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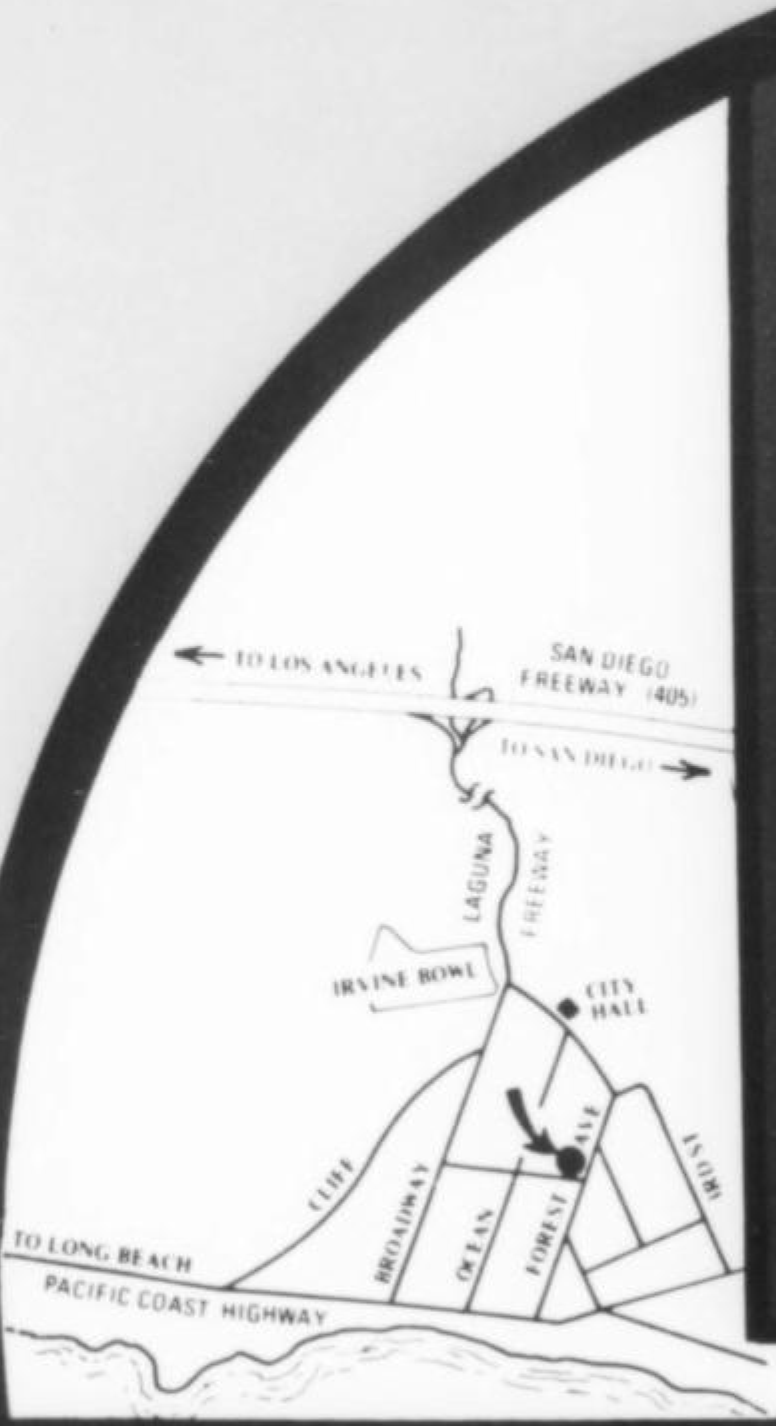
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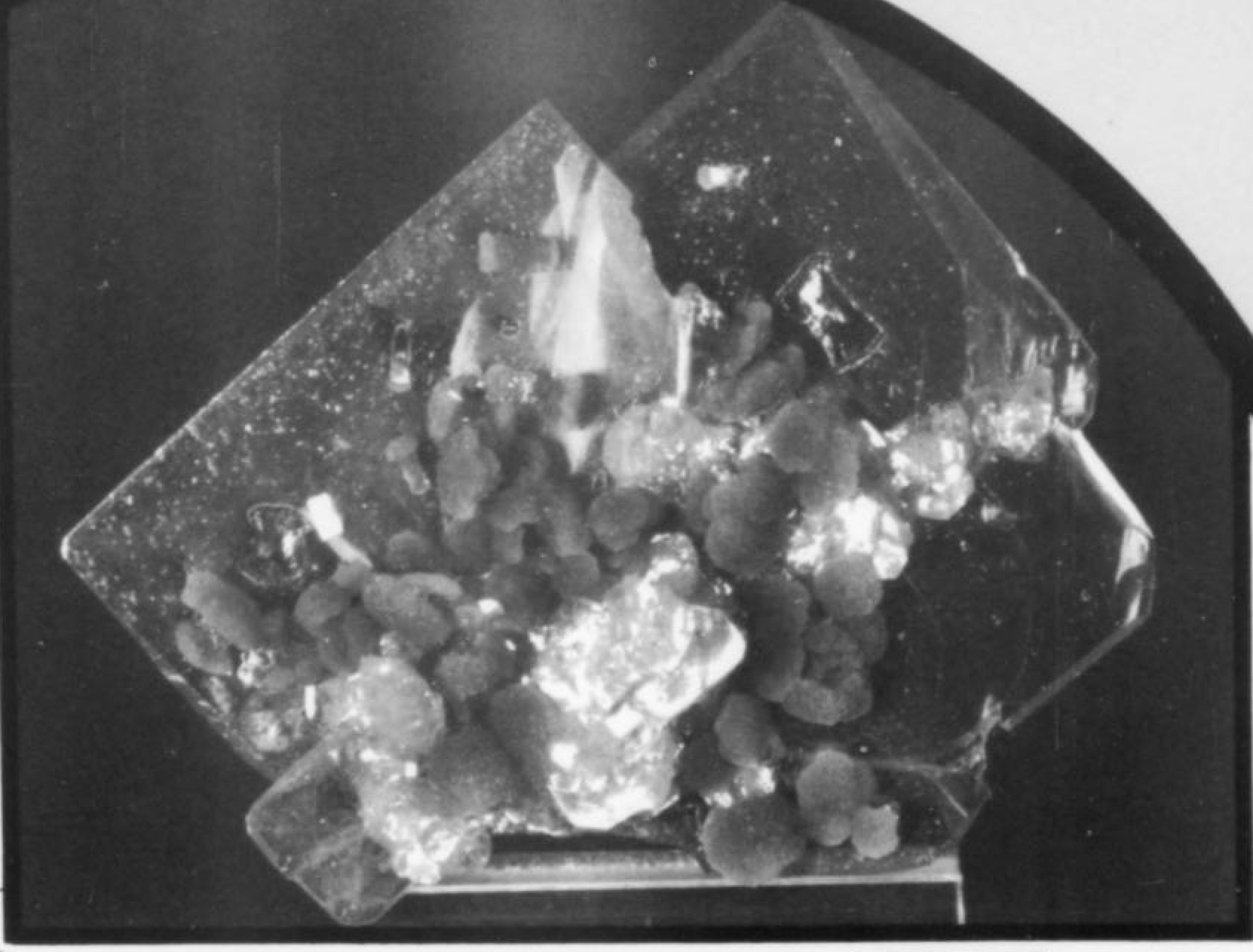


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COVER: KÄMMERERITE from the Kop Krom mine, Kop Dağları, Turkey. The crystals, from the collection of Roland Dietrich, are each about 1 cm. Photo by Olaf Medenbach.

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notes from the EDITOR

READERSHIP QUESTIONNAIRE

The response to our readership questionnaire has been excellent...well over 1000 responses have been received so far and they are still continuing to come in. I am told that a response of 5% is considered normal for such a questionnaire. Considering our circulation of 6000, we have already heard from more than 20% of our readers! The questionnaire asked 123 questions, some of which yielded multiple answers or essay answers...this means, of course, that our small staff will be busy for quite some time tallying the 160,000 or more individual responses to those questions. The only datum to emerge thus far is that an average of 2.1 people read each copy mailed out; our 6000 copies per issue are therefore read by somewhat more than 12,000 people.

TOURMALINE T-SHIRT

Who would have guessed it? You can now obtain a T-shirt emblazoned with a crystal drawing, chemical formula, and a variety of physical and crystallographic data...the mineral depicted is *uvite*, the new calcium-tourmaline first described last year by Pete Dunn, *et al.*, in the March-April 1977 issue of the *Record*. The T-shirt (available in S, M, L, or XL sizes) is available for $5.50 plus 50¢ postage from *Scientific T-Shirts, 82 Shirley Avenue, Buffalo, New York 14215*. Be sure to specify the uvite design...they also have T-shirts with a trilobite, eurypterid and giant beetle design.

UNIQUE EDMUND

As far as I know, there is no other supply company around that compares to *Edmund Scientific* (8875 Edscorp Building, Barrington, NJ 08007). Their new catalog contains over 4000 useful and hard-to-find items of a scientific nature. Just browsing through it, I noted the following items that might be of interest to mineral collectors: ultraviolet lamps, laboratory glassware, vacuum pump and chamber, ultrasonic cleaners, geiger counters, scales and balances, portable Bunsen burners, crystal growing kits, emergency chemical light tubes and battery-less flashlights, metal detectors, compasses, a map distance measuring guage, Dremel Moto-tools, stereo microscopes, hand lenses and fiber-optic equipment. In addition the catalog lists a mind-boggling array of fascinating gadgets and components from lasers to sniperscopes to solar energy panels, all at surprisingly low prices. I mention Edmund here because I know how frustrating it can be to have a brainstorm of an idea, and then not know where to buy the necessary equipment ("I wonder where I could get 4000 square inches of polarizing plastic sheet?"). Their 162-page catalog is free for the asking and may, of itself, stimulate a few brainstorms.

While you're sending for catalogs, send for *Ward's* summer catalog of science supplies (35¢): Ward's House of Science, P.O. Drawer 1749, Rochester, New York 14603.

KUNZ LETTERS

Larry Conklin has managed to reassemble a remarkable collection of correspondence to and from George F. Kunz (1856-1932). Kunz, after whom the spodumene variety *kunzite* was named, corresponded with a large number of people regarding his interest in gems and minerals. Included are letters to Kunz from no less than 48 different men after whom mineral species have been named, among them such greats as Canfield, English, Gordon, Palache, Ward, and Lindgren. A wide variety of other famous people, such as Max Bauer, Edward S. Dana, Irenee Dupont, William E. Ford, Charles Shepard, and perhaps 75 others are represented as well.

Quoting from Conklin's prospectus: "Perhaps the greatest strength of this collection lies not in the letters from the notables, but the letters from countless correspondents who notified Kunz, through his vast network via the U.S. Geological Survey, of the almost daily discoveries of new gemstone materials or minerals."

This collection of letters is for sale; interested parties should write to Larry Conklin, R.R.1, Box KH 29, Kent, Connecticut 06757. He has prepared a preliminary prospectus detailing the more famous names represented.

THE NEW COPYRIGHT LAW

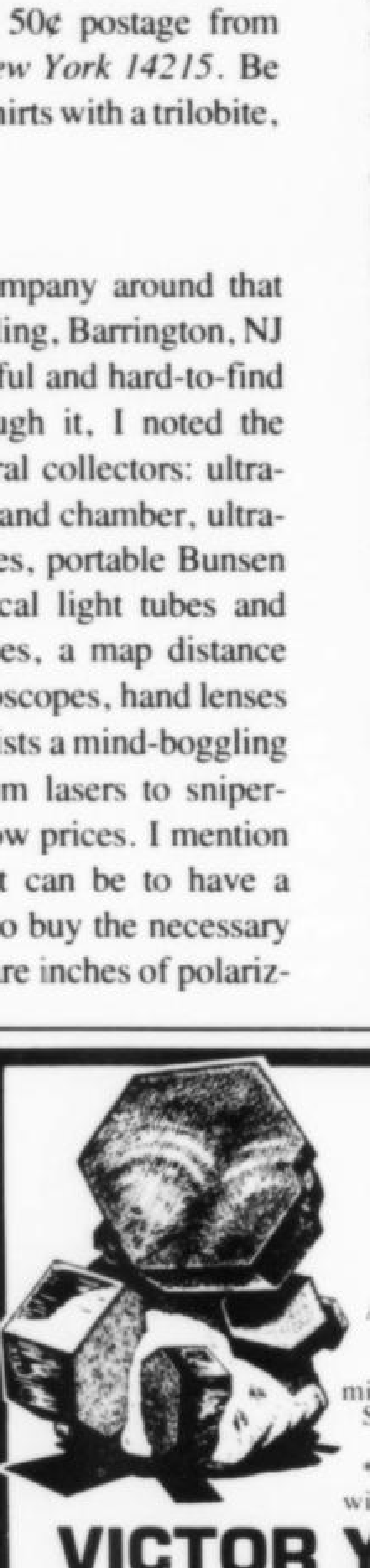
Since the passage of the new copyright law, there has been some confusion among librarians as to what they should allow to be copied by xerox or other photocopying processes. Because some instructors occasionally wish to copy *Record* articles for classroom use, a clarification here might be helpful. *Circular R21, Copyright and the Librarian*, is available at no charge from the Copyright Office, Library of Congress, Washington DC 20559. It describes exactly what types of articles can be copied for classroom use *without permission*. Limitations based on brevity, spontaneity and cumulative effect are imposed, but these will not normally be a hindrance to copying *Record* articles. If your librarian is reluctant to allow you to copy articles from the *Record* or any other publication for classroom use or personal research, send for a copy of *Circular R21* to show her. Librarians are understandably displeased with having the responsibility of enforcing the copyright law around the Xerox machine, but if you can show them you are not violating the rules there will be no difficulty.

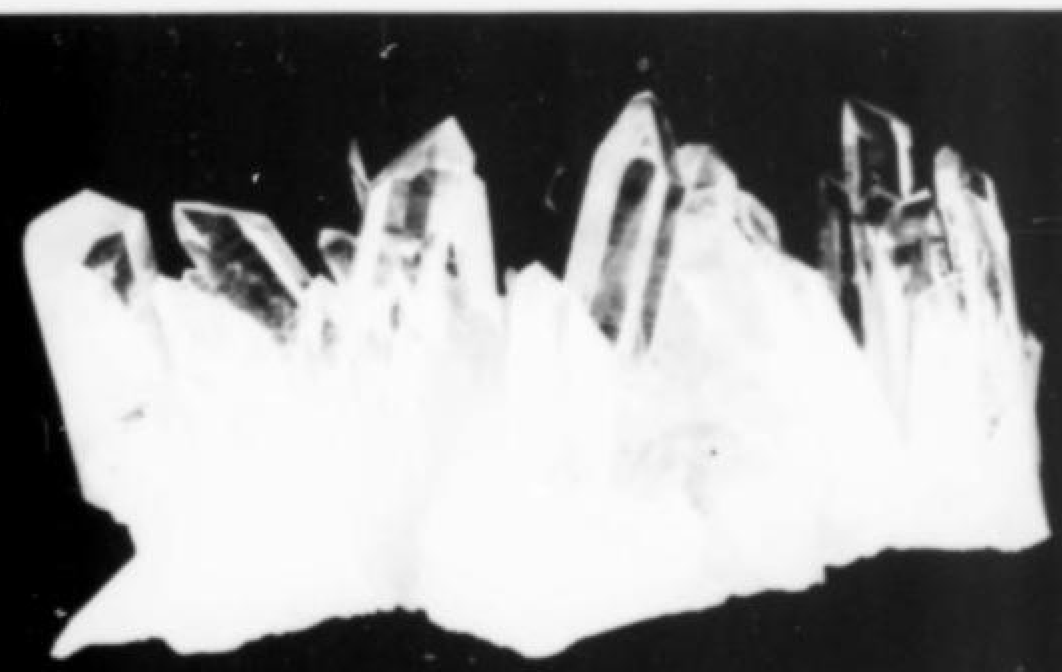
THANKS...

...to Randolph Rothschild, once again, for contributing the funds necessary to add color to this issue.

OVERSIGHT DEPT.

Two names were accidentally omitted from the list of donors published in the May-June issue: Robert L. Thompson (Socorro, New Mexico) and Robert W. Stevens, (Columbiana, Alabama). The owner of the fine Old Yuma mine vanadinite pictured on page 195 is Ray DeMark; Ray collected the specimen himself.





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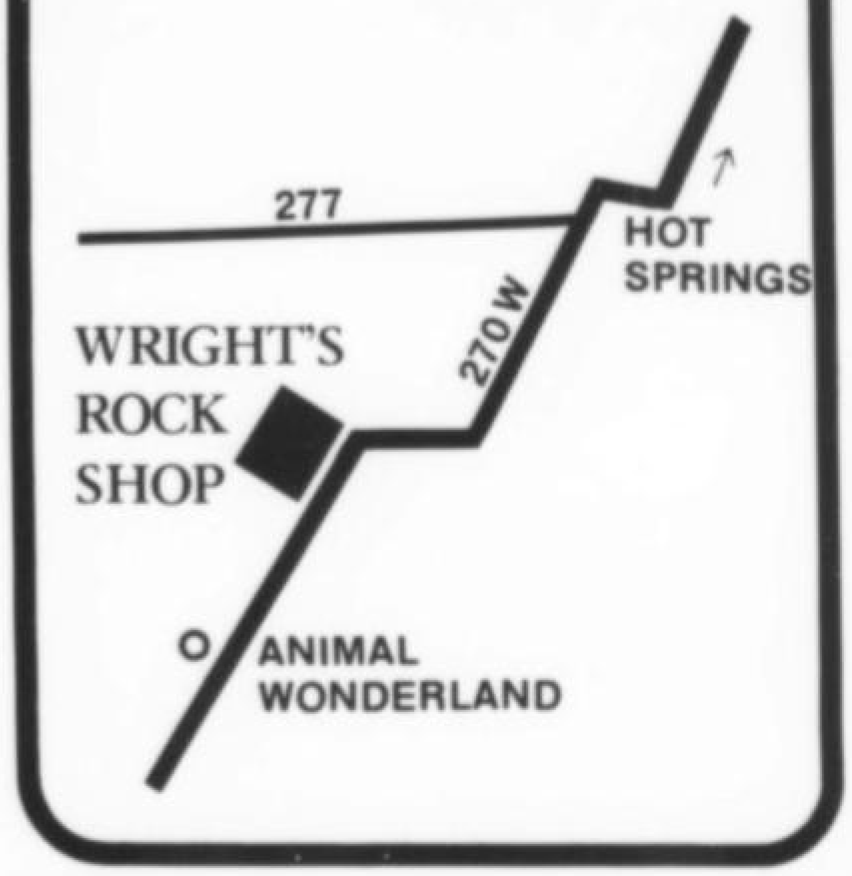

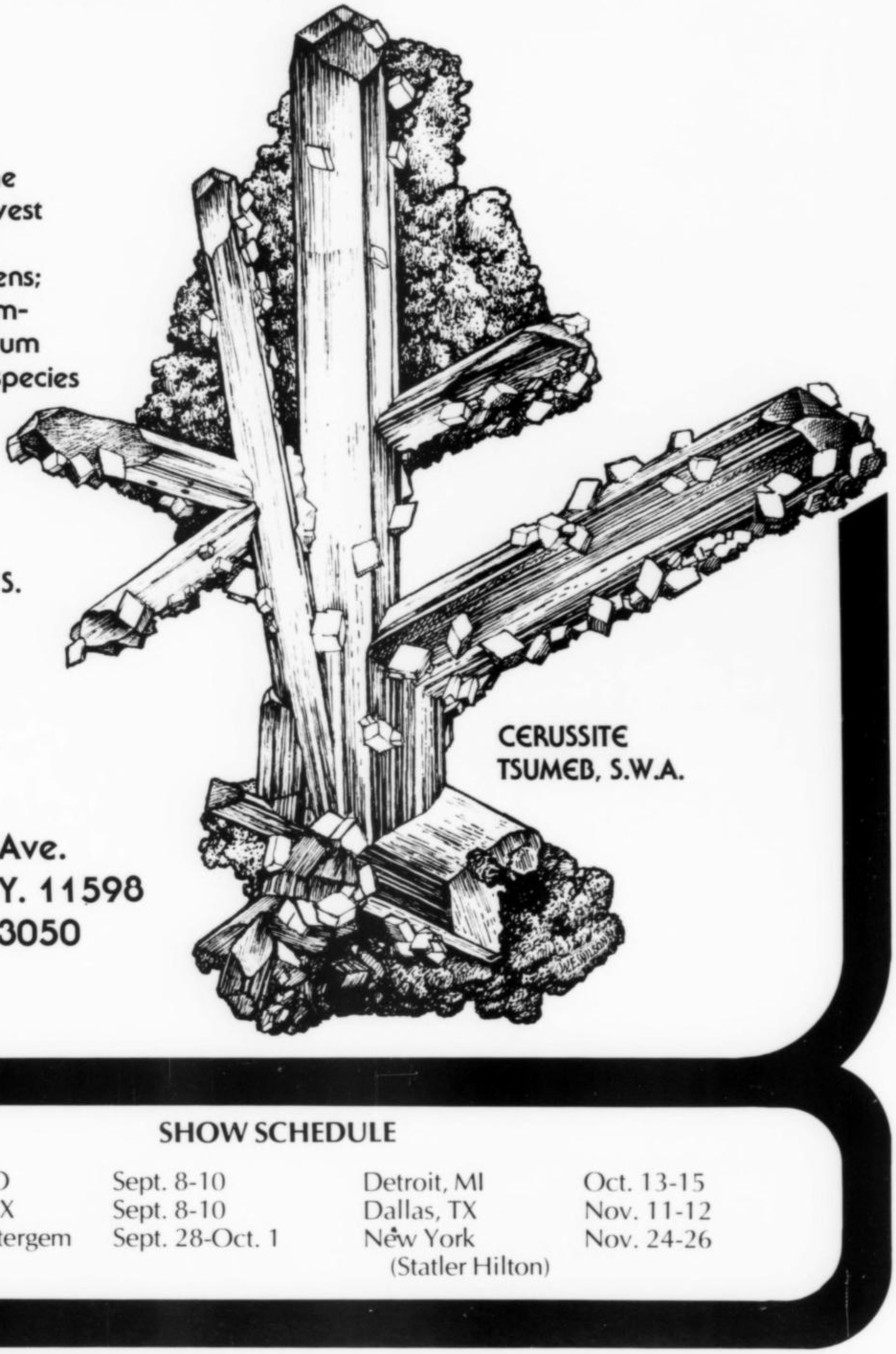

CERUSSITE
TSUMEB, S.W.A.

Kämmererite

from the Kop Krom mine, Kop Dağları, Turkey

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***Figure 1*. The Kop Krom mine, Kop Dağ. Photo by R.D.**

Superb specimens of kämmererite, a chromian variety of clinochlore, have recently been discovered at a new locality in the remote Kop Dağları (Kop Mountains) of eastern Turkey. Many interesting crystal habits are known, including fine crystals and twins to nearly 2 cm in size.

INTRODUCTION

Rich chromium ore has been found for many years in the Kop Dağları*, between the towns of Erzurum, Erzincan and Gümüşane, near Aşkale, in eastern Anatolia, Turkey (Fig. 2). Due to the limited distribution of the ore, the remoteness of the area, and the primitive mining methods used, these small deposits of chromite in serpentine have never achieved major economic importance. Most of the small mines produced little and closed after a short time.

Most of the deposits are situated high up in the treeless mountains far away from the larger villages. They can be reached only by field vehicles and trucks, via roads leading along dangerous, steep cliffs, over small creeks and through narrow passes, with the ever present danger of breaking an axle. The primary vehicle for the natives, as it was in the time of Christ, is still the donkey.

The mountain district is sparsely settled, with a few small and very poor villages consisting of 10 to 25 flat cabins of sun-dried brick housing 100 to 200 people. Many of the natives, both adults and adolescents, are now employed in the chromite mines. Near the villages there are a few meager fields, small and dried out; the only trees in the area mostly surround the spring which provides life-sustaining water for the village.

In the lonely highlands a stranger will encounter young shepherdesses with long rifles on their backs, herding small flocks of sheep, goats and cattle which form the basis of life for the natives. The people are a robust and frugal race living a scanty life in the remote highlands but very friendly and hospitable toward strangers (Fig. 3).

During the hard winters, coal and wood are unavailable; cakes of dung, mixed with chaff and dried in the sun during the summer, are burned for a little heat.

