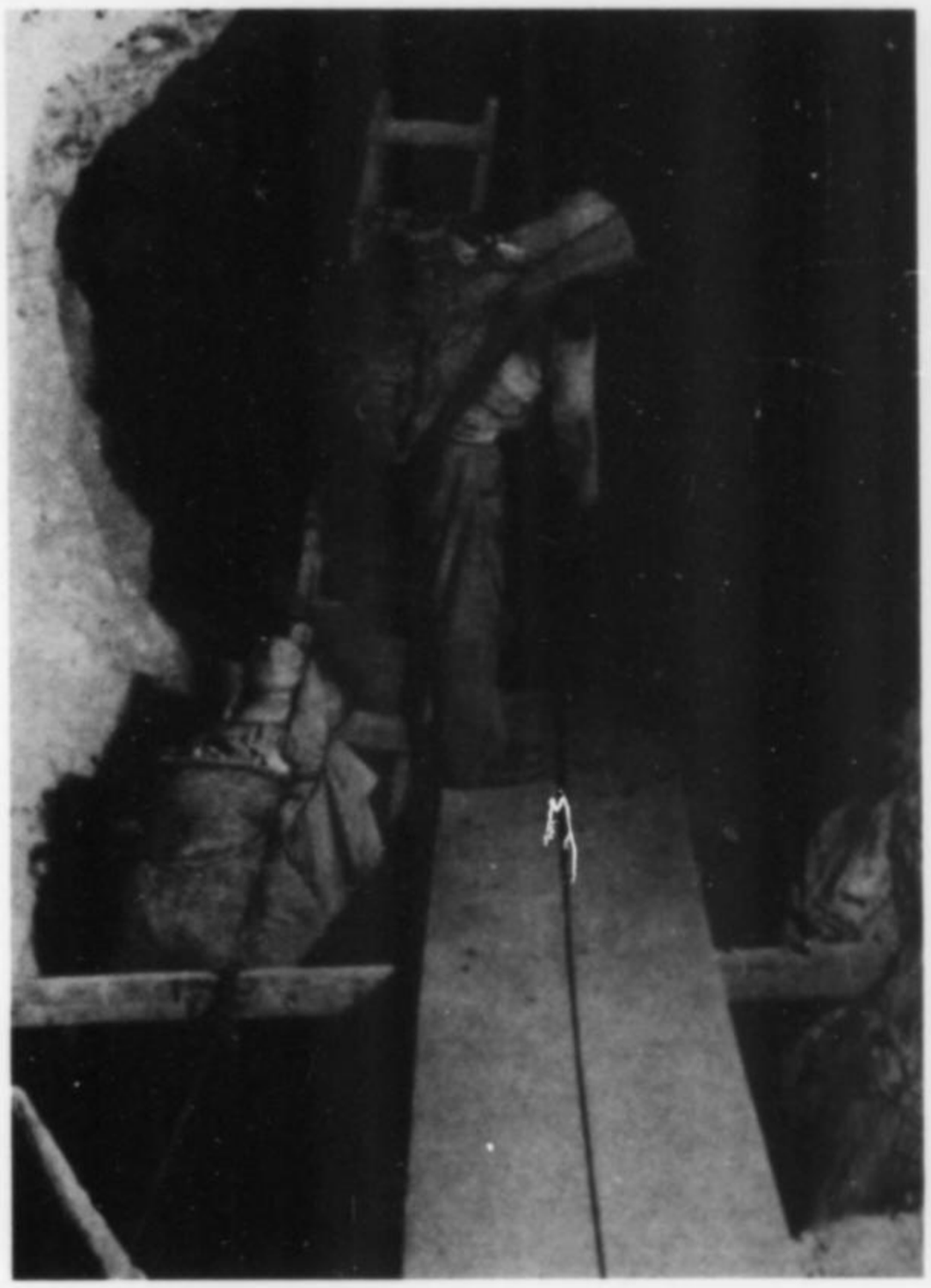


Figure 3. **Mexican miners carrying 80-pound bags of cinnabar ore in a mine in the Terlingua district. (Photo courtesy of the Smithers Collection, University of Texas at Austin.)**

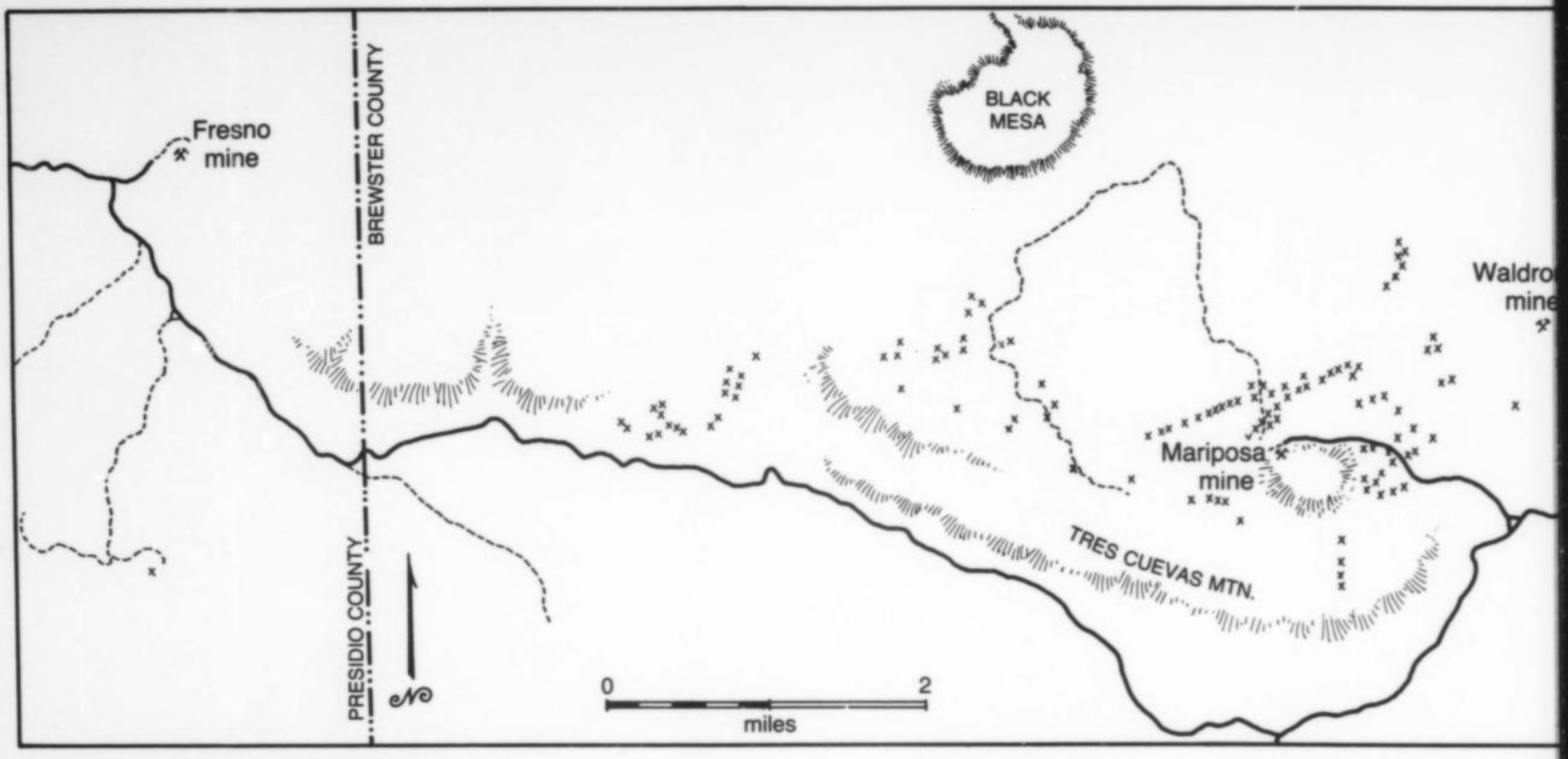


Figure 4. **Major mines in the Terlingua district.**

Figure 5. **Waldron mine, ca. 1916. (Photo courtesy of the Smithers Collection, University of Texas at Austin.)**

mantled . . . perhaps the metals had pooled in open spaces of the foundation structure during its many years of operation.

The Fresno mine was opened about 6 miles to the west and became a steady producer, expanding the boundaries of the district. It exploited an orebody less than 30 meters below the surface. Exploratory adits and winzes were also extended at Maggie Sink and the Contrabando dome, but the post–World War II drop in prices caused all mines in the district to close by 1947. Roughly 150,000 flasks of mercury had been produced during the history of the district. (See Yates and Thompson (1959) for a more detailed history of the district.)

Since 1947 production in the district has been small. The rise in mercury prices during the 1950's caused some small-scale exploration and development at the Rainbow mine, the Fresno mine, Contrabando dome and other mines in the district. Another surge in mercury demand and prices in the late 1960's–early 1970's spurred additional operations at the Study Butte mine and Colquitt-Tigner (Waldron) mine by Diamond Shamrock, and at the Fresno and Whit Roy mines by Anchor Mining (Sharpe, 1980).

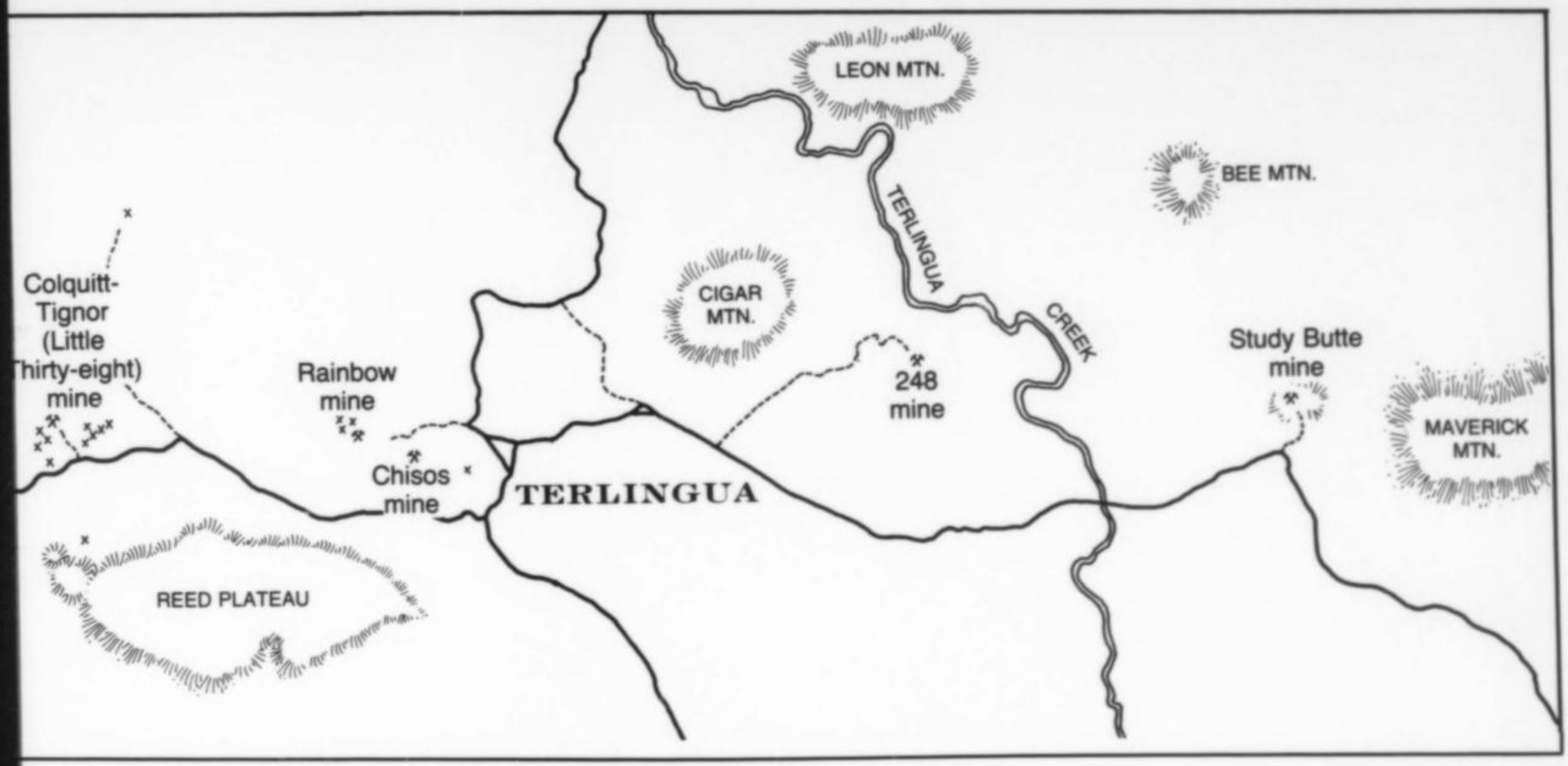
Although most of the known orebodies have been worked out, many favorable geologic structures in the area have yet to be drilled and sampled, so the possibility of renewed mining in the future cannot be ruled out.

MINES AND PROSPECTS

The leading producer in the district was the Chisos mine, which operated almost continuously from 1902 to the mid-1930's, yielding about 100,000 flasks of mercury (two-thirds of the total for the district). The mine consists of roughly 37 km of underground workings extending laterally east and west for about 900 meters, north-south for 770 meters and to a depth of 260 meters. There are 17 levels at 50-foot intervals, and many sub-levels. Orebodies here are structurally related to the Long Draw graben, and are the only economic deposits to be mined from calcite veins in the Boquillas flags.

Though classified with the calcite veins, the richest orebody at the Chisos mine had some notable characteristics of its own. It was first encountered on the 550-level (and named the 550 orebody), as two elongate, low-angle orebodies roughly 9 by 12 meters in cross-section which plunge gently toward each other from the east and the west, merging at the 600-level and continuing downward as a single pipe-like orebody (named the Pipe body) for another 60 meters. There were also several limestone-clay contact deposits in the Chisos mine, including one orebody mined over a distance of nearly 500 meters.

Second in production for the district is the Mariposa mine, which yielded roughly 30,000 flasks of mercury from 1895 to 1945. Almost all ore was removed from surface workings and shallow stopes, although workings were extended as deep as 100 meters, and several ore-filled natural caves were encountered. Many rich pockets of ore were mined, including one which contained 20 tons of ore averaging 50% mercury. The principal ore mineral was cinnabar, but significant quantities of native mercury and other rare mercury minerals were removed as well. In fact, the Mariposa mine has produced a wider



variety of mercury minerals than anywhere else in the world: thirteen, including cinnabar.

The many other mines in the district are all of much lower production. The Fresno mine yielded 2000 flasks of mercury, mostly from an irregular cave-fill zone where powdery, laminated cinnabar was found associated with and replacing clay. The Margaret D mine contained the longest and most continuous cinnabar orebody in the district, over 2000 meters long, which yielded perhaps as much as a few thousand flasks. Some of the rarer mercury species occurred at the Margaret D. The Rainbow mine is among the deepest in the district, and yielded much ore of exceptionally high grade. The Two-Forty-Eight mine exploited a large breccia pipe to a depth of about 250 meters; the only important ore mineral was cinnabar, but hydrogen sulfide gas filling pockets presented a hazard to miners. The Study Butte mine is reported to have produced $500,000 in mercury from 1915 to 1920, and ranks as the third largest producer in the district. Many very small mines, pits and prospects exist throughout the district. Some of these are listed in Table 1, and discussed in varying detail by Yates and Thompson (1959), although little is known about their mineralogy beyond the general abundance of cinnabar.

***Table 1*. Mines and prospects in the Terlingua district (Yates and Thompson, 1959). Total production, in flasks of mercury, is given in parentheses.**

Bob's mine (?)
Brown prospects (none)
Canyon group (?)
Chisos mine (100,000)
Contrabando Dome prospects (minor)
Croesus claim (minor)
Duncan group (minor)
Fresno mine (2000)
Lafarelle prospects (?)
Le Roi prospect (none)
Little Thirty-Eight mine (major)
Lowe prospect (?)
Margaret D lode (major)*
Mariposa mine (30,000)*
Monte Cristo claim (minor)
Natural Resources Inc. claim (minor)
Prospects in Sec. 98 (?)
Rainbow mines (major)
Rio Grande prospect (?)
Rio Grande Quicksilver Co. claims (minor)
Sample group (minor)
Star mine (?)
Study Butte mine (major)
Tarrant property (?)
Two-Forty-Eight mine (major)
Waldron workings (minor)

*Known to have produced some of the unusual mercury minerals.

GEOLOGY

The geology of the Terlingua district has been discussed by Yates and Thompson (1959) and Ridge (1972), from which the following summary has been drawn.

The deposits occur along a 32-kilometer belt lying mostly in Brewster County but extending a short distance into neighboring Presidio County. All of the sedimentary rocks are Cretaceous in age, ranging from the Lower Cretaceous Devil's River Limestone up through the Grayson Formation (an almost structureless clay), the Buda Limestone, the Boquillas flags, the Terlingua Clay, the widely but irregularly distributed Aguja Formation of interbedded sandstones and clays, the Upper Cretaceous Tornillo Clay and finally a sequence of Tertiary lava flows and clastic rocks.

Following deposition of the sedimentary rocks, the area suffered deformation in an episode known as the Terlingua domed uplift, resulting in the formation of many faults and grabens. Subsequently a variety of alkalic igneous rocks intruded the sedimentary sequence at shallow depth, producing smaller-scale faulting, doming and deformation but virtually no contact metamorphic effects. Localized hydrothermal activity in the sedimentary rocks has resulted in mineralized breccia pipes and caverns. The pipes, 20–150 meters in diameter, are usually vertical and cylindrical in form, containing only down-dropped rubble; this suggests that these are collapse breccias which were not formed by any kind of explosive activity.

The orebodies were most certainly formed by solutions related to the igneous intrusions, but the lack of any post-ore faulting suggests this occurred at the end of orogeny, during the Middle Tertiary period.

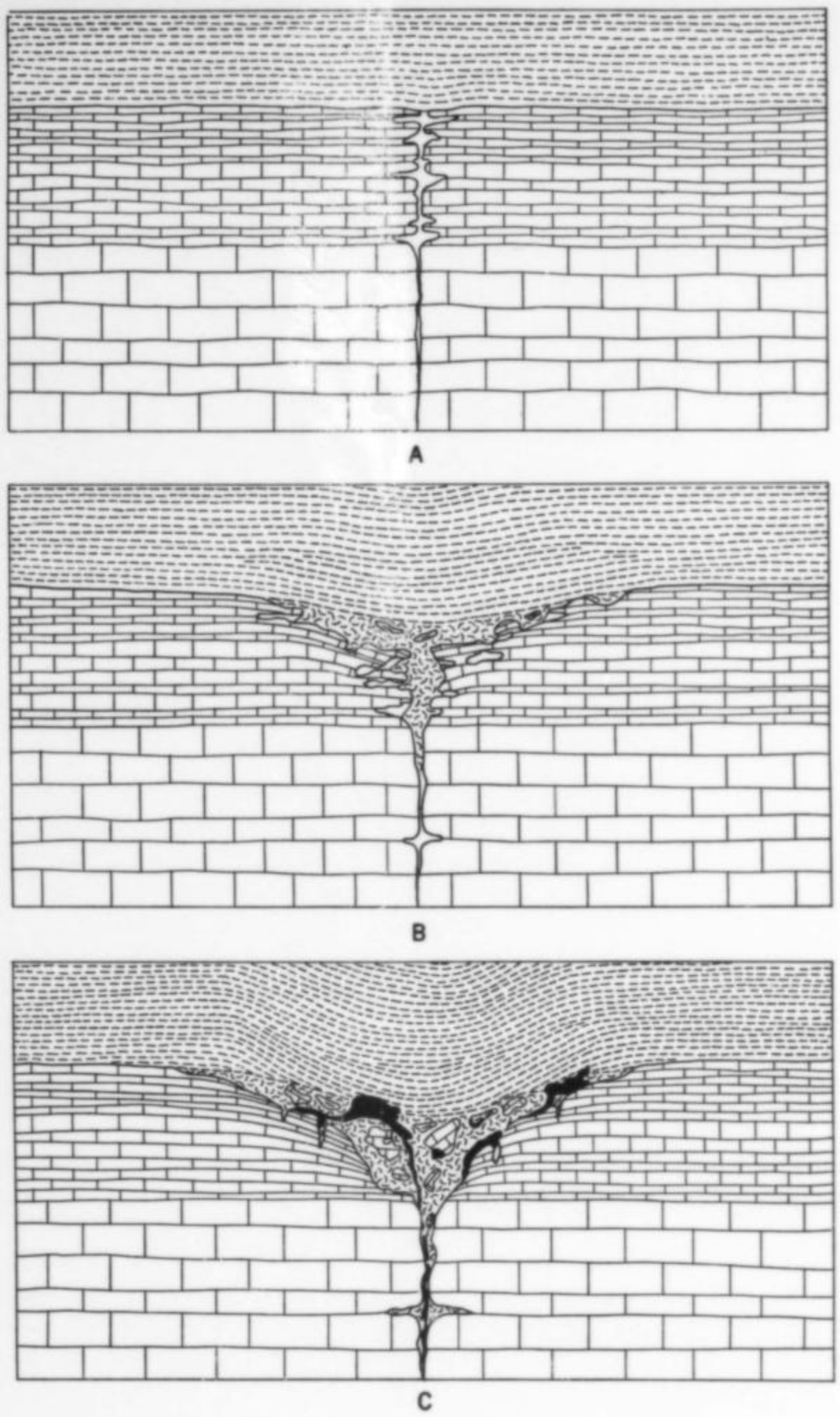


Figure 6. **Idealized sections showing development of limestone-clay contact or "cave fill" deposits. Cinnabar mineralization occurs during the final phase, shown in black (Yates and Thompson, 1959).**

Most of the important ores of the district are contact deposits in the Devil's River–Grayson limestones and clays. Mineralization also occurs as calcite vein deposits in the Boquillas flags, as part of the breccia pipes, and as fracture fillings and breccia disseminations in the igneous rocks.

Most of the mercury ore produced was in the form of extremely fine-grained cinnabar intimately mixed with clay; however a range of other rare and well crystallized mercury minerals have been found in the limestone-clay contact deposits. Some of these minerals contain mercury in the mercurous state, a peculiarity not known in the more common mercury-containing species (with the possible exception of calomel). Abundant calcite and minor fluorite, barite, chalcedonic quartz and hydrothermal pyrite plus a little marcasite also occur in the limestone-clay deposits. Calomel appears to be the oldest of the mercury minerals, followed in order by mosesite, kleinite, terlinguaite, eglestonite, and finally montroydite. Cinnabar appears to have formed later than all of these minerals except montroydite and perhaps native mercury. Mercury may have been deposited continuously throughout the period of mineralization, as was calcite.

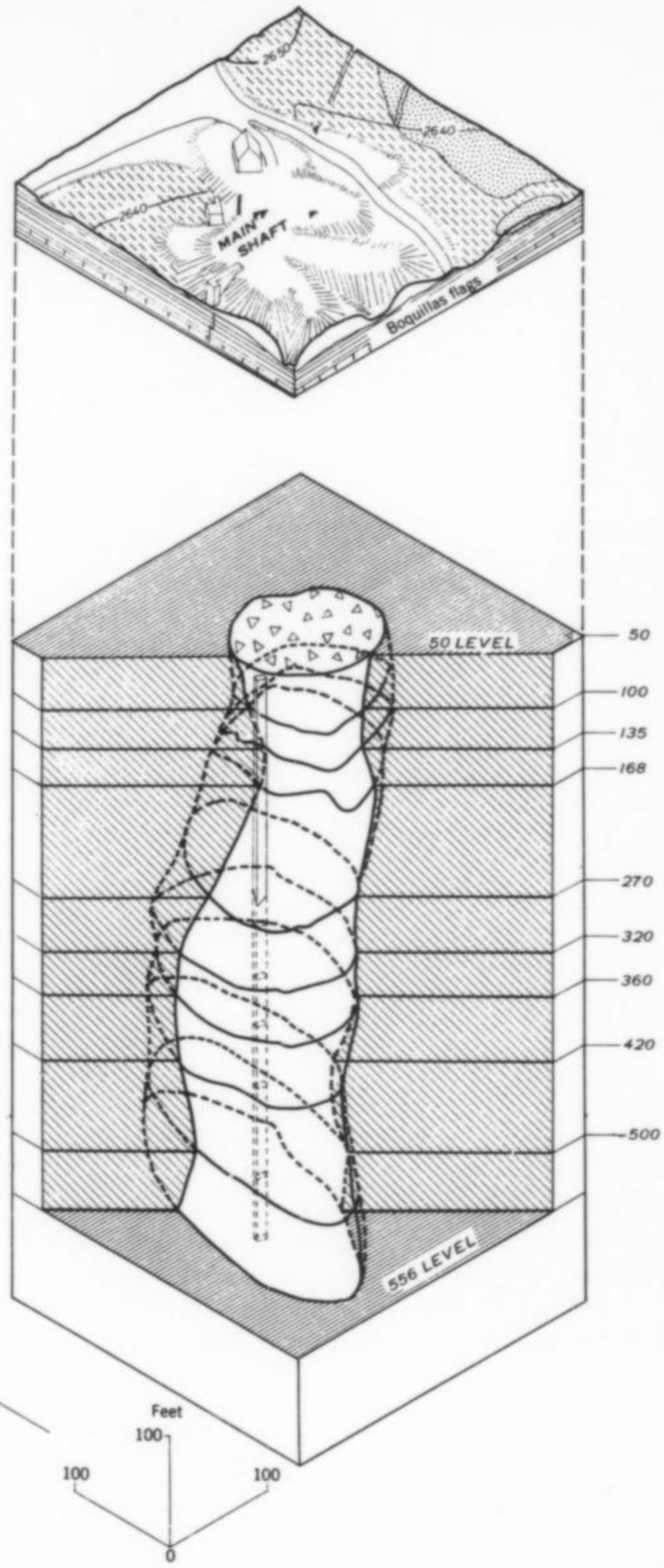
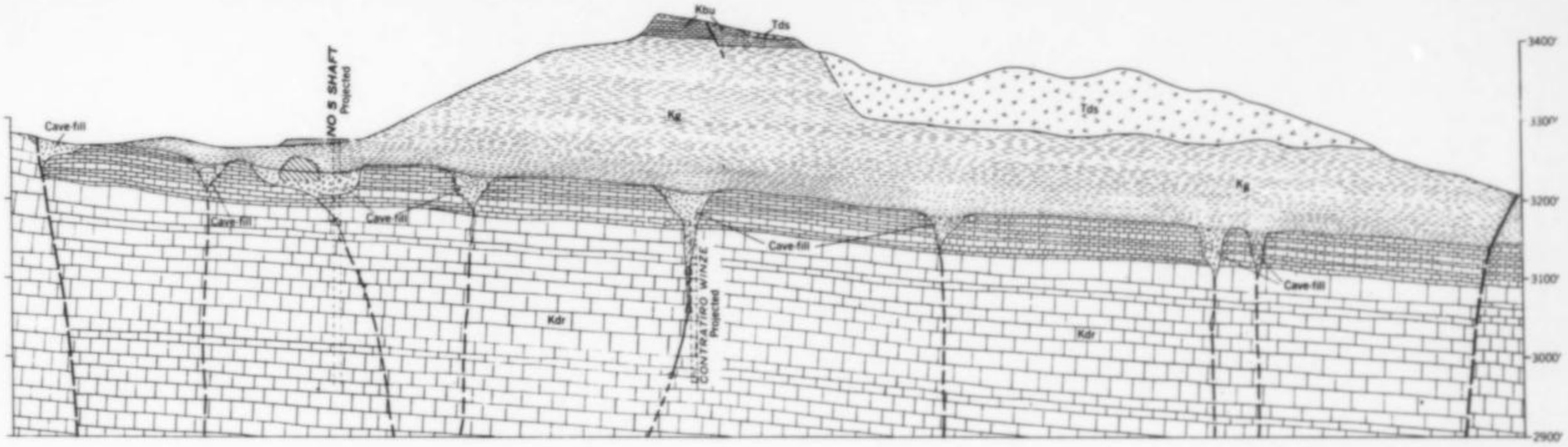


Figure 7. **Isometric projection showing the mineralized breccia pipe of the 248 mine (Yates and Thompson, 1959).**

The mercury minerals were probably deposited at low temperature (100° to 200°C, and certainly no higher than 300°C), under a cover of no more than 600 meters. Thus the ores should be classified as epithermal. Yates and Thompson (1959) firmly conclude that the rare mercury species were formed by hypogene (and not supergene) processes.



EXPLANATION

SEDIMENTARY ROCKS

QUATERNARY
- Qal — Alluvium

TERTIARY
- cf — Cave-fill

CRETACEOUS
Upper Cretaceous
- Kbu — Buda limestone
- Kg — Grayson formation

Lower Cretaceous
- Kdr — Devils River limestone

Contact
Dashed where indefinite; dotted where covered by dumps or alluvium

Fault
Long dashes where approximately located, short dashes where covered by cave-fill; dotted where concealed

IGNEOUS ROCKS

TERTIARY
- Tds — Dikes and sills of porphyritic soda latite
- Tb — Intrusion breccia
  Blocks and fragments of baked Grayson formation and Devils River limestone in matrix of soda latite

100 0 100 200 300 400 500 Feet
Contour interval 50 feet
Datum is mean sea level

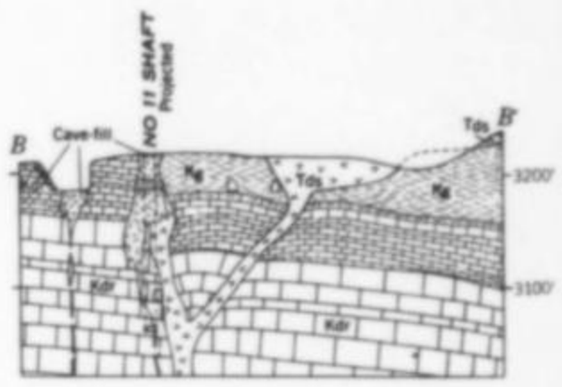


Figure 8. **Cross section (N60°W) through the Mariposa mine, showing limestone-clay contact "cave fill" deposits (Yates and Thompson, 1959).**

MINERALOGY

The mercury minerals for which Terlingua is famous rarely form as anything larger than a microcrystal. Most of the Terlingua ore does not contain any of the odd mercury minerals for which the locality is known. When found, the mercury minerals occur with a pink gangue of clay or a coarsely crystalline calcite. These minerals include eglestonite, terlinguaite, montroydite, mosesite, kleinite, comancheite, pinchite and gianellaite. The Terlingua district is the type locality for these eight mercury minerals, some of which occur as colorful microcrystals. Tables 2, 3 and 4 summarize data on the abundance, mercury contents and associations of the Terlingua minerals.

Analcime $NaAlSi_2O_6 \cdot H_2O$

Analcime is very abundant in the upper levels of the Two Forty-Eight mine. It forms colorless euhedral microcrystals, stained light brown by associated bitumens.

Barite $BaSO_4$

Barite occurs as white to pale yellow-tan nodular masses in the cave-fill at Terlingua. The best crystals line vugs in the surrounding limestone. Hydrocarbon inclusions stain the barite black. Barite occurs most prominently in mines in the western portion of the district.

Calcite $CaCO_3$

Calcite is the single most abundant mineral at Terlingua. Euhedral crystals to 30 cm (12 inches), generally scalenohedrons but also rhombohedrons, are found in cavities in the limestone veins. The calcite of Terlingua is usually colorless to white; often colored gray, tan or yellow-brown; rarely pale green, red, pink or black varieties are uncovered (Yates and Thompson, 1959).

