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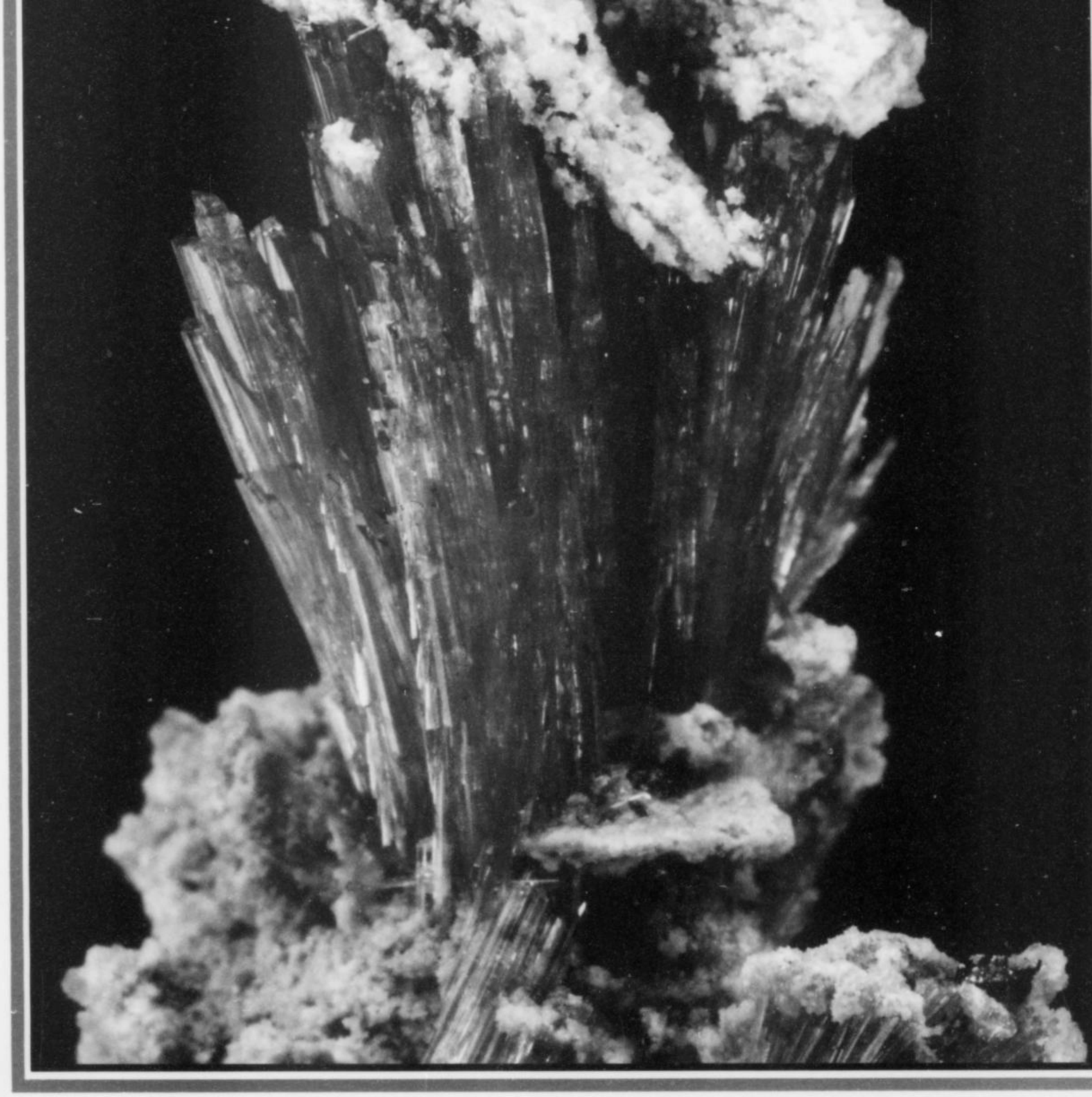

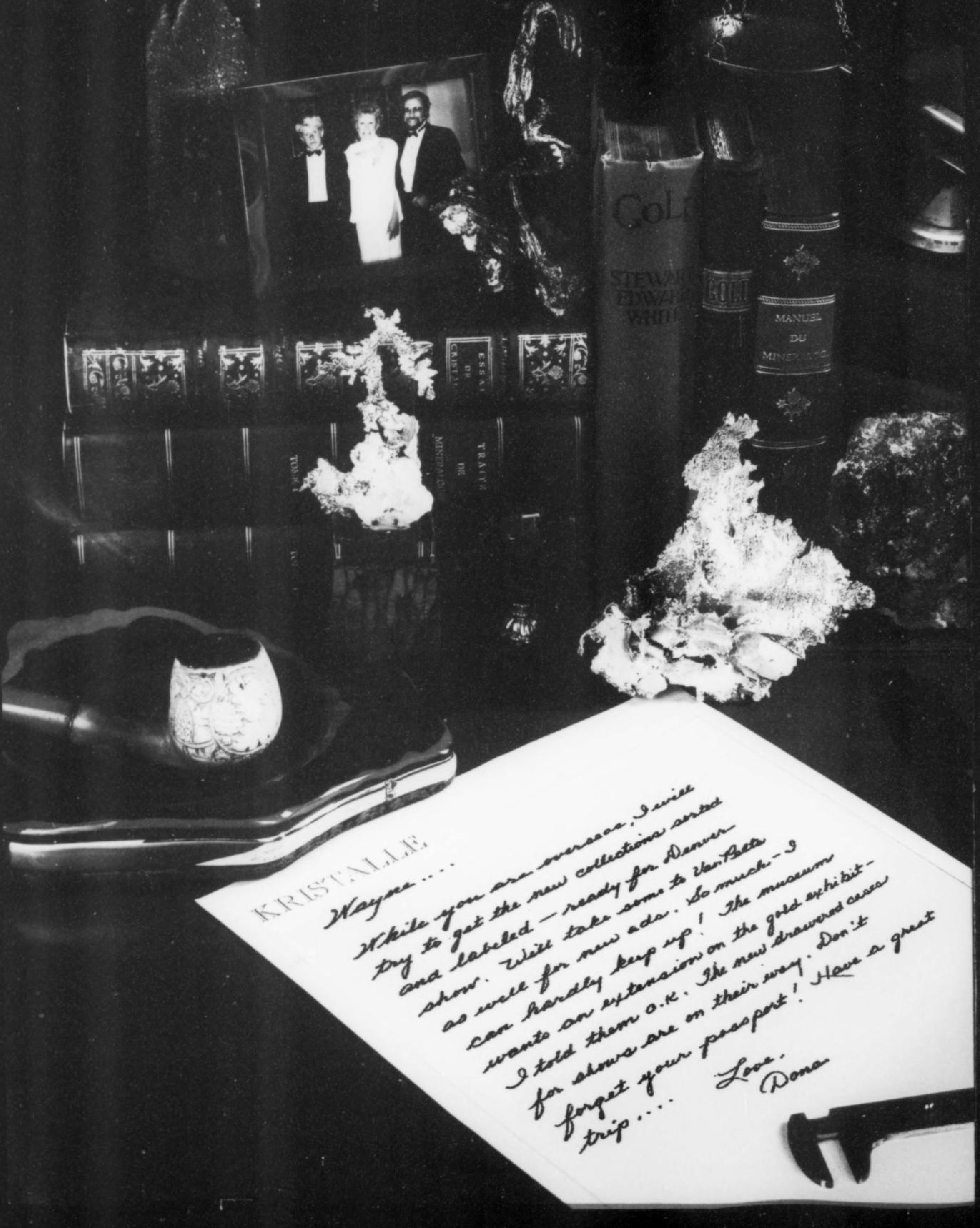

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*Continued on p. 392

THE MINERALOGICAL RECORD

July–August 2005 Volume Thirty-six, Number Four

Articles

Columns

COVER:
WARIKAHNITE, 4.9 cm, from O Stope, 31st Level of the Tsumeb mine, Namibia. William Pinch collection; Jeff Scovil photo. For more background on this specimen see the note on page 315.

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notes from the EDITORS

The Mineralogical Record Museum of Art

Many collectors these days have an interest in collectible mineral art and also in mining art. Mineral art has been a feature of the cultural landscape of the mineralogist since Conrad Gesner's *De omni reum fossilium* was published in 1565. The fact is, you can write about mineralogy, but illustrations of actual crystals and specimens have always been indispensable adjuncts to the text. Even in modern times, despite the advent of high-quality color photography, the artist still finds a place as a creative interpreter of the mineral world.

One definition of art is that it allows a person (the artist) to show everyone else, through creative highlighting and emphasis, the aspects of a certain scene or subject which he finds most beautiful and interesting. Those two words, "beautiful" and "interesting," neatly capsulize the aesthetic and the scientific components of the mineral world that each person, in his own particular mix, finds appealing. Just as a mineral collection demonstrates, by its selection, the aspects of the mineral world favored by the collector, so also do mineral artworks demonstrate the nature of one person's appreciation of minerals.

The artist can tailor his approach to the needs at hand. If rigorous scientific illustration is the goal, the artist can provide a specimen portrait unencumbered by focus limitations or lighting problems, clearly exhibiting the physical characteristics of most interest for that species. On the other hand, if aesthetic enjoyment is the goal, the artist can select specimens, lighting angles, backgrounds and focal qualities that best reveal the aspects he finds most attractive and satisfying to the soul.

Over the centuries many talented artists have applied their skills to the representation of mineral specimens. And many more find themselves at least tempted to give it a try. Wouldn't it be instructional and interesting to see a museum exhibit of mineral art spanning the centuries, all lined up for study and comparison? We thought so too, and thus was born the idea for the *Mineralogical Record Museum of Art,* a virtual museum that is now a part of our recently remodeled website at www.MineralogicalRecord.com. The artworks are arranged there in galleries, each gallery devoted to the works of a particular artist (or of the artists gathered by a particular author). Biographical notes are included, along with small "thumbnail" images of each artwork and its title, medium, size, date, and owner. Clicking on the thumbnail image calls up a much larger image of that particular artwork.

The entire historical range of mineral and mining art is spanned, from ancient times to artists alive and producing fine art today. At present ***over 1,000 works of art*** are viewable, and more will be added as time goes by. This is a non-commercial site, so artworks are not sold or priced here, but contact information is given for working artists, and readers who appreciate their style may contact them directly for more information on the current availability of their work, and their willingness to accept commissions.

As mentioned, mining art is also included. We are attempting to document every kind of depiction of mining and miners that has appeared since the ancient Greeks, right on up to the beautifully engraved scenes on mining stock certificates, and the work of modern painters, scattered throughout the world's museums and private collections. Obviously this is a big project and it will be an ongoing one for us for the foreseeable future.

The Museum is open to additions. Mineral and mining artists are cordially invited to submit samples of their work (in digital form, as transparencies or as prints) for evaluation and, if approved, will be given their own gallery at no cost. The criterion is simply that the artwork must be of "museum quality," exhibiting a required level of professionalism. As much as we want to encourage artistic amateurs and beginners, the MRMA is not the place to show their works.

This is a project that can benefit from the help of our readers. For example, the work of the late Mrs. Ingeborg Vass of Alexandria, Virginia is superb, but rare. We'd like to show more examples, but we don't know where they are. Some people reading this may have some of her watercolor paintings in their possession; if so, we would very much appreciate receiving high-resolution scans or good photos to post in her gallery.

Paintings of mining scenes are scattered even more widely. A particular art museum or historical society may possess only one or two. If you happen to spot a good one, let us know and we will work to obtain an image to post. We especially need contacts in European art museums.

Please check out the Mineralogical Record Museum of Art and let us know what you think. Its construction costs were entirely paid for by donations from Kathryn and Bryan Lees, Rob Lavinsky, Susan Robinson and Wendell Wilson, so admission is free.

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Recently Posted on *Axis*

MARONG, D. M. (2005) The development of precision in locality notations: some classical and some modern methods. *Axis,* volume 1, number 4, pages 1–9.

Field collectors today can learn from the mistakes of the past when recording the sites of their discoveries. Otherwise, many localities which may be well-known today could become the lost localities of tomorrow. Modern technologies such as GPS (Global Positioning Systems) offer the opportunity to achieve significantly greater precision when their reference grid systems of notations are fully understood.

COOPER, J. F., Jr., DUNNING, G. E., HADLEY, T. A., and MOLLER, W. P. (2005) The Sulfur Hole, Calico District, San Bernardino County, California. *Axis,* volume 1, number 5, pages 1–14.

The Sulfur Hole was discovered in the 1880's by local borax miners who were searching for a possible source of agricultural sulfur. The deposit has produced an attractive suite of colorful, well-crystallized, hydrous sulfates including coquimbite, halotrichite, krausite, metavoltine, potassium alum, quenstedtite, rˆmerite and voltaite. Associated minerals include botryogen, copiapite, anhydrite, gypsum, melanterite, marcasite and sulfur.

WARIKAHNITE

Some Background on the Cover Specimen

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Pittsford, New York 14534

Every year at Tucson I am always looking for that one killer specimen that will make my whole show. Some years that one specimen never seems to turn up, but this year (2005) it turned up in a rather unexpected place. Early in the show I was at the Clarion Inn looking over dealers' shoulders as they were setting up. I was watching Clive Queit unpack, and bugging him as usual about anything new he might have which would be of interest to me. I bought a few interesting specimens but nothing really for me to keep, when he reached under the table and pulled out a small bag which contained a few select pieces from his personal collection. The first one he showed me was a superb scorodite from Tsumeb which really piqued my interest. He then quietly handed me the warikahnite (shown on the cover of this issue) and said nothing. (This is typical of Clive.) Now it takes a lot to surprise me in the mineral world, but when he handed me this it about blew me away. I had never seen a warikahnite even approaching this one in size or quality, nor had I ever heard of one like this being found. After I recovered from just seeing the specimen I had to ask the price.

After recovering the second time I had to call my wife and convince her that I had not lost my mind (once again), and that it was actually okay to pay more for a mineral than I had paid for our first house. I'm happy to say that the warikahnite has now found a new home next to my andyrobertsite and a few other Tsumeb treasures.

The mineral species warikahnite is a zinc arsenate—$Zn_3(AsO_4)_2 \cdot 2H_2O$. It is triclinic, space group $P1$, and has a perfect cleavage on {001}; hardness equals ~2 and its color (from the original find) is described as colorless to pale yellow. Its specific gravity is 4.24. Any other pertinent data can be found in the usual mineralogical references.

The mineral was first discovered by Clive Queit and named in 1979 (Keller, Hess and Dunn, 1979) after Walter Richard Kahn of Bayersoien, Germany, a well known mineral collector specializing in Tsumeb minerals. In the first find of warikahnite in the E9 pillar, 31st level, it was associated with "pale to emerald-green cuprian adamite, white koritnigite, blue stranskiite, pale sea-green crystals of helmutwinklerite, and white corroded crystals of claudetite, ludlockite, tsumcorite and lavendulan. The colorless warikahnite is very unpretentious and may be overlooked." The crystals were described as being 0.5 × 0.5 × 3 mm, mostly as radiating or subparallel intergrown aggregates of acicular or bladed crystals elongated on [100]. As far as I have been able to determine, there were only a few small specimens found, most of which went to museums as type material. The types are housed at the University of Stuttgart, Germany; Harvard University, Cambridge, Massachusetts; and the Smithsonian Institution, Washington, D.C. (Anthony *et al*., 2000).

The second and most important find was made in 1984, in the O stope on the 31st level of the Tsumeb mine, by Hannes Schoombie, who was at that time working as a miner there. According to Clive Queit, who saw the contents of the pocket, there were a total of about 5 small specimens and the one pictured here was the best of them. Most of the specimens have crystals of 1 cm to 2 cm in length with none of the associated minerals from the previous find. The only associated mineral is quartz. The pictured piece has a number of fine crystals on the matrix measuring up to 2 cm in length. The main group of crystals, however, is wheat-sheaf-like and extends through the specimen, measuring 3 cm in length and 1 by 1.8 cm in cross-section; it actually constitutes the bulk of the specimen. The crystals are terminated and a beautiful yellow-orange in color. The entire specimen measures 3 × 4.9 cm.

One of the other specimens from this pocket belongs to George Gebhard and can be seen in both his *Tsumeb* (1991) and *Tsumeb II* (1999) books, while another can be seen in Keller (1984). This specimen belonged to Walter Kahn at the time and is now on exhibit in the mineral cabinet at the Technical University of Brunswick, Germany, (Burchard and Bode, 1986) which today houses the entire Tsumeb collection of Walter Kahn. Another fine spray of 1-cm crystals is in the collection of Mark Feinglos. And I am aware of at least one other specimen in a private collection which I am aware of. Warikahnite is and will remain one of the great rarities and classics of Tsumeb.

More recently warikahnite has been found as microscopic white needles at Lavrion, Greece (known previously as Laurium to most collectors) and at the nearby locality of Plaka, Greece, also as microscopic white needles. **(ref 7)** I have not examined any of the Greek specimens.

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Famous Mineral Localities:

KLEIN SPITZKOPPE

NAMIBIA

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Klein Spitzkoppe has been producing topaz crystals for over 100 years. Since the discovery of the pegmatite in 1889, many fine crystals have been collected and thousands of carats of gemstones have been faceted from colorless, transparent, so-called "silver topaz." Most topaz specimens consist of loose crystals, but some rare matrix pieces with microcline and smoky quartz are known. Associated collectable minerals including beryl (aquamarine), green fluorite, phenakite and bertrandite have also been found there.

LOCATION

Klein Spitzkoppe is a granite inselberg ("island mountain") located in southern Damaraland, Namibia, 110 kilometers northeast of the coastal harbor town of Swakopmund. The mountain peak is 1,580 meters above sea level. Approximately 12 km east-northeast of Klein ("small") Spitzkoppe is another granite inselberg, Gross ("large") Spitzkoppe, which has an elevation of 1750 meters above sea level. Both of these mountains form impressive topographic landmarks that can be seen from many kilometers away, rising high above the surrounding Namib Desert calcrete plains. The name "Spitzkoppe" has been spelled several ways in the literature, for example "Spitzkopje" (Heidtke and Schneider, 1976; Leithner, 1984), "Spitzkop" (Mathias, 1962) and the version used in this article, Spitzkoppe. This latter spelling is the one used on the geological maps of the region. *Spitz* is German for "peak" and *koppe* refers to a "hilltop."

Access to Klein Spitzkoppe is easy, and the locality can be reached using a conventional vehicle. The main paved road that connects Windhoek to Swakopmund (B2) passes south of the Spitzkoppe and both mountains are clearly visible from the road. Approximately 100 km northeast of Swakopmund, a road leads northwest from B2 to the coastal village of Heinties Bay. About 30 km from this turnoff, this dirt road passes close by the Klein Spitzkoppe. Local diggers ply their stocks along this road, and sometimes reasonably good quality specimens can be purchased at fair prices. Some caution should be exercised, however, because more and more specimens from other neighboring localities like Erongo and the Brandberg are being mixed in with the Spitzkoppe material, so buying on site does not guarantee that the pieces come from Klein Spitzkoppe. Most, if not all, of the topaz, aquamarine and other collectable minerals such as fluorite are extracted by the local Damara workers who live in very rudimentary shacks close to their respective diggings. They either dig randomly in the weathered granite outcrops where it is relatively easy to pry crystals loose from their matrix, or they collect topaz from alluvium and alluvial scree. These latter crystals are usually water-worn and are more suited for faceting and jewelry purposes than as mineral specimens.

HISTORY

The two Spitzkoppen have been known since antiquity. Although no archeological evidence exists to prove that the Bushmen

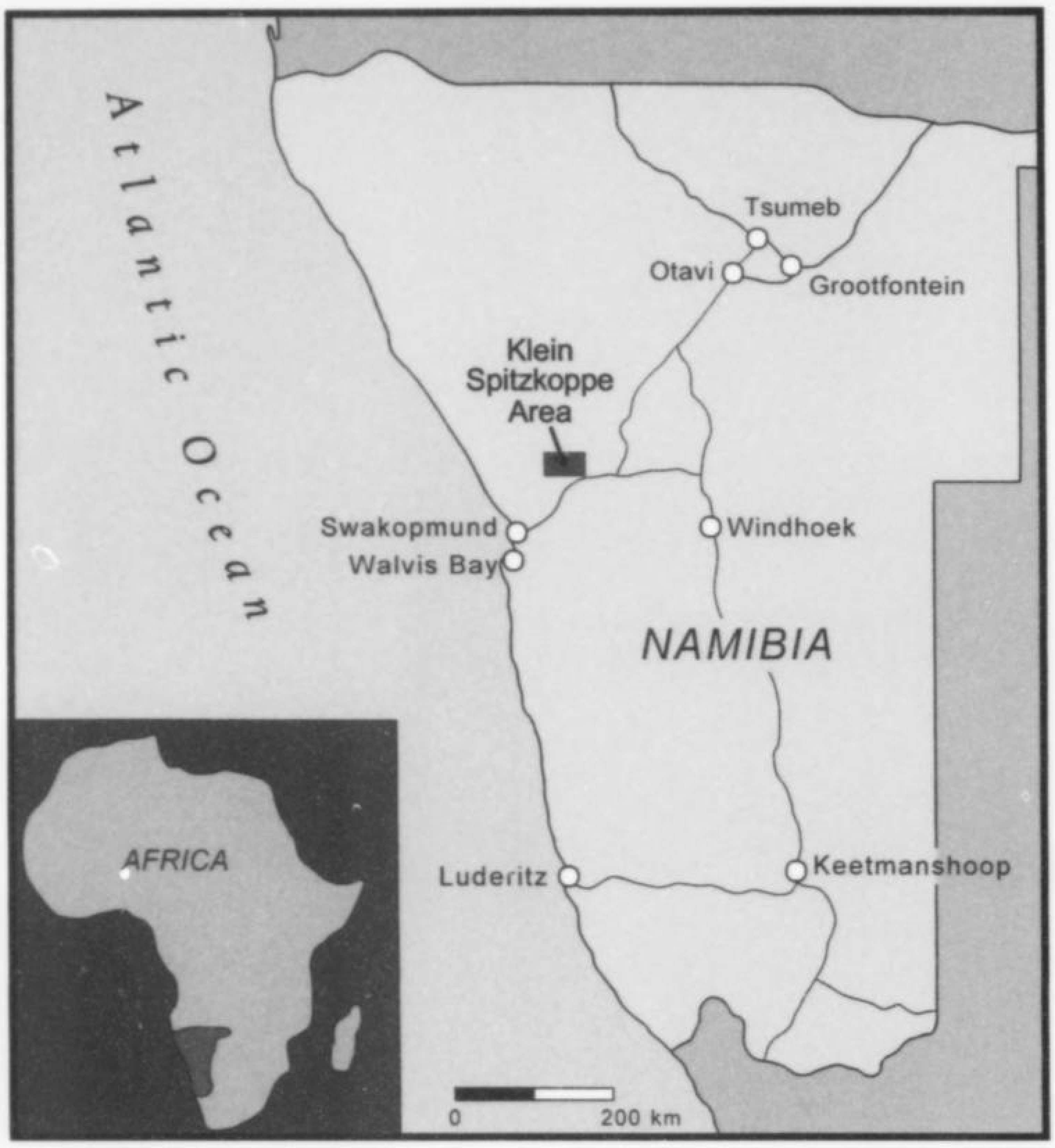


Figure 1. **Locality map of Namibia showing the geographic location of Klein Spitzkoppe (red box refers to Fig. 2).**

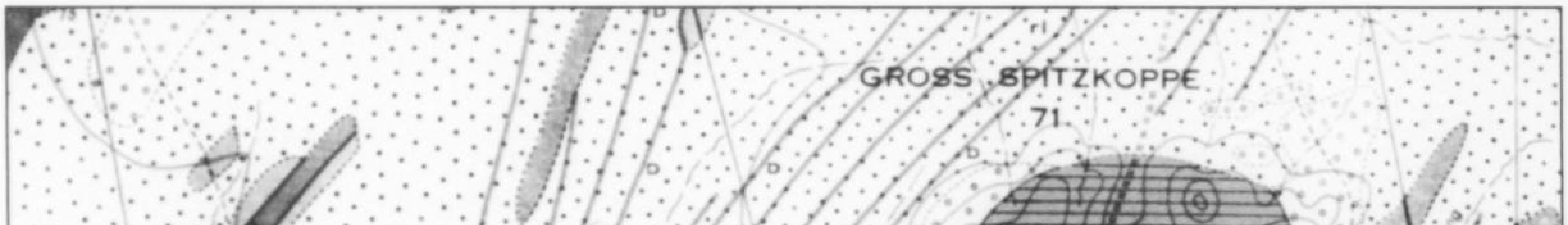


Figure 2. **Portion of the historical geological map of the Karibib area, compiled by Frommurze *et al.* (1942). Note the location of Gross and Klein Spitzkoppe (orange), situated 12 km apart, surrounded by eolian (windblown) desert sand (yellow). The location of the topaz and aquamarine workings can be seen on the southwestern flank of Klein Spitzkoppe mountain.**

Figure 3. **Klein Spitzkoppe with an indigenous *Euphorbia* succulent bush in the foreground. Bruce Cairncross photo.**

collected crystals, their paintings adorn some of the granite overhangs at Klein Spitzkoppe.

The topaz deposits at Klein Spitzkoppe were first described in the late 19th century German literature by Hintze (1889). At the time, the locality was known as the Keins-Berge, although the Dutch name, "Spitzkoppjes" was already used to name several steep-sided inselbergs and isolated mountains in the Damaraland region. Hintze (1889) received loose crystals of topaz and fragments of beryl from Klein Spitzkoppe that were originally collected by Baron von Steinäcker, but these were passed on to Hintze by G. Gürich. These specimens were used to describe the morphology and crystallographic forms of the Klein Spitzkoppe topaz. The Namibian specimens were described as being reminiscent of crystals from Russia as they showed a similar morphology and were also transparent.

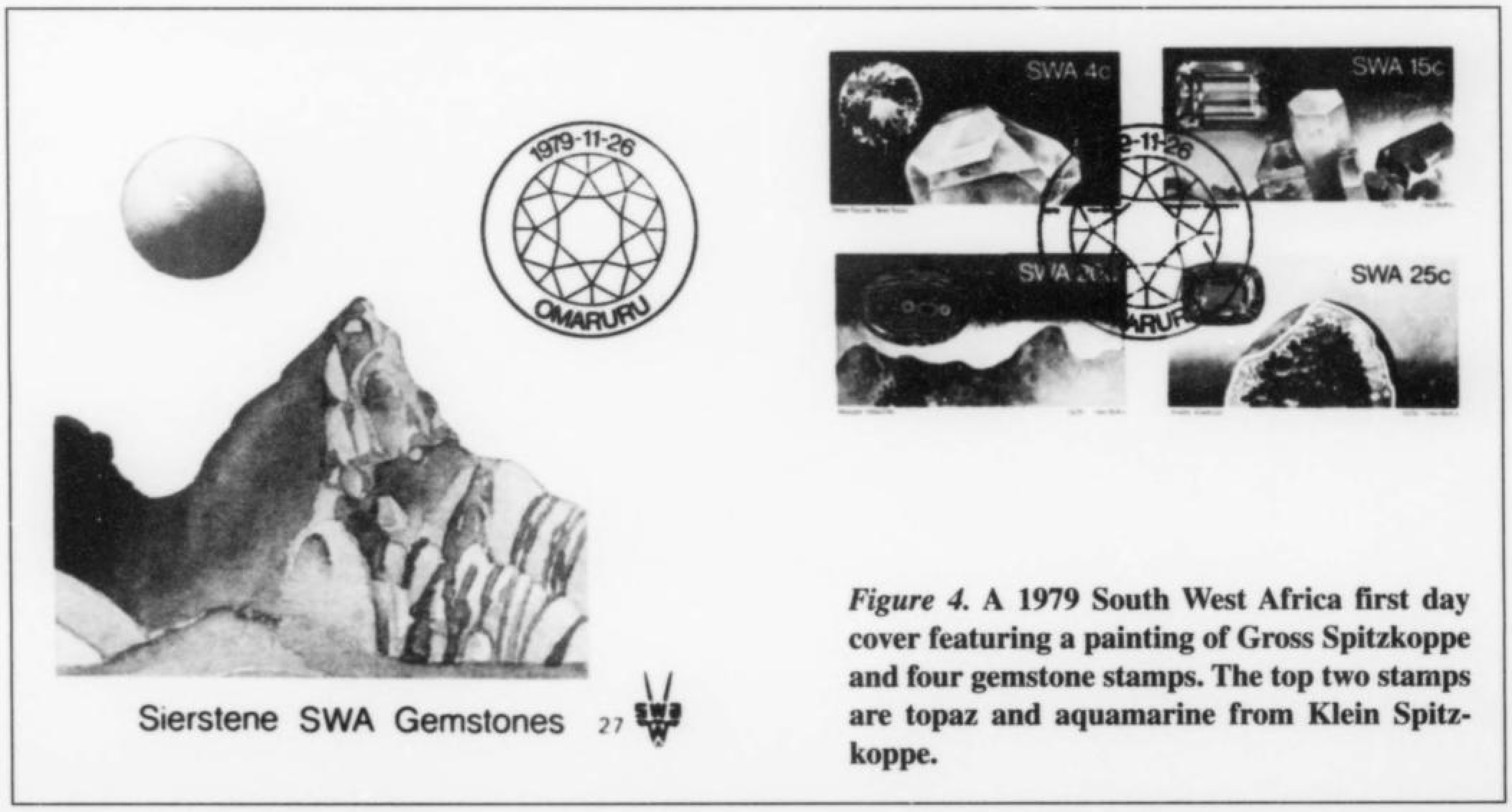


Figure 4. **A 1979 South West Africa first day cover featuring a painting of Gross Spitzkoppe and four gemstone stamps. The top two stamps are topaz and aquamarine from Klein Spitzkoppe.**

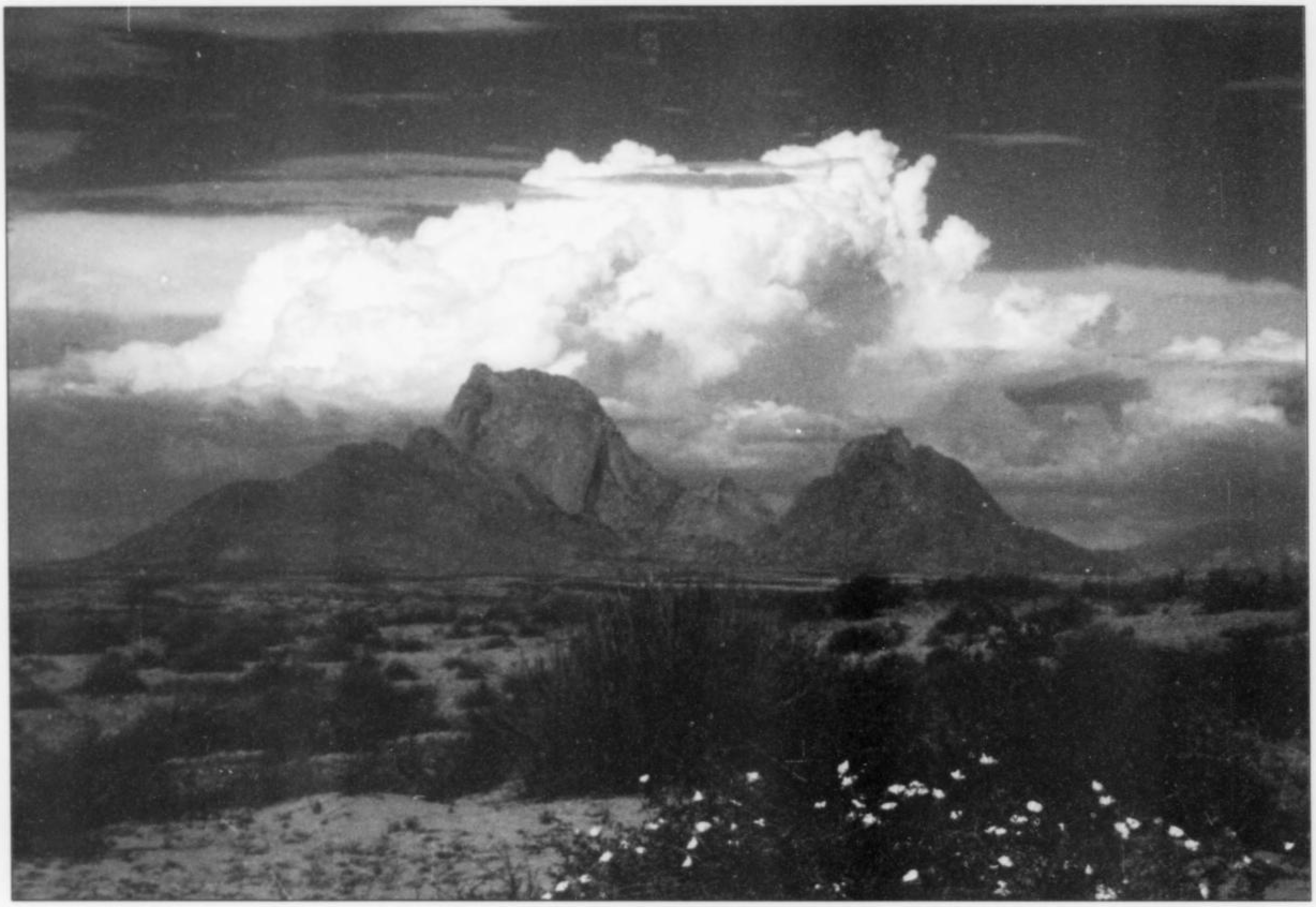


Figure 5. **Gross Spitzkoppe, viewed from the Klein Spitzkoppe, with a rare desert storm brewing in the background. Bruce Cairncross photo.**

The main period of topaz "mining" in Namibia was during the 1930's, and from 1930 to 1938, 34.5 kg of faceting-grade topaz was mined in Namibia, mostly from the Klein Spitzkoppe deposits (Schneider and Seeger, 1992a). In more recent times, production figures have not been systematically recorded and most topaz mining is carried out informally by the Damara diggers. Aquamarine is also extracted from the miarolitic pegmatite cavities in the granite, but is less commonly encountered than the topaz. Although no production figures are available, many carats of aquamarine have also been cut from material collected at Klein Spitzkoppe. Yellow beryl (heliodor) is also infrequently encountered in the pegmatites and some fine gems have been cut from this material as well.

Apart from small-scale, informal gemstone mining, granite was also exploited on a larger scale at Klein Spitzkoppe. Until 1998, the yellow granite, known colloquially as "Tropical Sun," was quarried by one company, the African Granite Company (Pty) Ltd., for building stone. These operations are dormant at present and the company no longer owns the quarries. Blocks of quarried granite are still scattered around on the surface near the quarry. Most of the granite was exported to Germany and Japan where it was utilized for cladding and domestic applications (ASSORE, 1996).

Klein and Gross Spitzkoppe were systematically mapped during 1928, and the regional geology was later revised in 1937. The results of this mapping project were published several years later (Frommurze *et al.*, 1942). A detailed 1:125,000 geological map accompanies the Frommurze *et al.* (1942) report, which provides a brief description of the topaz occurrences at Klein Spitzkoppe, including a detailed map of some of the topaz localities. Prior to this, the two Spitzkoppe mountains had been shown on an older (1923) 1:1,000,000 geological map detailing the central part of Namibia (then South West Africa). This was produced for the Deutsche Kolonial-Gesellschaft für Südwest-Afrika by Reuning (1923) and represents one of the oldest geological maps for the region.

REGIONAL AND LOCAL GEOLOGY

The alkali granites that host the gemstones are late Jurassic to early Cretaceous in age, approximately 135 million years old (Miller, 1992), and have been classified as A-type within-plate granites (Frindt *et al.*, 2004). This group of late to post-Karoo (younger than 140 million years old) intrusive granites into which Klein Spitzkoppe falls, occur over a wide area of Namibia (Haughton *et al.*, 1939; Botha *et al.*, 1979), and other somewhat similar granites contain economic deposits of tin, rare-earth elements, tungsten, copper, fluorite, tourmaline and apatite (Miller, 1992). The host rock to the topaz and aquamarine is a pale gray to pale yellow-brown granite. The granite is medium-grained to coarse-grained and consists predominantly of quartz, plagioclase and microcline, with accessory magnetite, hematite and limonite. Although the granite has a very even and consistent texture and grain size, attributes that are well-suited for building stone (Diehl, 1992), it contains miarolitic pegmatite veins and vugs in which the gemstones and other collectable minerals are found (Jahn, 2001). The pegmatites are commonly narrow (less than 5 cm wide) linear features that cut across the granite. In places, they randomly pinch and swell into cavities varying in size from that of a coffee cup to

Figure 6. **A group of local Damara diggers selling their specimens on the side of the road. Note that most of the large black schorls on the table are from Erongo, not Klein Spitzkoppe. Bruce Cairncross photo.**

Figure 7. **A 1992 photo of the "Tropical Sun" granite quarrying operation. Photo courtesy of ASSORE.**

football-size. Well-documented pegmatites occur on the eastern and southwestern sides of Klein Spitzkoppe (Frommurze *et al.*, 1942; Schneider and Seeger, 1992a):

> The drusy pegmatites . . . vary in width between 8 inches and 14 inches. The cavities are lined with euhedral crystals of smoky quartz, greenish perthitic orthoclase . . . , blades of dark bottle-green biotite, and crystals of beryl (aquamarine) and topaz. (Frommurze *et al.*, 1942)

These pegmatites seldom exceed 1 meter in width and are usually less than 200 meters along strike. One of the pegmatites

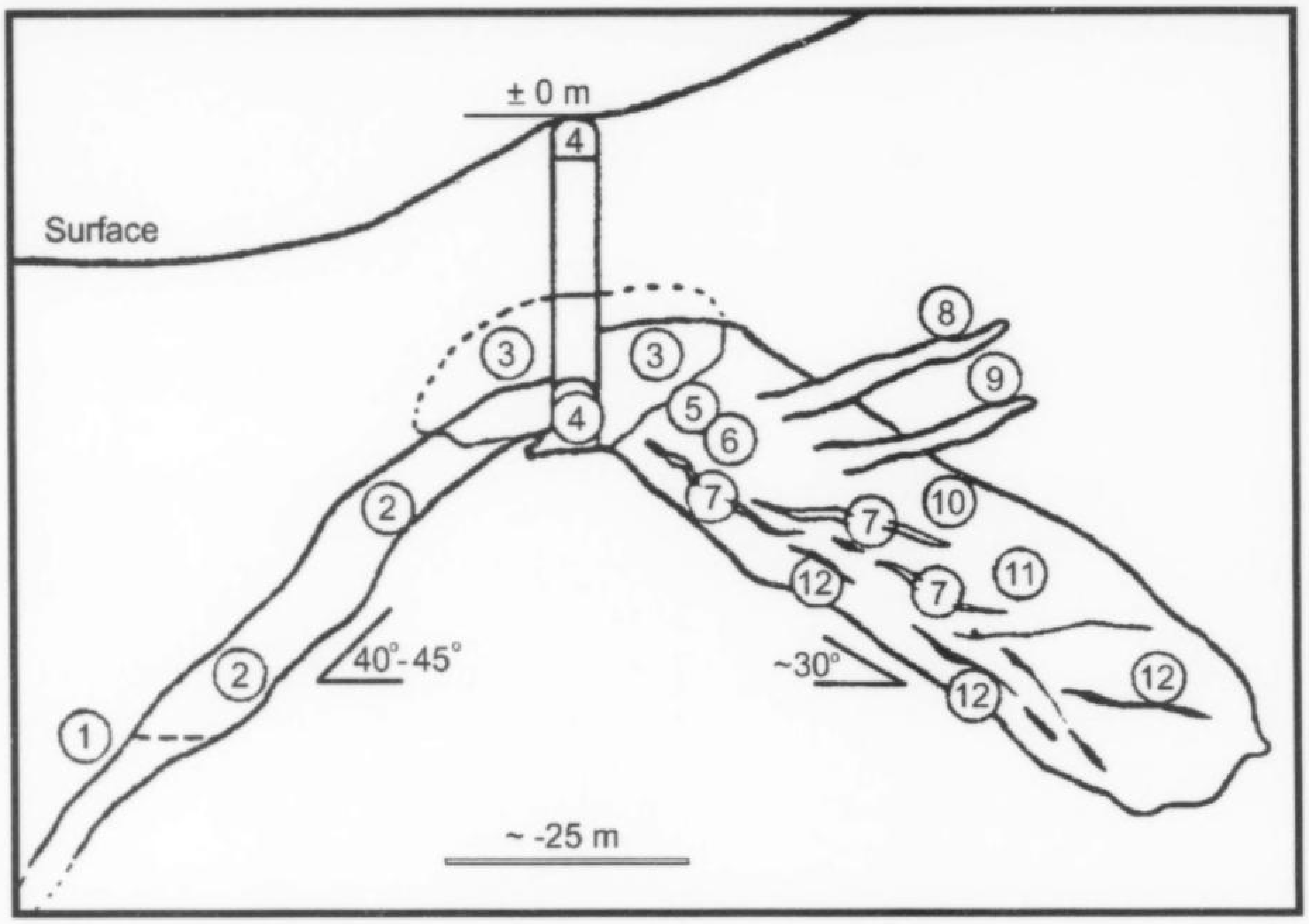


Figure 8. **Generalized cross-section of Stiepelmann's pegmatite by Ramdohr (1940a). Note that dimensions are approximate. The numbered zones in the sketch are: (1) Water table. (2) Open zones in quartz veins with quartz crystals 1 meter long and 35 cm wide that resembled mine timbers. (3) Massive quartz with fine grained albite. (4) Vertical shaft that became declined and less steep with depth until approximately horizontal at the bottom. (5) Orthoclase crystals associated with bertrandite and phenakite. (6) Dense mass of fine-grained mica with dispersed phenakite, bertrandite and leached beryl. (7) Blue beryl in stockwork veins, associated with feldspar. (8 & 9) Two "tubes" with large mica crystals and beautiful, pale blue beryl, quartz and rare fluorite. (10) Location of huge resorbed/altered topaz crystals. [Note: Ramdohr states that topaz crystals measuring 8 × 12 × 15 cm and weighing over 2 kg came from other localities in Klein Spitzkoppe, but that the altered topaz crystals from Stiepelmann's pocket were even larger.] (11) Zone of large amounts of phenakite. (12) Yellow beryl with some pockets and veins of yellow beryl together with yellow fluorspar. From zones 7 to 12 described above, there are aquamarine crystals and golden beryl.**

was mined via an underground shaft at the so-called Hassellund's Camp (Frommurze *et al.*, 1942), and its geometry was observed and described. The veins tend to pinch and swell and, where sufficient space occurs, euhedral crystals of quartz, feldspar and fluorite are encountered. These usually form drusy linings in the cavities. Vugs commonly contain biotite. The topaz and aquamarine tend to be more abundant where associated with the quartz-feldspar assemblage, rather than with biotite.

One remarkable exception, with regard to pocket size, is "Stiepelmann's pegmatite," discovered in the mid-1930's. This is the largest cavity known and produced many specimens (Medenbach, 2001). Ramdohr (1940a) gives a detailed description of the mineralogy and general dimensions of Stiepelmann's pocket, based on descriptions given to Ramdohr by Stiepelmann himself. The zone was approximately 100 meters long, and in places, pockets were up to 20-25 meters wide.

The Gross Spitzkoppe and Klein Spitzkoppe are geologically similar in age and rock type, yet topaz and aquamarine are virtually confined to the Klein Spitzkoppe. No adequate explanation for this difference has been forthcoming, but it has been suggested that the Gross Spitzkoppe may have been "unroofed" and the mineralized upper portion that would have contained trapped, mineralizing fluids has been eroded away (R. Miller, personal communication, 1999).

MINERALS

Albite $NaAlSi_3O_8$

Albite occurs as well-formed white crystals up to 2 cm on edge, with microcline. Most of the albite crystals are transparent to translucent (Beyer, 1980). Epitactic overgrowths of albite are common on many microcline crystals.

Axinite Group $(Ca,Mn,Fe,Mg)_3Al_2BSi_4O_{15}(OH)$

Beyer (1980) reports seeing a single specimen of axinite consisting of a 3-mm purple-brown crystal from a vug, associated with albite, black fluorite (yttrofluorite) and microcline.

Bastnäsite-(Ce) $(Ce,La)(CO_3)F$

During September-October 2004, local diggers re-entered the old Stiepelmann workings and collected specimens (Uli Bahmann, personal communication). One of the species they found, which has been positively identified at the University of Johannesburg, and illustrated here, is bastnäsite-(Ce). The 2.7-cm specimen has two small topaz crystals attached, attesting to its Klein Spitzkoppe pedigree. This is the first reported occurrence of this species from Klein Spitzkoppe. Apart from this new discovery, crystals of phenakite a few millimeters in size were also collected. Apparently, some of these are on matrix but many have been glued onto the rock.

Figure 9. **Bastnäsite-(Ce) crystal, 2.7 cm, with a small topaz attached, from Stiepelmann's workings, Klein Spitzkoppe. Uli Bahmann collection; Bruce Cairncross photo.**

Bertrandite $Be_4Si_2O_7(OH)_2$

Bertrandite occurs as millimeter-size, highly lustrous, tabular crystals found in the so-called "Stiepelmann pegmatite" (Beyer, 1980). It can also be found as anhedral, granular crystals which are difficult to identify visually. Bertrandite forms at the expense of beryl and is paragenetically the last beryllium-bearing species to crystallize. Small, white to colorless crystals on microcline have been described by Frommurze *et al.*, 1942.

Beryl $Be_3Al_2Si_6O_{18}$

Aquamarine and yellow and green beryl are found at Klein Spitzkoppe. Aquamarine is found associated with microcline, smoky quartz, topaz, bertrandite, phenakite and fluorite (De Kock, 1935; Frommurze *et al.*, 1942; Schneider and Seeger, 1992a; Jahn, 2001). Apart from gem-quality aquamarine, other varieties of beryl are also present. These include hexagonal, prism-etched, transpar-

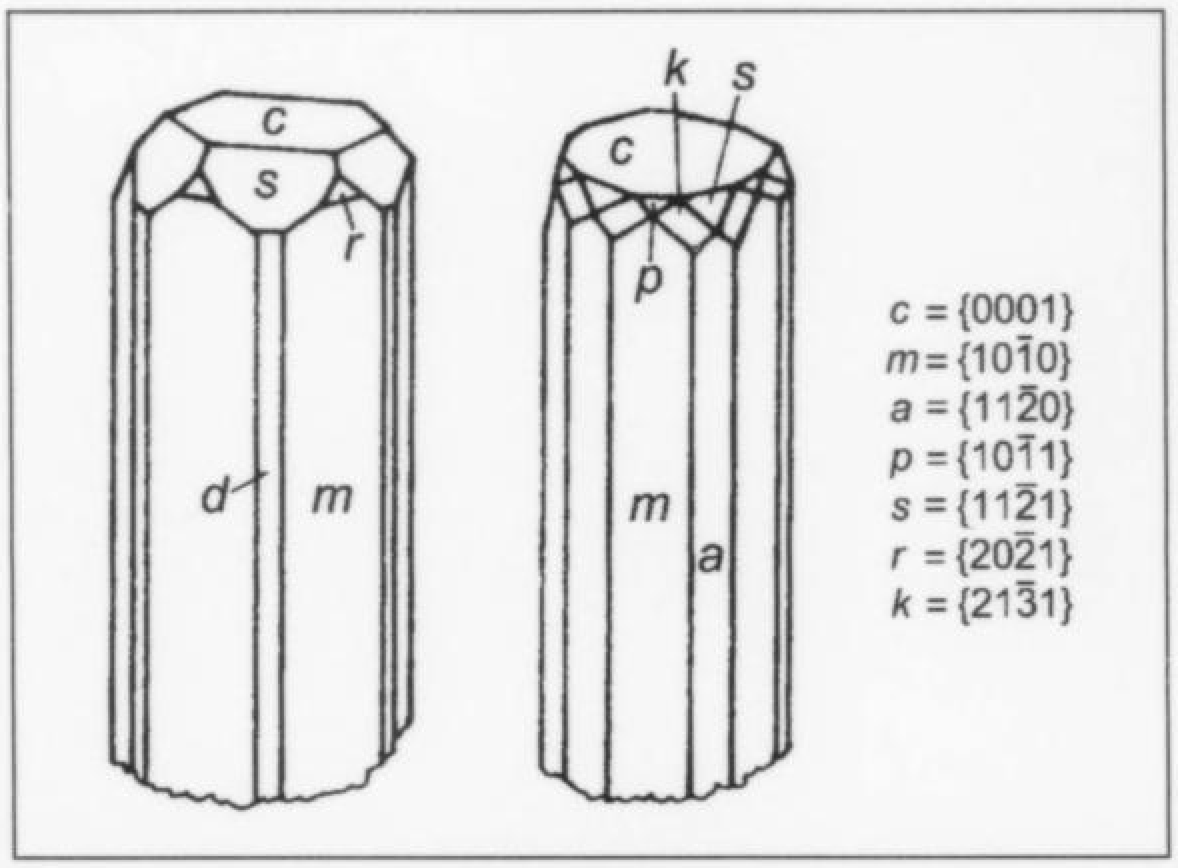


Figure 10. **Aquamarine beryl, crystal drawings of Klein Spitzkoppe specimens (Beyer, 1980).**

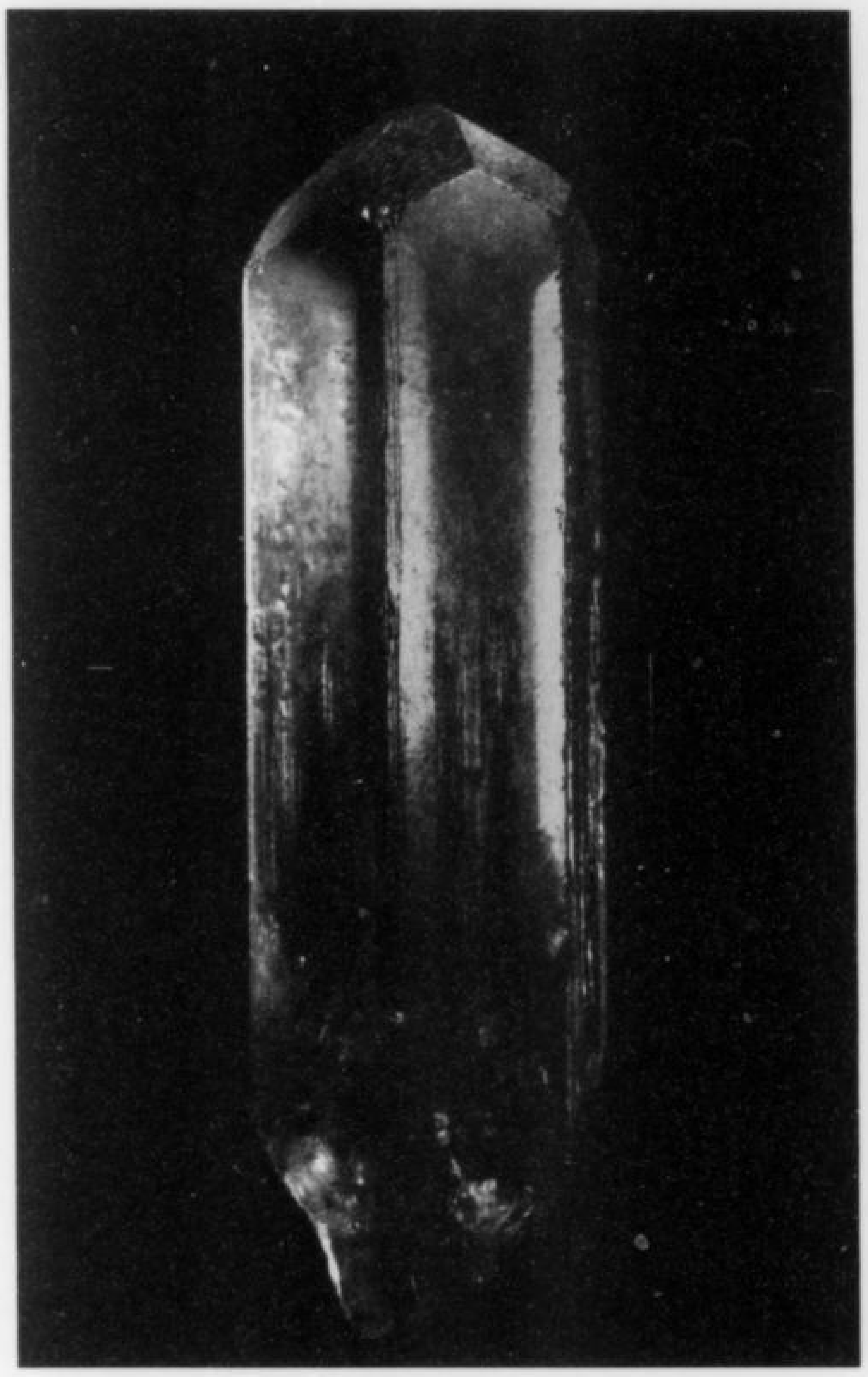


Figure 11. **Green beryl crystal, 8 cm, from Klein Spitzkoppe. William Larson collection; Wimon Manorotkul photo.**

Figure 12. **Beryl—a yellow, complexly terminated crystal, 1.4 cm, from Klein Spitzkoppe. Author's collection and photo.**

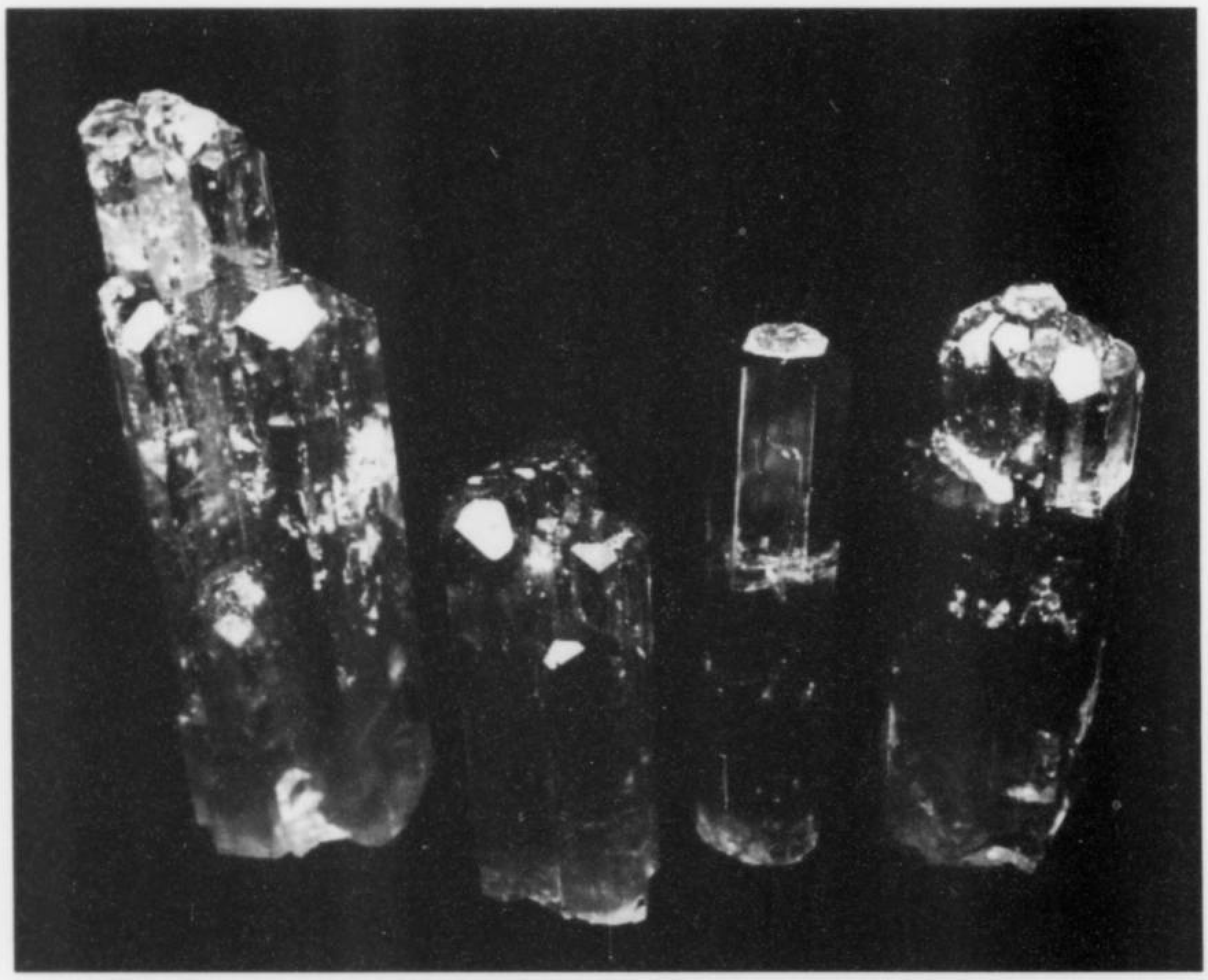
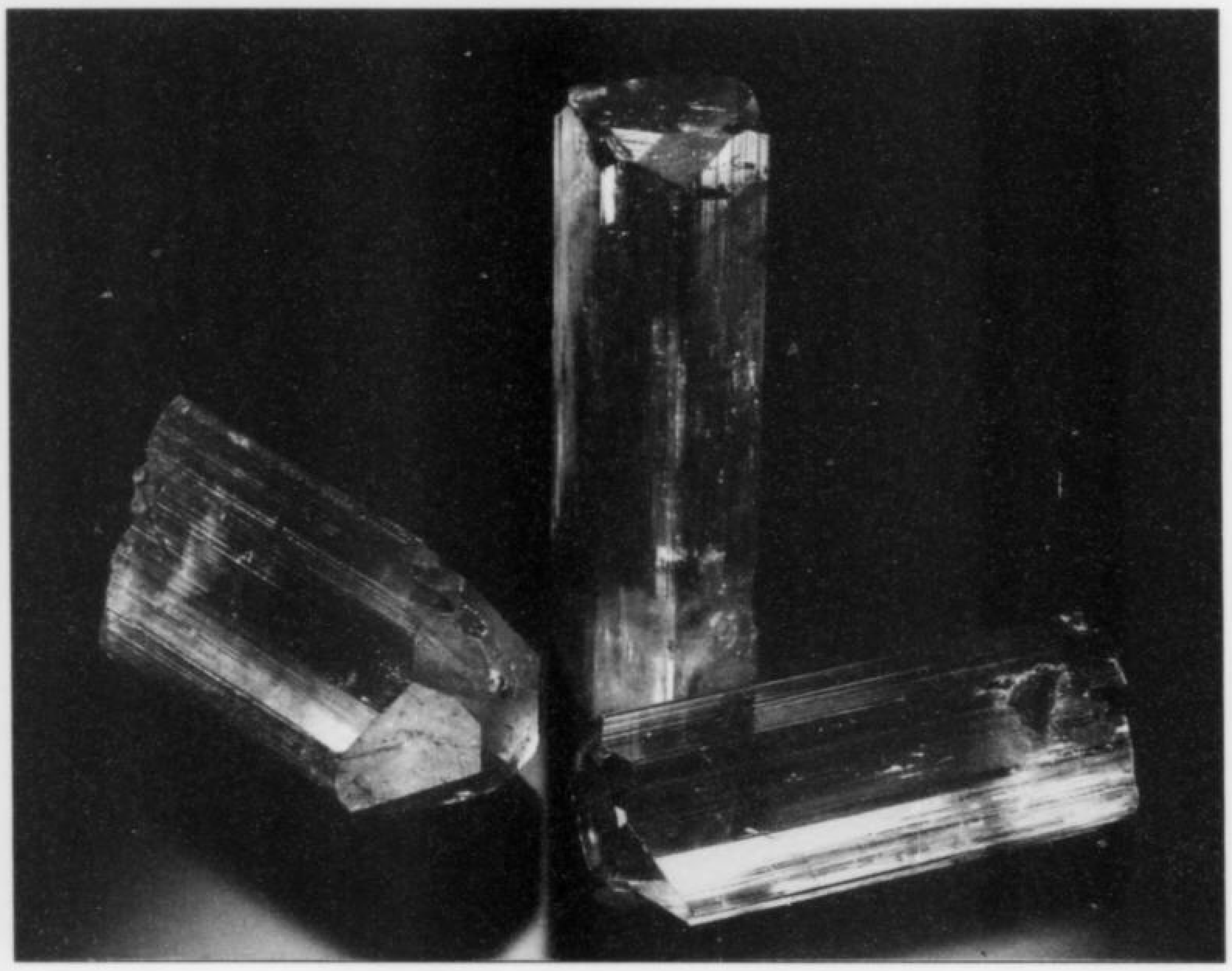


Figure 13. **Aquamarine beryl crystals to 6 cm, from Klein Spitzkoppe. Smithsonian collection; Wendell Wilson photo.**

Figure 14. **Aquamarine beryl crystals to 5.5 cm, from Klein Spitzkoppe. William Larson collection; Jeff Scovil photo.**



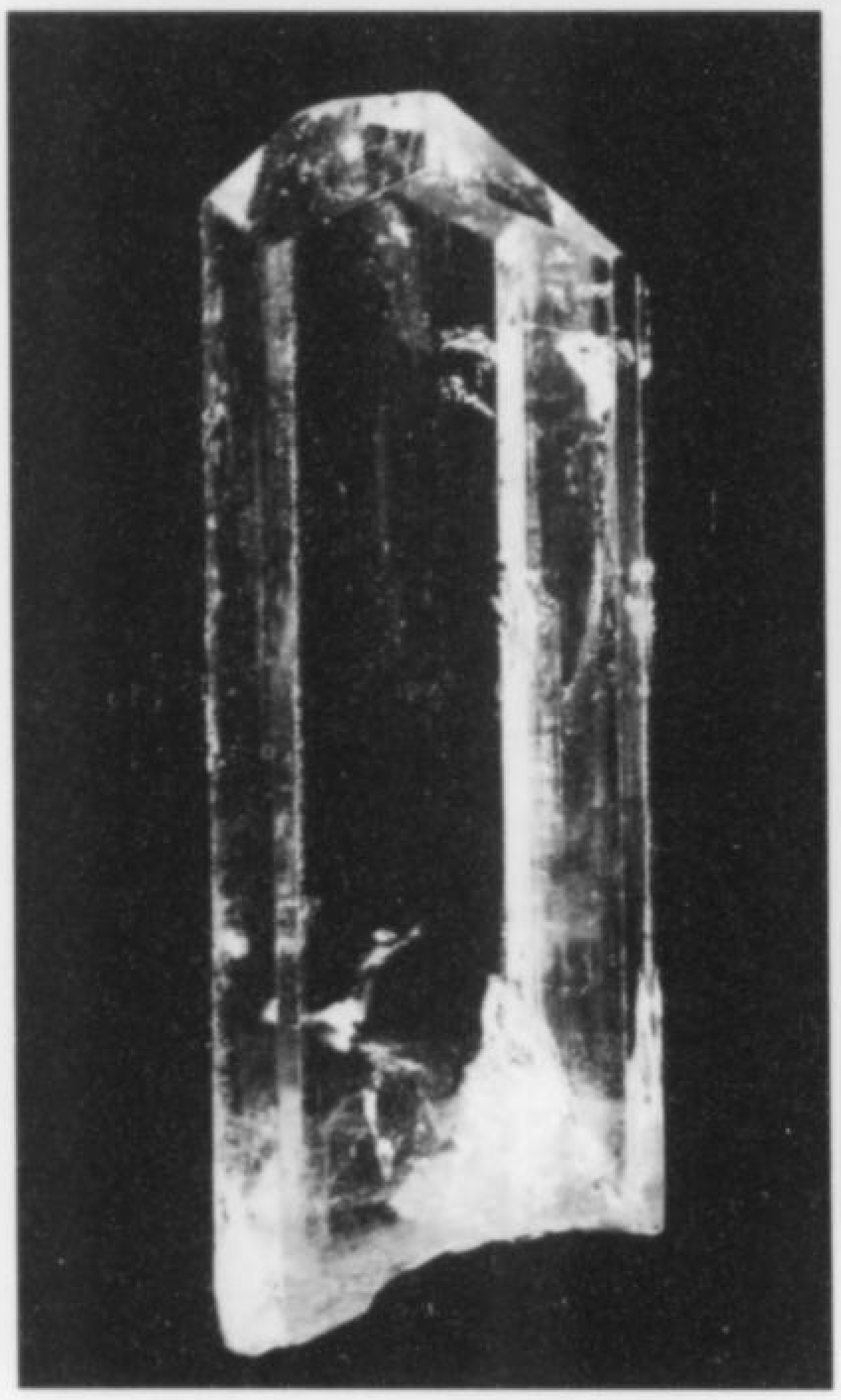


Figure 15. **Beryl—a 3.4-cm yellow crystal from Klein Spitzkoppe. Johannesburg Geological Museum collection, no. 65/116; Bruce Cairncross photo.**

ent to translucent green crystals and also yellow crystals up to 6 cm long (Heidtke and Schneider, 1976). The largest documented aquamarine from Klein Spitzkoppe measures 12 cm long and 5 cm in diameter (Ramdohr, 1940a). According to Frommurze *et al.* (1942):

> The beryl occurs . . . in well-formed hexagonal crystals and is invariably very clear and transparent. The color varies from pale-green to dark sea-green and the bluish-green of precious aquamarine. Occasionally very deep-green varieties approaching emerald, and yellowish varieties known as heliodor are found.

