THE MINERALOGICAL RECORD

SEPTEMBER–OCTOBER 2008 • VOLUME 39 • NUMBER 5

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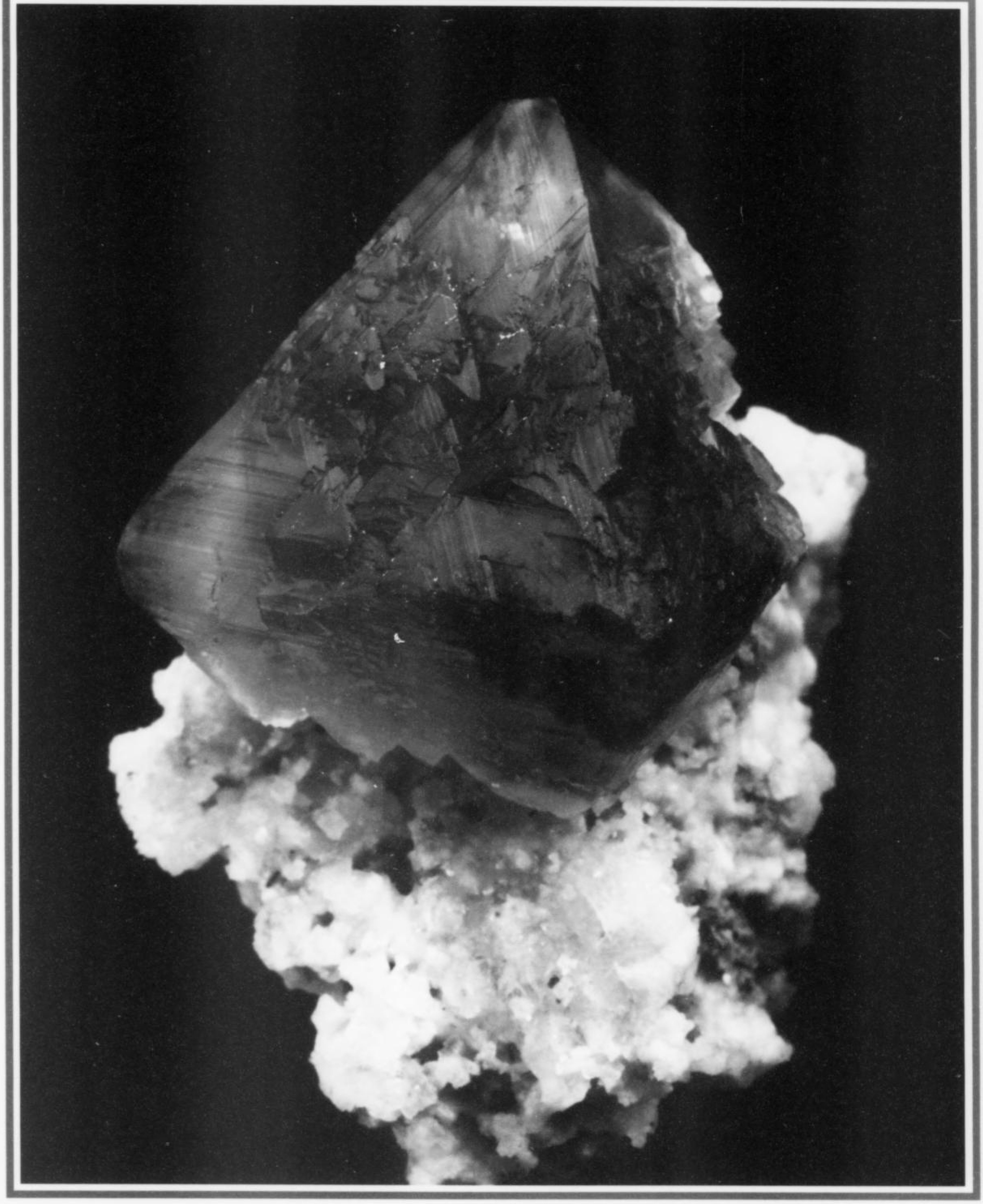

The Mineralogical Record

The International Magazine for Mineral Collectors

VOLUME 39 • NUMBER 5 SEPTEMBER–OCTOBER 2008

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Continued on page facing inside back cover

Articles

Columns

COVER:
FLUORITE, 4.6 cm, from Chamonix, Haute Savoie, Rhône Alps, France. Stonetrust specimen; Jeff Scovil photo.

THE MINERALOGICAL RECORD (ISSN 0026-4628) is published bi-monthly for $58 per year (U.S.) by Mineralogical Record, Inc., a 501c(3) non-profit organization, 7413 N. Mowry Place, Tucson, AZ 85741. Periodical postage paid at Tucson, Arizona and additional mailing offices. Postmaster: send address changes to the above address.

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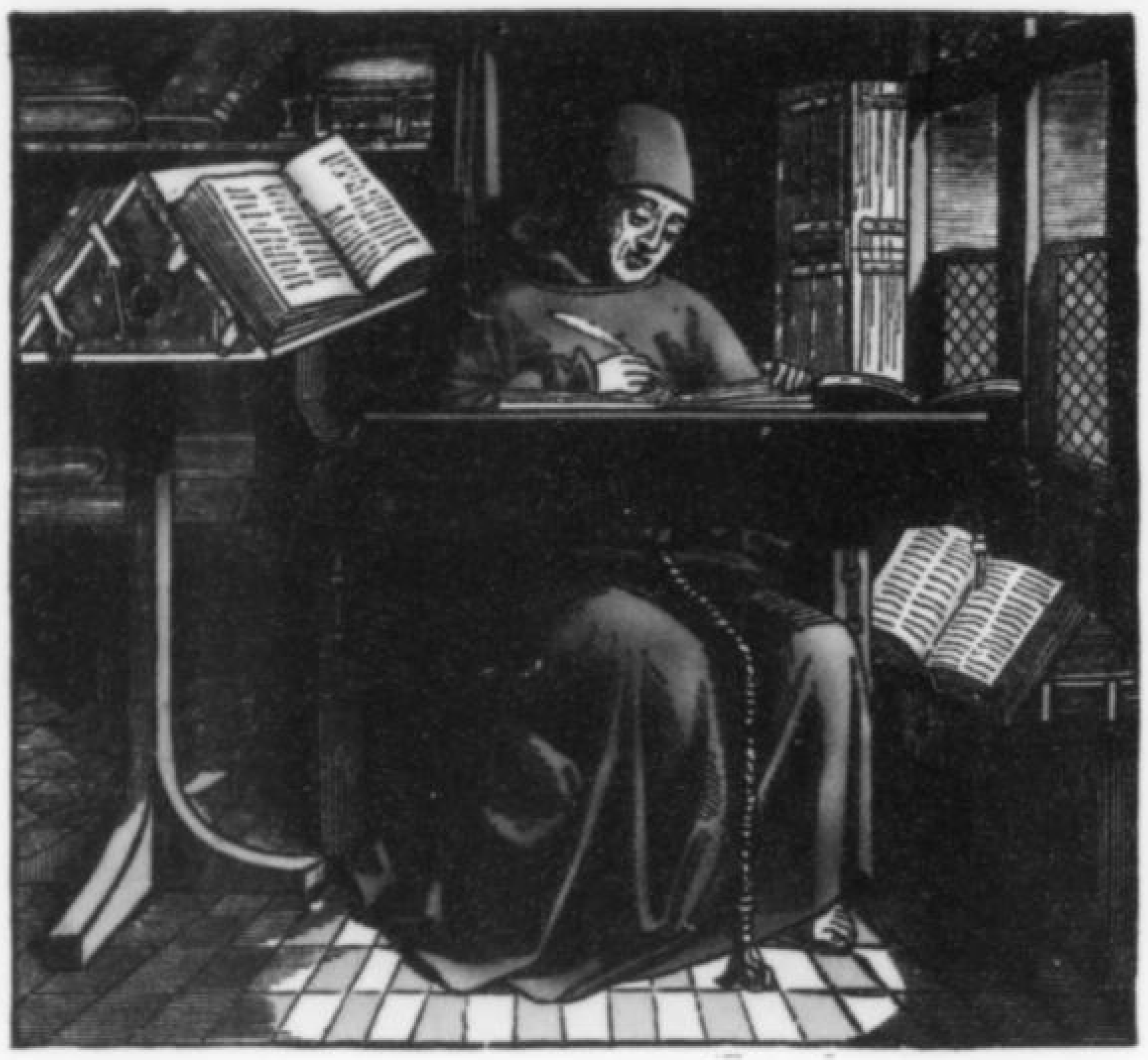


Notes from the Editors

Martian Water?

Planetologists have been debating the existence, or former existence, of water on Mars for years. Geomorphologists are thoroughly convinced that only flowing water could have produced many of the outwash features that are visible in photos taken from orbit, so the real questions are more along the lines of (a) how that water could have been sequestered in a near vacuum, (b) how it could have been released to flow across the surface before evaporating, and (c) whether there is any significant amount still remaining. With regular reports coming in these days from the *Phoenix* Mars Lander, the primary mission of which is to confirm the existence of water there, it is worth considering the experiment conducted a couple of years ago by Ronald C. Peterson—in his garage.

Prof. Peterson, a mineralogist at Queen's University, was interested to learn that the Mars Exploration Rover *Opportunity* had detected magnesium sulfate at the Martian surface, and he got to wondering what mineral phase would appear when magnesium sulfate crystallizes from a saturated solution at subzero Celsius temperatures. It so happened that his unheated garage in Kingston, Ontario provided just such an environment in early January, so he bought some epsom salts at a local drug store and mixed up a saturated solution in his garage. After a few days some crystals had indeed appeared, but they were obviously not orthorhombic epsomite ($MgSO_4 \cdot 7H_2O$). The crystals had tapered shapes closely resembling the shape of tiny voids seen in sediment photographed by the microscopic imager on *Opportunity*.

Peterson packed his sample in snow, stowed it in a cooler, and rushed it across town to his diffractometer lab where he was able to gather X-ray data on the mystery phase before it melted. The crystal structure solution showed it to be triclinic $MgSO_4 \cdot 11H_2O$ (a compound known as Fritzsche's salt, formerly thought to hold 12 waters instead of 11). This compound has a very low latent heat of fusion, and melts incongruently above 2° C to a slurry mixture of 70% (by volume) microcrystalline epsomite (containing the usual 7 water molecules) and 30% liquid water. If significant evaporite deposits of this previously unknown mineral exist on Mars, it could conceivably melt incongruently in response to slight heating episodes and could rapidly evolve large amounts of liquid water that would wash out across the surface and then evaporate.

Peterson's work is reported in *Elements* (October 2006) and in *Geology* (November 2006). While on the subject of epsomite, readers might enjoy taking a look at A. D. Fortes' 2005 article, "From Surrey to the moons of Jupiter (via Mars): The story of epsomite," posted at www.MineralogicalRecord.com in the *Axis* section.

Mineral-of-the-Month Club

We want to plug a worthy cause: The Mineral-of-the-Month Club—you've probably heard of it occasionally for years, and have perhaps dismissed it as being too entry-level, and too far below the radar of the advanced collector to be worthy of notice. But the field of mineral collecting needs a constant infusion of new young collectors if it is to remain healthy, and a gift subscription to the Mineral-of-the-Month Club can serve as a useful stimulus to the beginner.

Proprietors Cheryl and Richard Sittinger have set up a system that is ideal for budding young collectors. All Club members receive a quality mineral specimen delivered to their door each month along with a detailed write-up explaining its composition, crystal structure, collecting localities (including information about public collecting where possible), technological and decorative uses, history and lore, and other interesting information. The Silver level features small, study-size specimens, for $8/month. Most Silver-level specimens are between ½ × 1 inch and 1 × 2 inches, with a few smaller, and some larger. The Gold level specimens ($26.50/month) are larger, and are suitable for display; most are between 2 × 2 and 3 × 4 inches in size, with some smaller and some larger. Knowledgeable collectors who have seen examples agree that they are good specimens and well worth the money. Each new Club Member receives a free copy of the DK Pocket Book *Rocks and Minerals*, containing hundreds of beautiful photographs. And every month each Club member also receives an informative newsletter which highlights newsworthy events in the mineral world.

Giving mineral books as gifts to young beginning collectors is always great, but nothing quite stimulates the collecting impulse like actual specimens. We heartily recommend the Mineral-of-the-Month Club. After all, the successful encouragement of young potential mineral collectors will eventually result in new subscribers to the *Mineralogical Record*! We're all for that.

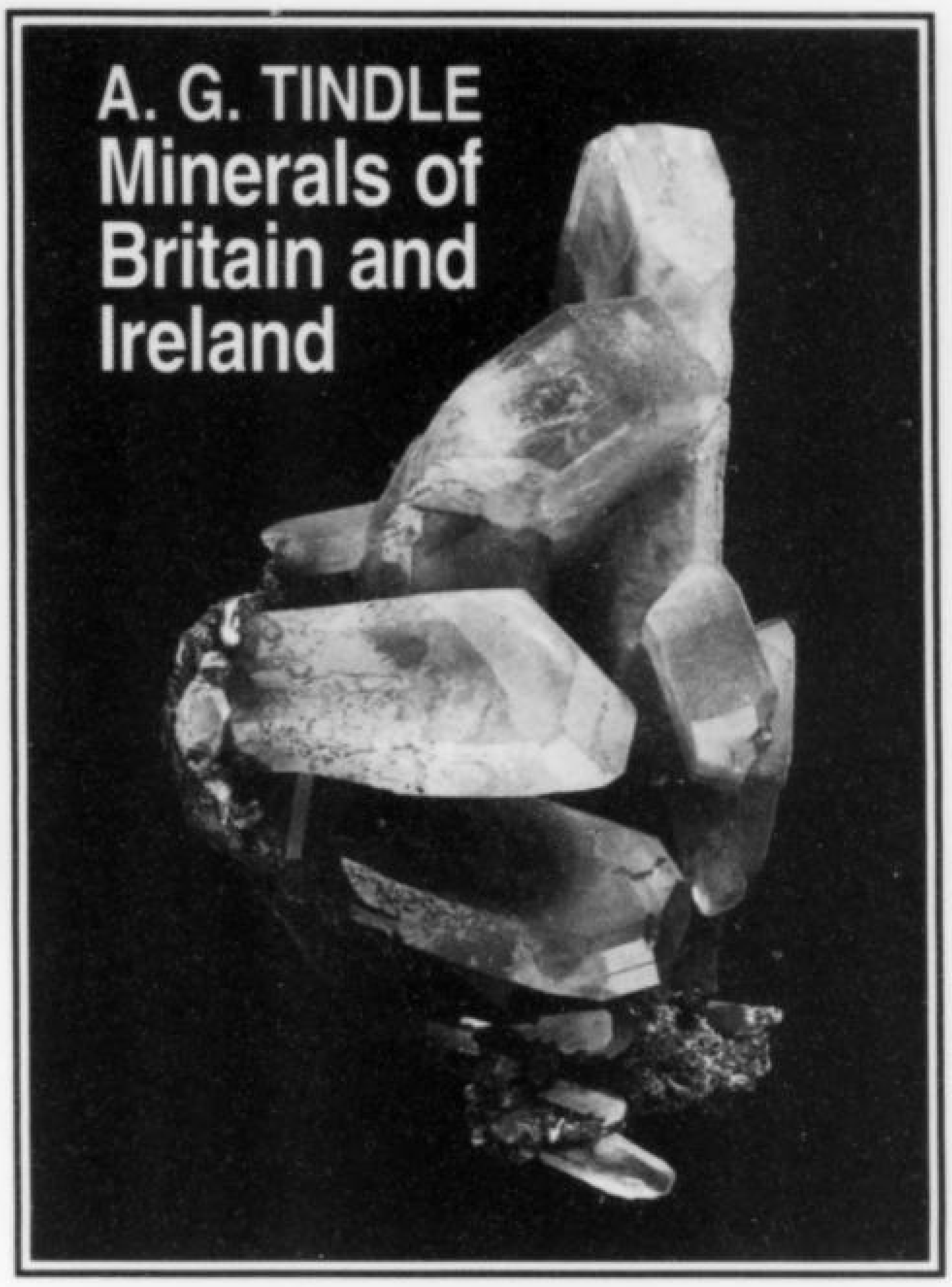
Visit their website at www.MineraloftheMonthClub.org.

K. C. Pandey Honored

Krishna Chandra "K. C." Pandey, Indian mineral dealer (Superb Minerals India), mineral collector and founder of the Gargoti mineral museum in Nasik, was presented with the "Pride of India" award by Peter Kaestner, Consul-General, Embassy of United States in India. The award, instituted by the Indo-American Friends Group, was presented at a gala ceremony held on May 30, 2008 at the India International Centre in New Delhi, before a distinguished gathering of parliamentarians, ministers, diplomats, bureaucrats, academicians, artists, business professionals and members of the media.

The award was presented in recognition of Mr. Pandey's contributions in the promotion, preservation, collection, and popularization of India's rich and varied mineral heritage throughout the world.

K. C. Pandey (right) receiving the "Pride of India" Award from Peter Kaestner, Consul-General of the American Embassy in India.



Although the international mineral community has come to appreciate this heritage, Mr. Pandey lamented that the Indian government and the general populace in India unfortunately remain largely oblivious, and consequently much work remains to be done in raising the national consciousness.

Mr. Pandey, a former Indian naval engineer, took premature retirement in order to pursue his mission of preserving and popularizing India's mineral heritage. His passion for minerals, and Indian minerals in particular, resulted in the establishment of the Gargoti museum, India's only mineral museum. This museum has one of the world's finest collections of Deccan zeolites and associated minerals, as well as minerals from worldwide localities and even from the Moon and Mars. Specimens on loan from the Gargoti museum have been exhibited at the Houston Museum of Natural Science, the Carnegie Museum of Natural History, the Smithsonian Institution and the Natural History Museum in London.

New Book!

A long-awaited new book has just been published on the minerals of Great Britain and Ireland, by Andrew Tindle, Senior Project Officer in the Department of Earth Sciences at the Open University in Milton Keynes, UK. Tindle, the author of over 90 scientific papers and two books, has compiled an exhaustive and up-to-date review of British mineral occurrences, including many discoveries that have not previously been reported in the literature. The work is meticulously referenced, including much information taken from the collector literature.

One must go back to *The Manual of the Mineralogy of Great Britain and Ireland* (1858) by Robert Philips Gregg and William Garrow Lettsom to find another comprehensive work on this subject. Since that time, over 900 more species have been found in Great Britain and Ireland; 2,200 species are listed in the book, over 1,000 of which have been analytically confirmed by the author. And unlike Gregg and Lettsom, Tindle has the advantage of being able to include over 550 illustrations, most of them in color—and many of them taken by the late Mick Cooper, whose obituary follows on the next page.

This is a monumental effort that should prove extremely useful to mineral collectors, dealers, curators and mineralogists. Early comments from reviewers in England have bordered on ecstatic: "A magnificent contribution to topographic mineralogy" (Chris Stanley, Natural History Museum); "This really is THE definitive book on British mineralogy" (Roy Starkey); "The information is of an extremely high quality throughout . . . a masterpiece on British mineralogy that is unlikely to be bettered for another 150 years" (Jolyon Ralph, Mindat).

The book is hardcover, 624 pages, 8.6 × 10.9 inches, and is priced at $190 plus shipping. Copies in North America are available from the Mineralogical Record through our online bookstore at www.MineralogicalRecord.com, and by email to the Circulation Manager at minrec@aol.com. (Wholesale copies can be ordered by legitimate book dealers via the email address.)

Died, Marvin Rausch, 77

Marvin Dean Rausch, well-known Massachusetts mineral collector, was born in Topeka, Kansas on June 27, 1930, the son of the late Grover H. and Ruby R. (Laing) Rausch. Marv earned his BS and PhD degrees from the University of Kansas, receiving his doctorate in organic chemistry in 1955. He then served in the Air Force as a Projects Officer at Wright-Patterson Air Force Base in Ohio from 1955 until 1957. This was a period of active Air Force interest in organosilicon and organometallic chemistry. He remained in the Air Force reserves until his discharge as a Captain in 1967.

Marv traveled to Munich, Germany in 1957 as the second postdoctoral associate of the Nobel Prize-winning chemist Prof. E. O. Fischer. Upon his return from Germany he joined the Central Research Department of the Monsanto Chemical Corporation. In September of 1963 he joined the faculty of the University of Massachusetts in Amherst and became Full Professor in 1968, retiring as Professor Emeritus in 2001. He remained active in the field of organometallic chemistry throughout his career. He was one of the

Marvin Rausch (1930–2008)

first Chairmen of the Organometallic Subdivision of the American Chemical Society's Division of Inorganic Chemistry. Marv was also the Permanent International Secretary of the International Conference on Organometallic Chemistry.

Marv's favorite avocation was mineralogy and he built one of the best private mineral collections in New England, specializing in very fine cabinet-size specimens. We first met Marv many years ago when he arrived in Tucson and requested the names of some mineral dealers from Wendell Wilson. He arrived at our home and from that day forward became a good friend. An amethyst specimen from Veracruz, Mexico was the first mineral he purchased from us, which he then photographed and used as an emblem on all of the mineral labels for his collection. Soon Marv was attending many mineral shows, including those in Detroit, Tucson and Denver, and always volunteered to help us set up the glass cases in our Western Minerals show booth. His height was a big help in reaching the top tier. After show hours, Marv and other friends would join us for dinner.

Marv was impressed with the Munich Show and the wonderful material presented there, so he attended annually, and was fairly fluent in German. He accompanied us on our first trip to Munich and Czechoslovakia. He made arrangements with the curator of the National Museum in Prague for us to attend their mineral show there. It was still a communist country at that time, and it was quite an experience seeing armed Czechoslovakian and Russian soldiers on every corner.

Marv also enjoyed coming to Tucson during spring breaks. During his stay with us we spent the time visiting old mines, collecting minerals, hiking and visiting other mineral collectors. On one occasion, we took a five-mile hike to the top of Gunsight Pass in the Santa Rita Mountains. After a daily outing, Marv liked to swim in the pool and relax in the hot tub with a good glass of wine. His gentle nature and friendly conversations always made his presence a pleasure. He will be missed.

Marv died May 2, 2008 in Amherst. He is survived by his wife, Jane (Meyer) Rausch; a daughter, two grandchildren, and his first wife, Carol Kreischer of Ann Arbor, Michigan.

Gene and Jackie Schlepp

Died, Michael P. Cooper, 61

Michael Philip "Mick" Cooper was born in Nottingham, England on October 11, 1946, and died suddenly but peacefully in his sleep on the night of June 2nd-3rd, 2008, aged just 61. His loss was keenly felt by his wife Catherine Foley and by his estranged sister and family. Naturally, he will also be deeply missed by his many friends and work colleagues in Nottingham, by his band members and fans as an accomplished guitarist and by those he met in his professional world of museology, photography and mineralogy. In almost every sense (except for health) he was in his prime, having recently published a landmark book, his own *magnum opus, Robbing the Sparry Garniture; a 200-Year History of British Mineral Dealers*, with the Mineralogical Record, for whom he was also an associate editor. He had just taken on the role of Newsletter Editor for the Russell Society. Another book on the "collector, con-man and crank" John Calvert is close to publication (co-authored with Geoff Blackburn). A couple of months before his death he had attended the Rochester Mineralogical Symposium as guest speaker.

Mick's initial fascination with minerals began, as he recounted in the Preface to his latest book "on the steps of the library at Bilborough Grammar School" when a friend showed him some calcite and galena from Derbyshire. Leaving school with excellent grades he enrolled on a chemistry degree course at the University of Manchester Institute of Science and Technology. At the time, R. S. W. Braithwaite was a lecturer there and, as Jim Knight recalls, in all there was a group of five keen field mineralogists including Mick and also Terry Seward (later to become Professor of Geochemistry at ETH Zurich). For whatever reason, he failed to complete his degree. One might speculate that even at that time, maintaining a balance between his many competing interests was not easy. Mick recounts that he worked in "dyestuffs and microbiology laboratories for several years" and tested sewage farm effluent biodegradability using beef extract rather than the real stuff. In the 1970s the arts world beckoned and he worked "in a small and destitute private art gallery selling prints and pottery. This was dramatically cut short by illness" and he was fitted with a mechanical heart valve in 1976.

He recuperated back in Nottingham and "after stints as this and that (photojournalist, crossword setter, pop festival security guard, etc.), he became a collections cataloguer" in Wollaton Hall, Nottingham's natural history museum, initially cataloguing beetles. It was in 1980 while visiting a friend in Dublin that he was introduced to Catherine Foley who became his wife and the great love of his life.

In 1985 I received a letter from Mick introducing himself and requesting access to photograph some Natural History Museum (NHM) specimens for a proposed article on the minerals of the Caldbeck Fells for the *Mineralogical Record*. We got on supremely well from day one. In fact, each of us sparked the enthusiasm of the other to such an extent that soon the planned article had outgrown itself and had become, by 1987, a proposal to follow *Minerals of Cornwall and Devon* as a book in a planned series.

Our local haunt during his visits to South Kensington was the rather tired atmospheric Polish restaurant *Cafe Daquise*, but the kaszanka, golabki and Okocim led to many a stimulating discussion. *Minerals of the English Lake District: Caldbeck Fells*, to give it the full title insisted on by the Natural History Museum Publications Department, was published in 1990 to widespread acclaim, but the largish print run of 5,000 didn't sell at the required rate and NHM interest in further books in the "Minerals of . . ." series waned, which we both found frustrating as we'd talked of the possibility of a Peak District book, appropriate, we felt, for two Nottinghamians, to "square the circle." Meanwhile our commitment to producing an article for *Mineralogical Record* led to a Caldbeck Fells pyromorphite-fest in 1991. This was followed much later by an article in *Lapis* in 1997.

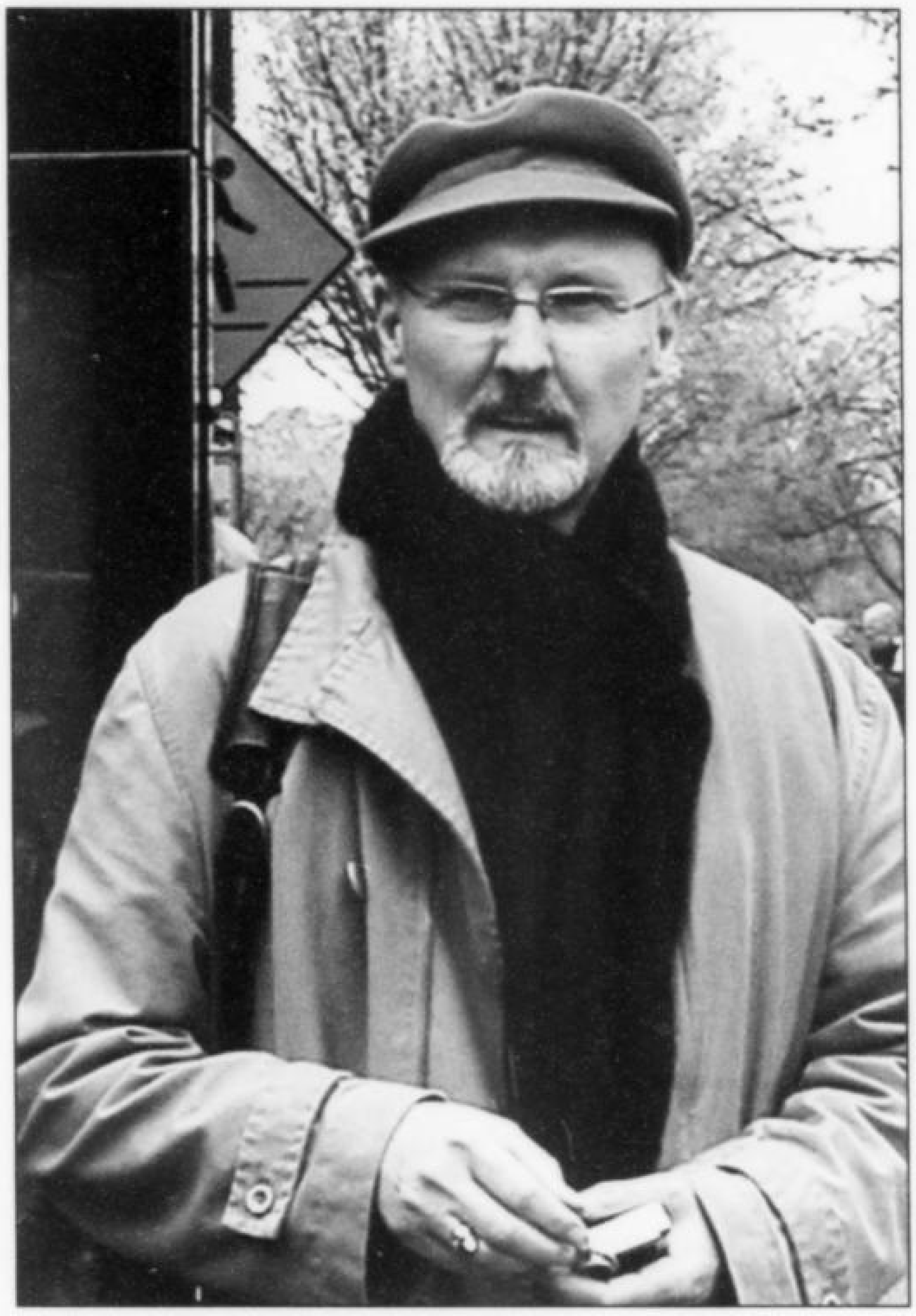


PHOTO BY JOHN S. WHITE

Michael P. Cooper (1946–2008)

By 1992 Mick had become Registrar and Information Technology Manager for the City of Nottingham Museums and Galleries, and museology was now to play an even greater role in his life since he was finally able to indulge his "multiple interests in science, history and art across the spectrum of museum disciplines." He was highly regarded for his work on the Museums Documentation Association (now known as The Collections Trust) SPECTRUM standards, and indeed one of the last occasions I saw him was at the launch of the Museums Association "Collections for the Future" report at Tate Modern, London, in 2005.

His photographic skills had been honed with his brother Peter much earlier during bird watching and mineral collecting visits to the Caldbeck Fells, but as news of his expertise as a mineral photographer spread he became increasingly in demand. From 1988 to 1994 he was an editor, designer and photographer for the *UK Journal of Mines and Minerals* and, following the success of the Caldbeck Fells book, Mick was called on to help illustrate books on the topographic mineralogy of Wales (1994), Långban (1999), and Scotland (2002). He reported and photographed the Munich and Sainte-Marie-aux-Mines mineral shows for the *Mineralogical Record* as European Correspondent between 1992 and 2000.

Mick styled himself a mineralist, and established an archive of mineral collectors' ephemera including collectors' and dealers' labels. He was fascinated by historical mineralogy, particularly the often colorful lives of mineral dealers. Articles on the Bryce Wrights, the Humphreys, Forsters and Heulands published around 2000 were the aperitif for *Robbing the Sparry Garniture.* Another excellent article he wrote and illustrated for the *Mineralogical Record* dealt with the resurrection of the Chatsworth House mineral collection over a period of more than 10 years by a team of Russell Society volunteers led by him.

It is clear from the messageboard posts on mindat.org that Mick touched people in many different ways, but there are threads running through all the posts. Depth of knowledge and passion for whatever he was involved in are recurring themes. Notably, he was the best writer that W. E.Wilson had dealt with in 32 years at *Mineralogical Record.* He was never trivial or superficial; on the contrary he was a scholarly professional, meticulous in seeking out the truth, digging not as deep as necessary but as deep as possible. His self-deprecating wit, positive cynicism and great (very British) sense of humour made it a pleasure to be in his company. Of course, he could also be a quirky, awkward character on occasion. For all his inspirational qualities this multi-talented man will indeed be deeply missed.

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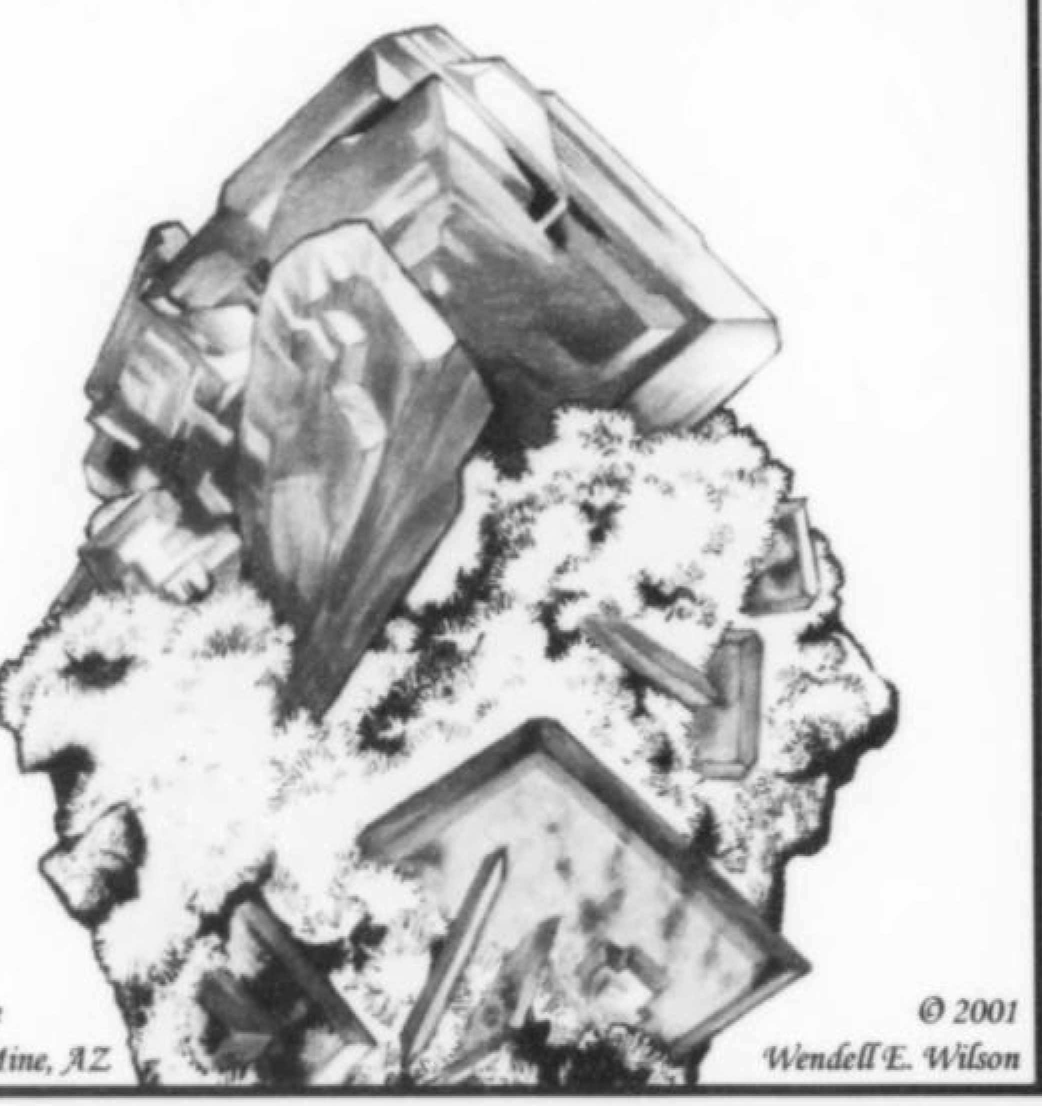
C. J. Stanley

Errata

In the first paragraph of the article in the previous issue on Herb Obodda, a fragment of type, -"fore the parade of"- was cut out of the first sentence and deposited at the end of the paragraph by the software which converts magazine text to the printer's format. (So the error was not present on proofing copies.) The first sentence should read: "Many years before the parade of competitors in the mineral business began their incursions into this wild and often forbiddingly mountainous country, Herb was making regular visits there and establishing contacts with potential suppliers of specimens."

And that's a Colt, not a Kalashnikov, in Figure 11. We apologize for the errors.



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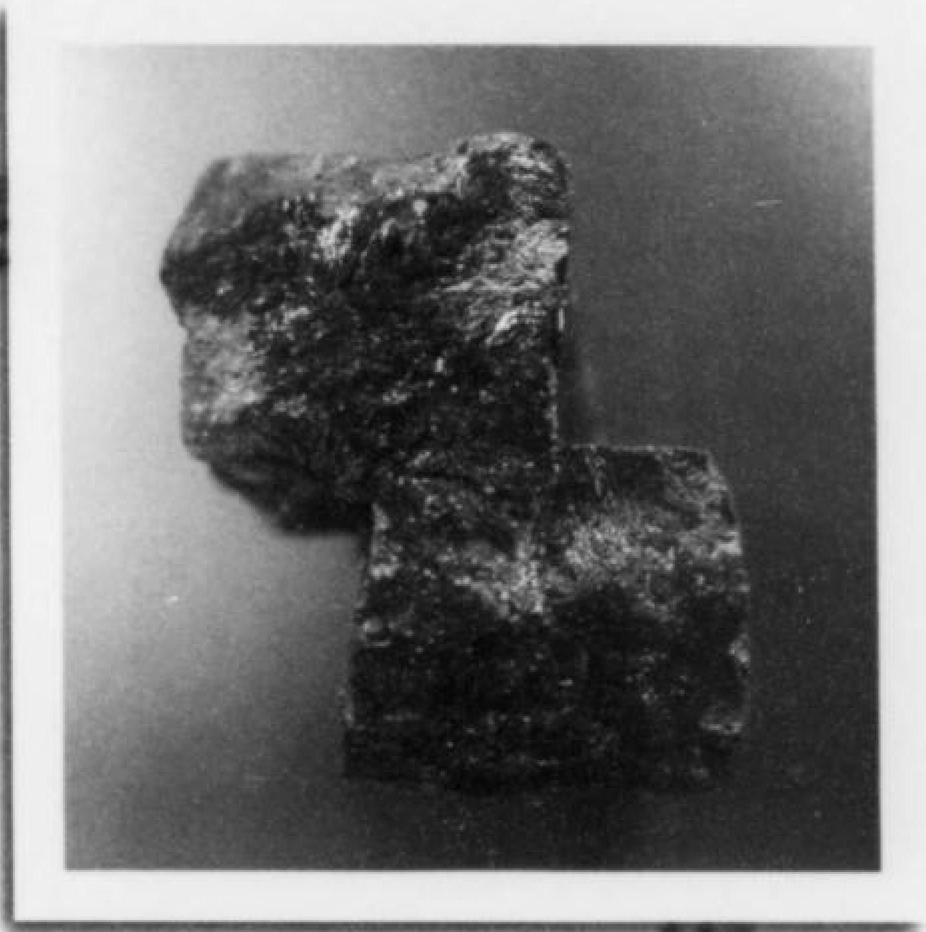

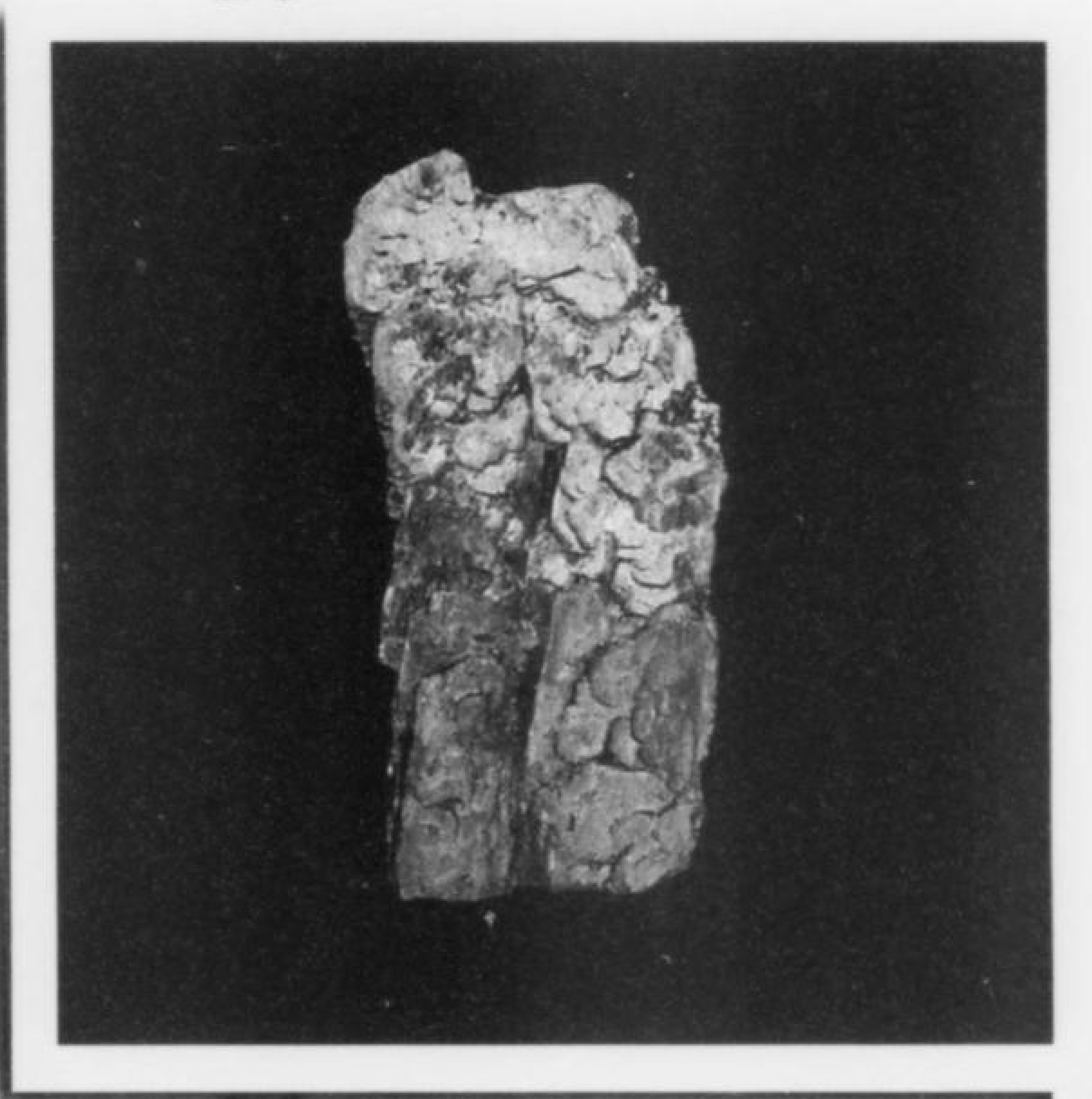

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Famous Mineral Localities:

The

Königskrone Topaz Mine

Schneckenstein, Saxony, Germany

Helmut Leithner
Kreisstrasse 12
D-90596 Schwanstetten
Germany

For over 250 years, the world-famous Schneckenstein occurrence in Saxony yielded extraordinary crystals of wine-yellow topaz. It may be considered the type locality for topaz, and was for many years the primary source of gem topaz in Europe. Schneckenstein crystals were measured and illustrated by Haüy for his ground-breaking work on crystallography published in 1801, and have been illustrated in many other works since that time. The site has a long and involved history of mining and collecting and, amazingly, is not yet exhausted.

INTRODUCTION

The mineral-rich Erzgebirge ("Ore Mountains") straddle the boundary between Germany and the Czech Republic. In the western part of the range, just north of the border, lies the famous Schneckenstein locality, known for centuries as a source of yellow gem topaz. In fact, the Schneckenstein occurrence appears to have been the primary source of yellow topaz gems in Europe until the "Imperial" topaz from Ouro Preto, Brazil began replacing it in the 1770s (see Cassedanne, 1989).

Topaz is found throughout the region, in pegmatites and in greisens in and adjacent to cupolas of a large batholith that underlies the area. This tin-topaz province is 150 km long and 60 km wide in places. Granite crops out in 20% of the area, and lies at a shallow depth under much of the other 80%. The cupolas which developed in the apices of granite plutons contained a high concentration of volatiles (which deposited the rich metalliferous veins of the region) as well as the fluorine necessary to produce topaz. More than a thousand mineralized areas are known in this district (Laznicka, 1985), yielding ores of tin, tungsten, silver, copper, iron, lead, zinc and uranium, as well as fluorite, barite and topaz at many of the localities. Pale yellow topaz is found at Sadisdorf and Niederpöbel, whereas Schneckenstein is noted for topaz of a pleasing wine-yellow color.

LOCATION

The Schneckenstein (literally "snail-stone"), a small rocky prominence or monadnock standing about 24 meters high, is located about 10 km south-southeast of Falkenstein and 30 km northeast of Bad Elster in the Vogtland region of Upper Saxony, Germany. (Leithner, 1980). It is the remnant of a volcanic plug which tapped the magma body that, upon cooling, formed the Eibenstock granite that underlies much of the area. The source of the name is unknown; perhaps the early inhabitants thought the rock looked like a snail shell. Or per-

Figure 1. **Location map showing the Schneckenstein in the German Erzgebirge, Saxony.**

haps it drew its name from the nearby village of Schoneck and was originally called the "Schoneckenstein"; the citizens there referred to their town informally as "Schnock," which could easily have been transformed over time into "Schneck" (Russ, 1989).

HISTORY

In 1723, the gemstone inspector in Schneeberg, Christian Richter, told Ignaz von Born, an Austrian mining geologist, the following story about the initial discovery of topaz at Schneckenstein. A tailor living in the village of Stützengrün had told Richter what he had heard from a man who was a charcoal maker in the forest of the Schneckenstein area. While collecting wood for his business, the charcoal maker discovered a rock with "*Zacken daran hingen die weiss, gelb, und grün aussägen*" ("jagged pieces attached to the rock, having white, yellow and green colors"). Richter went to the location to see the rock for himself; unfortunately he failed to recognize that the "jagged pieces" were, in fact, topaz crystals.

Apparently the charcoal maker also told others about the find. In 1727, Christian Kraut, a fuller and draper from the town of Auerbach, developed the Schneckenstein location into a mine "*für Christallen-Stein und allerlei Metall und Mineralien*" ("For crystal specimens, all sorts of metals and minerals"). From that point onward the quiet times in the area were over. Kraut began mining on April 8, 1727, with the permission of von Trützschler, the property owner, but on July 2 his operations were suspended by order of the mining office. Elector August II The Strong (1670–1733) of Saxony, having become interested, purchased the property from von Trützschler and then, two months later, authorized Kraut to continue mining and selling the topaz; he called the Schneckenstein workings the Königskrone ("Kings Crown") mine. Of course, the Elector required that the best topaz crystals had to be turned over to him; crystals of lesser quality were sold to pharmacists, along with the associated quartz crystals, for 16 groschen (about 80 cents) per pound. The pharmacists, in turn, sold the crystals to buyers in Bohemia and in Venice, Italy and elsewhere for cutting. The cut gemstones then came back to Saxony as "oriental topaz," with improved value and higher prices.

In the fall of 1727, Kraut founded a labor union with people mostly from the Elector's court in Dresden. Present from the beginning was the famous art lover Count Heinrich von Brühl, who later became quite powerful as prime minister of Saxony. At about the same time that mining started at the Königskrone mine, the area was surveyed, staked out and handed over to the topaz union. Steady mining from then on was carried out using hammers and chisels, drilling and blasting, followed by hand-sorting

Figure 2. **August II "The Strong" (1670–1733), King of Poland and Elector of Saxony, who purchased the Schneckenstein property in 1727 and granted permission for others to mine topaz there, provided that they turned over to him the best gem crystals. Painting by Louis de Sylvestre (1675–1760), now in the Gemäldegalerie, Dresden.**

to recover the topaz. To make the topaz more easily visible, the rock was washed with water from a well: in the realistic engraving by Charpentier (1778), the windlass for this well is clearly visible near the miners' barracks.

In 1728, just one year after topaz mining began at Schneckenstein under the direction of Christian Kraut, Dr. Johann Adam Göritz of Regensburg, Bavaria published a report on the topaz discoveries at Schneckenstein. Johann Friedrich Henckel (1678–1744), a member of the Freiberg Mining Board, was a physician and mining inspector, and in the latter capacity he visited the topaz quarry several times between 1737 and 1739. In his 1737 reports on the mine Henckel is believed to be the first person to apply the name "topaz" to what we consider as that mineral today; up to that time "topazius" had been the name for peridot olivine.

After 1739 the labor union was unable to work the site profitably. Highgraders were a serious problem; they appeared at night and on Sundays, and the illicit collecting could not be stopped because the location was too remote.

The vice-inspector of mines in Freiberg, Johann Gottlieb Kern, visited the Schneckenstein, where he made notes and drew sketches of the outcrop, and then wrote a "Mining Report" in 1740. He expressed his concern that blasting might destroy the Schneckenstein rock. In 1744 Kern wrote (but did not publish) his *Umständliche Beschreibung des Schneckenstein, oder des sächsischen Topasfelsens* ("Detailed description of the Schneckenstein, or the topaz rock from Saxony"). This work appears to be the first publication ever devoted to a specific gemstone deposit. Kern was interested mainly in studying the topaz occurrence for clues that might lead to the discovery of other gemstone deposits. However, he never published his two papers. In 1776, following Kern's death, Ignaz Edler von Born, the prominent Austrian mining geologist, organized and edited Kern's work for publication.

Johann Gottlieb Kern
vom
Schneckenſteine
oder dem
ſächſiſchen Topasfelſen.

Zum erſtenmal herausgegeben,
und
mit Anmerkungen vermehret
von
Ignatz edlen von Born

Herrn auf Altzedlitſch, Inchau ꝛc. der kaiſ. Akademie der Naturforſcher, der Akademien der Wiſſenſchaften zu London, Stockholm, Lund, Siena, München, Burghauſen; der Ackerbaugeſellſchaft zu Padua, und der naturforſchenden Freunde zu Berlin Mitgliede.

Mit fünf Kupfertafeln.

Prag 1776.
bey Wolfgang Gerle, Buchhändler.