Some masses of calcite at Terlingua have peculiar fluorescent patterns. A massive white variety fluoresces a strong sky-blue or violet-blue under shortwave ultraviolet light and phosphoresces the same color for several seconds. In longwave ultraviolet light, the same specimen will fluoresce a strong pink but will have a phosphorescence similar to that seen under shortwave light.

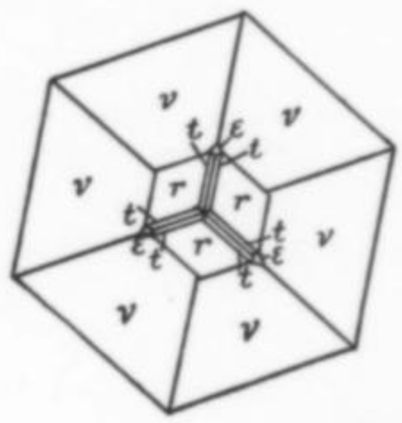
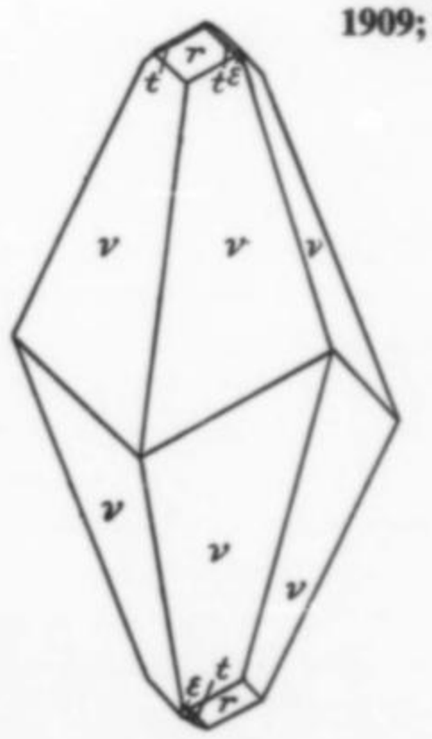
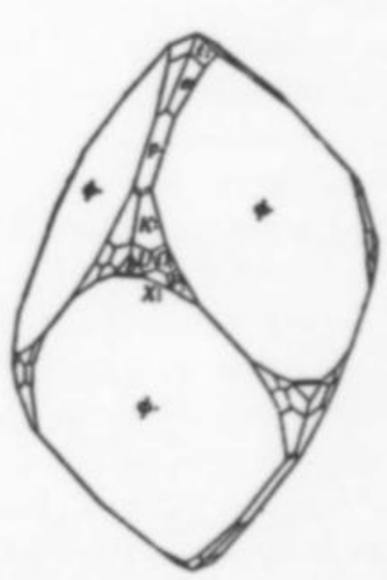


Figure 9. **Calcite crystal drawings, Terlingua (Hillebrand and Schaller, 1909; Eakle, *Bull. Univ. Calif.*, 1907).**





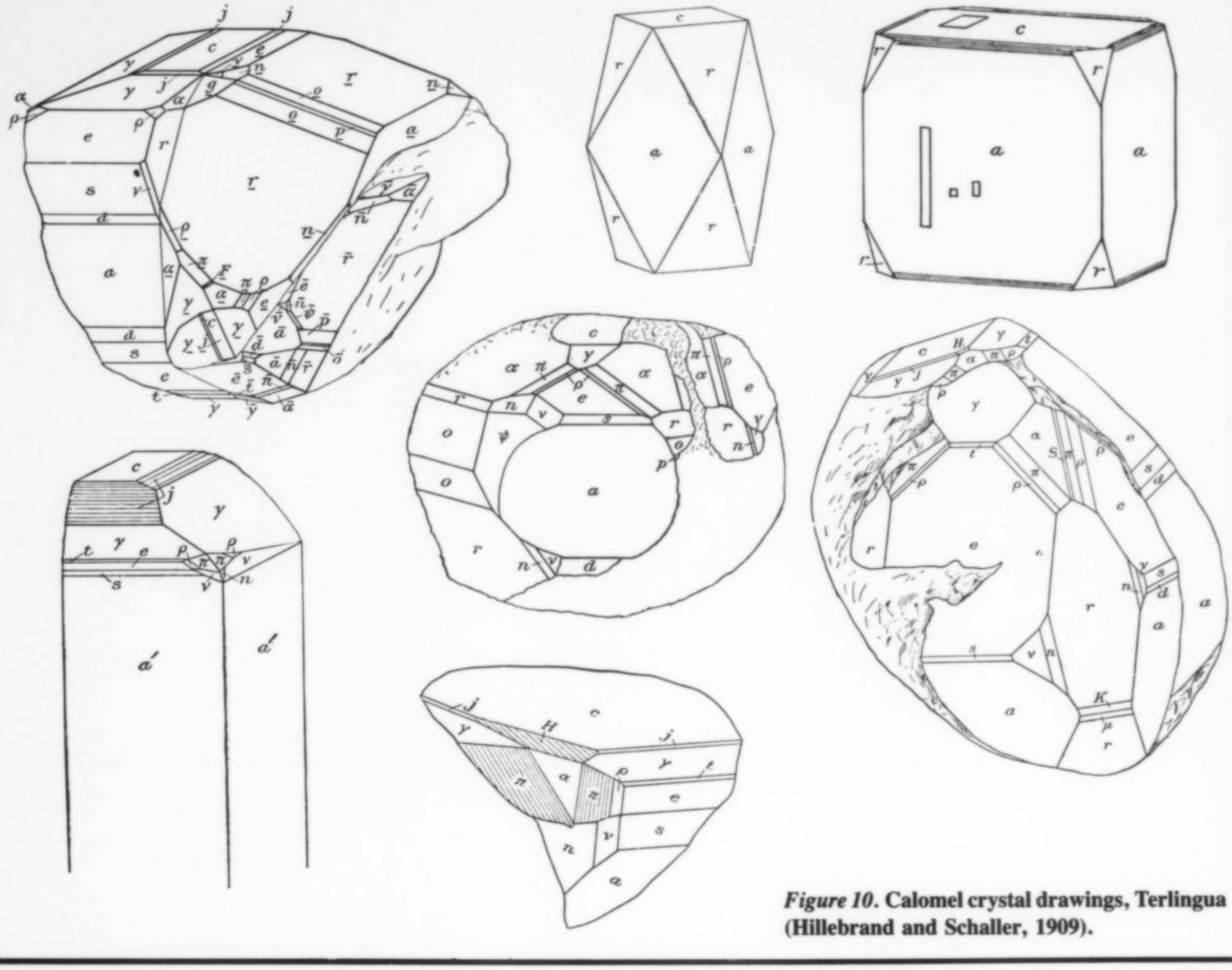


Figure 10. **Calomel crystal drawings, Terlingua (Hillebrand and Schaller, 1909).**

Calomel Hg_2Cl_2

Calomel occurs in distinct white, gray or tan-colored adamantine crystals, equant to short prismatic, often deposited on a layer of anhedral to subhedral calomel. The crystals are tetragonal prisms, commonly twinned. Calomel possesses a good cleavage on {100} which makes cleaved crystals appear much like terminated crystals. Calomel occurs with terlinguaite, eglestonite, montroydite, mercury and calcite. Some calomel fluoresces brick-red under ultraviolet radiation.

Cinnabar HgS

Acicular prismatic to thick tabular crystals of ruby-red cinnabar occur with native mercury in calcite veins. However, most cinnabar occurs in dark red microcrystalline masses admixed with mercury.

Comancheite $Hg_{13}(Cl,Br)_8O_9$

Comancheite forms either minute anhedral crystalline masses or fragile groups of minute acicular crystals on calcite. Crystals are transparent to translucent, averaging 80 μm long and 3–4 μm wide. The color is yellow to orange-red for crystals and red for masses, both possessing a vitreous luster. Comancheite was named in honor of the Comanche Indians, perhaps the first miners at Terlingua, who used cinnabar as warpaint. Comancheite occurs on banded, colorless to yellow-brown calcite crystals from the Mariposa mine, associated with minor amounts of goethite, hematite and quartz. The Mariposa mine is the type and only known locality for comancheite (Roberts *et al.*, 1981).

Edgarbaileyite $Hg_6^{+2}Si_2O_7$

Edgarbaileyite, a new mineral just described from California and Texas (Roberts *et al.*, this issue), is the first known silicate of mercury. Edgarbaileyite (from Terlingua) is characteristically intergrown with montroydite, forming sheaved aggregates to 0.2 mm. Distinct crystals of a platy habit to 200 μm have also been noted. Edgarbaileyite is photosensitive, much like terlinguaite. Fresh surfaces are lemon-yellow to orange-yellow and exposed surfaces vary from dark olive-green to a paler greenish yellow to dark green-brown. Crystals are translucent with a vitreous luster while masses have a resinous luster and are opaque. Edgarbaileyite occurs with montroydite, terlinguaite, eglestonite and metallic mercury in and on a matrix of calcite, barite and quartz. It was named in honor of Dr. Edgar Bailey, who did a great amount of work in the Terlingua district.

Eglestonite Hg_4Cl_2O

Eglestonite occurs as well-formed isometric crystals up to 1 mm in diameter, similar in appearance to sphalerite. The crystals are yellow to yellowish brown and quickly darken to black on exposure to sunlight. The mineral has a brilliant adamantine to resinous luster. Eglestonite occurs with terlinguaite, calomel, montroydite, native mercury and calcite. It was named in honor of Professor Thomas Egleston, founder of the Columbia School of Mines and professor of mineralogy at Columbia University (Moses, 1903).

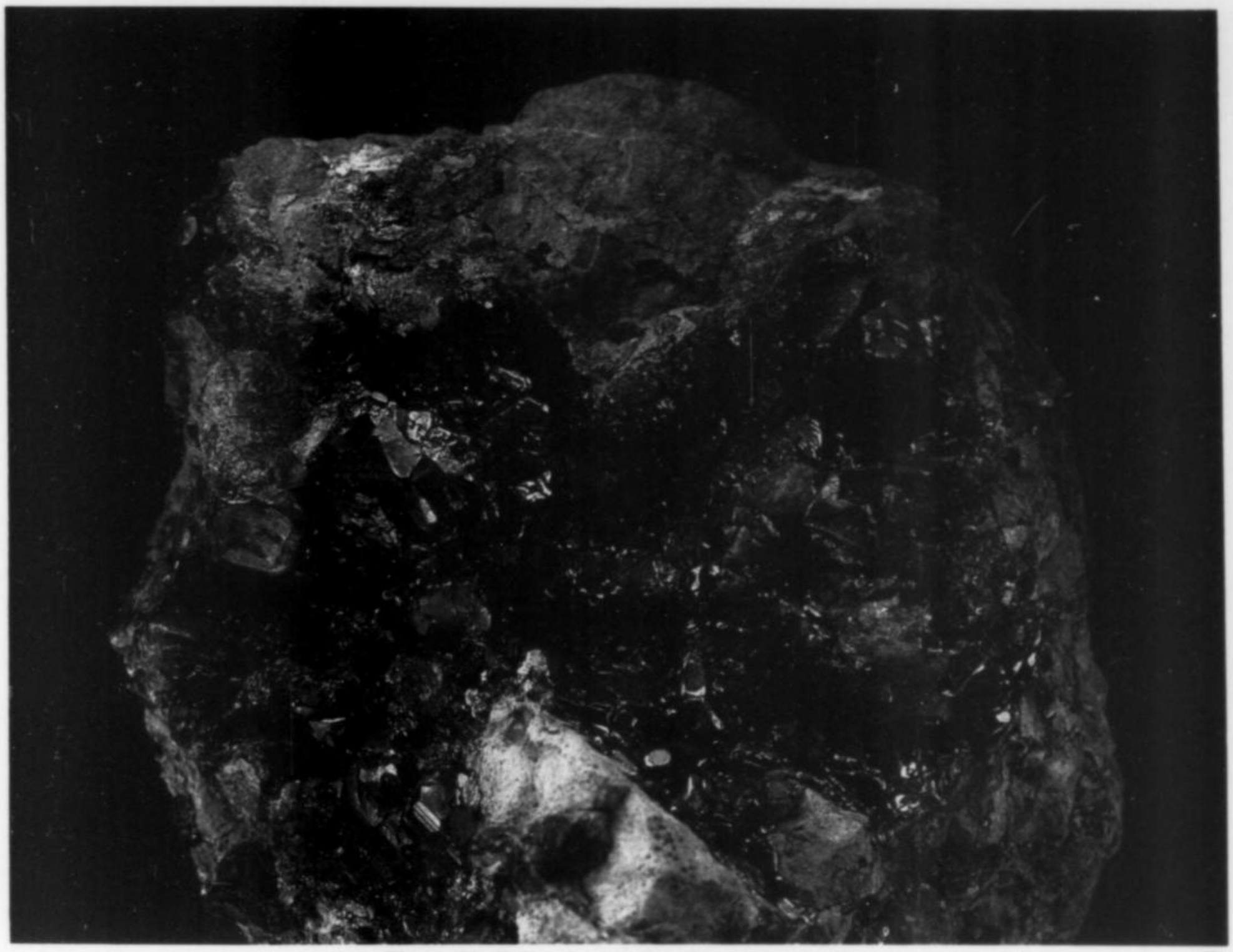


Figure 11. **Calomel crystal pocket in matrix, 4 cm across, from Terlingua. Forrest Cureton specimen.**

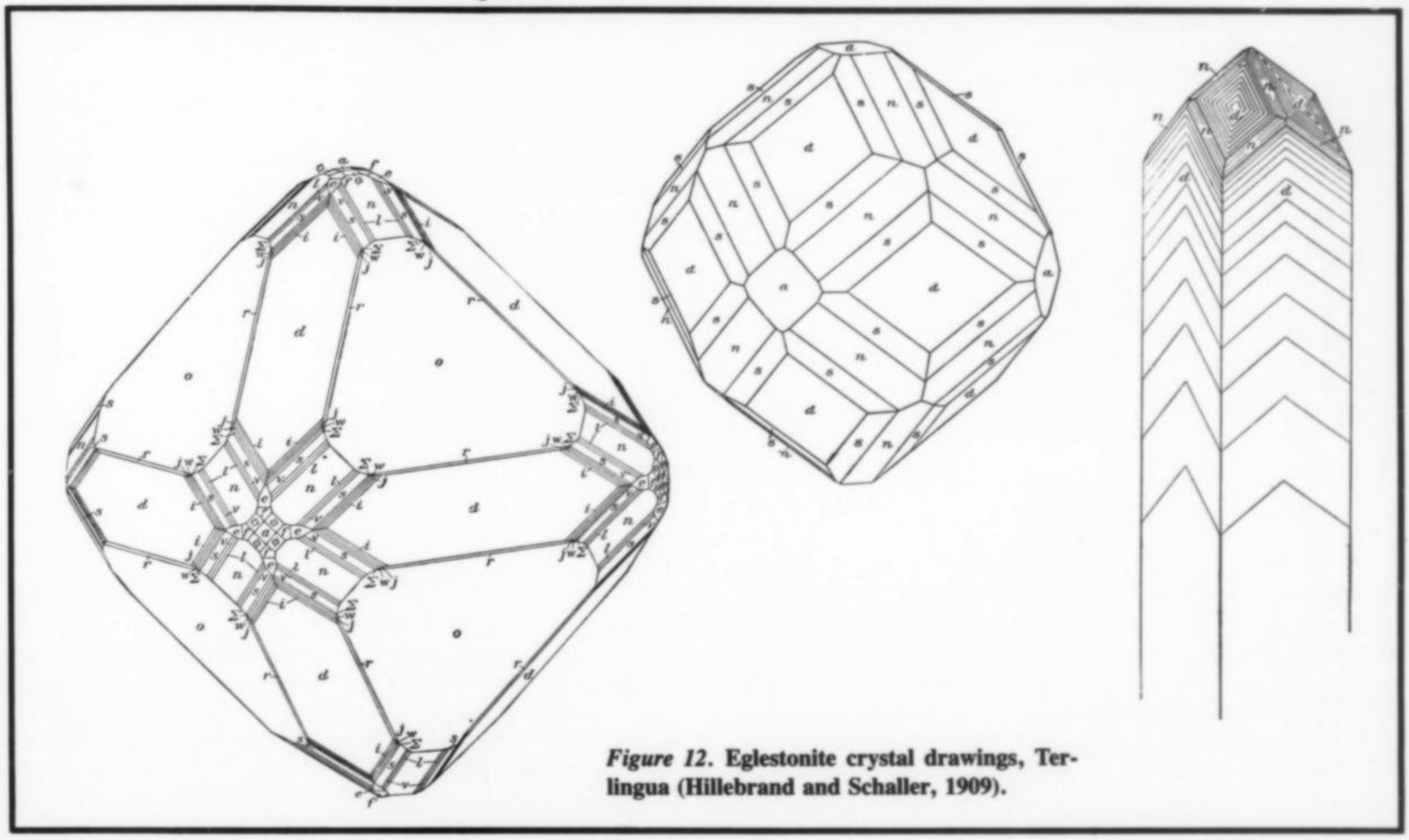


Figure 12. **Eglestonite crystal drawings, Terlingua (Hillebrand and Schaller, 1909).**

Fluorite CaF_2

Euhedral cubes of fluorite are occasionally seen on specimens of cave-fill. The fluorite is colorless to pale yellow-brown and very transparent. A crystal of fluorite replaced by calcite was found on the dump of the Little 38 mine.

Gianellaite $Hg_4(SO_4)N_2$

Gianellaite occurs as aggregates of minute, flattened, subhedral crystals. These groups of crystals may cover several square centimeters. A few distinct crystals to about 1 mm have been found. The crystals are mainly distorted octahedra, rarely with dodecahedral modifications. The color is straw-yellow to gray, depending upon the amount of included or surrounding hematite. Gianellaite was named in honor of Dr. Vincent Gianella, geologist of the Mackay School of Mines, University of Nevada.

Gianellaite occurs in the Perry pit of the Mariposa mine, on fracture surfaces and veinlets in the limestone. These fracture surfaces commonly contain a layer of fine-grained hematite on which the gianellaite is deposited. Associated minerals include "ramshorn" gypsum, calcite crystals, native mercury, cinnabar specks, fine-grained montroydite, terlinguaite groups, yellow-orange kleinite and calomel crystals (Tunell *et al.*, 1977).

Gypsum $CaSO_4 \cdot 2H_2O$

Well-formed "ramshorn" gypsum formations up to 30 cm (12 inches) long have been found in limestone caverns. Gypsum also occurs as cross-fiber vein fillings ("satin spar"), and as long, slender prisms and curved crystals.

Hematite Fe_2O_3

Hematite crystal plates occur at the Colquitt-Tignor mine (Yates and Thompson, 1959), and fine-grained hematite occurs at various other locations in the district.

Jarosite $KFe_3(SO_4)_2(OH)_6$

Jarosite occurs as minute, pale yellow-brown to dark resin-brown pseudocubic crystals and porous brown masses. Jarosite can still be collected on the dumps of some of the Terlingua mines.

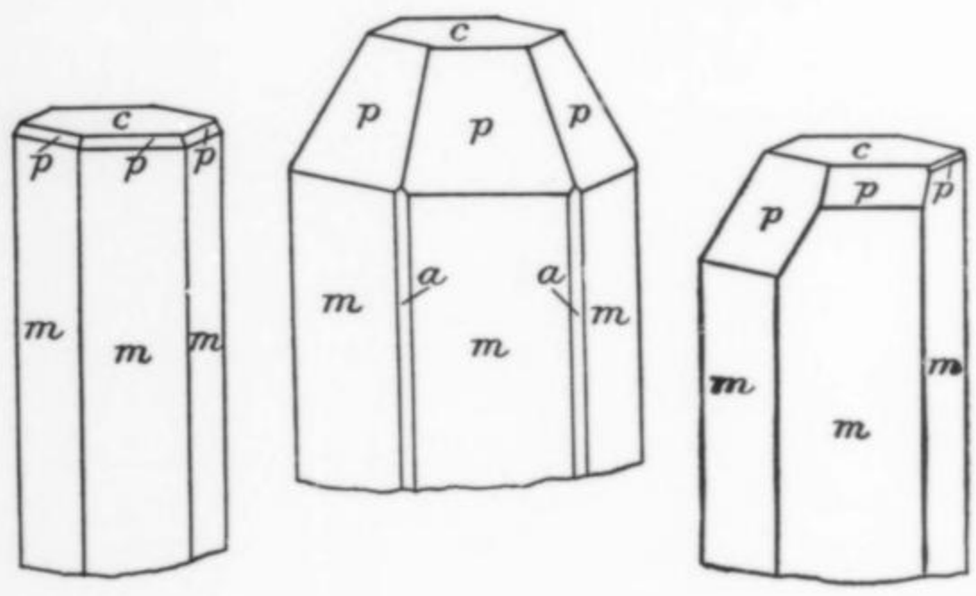


Figure 13. **Kleinite crystal drawings, Terlingua (Hillebrand and Schaller, 1909).**

Kleinite $Hg_2N(Cl,SO_4) \cdot nH_2O$

Kleinite occurs as minute yellow crystals on calcite. The crystals darken to orange on exposure to sunlight, but after a period of time in darkness will return to their original color (Hillebrand and Schaller, 1909). The crystals are hexagonal prisms, terminated in varying degrees by hexagonal bipyramids and basal pinacoids. Kleinite occurs with terlinguaite, calomel, gianellaite, native mercury, mosesite, barite and calcite. It was named in honor of Professor Carl Klein (1842–1907) of Berlin.

Mercury Hg

Native mercury is the second most important ore mineral at Terlingua. Some cavities in calcite veins have produced over 9 kg (20 pounds) of the native metal (Hill, 1903). Microscopic globules of mercury are found intimately mixed in the crystalline calcite, clay and the Cretaceous limestone. Mercury has been found filling hollows in terlinguaite and montroydite crystals. "Amalgam" from Terlingua is a local term applied to a mixture of mercury and cinnabar (Hill, 1903).

Metacinnabar HgS

Metacinnabar occurs as black earthy to crystalline masses. Metacinnabar is often coated with native mercury which disguises the black metallic nature of the mineral. Minute euhedral crystals showing a dodecahedral habit have been reported (Forrest Cureton, 1988, personal communication).

Montroydite HgO

Montroydite occurs as deep red, equant to elongated prismatic crystals, which are often found naturally bent or twisted, attesting to their remarkable flexibility. Scepter growths consisting of an equant crystal perched on the termination of an elongated prismatic crystal have also been noted. Prismatic crystals up to 2.5 cm (1 inch) have been recorded. Brown crystalline masses in worm-like and spherical shapes occur, as well as powdery masses.

Montroydite is commonly associated with terlinguaite and native mercury with a matrix of crystallized calcite, rarely with calomel, gypsum, eglestonite, or pinchite. Crystals of montroydite commonly enclose native mercury. The Mariposa mine is the type locality for montroydite, and specimens of this mineral are found rarely on that dump. Montroydite was named in honor of Montroyd Sharpe, one of the original owners of the Mariposa mine.

Mosesite $Hg_2N(Cl,SO_4,MoO_4,CO_3) \cdot H_2O$

Mosesite occurs as minute canary-yellow to lemon-yellow crystals associated with calcite, gypsum and montroydite. It occurs chiefly as simple octahedra, rarely with the modifying forms {100}, {211}, {411} and {611} (Canfield, 1913). Much mosesite is twinned on the spinel law, which in one case was found to be repeated five times. Mosesite was named in honor of Professor Alfred J. Moses, who was the first to describe the unusual mercury salts of Terlingua (Canfield *et al.*, 1910).

Natrolite $Na_2Al_2Si_3O_{10} \cdot 2H_2O$

Radiating crystals of natrolite occur with cinnabar and quartz in collapse breccia from the Fresno mine.

Pinchite $Hg_5O_4Cl_2$

Pinchite occurs as minute, dark brown to black, euhedral, orthorhombic crystals. The crystals are found in sizes up to 1 mm, and have two distinctly different habits. The more abundant habit consists of slightly elongated prismatic crystals. The other habit resembles rectangular plates with the form {012} truncating one of the four corners. Pinchite was named in honor of William W. Pinch of Pittsford, New York, who first recognized the crystals as a possible new species. Terlingua is the type and only locality for pinchite, there being only one specimen known. Pinchite is associated with montroydite and terlinguaite (Sturman and Mandarino, 1974).

Schuetteite $Hg_3(SO_4)O_2$

Schuetteite at Terlingua is a post-mining product found on the remains of the Chisos furnace. The mineral was named in honor of Curt Nicolaus Schuette, mining engineer and geologist, a specialist on quicksilver deposits. Schuetteite forms yellow to yellow-orange aggregates of hexagonal crystals which coat bricks from the dismantled Chisos furnace. In some cases, schuetteite is associated with montroydite, calomel, artificial gypsum and cinnabar. The mineral formed

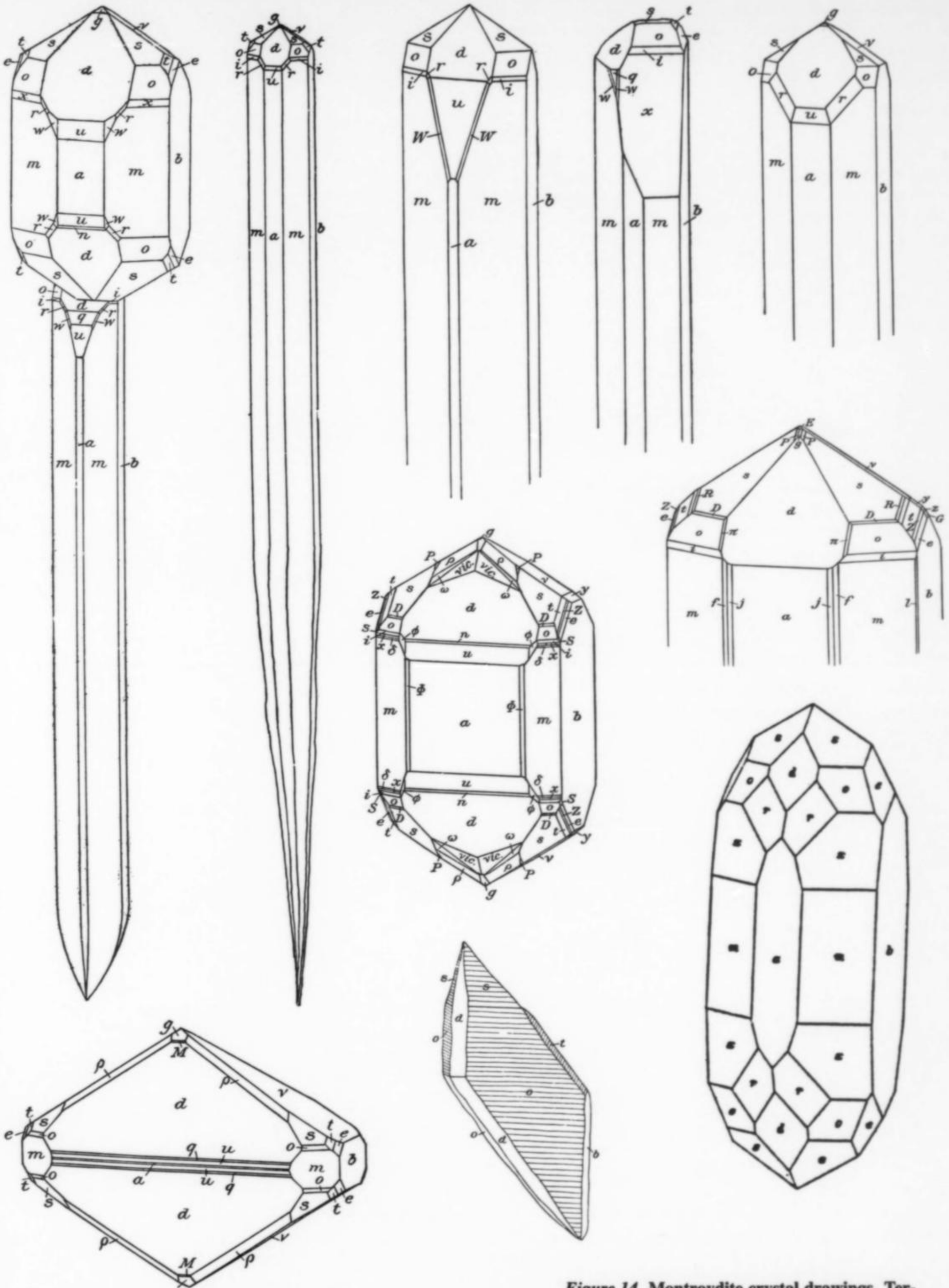
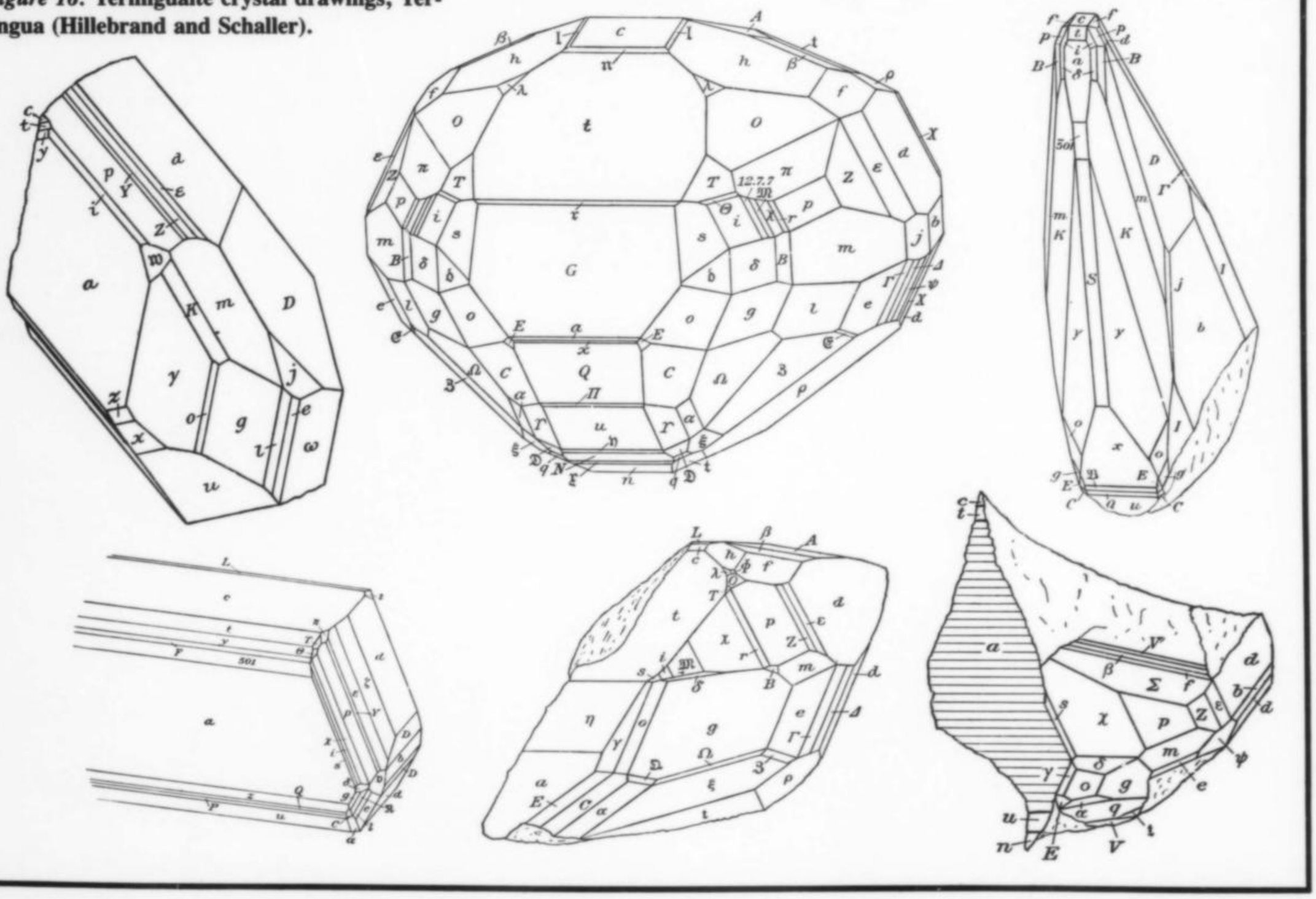


Figure 14. **Montroydite crystal drawings, Terlingua (Hillebrand and Schaller, 1909; Moses, 1903).**

Figure 15. **Montroydite on calcite crystals, Terlingua (Hillebrand and Schaller, 1909).**

Figure 16. **Terlinguaite crystal drawings, Terlingua (Hillebrand and Schaller).**



at Terlingua is a result of acidic sulfate waters reacting with elemental mercury contained within the furnace bricks, although it does occur under completely natural conditions at other localities (Bailey *et al.*, 1959).