According to Leithner (1984), two crystal habits of beryl have been found:

(1) Hexagonal prisms up to 7 cm long and 1 cm thick with flat (basal pinacoid) terminations. These are usually blue, blue-green and translucent.

(2) Long needle-like crystals, up to 5 mm thick and several centimeters long which are flawless and blue to colorless with

pinacoid and hexagonal bipyramidal terminations. This beryl habit occurs in miarolitic cavities, in crystals replacing feldspar (Beyer, 1980).

One crystal described by Beyer (1980) measures 2 cm, and is completely colorless, except for a rose-red core! Faceted aquamarine from Klein Spitzkoppe in stones over 20 carats is not uncommon.

Yellow beryl has been found in Klein Spitzkoppe pegmatite veins where it is usually associated with fluorite and finely crystalline mica, and it also occurs intergrown with orthoclase (Schneider and Seeger, 1992a; Heidtke and Schneider, 1976; Strunz, 1980). The first known locality for yellow beryl was a pegmatite situated close to Rössing, in the Swakopmund district (Kaiser, 1912). The Rössing material was described by Hauser and Herzfeld (1914); the color ranges from deep golden yellow to pale yellow and yellow-green. Crystals measuring 12 cm along the *c*-axis and up to 5 cm in diameter have been recovered from Klein Spitzkoppe. Some yellow beryl crystals display naturally etched crystal faces, the most common feature being hook-shaped patterns developed on the basal pinacoid faces (Leithner, 1984). Fake specimens of aquamarine are known from Klein Spitzkoppe (see Fig. 12 in Dunn *et al.*, 1981).

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

Biotite is virtually ubiquitous in the veins and cavities that occur in the Klein Spitzkoppe granite. It occurs as hexagonal, dark brown to dark green crystals up to 20 cm diameter in some of the larger pegmatites.

Euclase $BeAlSiO_4(OH)$

Euclase crystals up to 5 mm have been identified on one specimen from Klein Spitzkoppe (Beyer, 1980). These are colorless to pale-yellow and transparent, and are associated with microcline, fluorite, hydroxyl-herderite, bertrandite and large quartz crystals.

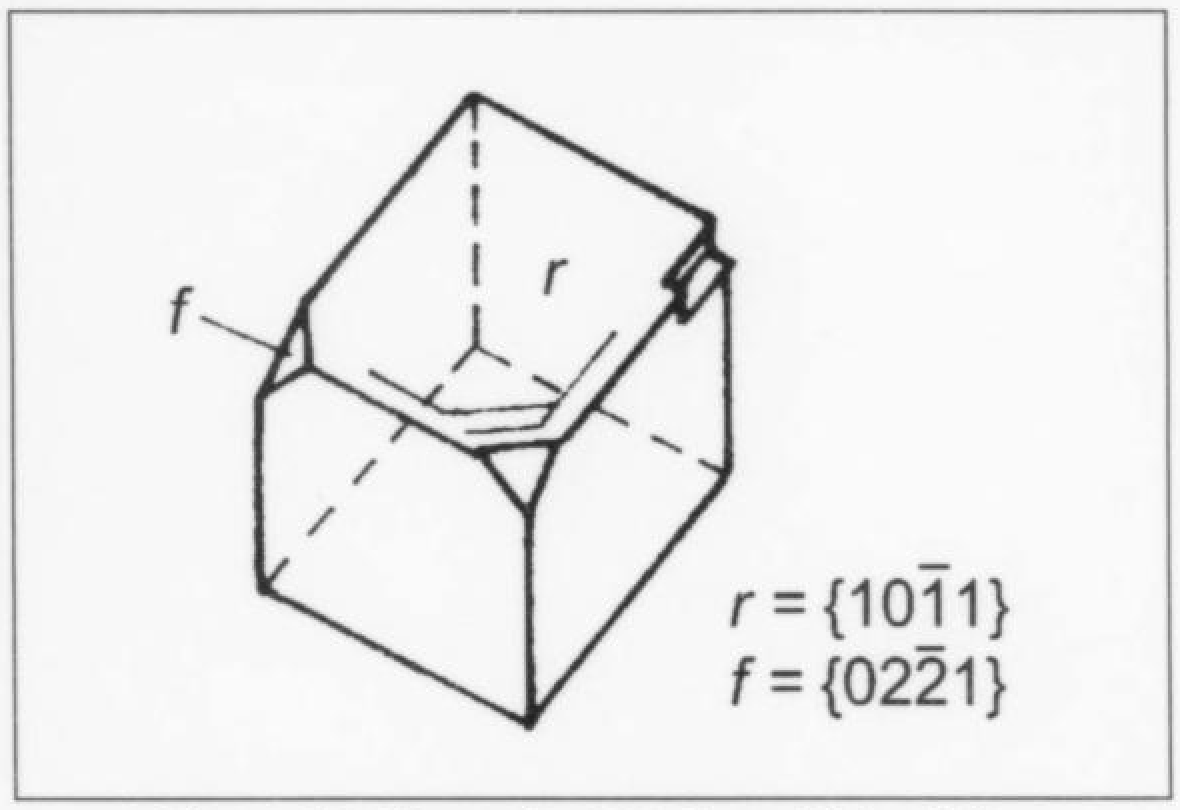


Figure 16. **Florencite-(Ce) from Klein Spitzkoppe, crystal drawing (Beyer, 1980).**

Florencite-(Ce) $CeAl_3(PO_4)_2(OH)_6$

Florencite-(Ce) occurs as small, pale yellow to colorless rhombohedrons and pseudocubic crystals a few millimeters in size (Medenbach, 2001). These were originally called "stiepelmannite," after the Stiepelmann pegmatite in which they were discovered at Klein Spitzkoppe (Ramdohr, 1940b), but that name, along with its species status, is now discredited.

Fluorite CaF_2

Fluorite occurs both at Gross Spitzkoppe and Klein Spitzkoppe, and specimens from the two different deposits should not be confused with each other. Fluorite from Gross Spitzkoppe is associated with tremolite, garnet and calcite in the Karibib Formation marbles (Schneider and Seeger, 1992b). Most of this fluorite is white but its color can also range to deep purple. Pale blue to deep purple fluorite in cubes up to 1 cm have been found there, as well as colorless crystals. Klein Spitzkoppe fluorite, on the other hand, is typically a distinctive and vibrant emerald-green and is in some cases associated with matrix specimens of topaz, microcline and quartz. Some of the fluorite is found intergrown with the topaz. The most common crystal form is cubic, although octahedral habits have also been observed; Stiepelmann's pegmatite yielded both varieties. Associated minerals include topaz, microcline, schorl, albite and goethite. Ramdohr (1940a) described brown, green and colorless fluorite cubes up to 10 cm on edge from Klein Spitzkoppe. The yellow-brown varieties are fluorescent. Several dozen loose, cream-white, 1-cm to 2-cm octahedral fluorite crystals were collected from a small vug in 1998 (Messner, personal communication, 1998). Crystals of black so-called "yttrofluorite" (tveitite-(Y)?) have also been found at Klein Spitzkoppe.

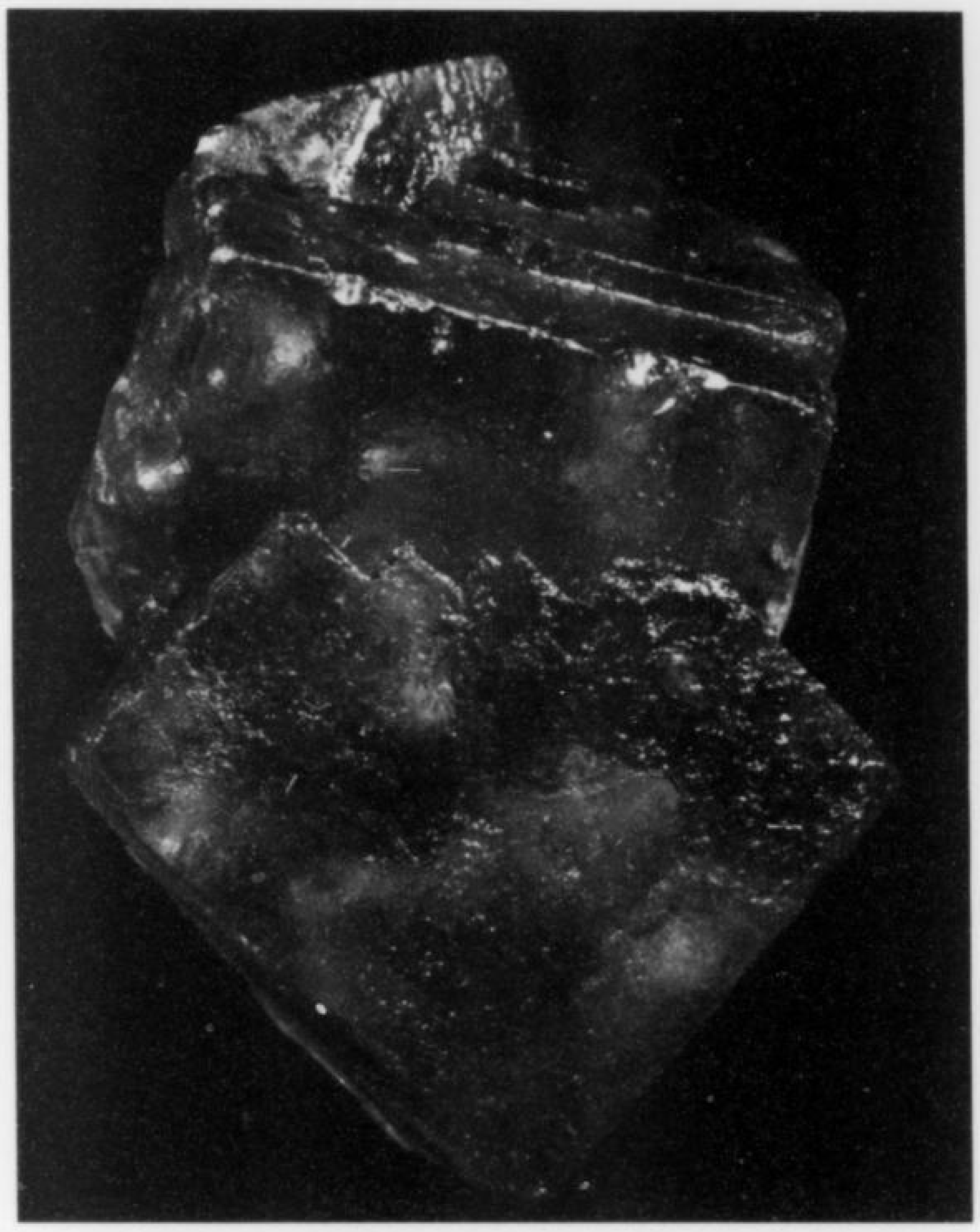


Figure 17. **Vibrant green fluorite cubes, 3.2 cm, from Klein Spitzkoppe. Desmond Sacco collection; Bruce Cairncross photo.**

Goethite α-$Fe^{3+}O(OH)$

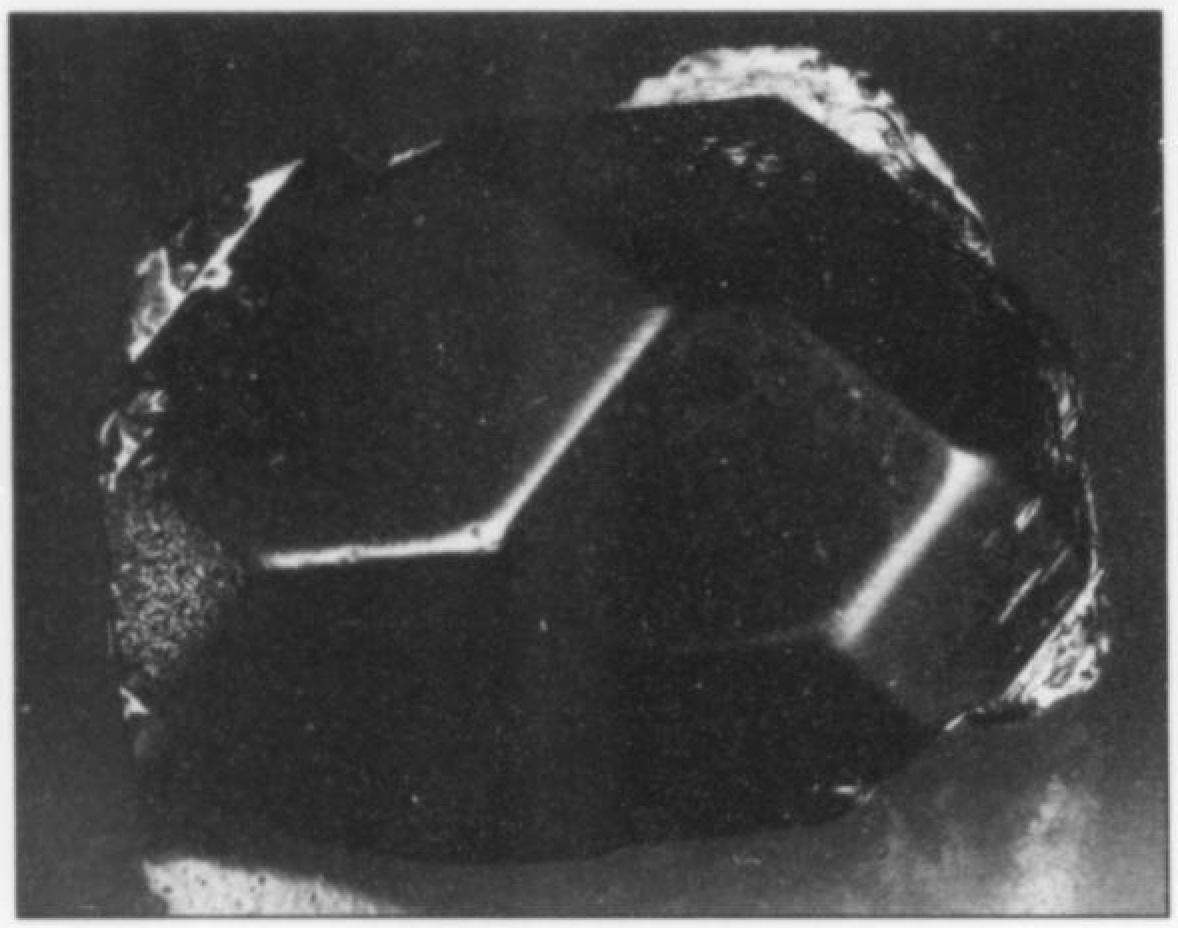
Rare pseudomorphs of goethite after small hematite *eisenrosen* ("iron roses") are known, but are uncommon. Siderite crystals (see below) are commonly found pseudomorphically altered to goethite. Goethite commonly forms brown coatings that have to be cleaned off of some specimens.

Hydroxyl-herderite $CaBe(PO_4)(OH,F)$

Beyer (1980) states that only a single crystal of "herderite" is known from Klein Spitzkoppe, associated with euclase. The identification was based on goniometry, so the mineral is most likely hydroxyl-herderite, inasmuch as true herderite ($F > OH$) is virtually unknown in nature (Mandarino and Back, 2004).

Figure 18. **Octahedral fluorite crystals on drusy quartz, 4.5 cm, from Klein Spitzkoppe. Author's collection and photo.**

Figure 19. **Yttrian fluorite crystal, 2.1 cm, from Klein Spitzkoppe. Philip Hitge collection, Bruce Cairncross photo.**



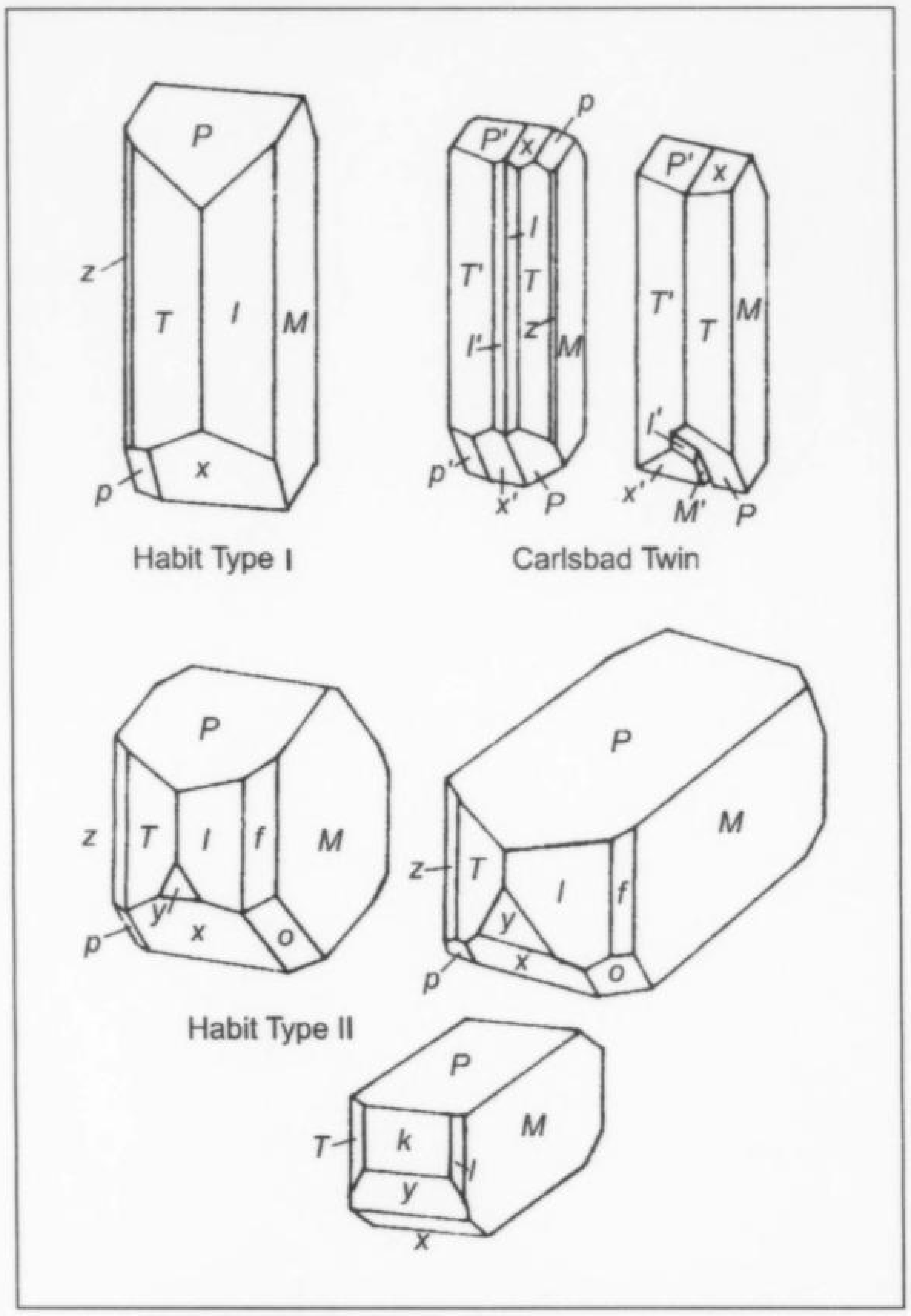


Figure 20. **Microcline from Klein Spitzkoppe, crystal drawings (Beyer, 1980).**

Microcline $KAlSi_3O_8$

Microcline is the most common feldspar at Klein Spitzkoppe. It occurs there as blocky, fist-sized, euhedral crystals up to 15 cm in the miarolitic cavities in the granite. Surfaces of most crystals are smooth and unaltered while others have highly corroded, pitted and etched crystal faces. Baveno twinning is particularly common in the larger crystals. Most of the crystals are pale brown to brownish pink to white. Pale green to medium green "amazonite" varieties are also found, but these are not of comparable quality to the darker green amazonite of localities such as those in Colorado. Microcline is most commonly associated with quartz, topaz, needle-like schorl and, more rarely, ferberite. Where phenakite is found, it is virtually always associated with microcline crystals.

Molybdenite MoS_2

A few crudely-formed hexagonal plates of molybdenite up to 1 cm diameter, associated with biotite and beryl imbedded in microcline, came from one of the pegmatite veins (Beyer, 1980).

Muscovite $KAl_2(Si_3Al)O_{10}(OH,F)_2$

Muscovite is not particularly abundant and rarely occurs in euhedral crystals. Rather, it is present as fine-grained crystals in the granite and pegmatites. An exception is the secondary, pale green form of muscovite that occurs as parallel, intergrown hexagonal plates and rosettes in vugs associated with fluorite.

Phenakite Be_2SiO_4

Small, 2-mm to 3-mm, transparent phenakite crystals have commonly been found in Stiepelmann's pegmatite (Frommurze

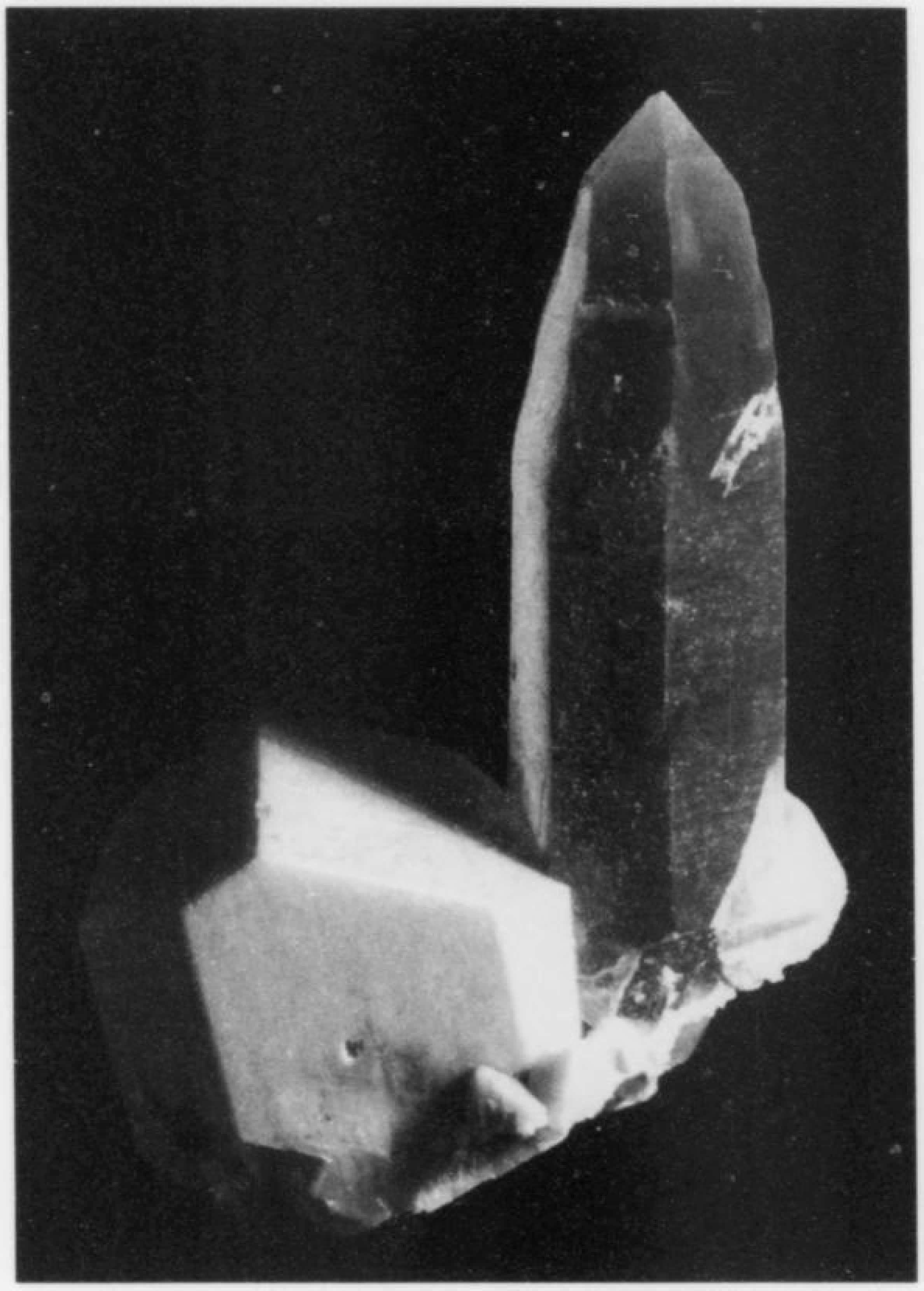


Figure 21. **Microcline feldspar with quartz, 2.8 cm, from Klein Spitzkoppe. Author's collection and photo.**

et al., 1942). These occur on microcline and distorted quartz crystals (Beyer, 1980). Some of these phenakite crystals are bright yellow in color. Pale blue-green crystals can be found on euhedral microcline where they form trigonal prisms and bipyramids. Aggregates of pale yellow phenakite crystals up to 10 cm in diameter have been found where beryl has been noticeably leached, providing the source of Be (Ramdohr, 1940a). Beyer (1980) also reported phenakite as well-terminated, lustrous, centimeter-long crystals 2–3 mm thick.

Quartz SiO_2

Quartz is one of the most common minerals found at Klein Spitzkoppe. It occurs in several habits and is associated with most of the other species (Beyer, 1980). Loose, smoky quartz crystals are synonymous with the locality and these vary from pale gray to virtually opaque black.

Quartz occurs with topaz, microcline, fluorite, albite and siderite. Dauphiné twins and Japan-law twins have been reported but are rare; the latter may actually be intergrown crystals and not Japan-law twins *per se*. Rose quartz is infrequently found as massive lumps in isolated veins, and sometimes encloses beryl crystals (Ramdohr, 1940a). No euhedral or subhedral rose quartz crystals have been described. Sceptered quartz, partly amethystine, is periodically collected, but not very often. Quartz crystals have also been found with inclusions of fine, acicular schorl (relatively common) and rutile (rare).

Rutile TiO_2

Rutile is very rare at Klein Spitzkoppe and has been reported as small, needle-like crystals enclosed in topaz (Beyer, 1980) and in quartz.

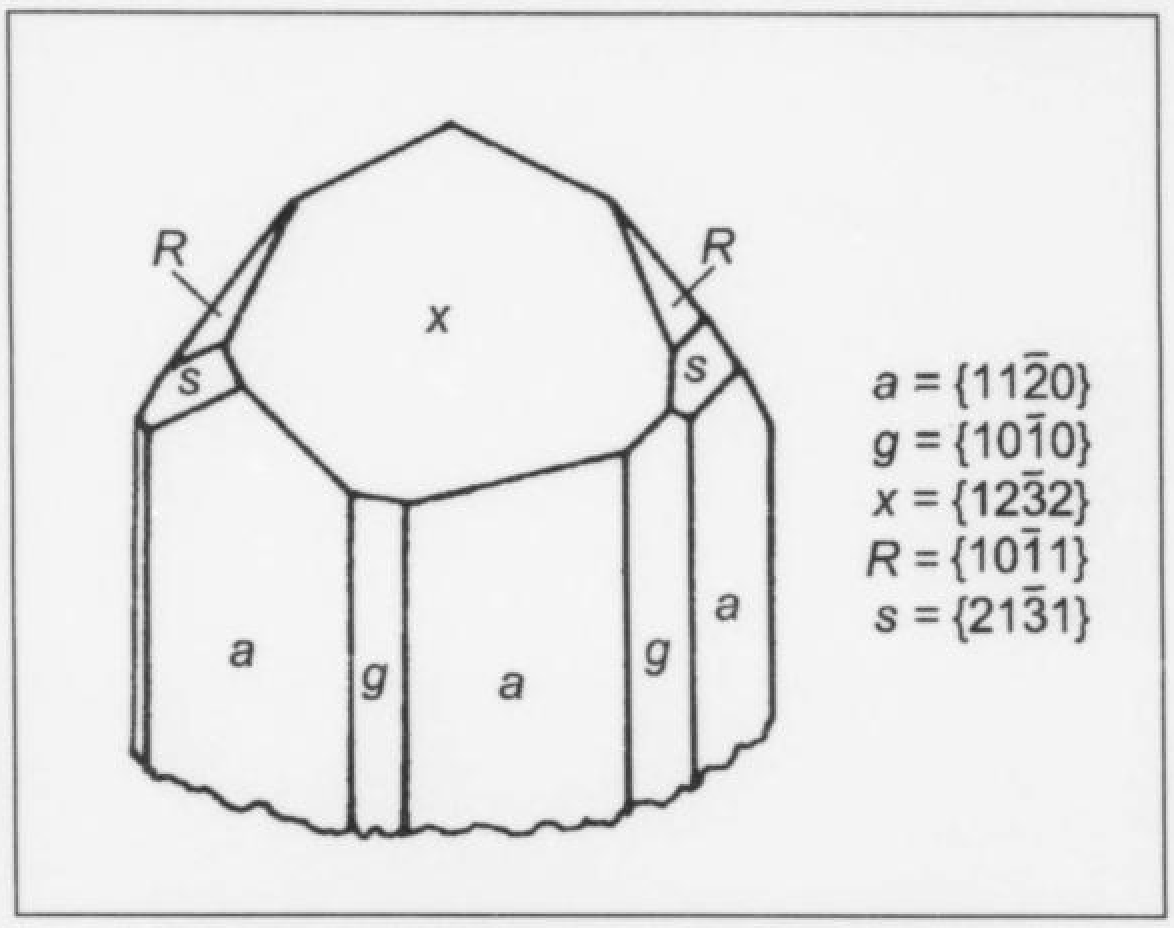


Figure 22. **Phenakite from Klein Spitzkoppe, crystal drawing (Beyer, 1980).**

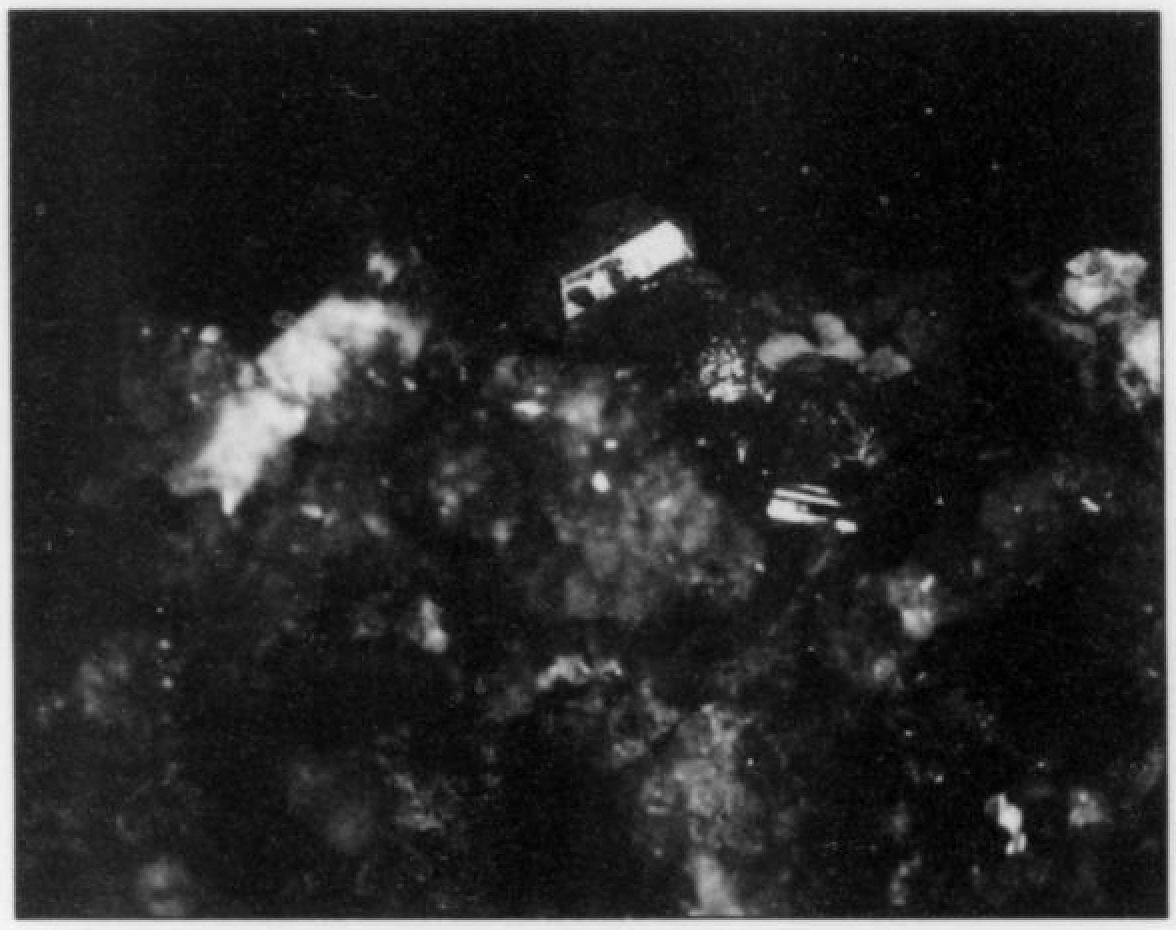


Figure 23. **Phenakite crystals (the largest is 7 mm) with microcline, from Klein Spitzkoppe. Museum Africa collection; Bruce Cairncross photo.**

Scheelite $CaWO_4$

Scheelite is also rare at Klein Spitzkoppe. One specimen consists of yellowish, greasy-lustered, tetragonal, bipyramidal scheelite crystals associated with fluorite, siderite and quartz (Beyer, 1980). Another has been described associated with microcline and bertrandite (Beyer, 1980).

Schorl $NaFe^{2+}_3Al_6(BO_3)_3Si_6O_{18}(OH)_4$

Very little colored, gem-quality tourmaline has been found in the Klein Spitzkoppe pegmatites, in contrast to the fine elbaite that is mined in the neighboring Karibib-Usakos Li-pegmatites. Very dark green to blue-green prismatic crystals up to 2 cm long have been found rarely at Klein Spitzkoppe. Schorl varies from small, needle-like prisms to pencil-sized crystals and is associated with quartz, topaz (sometimes as inclusions in both), microcline, aquamarine and fluorite. Several years ago, striated, blue prismatic aquamarine crystals were collected that are partially filled by acicular schorl crystals. Nowadays, much of the schorl that is purported to originate from Klein Spitzkoppe has in fact been collected in the nearby Erongo Mountains.

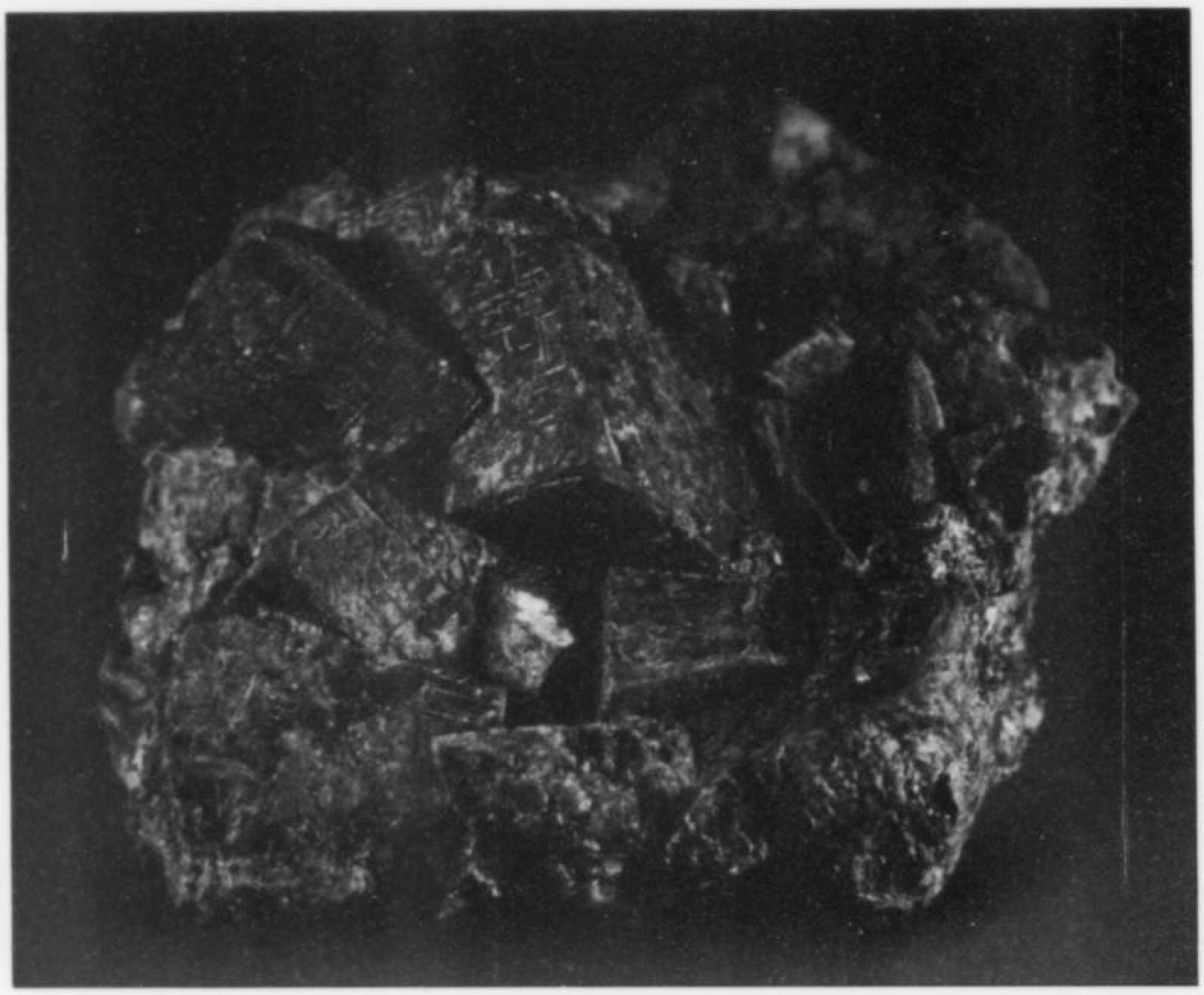


Figure 24. **Siderite crystals, partially replaced by goethite, 5.8 cm, from Klein Spitzkoppe. Author's collection and photo.**

Siderite $Fe^{2+}CO_3$

Siderite is the only carbonate mineral found at Klein Spitzkoppe. The rhombohedral, chocolate-brown crystals are partially to completely replaced pseudomorphically by goethite. These crystals are generally less than 1 cm and occur scattered about on microcline and attached to quartz crystals. Siderite is also found as aggregates composed of euhedral crystals 2 to 3 cm in size, but some larger crystals originated from the Stiepelmann deposit.

Topaz $Al_2SiO_4(F,OH)_2$

The more famous occurrences of topaz worldwide have been fairly well documented (e.g., Hoover, 1992; Menzies, 1995), but Klein Spitzkoppe is usually only briefly mentioned in these and other topaz-related publications. The reasons for this are probably twofold. Firstly, very little has been published on the Klein Spitzkoppe granite, and even less has been written about the pegmatites and topaz *per se*. The notable exceptions are the articles that have appeared in the German literature (Ramdohr, 1940a and 1940b; Leithner, 1984; Beyer, 1980) and a few others. Secondly, other famous topaz localities such as those in Brazil, the U.S., the Commonwealth of Independent States, Pakistan and Madagascar (Menzies, 1995) have most likely eclipsed the Namibian deposits because they are better known, thanks to their abundance at mineral shows, in museum exhibits and in private collections.

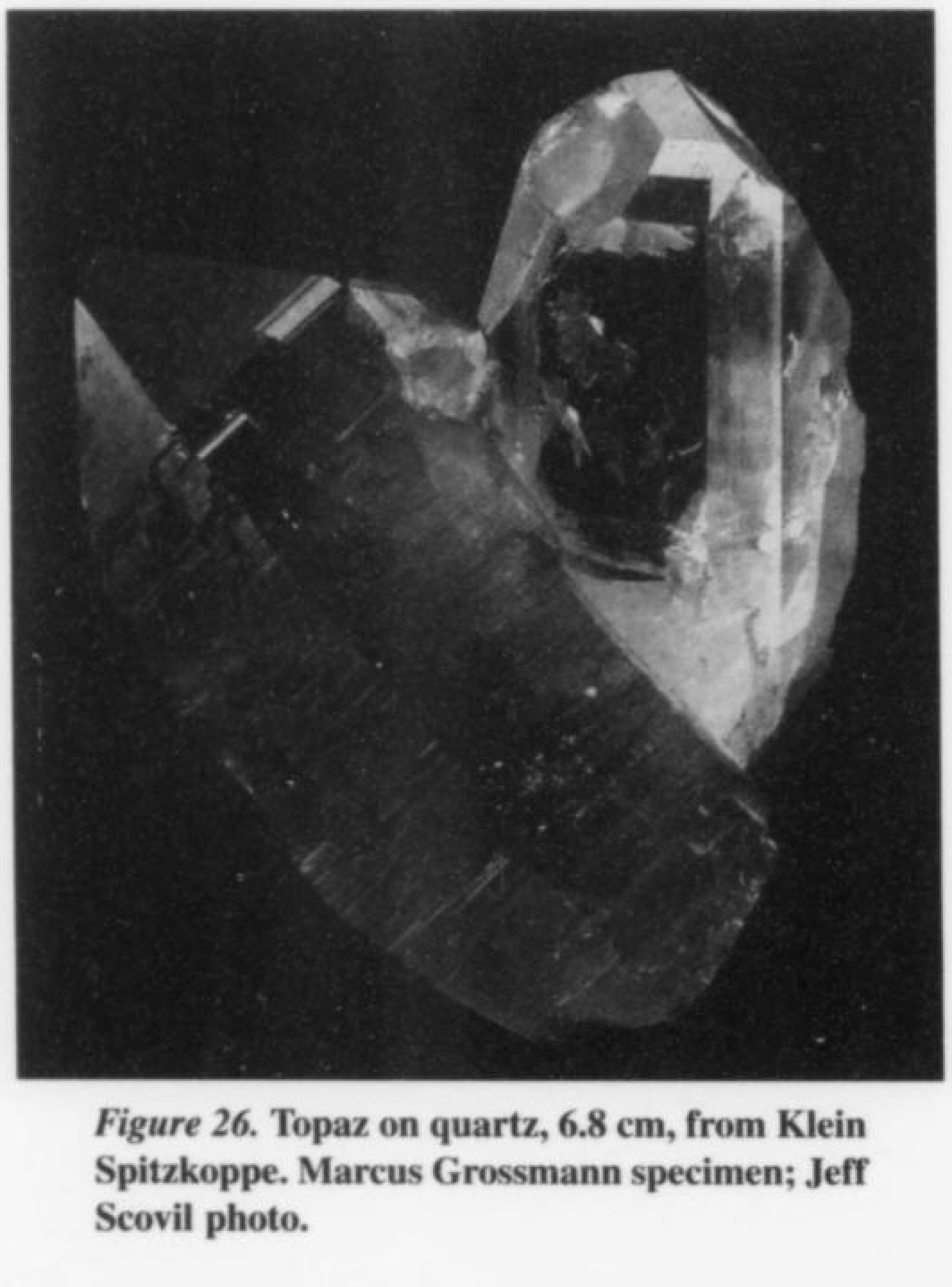


Figure 26. **Topaz on quartz, 6.8 cm, from Klein Spitzkoppe. Marcus Grossmann specimen; Jeff Scovil photo.**

Figure 25. **Smoky quartz with topaz, 3.6 cm, from Klein Spitzkoppe. Author's collection and photo.**

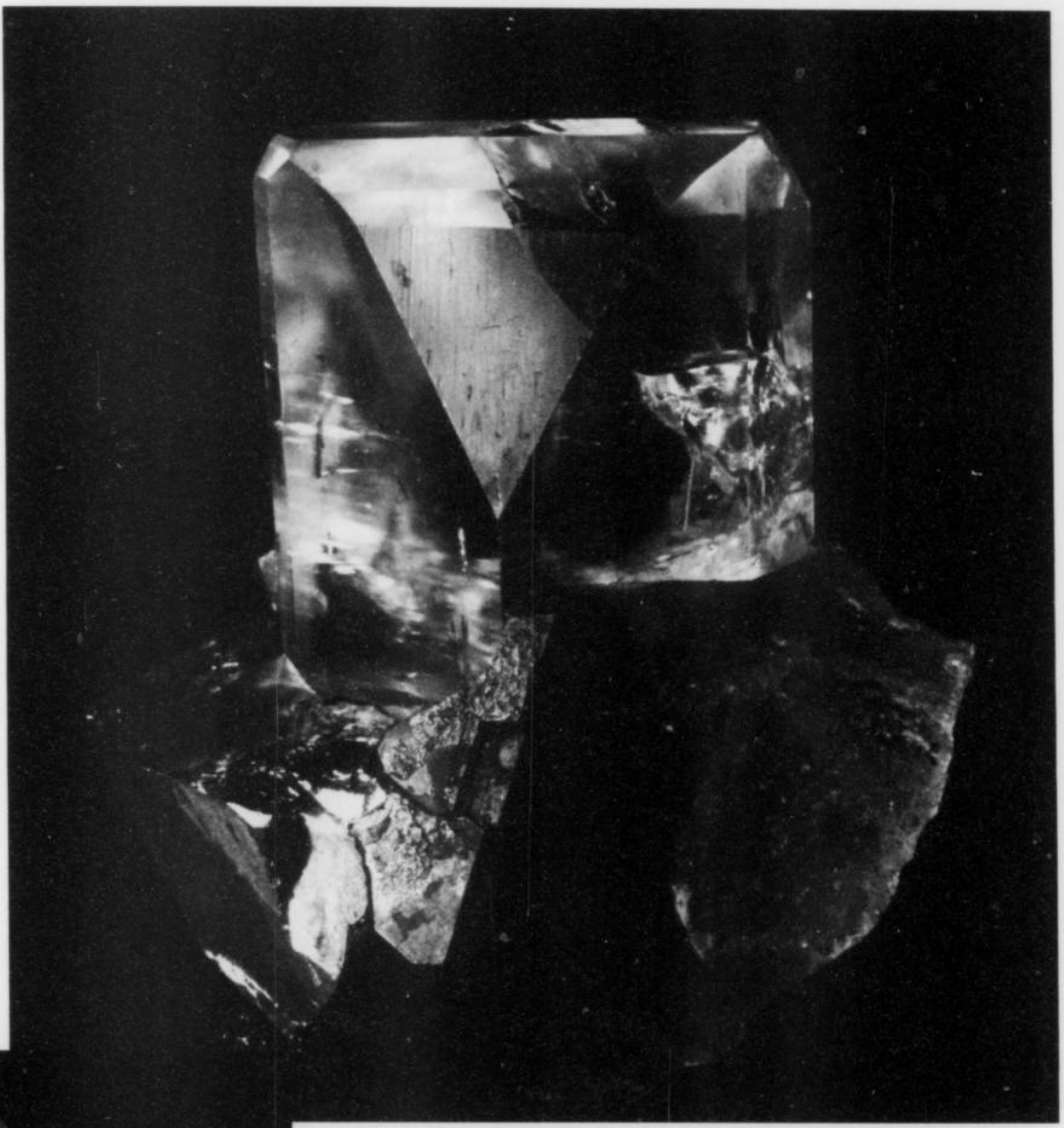
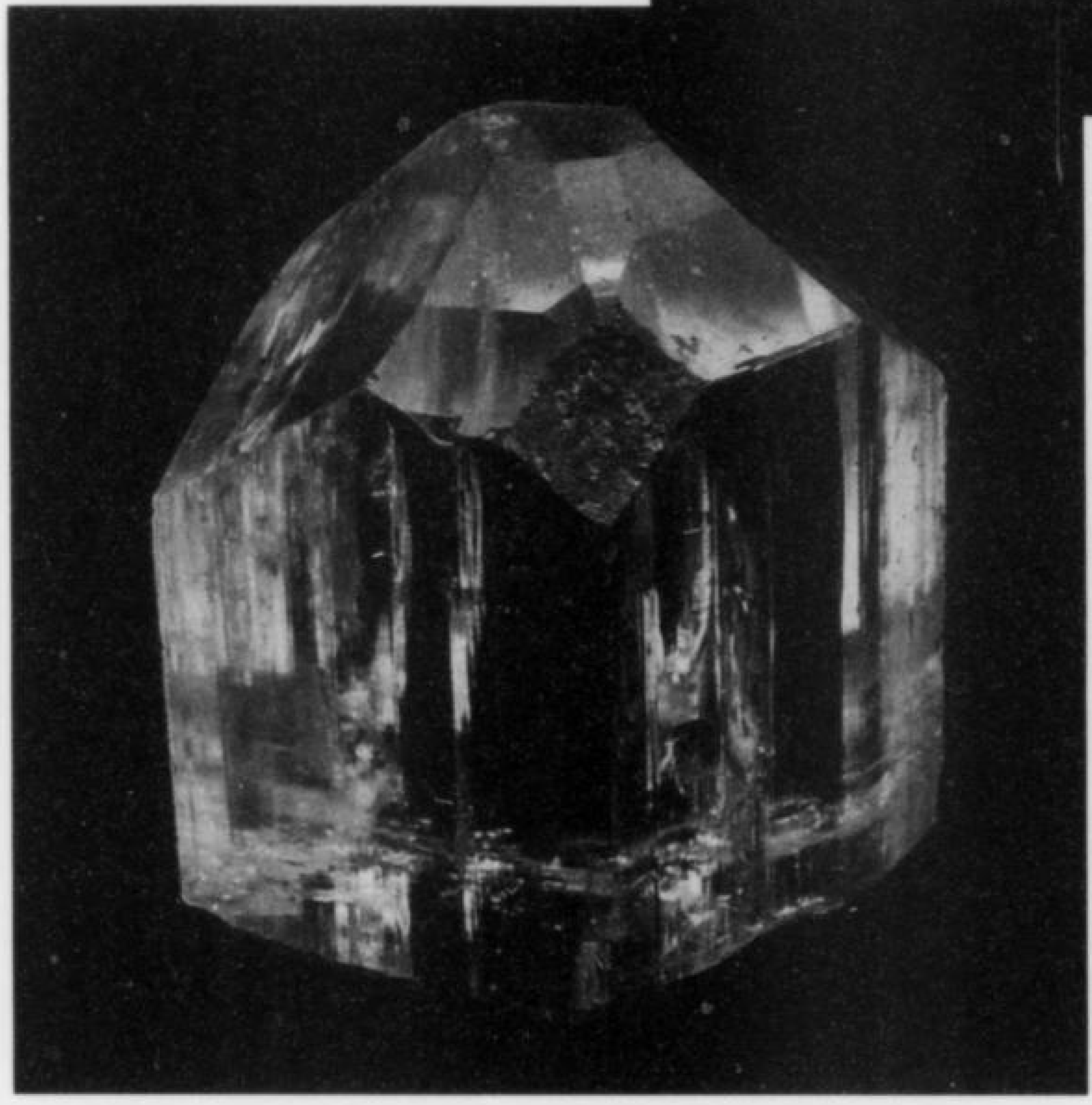


Figure 27. **Topaz, 4.5 cm, perched on a smoky quartz crystal, from Klein Spitzkoppe. Desmond Sacco collection; Bruce Cairncross photo.**

Figure 28. **Topaz crystal, 3.9 cm, from Klein Spitzkoppe. Canadian Museum of Nature collection; Jeff Scovil photo.**



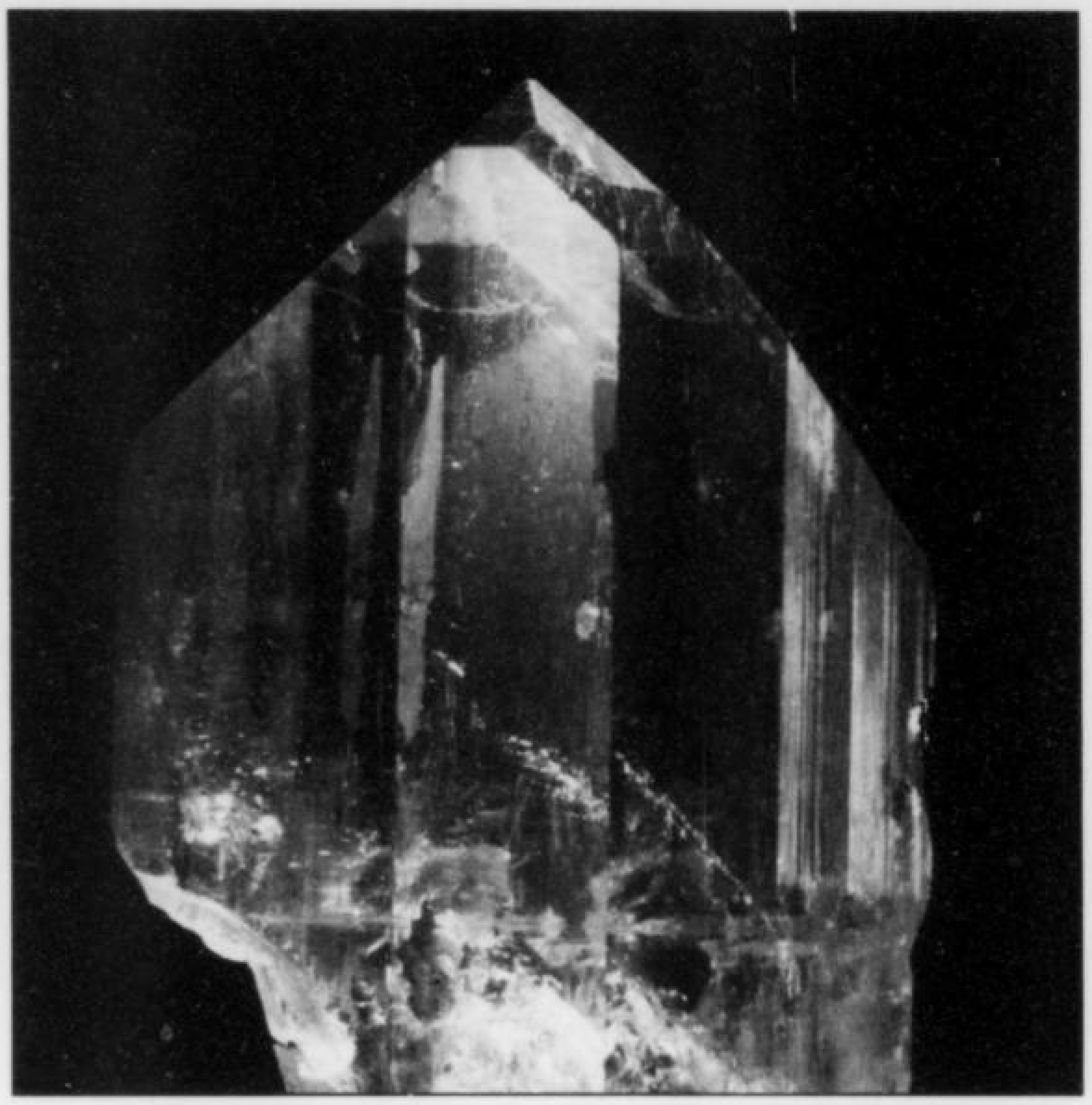


Figure 29. **Topaz—a pale yellow, 10.5-cm crystal (484.8 gms) from Klein Spitzkoppe. Colored topaz such as this one, are considerably rarer than the colorless varieties. Desmond Sacco collection; Bruce Cairncross photo.**

Another mitigating factor in the popularity of Klein Spitzkoppe topaz popularity may be that it is rarely found as matrix specimens, but rather as loose, single crystals.