Figure 3. **Title page of J. G. Kern's groundbreaking description of the Schneckenstein topaz deposit, written in 1744 and published by Ignaz von Born in 1776.**

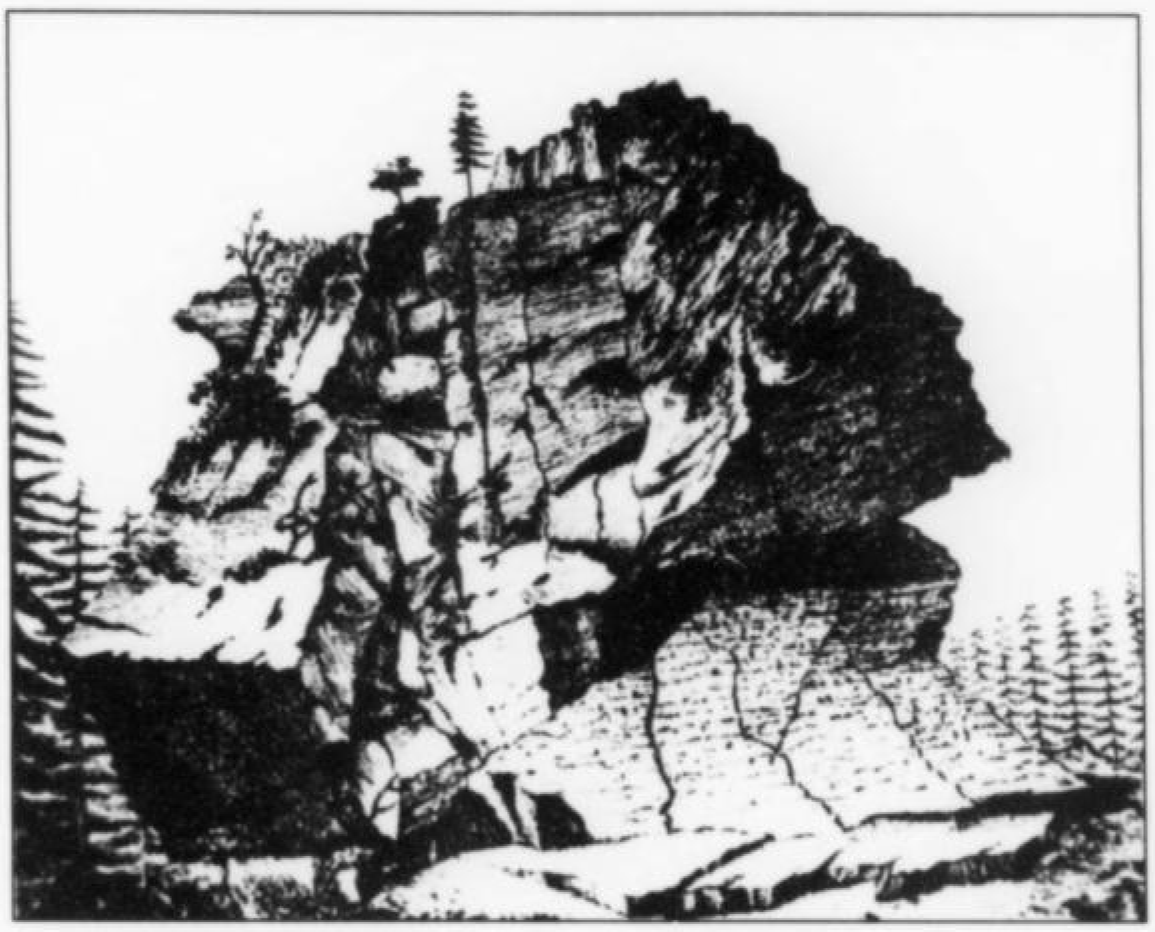

Figure 4. **A view of the Schneckenstein from the west, published by Kerns (1744) in his *Umständliche Beschreibung des Schneckensteins* ("Detailed description of the Schneckenstein").**

According to Lahl (1990), only four or five topaz crystals out of a hundred were of high enough quality to be faceted. Gemmy quartz crystals between 1 and 3 cm in size were also cut. It was reported that the production of gem topaz during the year 1738 totaled about 32 kg. The best topaz gemstones were graded into three categories called "ring stones," "shirt-button stones," and "clasp stones." The very finest of the faceted topaz gems were the most sought after, and were set in rings. Material which could only be used to frame larger gemstones in a piece of jewelry was called *carmosier*. The lowest quality was called *brack*, the designation for "*unreines Gut—so nicht zu gebrauchen*" ("dirty stones—not usable"). The biggest ring stone, according to the ledger at the Königskrone mine, weighed in at 8.5 carats.

One story from the early days of mining relates that a member of the mining crew had stored quite a lot of topaz crystals in his home; after a fire destroyed the house, other miners searching through the rubble found about 50 kg of topaz which had been turned from yellow to colorless by the intense heat.

The union ended mining at Schneckenstein in 1744. But from 1751 to 1757, under the management of Edlen von der Planitz, mining resumed. Between 1759 and 1796 the Schneckenstein was worked on a limited scale by the Vice-Mining Director of Saxony, Peter Nikolaus Freiherr von Gartenberg, but in 1788–1796 mining was greatly reduced because of poor sales. The locality was patrolled to keep the robbers away, and specimen material, including turbid (non-gem-grade) topaz crystals, was collected on a small scale. The old dumps were also worked over for specimens. From its establishment in 1727 until 1797 the total output of the mine has been estimated at about 150 kg of topaz crystals.

On August 8, 1800, the Elector granted permission to the Mining Academy in Freiberg to work the Schneckenstein dumps for topaz specimens and to occasionally do some blasting in the rock as necessary; this permission lasted until 1847. Between 1849 and 1851 C. A. Löffler, a miner from Freiberg, became successor in the

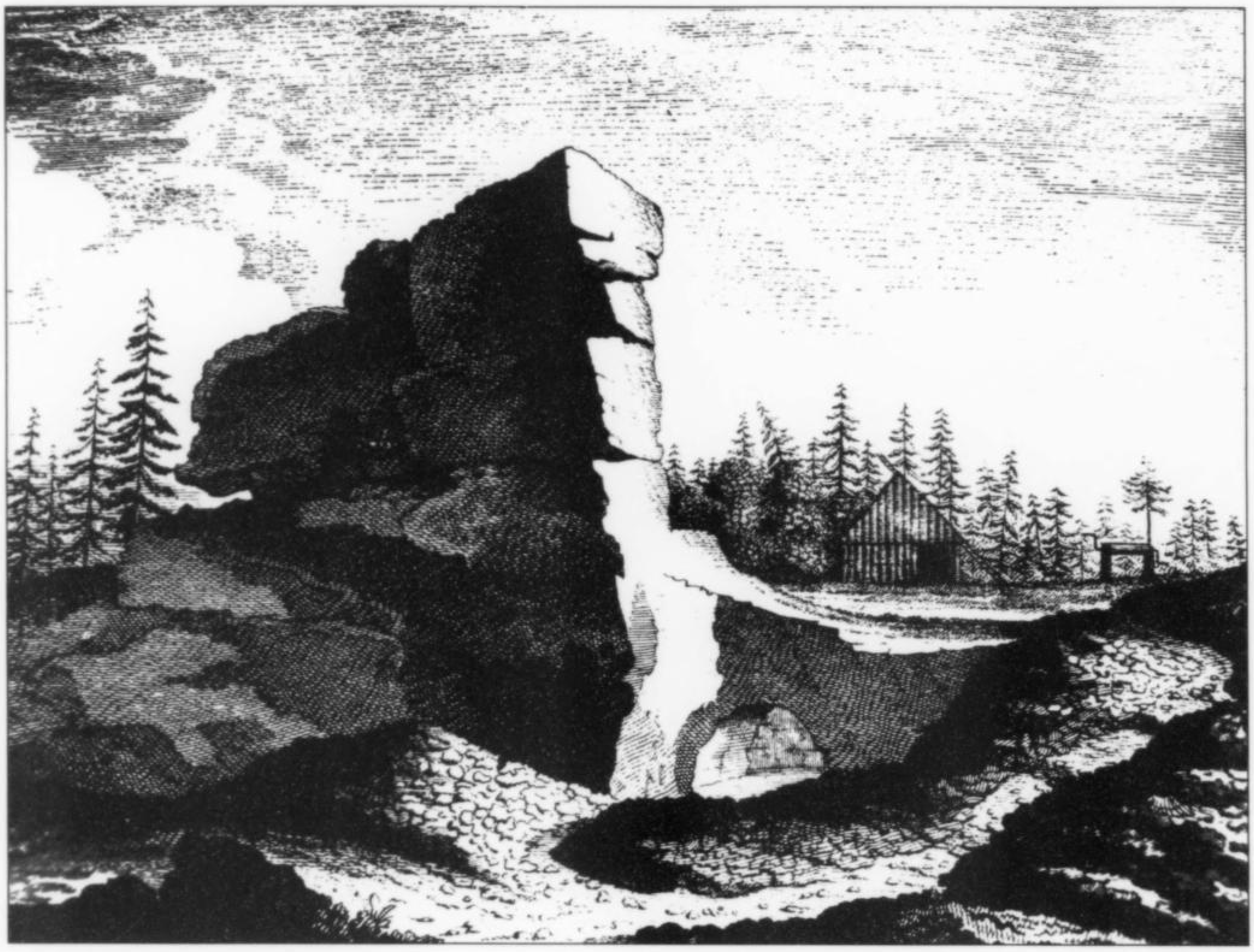

Figure 5. **The workings on the southern side of the Schneckenstein (Charpentier, 1778).**

Figure 6. **The northern side of the Schneckenstein; hand-colored engraving from Wilhem's *Unterhaltungen aus der Naturgeschichte* (1828).**

Figure 7. **A collectible trading card with a chromolithographic depiction of the Schneckenstein workings and a topaz specimen, published by the manufacturers of Liebig's meat extract (ca. 1890s).**

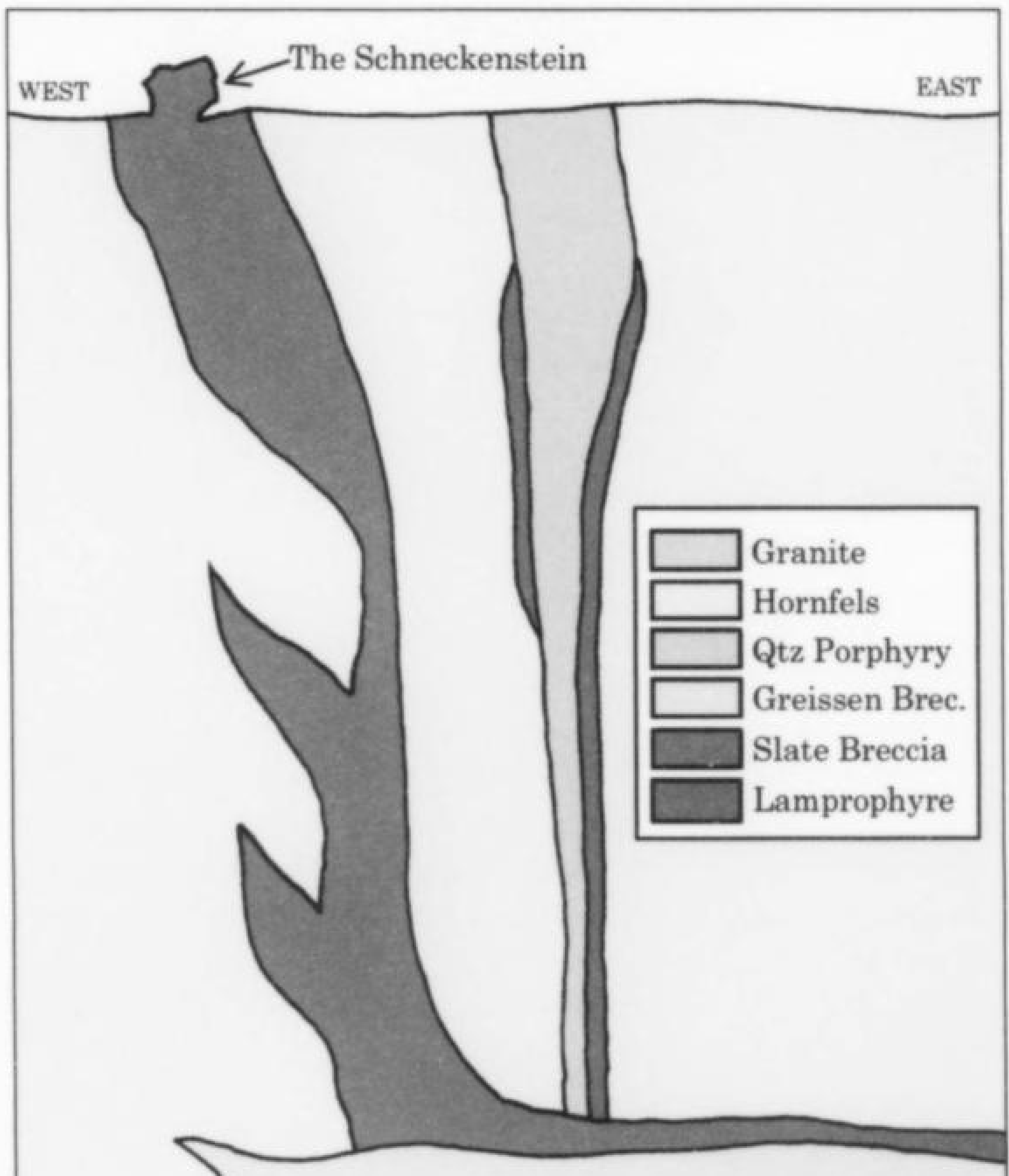

Figure 8. **Geological cross-section of the Schneckenstein area, showing the volcanic vent or pipe terminating in the Schneckenstein monadnock and its relation to the source granite below (adapted from Rösler, 1968).**

mining school's mineral sales department with the stipulation that he mine only on the south side of the Schneckenstein; this was the first attempt to preserve the rest of the occurrence for later generations. The mining carried out by Löffler was the last to occur at Schneckenstein.

But even after formal mining had ceased, collecting at Schneckenstein continued. Frenzel, writing in 1874, stated that there had been a bustling trade in Schneckenstein topaz specimens in the past, but that at the time almost nothing was being found. Nevertheless, collectors and gem hunters have been finding crystals sporadically at Schneckenstein even in recent decades.

GEOLOGY

According to Mende (1929), the topaz at Schneckenstein was created by contact of the Eibenstock-Neudecker granite massif with older schists, which had been under tectonic pressure from the northeast, compressing and laminating the schist formations. At weak spots and northwest-facing pressure-fissures, granite magma welled up (Fig. 8) and in the process altered the surrounding country rock through contact metamorphism. This created an andalusite-mica-cordierite hornfels skarn, as well as mottled schist and *fruchtschiefer* (a kind of spotted slate). The contact aureole is about 2 km wide.

At the same time, deformation of the overlying rocks, as well as vertical movements at the contact between the granite and the newly formed schist, created brecciated zones. The volatile components (F, Cl, B, and H_2O) of the residual solution reacted with the new contact-metamorphic minerals, forming tourmaline schist from andalusite, and topaz and quartz from feldspar, generating the tourmaline-topaz-quartz breccias. Around the same time, the granite

Figure 9. **The Schneckenstein in 2008; photo by the author.**

margin was impregnated with cassiterite, leading ultimately to the formation of greisens.

The geology of the topaz-bearing body at Schneckenstein has been well defined by drilling and underground workings which extend to a depth of 50 meters. Figure 8 shows an east-west cross- section through the Schneckenstein volcanic vent and through a related vent nearby. The country rock is a hornfels which was brecciated and altered in the Schneckenstein vent pipe. The material within the vent consists of fist-sized fragments of country rock altered to a quartz-tourmaline-topaz rock, cemented together by a white to yellow quartz and wine-yellow topaz.

Numerous late-stage veins (not shown in Fig. 8) containing Fe, Cu, Pb and Zn sulfides cut the vent rocks, the hornfels, and the underlying Eibenstock granite. Late-stage solutions have altered the topaz in places to kaolinite. The Schneckenstein occurrence is genetically similar to the tin deposit at Mount Bischoff, Tasmania.

The rock in the second vent is a quartz porphyry which also contains topaz, and there is a long contact zone into which a lamprophyre was intruded.

Minor minerals contained in the cement of the breccia body at Schneckenstein include tourmaline, fluorite, wolframite, molybdenite, ilmenorutile, apatite, chalcopyrite, malachite, azurite, and (rarely) cassiterite, turquoise, pyrite, wavellite and gold. The breccia is characterized by numerous vugs reaching 30 cm across, containing transparent quartz and gemmy topaz crystals. Minor tourmaline, fluorite, and pyrite are also found within the pockets.

In 1950 a tunnel was driven from the 775-meter level of the Tannenberg tungsten-tin mine near the town of Muhlleiten to the Schneckenstein volcanic pipe. Where the tunnel intersected the pipe at a depth of about 100 meters below the surface, the pipe was found to measure about 35 × 110 meters, with very sharply defined contacts with the surrounding phyllite. The topaz-rich breccia showed essentially the same mineral assemblage as that found at the surface outcrop, but with some differences in relative proportions with depth. Tourmaline and wolframite were more common at depth than near the surface, whereas topaz was seen to be less common, and molybdenite was found only in the lower zone (Russ, 1989).

Paragenesis

A greisen is defined as a pneumatolytically altered granitic rock composed largely of quartz, mica and topaz. In the greisenization process, often taking place in the fractured rock above a magma chamber, feldspar and muscovite are converted to an aggregate of quartz, topaz, tourmaline and lepidolite by the action of water vapor containing fluorine (Jackson, 1997). Topaz-formation temperatures in greisens are at or below the solidus temperature of the magma; topaz crystals formed in this setting are generally small. Schneckenstein is an example of a topaz greisen that has been a historically important gem topaz producer.

The relationship of the temperature of formation of topaz to its F/OH ratio is worth considering. Empirical evidence suggests that formation temperature is an important (but probably not the only) factor in determining the F/OH ratio. If this is the case, then variations in physical properties can provide useful clues to the origin of individual crystals. Rosenberg (1972), in his studies of synthetic topaz, showed a direct relationship between the formation temperature and the F/OH ratio. Lower temperatures were associated with a higher OH content. These data, he pointed out, were valid only for formation under closed-system conditions. Many geologists believe that most pegmatites form as closed systems, so that Rosenberg's data may be used to estimate formation temperatures of many pegmatitic topaz occurrences.

Roedder (1984), on the other hand, believes that pegmatites generally form as open systems, and that the gemmy, euhedral crystals present in the pocket pegmatites formed by crystallization

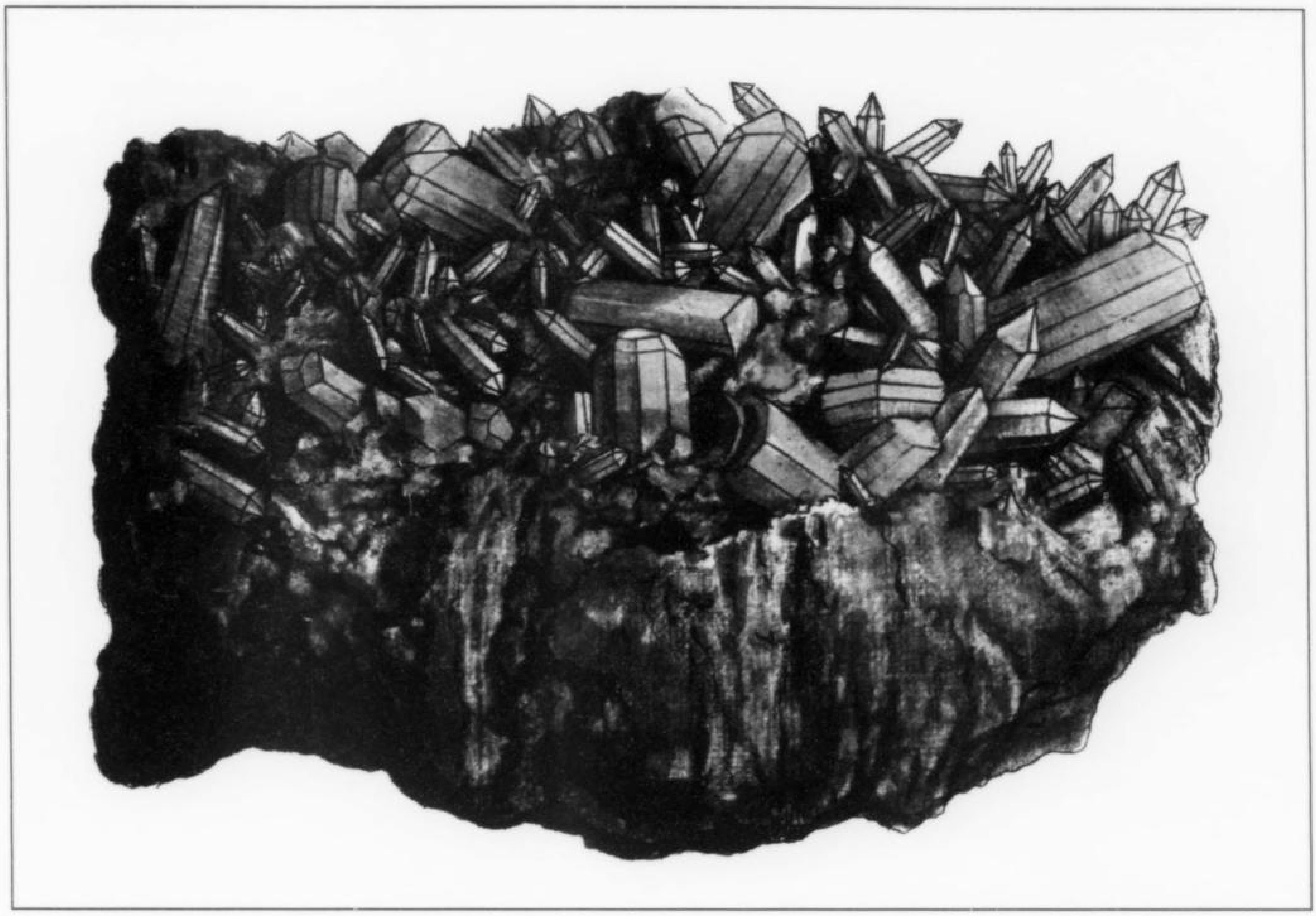

Figure 10. **The earliest known illustration of a Schneckenstein topaz specimen, in Gautier d'Agoty's *Histoire Naturelle Règne Minéral* (1781). Plate no. 54 shows this hand-colored illustration of a superb cabinet specimen, 14 cm across. The original specimen survives in a damaged state in the Yale University collection. (Mineralogical Record Library.)**

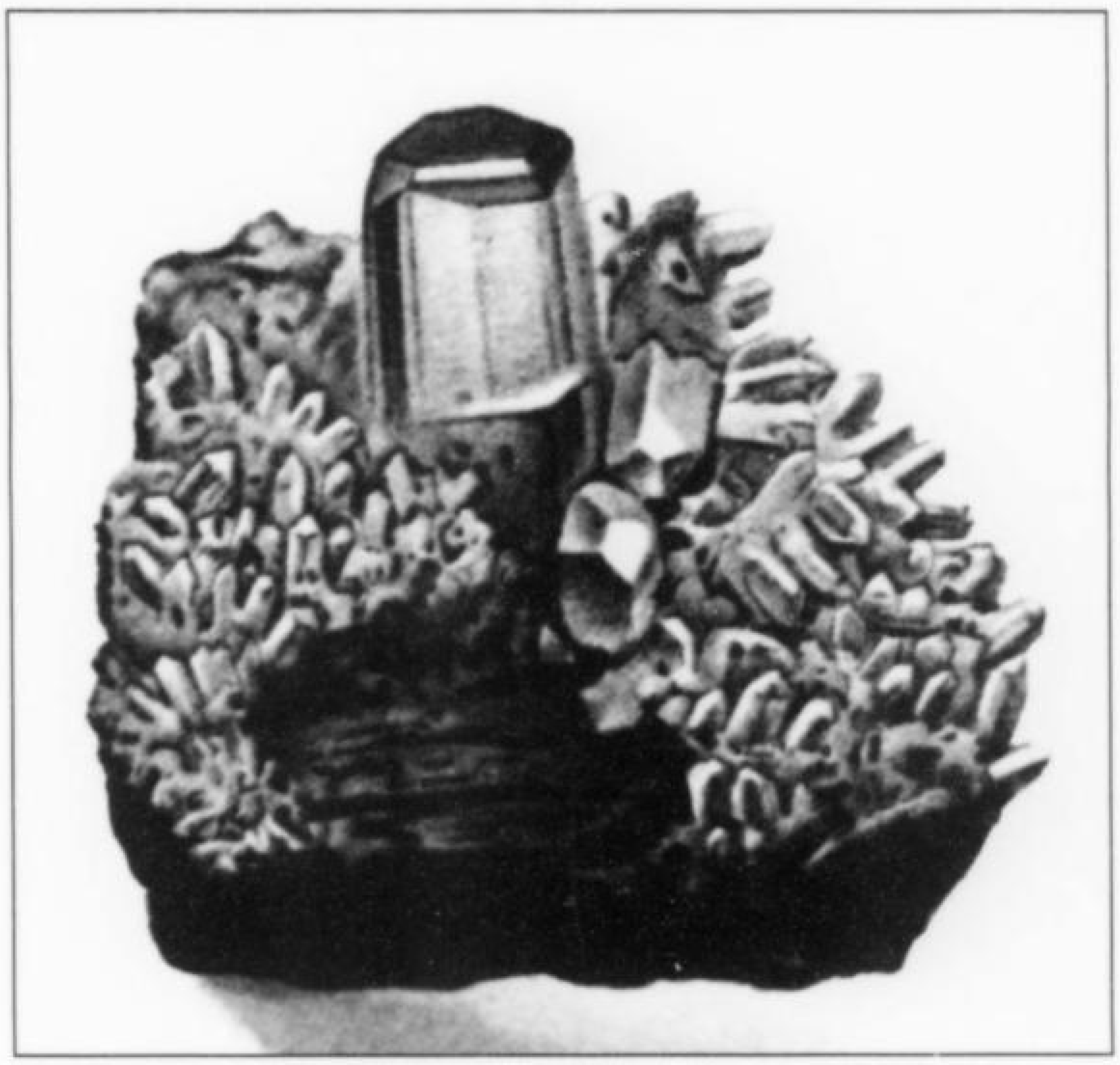

Figure 11. **Topaz with quartz and kaolinite on matrix from Schneckenstein; plate 13 from Bauer's *Precious Stones* (1904) (Mineralogical Record Library). This specimen was formerly in the collection of the mining academy in Berlin, and was destroyed by fire during World War II.**

from a hydrothermal fluid, not a melt. The fluid-inclusion studies of Roedder provide some additional information to help in defining the formation temperatures of some topaz. Unzoned pegmatites have inclusion-homogenization temperatures of 690 to 540° C, and thus the pocket pegmatites would probably form below this range. Inclusions in topaz from the Volynsk region in the Ukraine have been studied extensively by Russian researchers. Roedder, in discussing those studies, notes that homogenization temperatures as high as 740° C have been erroneously reported for this material, and that values closer to 400° C, obtained on selected inclusions, more probably represent the approximate formation temperature. He also discusses the homogenization temperatures of minerals obtained from a number of tin-tungsten greisens, showing a range of from 150 to 600° C. Most temperatures are in the range of 300 to 400° C. In most of these deposits topaz is believed to predate the ore minerals, so that it would be expected to have somewhat higher homogenization temperatures.

A homogenization temperature for topaz from Schneckenstein has been reported at 554° C (Roedder, 1984).

SCHNECKENSTEIN TOPAZ

Early Illustrations

The earliest illustration of a Schneckenstein topaz specimen appears to be that of Fabien Gautier d'Agoty, in his *Histoire Naturelle Règne Minéral* (1781). His plate no. 54 shows a hand-colored illustration of a superb cabinet specimen, 14 cm across, with a pocket filled with quartz crystals and yellow topaz crystals to 2.5 cm. The illustration was drawn by François Louis Swebach-Desfontaines (ca. 1740–1792) from a specimen in the collection of Jean Gigot d'Orcy (1733–1793) (Wilson, 1995). Gigot d'Orcy lost his life in the French Revolution, and his mineral collection was later sold to a wealthy American collector, Col. George Gibbs (1776–1833); Gibbs sold his 20,000-specimen collection to Yale University in 1825 (Wilson, 1994). The Schneckenstein specimen

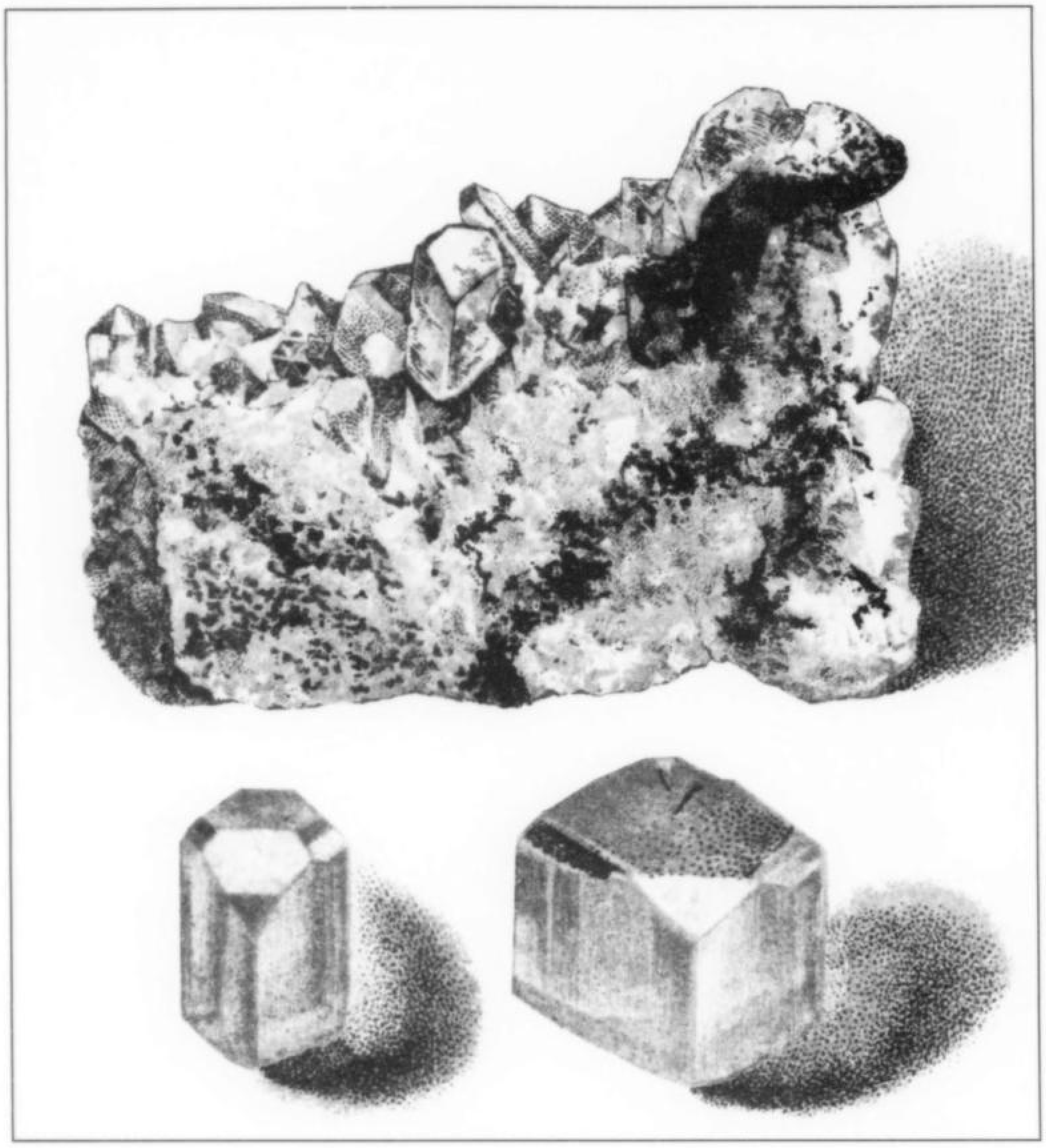

Figure 12. **Topaz and quartz matrix specimen (6.3 cm) and two single crystals from Schneckenstein. From Brauns' (1903) *Das Mineralreich* (Mineralogical Record Library).**

(or at least a ghost of it) survives there today, but most of the fine topaz crystals have been broken off, with only the broken crystal bases remaining on the matrix (see the photo in Moore, 1999).

Feuchtwanger (1859) describes crimson as well as yellow Saxon topaz, and Streeter (1877) mentions that white, yellow, and pale violet crystals were found. The lamprophyre present in the deposit may have been the source of the chromium which presumably lends the crimson or violet color to the crystals.

Brauns (1903) published a chromolithographic illustration of a matrix specimen of Schneckenstein topaz, and two single crystals. Bauer (1904) shows a color comparison between typical pale yellow Schneckenstein topaz and more deeply colored Ouro Preto topaz, as well as illustrating the typical habits of crystals from both localities. The Schneckenstein crystals generally have a large well-developed basal pinacoid that is not seen on Ouro Preto crystals. Also, Schneckenstein crystals are generally smaller, averaging only about 1 cm—the largest may reach 5 cm across and 9 cm long, but such large crystals are quite rare. Another source (Lahl, 1990) mentions a topaz crystal weighing 220 carats; the largest faceted Schneckenstein topaz known is a 176-carat stone in the Green Vaults of Dresden.

Chemistry

Topaz is an aluminum fluorosilicate having the formula $Al_2SiO_4(F,OH)_2$. The composition is relatively invariant except for the substitution of OH for F. This substitution is limited to a maximum of about 30 mole % OH in place of F in natural topaz. Pure hydroxyl-free topaz contains 20.6 weight % F. Near end-member topaz was reported from Schneckenstein by Fricke (1949), containing 18.62 weight % F, 56.54 weight % $A1_20_3$, and 33.53 weight % SiO_2.

The F/OH ratio in topaz affects many physical and optical properties, which vary continuously as a function of the ratio. Consequently the properties of the mineral vary along a continuum, i.e. the gemological literature is misleading when it describes, as it often does, merely two distinct types—a low-density type with high index of refraction and yellow to orange color, and a high-density type with low index of refraction and a blue to colorless appearance.

Crystal Morphology

Haüy (1801) was the first to describe and illustrate the richness of crystal forms and habits shown by topaz from Schneckenstein (Fig. 13). More than 140 different forms were reported by Frenzel (1874). The morphological features of topaz observed in many crystals belong to the orthorhombic dipyramidal class 2/m 2/m 2/m, and space group *Pbnm* (Gaines *et al.*, 1997). Parise *et al.* (1980) and Frye (1981), however, state that topaz can also be triclinic pseudo-orthorhombic (space group *P*1). The higher hydroxyl content is the culprit, and a pyroelectric property also appears. As stated earlier, the habit of a topaz crystal is a complex function of the physicochemical conditions under which it grew.

Several different environments or models have been observed for the primary formation of topaz. These are, in order of decreasing temperature of formation: topaz rhyolites, pegmatites, greisens, and hydrothermal veins. Pough (1964) has described the typical habits associated with each of these genetic models, lumping the pegmatitic and greisen modes of formation together because crystals from them show no difference in habit. His summary of the typical habit is as follows: For rhyolitic topaz, a fairly large basal pedion {001} with two equally developed prisms (third order, {110} and {120}, two dipyramids typically {*h*11} and {112}, two first-order prisms typically

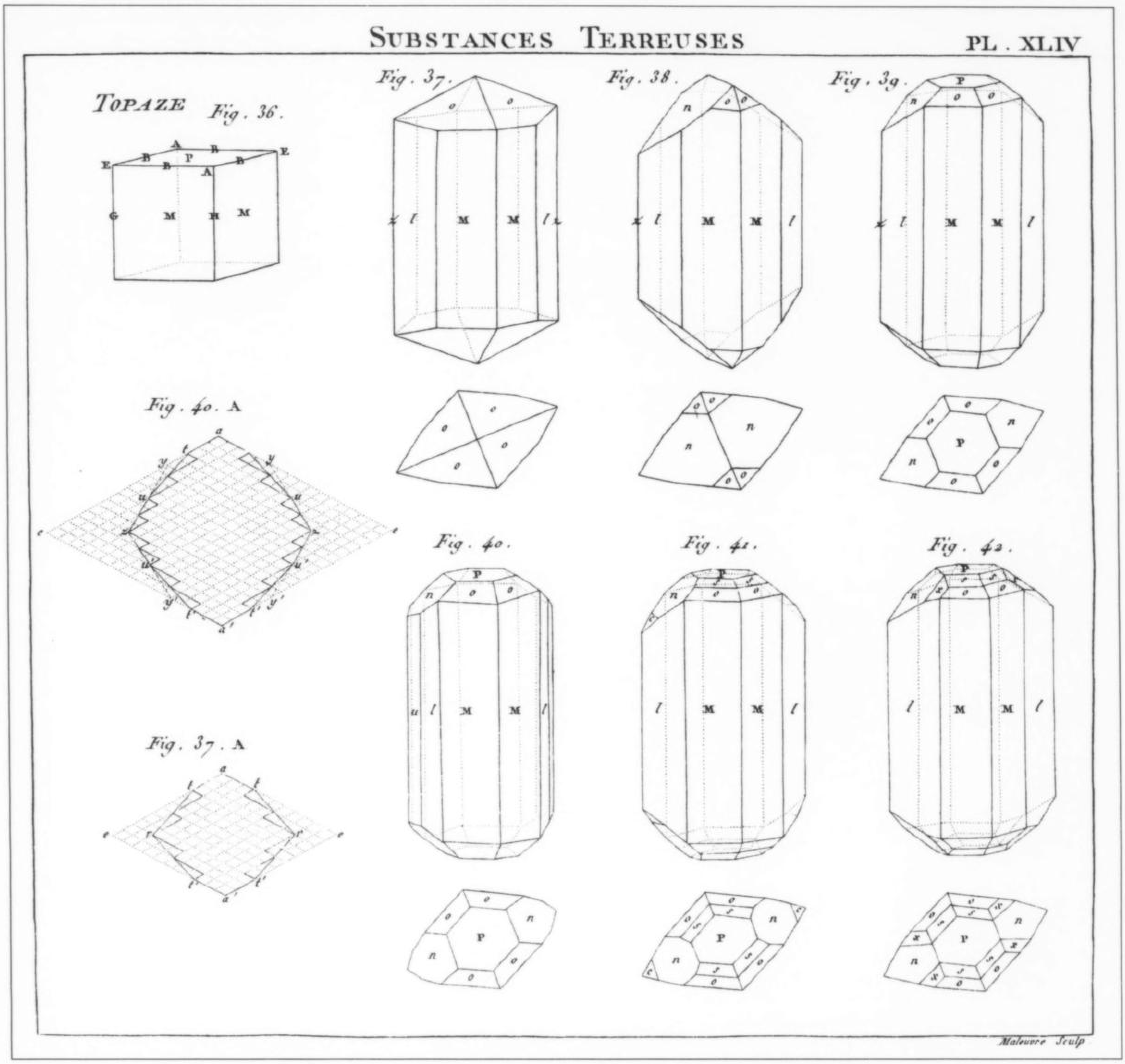

Figure 13. **Haüy's (1801) crystal drawing of topaz from Schneckenstein.**

{021} and {*hk*1} and one second-order prism). For pegmatite/greisen topaz, a large basal pedion {001}, with one or two domes and one or two dipyramids is more typical. (He does not mention the third-order prisms.) The habit of the vein-type topaz as at Ouro Preto, Brazil, is characterized as being long and slender, terminated by a simple dipyramid {123}, and not at all like pegmatitic topaz.

The prism faces of topaz crystals commonly show longitudinal fluid cavities and incipient transverse cleavage which can produce iridescent colors. They are usually attached to matrix at one end and thus usually show a cleavage plane so that doubly terminated crystals are rare. Hemimorphic topaz crystals (though common in the Ouro Preto deposits) and twins are unknown from Schneckenstein.

Color

Agricola (1546) wrote: "*Auri autem fulgor topazion a callaide pallidius virente separate*" (the head-color of the topaz is wine-yellow), but he was probably referring to olivine. It appears that Henckel (1737), in describing the yellow topaz from Schneckenstein (*topazius vera Saxonia*), was the first to assign the name "topaz" to the aluminum fluorosilicate that we know today by that name. A yellow color in topaz has been reported with increased amounts of chromium, manganese, cobalt and vanadium (Deer *et al.*, 1982). Traces of chromium (less than 100 ppm) have been reported in high-fluorine topaz from Schneckenstein (Ribbe and Rosenberg, 1971). The yellow color of Schneckenstein topaz, however, is thought to be due to the presence of color centers—defects in the crystal structure that selectively absorb a component of visible light (Petrov, 1978). The topaz at Schneckenstein varies from colorless to wine-yellow, honey-yellow, dark-yellow, orange, rose-red, wine-red, pale violet and green ("Saxon chrysolite").

THE SCHNECKENSTEIN NATURE MONUMENT

The Schneckenstein is one of Europe's most famous nature monuments. In early reports the bridge to the fault pit and the nearly buried shaft head were mentioned as historically important

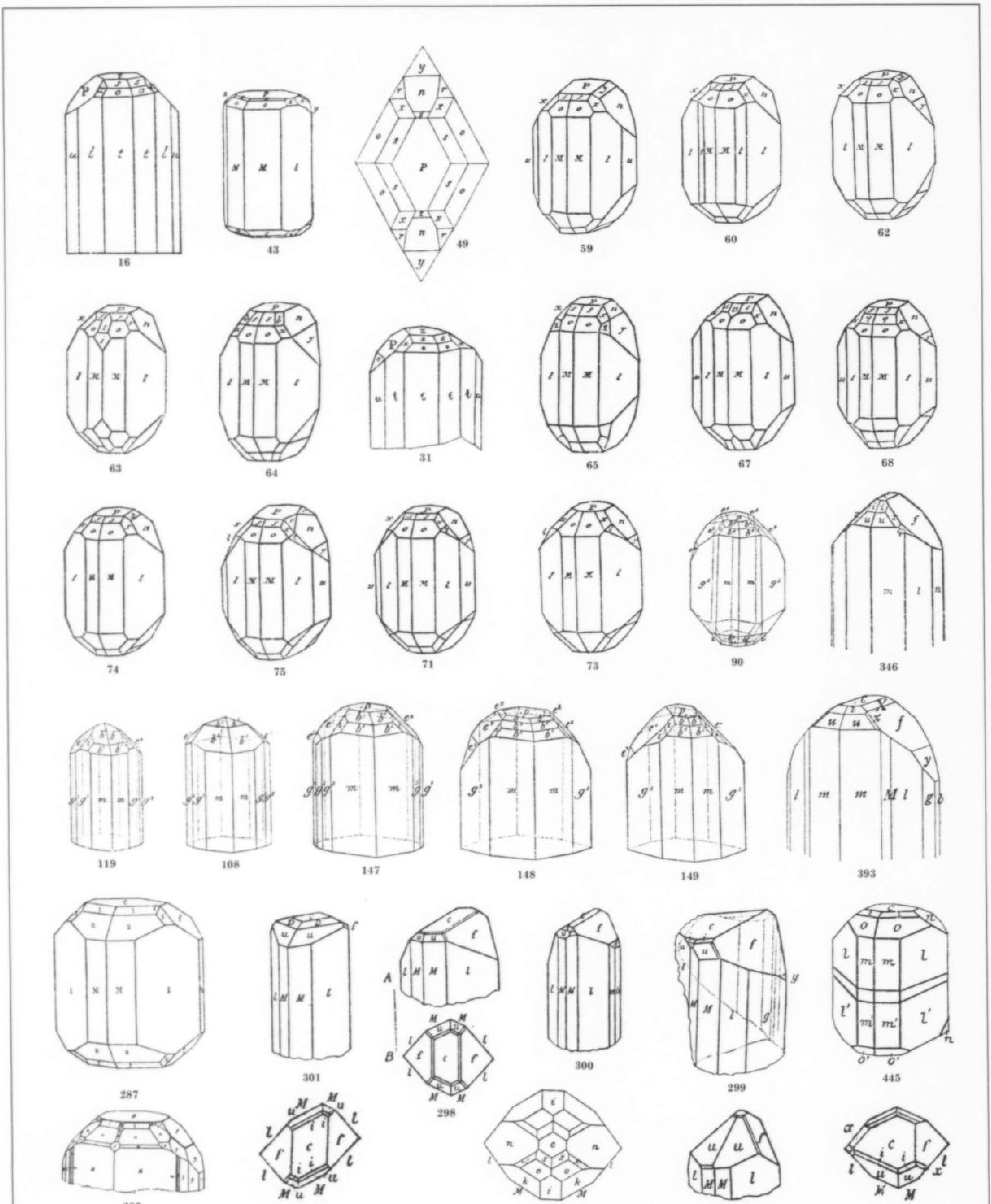

Figure 14. **Crystal drawings of Schneckenstein topaz taken from Goldschmidt (1922). The drawings originally came from a variety of previously published works including Monteiro (1811), Haüy (1823), Mohs (1824), Sillem (1827), Presl (1837), Lévy (1837), Sadebeck (1876), Laspeyres (1877), Grünhut (1884), Dana (1892), Eakle (1898), Beckencamp (1908) and others (see Goldschmidt for references).**

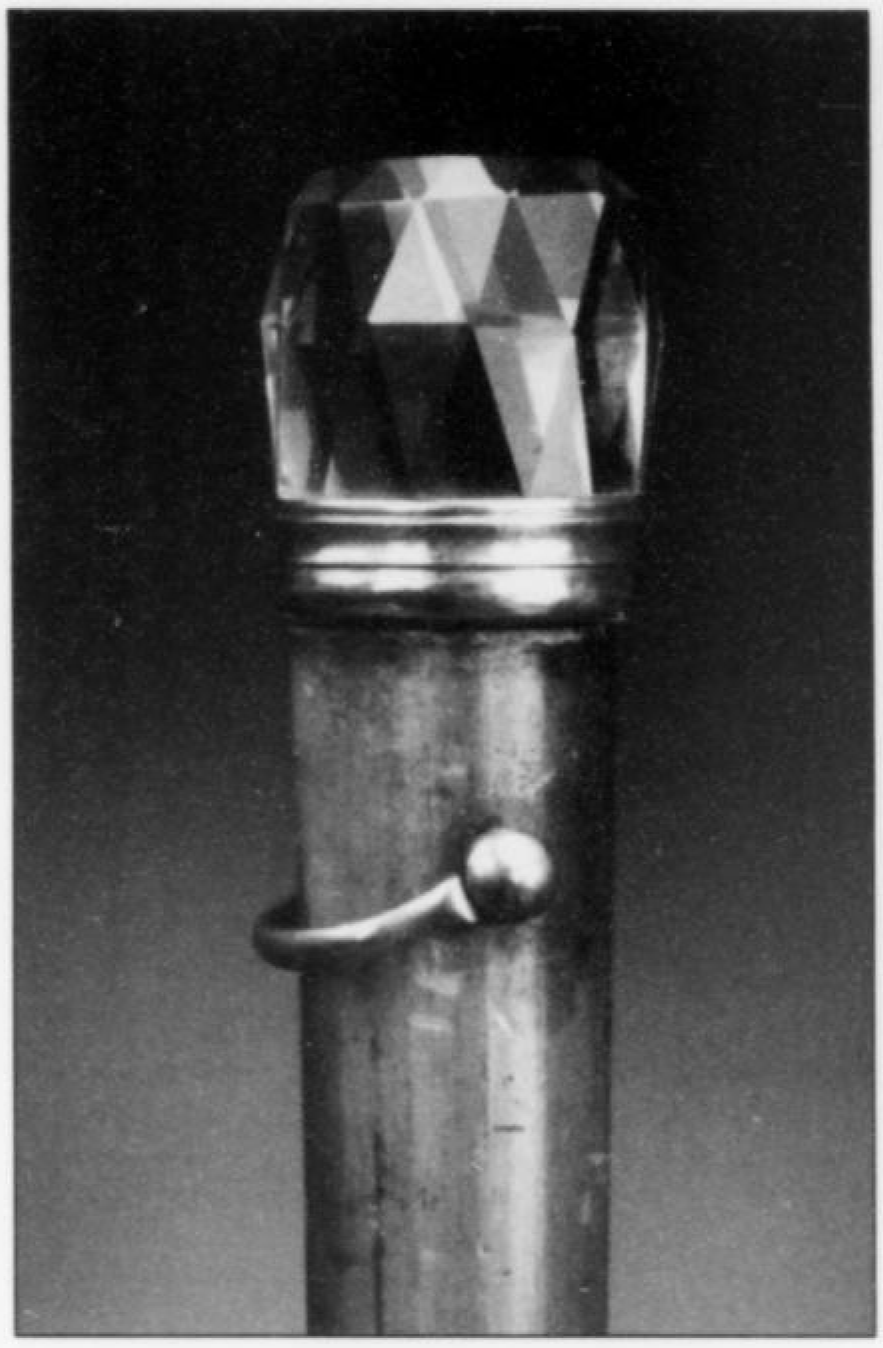

Figure 15. A walking stick with a 2.3-cm finial of faceted topaz from Schneckenstein, made by J. H. Köhler in Dresden in 1734. Green Vaults collection and photo, Dresden.

Figure 16. Topaz crystal pocket, 3 cm across, from Schneckenstein. Freiberg Mining Academy collection; A. Massanek photo.

Figure 17. Topaz crystal, 1.4 cm, with quartz crystals and kaolinite, from Schneckenstein. Freiberg Mining Academy collection; R. Bode photo.

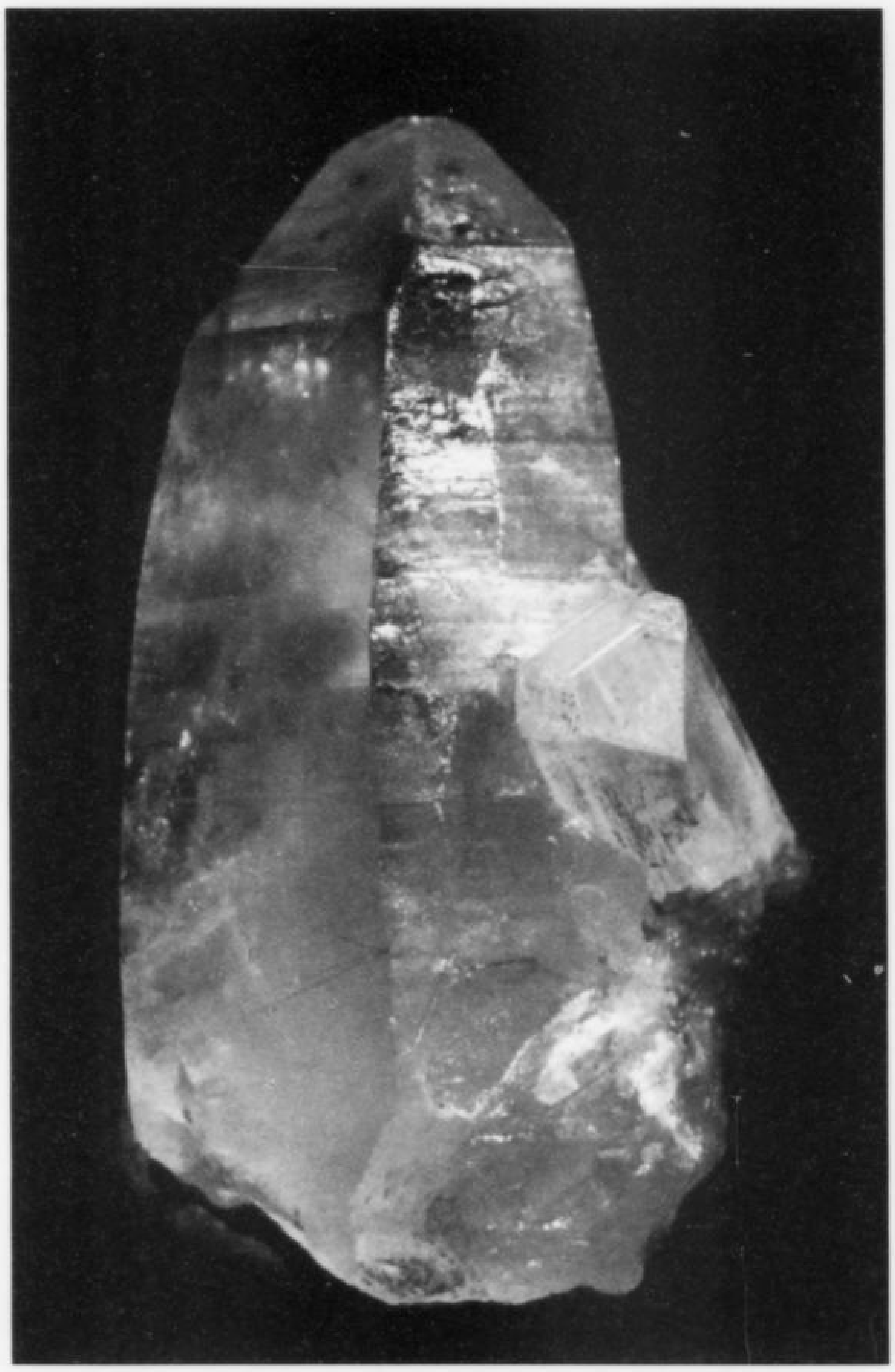

Figure 18. A large quartz crystal, about 5 cm tall, with attached topaz crystal, from Schneckenstein. Freiberg Mining Academy collection; A. Massanek photo.