Terlinguaite Hg_2ClO

Terlinguaite was the first unusual mercury mineral to be discovered. Much terlinguaite occurs in powder form, although distinct adamantine crystals and crystalline crusts have been found. Terlinguaite is sulfur-yellow to brown, darkening to olive-green on exposure to sunlight. The mineral was named in honor of its type locality. Terlinguaite

Table 2. **The minerals found at the Terlingua, Texas, quicksilver district.**

Mineral	*Abundance*	*References*[1]
Alunite	R	16
Analcite°	C	16
Anhydrite	R	16
Aragonite	C	5, 16
Barite	U	5, 16
Beidellite°	A	16
Calcite	A	5, 7, 16
Calomel	R	7, 8
Carnotite	U	4
Cinnabar	C	5, 6, 16
Comancheite*	ER	11
Edgarbaileyite	ER	12
Eglestonite*	V	7, 8
Epsomite	R	16
Fluorite	U	5, 16
Gianellaite*	ER	11
Gypsum	A	5, 7, 16
Hematite	C	5, 16
Hydrocarbons (bitumen)	U	5, 16
Ilmenite°	U	16
Jarosite	U	7, 16
Kaolinite°	A	16
Kleinite*	V	7, 8
Limonite (and goethite)	C	5, 16
Marcasite	U	5, 16
Melanterite	U	5, 16
Mercury (native)	U	5, 6, 7, 16
Metacinnabar	V	5, 6
Montroydite*	V	7, 8
Mosesite*	V	2, 3
Natrolite°	C	16
Pinchite*	ER	14
Psilomelane (wad)	R	5
Pyrite	C	5, 16
Pyrolusite	U	5
Quartz (chalcedony)°	U	5, 16
Schuetteite (man-made)	V	1
Scorodite	U	9
Terlinguaite*	V	7, 8
Titanite°	U	16

*Originally described from Terlingua
°Found in the surrounding igneous country rock
[1]Numbers refer to the numbered references at the end of this article.
Symbols Used:

A	=	Very Common	R	=	Rare
C	=	Common	V	=	Very Rare
U	=	Uncommon	ER	=	Extremely Rare

Table 3. **Formulas, mercury contents, and relative abundances of the Terlingua mercury minerals.**

Mineral	*Formula*	*% Hg*	*Abundance*
Mercury	Hg	100.0	C
Montroydite*	HgO	92.6	V
Terlinguaite*	$Hg^{+1}Hg^{+2}ClO$	90.6	V
Eglestonite*	$Hg_4^{+1}Cl_2O$	90.2	V
Pinchite*	$Hg_5Cl_2O_4$	88.1	ER
Edgarbaileyite	$Hg_6^{+1}Si_2O_7$	87.7	ER
Gianellaite*	$Hg_4(SO_4)N_2$	86.6	ER
Cinnabar	α-HgS	86.2	C
Metacinnabar	β-HgS	86.2	V
Kleinite*	$Hg_2N(Cl,SO_4)\cdot nH_2O$	86.1[a]	V
Calomel	$Hg_2^{+1}Cl_2$	85.0	U-R
Mosesite*	$Hg_2N(Cl,SO_4)\cdot H_2O$	84.5[b]	V
Schuetteite°	$Hg_3(SO_4)O_2$	82.4	V
Comancheite*	$Hg_{13}(Cl,Br)_8O_9$	81.7[c]	ER

*Terlingua is the type locality for this mineral
°A smelter product at Terlingua (Bailey *et al.*, 1959)
[a]Mercury content for kleinite with $Hg:Cl:SO_4:H_2O$ 16:2:1:2
[b]Mercury content for mosesite with $Hg:Cl:SO_4:H_2O$ 16:2:1:4
[c]Mercury content for comancheite with Hg:Cl:Br 26:9:7

Symbols Used:

C	=	Common	V	=	Very Rare
U	=	Uncommon	ER	=	Extremely Rare
R	=	Rare			

Table 4. **The abundance of the associations of the Terlingua mercury minerals.**

Terlingua District Mineral Associations (refs. 2, 3, 5, 6, 7, 8, 11 12, 14, 15, 16)	CALOMEL	CINNABAR	COMANCHEITE	EDGARBAILEYITE	EGLESTONITE	GIANELLAITE	KLEINITE	MERCURY	METACINNABAR	MONTROYDITE	MOSESITE	PINCHITE	TERLINGUAITE	BARITE	GOETHITE	GYPSUM	HEMATITE	QUARTZ	CALCITE	PINK GANGUE
Calomel		R			U	R		C		R		U								C
Cinnabar	V					V		A					V						C	
Comancheite															C		C	C	A	
Edgarbaileyite					V				V	V			V	V				V	V	
Eglestonite	C			V				A		U			R							
Gianellaite	U	U					C	C		U			U				C			
Kleinite								U			U			C						
Mercury	V	A		V	V	V	V		V	V	V		V						C	
Metacinnabar	?	?						A					?						A	
Montroydite				V				A				V								?
Mosesite							C	U					U			U			C	
Pinchite									?				?			C				
Terlinguaite	C	R		V	R	R	U	A	?	C	R	V								

A = Very Common R = Rare
C = Common V = Very Rare
U = Uncommon ? = Not Determined

occurs with montroydite, eglestonite, pinchite, native mercury and calcite. In some cases, terlinguaite crystals enclose liquid mercury (Hillebrand and Schaller, 1909).

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Davis Hill
near Bancroft, Ontario:
an occurrence of large nepheline, biotite and albite-antiperthite crystals in calcite-cored vein-dikes

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Spectacular crystals of nepheline, biotite and albite-antiperthite line the walls of vein-dikes at Davis Hill. Many excellent specimens have been recovered in operations conducted by the National Museum of Canada.

LOCATION and ACCESSIBILITY

The occurrence is on a shoulder of Davis Hill, on Lot 25, Concession XIII of Dungannon Township in Hastings County, Ontario. It is about 4 km east-northeast of Bancroft, from which it can be reached via the East Road (Ontario Highway 500). The peak of Davis Hill is indicated by a closed 1,400-foot contour on the 1:50,000 *Bancroft Sheet* (31 F/4) of the National Topographic Series of Canada. The showing is indicated by "Ne" and three trench symbols on Ontario Department of Mines Geological Map No. 1955-8 (1 inch = ½ mile) by D. F. Hewitt and W. James (1956). The occurrence is about 600 meters south-southeast of the Princess sodalite mine, with access as follows: From Highway 28, at about 0.4 km west of the Princess mine, there is a turn-off southeastward onto a by-passed segment of the Old East Road. Within 180 meters, the road is reduced to a footpath along the top of a beaver dam built in the former roadway. About 400 meters east of the dam, a rough access road takes off southwestward, spiraling up the side-hill. At 180 meters it bends southeastward, then terminates at the workings, 120 meters beyond.

HISTORY

Discovery and Exploitation for Specimens

In 1937, I was one of a small party of mineral collectors from Philadelphia that stumbled on the occurrence quite by accident. Misinterpreting Sam Gordon's directions to Cancrinite Hill, we wound up on top of the wrong hill. The spectacular veins were exposed in an old stripping and small pit that had been opened to exploit large books of black mica. That work had been done early in the century, when a great deal of phlogopite was being mined in the region, but the prospect was abandoned when no market could be found for the heavy, brittle and more electrically conductive iron-rich biotite.

During a season of professional mineral collecting in 1941, my wife Pauline and I spent a month at the site, using only hand tools—blast holes were drilled with handsteels. The resulting specimens found their way into many museums and private collections, mostly through Schortmann's Minerals in Massachusetts.

In the autumn of 1966, I conducted a National Museum of Canada mining operation for specimens, using a local crew. This included rehabilitation of an abandoned portion of the Old East Road and the old access road, and extension of the original stripping by bulldozer. Veins were again cleaned out by hand to minimize damage to the crystals—tools fashioned from hardwood were advantageous—but drilling was done with a gasoline-powered jackhammer. Large specimens were split out and trimmed by plug-and-feathering. Several hundred tons of rock were broken and moved, of which about 4 tons were taken back to the museum for processing. The geology was mapped in detail the following spring.

During the 24th International Geological Congress in the summer of 1972, the museum staff opened some veins for examination by participants of the pre-Congress and post-Congress Field Excursions A47 and C47, "Classic Mineral Localities in Ontario and Quebec."

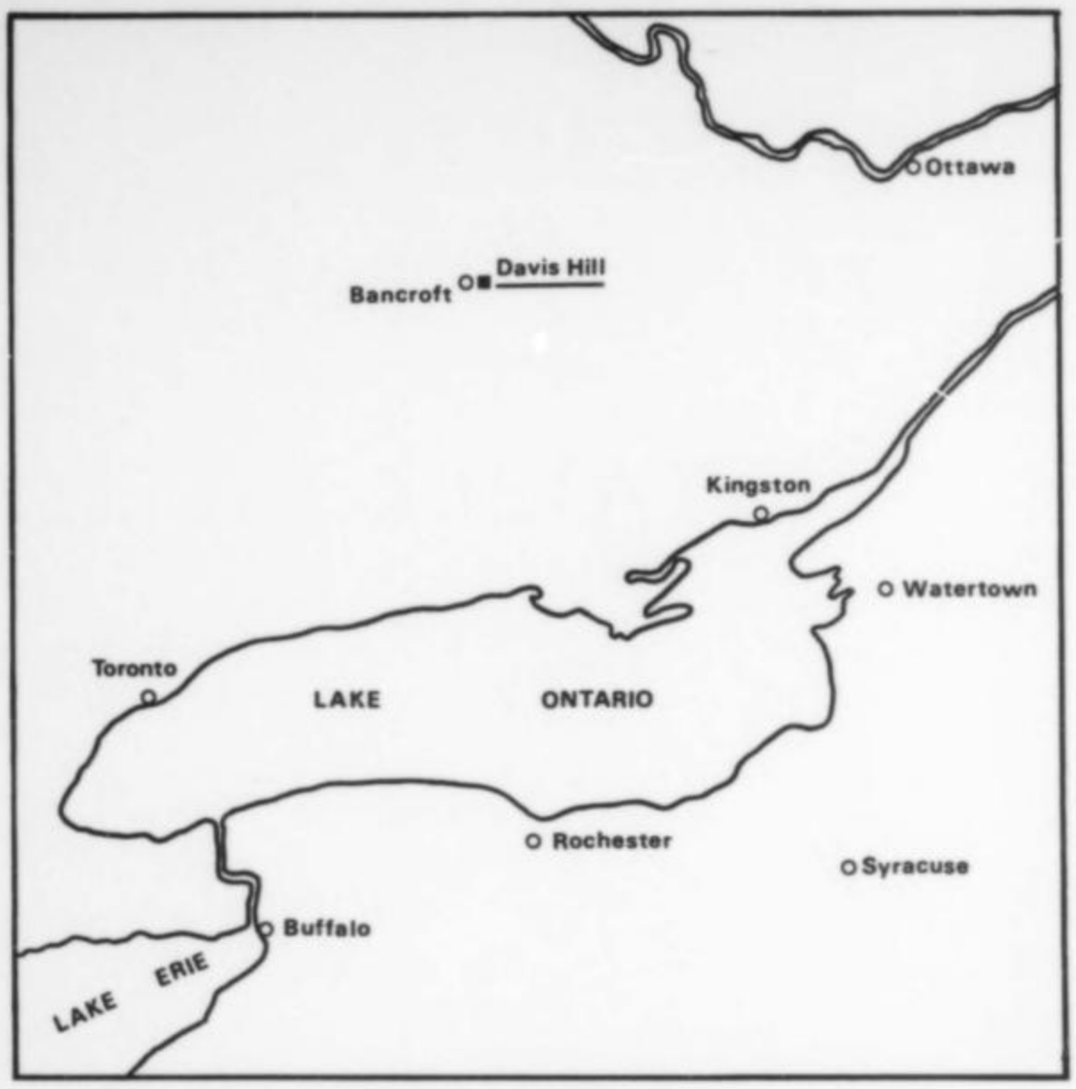


Figure 1. **Location map.**

During site preparation, and in the two-week period between excursions, the staff collected additional material, which is also being processed to provide specimens for the museum's collections and for exchange.

Exploration for Ceramic Materials

In the 1920's and 30's, the ceramic raw-material potential of the southeastern Ontario belt of nepheline and corundum gneisses was intensively investigated. Gneissic "nepheline syenite" is now being mined on Blue Mountain in Methuen Township, about 50 km south-southwest of Bancroft. One of the earliest and most active proponents was Norman B. Davis, a well-known mining engineer and consultant, who was then manager of the Canadian Flint and Spar Company. Among the many holdings taken up in his name, one became known as Davis Hill, and another the Davis quarry, which was opened on a nepheline-albite-biotite pegmatite in the nearby York River belt to produce the grit for Bon Ami ("Hasn't scratched yet") scouring powder. Norm Davis always made a special effort to recover mineral specimens and research materials encountered in his operations. The mineralogical papers of Hugh S. Spence, H. V. Ellsworth and others abound with credits for specimens he furnished. His personal collection was donated to Carleton University in Ottawa prior to his death.

The Canadian Flint and Spar Company (an affiliate of O'Brien Mines, Ltd.) was taken over by the Consolidated Feldspar Company, which was in turn taken over by the International Minerals and Chemical Company. Recently, all of the southeastern Ontario holdings of this company were acquired by Indusmin Ltd. These include, among others, Davis Hill, the Davis quarry and the Blue Mountain nepheline syenite quarries, which had been staked by Norm Davis. It is possible that one or more of the hills of nepheline-rich gneiss in the Bancroft area will be mined for glass, pottery and filler grades of "nepheline syenite" before the end of this century.

Exploration for Aluminum

In 1941, when submarine warfare was taking a high toll of bauxite ships from Dutch Guiana (now Surinam), alumina sources were sought within the North American continent. Research proved that hydrated alumina could be produced by sintering the nepheline-rich gneisses with limestone. Exploration of the nepheline-bearing rocks and limestones of the Bancroft area was undertaken jointly by the Aluminum Company of Canada and Ventures, Ltd., a major Canadian mining company. Participation in this project was my initiation into a career in mineral exploration and related fields of applied geology and mineralogy.

Davis Hill was mapped at 200 feet to the inch, and about 500 meters of diamond drilling was done. A vertical hole was collared near the mica prospect (the old pit furnished the drilling water), and two parallel 45° holes, 120 meters apart, were collared near the base of the hill. The Bancroft-area project did not get beyond mine and plant-site selection—by then submarine depredations had been brought under control, and operations would not have been economic under ordinary conditions.

Several years ago a cartel formed by various bauxite-producing countries, analogous to that of the petroleum-producing countries, caused revival of interest in non-bauxite sources of alumina, including various North American deposits of clay, shale, alunite, alkaline rocks and anorthosite. Aluminum is produced from the nepheline-bearing igneous rocks of the Kola Peninsula in northern Russia, with phosphate (apatite), rare-earths and even fine mineral specimens as by-products.

Figure 2. **Hand-steel drilling by the author, 1941 operation. A large biotite crystal is visible along the wall of the vein. Tree is rooted in a soil-filled fissure resulting from the weathering out of vein-core calcite. Photo by Pauline Moyd.**

GEOLOGICAL SETTING

The Davis Hill veins and other well-known mineral localities (Princess sodalite mine, Cancrinite hill and the Lillie Robertson corundum occurrence) occur within a series of alkaline gneisses that extends for about 6.5 km eastward from Bancroft. This zone forms part of a 200-km north-northeast-trending belt of Precambrian nepheline-bearing and corundum-bearing gneisses that includes many other well-known mineral occurrences, among them the Craigmont, Egan Chute and Gutz corundum deposits described by H. R. Steacy *et al.* (1982). These and many other occurrences throughout the belt are included in A. P. Sabina's 1986 publication.

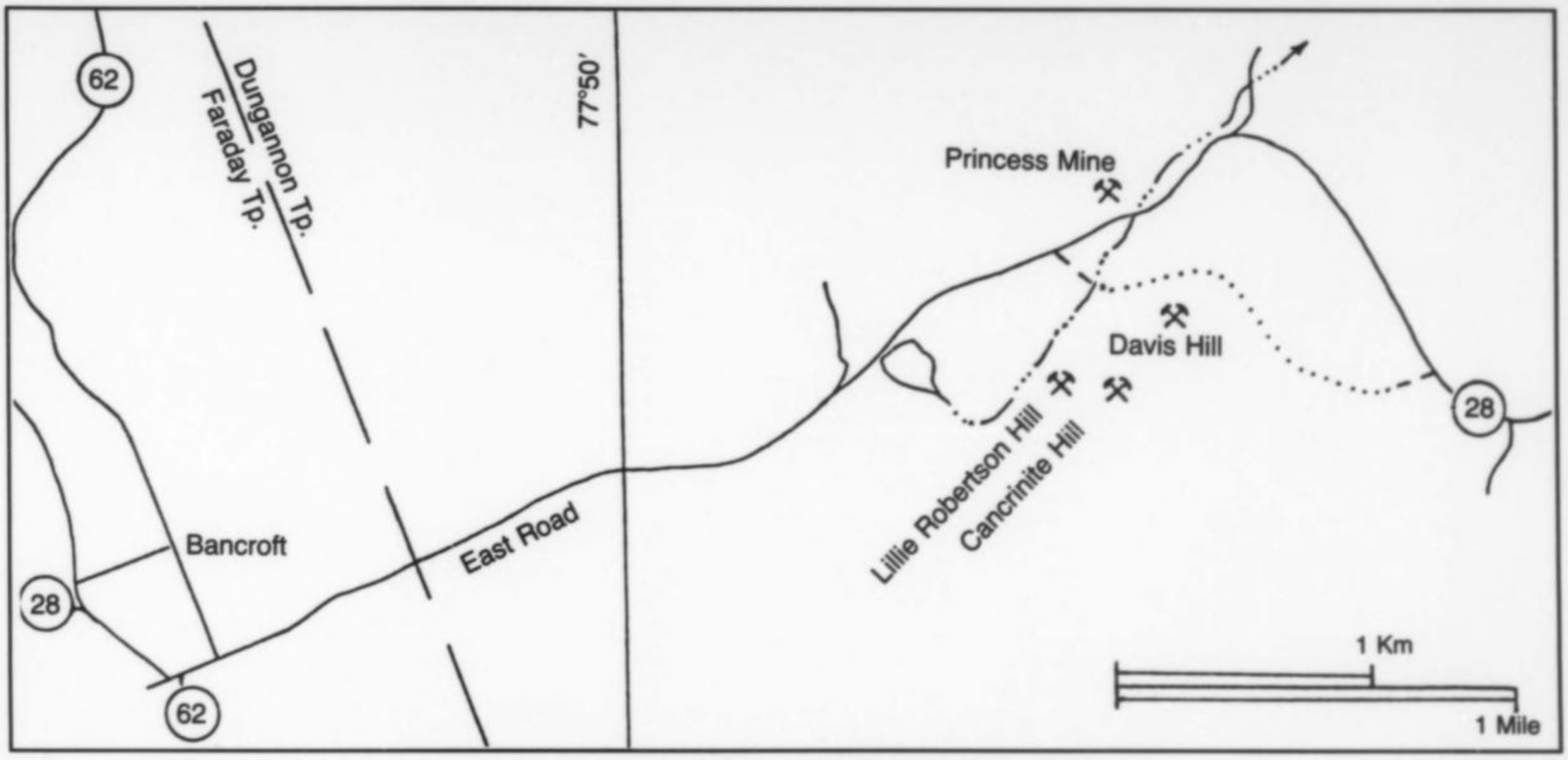


Figure 3. **Mineral localities along Bancroft's East Road.**

The alkaline gneisses of the Bancroft series, which are underlain by marble and interlayered with other metasedimentary rocks of the late Precambrian Grenville Group, are now generally considered to be nephelinized gneisses derived from sediments. Along the East Road, this series dips steeply to the southeast and may form an overturned, northeastward-plunging syncline, with nepheline-rich gnesisses on both limbs, and nepheline-poor to nepheline-free gneisses in the core. According to this interpretation, the Princess mine lies on the north limb, and the Davis, Cancrinite and Lillie Robertson hills form part of the south limb. On Davis Hill, however, the gneisses strike northward because of a small fold superimposed on the major structure. Locally, the nepheline-rich gneisses have been recrystallized to coarse, pegmatite-like patches, but with little or no change in mineralogy. The Bancroft series is intruded by many massive, sharply defined syenitic-to-granitic dikes that are offshoots from post-tectonic stocks that crop out in the area.

The major minerals of the nepheline-rich gneisses in the Bancroft series are nepheline, alkali feldspars, biotite, magnetite and calcite. Diamond drilling showed that Davis Hill averages about 24% Al_2O_3, with a nepheline content of about 55%.

VEIN-DIKES

At the Davis Hill showings, dilated joints and fractures contain fissure veins that have central fillings of very coarsely crystalline calcite. The walls of the veins are lined with large, inward-growing, well-formed crystals of nepheline, biotite and antiperthite, together with minor amounts of apatite, magnetite, tourmaline, zircon and sulfides. Veins range from less than 30 cm to more than 30 meters in length, and from a fraction of a centimeter to more than 1 meter in width. Pinching and swelling is common, and many vein-dikes are pod-like. In plan view, most of the veins transect the foliation of the enclosing gneiss at about 90°, and dip moderately to steeply northward. Some, however, are less steep and may curve in both plan and section, crossing or coalescing with the steeper veins. Brecciated zones in the gneiss also contain pockets of coarsely crystallized vein minerals. The vertical drill hole intersected similar veins to a depth of about 40 meters below the outcrop.

In the veins, as well as in the adjacent host rocks, sodalite and cancrinite occur as hydrothermal alteration products; many of the nepheline crystals have been partially replaced by sodalite. Natrolite

Figure 4. **Use of wooden tool to expose a nepheline crystal partially weathered out of vein-core calcite. Antiperthite crystals project from the hanging wall. Photo by the author.**

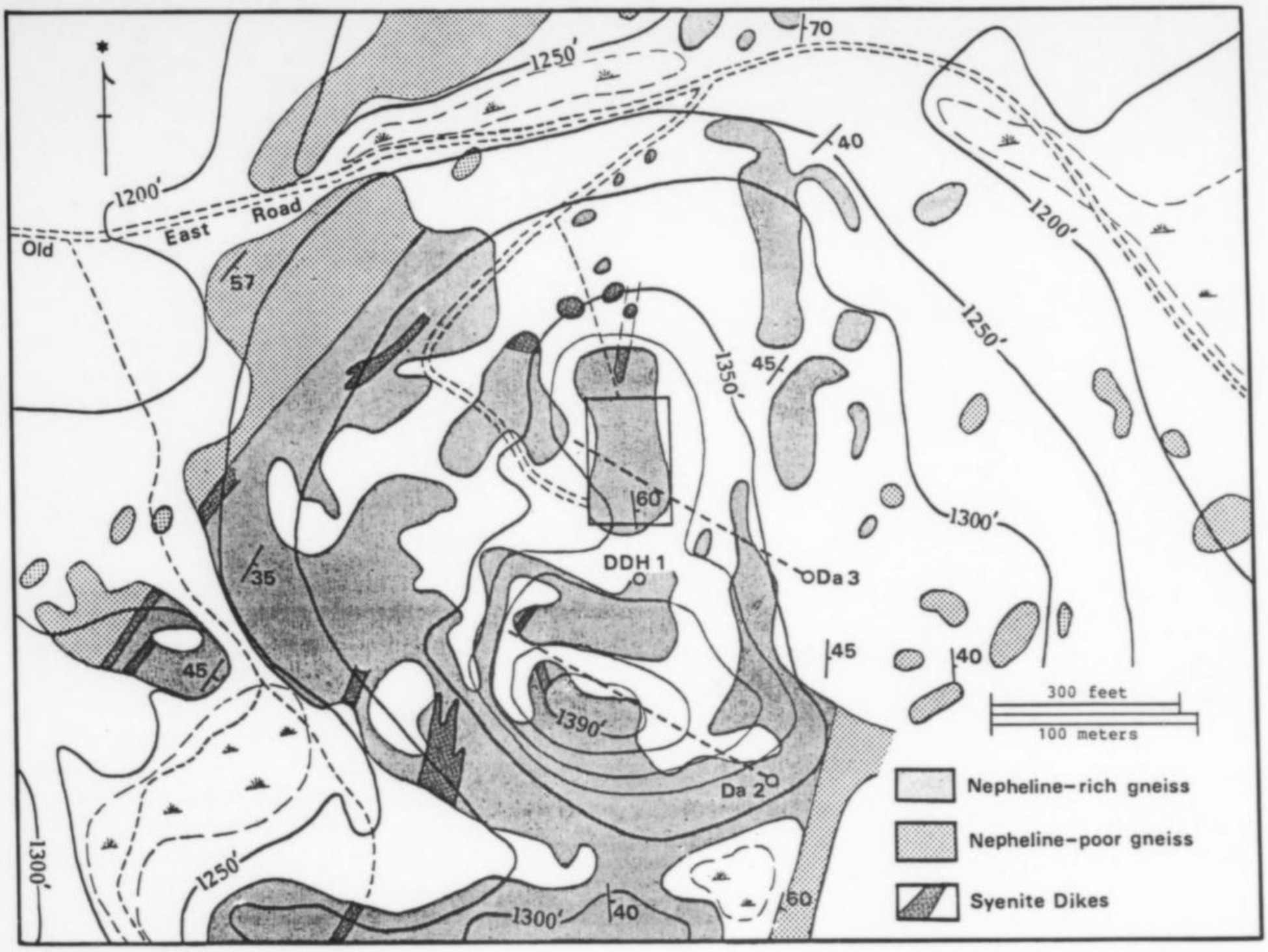


Figure 5. **Davis Hill geology. The rectangle outlines the vein-dike exposures. Diamond drill hole no. 1 is vertical, holes Da-2 and Da-3 were drilled at 45°. Modified from S. V. Burr and W. G. Gummer (1942).**

and "hydronephelite" are common lower-temperature alteration products. Late differential movements have produced rhombohedral pressure-parting and flowage structures in the calcite, bending and slippage along cleavage planes in the biotite, and fracturing of the nepheline and antiperthite crystals.

Near the surface, much of the calcite has been leached away, leaving fissures filled with boulders, sand, clay, soil and humus that afford excellent rooting for shrubs and trees.

MINERALOGY

Albite-Antiperthite $X[(Na,Ca)Al(Al,Si)Si_2O_8]\cdot Y[KAlSi_3O_8]$

Grayish white, moderately to sharply tapered crystals of alkali feldspar range up to 15 cm in length. Common forms of the monoclinic and pseudomonoclinic feldspars are developed to a greater or lesser extent on most of the crystals: basal pinacoid $c\{001\}$, side pinacoid $b\{010\}$, negative second-order and third-order pinacoids $x\{\bar{1}01\}$ and $y\{\bar{2}01\}$, first-order prism $n(021)$, third-order prisms $m\{110\}$ and $z\{\bar{1}30\}$, and negative fourth-order prisms $o\{\bar{1}11\}$, and $u\{\bar{2}21\}$. The tapered appearance of most of the crystals is caused by the dominance of steep "back faces," $y(\bar{2}01)$ and $u(\bar{2}21)$ and $(\bar{2}\bar{2}1)$, in some cases almost to the exclusion of other terminal faces. There are all gradations from the relatively rare, more or less blocky crystals to the highly tapered crystals.