Topaz can be found in several localities in Namibia (Schneider and Seeger, 1992a), but, as mentioned, the first recorded discovery was from Klein Spitzkoppe during the 1880's (Hintze, 1889). All of the topaz thus far recovered has been found in miarolitic, syngenetic pegmatites in the Mesozoic alkali granite (Menzies, 1995). Topaz is probably the best-known gem species from Klein

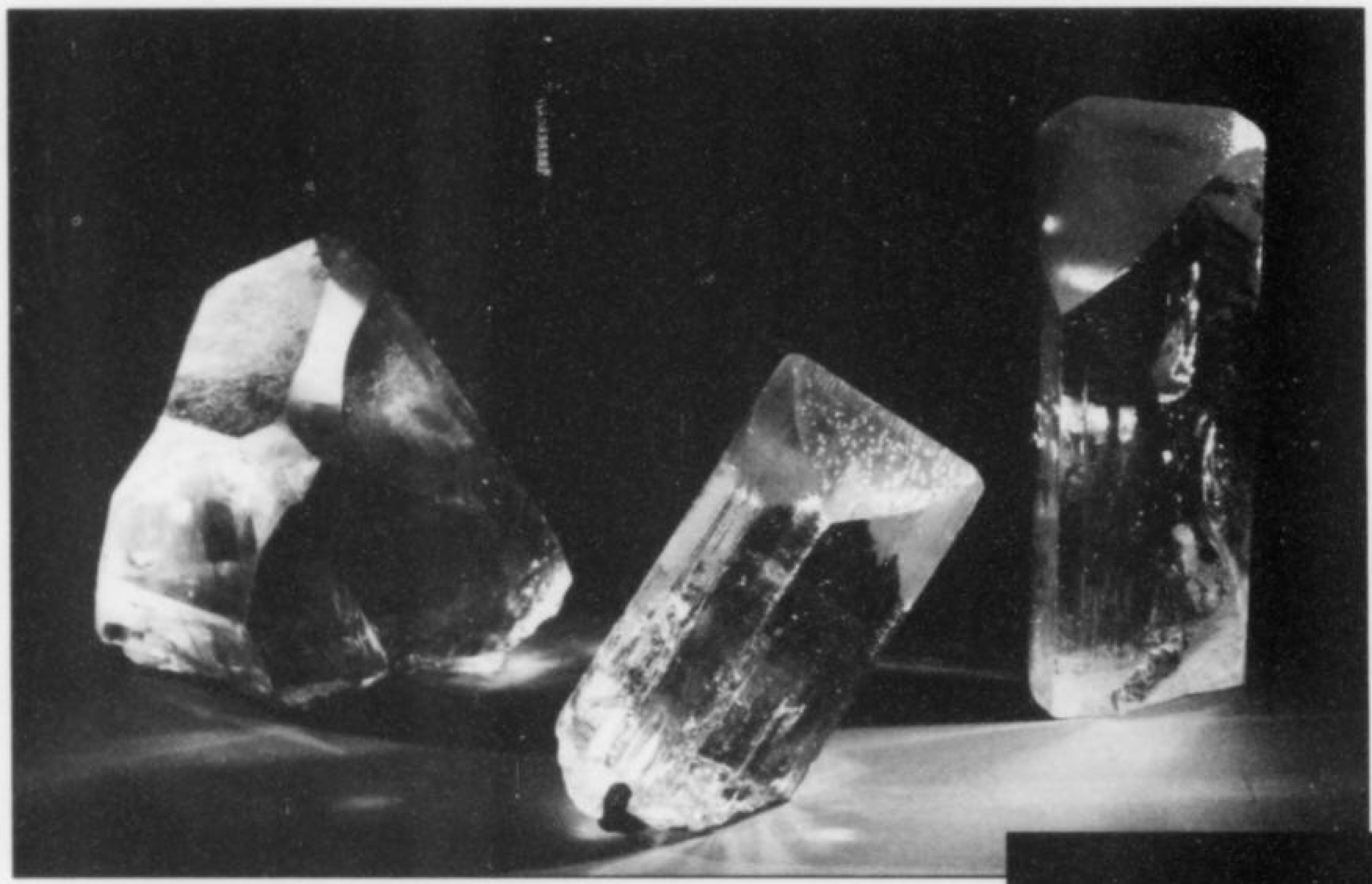


Figure 30. **Topaz—three crystals from Klein Spitzkoppe. Most of the specimens collected have been broken off of their pegmatite host rock; removing specimens intact on matrix is extremely difficult. The crystal on the right is 5 cm. Author's collection and photo.**

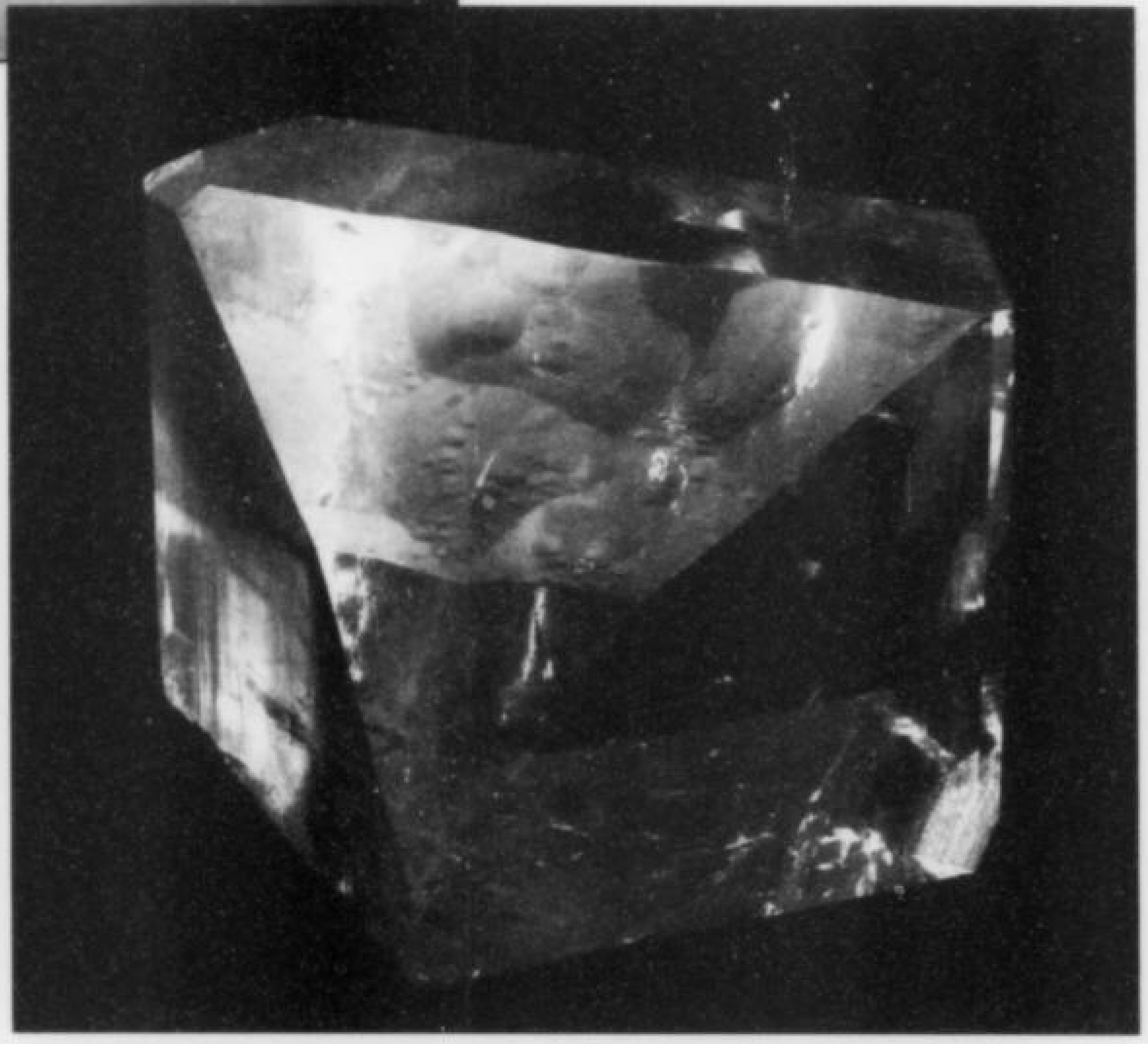


Figure 31. **Blue topaz crystal, 5 cm, from Klein Spitzkoppe. William Larson specimen; Wimon Manorotkul photo.**

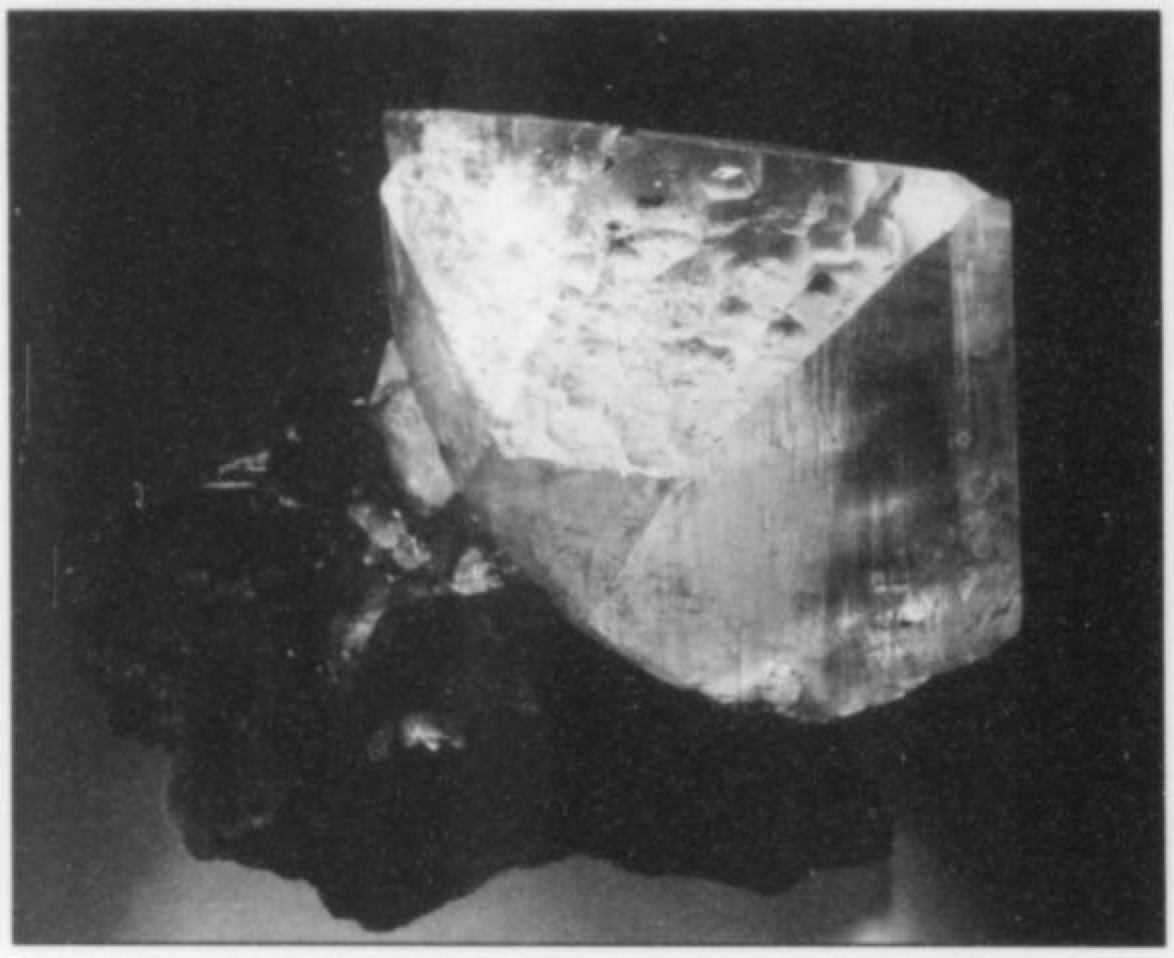


Figure 32. **Topaz on quartz, 9.4 cm, from Klein Spitzkoppe. Martin Zinn collection; Jeff Scovil photo.**

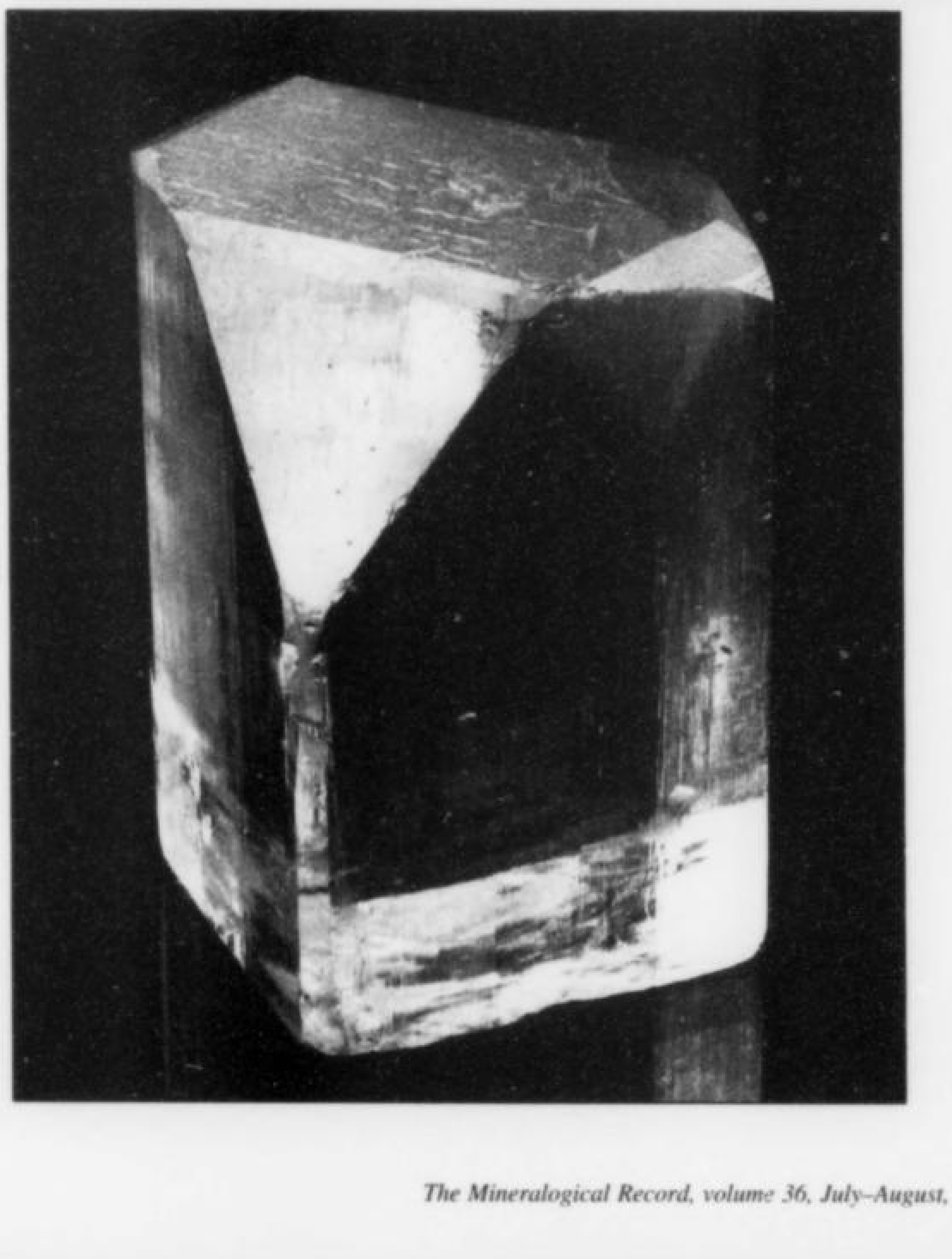
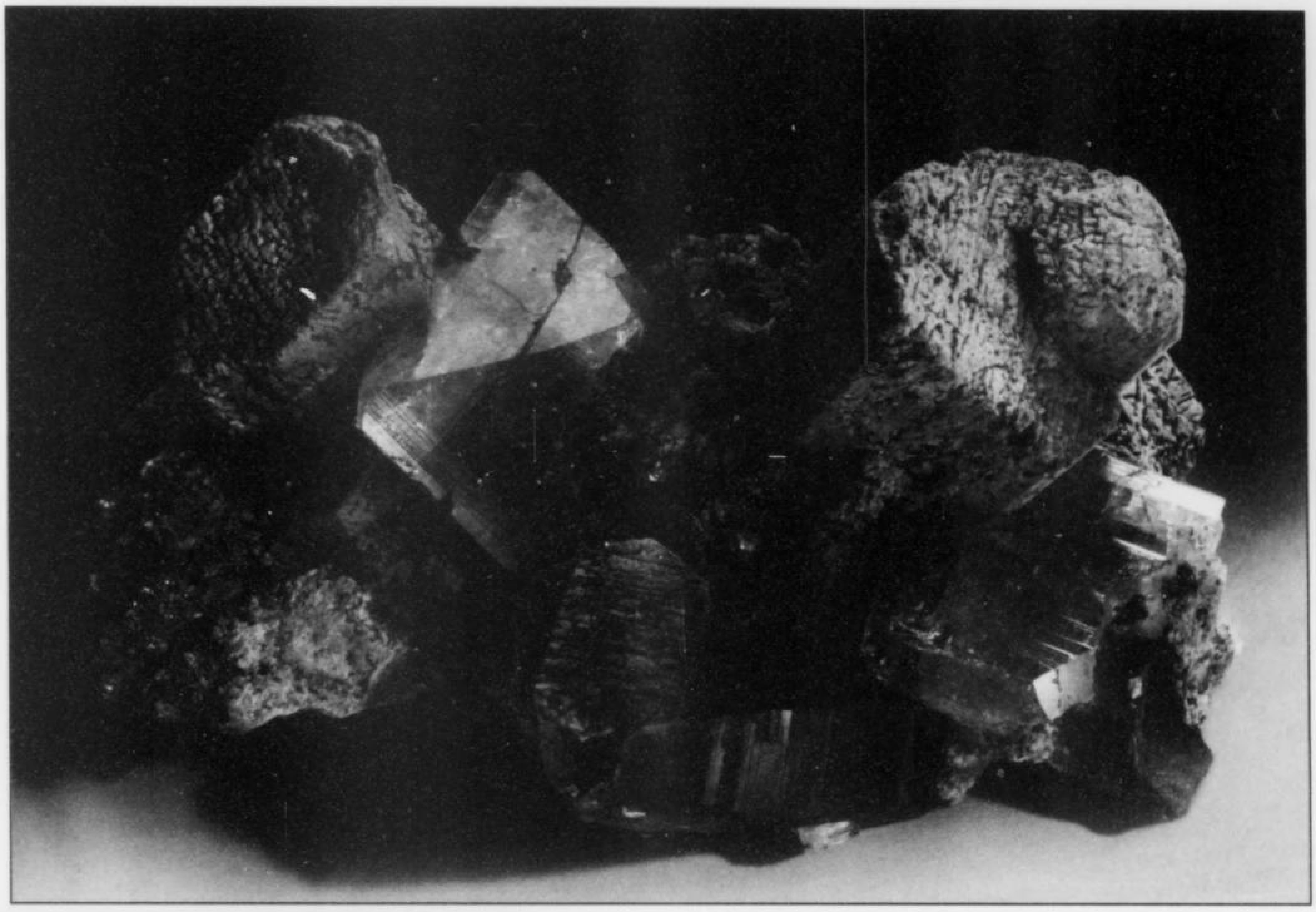


Figure 33. **Topaz crystal, 3.5 cm, from Klein Spitzkoppe. William Larson specimen; Wimon Manorotkul photo.**

Spitzkoppe, and justifiably so. Crystals over 10 cm in length are well-known and Ramdohr (1940a) reports one specimen measuring 8 × 12 × 15 cm and weighing over 2 kg. Loose, colorless crystals of 1–2 cm in length are abundant, and bags full of this material have been collected in the past (Bürg, 1942; Anonymous, 1946). Much of the topaz occurs in alluvium and in ephemeral fluvial deposits close to Klein Spitzkoppe. The crystals are invariably colorless, the so-called "silver topaz," although other color variations do occur, notably pale blue and pale yellow. Most of the color variations, whether natural or artificially induced, are produced by color centers activated by irradiation (Hoover, 1992). This includes the various shades of yellow, brown and blue. Blue colors are usually produced by electron or neutron bombardment (D. Burt, personal communication, 1997). Less valuable yellow or brown shades can be removed by heating. Exposure to sunlight will destroy much of the yellow and brown coloration, which may explain why most of the Klein Spitzkoppe topaz collected from



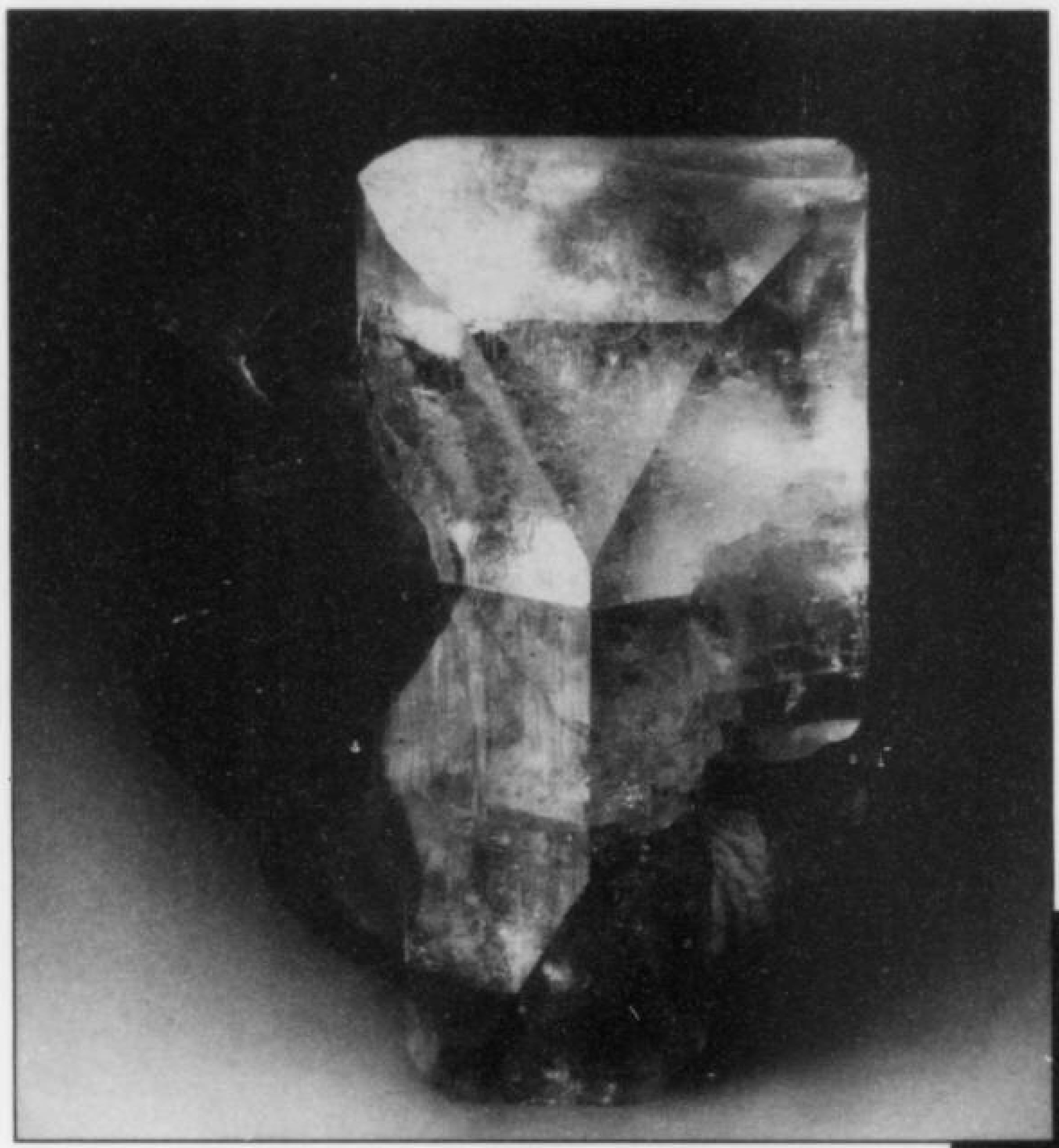


***Figure 34.* Topaz and other minerals on a large, 20.5-cm, matrix specimen from Klein Spitzkoppe. Pale-brown, Baveno twinned orthoclase crystals are associated with two large topaz crystals and several smaller ones, and a smoky quartz crystal in the center foreground. Small, pale green fluorite crystals are attached on the rear of the specimen. Rob Smith collection; Bruce Cairncross photo.**

exposed, weathered surfaces is colorless. An exception to the irradiation effect is the red-pink variety of topaz which owes its unique color to the presence of Cr^{3+} (Hoover, 1992).

Transparent crystals have been faceted into fine gems (Cairncross *et al.*, 1998). Not all crystals are gem-quality, inasmuch as internal fractures and macroscopic inclusions are very common. Several topaz habits are known, and five commonly occurring variants have been described by Beyer (1980):

***Figure 35.* Doubly terminated topaz crystal on smoky quartz, 6.5 cm, from Klein Spitzkoppe. William Larson specimen; Wimon Manorotkul photo.**

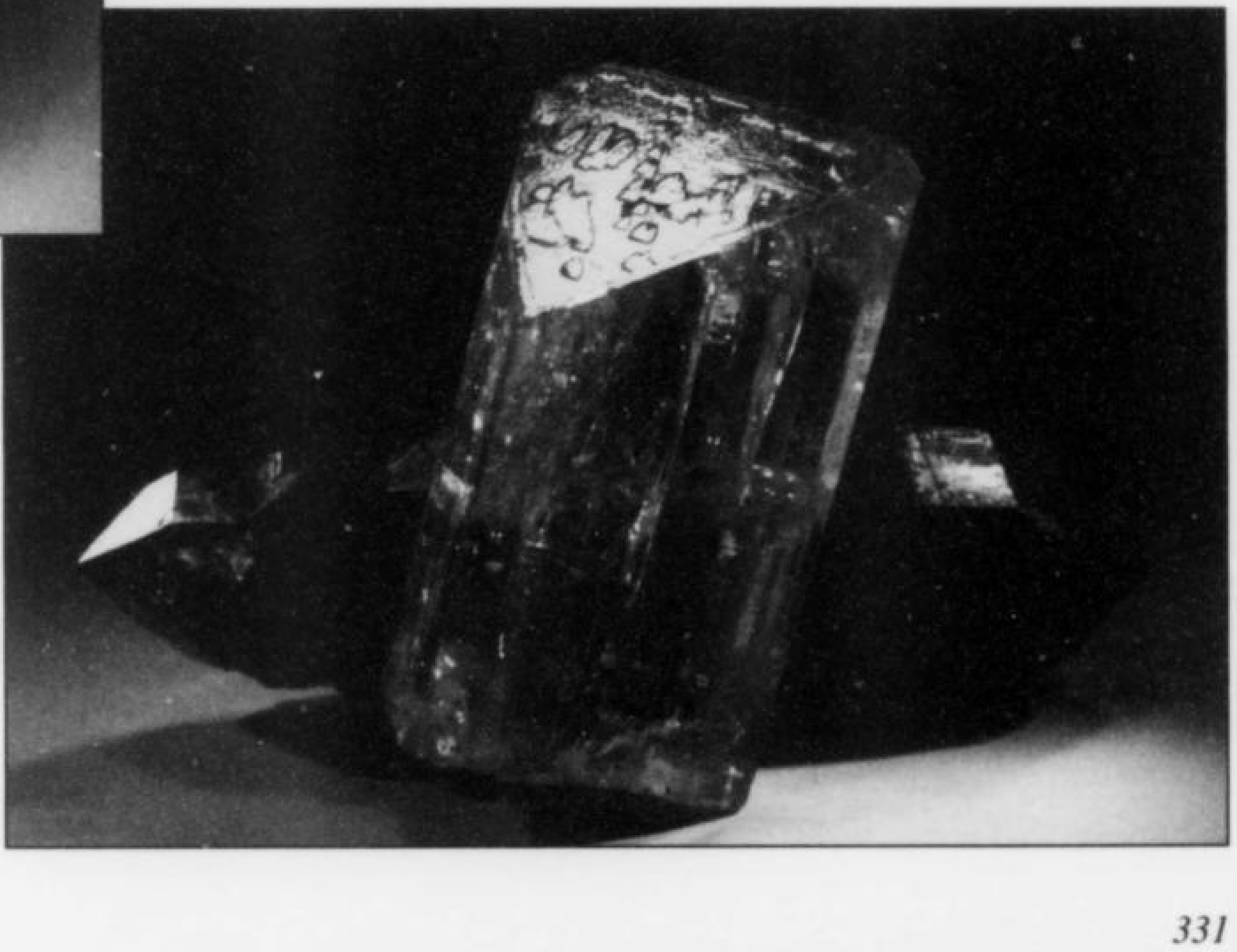


***Figure 36.* Topaz—a 5.2-cm crystal attached to a doubly terminated smoky quartz crystal from Klein Spitzkoppe. Desmond Sacco collection; Bruce Cairncross photo.**

Figure 37. **Topaz, an 8 × 8-cm crystal attached to a 13.5-cm dark smoky quartz crystal from Klein Spitzkoppe. Desmond Sacco collection; Bruce Cairncross photo.**

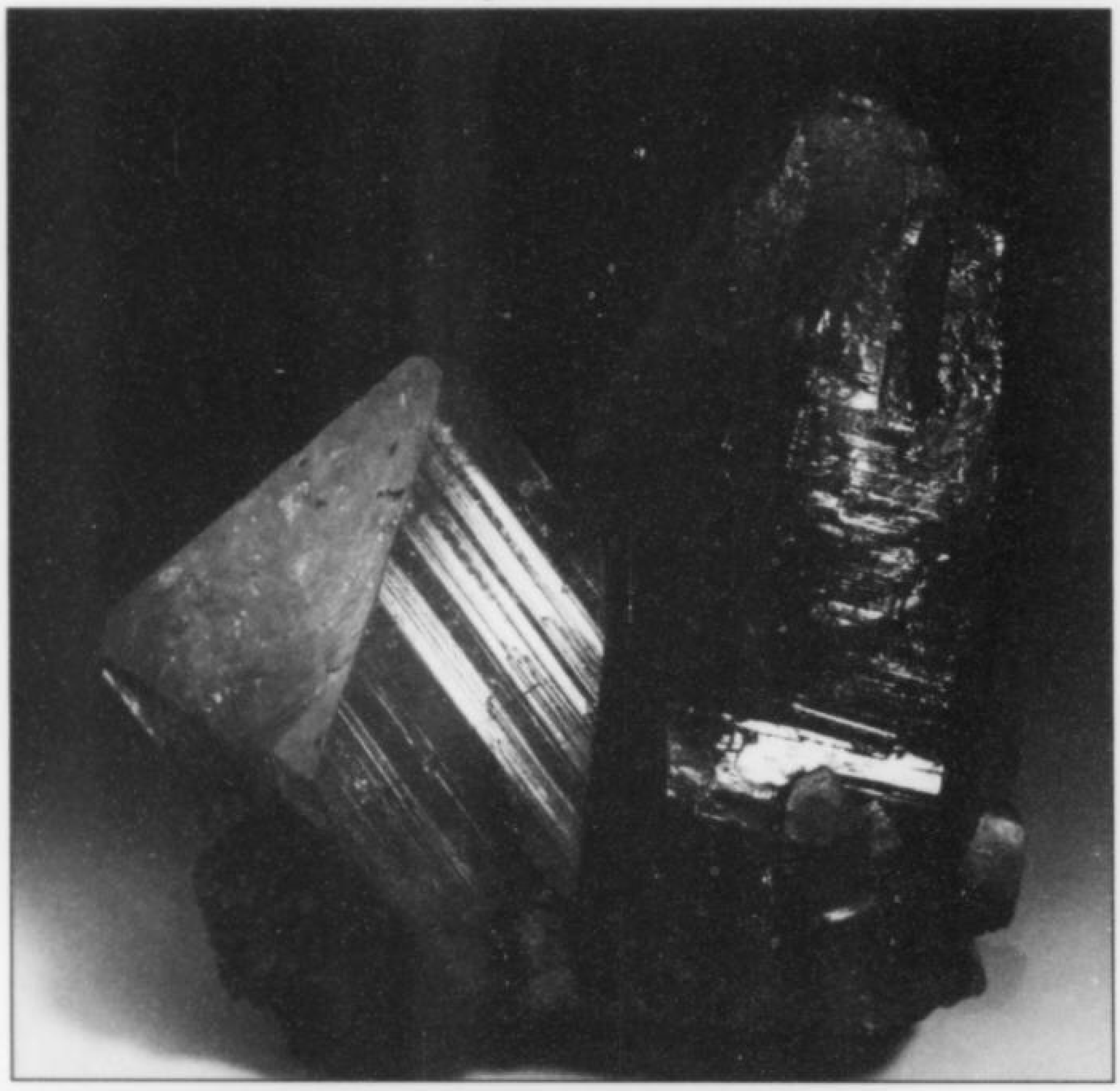


Figure 38. **Topaz—a rare pale-blue, 2.8-cm multiply terminated crystal from Klein Spitzkoppe. Author's collection and photo.**

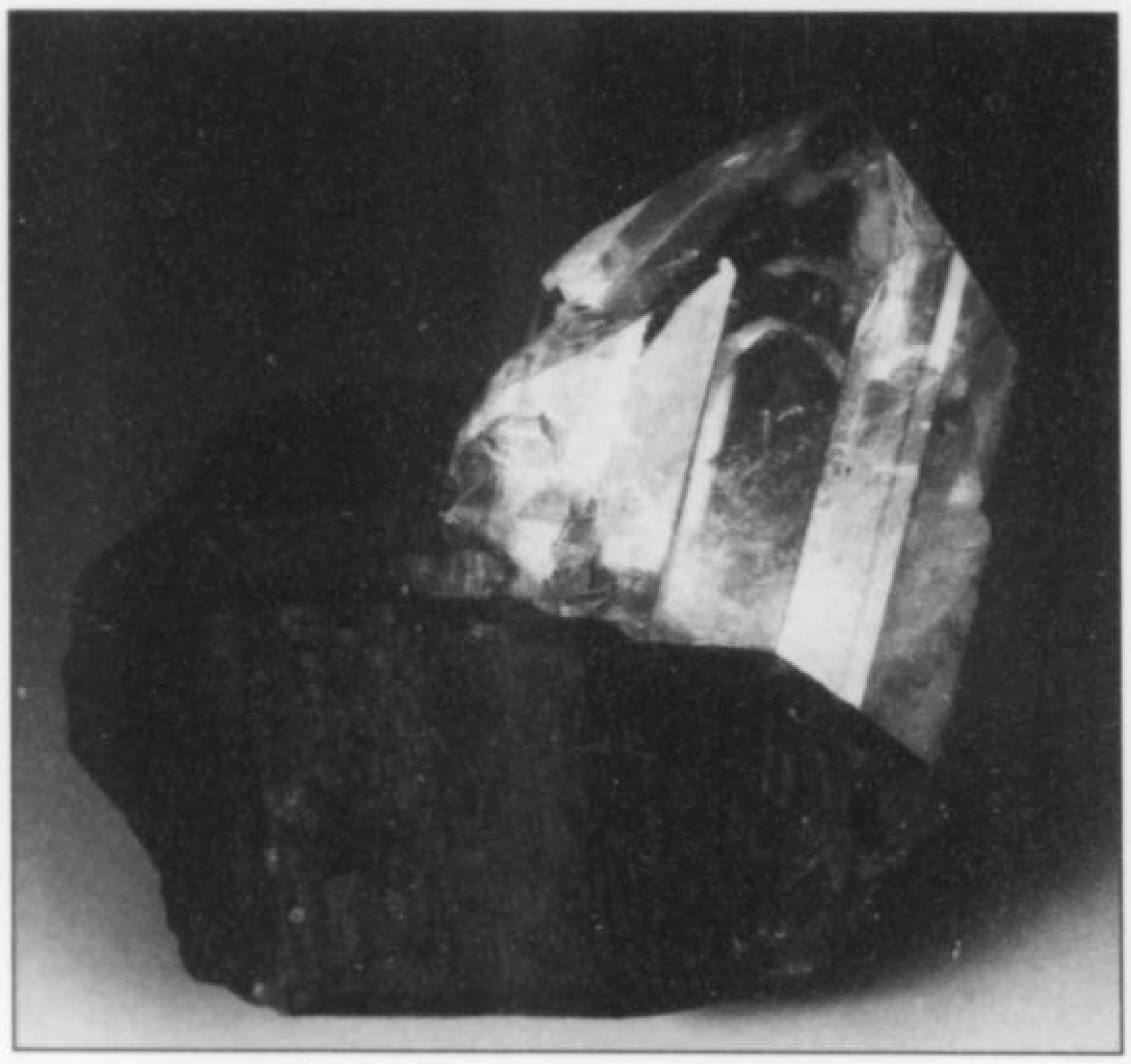


Figure 39. **Topaz on smoky quartz, 4.5 cm, from Klein Spitzkoppe. William Larson collection; Wimon Manorotkul photo.**

Figure 40. **Transparent topaz, 3.8 cm, on granite matrix from Klein Spitzkoppe. Desmond Sacco collection; Bruce Cairncross photo.**

Type I topaz consists of simple forms and is usually colorless.

Type II topaz includes complex prismatic habits and is usually colorless.

Type III topaz consists of complex, prismatic, stubby yellow crystals.

Type IV topaz displays simple prismatic forms, is usually yellow in color, and is associated with unaltered microcline.

Type V topaz is characterized by long, thin prismatic crystals having a yellow color.

Types I and III are always transparent, with highly lustrous crystal faces. These occur in vugs in and on microcline, occasionally associated with black schorl. Type V is the last habit to crystallize and is always associated with needle-like crystals of aquamarine and highly corroded microcline feldspar. The types I and II are associated with large quartz crystals, biotite, pale green fluorite, tourmaline and rutile. Outstanding specimens of gem-quality, euhedral topaz crystals perched on or partially overgrown by highly lustrous smoky quartz are among the most sought after

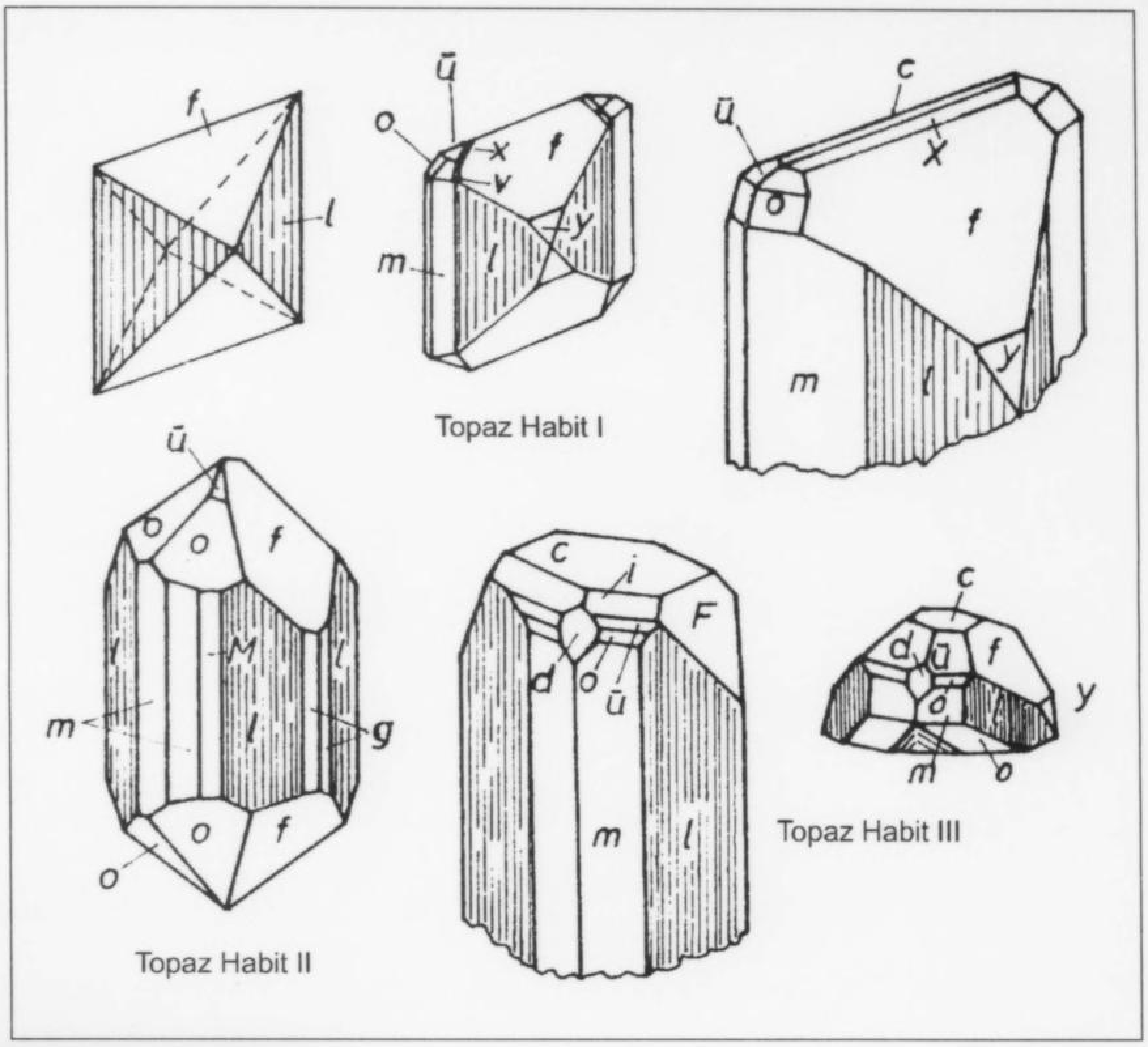


Figure 41. **Topaz from Klein Spitzkoppe, crystal drawings (Beyer, 1980).**

Figure 42. **Topaz—a large, 12.1-cm (761 gm), heavily striated and etched crystal from Klein Spitzkoppe. Author's collection and photo.**

collector pieces from this locality (Cairncross, 2000). Other desirable matrix specimens consist of topaz on white or pale yellow microcline. In some rare instances, topaz and sea-green fluorite are found together, but this association is rare.

It is interesting to note that the crystal morphology of the topaz is easily recognized and very well copied by the local diggers who like to fashion topaz look-alikes from fluorite.

Detailed crystallographic descriptions of the forms and habits of Klein Spitzkoppe topaz have already been systematically undertaken and previously published (Hintze, 1889; Ramdohr, 1940a; Beyer, 1980).

OTHER MINERALS

Other, less common mineral species that have been reported from the Klein Spitzkoppe occurrences include bixbyite, chabazite, columbite, euxenite-(Y), gibbsite, nacrite, opal (hyalite), pyrophyllite, talc, ferberite and zircon. As far as could be determined, these have generally not been found in collector-quality specimens.

Some copper-bearing minerals have been found at a cassiterite prospect located on the northwestern flank of Klein Spitzkoppe (Frommurze *et al.*, 1942). An excavation was made into a green-colored gossan prior to 1940. Cassiterite crystals associated with vuggy quartz have been found in this oxidized zone. Lining the walls of cavities were microcrystals of scorodite, chenevixite, shattuckite, chrysocolla and malachite. The scorodite occured as ". . . well crystallized tiny crystals sometimes projecting into cavities," while the chenevixite ". . . occurs in veinlets and cavities . . . with a colloform structure" (Frommurze *et al.*, 1940). The supergene sulfides include microscopic aresenopyrite, covellite and chalcocite.

CURRENT STATUS

Topaz, and to a lesser degree aquamarine, continue to trickle out from the Klein Spitzkoppe pegmatites. The crystals are either collected from weathered granite pegmatites or alluvium, or they are removed from the miarolitic cavities by the local native artisans.

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Dertien dood op paaie

'n Swart Paasfees

2 Paaie

Gru-moord by Spitzkoppe

Daniël

Figure 43. **Front page of the local *Republican* Newspaper, April 16, 1999. The top headline reads "a black Easter," referring to Namibian road deaths over the Easter weekend. The lower headline reads "Gruesome murder at Spitzkoppe," referring to the murder of a German tourist at the Gross Spitzkoppe.**

No large-scale mining of topaz or aquamarine is envisaged in the foreseeable future. But, because the veins are dispersed over a fairly wide area rather than being concentrated in a small zone which could easily be mined out, the supply of gem rough, as well as specimen-grade crystals, will most likely continue for some time.

Visitors to the Gross and Klein Spitzkoppe areas should exercise reasonable caution and should not explore remote parts of the mountains alone. Several years ago, in April 1999, a German tourist was murdered at Gross Spitzkoppe. This was the first incident of its kind in the area, and is probably unlikely to recur, but visitors should be aware of it nonetheless.

The land that contains the Klein Spitzkoppe pegmatites is State-owned, and it is necessary to obtain the relevant prospecting licenses in order to legally explore and dig for specimens. Namibian law also requires a permit for the export of gemstones and minerals from the country.

ACKNOWLEDGMENTS

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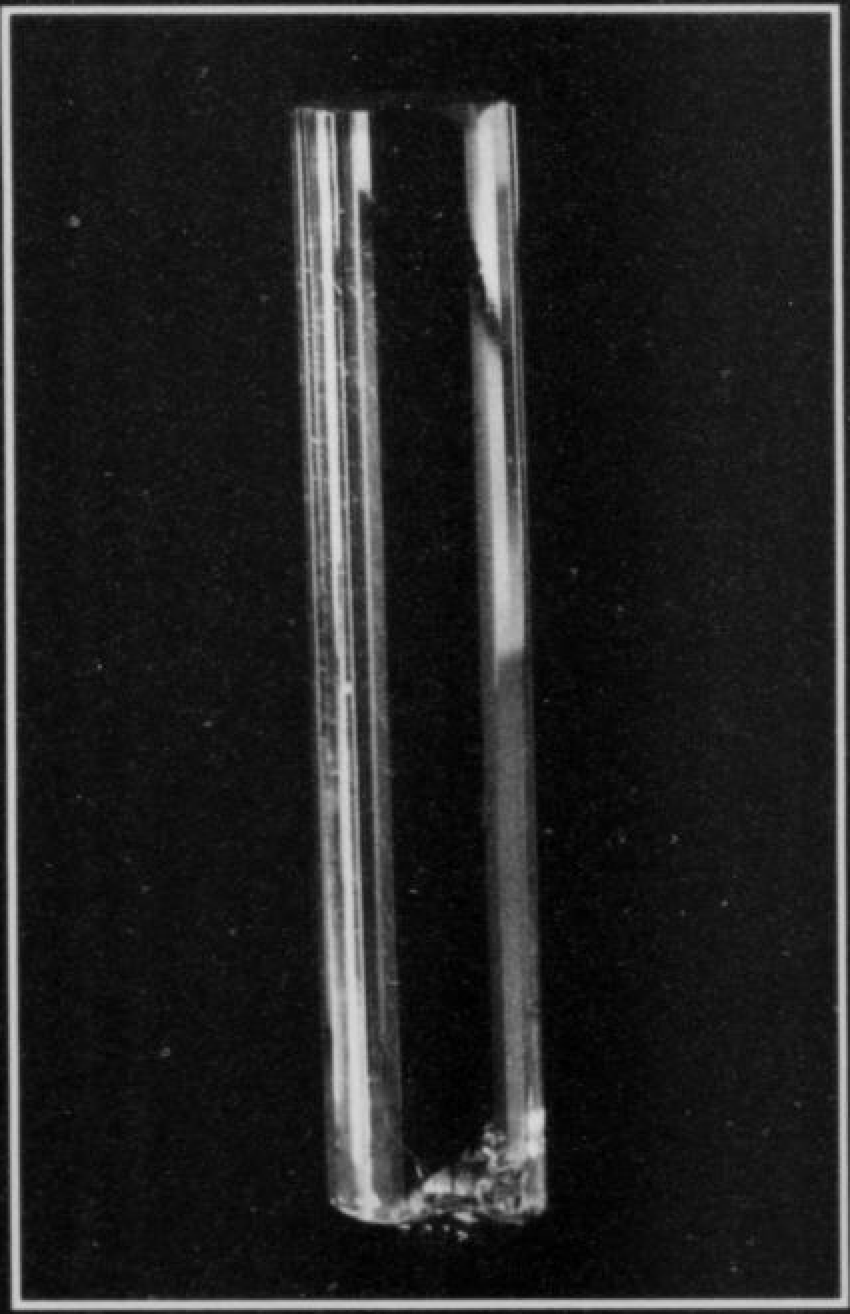

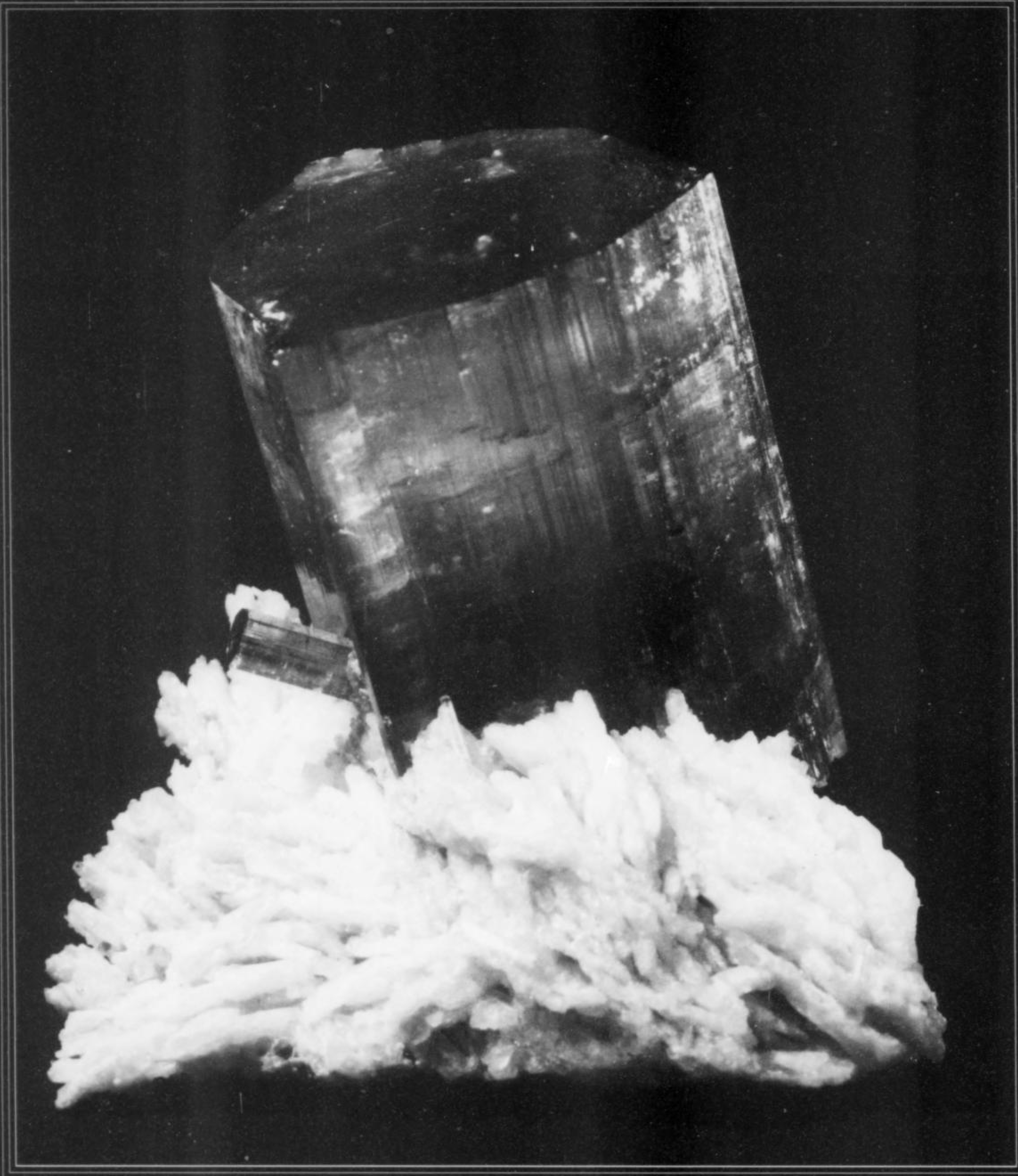

THE CLEAR CREEK MINE

SAN BENITO COUNTY, CALIFORNIA: A UNIQUE MERCURY LOCALITY

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From the first discovery in 1959 until the present, the abandoned Clear Creek mine has yielded an exceptional suite of rare and unusual mercury-bearing minerals unequaled in the world. Among those recently described as new are aurivilliusite, clearcreekite, deanesmithite, edgarbaileyite, edoylerite, hanawaltite, peterbaylissite, wattersite, szymańskiite, tedhadleyite and vasilyevite. In addition, seven new mercury-bearing species are currently under study. Other mercury-bearing minerals identified from the mineralized veins include montroydite, schuetteite, calomel, gianellaite, mosesite, terlinguaite, eglestonite, metacinnabar, cinnabar, native mercury and the second world occurrence of donharrisite.

INTRODUCTION

The Clear Creek mercury mine has produced some of the rarest and most exotic mercury-bearing minerals known. Once worked for its native mercury and cinnabar, this small, elongated mineralized zone has produced, to date, 29 mercury-bearing minerals, the majority of which are new to the mineral science. This wealth of rare mercury-bearing minerals prompted our study of this old, long-abandoned mine to better understand its complex mineralogy, geochemistry and paragenesis.

LOCATION

One of several mines in the old Flint Group, the Clear Creek mine is located in the Clear Creek drainage area of the New Idria mining district, San Benito County, California. This district is one of the oldest and best known mining districts in California, a state famous for its mercury deposits. The exact location of the Clear Creek mine is 120°44′12″ W. and 36°23′3″ N., or E$^1/_2$ of the SW$^1/_4$ of section 2, T. 18S., R. 11E., Mount Diablo Meridian, on the Idria 7$^1/_2$-minute Quadrangle map produced by the U.S. Geological Survey. The mine workings are located in the barren hills above the north bank of Clear Creek, at an elevation of approximately 1235 meters.

Three distinct workings comprise the Clear Creek mine. The northernmost workings, which now consist of an elongated pit, is the Clear Creek mine proper and is referred to here as the "upper

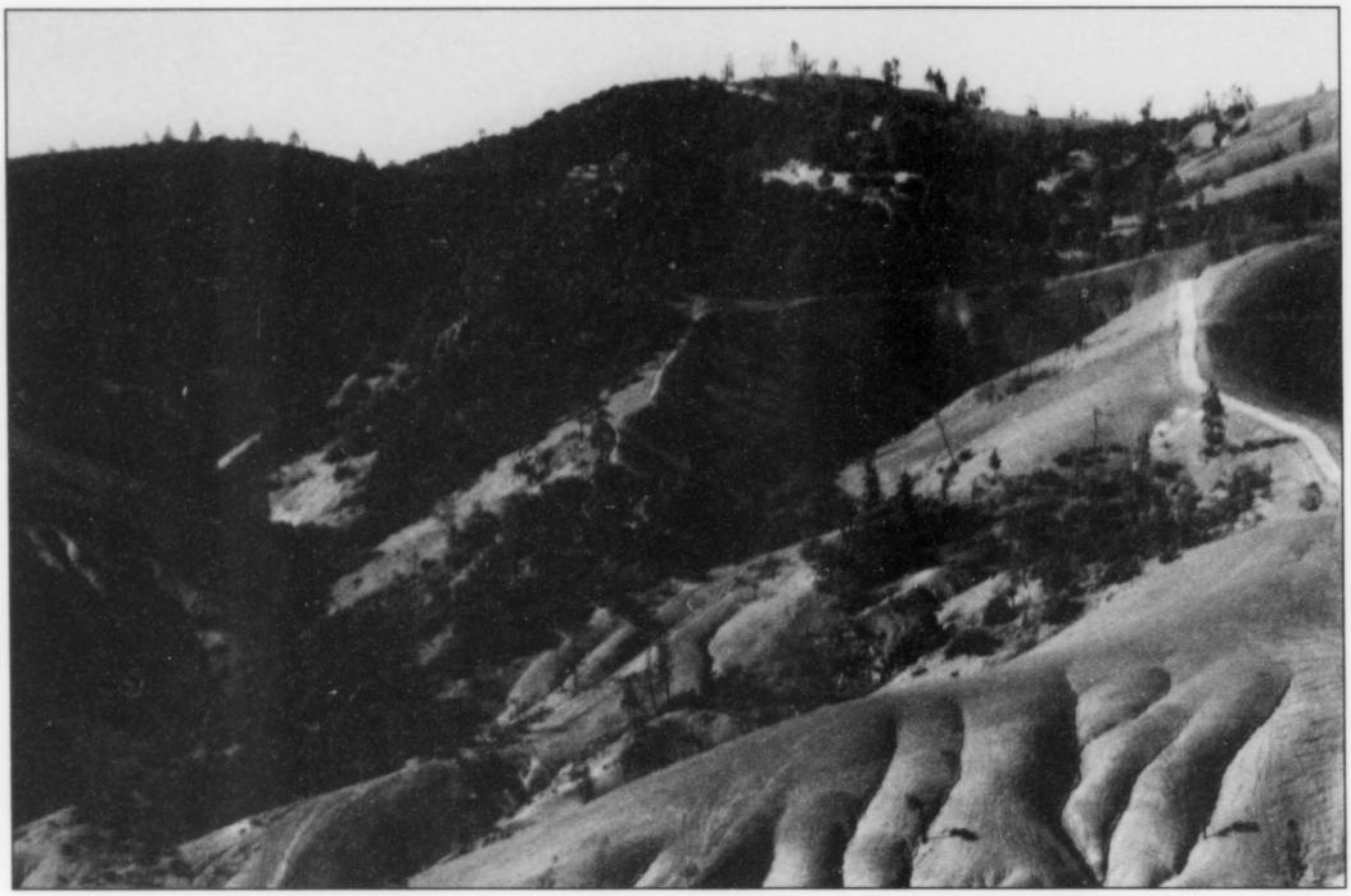


Figure 1. **View from across the Clear Creek drainage, near the Alpine mine, looking north toward the Clear Creek mine. The main mine is the white scar at the top center. The lower workings are at the very center. May, 1996. Ted Hadley photo.**

workings." About 300 meters south of this upper mineralized zone are the "middle workings," a small group of cliff faces and pits. Further below this locality are the southernmost or "lower workings," often referred to as the Clear Creek claim (120°43′58″ W. and 36°22′59″ N., or in the NW$^1/_4$ NE$^1/_4$ sec. 11, T. 18S., R. 11E.), approximately 100 meters south of, and 100 meters lower in elevation than, the upper workings. It is at these southernmost workings that the majority of the recently described rare mercury minerals occur. For this paper, the name "Clear Creek mine" is used to describe all three mineralized areas collectively.

HISTORY

Mining History

Historical accounts of the mines in the Clear Creek drainage area of the New Idria mining district are given by Bradley (1918), Eckel and Myers (1946) and Linn (1968). In a district as old as New Idria, it is not surprising that many mines and prospects have changed names several times and their production records have been lost or were never recorded.

The New Idria mercury deposit, destined to become second only to the New Almaden deposit amongst North American mercury producers, was discovered about 1853 by two Mexican prospectors who had first explored a small body of chromite in the mistaken belief that it was silver ore. They also mistook the cinnabar in the New Idria outcrops for a silver mineral. Its true identity was soon learned and the first mercury was produced in 1854, though not by the original discoverers. Beginning with the recognition of cinnabar at New Idria in 1853, nearly a score of smaller mercury-bearing deposits were discovered in the Clear Creek area to the southwest.

These smaller deposits were worked by Mexican miners using hand tools and small-charge explosives. Where practical, the ore was processed at each mine in crude retorts fired by local timber. The expelled mercury vapors were then condensed by air or water cooling, depending on the availability of water. The influence of the early Mexican miners in the district is revealed by the names of these mines, which include the Anita, Chiquita, Del Mexico, Don Juan, Don Miguel, Esmeralda, Hernandez, Picacho, Mexican, Monterey, Ramirez, Rita, Santa Margarita, San Benito and Spanish. Most of these mines were later renamed or merged with other mines, and are currently idle and (in most cases) abandoned. At present no mercury mining is being conducted in the district.

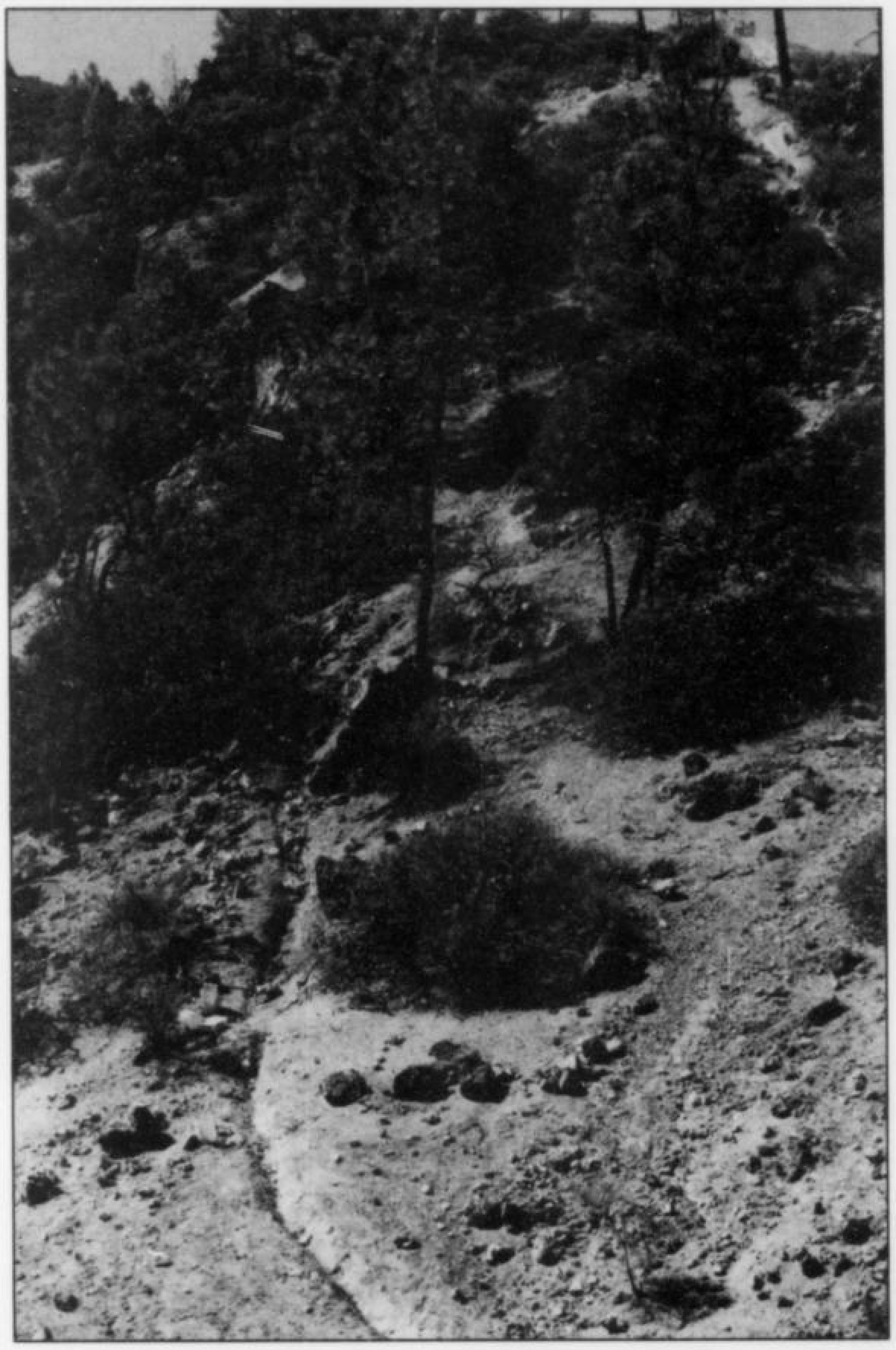
The mercury-bearing zones in the Clear Creek area south of New Idria are situated along a northwest-southeast trend of randomly exposed silica-carbonate rock, and include the Clear Creek, Red Rock, Alpine, Fourth of July, Andy Johnson and Picacho mines. Most of these bodies are very shallow and nearly all the ore produced was taken from open cuts or boulders on the surface. Eckel and Myers (1946) state that the shallowness of the orebodies, and the failure of several extensive exploratory adits to encounter anything but unaltered serpentinite, are due to the fact that the shear zone dips to the southwest at low angles. Many of the tabular outcrops thus represent discontinuous remnants perched on hill slopes. The Clear Creek mine is situated within the northwestern part of this prominent zone of ocherous, silicified rock which strikes approximately north 30° west.

Records for the Flint Group show the discovery as pre-1880 (Bradley, 1918), with the last year of recorded production as 1942. Following this date, no records of production have been published. Operation of these mines has been highly sporadic, and production was minor over the history of the district. Linn (1968) estimates that the total combined production of all these Flint Group mines is less than 10,000 flasks of mercury (one flask contains 34.5 Kg of mercury).

In 1955, the Clear Creek mine was renamed the Morning Star mine by a Mr. Nepper, a tool sharpener employed at the New Idria mine. During the following ten years or so, he removed the overburden above the two adits by bulldozing along the mineral-

***Figure 2.* View of the open pit, upper workings, Clear Creek mine looking south. Ted Hadley photo.**

***Figure 3.* View of the lower workings area (central tree and large rock) where many of the rare mercury minerals were discovered. May, 1994. Ted Hadley photo.**



ized zone. With the aid of several employees, he selectively sorted the ore and transported it to New Idria for processing. It is reported that the ore he removed resulted in the recovery of about 100 flasks of mercury. During this same period of time, Nepper also worked the Alpine mine, which can be seen across Clear Creek canyon at about the same elevation as the Clear Creek mine.

The Clear Creek mine was described by Bradley (1918) as being operated through two tunnels with about 200 meters of total workings. Today, the upper workings consist of an elongate open pit 20 meters wide, 10 meters deep and about 100 meters long. Examination of the remaining mine tailings indicate that the original workings consisted of two obliquely intersecting tunnels at different elevations. The intersection point of the tunnels was apparently at the center of the orebody. Few remnants of the original retort remain. There is no evidence of ore processing at the middle workings and all that remains of the retort at the lower workings is a small burnt-ore pile and a few bricks.