Figure 19. **Topaz crystal, 1.7 cm on an edge, with quartz and kaolinite from Schneckenstein. Formerly in the P. Pölz collection, now in the collection of Dr. Langer; H. Leithner photo.**

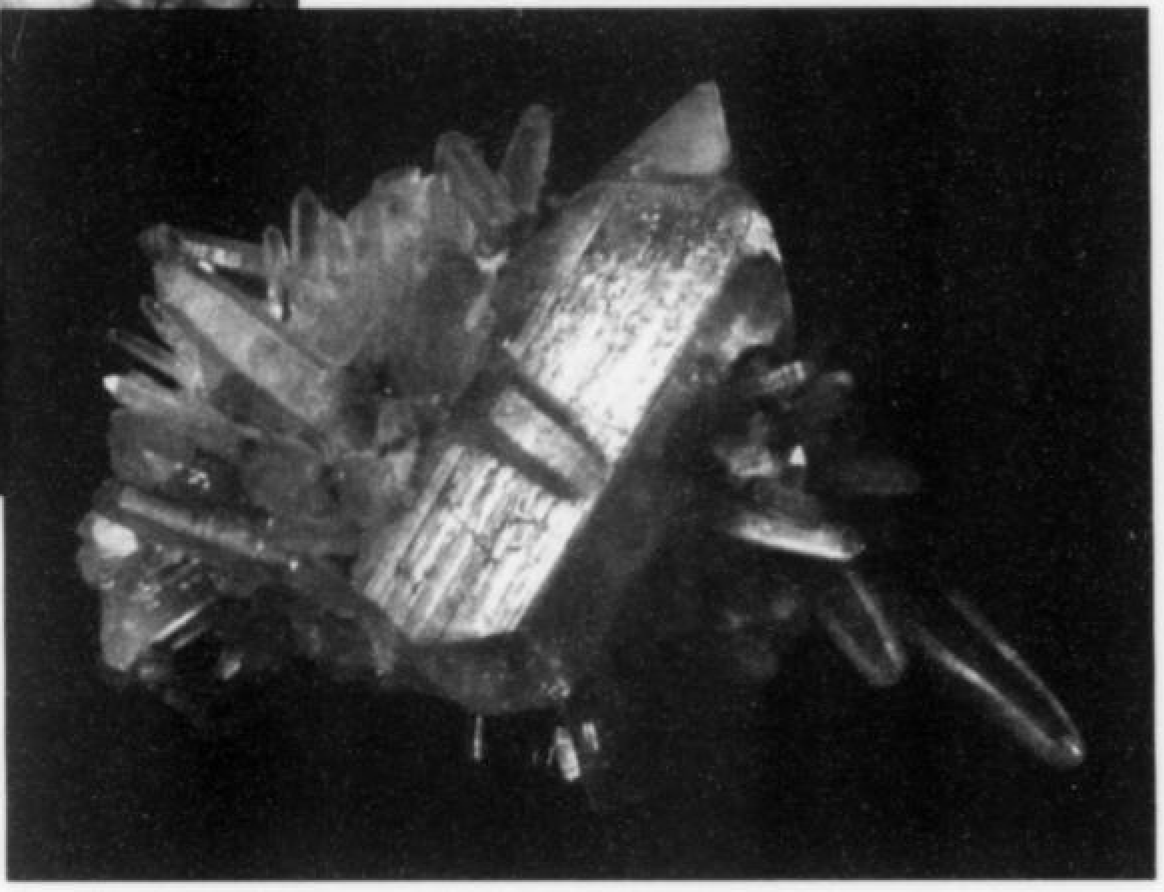

Figure 20. **A 1.8-cm doubly terminated topaz crystal (very rare) with quartz from Schneckenstein. Author's collection (formerly) and photo; now in the collection of P. Wondratschke.**

mining artifacts. In 1902 the Naturfreunde ("Friends of Nature") of Klingenthal constructed a railing to make the climb up the rock easier; it was replaced in 1960. There are also hand-hewn stone steps that probably date back to 1829.

In 1937 the area encompassing the Schneckenstein rock and all the dumps came under governmental protection and was declared a Nature Monument. However, conservation efforts around the Schneckenstein were not very effective prior to 1973; unauthorized mineral collecting there continued apace and the dumps were getting larger every year. Spruce trees growing at the edge of the forest were undermined by diggers and eventually fell down. The foot traffic of an increasingly large number of visitors prevented young trees from taking hold up to 30 meters from the rock. Then in 1973 the protected area around the Schneckenstein rock was enlarged, a fence was erected, and visitors were thereafter required to stay on clearly marked paths; specimen collecting was prohibited.

For many years, and especially since the beginning of the 20th century, the Schneckenstein has been a magnet as a scientific destination for mineralogists, geologists and amateur collectors. Hikers can reach the locality from the town of Mühlleiten-Tannenbergsthal. Another trail goes from the Muldenberg dam to the monument in about an hour and a half on foot. The mixed woods prevent a clear sight toward the Schneckenstein, especially coming from the southwest, but when visitors finally reach the top of the rock at about 860 meters elevation they are rewarded with a fine scenic view that they will remember for a long time.

A large number of topaz specimens have been collected at the Schneckenstein over the years, and consequently even today a collector can still purchase Schneckenstein topaz on the mineral market.

ACKNOWLEDGMENTS

The author gratefully acknowledges the generous assistance of Dr. G. Sansoni and A. Massanek in Freiberg; K. Fischer in Starnberg; G. Hofmann in Nürnberg; P. Huber in Wiener Neustadt; S. Schiller in Falkenstein; and K. H. Russ in the U.S.; Dr. A. Kampf in Los Angeles and Dr. W. E. Wilson and T. P. Moore in Tucson reviewed and augmented the manuscript. My thanks go as well to the many photographers who submitted photographs.

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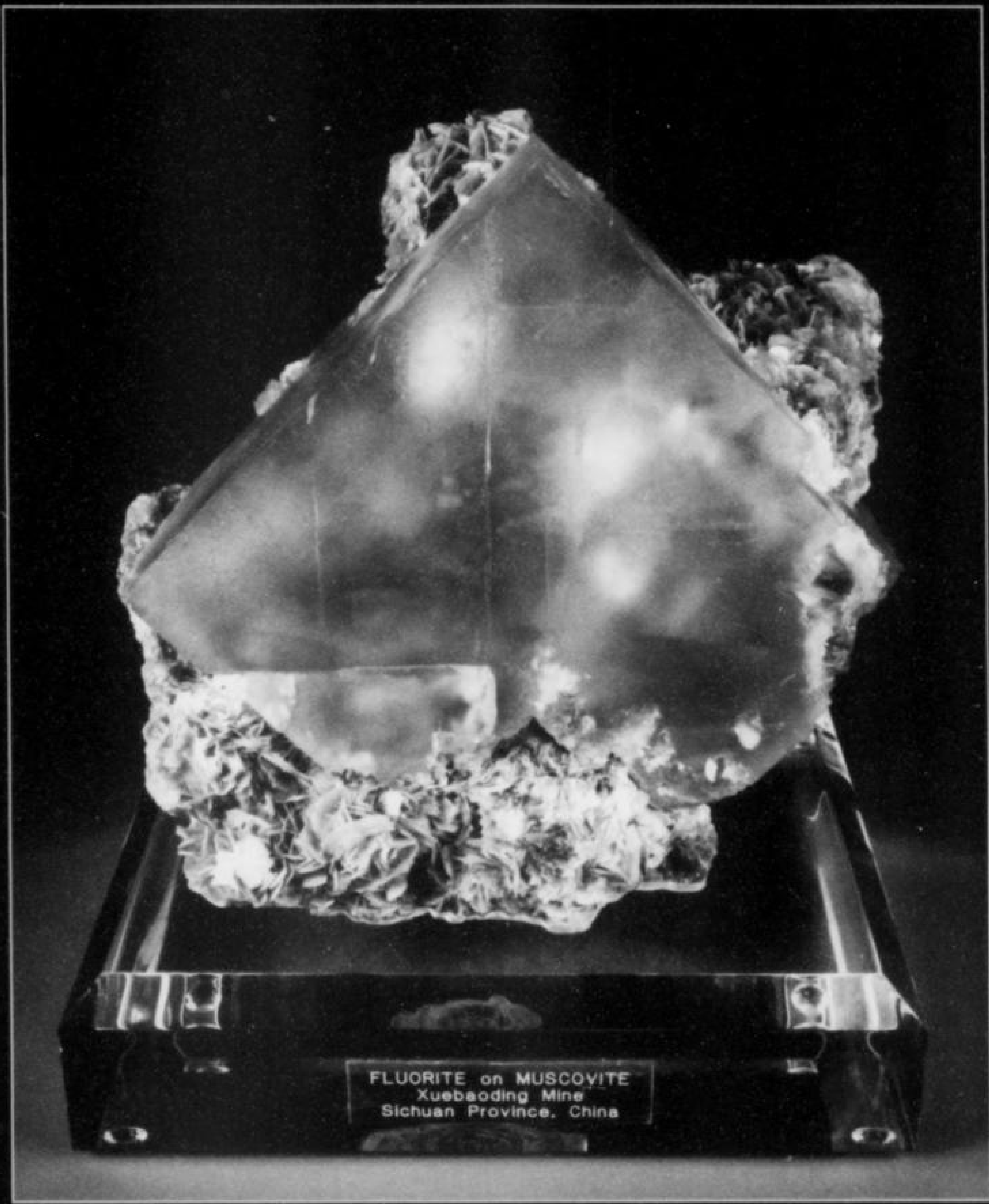

JIM GEBEL COLLECTION

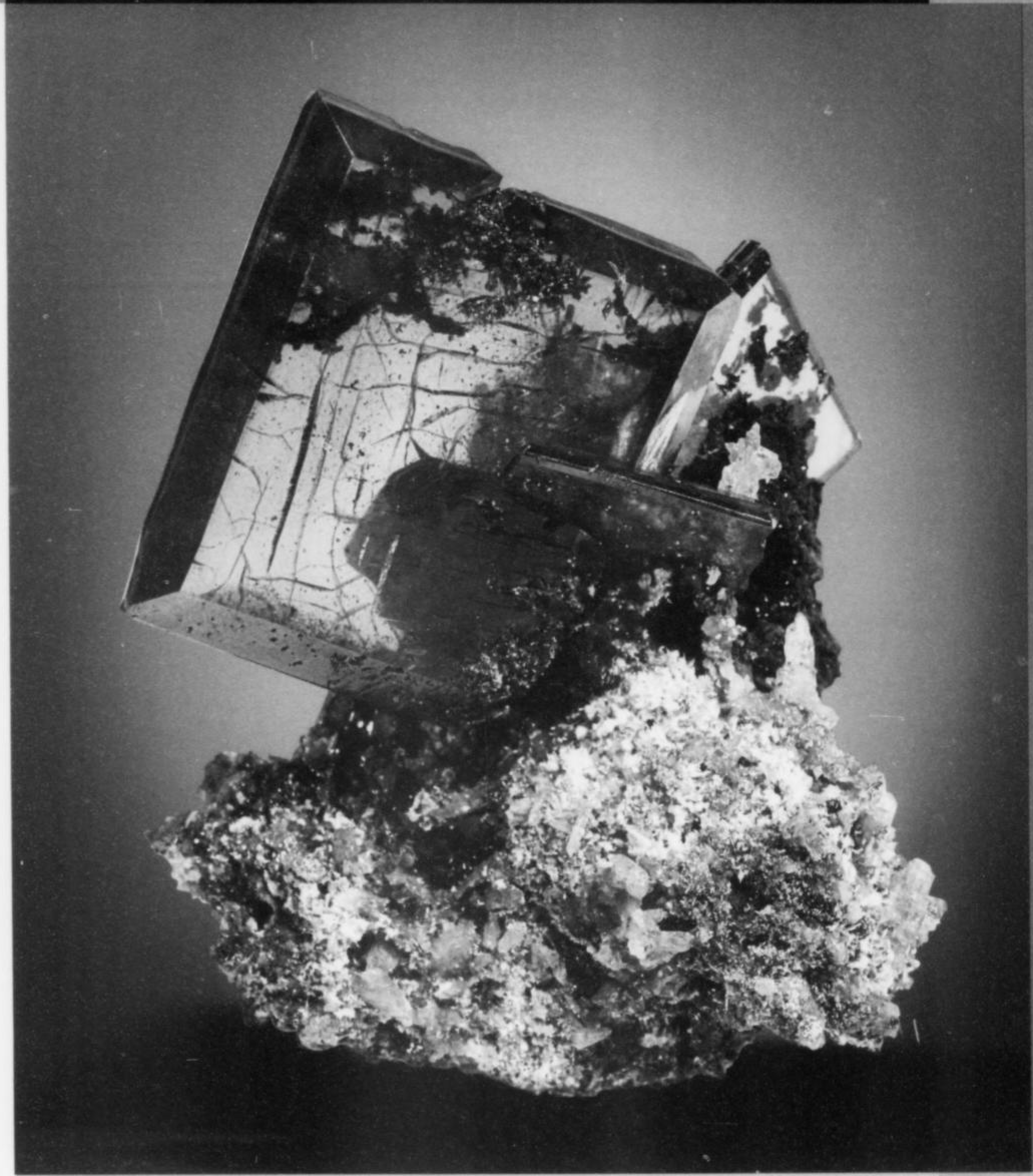

Photo by Jeff Scovil

OLMIITE AND POLDERVAARTITE
from the
KALAHARI MANGANESE FIELD
NORTHERN CAPE PROVINCE
REPUBLIC OF SOUTH AFRICA

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Poldervaartite was described in 1993, based on attractive specimens collected at the Wessels mine in South Africa. Around 2001 a bonanza of fine specimens presumed also to be poldervaartite was discovered at the nearby N'Chwaning II mine. Subsequent investigations have shown the N'Chwaning II specimens to be a new species, olmiite, the Mn analog of poldervaartite. The two species cannot be distinguished visually.

INTRODUCTION

Poldervaartite, a calcium-manganese silicate, was described in 1993 by Dai, Harlow and McGhie as a new species from the Wessels mine, Kalahari Manganese Field, Republic of South Africa. It occurred sparingly in fine crystals and crystal aggregates, and, although several small finds are known, it can be considered a rather rare mineral, much in demand by collectors. Thus the mineral community was elated when, about eight years later, many fine specimens of a poldervaartite-like mineral in cream to pink to red crystals from another locality in the Kalahari Manganese Field, the N'Chwaning II mine, appeared on the market.

The external appearance of the N'Chwaning II mine mineral and that of the Wessels mine poldervaartite are similar but not identical; furthermore, the former mineral shows a wide variety of colors and habits of crystal aggregates. Surprisingly, no specific investigation seems to have been carried out until one of the authors (RP) acquired and examined a number of specimens from both localities and submitted his material to Paola Bonazzi and her colleagues at the Earth Science Department of the University of Florence, Italy. The work carried out there led to the approval of a new species, olmiite, the Mn-dominant analog of poldervaartite.

Some questions of interest regarding the specimens from the new find remained open: Are they all to be classified as olmiite? Do olmiite and poldervaartite occur together? Can olmiite be distin-

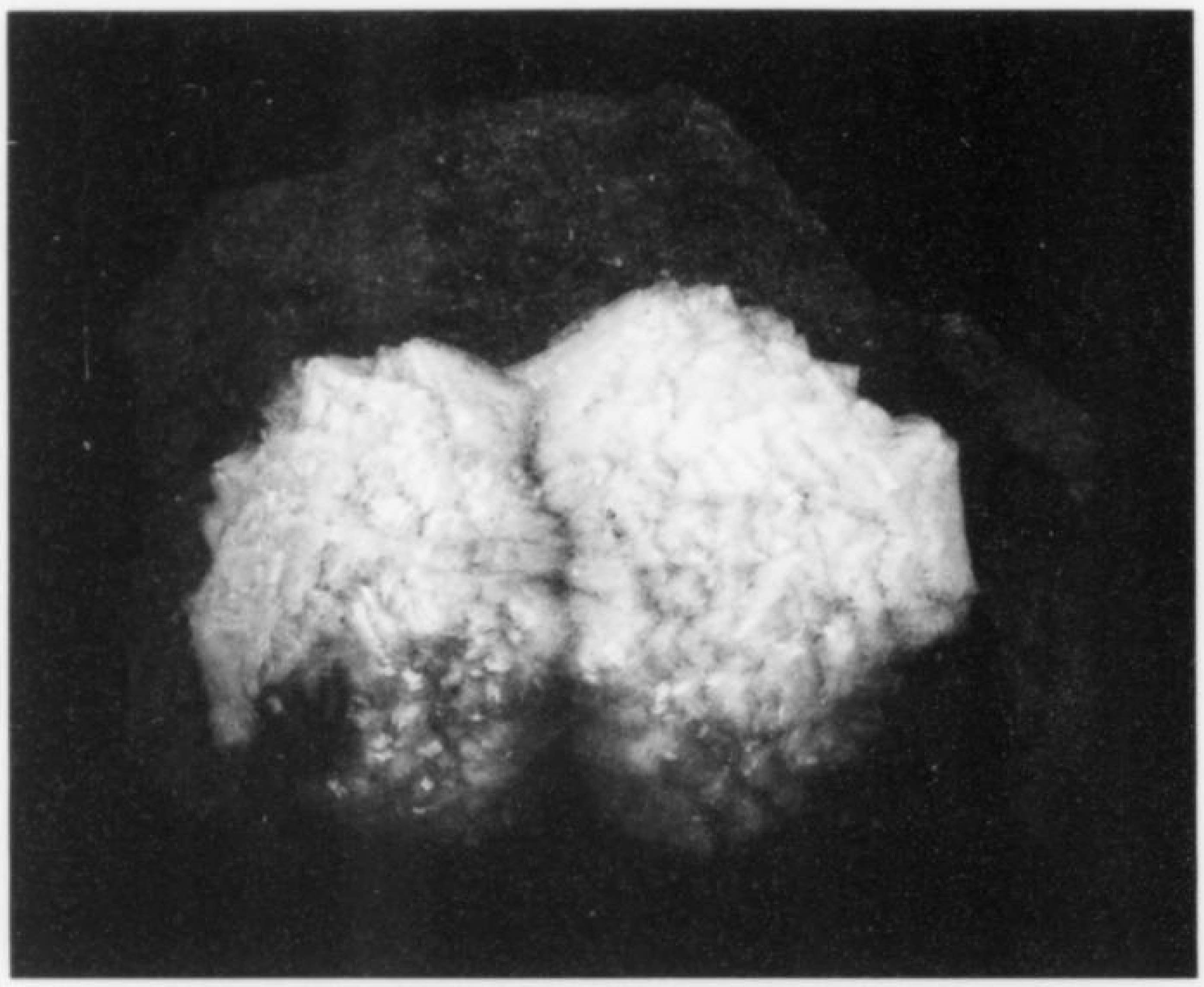
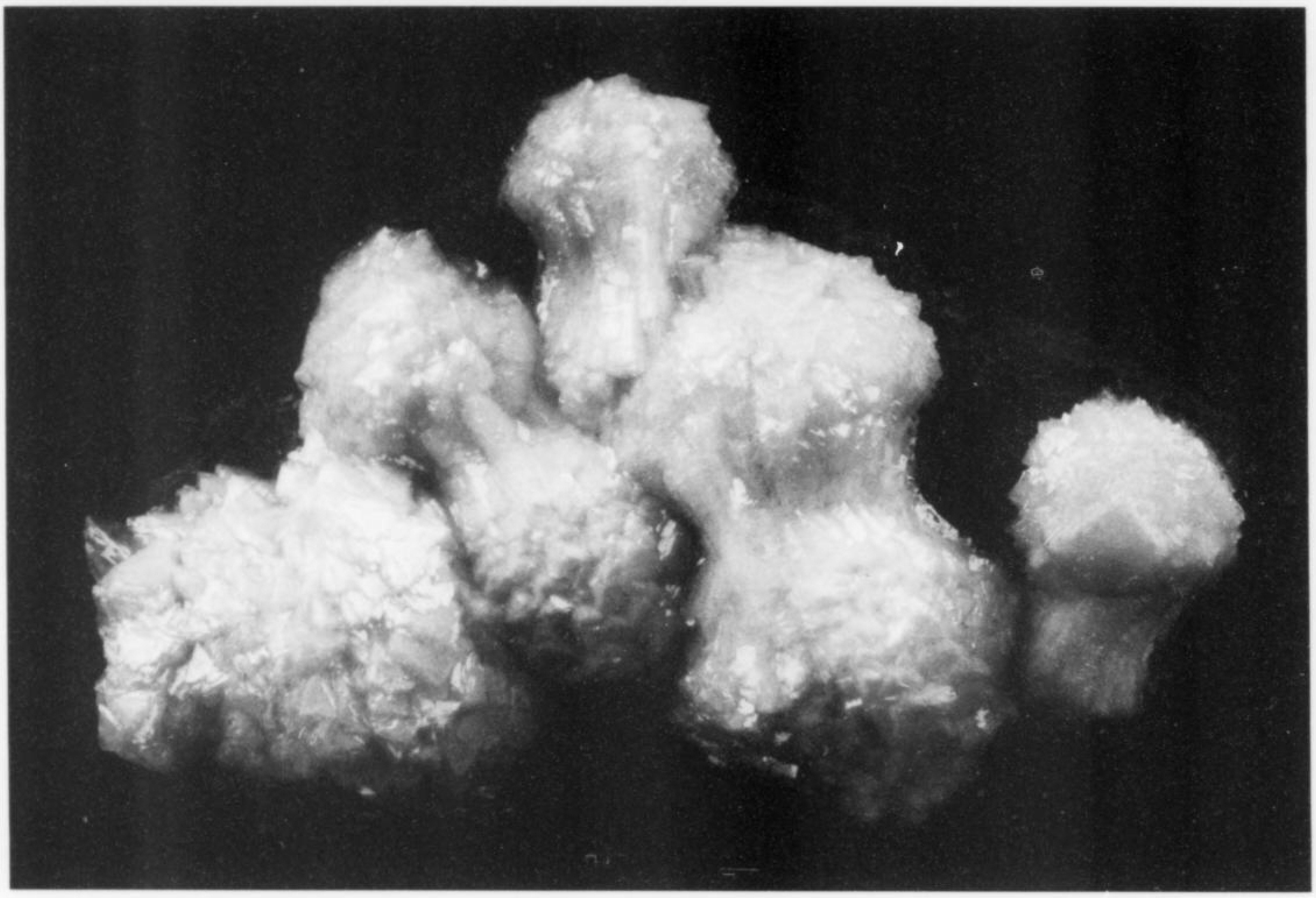


Figure 1. **Globular aggregate of olmiite crystals on matrix, 3 × 3.5 cm, from the N'Chwaning II mine. Desmond Sacco collection, now in the Renato and Adriana Pagano collection, no. 10279; Roberto Appiani photo.**

Figure 2. **Olmiite crystal aggregates showing typical wheat-sheaf habit, on matrix, 6 × 4 cm, from the N'Chwaning II mine. Renato and Adriana Pagano collection, no. 8278; Roberto Appiani photo.**



guished visually from poldervaartite? To answer these questions, an experimental investigation was carried out by the present authors.

POLDERVAARTITE—WESSELS MINE

The Kalahari Manganese Field localities came to the attention of the curatorial and collector communities in the 1970s. Their fame was mainly due to the spectacular Hotazel rhodocrosite crystal groups, but many other mineral species were also reported (Wilson and Dunn, 1978; Cairncross *et al.*, 1997, Von Bezing *et al.*, 1991; Cairncross and Dixon, 1995). Some of these works include excellent photographs of the most important minerals from the area and also describe the geography and the geology of the Kalahari Manganese Field deposits, which, aside from their scientific and collecting appeal, are of great industrial importance.

Poldervaartite from the Wessels mine was described by Dai *et al.* (1993), who reported the general formula:

$$(Ca_{2-x}Mn_x)SiO_4 \cdot H_2O, \text{ with } x = 0.28\text{–}0.52.$$

The formula adopted by the International Mineralogical Association's Committee on New Minerals and Mineral Names, was:

$$Ca(Ca,Mn)(SiO_3OH)(OH).$$

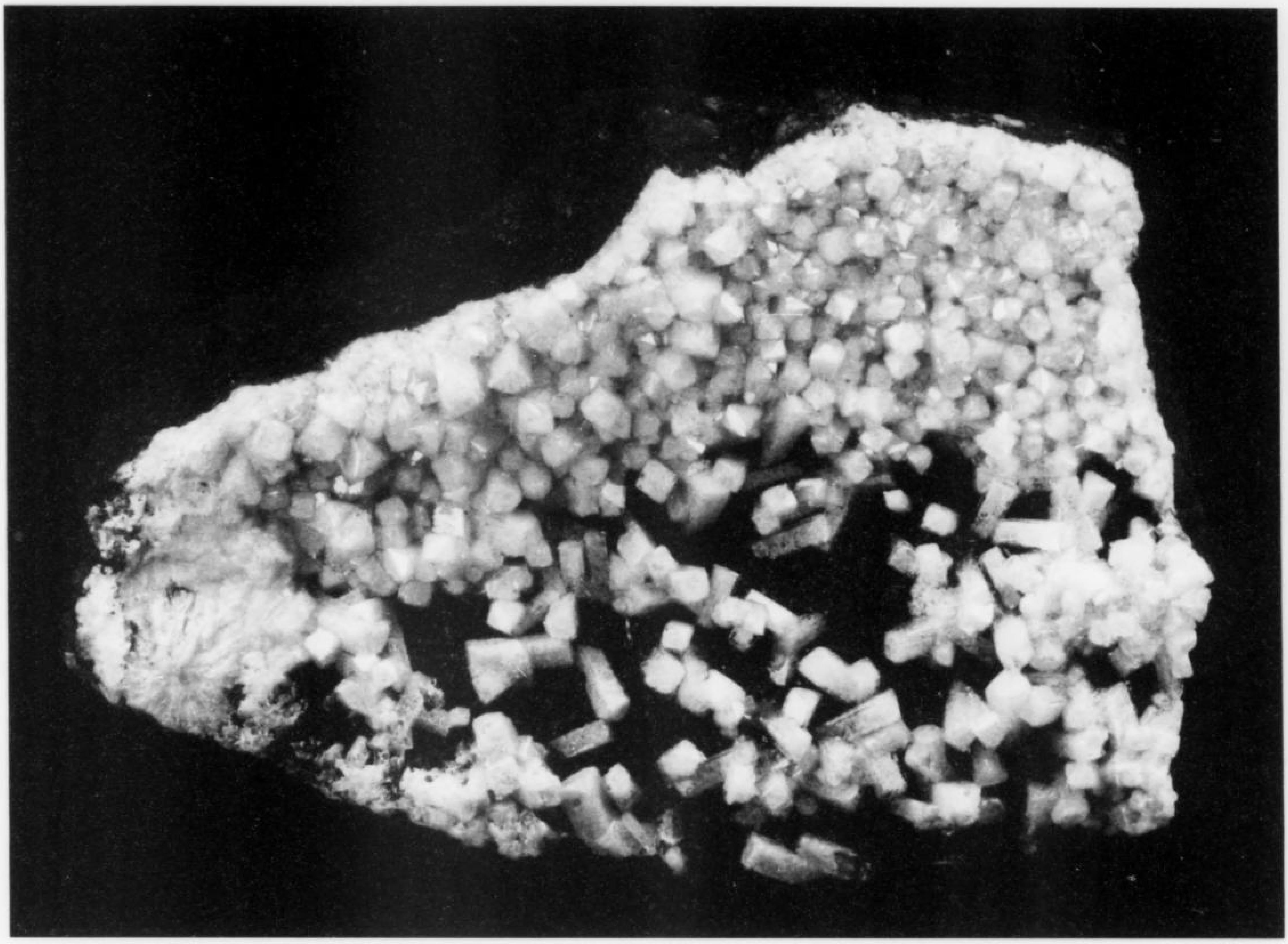


Figure 3. **Olmiite crystals on matrix, 3 × 4.5 cm, from the N'Chwaning II mine. Renato and Adriana Pagano collection, no. 8786; Roberto Appiani photo.**

The poldervaartite structure, discussed in detail by Dai *et al.* (1993), includes two sites, *M*1 and *M*2, hosting divalent ions: Ca resides in *M*1, while *M*2 hosts dominant Ca and subsidiary Mn. The type material came from a pocket in massive braunite and hausmannite and was associated with henritermierite, calcite, bultfonteinite and hematite. This association suggests that the minerals were deposited by hydrothermal fluids rich in Ca, SiO_2 and CO_2 circulating in the Mn-rich host rock. The original poldervaartite crystals were described by Dai *et al.* (1993) as having a wheat-sheaf to euhedral habit, with colorless, transparent cores and milky white rims. The electron probe microanalyses did not show any compositional variation related to this zoning.

At least five (limited) finds of this mineral in fine pink to peach-colored crystal aggregates and sprays of small amber-colored prismatic crystals have been reported (Cairncross *et al.*, 1997 and 2002). Some of these finds occurred before poldervaartite was studied and named, but all available specimens soon disappeared from the collector market. Thus the poldervaartite from the Wessels mine can be considered uncommon, if not rare.

"POLDERVAARTITE"—N'CHWANING II MINE

In the last months of 2001, very attractive new specimens from another location in the Kalahari Manganese Field, the N'Chwaning II mine, became available. Some of these specimens show whitish to cream to flesh-pink crystals. The broken sections are opaque and pink, with a sheaf-like structure. In other specimens the mineral forms cream to pink crystals on matrix, often as cauliform crystal aggregates up to 3 cm in diameter, or with cream to orange-colored crystals, commonly in globular or wheat-sheaf aggregates and as crystals on matrix. In some cases both the individual crystals and the crystal aggregates are glassy, pink to raspberry-red in color, shiny and sparkling, and form very showy and desirable matrix specimens. Frequently the prismatic crystals are nice and lustrous on the outside but, when broken, they show a very porous, corroded internal structure.

The various habits of this mineral are illustrated and described in detail by Cairncross *et al.* (2002). The N'Chwaning II material is similar to the Wessels mine poldervaartite in crystal shape, color and general external characteristics, and they both fluoresce a deep red color under shortwave ultraviolet light. Thousands of these specimens from the N'Chwaning II mine were collected and sold as poldervaartite.

OLMIITE—A NEW SPECIES

The purpose of the investigation carried out at the Earth Science Department of the University of Florence, Italy was to determine if the mineral from the N'Chwaning II mine is indeed poldervaartite. The results of this investigation are reported in detail by Bonazzi *et al.* (2007).

In summary, it was found that in the three N'Chwaning II mine samples examined, Mn largely prevails over Ca in the *M*2 site. The chemical analyses yielded the formula:

$$(Ca_{2-x}Mn_xFe_y)[SiO_3(OH)](OH)$$
$$\text{with } x = 0.84\text{–}0.86 \text{ and } y = 0.01,$$

ideally:

$$CaMn[SiO_3(OH)](OH).$$

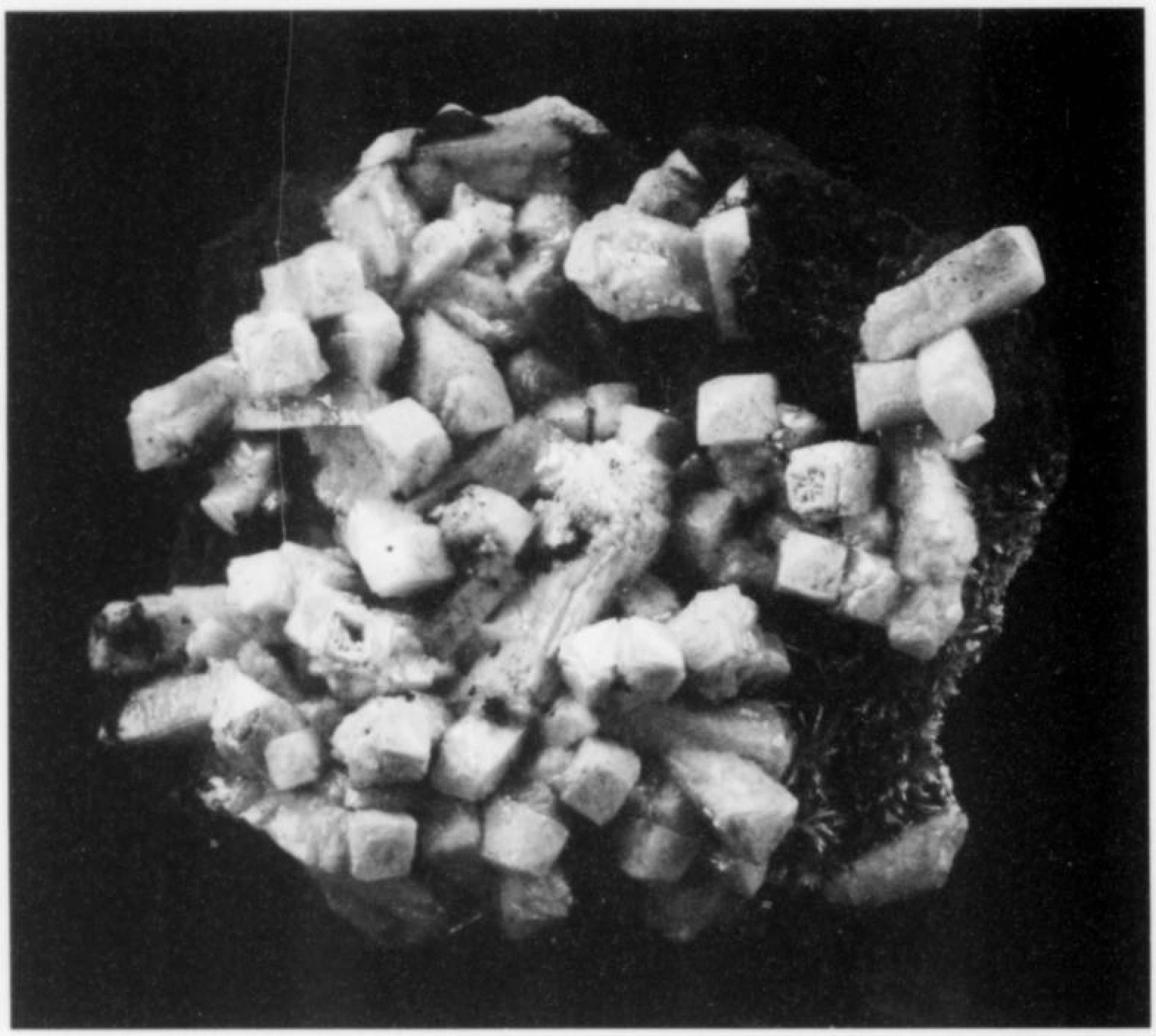
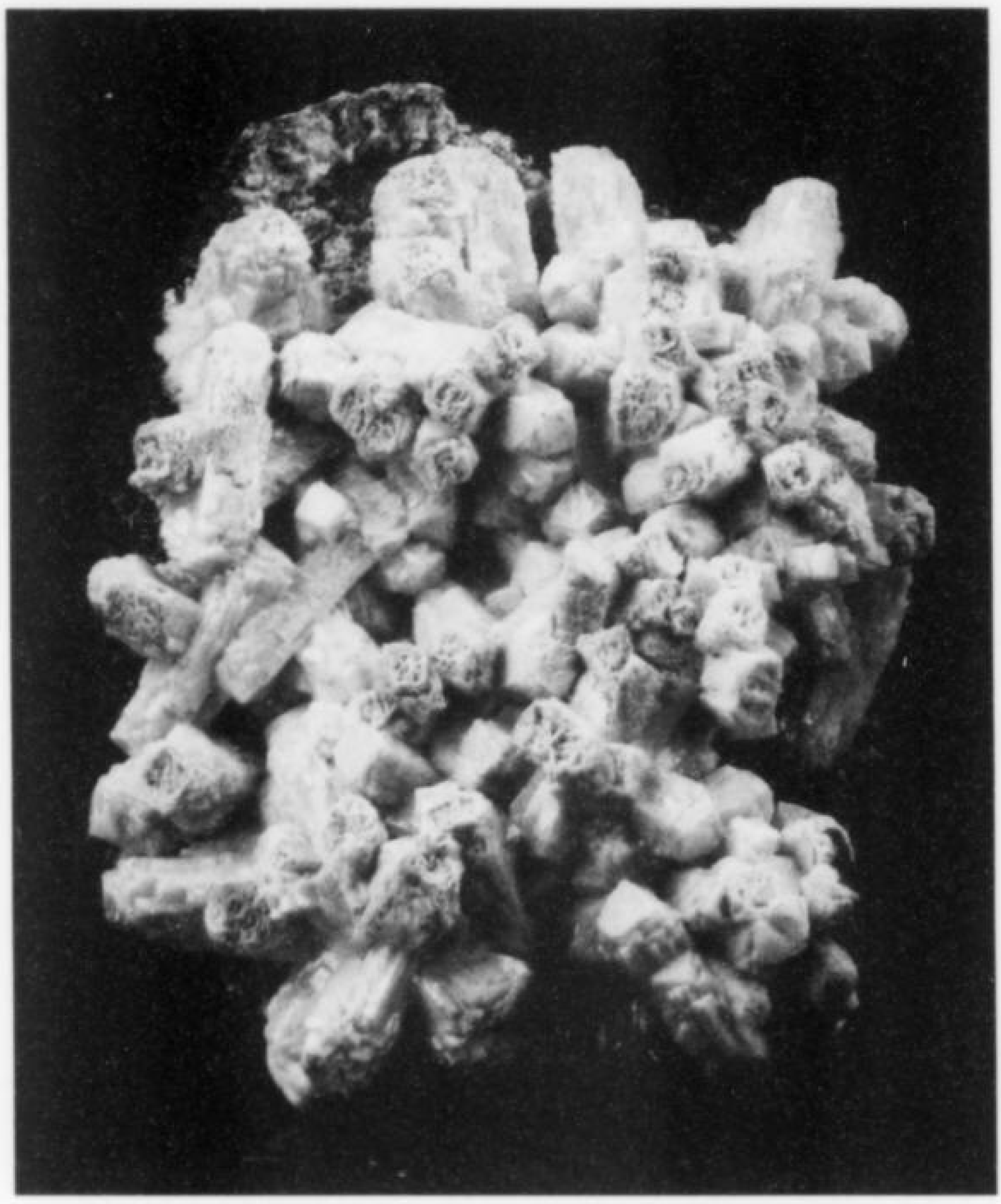


Figure 4. **Olmiite crystals, on matrix, 3.5 × 4.5 cm, from the N'Chwaning II mine. Some of the crystals show the typical internally corroded structure. Renato and Adriana Pagano collection, no. 8787; Roberto Appiani photo.**

Figure 5. **Olmiite crystals (to 1.5 mm) showing typical internal corroded structure, on matrix, 5 × 6 cm, from the N'Chwaning II mine. Renato and Adriana Pagano collection, no. 8279; Roberto Appiani photo.**



This allowed the authors to define a new species, the Mn-dominant analog of poldervaartite, duly submitted to the International Mineralogical Association and approved with the name of *olmiite*. The name honors Filippo Olmi (1959–2005), in recognition of his mineralogical work at the CNR-Istituto di Geoscienze e Georisorse of Florence, Italy.

Olmiite is orthorhombic, space group *Pbca*, and is isostructural with poldervaartite, with Mn prevailing over Ca in the *M*2 site, causing a significant difference in the unit cell parameters and cell volume. The optical properties are also a little different.

OLMIITE—AN EXPERIMENTAL REVIEW

The crystal habit and most other physical properties of the two minerals (Table 1) are very similar. Therefore the original description is not of much use in distinguishing olmiite from poldervaartite, nor does it indicate whether the two minerals coexist at the same locality or in the same specimen. To distinguish the two species from each other it is necessary to perform accurate analyses, either chemical (to determine the Mn:Ca ratio), or by X-ray diffraction (to measure the unit cell parameters)—not an easy task for the many collectors who own specimens of the N'Chwaning II material. Consequently, further work was carried out to address the questions still open on the poldervaartite vs. olmiite problem.

After a preliminary examination of the material available, consisting of about 25 specimens from the N'Chwaning II mine, the following samples, representing the various habits of crystals and crystal aggregates, colors etc. were selected, embedded in resin and polished:

no. 8280b	Red crystal, glassy rim, pink core
no. 8281b	Red crystal, glassy rim, pink core (cross-section)
no. 10278b	Pink-grayish crystal with oyelite (cross section)
no. 8787c	Pale brown crystal; porous, corroded-looking core
no. 10280b	Red crystal aggregate, glassy rim, pink radiating core structure
no. 10279	Pink cauliform crystal aggregate, radiating structure

A first set of data were obtained at the Natural History Museum of Milan (Italy) using their scanning electron microscope JEOL 5610LV equipped with a Gresham EDXS microprobe. Backscatter images were obtained and semi-quantitative analyses were conducted, showing significant contents of Mn which indicated that most or all the specimens examined were olmiite.

Quantitative analyses were then performed on the same samples at the Department of Geosciences, University of Padua (Italy), using a WDS electron microprobe CAMECA SX 50 with a detection limit

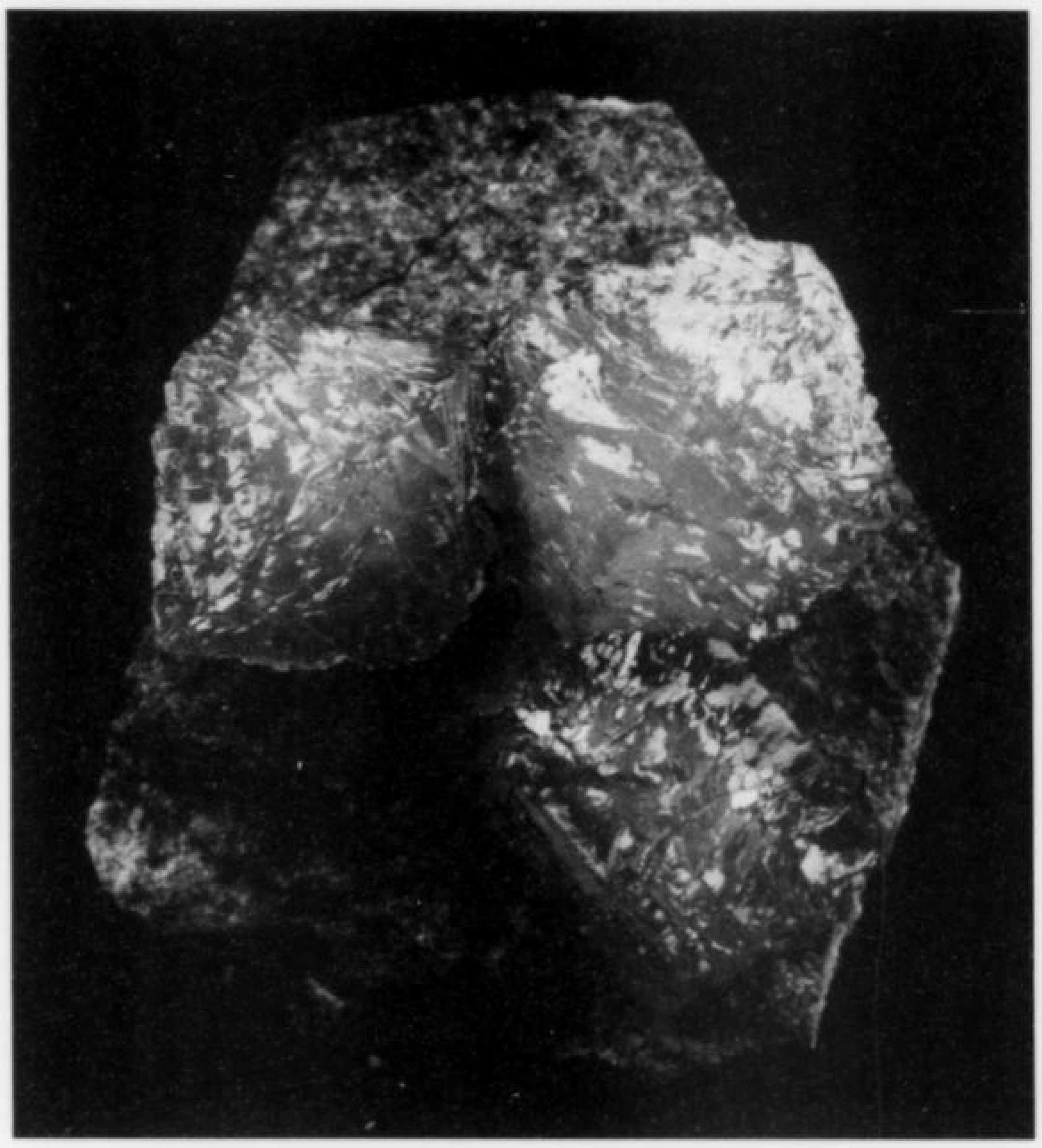


Figure 6. **Red olmiite crystals on matrix, 3 × 2.5 cm, from the N'Chwaning II mine. Renato and Adriana Pagano collection (no. 8281); Roberto Appiani photo.**

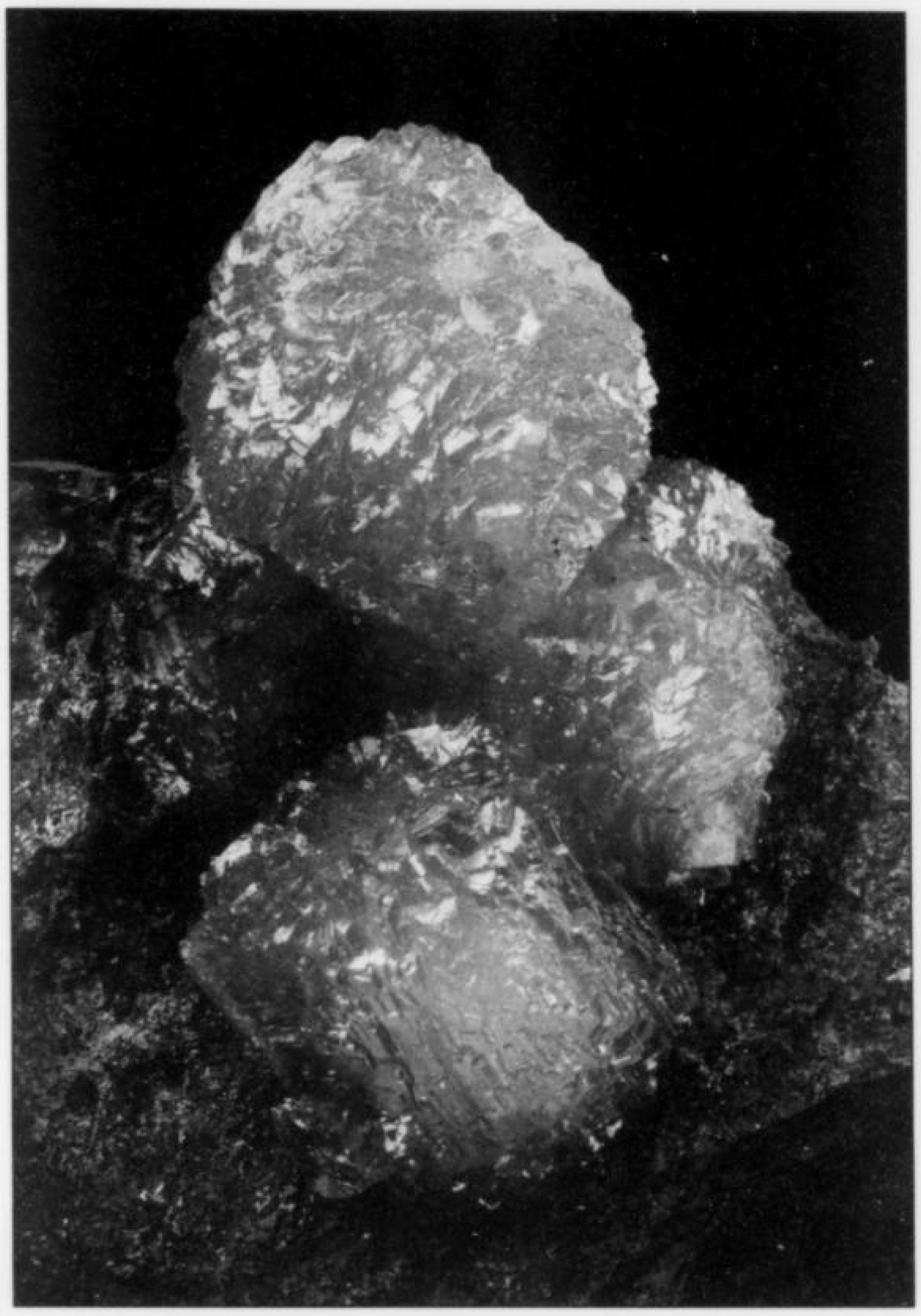


Figure 7. **Red olmiite crystal aggregates, 4 × 2.5 cm, from the N'Chwaning II mine. Renato and Adriana Pagano collection, no. 8280; Roberto Appiani photo.**

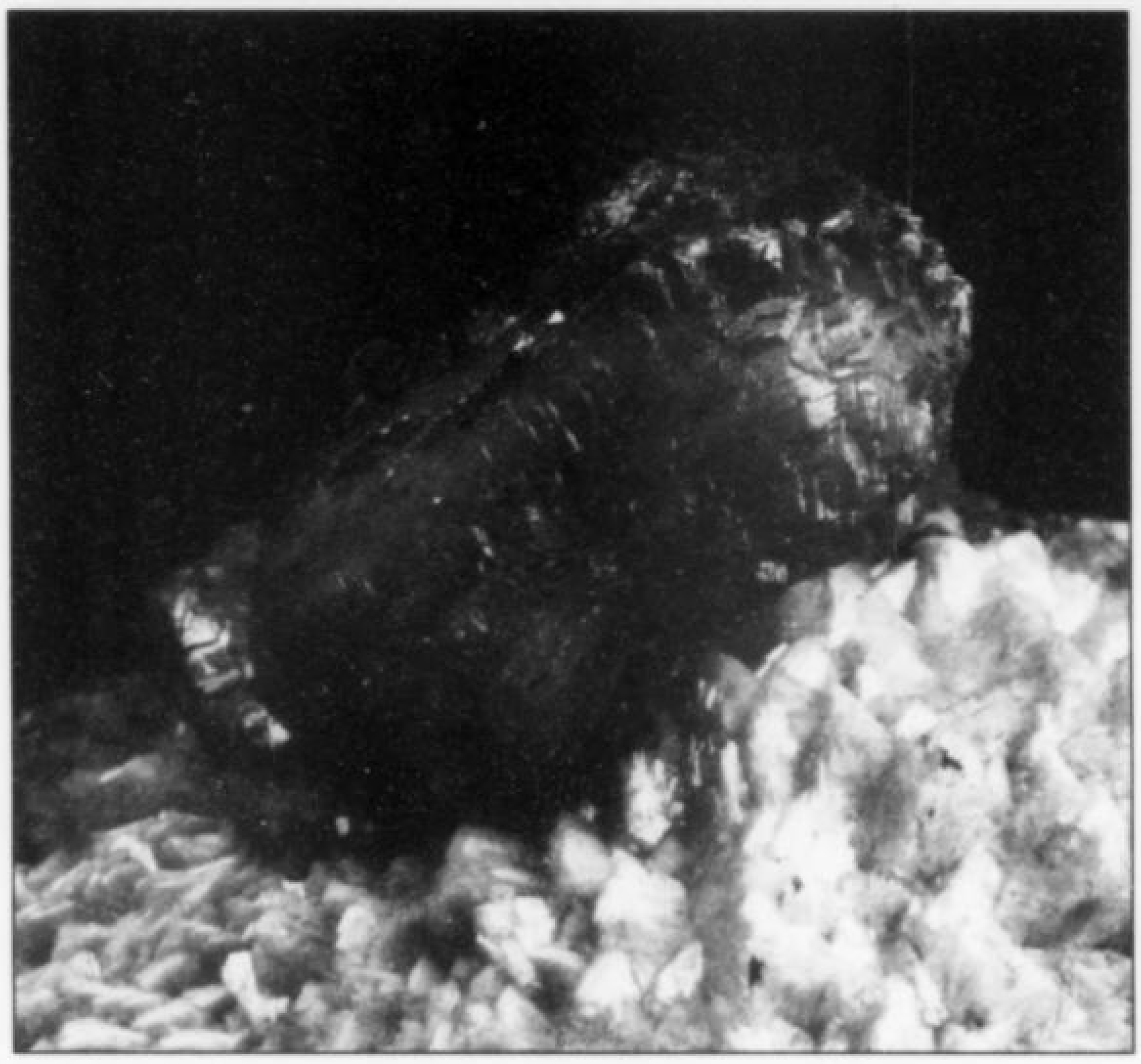


Figure 8. **A second-generation 2-cm olmiite crystal on a druse of primary olmiite crystals, from the N'Chwaning II mine. Renato and Adriana Pagano collection, no. 10280; Roberto Appiani photo.**

of 0.02 wt%, 20 kV accelerating voltage, 20nA sample current and 1–2μm beam diameter. The results of the analyses (average of three spots per area of the specimen) are reported in Table 2.