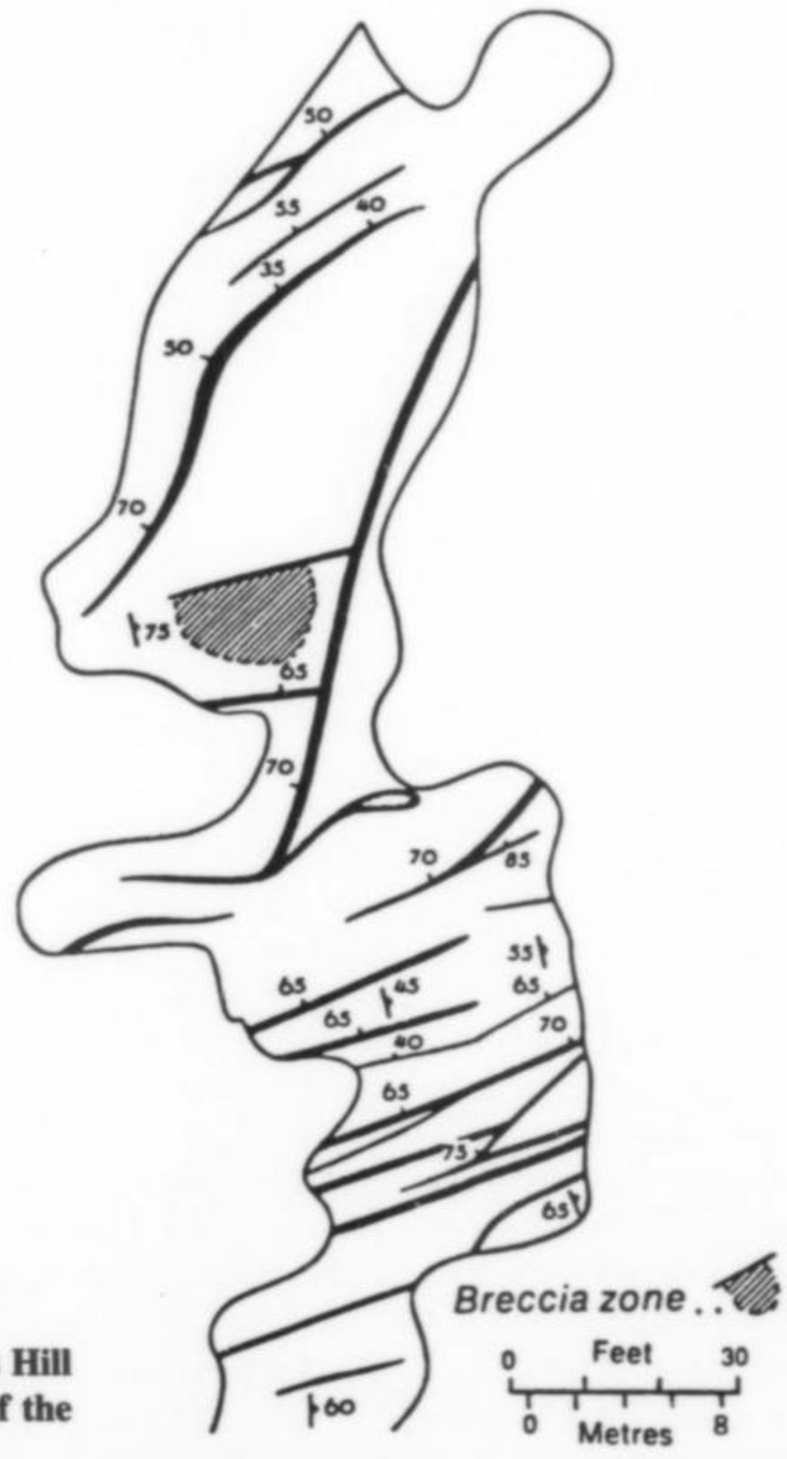


Figure 6. **Vein-dikes exposed in the Davis Hill stripping. Dip of the veins and foliation of the alkaline gneiss host-rock are indicated.**

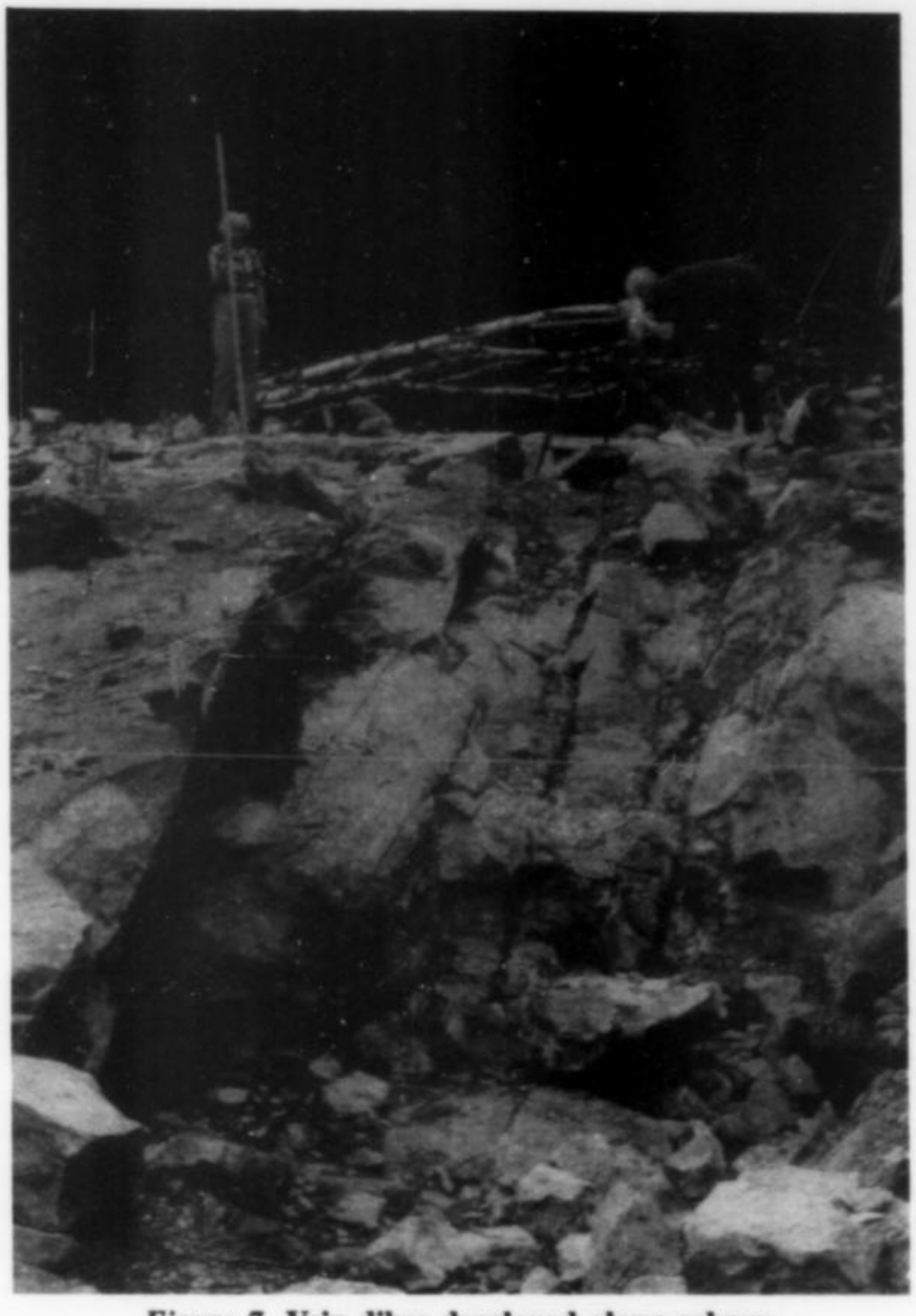


Figure 7. **Vein-dikes developed along subparallel joints that transect the foliation of the alkaline gneiss. Pauline Moyd on rod, Robin Lee Munroe at plane table. Photo by the author.**

Although externally euhedral, each crystal now consists of a mosaic of tiny irregular domains of albite that are elongated parallel to the *c* axis. These may be distinguishable megascopically on cleaved {001} surfaces, but are particularly obvious in thin section because of offset or slightly rotated albite twinning. Microcline, in the proportion indicated by the accompanying chemical analysis (Table 1), occurs as small amoeboid (even wrap-around) bodies between albite domains. In thin sections parallel to (001), albite twinning can be seen to carry through from the albite to the microcline, with the pericline twinning

EDITOR'S NOTE: Perthite terminology

Perthite: A variety of alkali feldspar consisting of parallel or subparallel intergrowths in which the K-rich phase (usually microcline) appears to be the host from which the Na-rich phase (usually albite) exsolved.

Antiperthite: Like perthite, except that the Na-rich phase appears to be the host from which the K-rich phase exsolved.

Mesoperthite: A variety of perthite consisting of about equal amounts of K-feldspar and Na-feldspar, i.e. intermediate between perthite and antiperthite.

Microperthite: A variety of perthite in which the lamellae (5–100 microns wide) are visible only with the aid of a microscope.

Cryptoperthite (and Crypto-antiperthite): Extremely fine-grained varieties of perthite in which the lamellae are of submicroscopic dimensions (1–5 microns wide) and are detectable only by x-ray or electron microscope analysis.

(Bates and Jackson, *Glossary of Geology*, 1987.)

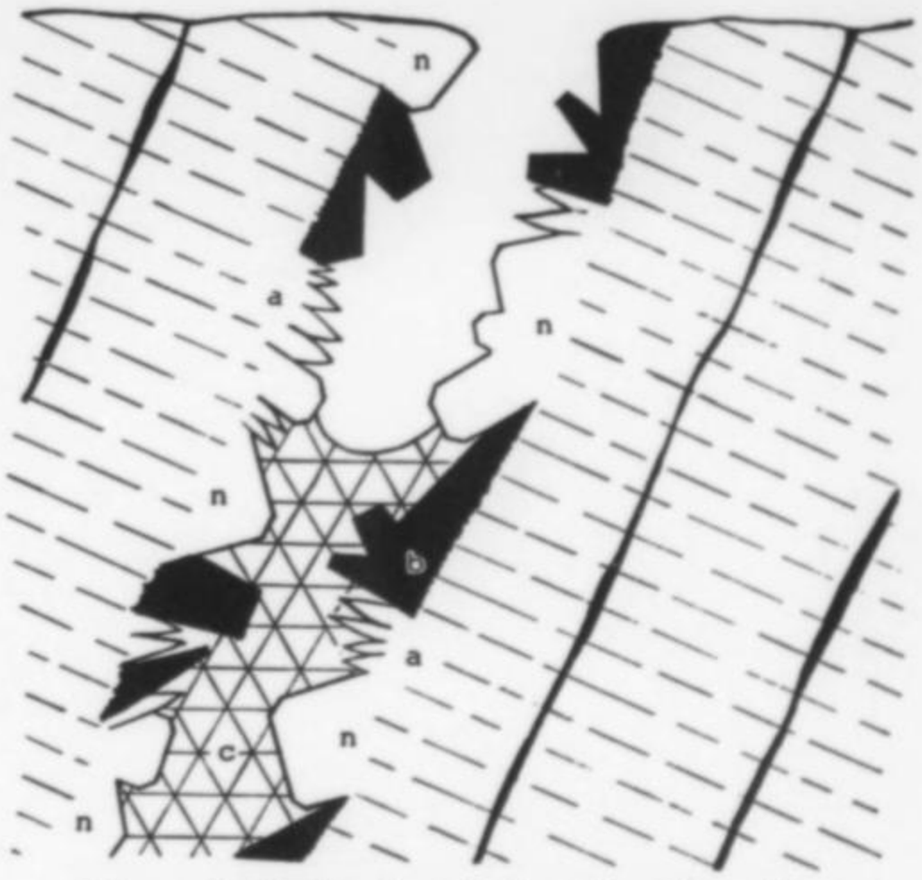


Figure 8. **Idealized vertical section through a vein-dike. Nepheline (n), antiperthite (a), biotite (b) and partially leached calcite core (c).**

of the microcline approximately normal to the albite twinning. The shared twinning and the textural relations appear to indicate replacement of albite by microcline.

The albite of the domains is somewhat milky and shows a blue-tinged moonstone-like iridescence on or nearly parallel to the (001) plane. Low indices of refraction and low calcium content indicate crypto-antiperthite rather than peristerite.

Overgrowths of transparent, colorless albite form rims 2 to 3 mm thick that are in crystallographic and optical continuity with the underlying crypto-antiperthite but lack its opalescence and iridescence. The surfaces of the crystals are irregular because the transparent albite forms small, ridge-like parallel-growth units that are aligned with the *c*-axes. In lateral growth, some of the ridges of transparent albite entrapped and isolated inter-ridge calcite, resulting in a growth-ring formed of micro-inclusions of calcite just within the periphery of each

Table 1. **Chemical analyses of nepheline, antiperthite and biotite crystals from Davis Hill.**

	Nepheline* NMNS 36444	Antiperthite NMNS 36445	Biotite NMNS 42685
SiO_2	44.01	67.20	35.78
TiO_2	ND	0.00	1.81
Al_2O_3	33.1	19.20	14.40
Fe (total as Fe_2O_3)	ND	0.07	ND
Fe_2O_3	0.13	ND	6.31
FeO	0.03	ND	19.67
MnO	ND	0.00	0.33
MgO	ND	0.01	7.70
CaO	0.19	0.06	0.04
K_2O	5.52	4.48	9.12
Na_2O	16.2	8.48	0.39
Li_2O	ND	ND	0.20
Rb_2O	ND	ND	0.10
CO_2	0.18	ND	ND
H_2O (total)	0.36	0.14	2.94
F	ND	ND	1.84
Less O≡F	—	—	−0.76
Total	99.7+	99.64	99.87

*Combined analytical procedures

Figure 9. **Biotite and nepheline crystals lining the wall of a vein. Photo by the author.**

Figure 10. **Nepheline and biotite along a wall of the largest vein. Photo by H. R. (Hal) Steacy.**

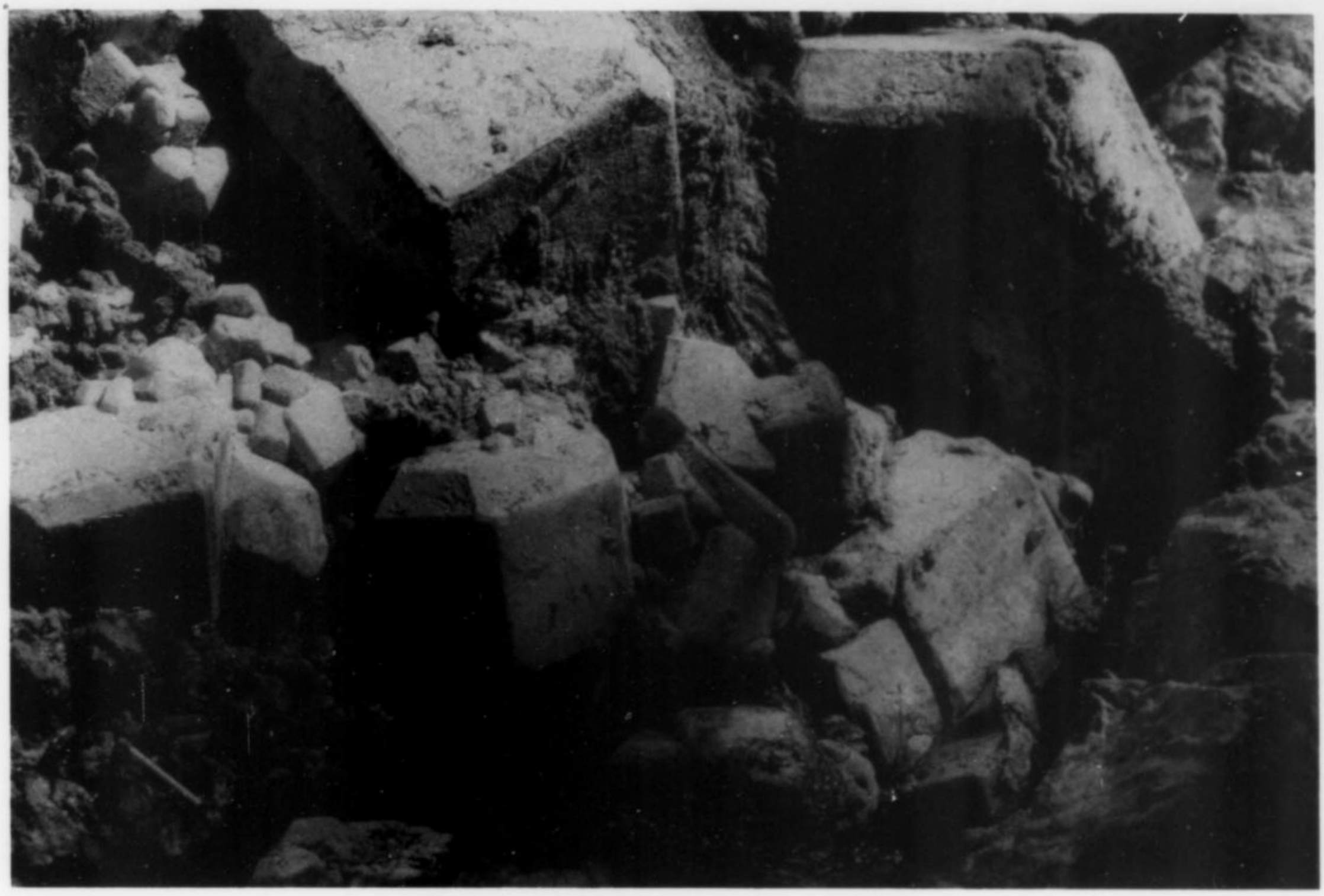


Figure 11. **Nepheline and biotite lining a wall of the largest vein. Apatite clusters are visible at top-center and bottom-center. Photo by Robert A. Ramik.**

Figure 12. **Tabular crystals of nepheline, with biotite and antiperthite. The dark patches on the 20-cm wide terminal face are partial replacements by blue sodalite. National Mineral Collection of Canada. Photo by Graham Runnells.**

Figure 13. **Side view of the 20-cm wide nepheline crystal. Prism faces are 9 cm high. National Mineral Collection of Canada. Photo by Graham Runnells.**

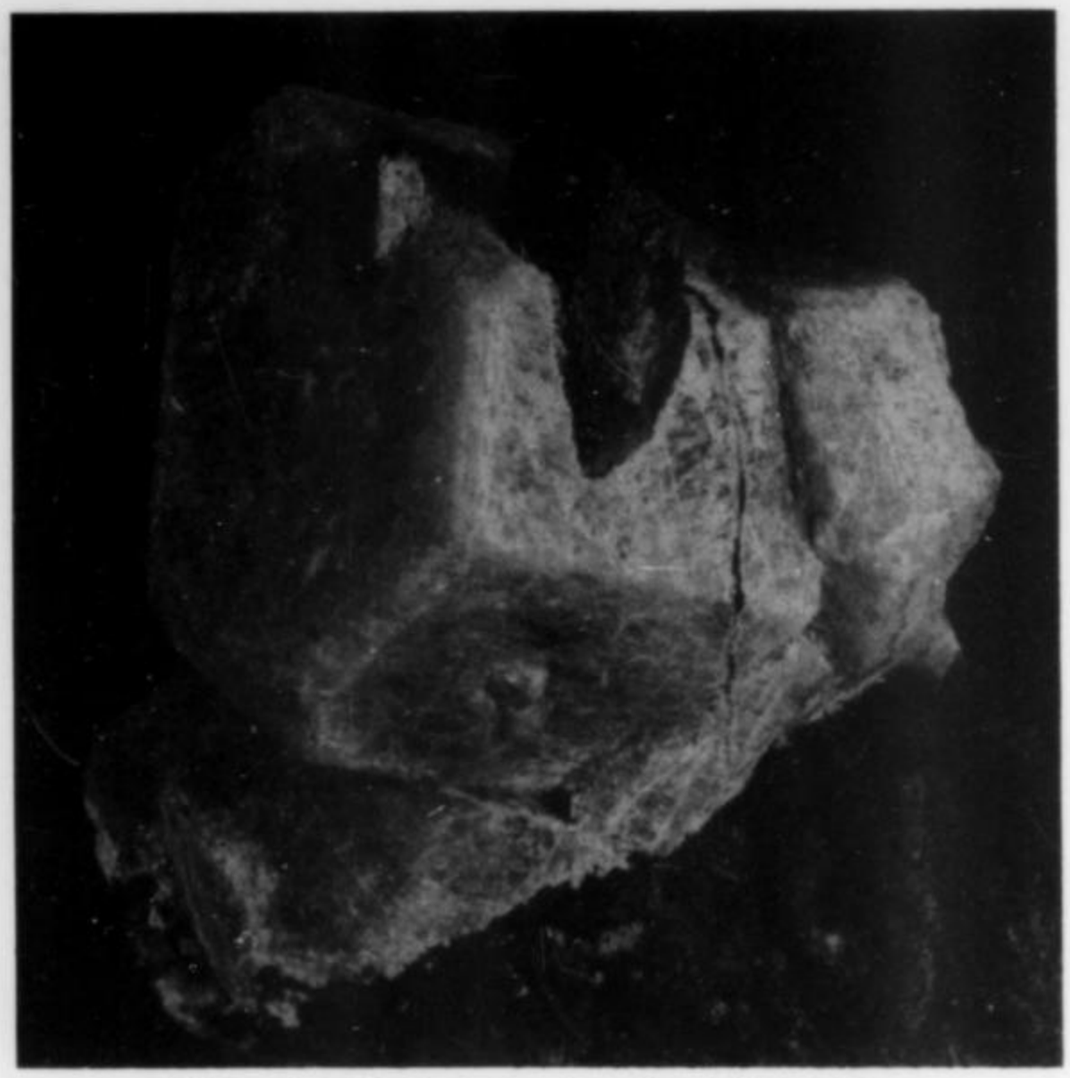


Figure 14. **Nepheline and antiperthite. Ridge-like overgrowths of transparent albite appear on the antiperthite. Terminal face of the nepheline is 8 cm wide. National Mineral Collection of Canada. Photo by Graham Runnells.**

Figure 15. **Biotite and relatively fresh nepheline; the specimen is 22 cm wide. National Mineral Collection of Canada. Photo by Graham Runnells.**

crystal. Tiny, haphazardly oriented, rounded crystals of the same colorless albite form granular aggregates on some of the antiperthite crystals. These features indicate initial monoclinic crystallization of a homogeneous feldspar of essentially the present overall composition, followed by readjustments in response to varied and fluctuating metamorphic environments:

1. Exsolution of a K-rich phase, probably in one of the typical perthite patterns.
2. Breakdown of the host crystal into discrete Na-rich domains.
3. Migration and interchange of K and Na ions via the discontinuities between domains, forming the present configuration of K and Na feldspars.
4. Exsolution of microlamellae of K-feldspar from the Na-rich feldspar, giving rise to the opalescence and iridescence.
5. Overgrowth of nearly pure transparent albite.

The accompanying chemical analysis (Table 1) and physical constants are averaged effects because of the exsolution and intergrowth features at various scales. Density (by Berman balance) = 2.62 g/cm^3; refractive indices (D) of the plagioclase: α = 1.525(2), β = 1.529(2), γ = 1.536(2).

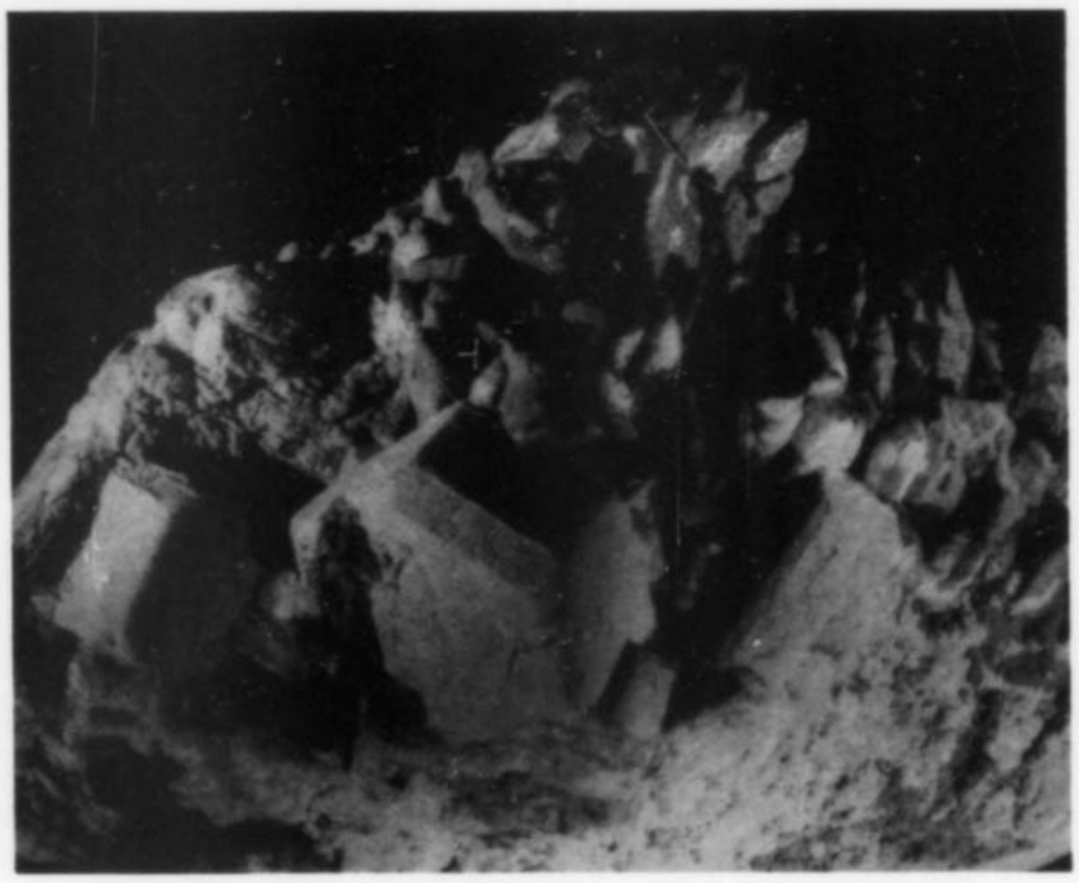


Figure 16. **Nepheline and antiperthite. Terminal face of the largest nepheline is 7 cm wide. National Mineral Collection of Canada. Photo by Graham Runnells.**

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

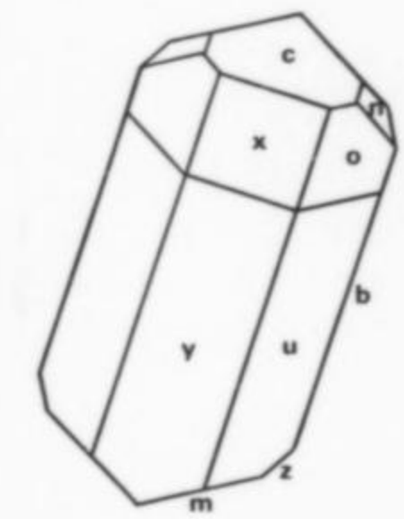
Iron-rich biotite occurs as prismatic, usually tapered crystals up to about 67 cm. The major habit is the pseudo-hexagonal prism, which combines the prism *m*{221} and the side pinacoid *b*{010}. Although many crystals show basal terminations *c*{001}, most of these are probably cleaved surfaces. Oscillatory growth and almost ubiquitous tapering, even curving, make it difficult, if not impossible, to distinguish any other forms.

The freshest, least-contorted crystals afford elastic, mirror-like black cleavage plates that are opaque except in very thin films (which are brownish green). Most of the crystals, however, are brittle and break up into small blocky fragments because of distortion and fracturing caused by late-stage differential movements. Many crystals are offset along the basal cleavage, and some bent or broken crystals show lit-par-lit invasion by calcite. Crystals in the leached zones have been partially weathered to a golden vermiculite.

A chemical analysis of the fresh biotite is shown in Table 1. The iron-rich biotites of the nepheline pegmatites and the nepheline-bearing and other vein-dikes of the Bancroft region were commonly labeled lepidomelane, a term now superseded by ferrian biotite. This appears to be particularly appropriate for the Davis Hill biotite, with its relatively high ferric iron content.

Physical constants include: density (in heavy-liquid suspension) = 3.12 g/cm^3; refractive indices (D) α = 1.591(2), β and γ = 1.649(4) 2V = 0°; pleochroism: X = light brown, Y and Z = green.

Figure 17. **Biotite crystal, 15 cm long. National Mineral Collection of Canada. Photo by Graham Runnells.**



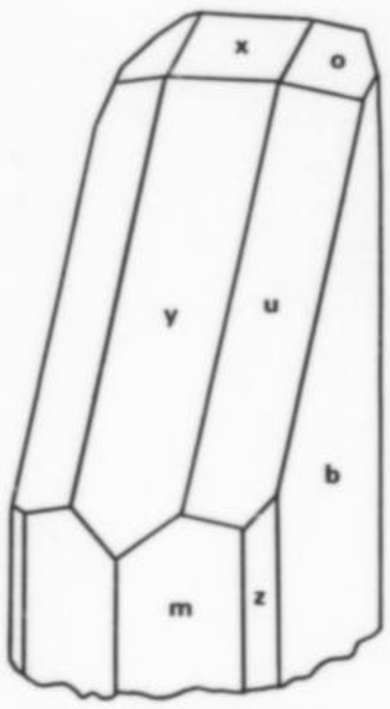


Figure 18. **Antiperthite crystal, idealized. In standard orientation, the steep faces responsible for the tapered habit would appear only on the back and bottom of the crystal.**

Figure 19. **Part of a thin section parallel to the (001) plane of a euhedral crystal of antiperthite. Divergent sets of twinning lamellae mark the individual domains of albite. Crossed polars, field 2.3 mm. National Mineral Collection of Canada. Photo by Claudia Gasparini.**

Figure 20. **Part of a thin section parallel to the (001) plane of a euhedral crystal of antiperthite. The albite twinning of the albite domains carries through into the microcline bodies that are interstitial to (and partly replace?) those domains. Crossed polars, field 2.3 mm. National Mineral Collection of Canada. Photo by Claudia Gasparini.**

Calcite $CaCO_3$

The central portions of the veins consist almost exclusively of coarsely granular white calcite. Where sheltered from differential stresses, e.g. in embayments between some of the larger crystals projecting from the walls, anhedral crystals of calcite may exceed 10 cm. Most of the calcite, however, has been subjected to flowage and fracturing. Solution-weathering brings out cleavage, pressure-parting and later fracturing. Density, indices of refraction and brownish discoloration on weathering indicate minor iron content. Physical constants include: density (by Berman balance) = 2.63 g/cm^3; refraction indices (D): $\omega = 1.665(4)$, $\epsilon = 1.491(2)$.

Figure 21. **Apatite crystals "floating" in vein-core calcite. The specimen is 10 cm wide. National Mineral Collection of Canada. Photo by author.**

Cancrinite $Na_6Ca_2Al_6Si_6O_{24}(CO_3)_2$

Pale yellow, cleavable masses of cancrinite occur in the same manner as the sodalite, but to a much lesser extent.

Fluorapatite $Ca_5(PO_4)_3F$

Single green prisms of fluorapatite up to 10 cm long and radial aggregates are intergrown with other crystals lining the veins, but some are also free-floating within the calcite vein-cores. Many have the fused-edge, fire-polished appearance common in crystals that have grown in marble. A determination by Victor Chanto at the University of Texas showed only 35.6(4.2) ppm of chlorine (D. S. Barker, personal communication, 1969).

"Hydronephelite" and "Gieseckite"

The material called "hydronephelite" is actually a fine-grained mixture consisting principally of natrolite with varying amounts of other minerals, including analcime, micas and clay minerals (Edgar, 1965). Color ranges from milky white through pink or gray and pale green. Somewhat similar medium to dark green waxy aggregates, but with generally lower natrolite content, have been termed "gieseckite." These materials occur only as late-stage hydrothermal alterations of nepheline and, in some cases, the associated alkali feldspars. At Davis Hill, the vein-minerals are substantially free of hydronephelite, but patches have replaced some of the alkaline gneiss host-rock.

In the nepheline pegmatites of the nearby Davis and Robbins-Lumb quarries, large crystals of nepheline are gradationally altered along crystal boundaries, or along fractures that transect the crystals. A core of fresh nepheline is successively replaced by zones of white cancrinite, white to pink hydronephelite, and finally green gieseckite. At the Blue Mountain quarries, joint blocks of the medium-grained, gneissic nepheline-feldspar rock show a similar series of alterations along joints. Joint-controlled alteration is very well shown by the nepheline-rich rock exposed in the adit at the Craigmont corundum mine.

Muscovite in sericite-like masses, and locally in plates up to 5 mm wide, occurs in the Davis Hill natrolite-hydronephelite zones.

Magnetite $Fe^{+2}Fe_2^{+3}O_4$

In the Davis Hill veins, magnetite has been noted only as small, splendent, irregular grains disseminated through the other minerals, although well-formed magnetite octahedra and masses of lodestone showing octahedral parting occur in vein-dikes at the Princess sodalite mine and other nearby localities.