Here in the mountains the Moslems are a little less orthodox, in contrast to the rest of Eastern Anatolia. *Ramasan*, the Islamic Shrovetide,

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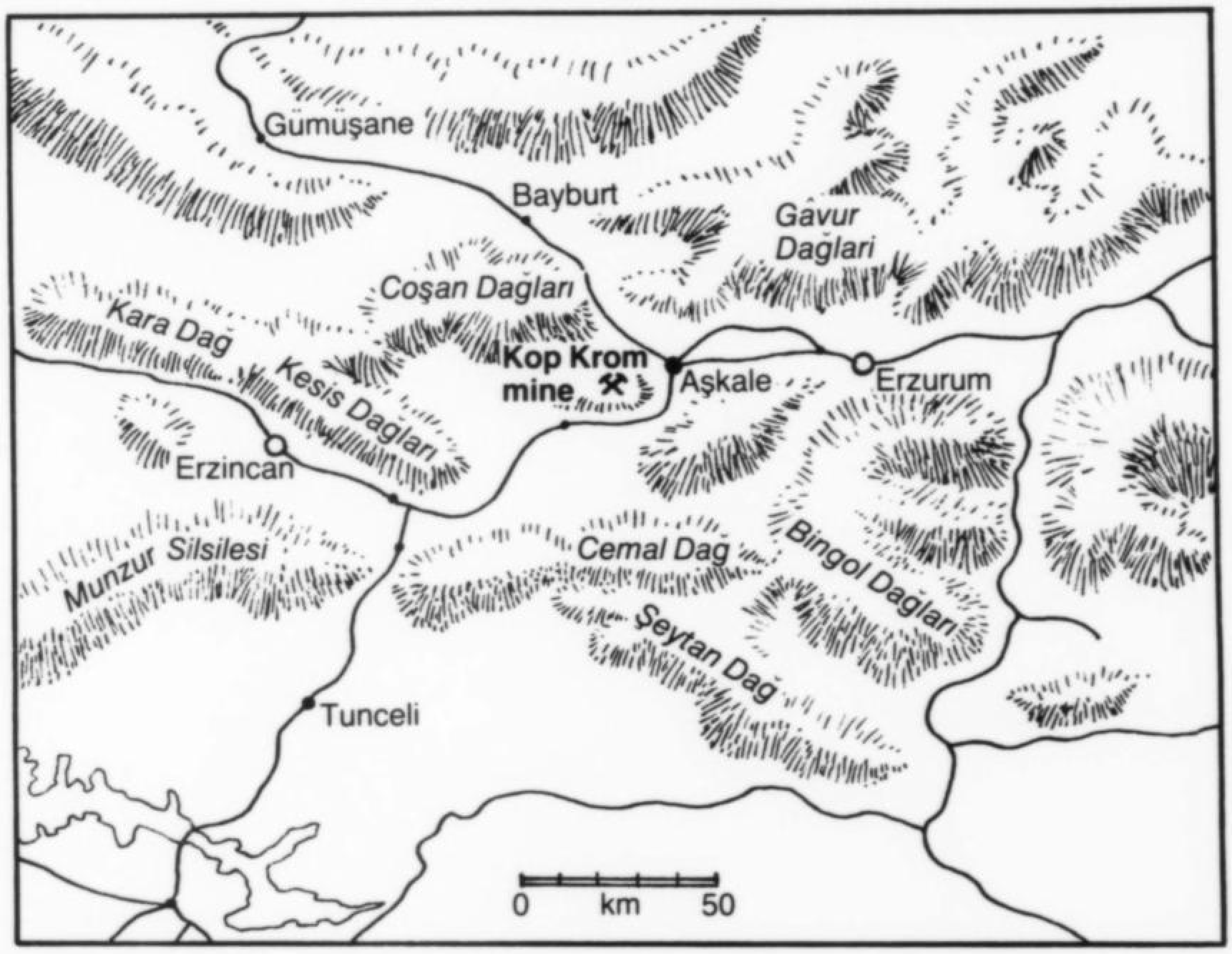
**Kop Dağları* means Kop Mountains. *Kop Dağ* is the singular form, meaning Kop Mountain.

***Figure 2*. Location maps.**



is observed less strictly and only some of the women commonly wear veils. Schools are difficult to reach; girls generally do not learn to read and write, and boys start going to school only when old enough to master the long, rocky footpaths through the mountains.

During most of the year the mountains are burned brown by a merciless sun in a cloudless sky. Only rarely do a few clouds from the Black Sea reach this area and drop some rain. Nevertheless the fields do yield some corn, which is threshed by archaic methods; the corn is then separated from stones and sand on a washing step by a gravity settling process. Finally the corn is dried by sun and wind while spread on large cloths.

CURRENT MINING ACTIVITY

A small chromite mine in the Kop Dağları, located about 10 km from the railway station of Erbas Istasyonu, also called Pembe Güle ("violet rose"), was mined several decades ago. A small number of large and well formed kämmererite crystals to 1 cm in size were found there (Schumacher, 1958). The mine was abandoned many years ago, but reopened for a short period last year; it is now closed.

During the last few years another chromite deposit, located about 10 km from the Pembe Güle mine, has been discovered and bears considerable promise; it is known as the Kop Krom Maden (Kop Chrome mine). A large ore body is known to exist there although its true extent has not yet been fully defined. The mountain in which the deposit is located is called Kop Dağ by the local natives (not to be confused with the larger Kop Dağ near the route from Aşkale to Gümüşane). Three workings have been driven into the ore body, revealing a predominantly compact chromite ore without large interlayers of serpentine matrix. The ore body appears to broaden with depth, as far as can be seen currently. The presently active workings are called the *Doğu oçak* (*Doğu oçak* = "Eastern workings") (Fig. 1). The *Batı oçak* ("Western workings") and also the *Sulu oçak*, ("Wet workings") situated very close by in the neighboring mountain, show promising ore but are currently not being worked because of the extraordinary output (relative to other Turkish mines) of the Doğu mine (more than 30,000 tons of high-grade chromite ore during the last year).

Near the base of the mountain is the mining camp of Santiya, a small workmen's colony consisting of a few clay brick cabins and an engineer's office at an altitude of about 2000 m (6500 feet). During the hard winters the camp lies buried under enormous masses of snow. The area is often attacked by packs of hungry wolves coming down from the mountains, so the people must always carry rifles. The mine is worked through the winter, although production is stored on the dumps until summer when the ore is transported by heavy duty trucks along a bad road down to Erbas Istasyonu.

MINERALS

Kämmererite (chromian clinochlore) $(Mg,Cr,Al)_6(Si,Al)_4O_{10}(OH)_8$

Species status

Kämmererite was first described by Nordenskiöld (1841) based on material from Lake Itkul, Bisersk, Siberia, U.S.S.R. The name was given in honor of the "mining apothecary" A. Kaemmerer of St. Petersburg. Lapham (1958) and Bailey (1975) have given historical accounts of the classification and nomenclature of chromian chlorites. Lapham (1958) proposed a classification based on whether chromium occupies octahedral or tetrahedral sites, suggesting the names kämmererite and kotschubeite respectively for cases where the chromium content is greater than 2%. Since the time of Lapham's investigation the structures of several Cr-containing chlorites have been solved, and no example of tetrahedrally coordinated chromium was found. Further studies by Bayliss (1975) and Bish (1977) confirmed this observation, indicating that the structural classification of Lapham is not well-founded. Considering the small amount of chromium involved (less than 10%) Bish (1977) suggests that the chromian chlorites are not sufficiently different to justify status as separate species, and proposes that chromian be used instead as the prefix for other valid chlorite species names where chromium is present. Kämmererite would therefore be a chromian clinochlore. It might more accurately be described as a chromian penninite, based on the chemical analyses given on Table 1 and the classification of Hey (1954); penninite is currently considered to be a pseudo-trigonal variety of clinochlore (Fleischer, 1975).

Composition

The chromium content of Kop Krom mine kämmererite differs markedly between the different generations of crystallization, generally increasing with time. In the peripheral zones of larger crystals the chromium content often reaches a maximum (Krause, 1964). The analyses of six samples from the main period of growth are given in Table 1, in weight percent. As will be mentioned later, many other variations in composition are known from the Kop Krom mine, and

Figure 3. **Change of shift at the Kop Krom mine. Photo by R.D.**

Figure 4. **An old miner near the Kop Krom mine. Photo by R.D.**

these analyses may not be representative of the deposit as a whole. However, the average of these six analyses yields a kämmererite formula as follows:

$$(Mg_{5.19},Cr_{0.47},Al_{0.25},Fe_{0.07},Mn_{0.01})\ (Si_{3.24},Al_{0.76})O_{10}(OH)_8$$

A simplified version suitable for mineral labels would be:

$$(Mg,Cr,Al)_6(Si,Al)_4O_{10}(OH)_8$$

Table 1. Analyses of kämmererite from the Kop Krom mine, Kop Dağ.

	1	2	3	4	5	6	Average
SiO_2	33.68	33.47	33.33	33.52	33.76	33.70	**33.58**
Al_2O_3	9.22	9.02	9.22	7.81	9.21	8.78	**8.88**
Cr_2O_3	6.05	6.24	5.99	7.63	5.31	5.83	**6.18**
FeO	0.84	0.80	0.81	1.04	0.78	0.79	**0.84**
MnO	0.08	0.05	0.08	0.10	0.06	0.08	**0.08**
MgO	36.04	35.99	35.97	35.48	36.52	36.36	**36.06**
H_2O**	14.09	14.43	14.60	14.42	14.36	14.46	**14.38**
Total**	100.00	100.00	100.00	100.00	100.00	100.00	**100.00**

* Analyses by electron microprobe performed by Kurt Abraham. All analyses have been corrected for fluorescence, absorption, etc. Standards used were MgO (synthetic), Al_2O^3 (synthetic), SiO_2 (synthetic), Cr_2O_3 (synthetic), metallic Mn and metallic Fe; accellerating voltage 20 kv, emission 30 nA.

** H_2O calculated by difference.

Varieties and habits

During the last two years only a few zones with open cavities have been encountered in the Doğu oçak. The kämmererite veins, widespread throughout the orebody, here contain cavities lined with crystals of superb size and quality unlike any seen before. Crystals found range up to nearly 2 cm, have a marvelous deep purple color and a brilliant luster. The larger crystals in particular have caused a sensation among mineral collectors within the last year. The following discussion is based on material found over a period of several years at the Kop Krom mine.

Several generations of kämmererite are in evidence at the Doğu oçak. The earliest crystallizations are characterized by a very low chromium content and a very pale or nearly white color. Spherulitic aggregates of a pink color belong to the earliest phase of crystallization. They consist of soft, massive to laminated kämmererite with small, distinct crystals covering the outer surface (Fig. 8); the color and chromium content increase from the cores outward.

During the earlier phases of crystallization an extreme form of skeletal growth was common. As can be seen in the SEM photos (Figs. 5, 6, 7), these skeletal growths consist of elongate, 1 or 2 mm crystals of roughly acicular form with repeated internal twinning. It is interesting to note that the direction of elongation is not the *c* axis but rather a direction roughly parallel to a face of the pseudorhombohedron. The pinacoids are therefore always at an angle to the elongation. These crystals are very low in chromium and are nearly white in color (Fig. 9); they are therefore properly referred to as clinochlore.

Well-formed acicular crystals of kämmererite, elongated parallel to *c*, are found as an overgrowth on the above-mentioned spherulitic aggregates. These crystals are brilliant and transparent (Figs. 10, 11), exhibiting a very steep development of the pseudohexagonal pyramid and commonly terminated by the pinacoid. The crystal diameter increases outward from the point of attachment. Some crystals are terminated by faces of the normal pseudorhombohedron. These crystals represent the transition to the second phase of crystal growth wherein the chemical and physical conditions favored the formation of large, well-developed, lustrous crystals.

The high chromium content of kämmererite formed during the second phase lends an indescribable, deep purple color to the crystals. The pinacoidal termination is rare on such crystals; it may be distinguished from cleavage faces by the presence of growth features (Fig. 26). A sharp termination composed solely of the pseudorhombohedron faces is most common.

Many of the well-formed crystals of kämmererite are found as a second generation of growth on the acicular clinochlore mentioned above. Commonly the walls of small cavities are completely covered by a carpet of this kämmererite in crystals to a few millimeters. In a few rare cases, where the cavities are wide enough, large single crystals of ideal shape to nearly 2 cm in size are found. Some crystals show a

Figure 5. Acicular skeletal growth of clinochlore surrounded by later generation kämmererite. The field of view is about 1.7 by 1.7 mm. Scanning electron microscope (SEM) photo by Kurt Muth.

Figure 6. Acicular skeletal clinochlore specimen shown in the preceding figure. The field of view is about 0.34 by 0.34 mm. SEM photo by Kurt Muth.

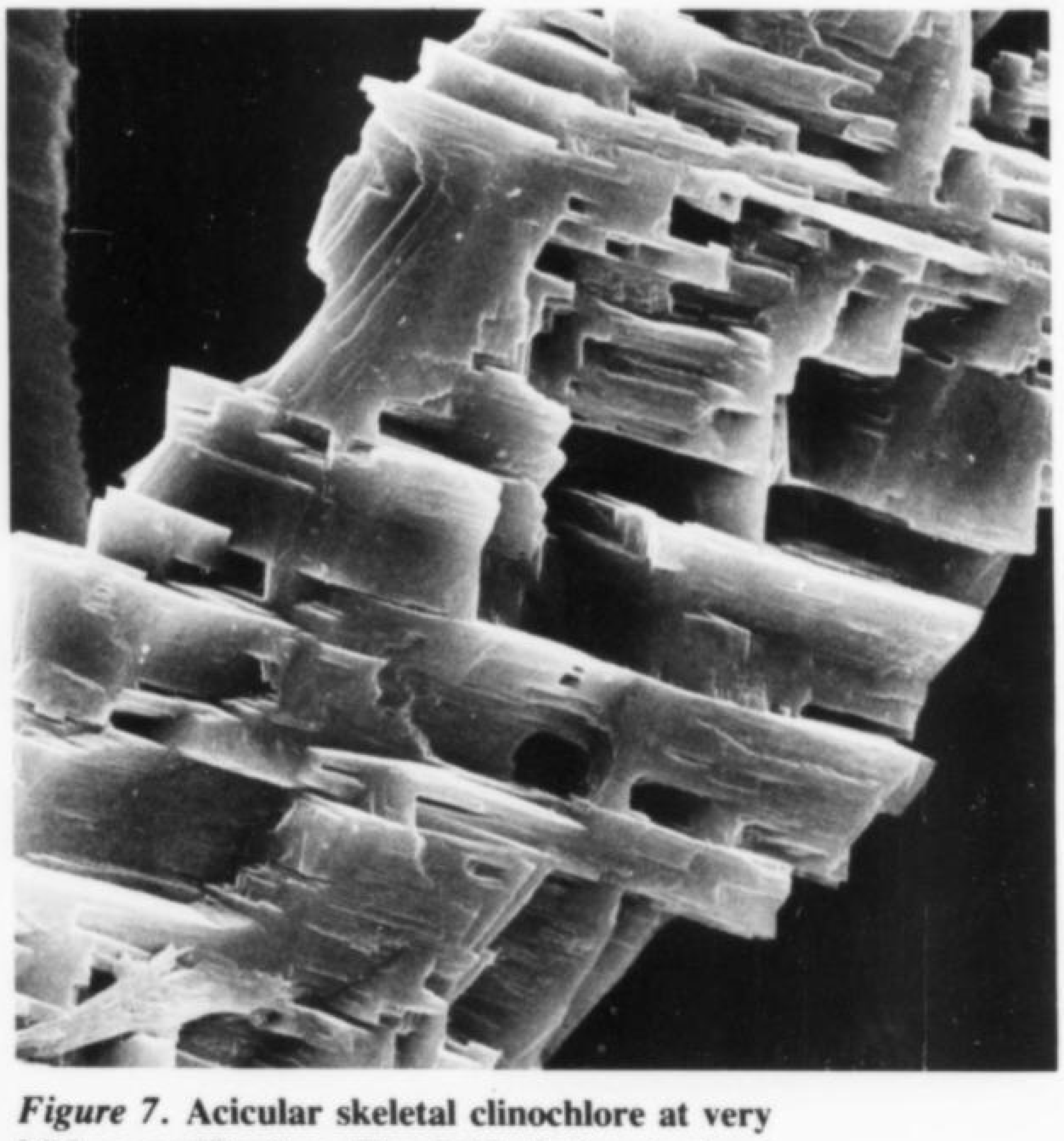


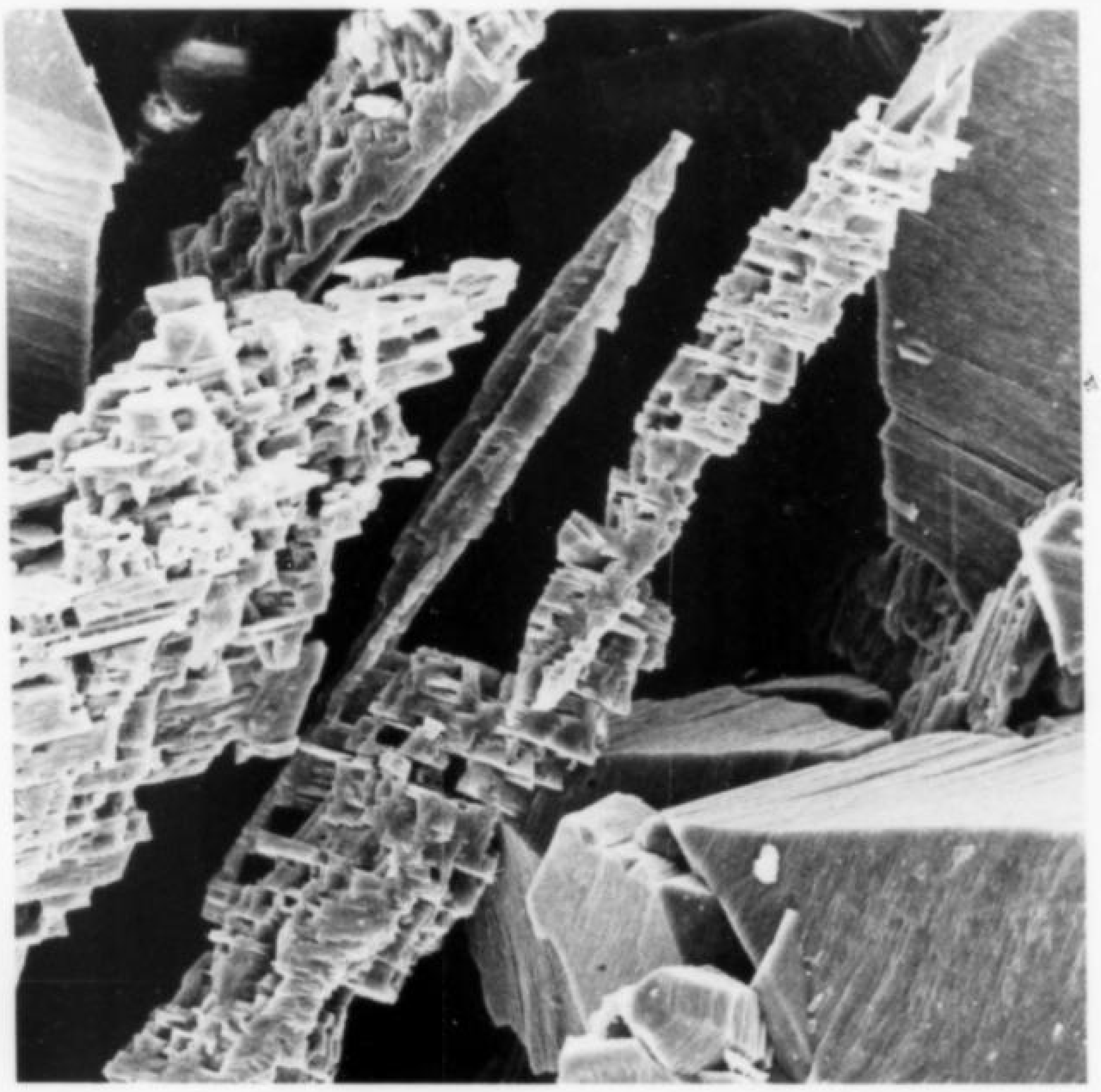
Figure 7. Acicular skeletal clinochlore at very high magnification. The field of view is about 0.05 mm by 0.05 mm. Note the obvious twin plane crossing the center of the specimen. SEM photo by Kurt Muth.

pronounced chromium zoning indicative of the increase in chromium content during growth. Specimens were found having an interior "phantom" of white clinochlore surrounded by a crystal of purple kämmererite (Fig. 12).

In the last phase of growth chromian clinochlore formed as a crust of tiny pink microcrystals over larger crystals of kämmererite.

Even during the main period of kämmererite formation there were variations in growth favoring different crystallographic directions. Some specimens have been found that are tabular parallel to pseudorhombohedron face, sometimes twinned to form "butterflies."

In some cases tabular growth approximately normal to *c* appears to have at first been dominant, followed by a period of pseudorhombohedron growth, resulting in plates with pointed crystals issuing from the centers. As in Figure 13, these crystals are commonly twinned as well.



Another habit consists of platy aggregates to 5 mm, with many crystal points protruding from their surfaces in both directions. These plates sometimes give the appearance of rose petals (Fig. 14).

A tabular habit of some chromian clinochlore crystals has developed into snowflake-like crystals with six platy "leaves" extending from a central plate (Fig. 15). These were formed during the first period of crystallization.

Yet another habit consists of a steep pseudohexagonal pyramid with several re-entrant angles along the length of the crystal (probably representing twin planes). The result is a pagoda-like appearance (Fig. 16).

The Kop Krom deposit has often been subjected to tectonic movement resulting in alteration of the growth conditions as well as displacement of crystals. Kämmererite crystals broken along the basal cleavage and later rehealed, sometimes with an additional coating of calcite, are common (Fig. 17).

Color

The color of kämmererite varies noticeably with the type of illumination used. Under incandescent light the crystals are a brilliant magenta, as shown on the accompanying photos. However, under sunlight or fluorescent light the crystals appear distinctly bluer, almost violet, with a grayish cast. Specimens to be displayed will be more attractive under "warm" incandescent light.

Twinning

Two kinds of twins have been observed on Doğu oçak material. The most common type is a simple contact twin on (001) (penninite law).

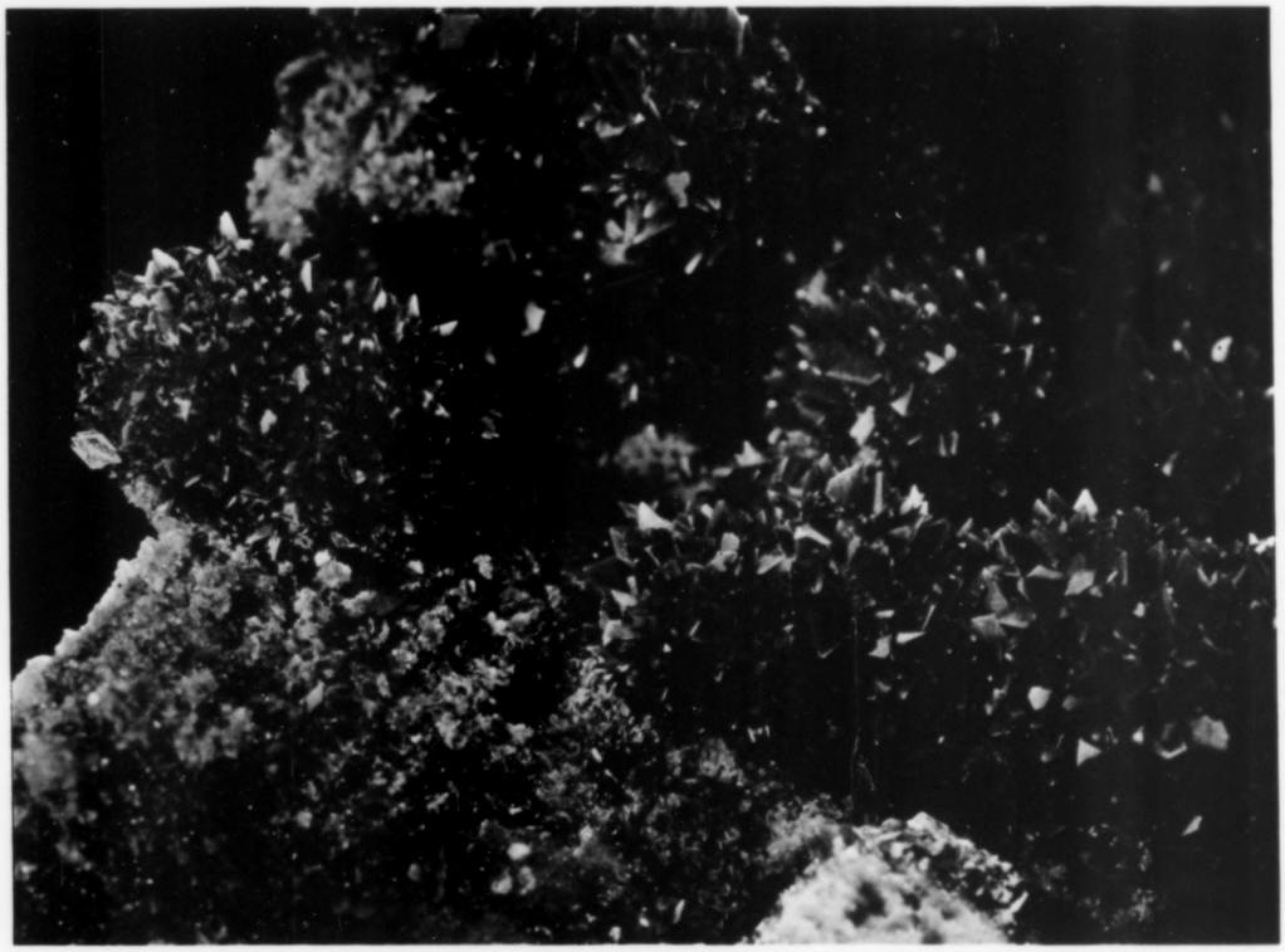


Figure 8. **Kämmererite crystals coating spheroidal aggregates of chromian clinochlore. The aggregate at left measures 6 mm across. Photo by O.M.**