Numerous other small, unnamed, surface workings and scattered piles of retorted ore are visible along the ore trend from the Clear Creek mine down slope to Clear Creek proper. Most of these early workings were of the "pick and shovel" type and produced little ore.

Collecting History

The history of mineral collecting at the Clear Creek mine and the surrounding areas extends back to at least 1959 with the

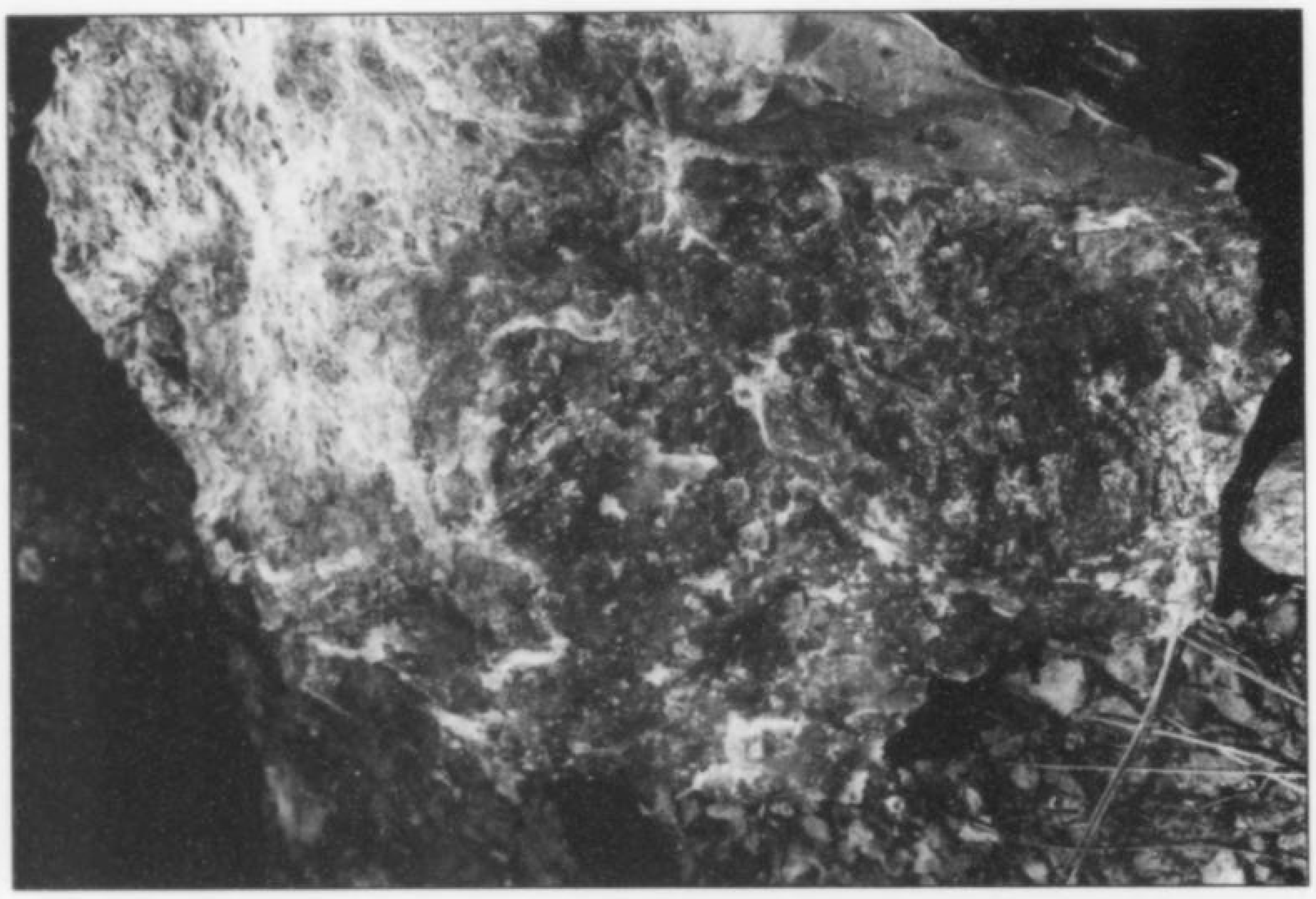


Figure 4. **Typical exposed vein showing cinnabar and other mercury minerals in silica-carbonate rock, approximately 36 cm wide. Clear Creek mine, lower workings. Ted Hadley specimen and photo.**

Figure 5. **Native mercury vein on discovery rock, Clear Creek mine, lower workings. Hands are of Mr. Carlo Rovetta. Ted Hadley photo.**

discovery by the late Mr. Edward H. Oyler of a mercury mineral that eventually was named in his honor, edoylerite. Mr. Oyler collected extensively in this area for over twenty-five years. In addition to edoylerite, other newly described minerals first collected from the Clear Creek mine by Mr. Oyler include clearcreekite, deanesmithite, edgarbaileyite, hanawaltite, peterbaylissite, szymańskiite, wattersite and a mineral similar to edoylerite that is under study.

Because these newly described mercury-bearing minerals are very scarce within the thin quartz veins, field identification is tenuous at best, due to their diverse habits, size and colors. The rarer mercury-bearing minerals are best identified by X-ray powder-diffraction methods because each species has a unique diffraction pattern, even though many share very similar megascopic properties. For example, edgarbaileyite occurs as massive lumps, spheroids, thin coatings and complex angular aggregates of minute crystals with colors ranging from bright yellow through dark green to black. This entire color variation can often be seen in a single sample. Like edgarbaileyite, montroydite can also exhibit various habits and colors ranging from thick bladed crystals to thin hair-like needles in colors ranging from pale yellow to deep reddish brown to black.

Our interest in the Clear Creek mine was initiated in 1990 by the description of edgarbaileyite, the first of the rare mercury-bearing minerals that was formally described. Early trips to the area yielded small, rich hand-samples containing a plethora of varicolored mercury mineralization. Extensive macroscopic and energy-dispersive spectrometry (EDS) examinations were used to make the initial identification of the more common mercury minerals. As additional collecting was done, we became more familiar with the diverse habits and colors displayed by these minerals. Because of this diversity, X-ray powder-diffraction utilizing Debye-Scherrer cameras was the principal method used for identification, and this further aided subsequent macroscopic identification. As our experience grew, several unidentified phases were recognized, resulting in the discovery of an additional nine new mercury-bearing phases that are currently under study or have been described.

To best observe the mercury mineralization within the large silicified field rocks, which are often quite hard, they must first be reduced by sledgehammer, followed by further reduction in vol-

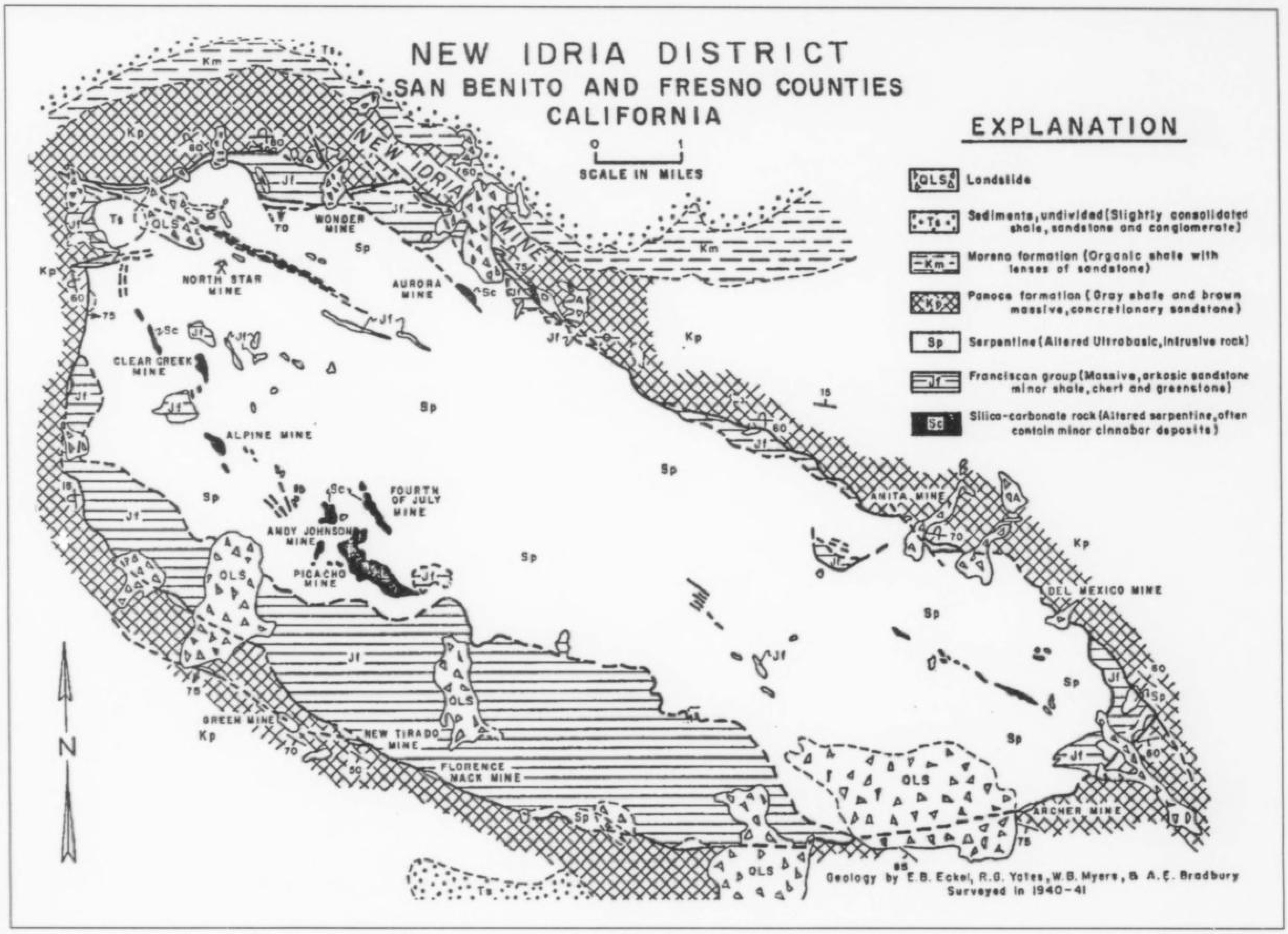


Figure 6. **Geologic map of the New Idria mining district (after Linn, 1968).**

ume using a hydraulic wedge breaker. This is followed by carefully opening the thin mercury-bearing quartz veins using a small trimmer. These final samples, which range in size from two to four centimeters, are then examined under a fiber-optic illuminated binocular microscope using up to 40X magnification. The freshly exposed surfaces often contain as many as six different mercury minerals, ranging in habit from individual crystals to subhedral and anhedral masses, and also intimate mixtures displaying various colors. Also, along these thin quartz veins small voids can be encountered which individually can host different associations of mercury minerals. The resulting identified minerals are then placed in individual plastic boxes to prevent damage and to reduce the potential danger from exposure to native mercury and its vapors. Those minerals that are known to be light-sensitive are put in black plastic boxes.

GEOLOGICAL SETTING

The geological features of the New Idria serpentinite body and surrounding formations have been described by Eckel and Myers (1946), Linn (1968), Fox (1983), Studemeister (1984), and Coleman (1986). This large, elongate, tectonically emplaced serpentinite body, which measures about 19 km long by 6 km wide by 5 km deep, intrudes parts of the Panoche Formation (Upper Cretaceous) and the Franciscan Complex (late Mesozoic to early Tertiary), and forms the core of a large anticline that lies between the San Andreas fault and Coast Ranges to the west and the Great Valley to the east.

Tertiary- and Mesozoic-aged sedimentary rocks surrounding the serpentinite body have been folded into a series of anticlines and synclines whose axes form acute angles with the northwest trending San Andreas fault. The contact of the serpentinite with the surrounding sediments is marked by high-angle faults and shear zones that record the upward tectonic movement of the New Idria serpentinite body. The structural position of the New Idria serpentinite body suggests that it may represent serpentinized peridotites that originally made up part of the Late Jurassic-aged Pacific oceanic crust. Post Jurassic-aged subduction of the peridotites emplaced them under the growing Franciscan accretionary wedge. Following serpentinization, a northwest-southeast fault formed within the serpentinite at depth. This fault zone, which now lies nearly parallel to the boundary of the western edge of the serpentinite body with the Franciscan Complex, was then silicified by fluids along a trend from what is now the Clear Creek mine at the northern end to the Picacho mine at the southern end.

Studemeister (1984) suggested that prograde metamorphism of Mesozoic-aged sediments released mercury-bearing fluids that migrated along fractures in the silicified serpentinite. He stated that these sediments were the principal source for the mercury-bearing fluids in the majority of mercury mines within the New Idria district, although he presented no geochemical evidence.

MINERALOGY

Besides the accessory minerals normally encountered in serpentinite, the silica-carbonate replacement rocks host a number of rare mercury-bearing minerals, most of which are unique to the Clear Creek mine. This uniqueness is the principal reason for our extensive examination of the mine and its mineralogy.

Examination of the mercury-bearing rocks at the nearby Red Rock, Fourth of July, and Andy Johnson mines has revealed only native mercury and cinnabar. Rare coatings of one of two new unknown mercury silicate minerals were discovered at the Picacho mine; edgarbaileyite has been identified with cinnabar from the Alpine mine (Ed Oyler, personal communication).

Mercury Minerals

Aurivilliusite $Hg^{1+}Hg^{2+}OI$

A subhedral-shaped thin sub-metallic patch coating quartz collected from the lower workings was determined to contain two new mercury-bearing phases by XRD tests. This first phase, aurivilliusite, was formally described by Roberts *et al.* (2003a); it is intimately associated with CCUK-15, a similar mercury oxy-halide.

Aurivilliusite is dark gray-black with a dark red-brown streak. During work on this sample, aurivilliusite was subsequently identified with the synthetic compound $Hg^{1+}Hg^{2+}OI$ by comparison of unit cell and X-ray powder diffraction data. This natural phase is extremely rare at this locality, with only one confirmed specimen known. The artificial compound was synthesized by Stålhandske *et al.* (1985) at 450°C from a mixture of HgO and Hg_2I_2.

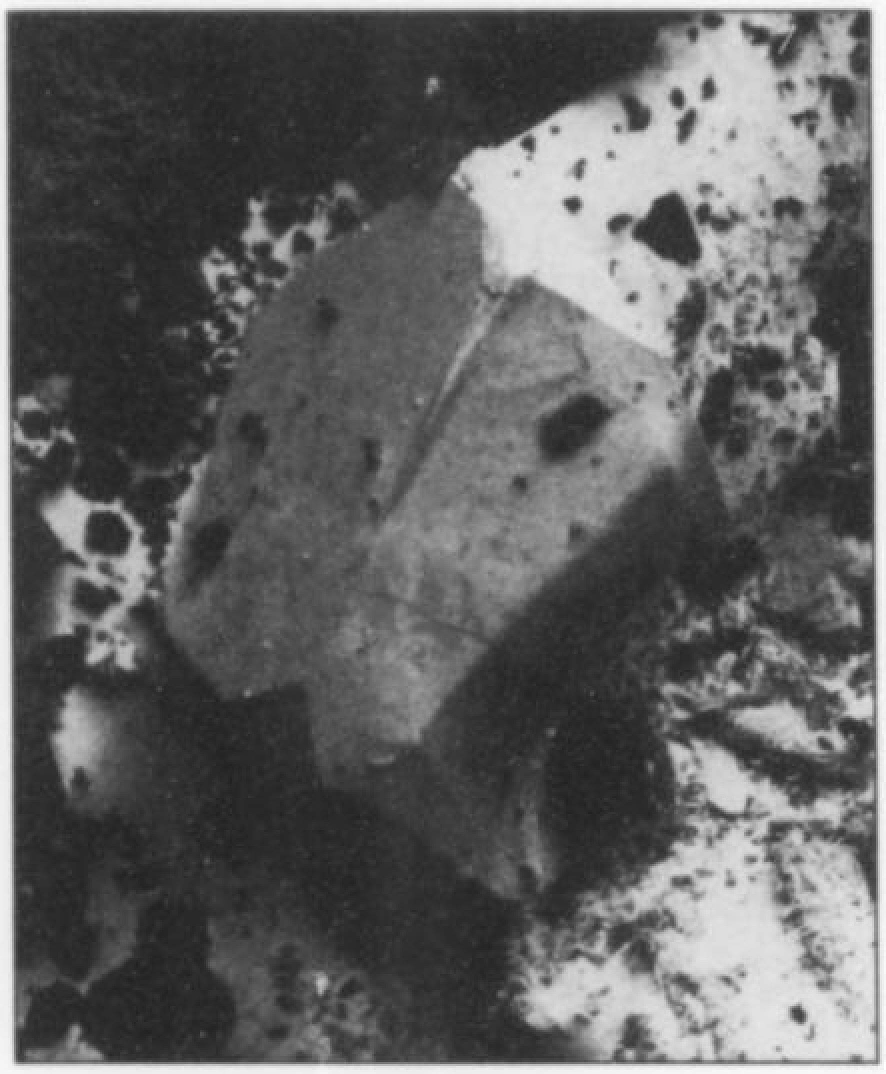


***Figure 7.* Clear, interpenetration twins of calomel, to 300 microns long, in native mercury. Clear Creek mine, lower workings. Gail Dunning specimen and SEM photo.**

The aurivilliusite structure consists of infinite zigzag $-Hg^{2+}$-O-Hg^{2+} chains, running in the [010] direction, which are condensed by [Hg^{1+}-Hg^{1+}] groups to form folded layers. These layers are further connected by weak Hg^{2+}-O bonds to form a three-dimensional structure. The iodine atoms are situated within cavities in the layers and are weakly bonded to Hg^{2+}.

Calomel $Hg_2^{1+}Cl_2$

Calomel is very rare at the Clear Creek mine, and has been found only in small amounts at the lower workings. There it occurs as massive coatings and as clear to pale yellow striated crystals associated with native mercury, montroydite, cinnabar and, very rarely, hanawaltite. It can be distinguished by its red fluorescence under short-wave ultraviolet light. The crystals usually do not exceed 0.1 mm and are often much smaller. On some specimens, calomel shows evidence of dissolution, resulting in a frosted appearance.

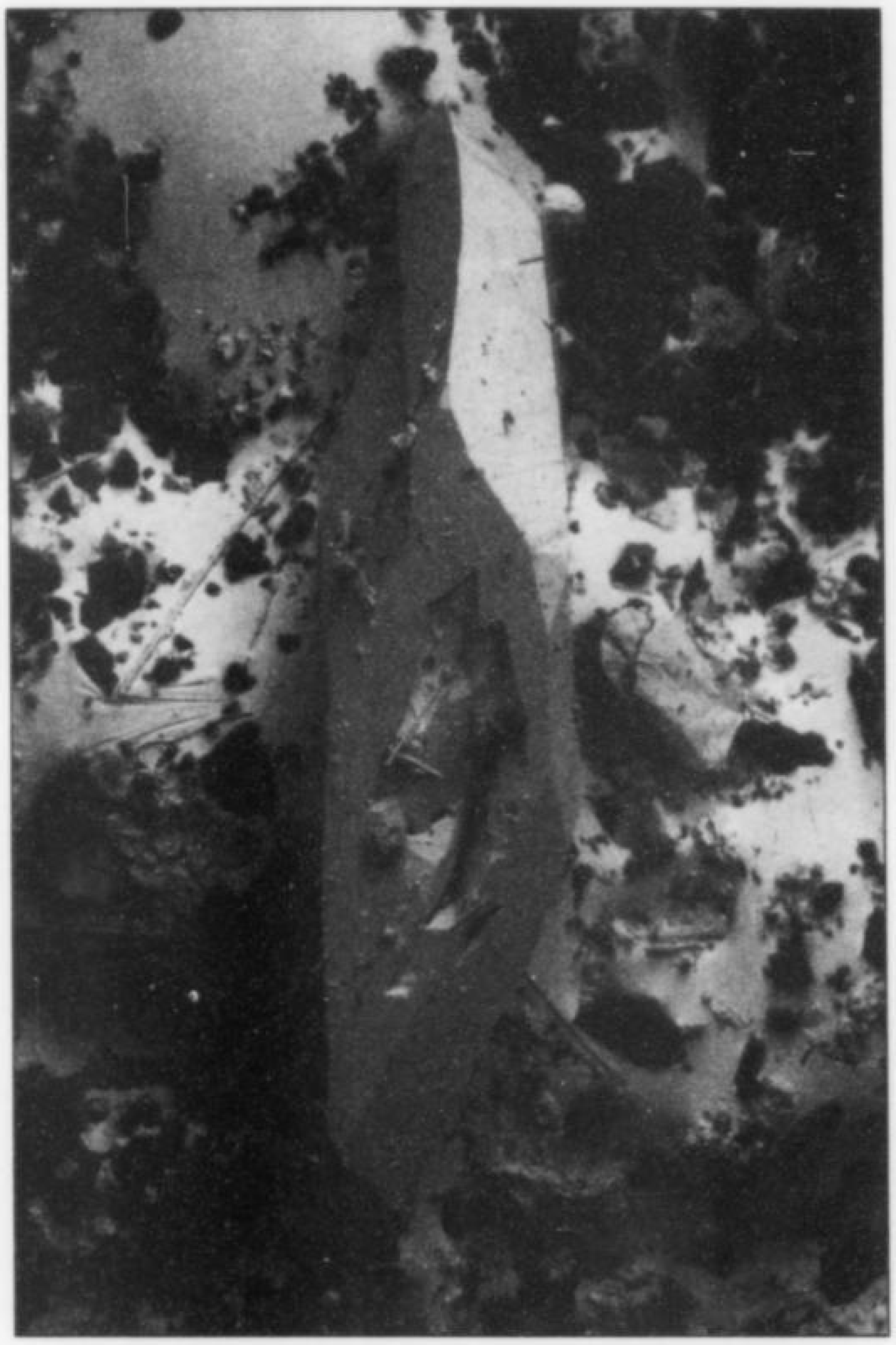


***Figure 8.* Clear, complex calomel crystal, to 300 microns long, in native mercury. Clear Creek mine, lower workings. Gail Dunning specimen and SEM photo.**

Cinnabar HgS

Cinnabar is the major ore of mercury at the Clear Creek mine. It occurs mainly as massive vein-fillings with quartz in the highly silicified serpentinite (lower workings), or as films along shear surfaces in opalized serpentinite (upper workings). Euhedral to subhedral crystals are uncommon in the thicker parts of the veins. Rare acicular hairs of cinnabar occur in open cavities along some quartz seams. Most crystals of cinnabar show typical forms, although very unusual growth habits (loops, rings and curved forms) have been observed. In the upper and middle workings, cinnabar is confined to the fracture surfaces of the low-grade opalized serpentinite, and is often associated with pods of native mercury and rare edgarbaileyite, wattersite and CCUK-8, a hydrous mercury chromate-sulfide similar to edoylerite in composition.

In the rocks of the lower workings, which have been extensively silicified, cinnabar is often localized within quartz veins, although usually it is confined to the silica-carbonate-quartz margins. In parts of these veins, cinnabar often shows the effects of chemical dissolution by post-depositional low pH hydrothermal solutions. This has resulted in the formation of several unique and rare mercury minerals, including deanesmithite, edoylerite and CCUK-8. Cinnabar and pecoraite have been observed as alteration products of rare donharrisite associated with contemporary cinnabar in samples from the lower workings.

Clearcreekite $Hg_3^{1+}(CO_3)(OH)\cdot 2H_2O$

The very rare hydrous mercury carbonate mineral, clearcreekite (Roberts *et al.*, 2001), occurs as two small crystals with a pale greenish-yellow color that were discovered from the lower workings of the Clear Creek mine by Edward H. Oyler. They are subhedral, tabular {100} with a maximum dimension of 0.17 mm and generally are similar in habit to terlinguaite crystals found at the locality. Associated minerals on the sample include edoylerite and cinnabar, although these are not near the clearcreekite crystals. Crystal structure data indicates that it is polymorphous with peterbaylissite but that the two structures are very different.

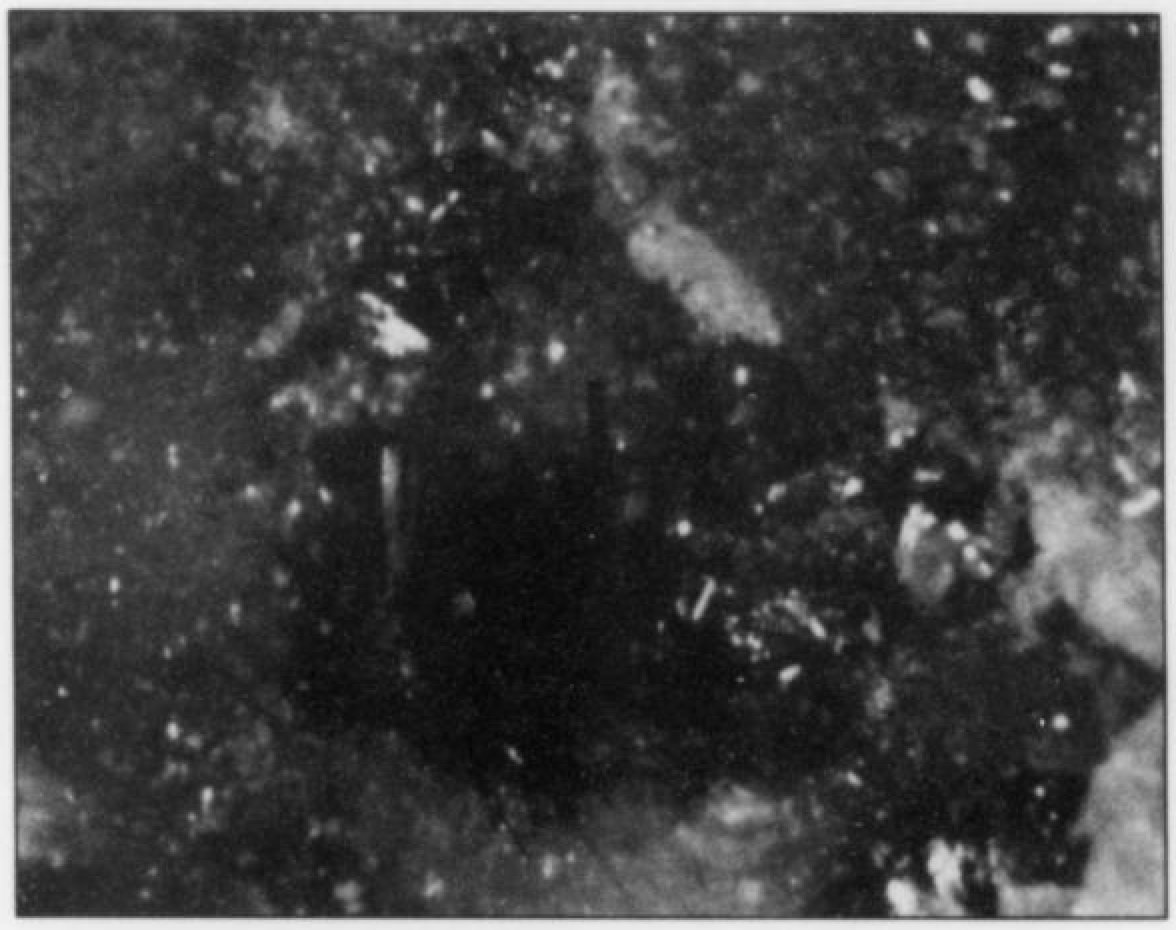


***Figure 9*. Orange bladed crystals of deanesmithite, to 0.2 mm, with yellow-orange edoylerite and cinnabar on quartz. Clear Creek mine, lower workings. Ted Hadley specimen and photo.**

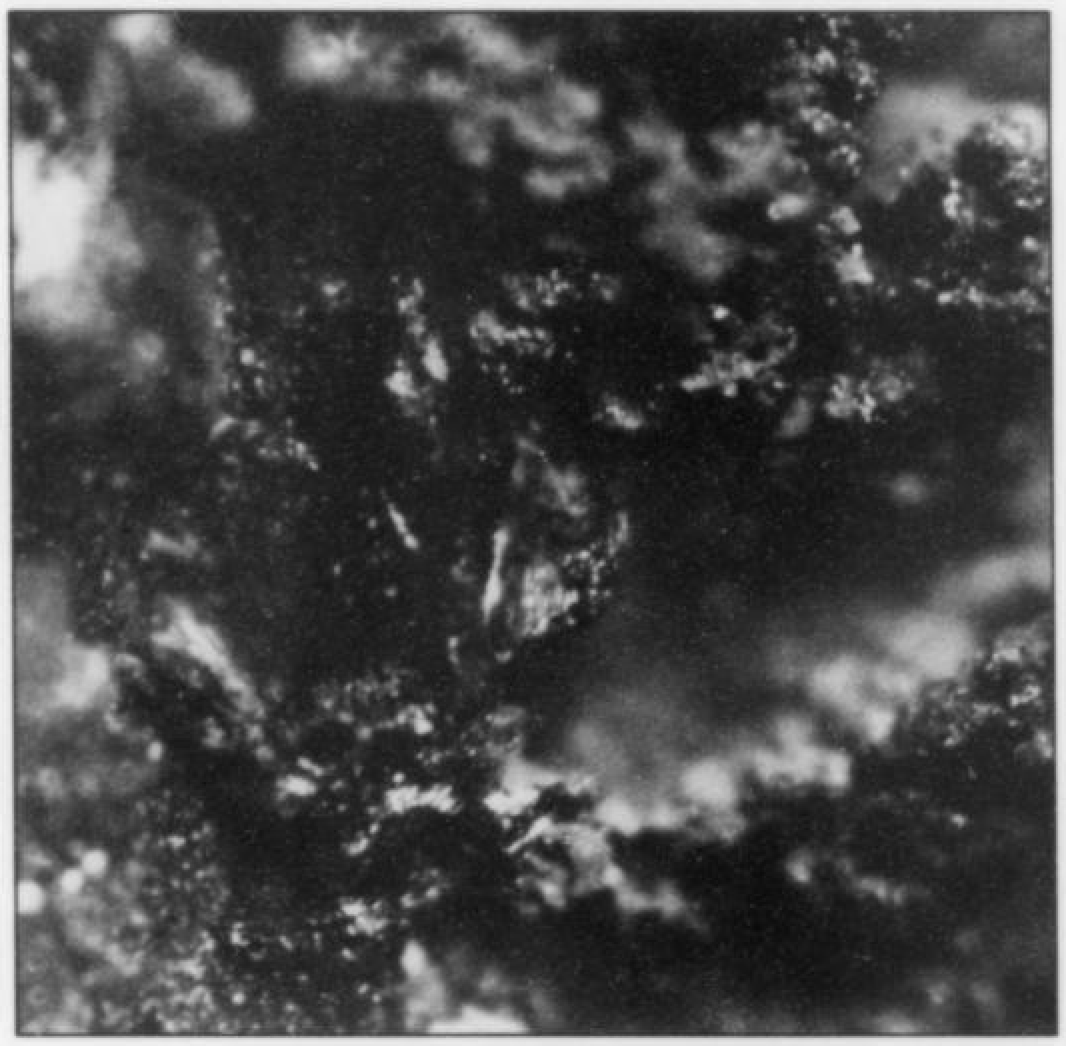


***Figure 10*. Deanesmithite crystals to 0.5 mm, from the lower workings, Clear Creek mine, lower workings. Gail Dunning collection; Dan Behnke photo.**

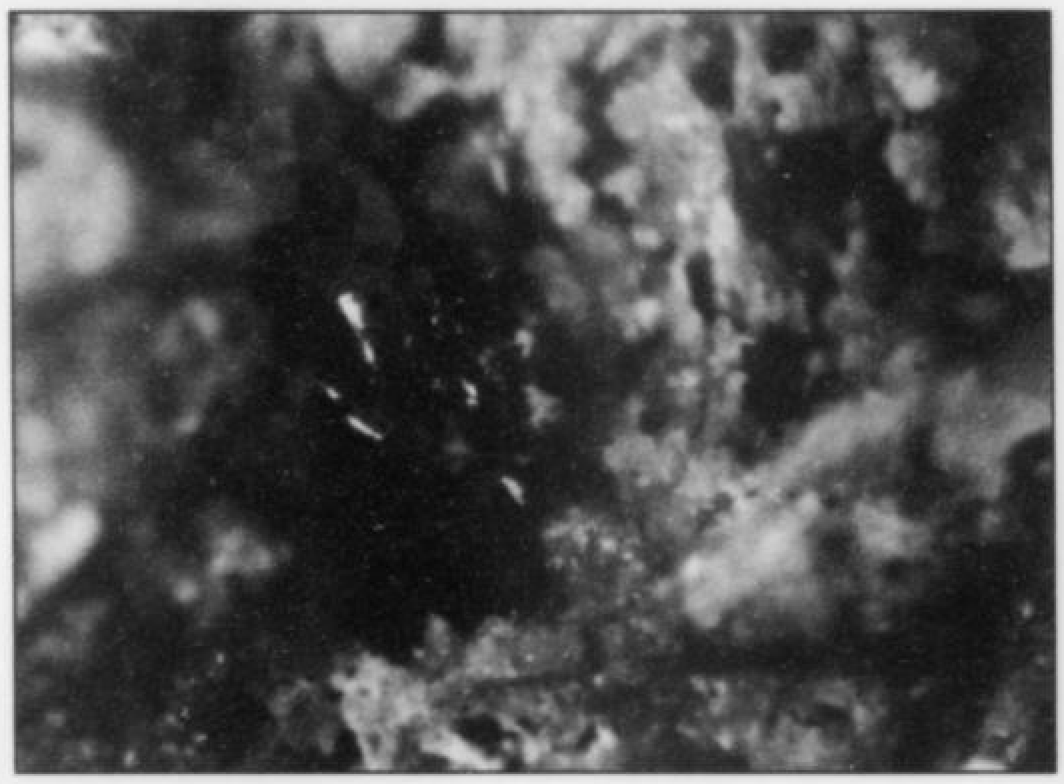


***Figure 11*. Delicate spray of orange deanesmithite crystals on quartz, 0.3 mm. Clear Creek mine, lower workings. Sharon Cisneros specimen; Ted Hadley photo.**

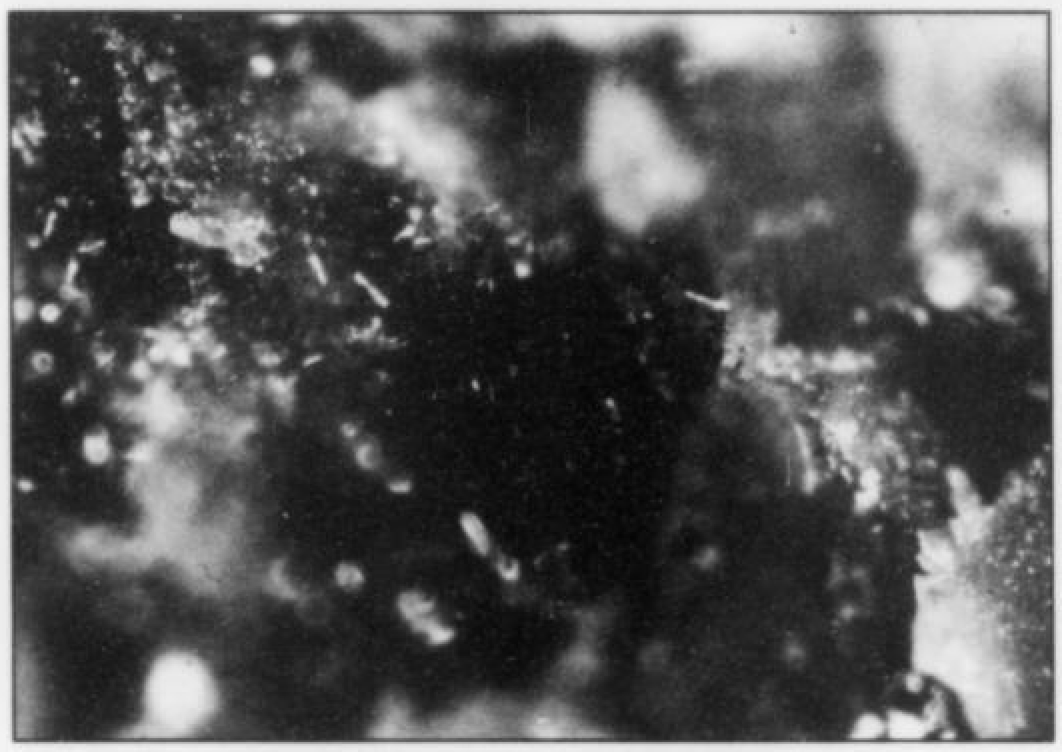


***Figure 12*. Deanesmithite crystal cluster, 0.3 mm, on quartz from the Clear Creek mine, lower workings. Gail Dunning collection; Dan Behnke photo.**

***Figure 13*. Thin, elongated blades of orange deanesmithite, 0.1 × 30 microns, surrounded by terminated edoylerite crystals in cavity. Clear Creek mine, lower workings. Gail Dunning specimen and SEM photo.**

Deanesmithite Hg$_2^{1+}$Hg$_3^{2+}$(Cr^{6+}O$_4$)OS$_2$

Deanesmithite was discovered in 1988 by Edward H. Oyler from a float rock at the lower workings of the Clear Creek mine. Megascopically, it resembles montroydite but is much redder in color. A preliminary X-ray powder-diffraction examination proved this mineral to be new. Its full description has been reported by Roberts *et al*. (1993). Szymański and Groat (1997) have shown that the crystal structure of deanesmithite exhibits numerous similarities to the structure of wattersite.

Deanesmithite is generally associated with edoylerite and anhedral crystalline masses and powdery coatings of cinnabar. The crystals occur as fan-shaped elongate [001] prismatic aggregates up to

1 mm long, and as isolated bladed to tabular [010] aggregates of crystals. Forms reported by Roberts *et al.* (1993) include {100}, {310}, {001}, {510}, {011}, {010}, {210}, {310}, {410}, {510}, {610}, {110}, {320}, {210}, {023}, {032}, and {101}.

When fresh, it is orange-red and is distinctive against the deep red cinnabar. On weathering, it appears brown, with a submetallic luster. Fine radiating clusters of deanesmithite have also been identified in cavities within the silica-carbonate host rock, where the carbonate minerals have been leached by acidic fluids. In several samples, fine sprays of edoylerite have been identified in adjacent leached cavities. Deanesmithite rarely has been observed coated by CCUK-8.

Donharrisite $Ni_8Hg_3S_9$

Donharrisite occurs as rare bronze metallic masses associated with cinnabar along thin veins in the silica-carbonate rocks. One specific instance showed it together with cinnabar cutting across a quartz vein devoid of mercury mineralization. Textural observations suggest that donharrisite formed prior to or contemporaneously with cinnabar but from the same sulfide-rich fluids. Rims of rare secondary cinnabar and pecoraite surround several of the partially oxidized donharrisite masses.

Donharrisite was suspected after an EDS examination and confirmed by X-ray powder-diffraction; it represents the second world occurrence. This rare sulfide of mercury and nickel was initially characterized by Paar *et al.* (1989) from a museum sample collected before 1834, probably from the former Erasmus mine, Leogang, Salzburg Province, Austria. There, it is associated with cinnabar, native mercury, sphalerite, tennantite, chalcopyrite, polydymite and pyrite.

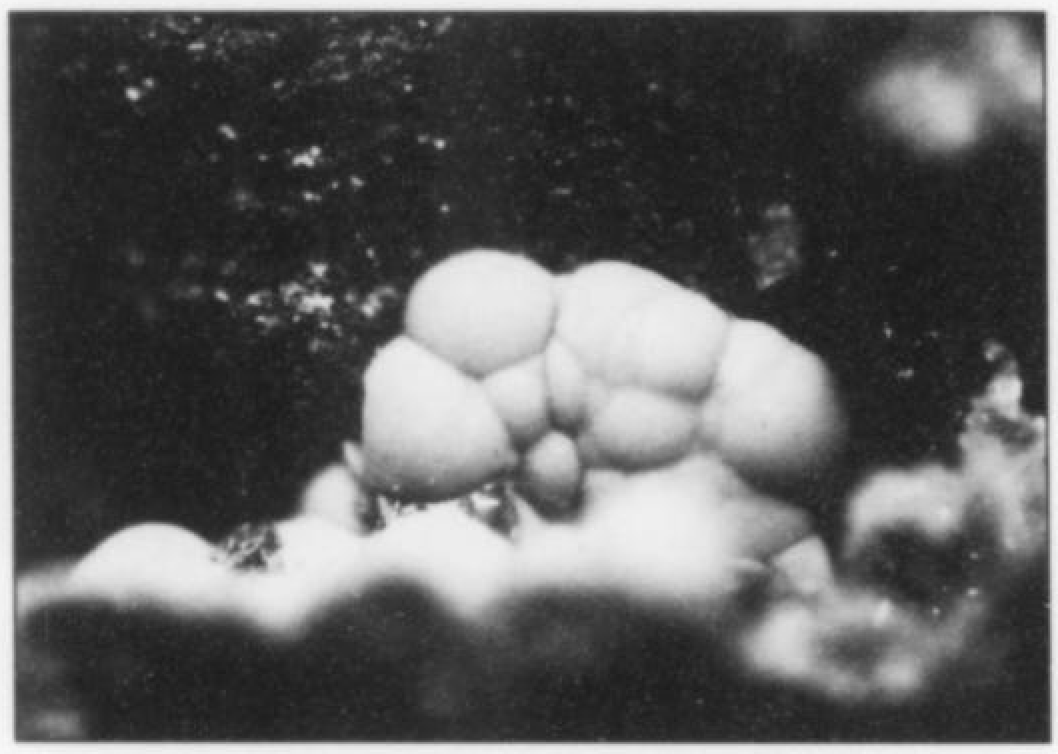


Figure 14. **Exceptional group of yellow botryoidal edgarbaileyite, 0.2 mm group with green nickel-bearing serpentinite. Clear Creek mine, upper workings. Ted Hadley specimen; Dan Behnke photo.**

Edgarbaileyite $Hg_6^{1+}Si_2O_7$

Edgarbaileyite, the first known natural silicate of mercury, was discovered by Leo Rosenhahn in 1963 at the Socrates mine (type locality), Sonoma County, California and described by Roberts *et al.*, 1990a. In 1972, Edward H. Oyler collected similar-looking material from the lower workings of the Clear Creek mine and this was submitted for X-ray identification. It was found to be identical to the material from the Socrates mine. In addition, the same mineral was identified by the late Dr. Alan J. Criddle on a Terlingua, Texas specimen in The Natural History Museum, London, England. The mineral also has been identified from the Alpine mine, just south of the Clear Creek mine, associated with cinnabar, montroydite and native mercury in quartz-lined cavities.

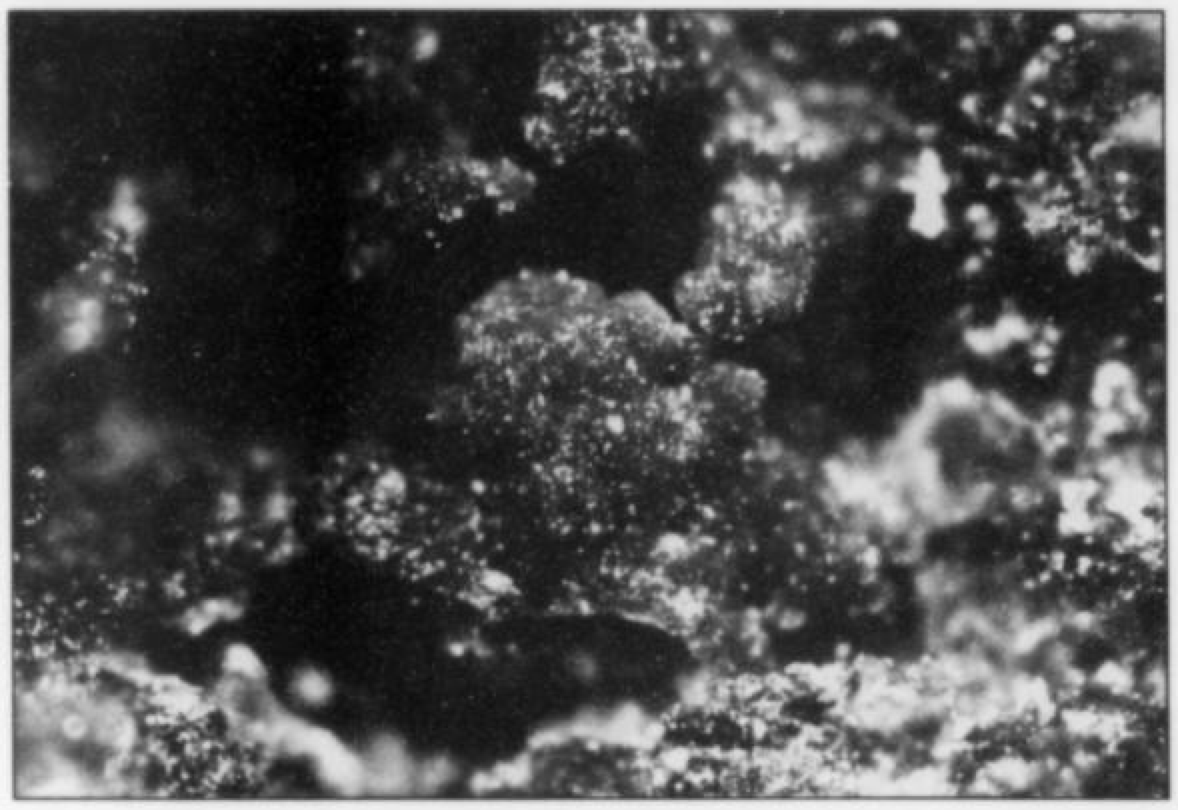


Figure 15. **Brownish-orange group of unusually large edgarbaileyite crystals, 0.9 mm central zone. Clear Creek mine, upper workings. Ted Hadley specimen; Dan Behnke photo.**

Figure 16. **Crude yellow edgarbaileyite crystals, to 30 microns, on quartz. Clear Creek mine, upper workings. Gail Dunning specimen and SEM photo.**

Angel *et al.* (1990) reported the crystal structure of edgarbaileyite from the Texas locality and established the stoichiometry from the structure determination.

At the Clear Creek mine, edgarbaileyite occurs at all three workings as cryptocrystalline masses, velvety spheres, and rarely as complex aggregates of twinned platy microcrystals. The mineral is extremely variable in color. Freshly exposed material is lemon-yellow to orangish-yellow, and exposed surfaces are varicolored from dark olive-green, to a lighter yellowish-green, to a dark green-brown grading into black. Very fine nodular masses occur lining quartz cavities in the lower workings. It is generally associated with most of the described mercury-bearing minerals, especially native mercury, wattersite, montroydite and etched cinnabar. In some specimens edgarbaileyite has been observed covering the linings of microcavities, where it has been subsequently covered by quartz and then by a second generation of edgarbaileyite. At the upper workings, it is often seen as a smooth coating over highly corroded cinnabar and is associated with small spheres of native mercury.

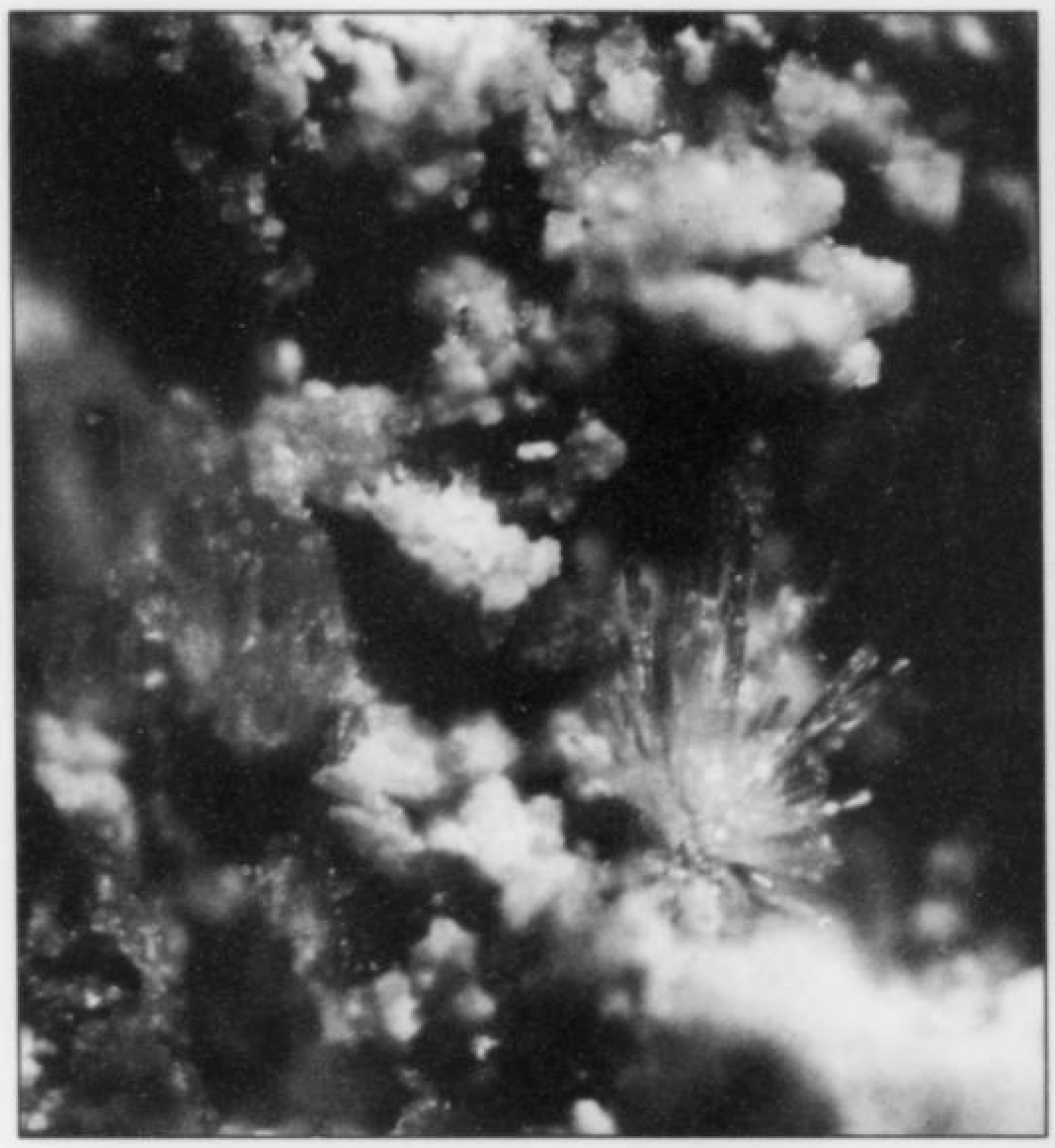


Figure 17. **Exceptional crystal group of yellow edoylerite, 0.6 mm long, with red cinnabar on quartz. Clear Creek mine, lower workings. Gail Dunning specimen; Dan Behnke photo.**

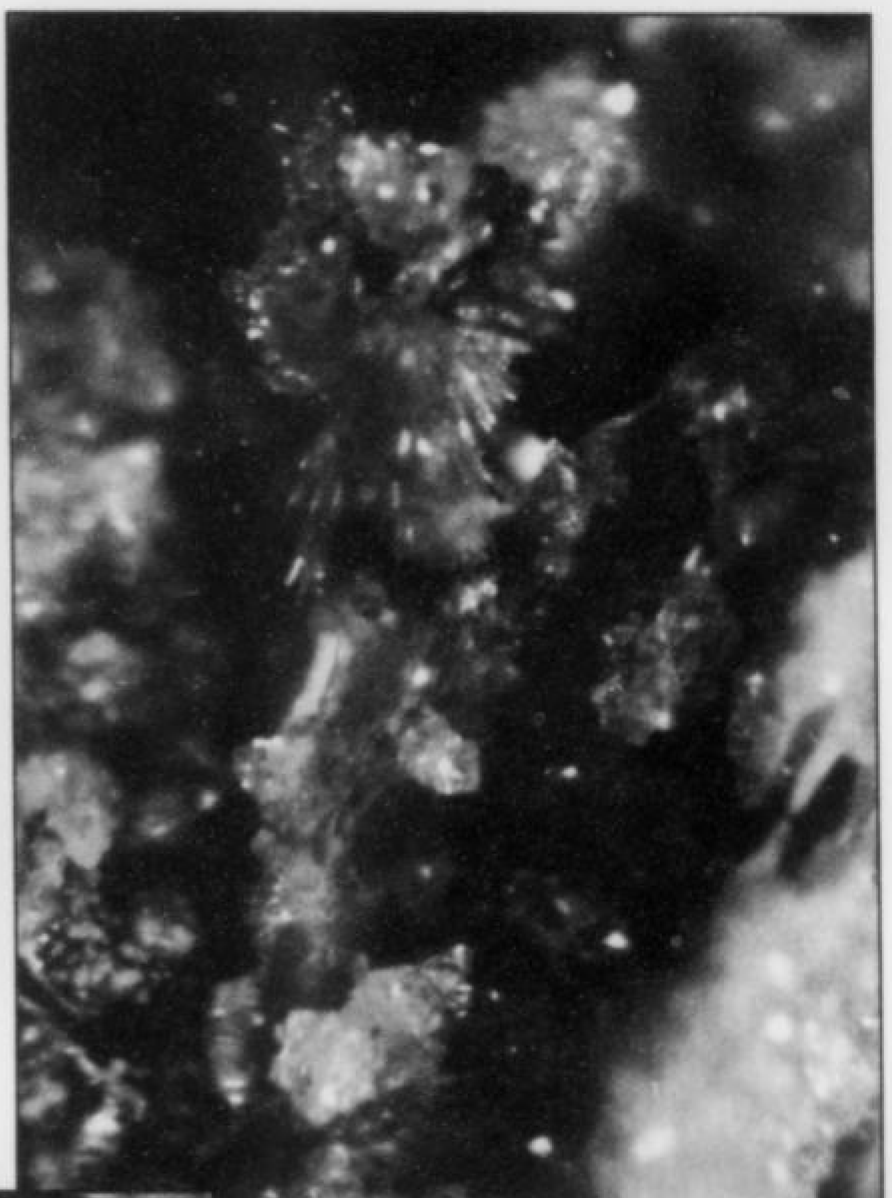


Figure 18. **Exceptional spray of edoylerite crystals, 0.4 mm long, with secondary cinnabar crystals on quartz. Clear Creek mine, lower workings. Gail Dunning specimen; Ted Hadley photo.**

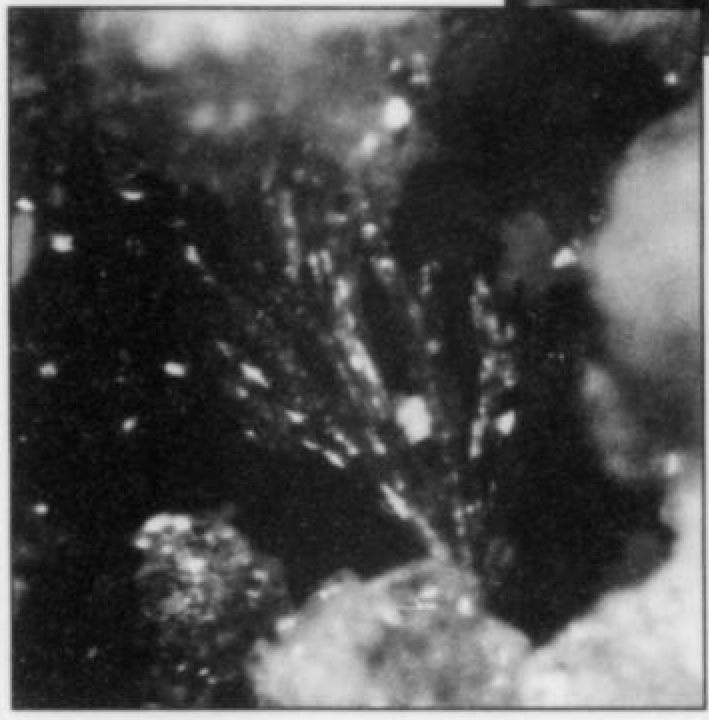


Figure 19. **Exceptional crystal group of yellow edoylerite, 0.6 mm long, on quartz. Clear Creek mine, lower workings. Gail Dunning specimen; Ted Hadley photo.**

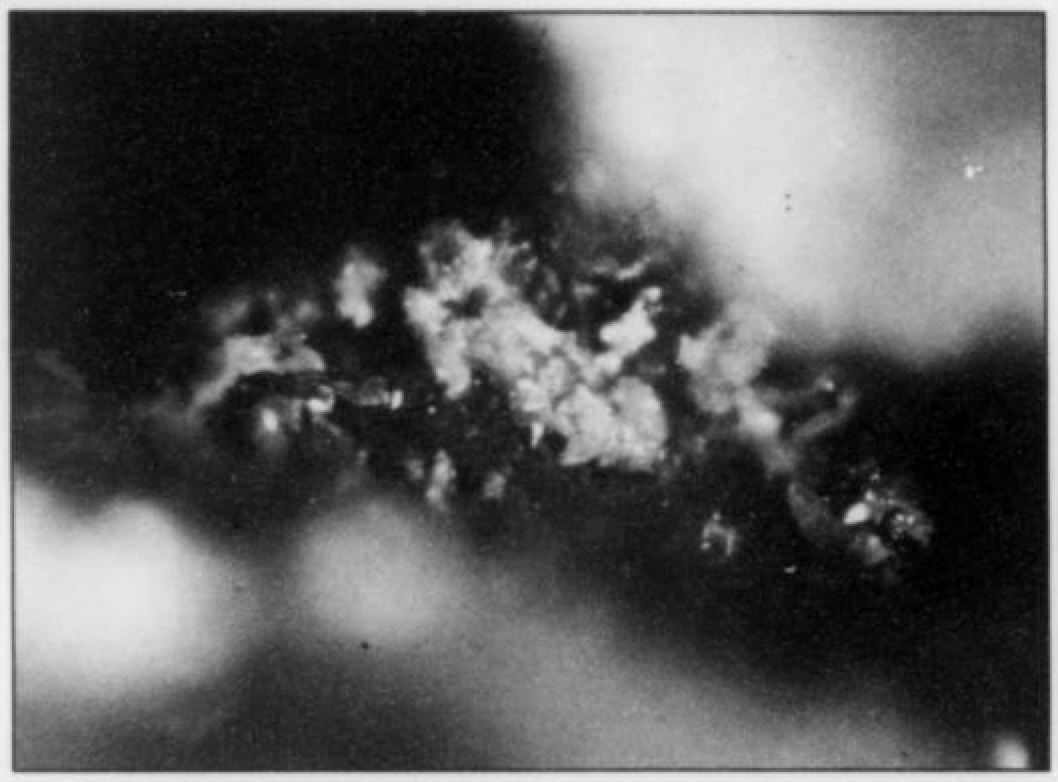


Figure 20. **Group of yellow-orange edoylerite crystals, 0.65 mm, on red cinnabar in quartz cavity. Clear Creek mine, upper workings. Ted Hadley collection; Dan Behnke photo.**

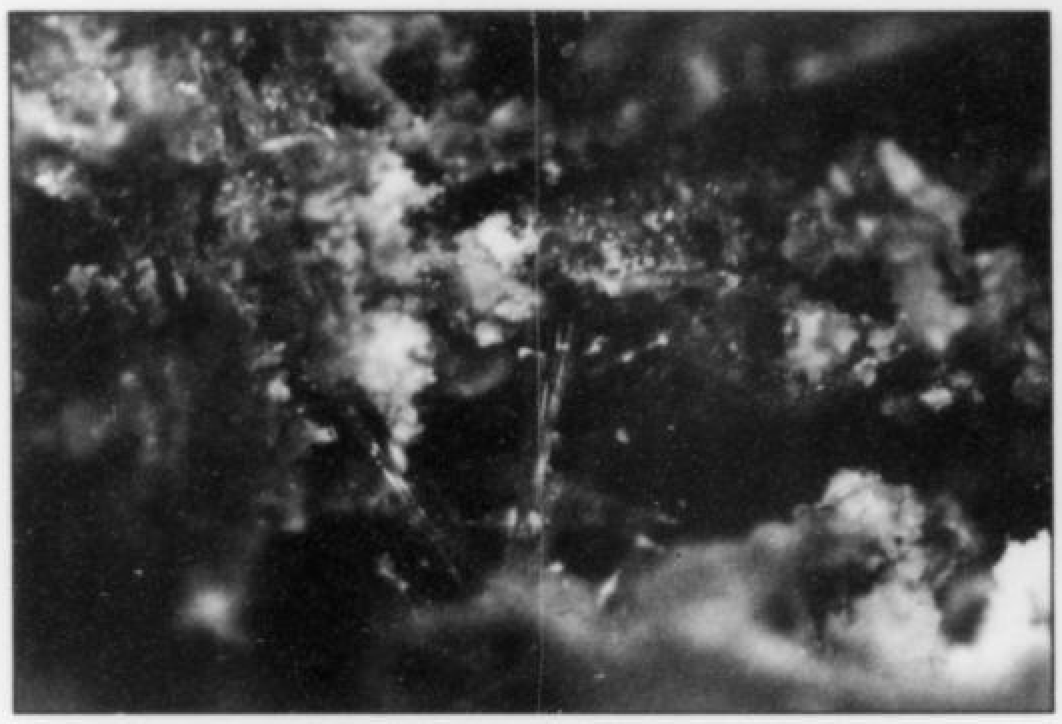


Figure 21. **Group of yellow edoylerite crystals to 0.3 mm in quartz cavity. Clear Creek mine, upper workings. Ted Hadley collection; Dan Behnke photo.**

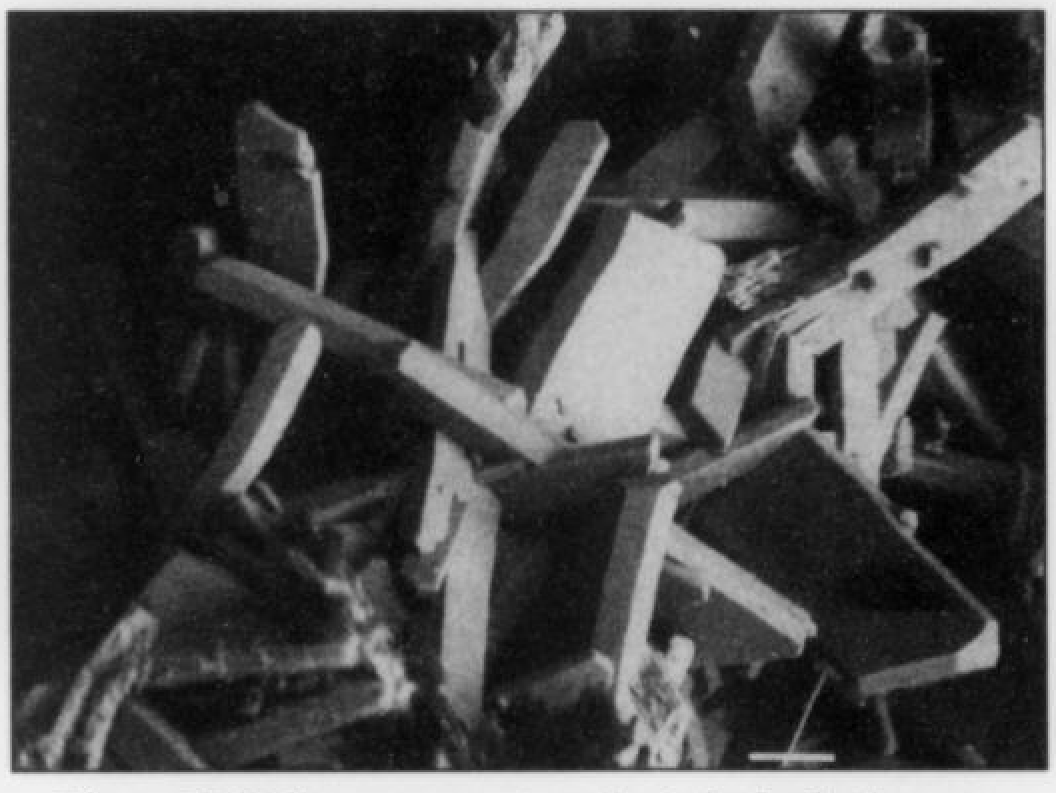


Figure 22. **Yellow-orange, terminated edoylerite crystals, 5 × 50 microns, in cavity showing many of the reported forms. Clear Creek mine, lower workings. Gail Dunning specimen and SEM photo.**

Edoylerite $Hg_3^{2+}(Cr^{6+}O_4)S_2$

Edoylerite was discovered by Edward H. Oyler from the lower workings of the Clear Creek mine and described by Erd *et al.* (1993). It typically occurs as acicular to stellate, and as equant prismatic crystals on and around corroded masses of cinnabar. Crystal forms reported by Erd *et al.* (1993) include {010}, {111}, {001}, and {101}. It also has been found as isolated groups of divergent, acicular crystals lining cavities in porous silica-carbonate rock associated with individual crystals of second-generation cinnabar. Occasionally, it is associated with deanesmithite and postdates it in the same micro-environment. Other close associations include native mercury, montroydite and edgarbaileyite. The color

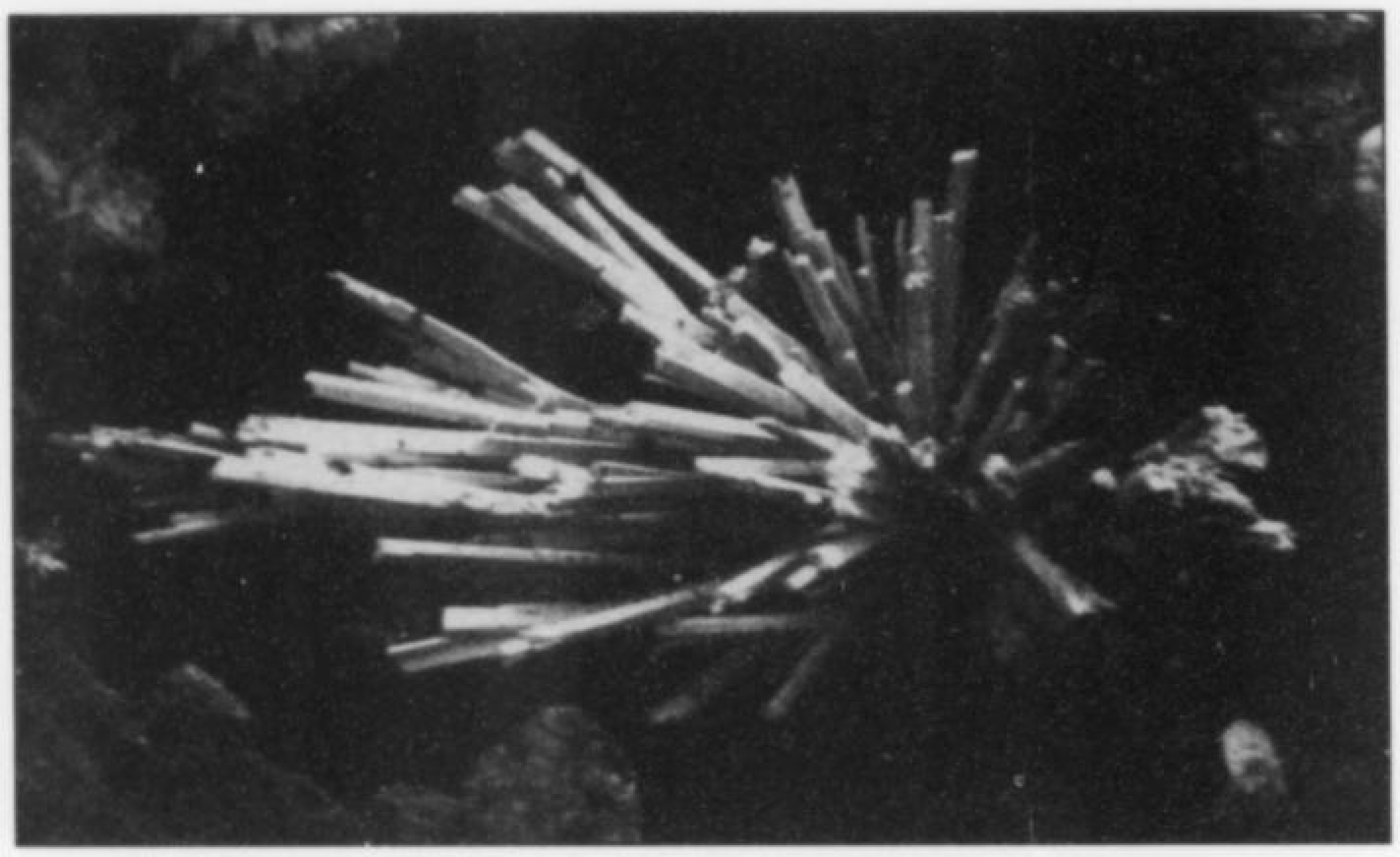


Figure 23. **Yellow-orange spray of acicular edoylerite crystals, 10 × 300 microns, in cavity. Clear Creek mine, lower workings. Gail Dunning specimen and SEM photo.**

ranges from canary yellow to orange-yellow as the crystals become thicker. It can also have a slight greenish color in some of the more massive material.