Some of the material made available for the original work by Bonazzi *et al.* (2007) was also re-examined (L. Bindi, personal communication). The results of the microprobe and single crystal X-ray diffraction analyses performed with the same equipment and methods described by Bonazzi *et al.* (2007) in the original work indicated that all of the specimens examined are olmiite.

The first conclusion is that all of the analyses show a marked Mn dominance in the *M*2 site, even higher than that reported in Bonazzi *et al.* (2007): several of the specimens analyzed are very close to being end-member olmiite. Since the specimens are representative of the different colors and crystal aggregation habits of the material from the N'Chwaning II mine, it can safely be concluded that they should all be called olmiite.

The pink-reddish crystals similar to those of specimens 8280 and 8281 show a deeper pink inner core, and a glassy, almost colorless outer layer. Therefore both the central areas and areas near the external rim of some crystals were examined. Many spots of specimen 8280b were analyzed, traversing along a straight line from the rim to the core. The results show that the sample is all olmiite, with Mn content decreasing, and Ca increasing, from rim to core.

An X-ray powder diffraction analysis was carried out on specimen 8280b using a Phillips X-Pert Pro powder diffractometer. The results confirmed the presence of prevalent olmiite with minor hematite, most likely finely dispersed as inclusions in the olmiite.

The refined cell parameters of olmiite obtained by the Rietveld method were found to be:

a = 9.2672(2) Å
b = 9.0640(2) Å
c = 10.4042(2) Å
V = 873.934(21) $Å^3$

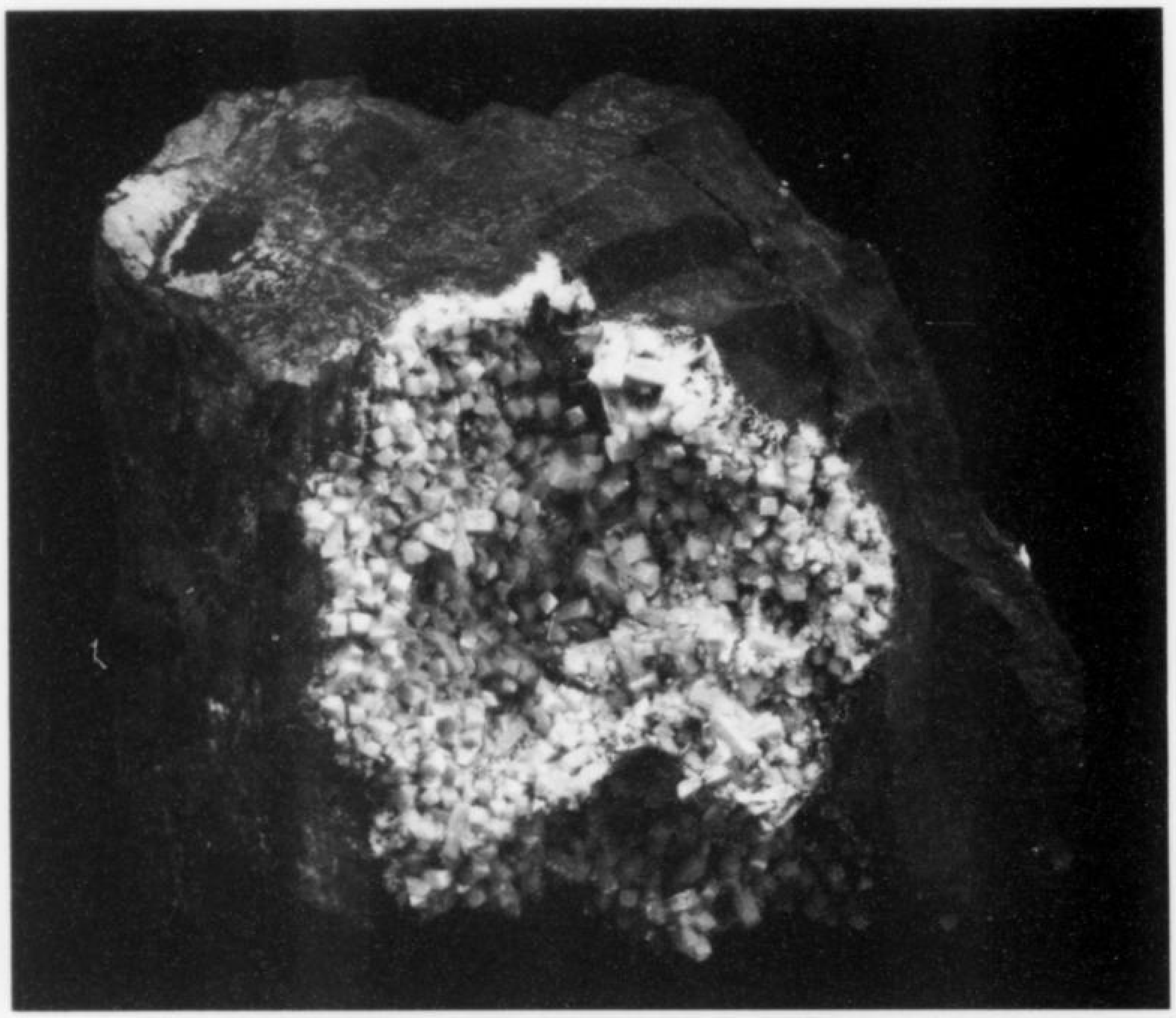
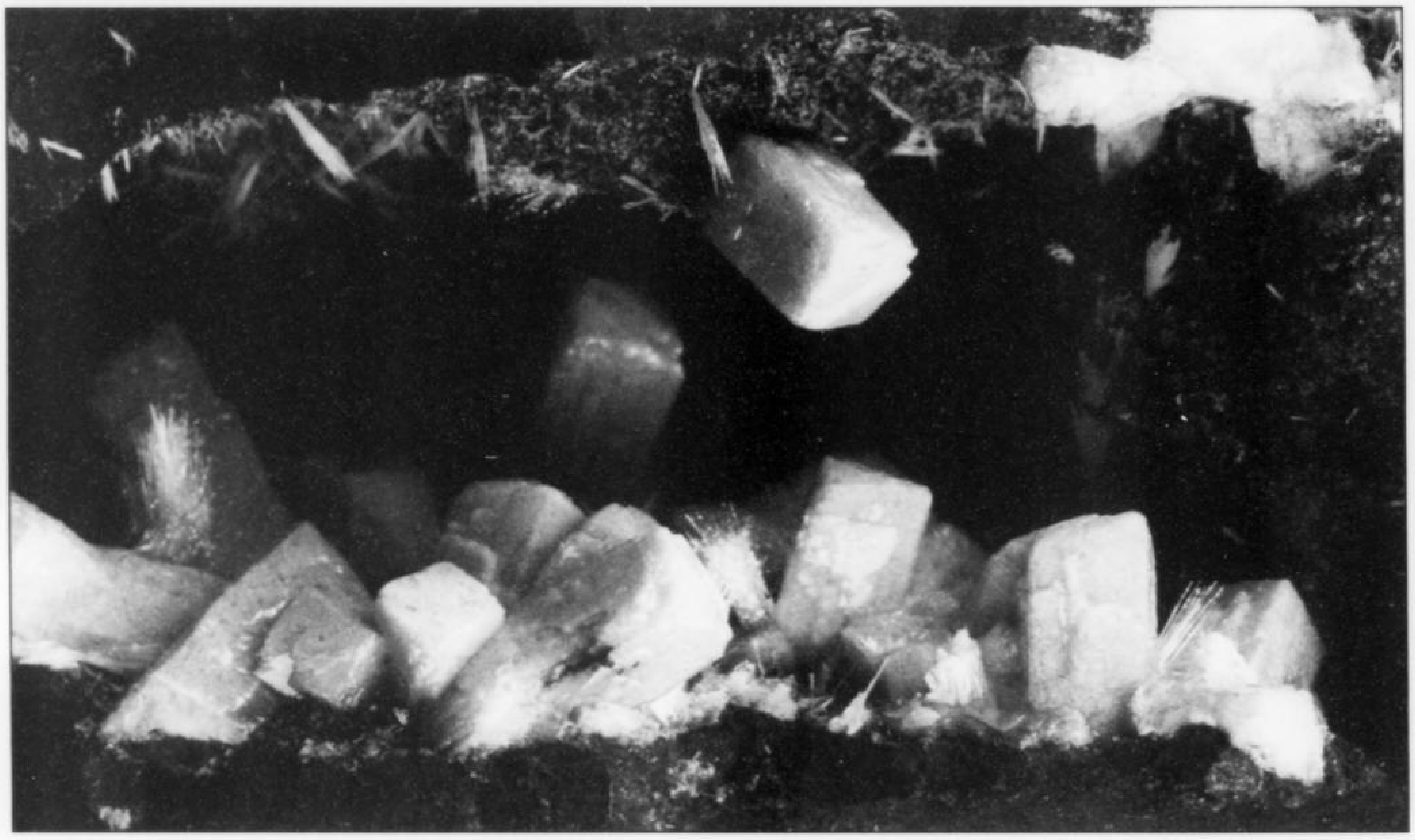


Figure 9. **A cabinet specimen of olmiite crystals on matrix, 10 × 11 cm, from the N'Chwaning II mine. Renato and Adriana Pagano collection, no. 10216; Roberto Appiani photo.**

Figure 10. **Olmiite crystals, 3 to 5 mm, with acicular celestine crystals, from the N'Chwaning II mine. Renato and Adriana Pagano collection, no. 10216; Roberto Appiani photo.**



All are in good agreement with values reported by Bonazzi *et al.* (2007) for olmiite.

The present investigation addressed mainly the N'Chwaning II material, but two samples from the type locality, the Wessels mine, were also considered. A first specimen, similar to that shown by Cairncross (1997), page 121 (Dixon collection) has sharp, transparent pink crystals associated with yellow sturmanite and acicular celestine. A crystal taken from that specimen was analyzed at the University of Florence (L. Bindi, personal communication) by single crystal X-ray diffraction. The refined unit cell parameters were found to be:

a = 9.396(2) Å
b = 9.139(1) Å
c = 10.378(3) Å
V = 891.1(4) Å^3

All are in good agreement with the parameters published by Dai *et al.* (1993) for poldervaartite.

A second specimen, very similar to that in the Desmond Sacco collection, shown in Cairncross *et al.* (2000), p. 338, and Cairncross (1997), p. 121, was analyzed by electron microprobe. The chemical analysis results (Table 3) show that the CaO content ranges between

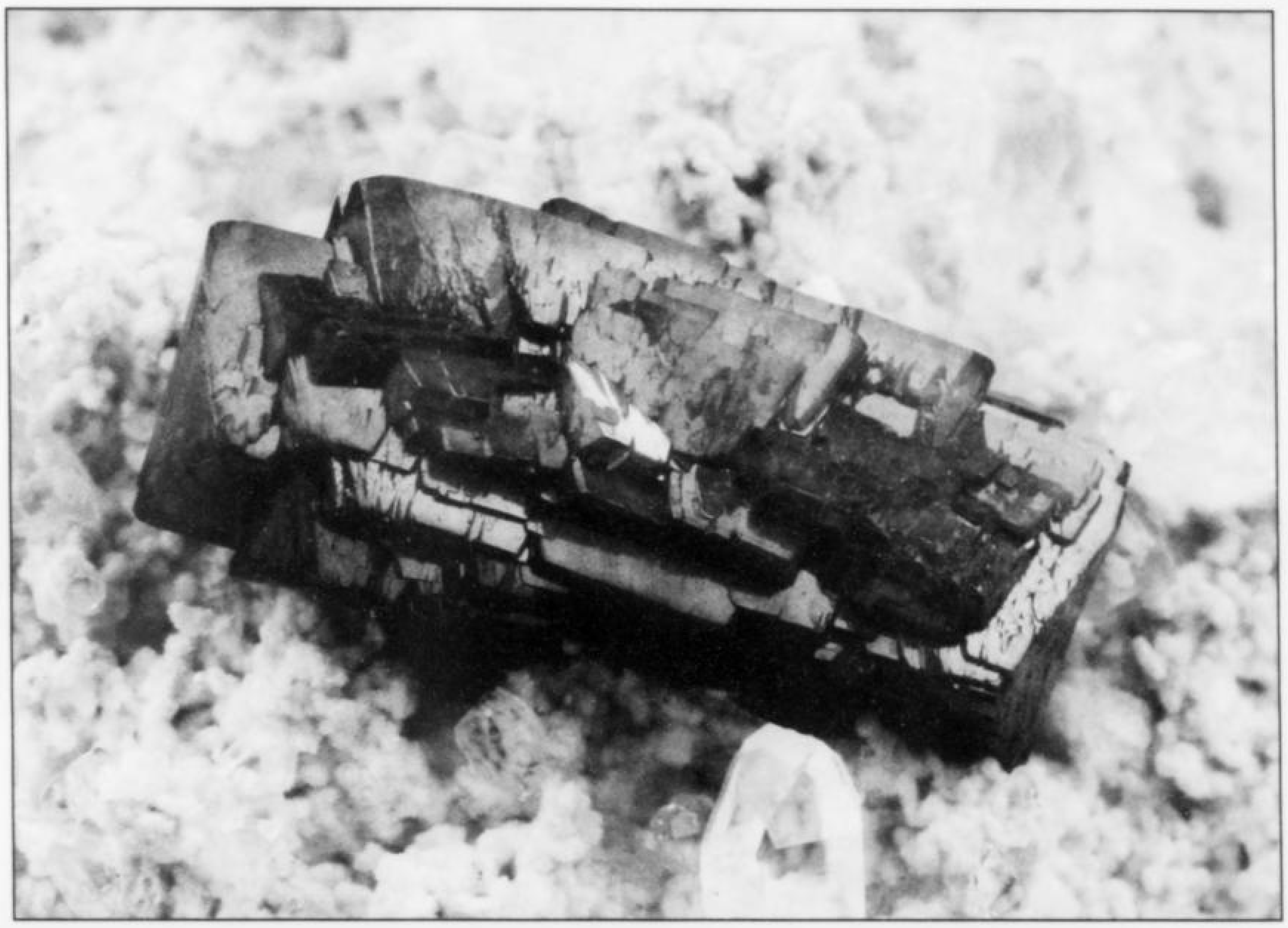


Figure 11. **Doubly terminated, 1.5-cm olmiite crystal on matrix covered by small acicular oyelite crystals, with colorless, perfectly clear calcite crystals, from the N'Chwaning II mine. Renato and Adriana Pagano collection, no. 10278; Roberto Appiani photo.**

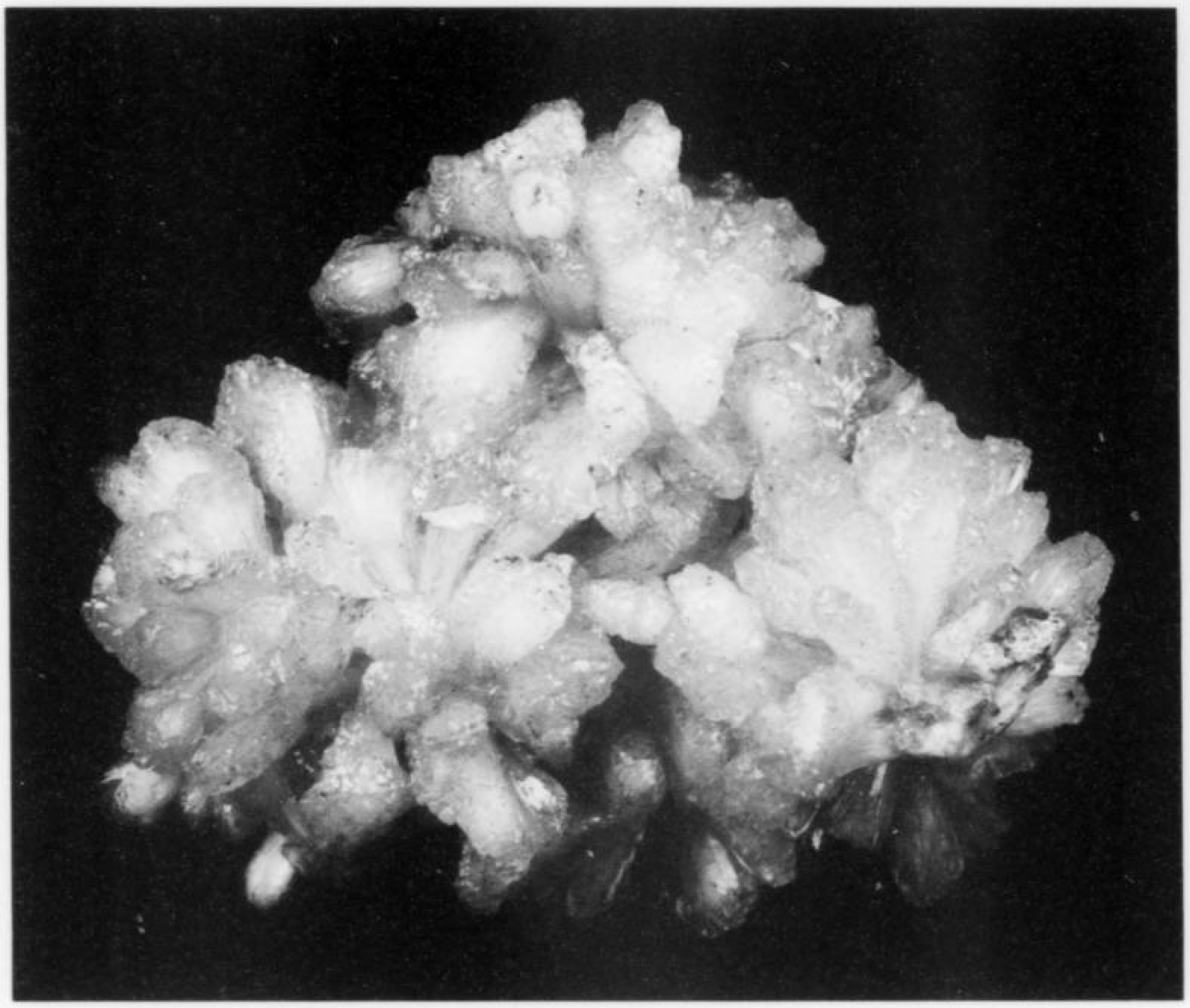


Figure 12. **Poldervaartite-olmiite crystal aggregate, 3.5 × 4.5 cm, from the Wessels mine. Renato and Adriana Pagano collection, no. 6810; Roberto Appiani photo.**

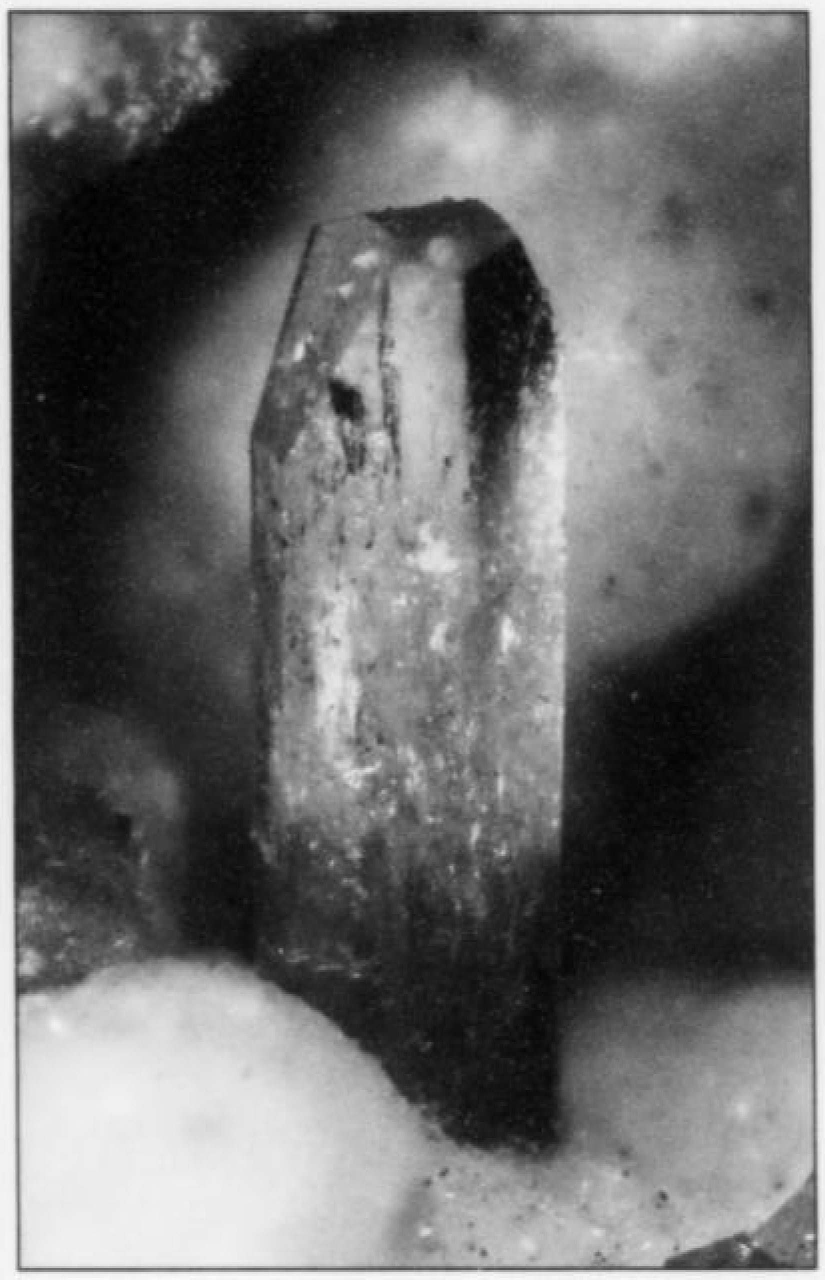


Figure 13. **Transparent, 1.5-mm poldervaartite crystals with celestine and sturmanite on matrix, 3.5 × 4.5 cm, from the Wessels mine. Renato and Adriana Pagano collection, no. 7172; Enrico Bonacina photo.**

40.54 and 41.26 wt%, much higher than in any of the N'Chwaning II specimens. The Mn atoms per formula unit are slightly less than the Ca apfu at some points and slightly above at others. Thus this specimen contains both poldervaartite and olmiite.

CONCLUSIONS

All the specimens of "poldervaartite" collected at the N'Chwaning II mine in 2001 and later can reasonably be attributed to olmiite, as no poldervaartite was detected in samples showing different habits, crystal aggregations and colors. The Wessels mine specimens most likely contain real poldervaartite and, in some cases, also olmiite.

Thus poldervaartite remains a rare mineral, while olmiite is a new species that, unlike many new minerals approved in recent years, is well crystallized, fairly abundant and forms very attractive specimens, from micromount size to cabinet specimens—a real blessing for all mineral collectors!

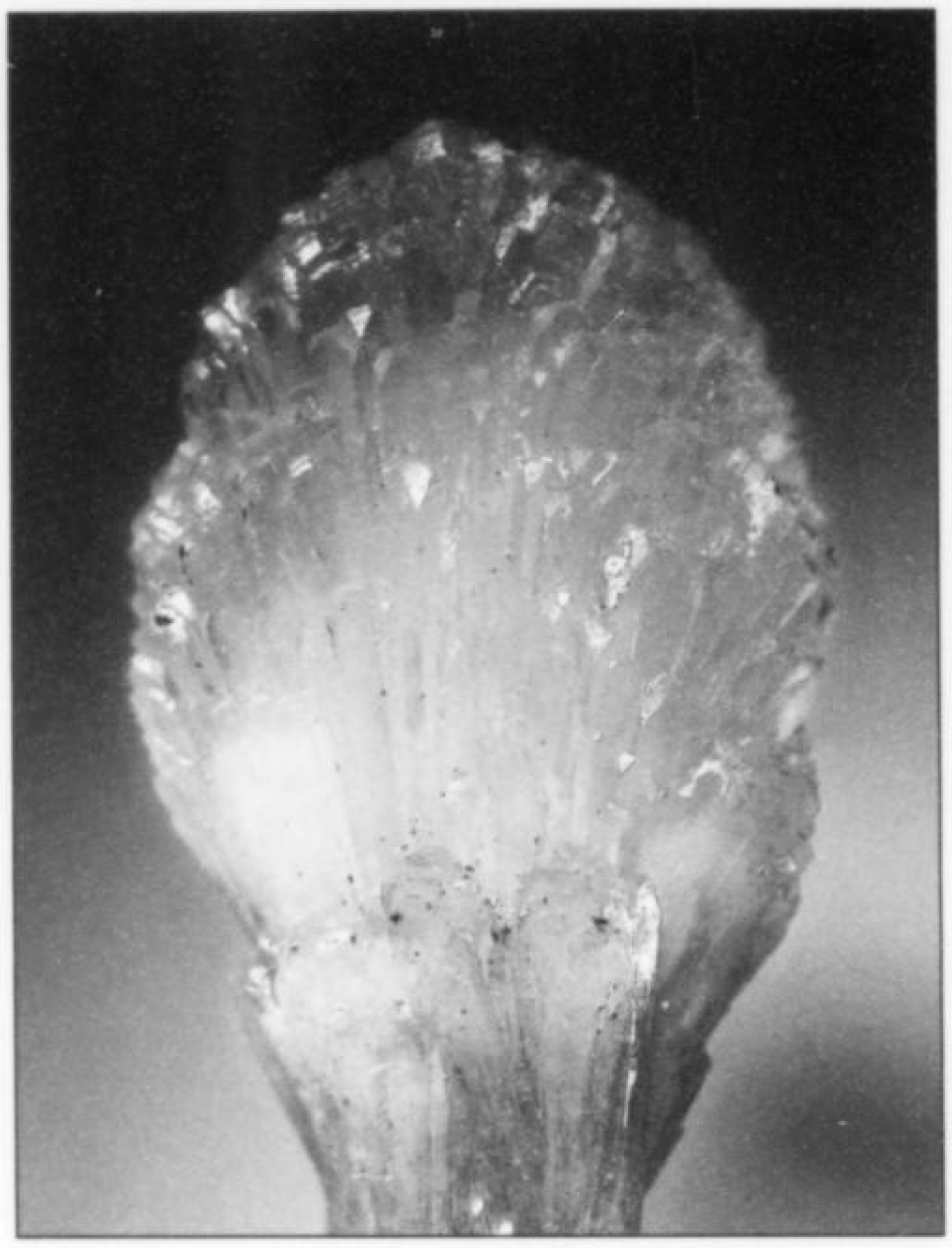


Figure 14. **Poldervaartite-olmiite fan-shaped crystal aggregate, 1.2 cm, from the Wessels mine. Renato and Adriana Pagano collection, no. 6810b; Enrico Bonacina photo.**

Figure 15. **SEM backscatter image of olmiite near the rim of specimen no. 8280b, showing brighter areas with higher Mn content.**

Table 1. **Comparison of poldervaartite and olmiite.**

	Poldervaartite *from Dai et al. (1993)*	**Olmiite** *from Bonazzi et al. (2007)*
Authors' analysis	$(Ca_{2-x}Mn_x)SiO_4 \cdot H_2O$, with $x = 0.28$–0.52	$(Ca_{2-x}Mn_xFe_y)[SiO_3(OH)](OH)$ with $x = 0.84$–0.86, $y = 0.01$
Authors' proposed ideal formula	$Ca(Ca_{0.5}Mn_{0.5})(SiO_3OH)(OH)$,	$CaMn[SiO_3(OH)](OH)$
IMA accepted formula	$Ca(Ca,Mn)(SiO_3OH)(OH)$	$CaMn[SiO_3(OH)](OH)$
Density, g/cm^3	2.91	3.05
Hardness, Mohs	5	5–5½
Cleavage	None	None
Habit	Wheat-sheaf to euhedral prismatic	Wheat-sheaf to euhedral prismatic
Color	Colorless to milky white	Pale to reddish pink
Fluorescence .(SW UV light)	Deep red	Deep red
Tenacity	Very brittle	Very brittle
Symmetry	Orthorhombic	Orthorhombic
Space group	*Pbca*	*Pbca*
Cell parameters	a 9.398(1) Å	9.249(3) Å
	b 9.139(2) Å	9.076(9) Å
	c 10.535(2) Å	10.342(9) Å
	V 904.8(3) Å^3	868(1) Å^3

Table 2. **Analyses of typical N'Chwaning II mine olmiite specimens.**

	8280b		*8281b*		*10278b*		*8787c*		*10280*			*10279*			
	R	*C*	*R*	*C*	*R*	*C*	*R*	*C*	*R*	*I*	*C*	*R*	*I*	*I'*	*C*
SiO_2	28.10	29.03	28.91	28.84	29.12	29.38	29.17	29.37	29.62	29.01	29.46	29.25	29.10	29.17	29.31
CaO	30.70	32.77	31.45	35.22	27.59	27.64	26.93	27.14	28.65	29.04	27.96	27.78	27.61	27.31	28.12
MnO	29.16	27.07	28.86	24.07	32.91	32.56	34.06	33.42	31.67	31.25	32.16	33.55	32.62	34.16	32.76
Total	87.97	88.87	89.22	88.13	89.62	89.58	90.16	89.93	89.94	89.30	89.58	90.58	89.33	90.64	90.19
Si	0.99	1.00	1.00	1.00	1.01	1.01	1.01	1.01	1.01	1.00	1.01	1.00	1.01	1.00	1.01
Ca	1.16	1.21	1.16	1.30	1.02	1.02	0.99	1.00	1.05	1.08	1.03	1.02	1.03	1.00	1.03
Mn	0.87	0.79	0.84	0.70	0.96	0.95	0.99	0.97	0.92	0.92	0.94	0.97	0.96	0.99	0.95

Notes—Data are average of three spot analyses. R = crystal rim area. C = crystal core area. FeO < 0.02%, instrument detection limit.

Table 3. **Analyses of Wessels mine specimen no. 6810, poldervaartite–olmiite.**

	Point 1	*Point 2*
SiO_2	29.50	29.03
CaO	41.26	40.54
MnO	17.02	18.05
Total	87.78	87.62
Si apfu	1.00	0.99
Ca apfu	1.51	1.49
Mn	0.49	0.52

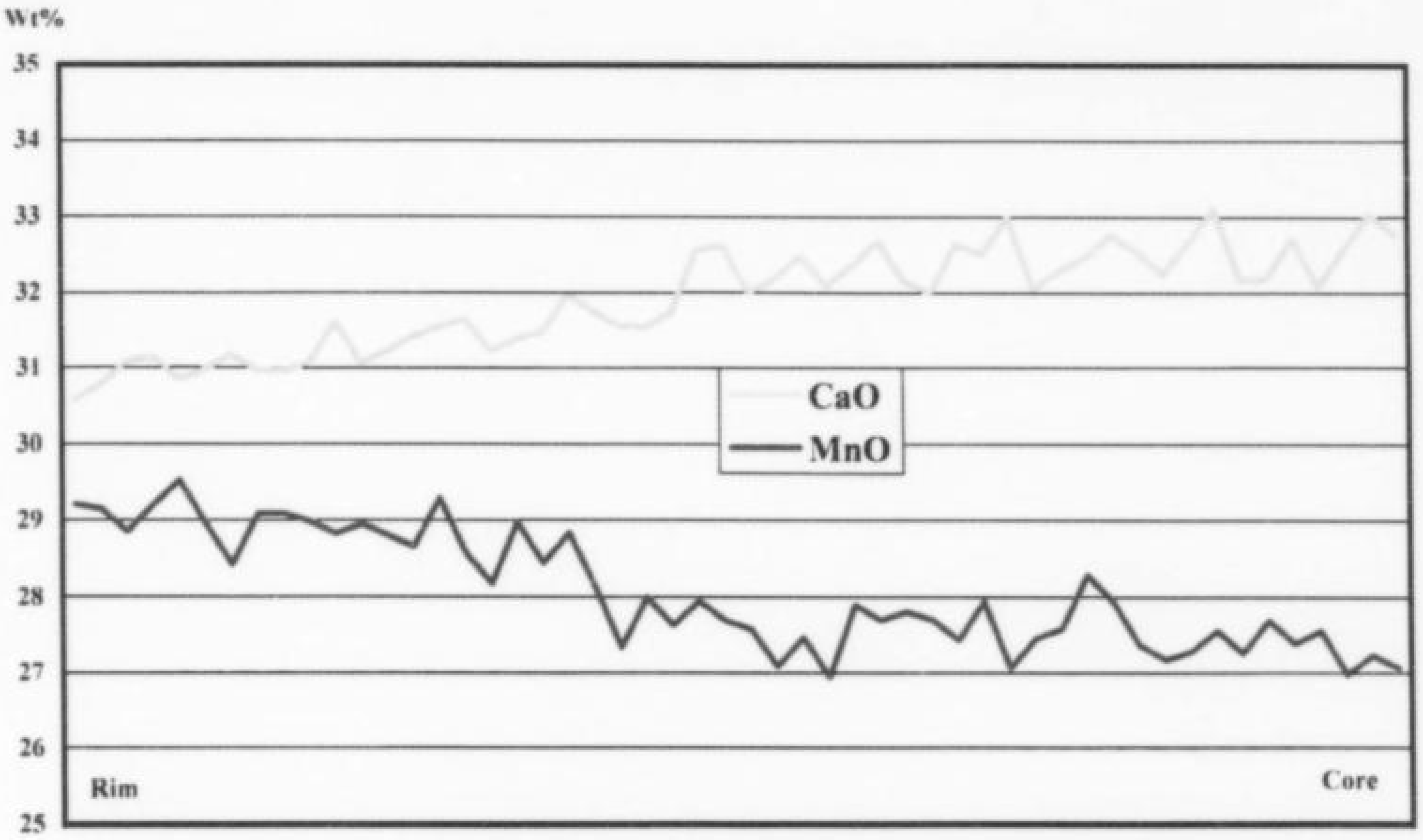


Figure 16. **CaO and MnO variations from rim to core in specimen 8280b. The midpoint in the poldervaartite-olmiite series, where Ca = Mn in the M2 position, is at 42.55 wt.% CaO and 17.94 wt.% MnO. Therefore, with MnO consistently at or above 27 wt.%, specimen 8280b is olmiite, from rim to core.**

ACKNOWLEDGMENTS

The authors wish to thank Paola Bonazzi, Earth Science Department, and Luca Bindi, Natural History Museum, Mineralogy Section, University of Florence, for making available some unpublished data and for offering constructive suggestions. Thanks also to Federico Zorzi and Raoul Carampin, Geoscience Department, University of Padua, for their cooperation in performing X-ray diffraction and electron microprobe analyses.

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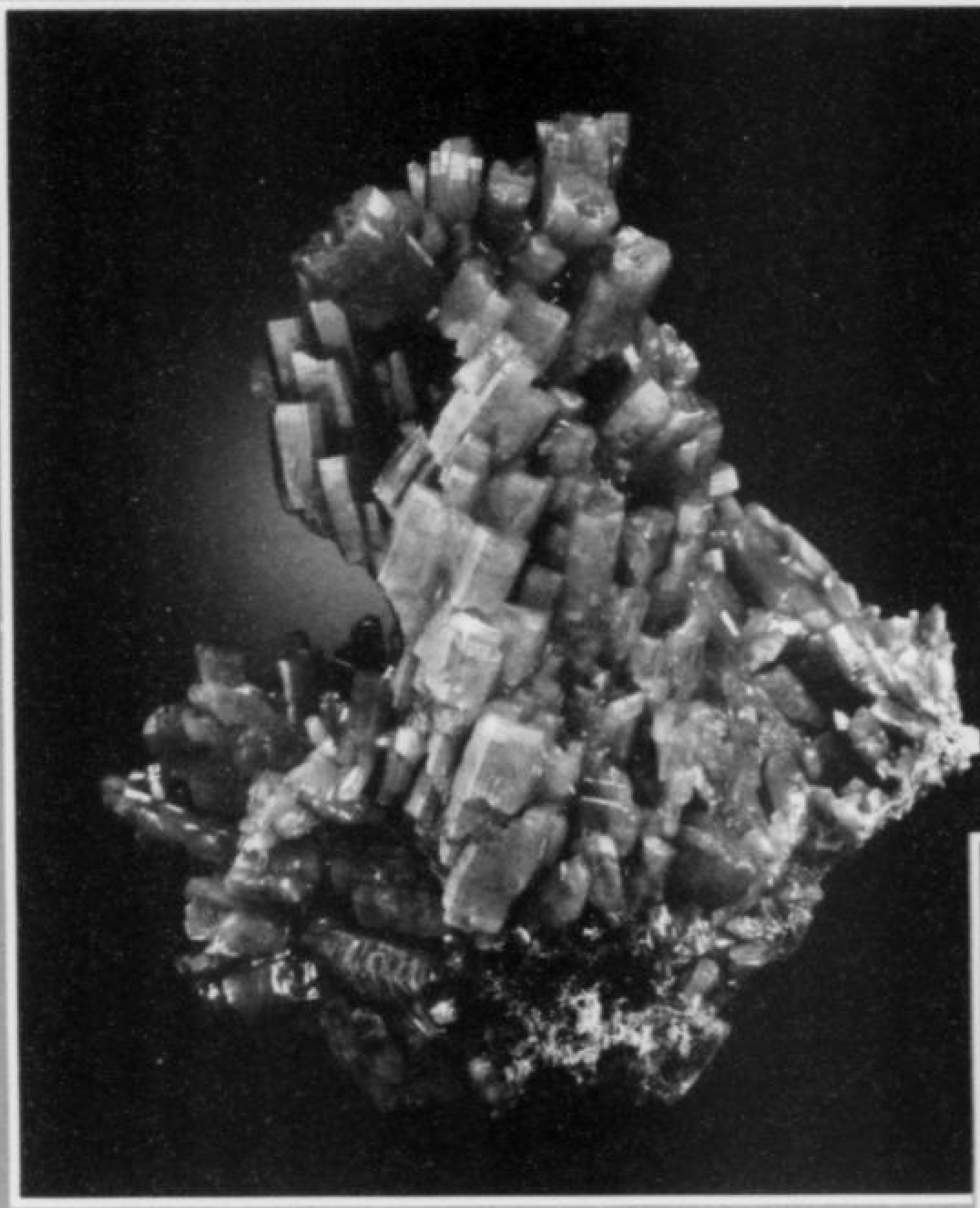

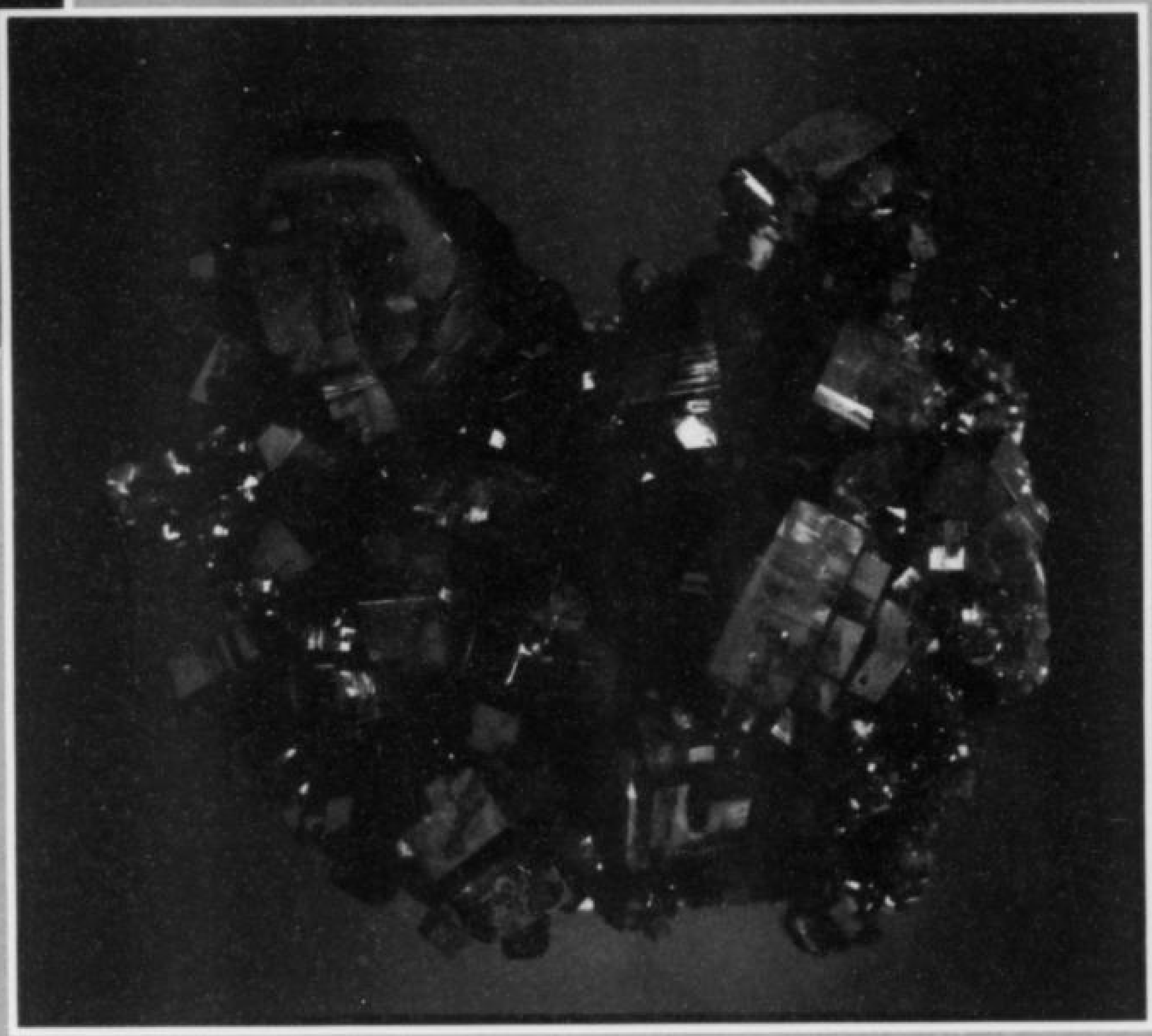

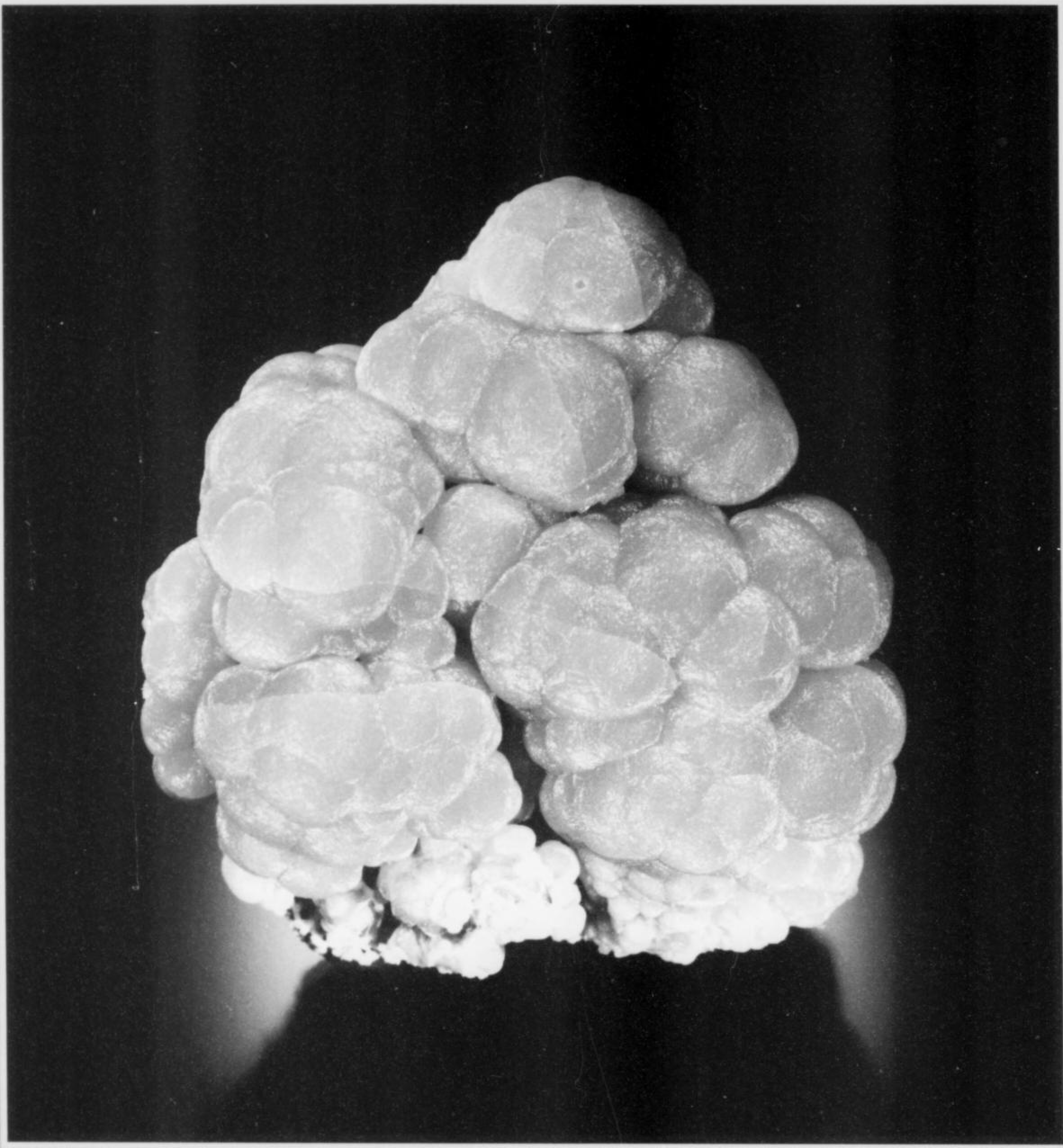

An Appraisal of HAÜY'S WOODEN CRYSTAL MODELS

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The development of the first wooden crystal models for teaching purposes is a little-known chapter in the early history of mineralogy and crystallography. René-Just Haüy, the father of modern crystallography, produced several large sets of models based on his idealized crystal drawings; only two of those sets survive today. Careful measurements show that his models are accurate and true representations of identifiable minerals

INTRODUCTION

In 1918 the Mineralogical Society of America celebrated the 175th anniversary of the birth of Abbé René-Just Haüy with a symposium (Kunz *et al.*, 1918). The 200th anniversary was celebrated by the *Société française de Minéralogie* in Paris in 1944 (Lacroix, 1944). Both symposia highlighted Haüy's life, his genius in offering a theory explaining the geometry of crystals, his work in physics and his work in founding the modern science of crystallography.

Haüy's theory of the geometry of crystals was presented to the *Académie Royale des Sciences* in Paris, France in 1784. It is now formulated as the second law of crystallography (the Law of Rational Indices). His *Traité de Minéralogie*, published in 1801, provided the first rational system for classifying and identifying minerals. In its five volumes Haüy compiled the harvest of 20 years of his own research with all known historical, physical and chemical data, and the results of other researchers for each mineral studied. It contained a nomenclature, using Lavoisier's new chemistry, as well as an ordering of the minerals into classes and genera. However, its true value lay in the descriptions and drawings of the crystals. The drawings and the accompanying interfacial angles of the crystals provided a method of species identification.

None of the lectures in the two commemorative symposia mentioned that Haüy had created still another aid to mineral identification: his collections of wooden models representing all of the described mineral crystals. The existence of those collections seems to have been forgotten, though they played an important role in teaching mineralogy throughout the 19th century. When original collections of wooden models became scarce, early in that century, duplicates were created by Mathieu Alexandre Allizeau (1771–1823?) in Paris and Nathaniel John Larkin (1781–1855) in London. In the second half of the 1800s, Dr. August Kranz in Bonn offered sets of duplicates (Krantz, 1862). Of the seven collections of wooden crystal models made under the direct supervision of Haüy himself, only two have survived.

We will review here the ingenuity of Haüy's work in establishing the foundation of crystallography and mineralogy, and will touch on Haüy's teaching methods that led to the introduction of wooden models in courses on crystallography. Attention is then focussed on our work in identifying the minerals that Haüy studied and modeled. The results, gleaned from stereographic projections of the models, show that Haüy's crystal models are not mere abstractions but are true and accurate representations of many identifiable minerals.