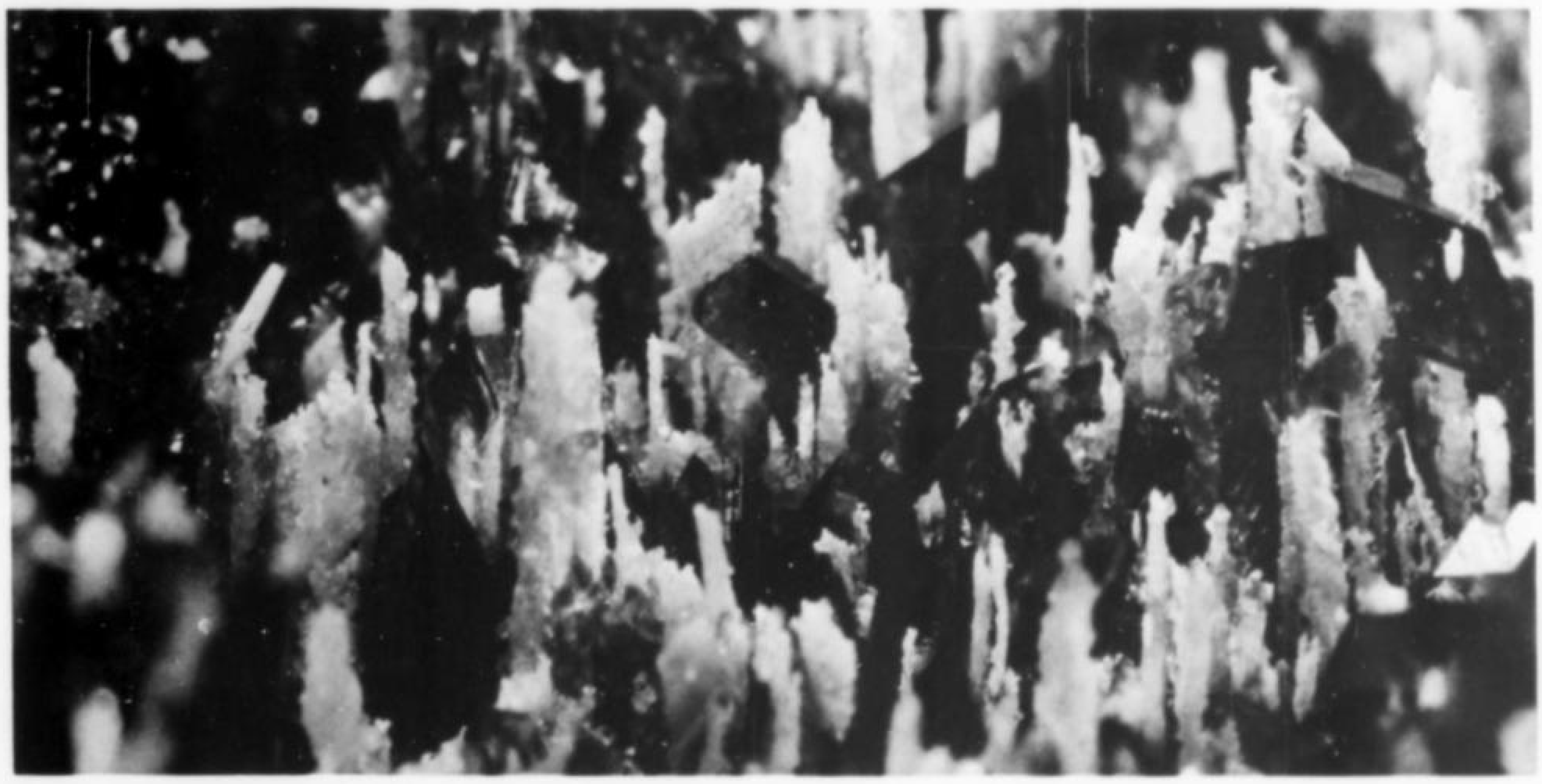


Figure 9. **White skeletal clinochlore as shown in Figures 5 through 7, associated with later kämmererite. The clinochlore needles are 1 to 2 mm tall. Photo by O.M.**

Figure 10. **Acicular kämmererite from the Kop Krom mine. The crystals are 1 to 4 mm long. Photo by O.M.**

Figure 11. (above) **Elongated pseudohexagonal crystals of kämmererite. The crystals are about 1 mm long. Photo by O.M.**

Figure 12. (right) **Kämmererite crystals containing phantoms of white clinochlore from the Kop Krom mine. The crystals are about 1 mm in length. Photo by O.M.**

Figure 13. (below) **A tabular, twinned kämmererite crystal with a later growth of pseudorhombohedral habit. The crystal is 1.3 by 1.5 mm in size. SEM photo by Kurt Muth.**

Figure 14. **Extreme tabular or platy development of kämmererite crystals from the Dogu oçak. Note the tiny, pointed crystals grown on the surfaces of the plates. The crystal plates are about 5 mm across. The wispy white membranes are chrysotile. Photo by O.M.**

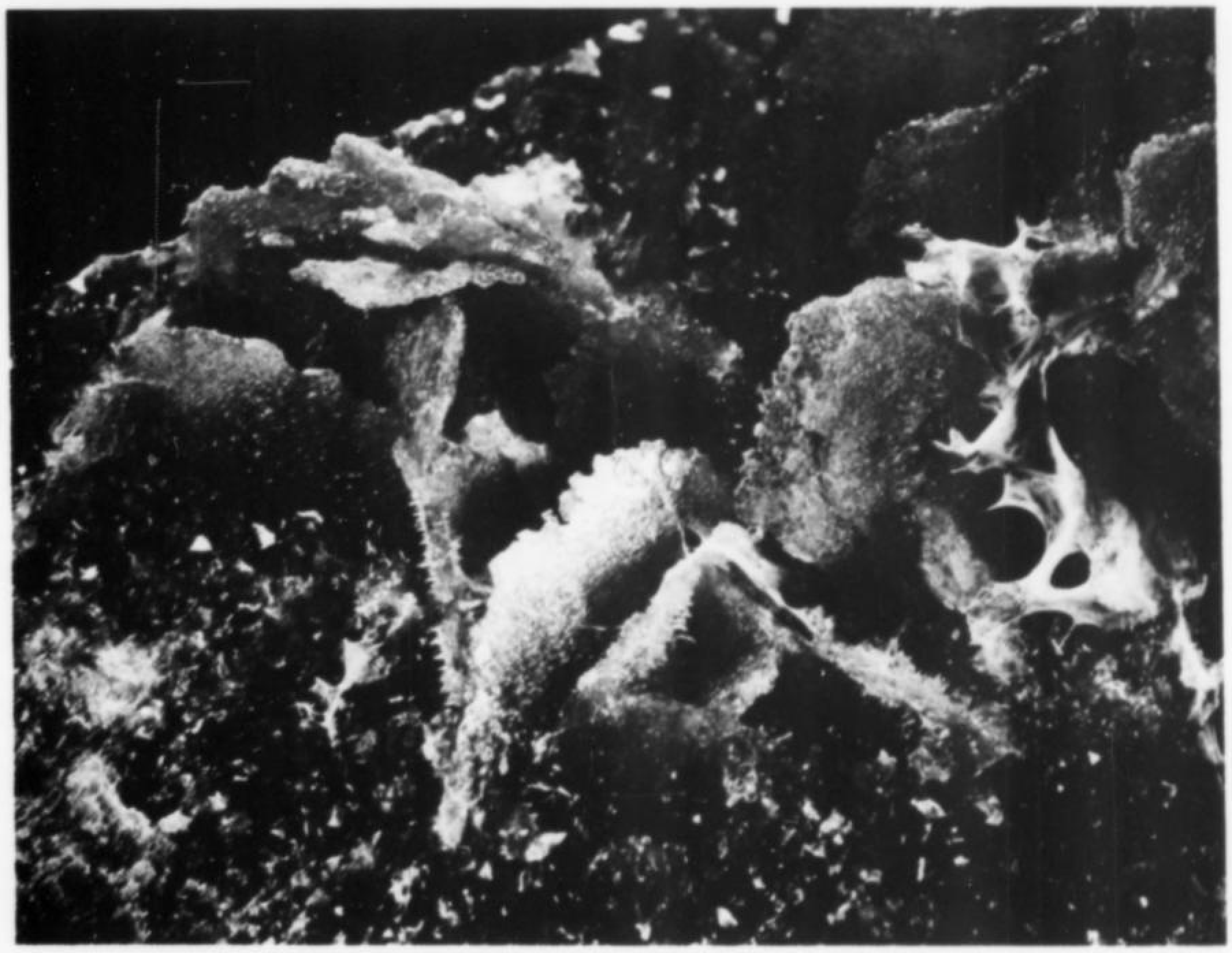


Figure 15. (below) **A pink chromian clinochlore crystal showing a snowflake-like development. The crystal is 0.2 mm in size. Photo by R.D.**

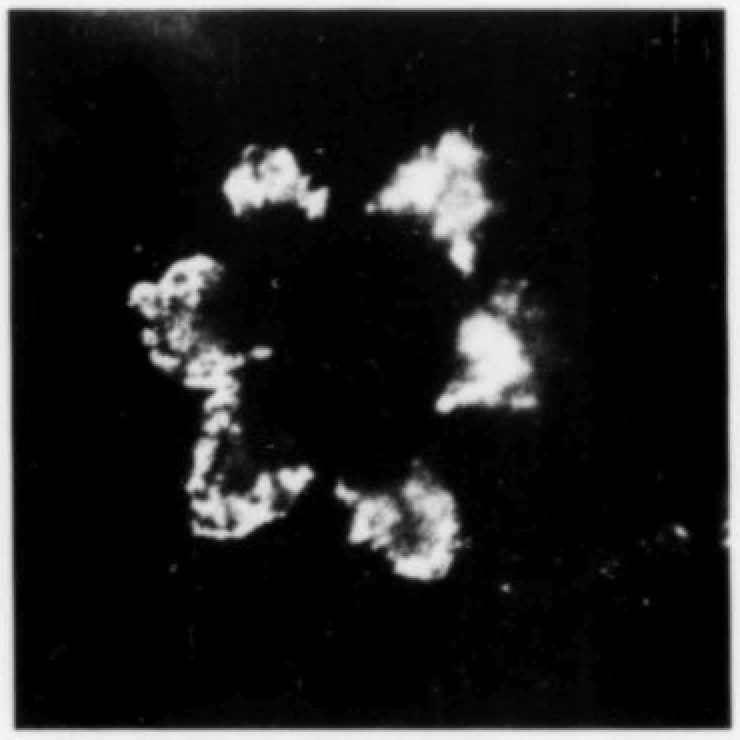


Figure 16. (left) **A pseudohexagonal crystal of pink chromian clinochlore showing re-entrant angles which gave a pagoda-like appearance. The crystal is about 0.5 mm tall. Photo by R.D.**

Figure 17. (below) **A kämmererite crystal broken by natural tectonic movements. The crystal is about 6 mm long. Photo by O.M.**

***Figure 18.* Kop Krom mine kämmererite crystals contact twinned according to the penninite law. The crystals are about 5 mm in length. Photo by O.M.**

Such crystals appear to have a mirror plane through the center perpendicular to the *c* axis (Fig. 18).

The other type of twin is rare: a penetration twin according to the penninite law (Fig. 19), resembling in appearance the twinned cinnabar from Hunan, China. A possible third type consists of two pseudorhombohedral individuals interpenetrating with the *c* axes forming an angle (Fig. 20). These intergrowths have not been fully studied yet, and were observed on only a very few (but identical) examples; they are not yet established as twins.

Uvarovite $Ca_3Cr_2(SiO_4)_3$

The calcium-chromium garnet uvarovite occurs rarely, lining fissures in the chromite ore, forming bright green crusts and powdery coatings to several mm in thickness. Slickensides coated by a film of uvarovite have been observed. Extremely rare, well-formed, deep green, lustrous crystals to 2 mm in size have been found. These crystals, generally composed of the dodecahedron and trapezohedron (Fig. 22), occur on chromite with large kämmererite crystals.

Calcite $CaCO_3$

Calcite is found in small amounts at the Doğu oçak as well-formed crystals reaching several cm in size, generally having frosty, etched faces. Combinations of the prism, rhombohedron and/or scalenohedron are common. Crusts of small rounded aggragates on chromite or kämmererite are typical, as well as coatings of small, flat rhombohedrons. Fine, doubly terminated prismatic crystals are sometimes found perched on kämmererite (Fig. 23). Prismatic calcite crystals are commonly observed extending from small, spherical aggregates of microcrystalline calcite.

Brucite $Mg(OH)_2$

Three habits of brucite have been observed at the Doğu oçak. Crusts of very sharp, flat rhombohedrons occur lining fissures. Sometimes very small, flat rhombohedrons of the same type are found sprinkled on kämmererite or suspended on thin chrysotile membranes. By far the most attractive habit, however, consists of small, transparent, marvelously formed "roses" composed of many rhombohedral crystals with prominent pinacoidal faces.

These brucite roses form a beautiful contrast resting on dark red kämmererite. They can reach nearly 3 mm (Figs. 24, 25). A third form of brucite occurs in plates and thin, transparent leaves intergrown with compact chrysotile. Brucite also occurs as compact intermixtures with calcite forming large, stalactitic white masses.

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

Hydromagnesite occurs as thick, white, loose encrustations consist-

***Figure 19.* A kämmererite crystal exhibiting a penetration twin according to the penninite law. The crystal is about 6 mm in height. Photo by O.M.**

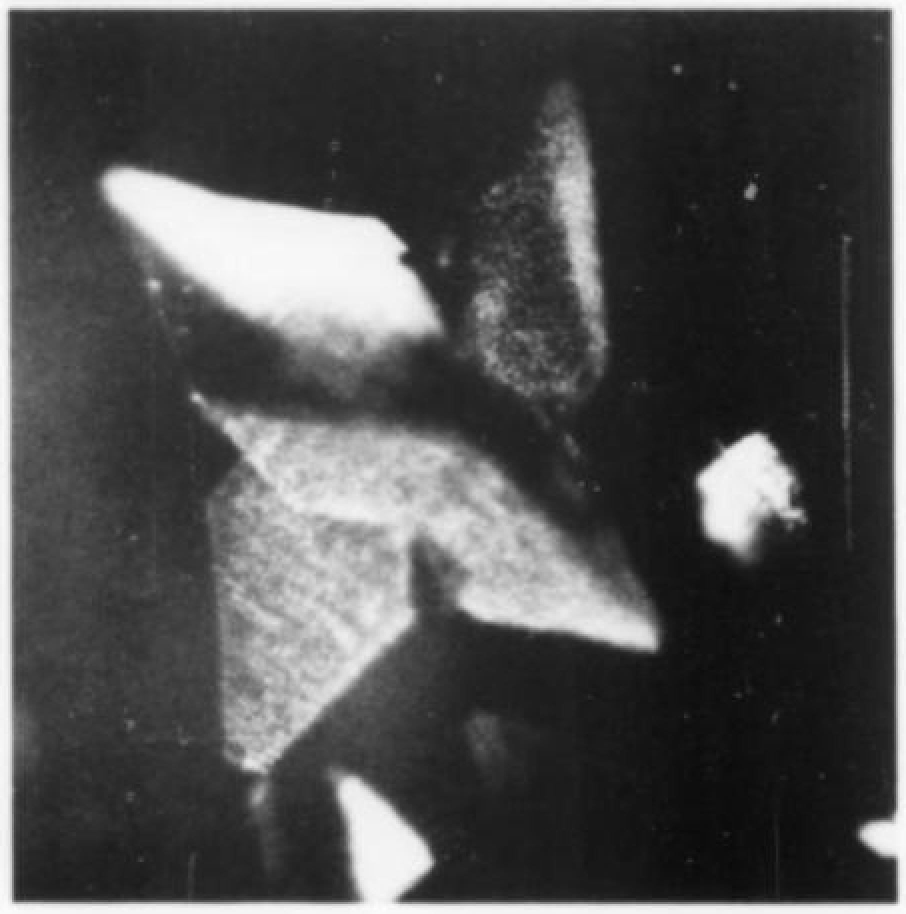
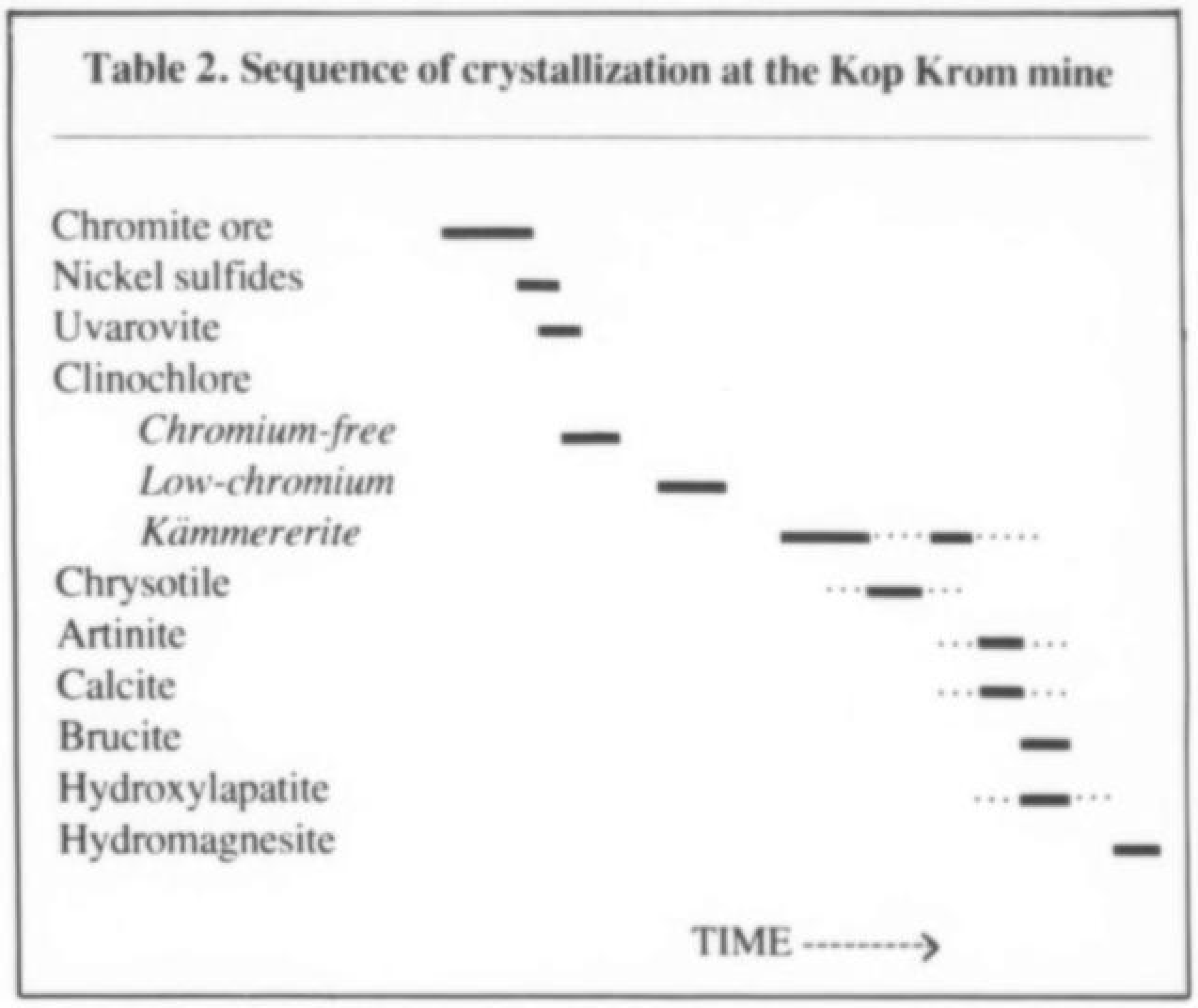


***Figure 20.* Kämmererite exhibiting an intergrowth suggestive of possible penetration twinning. The crystals are about 1.5 mm long. Photo by R.D.**

Table 2. Sequence of crystallization at the Kop Krom mine



ing of aggregates of very small, white blades. Tiny white spheres and nodules have been found on kämmererite (Fig. 26), chromite and artinite and, at least partially, as an alteration product of brucite. Very attractive pseudomorphs of hydromagnesite after brucite roses have been found in which a core of unaltered brucite remains. Very attractive specimens of artinite spherules and tufts with tiny spheres of bladed hydromagnesite perched on them have been found that are very similar to specimens from San Benito County, California (Cisneros, Witkowski and Oswald, 1977).

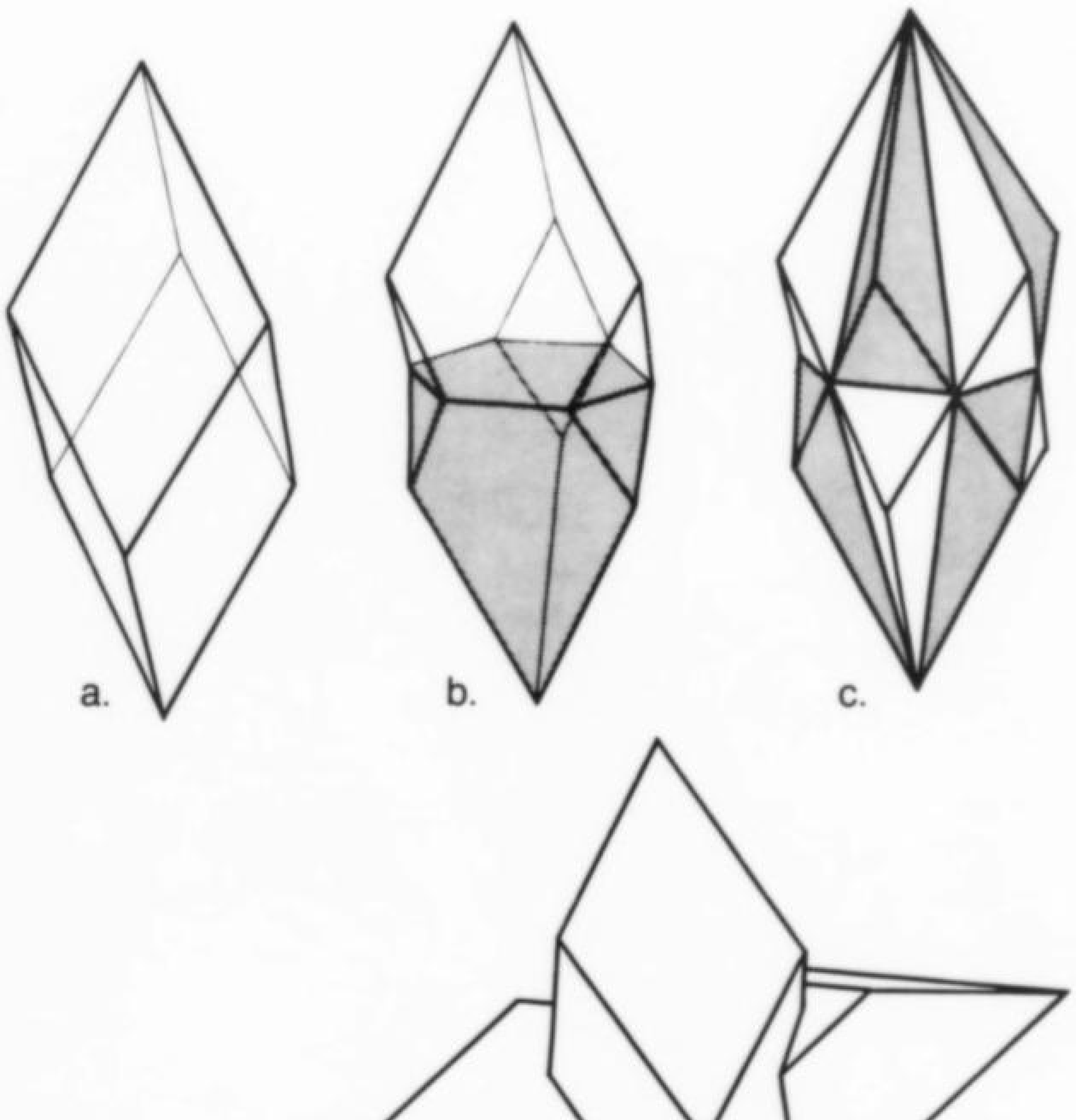


***Figure 21.* Sketches illustrating a single pseudorhombohedral crystal of kämmererite (possibly generated by polysynthetic twinning on the mica law) (a), a simple contact twin according to the penninite law (b), a penetration twin according to the penninite law (c), and an interesting intergrowth of possible crystallographic significance (d). (Sketches by Wendell Wilson.)**

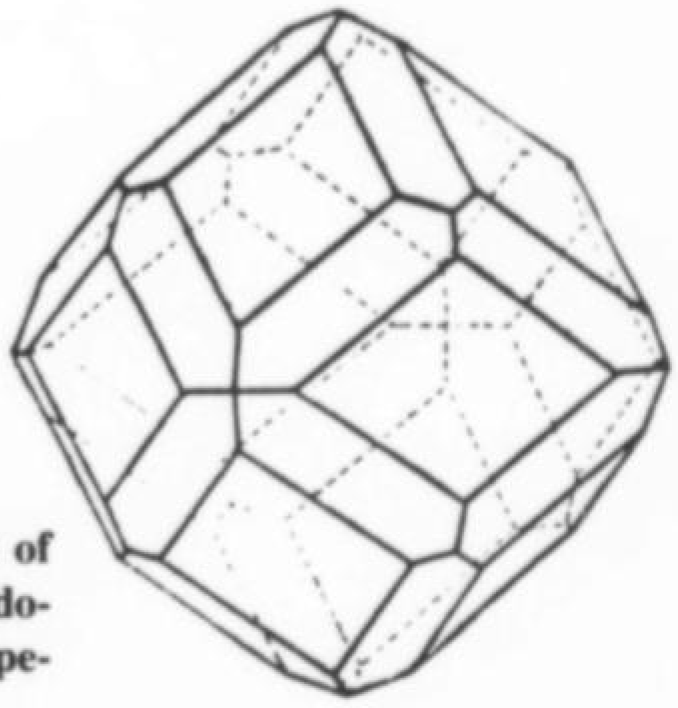


***Figure 22.* The crystal habit of Kop Krom mine uvarovite: dodecahedron modified by trapezohedron.**

Artinite $Mg_2(CO_3)(OH)_2 \bullet 3H_2O$

Artinite is very common in the Kop Dağ region. It occurs disseminated in the altered serpentine rock, often as a network of thick veins, and also coatings of snow-white spheres and fine, silky needles lining cavities. The needles sometimes have a pale green sheen. Large specimens of excellent quality have been found, but safely transporting the extremely delicate snow-white crusts over rocky, dusty mountain roads is quite a problem.