At both the lower and upper workings, it can be found intimately associated with CCUK-8, a hydrous mercury chromate sulfide with similar composition, but edoylerite always precedes it in formation. Superb specimens have been discovered at the lower workings and are very attractive, especially when associated with water-clear quartz crystals.

The crystal structure of edoylerite has been reported by Burns (1999) and contains three symmetrically distinct Hg^{2+} sites, each of which is strongly bonded to two S anions to form approximately linear S-Hg-S clusters. These clusters link to form crankshaft-type chains composed of eight-membered rings of alternating Hg^{2+} and S that are parallel to [101]. Hg^{2+} cations are weakly bonded to additional anions, resulting in distorted-octahedral coordinations in two cases and a pentagonal bipyramidal coordination in the other case. The Hg^{2+} polyhedral link to each other and to CrO_4 tetrahedra by sharing of polyhedron edges and corners, resulting in a heteropolyhedral framework structure.

Figure 25. **Needles of yellow eglestonite, 0.3 mm long, on quartz with native mercury. Crystals are elongated in the [100] direction. Clear Creek mine, upper workings. Ted Hadley specimen and photo.**

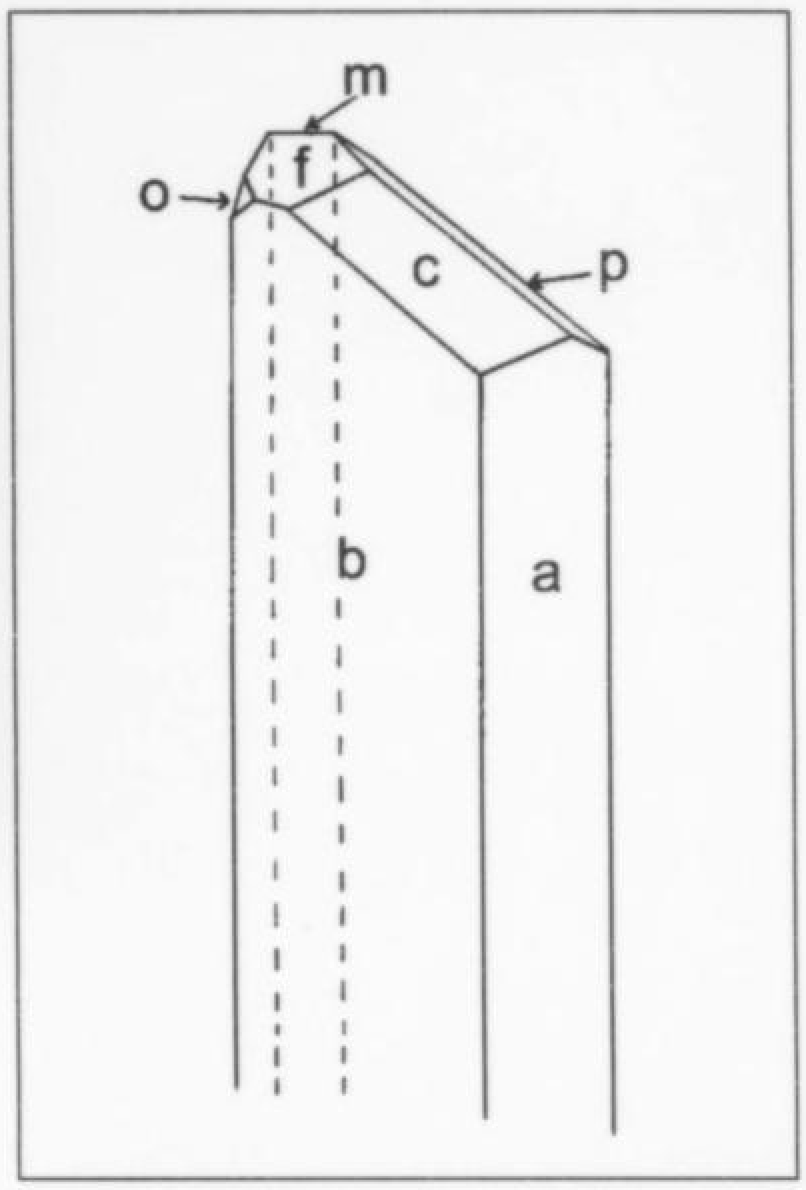


Figure 24. **Edoylerite crystal drawing showing the basal pinacoid *c*{001}, the side pinacoid *b*{010}, the front pinacoid *a*{100}, the positive second-order pinacoid *p*{011}, the negative second-order pinacoid *f*{101}, the third-order prism *m*{110}, and the negative fourth-order prism *o*{111}. All forms are not present on every crystal.**

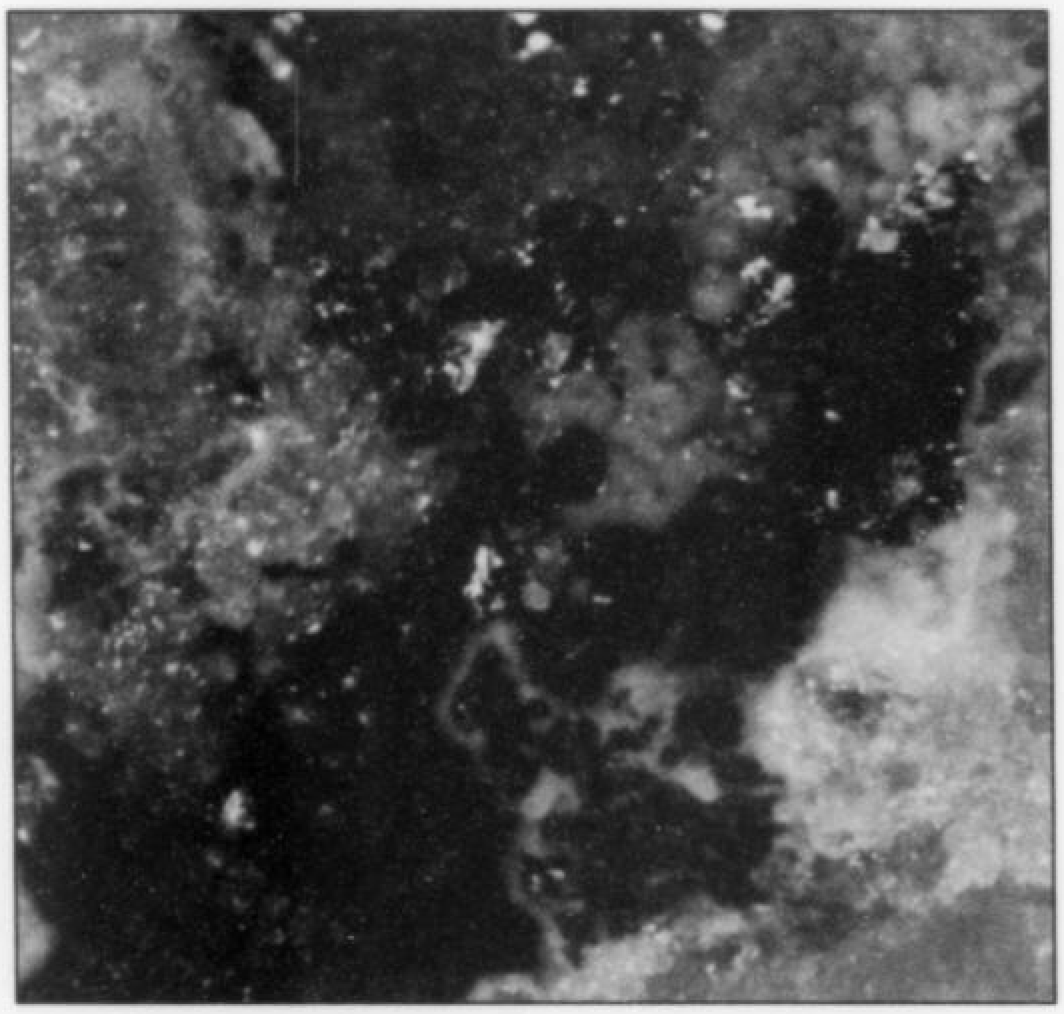


Figure 26. **Striated blocky crystals of eglestonite, to 0.13 mm, with yellow edgarbaileyite on quartz. Clear Creek mine, lower workings. Gail Dunning specimen; Ted Hadley photo.**

Eglestonite $Hg_6^{1+}Cl_3O(OH)$

Eglestonite occurs as deeply striated cubic and dodecahedral crystals with a blocky habit, and as thinly elongated spears with apparent twinning. The color ranges from deep lemon-yellow to orange-yellow to black, with the latter especially evident in thicker sections. Upon exposure to light, eglestonite may darken to black, though it is often that color in fresh specimens. It is most easily recognized by its greasy luster. Eglestonite is most often associated with edgarbaileyite, native mercury, cinnabar and wattersite coating quartz cavities. Slender crystals often protrude through spheres of native mercury or occur as free crystals extending across spherical cavities in quartz. Mereiter *et al.* (1992) have recently revised the chemical formula for eglestonite.

Gianellaite $Hg_4^{2+}N_2(SO_4)$

Massive gianellaite has been identified from the lower workings by X-ray powder-diffraction and microchemical methods. It has been observed as isolated masses to 0.08 mm within quartz vein cavities, and is associated with terlinguaite and cinnabar. It is yellow to greenish-yellow to black upon exposure to light. Although the composition and crystal structure of gianellaite are similar to that of mosesite, the two minerals have not been observed together. The mineral was first described by Tunell *et al.* (1977) from the Mariposa mine, Terlingua district, Brewster County, Texas, where it is associated with terlinguaite, calomel, montroydite, native mercury and cinnabar.

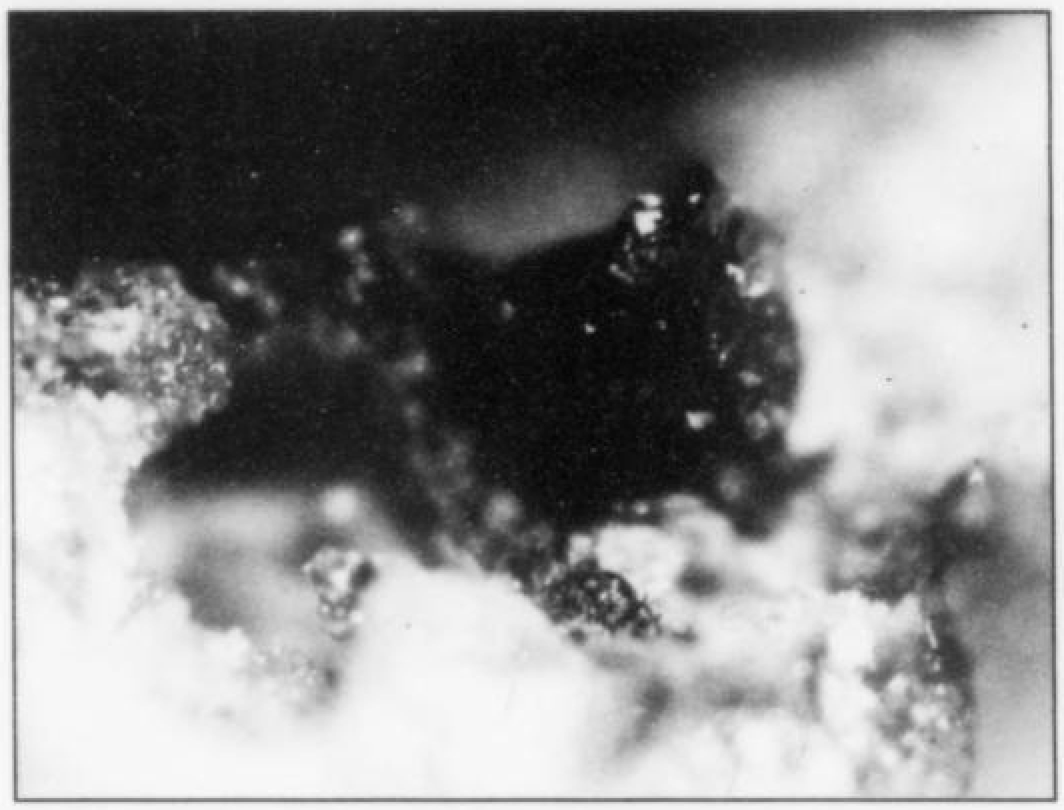


***Figure 27.* Black hanawaltite crystal, 0.2 mm, from the Clear Creek mine, lower workings. Gail Dunning collection; Dan Behnke photo.**

Hanawaltite $Hg_6^{1+}Hg^{2+}[Cl_{1.47}(OH)_{0.55}]O_3$

The specimen on which hanawaltite was originally discovered was collected in 1962 by Edward H. Oyler and was identified as a new mineral in 1991. Its description and crystal structure formally reported by Roberts *et al.* (1996). This holotype specimen was collected from a float rock that was situated approximately 15 meters west of the original edoylerite discovery. Hanawaltite resembles wattersite and varies from black to very dark brown-black. The hanawaltite-bearing area on the original sample measures 8 × 2 mm and is located on a quartz-rich fracture. The mineral occurs as isolated subhedral crystals that are intimately associated with greenish-brown resinous calomel, globules of native mercury, cinnabar and varicolored montroydite.

Two additional hanawaltite samples were discovered from the lower workings during our study. The host rock is a brecciated silica-carbonate rock composed principally of ferroan magnesite and quartz. One of these two samples was used to improve the R index and the standard deviations of the atomic positions. The revised results are reported by Grice (1999).

The hanawaltite structure has two distinct layers; a Hg^{1+}-Cl-O layer consisting of ribbons of $[Hg\text{-}Hg]^{1+}$ dimers resembling the configuration in calomel structure and a Hg^{2+}-Hg^{1+}-Cl-O layer with alternating mercurous and mercuric oxychloride chains.

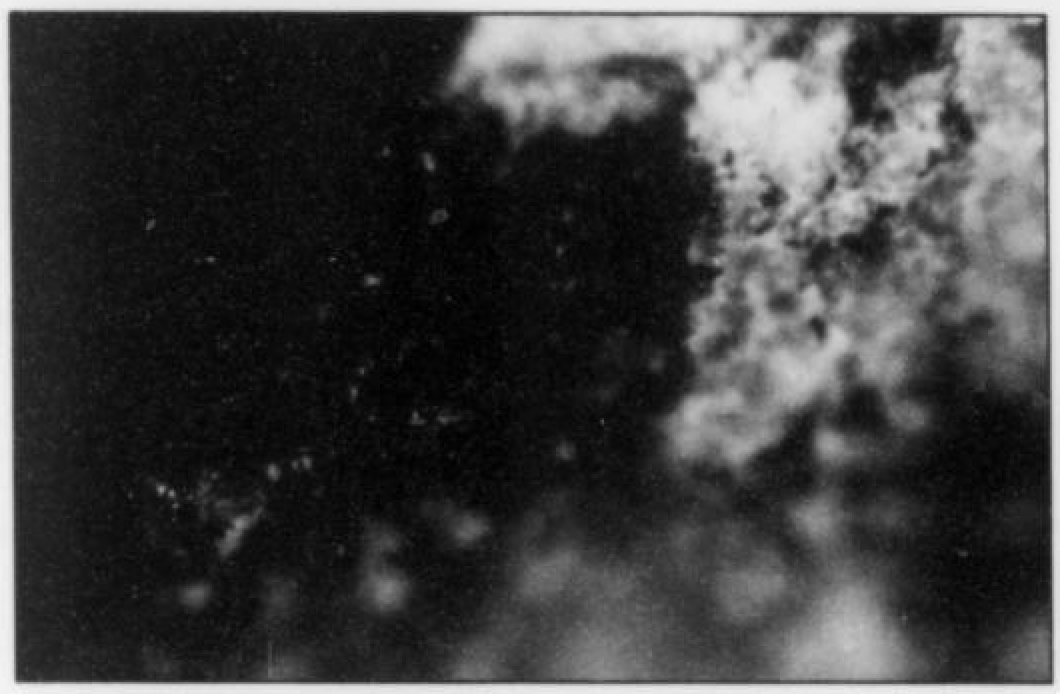


***Figure 28.* Black crystal section of very rare hanawaltite, 0.7 mm, Clear Creek mine, lower workings. Gail Dunning specimen; Ted Hadley photo.**

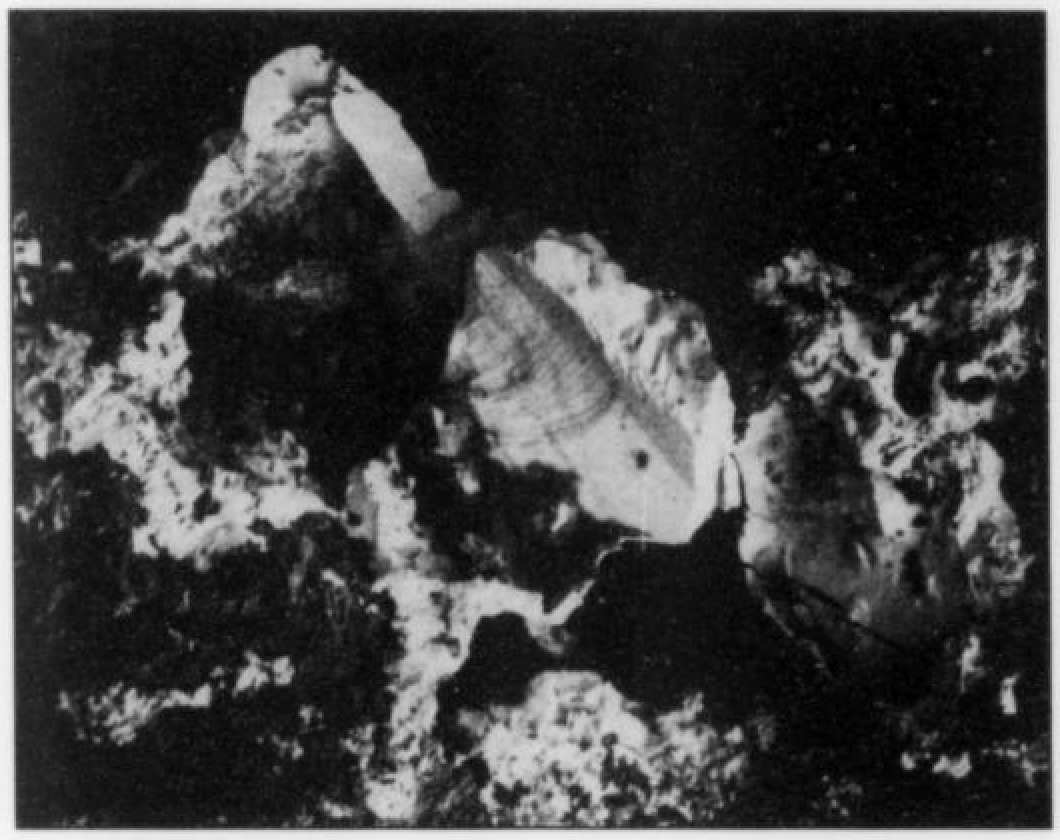


***Figure 29.* Black hanawaltite crystal section, 1 mm long, showing possible crystal faces, associated with calomel and cinnabar. This is the second known specimen discovered from the Clear Creek mine, lower workings. Gail Dunning specimen and SEM photo.**

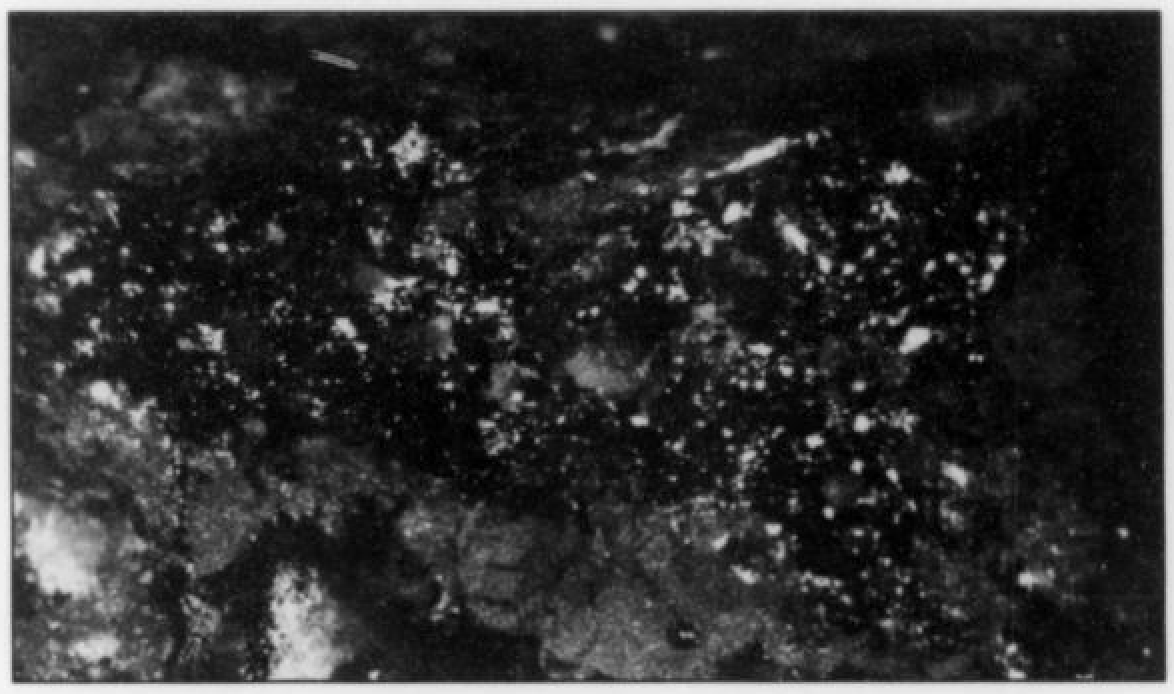


***Figure 30.* Typical exposure of native mercury on cinnabar. 4.5 mm wide specimen. Clear Creek mine, upper workings. Ted Hadley specimen and photo.**

Mercury Hg

Bright silvery droplets and coatings of native mercury fill cavities and veins throughout the mine, often in volumes exceeding 1 ml. It is generally associated with cinnabar, edgarbaileyite, eglestonite, montroydite, mosesite, szymańskiite and wattersite. As native mercury is highly mobile, precise paragenetic relations can be difficult to establish.

Most native mercury has been found either filling isolated cavities in quartz veins or associated with cinnabar as vein fillings.

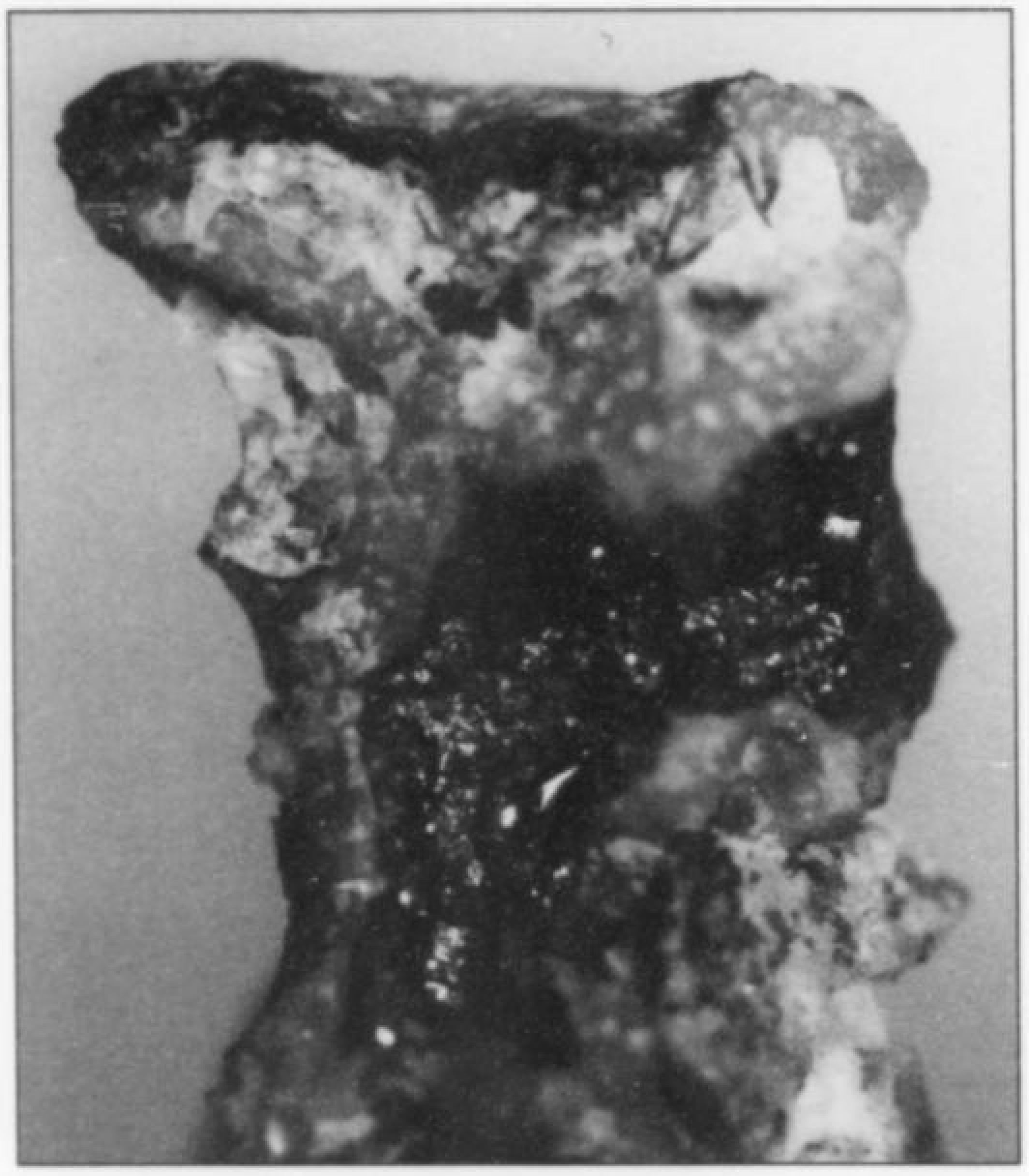


Figure 31. **Typical quartz microvoid containing native mercury on edgarbaileyite with minute wattersite crystals. 6 mm wide specimen. Clear Creek mine, upper workings. Ted Hadley specimen and photo.**

Figure 32. **Orange montroydite crystal, 0.3 mm, with native mercury, from the Clear Creek mine, lower workings. Gail Dunning collection; Dan Behnke photo.**

This native mercury shows a strong bond with the quartz that is difficult to break. When a native mercury-containing cavity is split open, quartz fragments will also adhere to the mercury globules. However, when purified mercury is placed in one of these cavities it will not adhere to the quartz. This strong affinity for quartz is not unique to Clear Creek native mercury, and has been observed at other localities. In many instances, individual spheres of mercury show surface oxidation colors that range from pale gray to bronze. Historically, the Clear Creek mine was noted for its abundance of native mercury.

Metacinnabar Hg(S,Se)

Black coatings of metacinnabar, some of it selenian, have been identified at the lower workings by XRD where it is associated with cinnabar. It is very uncommon at the deposit, in marked contrast to the New Idria mine, where it is more abundant.

Montroydite HgO

Montroydite is a common mineral at all of the workings. It occurs as spear-shaped crystals and hair-like mats of needles that are usually flattened, as radiating groups of crystals and as blocky irregularly-shaped masses of fine-grained crystals. The color ranges from reddish-brown to bronze, yellowish-brown, pale yellow, reddish-orange and black. It is most commonly observed covering or attached to wattersite, native mercury, edgarbaileyite, eglestonite and cinnabar. Occasionally, it is found as hard shells that are epimorphous after native mercury.

Mosesite $Hg_2^{2+}N(Cl,I,Br)\cdot H_2O$

Mosesite is a very rare mineral and is found only at the lower workings. It most often occurs as a coating on clear quartz crystals within closed cavities associated with native mercury and CCUK-10, a mercury nitrogen-halide. Crystals are rare but, when encountered, show the forms {001}, {012}, {112} and either the forms

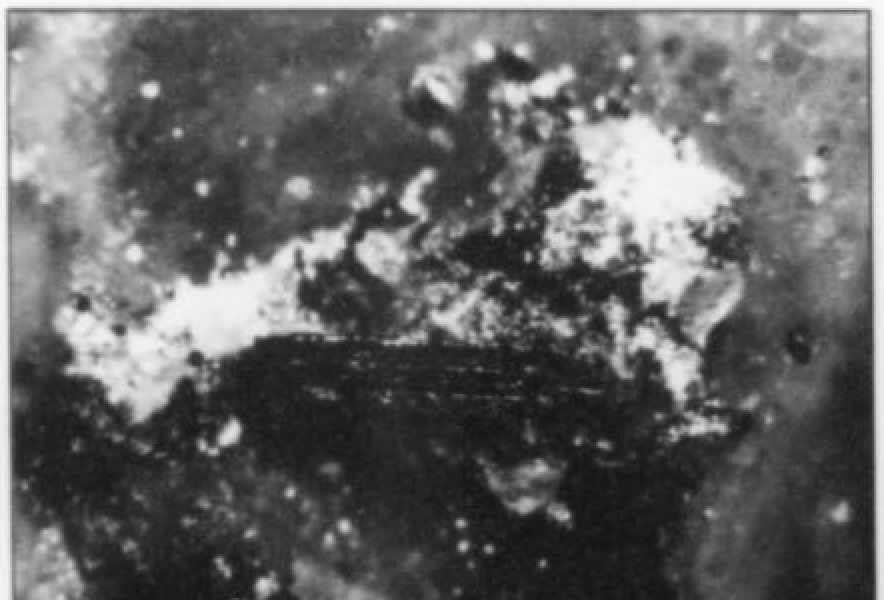


Figure 33. **Spear-shaped montroydite crystal, 0.8 mm, on native mercury. Clear Creek mine, lower workings. Gail Dunning specimen; Ted Hadley photo.**

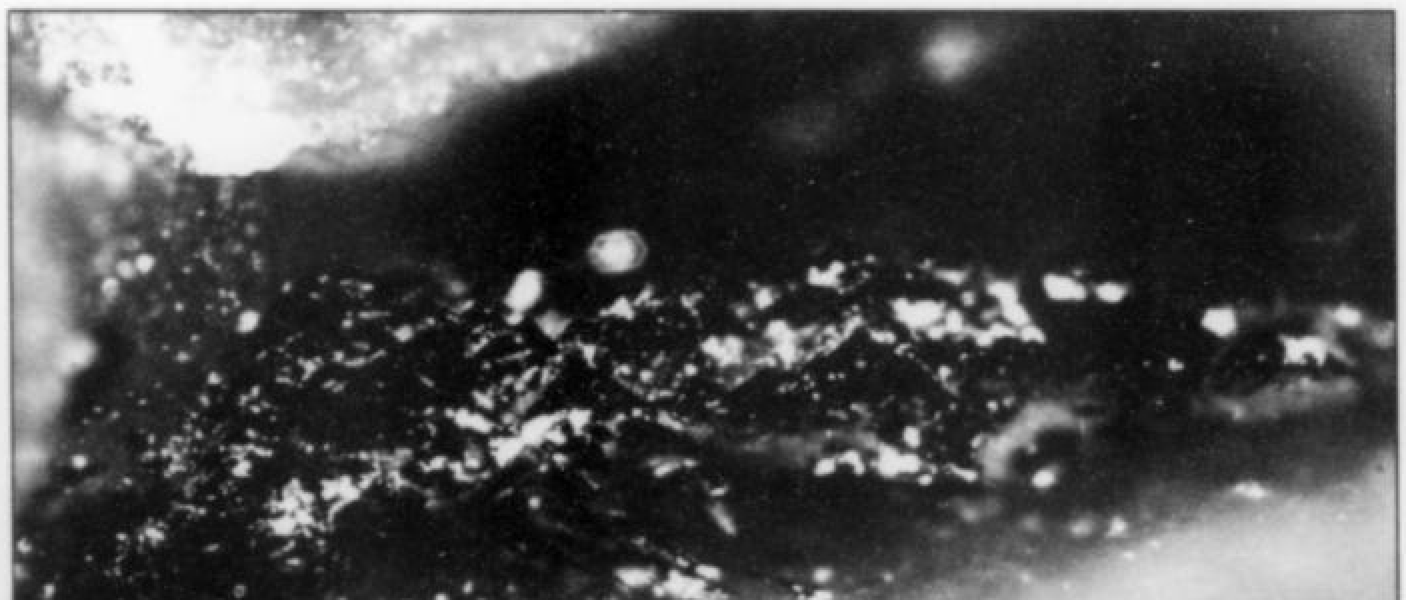


Figure 34. **Dark brown montroydite crystal, 7 mm, with silvery native mercury, from the Clear Creek mine, lower workings. Gail Dunning collection; Dan Behnke photo.**

{114} or {116}. Most crystals are complex intergrowths. Canfield (1913) observed the forms {001}, {111}, {116}, {114} and {112} on crystals from Terlingua, Texas. Bird (1932) observed {011} on crystals from Nevada. Other anions substitute readily for chloride in mosesite, as discussed by Switzer *et al.* (1953). The substitution of $Cl^- \rightarrow 1/2(SO_4)^{2-}$ gives the sulfate-dominant analog gianellaite (see above). EDS analysis of the deep red "mosesite" shows iodide prevalent over chloride and bromide. Srinath *et al.* (1951) have shown that Millons's base ($Hg_2NOH\cdot 2H_2O$) was easily converted to a series of ion-exchange compounds, including Hg_2NI. This implies that the different anion compositions of mosesite-like minerals may either reflect fluid compositions at the time of growth or subsequent ion exchange. Rouse (1975) reports additional data for mosesite which includes a supercell with $a = 28.8$ Å, a factor of 8 times larger than that of the cubic cell. There is also a second subcell with $a/12 = 2.38$ Å.

Peterbaylissite $Hg_3^{1+}(CO_3)(OH)\cdot 2H_2O$

This basic carbonate of mercury (which is chemically identical to clearcreekite) was described by Roberts *et al.* (1995) from a single sample collected by Edward H. Oyler in 1960 and later identified as a new mineral in 1985. Peterbaylissite occurs both as isolated and clustered crystals on a secondary yellow-brown crust composed of ferroan magnesite and quartz. Individual crystals range in size from 20 to 200 microns. The crystals are subhedral to euhedral, and are somewhat elongate, possessing a wedge-like shape. The mineral is opaque and black to very dark red-brown with a dark brown-black streak. Associated mercury-bearing minerals on the holotype sample are cinnabar, metacinnabar and native mercury. Roberts *et al.* (1995) state that peterbaylissite probably formed as an alteration product of pre-existing mercury minerals such as cinnabar.

Schuetteite $Hg_3^{2+}(SO_4)O_2$

A single specimen of schuetteite-bearing vein material was discovered with small individual cinnabar masses, some of which have partially been replaced with gray CCUK-14, a rare mercury silicate. Dispersed between, and sometimes surrounding these individual cinnabar masses are orange-yellow masses of microcrystalline schuetteite. The mineral's identity was confirmed by X-ray powder-diffraction methods. Bailey *et al.* (1959) have described a number of schuetteite occurrences in the western United States and give a thorough description and discussion of the origin of schuetteite.

Szymańskiite $Hg_{16}^{1+}(Ni, Mg)_6(CO_3)_{12}(OH)_{12}(H_3O)_8^{1+}\cdot 3H_2O$

Szymańskiite was described by Roberts *et al.* (1990b) from a specimen discovered at the lower workings of the Clear Creek mine. It was first encountered by Richard C. Erd during megascopic examination and routine X-ray powder-diffraction characterization of mercury-bearing minerals collected in 1972 by Mr. Oyler. Initially, the mineral was thought to be a small spray of stibnite in a tiny vug of a hand specimen composed principally of blackish chert and white, well-crystallized quartz. After part of this spray was crushed for confirmatory X-ray analysis, it was found to have a core of a clear, light sky-blue crystalline material. The mineral is surrounded but not overgrown by massive, amber edgarbaileyite, which in turn has mm-size needles of red montroydite perched on it.

Individual crystals of szymańskiite are acicular to prismatic, euhedral to subhedral. They are elongate [0001], with striations parallel to [0001] on {$10\bar{1}0$}. Forms observed are {$10\bar{1}0$} and {0001}

Szymańskiite, as sky-blue, small anhedral grains and acicular, terminated hexagonal crystals, has been recently discovered on

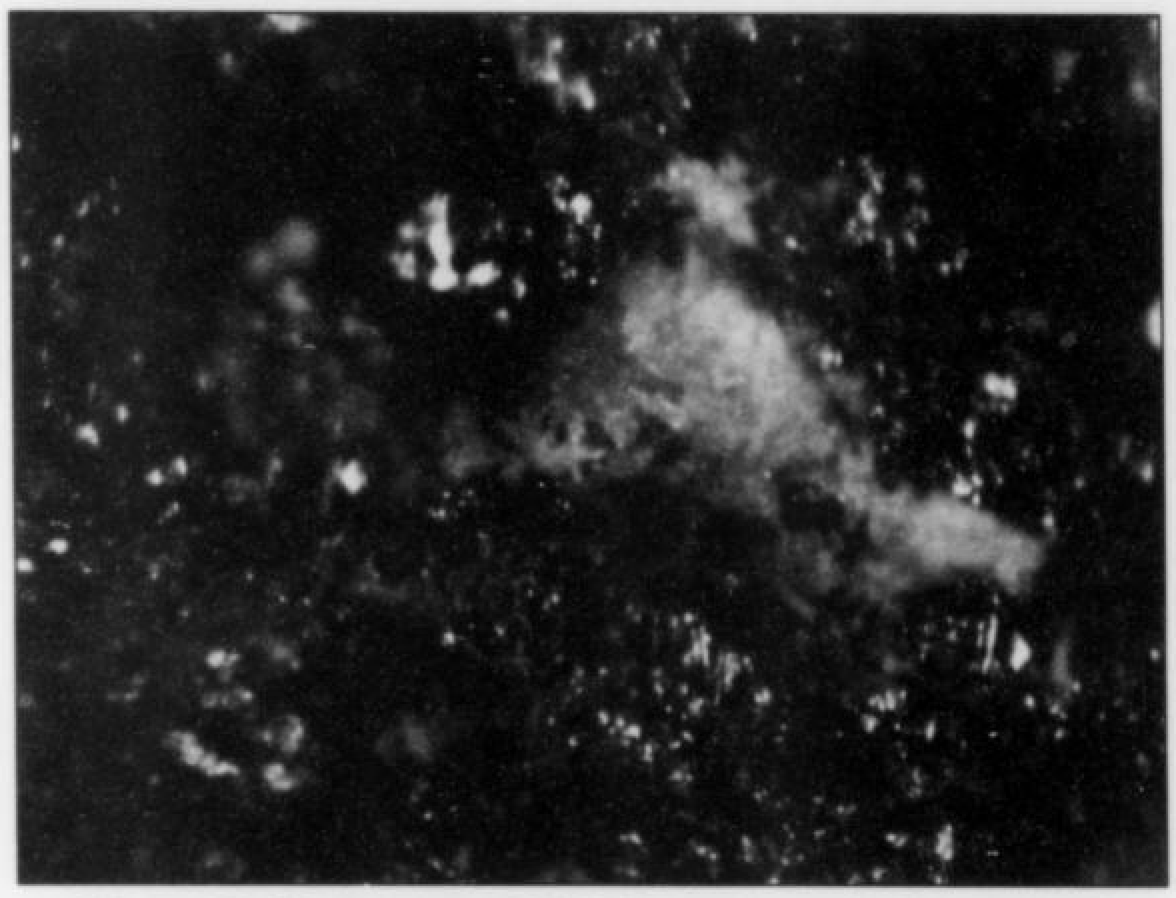


Figure 35. **Fine group of light blue szymańskiite crystals with cinnabar and native mercury. Clear Creek mine, lower workings. Crystals to 0.06 mm, 0.45 mm group. Gail Dunning specimen; Ted Hadley photo.**

Figure 36. **Striated, prismatic crystals of sky-blue szymańskiite, 5 × 100 microns, on quartz. Clear Creek mine, upper workings. Gail Dunning specimen and SEM photo.**

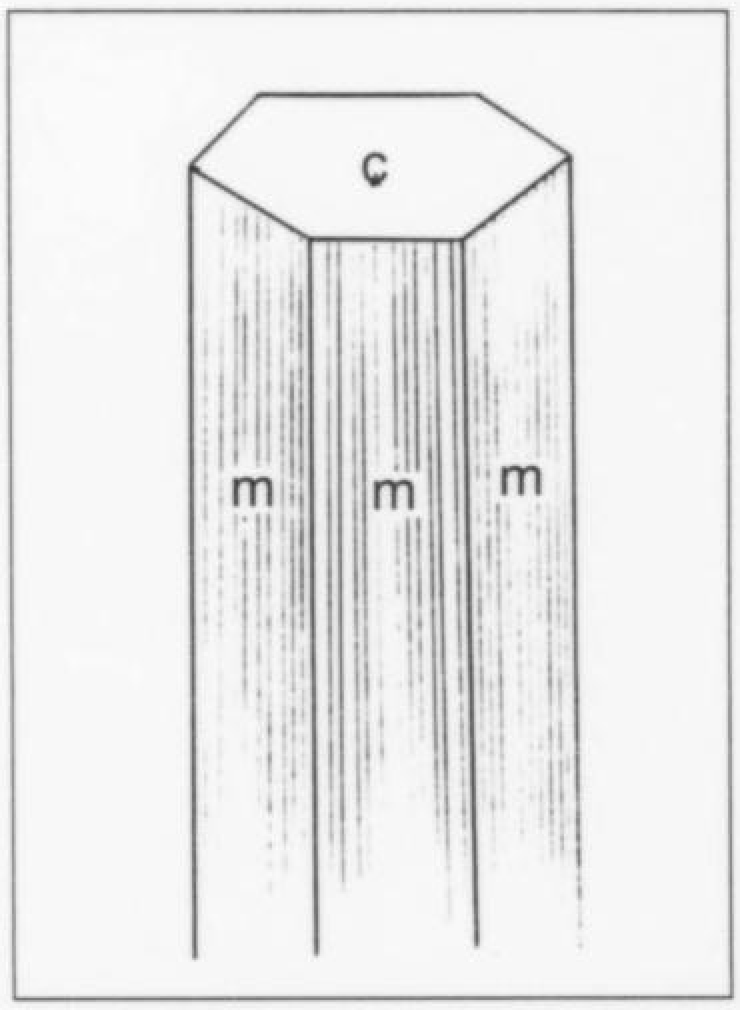


Figure 37. **Szymańskiite crystal drawing showing the first-order prism form *m*{1010} and the minor basal pinacoid *c*{0001}. The crystals are striated parallel to [0001] on {1010}.**

quartz in silicified serpentinite cavities from the upper workings, and is closely associated with native mercury, pecoraite and edgarbaileyite. A small cinnabar-lined cavity containing two crystalline masses of szymańskiite was also discovered in the lower workings in 1996.

The crystal structure of szymańskiite was solved by Szymański and Roberts (1990). The structure contains Hg^{1+} in near-linear coordination of –O-Hg-Hg-O, as well as a second chain containing Hg^{1+} atoms and trios of oxygen atoms in a face-sharing column of the form $–Hg-O_3-Hg-Hg-O_3-Hg$. The ordered part of the structure contains these mercury coordination chains, as well as (Ni,Mg)-O distorted octahedra, held together by carbonate groups. Between the clearly defined tubular walls of the structure, there are very large tunnels within which the remaining portion of the structure is disordered. The structure can be regarded as a non-silicate zeolite.

Tedhadleyite $Hg^{2+}Hg^{1+}_{10}O_4I_2(Cl_{1.2}Br_{0.8})$

Tedhadleyite, formally described by Roberts *et al.* (2002), is the first of the new mercury oxy-halide minerals rich in iodide discovered during this study. It was discovered in 1994 during a routine X-ray powder diffraction of a submitted sample containing an elongated dark brown material in a quartz cavity from the lower workings. Initial EDS showed major mercury and iodine with lesser amounts of chlorine and bromine. It is an extremely rare constituent at the Clear Creek claim and occurs as a single spheroidal hollow mass that appears to be pseudomorphous after native mercury.

A paper describing the crystal structure of tedhadleyite is in preparation. Preliminary aspects of the structure consist of strong covalently bonded O-Hg-O and O-Hg-Hg-O groups and complex slabs parallel to (010), with halogen sites midway between adjacent slabs. Square rings consisting of four $[Hg-Hg]^{2+}$ dimers are joined to four more rings via two types of linkage: O-Hg-O and O-Hg-Hg-O (Mark A. Cooper, personal communication, 2003).

Terlinguaite $Hg^{1+}Hg^{2+}OCl$

Terlinguaite is very rare in the deposit and only a few specimens have been identified. It generally occurs as dark-brown masses of subhedral crystals, although at least two euhedral, prismatic crystals have been found associated with eglestonite and montroydite in the lower workings. Under the microscope it is difficult to identify when it is mixed with montroydite.

Vasilyevite $Hg^{1+}_{20}O_6I_3(Br_{1.6}Cl_{1.4})[(CO_3)_{0.8}S_{0.2}]$

Vasilyevite is an extremely rare constituent at the Clear Creek claim and has been formally described by Roberts *et al.* (2003b). To date this somewhat inconspicuous mineral has been identified on five micromount specimens that were collected in the mid-1990's and occurs within less than 5.0 mm-sized or less quartz-lined microcavities in centermeter-sized quartz veins. The cavities containing the new mineral are typically monomineralic. In four of the micromounts, vasilyevite occurs as anhedral, almost cryptocrystalline, masses, less than 0.5 mm in size. It is silvery-gray to black to dark red-black with a red-brown streak. Outward form and color can be easily mistaken for either tedhadleyite or aurivilliusite, both of which are extremely rare constituents at the mine. It is opaque and brittle, with an adamantine to metallic luster, and is nonfluorescent.

Cooper and Hawthorne (2003) have determined the crystal structure for vasilyevite. Other mercury minerals with structures most resembling that of vasilyevite are poyarkovite, $[Hg_2]OCl$, and eglestonite, $[Hg_2]_3Cl_3O_2H$, although the additional topological complexity of vasilyevite arises from the fact that polymerization in the *c* direction involves a crankshaft configuration rather than a linear motif.

Figure 38. **Black wattersite crystals to 0.4 mm, from the Clear Creek mine, lower workings. Gail Dunning collection; Dan Behnke photo.**

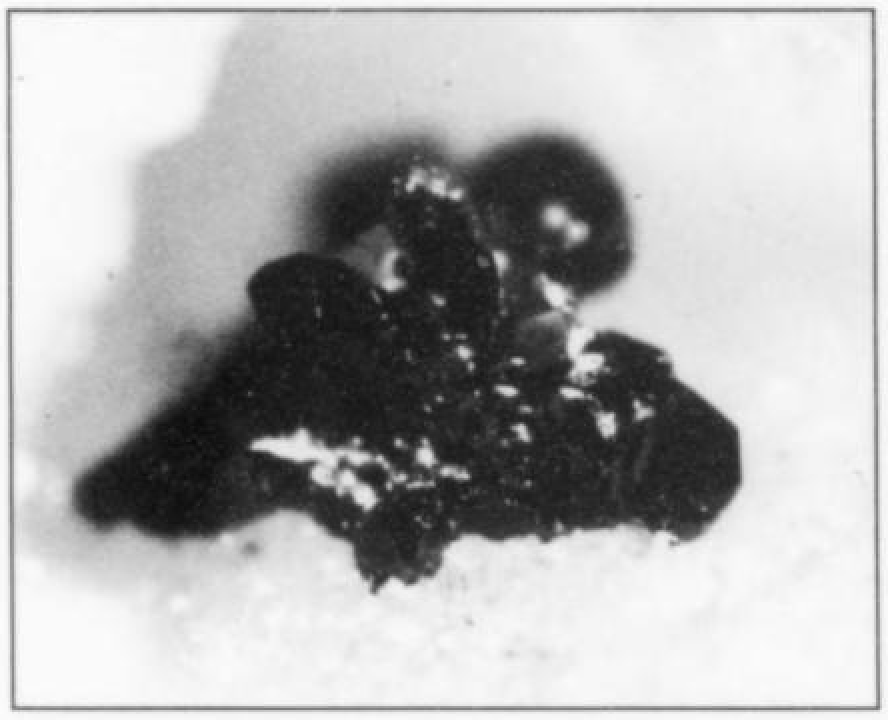


Figure 39. **Black wattersite crystals to 0.6 mm, from the Clear Creek mine, lower workings. Gail Dunning collection; Dan Behnke photo.**

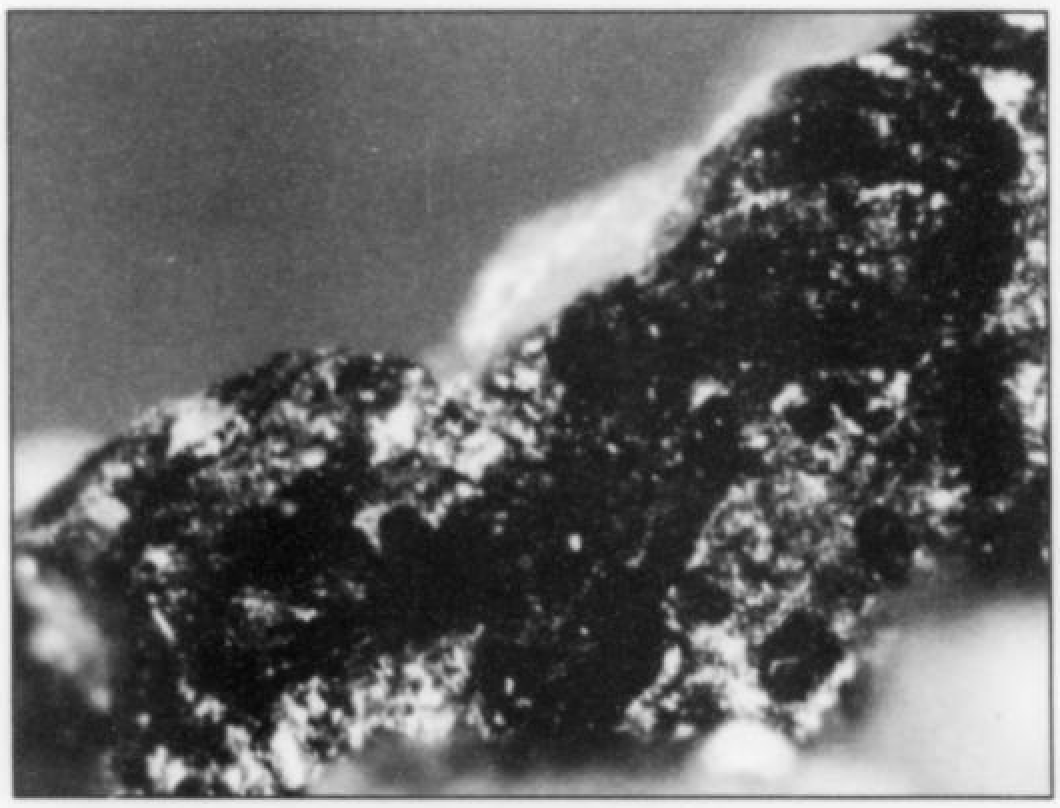


Figure 40. **Exceptional crystal group of wattersite on edgarbaileyite with native mercury from the Clear Creek mine, lower workings. Individual crystals 0.2 mm. Gail Dunning specimen; Ted Hadley photo.**

Wattersite $Hg^{1+}_4Hg^{2+}(Cr^{6+}O_4)O_2$

This mineral was identified as a new species by Richard C. Erd on specimens collected by Edward H. Oyler from the lower workings of the Clear Creek mine and formally described by

Figure 41. **Black wattersite crystal group, 0.8 mm, from the Clear Creek mine, lower workings. Gail Dunning collection; Dan Behnke photo.**

Figure 42. **Black wattersite crystal group, 1 mm, from the Clear Creek mine, lower workings. Gail Dunning collection; Dan Behnke photo.**

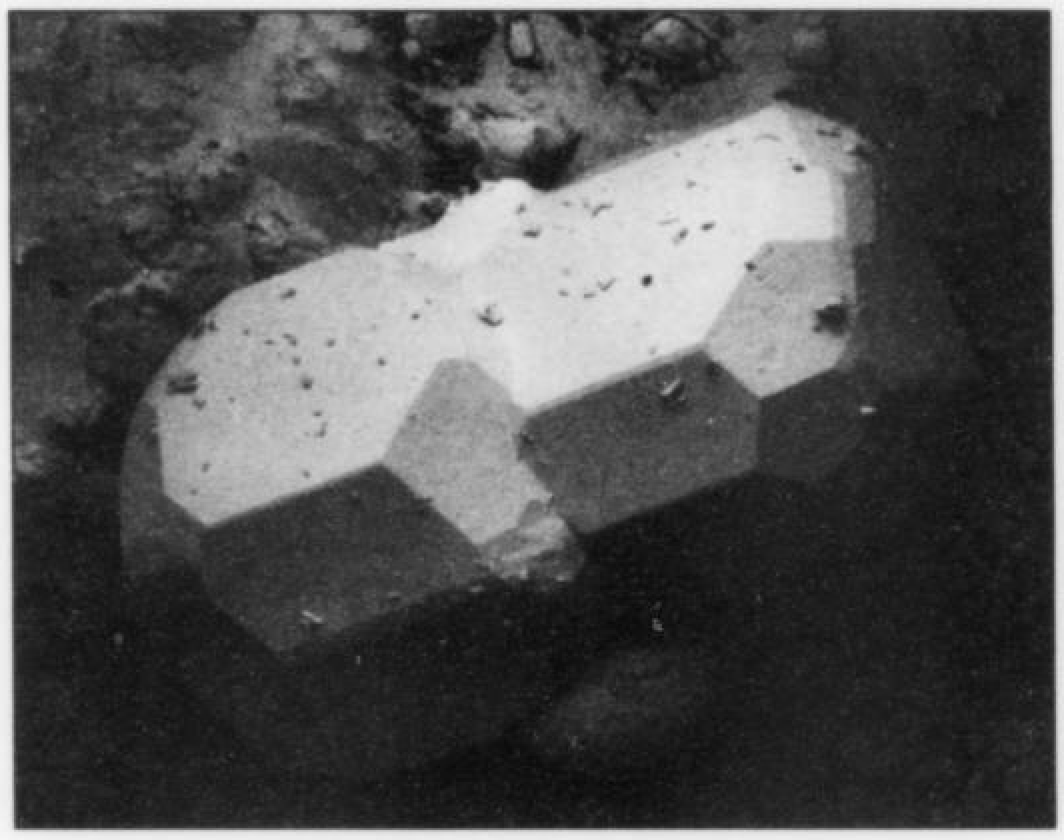


Figure 43. **Two highly modified attached crystals of wattersite on edgarbaileyite, from the Clear Creek mine, lower workings. Gail Dunning specimen and SEM photo.**

Figure 44. **A divergent group of prismatic, black wattersite crystals, to 300 microns, in quartz cavity. Clear Creek mine, lower workings. Gail Dunning specimen and SEM photo.**

Roberts *et al.* (1991). Wattersite is commonly associated with native mercury, edgarbaileyite, montroydite and eglestonite. It is one of the few minerals from the mine that is well crystallized, occurring as sharp crystals with a bright metallic luster, often as single or multiple groups. Individual crystals are dark reddish-brown, but masses tend to appear black. Deep-red internal reflections are characteristic of wattersite, especially when seen on thin edges.