HAÜY'S CRYSTALLOGRAPHY AND IDEALIZED FORMS

In 1784 René-Just Haüy presented to the *Académie Royale des Sciences* the first results of his analyses of crystals by means of cleaving them until a simple shape emerged. At the same time he presented a general theory explaining the underlying geometric

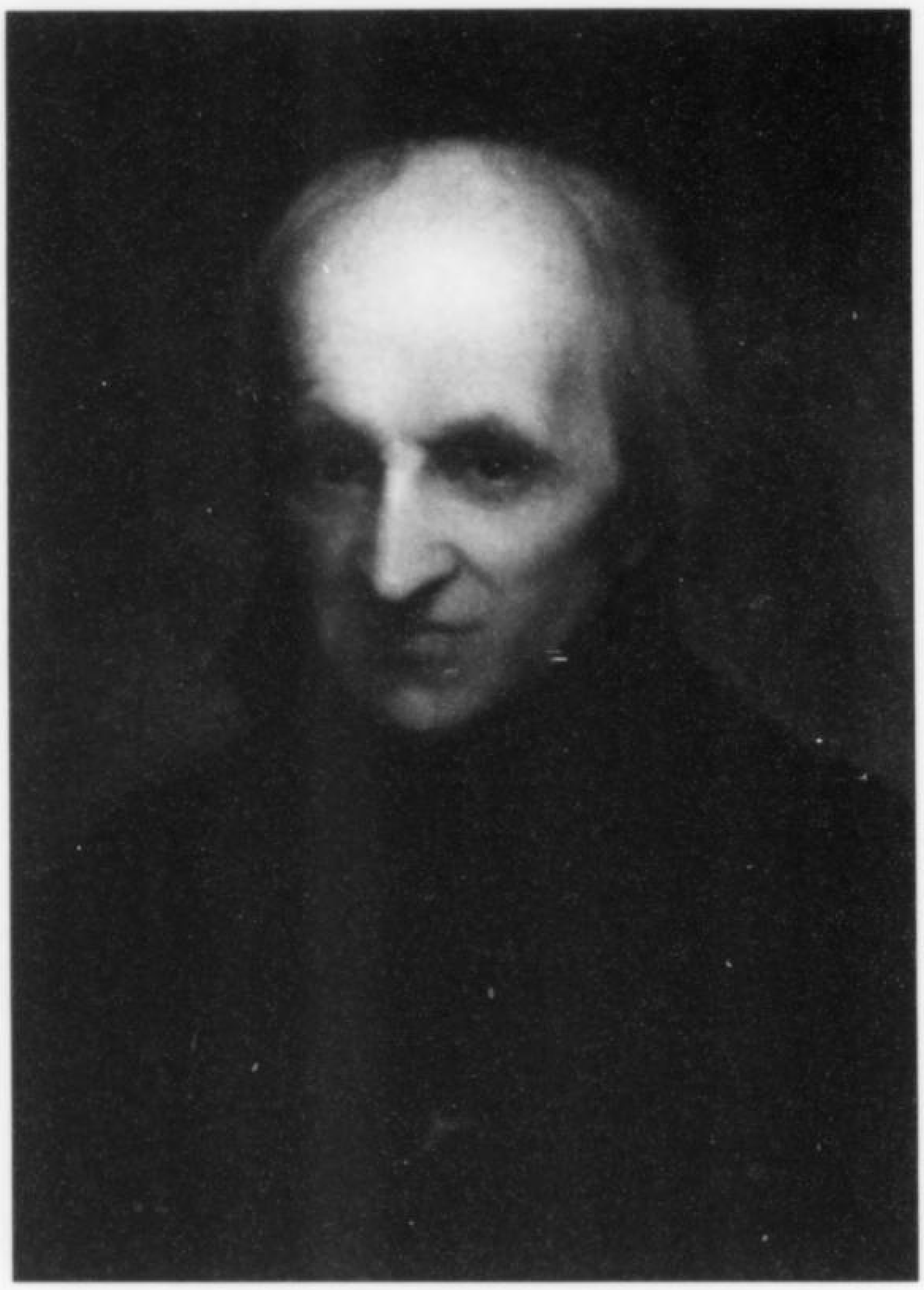
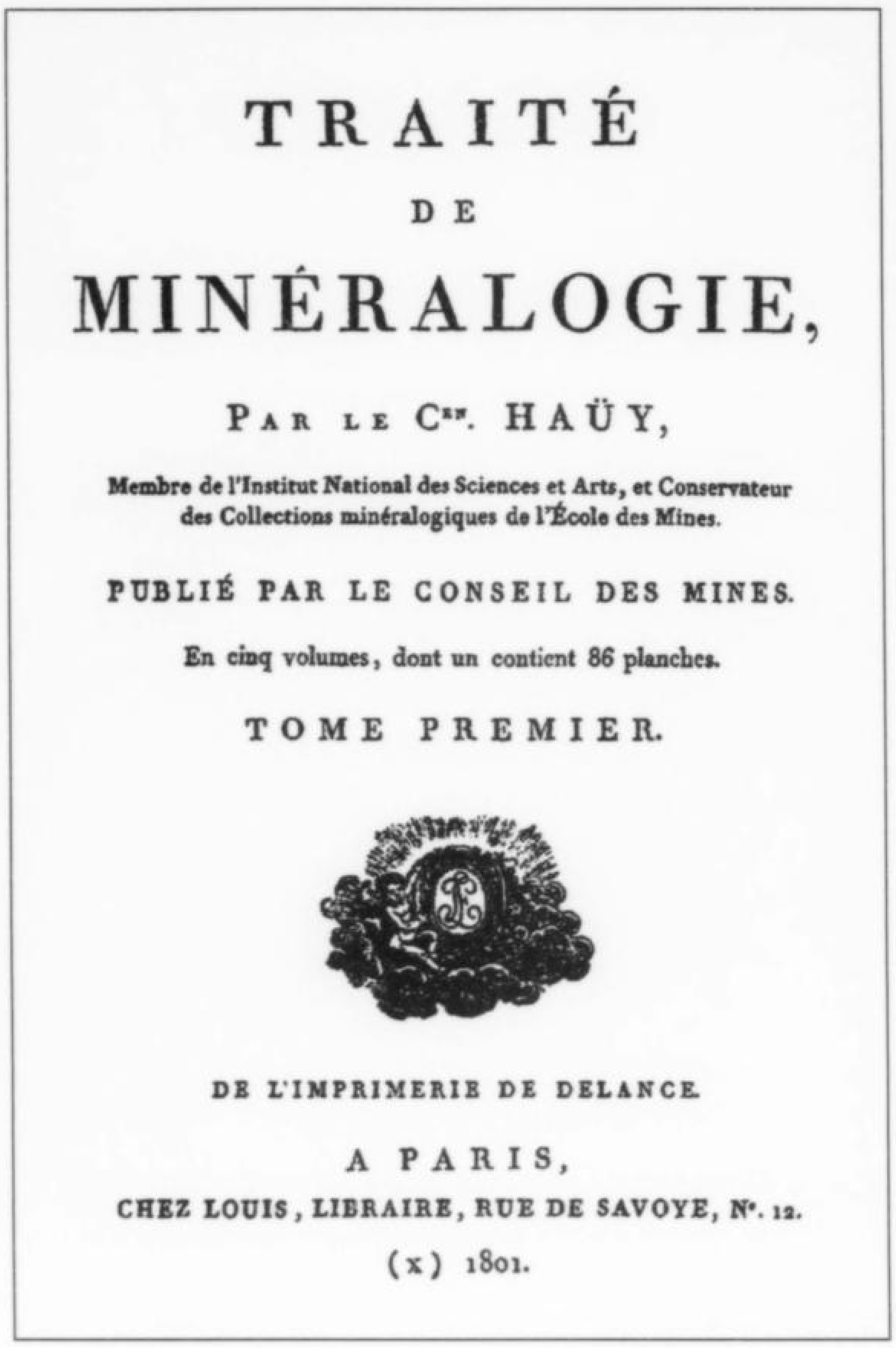


Figure 1. **René Just Haüy (1743–1822), the French abbot who established the foundation of modern crystallography. Portrait by the American artist Rembrandt Peale (1808); collection of Mr. and Mrs. Fred D. Bentley.**



TRAITÉ
DE
MINÉRALOGIE,
PAR LE C^{en}. HAÜY,
Membre de l'Institut National des Sciences et Arts, et Conservateur
des Collections minéralogiques de l'École des Mines.
PUBLIÉ PAR LE CONSEIL DES MINES.
En cinq volumes, dont un contient 86 planches.
TOME PREMIER.

DE L'IMPRIMERIE DE DELANCE.
A PARIS,
CHEZ LOUIS, LIBRAIRE, RUE DE SAVOYE, N^{o}. 12.
(x) 1801.

Figure 2. **The title page of Haüy's ground-breaking work, his Treatise on Mineralogy, published in Paris in year "X," i.e. 1801: the tenth year after 1791, when the new French constitution was ratified following the French Revolution.**

structure of crystals and its relationship to the resulting exterior crystal morphology (Hooykaas, 1994). In the following years he applied this theory to a growing number of mineral species. His studies progressed to a new level when he developed idealized forms and habits for the minerals he studied.

Haüy's Work on Crystals

Haüy's theory of crystals originated with his work on calcite. When cleaving calcite crystals "along their natural joints" he could always find cleavage fragments having a simple rhombohedral shape. He then postulated that all crystals are built up from small blocks of the same shape. Forms like the scalenohedron can be generated by stacking tiny rhombohedrons in a certain way.

To apply this theory to another mineral Haüy had to cleave crystals of it until the most fundamental shape or "kernel" emerged and its angles could be estimated. He then derived the actual crystal faces by stacking the kernel shapes like building blocks and determining the ratio of rows of layers to offsets needed to approximate the angle of a face.

The method worked fine when applied to crystals of sufficient size and cleavability. But when tackling minerals in tiny and distorted crystals, or minerals lacking good cleavage, the method had to be reversed. In those cases the form and dimensions of the kernel were imagined "in analogy" with other cases. The measured interfacial angle gave the slope and from this slope a ratio in small integers could be estimated. Combined results from different slopes could lead to a convincing analysis. Thus in Haüy's method the interfacial angles were the primary data, and geometric calculation became the most important tool. Meanwhile the exterior form gained more importance and the primacy of the kernel diminished.

Haüy's Creation of Idealized Forms

Haüy used the contact goniometer—invented by his friend Arnould Carangeot (1742–1806) and at that time the only instrument available for this purpose—to measure interfacial angles. It was accurate to about a third of a degree. After measuring a certain angle several times, Haüy found that his results might vary by 0.5 degree or more. To overcome this uncertainty, he began by using his best approximation of the angle to draw an orthogonal triangle and determine the ratio of lengths of the triangle's sides. This ratio usually involved two rather high numbers; however, Haüy believed that the "true" ratio must generally involve rather small numbers, so he adjusted the ratio to the nearest low numbers or square roots of low numbers. From this "true" ratio he was then able to calculate a much more precise angle, with a "precision of 1 second of arc." He called this procedure "finding the limit."

He tackled the problem that parts of crystals were hidden in the matrix or ground mass by assuming that the hidden parts of the crystals carried the same faces and symmetry as the visible portions (Blondel-Mégrelis, 1981).

Calculating and sketching, Haüy gradually developed an image of an enlarged and idealized crystal. These images are drawn more or less in perspective in the Atlas, volume five of his *Traité de Minéralogie* (1801). For most minerals, a range of figures is presented, beginning with figures showing a minimum of crystal forms (usually only one) and ending with figures which combine all of the observed forms. There is no proof that Haüy actually saw all of these combination habits in real crystal specimens. Later, in a defense of his method, he pointed out that he did not have complete or undistorted crystals to work with (Haüy, 1818). Nevertheless, in presenting these figures in his mineralogy, he implied that they were all drawings of real crystals rather than abstractions or theoretical composites.

The first 23 plates of the Atlas have no function in the identification. They serve merely to illustrate the geometric theory of Haüy's crystallography. In the other 63 plates some figures refer more directly to Haüy's calculations for particular minerals. Table 1 shows the number of drawings of different kinds in those 63 plates.

HAÜY'S DESIGNATION OF MINERALS AND CRYSTALS

In the Atlas of 1801 the crystal forms, grouped together under specific mineral names, are designated only by figure numbers. A researcher trying to identify minerals from specimens of matrix with only parts of crystals sticking out could find the tentative mineral by comparing the visible forms with the illustrations. The interfacial angles, given in the text volumes, could then provide the identification. The mineral would get a name and even the crystal forms could be listed by names. The flaw in this method was that minerals and habits not yet studied by Haüy could not be identified. However, Haüy himself and all other researchers were free to supplement the method with new data as they became available. Table 2 shows the number of minerals in Haüy's *Traité de Minéralogie* of 1801.

Table 1. **Drawings and crystal forms in the Atlas of Haüy's *Traité de Minéralogie*.**

Application of the drawings	*Number of drawings*
1. drawings of single crystal forms	494
2. drawings of single crystal forms and used for 58 isomorphs	37
3. drawings with lines used for calculating limits	18
4. drawings showing other geometric features	89
5. total of drawings in the Atlas	638

Table 2. **Minerals and crystal forms in the Atlas of Haüy's *Traité de Minéralogie*.**

Mineral classes	*Number of minerals*	*Number of forms*
1. class 1; 'substances acidifères'	14	125
2. class 2; 'substances terreuses'	38	186
3. class 3; 'substances combustibles'	3	13
4. class 4; 'substances métalliques'	39	204+58=262
5. appendix including sahline	3	3
6. minerals without crystal forms	1	
7. total of minerals/forms	98	589

Names of crystal forms

The foundation on which Haüy built his crystallography was the calcite scalenohedron, a form studied and named by Bergman as the *dent de cochon* ("pig's tooth") form. Not only could Haüy cleave a calcite scalenohedron down until the rhombohedron emerged, but he could also derive the scalenohedral shape by stacking up tiny rhombohedrons in parallel (Haüy, 1801). From this Haüy became convinced of the validity of his hypotheses.

A construction of that kind could produce two different scalenohedrons. He therefore renamed the mineral *metastatique* and thereafter he gave all of his idealized forms names. These names are not based on any preconceived idea or system. There are names referring to geometric forms, for example *cubo octaèdre* (a crystal combining the faces of a cube and an octahedron) and names revealing the number of faces, e.g. the name *eptahexaèdre,* meaning seven ranges of six faces. Names referring to special features were also used, such as *épointé*, meaning a truncated crystal. There are even names indicating how the form could emerge by splitting pieces of the kernal shape at the edges and points. Haüy (1822) later provided an explanation of all the names. Although the names themselves are carefully chosen, the medley is clearly the product of a man feeling his way through unknown territory.

Mineral Names

Haüy's division of minerals into classes had nothing to do with symmetry or symmetry elements. It was based instead on chemical differences, in accord with Lavoisier's new chemistry. The first class consisted of the salts of the light metals, i.e. the alkalis. The salts of metals forming ores were brought together in class four. Salts of the same metal were grouped together in subclasses. The minerals of these classes were given chemical names, but to emphasize the priority of the metals Haüy modified the nomenclature of Lavoisier somewhat. Our well-known mineral calcite became C*haux carbonatée* instead of C*arbonate de chaux. Fer sulfuré* and *Fer sulfaté*, quite different but both iron minerals, fell into the same subclass.

The third class consisted of the few minerals that are combustible, for example sulfur and diamond.

The second class had no subclasses. It listed silicates as separate species. Analytical chemistry was at that time still in its infancy and it could not sufficiently characterize the different silicates. Consequently Haüy could not use a chemically based nomenclature for them. Instead he invented names for these minerals derived from Greek terms describing special properties. Dana, nearly 70 years later, criticized Haüy for not using the suffix "*-ite*" in most of these names, ". . . forgetting that the unity of law that he [Haüy] has found in nature should be a feature of scientific language" (Dana, 1868). Abraham Gottlob Werner had already employed this suffix frequently, but most of Werner's minerals having this suffix belonged to Haüy's classes one and four, and were therefore overruled by the chemical nomenclature.

Gratacap (1918) remarked that "Haüy was seriously disturbed by the poor definition of his second class, and hoped that the developing mineral chemistry would throw more light on these minerals." Since Haüy's time chemistry has indeed developed, but it has not been used to produce a good chemical nomenclature for minerals. On the contrary, most minerals today carry names the origin of which is seldom remembered.

HAÜY'S CRYSTAL MODELS

In 1793 Haüy was given a chair in crystallography at the *École des Mines* in Paris. In teaching the intricacies of crystal geometry and morphology, he soon improved his presentations by using crystal models. Some years earlier, Jean-Baptiste Romé de l'Isle (1736–1790) had produced sets of crystal models in terra cotta as

Figure 3. **The 18th-century interior of Teyler's Museum in Haarlem, Netherlands. Mineral specimens are exhibited in the central showcases. One of the two known near-complete sets of Haüy's wooden crystal models is preserved here, acquired by the museum in 1802–1804.**

an accompaniment to his *Essai de Cristallographie* (1772). However, clay had a number of disadvantages as a medium for creating crystal models (Touret, 2004); Haüy chose instead to have his new models made from dense, fine-textured pear wood by experienced woodcarvers.

One by one Haüy's demonstration models were carefully sculpted by Claude Pleuvin Sr., the master woodworker and cabinetmaker of the *École des Mines*. As Haüy steadily extended the range of minerals studied, he needed more models to show his idealized crystal forms. He displayed the models on his worktable, together with the remnants of the studied (smashed) crystals and other mineral specimens. When Haüy's *Traité de Minéralogie* was published, the collection of models became an entity: a distinct tool in the practice of mineralogy.

Models in Haüy's Crystallography

The first models were fairly simple: cubes and rhombohedrons serving as kernels (*primitive*) and sets of plates, systematically reduced in form and/or area, meant to stack on the faces of the kernel model. Intersecting grooves on the plates imitated the edges of the building blocks (*molécules substractives*). The connection between the number of omitted rows and the gradient of a face was then apparent. But in their mutual relationship the dimensions of the wooden kernel, the thickness of the wooden plates and the distances between the grooves had to be carefully chosen to fit the theory.

Later models were more ingenious, inolving a stack of plates that interlocked with another stack to make adjacent faces around or on top of the kernel. Still others were elaborate; in some cases a massive piece of wood was gradually chiseled away to show steps and ridges suggesting faces tapering to edges and peaks.

At first the models were named *modèles composés des lames décroissantes*; later they were taken together under the name *décroissements* (decrements). We have shown (Saeijs, 2003) that a complete set of decrements consisted of 15 models, but that its individual elements could not be determined from the early literature.

Targionni Tozzetti (1795) tried to reproduce one of the earlier Haüy models, but was lacking in craftsmanship. The publication of his report nevertheless shows that Haüy's theory and the models made by Pleuvin Sr. were already widely used in teaching crystallography.

In 1799 Professor Brugmans in Leiden in the Netherlands owned a set of decrements. But he also had a set of Haüy's *primitives* (Hooykaas, 1949). This reveals a new step in Haüy's crystallography; he had developed a code, a type of formula, describing the exterior form of a crystal. In the code, letters were used to indicate the faces of the *primitive*, while subscripts and superscripts gave the ratio of reduced rows necessary to form the faces of the crystal. The code read as a plan to cut off chips from edges and solid angles of the *primitive* in order to get at the gradient or angle of each face. With the formula of a crystal and its mineral's *primitive* the crystal could be visualized and drawn. Throughout the 19th century copies of sets of *primitives* were used in teaching crystallography. A set made by Allizeau in Paris is still kept in the museum of the university of Groningen, Netherlands.

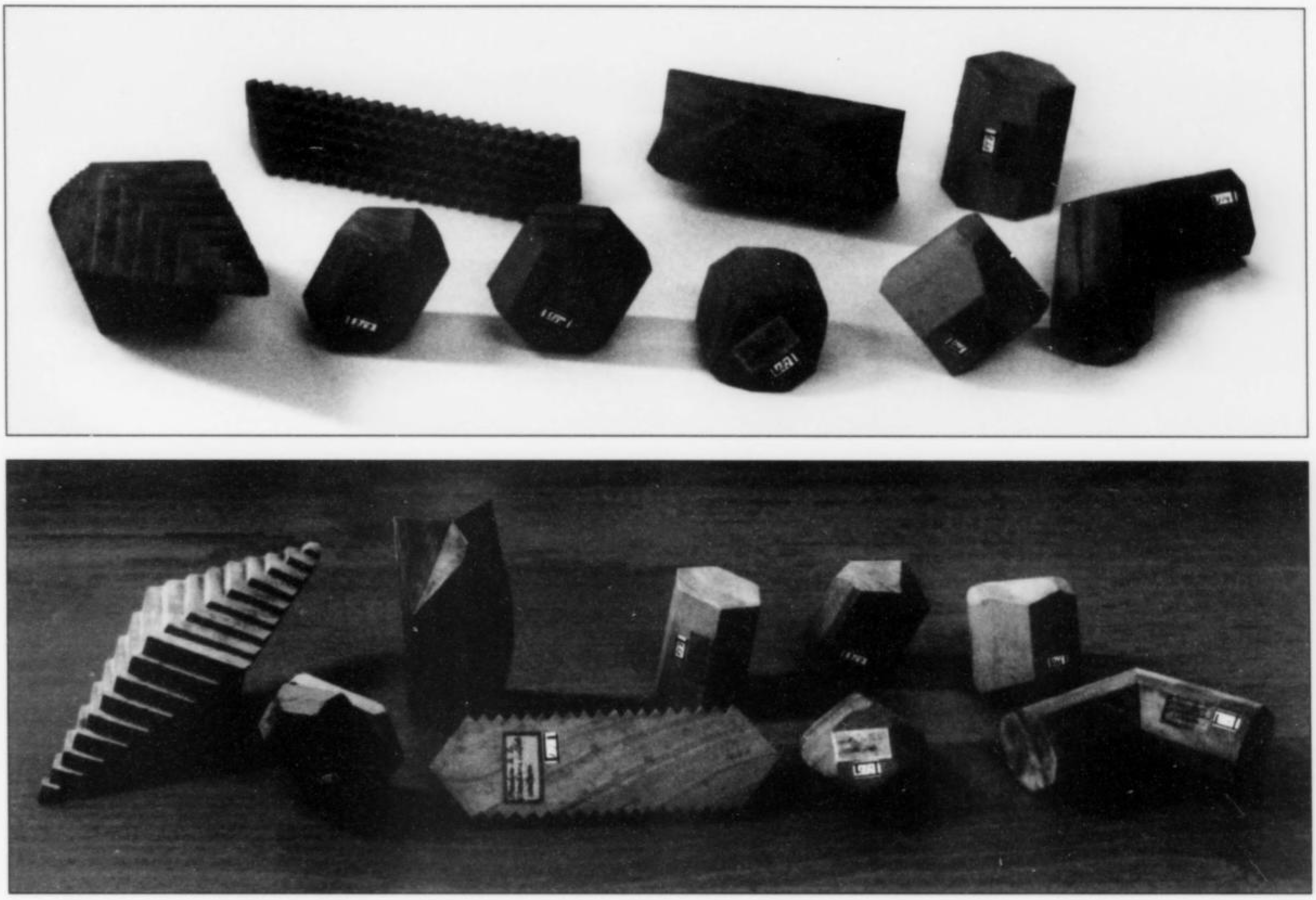


Figure 4. **Some Haüy crystal models: two decrements, three twins (one of which is a pivoting model) and four models of different classes. Authors collection.**

Models in Haüy's Mineralogy

Pursuing his research in minerals and at the same time lecturing, Haüy felt the need to make his results regarding crystal forms and interfacial angles more understandable and easier to sort and show. There is no written description of the method Haüy used to show Pleuvin Sr. the idealized forms he wanted made. Giving Pleuvin good crystals to copy would have been the easiest way. But Haüy had no good crystals. He lacked the means to buy good specimens, and had extracted his knowledge from poor and inadequate material. So Haüy must have instructed Pleuvin by means of sketches and notes showing the values of the interfacial angles. A woodworker in those days based his constructions and inlays on only a few simple angles. But Haüy's angles varied widely. Pleuvin therefore had to use a goniometer too, sculpting test models until a prototype emerged that satisfied Haüy. In this way Haüy slowly built a collection of models of all the idealized mineral crystals.

The potential of the finished collection of prototypes became apparent when Haüy was preparing his *Traité de Minéralogie* for publication. He realized that, for buyers who could afford it, a collection of wooden crystal models would make his mineralogy more accessible than could the codes in the text and the figures in the Atlas. And Pleuvin could go on earning some extra money without taking up Haüy's time, for he could make new collections by copying the prototypes. With Haüy living near the *École des Mines*, the prototypes were within easy reach for Pleuvin.

COLLECTIONS OF HAÜY'S CRYSTAL MODELS

Simultaneously with the publication of his *Traité de Minéralogie,* Haüy announced that wooden models were also available. This was premature, for there were no collections in stock and he had not realized how much time it would take to produce one. In no time, four such collections were ordered, and Pleuvin Sr. died before he could begin producing them. Haüy felt obligated to set up the production himself. Under his supervision, six collections were made in two and a half years. Only two of these have survived; one is preserved in *Teyler's Museum* in Haarlem, Netherlands and another, smaller one, is in the author's possession. Since its acquisition the first collection has become somewhat depleted, but it is supported by very good historical documentation. The second set may at first appear to be somewhat depleted as well, but in fact it is probably essentially complete, and we have augmented it with a crystallographic description for each model.

A collection of similar models, kept in the *Muséum national d'histoire naturelle* in Paris, France, may have originated from Haüy but its historical value has been destroyed because all of the labels have been removed and the faces of the models have all been painted in a system of colors.

The Collection at Teyler's Museum

Hooykaas (1949) discovered correspondence between Haüy and Martinus van Marum, the first director of *Teyler's Museum*. The 24 letters written between December 1799 and September 1806 have as their main subject the acquisition of a collection of wooden crystal models, and that collection was forthwith rediscovered in the museum.

The author found some unpublished lists that had been written between the times of the letters. With these it can be proven that this collection was indeed made under the supervision of Haüy,

***Figure 5.* Van Marum visited Haüy's workshop in Paris in the fall of 1802 and picked up 62 crystal models, the majority of which (shown here) are still preserved in Teyler's Museum.**

and it has been possible to reconstruct the deliveries in sequence and content (Saeijs, 2003).

By the end of 1801 Van Marum already had a considerable number of mineral specimens in his collection. He wanted to display them in a special room but he had no logical system by which to arrange them. In browsing through the recently published *Traité de Minéralogie* he saw that Haüy had provided the needed system for identifying and classifying minerals. Van Marum surmised that the wooden models which Haüy offered could boost the educational value of a mineralogical exhibit. Immediately he wrote Haüy and ordered a collection. He claimed priority, "for he had in 1799 already ordered a set of models and had never received an answer." (He failed to mention that this previous order was for models he had seen at professor Brugmans' house.)

Haüy's answer was ambiguous as well: "I feel honored to receive your order for a collection of wooden crystals. I engaged at once Pleuvin Sr., who promised to make the collection. But I am not his master. He works for himself and favors the most adroit customers first. He died before he could start working for you."

The letter continues: "There is now only Journy, an apprentice of 16 years. Pleuvin's son, though he has other tasks in this laboratory, has consented to be his master. Together they are overwhelmed with their own work. Nevertheless they have promised me to make a collection for you. I hope to send it to you in a couple of months. The price will be 355 *livres*."

Van Marum was not happy with the new woodworkers: "If someone who has a collection made by Pleuvin Sr. dies, I would be grateful if you could obtain it for me." Van Marum did accept the price, but he also expressed anxiety that it would be a long time before he could expect delivery.

And indeed the proposed time suggests that Haüy and the woodworkers did not have a clear idea of how much work it would

Liste des Crystaux

chaux carbonatée primitive
c.c. équiaxe
c.c. inverse
c.c. métastatique
c.c. contrastante
c.c. mixte
c.c. basée
c.c. unitaire
c.c. prismée
c.c. binaire
c.c. imitable
c.c. birhomboïdale
c.c. prismatique
c.c. apophane
c.c. uniternaire
c.c. bisunitaire
c.c. dodécaèdre
c.c. dodécaèdre raccourcie
c.c. contractée
c.c. dilatée
c.c. sexduodécimale
c.c. bisalterne
c.c. bisalterne prismée
c.c. binoternaire
c.c. bibinaire
c.c. trirhomboïdale
c.c. équivalente
c.c. persistante
c.c. acutangle
c.c. analogique
c.c. rétrograde
c.c. soustractive
c.c. zonaire
c.c. émoussée
c.c. progressive
c.c. paradoxale
c.c. complexe
c.c. ascendante
c.c. triforme
c.c. doublante
c.c. continue
c.c. bigéminée
c.c. surcomposée
c.c. sorifère d'hexaèdre
c.c. quadrirhomboïdale, nouvelle chaux

chaux phosphatée primitive
c.f. annulaire
c.f. émarginée
c.f. unibinaire
c.f. pyramidée
c.f. didodécaèdre

chaux fluatée primitive
c.f. primitive cunéiforme
c.f. cubique
c.f. cubo-octaèdre
c.f. émarginée
c.f. cubo-dodécaèdre
c.f. bordée
c.f. hexatétraèdre

forme primitive de la chaux sulfatée
c.s. trapézienne
c.s. équivalente

2ccu ~~manquant~~
Fig 7 Chaux carbonate cuboïd
30 — hyperoxyde
(34 — octoduodecimale)
33 — perido decaedre
35 — analogique prism
38 — disjointe
46 — Delotegue
63 Chaux phosphate pérido
43 — fluate dodeca
(162 — fluate triforme)
99 Chaux sulfatée

***Figure 6.* Van Marum's first 62 crystal models are itemized on this "*Liste des Crystaux*," written in the very fine and regular hand of an unnamed person whom Haüy said was "living also in this building, charged with labeling." Teyler's Museum archives.**

entail. Much later a letter reveals that one woodworker, even when already skilled in this type of work, could not make more than six models a day "using all his time." One decrement would take four or five days to make.

Reconstruction of price and content shows that the price of 355 livres breaks down to 537 ordinary models (*simples*) at 10 *sous*, 11 twin models (*macles*) at 20 *sous* and 15 decrements at 100 *sous*. [1 *livre* or French pound = 20 *sous*.] Hence one skilled worker would need 150–170 full days, i.e. 25 to 28 weeks, to make a complete collection. The quoted price then means daily earnings of only 2.1 to 2.3 *livres*. Held against the normal daily wage of 5 to 6 *livres* that a skilled worker could command, the quoted price was clearly based on the idea of "moonlighting", i.e. working during their spare time, as Claude Pleuvin Sr. used to do for the crystallographic models. Being overwhelmed by the demands of their normal work, and only just beginning to learn this new type of craftsmanship during only a few hours a day, there was no chance that Pleuvin Jr. and Journy could deliver a collection in less than a year.

Figure 4 illustrates two decrements, including three twins (one of which is a pivoting model), and four models of different crystal classes.

Van Marum had reckoned to be first, but by March of 1802 he had already been pushed back to fourth in line. Napoleon had ordered the *École des Mines* to move to the Alps. Haüy was given a chair in mineralogy at the *Muséum national d'histoire naturelle* in Paris. He had to move to rooms there, taking with him all of his material, including the prototypes from which the copies were to be made. Pleuvin and Journy lost their jobs and access to the prototypes. On top of all this, three French national institutes, namely the *École des Mines*, the *Muséum national d'histoire naturelle* and the *École Centrale du Puy de Dôme*, together having several thousand students, were going to be teaching Haüy's mineralogy. They required prompt delivery of crystal models. Haüy then set up Pleuvin and Journy in a room at the *Muséum* to make the model sets. He expected fast work from them, because now they could devote full time to the task.

Haüy soon found out that his troubles were not over. It turned out that Pleuvin, as master of the woodworking shop, was unable to devote all of his time to cutting and polishing crystal models. He lost time in talking to customers, in supervising Journy and in searching the city for old furniture containing usable parts of pear wood suitable for making the models. And there were always mishaps, small accidents, and models that failed to turn out right. Fortunately the apprentice, though at first doing only odd jobs around the shop, was gradually able to start making wooden preforms. Nevertheless, no more than two collections a year could be produced.

Van Marum became impatient and went to Paris in the fall of 1802. When he left Haüy's workshop he took with him a first lot of 62 *simples*. (The majority, still preserved in the museum, are shown in Figure 5.) These were noted on a "*Liste des Crystaux,*" written in the very fine and regular hand of an unnamed person "living also in this building, charged with labeling." This important list with its handwriting is shown here as Figure 6.

Trusting in the promise of prompt deliveries to come, Van Marum started to arrange his minerals. He then received Haüy's letter of December 26, 1802, which told him that the famous Abraham Gottlob Werner had arrived from Freiberg, Saxony and planned to use Haüy's mineralogy in his next course at the Mining Academy; Werner needed a collection urgently. "And the price of a collection is too low!" wrote Haüy. "Pleuvin earns now only one *écu* a day. [1 *écu* = 3 *livres* .] He has a family depending on him and they cannot subsist on such earnings. I had to advance their wages. They are already in my debt for a considerable sum, which they cannot pay back." This letter quoted the new price of "at least 600 *livres,*" which breaks down to 578 *simples* at 16 *sous*, 11 *macles* at 31 *sous* and 15 decrements at 162 *sous*. (This means that the models of the isomorphs indicated in Table 1 were now included.)

Van Marum was furious. He expressed his indignation immediately, writing: "I don't see why the celebrity of Mr. Werner gives his friends the right to break their promises." Haüy reacted by collecting all models he could find and dividing them in two parts, one to keep Werner satisfied and one to send to van Marum. Supplemented by a week's production of 48 models, this second delivery of 248 models completed for Van Marum the set of 310 *simples* needed for his exhibition of classes 1 and 2. The scrupulous Haüy must have given Werner about the same number of models. These models, spread somewhat thinly but adequately over the four classes and the appendix, were supplemented by a complete set of decrements.

For Van Marum further deliveries, with models for the other classes, eventually arrived in the following years. The correspondence (from which the quotations here are taken) continued thoughout 1803 and 1804 but petered out in 1805/1806. It contains further indications that in 1803 the interest in obtaining collections was already waning. Haüy offered Barnaart, van Marum's friend, a complete collection "ordered by someone who has not returned." And

Table 3. **Models acquired by Van Marum, their description and identification.**

Description and presence in the Museum	*Number of models*
1. described by drawings in the Atlas; present in the Museum	507
2. idem; whereabouts not known	82
3. developed after 1801, without model drawings; still present	53
4. idem; whereabouts not known	3
5. total of models of crystal forms acquired by van Marum	645
6. décroissements acquired by van Marum; original composition of the set unknown; only loose parts present	15

Table 4. **Haüy's minerals and models of their crystals in Teyler's Museum.**

Mineral classes	*Number of minerals*	*Number of models*
1. class 1; 'sustances acidifères'	14	149
2. class 2; 'substances terreuses'	36	179
3. class 3; 'substances combustibles'	3	10
4. class 4; 'substances métalliques'	39	219
5. appendix including sahline	2	3
6. minerals without models as in table 2	1	
7. minerals without models in this collection	3	
8. total of Haüy's minerals/ Teyler's models	98	560

the woodworkers were able to start making the isomorphs as well as models of crystals newly studied by Haüy, which are indicated in Table 3 as "developed after 1801, without model drawings." All of these were also offered to and made for van Marum. In August of 1804 van Marum received his sixth and last shipment of 38 of the "later developed" models. In the meantime Journy had left, and when Pleuvin met with an accident, all model making ceased.

Table 3 summarizes the collection which was acquired by Van Marum and, in large part, is still present in Teyler's Museum. The first two lines of the table represent the 589 crystal drawings in the Atlas. Table 4 shows the number of minerals in Haüy's mineralogy and how the models in the museum are distributed over the classes.

The Author's Collection

The history of the collection in the possession of the author is not documented, and its whereabouts in the 19th century remain unknown. Throughout the 20th century it was kept in the museum of a religious order. This museum, containing natural history collections purchased from various commercial suppliers, was established toward the end of the 19th century as an educational facility for the promotion of an evolutionist philosophy instead of the creationist one. The huge collection of minerals, rocks and ores was purchased from the firm of Dr. F. Kranz in Bonn, Germany.

The Kranz company was already selling good collections of wooden crystal models illustrating the 32 symmetry classes. But only Haüy's crystal model collection was present in the museum. This suggests that the Haüy crystal model collection had already been present in the museum for much of the 19th century, and consequently there was no need to buy another one, because their aim was not to teach crystallography. Unfortunately the order does not divulge data on its members or its property. The library of the order, including a copy of Haüy's *Traité de Minéralogie*, has been sold to the University of Maastrichtt.

After acquiring the collection from the museum, the author discovered its probable historical value and compared the models with those preserved in Teyler's Museum. The shapes and forms proved to be the same, with only small differences attributable to individual craftsmanship. The same labels, the appropriate names on them, and the handwriting all constitute convincing proof of the authenticity of the collection as one made under Haüy's supervision.

There are, of course, some differences between this collection and the one in Teyler's Museum. Only four are mentioned here.

(1) In Haüy's textbooks the crystal forms are provided with a figure number and a crystal name. Some, mostly twin forms, are only designated by a figure number. Six of the author's models carry labels with these figure numbers whereas the similar Teyler's Museum models carry new names that are not mentioned in the textbooks. For example: the model W 251, '*Feldspath fig.92*' in the

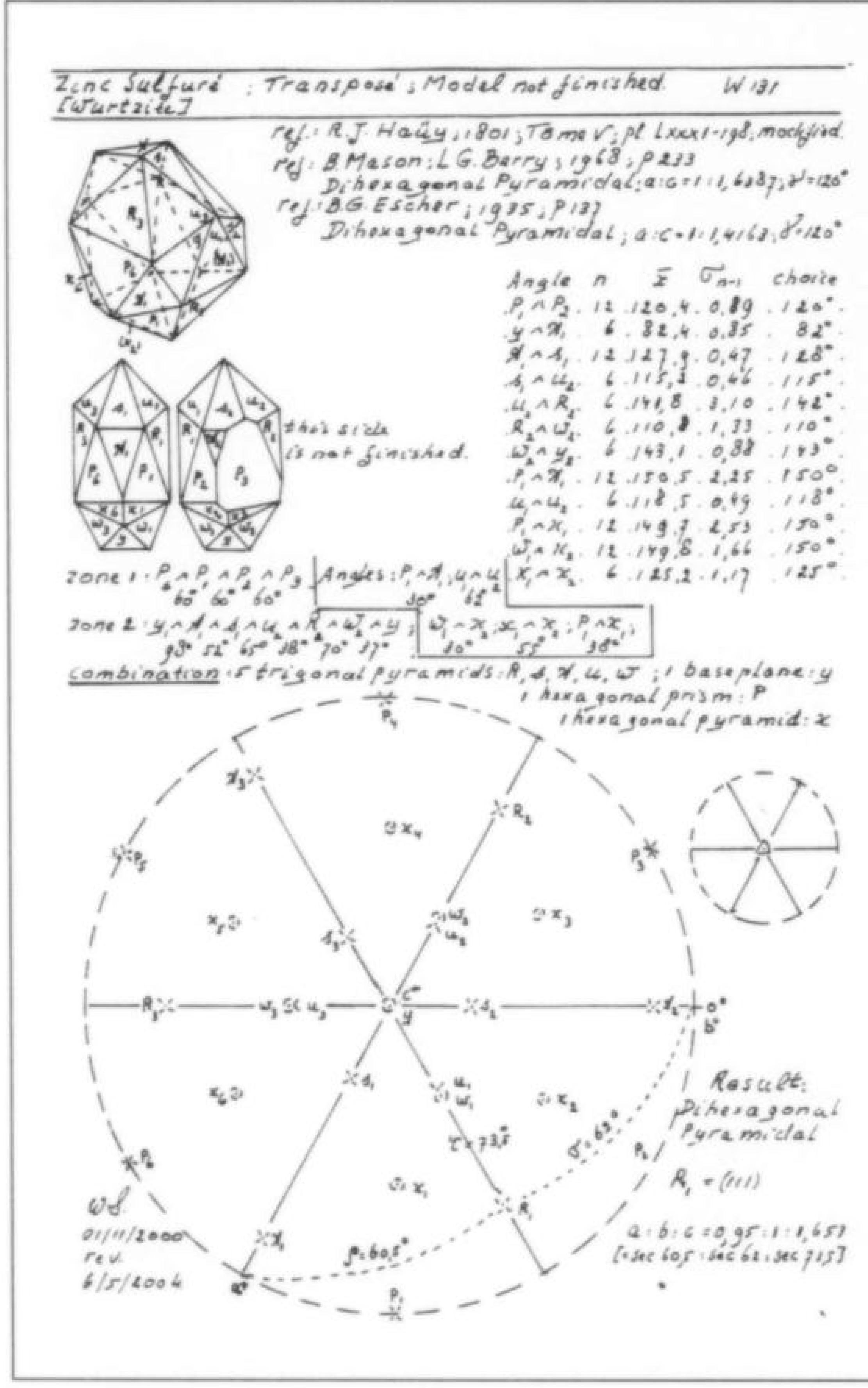


Figure 7. **The Haüy crystal model in the author's collection, number W 131, "*Zinc Sulfuré Transposé*," was delivered to the buyer (Abraham Gottlob Werner) before the woodworkers had finished smoothing all of its faces. Shown here is a stereographic projection and crystallographic analysis of that model.**

author's collection is similar to K 223, '*Feldspath Hemitrope var. a*' in the Teyler's Museum collection.

(2) The author's model W 131, '*Zinc Sulfuré Transposé,*' drawings of which are shown in Figure 7, was delivered before the woodworkers had finished smoothing all of its faces.

(3) Van Marum ordered, received and paid for a set of 15 decrements at a time when he had already lost much of his interest in crystallography and mineralogy. One cannot now, if ever, reconstruct these decrements from the many bits and pieces kept together with the Teyler's Museum collection of models. The author's collection, however, contains an identifiable set.

Table 5. **Haüy's minerals and models of their crystals in the author's collection.**

Mineral classes	*Number of minerals*	*Number of models*
1. class 1; 'substances acidifère'	13	70
2. class 2; 'substances terreuses'	36	113
3. class 3; 'substances combustibles'	3	8
4. class 4; 'substances métalliques'	33	115
5. appendix	1	1
6. minerals without models as in table 2	1	
7. minerals without models in this collection	11	
8. total of Haüy's minerals/ author's models	98	307

(4) Table 5 summarizes the author's collection. With only 307 crystal models (not counting the decrements) it seems as if it might be a seriously depleted one. But of the maximum of 85 *primitives* described in the Atlas, 60 of them are still present, which seems overabundant when compared with the 66 *primitives* in the only slightly depleted collection of Teyler's Museum.

The four differences suggest that the author's collection is not depleted but, on the contrary, is actually the complete Werner collection. The number of models, spread somewhat thinly over all the classes, the overabundance of the *primitives*—essential in using the codes—and the set of decrements point to Werner's needs, whereas the use of figure numbers points to an early delivery, done before Haüy had given them names. And the unfinished model points to great haste. These features are all consistent with Haüy "scraping the barrel"! There is no proof that Werner ever received models to complete or extend his collection. But as it is, the collection was certainly good enough for Werner to use in teaching Haüy's crystallography.

MODELS LOOKED AT FROM EVERY ANGLE

Van Marum had ordered a goniometer but never received one. Consequently he never measured the interfacial angles on crystals in his mineral collection in order to compare them with the values in the text. There has thus been no proof, up to now, of the usefulness of these values in identifying minerals. The author has filled that gap by measuring and plotting all of his crystal models and some of the models in the Teyler's Museum collection. Table 6 shows the number of minerals represented by models which have been measured. It lists a tentative total of minerals because Haüy could have attributed different mineral names to dissimilar-appearing crystals of the same mineral; for example, in the case of the not yet identified minerals *sphène*, *titane silico calcaire* and *spinthère*. On the other hand, there are three examples in which one of Haüy's models is assigned to two different minerals.

The models

The models, measuring 5 to 8 cm, are made of old pear wood. They have smooth faces, sharp edges and sharp, solid angles. That means they were not finished by sandpapering but by careful chiseling with very small, sharp tools. They carry small labels, measuring around 9 to 16 mm and cut by hand from circa 90 grams laid paper. These labels are rimmed with a red ink. Haüy's names of the minerals and crystal forms are written in a very fine, regular hand in black. This handwriting, which is the same as on the "*Liste des Crystaux,*" is definitive proof of the authenticity of the models.

The models show the same faces as the figures in the Atlas, although there are small deviations in the forms of faces. A close inspection reveals more serious imperfections. For example, the faces are always slightly convex, and also some of the interfacial angles, which should be identical, are actually not quite equal. Differences of several degrees may exist. Apparently the woodworkers had understandable difficulty in getting the interfacial angles perfect, and in trying to improve them they sometimes took off very fine chips near the edges. Of course the smaller the face is the greater the imperfections tend to be. The author's model W 131, "*Zinc Sulfuré Transformé,*" already mentioned as Figure 7, illustrates this working method. It is unfinished and on one face the lacquer from old furniture is still present.

Identifying Haüy's minerals

Van Marum's work centered on the question: "Can I identify my mineral as one described by Haüy?" Our question is: "Which modern mineral *is* the one described by Haüy?" Haüy's mineral names do not necessarily imply obvious answers. Since his time, many new mineral species have been discovered, some of them incorporating identical chemical elements and even found in the same mines. Is Haüy's "*cuivre sulfaté*" then chalcanthite, brochantite or antlerite? What is "*cuivre gris*" that is treated by Haüy as an isomorph of "*cuivre pyriteux*"?

To identify a mineral by morphology today, the values of all interfacial angles must be used to calculate its crystallographic geometry. There are conventions in modern crystallography designed to assist in finding and using the data; these involve the choice of the primary faces and principal axes on the crystal, and the direction of the axes and therefore the proper positioning of the crystal.

To identify a mineral by Haüy's method, the crystals themselves

Table 6. **Minerals measured by using available models.**

Source of the models	*Class 1*	*Class 2*	*Class 3*	*Class 4*	*Append.*	*Total*
1. Author's collection	13	36	3	33	1	86
2. Extra by splitting a Haüy mineral		2		1		3
3. Teyler's collection		1		1	2	4
4. Minerals without models	1	1		6		8
5. Tentative total of Haüy's minerals	14	40	3	41	3	101

were compared with the drawings in the Atlas. Some proof was then found when the interfacial angles conformed to values given in the descriptive text for a particular mineral. However, the perspective of the drawings makes it difficult to determine the crystallographic axes. Without them there is no trustworthy way to identify a mineral solely from the drawings and the "limit" values of Haüy's interfacial angles.

To identify the minerals represented, the author measured the actual models, because they can be taken as a summary result of Haüy's work, embodying the veracity of his idealized forms, the exactness of his interfacial angles and the accuracy of the approved models. Furthermore they can be treated as real crystals, provided that the deviations made by the woodworkers can be accounted for.

A goniometer is good enough for determining interfacial angles because its inaccuracy of 0.3 degree of arc is far less than the deviations inherent in the crafting process. All of the interfacial angles on the model are then measured. Only a brief description of the method of processing the data will be given here. The author has published a detailed description and account of his method elsewhere (Saeijs, 2004).

A peculiarity of crystals is their zonal relationship that sets them apart from mathematically symmetric bodies. This means that each face of a crystal is part of at least one zone, i.e. a group of faces that cut each other along parallel lines. The common direction of these lines is the zonal axis. The faces of the zone, or their extensions, intersect an imaginary plane perpendicular to this axis. By doing so the intersections form a polygon of which the angles are the angles between the faces of the zone. The symmetry elements of a crystal require that there be several analogous interfacial angles in a zone, and that there are also some analogous zones on the crystal. After measuring all individual interfacial angles, the average of each set of analogous angles will approach the value given by Haüy. Geometry demands that the sum of these averages in the polygon of the zone is an exact multiple of 180 degrees. In this way the use of the zonal relationship irons out the deviations in the models.

Each face of a crystal or model is cut by at least three other faces, making it a part of at least three zones. This aspect of the zonal relationship opens the possibility of finding the position of each face by a successive triangulation based on the position of the chosen primary faces. The triangulation is executed on a stereographic projection of the model. Here the faces are represented by their normals and these are represented by points. The pattern of points reveals the symmetry elements of the model and the position of the crystallographic axes with the axial angles between them. The axial ratio is calculated from the ratio of the values of arcs between the projection point of some plane, that cuts all three axes, and the position points of these axes. The stereographic projection of a model is drawn at the bottom of a transparent sheet and joined by the outcome of the analysis of the model. On the middle section the measurement data from which the projection is derived are reported. The top section carries Haüy's names for the mineral and the crystal form and, in brackets, the mineral's modern name. A drawing of the model, frequently equal with Haüy's drawing, and some references complete the report.

Figure 7 is a copy of one of the 500 prepared sheets. Between these 500 there are 127 sheets representing another method of identifying the model's associated mineral species, one that does not require calculation of the axial ratio. This method consists of first preparing a stereographic projection with seven or more important faces of the crystals of a mineral thought to be the same as the unknown, calculated from the crystallographic data reported in the literature. This projection—the "reconstruction"—is used as an overlay to search for a pattern of coinciding points on the sheets of the models. Haüy's mineral is declared "conformal" when it is properly identified through its model using the calculation method or using this visual comparison. Tables 6 and 7 summarize the results of the author's investigation. "Not conformal" means that the modern mineral has not yet been identified or that the proof has not yet been found. As the tables show, more than 80% of Haüy's minerals have been identified, thereby giving evidence of the reliability and accuracy of Haüy's work and the skill of his woodworkers.

COMMENTS on PARTICULAR MODELS

The brief general description of the author's method of analyzing the models omits many of the special measures that sometimes had to been taken to identify particular minerals. Following are some examples.

Sphalerite and Wurtzite

Haüy's *zinc sulfuré* is represented in the Atlas by eight crystal drawings. The drawings as well as the models show that three of them are rather complex. One of these is the previously mentioned unfinished model, W 131, "*zinc sulfuré transposé,*" shown in Figure 7. To explain these complex forms Haüy chose, surprisingly, an exceptionally complex primitive, a rhombododecahedral crystal. Careful measurement places the three models in the dihexagonal pyramidal class of modern crystallography. The very good axial ratio found on the model W 131 identifies the drawings as representing crystals of wurtzite. The four other models as well as the *primitive* are isometric hexoctahedral and therefore represent crystals of a different mineral, namely sphalerite. Wurtzite is the very high temperature polymorph of sphalerite and is not common. Its presence in Haüy's study is remarkable.