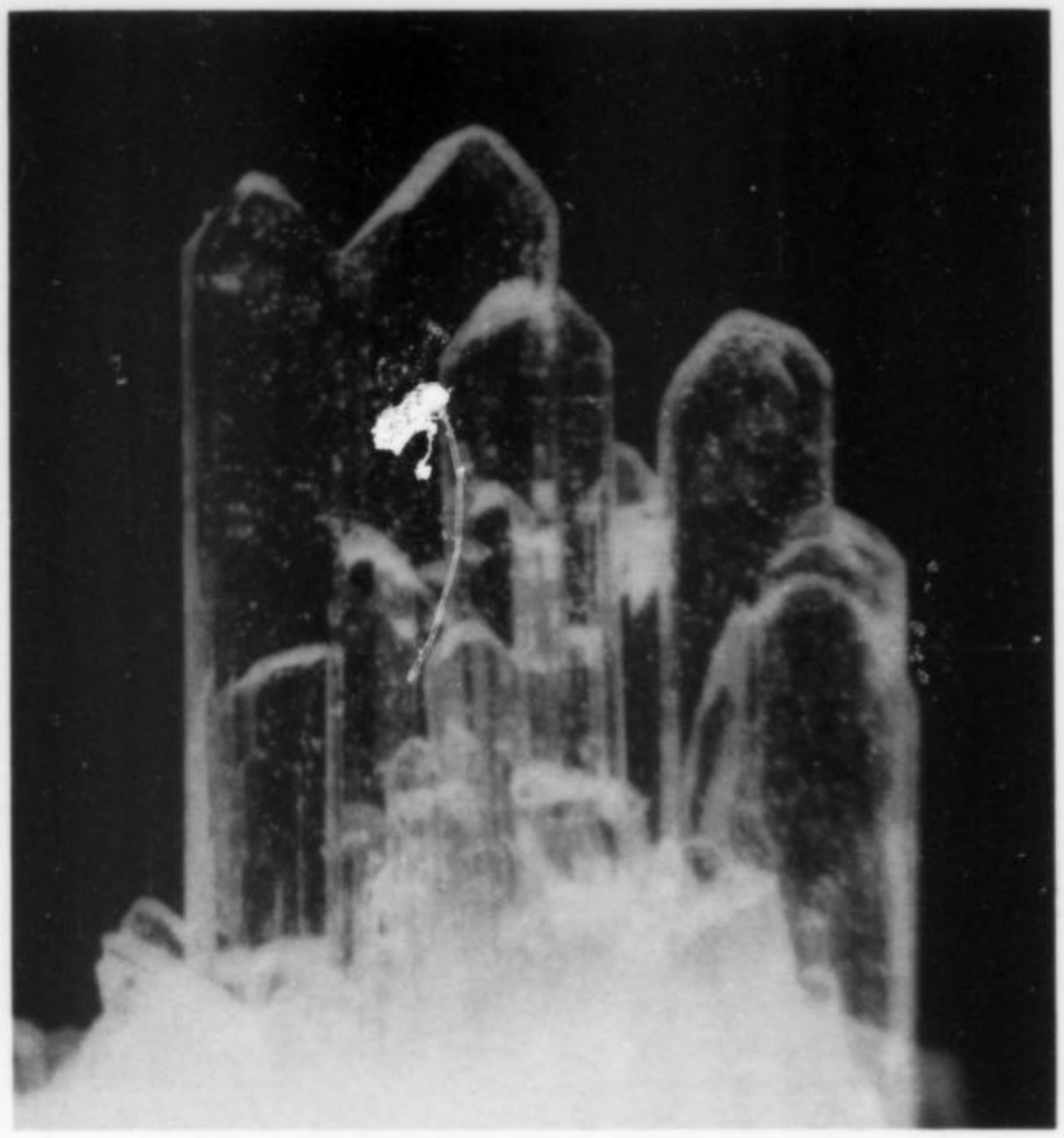


Figure 22. **Natrolite crystals about 1 cm long. National Mineral Collection of Canada. Photomicrograph by David M. Watson.**

Natrolite $Na_2Al_2Si_3O_{10}\cdot 2H_2O$

Criss-cross aggregates of white natrolite crystals occur in vuggy zones resulting from the hydrothermal alteration of nepheline crystals and adjoining wall rock. Colorless prisms up to 1 cm long extend into some of the vugs. Physical constants include: density (by Berman balance) = 2.23 g/cm³; refractive indices (D): $\alpha = 1.477(2)$, $\beta = 1.480(2)$, $\gamma = 1.490(2)$.

Nepheline $(Na,K)AlSiO_4$

Davis Hill nepheline crystals are probably the largest well-formed nepheline crystals known, with equidimensional to prismatic crystals ranging up to about 67 cm. The major forms are the first-order prism $m\{10\bar{1}0\}$ and the basal pinacoid $c\{0001\}$. Faces of the first-order dipyramid $p\{01\bar{1}1\}$ are present on most crystals but may be very unequally developed. Rarely, the basal pinacoid is subordinate to the pyramidal faces. Second-order prism faces $a\{11\bar{2}0\}$ occur only sporadically.

Colorless to pinkish limpid zones grade into somewhat milky and opalescent gray to white zones (caused by cryptic exsolution of a very minor amount of a phase richer in potassium?). Tiny inclusions of magnetite are common. Some crystals have been partially altered to blue sodalite or, less commonly, to yellow cancrinite.

Almost all of the crystals are traversed by networks of hairline cracks, along which many have broken, probably as a result of freeze-thaw action in the leached-out portions of the veins, which permitted access by soil fluids and rootlets. A powdery, white to rusty patina coats many of the crystals that had been subjected to soil-forming action in the debris-filled leached zones. The patina has been eroded from crystals that had later been exposed to open-air weathering, leaving somewhat rounded and smoothed corners and edges.

The proportion of Na_2O to K_2O is just about 3:1, as shown in Table 1. Physical constants include: density (by Berman balance) = 2.63 g/cm³; refractive indices (D): $\omega = 1.537(2)$, $\epsilon = 1.532(2)$.

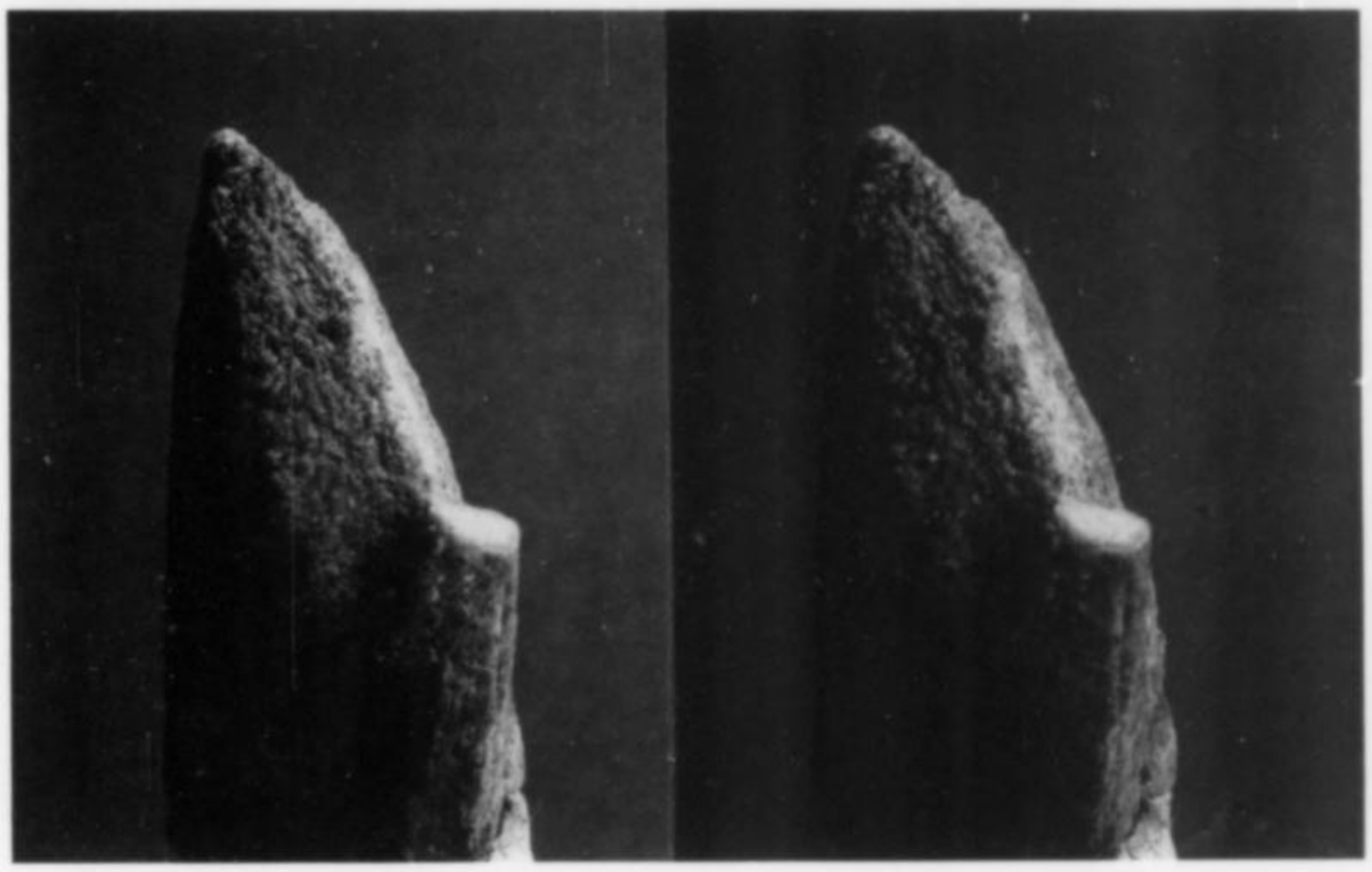
Pyrrhotite $Fe_{1-x}S$

Irregular blebs of pyrrhotite up to 1 cm wide occur in nepheline crystals and in the vein-core calcite. The pyrrhotite shows scalloped

Figure 23. **Nepheline and antiperthite crystals. The largest nepheline is 9 cm wide. National Mineral Collection of Canada. Photo by the author.**

Figure 24. **Blocky crystal of antiperthite 2.5 cm wide. Orientation is indicated by the topmost face, the basal pinacoid {001}, all others being back-of-crystal faces. National Mineral Collection of Canada. Stereo-pair photo by the author.**

Figure 25. **Steeply tapered antiperthite crystal 8 cm long. Stereo-pair photo by the author.**



Schorl $NaFe_3^{+2}Al_6(BO_3)_3Si_6O_{18}(OH)_4$

Splendent black prismatic schorl crystals up to 1 cm long occur in coarsely granular, recrystallized host-rock, and in some natrolite and hydronephelite replacement masses of this rock.

Sodalite $Na_8Al_6Si_6O_{24}Cl_2$

Pale blue to deep blue irregular sodalite masses of various sizes occur as partial to complete replacements of nepheline crystals in the veins. It also replaces nepheline and probably some of the feldspar of the wall rocks. Dodecahedral cleavage is well developed.

GENESIS

Nepheline-Rich Gneisses

Although these alkaline gneisses have been studied for nearly a century, their origin is still controversial. Their occurrence and genesis are discussed in some detail by Gummer and Burr (1946), Moyd (1949, 1964, 1972), Hewitt (1961), Hewitt and James (1956), Allen and Charsley (1968), Sorensen (1974), Appleyard (1974), Appleyard and Stott (1975), Currie (1975), Appleyard and Williams (1981), and Haynes (1986). These rocks have variously been considered as:

1. Intrusive (possibly even some extrusive) igneous rocks derived by differentiation of underlying crystallizing magmas, or by the partial melting of sub-crustal rocks.

2. Intrusive (and possibly even some extrusive) igneous rocks formed by the desilication of granitic magma through the incorporation and assimilation of limestone.

outlines indicating replacement of the other minerals, and is strongly magnetic. Minor amounts of pyrite and chalcopyrite are intergrown with the pyrrhotite.

Zircon $ZrSiO_4$

Nearly equant, well-formed, chocolate-brown crystals of zircon up to about 1 cm have produced radial shattering in surrounding minerals.

3. Alumina-rich laterites.
4. Analcime-rich sediments.
5. Products of the metasomatic alteration of metasedimentary, and even some meta-igneous rocks. The reacting fluids might have been any one, or a combination of:
   a. Differentiates released by crystallization of underlying alkaline magmas.
   b. Solutions derived from metamorphic reactions between halite-rich evaporites and associated sediments.
   c. Differentiates released on crystallization of underlying granitic magmas, or fluids released by partial melting of metasedimentary rocks at great depth. Under ordinary circumstances, such fluids might have granitized some of the overlying rocks. However, in traversing and reacting with the limestone-rich terrane, these fluids would have lost silica and gained carbon dioxide, and were thus able to syenitize, and even to nephelinize some chemically and structurally favorable portions of the overlying rocks. I personally favor this last interpretation.

It is generally agreed, however, that these alkaline gneisses had been formed and modified in the course of several tectonic, instrusive and metamorphic cycles.

Vein-Dikes in Basement Complexes

The Davis Hill veins constitute one of several kinds of calcite-cored "vein-dikes" that occur throughout the marble-rich, high-grade metamorphic terrane of the Precambrian Grenville geological province of southeastern Ontario and adjacent parts of Quebec and New York, as well as in similar terranes elsewhere, e.g. Oaxaca, Lake Baikal, Madagascar and Sri Lanka. Their occurrence and genesis are discussed in some detail by Spence (1920, 1929), Ellsworth (1932), Shaw *et al*. (1963) and Moyd (1972).

Such vein-dikes are characterized by walls lined with well-formed crystals of various rock-forming minerals, predominantly silicates, that project inward into a core of coarsely crystalline calcite that may have some associated fluorite or anhydrite. Free-floating euhedral crystals, particularly of the micas and apatite, but also titanite, uraninite, zircon, betafite, etc., are suspended in the calcitic cores of some bodies. Vein-dikes have supplied most of the world's phlogopite and, prior to the mining of sedimentary phosphate, most of the apatite; also minor amounts of biotite, fluorite and magnetite. Many have been explored for uranium and thorium but without significant production as yet. They have been major sources of fine mineral specimens, as exemplified in Ontario by the Lake Clear–Kuehl Lake occurrences, the Fission mine, the Silver Crater-Basin mine and various others described by Moyd (1972), Grice and Gault (1982), Robinson and Chamberlain (1982) and Steacy *et al*. (1982).

Such bodies have been called pegmatite dikes, veins, xenoliths, layers of skarn, and even mobilized skarn. H. V. Ellsworth (1932) called them vein-dykes on the basis of Spurr's proposal (1923) that "veindikes" be applied to deposits whose characteristics fall between dikes and true veins. Spurr's examples range from pegmatites, through quartz veins, to various kinds of metal-bearing veins, but no mention is made of the calcite-cored silicate-crystal-lined veins occurring in the Grenville and similar terranes.

Generally, the kind and composition of the vein minerals are closely related to the composition of the enclosing rocks. Thus nepheline crystals occur in the veins in nepheline-bearing gneisses, but quartz crystals may occur in the veins in quartz-bearing gneisses. In the Na-rich gneisses, the feldspar of the veins is antiperthite, but perthite is the feldspar of veins in the more common granitized gneisses. The mica of veins in iron-bearing gneisses might be black iron-rich biotite, whereas that of veins in iron-poor host rocks is generally phlogopite, ranging from various shades of brown to almost colorless. Similarly, ferrosalite crystals line veins in iron-rich amphibolites, but diopside occurs in veins in iron-poor calcareous gneisses, including the "metamorphic pyroxenites" which were derived from siliceous dolomitic limestones and are the most common host rocks of the phlogopite-apatite deposits.

Many vein-dikes are concordant with the foliation and layering of the enclosing rocks, but others transect these structures. Contacts between vein-dikes and wall-rocks are gradational. Except for the central core, systematic zoning is not very well developed, and the general impression is of more or less simultaneous rather than sequential development of the various minerals that line the walls. An unusual aspect of the paragenesis of many if not all of the vein-dikes is that the crystals projecting inward from the walls (as well as the free-floating crystals in the core) are later than, and have replaced, the already crystallized core-materials. This anomalous vein-development is indicated by rounded relics of core minerals within the well-formed crystals. Isolated pellets of coarsely crystalline calcite are common in apatite and hornblende crystals, and also occur in scapolite, titanite, betafite, uraninite and other minerals.

The tabular vein-dikes are part of a continuous series of transitional forms derived from parent gneisses. The simplest are coarsely crystalline, pegmatite-like patches developed by localized recrystallization of the constituents of the gneiss, with concommitant destruction of the gneissic structure. There is generally a gradation between unaffected gneiss and the coarsely crystalline patch. The major minerals of the recrystallized zone may be nearly identical to those of the parent gneiss, but in some occurrences there have been modifications in composition and adjustments to different thermodynamic conditions, e.g. the principal dark mineral of the gneiss may be hornblende, whereas that of the coarsely crystalline patch may be biotite or magnetite. The next transitional forms are pegmatite-like masses that contain small cores of coarsely crystalline calcite (rarely, some fluorite). Well-formed crystals surround and project into the cores. With increasing size of core, these bodies take on the appearance and characteristics of typical vein-dikes. The transitional forms generally occur as discrete isolated masses, but in some occurrences all types may be represented within a single complex body.

The crystal selvages of vein-dikes closely resemble the coarsely crystallized reaction rims that border recognizable intrusions of flow-age-marble into gneisses (e.g. the Silver Crater mine), and also the crystal rims developed on isolated blocks of gneiss enclosed in flow-age-marble. The calcite cores of at least some of the tabular vein-dikes might represent mobilized marble that had been forced into openings along foliation planes, joints and fractures, including the interstices between the blocks of "giant breccias."

In carbonate-bearing calc-silicate rocks as well as in the gneisses, there are transitional forms between host-rocks and vein-dikes, making it difficult to draw sharp boundaries. The process of development of diopside, scapolite and phlogopite metacrysts in marble is undoubtedly closely related to that of the development of crystals of these minerals in the vein-dikes that transect calcareous and magnesian metasedimentary rocks. The presence of large quantities of calcareous country rock has undoubtedly been a major factor in the genesis of the calcite-cored pods and vein-dikes. Some of the calcium of the calcite, fluorite, titanite, anhydrite and other minerals of the veins may have been derived directly from these rocks. Calcium could also have been made available through syenitization of calcic metavolcanic rocks, a process favored by the presence of CO_2-rich solutions. Carbon dioxide released during the widespread silication of marbles would have enhanced the fluidity and reactivity of hydrothermal solutions, whatever their origin. Truly igneous carbonatites do not appear to have been involved in the formation of the vein-dikes.

Many vein-dikes transect well-defined gneissic structures, and were thus formed later than the metamorphic events that produced those structures. A cool interval resulting from uplift and partial denudation would permit the development of joint-systems and fractures in the gneisses. Although the well-crystallized vein-linings appear to have been formed by hydrothermal re-working of wall-rock minerals, the stability range of the vein minerals is similar to that of the minerals

of the wall rocks. Re-heating under relatively static load through reburial, together with the intrusion of igneous bodies, would create a favorable environment for metamorphic reactions leading to the development of the pegmatite-like patches, the crystal-lined pods and the vein-dikes. Linear and planar textures are absent from all of these (except for appreciably later, fault-related flowage of the more plastic core minerals, with associated fracturing of the crystals).

Davis Hill Veins

The principal minerals of the Davis Hill veins are almost identical to those of the enclosing nepheline-rich gneisses. However, the veins are massive and transect the gneissic structures, and thus were formed during a subsequent metamorphic cycle. In an intervening period, the country rocks had risen and cooled sufficiently to permit the development of the joints and fractures that are now occupied by the veins and nearby felsic dikes. The stability range of the vein minerals is similar to that of the host rocks; thus maximum temperatures and pressures approached those of the preceeding cycle, but metamorphic reworking took place under relatively static load.

Early in this cycle, calcite deposition took place in one or more of the following ways:

1. Some of the calcite that had been disseminated through the host rocks may have migrated (in what form?) to openings along joints and fractures.

2. Calcium and carbonate released through metamorphic reactions at greater depth could have come to rest along joints and fractures.

3. The calcite might have been emplaced directly in the form of dike-like intrusions of flowage-marble mobilized from beds adjacent to the nephelinized metasediments.

With increasing load and temperature, the calcite recrystallized to form large anhedra. Calcite cores, wall rocks and enveloping fluids later reacted with each other to produce the selvages of large, well-formed crystals of nepheline, biotite and alkali feldspar. Primary fluids released on crystallization of the felsic igneous bodies might also have taken an active part. Or, at the least, heat from the intrusive bodies would have intensified the convective circulation of ambient fluids.

In the final stages of this cycle, governed by gradually declining temperatures and pressures, some of the vein and wall-rock constituents were altered to sodalite, cancrinite, natrolite and hydronephelite. The complex post-crystallization history of the antiperthite crystals also belongs to this period.

SUMMARY

Sedimentary rocks of the late Precambrian Grenville Group were subjected to several metamorphic cycles, in the course of which gneissic structures were imposed and nephelinization occurred. Between the waning of the next-to-last of those cycles and an early stage of the following cycle, jointing and fracturing developed, and flowage and intrusion of marble may have occurred. Temperatures, pressures and hydrothermal circulation engendered by reburial and by the intrusion of felsic magmas induced migration of calcite into joints and fractures in the nepheline-rich gneisses. Reactions between these calcite cores and the wall rocks formed the well-crystallized vein-linings. In later stages, veins and wall rocks were altered through retrograde metamorphic reactions. This was the final Precambrian metamorphic event in the region. From then to the present the veins were unaffected except for minor shearing, faulting and, ultimately, uplift, denudation and weathering.

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Notes from Europe

by **Thomas Moore**

LYON (FRANCE) SHOW 1989

Sometimes, in the right kind of mildly glum, harmlessly midlife-crisis sort of mood, I've felt guilty that in all these years of living in West Germany and exploring all corners of it, I have done no more than nibble tentatively at the edges of France. Incurious, uncultured slug (goes the mood), I have made only a couple-three quick beelines to Paris and back, a few brief runs down the west bank of the Rhine to Strasbourg or (*naturellement!*) to the Ste.-Marie-aux-Mines show, and an occasional condescending foray just over the border for dinner in Wissembourg where there's a fine restaurant. But I've never yet negotiated Provence, Normandy, Chateaux of the Loire, the Pyrenees—and I a descendent, yet (mood mellowing now), of Georges Clemenceau, the First World War's famous "Tiger," perhaps the most fiercely and possessively French of all the daguerrotyped heroes of History. So all right, *shame* on me then.

One weekend last November, my wife and I set out to rectify the imbalance a bit. Having secured and generously paid a babysitter whose batteries wouldn't run down over the three long days, we set out to visit the mineral show in Lyon, as promised in my last Note, and then to poke a bit into the French Alpine region, including a stop at Chamonix, at the foot of Mont Blanc. This last stop was necessary so that I could make an honest man of myself after having praised Chamonix's beauty in that same Note, without ever having actually checked the place out in person. And there, yes, was Mont Blanc in all its majesty, its snowy finery, in luckily cloudless weather, muscling itself up to its fellow titans whose phalanx surrounds the town, obliging skiers and walling France off from Italy. Chamonix itself I thought rather too "touristy," as we tourists say when we want to feel superior to ourselves, but those mountains truly are wondrous. And we found Lake Geneva and the rolling country around Besançon also pleasant.

Lyon, with 1.2 million people, is the second largest city in France. It is in the country's southeastern quadrant, astride the Rhone River a few tens of kilometers south of the erudite roadsign marking the latitude which is equidistant between the North Sea and Mediterranean coasts. And indeed there is a vaguely Mediterranean flavor about the place. For example, on the day we were there a warm, clear sunlight fell bright as wine from a cloudless sky over a shingly vista of red tile roofs and stark white buildings. As seen from a bridge on the river, this red-roofed clutter climbed irregularly upslope as if trying to reach the foot of the spiky, ornate, very Latinate medieval basilica perched dramatically on its matrix, *beg* pardon I mean its hilltop. In the city at large, occasional palm trees line the edges of parks; restaurants strongly emphasize seafood (probably brought up fresh from Marseilles every day on the Rhone, where all manner of boats traffic busily); and most especially nice was the Latin vivacity of the Saturday market where we bought, for later, our on-the-road lunch of fruit, local sausages and tastefully putrescent cheese. Everywhere the stores and shops, in a sort of rapture of civic pride, advertised a new local Beaujolais, but in general it would seem that no one industry, product, recreational activity or even postcard prospect distinguishes Lyon particularly—its dignified anonymity being precisely why we so enjoyed strolling in these unselfconscious untouristy streets, and hearing, incidentally, almost no Anglo-Saxon or Germanic voices at all.

The mineral show (Lyon's 14th annual) filled the spacious third floor of the ultramodern Palais des Congrès building on the north edge of town. The show was, like the city itself (and rather to my surprise), quite purely French with only a very few stray Italian and German dealers vying with about 75 French dealers in showing what was on the whole a quite high average caliber of specimen material. And here I must thank show manager Jean-Michel Laverrière (who, with his father, presides over *Laverrière Minéraux*, 17 Rue du Mail, 69004 Lyon), for his friendliness and helpfulness throughout my visit. And his minerals weren't bad either: for example, he had the show's most striking specimens of Chinese realgar and Peruvian rhodonite.

The show's generally high level of enthusiasm, intellectual energy and fun came in part from its abundance of special exhibits and extracurricular features. There were, most dramatically, two large "competitive" showcases devoted respectively to beryls and garnets, each case a genteel joust for prize medals and small cash awards. For these cases distinguished collectors entered mostly museum-sized giants of old and new classics—from pink Elba beryls and Val Malenco demantoid garnets to Colombian emeralds, Pakistani aquamarines, and a couple of fantastic specimens of the new grossular on epidote/diopside matrix from Afghanistan. Two other special showcases held respectively a fine small meteorite collection, courtesy of Paris dealer Alain Carion, and a French gemological institute's display of collector gemstones—several shelvesfull of loose faceted brilliants of minerals like cuprite, proustite, amblygonite, wulfenite, willemite, and rainbows of variously colored zircons and topazes. There were films being shown on diamonds, on emeralds, and on pearls; an audio-visual presentation on pocket crystallization of minerals; and a New Age lecture on "Minerals and Parapsychology" (hmmm). And there was a long, always frenetically busy snack bar with a special mission, it seemed, to push that new local Beaujolais. On Saturday night there was a banquet, and there was a party, and at the party, at Mineralogy's service, was a famous French disc jockey (or so I heard, for regrettably I couldn't stay for the festivities). This was, in short, both a serious and a lively show, a likable and a just slightly loopy one. But now it's time, certainly, to move on to matters mineralogical.

The most exciting of the "new" finds—for what's more exciting than an old classic occurrence revived?—was a selection of about a dozen fine cabinet specimens and about 30 equally fine thumbnails of axinite (all right: the species ferroaxinite, of the axinite group), from Le Bourg d'Oisans, Isere, France. These are the typical, legendary, flat "ax blade" crystals, rich rootbeer-brown and mostly gemmy, and very brightly glassy. The three best pieces consist of flat matrix plates each about 10 x 15 cm, covered with irregularly oriented gemmy axinite crystals to 3 cm long (priced at about $325), and a few top-quality thumbnails, clusters of 2-cm crystals, some with small chloritoid quartz crystals around the edges (to $160). The matrix is a white weathered schist with tiny quartz and epidote crystals, but one 5 x 5-cm piece consists entirely of a sharp, tabular, hexagonal prism of rich submetallic brown pyrrhotite blanketed on one basal face by bright glassy axinites to 1 cm. (Has anyone ever seen axinite on pyrrhotite from an Alpine pocket before?) The dealer, Michel Cabrol of *Merveilles de la Terre* (15 Rue de la République, 38000 Grenoble, France) said that this fresh batch of axinites had been collected in the early summer of 1988 by a friend of his, and collected, moreover (instant folklore entering here, as Cabrol admitted with a

Figure 1. **Chrysoberyl crystals, 4.3 cm, from Pancas, Espirito Santo, Brazil. Carlos Barbosa specimens.**

shrug and a smile), at the exact spot in the mountain where the original discoverer, one Albertazzo, made the first hit sometime back in the 17th century. Well, let's hope that when the search resumes next collecting season in that magic mountain (which by the way is called Rocher d'Armentier), Albertazzo's ghost will again be assisting prospectors in uncovering these beautiful classic pieces.

François Lietard of *Minerive,* a Himalayan-minerals specialist who's [redacted]ly good for a new surprise or two, was offering some gor[redacted] Pakistan, spessartines: brilliant deep red-orange trapez[redacted]on white feldspar, priced up to a rather mountainous $300 for a top thumbnail. More accessibly, he also had some thick blocky epidote crystals, singles and twins, without matrix but with a bright glassiness and rich internal green-yellow highlights, these from a newly discovered pocket in Val di Via, near Aosta, Italy. All are thumbnails ranging between $30 and $65.

Another surprise from Italy were some fine large cabinet specimens of white to colorless and transparent gypsum from the famous Niccioleta mine near Massa Marittima, Tuscany (see vol. 10, no. 5 for a full report on the minerals of this active mine). The new gypsums, mined at the end of last summer, were being offered by Nicole and Jean-Pierre Voilhes of the dealership *La Pierrerie* (Rue du Foirail, 63730 Plauzat, France). One huge piece has partially transparent to white monoclinic crystals in a flaring cluster on a matrix of drusy pyrite, the whole 30 x 35 cm. More attractive were about 10 specimens of the same style averaging about 12 cm long, priced reasonably at $40 to $80. Some of the gypsum crystals on one or two of these show minor dings, but on the whole they're in good shape, clean and excellent examples of the species.

The same dealership also had a few cabinet specimens, to 6 x 12 cm and $250, of a new variation on Romanian stibnite. The pieces consist of typical jackstraw clusters of steel-gray crystals coated selectively on one side only of all the crystals in a given group, with thick druses of tiny reddish quartz and colorless barite microcrystals. The coatings create a very pretty, sparkly "fringing" effect, as if Tinkerbell had flown straight through the pocket, leaving quartz/barite fairydust in her path but missing the shadowed sides of the stibnite prisms.

Fredric Escaut, whom I mentioned previously as having introduced the Peruvian rhodonites at Ste.-Marie this past summer, was back again with more fine Peruvian and Chinese things. The larger specimens included tetrahedrite in flashing large platy clusters to 10 cm across from Casapalca, Peru, and large, equally bright Chinese stibnites. But as for "what's new," well, he had also some mirror-faced tetrahedrite crystals in thumbnail singles and groups, and excellent thumbnail bournonites with good, sharp, gray cogwheels on sparkling drusy pyrite matrixes (looking much like the elusive examples from Trepča, Yugoslavia). These are from a new source, the Puca Raju mine, in which Peruvian province or near which town Escaut did not know.

At the Smithsonian Institution I've had the pleasure of seeing what former curator Paul Desautels himself affirmed were the finest chrysoberyls in the world: three huge examples of the sixling-twinned, gorgeously gemmy, oldtime yellow-green beasts from Minas Gerais (see cover photo on vol. 14, no. 4). But at Lyon the private collector Roger Titeux was displaying a recently mined, mammoth Brazilian chrysoberyl of entirely different style, now in his personal collection—i.e., not for sale. This piece may rival the Smithsonian's for world's best. It is a flat, perfectly developed fishtail twin, a floater 22 cm long, 18 cm across the twin wings at their widest point, and 2.5 cm thick. The color is a dark honey-brown or molasses-brown tending towards golden, and gemmy at the wingtips though the main mass is simply an opaque glassy brown. With a couple of others not quite as large, though still spectacular enough, this great piece was found in a prospect near Pancas, Espirito Santo, Brazil. And of course the word is that the pocket was entirely cleaned out, so that there are no more where these came from. Actually, both here and at Munich I did notice a small number of much smaller specimens of what's obviously the same material. Outside Titeux's hallucinatory ones, the best at Lyon were five thumbnails and a 3 x 4-cm miniature offered by Jacqueline Barbier (7 Rue Waldeck Rousseau, 38300 Bourgoin-Jallieu, France). One of these is a sixling, the others fishtails; the color is the same dark yellow-brown, with limited gemmy areas, though about half of the miniature's interior is gemmy—this one sold for $1200. I'm still looking for "my" thumbnail of Pancas chryso-

Figure 3. **Twinned chrysoberyl crystal, 18 × 22 cm, from Pancas, Espirito Santo, Brazil. Roger Titeux specimen; photo by Nelly Bariand.**

beryl—and meanwhile feeling privileged to have seen Titeux's ultimate monster (shown above).

Before saying goodbye to you and to this fall's show season I must institute (and high time too) an Errata subsection of this column. In vol. 20, no. 6, I drooled and frothed about the enormous Brazilian blue topaz on an even more enormous matrix that Helmut Brückner showed at Bad Ems last spring, reporting foolishly that the matrix was a meter (3 feet!) across. In writing to correct me, Helmut quotes a German proverb to the effect that the fish is usually bigger than the fish actually is, and specifies that the true measurements of the matrix are 30 x 40 cm, though I was right in saying that the topaz crystal itself is 11 cm high. The whole sorry misrepresentation might best be resolved, it seems, by reproducing here the picture that Helmut sent me, of Helmut himself (who, bear in mind, is *not* twelve feet tall) holding with justifiable pride this tremendous specimen.