Wattersite has been identified in three different forms: (1) as thin shell-like aggregates in vugs; (2) as deeply etched crystals on cinnabar, coated with CCUK-8; and (3), as small discrete crystals or crystal aggregates within cavities along mineralized quartz veins. It has been observed attached to edgarbaileyite and associated with both native mercury and montroydite, and to a lesser extent, cinnabar. Individual crystals are prismatic and elongate parallel to [001]. Twinning is common and is found as simple contact twinning on {100}. The twin axis is [001]. Roberts *et al.* (1991) reported sixteen different crystal forms for wattersite: {110}, {010}, {310}, {130}, {021}, {100}, {101}, {403}, {011}, {342}, {311}, {001}, {111}, {742}, {1i2}, and {312}.

Groat *et al.* (1995) have described the crystal structure of wattersite. The structure may be visualized as consisting of edge-sharing Hg octahedra with projecting CrO_4 tetrahedra forming zigzag infinite chains of composition $[HgCrO_6]^{6-}$ that extend parallel to [001]. These chains are linked by O-Hg bonds to the Hg-Hg dimers, which form gently modulated sheets parallel to (100).

Wattersite also has been identified from the Challenge deposit, near Emerald Lake, southwest of Redwood City, San Mateo County, California (R. C. Erd, personal communication, 1997).

CCUK–8 Hg^{2+}-CrO_4-S-nH_2O ?

CCUK-8, a new, undescribed hydrous mercury chromate-sulfide, occurs as powdery lemon-yellow massive crusts or as micron-

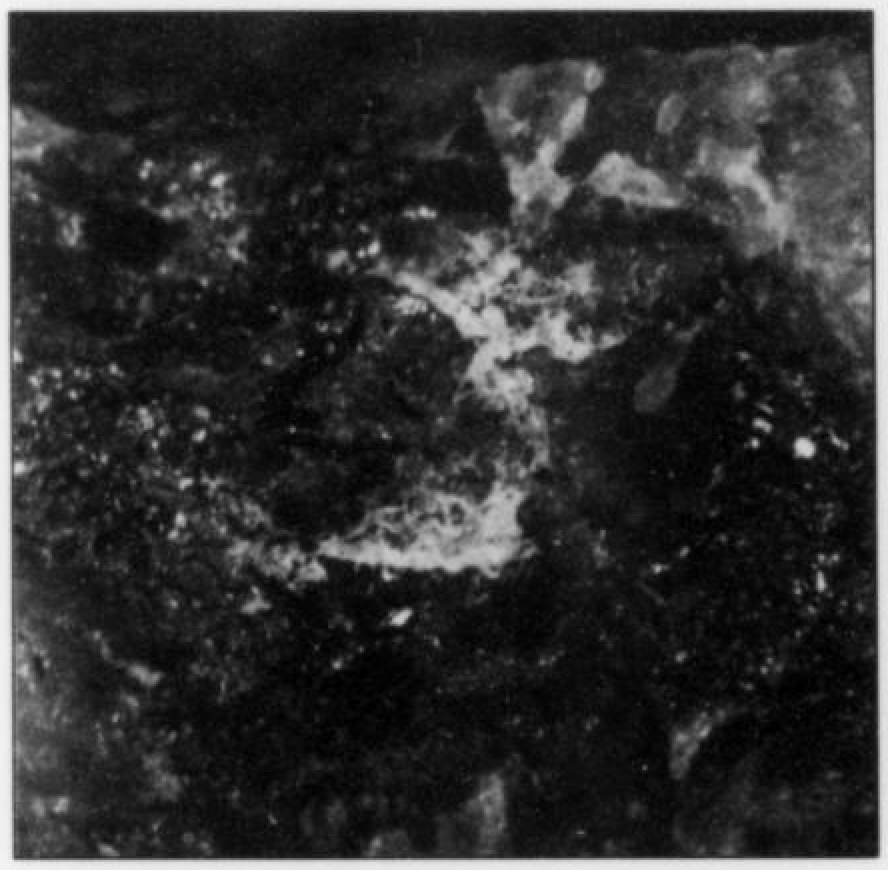


Figure 45. **Yellow microcrystals of CCUK-8 on cinnabar, Clear Creek mine, upper workings. Field of view 1.8 mm wide. Ted Hadley specimen and photo.**

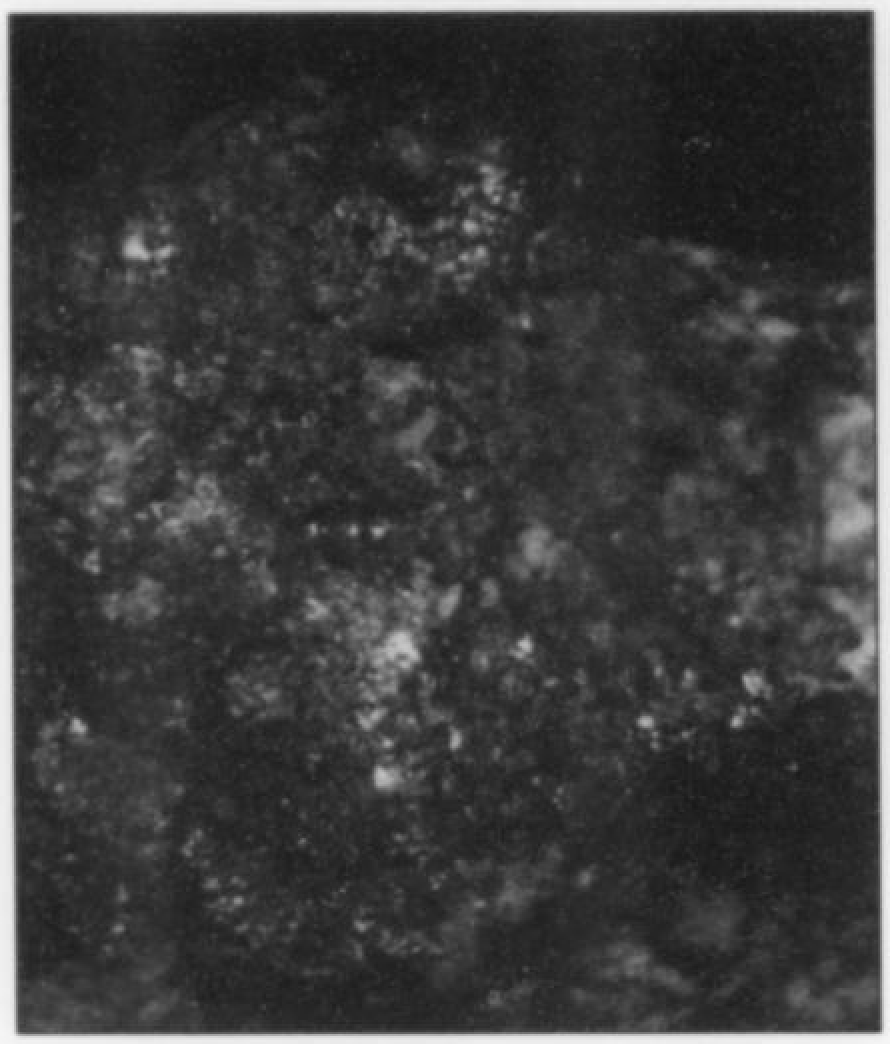


Figure 46. **Yellow microcrystals of CCUK-8 with yellow-orange edoylerite on cinnabar. Clear Creek mine, upper workings. Field of view 2 mm. Ted Hadley specimen and photo.**

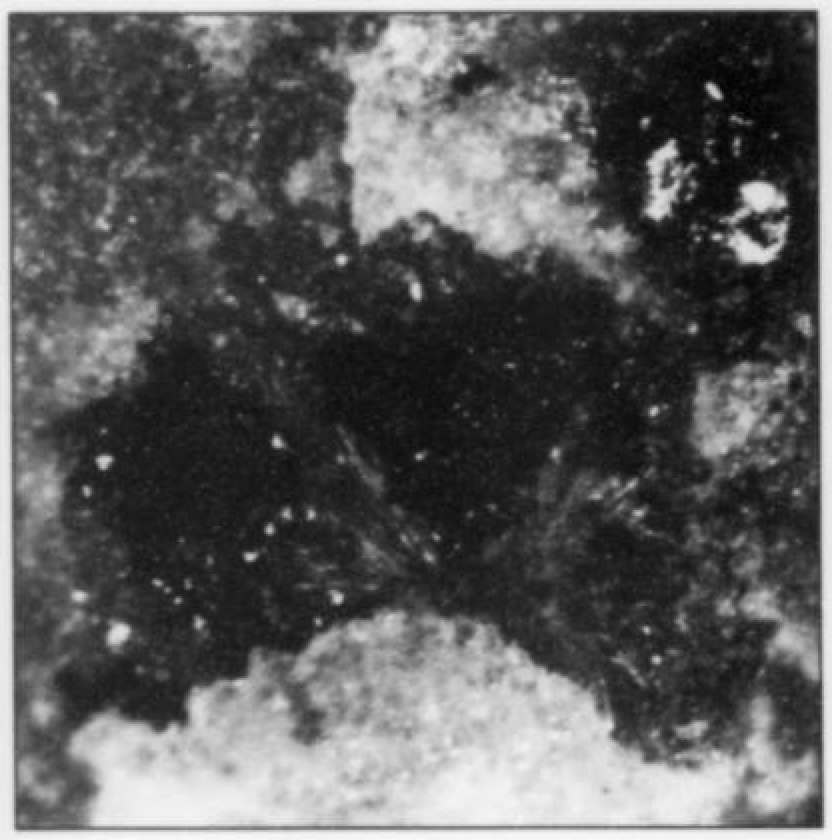


Figure 48. **Orange acicular crystals of CCUK-10 with black edgarbaileyite, 0.55 mm long on quartz. Clear Creek mine, lower workings. Gail Dunning specimen; Ted Hadley photo.**

Figure 49. **Yellow acicular crystals of CCUK-10, 0.4 mm in length with dark red iodine-rich mosesite (CCUK-18) on quartz. Clear Creek mine, lower workings. Gail Dunning specimen; Ted Hadley photo.**

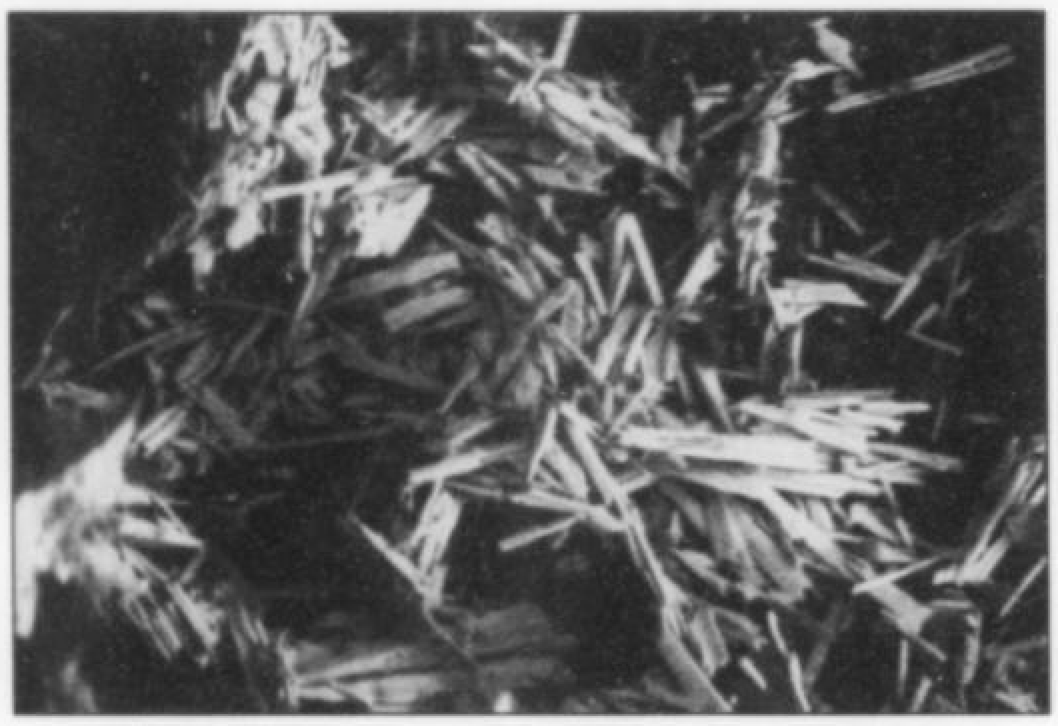


Figure 47. **Yellow acicular crystals of CCUK-8 on cinnabar, up to 200 microns long. Clear Creek mine, upper workings. Gail Dunning specimen and SEM photo.**

sized, prismatic crystalline aggregates and masses. Poorly developed subhedral to euhedral crystals, up to 0.1 mm long and less than 1 micron in cross section, have recently been found associated with cinnabar from the upper workings of the Clear Creek mine. Some of the larger crystals appear turbid, suggesting partial dehydration. The luster of the fine hair-like crystals is always dull. The mineral is often associated with edoylerite and dull (etched) cinnabar. It also has been found in association with etched wattersite at the upper workings. CCUK-8 seems to be one of the last mercury minerals to have formed during the chromate-rich hydrothermal event. The majority of CCUK-8 at the Clear Creek mine is probably of the dehydrated variety.

This mineral also has been identified from the Vaughn mine, east of Hollister, San Benito County, California, where it occurs associated with cinnabar in a hydrothermally altered serpentinite (R. C. Erd, personal communication, 1997).

CCUK–10 Hg-N-I-(Cl, Br)

This very rare mercury nitrogen-halide mineral was initially discovered by the late John L. Parnau (1906–1990) in the 1960's following field collecting from the lower workings. Unfortunately, this specimen was never submitted for identification but has been preserved in a private collection. During 1993, our collecting efforts revealed additional samples from a quartz vein in float rock, situated about 10 meters west of the original edoylerite discovery at the lower workings. This mineral is almost always associated with CCUK-18, the iodine analog of mosesite, but postdates it. It varies from bright yellow through various shades of yellow-orange to dark red-orange. The mineral has orthorhombic symmetry and a very large cell volume. It is found both as simple terminated crystals with an acicular radiating habit filling the spaces between clear quartz crystals and as fine acicular, slightly flattened crystals lining voids in massive quartz. Initial X-ray crystal structure data suggest that the mineral possesses a very complex structure.

CCUK–12 Hg-O-I-(Cl, Br)

This very rare mercury-bearing oxy-halide, designated CCUK-12, was collected in 1994 from the lower workings. It occurs as pale green, spear-shaped crystals associated with montroydite on a single specimen. Since insufficient material is available for complete characterization, no further work has been attempted on it as yet. Its X-ray powder-diffraction pattern does not match any mercury-bearing phase known to date; the structure is c-centered monoclinic. Preliminary EDS tests confirm the presence of iodine, chlorine and bromine.

CCUK–13 Hg silicate

A light pink unknown silicate of mercury has been observed as a microcrystalline coating (or replacement) on cinnabar associated with edgarbaileyite and montroydite from the lower workings. On one sample, it is coated by schuetteite. The cinnabar associated with CCUK-13 shows the effects of etching by low-pH hydrothermal fluids. A preliminary EDS analysis, using a light-element detector, shows only mercury, silicon and oxygen. The X-ray diffraction-pattern does not match that of any mercury-bearing phase known to date. Only a few specimens are known.

CCUK–14 Hg silicate

A second unknown silicate of mercury was recently discovered as a thin gray film replacing cinnabar and rarely coating CCUK-8 on cinnabar at the lower workings. On one specimen it is closely associated with schuetteite. It also has been identified at the Picacho mine, about 3.5 km to the south, replacing cinnabar on a single quartz specimen. The X-ray diffraction-patterns for both

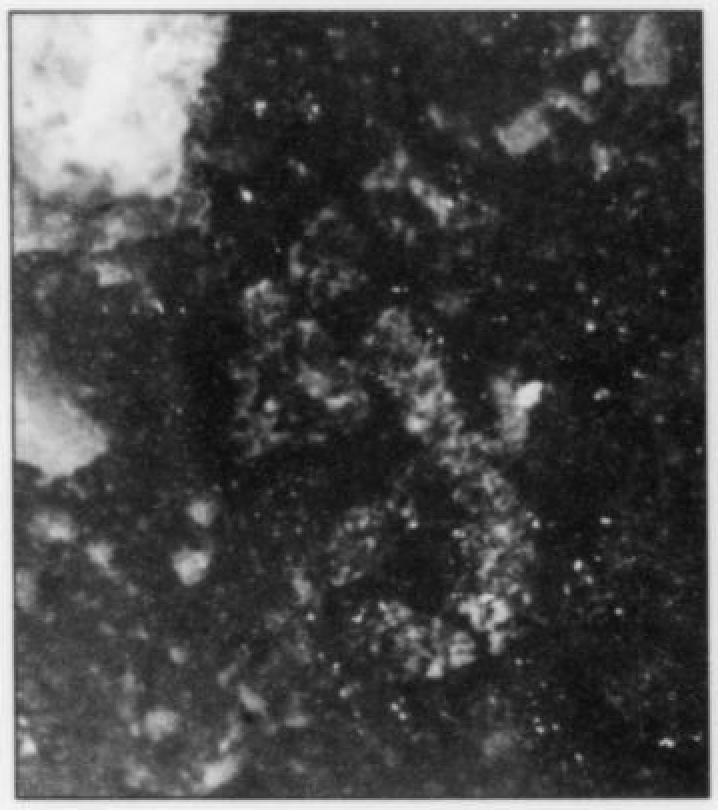


Figure 50. **Pale pink coating of CCUK-13 on cinnabar, 0.57 mm × 1.2 mm central area. Clear Creek mine, lower workings. Gail Dunning specimen; Ted Hadley photo.**

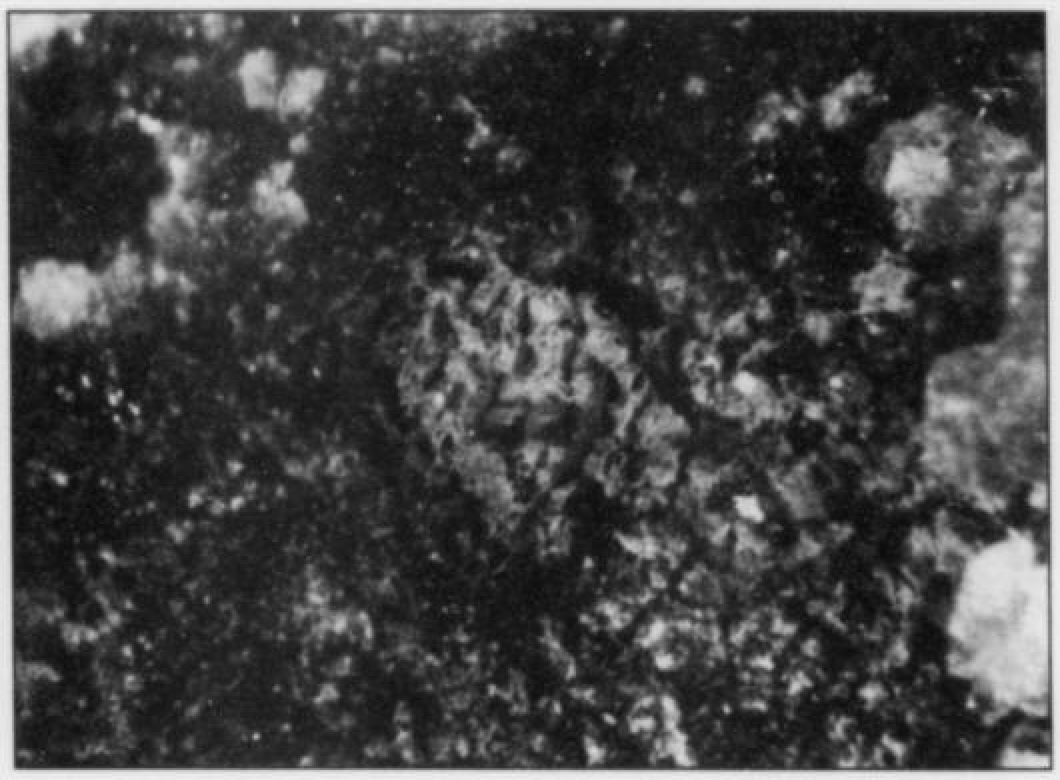


Figure 51. **Gray coating of CCUK-14 on cinnabar, 0.6 mm area. Clear Creek mine, lower workings. Gail Dunning specimen; Ted Hadley photo.**

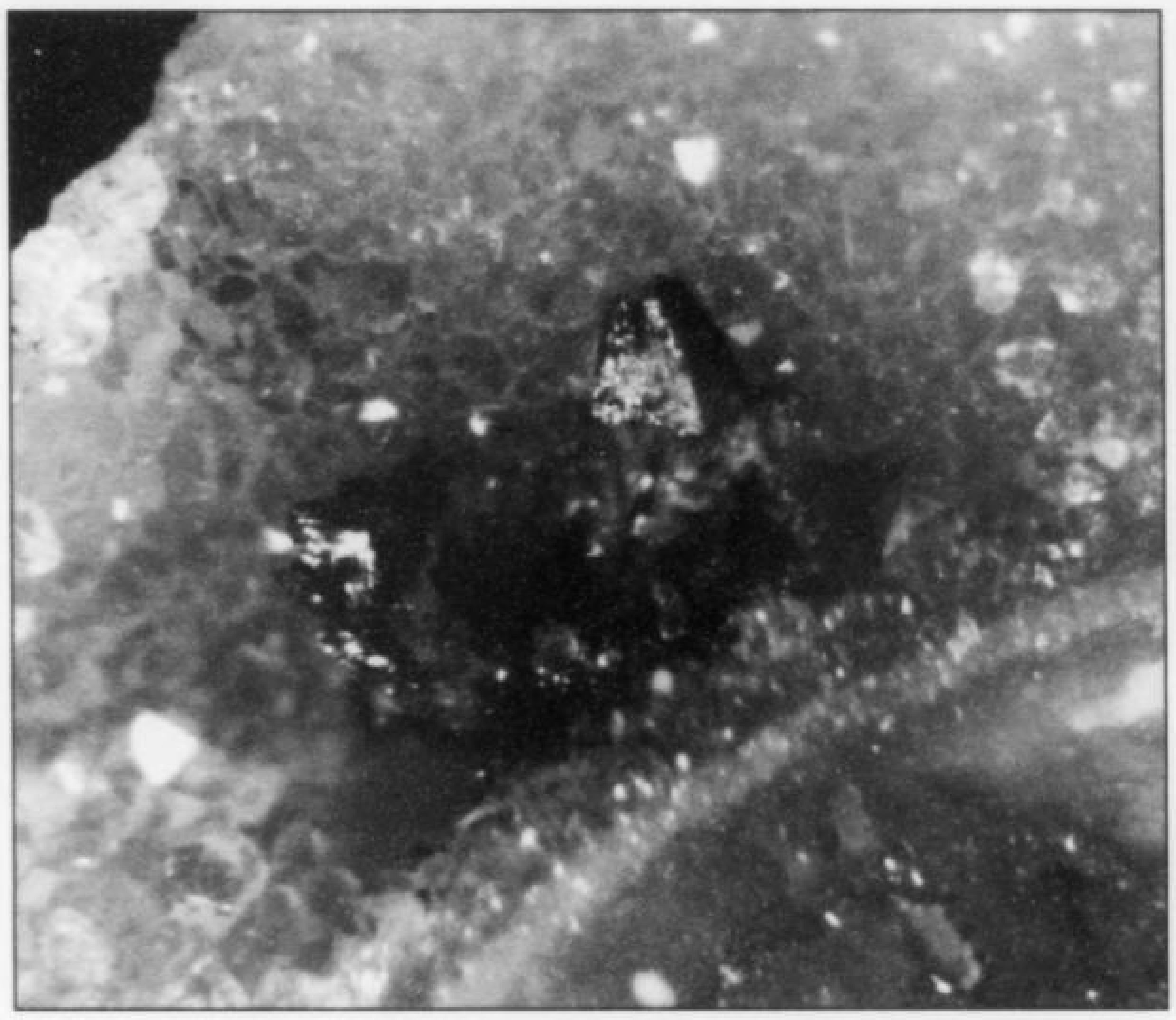


Figure 52. **Cavernous, red crystals of iodine-rich mosesite (CCUK-18) on quartz, 1.8 mm group. Clear Creek mine, lower workings. Gail Dunning specimen; Ted Hadley photo.**

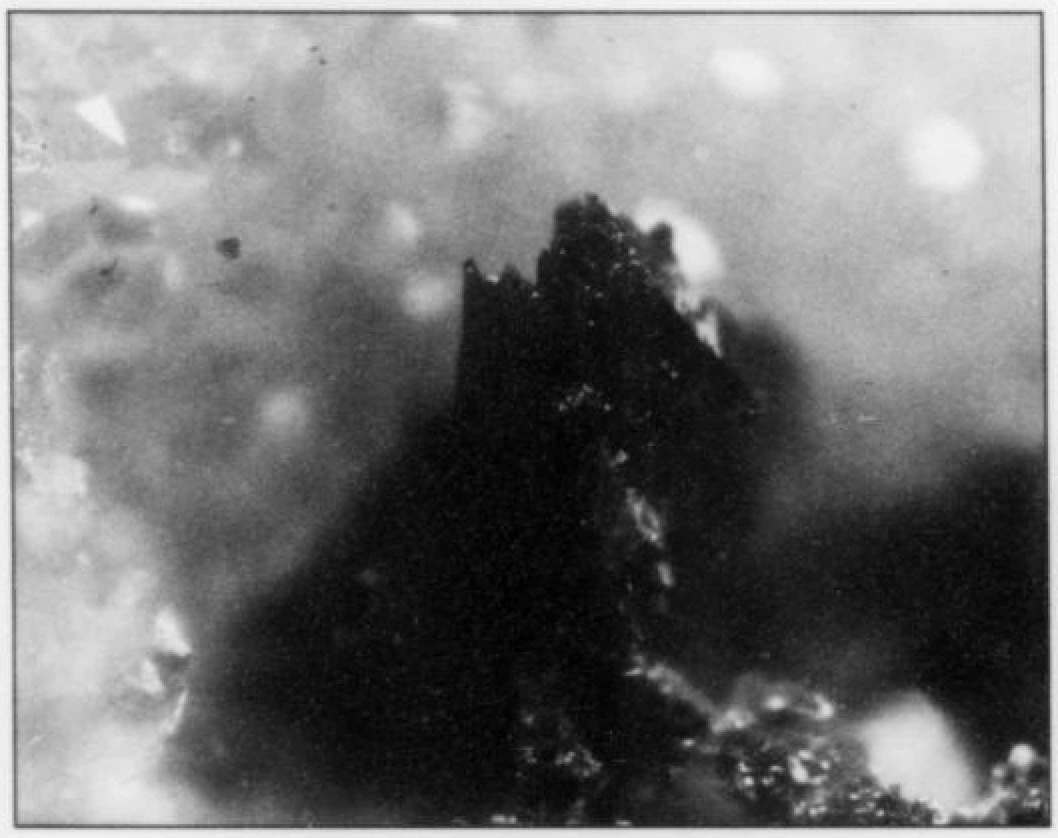


Figure 53. **Red crystals of iodine-rich mosesite (CCUK-18) to 0.7 mm on quartz, from the Clear Creek mine, lower workings. Gail Dunning specimen; Dan Behnke photo.**

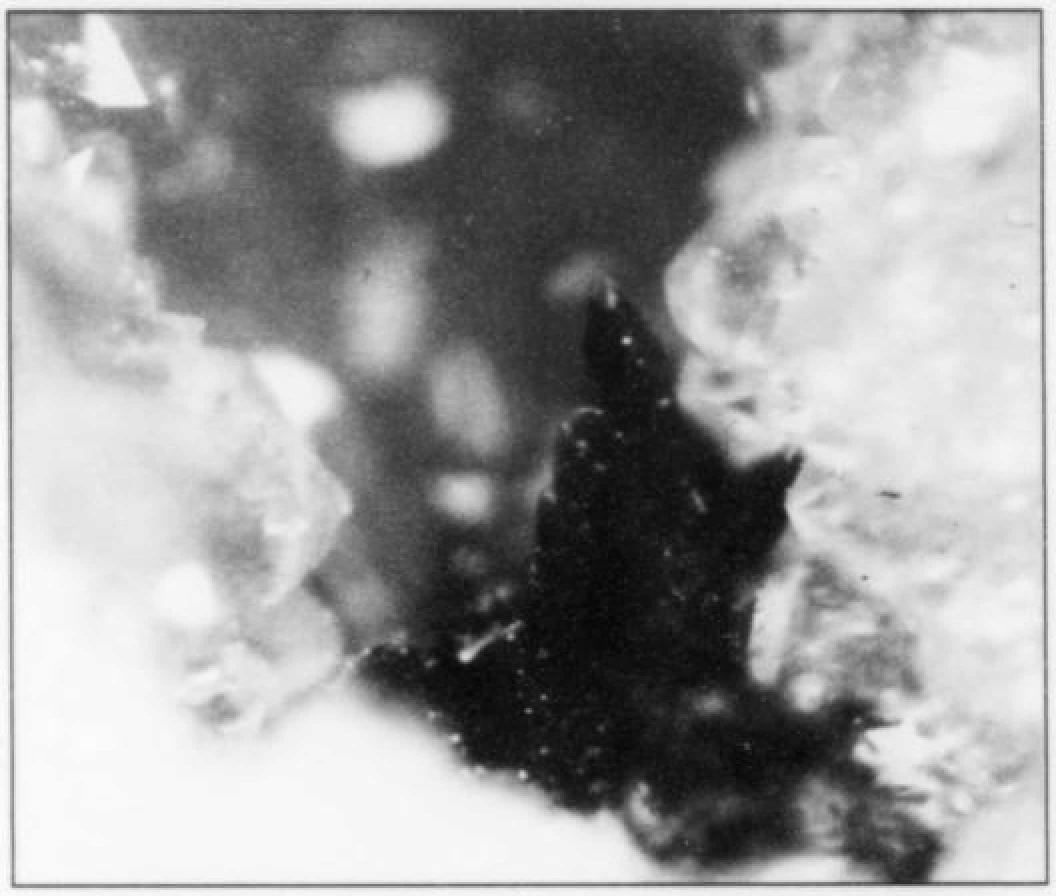


Figure 54. **Red crystals of iodine-rich mosesite (CCUK-18) to 0.3 mm on quartz, from the Clear Creek mine, lower workings. Gail Dunning specimen; Dan Behnke photo.**

localities are identical and match no mercury-bearing phase known to date. No crystals so far have been discovered. A preliminary EDS analysis indicated only mercury, silicon and oxygen. Only a few specimens are known. The extremely fine-grained nature of the mineral precludes any attempt to further characterize it at this time.

CCUK–15 $Hg^{1+}_{10}Hg^{2+}_{3}O_6I_2(Cl, Br)_2$

This very rare mercury oxy-halide was discovered as an inclusion during the X-ray powder diffraction study of the now approved mineral, aurivilliusite (Roberts *et al.*, 2003a). Both minerals are closely associated with native mercury, cinnabar and edgarbaileyite on quartz. CCUK-15 is megascopically indistinguishable from aurivilliusite, tedhadleyite, and vasilyevite. In general, CCUK-15 most closely resembles a metallic sulfide or sulphosalt in appearance. It is opaque with a metallic luster, brittle, has an uneven fracture and is non-fluorescent under both long- and short-wave ultraviolet light. The provisional formula is based on quantitative electron-microprobe analyses.

CCUK-18 $Hg^{2+}_{2}N(I, Cl, Br)\cdot H_2O$

This unknown has the X-ray powder diffraction pattern closely resembling mosesite but chemically is rich in I by EDS. It is generally found closely associated with CCUK-10 or isolated on the surfaces of quartz seams. Divergent deep red crystal groups that show a growth habit along one axis have been observed in quartz cavities. Initial X-ray diffraction patterns attempted during

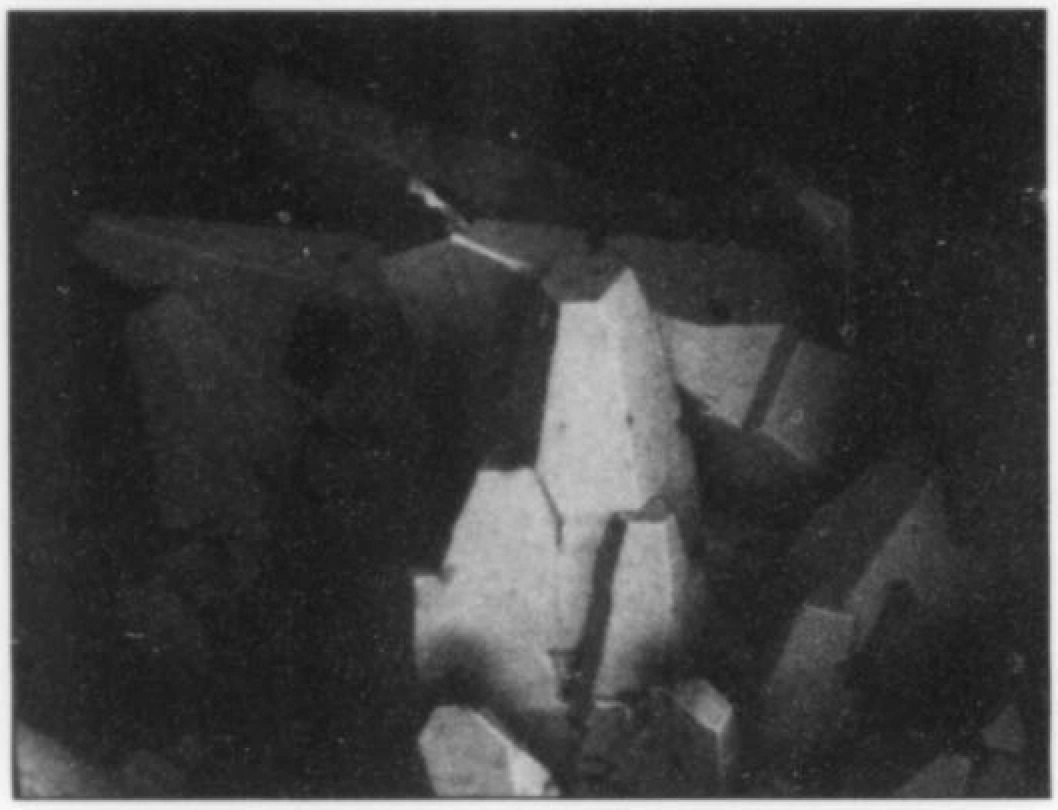


Figure 55. **Deep-red iodine-rich mosesite crystals (CCUK-18), to 50 microns long, showing an unusual pyramidal habit with the forms {114} or {116} and the {100} basal pinacoid; Clear Creek mine, lower workings. Gail Dunning specimen and SEM photo.**

structure work showed severe streaking, indicative of inhomogeneous strain of the structure and/or short-range ordering, presumably due to the large size of the I atom. Annealing of the sample with increasing temperatures failed to improve the diffraction pattern.

Associated Minerals

The majority of the accessory minerals were identified by Richard C. Erd using powder-diffraction and optical methods during the years prior to our involvement in the study of the Clear Creek mine.

Barite $BaSO_4$

Rare crystals of barite were found associated with cinnabar at the lower workings. The barite seems to be of late-stage origin.

Calcite $CaCO_3$

Calcite has been identified by powder-diffraction methods from the silica-carbonate host rock of the Clear Creek mine.

Dolomite $CaMg(CO_3)_2$

Dolomite is a common constituent of the silica-carbonate rock at the Clear Creek mine.

Eskolaite Cr_2O_3

Eskolaite occurs as massive green alteration halos around magnesiochromite grains in the silicified serpentinite rock margins with the silica-filled fractures. No crystals have been noted.

Goethite $FeO(OH)$

Minute spherical groups of goethite have been identified from the lower workings.

Gypsum $CaSO_4 \cdot 2H_2O$

Small amounts of gypsum associated with huntite have been identified in the silica-carbonate rock of the Clear Creek mine.

Hematite Fe_2O_3

Rare hematite pseudomorphs after pyrite occur on quartz from the lower workings. The interpenetrating cubes are coated with both massive and crystals of cinnabar, indicating their position in the paragenesis.

Huntite $CaMg_3(CO_3)_4$

Huntite has been identified on magnesite from the Clear Creek mine associated with gypsum.

Hydromagnesite $Mg_5(CO_3)_4(OH)_2 \cdot 4H_2O$

Hydromagnesite is a common constituent of the serpentinite surrounding the mercury-mineralized silica-carbonate rock.

Jarosite $K_2Fe_6(SO_4)_4(OH)_{12}$

Massive coatings of yellowish-brown jarosite have been identified from the lower workings by XRD. The mineral is not common and is confined to those rocks that are in the more acid environment.

Magnesiochromite $(Mg,Fe)Cr_2O_4$

Ferroan magnesiochromite is common both as anhedral masses and as octahedral crystals in the serpentinite. It is jet black and occasionally weakly magnetic. Many of the grains have been tectonically fractured and filled with cinnabar, but no visible reaction rims have been identified. Hydrothermal fluids have altered the mineral to eskolaite, which, upon further oxidation, has provided the chromate that formed the rare mercury-bearing chromates.

Magnesite $(Mg,Fe)CO_3$

Ferroan magnesite occurs abundantly as white to light-brown porcelainous masses above the upper workings on the ridge and also as a major constituent of the silica-carbonate rock in the area.

Magnetite Fe_3O_4

Some pyrite grains in silicified serpentinite matrix were observed to be rimmed or replaced by a black submetallic mineral. EDS analysis confirmed the sulfide as pyrite, and the black mineral to be an Fe oxide devoid of Mg or Cr. The black mineral was magnetic. Magnetite was presumably formed as an early product of pyrite oxidation, and the hematite pseudomorphs also observed may have been produced by further oxidation of precursor magnetite.

Melanophlogite SiO_2 + stabilizing gas molecules

Melanophlogite is a clathrate polymorph of silica stabilized by molecules of gases such as N_2, CO_2 and CH_4 (Nakagawa *et al.*, 2001) trapped within the crystal structure. It has been identified only from float boulders in the open cut of the upper workings (Dunning and Cooper, 2002). It occurs both as clear brilliant cubes and as small barrel-shaped aggregates pseudomorphic after an unknown mineral. It occurs principally coating open spaces in silicified serpentinite. No modifying forms have been identified so far. The crystals range in size up to 1 mm along an edge, and interpenetrating growths are common, although they are not as common as at other California localities. The mineral has partly inverted to chalcedony. Several small specimens have been recovered from rocks in the bottom of the open cut.

Millerite NiS

Millerite is ubiquitous but rare in the area and occurs as capillary crystals in quartz.

Montmorillonite $(Na,Ca)_{0.3}(Al,Mg)_2Si_4O_{10}(OH)_2 \cdot nH_2O$

Fine-grained montmorillonite has been identified by XRD from both the upper and lower workings.

Nimite $(Ni,Mg,Fe)_5Al(Si_3Al)O_{10}(OH)_8$

Nimite, a nickel chlorite, has been identified in the silica-carbonate rocks of the Clear Creek mine.

Opal $SiO_2 \cdot nH_2O$

Opal occurs as vein-filling masses throughout the deposit, especially in the upper workings.

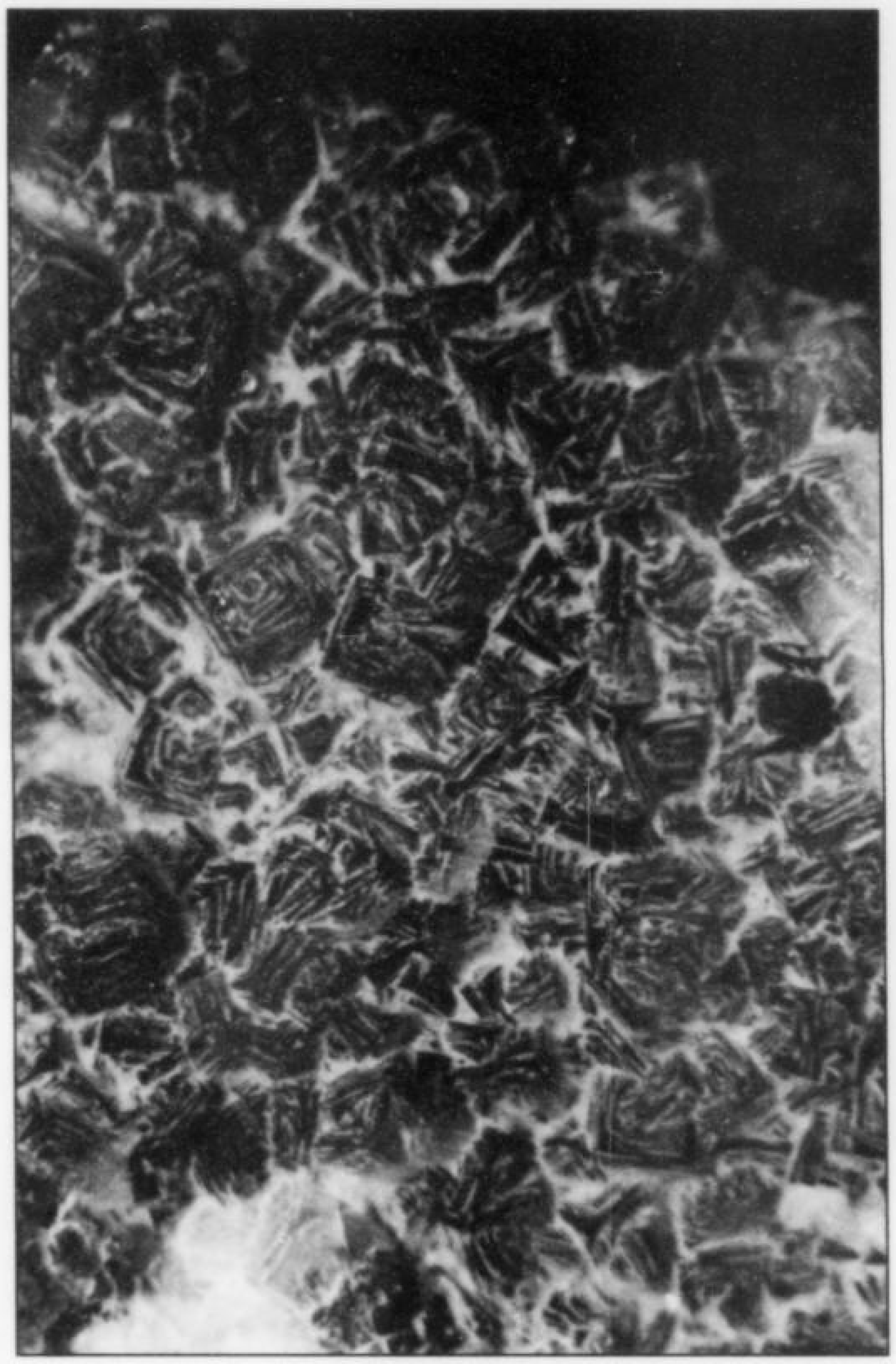


Figure 56. **Surface coating of interpenetrating cubes of melanophlogite on cinnabar. 9 mm field of view, 0.6 mm crystals. Clear Creek mine, upper workings. Ted Hadley specimen and photo.**

Pecoraite $(Ni,Mg)_3Si_2O_5(OH)_4$

Light apple-green spheroidal masses and minute spear-shaped crystals of pecoraite occur sparingly in the upper and lower workings, usually attached to quartz or cinnabar. It is generally associated with native mercury, edgarbaileyite and szymańskiite, and apparently formed by alteration of Ni-bearing sulfides (millerite and donharrisite), with which it is closely associated.

Pyrite FeS_2

Pyrite is an uncommon mineral in the mine and occurs as tiny octahedrons, cubes and masses in veins of quartz. Hematite pseudomorphs after cubes of pyrite coated with cinnabar occur very rarely. It has been very rarely seen replacing magnetite in the silicified serpentinite.

Quartz SiO_2

Quartz occurs as tiny vein-filling crystals, crystalline aggregates and chalcedonic masses. Some brown-white color-banded chalcedony has been found in the upper workings, as well as green botryoids with cinnabar inclusions which may be pseudomorphs after melanophlogite. The vein fillings are always small, and display several separate depositional episodes. The massive material is often pale-green and is highly fractured, with very thin layers of cinnabar lining fracture surfaces.

Reevesite $Ni_6Fe_2(CO_3)(OH)_{16}\cdot 4H_2O$

Light yellowish-green flakes of reevesite occur within the serpentinite adjoining the silica-carbonate rock of the Clear Creek mine.

Rozenite $FeSO_4\cdot 4H_2O$

White coatings of rare rozenite on cinnabar have been identified from the lower workings by XRD.

Sepiolite $Mg_4Si_6O_{15}(OH)_2\cdot 6H_2O$

Fine-grained, off-white sepiolite has been identified from much of the silica carbonate rock at the lower workings. It was identified by XRD.

Sulfur S

Rare massive sulfur has been identified in cavities of the mercury-bearing samples. It is associated with cinnabar only from the lower workings.

Talc $Mg_3Si_4O_{10}(OH)_2$

Talc has been identified by XRD from the silica carbonate rocks of the lower workings.

Todorokite $(Mn,Ca,Mg)Mn_3O_7\cdot H_2O$

Black coatings of todorokite are common throughout the silica carbonate rocks at the upper and lower workings. It was identified by XRD.

PARAGENESIS

Post-Serpentinite Mercury Mineralization

The mercury deposits of the Clear Creek area occur in altered rocks that are clearly related to the New Idria serpentinite intrusive. These rocks were formed at depth by direct replacement of serpentinite at low temperature and high pressure by silica- and carbonate-rich hydrothermal fluids (Barnes *et al.*, 1973) and were probably derived from silica in the lower marine sediments heated by Miocene-Pliocene-aged volcanics of the southern Diablo Range.

The silica-carbonate rocks contain variable amounts of coarsely crystalline quartz and its varietal forms, chalcedony and opal, with associated carbonate minerals (magnesite, dolomite, ankerite and calcite) and abundant microcrystals and grains of ferroan magnesiochromite and magnetite. The latter minerals formed within the serpentinite and remained in place during silicification of the host serpentinite. Initial mercury mineralization, in the form of cinnabar and perhaps minor native mercury, was confined to fracture networks within the silica-carbonate rock and along the softer contact margins of the partly altered serpentinite on either side of the highly silicified zone.

The main orebody of the Clear Creek mine (upper workings) consists of a partly silicified (opalized) green serpentinite composed of highly fractured meter-sized or larger blocks which contain thin veins of cinnabar associated with native mercury. Because of the low degree of silicification, the Hg-bearing fluids easily migrated along the shear planes of the opalized serpentinite, depositing the cinnabar and minor native mercury. Subsequent to this initial mineralization, small amounts of montroydite, eglestonite, wattersite, deanesmithite, edoylerite, edgarbaileyite, CCUK-8, and szymańskiite formed.

Although much smaller in size, the middle workings have exposed rocks very similar to those at the upper workings. Here, the opalized serpentinite rocks contain thin coatings and veins of cinnabar with isolated native mercury and small quantities of eglestonite and edgarbaileyite.

At the lower workings, the degree of silicification is much greater and consists of quartz interlayered with both ferroan magnesite and thin veins of opalized serpentinite. The silica-carbonate rock is characterized by a complex, highly developed fracture system. Cross fracturing is very common, with the fractures generally less than 10 mm wide. These fractures contain

***Table 1.* Minerals identified from the Clear Creek mine.**

Mineral	*Composition*	*Rarity*	*Location*
Mercury Minerals			
Aurivilliusite	$Hg^{1+}Hg^{2+}OI$	VR	L
Calomel	$Hg_2^{1+}Cl_2$	VR	L
Cinnabar	HgS	C	U, M, L
Clearcreekite	$Hg_3^{1+}(CO_3)(OH)\cdot 2H_2O$	VR	L
Deanesmithite	$Hg_2^{1+}Hg_3^{2+}(CrO_4)OS_2$	VR	U, L
Donharrisite	$Ni_8Hg_3S_9$	VR	L
Edgarbaileyite	$Hg_6^{1+}(Si_2O_7)$	Unc	U, M, L
Edoylerite	$Hg_3^{2+}(CrO_4)S_2$	Unc	U, L
Eglestonite	$Hg_6^{1+}Cl_3O(OH)$	Unc	U, M, L
Gianellaite	$Hg^{2+}{}_4N_2(SO_4)$	VR	L
Hanawaltite	$Hg_6^{1+}Hg^{2+}[Cl,(OH)]_2O_3$	VR	L
Metacinnabar	HgS	R	L
Montroydite	HgO	C	U, M, L
Mosesite	$Hg_2^{2+}N(Cl,I,Br)\cdot H_2O$	VR	L
Mercury	Hg	C	U, M, L
Peterbaylissite	$Hg_3^{1+}(CO_3)(OH)\cdot 2H_2O$	VR	L
Schuetteite	$Hg_3^{2+}(SO_4)O_2$	VR	L
Szymańskiite	$Hg_{16}^{1+}(Ni,Mg)_6(CO_3)_{12}(OH)_{12}(H_3O)_8^{1+}\cdot 3H_2O$	VR	U, L
Tedhadleyite	$Hg_{10}^{1+}Hg^{2+}O_4I_2(Cl_{1.2}Br_{0.8})$	VR	L
Terlinguaite	$Hg^{1+}Hg^{2+}OCl$	R	L
Vasilyevite	$Hg_{20}^{1+}I_3O_6(Br_{1.6}Cl_{1.4})_{\Sigma=3}[(CO_3)_{0.8}S^{2-}{}_{0.2}]$	VR	L
Wattersite	$Hg_4^{1+}Hg^{2+}(CrO_4)O_2$	Unc	U, L
CCUK -8	Hydrous mercury chromate-sulfide	Unc	U, L
CCUK -10	Hg-N-I-(Cl, Br)	VR	L
CCUK -12	Mercury oxy-halide	VR	L
CCUK -13	Mercury silicate	R	L
CCUK -14	Mercury silicate	VR	L
CCUK -15	$Hg_{10}^{1+}Hg_3^{2+}O_6I_2(Cl,Br)_2$	VR	L
CCUK -18	$Hg_2^{2+}N(I,Cl,Br)\cdot H_2O$	VR	L
Associated Minerals			
Barite	$BaSO_4$	VR	L
Calcite	$CaCO_3$	Unc	U, M, L
Dolomite	$CaMg(CO_3)_2$	C	U, M, L
Eskolaite	Cr_2O_3	Unc	U, L
Goethite	$FeO(OH)$	VR	L
Gypsum	$CaSO_4\cdot 2H_2O$	Unc	L
Hematite	Fe_2O_3	R	L
Huntite	$CaMg_3(CO_3)_4$	Unc	L
Hydromagnesite	$Mg_5(CO_3)_4(OH)_2\cdot 4H_2O$	C	U, M, L
Jarosite	$K_2Fe_6(SO_4)_4(OH)_{12}$	R	L
Magnesiochromite	$(Mg,Fe)Cr_2O_4$	C	U, L
Magnesite	$MgCO_3$	C	U, M, L
Magnetite	Fe_3O_4	R	L
Melanophlogite	$SiO_2 + CO_2 + N_2 + CH_4$	R	U
Millerite	NiS	Unc	L
Montmorillonite	$(Na,Ca)_{0.3}(Al,Mg)_2Si_4O_{10}(OH)_2\cdot nH_2O$	C	U, L
Nimite	$(Ni,Mg,Fe)_5Al(Si_3Al)O_{10}(OH)_8$	Unc	L
Pecoraite	$(Ni,Mg)_3Si_2O_5(OH)_4$	R	U, L
Pyrite	FeS_2	Unc	U, L
Quartz	SiO_2	C	U, M, L
Reevesite	$Ni_6Fe_2(CO_3)(OH)_{16}\cdot 4H_2O$	Unc	L
Rozenite	$FeSO_4\cdot 4H_2O$	R	L
Rutile	TiO_2	R	L
Sepiolite	$Mg_4Si_6O_{15}(OH)_2\cdot 6H_2O$	C	U, L
Sulfur	S	R	L
Talc	$Mg_3Si_4O_{10}(OH)_2$	C	U, L
Todorokite	$(Mn,Ca,Mg)Mn_3O_7\cdot H_2O$	Unc	U, L

R = Rare, VR = Very Rare, C = Common, Unc = Uncommon, U = Upper workings, M = Middle workings, L = Lower workings several generations of silica ranging from homogeneous chalcedony to banded chalcedony (agate) to drusy quartz. The chalcedony generally occurs along the center of the veins following the formation of earlier quartz. Based on extensive macroscopic examination of numerous field samples, mercury-bearing fluids initially deposited cinnabar and possibly native mercury, with minor metacinnabar and donharrisite along the margins of this fracture system. Mercury minerals identified from the lower workings that probably formed after the cinnabar include eglestonite, hanawaltite, peterbaylissite, clearcreekite, calomel, terlinguaite, wattersite, edoylerite, deanesmithite, szymańskiite, and seven unnamed minerals.

The difference in carbonate content of the mineralized host rocks between the upper and lower workings was determined to establish an approximate degree of silicification between the two locations. Analysis of typical hand samples of mineralized silica-carbonate rock from the upper workings gave an average of 30 weight percent carbonate. A somewhat lower average of 22 weight percent was determined for typical hand samples from the lower workings, representing a higher degree of silicification.

Paragenetic Sequence

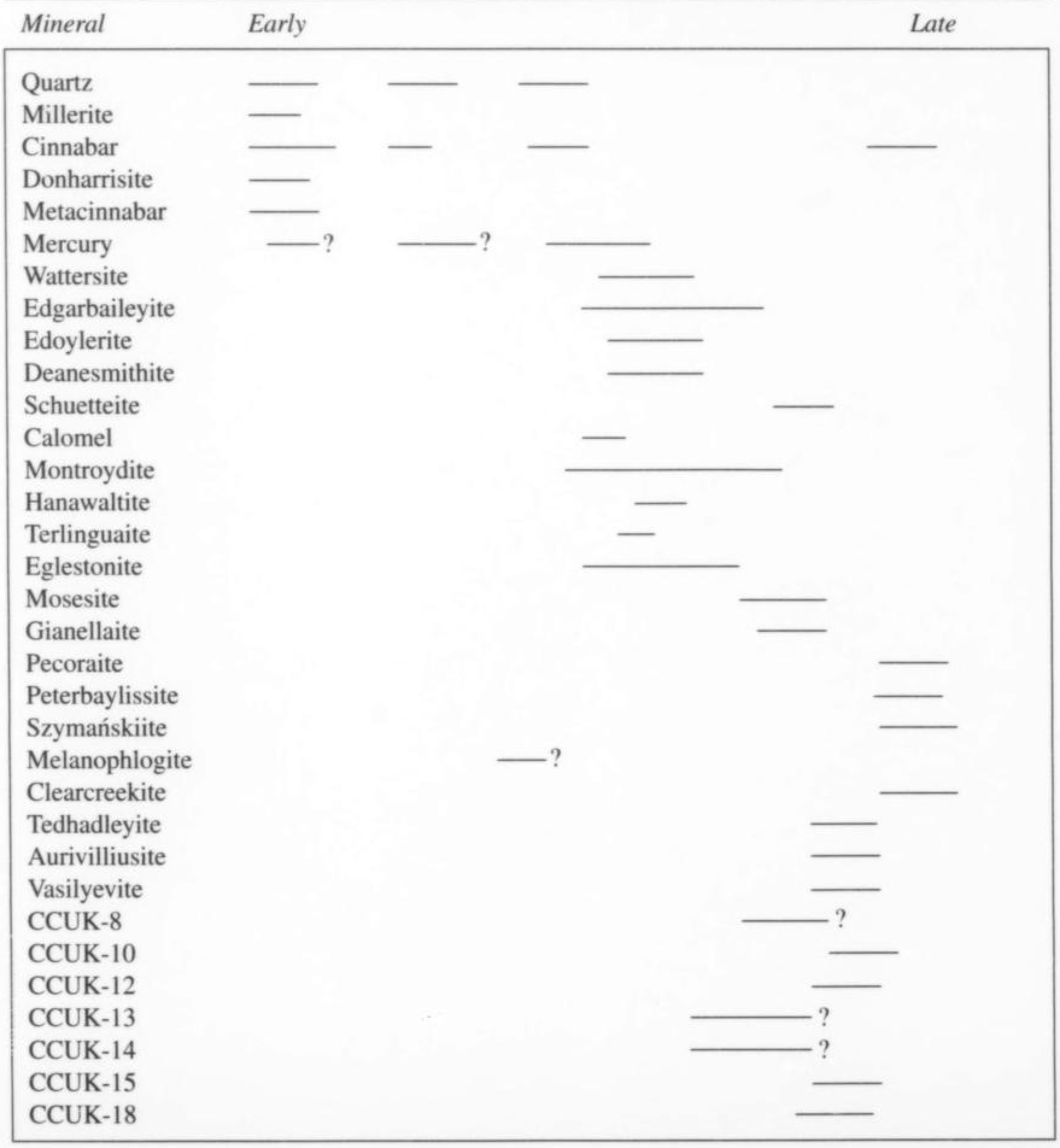
Our initial picture of the Clear Creek deposit paragenesis was deduced from the various mineral associations observed, their locations along the veins, and the relationships between mineral species within the micro cavities.

Establishing a paragenetic model for the Clear Creek mine was complicated by the diverse association of minerals in the numerous microvoids and thin lenticular veins on any give field sample. Also, the majority of mineralized rocks examined were found to be float material (lower workings) or rocks removed from the ore zone during mining operations (upper workings). The diverse assemblage of rare minerals identified at the lower workings has been found in isolated float rocks generally located near the bottom and southwestern portions of the outcrop. Rocks on the northern side of the outcrop contain only unaltered cinnabar and minor mercury. None of the newly described mercury minerals has been found in rocks exposed *in situ* despite extensive searching.

Three discrete phases of mineralization have been recognized from cross-cutting relationships. The first general episode recognized was a fracturing of the silica-carbonate rock which allowed the channeling of mercury-rich fluids and subsequent precipitation of primary cinnabar, with minor donharrisite, metacinnabar and probably native mercury along the fracture margins. Some cinnabar and possible native mercury also permeated into the lower grade silicified serpentinite wall margins. Generally, little silica accompanied this event.

Following this initial mercury mineralization, there was a second period of fracturing which resulted in cross and parallel fractures to the first set of fractures, with subsequent channeling of silica-rich fluids, with possible remobilization of earlier deposited mercury-bearing phases.

***Table* 2. Paragenetic timeline for the Clear Creek mine.**



Later, a third tectonic event re-fractured the older silica-rich veins with yet more deposition of minor cinnabar and possibly native mercury. Localized chemical reaction of pre-existing cinnabar and native mercury with invasive fluids occurred along selected portions of the deposit. Some mercury from the cinnabar and mercury combined with cations and anions present in the fluids to form the many rare mercury minerals localized within the quartz veins and adjoining leached silica-carbonate rock.

When these mineralized silica veins are opened, they often reveal abundant native mercury and cinnabar, with minor edgarbaileyite, eglestonite, montroydite and wattersite filling irregular cavities. The most interesting aspect of these cavities is that each one often shows a different combination of minerals even though the cavities generally are separated by only a few millimeters. These diverse micro-environments were probably formed during solidification of the silica-rich veins and represent one of the unusual aspects of the deposit. The observed associations suggest that reaction of earlier mercury minerals occurred with one or more fluid events to produce different suites of secondary minerals in different cavities. Because of the diverging bulk compositions of the various cavities, the mercury mineral suite cannot be represented as a single paragenetic progression, but rather as a network of pathways in which a variety of fluids react with a range of possible mineral associations at each stage.

The earliest phase of sulfide mineralization appears to have consisted of sulfides millerite, cinnabar, donharrisite and metacinnabar along the quartz veins. There were at least three separate periods of cinnabar formation generally associated with quartz veining. Rare donharrisite is restricted to thin veins associated with cinnabar. Subsequent decomposition of donharrisite resulted in secondary cinnabar and pecoraite. There was no evidence that it formed during either of two later distinguishable cinnabar crystallization episodes.

Some native mercury may also have precipitated very early in the mineralization sequence, contemporaneously with cinnabar. However, most of the mercury was likely derived from primary cinnabar by subsequent disproportionation or oxidation.

The majority of the rare mercury minerals are likely rather late, low-temperature precipitates. These minerals include montroydite (e.g. shells pseudomorphing mercury droplets) and oxy-chlorides such as eglestonite and terlinguaite, which appear to be derived by oxidation of mercury and reaction with OH^- and Cl^-. Edoylerite, deanesmithite and CCUK-8 appear to have formed by direct oxidation and reaction of cinnabar with chromate-rich fluid. Some CCUK-8 is relatively late on the basis of its epimorphic relationship to deanesmithite and edoylerite. Reaction of the chromate-bearing fluid in mercury/montroydite-bearing cavities formed wattersite. Edgarbaileyite would have formed from mercury by reaction with silica; it occurs in several generations in some cavities. Additional edgarbaileyite, as well as CCUK-13 and CCUK-14, are the silicates that appear to have formed by reaction of silica with cinnabar. The nitrides mosesite and CCUK-18 are associated with mercury/montroydite but gianellaite with cinnabar, which suggests that an ammonium-bearing fluid also reacted with both metal/oxide cavities and with sulfide cavities.

The (Br,I)-free chloride minerals appear to be derived from mercury and/or montroydite. Hanawaltite shows evidence of being an alteration product of earlier calomel. These latter minerals and terlinguaite are rare in comparison with eglestonite. A different fluid, richer in iodide with lesser chloride and bromide, may have been implicated in forming the iodide-rich minerals aurivilliusite, tedhadleyite, vasilyevite, CCUK-12 and CCUK-15 from mercury/montroydite. The association of CCUK-10 and vasilyevite with mosesite and its I-dominant analog CCUK-18 suggest that the iodide fluid postdates the ammonium fluid, and that CCUK-18 may have formed from Cl^- dominant mosesite by ion exchange as evidenced by red halos of CCUK-18 replacing mosesite on some samples. Particularly late-forming minerals include the sulfate schuetteite and associated silicates CCUK-13 and CCUK-14, which postdate cinnabar and CCUK-8 on edoylerite. The carbonates also appear to have been very late in the sequence since they have not been observed to be overgrown by any other mercury minerals.