Chalcanthite

There are six models of *cuivre sulfaté* in the author's collection. They are obviously triclinic, and have the same basic shape but are bounded by three, six, eight, nine, ten and ten pinacoids respectively. A crystal drawing of chalcanthite in Mason and Berry (1968) shows six pinacoids and the same general form as the models. The directions of the axes and the *prominent* faces chosen as (100), (010)

Table 7. **Number of Haüy's minerals identified by using the models.**

Source of the models	*Class 1*	*Class 2*	*Class 3*	*Class 4*	*Append.*	*Total*
1. conformal; isometric symmetry class	3	5	1	9		18
2. conformal; other symmetry classes	9	28	1	18	3	59
3. probable conformal		6		3		9
4. not (or not yet) found conformal	1		1	5		7
5. not ready						
6. no models available	1	1		6		8
7. tentative total of Haüy's minerals	14	40	3	41	3	101

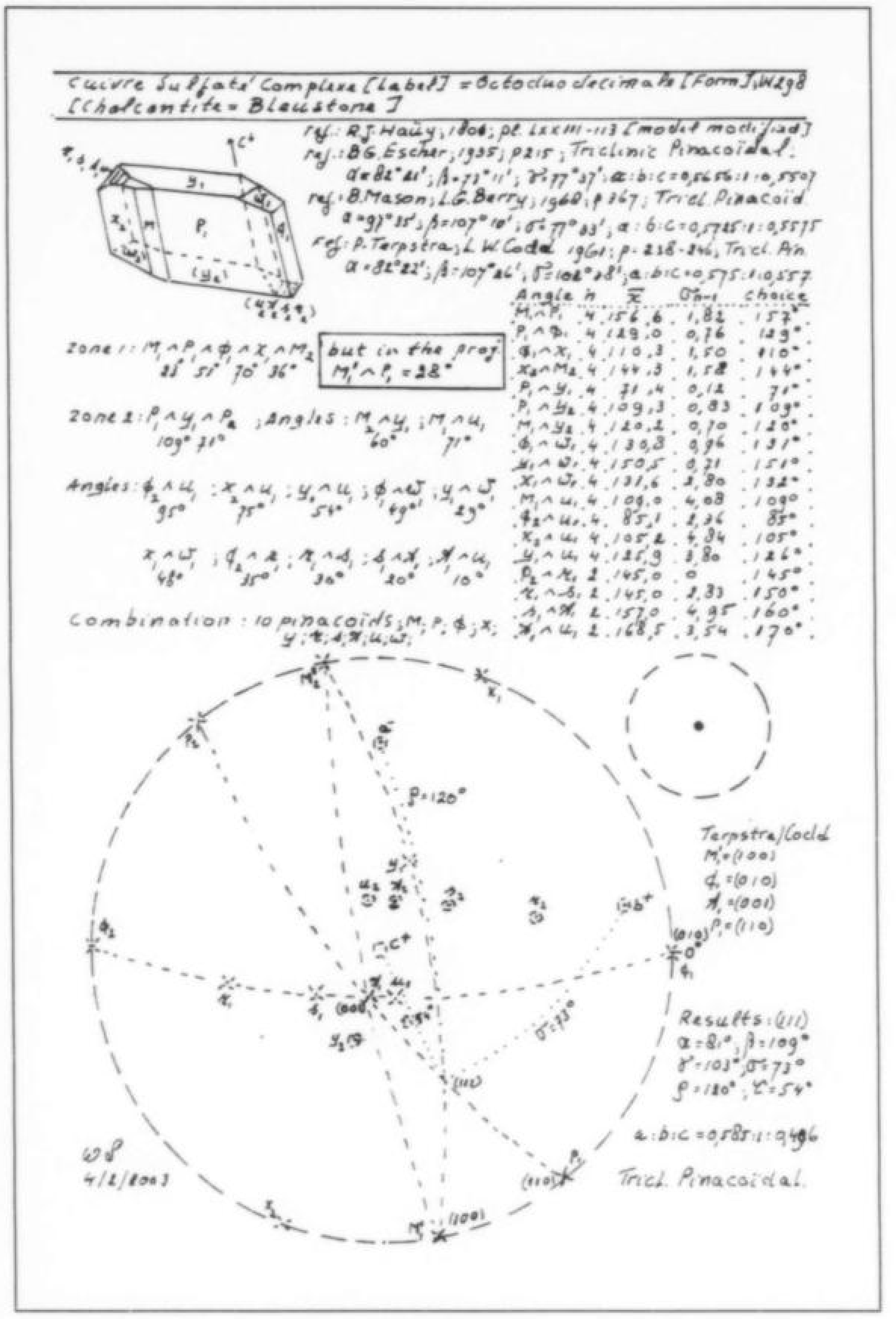


Figure 8. A stereographic projection and crystallographic analysis proving that Haüy's *cuivre sulfaté* crystal model (author's collection) represents the mineral chalcanthite.

and (111) are shown as well. The axial ratio given is the same as in two other textbooks, but between them there is quite a difference in the reported axial angles. No match with these data or with those of other copper sulfate minerals was found. Should *cuivre sulfaté* be designated as "not conformal"?

Terpstra and Codd (1961) use the values measured on a crystal of synthetic copper sulfate as an example in the calculation of data from two-circle measurements. The crystal is bounded by 14 pinacoids. But of these they use three *insignificant* ones as (001), (100) and (010). On only one of the author's models, i.e. W 298, "*cuivre sufaté complexe,*" these were present, and some zones coincided too. Plotting the model with these starting points resulted in good values for the axial angles but in a somewhat distorted axial ratio. Yet the azimuth of the face (100) on this model was, at 74 degrees, quite low in comparison with the azimuth values of 76, 80, 81 and 81 degrees of the other models and with the 79 value of Terpstra and Codd. The lack of symmetry in triclinic crystals of course limits the chances to correct deviations in each model. Tentatively using in this case the average of the azimuth values of the five different models the author was able to calculate from the stereographic projection an axial ratio a: b: c = 0.59: 1: 0.50 that is reasonably close to the a:b:c = 0.58: 1: 0.55 reported in textbooks. Therefore *cuivre sulfaté* is chalcanthite. Figure 8 is the stereographic projection that proves this identification.

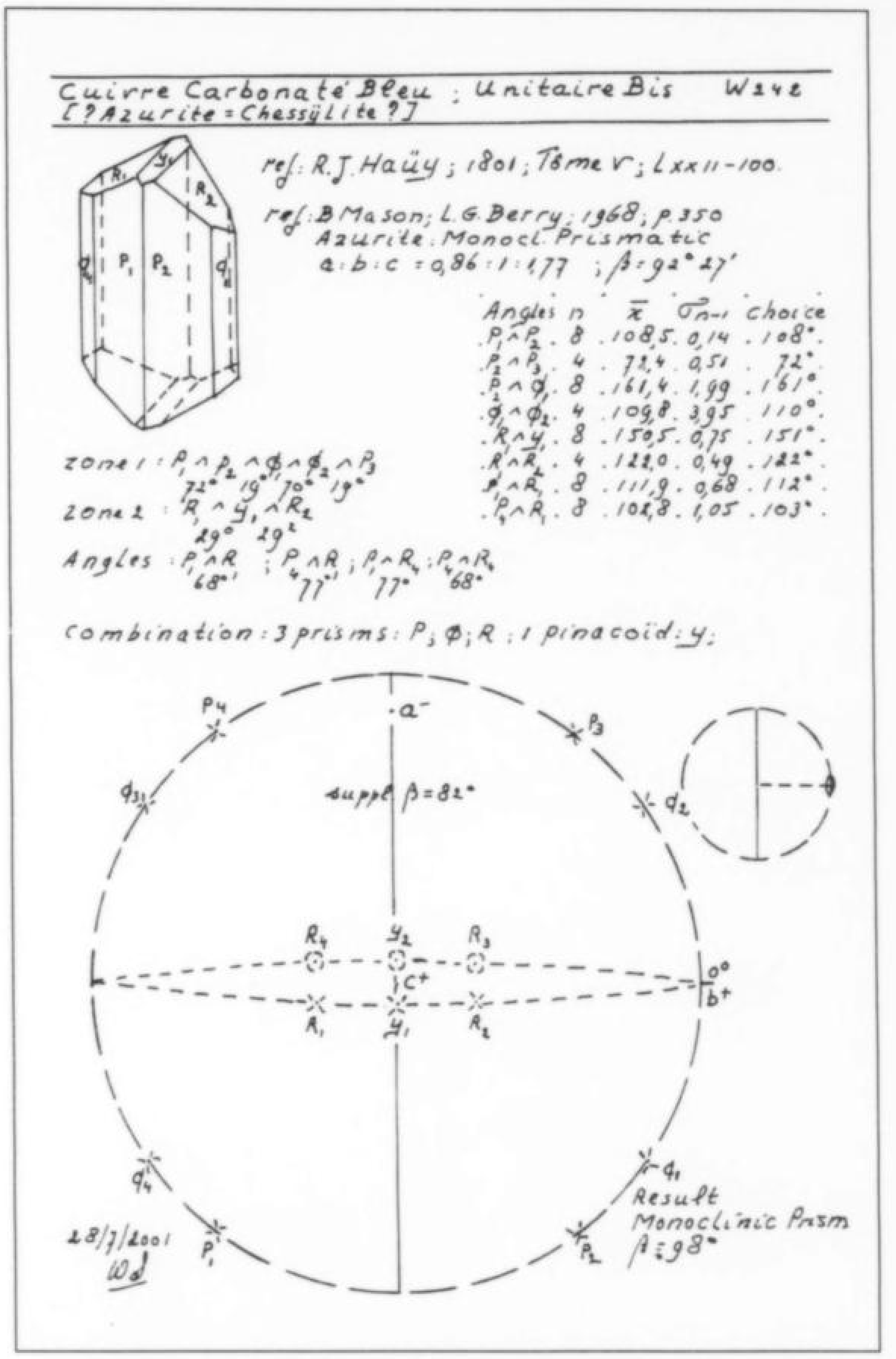
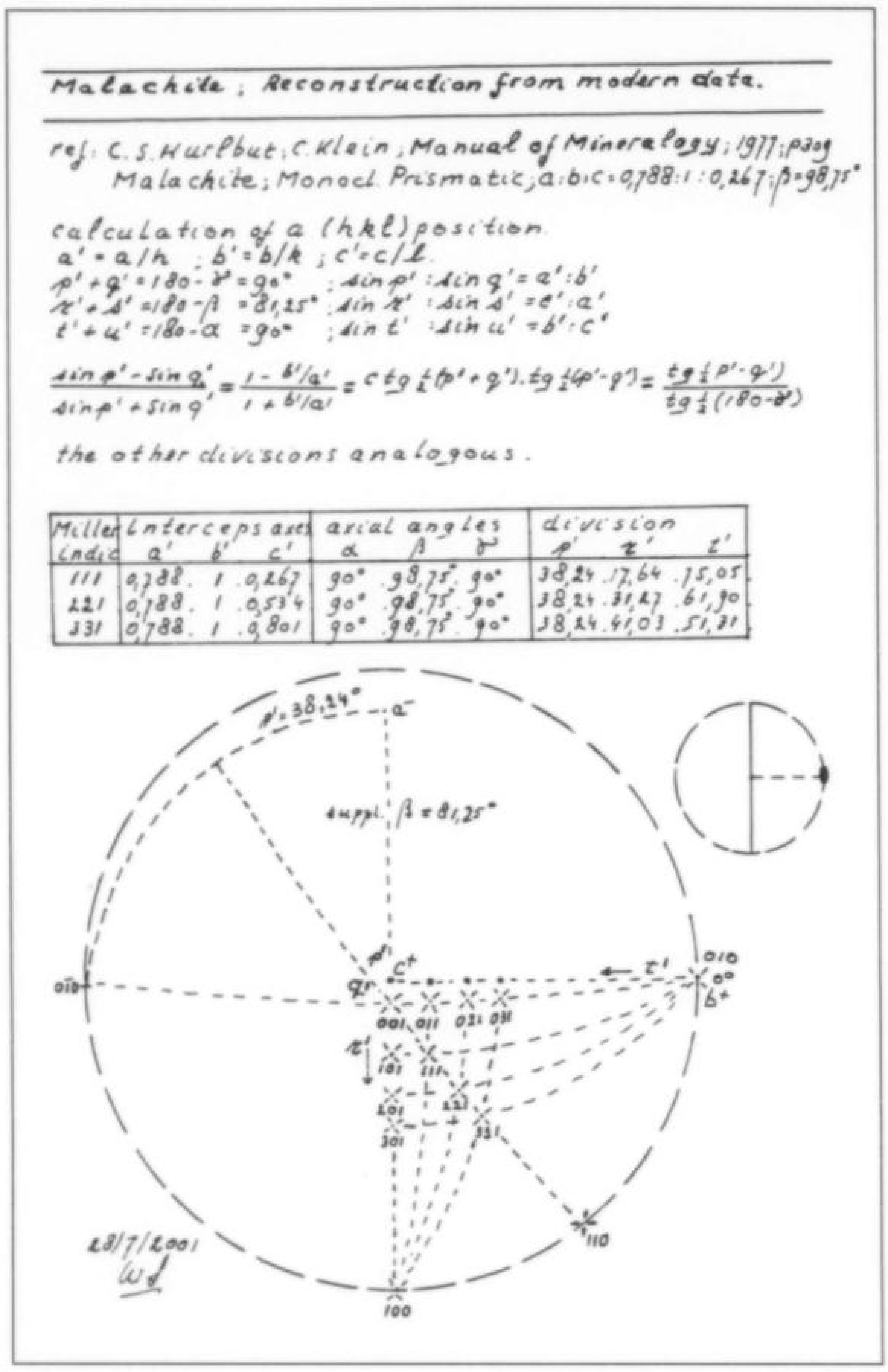


Figure 9. A stereographic projection and crystallographic analysis of the Haüy "*cuivre carbonaté bleu unitaire bis*" crystal model (author's collection). Although tentatively identified as the blue azurite, the projection does not match with the blue mineral. But a good match can be made with the reconstruction of the green malachite, shown in Figure 10. Hence the author concludes that Haüy's "blue copper carbonate" is actually a pseudomorph of azurite after malachite.

Cuivre carbonaté bleu

Another example is the case of "*cuivre carbonaté bleu*" versus "*cuivre carbonaté vert,*" tentatively translated as azurite and malachite. Haüy's description of the blue mineral is quite extensive, but that of the green one is scanty. In describing the blue mineral Haüy gives good pointers for calculating his "*limit,*" while also revealing flaws in the method. Nevertheless one can surmise the extent of Haüy's work on the mineral and the availability of good crystal material. There are seven models of the blue mineral and none of the green.

The projection of the model "*cuivre carbonaté bleu unitaire bis*" is shown in Figure 9. Although tentatively identified as the blue azurite, the projection does not match with the blue mineral. But a good match can be made with the reconstruction of the green malachite, shown in Figure 10. This is evident from the face R coinciding with (021), and the faces IJ with (001) and P with (110). Moreover the angles differ by only 0.75 degree. The other models


Malachite ; Reconstruction from modern data.

ref: C. S. Hurlbut; C. Klein; Manual of Mineralogy; 1977; p309
Malachite; Monocl. Prismatic; $a:b:c = 0{,}788 : 1 : 0{,}267$; $\beta = 98{,}75°$

calculation of a (hkl) position
$a' = a/h$; $b' = b/k$; $c' = c/l$
$p' + q' = 180 - \gamma = 90°$; $\sin p' : \sin q' = a' : b'$
$r' + s' = 180 - \beta = 81{,}25°$; $\sin r' : \sin s' = c' : a'$
$t' + u' = 180 - \alpha = 90°$; $\sin t' : \sin u' = b' : c'$

$$\frac{\sin p' - \sin q'}{\sin p' + \sin q'} = \frac{1 - b'/a'}{1 + b'/a'} = \mathrm{ctg}\,\tfrac{1}{2}(p' + q') \cdot \mathrm{tg}\,\tfrac{1}{2}(p' - q') = \frac{\mathrm{tg}\,\frac{1}{2}(p' - q')}{\mathrm{tg}\,\frac{1}{2}(180 - \gamma)}$$

the other divisions analogous.

Miller indic	interceps axes a'	b'	c'	axial angles α	β	γ	division p'	r'	t'
111	0,788	1	0,267	90°	98,75	90°	38,24	17,64	75,05
221	0,788	1	0,534	90°	98,75	90°	38,24	31,27	61,90
331	0,788	1	0,801	90°	98,75	90°	38,24	41,03	51,31

Figure 10. **A stereographic projection for a malachite crystal, based on modern data.**

of Haüy's mineral are good matches with malachite as well. Mason and Berry give the key to this riddle: "Azurite is less common than malachite, but it is often found as distinct crystals implanted on malachite or other secondary minerals, the crystals often altered to malachite pseudomorphs." Hence the author concludes that Haüy's "blue copper carbonate" is actually a pseudomorph of azurite after malachite.

CONCLUSIONS

Haüy's study of crystals led to the discovery of the second law of crystallography and the founding of mineralogy as a modern science. This involved the creation of wooden crystal models for teaching purposes throughout the 19th century. Only two collections of Haüy's original wooden models of mineral crystals survive today. Whereas the collection in Teyler's Museum has been identified by correspondence between Haüy and Van Marum, the author's collection of models is now tentatively identified as Haüy's consignment intended for Werner at the Freiberg Mining Academy.

The collections bear witness to Haüy's accuracy in the measurement of natural crystals, the development of the idealized forms, the sculpting of the models from old wood, his quality control over the fashioning phase, the labeling and finally the shipment. This accuracy has been demonstrated by the author's work in comparing the Haüy models with up-to-date crystallographic descriptions of the minerals. The author has created a crystallographic description for each model and has identified many of the species represented by Haüy's models. The details recorded on the descriptive sheets are condensed on Table 7 in which the number of identified minerals is summarized.

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1863.

HUBERT DE MONMONIER
(1919–2007)
AND HIS MINERAL COLLECTION

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California collector Hubert de Monmonier built a remarkable mineral collection of over 800 specimens, heavy in native gold and amethyst, and valued at over $7 million. In accordance with his family's early ties to mining in Arizona, he bequeathed his collection to the University of Arizona Mineral Museum in 2007.

Hubert Charles de Monmonier was born November 25, 1919, the son of Genevieve (1891–1982) and Eustace Basil Monmonier (1893–1982), an auto mechanic, blacksmith and civil engineer for a mining company. Although the family lived in Pearce, Arizona, Hubert was born at Genevieve's parents' home in Chicago, due to Genevieve's poor opinion of Arizona medicine. He was a descendant of Charles Felix Angelique de Monmonier (1763–1809), also known as the Chevalier Sconbecque (son of the Count de Sconbecque), who was born in Paris and emigrated to Baltimore around 1800, where he served as a Constable.

Hubert's grandfather, William Donlin Monmonier (1852–1930), was an attorney from Maryland who moved west in 1880, to Tombstone, Arizona Territory, just a year after Wyatt Earp and his brothers had arrived there. Bad blood developed between the Monmoniers and the Earps, a feud which Hubert (who was 10 years old when Wyatt Earp finally died) remained bitter about, even in his last years. Hubert's father Eustace was born in Tombstone in 1893; William worked as a merchant and later became a Justice of the Peace in Pearce, where his sons Charles and William Jr. (and probably Eustace as well) worked as miners in the gold mines of the Courtland-Gleeson District.

Hubert spent his childhood in Arizona, Texas and California, as his father moved around to different jobs. At the age of 9, he discovered a box of minerals under his Uncle Charlie's porch and immediately became an avid collector of minerals. He also had a lifelong interest in botany, and (after his family moved to California) he became one of the founders of the Southwest Cactus Growers, later known as the Los Angeles Cactus and Succulent Society, in 1935. In 1941 he entered a competitive exhibit at the Los Angeles County Fair—his first entrance into competitive exhibition. Remarkably, Hubert's cacti and succulents took seven first-place awards, and two second-place ribbons.

Hubert graduated from John C. Fremont High School in Los Angeles in 1937, and worked as a groundsman for the Los Angeles School District for nearly 40 years, interrupted only by service in the Army Corps of Engineers during World War II. He served in the 10th Mountain Division, one of the most decorated units of the war, and was stationed for a time at Camp Hale (now the Cooper Ski Area) just west of Leadville, Colorado. After the war Hubert took the opportunity to increase his earning capacity by taking a sheetmetal working course, and passed the final test in 1954. He continued working sheetmetal as part of his job for the next 23 years.

Hubert inherited a substantial fortune in his later years, and invested it in oil stocks and California real estate. In 1967 he purchased land in Vista, California where he started to build a world-class Aloe and cycad garden on weekends. He finally retired from the school system in 1977, and worked full-time thereafter on his propety in Vista, developing his garden and also his mineral collection. He purchased fine mineral specimens from a variety of sources including Cal Graeber, Bill Larson, Achim Karl, Tony Jones and Wayne Leicht, spending money when dividends were paid on his stock market investments. But there was no display of minerals in

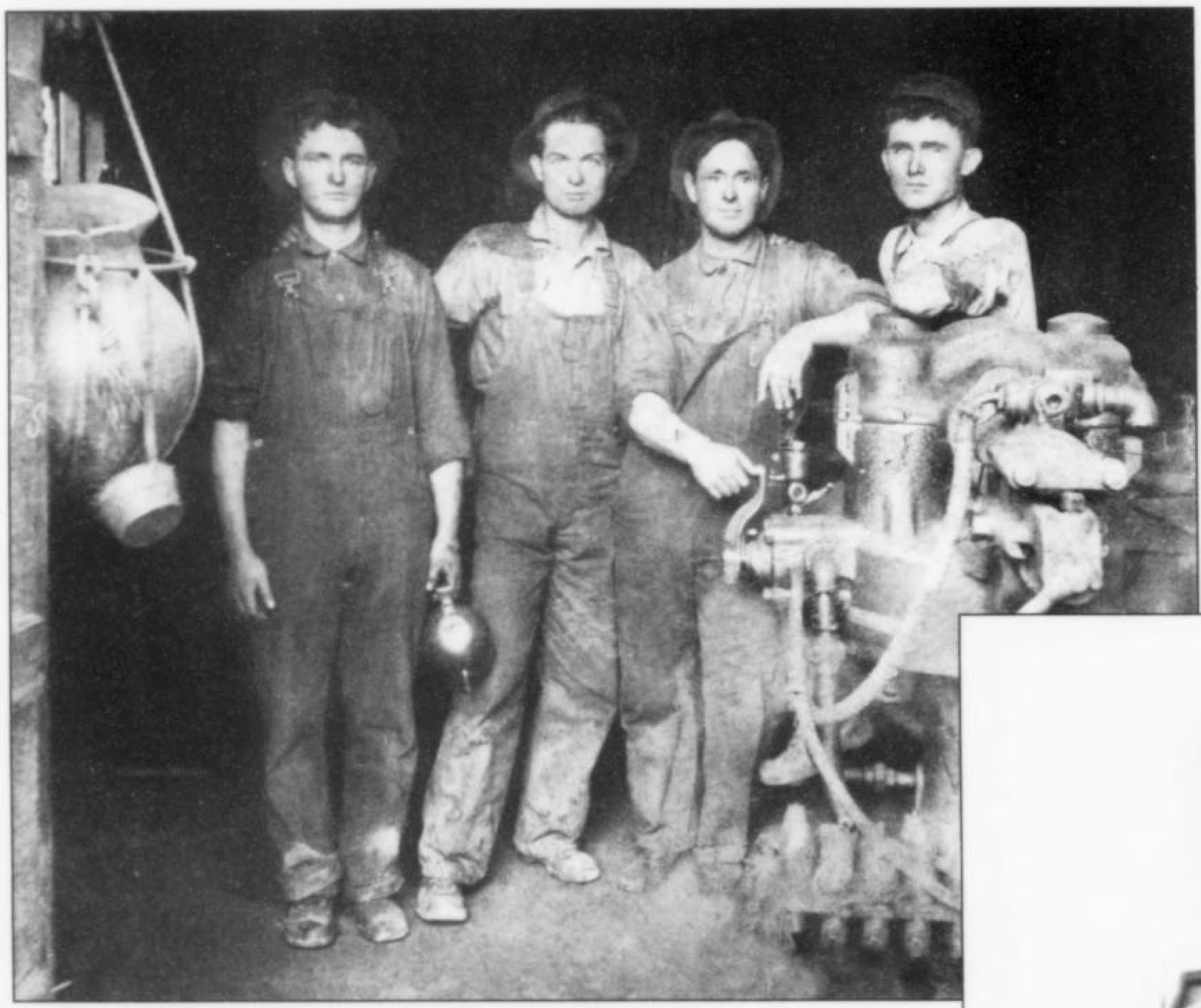


Figure 1. **Hubert de Monmonier's father, Eustace Basil Monmonier (left), and his uncle Charles Monmonier (third from left), in their blacksmith shop in Pearce, Arizona in 1913. Charles had worked as a miner in the Courtland-Gleeson district of Arizona and had a small mineral collection which inspired Hubert's interest as a child.**

Figure 2. **Hubert de Monmonier.**

Figure 3. **Hubert de Monmonier later in life.**

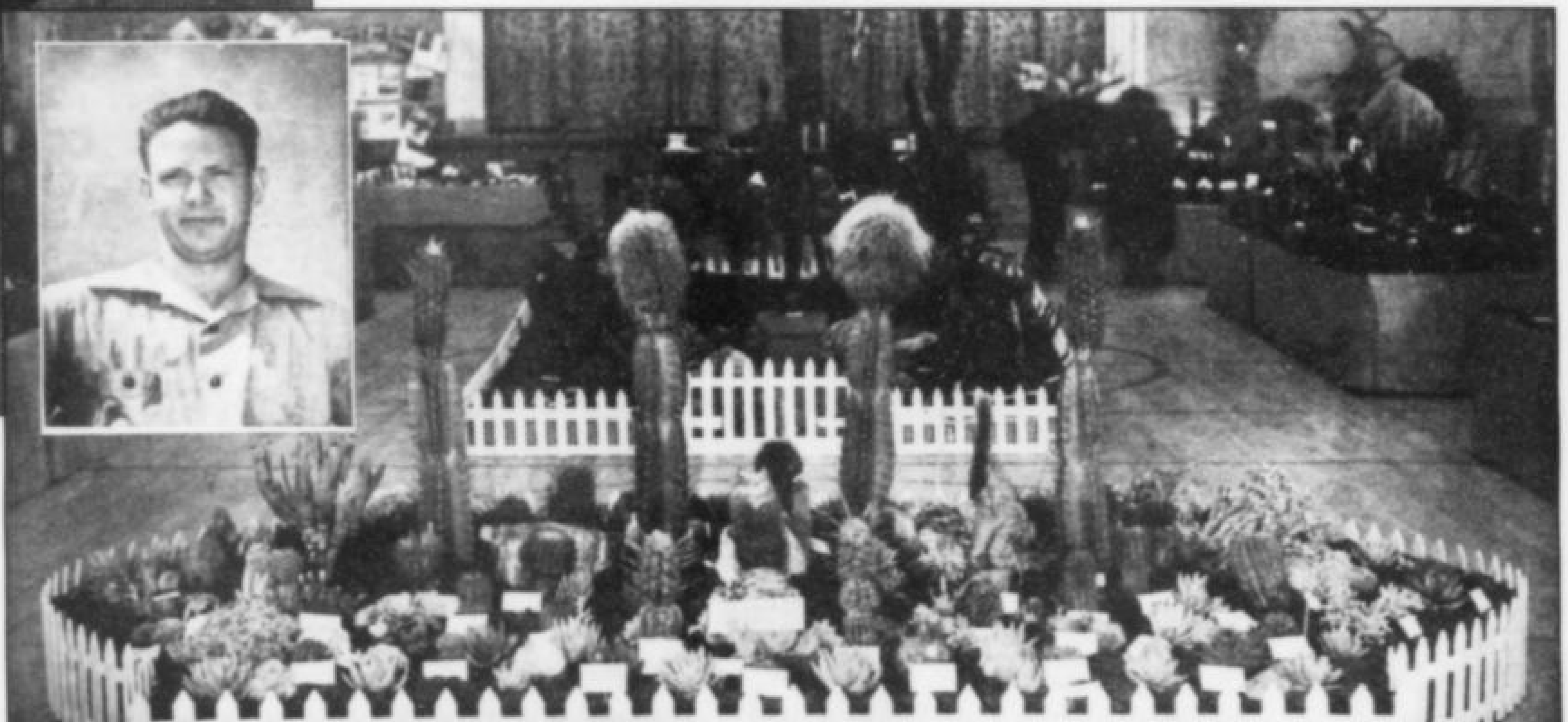


Figure 4. **When he was 22, Hubert de Monmonier's cactus exhibit won first place at the Los Angeles Cactus Show in 1941 (from *Desert Plant Life*, July–August 1941).**

Figure 5. Aquamarine beryl, 12.2 cm, from Volodarsk-Volynsk, Ukraine (no. 18428). Sven Bailey photo.

Figure 6. Cerussite, 11.4 cm, from Touissit, Atlas Mountains, Touissit District, Oujda-Angad Province, Morocco (no. 17814). Sven Bailey photo.

Figure 7. Manganite, 17 cm, Ilfeld, Harz Mountains, Thuringia, Germany (no. 18430). Sven Bailey photo.

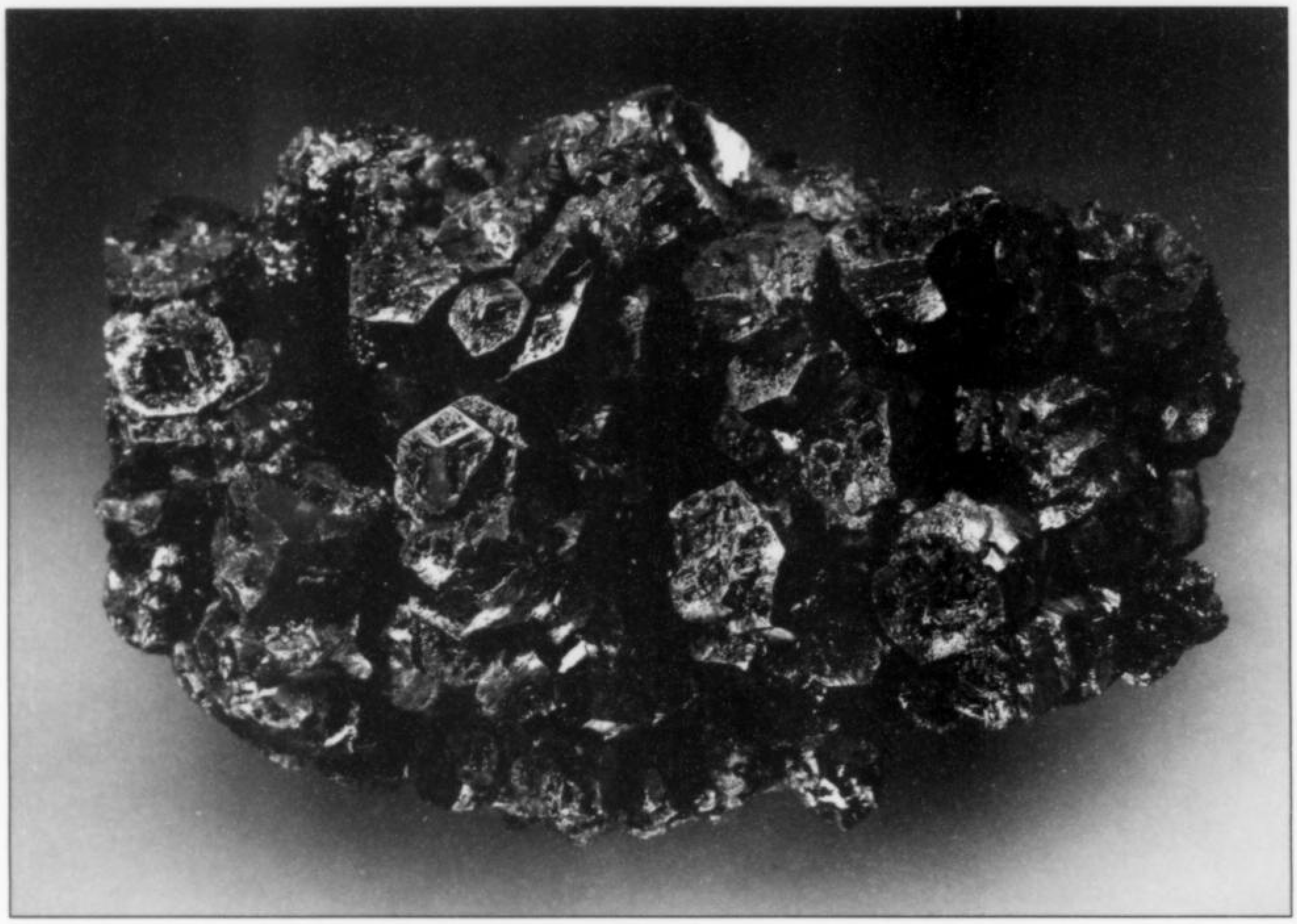


Figure 8. Pyrargyrite crystal cluster, 13.6 cm, from Hartenstein, Saxony, Germany (no. 18503). Sven Bailey photo.

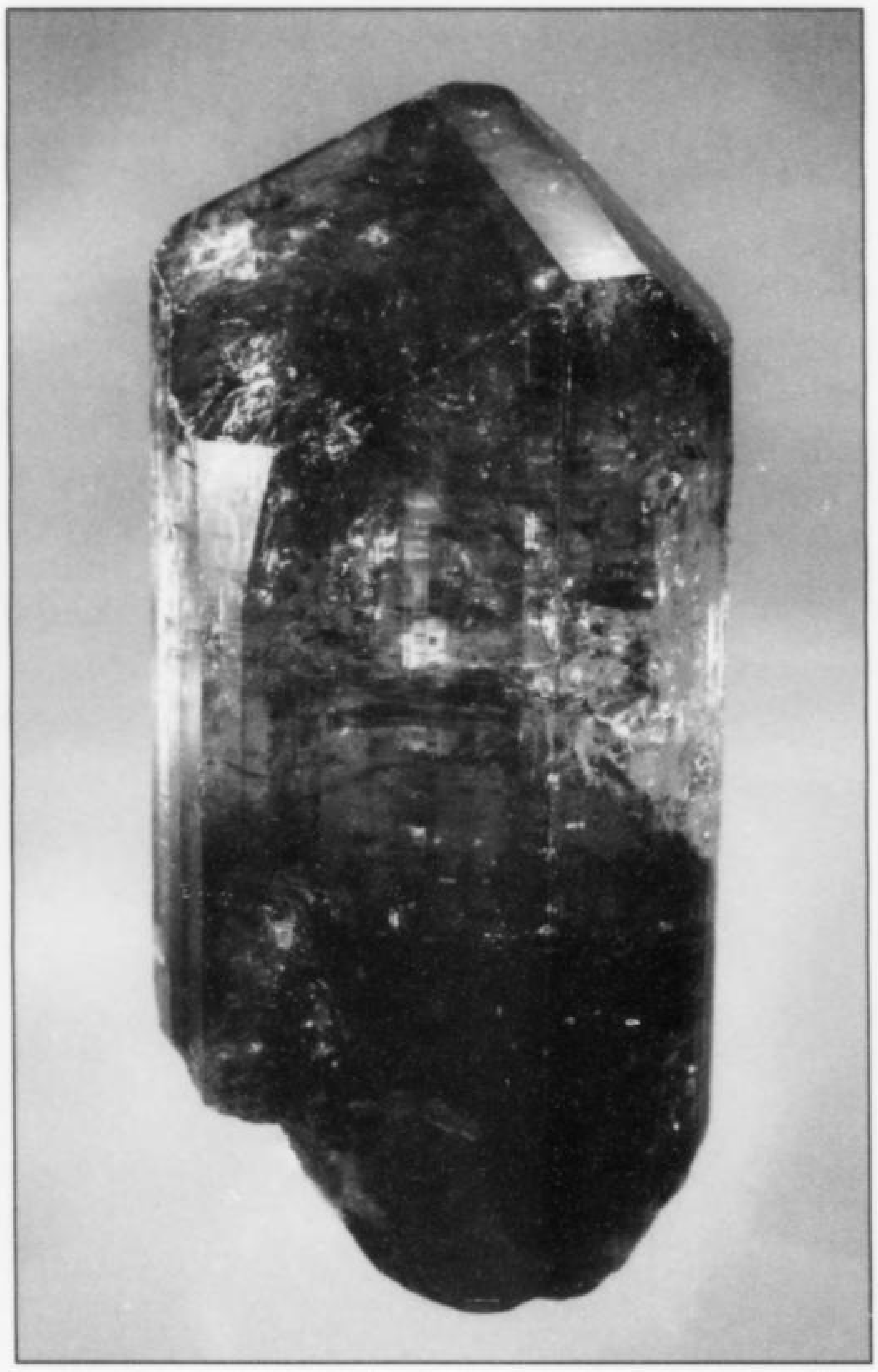
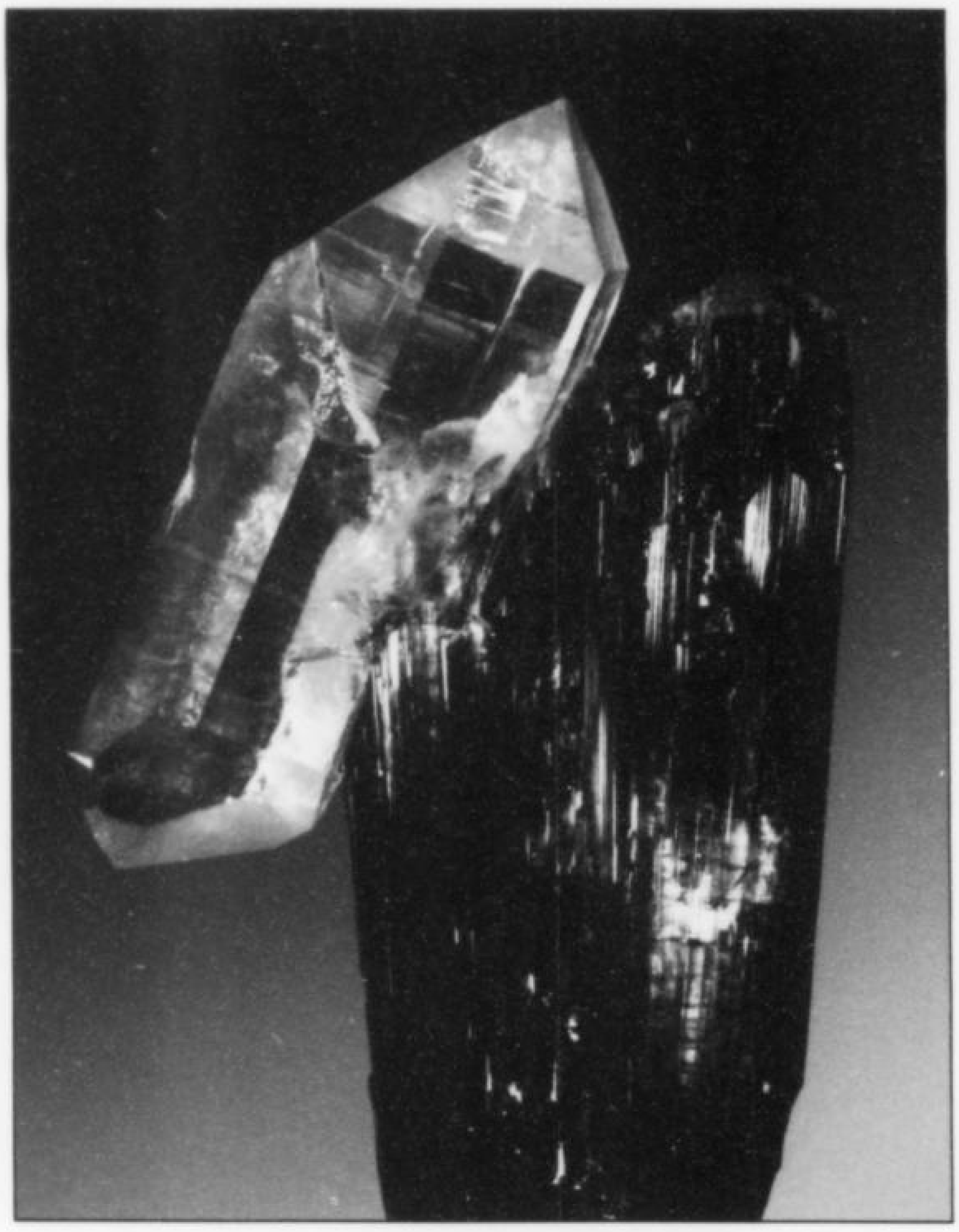


Figure 9. Liddicoatite crystal, 8.4 cm, from Madagascar (no. 17766). Sven Bailey photo.

Figure 10. Quartz on elbaite, 14.8 cm, from Minas Gerais, Brazil (no. 17768). Sven Bailey photo.



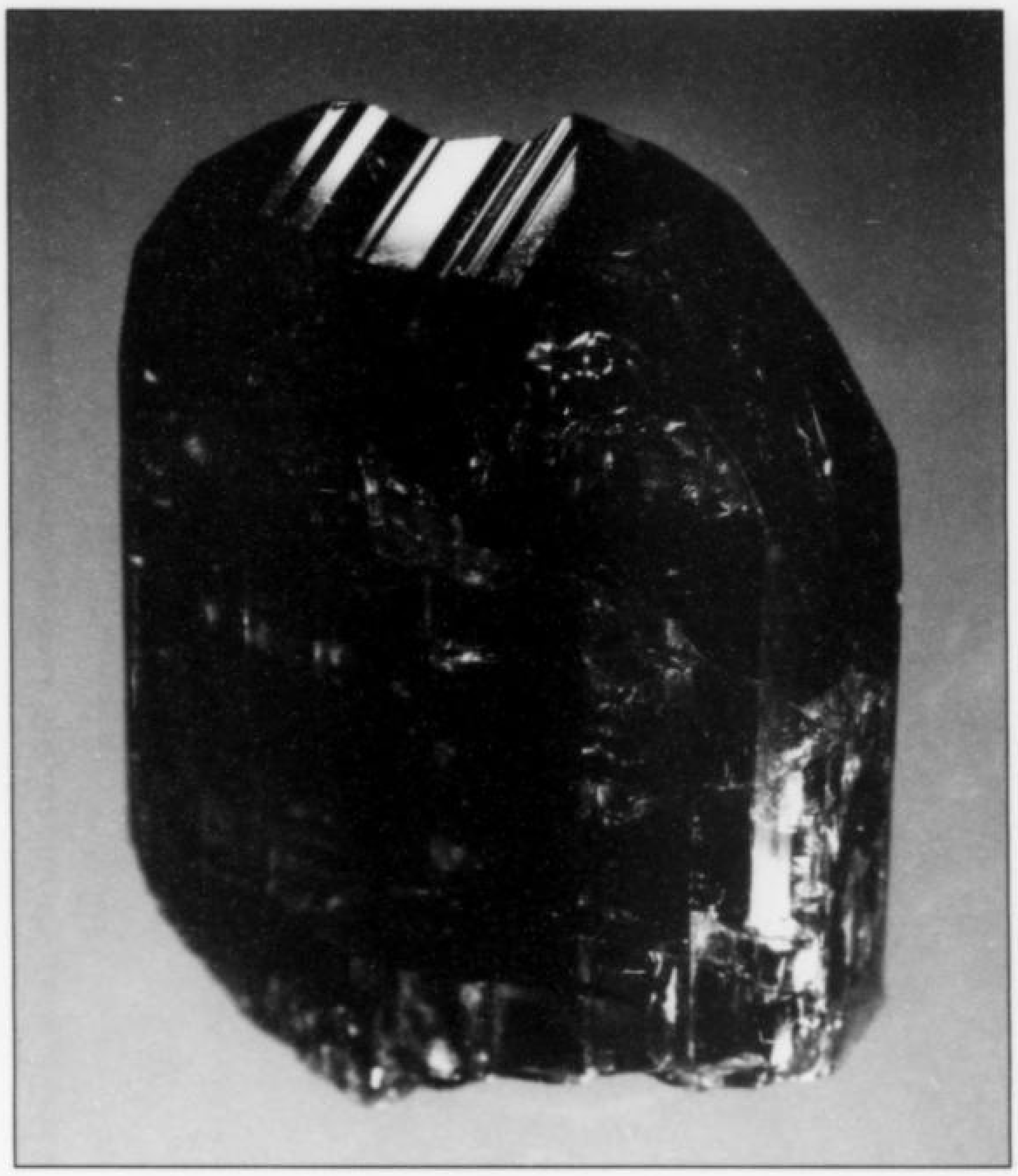
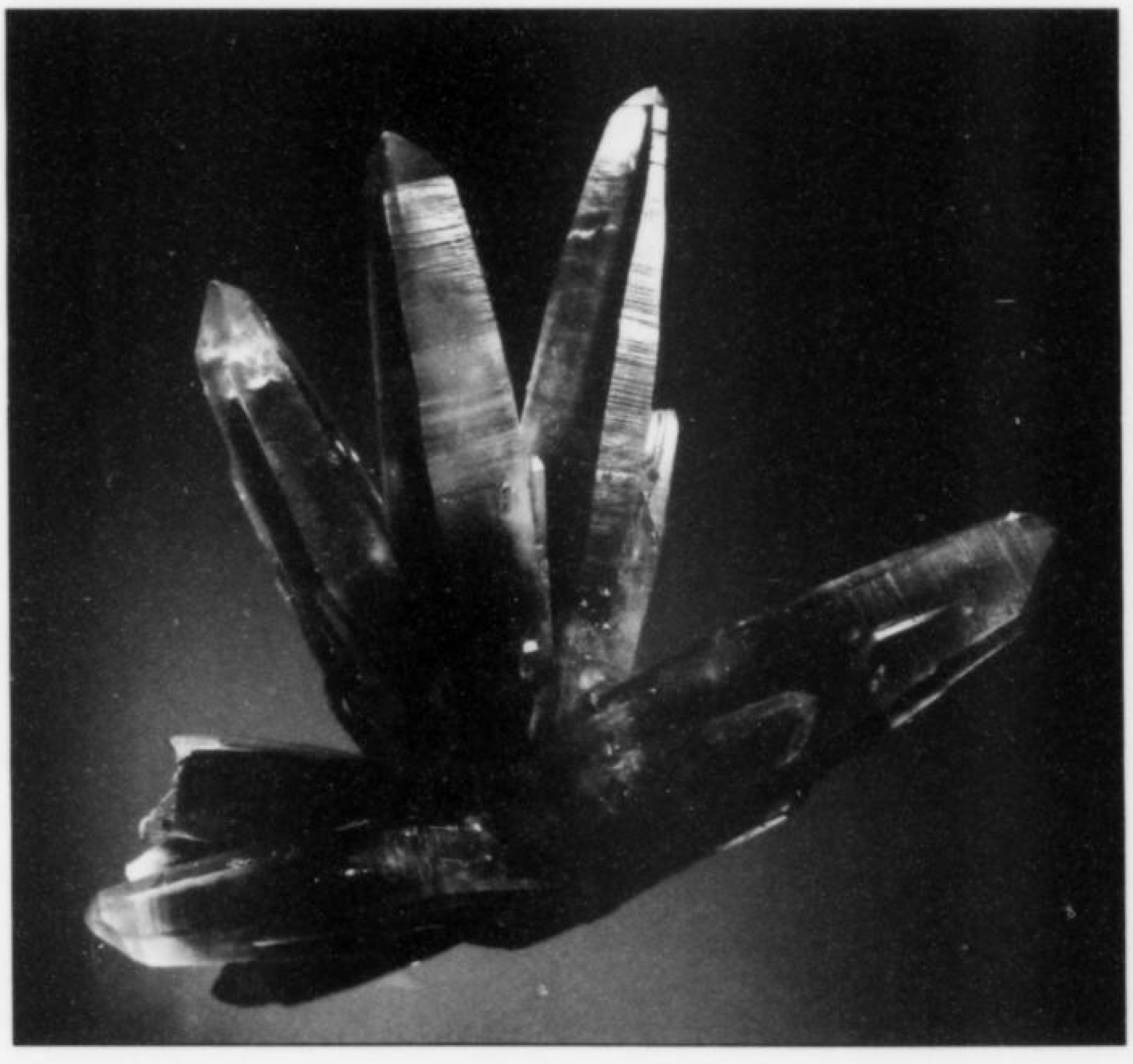


Figure 11. Zoisite, variety tanzanite, 5.6 cm, from the Merelani mine, Arusha, Tanzania (no. 17922). Sven Bailey photo.

Figure 12. Smoky quartz with rose quartz, 21.3 cm, from Taquaral, Minas Gerais, Brazil (no. 17771). Sven Bailey photo.

Figure 13. (below right) Silver, 6 × 14 cm, from Kongsberg, Buskerud, Norway (no. 18325). Sven Bailey photo.

Figure 14. Amethystine quartz, 11 cm, from the Valenciana mine, Amatitlán, Guerrero, Mexico (no. 18361). Sven Bailey photo.