Chrysotile $Mg_3Si_2O_5(OH)_4$

Secondary chrysotile occurs as dense, white to yellow, waxy masses filling the open spaces between chromian clinochlore crystals. Chrysotile is also common as very fine, thin, extremely homogeneous membranes loosely draped over kämmererite crystals (Figs. 14, 27). Even the microscope commonly fails to reveal the structure of these membranes, but SEM (scanning electron microscope) photos demonstrate that the membranes are composed of a netting of extremely thin, curving chrysotile fibers (Fig. 28). Late generation kämmererite crystals and brucite roses commonly occur suspended on these chrysotile membranes.

Figure 23. **Doubly terminated white calcite crystals to 2.5 mm perched on deep reddish purple kämmererite. Photo by O.M.**

Hydroxylapatite $Ca_5(PO_4)_3(OH)$

Hydroxylapatite occurs very rarely in the Kop Dağ area in association with calcite and kämmererite, forming loose heaps of brilliant, thin prisms with rounded terminations; individual crystals may reach 1 cm in length. Hydroxylapatite belongs to the late phase of mineralization, after the formation of the large kämmererite crystals. The identification of hydroxylapatite, as with the other rare minerals reported here, was made by infrared spectroscopy.

Acicular sky-blue unknown

Small nests of acicular, sky-blue to nearly colorless crystals have been observed in fissure fillings with compact chromian clinochlore. The acicular crystals are commonly grouped around weathered grains of nickel minerals (**heazelwoodite,** Ni_3S_2, and **pentlandite,** $(Ni,Fe)_9S_8$, have been identified by their powder patterns). The blue needles yield a pronounced X-ray reflection at 7 Å, but remain unidentified.

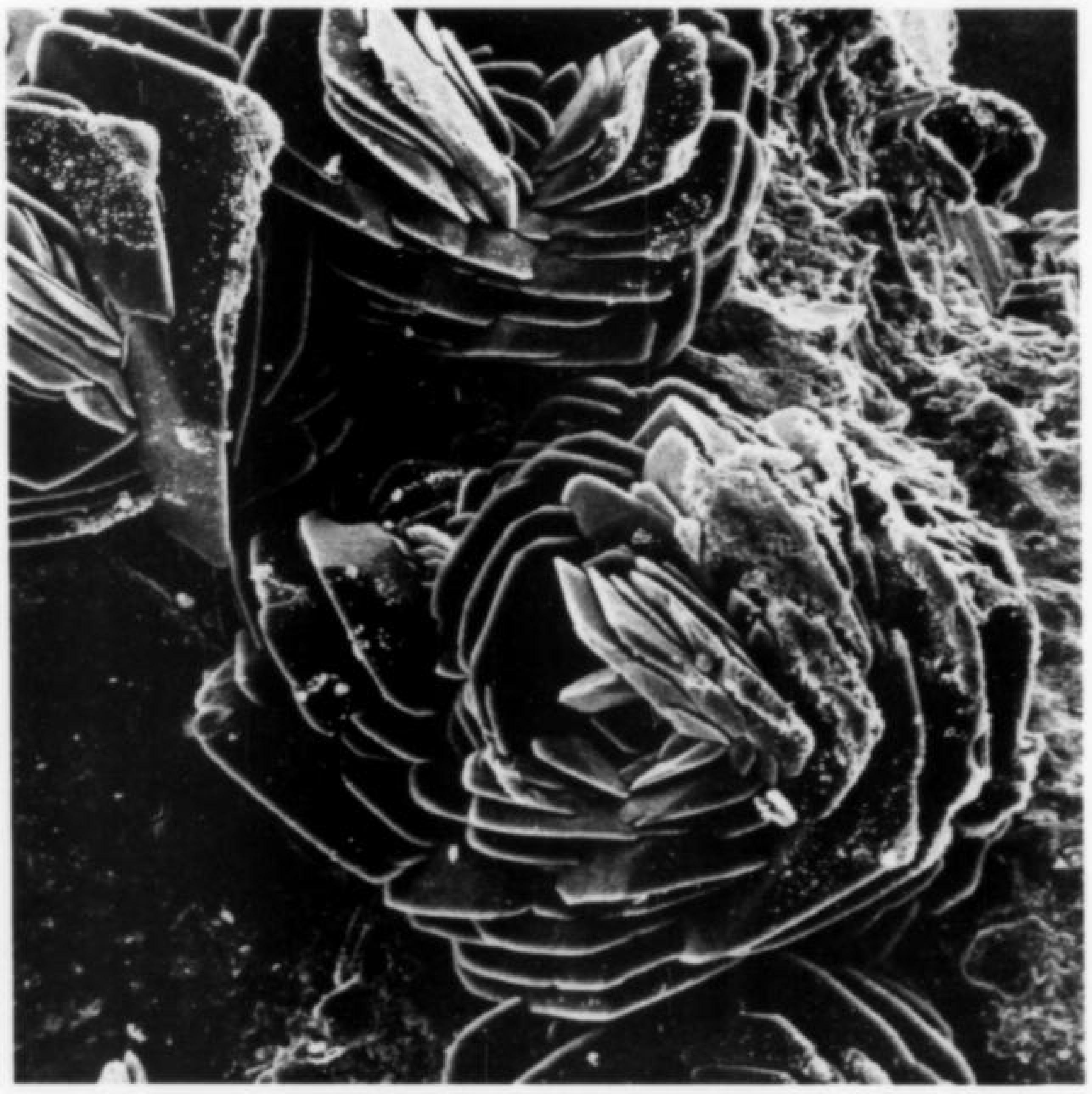
PARAGENESIS

During the Tertiary period the extensive, geologically old Kop Dağ serpentine region was subjected to hydrothermal alteration by solutions rich in carbon dioxide. Tectonic fracturing allowed alteration and deposition to take place along a dense network of fissures and cracks. Alteration of the serpentine resulted in the formation of secondary magnesium minerals while alteration of chromite liberated chromium later taken up in chlorite minerals and garnet. Veinlets of compact or laminated kämmererite impregnate chromite ore, locally to such an extent that dumps of dry ore show a pink to light purple color. Rare open cavities provided the opportunity for large, attractive crystals to form.

The sequence of crystallization, as far as it can be determined from specimens available, is shown on Table 2. There appear to be three distinct generations of clinochlore formation, as indicated below, which seem to have been separated by intervals during which physical and/or chemical conditions changed. As previously mentioned, the crystal habit as well as the chromium content differ for each of the generations.

Figure 24. **Transparent white brucite roses to 0.3 mm in size. SEM photo by Kurt Muth.**

Figure 25. **A brucite rose, transparent and colorless. The rose is about 0.3 mm across. SEM photo by Kurt Muth.**



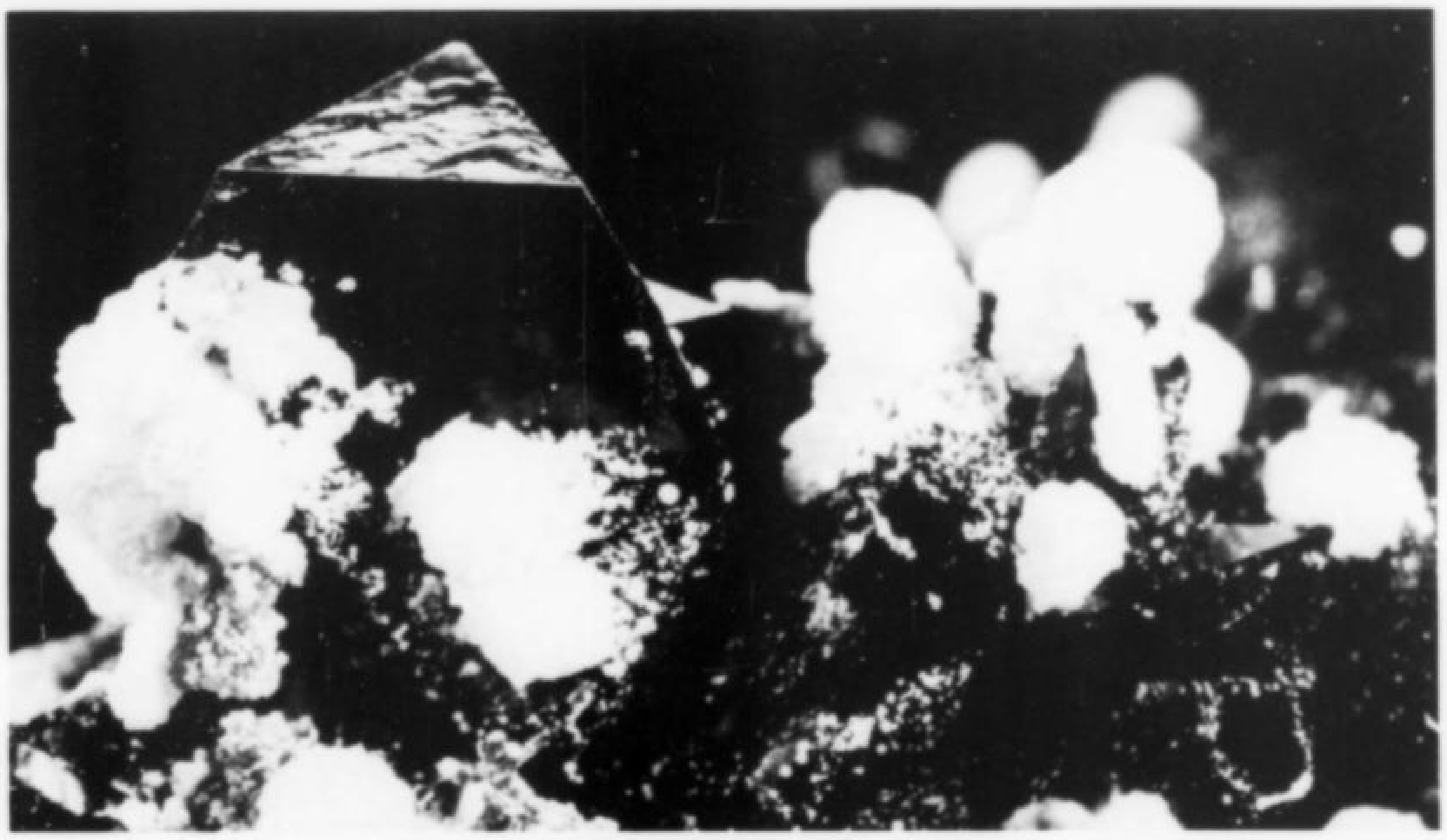


Figure 26. (left) **White hydromagnesite pseudomorphous after brucite with a large kämmererite crystal showing a natural pinacoid termination (not a cleavage; note growth features). The pinacoid is about 2.6 mm on an edge. Photo by O.M.**

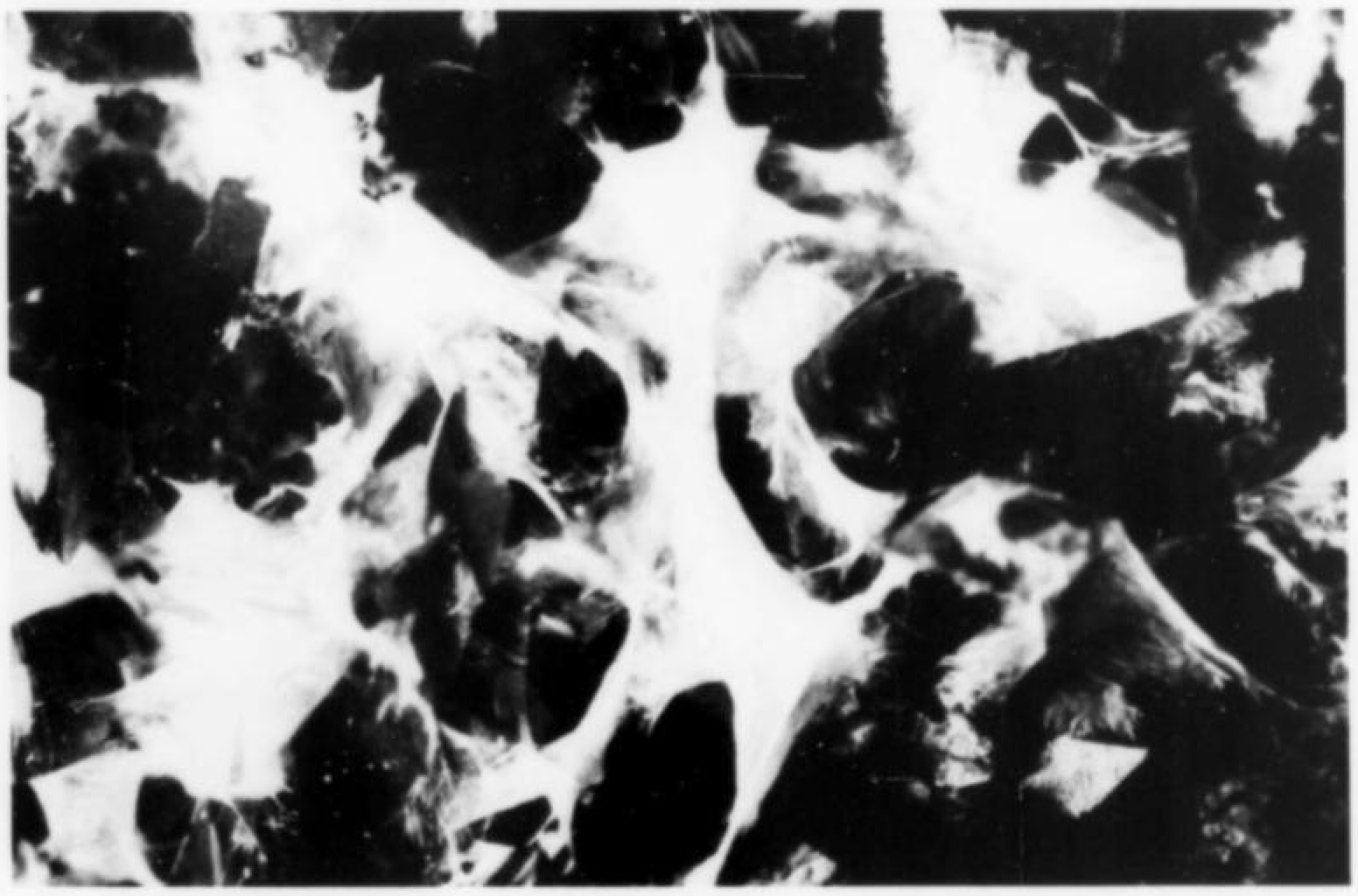


Figure 27. (below left) **Chrysotile fiber membranes partially covering reddish purple kämmererite crystals. The kämmererite crystals are about 2 mm in size. Photo by O.M.**

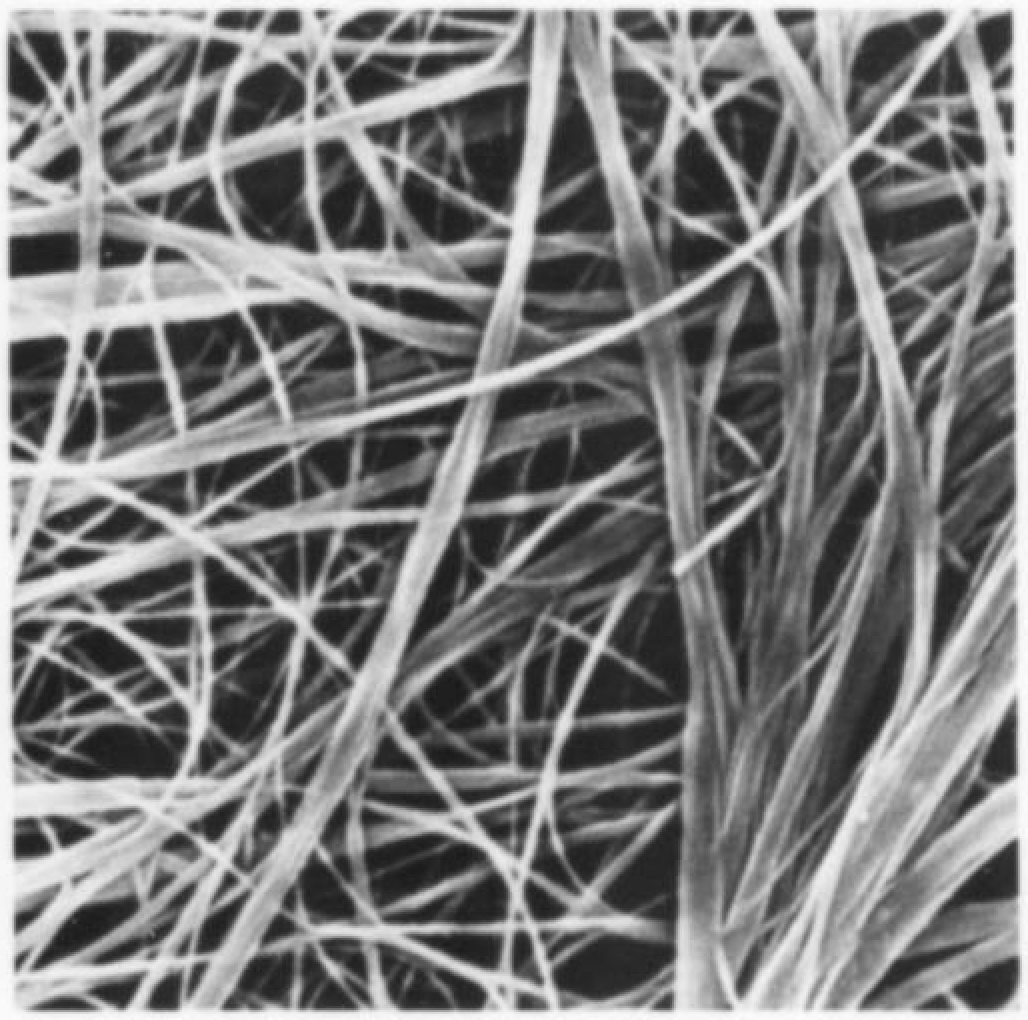


Figure 28. (below right) **Chrysotile fibers as shown in the preceding figure, under high magnification. The field of view measures about 0.01 mm across; the fibers are about 0.0001 to 0.0002 mm in thickness. SEM photo by Kurt Muth.**

ACKNOWLEDGEMENTS

First of all I want to thank my wife, Margot, who took part in all of the activities which have led to this article, from the first attempts to locate again the old kämmererite occurrences in Anatolia, to learning part of the Turkish language, and finally to the hard trip of thousands of miles through dusty country. Spending the night in poor Turkish shelters, the doors without lock or key, and living with the natives in the mud brick cabins high up in the mountains, removing numerous specimens from the mine with utmost care under a burning sun, she participated in every step of this exhausting project.

We are highly indebted to the chief engineers of the Kop Dağ mines, especially Bay Nezihi Gündoğdu, Hissedar, for the permission to visit the Kop Dağ deposits, and for his generosity and hospitality during our stay at the mine. Our warmest thanks and appreciation are also due to Fevzi Aksakal, Hinzora köyü, and to his family, who collected numerous excellent specimens of scientific interest which have formed the basis of this study, and who gave all possible help to us. I am particularly indebted to Olaf Medenbach, Ruhr-Universität Bochum, for the excellent color photographs taken of kämmererite specimens in our collection, and also to Kurt Muth, Kalle, Niederlassung der Hoechst A. G., Wiesbaden-Biebrich, for his skilful technique in obtaining the SEM photos. Thanks also to Gerhard Hentschel, Wiesbaden, for powder diffraction analyses and helpful discussions. Finally, my thanks to Kurt Abraham, Ruhr-Universität Bochum, for the electron microprobe analyses.

NOTE

It should be mentioned that entering the mining area is strictly forbidden to strangers without official permission of the chief engineers. The mine is patroled day and night by armed guards. Collecting of specimens by miners as well as visitors is prohibited.

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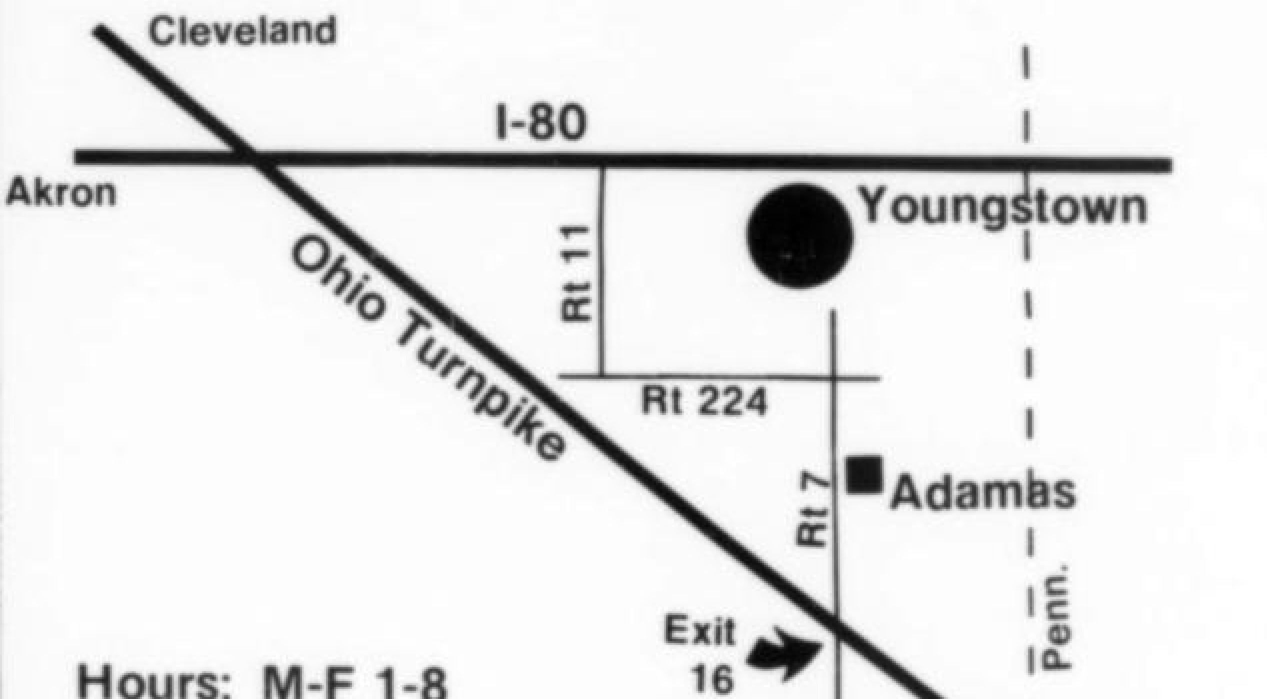
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I-80
Akron
Youngstown
Rt 11
Ohio Turnpike
Rt 224
Rt 7
Adamas
Exit 16
Penn.
Pittsburgh

THE HISTORICAL RECORD

by Ron Bentley
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Windsor, Connecticut 06095

While examining various aspects of the Historical Record over the last few months, I've been compiling letters, comments and odd bits of information which, by themselves, would not individually warrant a full column. They are, nevertheless, interesting, so for this issue the column will ramble over some of these items.

Judging by the number of people who have spoken to me at shows regarding label collecting, my name appears to be rapidly becoming a collectors' curseword. Those of you who have been stashing away your labels in a closet or a shoebox have been shamed into bringing them out and putting them into some sort of order. The profanity evidently begins when the couple of hours alloted to the job have been used and the job isn't even half done. However, with the perseverence of the true collector, you will end up with your time well spent and your collection's ancestry preserved.

Among the most common misconceptions held by the beginning label collector, and even some of the more experienced collectors, is the assumption that a handwritten label or one not carrying the collector's name is not worth keeping. This is certainly not true; if you can identify the collector's handwriting, or the style of the label, it is collectable. Consider, for example, the following excerpt from a letter I received from Benjamin Burbank, curator of minerals at Bowdoin College, Brunswick, Maine.

After reading your interesting article on labels in the September-October issue of the Mineralogical Record, I am taking the liberty of sending you, gratis, a few labels that may be of interest, although they are not quite like the illustrations with your article."

The labels were used by professor Parker Cleveland, the "father of American mineralogy," on both his private collection and that of Bowdoin College from 1808 until his death in 1858. As you undoubtedly know, he was professor of mineralogy and geology at the college and author of the first text published on those subjects in America, in 1816. During the years since, quite a few specimens have been lost, labels detached, and, as a result, no amount of detective work seems able to restore them. This means we have some labels without specimens, as is the case with the labels I am sending you. We do have the old catalogs written in Cleveland's own longhand, and they assign specimens to these numbers, giving localities and donors in most cases.