DISCUSSION

Source Rocks of Mercury

Krupp (1988) states that the low geochemical abundance of mercury in most common rock types makes it necessary that large source volumes are available from which the element can be extracted in order to form an economic deposit. The underlying sedimentary rocks of the Panoche Formation (Upper Cretaceous) and the Franciscan Complex (late Mesozoic to early Tertiary) are considered to be the principal source for the mercury mineralization of the New Idria district (Wells and Ghiorso, 1988; Studemeister, 1984; Moiseyev, 1971; Linn, 1968). Limited data suggest that recent marine clays contain many times the mercury content of average igneous rocks (Aidin'yan *et al.*, 1963). Krupp (1988) considers organic carbon-rich sediments, and in particular black shales, as having an order of magnitude higher mercury content than most other rock types that are frequently found in mercury ore districts. Such lithologies are likely to have been the source of the mercury at Clear Creek.

White (1957) and White and Roberson (1962) have suggested that mercury may be expelled from sedimentary rocks subjected to high temperatures. Abundant evidence indicates that mercury becomes concentrated in shallow epithermal deposits but is rare in mesothermal and hypothermal deposits except as broad geochemical halos that argue for its high mobility at elevated temperature (Barnes, 1967). Moiseyev (1971) presents a comparative study based on a non-genetic classification of mercury ore deposits from around the world and suggests that mercury is derived from sediments rather than from magmas and is mobilized by volcanic heat. Hence, the overall consensus is that Hg initially resides in sediments but is readily remobilized on heating due to burial or volcanic/tectonic activity. The transporting fluid could be interstitial connate water driven out by compaction, or metamorphic water released by reconstitution of hydrous minerals. Either would have been possible during the emplacement of the New Idria serpentinite body and its subsequent localized replacement by silica-rich solutions.

Mercury Transportation Mechanisms

The extreme insolubility of cinnabar and its higher-temperature polymorph metacinnabar is a potential difficulty in producing rich deposits of mercury minerals, since only vanishingly small amounts of mercury can remain dissolved in anoxic fluids that contain moderate sulfide concentrations. However, Dickson (1964) demonstrated that reduced solutions rich enough in sulfur to form sulfide complexes of mercury can dissolve appreciable amounts of mercury which can then be precipitated as cinnabar by cooling towards a solubility minimum at 100°C, or as a result of disassociation of the complexes on mixing with sulfur-poor waters. This is the most likely means by which mercury was introduced into the host rocks at Clear Creek, since the earliest mercury minerals to form appear to have all been sulfides: cinnabar or metastable metacinnabar, and donharrisite. The essential Ni content of donharrisite and the presence of mercury-free secondary Ni sulfides (millerite) suggest

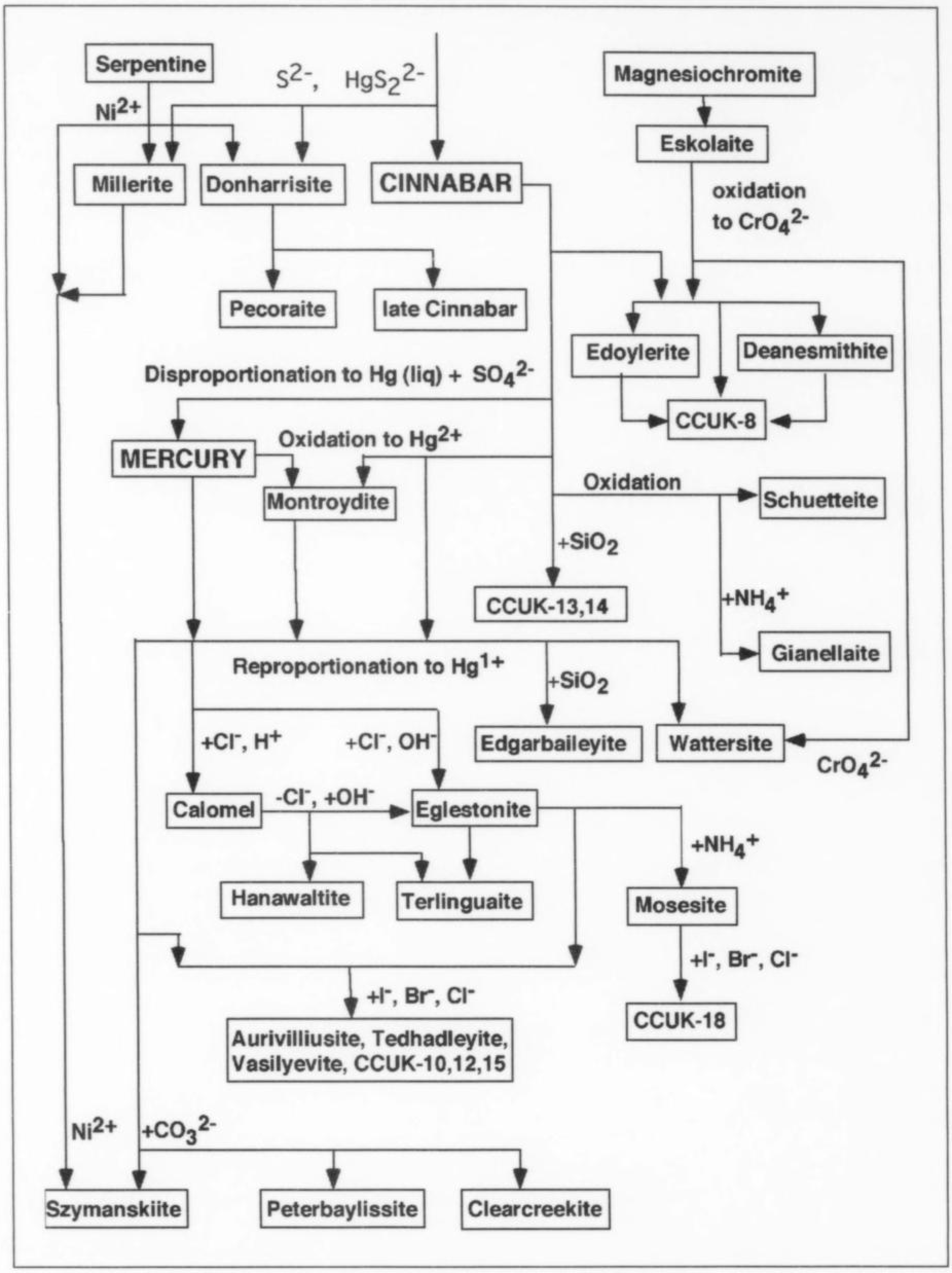


Figure 57. **Paragenetic flow chart for minerals formed by the alteration of native mercury and cinnabar at the Clear Creek mine.**

reaction between a fluid bearing Hg and S and a fluid containing Ni derived from the serpentinite. Alternative possibilities are that the mercury was transported in a less sulfidic or somewhat more oxidizing fluid as either the neutral atomic species or as organic complexes. Association of mercury mineralization with hydrocarbons is well known (Dickson and Tunell, 1968; White, 1981) and there are experimental data indicating that mercury is highly soluble in hydrocarbons (Okouchi and Sasake, 1981; Clever and Iwamoto, 1987).

According to Krupp (1988), the solubility of metallic mercury in aqueous solutions can exceed the previously calculated solubilities of mercury as sulfide complexes by a considerable margin. The calculations of Fein and Williams-Jones (1997) support this conclusion in the appropriate Eh range, but they go on to show that in the presence of organic compounds, such as alkanes, mercury-organic complexes are even more important. Another possible transport mode discussed by Fein and Williams-Jones (1997) is partitioning of mercury into the vapor phase. Since boiling is suppressed by pressure, this is not likely to be important for deep-sourced fluids.

Karpatite (native coronene, $C_{24}H_{12}$) occurs in several mercury mines in the district, and elsewhere in California mercury deposits, although not at the Clear Creek mine itself. At the Picacho and Andy Johnson mines, about 5.3 kilometers to the southeast along the same silica carbonate exposure, karpatite coexists with cinnabar and predates some quartz.

Melanophlogite does occur at Clear Creek, a mineral that requires some sort of stabilizing molecules such as CO_2, N_2, and CH_4 for its formation (Nakagawa *et al.*, 2001). However, since melanophlogite is very rare and found only at the upper workings, the stabilizing volatiles may have been restricted in their occurrence. Cinnabar has been observed coating and replacing melanophlogite, consistent with other field evidence implying early crystallization of the melanophlogite (Dunning and Cooper, 2002).

These observations imply that organic-mediated or vapor transport may have operated at some times and particular locations at Clear Creek, but the association with cinnabar suggests that sulfide complexes remained the dominant transport mode.

Source of Reacting Species

In general, it is straightforward to identify the sources for the various cations and anions that reacted to produce the observed diversity of mercury minerals at Clear Creek. Si for the silicates would have been abundantly supplied from the silica-rich fluids, veins and silicified host rock. Carbonate-rich host rock would have supplied carbonate. The cations Ni and Mg could have been derived from either serpentinite (nickel sulfides) or secondary carbonates.

Within the silicified serpentinite margins adjacent to the quartz-rich veins are abundant masses and crystals of ferroan magnesiochromite that show dark green rims. This very fine-grained dark green material was presumed to be an alteration product of ferroan magnesiochromite and was subsequently identified as eskolaite by X-ray powder-diffraction methods. Reaction of the magnesiochromite with, for instance, a carbonate-rich fluid presumably leached away the Mg and Fe, leaving the less mobile chromium oxide as a residual mineral. Finely divided eskolaite is likely the source of chromium for the several colorful mercury chromates identified in the veins.

White (1967) has recorded small but significant levels of ammonia, chlorine, iodine and bromine in the associated spring waters of certain mercury deposits within the Diablo Range of the Franciscan Formation. Ancient marine brines trapped in the underlying oceanic sediments can be rich in chlorine, iodine and bromine and afford the source for these elements identified in the several mercury halides isolated at Clear Creek.

Organic material in sediments may have contributed ammonia required for the formation of the nitride minerals. Mercury cations are soft (Pearson, 1973) and have a strong affinity for iodine and bromine as well as for ligands such as ammonia or nitride. Relatively covalent compounds in which mercury bonds to these species tend to be low in solubility and more stable relative to oxy-compounds than would be the case for a harder cation. Hence, these compounds occur as minerals at Clear Creek and other localities.

Thermochemistry and Conditions of Crystallization

The relative stabilities of the major minerals cinnabar, mercury and montroydite and some dissolved Hg complexes as a function of pH and redox potential (Eh) are well known (Krauskopf, 1951; Dickson, 1964; Barnes *et al.*, 1967; Hepler and Olofsson, 1975; Khodakovskiy *et al.*, 1975) and relationships at 25°C are well summarized for the major species by Eh-pH diagrams such as that in Brookins (1988). The data for cinnabar, mercury, montroydite and associated dissolved species were used as a starting point for understanding the conditions at which the other secondary minerals may have formed. Some results are summarized here of geochemical speciation calculations using additional data, which are reported in detail in a companion paper (in preparation).

At moderately acid to moderately alkaline conditions (pH = 4–10), predominant dissolved mercury species in the Hg-O-H-S system are typically sulfide complexes of Hg^{2+} such as HgS_2^{2+} and its protonated analogs under reducing conditions, neutral Hg° at intermediate redox potential, and Hg^{2+}, $HgOH^+$ or $Hg(OH)_2$ under oxidizing conditions. Each of these regimes has an associated mineral—cinnabar (HgS), mercury (Hg), and montroydite (HgO) respectively—in which the bonding and oxidation state of Hg are similar to those of the predominant dissolved complexes. These minerals are abundant at Clear Creek relative to the more complex mercury species, are sparingly soluble to highly insoluble, and play a major role in determining the concentration of mercury that can be carried in solution. The crossover from the regime of mercury to that of montroydite occurs as a result of mercury oxidation with increasing electrode potential: $Hg^{\circ} \rightarrow Hg^{2+} + 2e^-$. However, the transition from cinnabar to the neutral species with increasing Eh is a more complex disproportionation, involving reduction of the Hg^{2+} in cinnabar combined with oxidation of the sulfide to sulfate: $HgS + 8OH^- \rightarrow Hg + SO_4^{2-} + 4H_2O + 6e^-$. This happens at Eh very similar to that of the sulfide-sulfate couple in the Hg-free system, $S^{2-} + 8OH^- \rightarrow SO_4^{2-} + 4H_2O + 8e^-$. The existence of a stability field for the neutral metal at Eh higher than that for metal sulfide but lower than that for metal oxysalts is characteristic of extremely chalcophilic metals. The diagrams of Brookins (1988) show this behavior for Hg and Cu but not for the more lithophile Fe, Co and Ni. An important consequence of this phenomenon is that montroydite and cinnabar cannot coexist at thermodynamic equilibrium, and any observed association of these two is metastable. Coexistence is observed at Clear Creek, presumably due to the difficulty in dissolving cinnabar.

The redox relationships outlined above indicate that the general evolution of conditions in the Clear Creek mineralized zones involved (1) introduction of Hg in reduced, sulfidic fluids, forming cinnabar and minor donharrisite, (2) oxidative disproportionation of cinnabar to produce mercury and (3) further oxidation to produce montroydite. Montroydite dissolves in strongly acid or alkaline solutions, so the pH must have remained with a few units of neutrality to maintain montroydite stability.

In the absence of thermodynamic data for many of the rare minerals, speciation models including only the well-known species were used to predict the dependence of the relative (but not absolute) saturation of rare solid phases as a function of Eh, pH and the concentrations of dissolved cations and anions. In the model, chemically similar minerals were most saturated at similar Eh-pH conditions, and several different Eh-pH facies of secondary minerals could be distinguished. These would include:

(1) The Hg^{1+} oxy-compounds including edgarbaileyite and the carbonates peterbaylissite, szymańskiite and clearcreekite, which are confined to a narrow Eh band along the Hg-HgO buffer, and neutral to alkaline pH (unsurprising given the weakness of silicic and carbonic acids).

(2) Conversely, the halides and oxy-halides attain minimum solubility at Eh on (Hg^{1+} compounds) or just above (mixed valence and Hg^{2+} only) the Hg-HgO buffer. The pH for minimum solubility was always close to the acid limit of montroydite stability, ca. pH = 5.

(3) A puzzle was presented by edoylerite, deanesmithite and CCUK-8, which simultaneously contain Hg^{2+} and "oxidizing" chromate anions and "reducing" sulfide, and by wattersite, with "moderately reducing" Hg^{1+} combined with chromate and oxide. The model indicates that the presence of sulfide determines the Eh for the sulfide-chromates, which are most stable along the upper stability limit for cinnabar, consistent with their observed occurrence as cinnabar oxidation products. Conversely, wattersite ap-

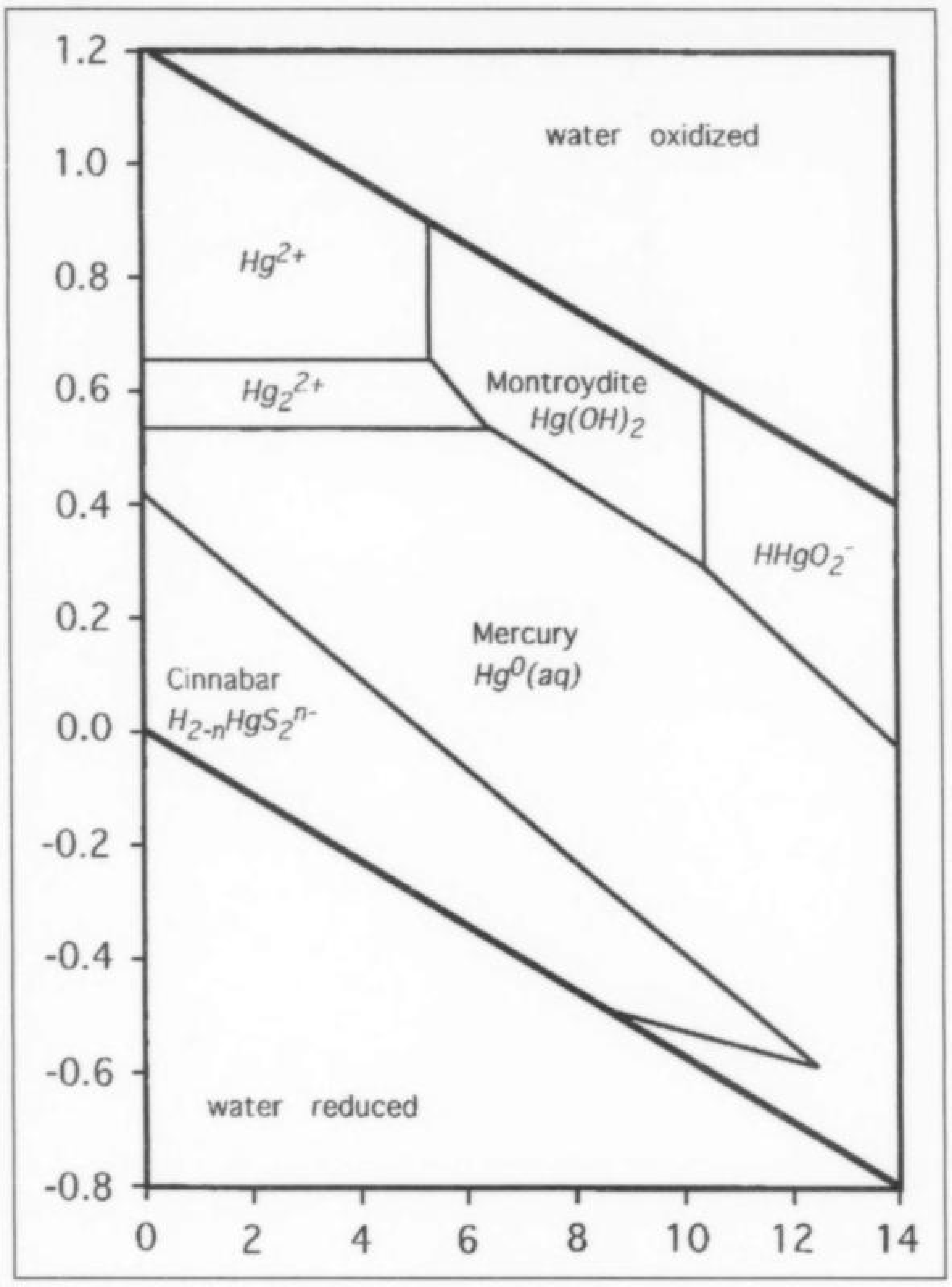


Figure 58. **Eh-pH diagram showing the stability fields for the various mercury-bearing species in the fluid state.**

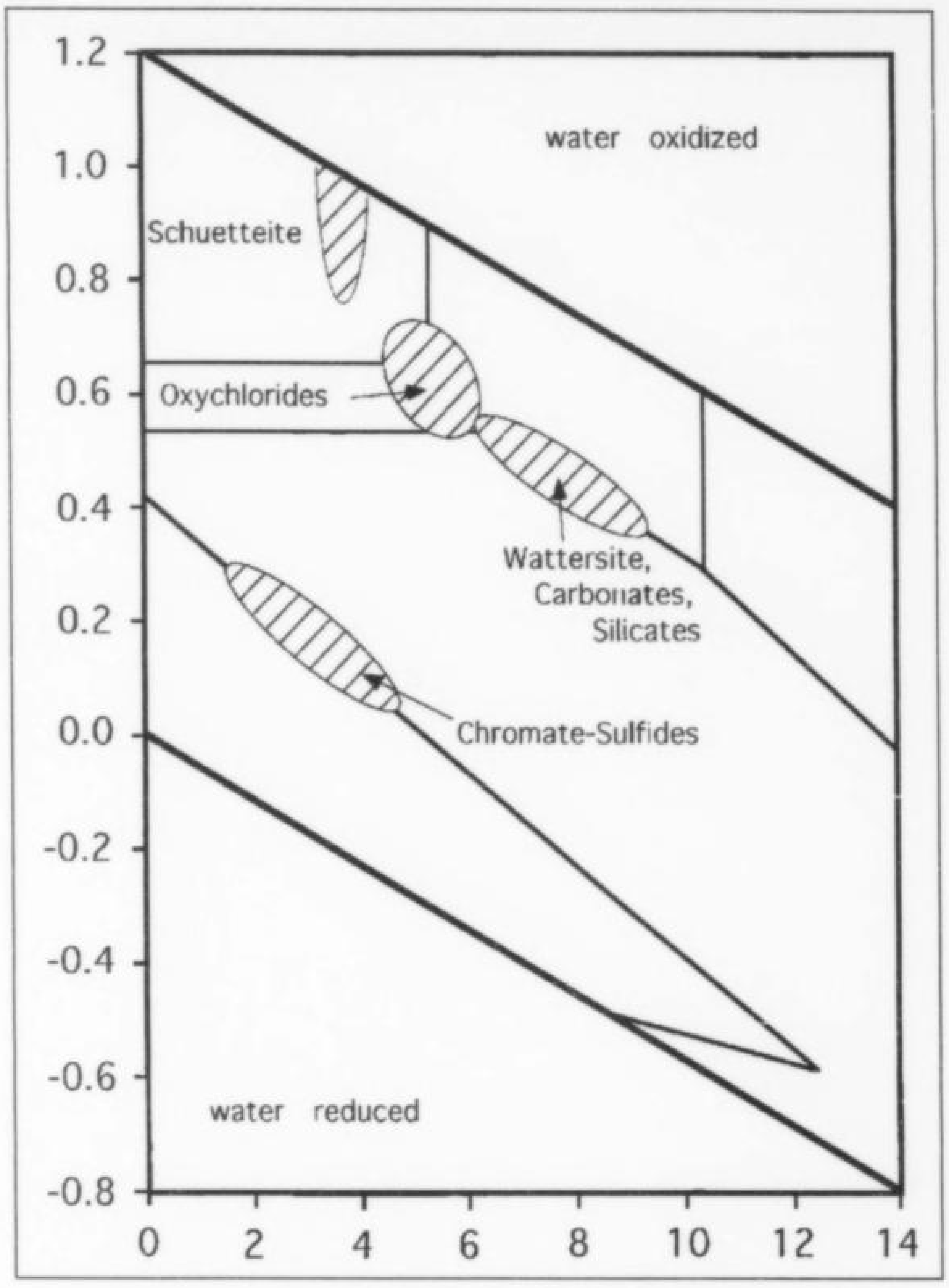


Figure 59. **Eh-pH diagram showing the stability fields for the various mercury-bearing species in the solid state.**

pears to be most stable under near-neutral conditions at the Hg-HgO buffer, similar to edgarbaileyite, which again is consistent with its observed mode of occurrence.

(4) The oxide-sulfate schuetteite is most stable under acid, oxidizing conditions. In many oxidizing zones of ore deposits, low pH values are attained on oxidation of sulfide to sulfate, simply because sulfuric acid is a much stronger acid than hydrogen sulfide. Such acidification was rare and very localized at Clear Creek, as evidenced not only by the occurrence of montroydite but also by the rarity of sulfur and schuetteite and non-occurrence of the sulfide-chloride, corderoite, $Hg_3S_2Cl_2$. In strongly acid conditions, oxidation of cinnabar would form sulfur: $HgS \rightarrow Hg^{2+} + S + 2e^-$, and reaction with dissolved chloride would form corderoite, which is less stable under near-neutral conditions. It is likely that the vast amount of carbonate in the deposit acted to neutralize the acid, and kept the pH near neutral. Avoiding the development of highly acid conditions appears crucial to the stability of many of the rare and unique species found at the Clear Creek mine.

ACKNOWLEDGMENTS

We take great pleasure in dedicating this paper to the memory of the late Mr. Edward H. Oyler (1915–2003), an ardent field collector and friend, who has specialized in mercury minerals for over thirty years. Without his persistence and enduring interest in mercury minerals, especially those of the Clear Creek mine, many of the new minerals that have been described from this mine might never have been discovered. He generously donated the best or sole specimens of clearcreekite, deanesmithite, edoylerite, hanawaltite, peterbaylissite and wattersite for their scientific study. It seems most appropriate to honor him in this way for his long and dedicated service to the science of mineralogy.

Richard C. Erd (U.S. Geological Survey, retired) suggested that a formal study be pursued to better understand the unique geochemical conditions and paragenesis of the mine. He graciously made available many references and all his notes on the mine and minerals so they could be incorporated into this study. We sincerely thank him for his continued encouragement and interest in this effort.

Andrew C. Roberts (Geological Survey of Canada, retired) provided numerous X-ray powder-diffraction analyses of minute crystals and masses that we thought were new or unusual. His timely identifications gave us the encouragement to continue the enormous task of reducing in size many hundred kilograms of rock samples in the hope of finding a single rare or new mineral.

We sincerely thank Susan Dunning for an early grammatical review of this paper that resulted in many improvements to its sentence structure.

Dan Behnke provided color photos for several of the mercury minerals. We sincerely thank him for his photographic skills.

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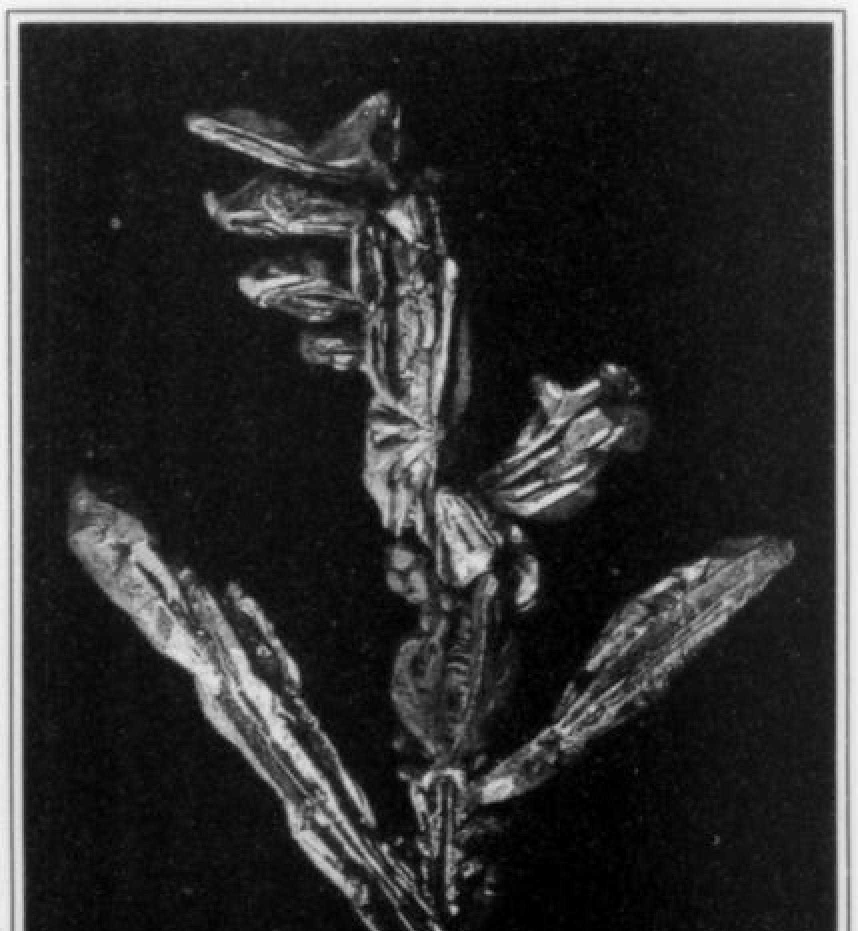
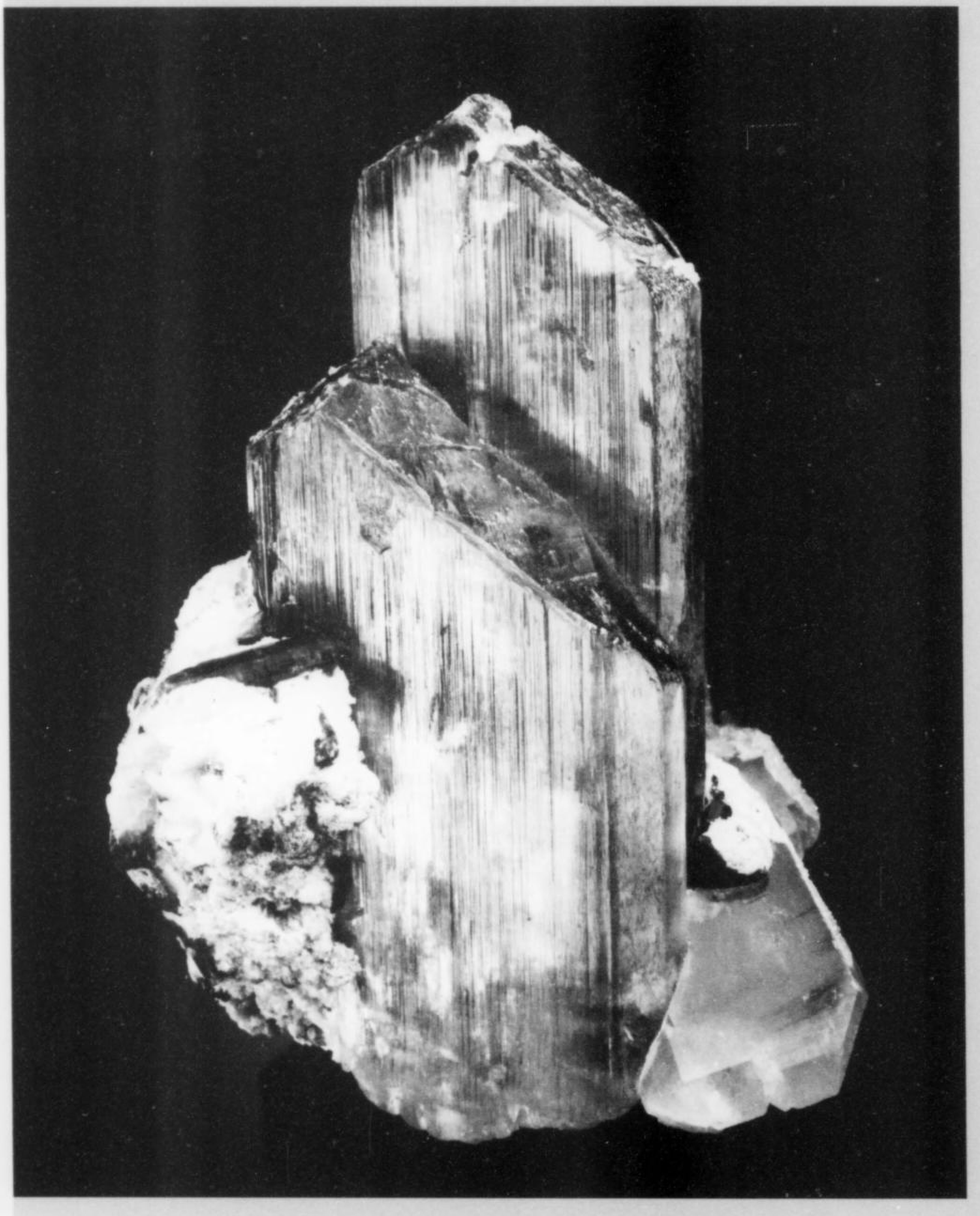


Copper, 4.5 cm, Kazakhstan

Jeff Scovil photo

From the Steve Neely Collection



SPODUMENE, 5.12 inches, from Mawi, Nuristan, Laghman Province, Afghanistan. Herb Obodda, Tucson Show 2004.

Jeff Scovil Photo

MICROMINERAL PHOTOGRAPHY *with* MULTIFOCUS PROCESSING

Volker Betz
Seifer Weg 2
65232 Taunusstein
Germany

Throughout the history of photomicrography, depth of field has been strictly limited by the laws of optics, and no amount of refinement in physical instrumentation could change those laws. Now, in the age of digital photography, software systems have been devised that will digitally combine only the sharp-focus zones from several different photos of the same subject taken at different focal depths. The incredible result is that important parts of micromineral photographs need never be out of focus again. We can now see fully focused microscopic scenes which the immutable laws of physics had formerly rendered impossible to view or create by any method.

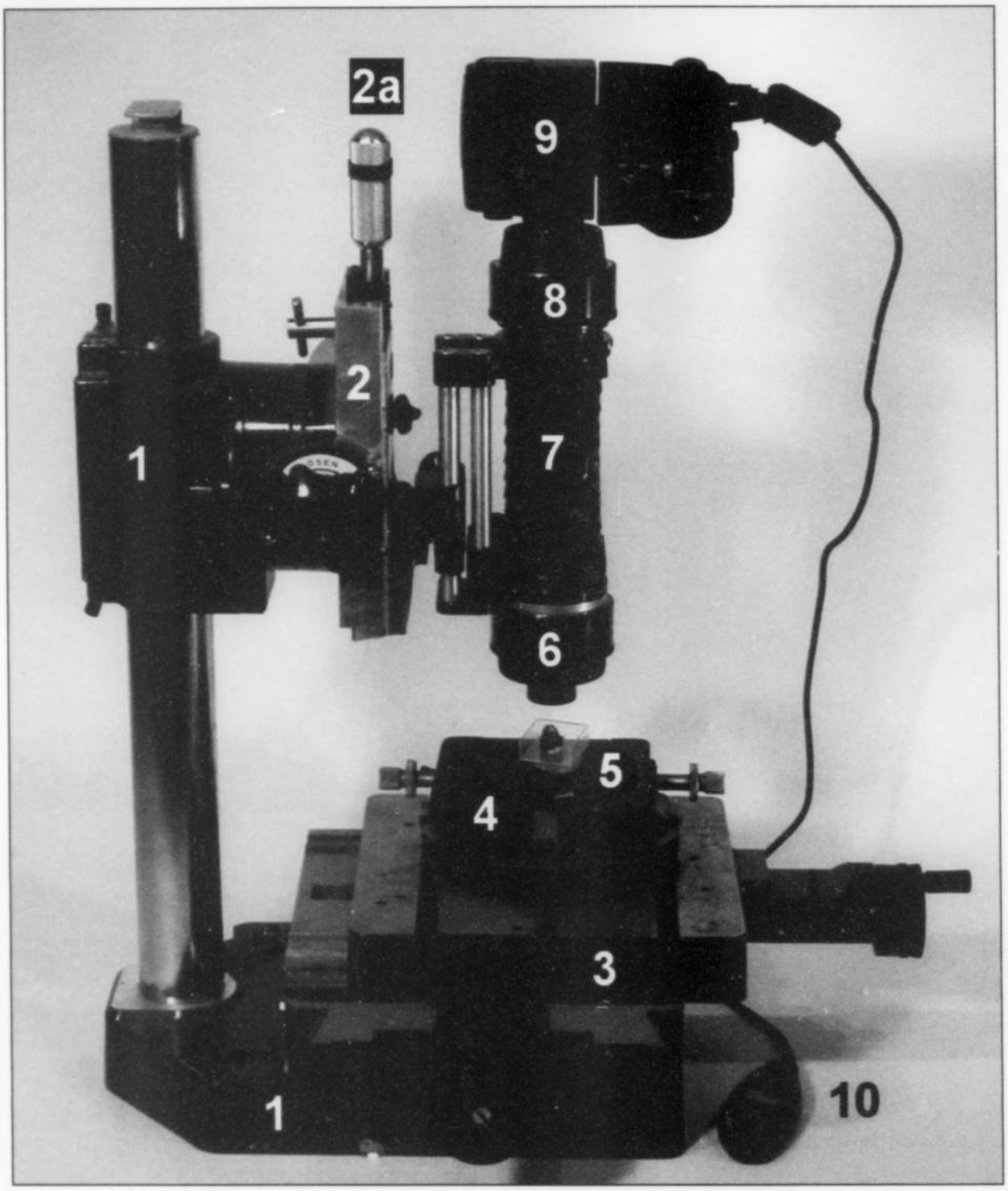
INTRODUCTION

The laws of physics and optics have always set frustrating restrictions on photomicrography: depth-of-field under high optical magnification is minimal at best, and even worse when lens apertures conducive to maximum photographic sharpness are employed. Some years ago mechanical experimentation began to explore the possibilities of "multifocus" techniques in which only the sharp-focus zone of a specimen is illuminated, while the coupled focus is gradually changed during exposure of the film so as to scan down the specimen. This technique worked well under certain circumstances but was mechanically cumbersome, and could not be adapted to the complex shapes and sizes of microminerals. In the last few years the steadily improving technology of digital cameras has reached a level of resolution which is almost equal to that of photographic film. Digital picture processing software, available for use on everyone's home computer, now allows the digital compositing of several photos together. This multifocus technique, applied to the photography of small minerals in the millimeter range, can multiply the depth of field by a factor of ten or more and increase resolution substantially, resulting in a photo quality formerly unachievable.

The procedure is easy to perform: A set of digital photos of a single specimen, typically five to 15 images taken at very small increments in focus, is loaded into the program and the sharpest parts from all of the individual photos are fused into one composite image to create the effect of extended depth of field. The process is rapid and easy to perform once the photos have been taken, but precise control of the lens-to-subject distance (along the z axis) while simultaneously avoiding any changes in the field of view along the x and y axes (up-down and left-right) requires special care.

Obviously the results of photomicrography can only be good if the optics employed are also excellent. Stereomicroscopes typically used by amateur mineralogists are designed for the buyer's budget and to support the requirements of the human eye. Most of these popular models of stereomicroscopes lack a fine-focus control which would allow precise adjustments of 0.1 mm or less while maintaining maximum optical resolution.

For photographic purposes (including for stereomicroscopy) the optical industry offers excellent equipment, e.g. the Leica M420, called a "Macroscope"—but at nearly ten times the price of a typical popular model of stereomicroscope. An alternative exists, however, for attaining good picture quality through the use of special macro lenses in combination with SLR-equipment, microscope adapters, and a digital camera. The set-up requires some tinkering on the part of the photographer in order to construct a mechanism for fine focusing and specimen handling. This kind of equipment, used by the author, is described here. It is similar to the equipment previously described for stereophotomacrography (Betz, 1990), with the exception of the use of a digital camera and better z-axis control.



EQUIPMENT

Mechanical tolerances for multifocus pictures are very small. The focus difference between the individual images in a photo stack is in the range of a few tenths of a mm or less, depending on the enlargement. A drilling stand with fine adjustment control will allow a series of photos to be taken in steps as small as 0.03 mm along the lens axis, and is stable enough to avoid any significant variation in the x and y axes during this process (Fig. 1).

The size of the field of view can be as small as 1 mm if the camera is zoomed. At such a small field of view, however, sufficiently precise manual manipulation of specimens is not possible. Rotation and two-track translation devices (x-y table) must therefore be used for the manipulation of specimens under the microscope. Normal photographic equipment for holding the camera and lens assembly is not stable enough; therefore, equipment sold for the drilling and milling of microscope parts is used instead.

The lenses I use are the Leitz Photar (25 mm), Zeiss Luminar (63 mm) and an Olympus macro lens (20 mm), some of them obtained on the second-hand market. A bellows of the kind made for use with SLR cameras works well as an extension tube. Adapters mount the lens with the RMS-head. At the camera end, an extension tube modified with a photo ocular is used and connected to my Nikon Coolpix 4500 digital camera. A digital single-lens-reflex camera would be an alternative if it can operate in the manual mode. The camera is triggered by an electrical remote control. The

Figure 1. **Digital photomicrography equip-ment used by the author: (1) Drilling stand (Proxxon); (2) Translation device for fine focus; (2a) Fine focus knob with 0.1-mm z-axis scale; (3) Two-track translation table (Proxxon) with 0.1-mm precision on x and y axes; (4) Rotation table with two-track translation table (used part from microscope); (5) Metal plate with mounted specimen; (6) Extension tube from SLR (Nikon) with RMS-adapter and macro lens (Photar 1:2.5, 25-mm); (7) SLR bellows (Novoflex) for Nikon; (8) Extension tube from SLR (Nikon) combined with ocular adapter (ProMicron) for Nikon Coolpix 4500; (9) Nikon Coolpix 4500 Digital Camera; and (10) Remote control for Nikon Coolpix.**

light sources are not shown in figure 1. Fiber optic devices and small halogen parabolic mirror lamps are useful for specimen illumination. As many as five or six different light sources can be used, most of them fitted with small diffusion screens.

PROCEDURE

Preparation

As every mineral photographer knows, a key factor in producing a high-quality photo is the selection of a suitable subject specimen. The best equipment is useless if this first requirement is not adequately addressed. Oftentimes a large number of specimens must be examined in order to find just the right one. For the selected specimens the best lighting combinations are then explored and the optimum viewing angle established. All this is done under a normal stereomicroscope. Finally the specimen is mounted on a small black metal plate using silicone putty.

The prepared sample is then transferred to the photographic device. The selected portion of the specimen is brought into the field of view by use of the x, y and z-axis controls, and the desired level of magnification is set by selecting an appropriate lens, extension length and zoom factor of the camera objective. The best results are obtained if the camera objective is set to infinite and maximum aperture. Maximum resolution is obtained if the zoom is carefully adjusted so that the vignetting at the edges of the picture just disappears. Magnification is primarily adjusted by focal length of the macro lens and bellows extension.

At this stage of the procedure the field of view can be rotated around the z-axis to find the best possible lighting directions and compositional orientation. Reflections from crystal faces can be adjusted to help to enhance the spatial effect (see Wilson, 2005), but need to be controlled very carefully. Final adjustments are made on the x and y axes for best field of view.

Taking the picture

The magnification obtainable with the equipment described here results from a combination of macro lens, extension (bellows and tubes), photo ocular adapter and digital camera lens. Resolution of

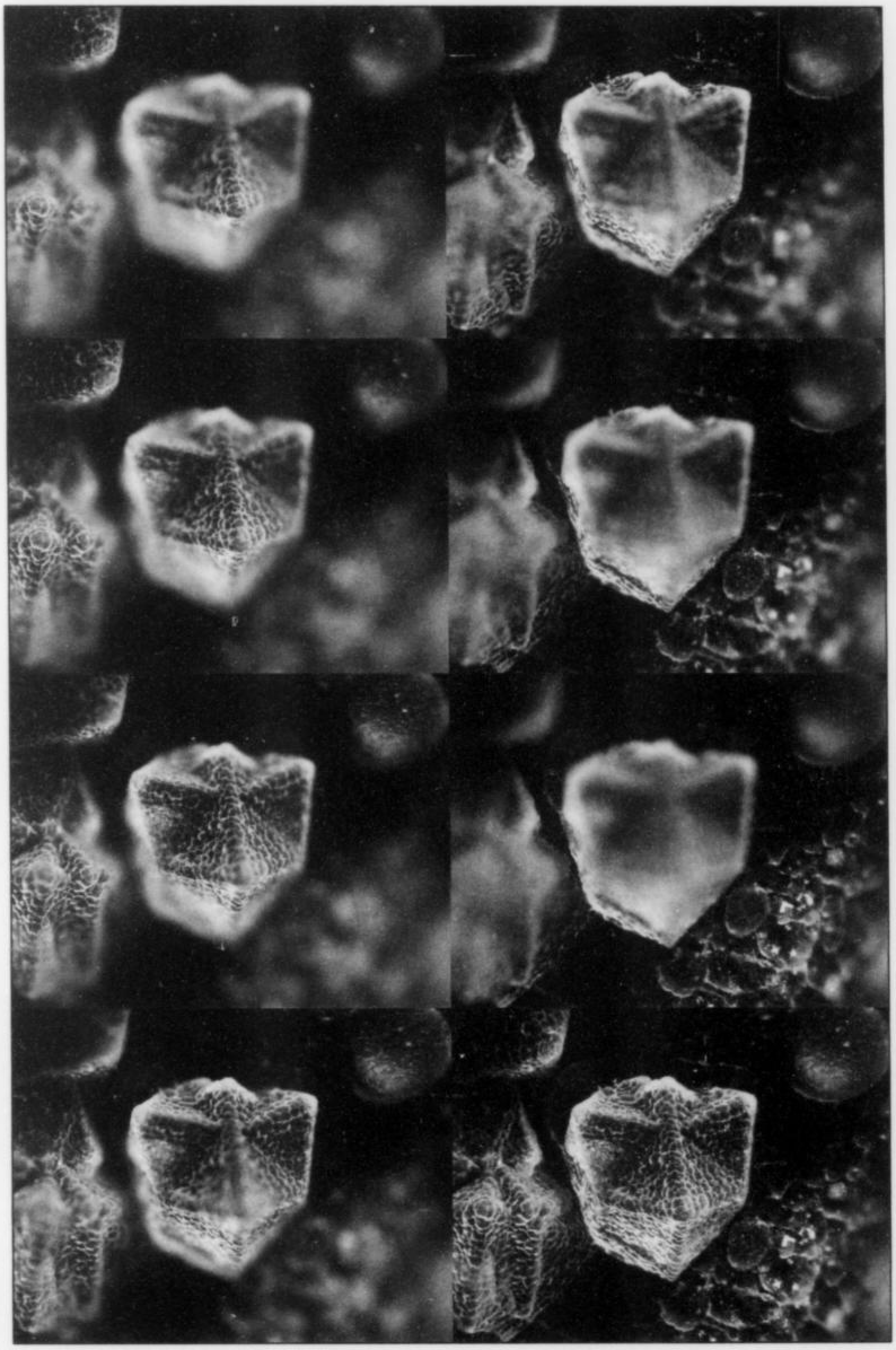


***Figure 2.* A set of photos taken at a range of focal settings, and the computer-composited resulting final picture (shown at lower-right). Faujasite and Phillipsite from Quarry I, Limberg near Sasbach, Kaiserstuhl, Baden, Germany. Field of view ca. 1.2 mm. Volker Betz collection and photos.**

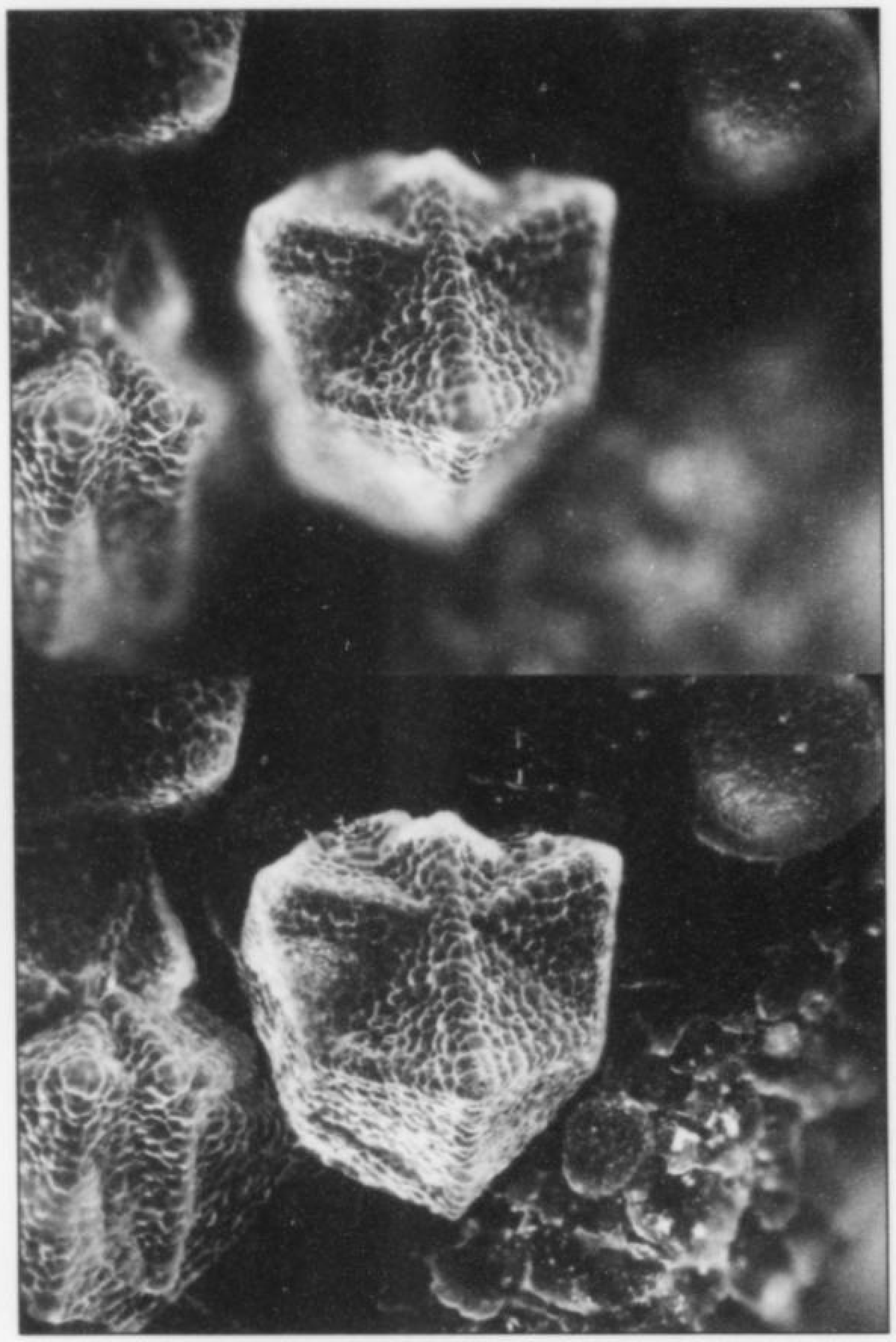


Figure 3. **The third image from the photo set shown in Figure 2, compared with the final result after computer-compositing the entire set of images.**

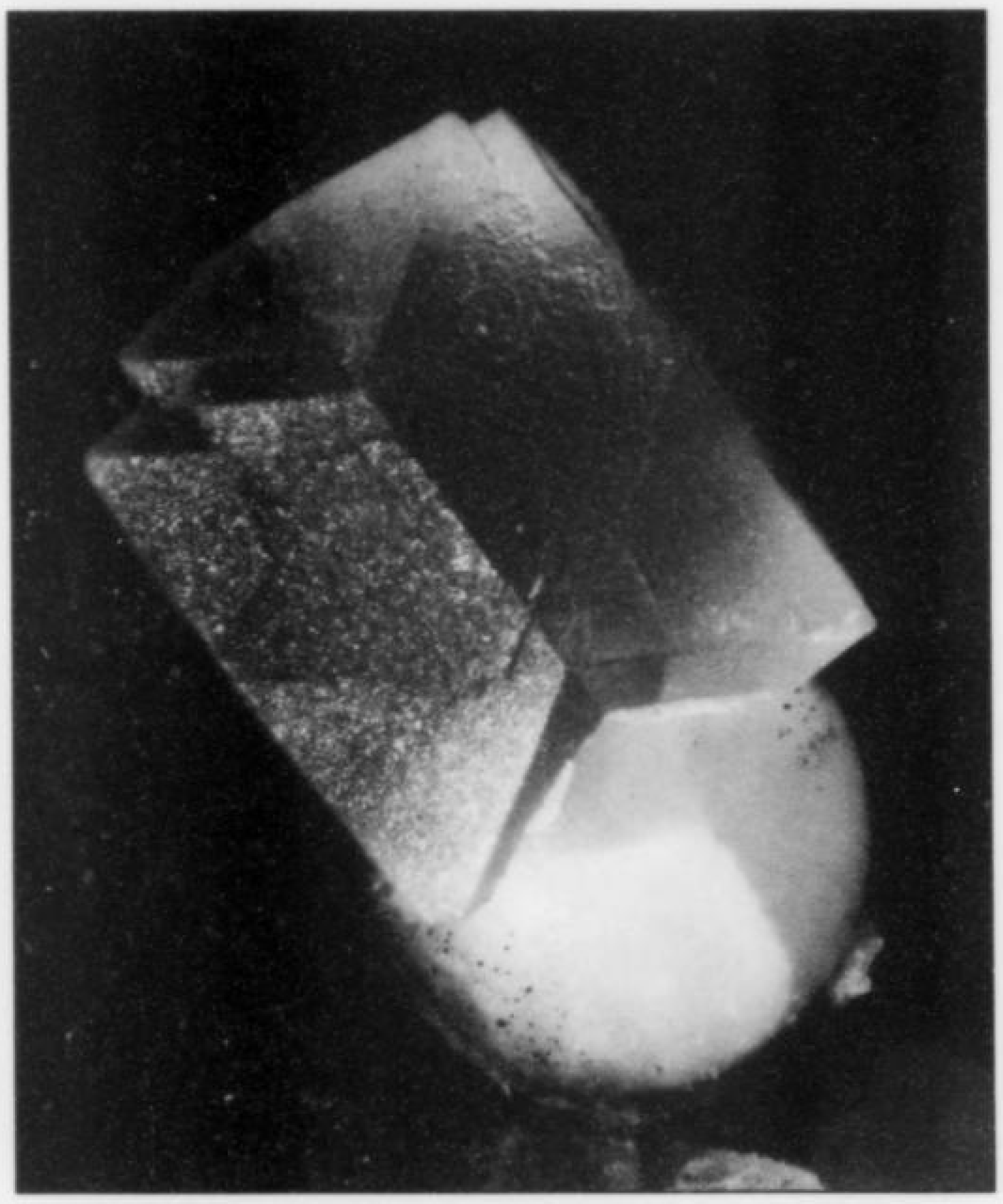


Figure 4. **Faujasite spinel-law twin, with a phillipsite sphere, from Gedern, Vogelsberg, Hessen, Germany. Field of view ca. 1.8 mm. Gerhard Braun collection; Volker Betz multifocus photo.**

Figure 5. **Faujasite octahedron, with phillipsite sphere, from Gedern, Vogelsberg, Hessen, Germany. Field of ca. 2 mm. Gerhard Braun collection; Volker Betz multifocus photo.**

lenses is generally not the best at the smallest aperture settings where depth-of-field is maximized. Since the multifocus method eliminates depth of field as a factor, however, we can maximize resolution by utilizing a large aperture on the macro lens and an open aperture of the camera lens, while setting the zoom roughly in the middle position where lens optics are optimized by the manufacturer.

Exposure time is dependent upon the usual factors. When intense halogen lamps are used, it is mostly in the range between 1/8 to 1/125 second. Long exposure times tend to cause extra noise in the digital picture and should be avoided. A first shot at a middle-focus depth can be taken to determine the correct exposure.

To begin the series of shots, the z-axis control is first adjusted so that the highest point of the specimen in the field of view is in sharp focus. The first exposure is taken and the focus is then moved downward step by step, taking a new photo at each increment. Focus difference between the pictures ranges from 0.03 mm (the smallest steps possible with the equipment) to a few tenths of a millimeter, depending on the magnification. Six to 15 exposures may be useful for most cases (the multifocus processing software can merge an unlimited number of exposures).

MULTIFOCUS PROCESSING

Following completion of the exposure series the system is left in the adjusted position and the group of digital images taken is transferred to the personal computer via the USB cable (or via a photo card reader). The photos are each checked for continuity in focus steps and for stability along the x and y axes. The group of photo files is then loaded into the multifocus processing software. Processing takes only a few seconds. I usually use Irfan View as a viewer and Helicon Focus Light as the multifocus software.

If the set of images is satisfactory the merging will work fine within the default parameters of the program. The resulting photo composite is saved and ready for further processing and viewing. (Other software packages may function in a similar way but have not been evaluated.)

FINAL PROCESSING

I utilize very little additional processing. After a possible cropping the picture is digitally sharpened (using Adobe Photoshop or Irfan View), and sometimes additional corrections are made for the gamma parameter and color balance. If the resulting picture is not satisfactory, it is discarded rather than being digitally "improved" any further, and a new series of images is taken.

SAMPLE PHOTOS

Figure 2 shows a set of 7 images taken at successive focal settings, and the final composited result. More details are visible in Figure 3—the third picture in the set is here compared with the final result after the processing. The aperture of the Leitz Photar 1:2.5/25 mm lens for this photo was set to 3.5. The Nikon Coolpix 4500 lens with Promicon microscope adapter was set to f/3.5. Exposure time was 1/8 second. Halogen parabolic reflector lamps with diffusion screens were used as light sources.

CONCLUSIONS

Digital photography combined with the multifocus technique offers amazing improvements in the quality of photomicrographs, here demonstrated with the photography of micromineral specimens. In addition to the remarkable elimination of most depth of field restrictions, a substantial improvement in overall sharpness is also achieved because the lens aperture can be set for maximum sharpness without having to consider the poor associated depth of focus. The multifocus technique is therefore truly revolutionary.

Commercially available hardware and homemade equipment configurations can be used by the amateur photographer. Software is available from vendors of microscope systems and software houses, including test versions (see the links listed below).

The necessary "extras" for multifocus photomicrography are a fine control of the lens-to-subject distance, in order to facilitate shooting a set of images at precisely graduated focal increments, the licence for the software (Helicon Focus Light cost about €100), and, of course, excellent optics. The time needed to expose and process an image set is only a few minutes.

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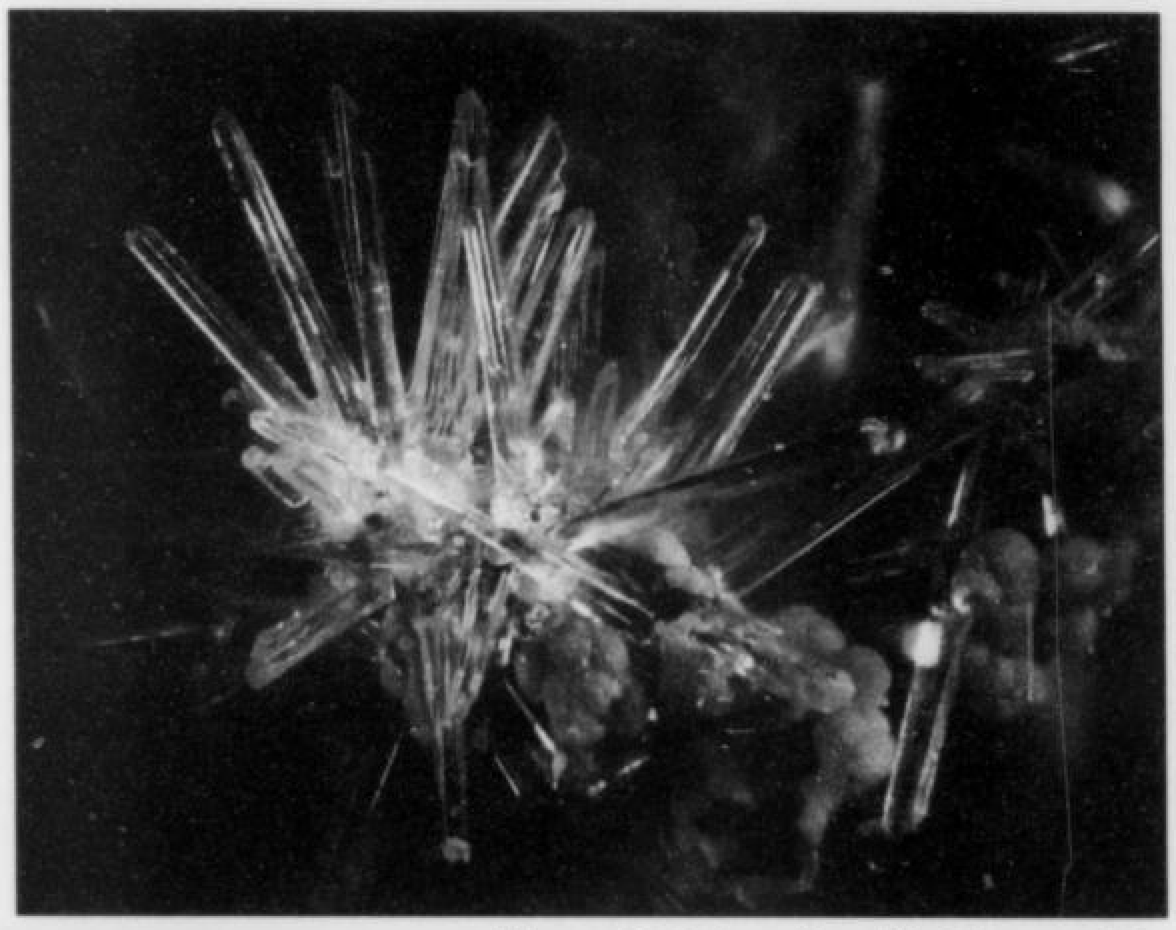
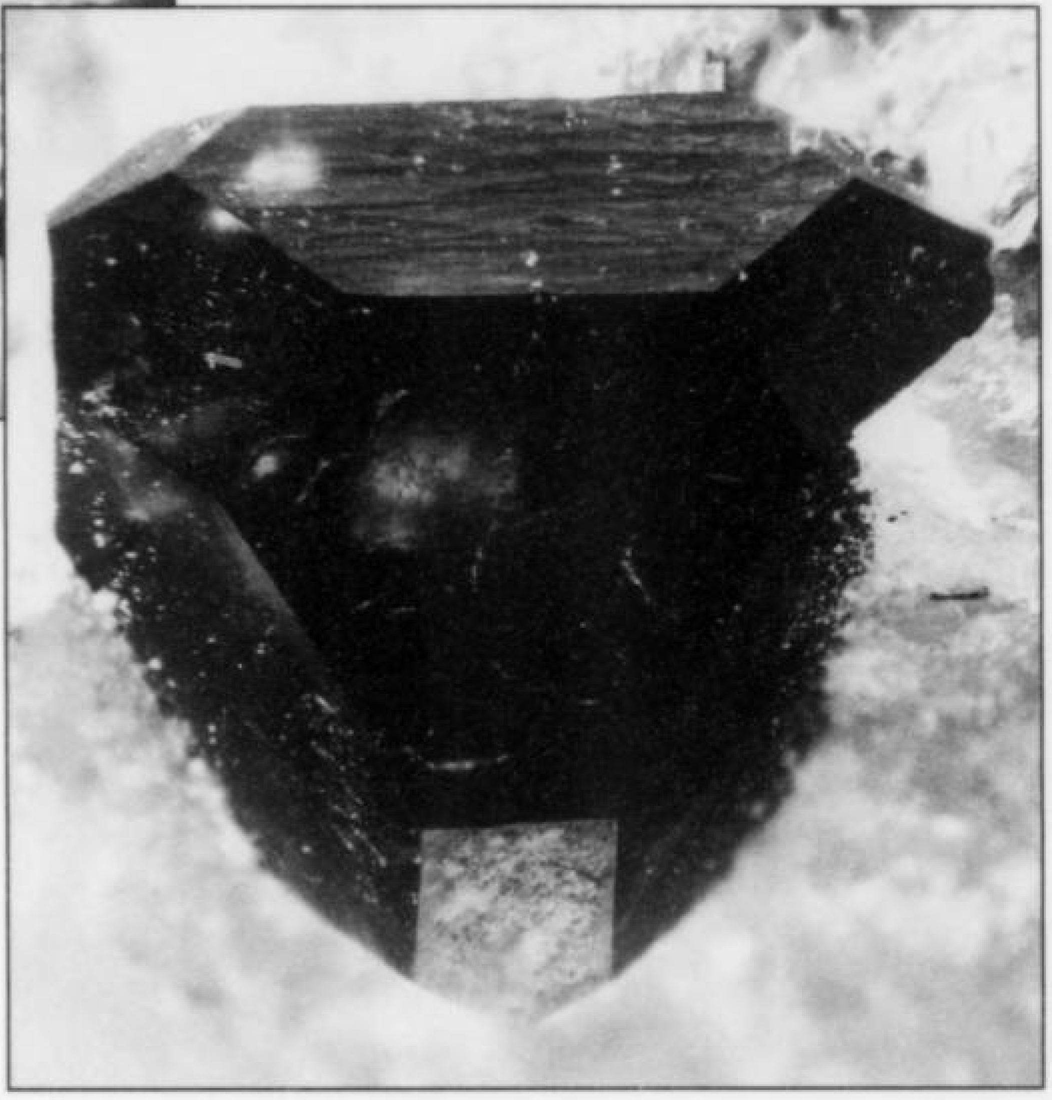


Figure 6. **Prismatic offretite crystals, perched on a hyalite sphere, from Mont Semiol, Loire, France. Field of view ca. 1.2 mm. Volker Betz collection and multifocus photo.**

Figure 7. **Yellow metaheinrichite crystal group, 1 mm, with red erythrite and dark red Fe-arsenate, from Schmiedestollen-Halde, Wittichen, Black Forest, Germany. Volker Betz collection and multifocus photo.**

Figure 8. **Boracite crystal, 5 mm, in halite/carnallite, from Bernburg, Sachsen-Anhalt, Germany. Volker Betz collection and multifocus photo.**



LINKS

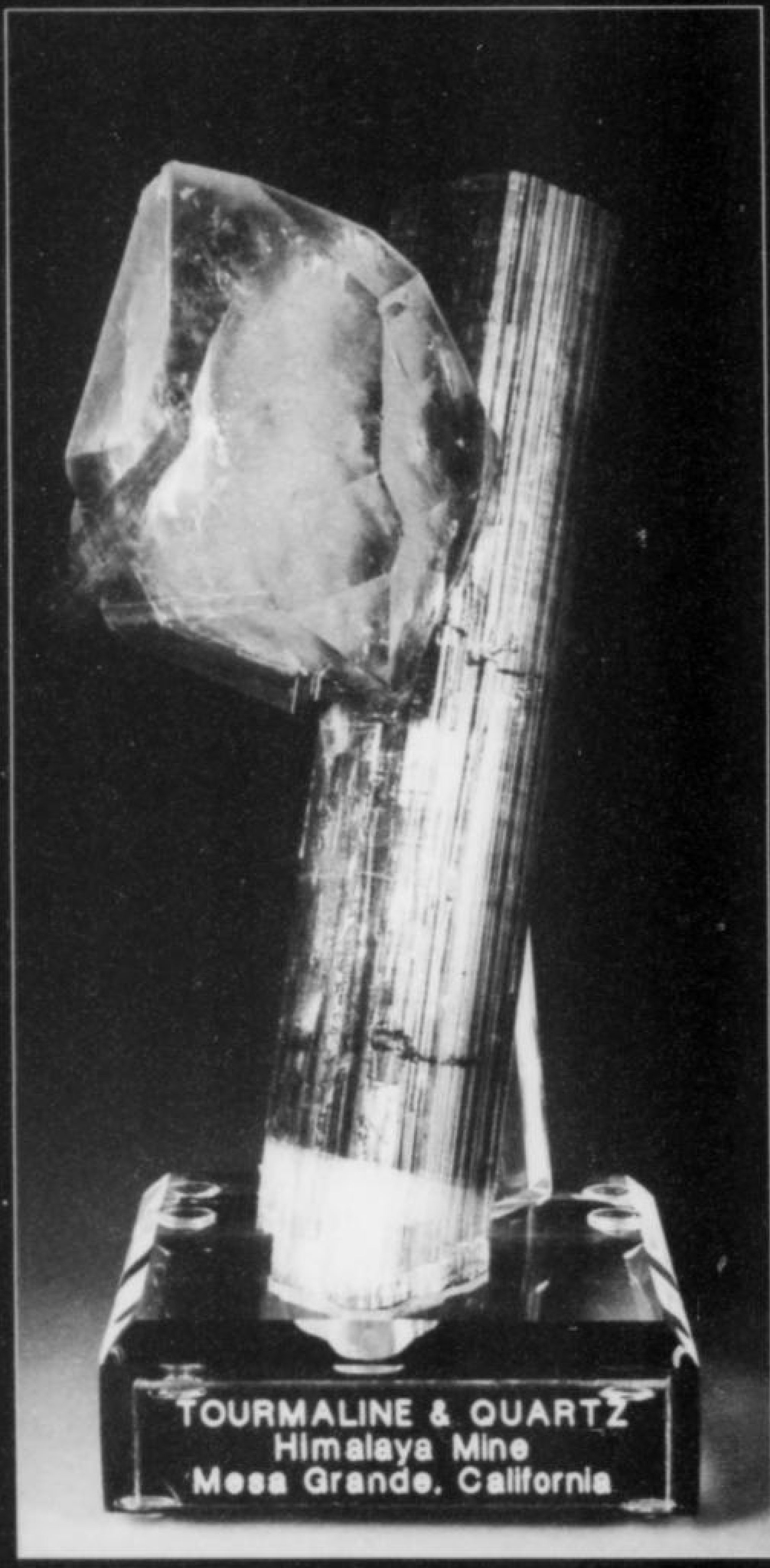
Many links can be found on the Internet by searching for "multi focus" or "multifocus." Only a few are listed below.