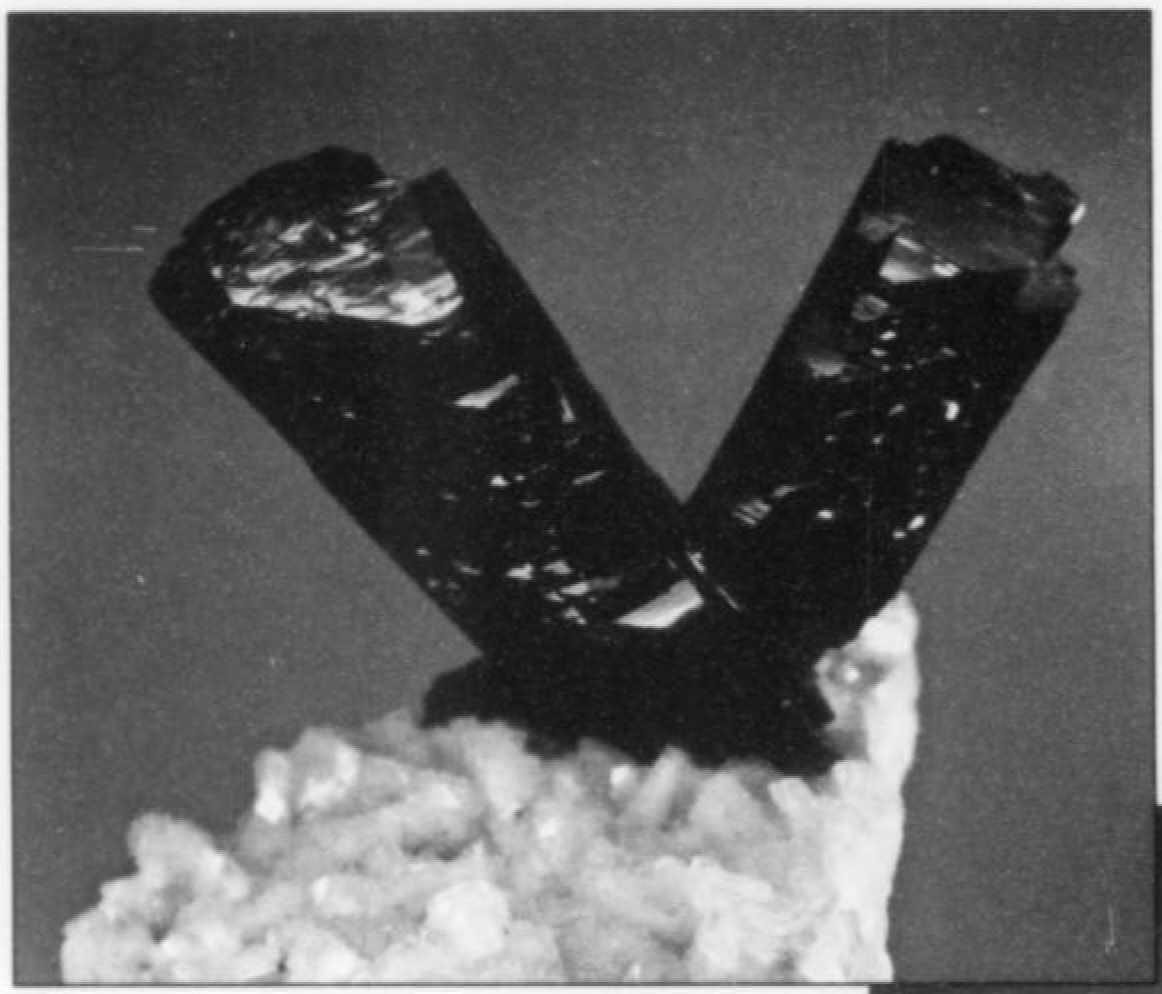


Figure 15. **Azurite crystals to 4.2 cm on pink dolomite, from the Touissit district, Oujda-Angad Province, Morocco (no. 17807). Sven Bailey photo.**

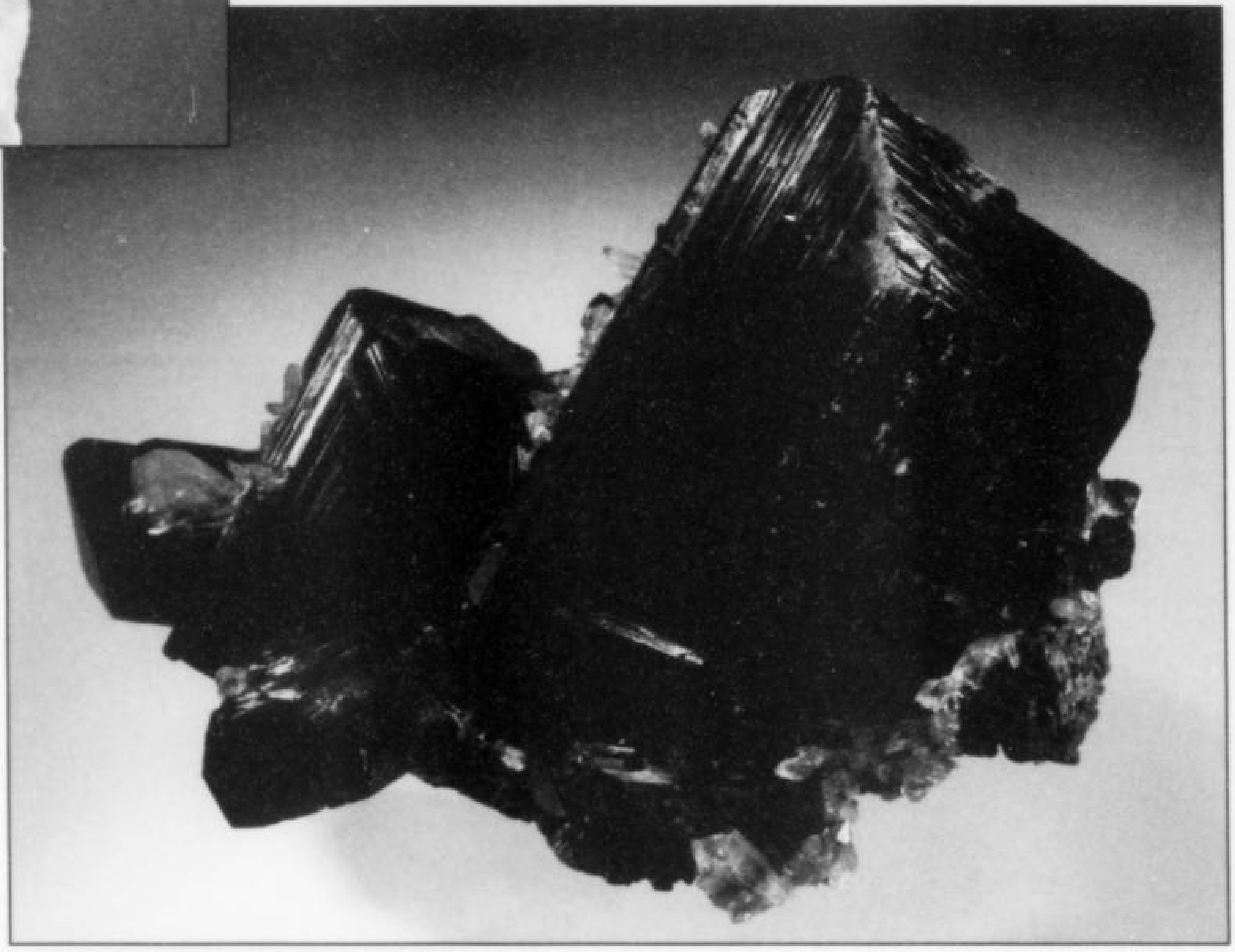


Figure 16. **Epidote with quartz, 14.3 cm, from Green Monster Mountain, Prince of Wales Island, Alaska (no. 18220). Sven Bailey photo.**

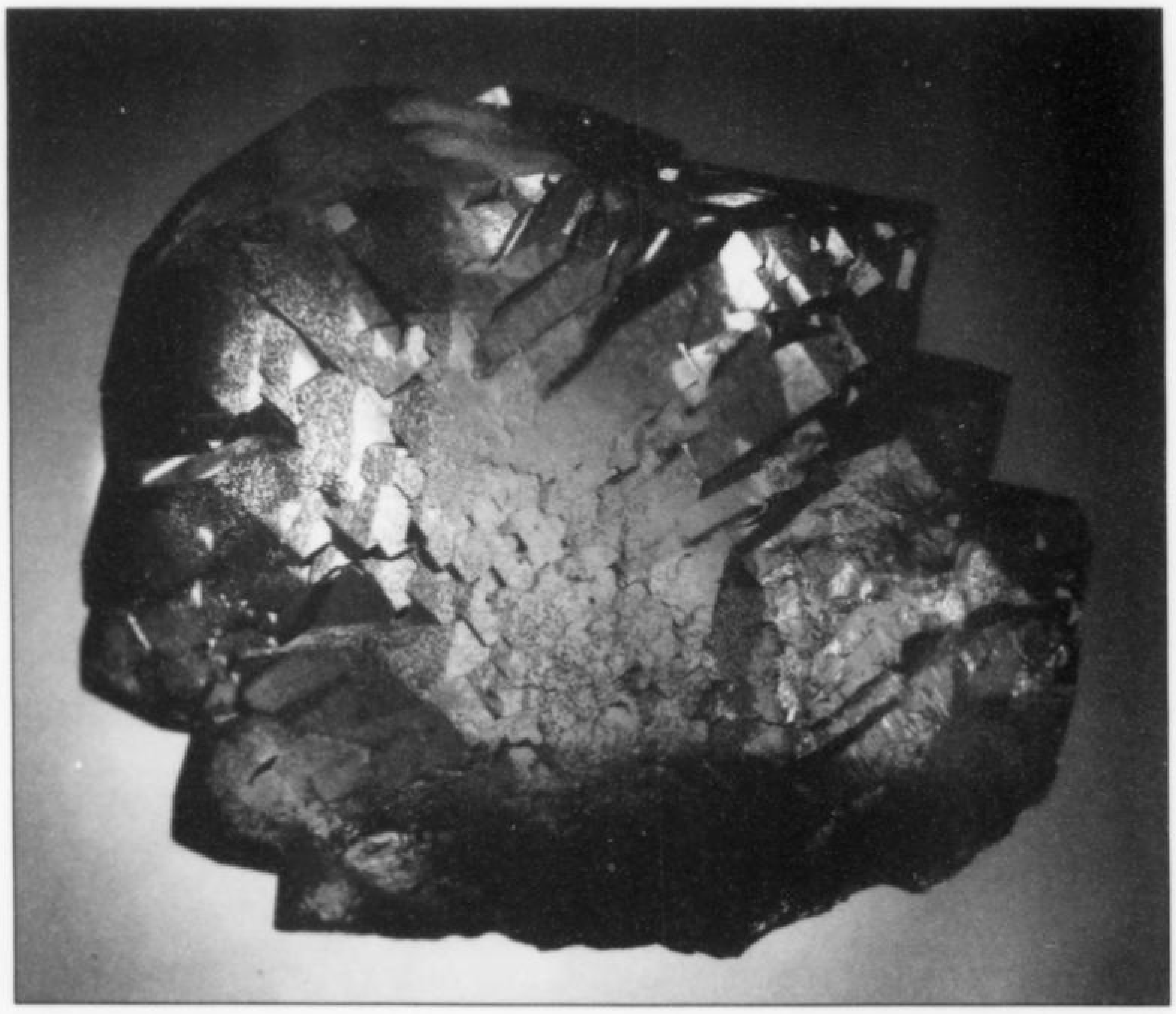


Figure 17. **Smoky quartz gwindel, 7.6 cm, from Val Strem, Sedrun, Mount Oberalpstock, Graubünden, Switzerland (no. 17776). Sven Bailey photo.**

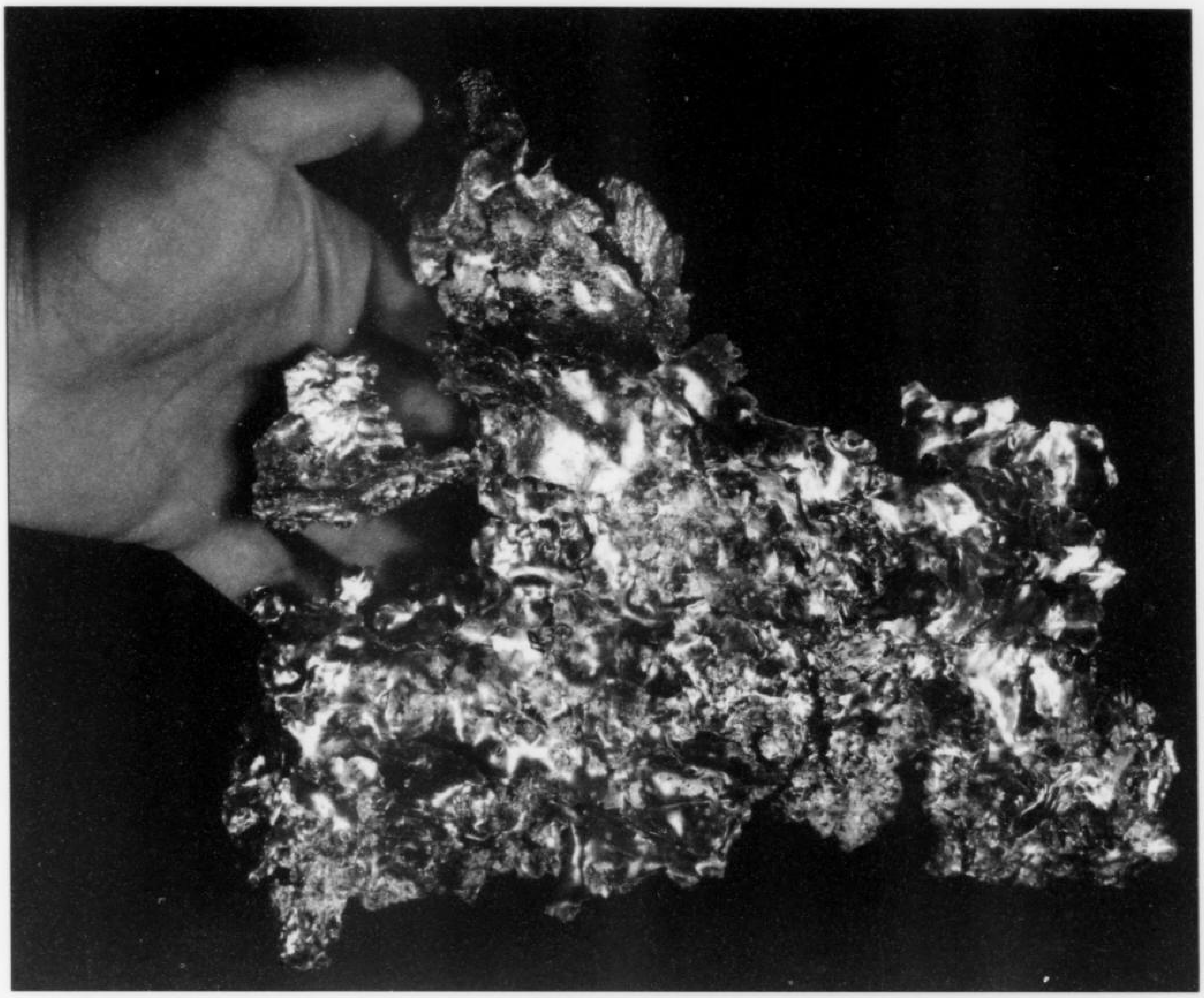


Figure 18. **Gold, 22 cm, from the Crystalline-Alabama claim, Jamestown, Jamestown District, Tuolumne County, California (no. 18403). Sven Bailey photo.**

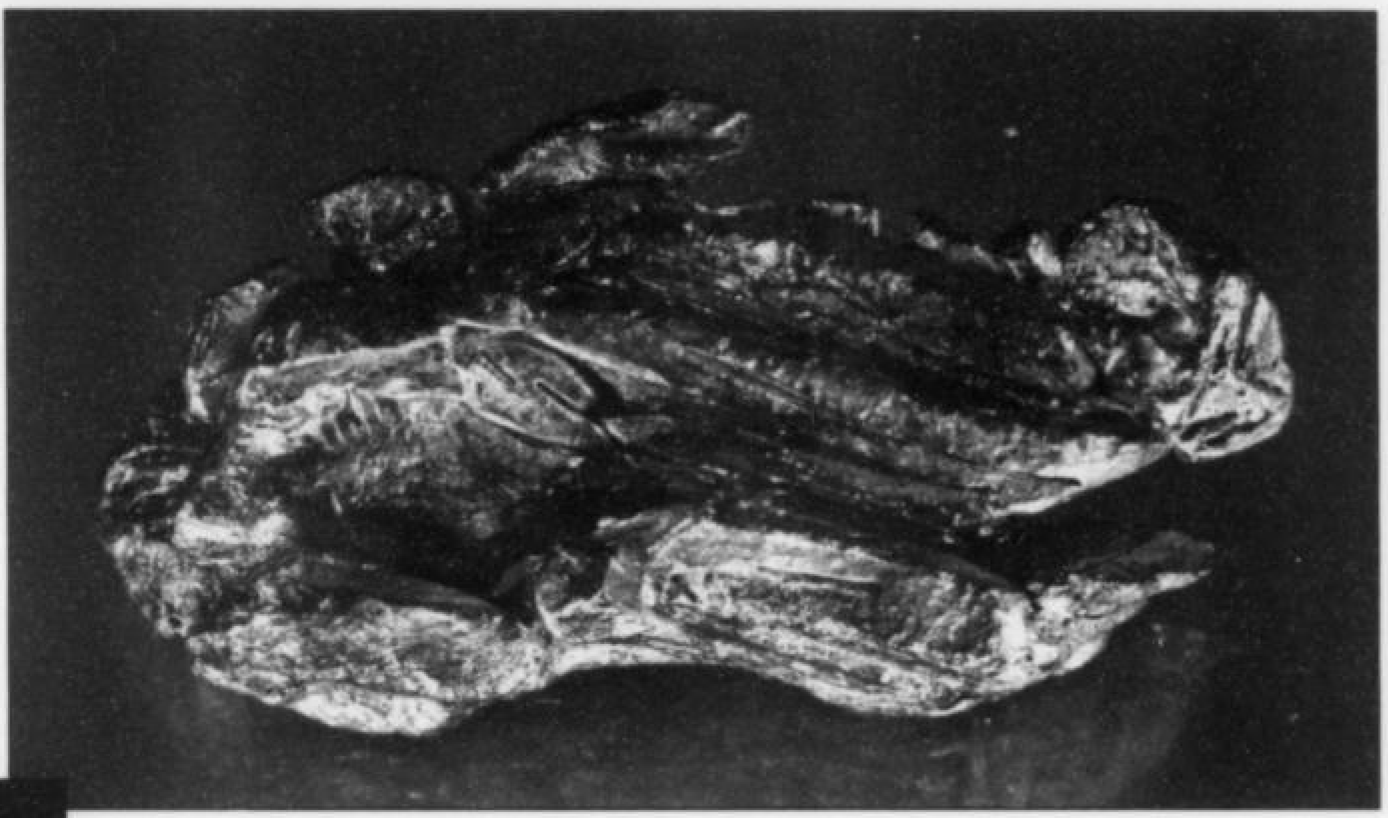
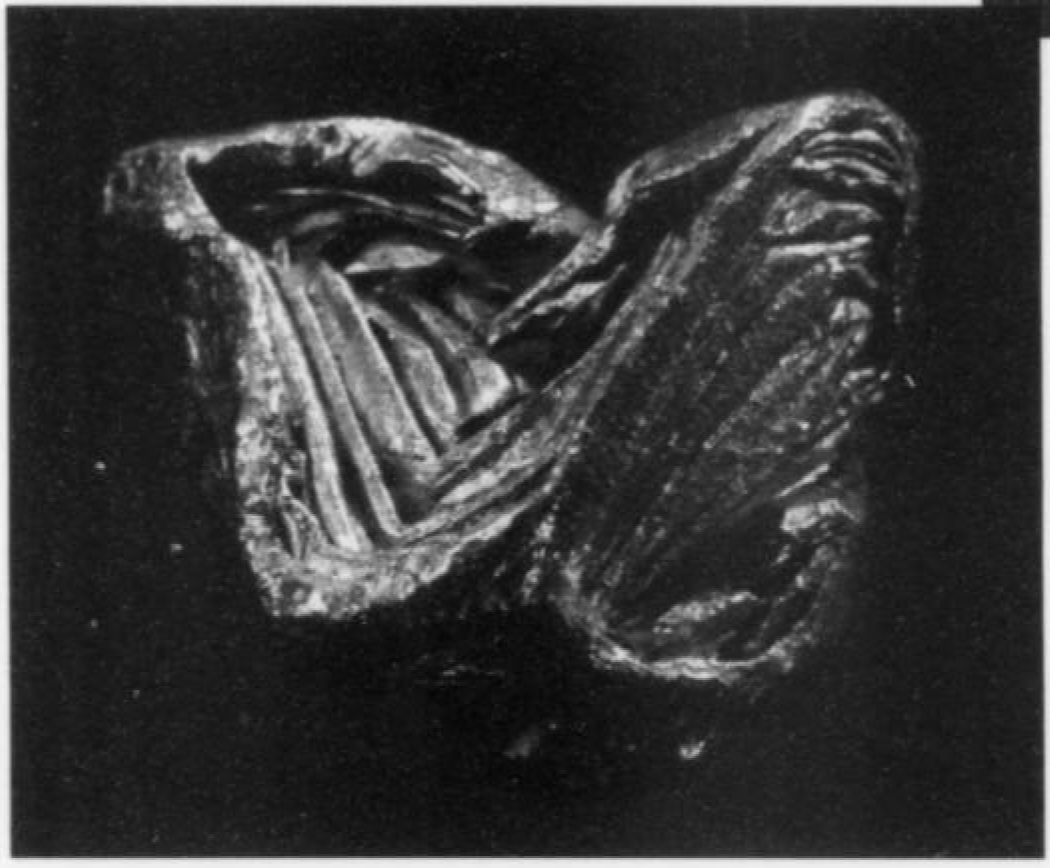


Figure 19. **Gold, 6.7 cm, from Icabarú, Bolívar, Venezuela (no. 18543). Sven Bailey photo.**

Figure 20. **Gold hopper crystal, 3.5 cm, from Icabarú, Bolívar, Venezuela (no. 18539). Sven Bailey photo.**



his home—all specimens were kept in individual boxes under his bed, and although he would show a few specimens to interested visitors, he never showed them all to any one person. Consequently the full scope of his collection was generally unknown in the mineral community. He was friendly but had no telephone and no television, preferring to enjoy his isolation most of the time.

Hubert de Monmonier, a lifelong bachelor, died on March 7, 2007 in Vista. Following his death, his superb collection of minerals and a collection of rare books were donated, in accordance with his wishes, to the Mineral Museum at the University of Arizona in Tucson. Some of his plants were donated to a local botanical garden. Over 300 of the best mineral specimens were placed in a special exhibition in the University of Arizona's Flandrau Science Center, debuting to the public during the Tucson Gem and Mineral Show

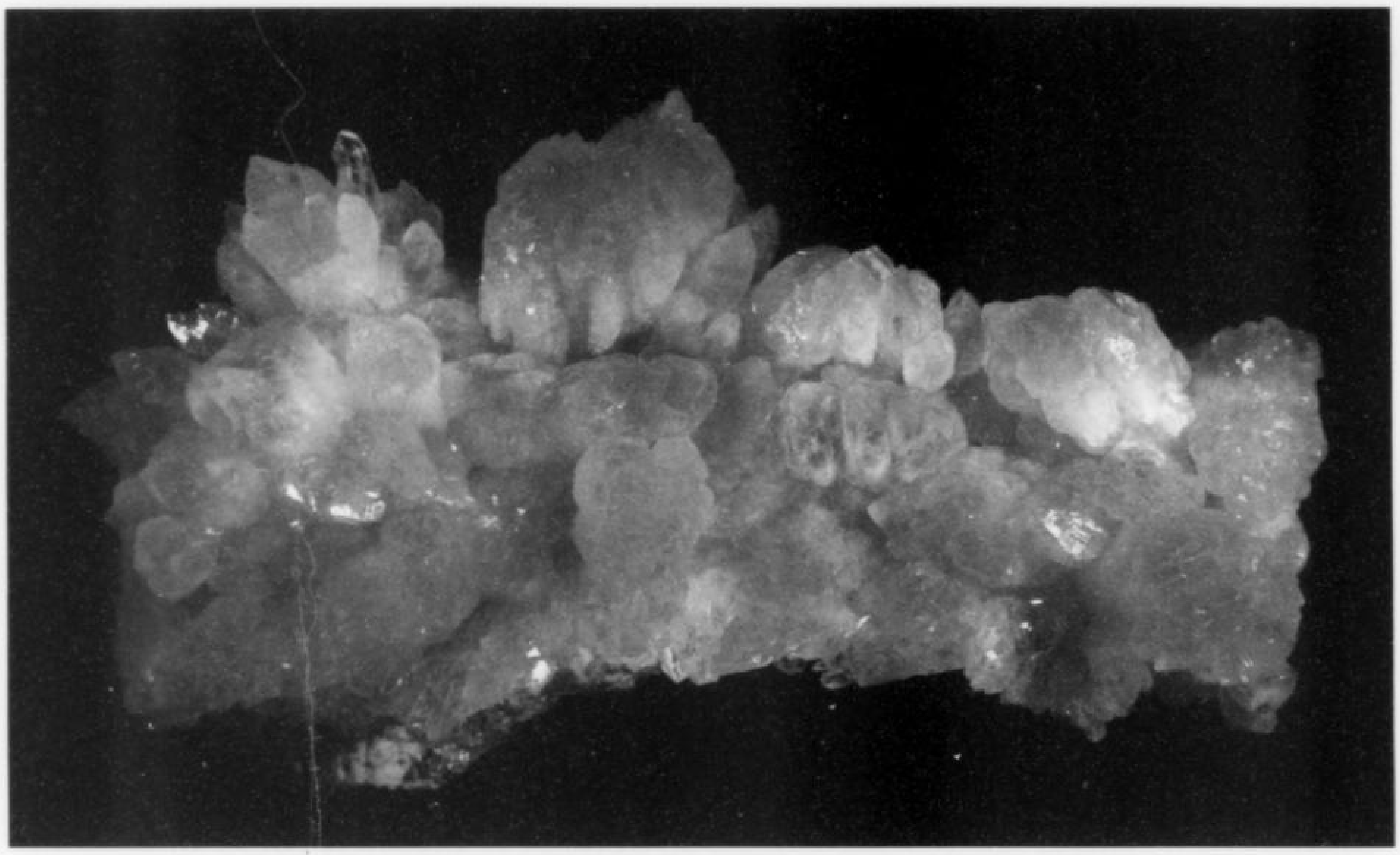


Figure 21. **Rose quartz, 16.3 cm, from Lavra da Ilha near Taquaral, Minas Gerais, Brazil (no. 18359). Formerly in the Frederick H. Pough collection; Sven Bailey photo.**

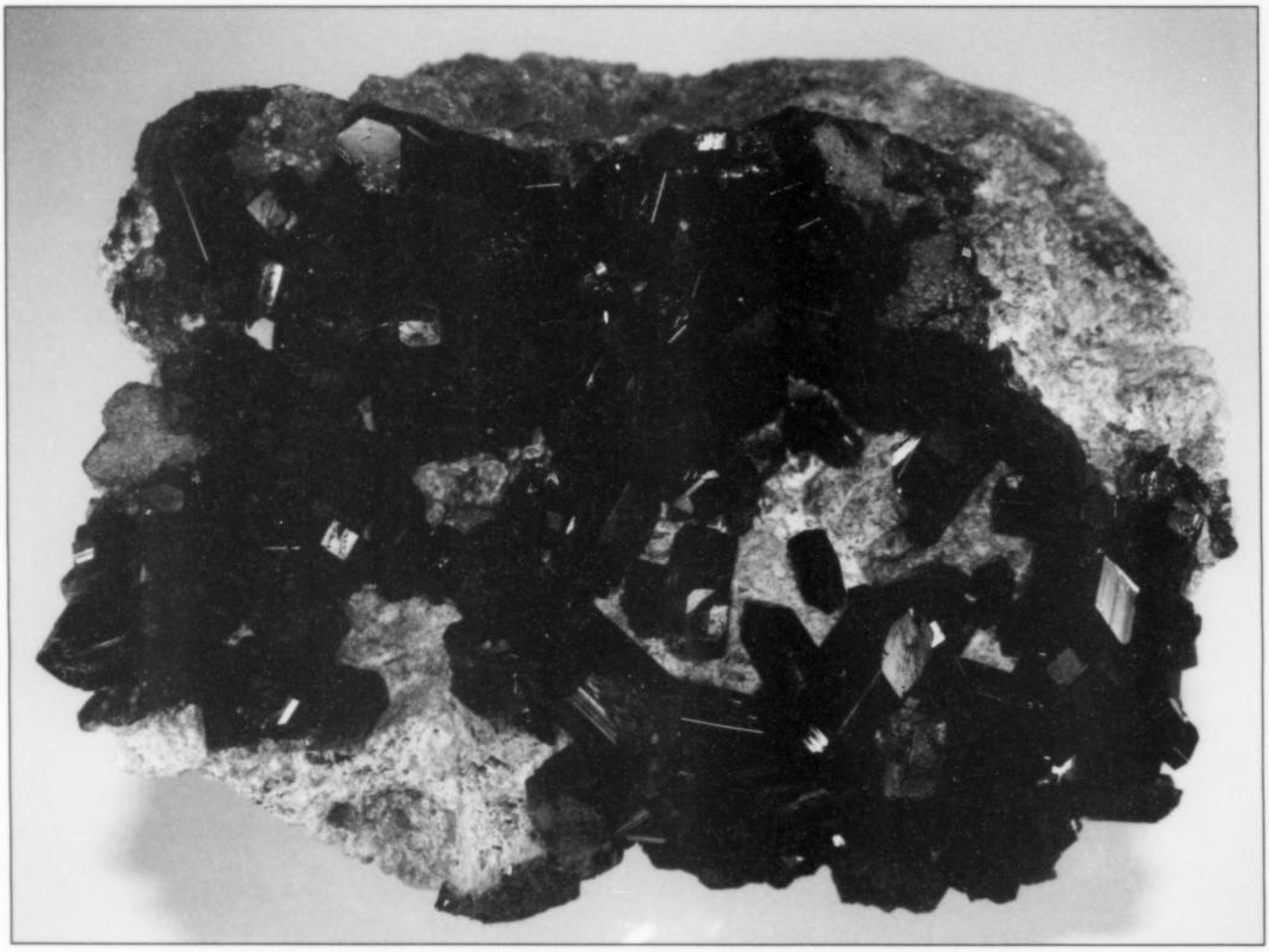


Figure 22. **Dioptase, 12 cm, from Altyn-Tyube, Kazakhstan (no. 17824). Sven Bailey photo.**

in February 2008. The exhibit (which has since been taken down) was called "An Unknown Treasure Comes to Tucson."

The Hubert de Monmonier mineral collection consists of 871 specimens representing 64 species, primarily gold (70 specimens), silver (44 specimens), tourmaline (146 specimens), beryl (38 specimens), and quartz (350 specimens), especially amethyst. One fine amethystine double flower comes from India. And there are three spectacular gwindels, from Russia, France and Switzerland. The collection also contains what may be the finest known Guerrero amethyst, with brightly lustrous crystals to 30 cm.

Hubert especially liked native metals; his collection contains two platinum nuggets from Russia, as well as 70 native gold specimens, including an amazing ribbon gold from Garden Valley, California; a large leaf gold from Jamestown, Tuolumne County, California; several fine Eagle's Nest mine golds; and two large and spectacular, somewhat waterworn gold crystals from Icabaru, Bolivar, Venezuela. Fine crystallized native silver specimens from Batopilas, Mexico are included, as well as excellent wire silvers from Kongsberg, Norway. A spectacular cabinet-size pyrargyrite crystal cluster from Hartenstein, Saxony rounds out the silver minerals suite.

Other minerals in the Monmonier collection include an excellent cabinet-size cluster of manganite crystals from Ilfeld in the Harz Mountains, Thuringia; a fine azurite from the Copper Queen mine, Bisbee, Arizona; another fine azurite from the Touissit mine in Morocco, accompanied by a cerussite crystal cluster from the same locality; a Tsumeb dioptase; a cabinet-size axinite-(Fe) (formerly called ferro-axinite); a very large blue zoisite (var. tanzanite) from Tanzania; and a large epidote crystal cluster from Green Monster Mountain, Prince of Wales Island, Alaska.

The University of Arizona's mineral collection was begun in 1892, and has continued to grow over the years. With the addition of the de Monmonier Collection, it now contains about 18,000 mineral specimens of various sizes plus around 7,000 micromounts. The Monmonier Collection is planned to be a centerpiece of the University's new Downtown Science Center, scheduled to begin construction later this year, for an eventual opening scheduled for 2011.

ACKNOWLEDGMENTS

Our thanks to Shirley Wetmore and Sven Bailey of the University of Arizona Mineral for information and photos regarding Hubert de Monmonier and his collection.

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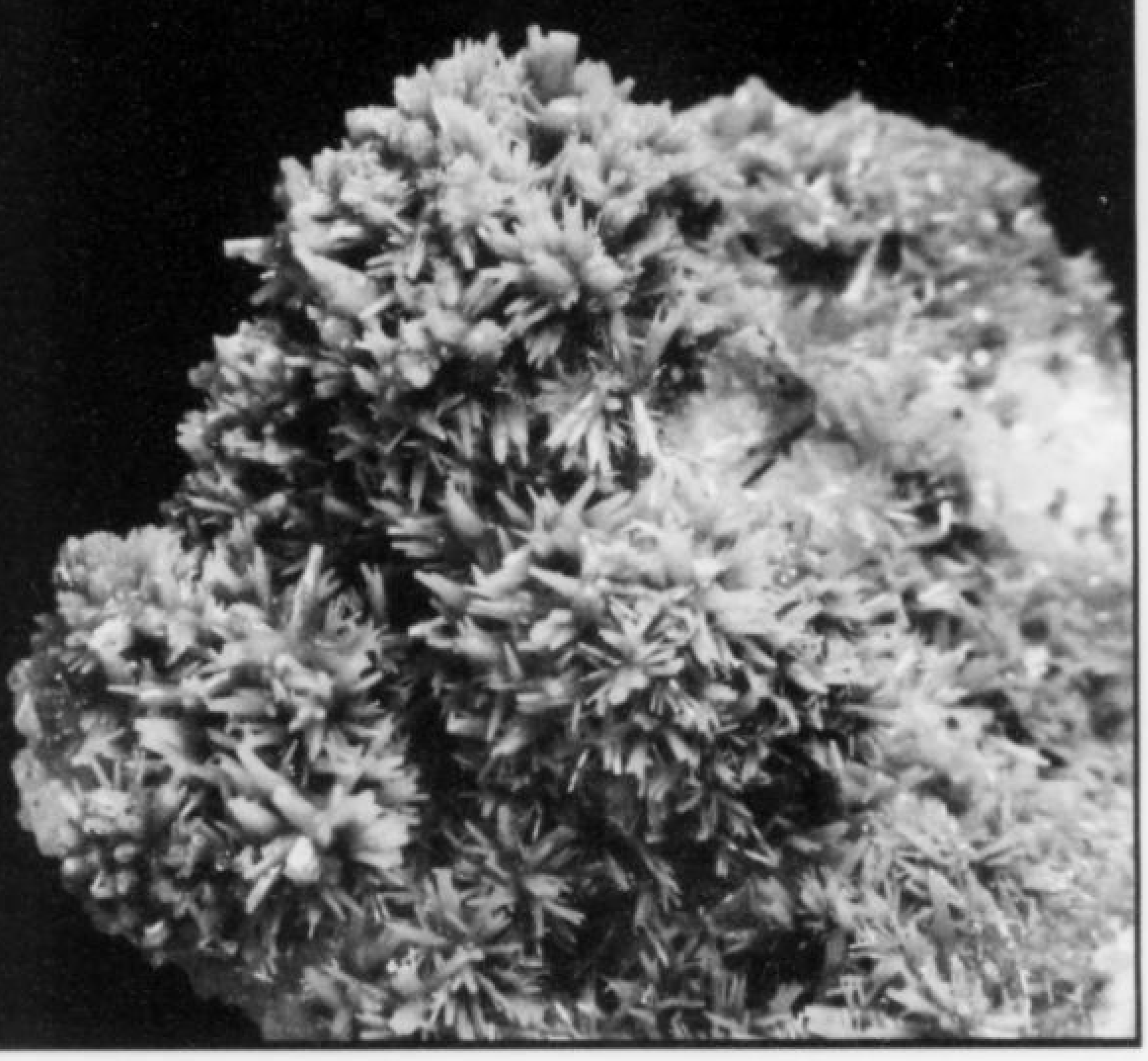

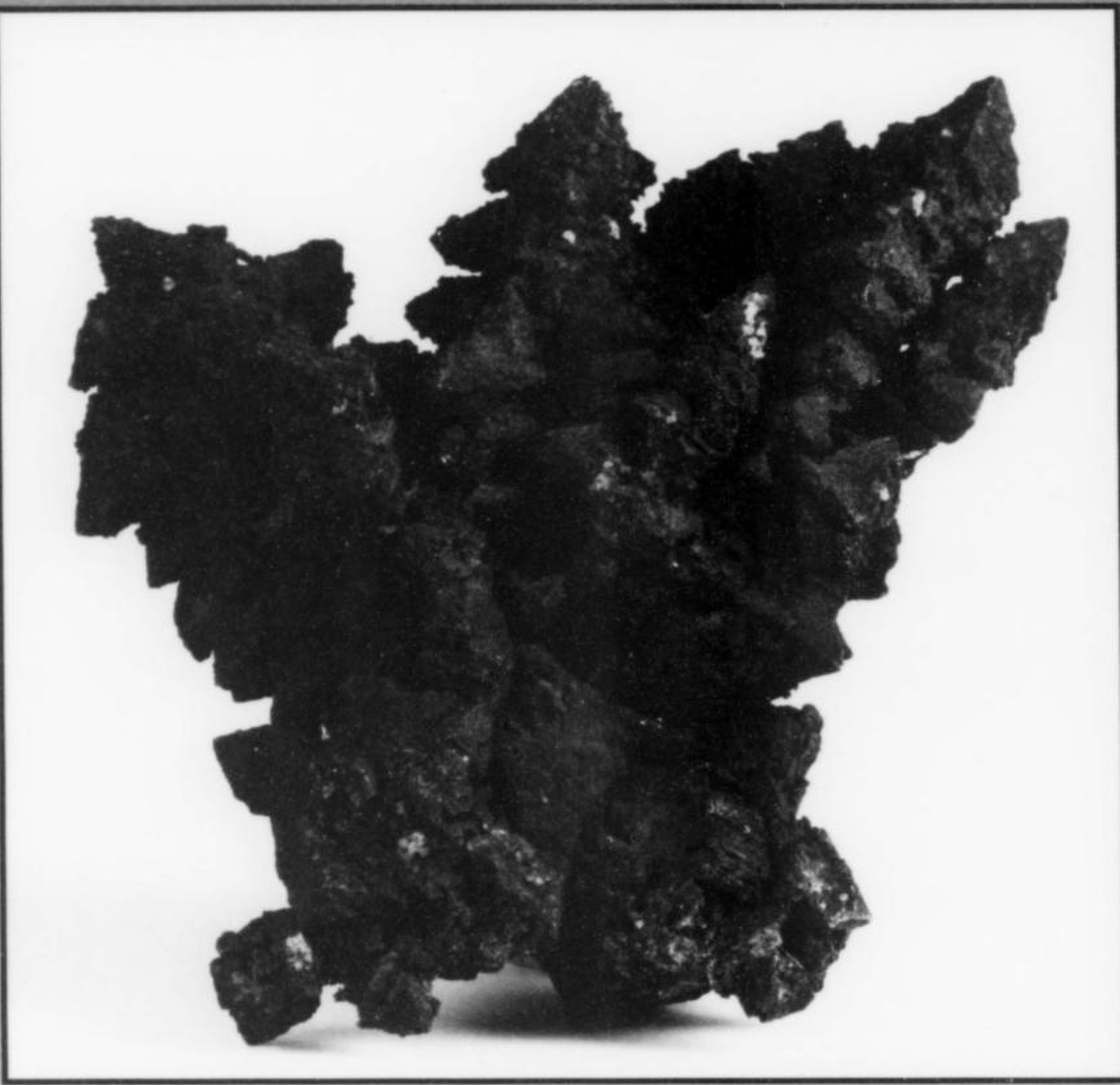

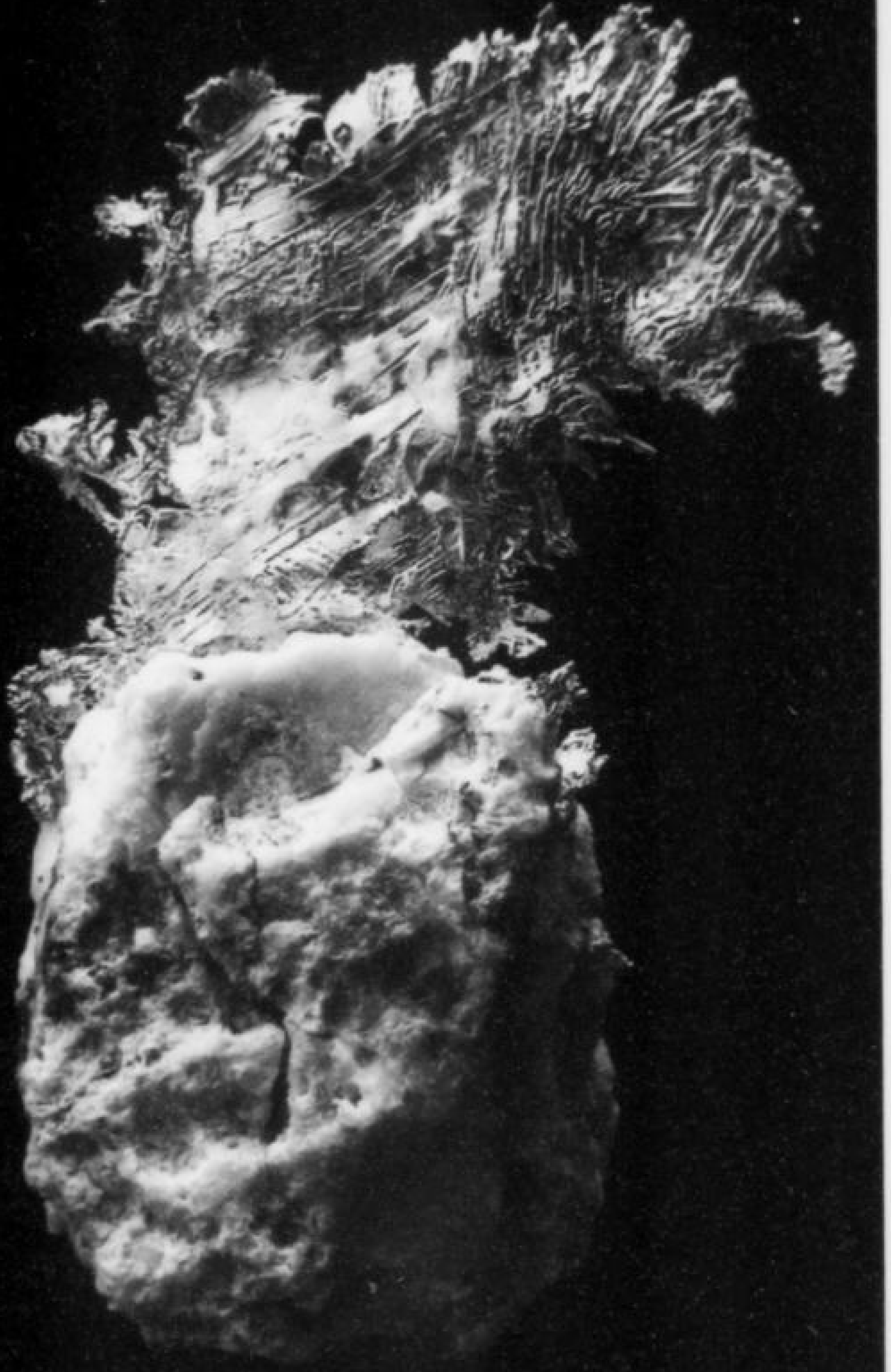

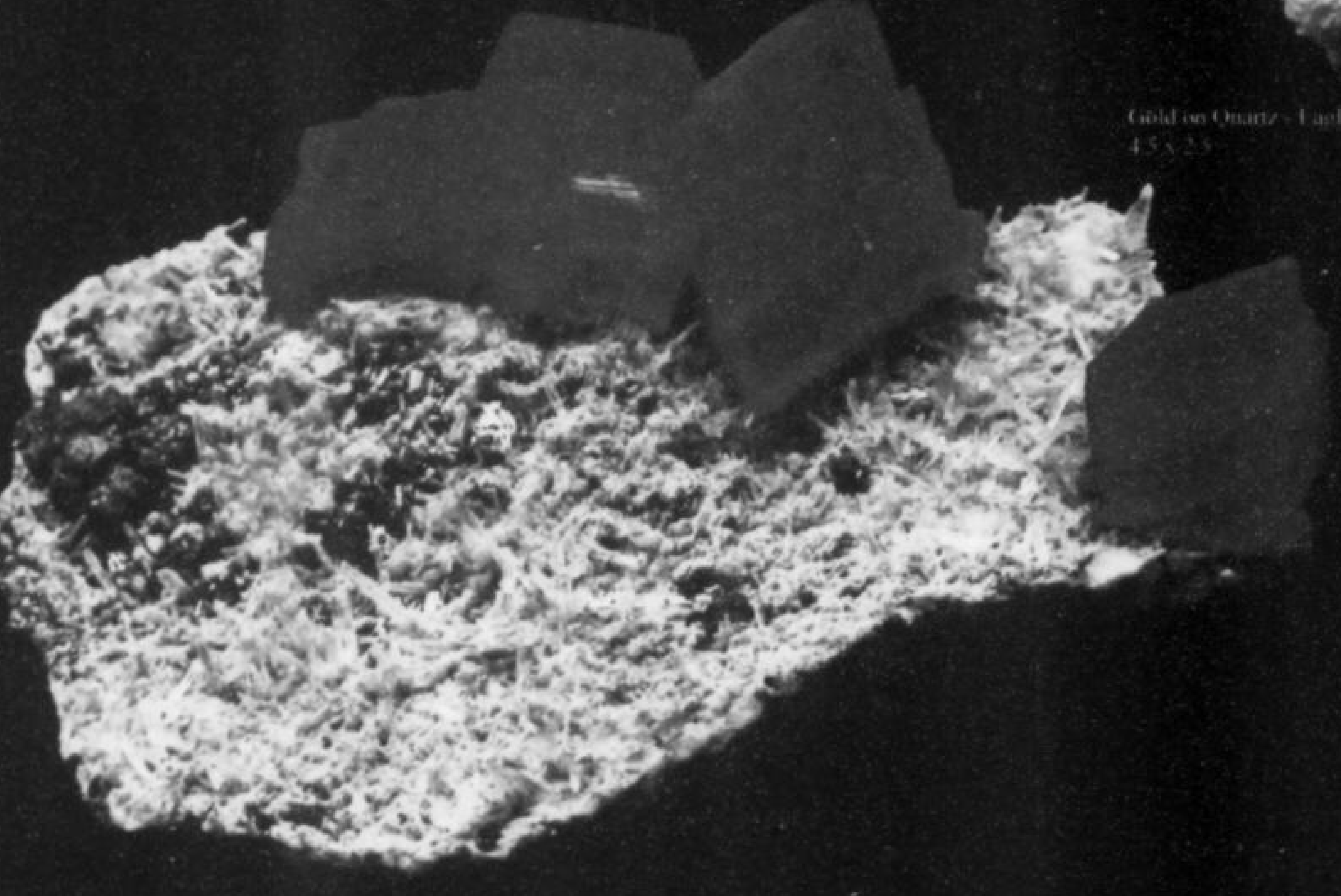

ABOUT MINERAL COLLECTING

PART 2 OF 5

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Some personal observations, ruminations, reflections, reminiscences, ramblings, digressions, grumblings, approbations, wisdom and advice gleaned from 50 years of collecting and dealing in minerals

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In mineral collecting, as in most avocations, it will take you about ten years to learn your way around the block, and then another ten years to get good at it. After ten years, if you have diligently applied yourself to all of the educational activities recommended in the previous installment, you should be able to look at a well crystallized mineral specimen and know what it is, where it is from and how good it is relative to others of its kind. If you can't, you may need another few years of seasoning, but who cares? It's great fun no matter what, and you can progress at your own pace.

How Much Can You Get?

Since the goal of all collectors is to get stuff, I thought that before I talk about the different kinds of mineral collectors I might talk a little about how much you can get, that is, how many mineral specimens you can hope to acquire in your collecting career. If you add one specimen a day to your collection, after ten years you will have 3,650 specimens—well, perhaps 3,652 if you take into account a couple of leap years. After 50 years of collecting one a day you will have something over 18,000 specimens. If you collect two or ten a day—well, you can run the numbers as well as I. So, since I myself have something like 20,000 specimens in my collection, I am about a one-a-day guy. There are others like me, and some have surpassed me by a considerable amount, certainly in quantity if not quality.

To put the size of collections in perspective, it is useful to consider mineral collections that have been formed in the past and those that are currently in the process of formation. I think that all of the large mineral collections without exception have been formed by individuals. Large mineral collections in museums are agglomerations of many large personal collections that have been given or (more rarely) sold to museums over the years. In recent times, were it not for the ability of collectors to donate specimens to museums and write off their appraised value against other income, the quantity of donations to museums would be considerably reduced. In this as in other facets of human activity, modern efforts equal and surpass those of previous generations.

The Past

The earliest private mineral collections in Germany in the 16th century were surprisingly similar to good study collections today. However, that purity of approach faded, and by the 17th century there were few, if any, collections devoted solely to minerals. Instead, natural history collections became "universal" in scope; the minerals were gathered together with other curiosities like

Collection of the British Museum
(1817)
Emerald
Somondoco (Chivor) mine, Colombia

Emerald crystals were being mined in Colombia by the Incas in 1537 when the Spaniards first encountered them, and many chests full of crystals were shipped back to Europe. This example (pictured in James Sowerby's Exotic Mineralogy, Plate 100, dated 1817) found its way eventually into the collection of the British Museum, and may well be one of those early specimens. Fine crystals are still being found in Colombia today, at the Muzo and Cosquez mines.

shells, fossils, plants and animals, and housed in special rooms or *Wunderkammern*. These collections were assembled by the wealthy for the amusement of their friends and the aggrandizement of their reputations as patrons of the arts and science. No attempt was made to differentiate minerals from fossils.

Mineral collecting was helped along by the Industrial Revolution, which necessitated the finding and exploitation of mineral resources to feed the growing demand for raw materials. The more raw materials that were needed, the more rock that had to be dug and moved to supply them. This brought many more mineral specimens within the reach of collectors. Originally only the super-wealthy and members of the aristocracy could afford to indulge themselves in such things, but as disposable wealth grew, even the middle class and people of more modest means could afford to collect minerals, although of course on a more modest level. It is interesting to note that in poor countries any museums, if they exist at all, are very meager affairs compared to those in richer countries.

Most old collections are and were sold by mineral dealers, but some were donated or sold intact to schools and museums. These formed the foundation of today's great institutional collections. Often these once-private collections, though perhaps not completely intact, are still recognized as subunits in today's institutional collections. Today the great institutional mineral collections are pretty much limited to the United States and Europe, with some in Canada, Australia and Japan.

The three great old collections in the United States are the Bement, Roebling and Canfield collections, and probably the Bement Collection was the greatest of these. Clarence S. Bement (1843–1923) was a wealthy manufacturer from Philadelphia who had the means to spend generously on his hobby. His collection was purchased by J. P. Morgan and presented as a gift to the American Museum of Natural History in New York City. It took two freight cars to carry the collection from Philadelphia to New York City.

Washington Roebling (1837–1926) was a civil engineer who was perhaps best known for his construction of the Brooklyn Bridge. Following his death, his collection was given to the Smithsonian Institution in Washington D.C., where it remains today, essentially intact. It contained about 16,000 specimens, and his specimens in the Smithsonian all have black catalog numbers preceded by an "R."

Frederick Canfield (1849–1926) was a mining man whose collection was particularly strong in minerals from Franklin, New Jersey. He also spent time in the mines in Bolivia and discovered the mineral that was eventually named after him: canfieldite. His collection consisted of perhaps 9,000 specimens that were also given to the Smithsonian Institution. His specimens bear catalog numbers that are preceded by a C, and (in accordance with a stipulation of the bequest) are never sold or traded.

The collection of German industrialist Carl Bosch (1874–1940) contained about 25,000 specimens. Before the Second World War his collection was shipped to the United States and was stored in the basement of Yale University for a number of years. Eventually it was sold to the Smithsonian Institution, and many of the specimens remain there today.

Museums in Canada, England, France, Germany, Australia and other countries each have major once-private collections that form the core of their holdings of mineral specimens. The list could go on and on but this will give you a little idea of what has gone before.

The Present: Institutional Collections

Currently the Smithsonian Institution may hold the record for the largest number of mineral specimens owned by an institution. Curator Paul Pohwat estimates the mineral collection at 375,000 specimens but adds that "Meteorites are a separate and similar total." This number is eclipsed, however, by the Smithsonian's Rock and Ore Collection, 95% of which needs to be stored at the Museum Support Center in Suitland, Maryland because of its size.

The great collection at the British Museum of Natural History (today called simply "the Natural History Museum"), according to curator Peter Tandy, has "in rather rounded figures . . . approximately 170,000 minerals, 121,000 rocks, 30,000 ores, 30,000 ocean deposit samples and 4,000 meteorites. The Harvard Mineralogical Museum contains about 75,000 mineral specimens, 150,000 rocks and 1,200 meteorites. The American Museum of Natural History has about 95,000 cataloged mineral specimens (with more to catalog) plus 20,000 rocks and 5,000 meteorites. I don't know any large museum in which the cataloging of the mineral collection is up to date: cataloging is a very time-consuming business and curators work at it only when they can or when they have volunteer labor they can trust to work on it. The Natural History Museum of Los Angeles County, by no means extraordinary in its mineral holdings, has about 150,000 specimens, of which about 100,000 are micromounts.