879 1866 1778

***Figure 1.* Parker Cleveland number labels. (Shown actual size.)**

Burbank goes on to explain that specimens in Cleveland's own collection have red numbers on a white background, while those belonging to the Bowdoin College collection have black numbers on a white background. So you can see that even labels as superficially insignificant as those shown here in Figure 1 can have great relevance to the Historical Record.

I mentioned in an earlier column that Larry Conklin had acquired a collection of "ancient" correspondence between Clarence Bement and various other dealers and collectors of the 1800's, such as Chamberlain, Ward, Palache, Dana, du Pont, Penfield, Canfield, Sheppard, Ferrier, Jefferiss, Bauer, Hamlin, and many others. Upon my return from the Tucson Show I found a copy of one of the more interesting letters waiting for me. It was from A. E. Foote to Clarence Bement and reads as follows:

On train near Guaymas, Mexico
Feb 14, 1894

Mr. C. L. Bement

Dear Sir,

Your letter of the 7th was rec'd yesterday just as I was packing my trunk to go to Boleo. The steamer, which goes only semioccasionally at the pleasure of the mining co had gone over on the 9th and my friend wrote me would probably go again on or about the 17th. I felt I must try to visit this unique locality so here I am on a train moving at the rate of 10 miles an hour, fare 10¢ a mile. Just at this moment we are stopping at a station whose name being translated means Pumpkin. There was very little to be got just now at Bisbee. I put a couple of men into the cave and packed 13 boxes of specimens that they got. Among them are what seemed to me at the time the best I ever saw. Certainly there were none in the collections at Bisbee that compared with them for beauty. You may find a few you would like. The cuprites and azurites & malachites you would not care for unless there was some small variety about them. I was there 2 weeks and shipped 18 boxes. I do not expect to get nearly as much bulk at Boleo but more that is rare and especially valuable. I shall look out especially for the crystallized gold and sharp-edged tourmalines when I get to California.

Yours sincerely,
A. E. Foote

Guaymas 15th. Got in this afternoon and take the steamer this evening. I hear some very remarkable stories about specimens but we shall know in a few days. I hope that you bought none of the Egleston lot.

The mineral symposium sponsored by the Rochester Academy of Sciences in April was as much of a delight to attend as ever. Very seldom do mineral dealers get the chance to attend lectures except at the Rochester Symposium, and I hope the tradition continues. Speaking of traditions, a new one was begun this year: the symposium's first annual mineral auction. It was a great success, and gives us label collectors a new label to lust after (Fig. 2). For those of you who haven't heard about the symposium, it is one of the most interesting mineral events in the country and I strongly recommend it to beginner and advanced collector alike. For a nominal registration fee you get three evenings and two days of good food, great lectures and exhibits, and fine comraderie.

Following my last column on labels, I received two letters dealing with the mounting of old labels. The first is from Peter Tarassoff of Quebec, Canada:

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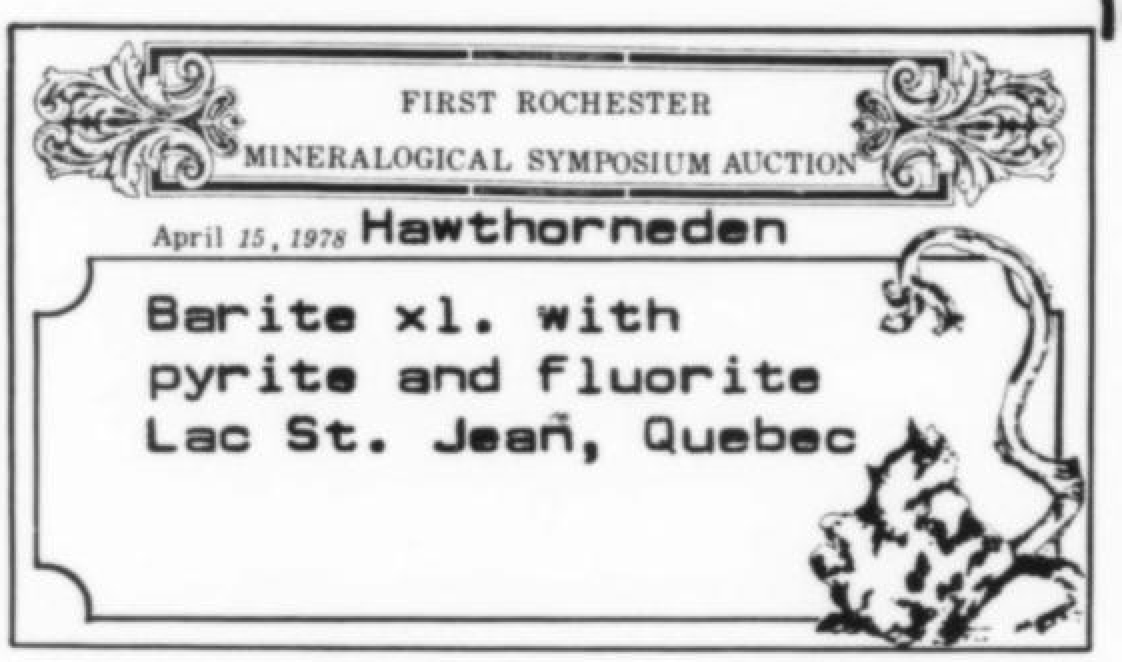
FIRST ROCHESTER
MINERALOGICAL SYMPOSIUM AUCTION
April 15, 1978 Hawthorneden
Barite xl. with
pyrite and fluorite
Lac St. Jean, Quebec

***Figure 2.* Rochester symposium auction label.**

As an alternative to using magnetic picture albums for labels, collectors might consider using the various types of transparent mounts used by stamp collectors. These come in a range of sizes, and are available with a black background. By using such mounts, the label collector has a much greater choice of colors, textures, and thicknesses for his album pages. The mounts also avoid the problem of contact with a gummed surface in the magnetic albums.

The second letter is from William Henderson, Jr., Stamford, Connecticut:

I have been enjoying your Historical Record column and it has finally inspired me to sort and mount the labels I have accumulated over the years.

In so doing I have hit on several ideas different from yours, and which offer some distinct advantages. First, I mount my labels on black pages. This affords a pleasant contrast, more pleasing than the white-on-white effect commonly seen. Second, I am just as concerned as you are that, over a period of time, labels will become irretrievably stuck to the so-called magnatic album pages currently available. I have gotten around this by using ordinary stamp collectors' hinges. All except the largest labels are easily held in place by a single stamp hinge. These hinges, when dry, peel from the back of a stamp or label with no ill effects or damage. They have been used for many years by stamp collectors, and should be completely reliable. Third, I obtain complete protection for my labels by purchasing black sheets punched for three-ring binders and protected by clear, wrap-around plastic covers. These are available at any good stationery store, and cost from 12¢ to 30¢ apiece, depending on quality and thickness. Finally, I add information not written on the label, notes written on the back of the label, or translations of foreign labels to the pages by typing the information on white paper and affixing the notes under the appropriate labels in the album. The result is very neat and attractive.

For those of you who have written requesting more information on *Marshall's Spray Glass*, I am still waiting for an answer from them regarding the locations of their distributors. In the meantime I have located a similar product made by the Bond Adhesives Company of Jersey City, New Jersey. It is called *No.205 Mirror Clear Glaze* and you can probably order it through your local lapidary dealer if he does not already stock it.

My last tidbit of information is an offer to any of you who are interested in collecting labels but who haven't really gotten into it yet. If you wish to write me and don't mind waiting a couple of weeks or so for a reply, I will be pleased to send you a selection of duplicates from my own collection at no charge. I only ask that you seriously intend to take good care of them (sounds like an adoption agency, doesn't it?), and that if you ever decide to stop collecting, you find a good foster parent to whom you can pass them on. I would also enjoy hearing from other label collectors interested in exchanging duplicates and information.

Until next time, remember, help save our history by saving your labels.

Photographic Record

by Wendell E. Wilson

ELECTRONIC FLASH TECHNIQUES

No great skill is required to take surprisingly good photographs of minerals using an electronic flash.* In fact, this is a technique that might be employed by virtually anyone, regardless of training or experience: all you need to know will be presented in this column.

Four pieces of equipment are essential, six if you will be taking shots requiring a tripod and cable release. These are: (1) a single-lens reflex camera, (2) a close-up (or macro) lens, (3) an *automatic* electronic strobe, and (4) a rotating strobe attachment bracket.

Armed with these items, the world is your oyster. The easiest place to start is at a mineral show. I have found that it is great fun to take pictures of showcases and specimens within showcases at mineral shows; in later years it is very interesting to look back through a collection of such slides. Furthermore, if you are one of those people whose mind quickly becomes flooded with mineral images at a show, and you later find that you can remember hardly anything of what you saw, your slide set will bring it all back. Whenever I am taking flash shots of showcases at a show, someone invariably asks me if the reflected flash on the showcase glass won't ruin my photo. Reflected flash is actually quite easy to avoid, whether you are standing up close or farther back. The only exception is a case with glass shelves, a glass back and glass sides that meet in the corner at 90° to each other; this produces what is called a corner mirror, and will reflect light directly back to the source *regardless* of the angle from which it comes. However, such cases at shows are rare, so this is not commonly a problem.

I have specified that you use an *automatic* electronic strobe for these shots. (This eliminates the need for tedious manual calculations.) These strobe units contain an electric eye. The strobe turns on when you push the shutter, and begins emitting light. The light bounces off the subject and is sensed by the electric eye. When the electric eye decides that enough light has bounced off the subject to make a good exposure it shuts off the flash. Most automatic electronic strobe units will produce a flash varying in length from 1/1000 second to an incredible 1/30,000 of a second.

So it becomes doubly important that you do not get a flash reflected back from a glass surface. Not only will it mar the appearance of your photo, but it will confuse the electric eye, resulting in an incorrect flash duration and an incorrect exposure.

When standing a few feet away from a case, all you need remember is that the glass case window will act as a mirror. If you stand so that you will not be able to see your own reflection in the "mirror," then your camera will not see the reflection of the flash either. Generally this means standing off to the right or left side (Fig. 1). If the case is low or its glass is tilted forward you can sometimes stand in front of the case on tip-toes and shoot downward at an angle.

If you wish to get up close and take pictures of individual specimens or groups within the case, your problem is slightly different. Generally with the camera very close to the glass there is little danger that the flash will reflect into the lens, but there is still the danger that the flash will reflect back into its own electric eye (Fig. 2), thereby ruining the exposure. You can protect against this in two ways. One method is to move closer until the strobe is actually touching the glass (Fig. 3). This allows no room for a reflection to enter the electric eye. The other method is to angle the camera to the glass sufficiently to keep the reflection from coming back.

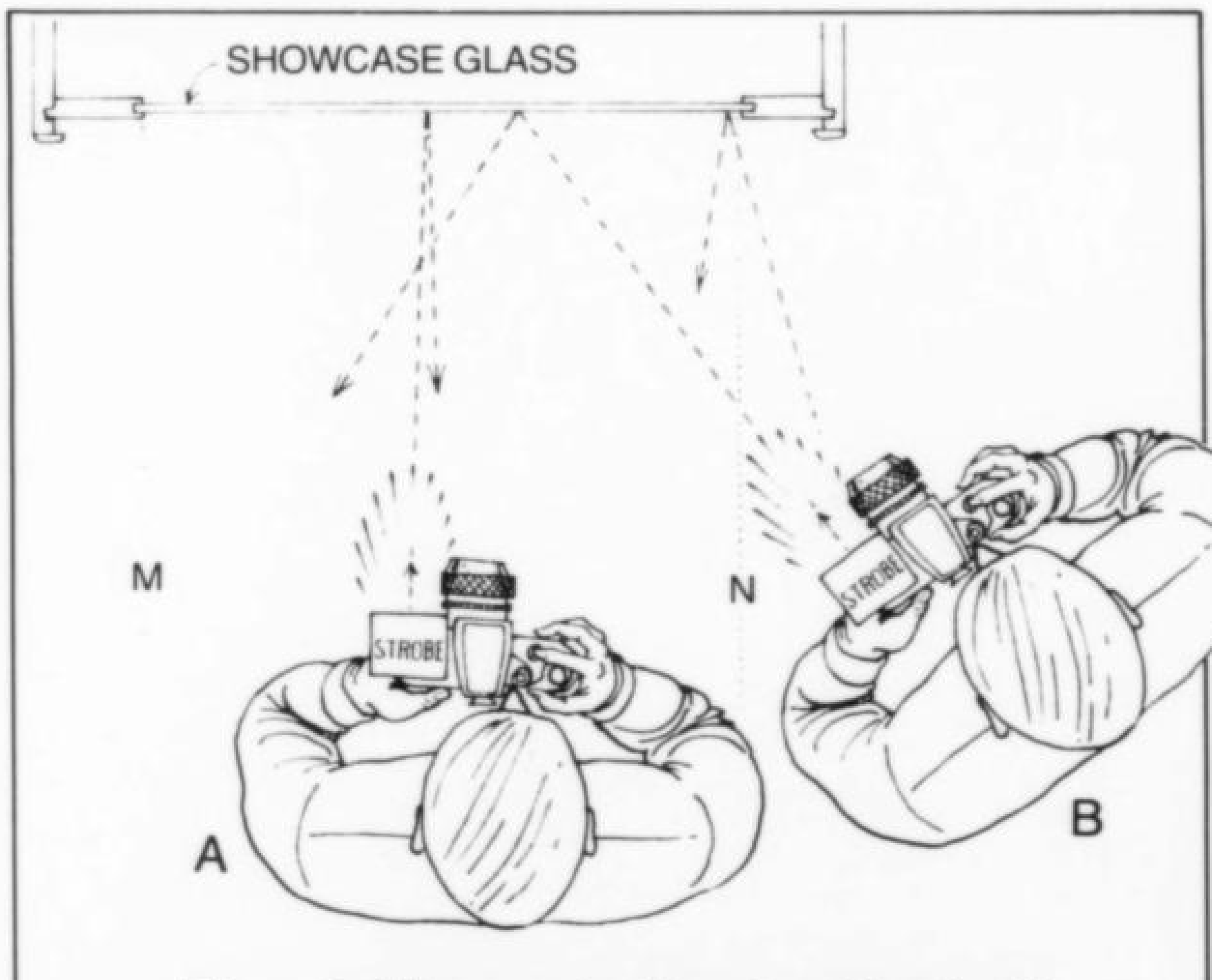

Figure 1. **The man standing at position A will see a reflection of his electronic flash in the showcase glass window. It is necessary to stand to the right of line N (or to the left of line M), as at position B, in order to avoid a reflection from the glass.**

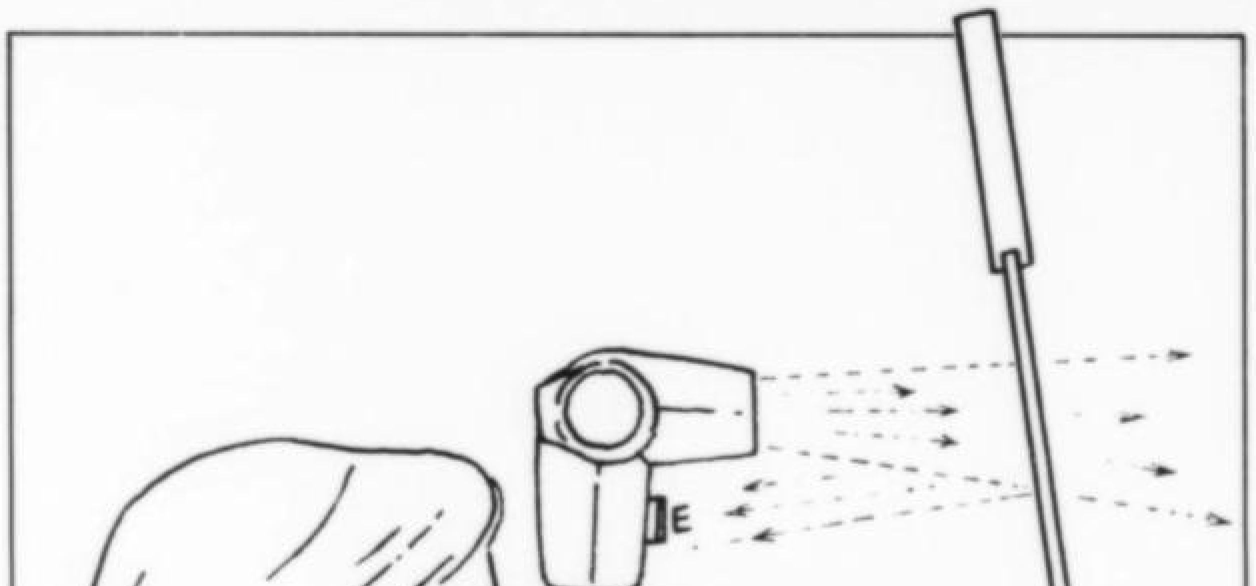

Figure 2. **Incorrect position for a close-up photo through showcase window. Note that the flash will reflect from the glass and confuse the strobe's electric eye (E).**

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* Hereafter I will refer to the instrument as a "strobe" to avoid ambiguity with its function of producing a "flash" of light.

***Figure 3*. Correct position for a close-up photo through showcase window. Note that the flash cannot reflect back from the glass into the electric eye or the lens.**

***Figure 4*. The difficulty with electronic flash used in close-up photography is that the flash will not shine on specimens that are too close to the lens.**

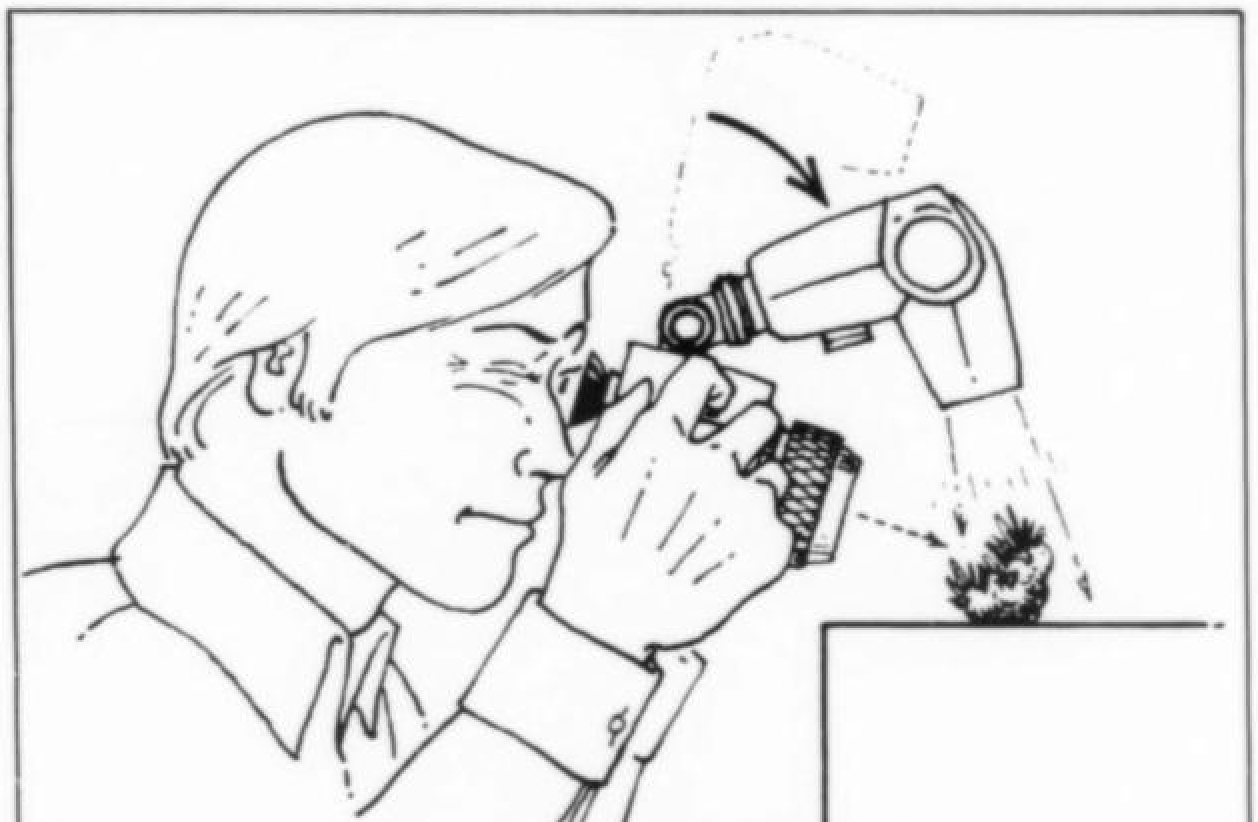

***Figure 5*. The addition of a rotating attachment bracket under the strobe allows the strobe to be tilted forward and down so that it shines on the specimen being photographed.**

In order to photograph a small specimen in the front row of the case you will find that an additional angular adjustment is necessary. The strobe is usually located several inches higher than the lens. If you look through the lens you may see the specimen framed perfectly, just a few inches away. The trouble is that the flash will shoot over its head (Fig. 4), and the specimen will not be properly illuminated. To correct for this you need a little attachment, available in most camera stores, that will allow you to tilt the strobe downward so that the flash is pointing at the specimen while the specimen is in front of the lens (Fig. 5).

Some strobe units allow you a choice of exposures. Naturally it is best to choose the setting which allows you to use the smallest f/stop so that you will have maximum depth of focus. There is also a setting for your film speed, and you will find that the higher the film speed, the smaller the f/stop you can use. Unfortunately you will also find that high-speed color films are noticeably more grainy, so that what you gain in depth of focus, you lose in overall sharpness. I still prefer to use Kodachrome 25 slide film because it has the finest grain. Using this film, with a film speed of 25, my strobe unit (a Vivitar 283) allows me to use f/5.6. If I wished to use f/16 a film speed of 160 would be required. That, however, presumes only one flash per exposure!

We can get around this f/stop limitation simply by making more than one flash per exposure. In order to do that, the camera must be placed on a tripod so that it does not move between flashes. The strobe is removed completely from the camera and held in the hand about the same distance from the specimen as is the camera. Using a cable release, with the shutter set on "B," you open the shutter, point the strobe unit at the specimen, flash it manually a certain number of times, then close the shutter. (The room must be rather dark when you do this.) The effect on film will be cumulative, as if only one much brighter flash had been used. This method has an additional advantage in that you can hold the strobe in a different position for each individual discharge and, in effect, light the specimen from several different angles using only one light source. The multiple-flash-and-tripod method works fine for set-ups too, where you can actually handle the specimen and place it on your own background material first.

Calculating the number of flashes to use for a given f/stop is easy. You simply double the number for each step smaller the f/stop is from what you would use for only one flash. In the case of my own unit, as I said, I can use f/5.6 and one flash. The next step is f/8, requiring 2 flashes; next is f/11 requiring 4 flashes; next is f/16 requiring 8 flashes.

You may notice in the owner's manual that comes with your strobe, that the manufacturer says your unit will function only as close as about 2 feet. I have found no difficulty as close as 2 inches, so don't let that bother you. But you will have to learn to compensate somewhat for the background material in the case or behind the specimen. If the material is very light you may have to overexpose by ½ stop or more to make the minerals come out light enough. Similarly, if the background is very dark, you may have to underexpose a little. This is because the electric eye in the strobe collects reflected light from the whole field of view and not just the specimen, but all you are concerned with is the specimen.

To see a few examples of how this works, see *What's New in Minerals?* in vol. 9, no. 3, page 192-194. The figures 1 through 4 were all taken using a hand-held camera with strobe, as was the legrandite in Figure 7. The legrandite, incidentally, was *moving* while I photographed it through the showcase glass; it was on a slowly revolving turntable. The fast flash easily produced a "stop-action" photo. In that same issue, in the article on the Kalahari manganese field, many of the photos were taken using a strobe (Figs. 6, 7, 8, 9, 13, 18 and 19). I was especially pleased with Figure 13, because that specimen had not photographed well under standard studio conditions with fixed lights. So you can see that even though the strobe is a great convenience for certain kinds of informal photography, it is actually capable of producing fine studio-quality photographs as well.

AIRPORT X-RAYS

There has been controversy for a long time regarding the possible "fogging" of undeveloped film by security inspection X-ray machines at airports. Considering that mineral photographers often travel to do photography, and also that many people photograph mineral localities while on collecting trips, I thought it would be appropriate to relate some new information on the subject.

The National Association of Photographic Manufacturers (NAPM), the trade association of the domestic photographic equipment and film manufacturing industry, says that the equipment used to screen hand luggage in the United States is safe for normal film. A spokesman for Eastman Kodak has agreed with the NAPM conclusion. Signs posted by the Federal Aviation Administration (FAA) at airport security checkpoints say inspection will not affect ordinary undeveloped film.

However, there is evidence to the contrary, and the FAA is currently being sued to change its signs to read "not film-safe." A comprehensive field test was commissioned by *Technical Photography* magazine. Tests were run at airports in Minneapolis, Chicago and New York. About half of the unprotected film showed a trace of fog, but probably not enough to concern any but "the most discriminating users." (That's us.) Seventeen percent of the unprotected film showed definitely noticeable fog, and there were a few examples in which the fog was so severe as to render the film completely unusable. The technical consultant who ran the test concluded that the possibility of fog is real and unpredictable.

Irwin Diamond, president of Sima Corporation (manufacturers of lead-lined safety pouches for carrying film), reports another study conducted at Chicago's O'Hare International Airport. The study, by high school senior David Joseph, won first prize at the Illinois Science Fair. Joseph's report concluded that the "fluoroscopic inspection devices definitely harm photographic film by increasing the grain size and the exposure index and by lowering the sharpness as well as worsening the contrast."