Au revoir, then, until next time.

Thomas Moore
Karlstalstrasse 9
D-6751 Schopp
West Germany

Figure 2. **Helmut Brückner with large Brazilian topaz on matrix.**

Torino!

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For a review of the show, see Mineralogical Record,
Nov.–Dec. 1987, page 433.

What's New in Minerals?

Tucson Show 1990

The world-famous Tucson Gem and Mineral Show drew a record 35,000 people this year, surpassing last year's attendance by about 3,000. The new Tucson Convention Center, remodeled and expanded since last year, was beautiful to behold despite some start-up difficulties. A new 89,000-square-foot exhibit hall held the TGMS show (minerals, lapidary and manufacturers, and wholesale all in one room), and the AGTA (American Gem Trade Association) show occupied two other halls on the premises.

Early action in minerals focused, as usual, on the motels. Attempting to cover mineral news in Tucson during the time of the Big Show is a unique challenge for the reporter. Dealers filter in from all parts of the world over a two-week period, each opening his door at a different time, except for those at the convention center. The "window of opportunity" for seeing the very best specimens which each has to offer can be quite short . . . a few days at most, and often only a few hours or even a few minutes. After that, it may be impossible to learn much directly about the great specimens that sold quickly. Mineral buyers as well as mineral reporters know this; consequently it is not uncommon to see a small mob milling about in front of a closed motel room door, waiting to charge inside and grab for the best specimens in a sort of "feeding frenzy." The opening of the TGMS show at the convention center can be almost as hectic; dealers there are barred from pre-show selling in order to maintain the level of excitement.

The highest concentration of motel mineral dealers has traditionally been found at the Desert Inn, and to a slightly lesser extent at the Travelodge and the La Quinta. This year, many dealers were wishing they could make a change for one reason or another. To almost everyone's relief, Marty Zinn (organizer of the Holiday Inn satellite show in Denver) has stepped in and is organizing a new motel show just for mineral and fossil dealers, to be held at the Executive Inn in 1991. He began with a sort of "hit list" of what he considered to be the most popular mineral and fossil dealers at the Desert Inn, Travelodge and elsewhere, knowing that if he got them to sign up they'd pull in the customers for everyone. The response was overwhelming, and within a few days he had enough dealers to fill the 130-room facility. Watch his ads for a complete dealer list.

Now to the minerals:

Carlos Barbosa at the Desert Inn had an interesting selection of rust-brown **ernstite** [$(Mn^{+2}_{1-x}Fe^{+3}_{x})Al(PO_4)(OH)_{2-x}O_x$] pseudomorphs after eosphorite [$(Mn,Fe^{+2})Al(PO_4)(OH)_2 \cdot H_2O$] from the famous brazilianite area near Linopolis, Minas Gerais, Brazil. The specimens, mostly thumbnail-size, have sharp, well-formed crystal shapes, in groups and as singles, some on quartz matrix. One large specimen has 10 to 12-cm crystals.

Barbosa also had more of the nice **chrysoberyl** crystals from near the town of Pancas, Espirito Santo. These are loose singles mostly, with a few small V-shaped twins here and there. The crystals are gemmy, with minor internal fracturing, and are thinly zoned brown in the core and yellow throughout the rest of the crystal. They are well-formed, with bright luster and good, though slightly etched, terminations. Crystal size is typically 1 to 5 cm, but an enormous 22-cm v-twin was exhibited at the Convention Center by Roger Titeux (see photos on pages 250–251).

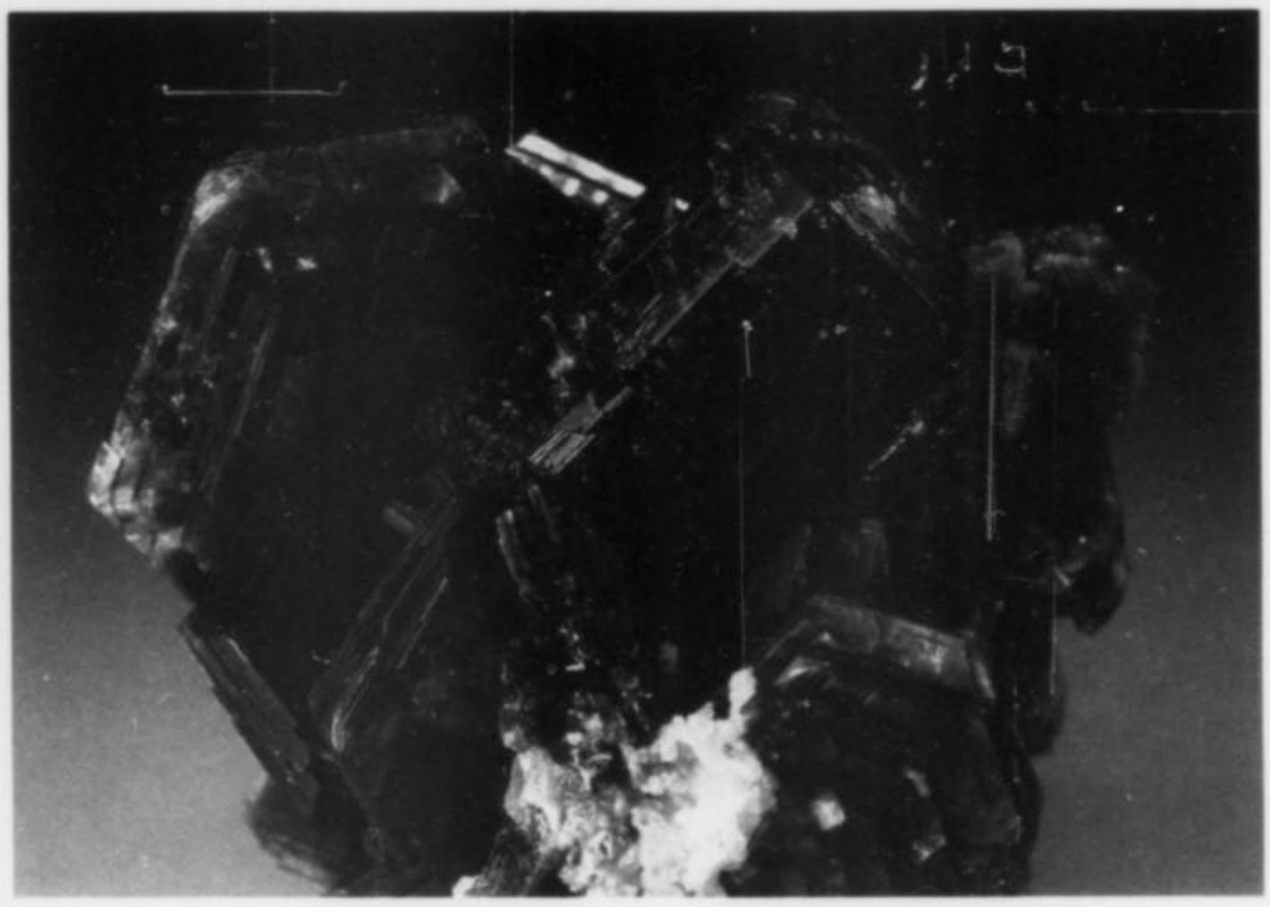
Several of the Brazilian dealers (including Luiz Menezes, Alvaro Lucio, Carlos Barbosa and Edson Endrigo) had specimens from a remarkable discovery made in August of last year at the José Pinto mine near Governador Valadares, Conselheiro Pena, Minas Gerais, Brazil. A large pocket there has yielded over one metric ton of extraordinary **muscovite*** specimens and over 100 kg of dark green **apatite** crystals and groups. The muscovite has formed as fine, large, hexagonal crystals to 5 or 6 cm, with subparallel rosette-like development on the surfaces. These occur singly and in groups up to large cabinet size, intergrown at various angles. The crystals are mostly the typical, pearly, silvery muscovite-gray but here and there the thicker and more transparent areas show a peculiar rose-brown color. The apatite crystals (found in the same pocket) are very dark green, almost black, although some crystals show a lighter colored, pale blue to yellow-green surface layer. They range in size from somewhat less than a centimeter to 5 or 6 cm, and from equant to two or three times longer (along *c*) than they are wide. The smaller crystals tend to show only the simple hexagonal prism and pinacoids, but the larger crystals are more often modified by one or two first-order hexagonal bipyramids (seen as a beveling around the edges of the *c* faces), rarely also one or two second-order bipyramids (beveling the corners of the *c* faces), and a second-order prism narrowly beveling the first-order prism edges. Luster is fairly brilliant on most crystals, especially on the *c* faces, although the prism faces can appear somewhat striated. The crystals show some transparency on thin edges but are too dark, even with strong back-lighting, to be called gemmy. The apatite occurs most commonly on white, corroded microcline crystals. A number of very large cabinet pieces of apatite on feldspar are said to have been removed and sold to Julius Petsch. Some fine small cabinet specimens of interlocking muscovite plates with intergrown, 2 to 3-cm apatite crystals were recovered as well. A very few specimens have frosty smoky quartz crystals to 8 or 9 cm. These are some of the finest muscovite specimens ever found, and will probably become "instant classics" representing the ultimate in development for the species. The associated apatites, less significant for their species because of their dark color, are nonetheless fine specimens well worth adding to any collection.

In addition to the above, Barbosa also had some micromount-size to thumbnail-size **wodginites** (lustrous black crystals to 5 mm, on matrix) from near Linopolis; **schneiderhoehnite** microcrystals from Galileia; fine **cassiterite** microcrystals from Resplendor; and lustrous, black **ferridravite** crystals of flattened habit, to 5 cm or so, from Malacacheta, Minas Gerais, Brazil.

Brad Van Scriver (12700 No. Bandanna Way, Tucson, AZ 85737) managed to resurrect an excellent old **wulfenite** discovery just in time for the show. Jack Beecroft, a former Texas rancher and part-time missionary, had been in the right place at the right time while traveling through Mexico in 1968. He was at Los Lamentos when one of the best and most distinctive pockets ever found there was discovered, and he was able to buy much of it. Miguel Romero and El Paso mineral dealer Jack Young also each got a few pieces, but Beecroft put his share into storage until this year. The wulfenite crystals are characterized by a very thick, blocky, square habit and bright orange color with a central semi-transparent zone parallel to the *c* faces. Specimens are typically very densely covered with crystals, usually with very little actual matrix underneath. Brad obtained Beecroft's entire lot, about five flats including perhaps 20 good-sized cabinet specimens from 7 to 20 cm and two flats of fine miniatures (the latter purchased for resale by Gene Schlepp of *Western Minerals*). Most crystals are 1.5 to 2 cm across and about 1 to 1.5 cm thick.

*Analysis by Peter Modreski, USGS, Denver, shows that the mineral is muscovite and not zinnwaldite as some dealers had labeled it. The muscovite identification has also been confirmed by Bart Cannon, Seattle.

Figure 1. (right) **Apatite crystal, 3 cm, with muscovite crystals from the Jose Pinto mine near Governador Valadares, Conselheira Pena, Minas Gerais, Brazil, Edson Endrigo specimen.**



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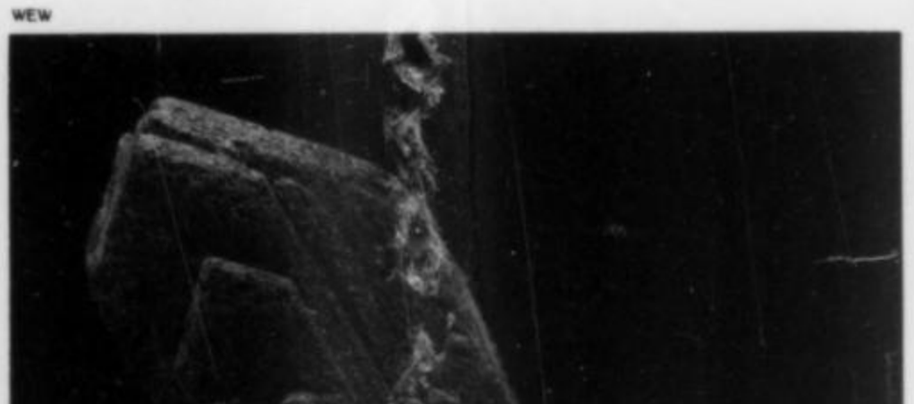

Figure 2. **Ernstite pseudomorph, 2.5 cm, from near Linopolis, Minas Gerais, Brazil. Carlos Barbosa specimen.**

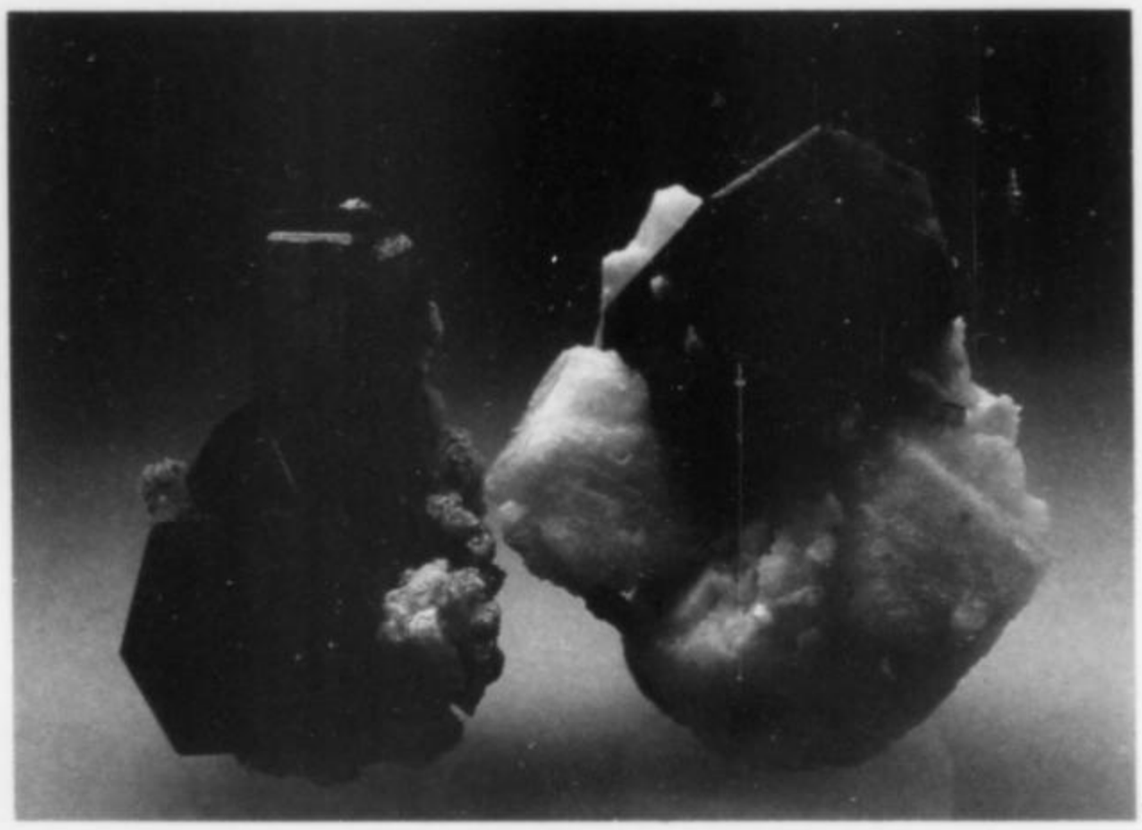

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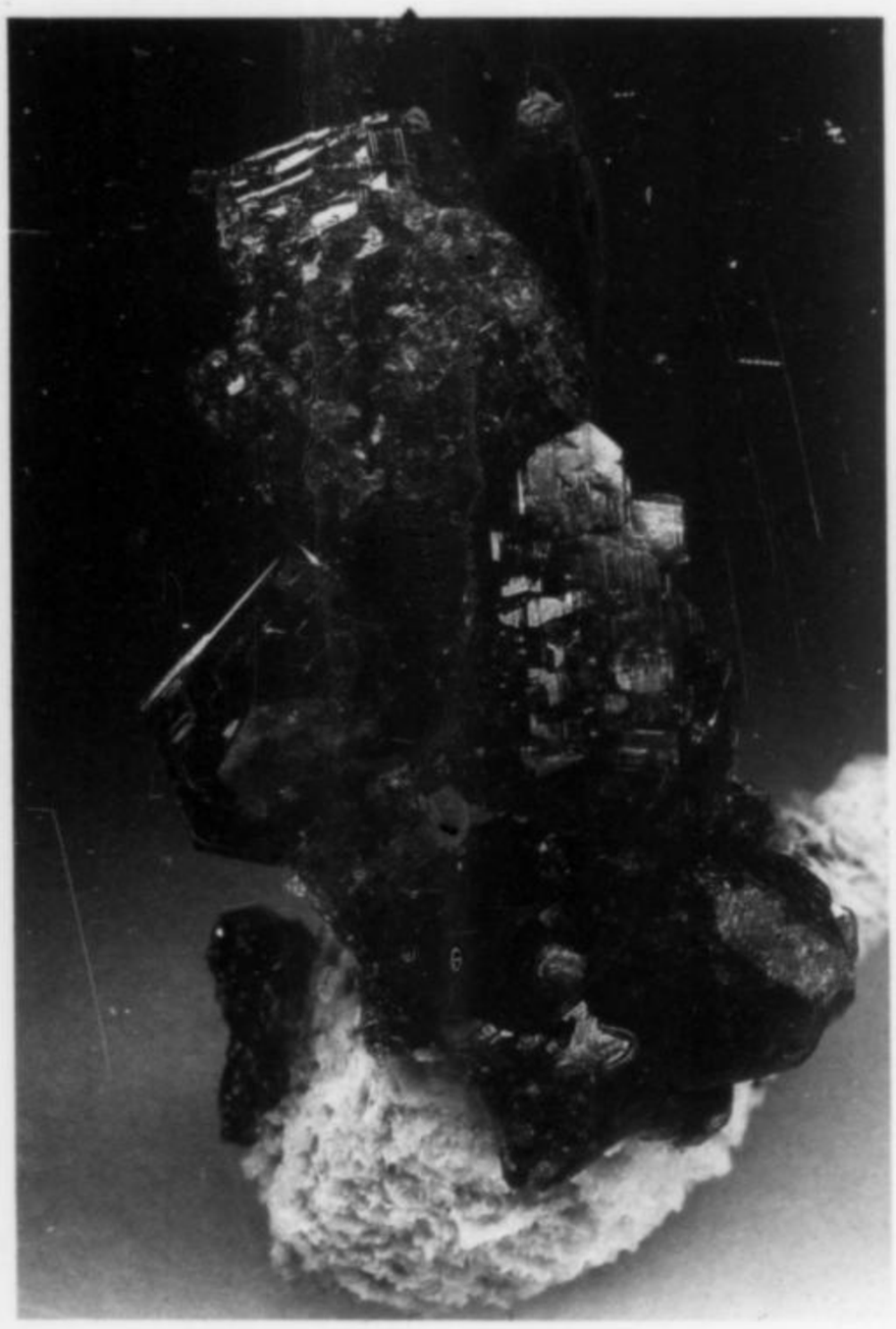
Figure 3. (left) **Reddish muscovite (backlit), 2 cm, with apatite from the Jose Pinto mine. Edson Endrigo specimen.**

Figure 4. **Apatite on white microcline from the Jose Pinto mine near Governador Valadares, Conselheira Pena, Minas Gerais, Brazil. Edson Endrigo and Carlos Barbosa specimens; now in the Tom Gressman and Tom Moore collections.**



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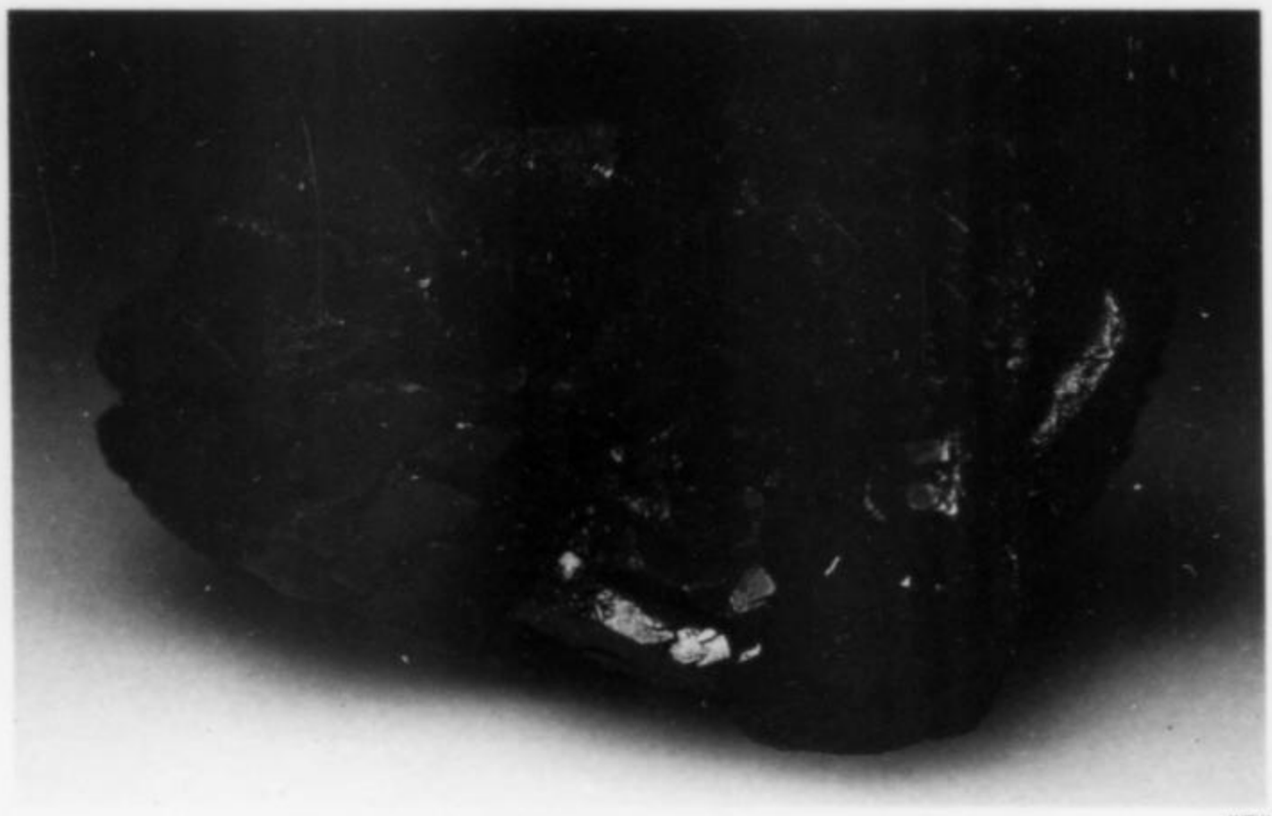

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Figure 5. **Azurite group, 6.8 cm, from Bou Beker, Morocco; Horst Burkard specimen.**

Figure 6. (right) **Apophyllite (stereopair) from the #2 quarry, Pashan Hills, Poona, India. The specimen is 7 cm tall; M. F. Makki specimen.**

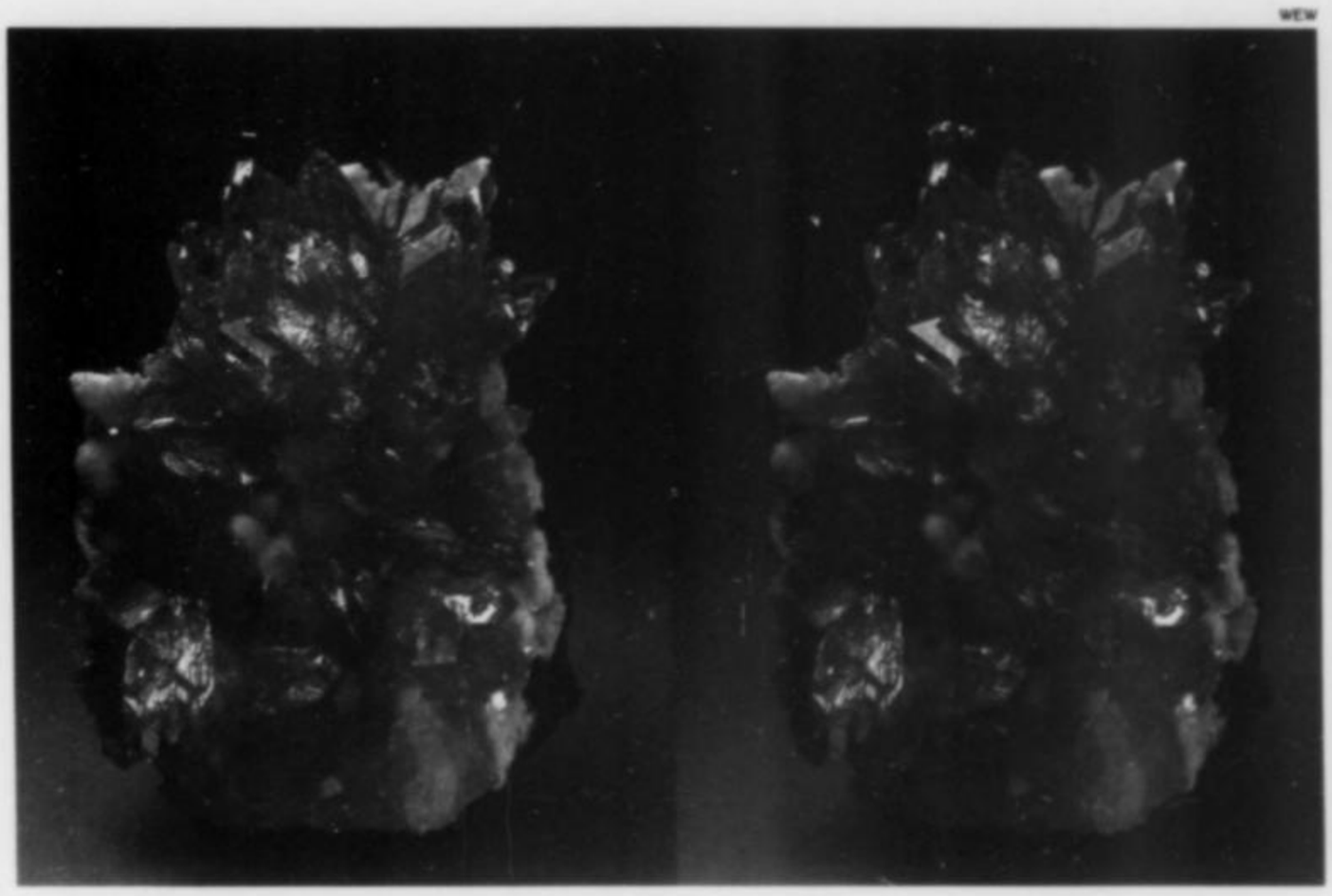


Figure 7. **Novacekite crystal, 2.4 cm, on magnesite matrix from Brumado, Bahia. Frank and Wendy Melanson specimen.**

Figure 8. **Apophyllite from the #2 quarry, Pashan Hills, Poona, India. The specimen is 15 cm across; M. F. Makki specimen.**

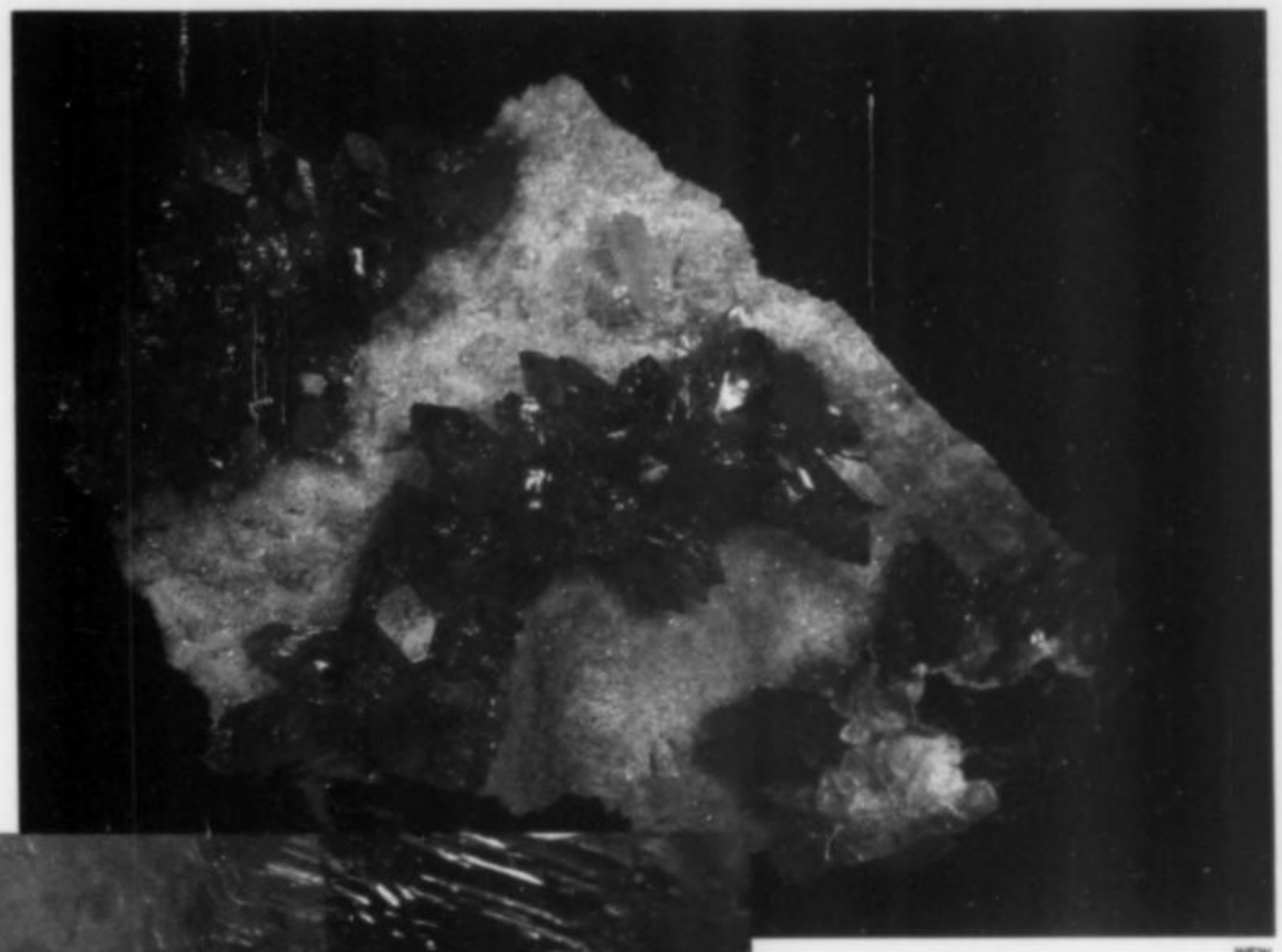


Figure 9. **Realgar crystal, 5.3 cm, with calcite from Shimen, China. Doug Parsons specimen.**

Most localities seem to have a limited ability to produce fine specimens, but one area no one thought would ever close is Poona, India. Rustam Kothavala, long-time dealer in Indian zeolites, filled his motel room this year with beautiful **green apophyllite** from Poona which may be the last of such material to come out. Poona apophyllite is generally elongated in habit, to over 6 cm, with steep, pointed terminations and with an attractive green color. Of the 12 quarries in Poona's Pashan Hills, only two have yielded green apophyllite; the so-called "#2" quarry produced 95% of all the green apophyllite, but Mujahid's quarry yielded some small, intensely colored crystals. The problem is that the quarries, operated by M. F. Makki, have been engulfed by expansion of the city of Poona. Because of their location having been included within the municipal limits, their quarrying licenses issued under the Maharashtra Minor Mineral Extraction Act were not renewed in 1986. However operations continued nonetheless. In late 1989 local residents took action to close the quarries, which they deemed a public nuisance endangering life and property (mostly because of the incessant blasting) in the surrounding residential areas. Local women even threatened to stage a *dharna* ("sit-in") at the quarries if operations there were not closed promptly. The quarry operators finally complied as of October 1, 1989. The specimens which Rusty had in his room at the Desert Inn were all from the private collection of the quarry owner, Makki. The only other locality in India for green apophyllite is near Nasik, where large, pseudocubic crystals are found.