The collection at the Mining Academy in Freiberg, Germany certainly deserves mention here as well. Andreas Massanek, the curator of the museum, informs me that the main collection has about 92,000 mineral specimens, 29,000 rock specimens, 120,000 ore samples and a stock of 400,000 specimens for exchange and scientific use. In October of 2008 the Mining Academy plans to open a new exhibition in the Freiberg castle with 5,000 specimens from Dr. Erika Pohl-Ströher. She has thus far donated 18,000 specimens and may donate many more.

Private Collections

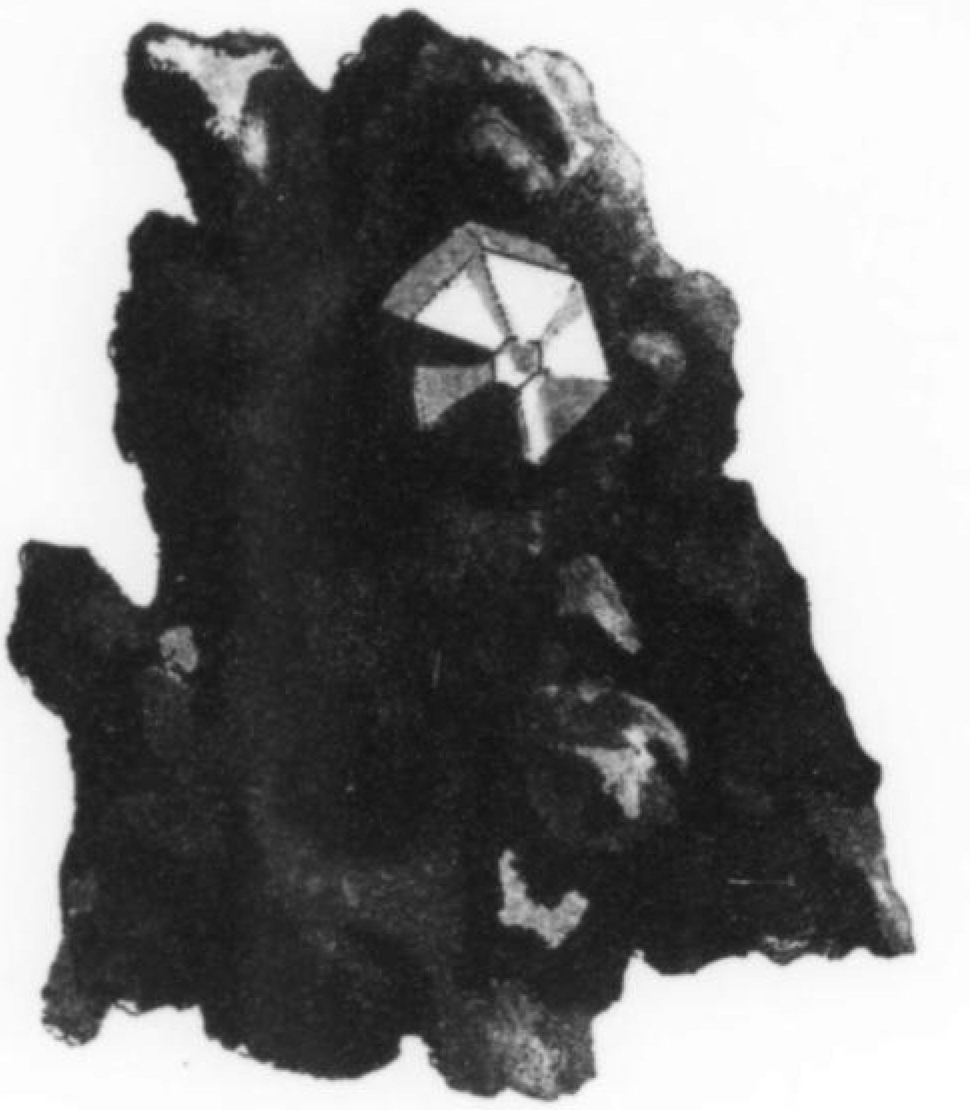
There are two very large private collections today that are probably more than twice the size of their next nearest rivals, and there are a few others that I will talk about which are worth honorable mention for one reason or another. All of these collections have been built with a lifetime of effort and at considerable expense. As you might expect, the more money and time that have been brought to bear, the more impressive and massive the collections are. These are the ones that I know about, but there may be others.

Certainly the most massive modern collection, and probably the one with the highest quality specimens, is that of a man who lives a bit north of New York City. He made his money in the high-tech communications industry, and he has been collecting minerals for decades—not just with the "silver pick" but also as a field collector in his early years. He is highly intelligent, knowledgeable and has excellent taste. His collection may rival or surpass those which belong to large public institutions, though he claims modestly that the commonly held notions about his collection are exaggerated. He prefers to remain anonymous, but he is known to many collectors and dealers in the mineral world as the "Black Hole" of the East—ostensibly because most of the specimens that pass his event horizon are rarely seen again. However, he does usually display something at each Tucson Show, and that is more than many collectors do. He also recently displayed some of his gold specimens at the American Museum of Natural History. He actually owns some specimen-producing mines and has operated them for some years for specimens and gem rough. I think little of this material has been sold. I have heard him complain about the difficulty in locating specimens in his storage facilities, usually in response to people who have asked—almost always in vain—to see his specimens. He frequently buys sizeable batches of fine specimens from specific localities, and during the "glory years" of specimen production in Peru, he had a man living in Lima (Terry Szenics) who would buy specimens for him, pack them in barrels and send them up to the States. He finally got so many pyrite specimens, and I mean fine ones, that he told Terry to stop sending pyrites. Once at the annual Denver Gem and Mineral Show, when the designated theme of the show was pyrite, I was asked to exhibit a couple of display cases of fine pyrite specimens from my collection. This collector came up to me and said "I need those specimens for my collection." I laughed and asked, "What do you want them for? To top off a barrel in your basement?" His only reply was a grin. I don't know that anyone has seen more than a few of his specimens, and in fact I think it is likely that even he has not seen them all. However, every so often a display case of some of his mineral specimens will appear at the Tucson Gem and Mineral Show, never under his own name, and people will cluster around that case and drool. One year it was crystals of Imperial topaz from his mine in Brazil; another year it was a little case of gorgeous Paraíba tourmalines (Cu-rich elbaite); and occasionally he exhibits one of his most famous "ikons," the Great Phosphophyllite. For many years he has been planning to build a private mineral museum that would be open to the public; when and if it finally opens, it will be an extraordinary event in the mineral world.

The other large private collection is that of a wealthy woman who lives in Switzerland and founded the Wella Balsam company many years ago. She has loved minerals and has collected specimens all her life. She has substantially supported many European mineral dealers with her purchases, and I have heard some of them saying "thank God" for Frau Dr. Erika Pohl. She has particularly loved Tsumeb minerals for many years and has many of them in her collection. She also has many good things from Morocco. She recently donated many specimens in her 60,000-piece collection to the School of Mines in Freiberg, Germany.

Collection of the
Technical High School, Stuttgart
(1905)
Stibnite
Ichinokawa mine, Shikoku, Japan

Stibnite was mined on Shikoku Island in Japan as early as the 7th century A.D., and the earliest collection known to possess a specimen was that of Kiuchi Sekitei in 1773. The mine continued in operation, occasionally yielding fine specimens, until 1957. Today most good stibnite specimens come from China. The illustration shown here is from Gustav Adolf Sauer's *Mineralkunde* (Stuttgart, 1905–6).



Collection of Philip Rashleigh
(1729–1811)
Chalcocite
Cook's Kitchen mine, Cornwall, England

From Rashleigh's (1797) book on his own collection, *Specimens of British Minerals Selected from the Cabinet of Philip Rashleigh* (vol. 1, plate XV). Rashleigh began collecting minerals around 1765, and assembled the finest private collection of Cornish minerals ever made. Most of it later ended up in the British Museum.

John Ebner, who lives in New Jersey, has about 55,000 micromounts, but he did not make them all himself: he has purchased individual collections made by other micromounters. He specializes in micromounts of species that were made by the people after whom the mineral was named.

Victor Yount, who lives in Virginia, specializes in calcite. He has been a collector and a mineral dealer for most of his life. He inherited a modest fortune from his family, which has enabled him to do less dealing and more collecting. He tells me he has about 10,000 specimens of calcite that he has collected over the years, and has many of them on display in about 100 meters of display cases at his home.

Probably the finest collection of rare species has been built by Mark Feinglos, who lives in North Carolina. He has about 3,500 of the 4,000 or so known species, which is about as much as anyone can ever hope to acquire. When you get a large collection of minerals you really stop counting. The thing that sets his collection apart is that many of his specimens are type specimens and are about as good as you can get for the species; that is, they are not just little specks in gelatin capsules. He doesn't even have some of the more common species because that is not where his interest lies.

On High-end Dealers and Heavy Hitters

At the highest level of aesthetic collecting and dealing, only very high-priced specimens are involved. Among these are what we might call the "world-class" specimens. The prices of such specimens in recent years have escalated into the realm of fine art prices (as the late Smithsonian curator Paul Desautels once predicted they would), and the specimens are indeed gorgeous. For many years back in the 1960s, for instance, $2,500 was about as much as you could ever hope to get for any mineral specimen unless its gem value was greater. Then in the 1970s it moved up another order of magnitude. Today the top price has escalated yet further, with some specimens reportedly being sold for over a million dollars.

There seems to be a significant cadre of world-class collectors active in the market today, but it wasn't always so. It used to be that, if the going price of a fine specimen was "X" dollars, someone would periodically come along and be willing to pay "2X." The guy who would pay "2X" often knew he was paying more than the market price, but he also knew that word of his purchase would spread and that he would then be offered first crack at other really fine specimens. It was kind of an advertising gambit on the part of the high-end buyer. When this type of collector stopped buying, reality would set in for a few months or a year until the next guy would come along and start paying elevated prices once again. Then the rush would be on again for the high end-dealers to romance him and sell him top-level specimens until his interest also waned.

Many of the top-level buyers today are not extremely knowledgeable about the technical side of mineralogy, and may not have been collecting seriously for very long. So (as is common in the antiques world and the art world) they work with one or a few trusted dealers, relying on them for advice. Before a dealer can sell specimens in this elevated market, he must first sell himself. Once he can convince the wealthy collector that he is knowledgeable and trustworthy, he is "in" and can sell that collector a lot of stuff. I say "him" because most of the buyers of expensive specimens are men.

Most of the really expensive specimens are not sold at gem and mineral shows, but directly to the well-heeled collectors. Nevertheless, high-end dealers do like to attend the big shows because there they have the opportunity to meet other heavy hitters. Of course, where so much money is involved, there is often a rather tense competition among dealers for the top clients. They will often try to coax the best clients away from each other. Sometimes real catfights erupt among the high-end dealers. Some dealers operate on the principle that there are no new customers, only other people's customers.

Once a dealer has developed a good relationship with a top-level buyer, he can sell him specimens, and he can also vet the offerings of other dealers who are not as well known to the buyer. Many dealers, rather than fight their way to the attention of a heavy hitter and try to convince him to buy their specimens, will simply give the specimen to the customer's preferred supplier and pay him a suitable commission to offer their specimen to the heavy hitter. Often the commission is 10 or 20 percent of the sale price. If the specimen is sold for $100,000, the preferred dealer will make $10,000 to $20,000 dollars for very little work. Museum curators have also been known to command good commissions when they become the trusted advisors of heavy hitters. This arrangement mimics behavior that has taken place for thousands of years. Those who have the ear of the king and the key to the throne room, profit handsomely.

Sometimes heavy hitters will put their purchasing decisions completely in the hands of one or two trusted individuals and pay them an agreed-upon commission to buy specimens for them. They use these people as fire walls to avoid having to deal with the hundreds of sellers that would be bothering them if it became generally known that they were in the market for top-level specimens.

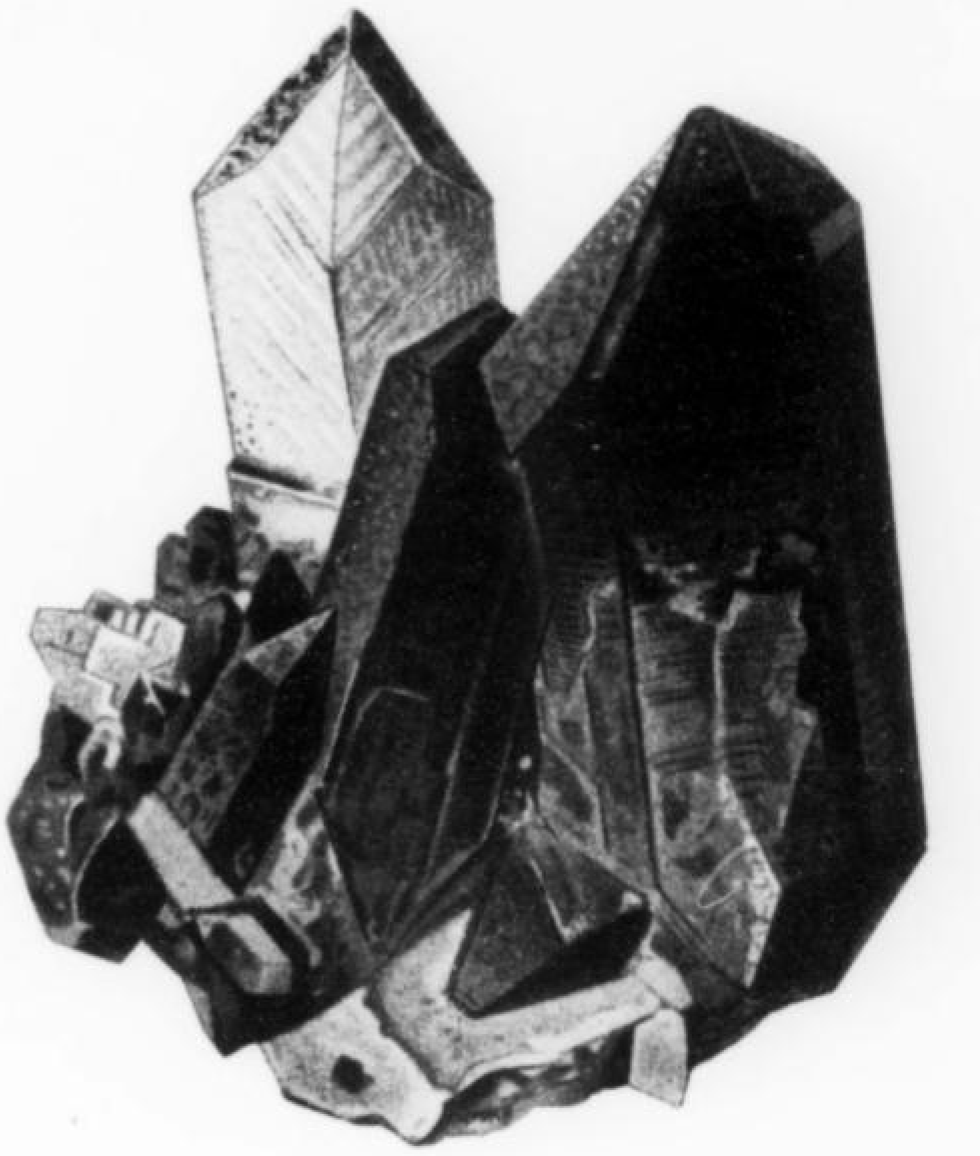
Like all high-end dealers in antiques, coins, jewelry, paintings, etc., the high-end mineral specimen dealers know that it is better if they can set themselves apart from the "riff raff" of dealers in lesser-quality specimens. They do this by segregating themselves as much as possible from those dealers who may sell good, but not the best, specimens. At the Tucson Show, for example, most dealers used to sell from rooms in inexpensive motels in the downtown area near the Convention Center. At these comparatively inelegant venues the top-end dealers and their clientele had to jostle cheek by jowl with their less well-heeled counterparts and occasionally suffer the outraged indignation of the older long-time collectors who were shocked by the current top-level prices. The top-level dealers had also grown reluctant to ask their best customers to visit such modest quarters—as one dealer put it, he was uncomfortable trying to sell someone a specimen that was worth more than the entire motel they were in. Consequently they established their own high-end show at a separate venue in a country club hotel in the northern part of the city.

Typically a high-end dealer gets nervous when one of his big buyers is in the room along with some of the old-time, knowledgeable but less well-heeled collectors. His fear is that the old-time collectors, who obviously know what they are looking at, will start saying things like, "I thought the specimen was fairly priced and was thinking about buying it until I realized I was off by two zeros! Can you believe it?" Or "Someone has got to be kidding on these prices. Just last year I bought one of these, even better than that one, and paid about ten percent of this price." These kinds of comments can be deadly, and only a limited number of them can be explained away. A common tactic to keep from scaring people away is to put on the labels of extra-expensive specimens "POR," which means "price on request." The implication is that if you are a person of modest means you can't afford the specimen.

Of course, to be fair, these old knowledgeable collectors are often living in the past, still thinking (or at least wishing) that a dollar today still had the same value as it had 10 or 20 years ago. They also don't want to accept the idea that the new, higher prices are real, because it means they won't be able to afford to add many fine specimens to their own collections. I must admit that I look at some of the specimens with high prices on the Internet and wonder who in the world is buying them. But in a gradually inflating economy, whether it be in 21st century America or the Roman Empire, many older people are outraged by rising prices.

Specialty Collectors

As a mineral collector you will soon find yourself becoming partialized to certain kinds of minerals. It may be that you will find yourself attracted to perfect small specimens like micromounts, thumbnails or miniatures. Perhaps you will find yourself drawn to minerals from one locality, state or region. Perhaps you will find you want to concentrate on a particular mineral like quartz or calcite, or on a particular mineral group like copper minerals, sulfosalts or feldspars. The possibilities are extensive. Often collectors will have general collections and sub-collections of various specialties. Of course, over time these preferences tend to change and morph into others. Specialty collecting is something that happens naturally to collectors and can produce very interesting collections. If you specialize you will soon find you know more about your specialty than almost anyone else, and you can build a unique collection that no museum can match. One collector I know joked that the longer you collect, the uglier the minerals you tend to acquire, and if you collect long enough you end up collecting only black ones. As some collectors mature, color becomes less important to them and other factors like crystal form and rarity become of paramount interest.



Collection of the
Technical High School, Stuttgart
(1905)
Orthoclase with Smoky Quartz
Baveno, Italy

The Baveno granite quarries on the shore of Lake Maggiore in Novara Province, Italy, have been worked since the early 1500s. Occasional pockets have yielded over 50 different mineral species so far, the most famous being twinned crystals of orthoclase called "Baveno twins." The example shown here is from Gustav Adolf Sauer's *Mineralkunde* (Stuttgart, 1905-6).

Field Collectors

I know a few collectors who hardly ever buy specimens. They collect their own. Some of these hardy individuals have spent their lifetimes running around, often in terrible weather, exploring remote places and dangerous abandoned mines. Some of them have transformed themselves into human TBM's (tunnel boring machines) and eat rocks for lunch. Well, if not rocks, terrible things from ancient tin cans that have been bouncing around in the back of the car/truck so long that the labels are long gone. Some of the things they have collected are amazing. However, unless you are very smart, extra hard-working, and lucky, I would advise you not to quit your day job. Most of the difficulty in making a living by field collecting is that you just can't move enough rock to get to the minerals that will allow you a comfortable life. But then again, who would describe field collecting as a comfortable life?

If you pursue this kind of collecting, you will get a lot of good exercise which will probably let you live years longer than if you choose the silver pick kind of collecting. There are few experiences in life as gratifying and as memorable as breaking into a wonderful pocket of beautiful specimens and collecting them. This experience is what usually hooks a collector for life and sets him on the path to being a dedicated field collector. You will not find many world-

Collection of W. Edmund Rundell
(1737–1815)
Pyrargyrite
Probably from the German Erzgebirge

This illustration was published in James Sowerby's *Exotic Mineralogy* (Plate 33, dated 1812). Fine specimens such as this can circulate for centuries in the best private collections; this one is in the Steven Smale collection today.

class specimens, but if you persist you can eventually put together a display that will stop traffic and be all the more impressive because you collected all of the pieces yourself.

Most field collectors don't work at it very hard, or if they do they live in areas that don't offer many good opportunities for field collecting. It used to be easier to collect in the field. Today it seems that most of the places you would like to collect are owned by someone else, posted "keep out" or closed to collecting for other reasons. Some really hard-core dudes make middle-of-the- night collecting trips into working quarries and underground mines, hang from ropes on rock faces, hiding out from the guards when they come around, and occasionally get busted for trespassing.

If you really want to get hard-core, here are some things you will need to learn to be a successful field collector. You will need to learn how to read topographic maps and how to find your way around geological libraries to locate leads to possible productive collecting areas. You will need to learn about various kinds of collecting tools, and, if you get serious, to learn about various kinds of heavy equipment and how to use explosives. Also you will need to learn the laws regarding explosives, claims, government land of various kinds, and the laws regarding trespassing. You will need to learn more than just a little bit about geology, and you will need to learn persistence. You will need to learn how to locate the owners of the land on which you want to work, and how to charm them into letting you collect on their property. You will need to learn how to use GPS (Global Positioning Satellites) equipment to find where you are relative to where you want to be. You will need to get a four-wheel-drive vehicle and learn how to set up a comfortable all-weather camp. You will have to learn how to sight-identify minerals and use a hand lens to identify minerals and rock types. You will need to learn about the various dangers present in abandoned mines: poisonous air, rotten timbers, dangerous ladders, water hazards, bad ground that may send a rock to squash you flat, and old explosives, to name just a few. It will help if you can learn some rock climbing techniques and how to get up and down ropes. You will need to develop the ability to drive night and day to get somewhere that is near nowhere. You will need to develop "the eye": a sort of psychic ability to discern where the crystals are hiding. Then, of course, you will have to learn how to clean and trim the specimens once you have collected them. Thank God this is only a hobby.

Field collectors are a remarkable and accomplished breed. They are perhaps the rarest and purest kind of mineral collectors. They hearken back to the very beginnings of what we now call the earth sciences, and in many ways they embody the simple thrill and youthful joy of the treasure hunt. If you look you will find them "out there" trekking over just one more mountain, digging down just another foot, and hoping for just a little bit longer that they will find something. But remember, the first law of field collecting states: "The best to be found is still in the ground and the best that has been found has been ground!" (that is, ground up into powder in the mill and processed into metal).

In the southwestern part of the United States there is a vast number of abandoned mines. Thirty years ago many were freely available for any fit person to explore, and many still are. Many of them are base metal mines with substantial oxide mineral components, especially large quantities of mixed iron and manganese oxides known by the old and venerable names "limonite" and "wad." Some of these mines are particularly dirty, and after collecting for a couple of days in one of them you come crawling out looking like a demon from the 9th circle of hell. You are completely filthy, impregnated with fine limonite dust which will take several long showers to remove, and your underwear will remain forever pink.

We were in central Arizona, and had left the mine in mid- morning to spend the next 5 hours climbing the steep trail up along the canyon wall to reach our car. Then we hit the road for the ten+ hour drive back to Los Angeles and our day jobs the next morning. After five or six hours we had to stop for gas. The doors flew open, and beer cans and an empty bottle of Thunderbird clattered out onto the concrete next to the gas pumps. We created a further disturbance with good-natured horse play and squabbling about who would use the bathroom first. There were a couple of cars full of good citizens gassing up at the same station. Simultaneously, they grabbed their kids, jumped back in their cars, rolled up their windows and locked the doors. Wow!! Did we cause that? Yes, I guess we did. It was at this point that I realized I had probably achieved some proficiency as a field collector and at the same time wondered just how much further down that road I wanted to go.

Micromount Collectors

What do you call a pygmy rapist? It's obvious! He is a "micromounter." I apologize; that was a terrible joke. Micromounters take big rocks and break them down into little ones and put them in little plastic boxes. Also, this is something you do for fun, not profit. You do it because you want to learn about minerals and in pursuing this collecting discipline you almost always end up learning more about minerals than your cousins with their big flashy expensive rocks who look at you as if you are afflicted with some sort of mental disorder. When and if you sell your micromineral collection, conventional wisdom tells a dealer that he can't pay more than about a dollar a specimen for the collection and make any money on it. I suppose it could happen, but I have never seen or heard of a case where a micromounter has made money. So resign yourself to the fact that you will never make any money by collecting micromounts—but on the plus side, you won't have to spend much either, except for the one-time expense of buying a good microscope. You will, however, spend huge amounts of time playing with rock trimmers, glue, and little plastic boxes.

Micromounting is a solitary discipline because of the considerable labor involved. The collector of flashy minerals merely buys his specimens and plops them in a drawer or a display case with a label that has been made by some dealer. You, on the other hand, must carefully examine mostly large, ugly- looking rocks under a microscope to locate the best nest of barely visible crystals, then break the rock down into little bits, taking care not to damage the tiny specimen(s) you are trying to create. Then you get to clean each specimen, mount it on a tiny pedestal of cork, plastic, cactus thorn, hair, etc. and carefully glue it into a tiny box, a tiny plastic mausoleum, where, with luck, the little specimen will spend eternity undisturbed and protected from the vicissitudes of life. Then you carefully label the box with information about its contents. And after all that, you have the privilege of looking at it from time to time and showing it to the occasional rare person of similar bent who might be interested in seeing it.

What on earth could induce someone to collect these kinds of mineral specimens? Well, just look through the microscope at some good micromounts and you will understand. There you are in a glass-bottom boat, slowly cruising above the most amazing fairy gardens of shapes and colors—things straight out of a science fiction movie. You could never invent or imagine such things. If these were blown up in size, they would put to shame most macro-size mineral specimens because of the perfection of their crystals. Once you are hooked, you usually spend the rest of your life chasing these tiny, perfect jewels. Yet micromounters are quite sociable creatures and have occasional conferences where they trade specimens among themselves, look at each others' specimens, and listen to lectures. They even have a Hall of Fame. Many advanced micromounters become photomicrographers (*note:* not "micro photographers"—which would be very tiny photographers) so they can better share their amazing little treasures with others. Their collections usually contain wonderful specimens of species not available to collectors of larger specimens because Mother Nature doesn't make them any larger. Micromounters are better at mineral identification than most other mineral collectors because they see a wider range of mineral species in good crystals than their cousins who collect larger specimens. There are many more minerals which exist as fine microcrystals than occur as larger crystals.

Each micromounter develops an individual style of mount. There are two or three more or less standard sizes of little plastic boxes used. In past generations, when small plastic boxes were not available, the variety of boxes and containers used by micromounters was quite diverse. It seems that everyone develops a somewhat different method of preparing these boxes, using different mounting materials and different labeling formats. Considerable ingenuity has been brought to bear on how to mount various kinds of specimens, such as tiny single crystals, unstable minerals, etc. The way each mounter prepares his specimens, prepares the boxes, mounts the specimens and labels them is like a signature. If you want to become a micromounter, I recommend a couple of books: *The Complete Guide to Micromounts* by Milton L. Speckles and *The Complete Book of Micromounting* by Quintin Wight (the latter is available from the Mineralogical Record Bookstore at www.MineralogicalRecord.com).

I was introduced to micromounting by Neal Yedlin, who was elected by his peers to their Hall of Fame. He collected other kinds of minerals and had a wonderful book collection as well. When I lived in New York City, I used to drive up to New Haven and visit him, and would usually buy a few specimens and books from him. He always made time for us to spend some time looking at his wonderful micromounts. I had always thought I would like to do that kind of collecting but never quite got to it because I was always chasing around to various countries trying to buy specimens for my wholesale mineral business. Then one day, because I got around, I happened onto an auction mandated by the state of Arizona for the estate of Bob Massey, who had died without a will and had no relatives to claim his things. Among many other items, his micromount collection was for sale. I am not sure what prompted me to bid on the collection, probably the memory of Neal Yedlin and his wonderful micromineral collection, but I was high bidder for the micromounts and hauled my treasure back to California.

Shortly after I purchased the collection I wandered into the room of one of the few dealers at the Tucson Show who catered to micromounters. There turned out to be a real nest of them in that room, and they were all talking to one another in the sociable way they do while looking through microscopes. Word of my purchase

Collection of the
Technical High School, Stuttgart
(1905)
Calcite
Bigrigg mine Cumberland, England

British calcite specimens from Cumberland have long been considered classics, and were available in abundance in the 19th century. The mines are now closed and specimens are rare and valuable. But calcite is among the most widely occurring minerals, and fine specimens are always available from a variety of localities. The example shown here is from Gustav Adolf Sauer's *Mineralkunde* (Stuttgart, 1905-6).

Collection of James Sowerby
(1757–1822)
Stilbite
Faeroe Islands, Denmark

Today, most zeolite specimens on the collector market come from the Deccan Traps of India. However, in the 18th century the main sources were the Faeroe Islands, Iceland, Scotland, and a few places in Central Europe.

had preceded me, and one of the ladies looked up from her scope and said to me, rather crossly, "What do you want a micromount collection for?" These people knew me as a wholesale dealer who sold large quantities of things like quartz crystals and Brazilian amethyst: in other words, a pillaging barbarian. The best way to defuse situations like this is to admit to what the person is implying about you. So I told her, "Well obviously to cloak myself in a veneer of mineralogical respectability." Another sour look and a bit of a stiff smile and the matter was closed. I was accepted into the pack . . . well, sort of.

In the years since that incident I have made it a point to salvage micromounts from many of the tens of thousands of specimens that flood through my warehouse. I've extracted many specimens that have the potential to make wonderful micromounts and shipped them off to my good friend Richard W. "Dick" Thomssen. He is a sharp geologist and a demon micromounter. He is no longer in retirement; a mining company has agreed to pay him to go back to work. He makes my micromounts for me. Now you know my dirty little secret. I am grateful that he considers the specimens I send him worthy of his time.

The mounting time Dick has saved me has enabled me to create and develop a computer database program that has the ability to make the labels for my micromounts and other specimens. This software application has gobbled up thousands of dollars in professional programming time and thousands of hours of my time for development and testing. It is becoming quite usable, and none too soon, as I am no longer able to print by hand the small, neat labels needed for micromounts. Even on my best day, I could never match the character compactness, legibility, and neatness that computer-printed labels provide.

I think a lot of dealers respect micromounters for their knowledge. More micromounters should approach dealers and offer to make micromounts for the dealer if the dealer will supply the specimens. Many dealers would be amenable to such an arrangement. Often when a dealer gets a collection, or just a lot of minerals, the haul includes specimens that could be judiciously trimmed to produce mount material without loss of value to the original specimen. I have "de-microed" a number of collections and many large lots of specimens and have harvested terrific micromount material.

If you become a micromounter, you can kiss certainty goodbye. In some instances you can look through your microscope and see sparkling, colorless, transparent hexagonal crystals with striations perpendicular to the C axis and the prism capped by six pyramids. And then you say to yourself, "Yes! That is certainly a quartz crystal." Certainty is a wonderful thing, but wait a minute! What are those little blue crystals down among the quartz crystals? OK, let's crank up the magnification. That's interesting: they are little dark blue cubes like boleite, but look at that strange cross-like pattern on the faces of the cubes? Those are pseudoboleites I think! Hmm! Certainty is beginning to slip a little. Hold the horses, what are those little green sprays of crystals down at the base of the cubes? OK, let's crank up the magnification again. Is that all we can do? Yes, we are at 100x. Gee, what can those green crystals be? Maybe pyromorphite? But is the chemistry right for this paragenesis? Oh my goodness, scattered in among the tiny green needles are some super-tiny little white needles that are barely visible; what could those be? Well, you are beginning to get the picture. "Big fleas have little fleas up on their backs to bite 'em, and little fleas have lesser fleas and so on *ad infinitum*."

Systematic and Rare Species Collectors

There are about 4,000 known "official" minerals, and each year roughly 50 more are approved by the Commission on New Minerals and Mineral Names (CNMMN) of the IMA (International Mineralogical Association). The number of minerals yet to be discovered probably exceeds the number already known. The number of known minerals is really very few compared to the numbers of species known in the plant and animal kingdoms. The number of known insect species exceeds a million and even the number of different fleas or tape- worms probably exceeds the number of described mineral species. With such a relatively limited number of species it is possible to build a collection that contains a majority of known minerals. No collection in the world has them all, and there are probably less than 25 collections in the world which have reached 80%. There may not be a single collection that has 90% of them. The people in charge of many large institutional collections frequently don't have any idea of how many species they have, or which ones they lack.

A lot depends on how much you believe the identification given by the labels accompanying the specimens, and which list of accepted species you are using. A few rare species collectors seem to derive most of their satisfaction from checking off minerals from their "want list." I think that this is a shallow sort of satisfaction, but I must admit I have found satisfaction in checking off a long-desired mineral species that had been absent from my collection. Most people who attempt this rigorous discipline learn far more about minerals than the average mineral collector.

The standard list that many collectors use as a bible is *Fleischer's Glossary of Mineral Species* by Malcolm E. Back and Joseph A. Mandarino. Europeans tend to use the Strunz mineralogical tables (*Mineralogische Tabellen*), first created in 1941 by the venerable Hugo Strunz (1910–2006) and updated periodically now by Ernest Nickel. The International Mineralogical Association has very recently posted a list of minerals on its website that will, at least for a while, be the most authoritative list of currently valid species. Many other collectors utilize the mineral database at mindat.org as their preferred list. Every mineralogist worth his salt has his disagreements with the IMA and with other mineralogists regarding exactly which species are valid or even what exactly constitutes a mineral. If you collect long enough, you will form your own opinions.

If you choose systematic species collecting, you will need to determine the size and quality that you plan to collect. Will you be willing to accept a fly speck of a mineral inside a small gelatin capsule Scotch-taped to a label? Many people dislike this minimalist approach, pointing out that if a specimen is so small that it would be entirely consumed by a test necessary to identify it, then you don't really have a specimen at all! On the other end of the spectrum is the rare species collector who insists that his specimens be at least an inch or more across, showing the mineral richly by eye and, if the mineral forms in crystals, showing well-formed crystals on the specimen. If you choose the latter collecting style you will likely never obtain even half the known species, since nature just doesn't make most minerals like that. Or even if one or two specimens like that really do exist, the odds are that they will never be offered for sale or trade. Most rare species collectors, when confronted with the choice between lowering their standards and never acquiring a specimen of a species, will usually cave in and accept specimens of lower quality, even sometimes a fly speck in a gelatin capsule, until they can get something better (which might not exist anyway).

Some dealers in mineral specimens have commented, only half in jest, that there is only one thing rarer than a rare mineral, and that is someone to sell it to. It has been joked that sometimes a mineral is so rare that it isn't even on the specimen. This means that often the amount of a particular mineral on a specimen is so small that it cannot be seen even with a powerful reflected-light optical microscope. Sometimes the amount of the mineral is so small that it can only be imaged with high-resolution scanning electron microscopes or microprobes. When it takes this kind of instrumentation to verify the presence of a mineral, the collector or curator is almost always at the mercy of the dealer selling him the specimen, because he does not have access to that kind of equipment. In such cases, it is a temptation for the rare unscrupulous dealer to label a likely-looking rock with the name of a really rare species, believing that it is unlikely that the fraud will ever be discovered. In the long run such dealers are eventually found out and are forced out of the business. The rare-mineral-collecting fraternity is small and word travels fast.

Collections of rare minerals are sometimes referred to as "arrow rocks" because dealers often glue tiny paper arrows onto the specimens that point to the minute area which contains the mineral of interest. Collections of rare minerals typically look terrible because in most cases the crystals, if there are any visible crystals at all, are so small they can only be seen with a microscope. Quite often what you are looking at in rare species collections are rocks with specks of rare minerals on them. For example, collections of minerals from the zinc mine at Franklin, New Jersey look like rock collections rather than collections of crystallized minerals. A friend of mine, Dick Hauck, had a wonderful collection of Franklin minerals, one of the best in private hands, and once was showing it to a beginning collector who liked to collect his own specimens. The beginner observed, "I see you like to collect your own specimens too"—meaning that my friend's collection looked like the rubbish he was used to collecting.

Rare species collectors are lonely people because there are not many people with whom they can share their avocation. They are the nomads of the mineral collecting fraternity. Information about the availability and quality of rare minerals is difficult to come by. A mineral may be rare, but it may be abundantly available at a particular mine. Such is the case of *teallite*, a rare sulfide of tin and lead that is one of the main ore minerals at the Carguaicollo mine in Bolivia. One afternoon Alfredo Petrov and I wandered into this remote mining camp and bought about 200 pounds of beautiful cleavable teallite at prices only somewhat higher than the smelter would pay.

Sometimes a species is *really* rare, i.e. only one piece the size of your fist or smaller was ever found. However, that piece can be broken up into hundreds of tiny specimens which can at least temporarily saturate the shallow market for such things. The truly difficult fact to know is that there was only one small piece found and it was broken into six 1-centimeter specimens and hundreds of tiny ones. A knowledgeable collector will know this and try to lay his hands on one of the centimeter-sized specimens rather than a gelatin capsule holding only a pitiful speck of the mineral. If only two specimens of a mineral are known, that fact will be enthusiastically advertised. If, however, 500 tons of specimens of a particular mineral have been found, this fact will not be advertised. The existence of huge quantities of a particular kind of specimen makes it

Collection of the Technical High School, Stuttgart

(1905)

Atacamite

New Cornwall mine, Kadina, South Australia

Mineral localities are often concealed for many years before becoming generally known. In the late 19th century the world's finest atacamite specimens were collected in South Australia and found their way into many prominent collections. They were all labeled "Burra Burra," South Australia, but have recently been determined to have come from a different mine 90 km away. The illustration shown here is from Gustav Adolf Sauer's *Mineralkunde* (Stuttgart, 1905-6).

"uncollectible." Not many collectors will put a piece of common Brazilian amethyst in their collections. A dealer may advertise *antlerite* as a rare species but fail to mention that at Chuquicamata, in northern Chile, home of the largest open-pit copper mine in the world, antlerite is a common ore mineral.

If you decide to collect rare minerals, keep in mind that you may only be able to recover a small percentage of your purchase price should you need to sell the collection. Here is more food for thought. Each year the IMA declares some minerals to be invalid because they are determined to be varieties of already known minerals or mixtures of more than one mineral. Most of the species that are approved are of little interest to the average collector because they are unattractive. There are approximately 40,000 mineral names that have at one time or another entered the mineralogical and geological literature. At one time, these were all considered to be valid minerals. For one reason or another, over the last century, most of these mineral names have fallen from favor and been cast upon the mineralogical rubbish heap. However, in nearly all cases, specimens by these names were once sold by mineral dealers. Using these numbers, it would appear only 10% of the minerals that were at one time considered valid, are still valid. Based on these numbers one could make the case that if you buy a specimen of a rare mineral species today, there is only a 10% chance that it will be considered a valid mineral 100 years down the road. That figure is probably too pessimistic because many old now-discredited species were first described using relatively primitive and unsophisticated analytical techniques. Far more accurate methods are available now. But even more accurate techniques will be available in the future.

The process of throwing out the names of minerals that are shown not to be valid and approving the names of new minerals will continue into the foreseeable future. We think, however, that the numbers of minerals cast into the outer darkness will diminish substantially because of the rigorous vetting process instituted by the hard-working members of the IMA-CNMMN.

The market for rare minerals is small, but the world market for them is large enough to keep a few dealers interested in obtaining and selling them as part or most of their inventory. It is interesting to note that in Russia a cottage industry has developed to find, describe, and sell rare specimens. The proceeds from these sales have helped keep some few of the mineral laboratories in Russia warm in winter.

Competition develops naturally in all fields of human endeavor, and the field of rare-mineral-collecting is no exception. The prime objective is to collect as many species as you can. The more successful you are, the smaller your "want list" will be. A small want list can, for advanced collectors, be a way of competing. He who has the smallest want list is king. If you are a rare species collector and can get your want list down to a page or less, that will usually impress and perhaps even intimidate your competitors. Once the list is down to a page, then you work toward making larger margins on your page, increasing the font size, and even perhaps some day decreasing the number of columns. You will, however, never get them all.

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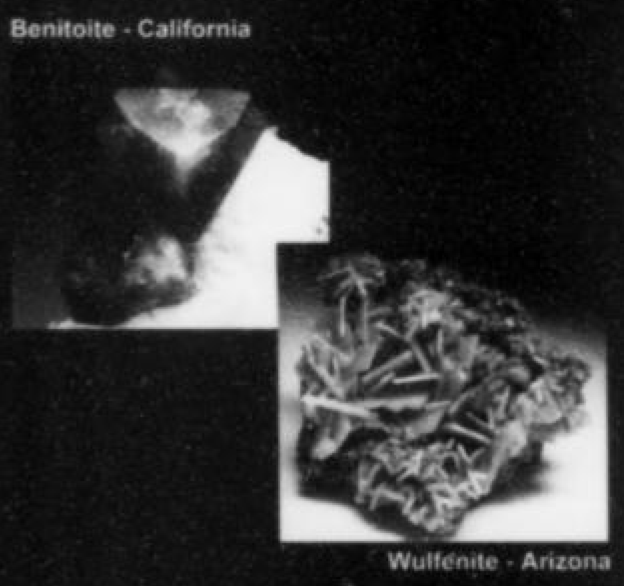

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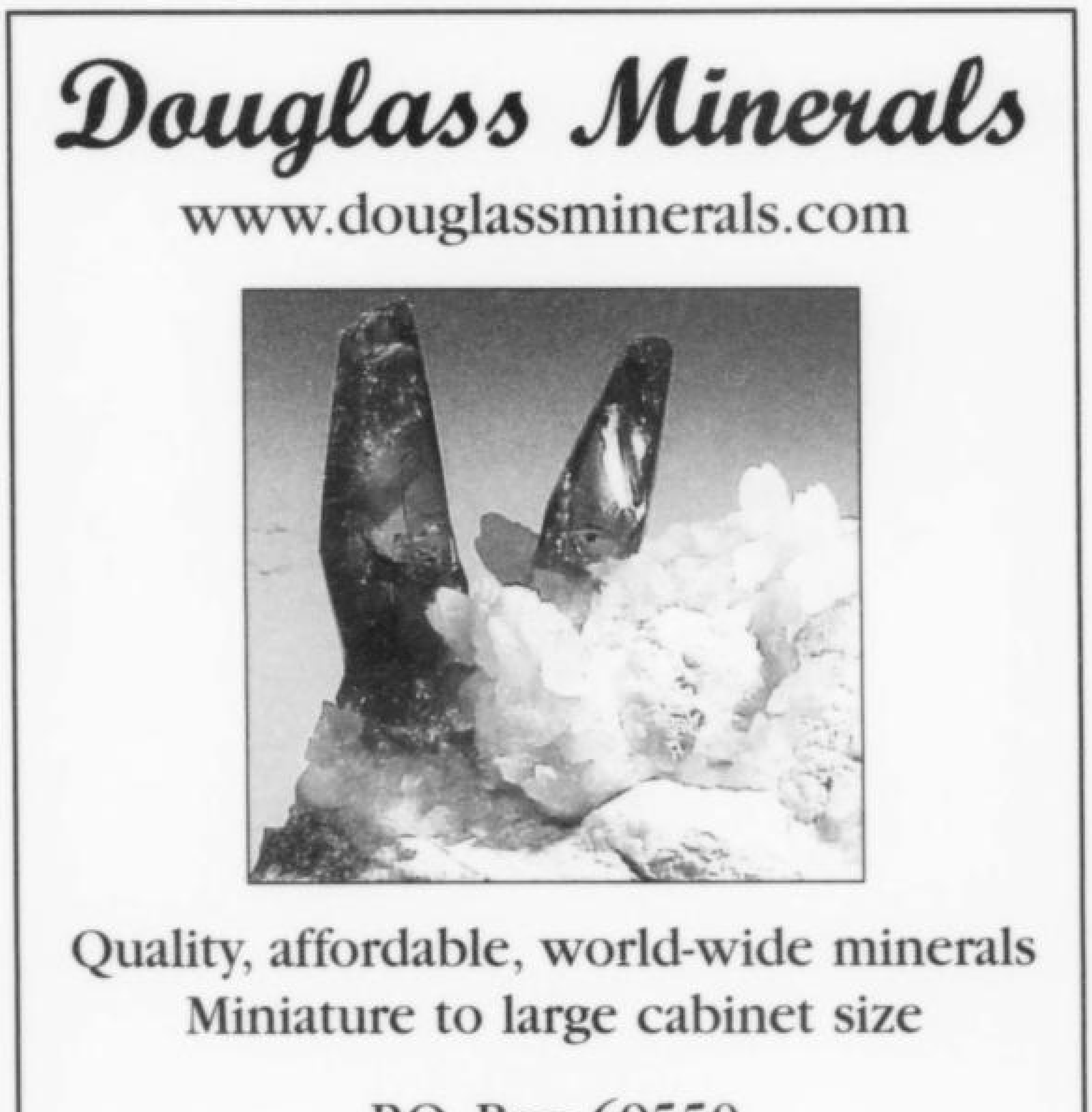

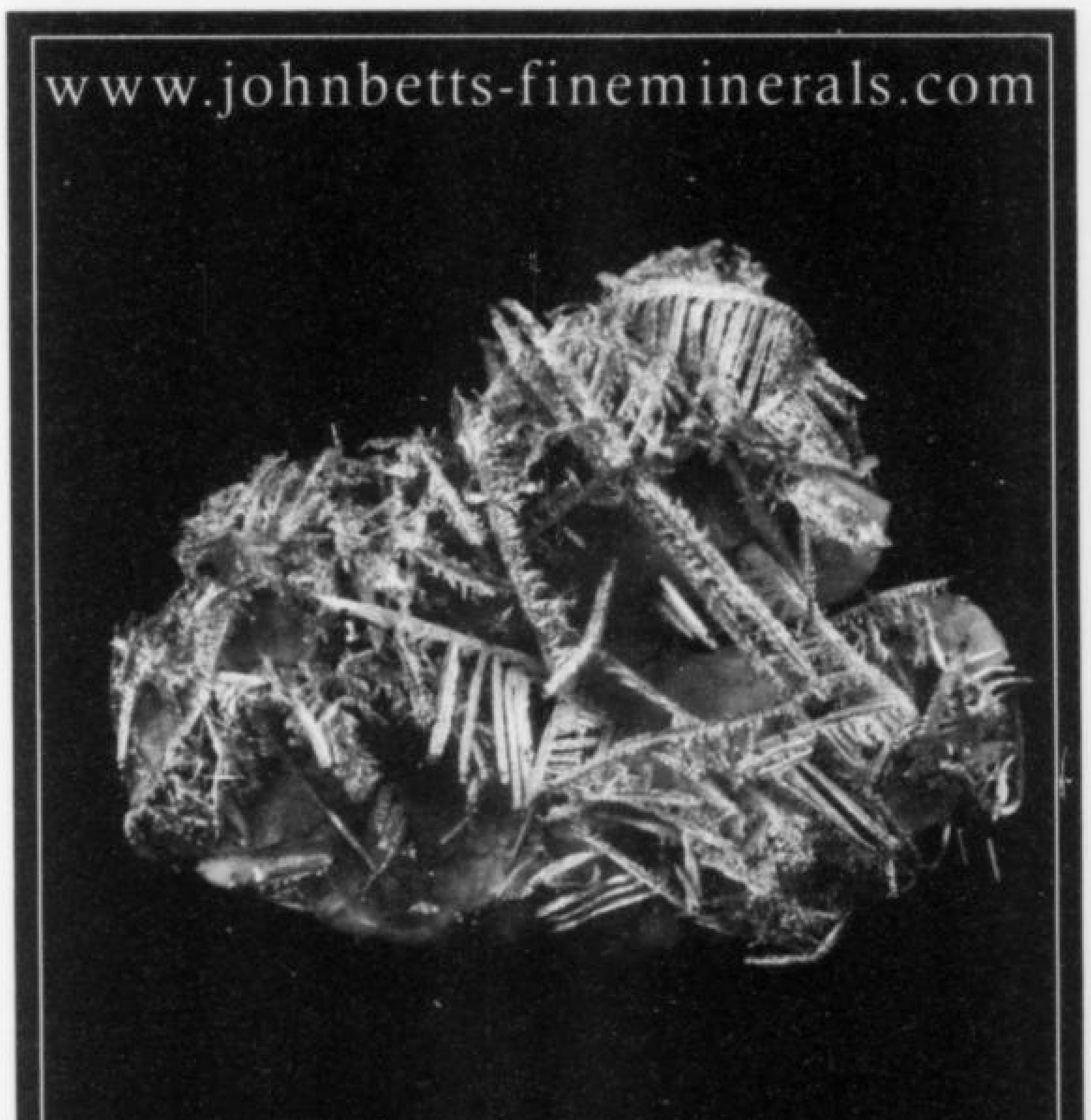


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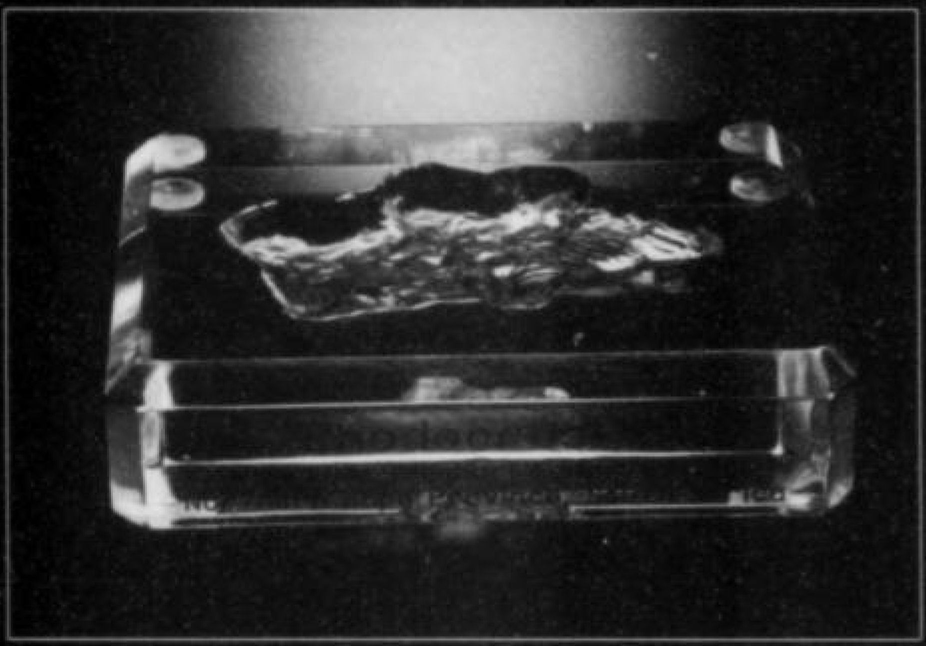


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Sept.-Oct. issue	June 15
Nov.-Dec. issue	Aug. 15

An additional 20 days past the closing date are allowed in which advertisers may make changes (excluding size changes) in ads already paid for.

Circulation
P.O. Box 35565
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Printing
Allen Press, Incorporated
Lawrence, KS

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