Even NAPM and Kodak agree that foreign airports and airlines present a definite danger to film. Their screening equipment may be less sophisticated, requiring more intense radiation to be used.

Most travelers do not realize that their carry-on luggage is not the only luggage X-rayed. The airlines are very secretive about their screening of luggage checked in for storage in the airplane's baggage compartment, but they've been known to scrutinize it by X-ray. So packing your film in luggage to be checked in is no safeguard.

What can you do? Request a hand-inspection of your carry-on luggage, and then make certain they don't send it down the X-ray conveyor belt anyway. Or purchase one of the lead-lined safety bags available in photography shops. Do take precautions...the danger appears to be real. ⊠

Mineralogical Notes

PSEUDOMALACHITE FROM AUSTRALIA

by D. H. McColl
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A new Australian discovery of pseudomalachite, $Cu_5(PO_4)_2(OH)_2$,* has been made at the West Bogan mine, near Tottenham in central New South Wales. Unlike most occurrences of this mineral, these new specimens illustrate most vividly the origin of the mineral name and, despite an observation back in 1920 that the color was unusally bluish, had been regarded as massive malachite ever since. Quite appreciable quantities have been used for lapidary purposes in the last decade or so.

***Figure 1.* Botryoidal pseudomalachite, 7 cm wide, from the West Bogan mine, near Tottenham, New South Wales, Australia.**

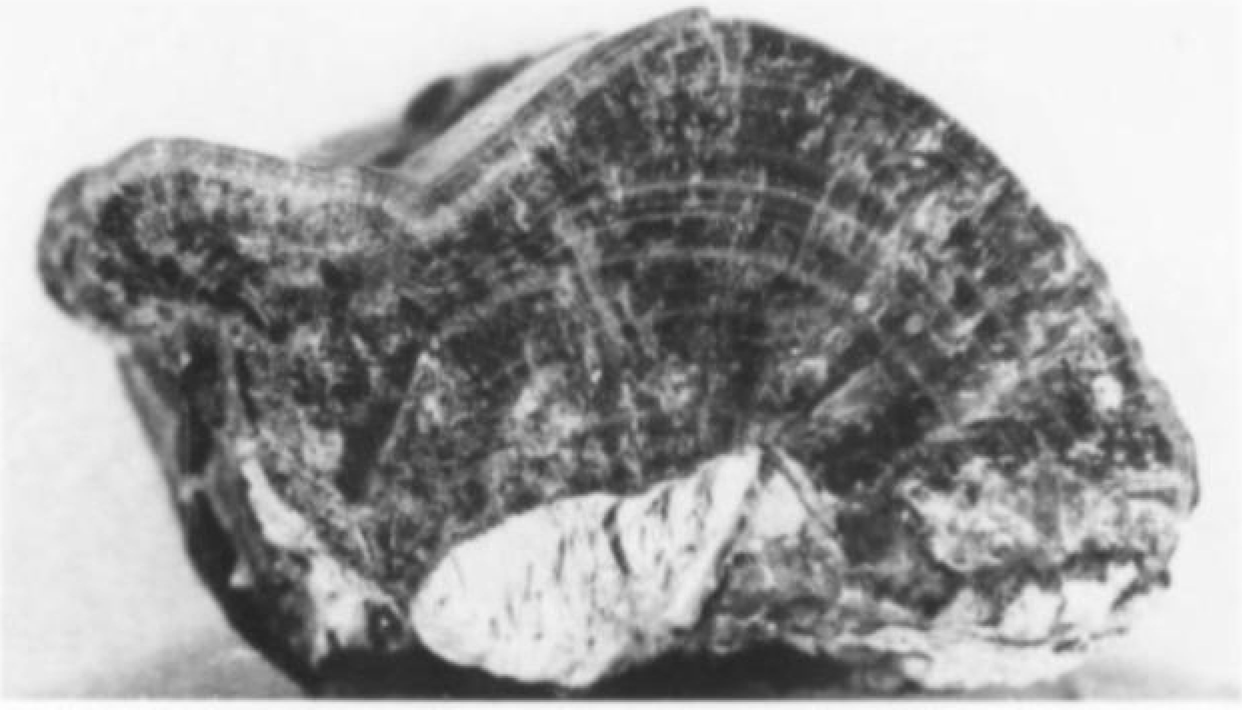

***Figure 2.* Botryoidal pseudomalachite, 4.5 cm across, from the West Bogan mine, near Tottenham, New South Wales, Australia.**

The illustrations show the form of typical specimens which have been deposited from solution in voids. The similarity to massive botryoidal malachite is very marked. Samples have been obtained which are up to 2 cm thick, with lustrous growth surfaces up to 12 x 10 cm. The bluish green color is distinctive and easy to recognize after it has been seen a few times.

Large massive pieces of pseudomalachite showing the resemblance to malachite are apparently quite rare. Dana's *System of Mineralogy* reports that such specimens once came from the Urals in Russia, and hearsay suggests that there were also some pieces from central Africa, but these new pieces are certainly finer than any others from Australian localities.

The new collapsed mine shaft is in flat, featureless country almost devoid of surface outcrop. The dump material consists of chlorite-sericite-quartz schist of probable Ordovician age, and a serpentinous talc rock. This possibly indicates that the mineralization is localized along the junction of an altered ultramafic intrusive plug where it has jointed and fissured the host metasediments, but there is no way to establish this without restoration of the mine.

Associated minerals are malachite, azurite, quartz and fairly fine drusy libethenite in prisms a few millimeters long. Cornetite was expected but was not found. A full description of the discovery is in *The Australian Mineralogist*, June/July 1978, 77-78.

---

*Note formula does not correspond with Fleischer. See recent publications on the structure of pseudomalachite.
GHOSE, S., Acta Cryst. (1963), 16, 124
SHOEMAKER er al. Am. Min. (62) 9, 10, p. 1042-1048.

YUGAWARALITE FROM BOMBAY, INDIA

by William S. Wise
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Introduction

Yugawaralite, a relatively rare calcium zeolite, $CaAl_2Si_6O_{16}\cdot 4H_2O$, has been found in specimens mined from the Khandivali quarry near Bombay, India. The specimens, imported by Rock Currier of *Jewel Tunnel Imports*, have exceptionally well formed, water-clear crystals up to 3 cm long.

Yugawaralite was first described by Sakurai and Hayashi (1952) from vein fillings near Yugawara Hot Spring, Kanagawa Prefecture, Japan. The zeolite has been found at three more localities in Japan, as vein fillings at Shimoda (Sameshima, 1969) and as a microcrystalline, metamorphic mineral in the Tanzawa Mountains (Seki *et al*, 1969) and the Onikobe geothermal area (Seki and Okumura, 1968); as well as in Alaska (Eberlein *et al*, 1971); in Iceland (Barrer and Marshall, 1965); Sardinia (Pongiluppi, 1977); and British Columbia (Tschernich and Wise, in prep.).

Figure 1. **Large (3 cm) blades of yugawaralite with hydroxyapophyllite (top), gray gyrolite, white sprays of okenite, and opalescent balls of prehnite, covering small crystals on altered basalt matrix. Currier specimen.**

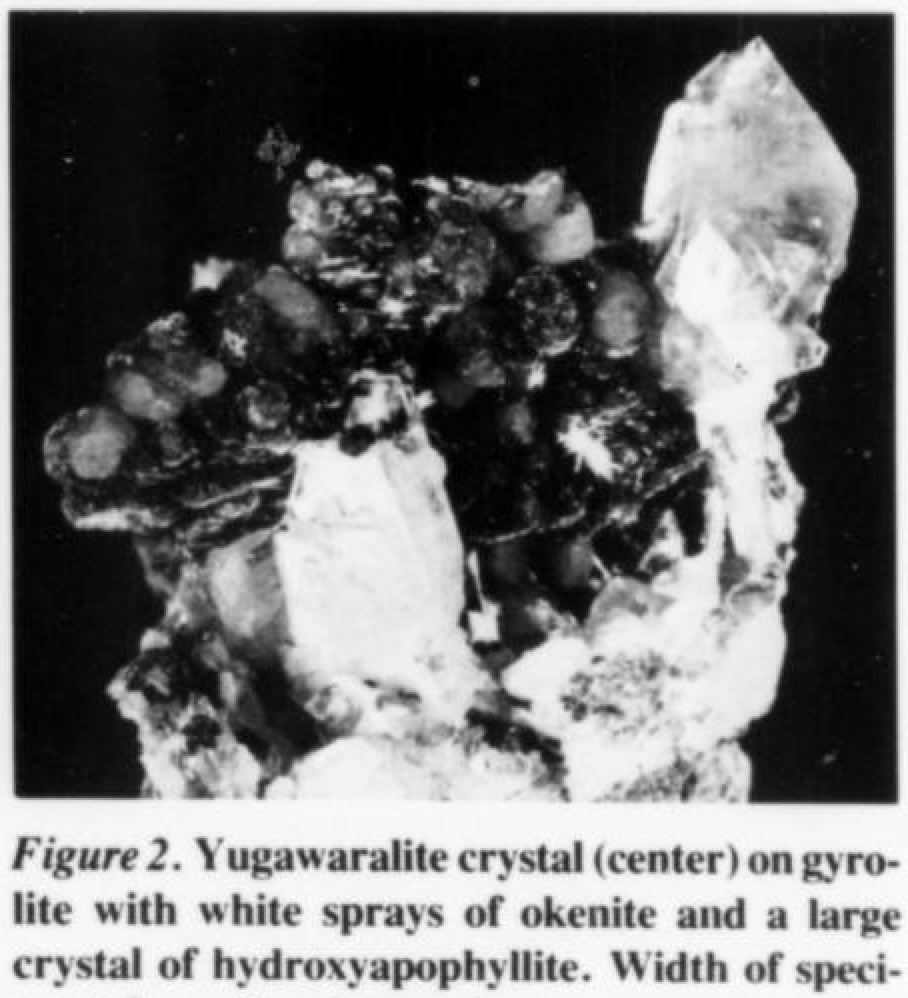

Figure 2. **Yugawaralite crystal (center) on gyrolite with white sprays of okenite and a large crystal of hydroxyapophyllite. Width of specimen 5 cm. Currier specimen.**

Association and description

Yugawaralite forms clear, bladed crystals up to 3 cm long (see Figures 1 and 2). It has grown with other zeolite and calcium silicates in breccia cavities, which have been exposed in the Khandivali quarry. The approximate growth sequence in the cavities is quartz and calcite, gyrolite, hydroxyapophyllite, laumontite, okenite, yugawaralite, gyrolite, prehnite, and calcite.

Yugawaralite crystals clearly display their monoclinic symmetry, and are similar to those described and illustrated by Eberlein *et al* (1971, Figure 3). Forms found on the Khandivali crystals are {001}, {010}, {021}, {110}, {100}, and {111}. Striations on the {010} faces (Figure 2) are parallel to the *a* axis direction.

Table 1 lists the chemical composition and physical properties determined from the Khandivali yugawaralite. The cell dimensions were refined from the X-ray powder pattern, which is nearly identical to that published by Eberlein *et al* (1971). When compared with data listed by Pongiluppi (1977) and Eberlein *et al* (1971), it is apparent that yugawaralite has a consistent composition (Ca-rich and Si/Al near 3.0) and physical properties; such a consistency is shared by few zeolites. The association with the higher temperature zeolite, laumontite, and prehnite also appears to be typical of the various occurrences.

Although only a few specimens have been recovered, these are among the best crystals of yugawaralite ever found at any locality.

Table 1.
Chemical composition and physical properties of the Khandivali yugawaralite

Microprobe Analysis

SiO_2	61.81
Al_2O_3	16.85
CaO	9.28
Na_2O	.05

remainder is H_2O

Fe, Mg, Sr, Ba, and K sought but not found

Cell Contents

$Ca_{.97}Na_{.01}Al_{1.95}Si_{6.05}O_{16}\cdot 4H_2O$

Density

2.25 g/cm^3

Refractive Indices

$\alpha = 1.493(2)$
$\beta = 1.499(2)$ 2V = 65°
$\delta = 1.503(2)$

Cell Dimensions (in A)

a = 10.09(2), b = 13.99(1), c = 6.71(1), B = 111° 20(3)′

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What's New in Minerals?

NEW TOURMALINE DISCOVERY IN BRAZIL

by **André Lallemant**
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A sensational discovery, made around April of this year, has been attracting the attention of mineral collectors worldwide. The discovery was made at the Itatiaia mine, 3 miles east of Conselheiro Pena, near Governador Valadares, Minas Gerais, Brazil. A pegmatite pocket there has been found to contain enormous, superb crystals of red elbaite ("rubellite") associated with fine albite, quartz, lepidolite and microcline. Both foreign and local experts who have seen the specimens agree that this may be the most important find of tourmaline, for size and quality of crystals, ever made in Latin America and perhaps the world.

The Itatiaia mine, owned by a farmer and leased by a local dealer, is currently being worked by Ailton, a hired *garimpeiro* who oversees a team of five miners. They have driven an adit horizontally into a hillside, through enclosing schist and into the pegmatite. Within the pegmatite they first encountered pockets containing beautiful plates of albite as large as 5 cm across, intergrown with attractive green elbaite crystals a few millimeters in diameter.

At a distance of about 60 m into the hillside, the *garimpeiros* broke into a pocket of elbaite and albite which was filled with mud and water. Ailton was impressed, and felt certain that another pocket lay directly above, from which water was entering the lower pocket. Ailton directed the excavation upwards, using carefully placed dynamite charges. Eventually a small opening into the upper pocket was achieved, revealing several lovely rubellite crystals.

After the discovery of this "bamboo" pocket, as the *garimpeiros* call it, the pocket dimensions were defined: a width of 2.0 m and a height of 2.5 m. It was uniformly lined with fine rubellite crystals in or on bright quartz, albite and lepidolite. The pocket was very clean, and acid cleaning of the specimens was not necessary.

Many of the rubellite crystals are of gem quality, and vary in size from a few millimeters to nearly a full meter. The color is a fine, rich magenta-red, and many crystals are doubly terminated. I have seen four large specimens, weighing from 30 to 40 kg each, having large rubellite crystals of gem quality associated with doubly terminated quartz and white plates of albite to 10 cm.

The dealer who is leasing the property has not permitted people to visit or photograph the occurrence. However, according to Ailton, there is a magnificent, terminated rubellite crystal suspended from the ceiling, which he describes as 40 cm long and 15 cm in diameter. The crystal is on a block of albite matrix weighing about 300 kb (660 pounds). Before cutting the specimen loose from the ceiling, the miners piled car tires underneath it to break its fall and protect it from damage.

Another remarkable specimen, named "the rocket" by the miners, consists of a rubellite crystal about 1 meter tall and 40 cm wide at the base, on a matrix of large, clear, bright quartz crystals.

This discovery, because of its extraordinary commercial value, has caused a great deal of excitement in and around Governador Valadares. Profits from the sale of specimens are being divided between the miners (20%) and the dealer lessee (80%). Their expectations are high because a single carat of cut, gem quality rubellite can bring as much as $210 . . . perhaps, they hope, as much as $600,000 per kg. This, combined with the size of the discovery and its remote location, has created a kind of "wild west" atmosphere in the area. Armed guards are everywhere, and no one is permitted near the mine entrance or warehouse. Even Brazilian Internal Revenue agents have been unsuccessful in their attempts to examine the discovery.

The dealers intention is to maximize his profits by attempting to sell every specimen as gem material over the next year or so. Recently he sold a doubly terminated rubellite crystal 1.5 by 10 cm for $1500.

The cut stones I have seen thus far are dazzling in their color (a delicate pink to a deep red), brightness and fire. Governador Valadares has "tourmaline fever" and everyone is talking about the unusual discovery. Ailton recently bought a new car and has moved into his new house.

EDITOR'S NOTE

Recently, at the International Show in Washington, D.C., a selection of small specimens from this find was seen. They were brought in by Brazilian dealer Luizhelio Barreto. The color, clarity and perfection of the crystals is certainly extraordinary. Most crystals in this small lot ranged from 1 to 5 cm and are associated with pale lavender crystals and masses of lepidolite. Luizhelio described a specimen he saw which was under guard in the warehouse in Governador Valadares. The specimen, probably "the rocket" described above by Lallemant, weighed several hundred kilograms and measured nearly a meter in height. The specimen sat on a table, beneath which were piled explosives; the owner is determined that if anyone tries to take this specimen from him he will destroy it first. The asking price, according to Luizhelio, is one million U.S. dollars. At $200 per faceted carat, 1 kg in faceted stones would yield the million dollars, so perhaps this price is not as outrageous as it sounds to a mineral collector. But it will take a brave and wealthy buyer to find out.

See *Bob Sullivan's Letter from Europe* (this issue) for additional comments on this discovery. ◆

Deep red tourmaline specimens from the Itatiaia mine, near Conselheiro Pena, Minas Gerais, Brazil. Above left: with lepidolite and quartz. Below right: 12-inche long quartz crystal with tourmaline and albite. Photos by André Lallemant.

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Ron Sohn, Dayton, Ohio
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Crystal Cabinet, Quincy, MA
Dr. David Garske, Elmhurst, IL
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George Robinson, Ogdensburg, NY
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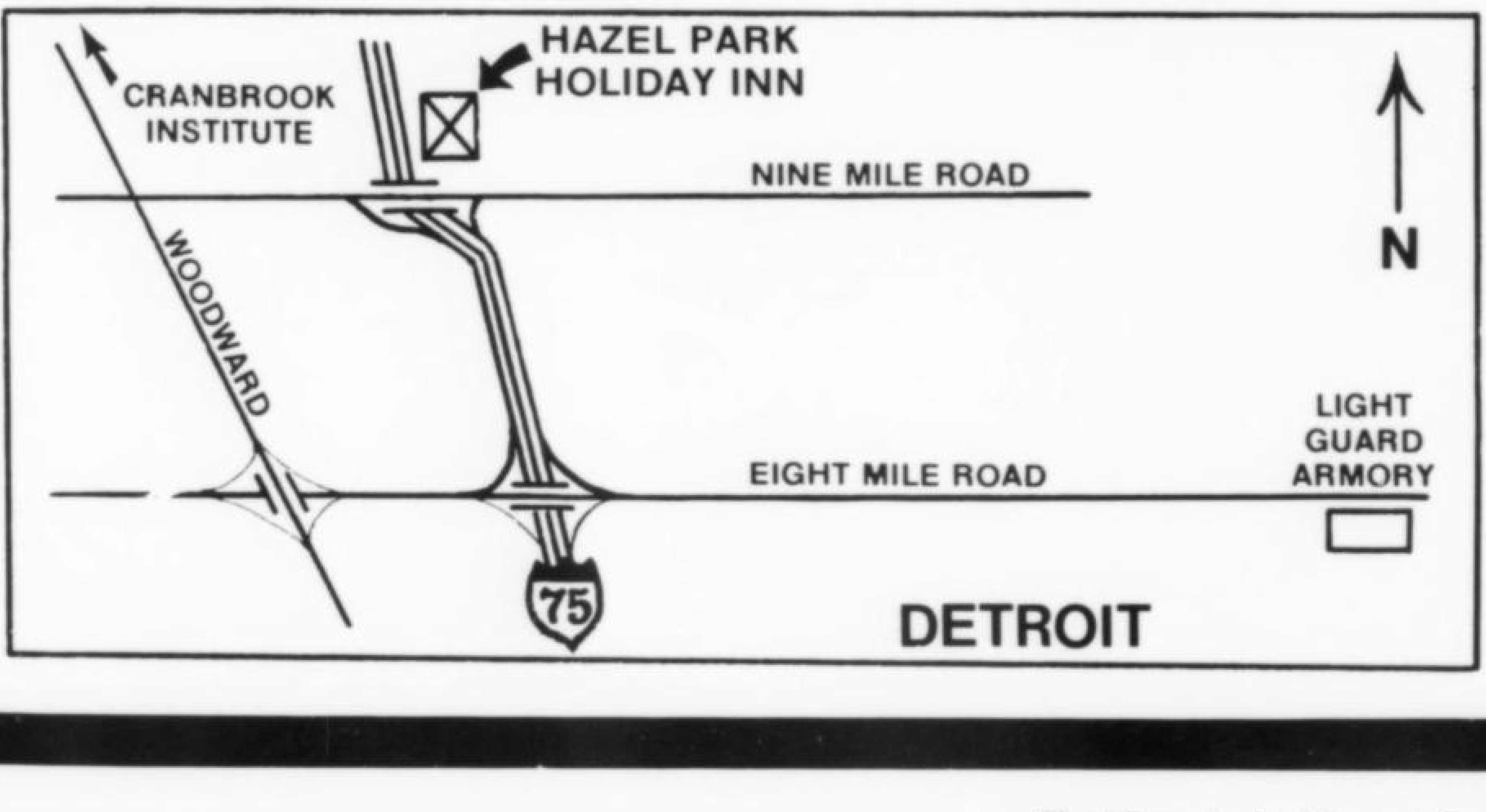

Famous mineral localities:

the pegmatites of Laghman, Nuristan, Afghanistan

Many gem crystals of spodumene, tourmaline and beryl have been extracted during the past few years from the pegmatite fields in eastern Afghanistan. In the region of Nuristan, the pegmatites appear to occur over a considerable area. In certain of these localities specimens of quite exceptional color and perfection have been found, easily rivaling those discovered in the other great worldwide deposits.

by **Pierre Bariand** and **J. F. Poullen**
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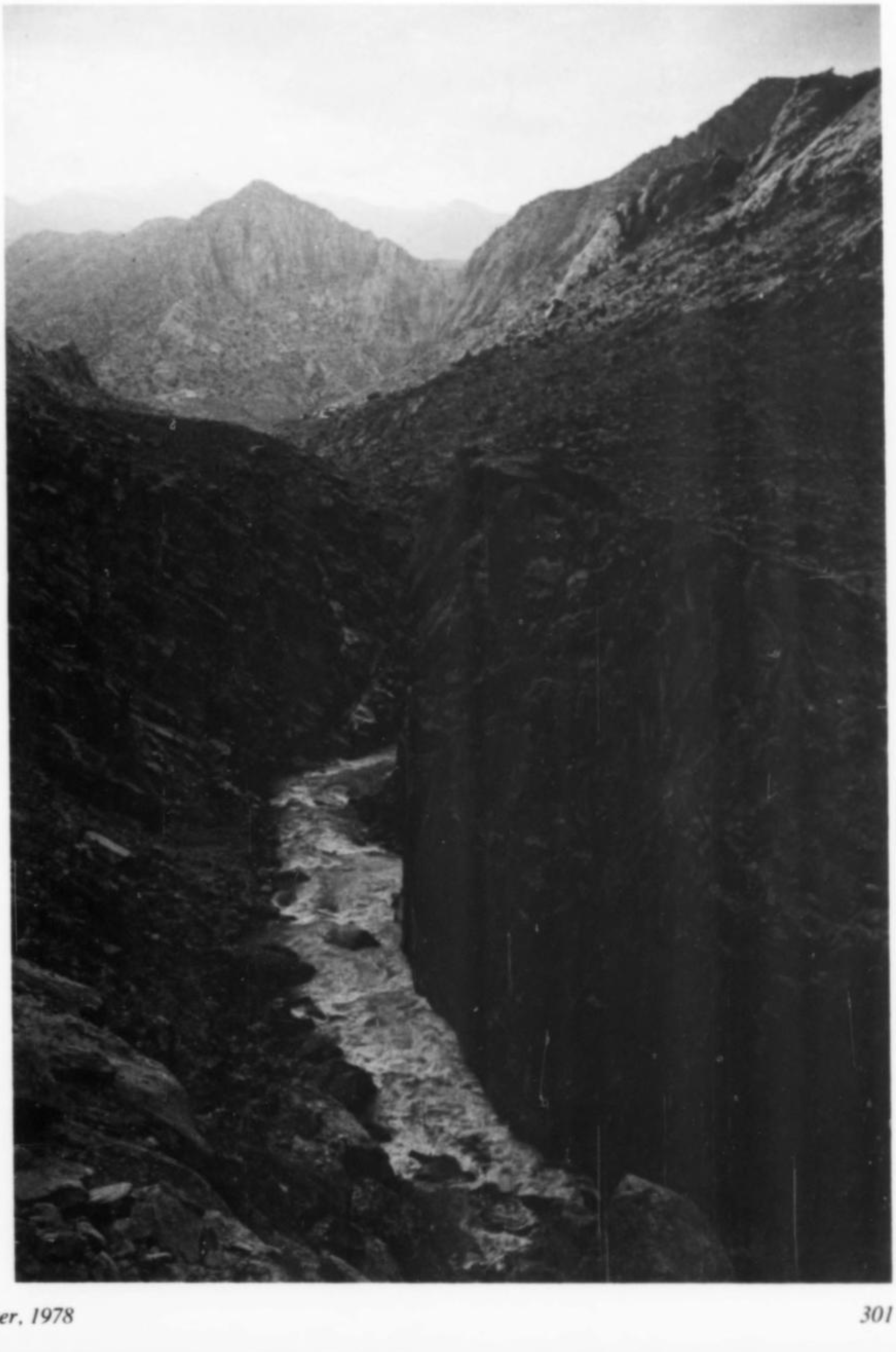

Figure 1. **Alingar Canyon near Nuristan, Afghanistan.**

INTRODUCTION

Until recently, Afghanistan was principally renowned in the world of the mineralogists and gemmologists for the famous deposits of lapis lazuli in the Badakhshan (a province in the northeastern part of the country, separated structurally from Nuristan by the Pandjshir fault) and also, in lesser measure, for the rubies in the Jegdalek marble near Sorobi. More recently, emeralds from Pandjshir valley and the

Figure 2. **Location of the map area shown in Figure 3.**

pegmatitic minerals of Nuristan have appeared on the market.*

However, in actuality the gems of Nuristan were discovered long ago, because during the archeological diggings done in the ruins of the ancient Greek town of Ay-Khanoum (Badakhshan), situated at the confluence of the Amou-Daria and Koktcha Rivers, some treasures were exhumed which contained, in addition to many fragments of lapis-lazuli, perfect crystals and gems of beryl which must have come from the high valleys of nearby Nuristan.