German dealer Rüdiger Hesse (Beethovenstrasse 41, D-7920 Heidenheim) brought approximately 100 specimens of deep blue **euclase** from the Lost Hope mine, Miami Pegmatite Fields, Karoi district, Rhodesia. All blue euclase from the district came from a single pocket discovered in 1977; these particular specimens had been sent to London where they have remained in storage since that time. Most of the lot is thumbnail-size but some are small to large miniatures and cabinet pieces. Renewed operations at the mine have produced no new specimens.

Chinese minerals, particularly the gemmy **realgar** crystals, were available from a number of dealers including Doug Parsons at the Travelodge and Ken Roberts at the convention center. Persons who have seen the occurrence at Shimen, Hunan province, describe it as a 2-meter-wide vein packed with realgar, orpiment and calcite. The Chinese are mining it for use as insecticide (!). Fine, gemmy crystals to more than 5 cm, and also some particularly nice scalenohedral **calcite** twins were for sale.

This was certainly the best year for **rose quartz** since the early 1970's. The Pitorra mine in Minas Gerais, Brazil, located about 20 km (?) from the famous but mined-out Sapucaia mine (where the first great output of rose quartz crystals originated several decades ago), has been yielding hundreds if not thousands of fine specimens of crystallized rose quartz. The crystals vary from sharp and lustrous to frosty and rather malformed with odd curved faces. Thumbnails to cabinet sizes were available, some with white feldspar matrix and others showing rosette-like nucleation of rose quartz growth around sharp, gemmy, pale smoky quartz crystals. The Brazilian dealers, especially Vasconcelos (P.O. Box 112, 35100 Governador Valadares) and several American dealers including Mike Ridding and Ken Roberts were well stocked with these specimens. Shale's Minerals (9234 West Pico Blvd., Los Angeles, CA 90035) at the convention center had a few rose quartz groups from the original Sapucaia find, obtained from the widow of the famous mineral dealer Martin Ehrmann after his death in 1972. These show the bright luster and peculiar terraced faces characteristic of that occurrence.

Horst Burkard (Dornheckenstrasse 20, D-5300 Bonn 3, West Germany) had returned from Morocco just days before the show, bringing several dozen fine **azurite** groups from the abandoned Bou Beker mine near Touissit. These were all collected in late January by local residents. Large miniatures to medium-size cabinet specimens comprised the lot, varying in habit from bunches of rosette-like flat plates to blocky crystals showing bright blue faces (due to a preferential second-generation azurite overgrowth) alternating with black faces. Some specimens consist of azurite crystal groups on malachite, and others are floaters, free of matrix.

Frank and Wendy Melanson (*Hawthorneden*) had a beautiful lot of thumbnail-size, canary-yellow **novacekite** crystals on magnesite matrix from the Brumado mine, Bahia, Brazil. The crystals are sharp and well-formed, and up to 2.4 cm or so in size.

Ken Roberts (*Roberts Minerals,* P.O. Box 1267, Twain Harte, CA 95383) had an extraordinary lot of **sceptered elbaite** crystals from Barra de Salinas, Minas Gerais, Brazil. The crystals have bright green, gemmy terminations 1 or 2 cm tall (along *c*), which appear perched on narrower multi-colored posts of heavily striated tourmaline. Most of the crystals are between 7 and 10 cm long. The color zone directly under the cap is a peculiar peach color which is unfortunately Ektachrome-invisible (making that portion of the crystals appear colorless on all the slides I took), followed by shades of red, a pinkish peach, and finally green on the longest crystals. Tourmaline, because of its polar crystal structure, tends to dissolve in corrosive pocket fluids by "burning down" from one end to the other like a cigar. This is probably the mechanism which removed the outer layer, except for the scepter cap; apparently some colors or compositions of elbaite are more readily soluble in pocket fluids than others.

Larry Conklin was carrying around a superb single crystal of **amethyst** in his pocket, neglecting to reveal the locality to onlookers who assumed it was from Pennsylvania. Actually the blocky, doubly terminated, 5.3-cm crystal is from Moro Goro, Tanzania, where the amethyst is mined as gem rough. The miners there, unaware of the value of crystals as specimens, have been cobbing out the gemmiest and best-colored areas, thus destroying the crystals. Larry obtained this one intact, however, and hopes to get more.

Readers of the recent article on California **stibnite** from the Stayton district near Hollister (vol. 20, p. 427) will be interested to learn that another California locality has recently been producing specimens. The McLoughlin mine, Lake County, yields lustrous, narrow stibnite crystals 5 to 8 cm in length, in intergrown groups free of matrix. Bruce and Jo Runner had several flats of this material.

A few years ago (vol. 12, p. 389) we reported on pale green, cuboctahedral **fluorite** from the Deer Trail mine near Marysvale, Piute County, Utah. A new pocket there was mined in early January by Mike Bergmann and Bob Johansing (*MinSpec Mining*, 617 N. State Street, Suite 152, Chicago, IL 60610). Approximately 600 specimens were removed, most of them cabinet size. The fluorite crystals, generally 1–2 cm in size, occur coated by a thin layer of milky white chalcedony which must be dissolved off in hydrofluoric acid. The resulting specimens are quite attractive, although the drusy quartz matrix develops a white, powdery look.

A new pocket of La Sal, Utah, **azurite** crystals, the best ever found there, was mined recently by Bob Lane (P.O. Box 26154, Phoenix, AZ 85068), Graham Sutton, Wayne Richards and Fred Lane. The occurrence, known as the Nevada Lode, in San Juan County, has produced specimens before (see vol. 12, p. 387). The typical habit is small crystals grouped in spheroidal bunches, commonly perched on malachite. Generally the luster has not been very good in the past, but some specimens from the recent find are brilliant and sharp. About 400 flats of specimens were recovered, half of good grade or better. Les Presmyk (*De Natura*) marketed many of the better cabinet pieces from his booth at the convention center, but Bob Lane at the La Quinta had the best thumbnails.

Mike Haritos (*S.T.D. Mineral Co.*) had a fine, new lot of Berg Aukas **descloizite**. This Namibian locality is surely the world's best source for the species. Large sawtoothed crystals to 6 or 7 cm, having good luster and a deep translucent brown color were available from the new lot, along with a number of fine Tsumeb **cuproadamite** groups.

One of the big producers in the Eastern Bloc these days is the 19th of September mine near Madan, Bulgaria. This operating mine has been producing fine cabinet specimens of **galena** in cuboctahedrons and cubes to 5 or 6 cm, associated with sphalerite, quartz, chalcopyrite, rhodochrosite and calcite. Ernesto Ossola (6, rue Neuve, F-30140 Anduze, France) had many pieces for sale at the convention center, as did Forrest Cureton in his room at the Travelodge.

Jose Brera Gadea (San Romualdo, 26-3ª Planta, Edificio Indubuilding Astygi, 28037 Madrid, Spain) had some of the new Peruvian **bournonite** groups from Quiruvilca. These consist of well-formed, lustrous crystals to about 1–1.5 cm, packed in groups without matrix. Miniatures and small cabinet specimens were available.

Gilbert Gauthier (7 avenue Alexandre III, 78600 Maisons-Laffitte, France) had a sizeable lot of several dozen yellow, water-clear **orthoclase** crystals from the classic occurrence at Itrongay, Madagascar. His largest crystal measures about 14 cm, but most are in the 3 to 5-cm range, and are only fragments. A few reasonably complete crystals were in the lot. Perhaps the best from this find was obtained through Tom Schneider by the Los Angeles County Museum of Natural History last December at the "Red Carpet" show in Santa Monica; it is a single blocky crystal about 10 cm and having good faces.

Arizona collectors Mark Hay (2410 E. Caballero, Mesa 85203), George Godas and Dick Morris had a sales room at the Travelodge, where they were offering hundreds of self-collected Arizona specimens. The striking thing about this room was the high quality of the specimens . . . all were expertly collected and trimmed, with damage almost non-existent. Fine **wulfenite** from many mines was accompanied by a wide range of other Arizona species. Even accounting for the small number of top pieces they must have kept for their own collections, their stock far outshined that of many full-time dealers.

Dalton and Consie Prince (*Collector's Choice*) at the convention center had a number of excellent Mexican specimens, which is their specialty. Two flats of specimens recently collected at Santa Eulalia consist of **rhodochrosite** in spherical crystal aggregates to 1 cm with small, frosty **hematite** roses and frosty, colorless and transparent **fluorite** balls to 1.5 cm. They also had more of the beautiful pale blue to turquoise-blue botryoidal **hemimorphite** crusts on matrix from the Santo Niño mine, Guadalupe, Durango, collected in the late 1970's. The clean color of these is strangely pleasing, and is hard to beat for perking up the color balance of an exhibit case.

Chuck Turley (*Silver Scepter Minerals*, P.O. Box 3025, Kirkland, WA 98083) had some exceptionally fine **tetrahedrite** and **pyrite** specimens from the Daly-Judge mine near Park City, Utah. Two fellows (names not disclosed) collected about a dozen flats of specimens from an occurrence about 3 miles into the mountain. Razor-sharp, black tetrahedrons 1–2 cm on edge were found, as well as less sharp crystals to 4 cm, on pyrite. The pyrite crystals are extremely brilliant, with washboard faces. Bryan Lees bought most of the lot.

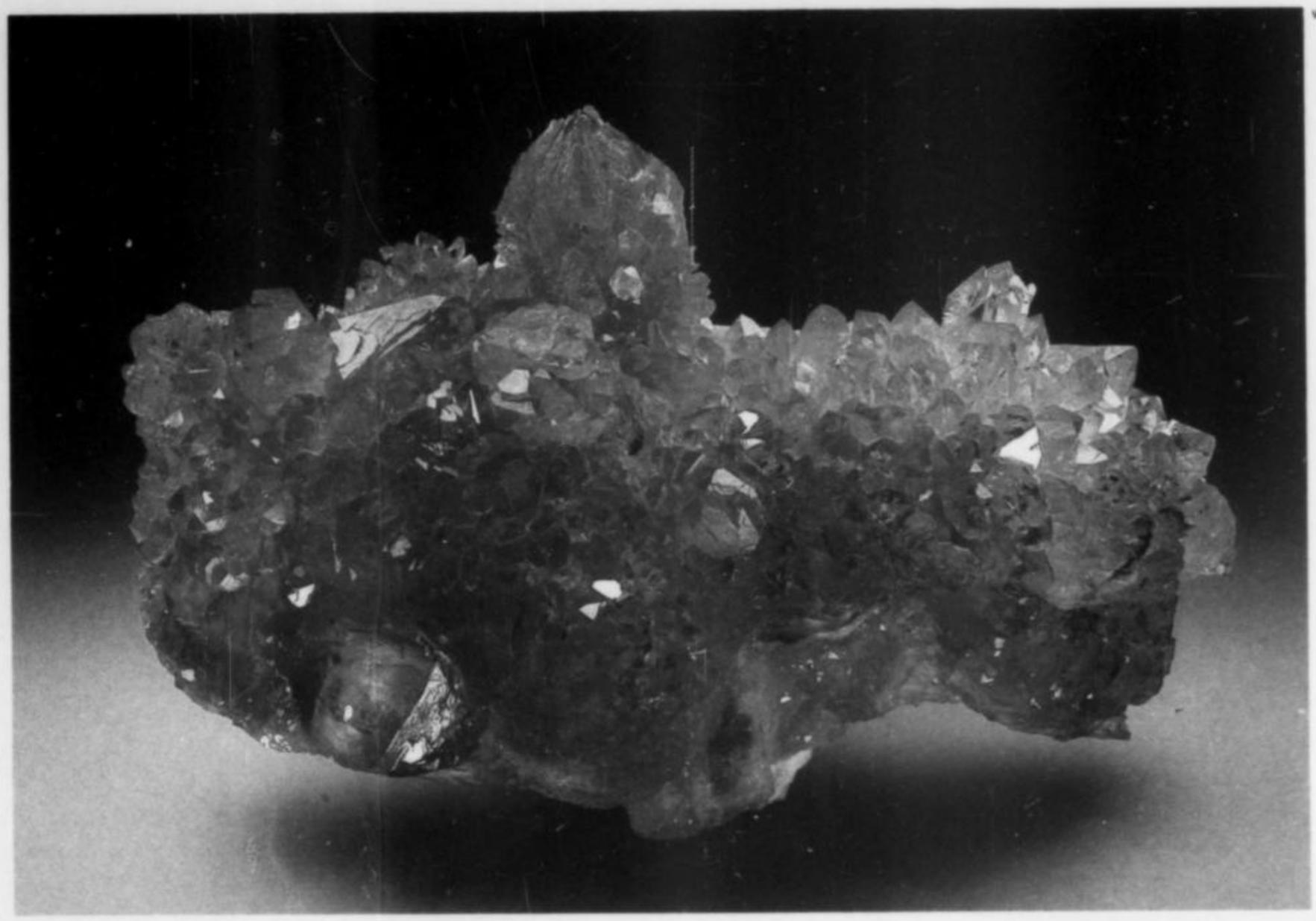
As I've said many times before, it would be nearly impossible to report on every noteworthy specimen among the million or so that are for sale at each Tucson Show. The above finds represent just the highlights. Other minerals seen and briefly noted include some new dioptase groups from Tsumeb, Namibia (*Pala Properties*); more fine Chinese cinnabars (Ken Roberts, Horst Burkard); and new azurites in large, lustrous, blocky crystals from Tsumeb (*Mineral Kingdom*).

Book collectors with some money to spend found many fine and rare titles for sale this year. Mary Murphy Hammid, in the Desert Inn, had Robert Boyle's *An Essay on the Origine and Virtues of Gems* (1672), a second edition of Tavernier's *Voyages* (1678), and the 1750 English edition of *The Mirror of Stones* by Camillus Leonardus (translated from the 1516 Latin edition, *Speculum Lapidum*). Mary was kind enough to direct me over to the Gemmological Association of Great Britain's booth at the AGTA show where Nigel Israel (*Nibris Books*, 14 Ryfold Road, Wimbledon Park, London SV19 8BZ England) had a few copies of a recent reprint of *Mirror of Stones* available for $80 a copy—roughly a tenth of the cost of an original. (Nigel has more copies and will accept mail orders at the above price.) Rick Blankenhorn of *The Gemmary* was set up at the convention center—his first time at the Tucson Show—where he offered rare books and rare scientific instruments. One of his rarest books was the 18 x 24-inch ("Atlas folio") copy of an early work on the mineralogy of Romania by A. F. C. Marsili entitled *De Mineralibus Circa Danubium Effossis* (1726). It includes 35 plates showing maps and mineral specimens. Some other highlights of Rick's stock included the 1881 facsimile reprint of *Lapidario del Rey D. Alfonso X*, a third edition (1647) of de Boodt's *Gemmarum et Lapidum Historia*, a second edition of Parker Cleaveland's *Elementary Treatise on Mineralogy* (1822), fourth, fifth and sixth editions of Dana, Haüy's *Tableau Comparatif* (1809), *Traite de Cristallographie* (1822), *Traite de Mineralogie* (1801) and three other Haüy titles, an excellent copy of *The Mineral Kingdom* by Kurr (1859), and Pryce's famous *Mineralogia Cornubiensis* [Mining in Cornwall] (1778). Herb Obodda, also at the convention center, had several rare books including the mines and minerals volume of Diderot's *Encyclopedie*.

This being officially the year for wulfenite at the TGMS show, wulfenite exhibits abounded. As usual there were the single-specimen competition cases in which anyone could enter his favorite wulfenite. There was also a very interesting case of numbered wulfenites for which showgoers were invited to guess the localities. Some were easy but others were quite difficult and, I assume, not typical of their localities. Other exhibit cases of wulfenite were displayed by Les and Paula Presmyk (labels included dealer or collector source as well as locality), Evan Jones, Bill and Roberta McCarty, Wayne and Dona Leicht, the Cleveland Museum of Natural History (including a truly exceptional San Carlos, Mexico, specimen), volunteers of the San Bernardino County [Cal.] Museum, Richard Bideaux, the Smithsonian Institution (generally specimens with thick crystals safe to ship), Miguel Romero, Harold Michel, William Moller, the University of California Santa Barbara, the Morris Museum, Ann and Nubbs McLoughlin, Garth Bricker (Red Cloud mine specimens and mining artifacts), the University of Arizona Mineral Museum and the Arizona Sonora Desert Museum. A number of wulfenites in these cases were "familiar faces" having been illustrated in the *Mineralogical Record* at one time or another in the past.

Other (non-wulfenite) items on exhibit which caught my eye were the Fersman Museum's Berezovsk gold thumbnails and Kazakhstan creedites; the Sorbonne's case of twinned crystals; Cal and Kerith Graeber's case of stalactitic minerals; Keith Proctor's ferrocolumbite crystal (about 4 cm) on matrix from Galileia, Brazil; Siber + Siber's magnificent case of Pakistan aquamarines, the finest of which has been purchased by the Smithsonian (see the cover of this issue); Bill Smith's historical case of Washington Roebling specimens including much interesting text; Alain Carion's 1720 ceremonial German miner's axe (*barte*) with engraved ivory handle; the Canadian Museum of Nature (formerly Canada's National Museum of Natural Sciences) exhibit including a superb Butte covellite in thick, hexagonal crystals; Bralorne mine (British Columbia) sponge gold specimens from Frank and Wendy Melanson and Helen and Rod Tyson; Bill and Elizabeth Moller's case of aesthetic specimens including a huge Gila County, Arizona, cuprite group with 2.5-cm octahedral crystals; and the California State Mining Museum's big Silver King mine, Arizona, silver. I especially liked the Freiberg Mining Academy's case, which included three specimens (proustite, Neudorf galena, erythrite) used as models for depiction on East German postage stamps, and also the Saxon mineralogist Johann F. A. Breithaupt's personal sealing-wax stamper made from a Ural Mountains aquamarine crystal, about 2.5 × 17 cm, the base polished flat and engraved with Breithaupt's name.

Our traditional Saturday night program began with a timely lecture by Peter Bancroft on mineralogical sights to see in Eastern Europe. Then came the awards ceremony. The third annual Carnegie Miner-

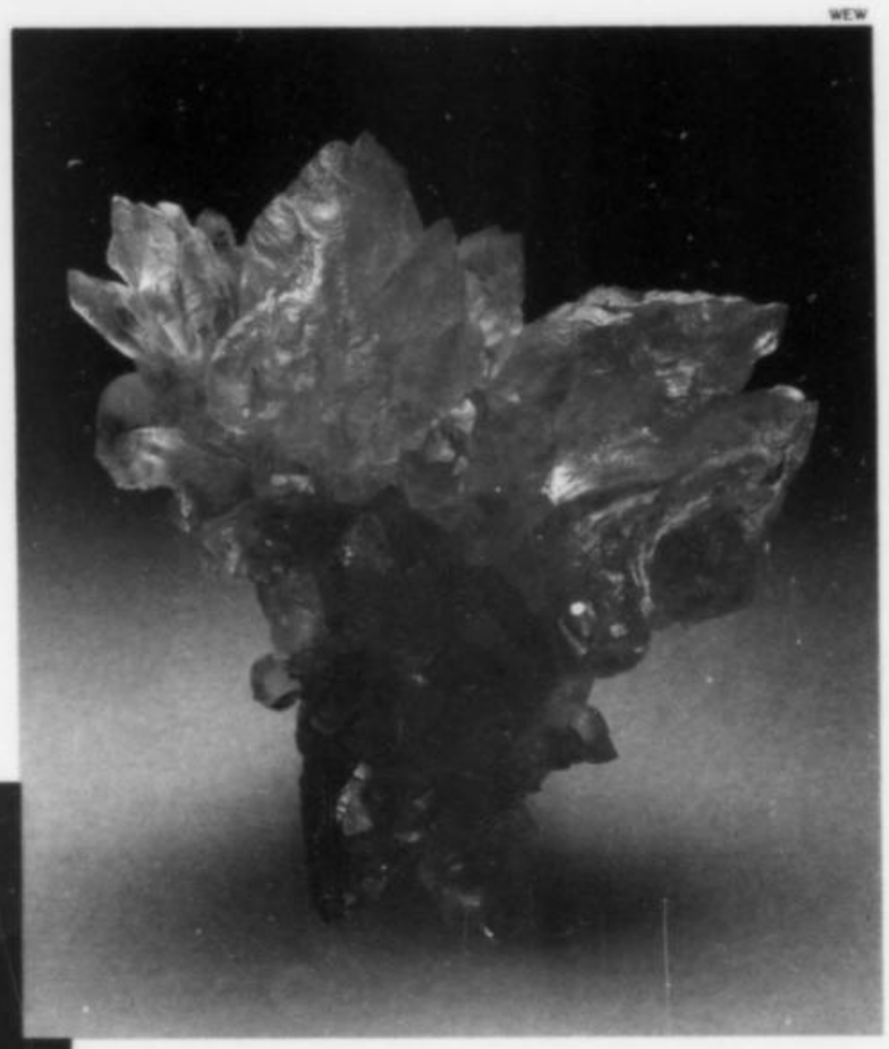


WEW

WEW

Figure 10. (above) **Rose quartz group, 14.8 cm, with pale smoky quartz crystals from the Pitorra mine, Conselheira Pena, Minas Gerais, Brazil. Mike Ridding specimen.**

Figure 11. (left) **Amethyst crystal, 5.3 cm, strongly backlit, from Moro Goro, Tanzania. Lawrence Conklin specimen.**



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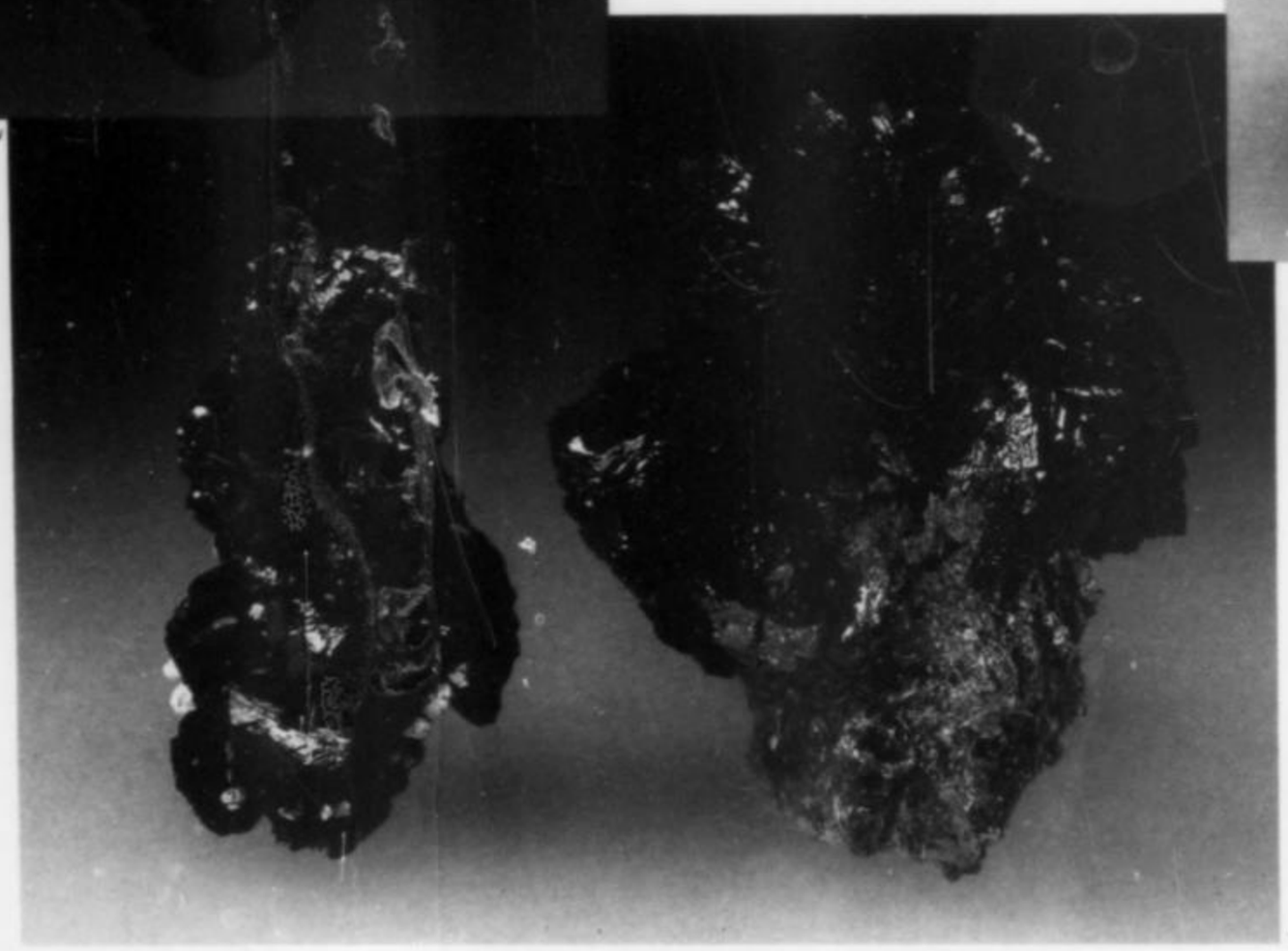

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Figure 12. **Rose quartz group, 5.7 cm, from the Pitorra mine, Conselheira Pena, Minas Gerais, Brazil. Mike Ridding specimen.**

Figure 13. **Azurites, 2.4 and 2.8 cm, from the Nevada Lode, La Sal, San Juan County, Utah. Bob Lane specimens.**

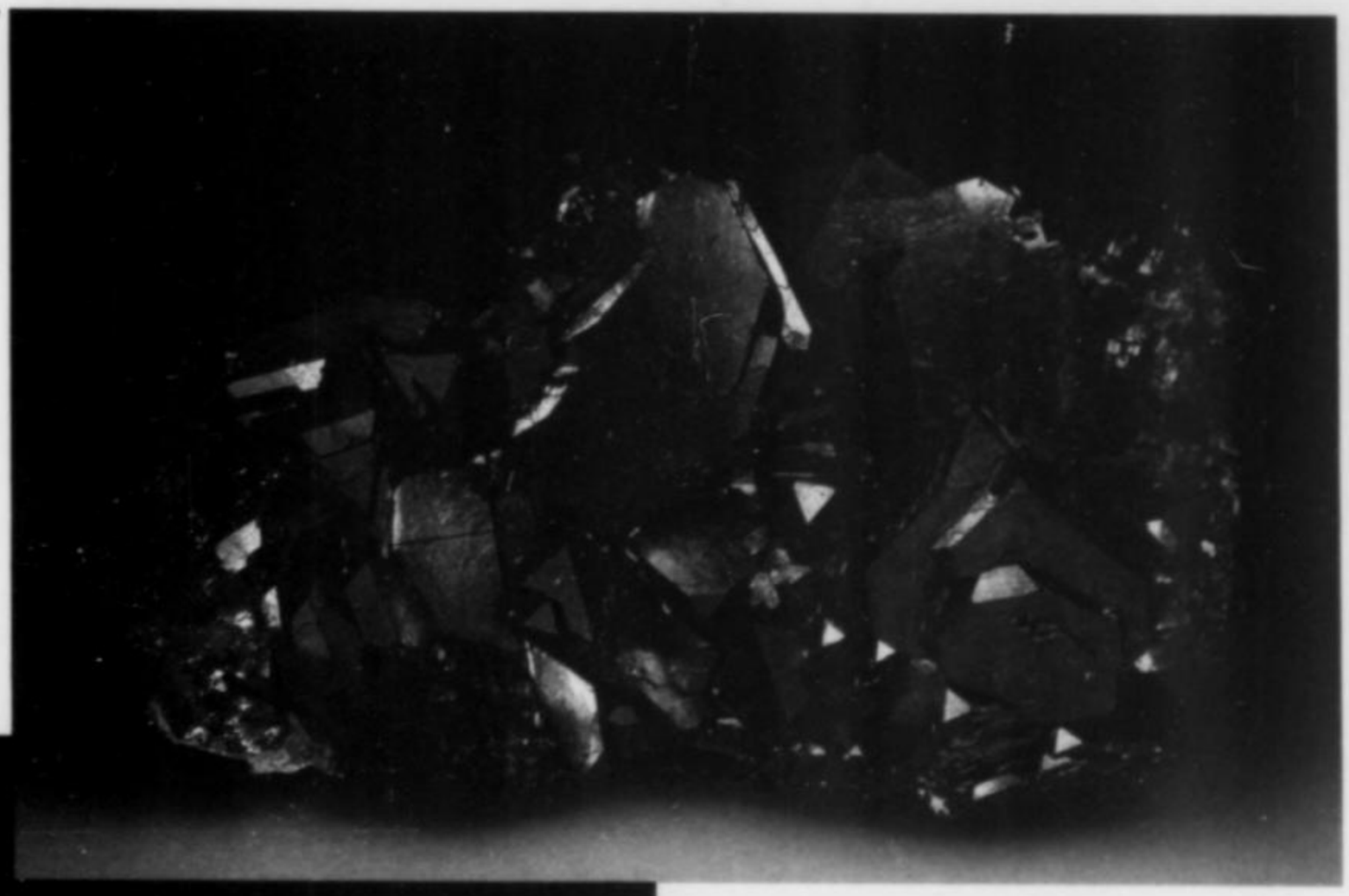
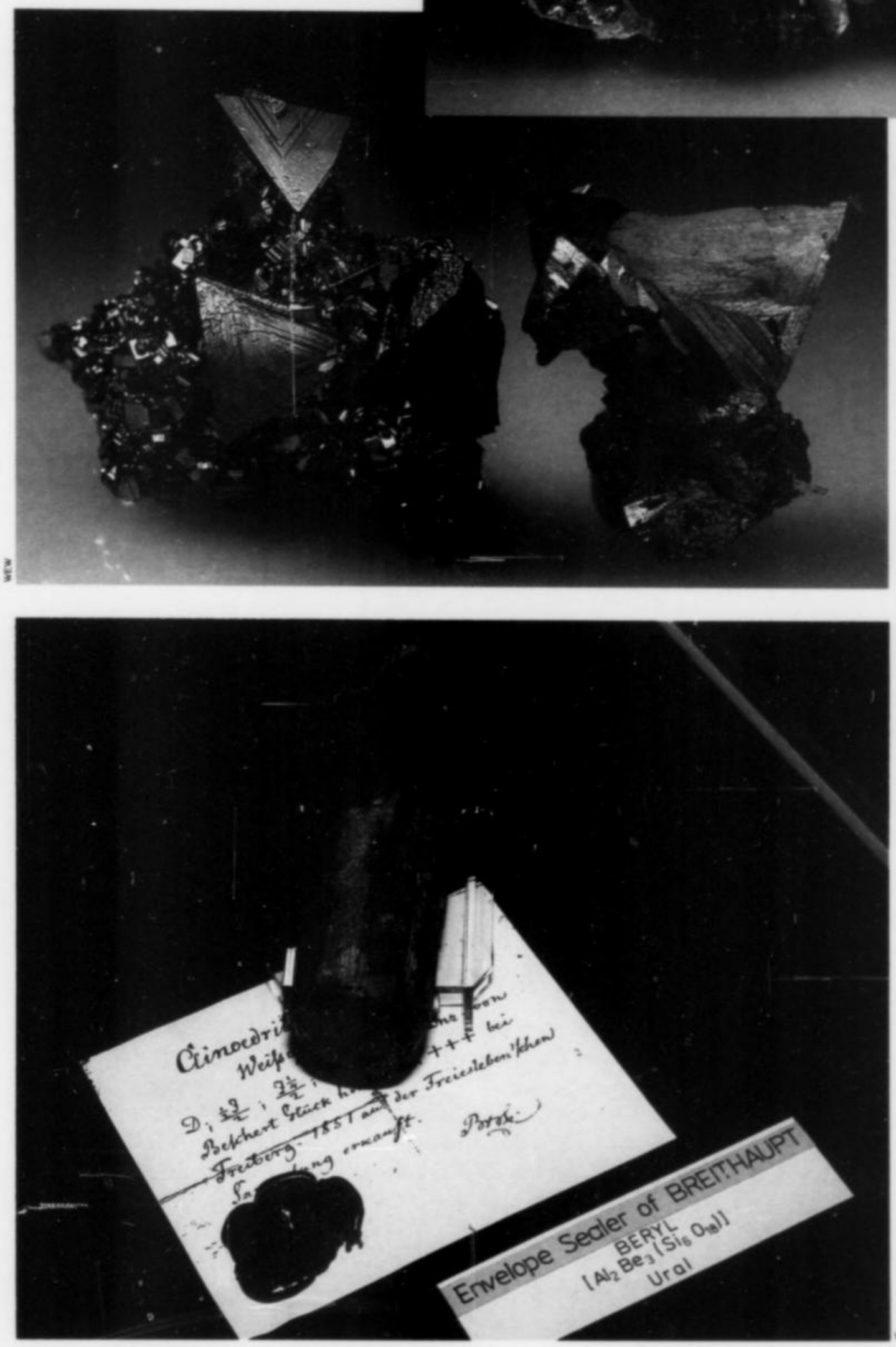