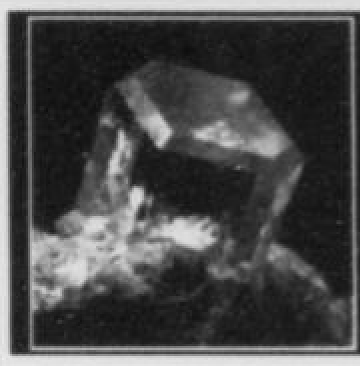
http://www.sgi.com/misc/grafica/depth
A short explanation how multifocus works

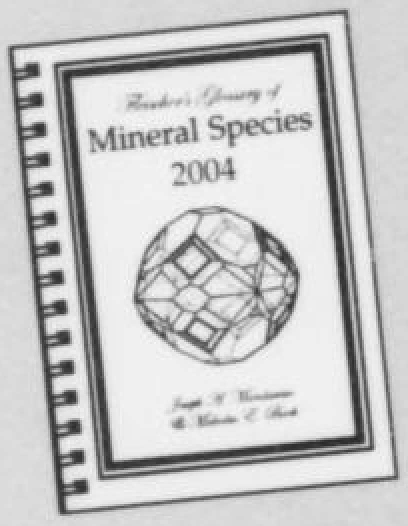
http://www.promicron.de/
Provides microscope adapters used, for Nikon and others

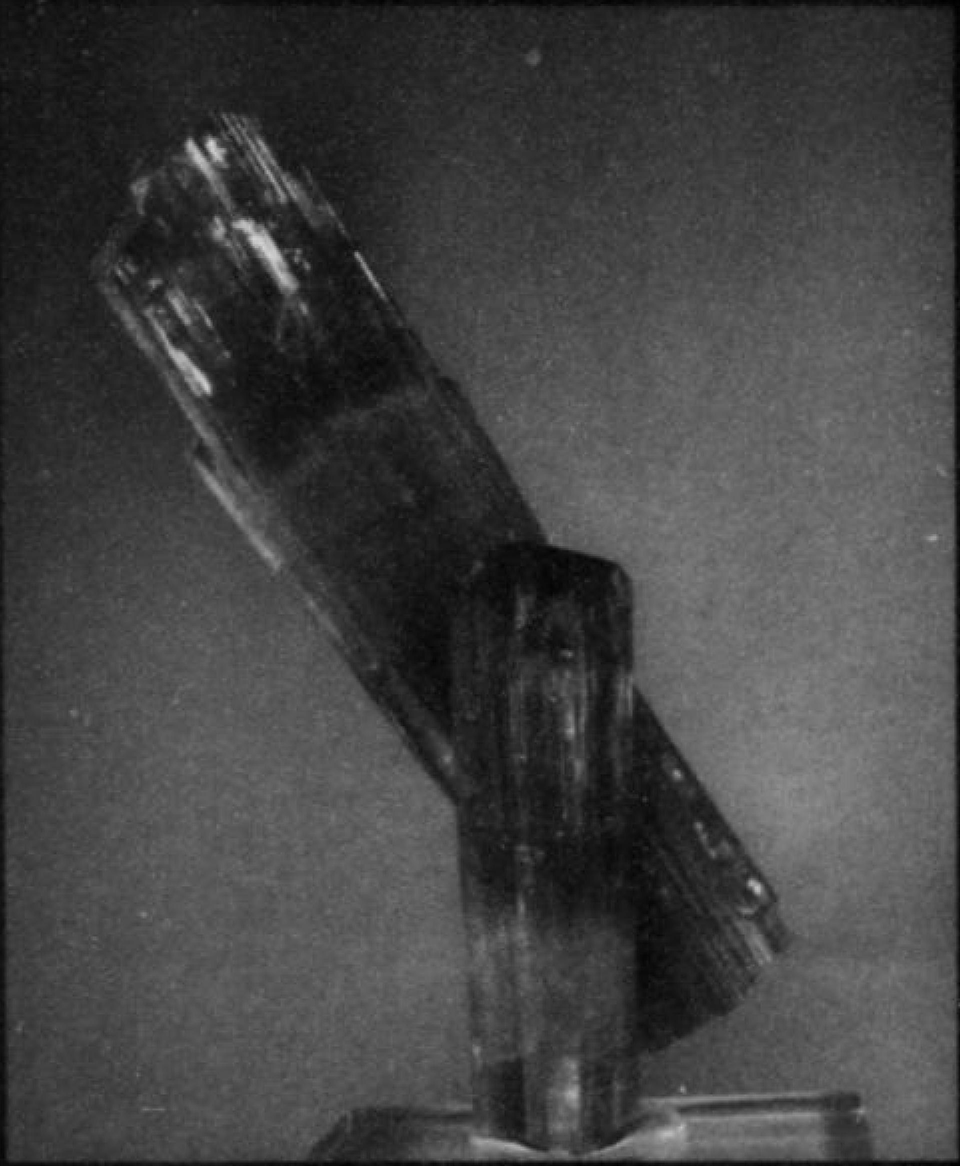
http://www.macrolenses.de/objektive.php
A page with an overview of macro lenses

http://helicon.com.ua *Provider of the Helicon Focus Software used for this paper. A test version can be downloaded.*

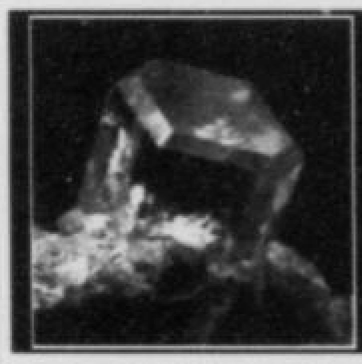

TOURMALINE & QUARTZ
Himalaya Mine
Mesa Grande, California





Elbaite - Paprock, Nuristan, Afghanistan - 8.6 x 5.0 cm

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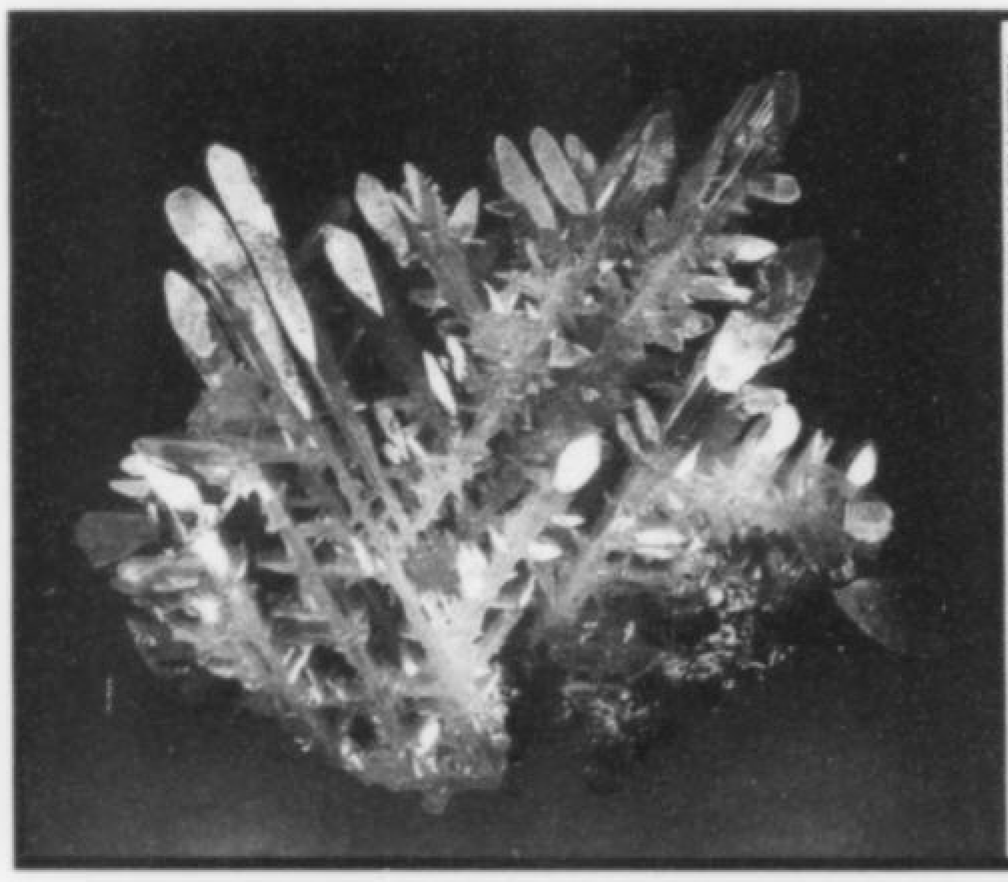

NIFONTOVITE

From Charcas, San Luis Potosi, Mexico

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Extraordinary crystals of the rare hydroxy-hydrated borate mineral, nifontovite, previously known only as tiny grains, have been discovered at Charcas, San Luis Potosi, Mexico. Two specimens have been recorded from this locality, but the location of only one specimen is currently known. This specimen is probably the world's finest nifontovite.

INTRODUCTION

Nifontovite is a hydrated calcium borate mineral, $Ca_3B_6O_6(OH)_{12}(H_2O)_2$, first described from the Novofrolovo mine in the Turinsk ore deposit, Central Ural Mountains, Russia (Malinko and Lisitsyn, 1961), where it occurs in a skarn associated with andradite-grossular and szaibelyite.

A second occurrence of nifontovite was reported by Kusachi and Henmi (1994) from crystalline limestone in the vicinity of skarns associated with quartz monzonite dikes in the Fuka Okayama Prefecture, Japan, about 40 km northwest of Okayama. Nifontovite formed there by hydrothermal alteration of an unknown anhydrous borate precursor.

Since then, extraordinary crystals of nifontovite have been discovered at Charcas, San Luis Potosi, Mexico. The crystals are up to 3.5 cm long, measure 5 × 9 mm in cross-section, and are transparent with a silky luster and good cleavage.

NIFONTOVITE FROM RUSSIA AND JAPAN

The chemical formula of nifontovite was originally described as $CaB_2O_4(H_2O)_{2-3}$ (Malinko and Lisitsyn, 1961), but solution and refinement of the crystal structure led to a revised formula: $Ca_3B_6O_6(OH)_{12}(H_2O)_2$ (Yegorov-Tismenko *et al.*, 1973). Chemical analyses of nifontovite from Fuka, Japan (Kusachi and Henmi, 1994) are in close agreement with the chemical formula derived from crystal-structure analysis.

In their original description of nifontovite, Malinko and Lisitsyn (1961) note that nifontovite occurs as colorless, transparent grains and crystals with dimensions 0.05 to 1.0 mm, occupying interstices between grains of garnet at the borders of druses in a crystalline limestone that shows some slight evidence of skarn formation, and as narrow (1–2 mm) monomineralic veins in the groundmass of the limestone.

Kusachi and Henmi (1994) described nifontovite from Fuka as consisting of aggregates of tabular crystals up to 5 cm long and 1.5 cm wide, and rarely as euhedral crystals up to 1 mm long associated with a large mass (3 × 2 m) of an unknown anhydrous borate and olshanskyite.

NIFONTOVITE FROM CHARCAS, MEXICO

In the late 1960's, one of us (FHP) started visiting mineral dealers in El Paso, Texas, and became friendly with Manuel Ontiveros. On one occasion, Manuel came up with an unknown mineral that resembled danburite from Charcas, San Luis Potosi, Mexico.

Figure 1. **Nifontovite from Charcas, San Luis Potosi, Mexico. The specimen is 2.1 × 4.2 × 5.5 cm, and the longest crystal measures 3.5 cm. William Pinch collection; Wendell Wilson photo.**

However, the appearance was not quite right for danburite, and the crystals looked monoclinic rather than orthorhombic. Moreover, there was no firm information as to the source of this mineral, and as a result, there was no work done on this specimen. Some years later, FHP was on a collecting trip to Charcas and the mineral surfaced again in material, primarily danburite and tabular calcite, offered for sale by the main dealer in town. The first specimen was then sent to William Wise, and he identified it as nifontovite.

The first specimen is now in the collection of William W. Pinch, and is the one described here. The second specimen passed to Miguel Romero, and its present whereabouts are currently unknown. Panczner (1987) described nifontovite from Charcas, San Luis Potosi, Mexico, as consisting of "crystals to 6 cm"; this statement is presumably an exaggerated reference to the specimen now in the Pinch collection.

In the other reported locations described above, the size of the grains and crystals of nifontovite does not exceed 1 mm. The Charcas sample pictured in Figure 1 is probably the world's finest specimen of nifontovite and is worthy of description, particularly inasmuch as the morphology of nifontovite has not previously been described because of the lack of good crystals.

CRYSTALLOGRAPHY

The Pinch specimen consists of six transparent, colorless, euhedral crystals attached to a grayish white fine-grained groundmass (Fig. 1). The largest crystal measures 5 × 9 × 35 mm and is elongated along the *c*-axis. A drawing of an idealized crystal is shown in Figure 2.

The faces are indexed on the following unit cell: $a = 13.12$, $b = 9.500$, $c = 13.56$ Å, $\beta = 119.6°$ (Kusachi and Henmi, 1994); this differs in orientation from the cell that was employed for the solution of the crystal structure (Yegorov-Tismenko *et al.*, 1973), as the latter uses the first (unconventional) monoclinic setting with the two-fold rotation axis oriented along the Z axis.

The dominant form is the prism {110} with all faces present, and the elongated crystal is terminated by the (001) face of the basal pinacoid {001}, the ($\bar{1}01$) face of the pinacoid {$\bar{1}01$}, and the ($\bar{1}11$) and ($\bar{1}\bar{1}1$) faces of the prism {$\bar{1}11$}.

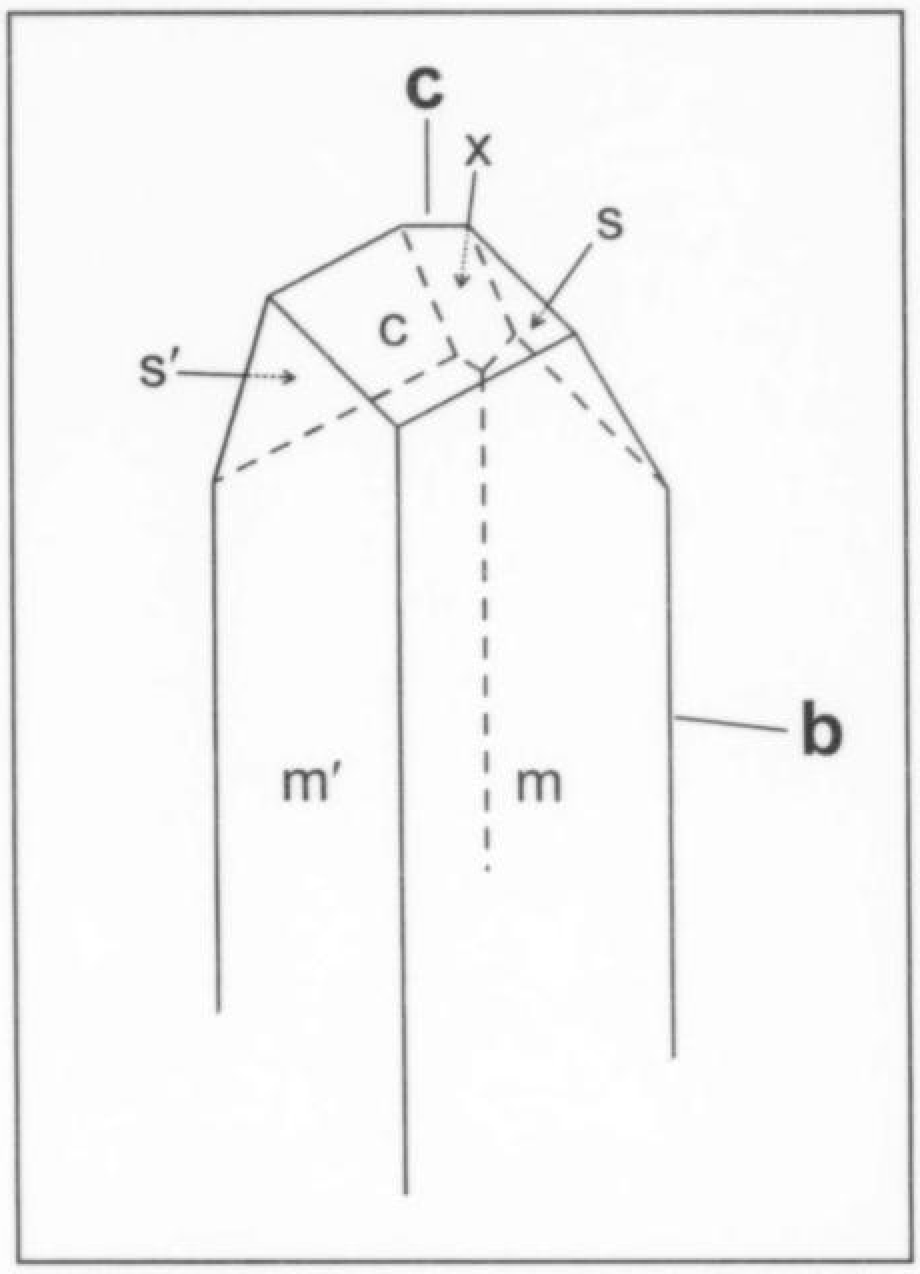

Figure 2. **Idealized crystal drawing of nifontovite; *c*(001), *m*(110), *m'*(1$\bar{1}$0), *s*($\bar{1}$11), *s'*($\bar{1}\bar{1}$1), *x*($\bar{1}$01). Note that the orientation of the crystallographic axes are modified from the setting used by Yegorov-Tismenko *et al.* (1973).**

ACKNOWLEDGEMENTS

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Letters

The Purpose of Museums

I was delighted to see Bill Smith's guest editorial last year (*It's The Artifacts, Stupid!*) in the *Mineralogical Record* decrying what has been happening to all too many natural history museums. It was a statement that is more than timely. Natural history museums have in recent decades been easily infiltrated by opportunists waving the banner of "education" as their means of entry into the upper levels of management. Whether their motives are pure or not remains to be seen, but the damage they have done and are doing may require decades more to rectify. True museums have never been, nor should they be, considered educational institutions. They have one function that they perform better than any other medium, and that is the displaying of objects which cannot otherwise be seen firsthand by the public. The public very definitely does not demand "interpretation." If, after having seen the objects, they want interpretation there are countless resources outside of the museum where they can find it. Secondhand educational fallout provided by an assembly of these artifacts (as Smith refers to them) is perfectly fine, but education as an objective is a serious distraction from the fundamental purpose behind the existence of natural history museums.

John S. White
Stewartstown, PA

[Note: The Mineralogical Record gives blanket permission for anyone to reprint Bill's guest editorial in its entirety. WEW]

Philadelphia Academy

[Note: The Friends of Mineralogy sent the following letter to the Philadelphia Academy of Science in response to their announced plan to liquidate their entire mineral collection by public auction. We reprint the letter here by request of FM President Bill Dameron. WEW]

April 26, 2005

Dr. D. James Baker, President
The Academy of Natural Sciences
1900 Benjamin Franklin Parkway
Philadelphia PA 19103-1195

Dear Dr. Baker,

The Friends of Mineralogy is a national not-for-profit organization of earth-science educators, museum professionals, scientists and mineral collectors. It is devoted to promoting, supporting, protecting and expanding the recovery, preservation and study of mineral specimens, and to furthering the recognition of the scientific, economic and aesthetic value of minerals.

We were saddened to learn about the Academy's intention to dispose of its famous and historic mineral collection by auction. In view of the tremendous loss this action could entail for the science of mineralogy and the damage it could do to the reputation of natural history museums in general and the Academy in particular if handled unwisely, we respectfully ask that you consider a suggestion.

Any collection as celebrated as that of the Academy contains among its holdings significant specimens which have been studied and written about, including many that are the original specimens from which new species were described. These specimens have unique and irreplaceable value to science, and must be preserved so as to be permanently available for reference. In addition, the Academy has many important specimens from historically significant collections and from mines and mineral deposits that are no longer extant. This mineral heritage is widely known and respected.

We believe there is a fiduciary and moral responsibility to preserve this core portion of the Academy collection together in a public institution, a duty which overrides immediate financial needs and which goes beyond any written letter of the law. The Academy was entrusted with the specimens by well-known scientists so that they would be available in a museum setting for fellow scientists and the general public. That is a trust which no scientific institution can ignore in good conscience.

In addition, collector support has long been a fundamental pillar of museum acquisitions, and widespread knowledge of your decision would have a chilling effect on future specimen donations to other museums.

The Friends of Mineralogy urges that you reconsider wholesale disposal of your collection, especially via auction, the least likely way to insure integrity of the collections. We request that you invite a small group of respected and knowledgeable mineralogical curators from other natural history institutions to come to the Academy and identify critical specimens that should be preserved, individually or as suites. We ask that, by whatever means, these core specimens of greatest value to science and history then be transferred to a respected and responsible institution devoted to the mineral sciences.

I have sent copies of this letter to some publications and curators of scientifically significant worldwide mineral collections in hopes they may have other ideas they could convey to you.

We look forward to hearing from you.

On behalf of the Board of Directors,

William H. Dameron, III
President, Friends of Mineralogy

Bull Creek Celestine

I would like to make some corrections and additions to the information on the Bull Creek celestine from Austin written up on page 144 in the Mar-Apr Issue of MR. The celestine from Bull Creek, like all the other celestine occurrences in central Texas, including the Dana locality in Lampasas County, does not come from the Upper Cretaceous Austin Chalk but from the Lower Cretaceous Glen Rose Limestone. The crystals of celestine occur in cavities in linear zones in the limestone that are now believed to have been formed by small masses of anhydrite long since removed. The celestine varies considerably in size and color even in the relatively small area where it is exposed along Bull Creek. The classic Bull Creek specimens are blue tipped crystals, the smaller being transparent, with white to pale gray prisms. Solid gray to blue crystals were more common in the west part of the canyon and the blue tipped on the east part. The specimens that Doug Wallace had were obtained from me and collected 6 to 12 years ago. I doubt that any more will be available unless some stash like mine is released because the last serious collectors that I know that ventured into to the area about 6 years ago were arrested, thrown in jail, and had their tools confiscated by the Austin Park police. Even though the collectors claim that they had permission to collect on the private land they were on. Evidently Austin, who had very little land in the canyon wants to make it a park. They do have a park south of the canyon along Bull Creek and ten years ago they allowed collecting there as long as you parked in designated parking areas. The Bull Creek locality was somewhat of a lost locality from the middle 1950s until about 1990 when Hank Brennecke of Corpus Christi, Texas revealed the location to me. It was obvious at that time that the locality had little or no collecting since the 1950s.

I hope this information is of some use.

Art Smith
Houston, TX

Thanks, *MR*

My lifelong interest in minerals had no direction until the summer of 1980 when I accidentally discovered the Arizona-I special issue of *The Mineralogical Record* in a rock shop. As a petroleum geologist I was initially unfamiliar with many mining terms and some mineralogical data, but constant perusal of the well-written articles in the *MR* and the acquisition of a complete set of back issues increased my knowledge and enjoyment. The *MR* has since become my "bible."

By the early 1980's I was attending the Tucson Show and the *MR* auction. And I was fortunate to win two Best-of-Species competitions at the Tucson Show. The *MR* has also become very important to me in the area of historical mineralogy, with its emphasis on antiquarian mineralogy books. I now have over 300 books in my mineral library, many of them antiquarian.

The *MR* relationship with the Tucson Gem and Mineral Show encouraged our local mineral group (the Mineralogical Association of Dallas) to exhibit our best specimens there every year since 1991. And imagine my surprise in July 2002, when one of my specimens (a fluorite) graced the front cover of *The Mineralogical Record*. What an honor! Even after 25 years as a subscriber I still wait impatiently every two months for the next *MR* and its treasures.

Wallace Mann
Dallas, TX

You have made every year of our lives happier and far more interesting since you began publishing *The Mineralogical Record*. I think we have every issue except the first two or three! This is a superb publication, and we are so grateful to be able to learn all the old mine histories and to know about all the localities we would miss otherwise. You can be proud of your beautiful publication, which we are so deeply fortunate to be able to follow all these years.

Mary Keelan
Charlottesville, VA

I would like to mention that the special issue on California Pegmatites (vol. 33, no. 5) was superb, not just for the description and photos of the great crystals, but also for the way the articles described the prospecting for pockets of gems. It was so realistic that it was like watching the events happening in front of my eyes. Most of us don't get the opportunity to see this in real life, but at least I could compare my many elbaite specimens with those illustrated, and learn more about where they came from. Thanks!

Mike Gough
Devon, England

Enclosed is my subscription renewal—At my age a one-year subscription to anything is an adventure. I have been loaning my issues of *The Mineralogical Record* to the public library in our town (must be read in the library, not checked out). This way the town can enjoy another year of your excellent magazine. You do a really fine job with your descriptions of classic localities.

My specialties in collecting are the Lovozero Massif occurrences, and Bolivian and English localities with emphasis on Cornwall and Cumbria. I attended the Tucson Show two years ago. Couldn't buy much, as I spent all I had just to get there. However, the memory remains and remains and remains.

D. Schultz
Bloomfield, NY

Field Collecting

The recent letter from William Hunt blaming sports for a decline in the number of young collectors may have some merit. But I feel that unless young people can actually get out and dig for their specimens in mines, quarries, dumps, road-cuts, etc., then mineral collecting becomes just a matter of money. I'm pretty sure that the guys who started out like me, collecting in the Lower New Street quarry (New Jersey), could attest to my thinking. Remember what Robert W. Service said in *The Spell of the Yukon*: "Yet, it isn't the gold that I'm wanting, so much as just finding the gold." That's the thrill of self-collecting, rather than simply buying. On the other hand, when I started out we didn't have access to worldwide sources of mineral specimens like we do today—the commercialization of the mineral business has served to provide access to specimens we never dreamed of!

Tom Fallon
Humble, TX

50-year History of the TGMS

Bob Jones and the entire staff at Mineralogical Record did a remarkable job putting together the *Fifty-Year History of the Tucson Show*! Your book enabled me to go back through the years, prior to my first visit in 1978, and then to reminisce through the following years. It was great to see the many fine collections that adorned the various shows, and to see photos of various collectors and dignitaries who contributed to making the Tucson Gem & Mineral Show the ultimate of all shows. However, it was sad to see photos of those who are no longer with us, one of the latest being Dave Shannon, a dealer who always catered to the collector and not the status symbol.

Again, a great issue!

Al Ordway
Hesperia, CA

I noticed a misidentification in the 50-Year book: On page 147, the dealer identified as Alexander Agafonoff is actually Dmitry Abramov. They were both among the founders of the Russian dealership called *Stone Flower*; another of the original partners, Nick Kuznetsov, is still involved, though he has shifted from mineral specimens to gems.

John Watson
Fallbrook, CA

Butte Notes

I enjoyed very much reading the Butte special issue back in January-February 2002. The well-written articles brought back vivid memories of my first job in mining as a mining engineering trainee with the Anaconda Company in Butte in the summer of 1960. I will never forget my first assignment, to muck out the sump at the bottom of the Steward shaft. My partner quit after the first day. Hanging air lines deep in the Steward mine was also challenging, as some of the rock faces were so hot you could not hold your hand on them. The comments by Duane Johnson on page 66 of the issue describe similar conditions in the East Colusa mine.

I would like to add some information on Butte mineralogy. During June of 1960 I was mucking out stopes and drifts that had been sealed for decades following a devastating mine fire on the 3200 level of the Steward mine. All of the headings were filled with debris (ore, waste rock, timbers, rails, etc.). Throughout the wet muck, copper had replaced the old mine rails. I recovered an 11 × 12-cm mass of pure copper coated by copper microcrystals.

Of greater interest, and not listed in the Butte issue, was my discovery of scheelite crystals in the Steward mine. Following a blast on January 15, 1960 I was running a slusher in the 3091 raise, 3000 level, when I saw light from my head-lamp reflecting off of some small crystals. I collected four specimens containing 2-mm crystals that looked to me like scheelite. I later took the specimens to Dr. John Guilbert, a Research Geologist at the Anaconda Geological Research Laboratory, and he confirmed it as the first known scheelite from Butte. I gave him two of the specimens for the Anaconda Reference Mineral Collection, and in exchange he gave me my choice from among a dozen or so small colusite crystals on enargite which had been collected by Bob Ingersol on the 3200 level of the Leonard mine. These crystals are similar to those shown on page 48, Figure 50, of the Butte issue.

Some time later, in the middle of my day shift at the Steward mine, I was told to report to the shaft station to be hoisted to the top. The skip was empty except for me, and I had the ride of my life. The rate of ascent was incredible, and as we came to the surface the skip missed the sheets and shot up into the headframe—I thought I was going to die. It turned out that the hoist man knew it was my last shift, and gave me a farewell ride. I reported to Mr. Shae's office, where he thanked me for the scheelite discovery (Dr. Guilbert had apparently told him about it), handed me airplane tickets, and told me I had been promoted—to work on a pioneering Induced Polarization (IP) geophysical study in the Escalante Desert of southwestern Utah.

Thanks again for the Butte issue. Keep up the good work.

Raymond Lasmanis
Castle Rock, WA

Chinese Practices

Having read the Tucson Mineralogical Symposium abstracts, I can easily say that, although the attitudes and practices of the Chinese mineral dealers may seem new and puzzling to the rest of the world mineral collector market, they are an old, long-solved problem to manufacturers and importers of the vast volume of other goods being exported from China, Taiwan and Japan. I will use industrial machinery as an example. Years ago when American Manufacturers started making machinery in Taiwan, they experienced massive and expensive quality-control problems which were responsible for the view that "made in Taiwan" meant cheap. When the American firms investigated the causes, they found that (among other issues) there was an attitude among the Taiwanese that quality control was the responsibility of the *buyer*, not the *maker*. American firms had to create extensive training and exchange programs over several years to train the various workers in the Chinese factories, and bring in the latest manufacturing equipment. From what I read, I would say the various Western mineral importers should start working with their Asian counterparts and the geo-scientific community to create programs to educate Chinese dealers and exporters to what Western dealers and collectors want, expect and are used to.

Edward Mattson
Ardsley, NY

Mineral Specimen Mortality

Your recent article on Mineral Specimen Mortality (July-August issue) brought to mind an early paper I found by John Mawe (1764–1829) in the 1818 edition of the Journal of Science and The Arts, London. In it Mawe describes the circumstances surrounding a find of apatite and schorl crystals from a granite pocket on Wolley Farm, near Bovey Tracey, Devon. At the time these large schorl and white apatite crystals were considered some of the finest known examples of the species and were illustrated by Sowerby in Volume 5 of *British Mineralogy*. Specimens from the find still exist and appear in Embrey and Symes (1987) *Minerals of Cornwall and Devon*. The initial find was made by farm workers, and the farmer, liking the "magpie appearance" of the specimens, utilized them in building a stone wall! Eventually some specimens found their way to local mineral collectors who informed Mawe of the find. Mawe was impressed enough to visit Wolley Farm and assisted in the search for additional pockets. He writes:

> "I handled the hack, and was fortunate enough to discover a cavity, partly filled with wet clay; well knowing that this must be the place for crystallization I was fearful of going incautiously to work, but after a moment's pause I took a handkerchief and tied hay in it, so as to form a bundle, which I gently introduced into the cavity, and afterwards cut away as much as I could of the exterior; I then wrenched the boundaries apart with the lever, and took the uppermost piece out with great care, and observing some of the earthy matter fall from it, I gave it to the farmer to hold, whilst I reached what had fallen. A minute could not have elapsed before I was on my feet to replace it, when, to my surprise, I found him in the act of taking a fork from the inside of his coat "to dress it", as he said; meaning to scratch and scrape off the clay. It was now accounted for how all the apatite crystals which had been received, were so mutilated, as he told me with an air of truth that he "dressed them all with his fork to send them away clean."

Surviving specimens from the find (particularly apatites) often bear the scars of the farmer's "dressing," and it is interesting to speculate how many superb specimens were destroyed in the process or consigned to trash by later collectors because of the mutilation. As a postgraduate student at the University of Cambridge I remember seeing specimens from the find in the Earth Science Department's outstanding collection of old classics, including a large lump of granite matrix (easily 2 feet across) studded with schorls and apatites. This piece still had some remnants of mortar attached; it had once been included in the stone wall on the farm!

Ben A. Grguric
Leinster, Western Australia

Museum Support Groups

I am writing to you regarding something that has bothered me for a long time: the lack of support groups for most of the museums listed in *The Mineralogical Record*'s "Museum Directory." The Los Angeles County Museum of Natural History and the New York State Museum seem to be the only ones having the benefit of such a group.

I have been associated with the L.A. County Museum for over 50 years in various capacities—some humble and some quite grand. In 1985 the Museum Director asked if I would form a Gem & Mineral Council to support the museum in general and the Mineralogy Department in particular. Of course I agreed to try, and with the aid of some wonderful, talented and enthusiastic people, a Board of Directors was formed to establish goals and procedures for the operation of such a council.

The rest, as you know, is history. The Council has grown in membership and effectiveness under the guidance of a very capable Board of Directors, and with the complete support of Dr. Anthony Kampf and his staff. Spectacular specimens have been added to our collection through the efforts of the Board and the membership; lectures and field trips—some off-shore—have been arranged; all of which have been received by our members with enthusiasm and participation.

Considering the success of *our* Gem & Mineral Council, I find it hard to believe that most of the listed museums have not followed our lead. The Council's success did not happen overnight. Indeed, there were bumps and detours along the road to where we are today. But because of the hard work and dedication of the Board of Directors and the support of the Museum staff and the membership, we made it happen.

Doug MacDonald
Indio, CA

Photo Caption Errata

In producing the recent article on the Cripple Creek district, Colorado (vol. 36, no. 2, p. 143–185), several errors involving figures and figure captions occurred; these are listed below. In particular, photographs of two specimens from the Calumet district, Chaffee County, Colorado were inadvertently included with the article. As well, a photograph of native tellurium (verified by X-ray analysis) was mistakenly labeled sylvanite. These photos are listed below with the corrections.

Figure 20. Heavy line indicates boundary of Cripple Creek diatreme breccia, not boundary of gold-bearing rock.

Figure 26. Matrix is quartz, not calcite.

Figure 34. Matrix is quartz, not calcite.

Figure 36. Should have no mine attribution (although these are usually labeled Cresson mine).

Figure 37. Should have no mine attribution (although these are usually labeled Cresson mine).

Figure 46. From Calumet mine, Chaffee Co., not Cripple Creek.

Figure 47. Should have no mine attribution.

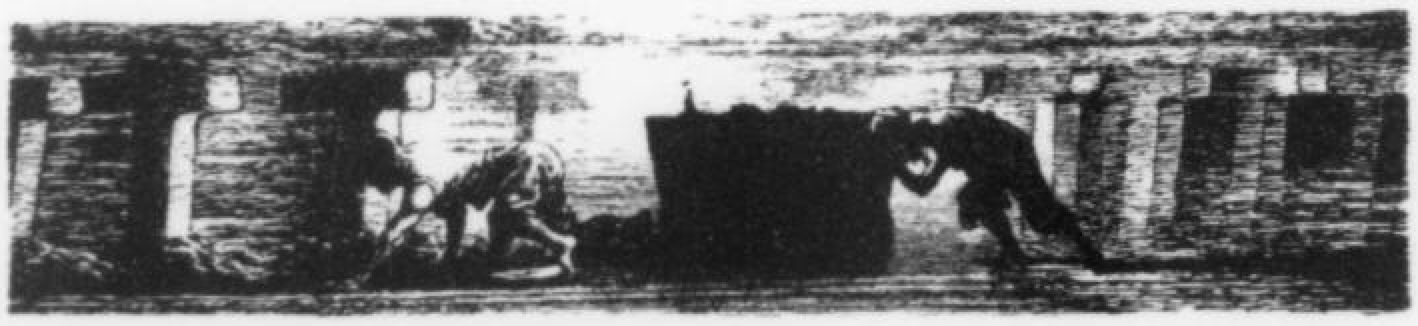
Figure 52. From Calumet mine, Chaffee Co., not Cripple Creek.

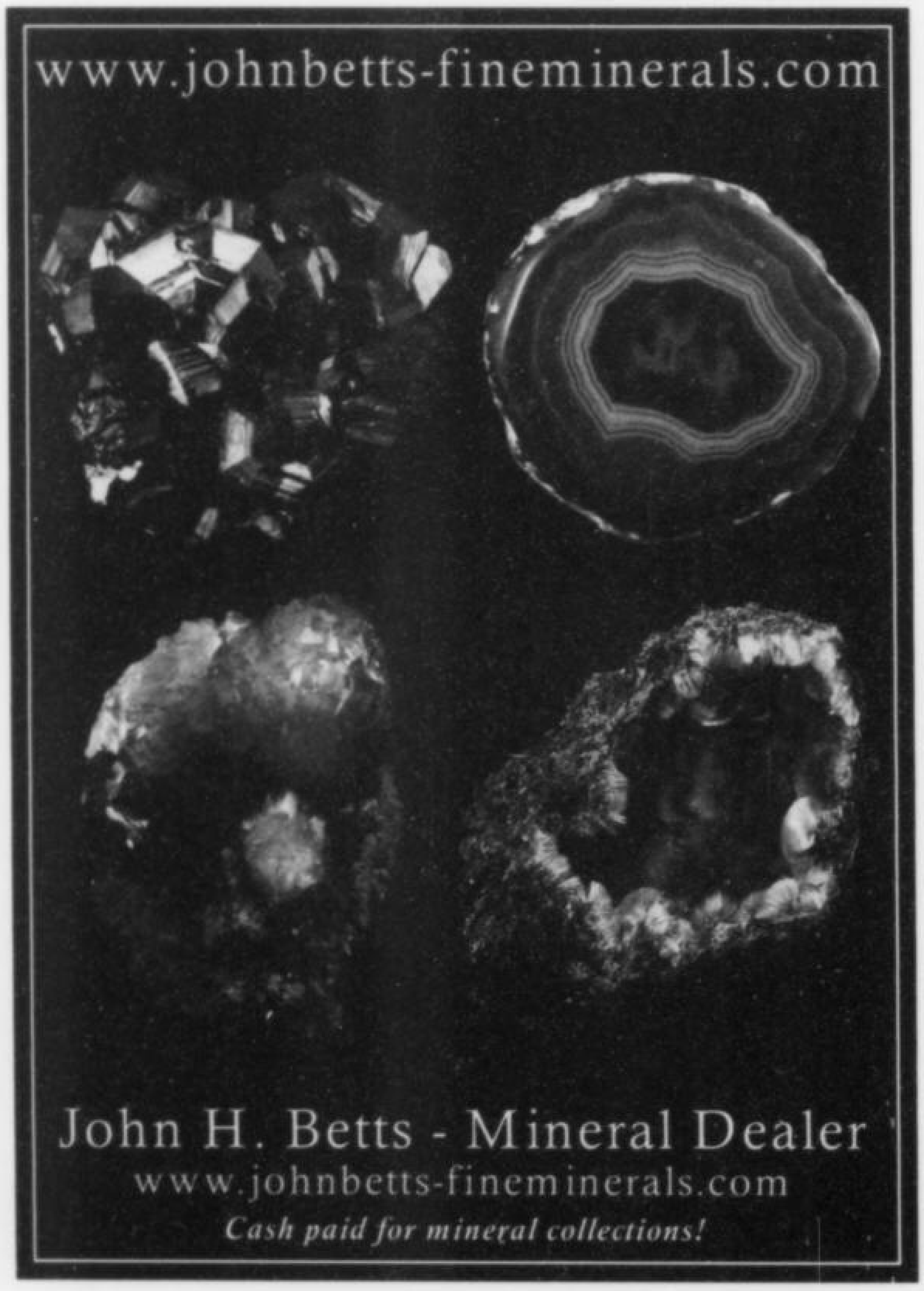
Figure 54. Should be tellurium, not sylvanite.

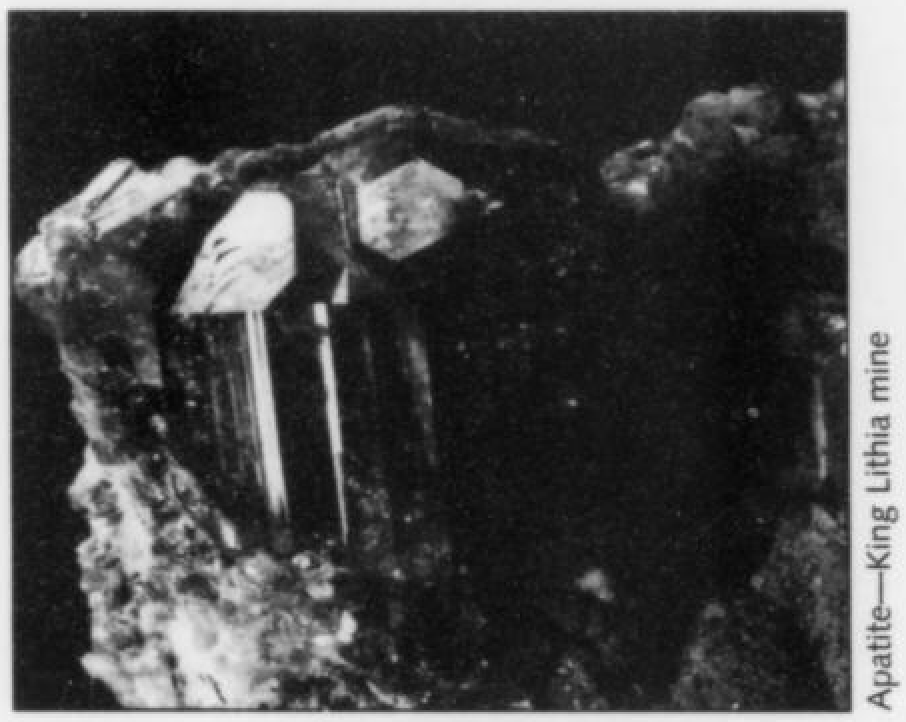
In Tom Moore's "What's new" report for the 2005 Tucson Show, the amethyst in *Figure 8* is incorrectly listed as being a 6-cm *Mountain Minerals and Gems* specimen from Jackson's Crossroads, Georgia. It is actually a 7.5-cm Jordi Fabre specimen from Antananarivo, Madagascar.

In that same report, the scapolite displayed at the Show and shown in *Figure 24* is from the Gene and Roz Meieran collection, not the Bill Larson collection.

The Mineralogical Record regrets these errors and apologizes for any inconvenience.







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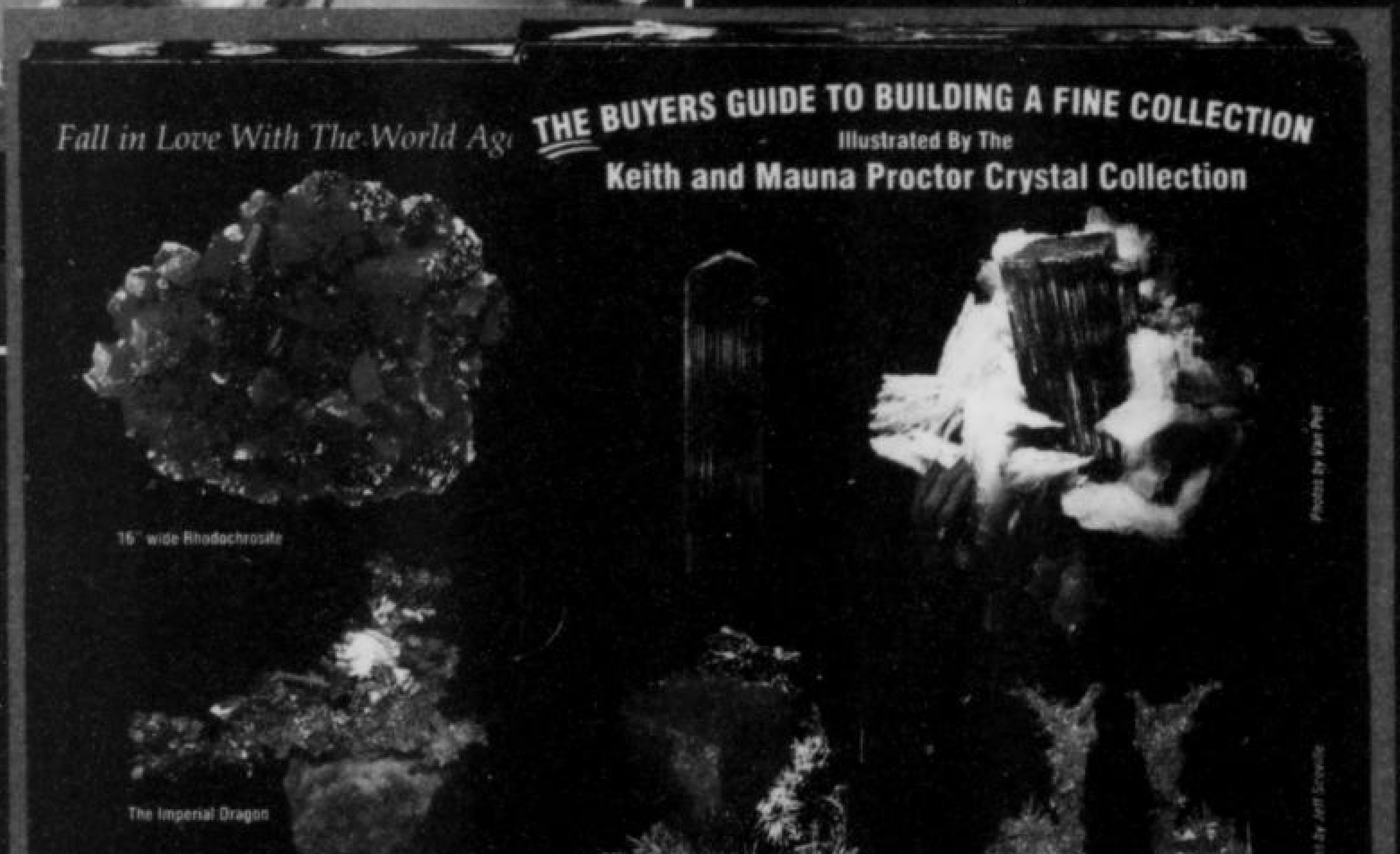

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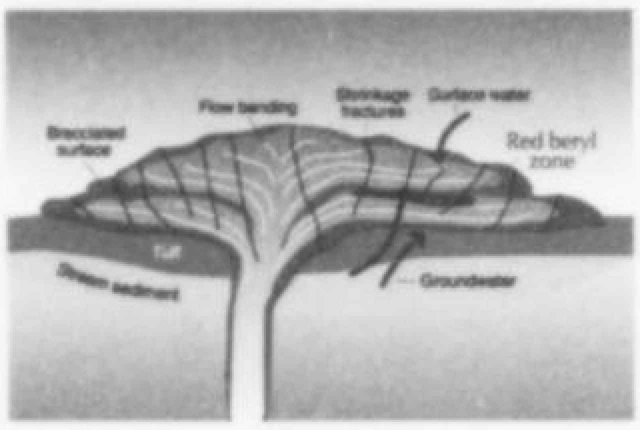

Brecciated surface
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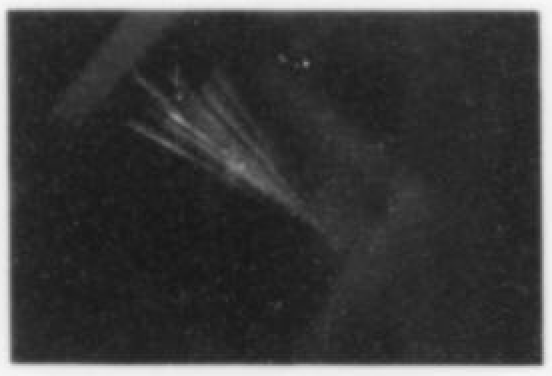

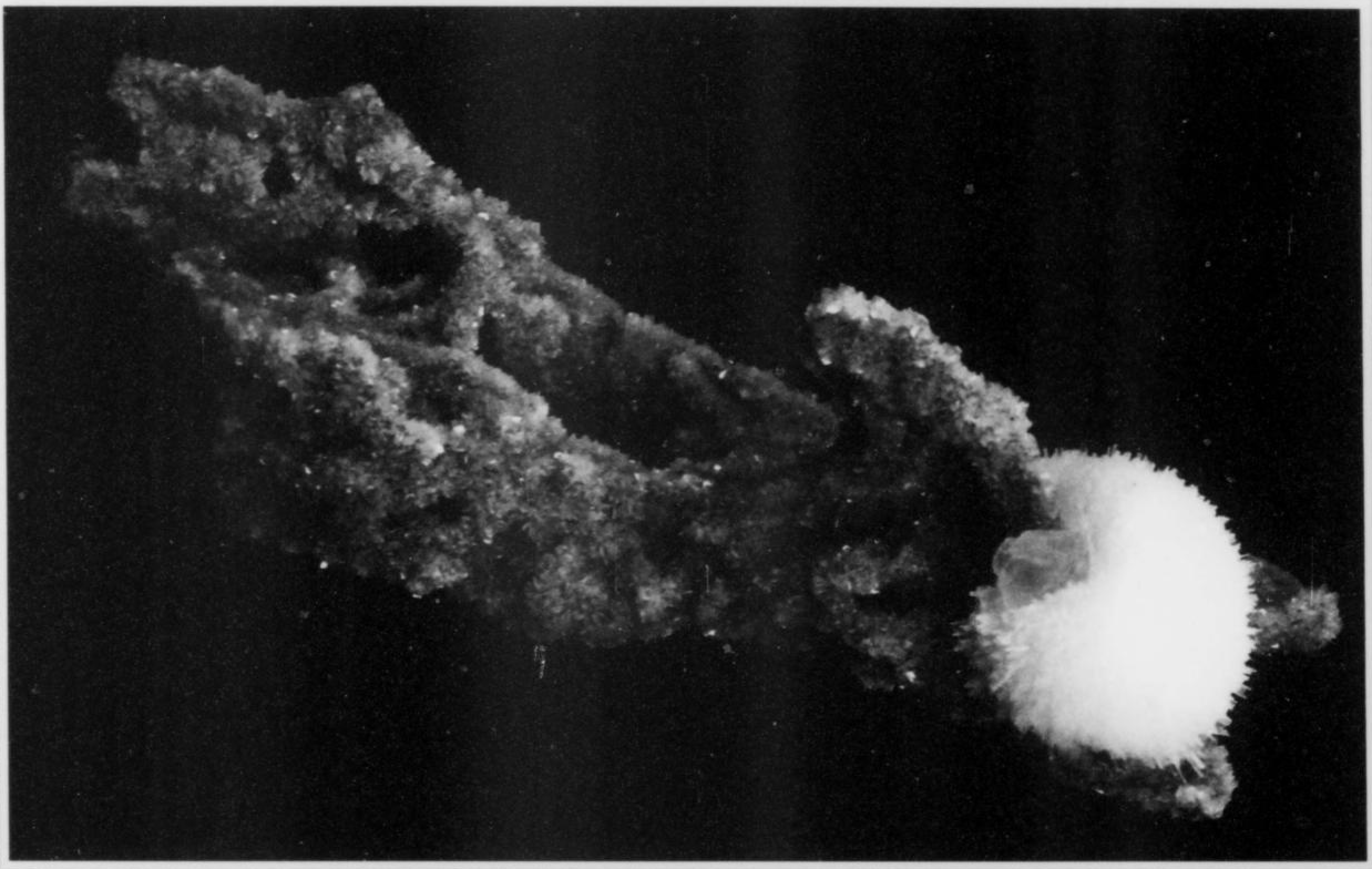

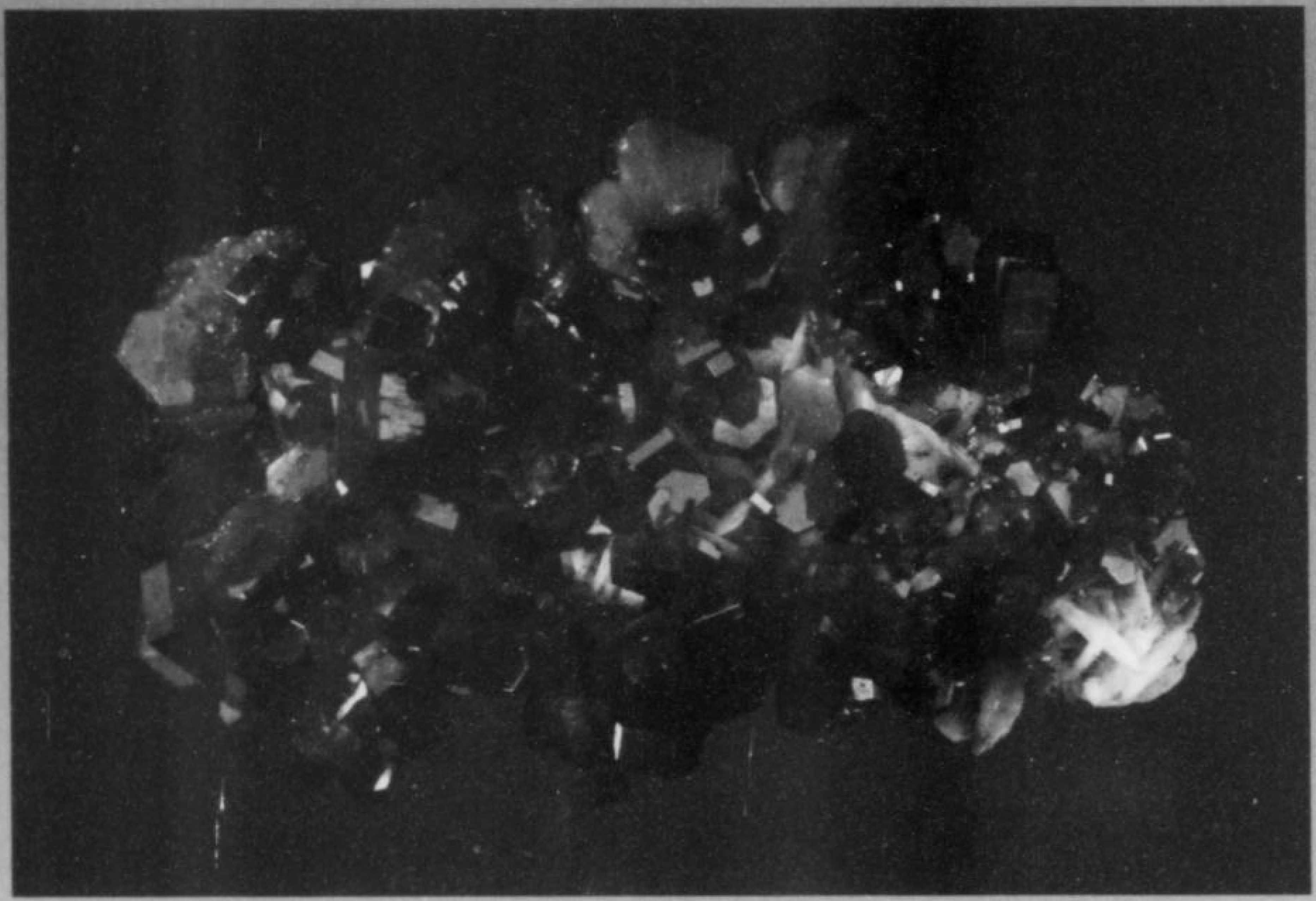

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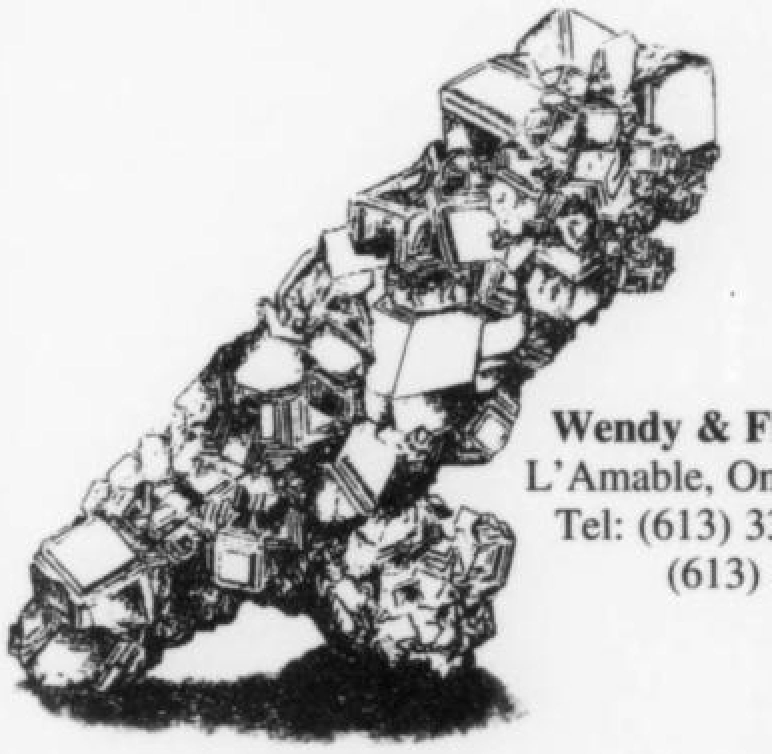

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