Even though Nuristan is geologically one distinct structural unit, essentially crystalline and limited on the south by the Quaternary basin of Jalalabad, it is administratively divided into two provinces: Laghman to the west, and Kunar to the east, bordering the Pakistani province of Chitral. The pegmatites of Kunar supply splendid crystals, especially of beryl, as in the celebrated deposit of Gur-Salak, and also of tourmaline and kunzite in the Kantiwa field. However, the best pieces seem to have been found in Laghman, and that is why in the main part of this article we limit ourselves to that province.

GEOLOGY

The three deposits that we were allowed to visit (Nilaw, Mawi, and Kurgal) are situated not far from the most important river in Laghman, the Alingar, which rises in the far north of the province and joins the Kaboul River in the south a few kilometers from Mehtar Lam.

The rock types are quite varied but always metamorphic or intrusive. They are mostly gneisses (complex migmatites), mica schists, quartzites and marble (which undoubtedly correspond to the original lithostratigraphic formations later metamorphosed), with diverse intrusions of granites (with biotite, amphibole or two micas) and of more mafic rocks such as diorite and gabbro. The metamorphism, which is imposed on an old sedimentary series, is weak in places; cross-bedding and graded bedding are still visible and the contact between the weakly metamorphosed series and the migmatites is relatively sharp.

The pegmatites, those of Nilaw and Mawi especially, occur as veins of highly variable size, from 10 cm to 40 meters in thickness and from a few meters to a few kilometers in length, in what has been called the *plutonic intrusion of Nilaw* (Fuchs *et al.*, 1974), which is composed of rocks ranging from diorites to gabbros, and which shows conspicuously in the broader migmatitic complex. The intrusion is rich in layers of marble with calcium silicates.

The vein network of pegmatites is more dense toward the southern end of the intrusion, especially at the points where it touches tourmaline-two-micas granite which is localized to the southeast. This granite seems to be the source of the pegmatite veins injected into the dioritic intrusion, since toward the west, in contact with the biotite-amphibole granite, the vein cluster is thinner and more sparse, and is replaced by breaks of the *alpine cleft* type containing adularia, chlorite, epidote and axinite.

The pegmatite veins in the Nilaw intrusion have a very characteristic, stratiform shape which may be described as "watch glass," horizontal in the center of the pluton and plunging slightly at the edges. This "ring dike" aspect can be explained as the sinking of segments around the edges of the roof of the subjacent reservoir. The products coming from the two-mica granite could then be injected into the empty spaces thus created. But it is possible to imagine other causes (form of the isotherms, reduction of volume of the diorite on cooling lateral compression, etc.).

In a more general way, the tectonic directions of the metamorphic rocks are consistently NNE-SSW, and the series of intrusions follows that orientation even though indiscriminately cutting all of the enclosing metamorphic formations. According to Fuchs *et al.* (1974) the geologic history of that region should be as follows:

A paleozoic sedimentary series, deposited on a basement of migmatites, was subjected to metamorphism and then to intrusion by various rock types (diorites, gabbros, and finally biotite-amphibole granites) leading to the remobilization of the migmatites. Fuchs *et al.* (1974) supposed that the intrusions appeared during the alpine cycle (the diorites may be of lower Cretaceous age and some of the granites of Oligocene age). The pegmatites in the pluton of Nilaw appeared later.

THE DEPOSITS

Even today the deposits of Laghman are difficult to reach due to the considerable distances that must be covered on foot. Neither mules nor horses can be obtained, which considerably limits the number of points accessible to a visitor.

At present, the end of the jeepable road is situated very far below the interesting sites. In 1977, this road, which leaves the Kabul Jelalabad route, goes straight northward to Mehtar Lam and ends several kilometers beyond the village of Nuristan (70 km after the fork) just at the point where a small, recently constructed bridge (Gandalabouk) crosses the Alingar River. Then a full day on foot is needed to traverse the 25 km of narrow gorges which separate that bridge from the nearest houses (5 houses, one belongs to the subgovernor) one hour away from the village of Dahaneh-Pyar, at the junction of the Kolum and Alingar rivers. Yet another full day is necessary to reach the deposit of Nilaw—15km of bad rocky trail.

Nilaw

The stratiform pegmatite vein can be easily seen even from far away, forming white bands that show clearly in the abundant vegetation of the little narrow valley of Nilaw. In several places the pegmatites have been exploited with the use of dynamite.

Afghan law prohibits anyone from exploiting deposits of any kind whatever, excepting the employees of the Ministry of Mines, who work periodically on the most interesting zones. That prohibition even applies to the local village inhabitants; but this does not stop the smugglers who come, from Kabul and elsewhere, well prepared to make a fortune by selling the products of their work in the markets, especially in Kabul Peshawar, Gilgit and even Tucson. The beryllium and lithium pegmatites of central Laghman are now prospected only for gems, and not for industrial elements such as Be, Li, Nb-Ta or Cs. In the Kunar field, beryllium is the only industrial element being exploited.

The extent of the pegmatite veins of the zone called *Kolum* (Nilaw-Mawi) seems to be associated with the nature of the enclosure. In the Proterozoic formations they rarely reach 100 m in length and do not exceed 10 m in width, while in the gabbro-dioritic intrusions they can be followed for several kilometers (up to 7 km for some veins) and certain local enlargements have a thickness of 50 m.

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*The exploitation of these was made possible by Russian Geologists who found the deposit in 1970.

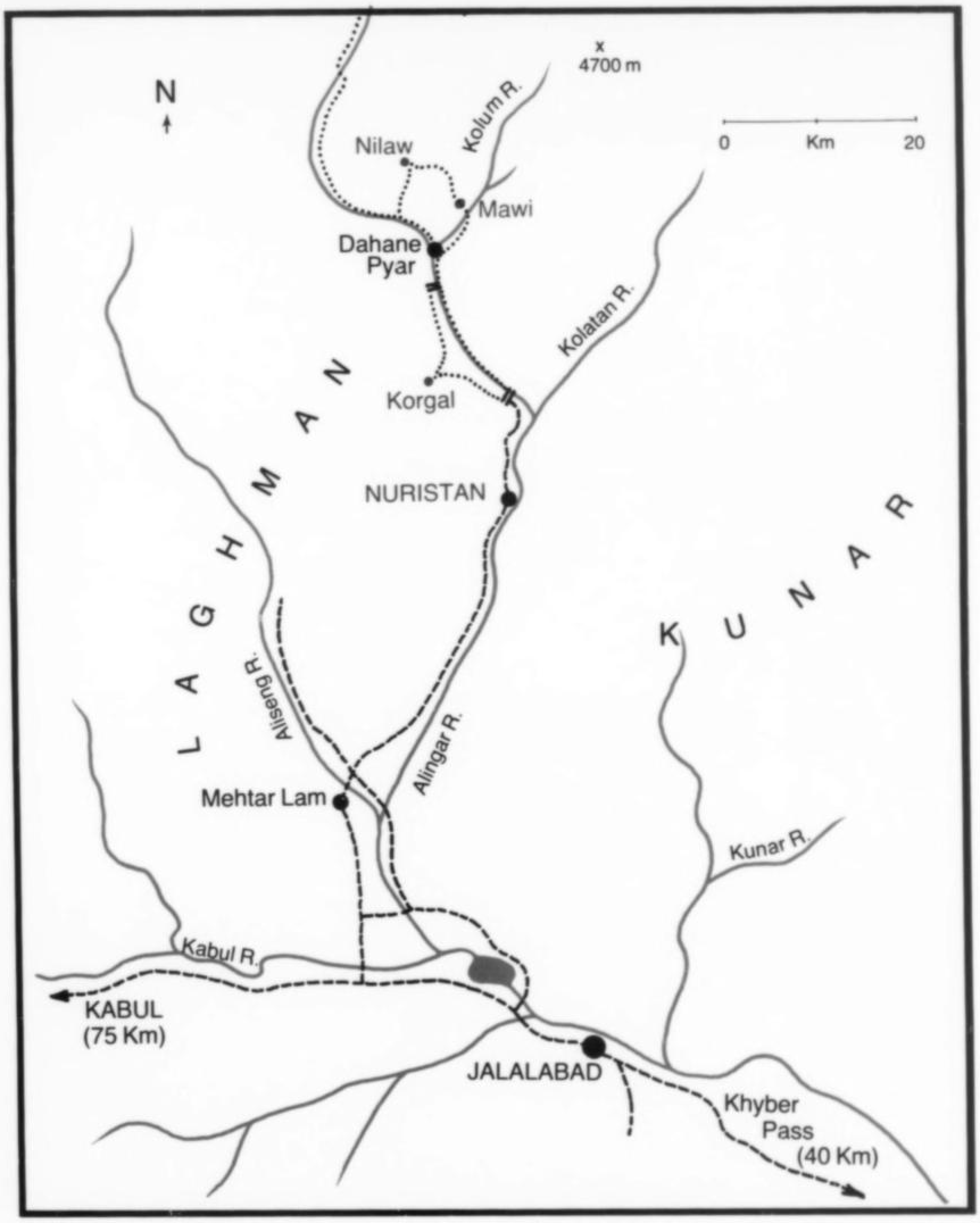


Figure 3. **Location of towns and deposits in the Laghman-Kunar area.**

Figure 4.

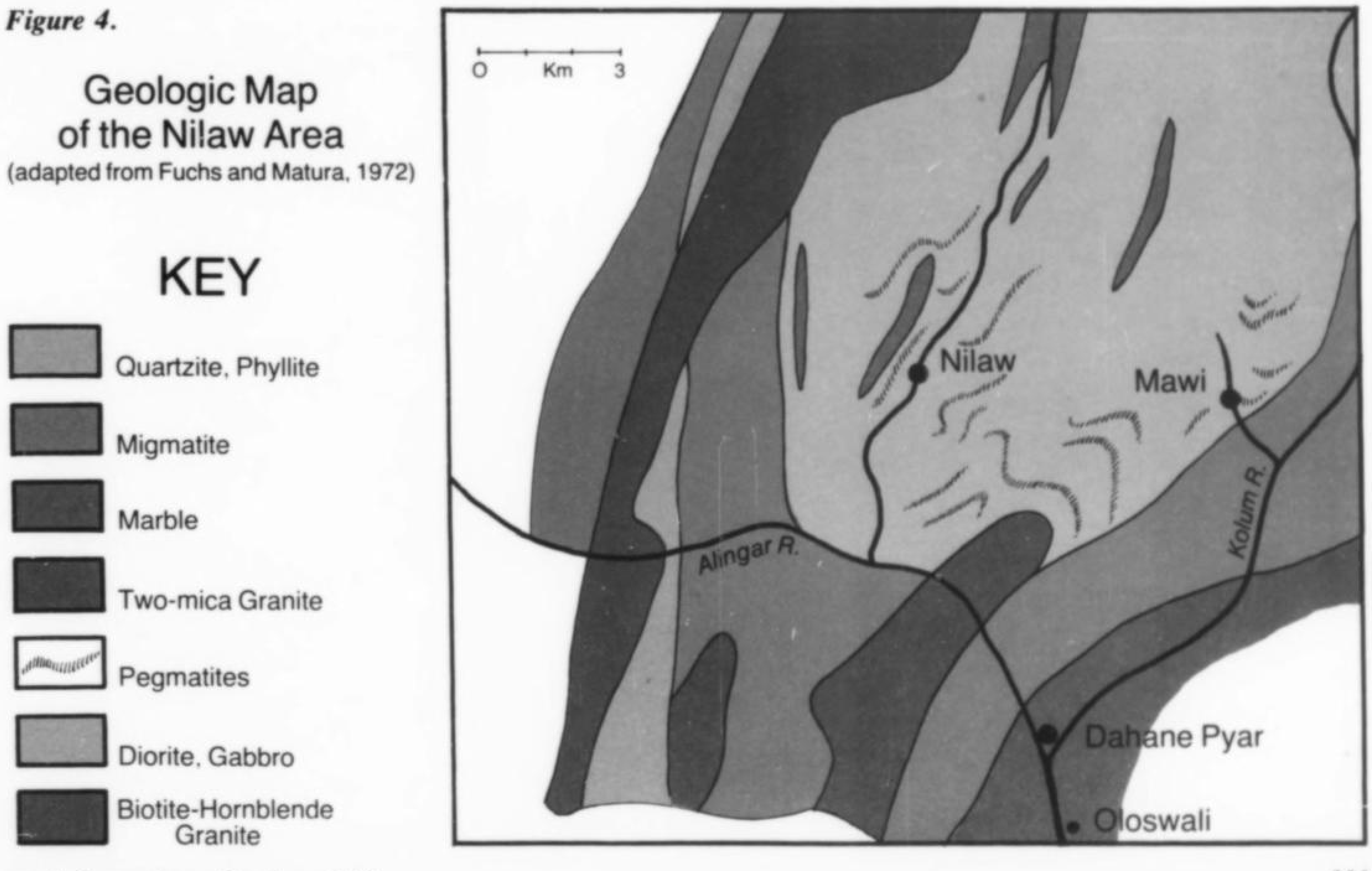


Figure 5. **Kunzite spodumene, 20 cm tall, from Mawi, Laghman, Afghanistan (collection of the Sorbonne). Photo by Nelly Bariand.**

According to Rossovskij *et al.* (1974) it is possible to define several types of pegmatitic veins from their mineralogic composition:

1) Oligoclase-microcline with black tourmaline and beryl.
2) Albitized microcline with more frequent black tourmaline and beryl.
3) Albitized microcline with black tourmaline, beryl and concentrations of lepidolite, multicolored tourmaline, spodumene, and pollucite.
4) Albite with segregations of lepidolite and spodumene.
5) Lepidolite, spodumene and albite.

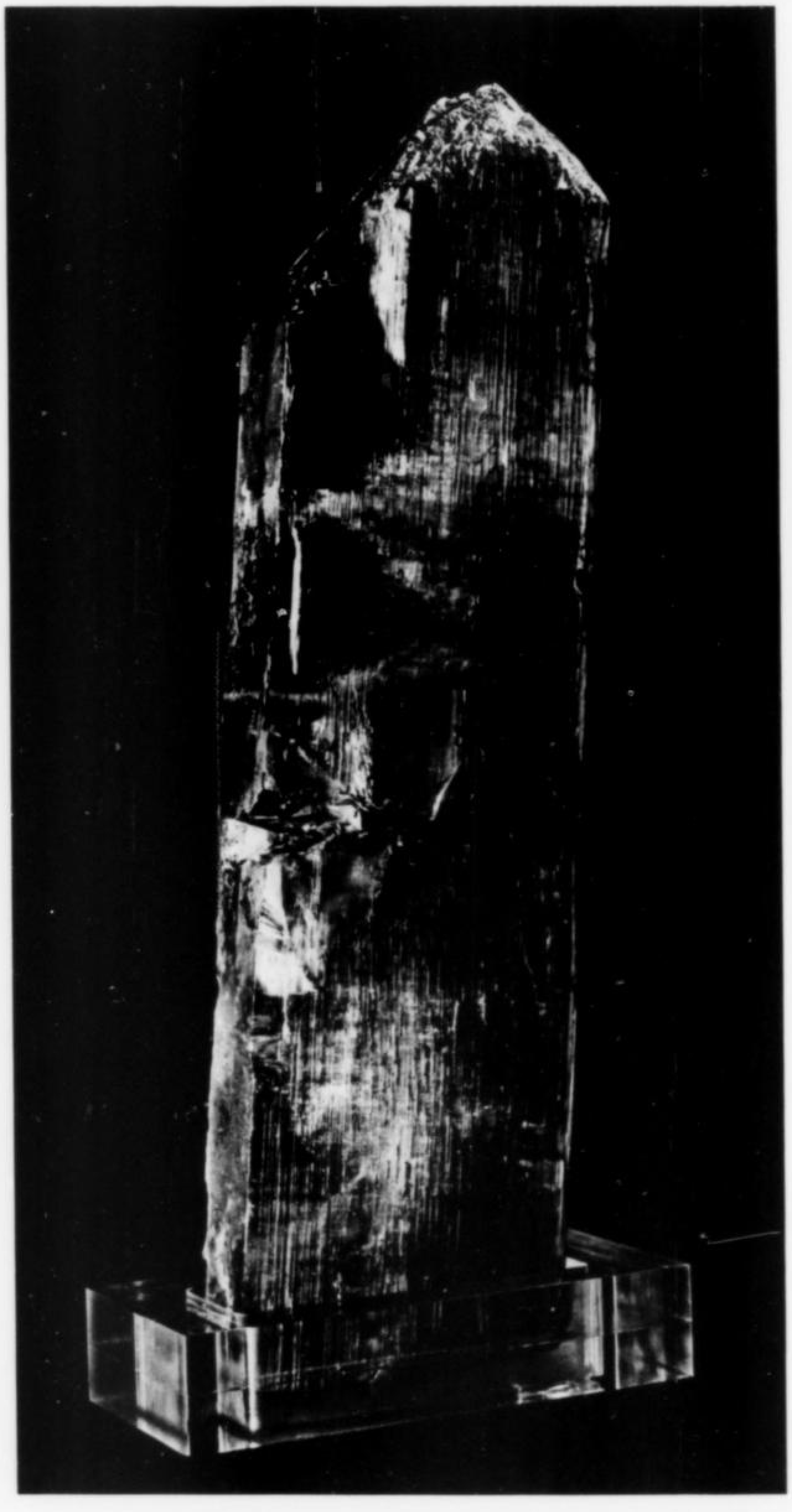
Three types of veins (2, 3 and 5) are found in the Nilaw field. The central part of the third type of vein shows lepidolite, blue cleavelandite, multicolored tourmaline, kunzite (lilac-colored spodumene), white-pink spodumene, beryl and pollucite. Microlite, manganotantalite, columbite-tantalite and cassiterite are present there and also in type 5. Fuchs *et al.* (1974) advance the figure of 1,000 tons of reserve of beryl in the veins where it is exploitable in segregations. The average contents of Li, Cs, Rb and Sn are also appreciable (Rossovskij *et al.*, 1974; Chmyriov *etal.*, 1975).

The workings that we visited cut the pegmatites only in a place where the thickness of the vein is about 15 m. The zonation of this body is assymetrical; fine grained in the lower levels, and in higher levels an assemblage of large size crystals, where quartz, microcline and spodumene dominate. The crystals of spodumene embedded in the rock are rosy and opaque, in immense sheafs with rather diffuse outlines. Crystal-lined cavities are mostly localized toward the top of the vein; those that we could examine are about 50 cm across and contain essentially large crystals of quartz and microcline. It is certain that they also contained crystals of kunzite as we saw elsewhere. Muscovite, black tourmaline and beryl are found in the matrix, as are also some phosphates of iron, manganese and lithium. At the top, limited to a layer 20 cm in thickness, the pegmatite is full of blades of columbite-tantalite. We have also noticed that the pegmatites at Nilaw, as at Mawi and Korgal, are invariably associated with amphibolites.

Mawi

East of Nilaw, not far from the Kolum River, is the famous deposit of Mawi where very large crystals of spodumene (green, blue, pink, yellow and colorless), beryl (morganite and aquamarine) and tricolored tourmaline were discovered. The path from Nilaw to Mawi is relatively

Figure 6. **Green spodumene crystal 60 cm tall. This is probably the finest crystal yet recovered. It is twinned and doubly terminated. From Mawi, Laghman, Afganistan (collection of the Sorbonne). Photo by Nelly Bariand.**



easy and can be covered in a half-day walk. It is necessary to cross the Koh-e-Sagoli range (altitude about 3,000 m), then descend again through the short valley of Mawi until the dumps that mark the zones of exploitation appear. It is difficult to judge the thickness of the Mawi pegmatites, but it is surely considerable. (According to Rossovskij, *et al*. (1976), the principal vein is about 40 m thick and runs for 1,200 m.) The following paragenesis can be recognized:

(1) Aggregates of quartz and muscovite of about 10 cm thickness first formed at the borders of the veins, in contact with the wallrocks, some with blue-green beryl crystals of large size.
(2) Biotite and microcline with quartz, aquamarine, and black tourmaline formed next. This association is only observable in the eastern part of the deposit.

***Figure 7*. Kunzite crystal, twinned, 15 cm tall, from Mawi, Laghman, Afghanistan (collection of the Sorbonne). Photo by Nelly Bariand.**

(3) A discontinuous zone of giant crystals of quartz and microcline then formed. The beryl crystals are found only in the apophyses of the principal vein.
(4) Then a "zone" of quartz and spodumene formed, which actually comprises local segregations with a thickness of several meters, also containing crystals of columbite-tantalite. The spodumene crystals of this "zone" are of great size (up to 2 m long).

Paragenetic stages 5 through 7 proposed by Rossovskij *et al*. consist of the associations albite-muscovite-quartz in various proportions, in places sugary, with concentrations of lepidolite, multicolored tourmaline and spodumene. The latter mineral seems the most sought after at Mawi. In July of 1973, 420 kg of spodumene were extracted there, and 176 kg in October-November of the same year. These figures lead one to suppose that the reserves are important. Estimates of reserves of beryl immediately exploitable at Mawi lead to a total in the vicinity of 50 tons. Tantalite and pollucite seem too dispersed to be of economic value.

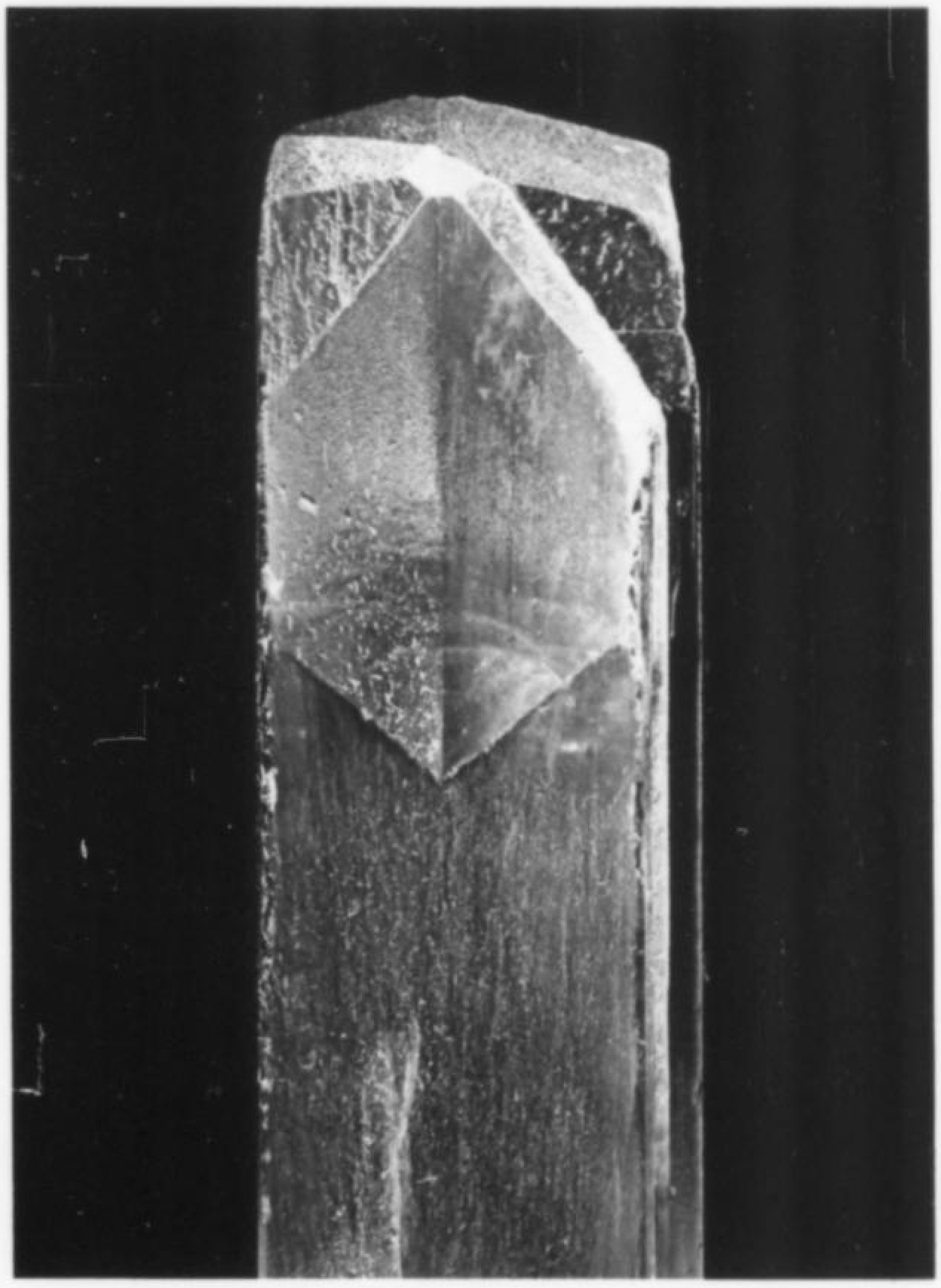


***Figure 8*. Spodumene crystal, twinned and showing re-entrant angle, from Mawi, Laghman, Afghanistan (collection of the Sorbonne). Photo by Nelly Bariand.**

On visiting several dumps, we were able to observe great plates of rock, covered with crystals of quartz, microcline and albite (cleavelandite), on which had been fixed the crystals of spodumene of which only the bases remain, individual crystals having been detached from their support by the gem hunters. However, spodumene lining cavities seemed rare and the production consists largely of isolated, free crystals that are extracted from pockets in altered pegmatite. The same appears to be true for beryl. We also found several specimens covered with little crystals of tricolored tourmaline and even colorless tourmaline (achroite). It is, however, illusory to imagine gathering beautiful crystals if one has only a geologist's hammer. Other minerals also caught our attention, notably some pretty spessartine garnets embedded in the pegmatite and also two enormous balls of botryoidal muscovite with a maximum diameter of 30 cm but, sadly, untransportable.