Figure 14. **Galena crystal group, 14.5 cm, from the 19th of September mine near Madan, Bulgaria. Forrest Cureton specimen.**

Figure 15. **Tetrahedrite crystals to 2 cm from the Daly-Judge mine, Park City, Utah. Chuck Turley specimens.**



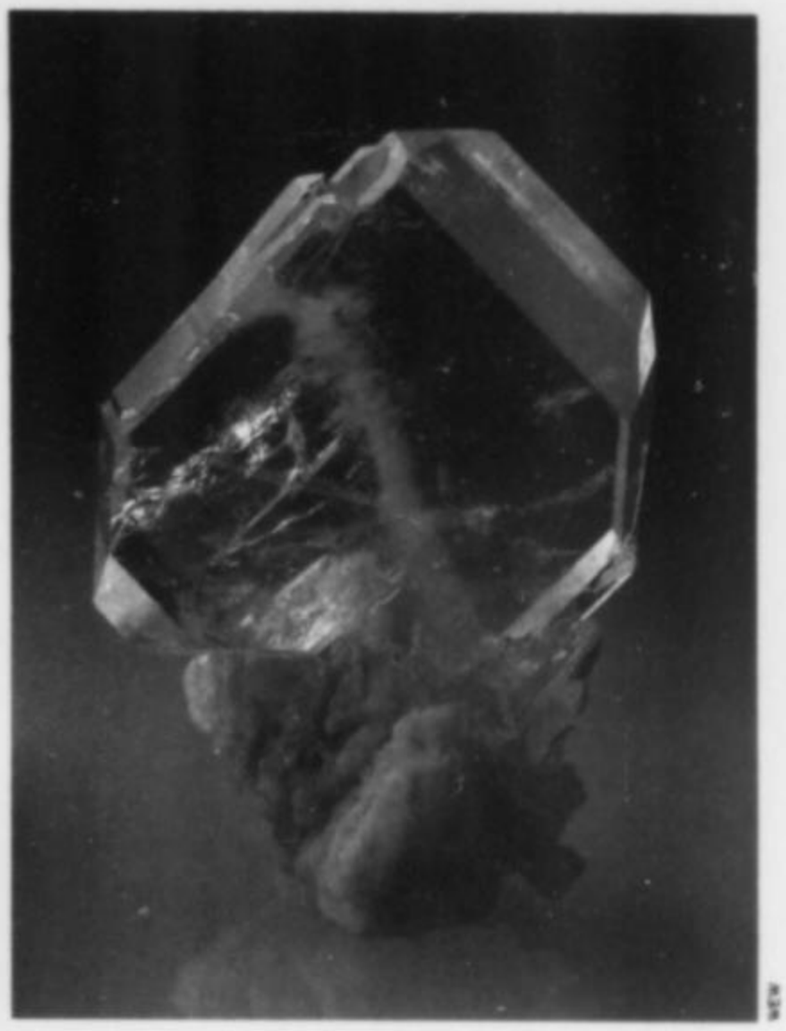


Figure 16. **Quartz crystal, 2 cm, with faden, from Mont Blanc, France. Mark Rogers specimen.**

Figure 17. **Johann Breithaupt's sealing-wax stamper, made from a Russian aquamarine crystal; collection of the Freiberg Mining Academy.**

alogical Award was presented by Carnegie collections manager Richard Souza to Frederick Pough; Fred accepted very graciously and turned the $1,500 award check over to the California State Mining and Mineral Museum in Mariposa . . . a fine gesture from one of the Grand Old Men of mineralogy. The Lidstrom award for best specimen went to Ann Meister, and the coveted McDole Trophy for "best rocks in the show" went to Steve Neely. Finally the annual Friends of Mineralogy award for best article in the *Mineralogical Record* went to Gilbert Gauthier, Armand François, M. Deliens and P. Piret for their article in the July-August issue on the uranium deposits of the Shaba (Katanga) region, Zaire.

I'd like to take this opportunity to thank the Tucson Gem and Mineral Society and Show Chairman Pat McClain for once again providing the lecture hall for our annual Saturday night fund-raising auction. Thanks to auctioneer Gary Hansen, auction manager Wendell Wilson, Sr., and our large staff of volunteers, it was a very successful event for us. The auction, operating on donated specimens since 1971, has been critical in assuring the survival and success of the *Mineralogical Record*.

W.E.W.

MINRECORDITE

One of the more difficult-to-obtain species is the Tsumeb mineral *minrecordite*, not necessarily because of its rarity but because of the instrumental analyses necessary to positively identify it. Marcianne MacDonald of *Conngems* (57 East Summer Street, Plantsville, CT 06479) reports obtaining 16 specimens collected in 1984 on Level 34 of the mine. The crystals are about 0.5 mm in size, and specimens range from 1.2 × 2.5 cm to 2.5 × 3.8 cm.

TOKYO SHOW 1989

[The following report was supplied by Dona Leicht of *Kristalle*.]

It is unusual that a first-time mineral show is the object of worldwide speculation, rumors, and enough stories to keep the tongues of the mineral collecting community wagging from year to year, but that is exactly the phenomenon created by the Tokyo International Mineral Fair in its first and second years. As a participant and observer, I'll attempt to give here a brief overview of what goes on in the Land of the Rising Sun.

The first show was held in June of 1988. It was the intriguing prospect of "new fields to conquer" that attracted several American and European dealers to attend when the invitation was put forth. We did not know what to expect, nor what collecting tastes in the Far East would be like. For most of us it turned out to be a great adventure and we found that business was good.

The second year saw over 90 dealers participating and an estimated attendance of 10,000. Attendance at the Tokyo show is hard to calculate for several reasons: there are no admission fees charged (the show is open to anyone just passing by); there are at least five or six entrances which are open at all times; and many of the attendees come down for only an hour or so during lunch break from the many surrounding office buildings.

The location of the show will surprise those accustomed to American and European shows. not a convention center, not a meeting room, nor even a conventional "building" as we think of it, but an open atrium between two high-rise buildings, it is officially known as the Shinjuku Daiichi Semei Building. One of the adjoining towers houses the show "headquarters," the Hotel Century Hyatt. A bit unusual? Of course. But remember that this is a city where, next to air, space is probably the most valuable item and the cost of any space in a more conventional setting would astound even the most casual billionaire. At any rate, it works. Temporary walls are moved in, tables spread around, floor lights attached, and *odoroku*: instant show! It is amazing to watch the metamorphism of the show space. In less than two hours after the show closing, one would never have known that anything had happened there.

The layout and location of the show allow for a diverse group of people ranging from disinterested casual passersby to serious mineral enthusiasts. Local collecting tastes are equally diverse. Dealers focus on various collecting topics such as gems, minerals, rocks and fossils, all typical to most shows; however, there is also a number of Japanese dealers devoting space to "rock appreciation." One of the most appreciated rocks is *meiseki* or "chrysanthemum stone" which enjoys a large following in Japan, particularly among the older residents. [Ed. note: "chrysanthemum stone" is a porphyry in which the phenocrysts form flower-like groups.]

Although collecting tastes run the gamut, there seems to be strong interest in large museum-size specimens featuring dramatic colors and strong, sculptural shapes. And Japanese collectors of cabinet-size and smaller specimens are always looking for minerals from classic Japanese localities. Understandably, there is a strong desire among these collectors to repatriate Japanese specimens, since virtually all specimen localities there are either closed or exhausted. This patriotic zeal can make it quite difficult to obtain top-quality Japanese specimens from Japanese dealers and collectors. Interestingly, there is a fairly good supply of Japanese species material, especially those minerals recently described.

The name Tokyo International *Mineral* Fair could be construed as somewhat misleading, considering that fossils probably command more space and attention than minerals at this show. The Japanese are avid fossil collectors. I have seen the most spectacular fossils turn up at the Tokyo show—a distinction that I used to equate in years past with the Munich show.

Displays are limited to one row of cases in which show participants are invited to exhibit one or two of their most stunning pieces. These displays are non-competitive and actually serve more as showcases for dealer merchandise than as educational or theme-oriented exhibits of the kind we are used to seeing.

What is unbelievable about this show is that only four hard-working individuals put the entire event together! My admiration goes out to Y. Suzuki of *Planey Company*, K. Jinbo of *Tokyo Science Company*, H. Hori of *Hori Mineralogy* (who handles the foreign end of planning) and J. Ohshima of *Forming Company*. Try to imagine a show such as Tucson or Munich with only four people to do the work and you can begin to appreciate exactly how devoted to this project these gentlemen are!

To more practical matters—is it expensive? Unfortunately, yes. The cost of the air-fare alone will preclude this from being on the list of shows to attend every year for most Americans and Europeans. The hotels are expensive if you're not careful, but fortunately Dr. Hori arranges with the Hyatt for a "special" rate for participants. This was about $165 per night for a large (unusual in Tokyo) room with full bath and lots of amenities. Warning, however: try not to eat in any of the hotels—the bill will set you back quite a few bucks. We found it more adventurous, fun and worthwhile to mingle out on the streets and eat along with the locals at tiny restaurants, in the train stations, or in any of the varied restaurants in local office buildings. The food is marvelous and always beautifully prepared. And yes, McDonald's is all over Tokyo in case you get a "Big Mac attack."

Public transportation is superb, as one would expect, and fairly inexpensive. Under no circumstances should an American rent a car in Tokyo! Traffic on the surface streets is probably some of the worst in the world. Narita Airport is fully two hours from town without any traffic, but allow up to 3 hours or even 4 before your flight departure for travel time (unless you take the underground train, but with lots of luggage this can be a hassle in itself).

The dates of the Tokyo International Mineral Fair for 1990 are June 1 through 5. *Sayonara!*

D.L.L.

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Letters

TSUMEB STAMPS

Our compliments to J. van Niekerk, designer of the recently issued Tsumeb stamps pictured above. These are fine examples of mineral art, perhaps inspired by certain photos in the Mineralogical Record's Tsumeb Issue (vol. 8, no. 3). Compare, for example, the cuprite stamp at left with the top two cuprite photos on page 72 of the Tsumeb Issue. Compare also the mimetite stamp with the front cover photo; compare the main crystal on the dioptase stamp with the photo on page 71; compare the azurite stamp to the photo on page 74; and compare the wulfenite stamp to the photos on page 79 (top right) and page 80 (top). To my eye, at least, there is no doubt. Ed.

PHOTO CREDITS

The pyromorphite in Figure 19 (vol. 20, no. 5, p. 380) has been in my collection for at least two years, yet its ownership is attributed to Gene Schlepp. The hematite in Figure 6 (p. 389) has been in my possession for some nine months, yet it is attributed to Don Olson/Marshall Sussman.

In the interests of accuracy, not to mention economics, shouldn't you check these matters and publish the correct [current] owner?

Edward E. David, Jr.
Bedminster, New Jersey

You raise a good point, about which many readers may be curious. It has long been our policy, at least for the editor's own photos, to cite the owner at the time the photo was taken. *There are two reasons for this: (1) The owner who loaned the specimen for photography is the person who took the risk that the specimen might suffer some kind of damage in the process (rare as that is). Consequently, that person deserves acknowledgment most. Mineral dealers especially expect the acknowledgment because of its promotional value to them . . . that may be the only reason they loaned the specimen to be photographed in the first place. (2) I and other photographers draw photos from large stock files, including slides taken over a long span of years. Hundreds of specimens are pictured in the* Mineralogical Record *each year, many of which will have passed through several hands since being photographed. We simply cannot afford the many hours and expense in detective work that would be necessary to trace ownership on* all *of these specimens up to the present day.*

This doesn't mean that we have anything against citing current owners (in addition to the original owners) when we know who they are. I am happy to do so, in the case of my own photos, and I don't dispute the benefits. But each photographer has his own policy on giving credit, and we can't make a commitment to be comprehensive. Ed.

RESEARCHER WANTED

I am preparing an article for the *Mineralogical Record* on the famous amethyst deposits at Artigas, Uruguay. Many of the amethyst specimens appear to have a peculiar form of penetration or contact twinning in which the *c*-axes are nearly but not quite parallel, and the termination is marked by a re-entrant angle. I would appreciate working with anyone who might be able to positively define this twin law. Multicolored adularescence is also observed in some of these twins. A study set of crystals can be shipped to any interested researcher, along with specimens that can be used for destructive analysis if necessary.

Jack Lowell
P.O. Box 424
Tempe, AZ 85281

NOTES ON DEIDESHEIM

Thomas Moore, the Mineralogical Record's European Correspondent, gave brief mention to the Deidesheim area, Rheinland-Pfalz, in his November-December column. But he did not go into much detail on this, one of the more interesting towns in West Germany from geological, oenological and cultural viewpoints.

I was first taken to the region over 20 years ago by a mineralogist from the Max Planck

Institut für Kernphysik in Heidelberg. It is, to my mind, one of the three outstanding wine regions of Germany, with eight of the top 25 Estates in the country. Before embarking on field trips in northern Europe now I always stop in the Deidesheim area to collect samples of Middle Haardt basalt, see the artesian well-fed public swimming pool, and see the Roman wine jugs and bottles in the Basserman-Jordan medieval wine cellars (which contains the oldest drinkable wine in Germany, in a Roman glass bottle dating to about 100 A.D.). The old town hall of Deidesheim and the church are also worth seeing.

Mineralogists, in my experience, are cultured people interested in art, history, wine and geology. The Deidesheim area has these attractions in abundance; I heartily recommend a visit.

Alvin J. Cohen
University of Pittsburgh

HOLLISTER STIBNITE

In our recent article, "Stibnites of the Stayton district, Hollister, California," an important reference to additional stibnites from the district was overlooked. Seven stibnite groups are contained in the collection of the California Academy of Sciences, located in Golden Gate Park, San Francisco. One of these groups has crystals up to 7.5 cm (3 inches) long.

Gail E. Dunning
Joseph F. Cooper, Jr.

MINERALOGICAL RECORD

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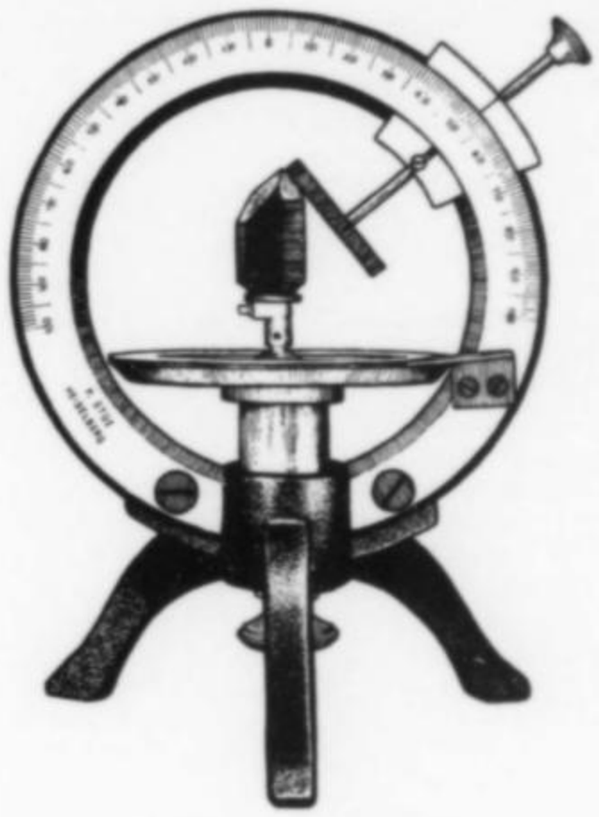

Presented here is a listing of everyone, according to our records, who donated to the auction this year, made a cash donation, donated library materials or served as a volunteer during the previous 12 months or so (except for a few people who wished to remain anonymous). If you made a donation or served as a volunteer and are *not* listed here, please write to the editor.

I know all the readers of the *Mineralogical Record* will join me in saying thanks to these generous people who help to keep our magazine going year after year. W.E.W.

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Listed below are the people who have generously contributed their time to help us out at the Tucson Show subscription table and auctions, and at other shows around the world since February 1989, including our foreign subscription agents.

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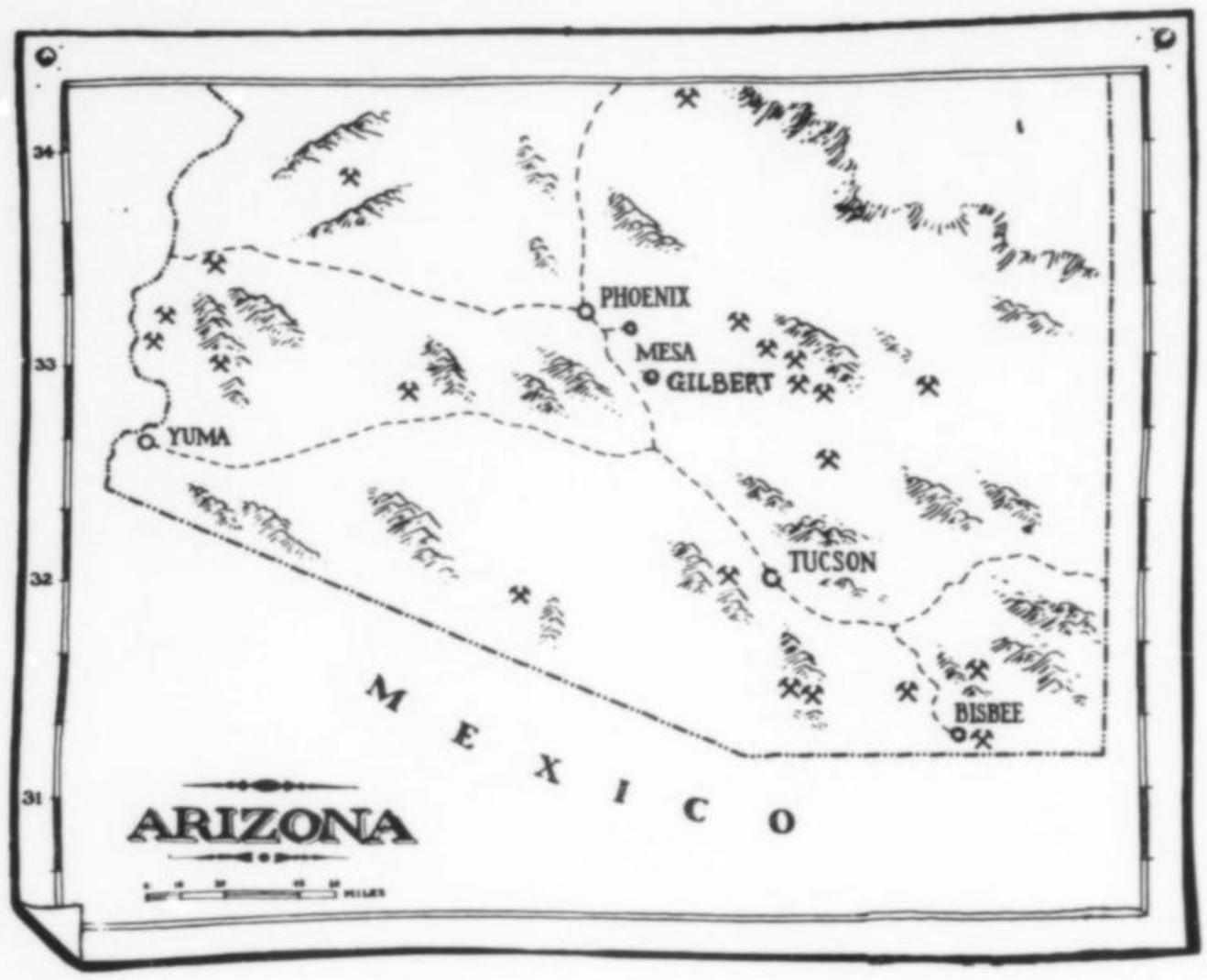

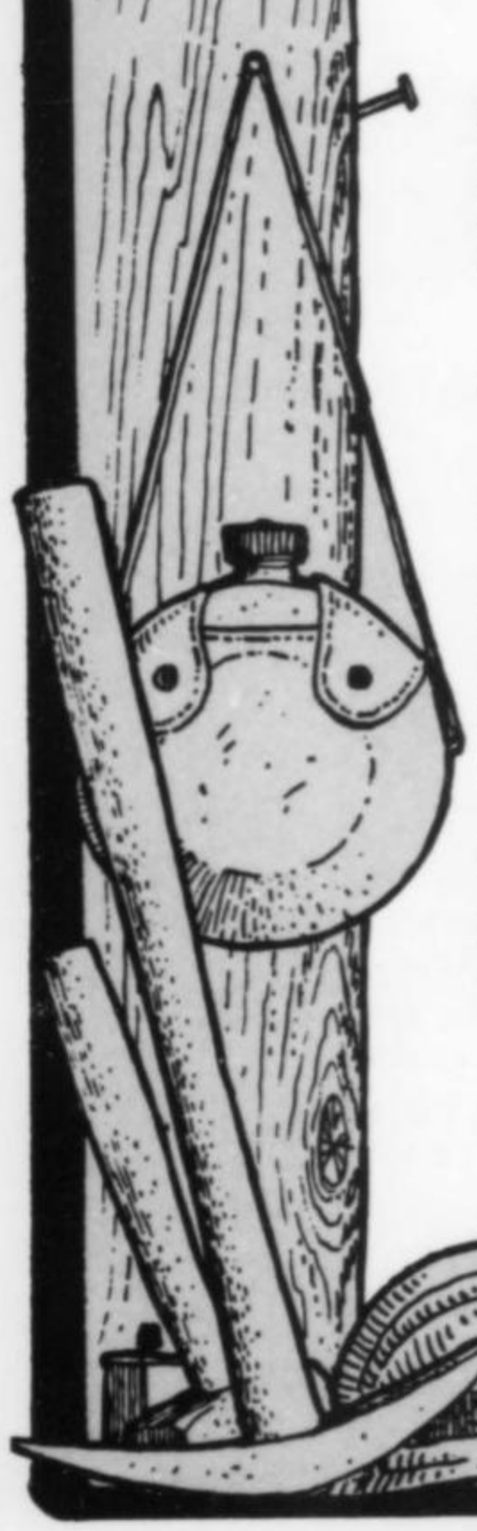

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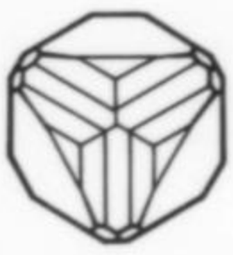

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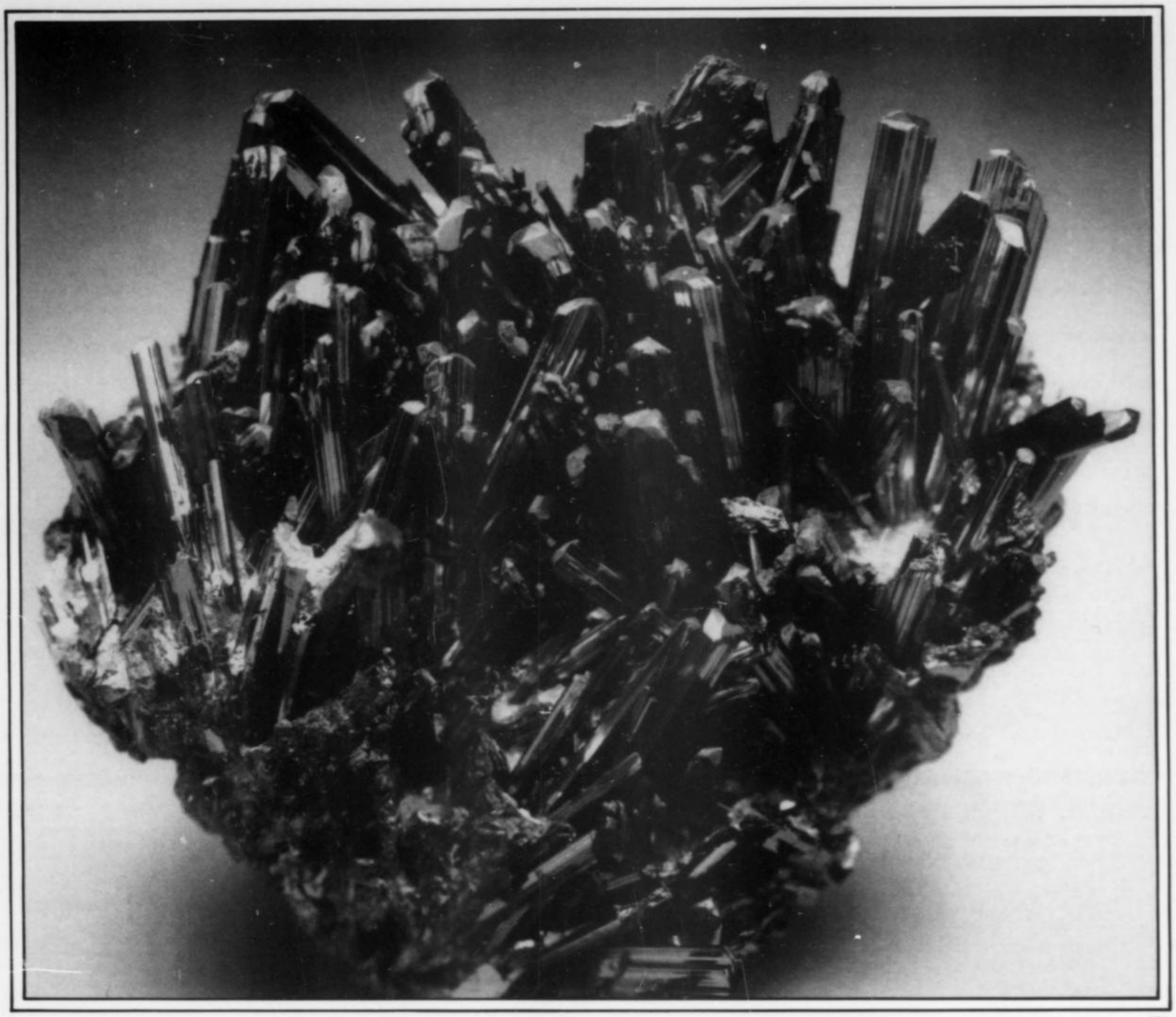

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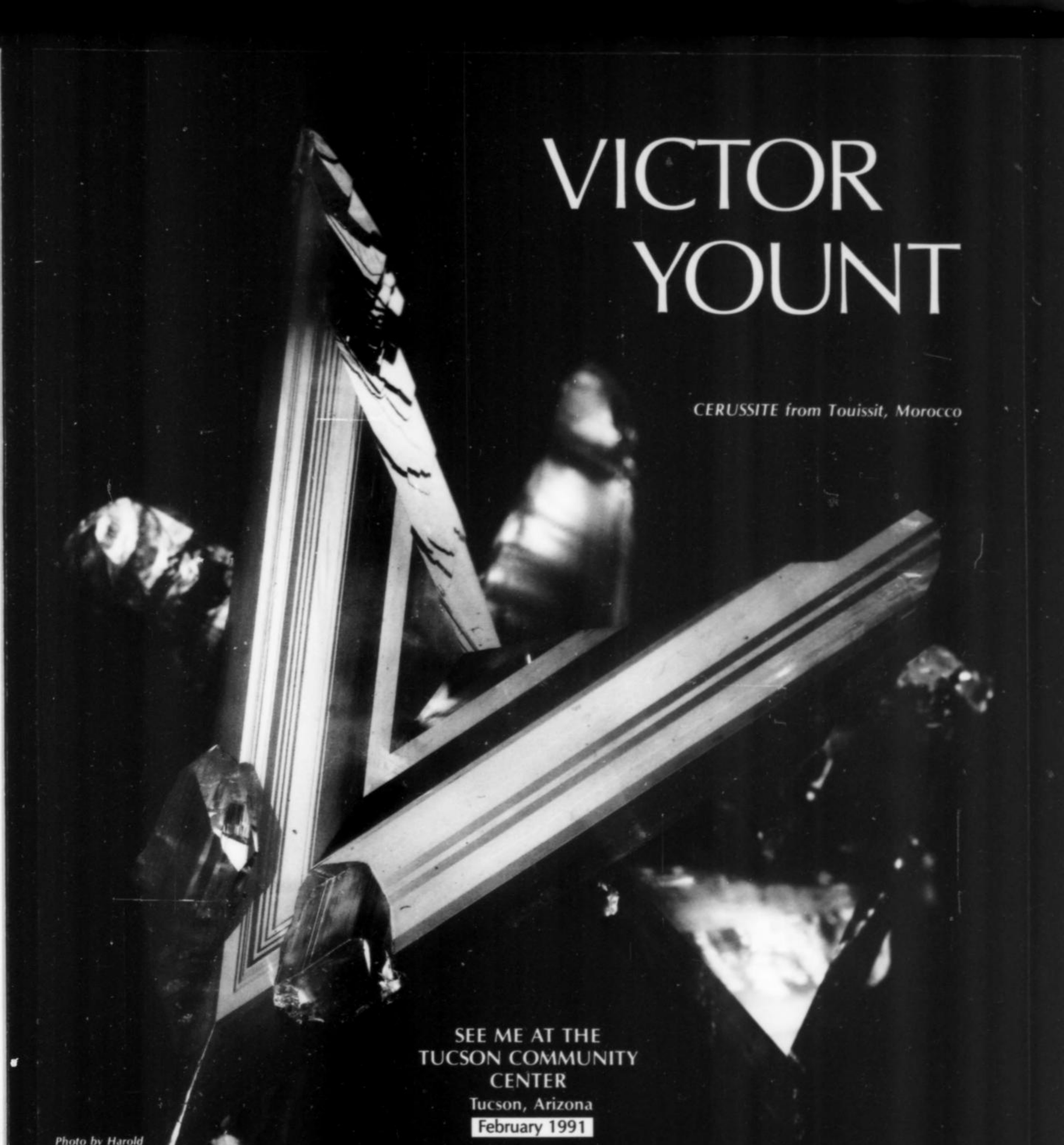

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