Korgal

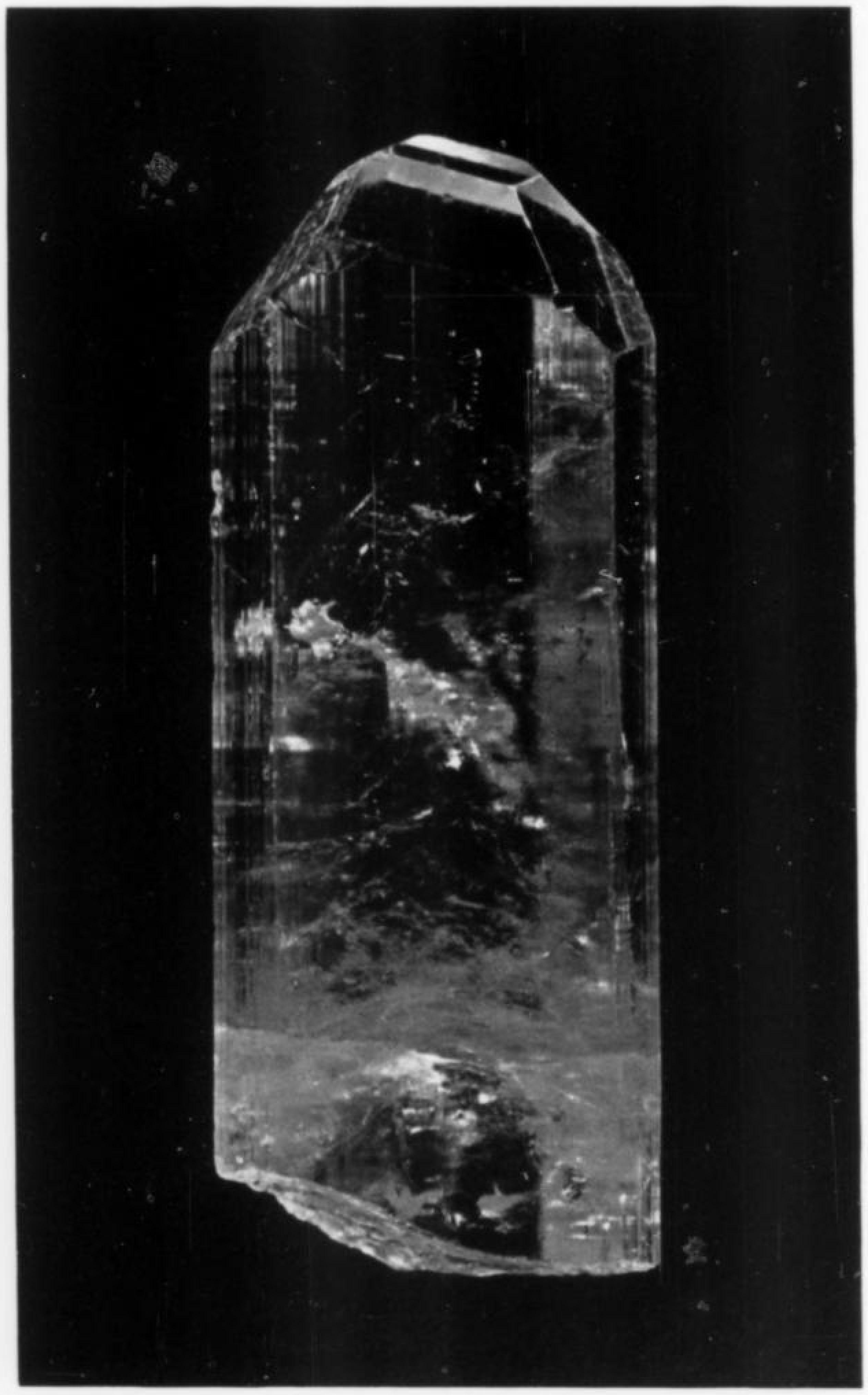
The deposit of Korgal is famous for its extraordinary, absolutely transparent green tourmaline, so sought after by the gems hunters. The mine is situated in a little valley on the other side of the Alingar River. From Dahaneh-Pyar, two ways of access are possible. The longer (a one and one-half day hike) consists of going back down the Alingar to the bridge, crossing the river at that point and searching for the path which takes off upstream in the direction of Dahaneh-Pyar. The second way is more dangerous but takes only a half day: at Oloswali, cross the Alingar River over the small bridge at the exit of the village, then go down the river along the slope to Korgal. Unhappily, this path is very often cut by rock cliffs that have to be jumped over, not without some acrobatics.

The deposit consists of several veins of pegmatite embedded in crystalline schists and garnet-sillimanite-biotite gneiss, all Proterozoic. The thickness of the veins is from 1 to 50 m, over a length of several hundred meters. Four typical mineral associations have been observed by Rossovskij *et al.*:

(1) Microcline-muscovite-black tourmaline granitic pegmatite, with sporadic manganotantalite and pollucite.
(2) Oligoclase-microcline-black tourmaline-muscovite-beryl.
(3) Oligoclase-microcline-black tourmaline-muscovite with segregations of lepidolite and multicolored tourmaline.
(4) Albitized pegmatite with microcline.

The pegmatite contains an abundance of gem crystals of tourmaline (green and sometimes pink), in places forming magnificent sheaves on muscovite. Spodumene and beryl seem less common. At Korgal, as in the other deposits, the phosphates triplite, purpurite and heterosite are rare, although eosphorite has been found. Clear, gemmy bastnaesite crystals, that we have heard about must come from the emerald mines of Pandjshir valley where some contact hydrothermal processes have affected the carbonate formation.

Figure 9. **Elbaite tourmaline crystal 4 cm tall from Mawi, Laghman, Afghanistan (collection of the Sorbonne). Photo by Nelly Bariand.**



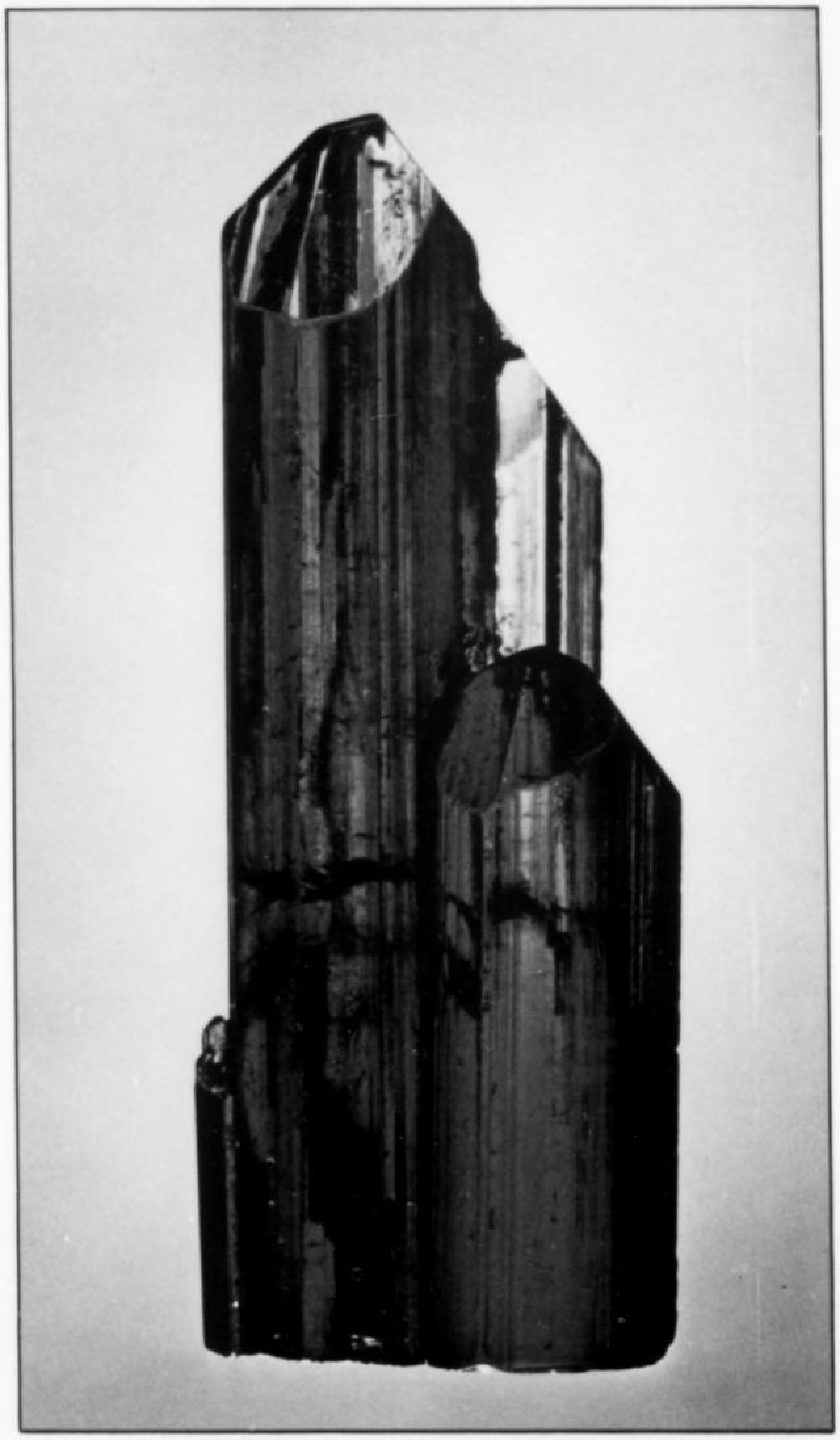


Figure 10. **Elbaite tourmaline crystal 6 cm tall from Korgal, Laghman, Afghanistan (collection of the Sorbonne). Photo by Nelly Bariand.**

MINERALS

The minerals that we have observed are very typical of pegmatites rich in Be and Li: quartz, microcline, albite, lithium-tourmalines, pink and blue beryl, spodumene, muscovite, lepidolite, triplite, heterosite, purpurite, manganotantalite, columbite-tantalite, cassiterite, spessartine, violet apatite and pollucite. Under present conditions, it is only the gem minerals (tourmaline, spodumene and beryl) that make these deposits interesting.

Tourmaline is the most remarkable mineral. It is present in an astonishing variety of forms and colors. Great pink crystals with flat terminations with many striations, sprinkled with lepidolite, very much resembling those from Pala, California, have probably been extracted in the region of Korgal. At the home of a merchant in Kabul we noticed one section of such a crystal that was 30 cm in diameter. The small, tricolored crystals (pink base, green center, colorless top) seem more characteristic of Mawi. The yellow-brown tourmaline crystals seen in the bazaar in Kabul are of unknown provenance (probably Kantiwa field) as well as the crystals of deep blue color. The crystals of green, and especially the most valued shades of blue, green and emerald green, come from Korgal. Multicolored crystals grade smoothly from one color to the next. The terminations of the little crystals are in sharp

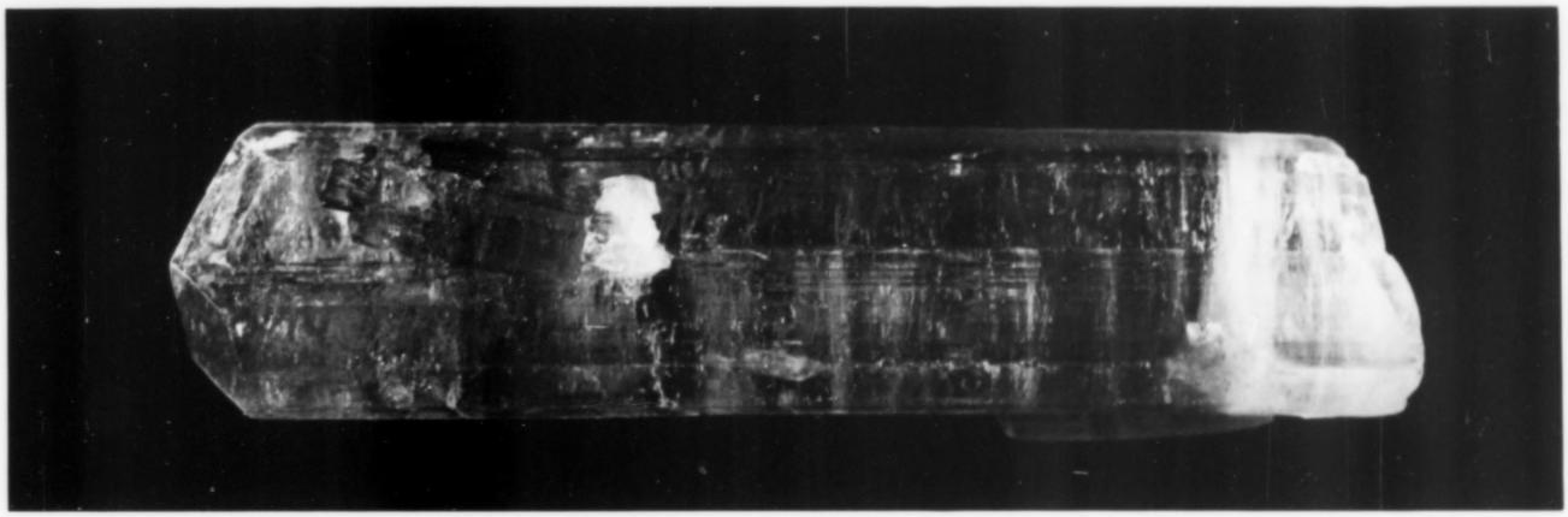


Figure 11. **Elbaite tourmaline crystal 6 cm long from Korgal, Laghman, Afghanistan (collection of the Sorbonne). Photo by Nelly Bariand.**

pyramids due to the predominance of the faces {02$\bar{2}$1} which are progressively supplanted in the course of mineral growth, by the faces {1011} by elimination of the forms which have a greater rate of growth. The large crystals, which can reach 2 by 15 cm and perfectly transparent, are terminated by the low-angle pyramid {10$\bar{1}$1}.

Beryl is especially abundant in the Kunar area, but the gem varieties, aquamarine and morganite, are found mainly in the Laghman district, where they occur with the basal pinacoid characteristically well-developed. Loose crystals and crystals on matrix have been recovered. The tint varies from pink to brownish pink. Gem aquamarine crystals of a beautiful, intense blue have shown up, but it is possible that this discovery was made at Gur-Salak in Kunar.

Spodumene from Laghman has also acquired a just fame. This region has produced some gem crystals of astonishing size (up to a meter long). The diversity of colors, purples, pinks and greens, is almost indescribable. One even finds bicolored crystals, though a true hiddenite has not yet been reported. The shape is, in general, classic: elongated clinoprisms flattened parallel to the striated {100} face. However, certain of these prisms are limited laterally by {010} on one side, and by the face {110} (parallel to cleavage) on the other side, in such a way that it appears to be a crystal broken along the plane of cleavage. This is an error and it is easy to check by observing the corrosion figures on the {110} face which can also be a crystal face. Several individuals reveal a roughly square section, in consequence of the equal development of the {010} and {100} forms. We have also brought back a crystal, remarkable by the abundance of lateral faces, which clearly shows the twin on {100}, having a characteristic re-entrant angle between the two individuals that we have never before seen.

Unlike the large spodumene crystals from pegmatites in California and in Minas Gerais, Brazil, Laghman spodumene crystals have remarkably flat and well-developed faces and relatively sharp, rather than rounded, edges.

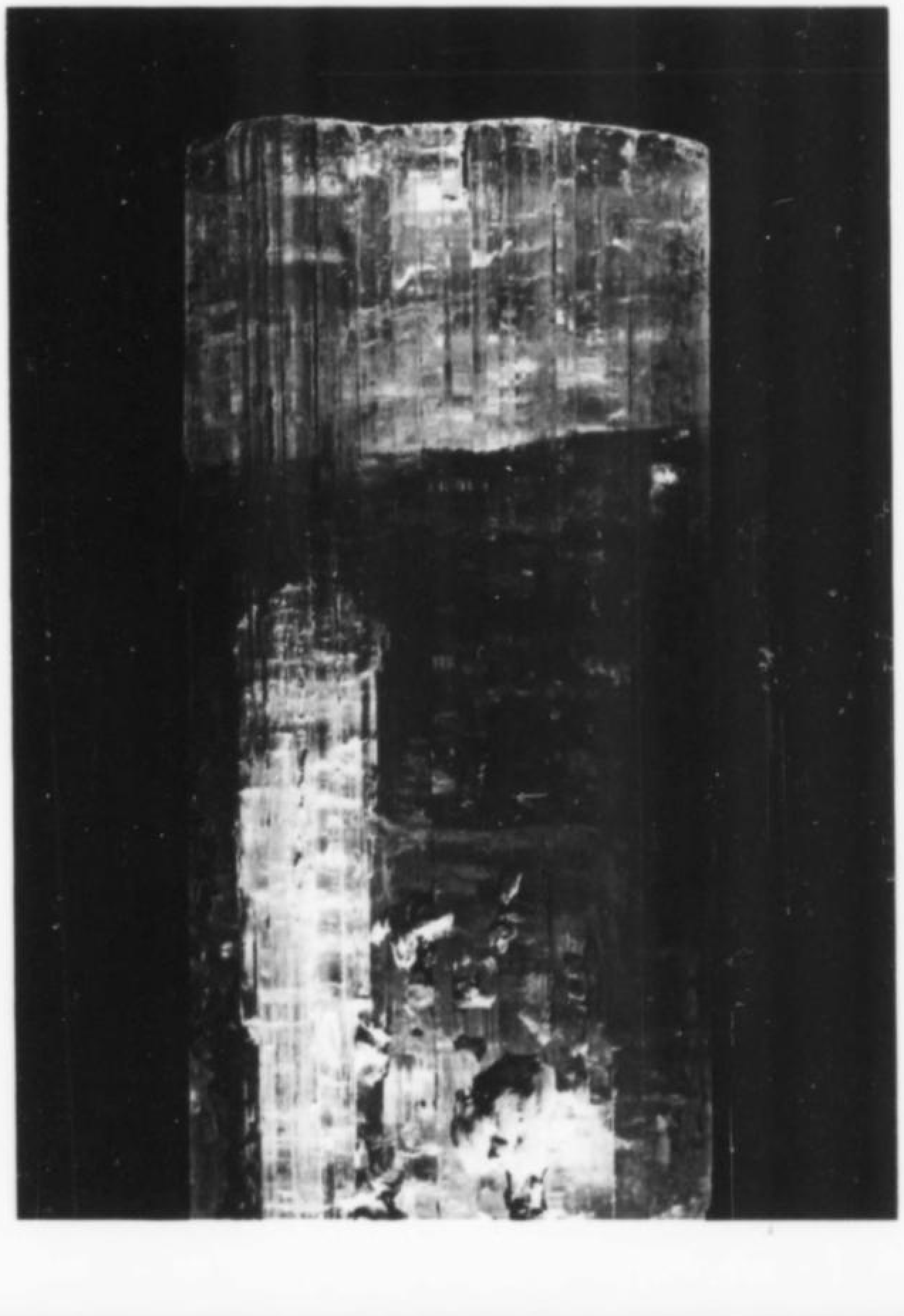
The other interesting peculiarity of Laghman spodumene is its occurrence in cavities or pockets of crystals, for example one superb specimen that we could only admire: a large crystal of microcline (20 kg) on which a 15-cm crystal of transparent pink spodumene was attached. We also found parallel groups of crystals composed of two or three individuals. Crystals of spodumene with attached crystals of tourmaline are also known.

Just as for tourmaline, the spodumene is used in jewelry and sold at a price per carat. However, gem spodumene is less valued than tourmaline because it sometimes fades in the light and has a tendency to cleave easily while being cut.

EDITOR'S NOTE

The government of Afghanistan was overthrown in April, 1978, by a leftist revolutionary group, casting some doubt on the future accessibility of Afghan minerals to foreigners. Although the new government is clearly more radical than its predecessor, American State Department officials familiar with the area say it is far from certain that Afghanistan will become a Soviet satellite. The new government party was reportedly not accepted as a communist party by Moscow. Accounts of the April 27 upheaval obtained by U. S. officials indicate the Soviet Union had no part in preparing or executing the coup. The assessment in Washington is that the new government will lean more toward the Soviets than the previous regime; however, Afghanistan has historically had close relations with its Russian neighbor while nevertheless placing a high value on its own independence. Officials of the coup have spoken of a "positive neutrality" in foreign affairs, with relations to other countries determined by the extent of their political and economic

Figure 12. **Elbaite tourmaline crystal 6 cm wide from Mawi, Laghman, Afghanistan (collection of the Sorbonne). Photo by Nelly Bariand.**



support. The officials said that Afghanistan will not accept aid with strings from any nation. Moscow immediately recognized the new government and has offered about $16 million in civil aid. The United States has also recognized the new regime and offered to continue economic aid which has been about $20 million annually in the past. Most of the 60 advisors from the United States in Afghanistan at the time of the coup are expected to remain, and West Germans have been asked to stay on as police advisors (Oberdorfer, 1978). There is, therefore, reason for cautious optimism that exports of mineral specimens and gems might be able to continue.

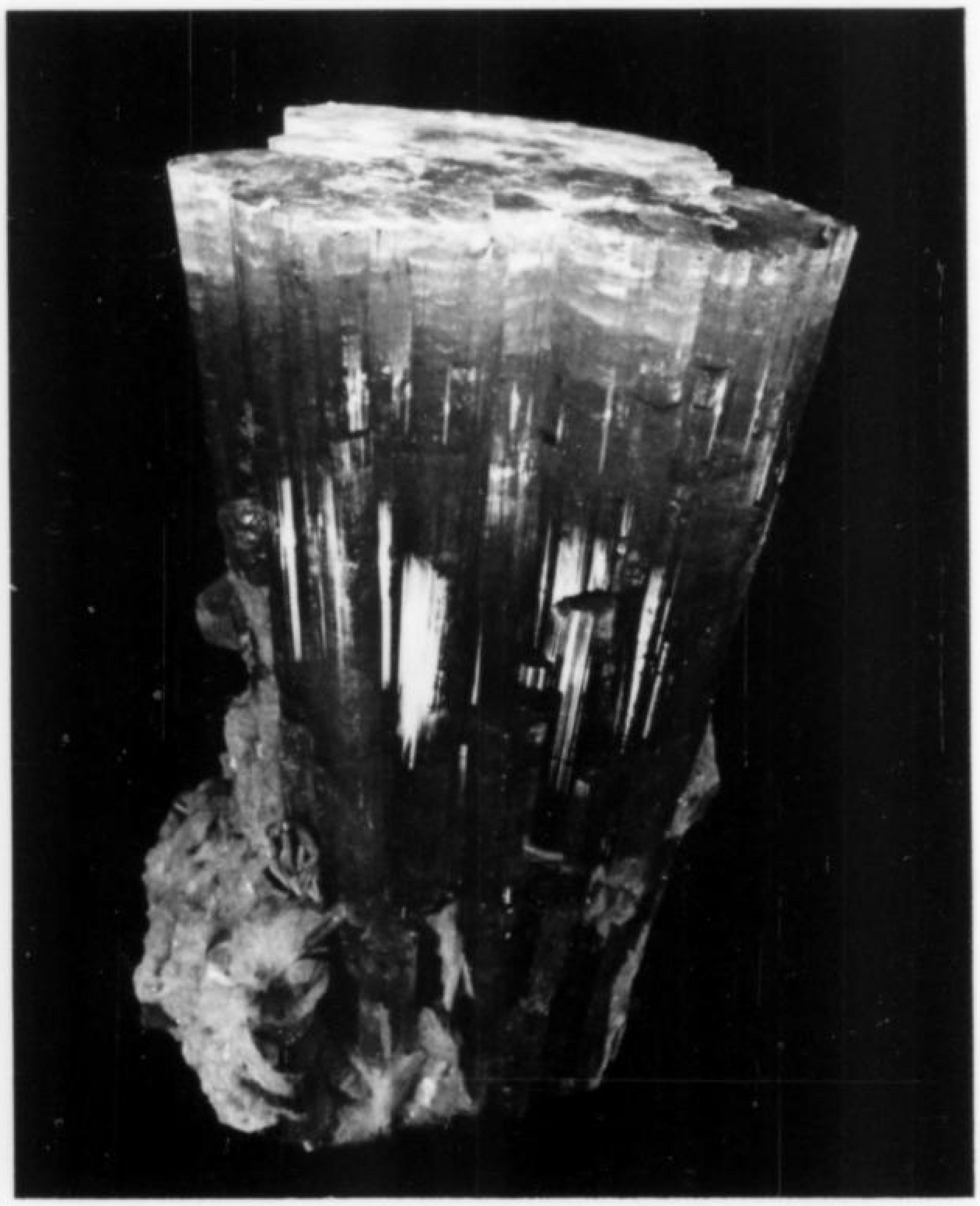
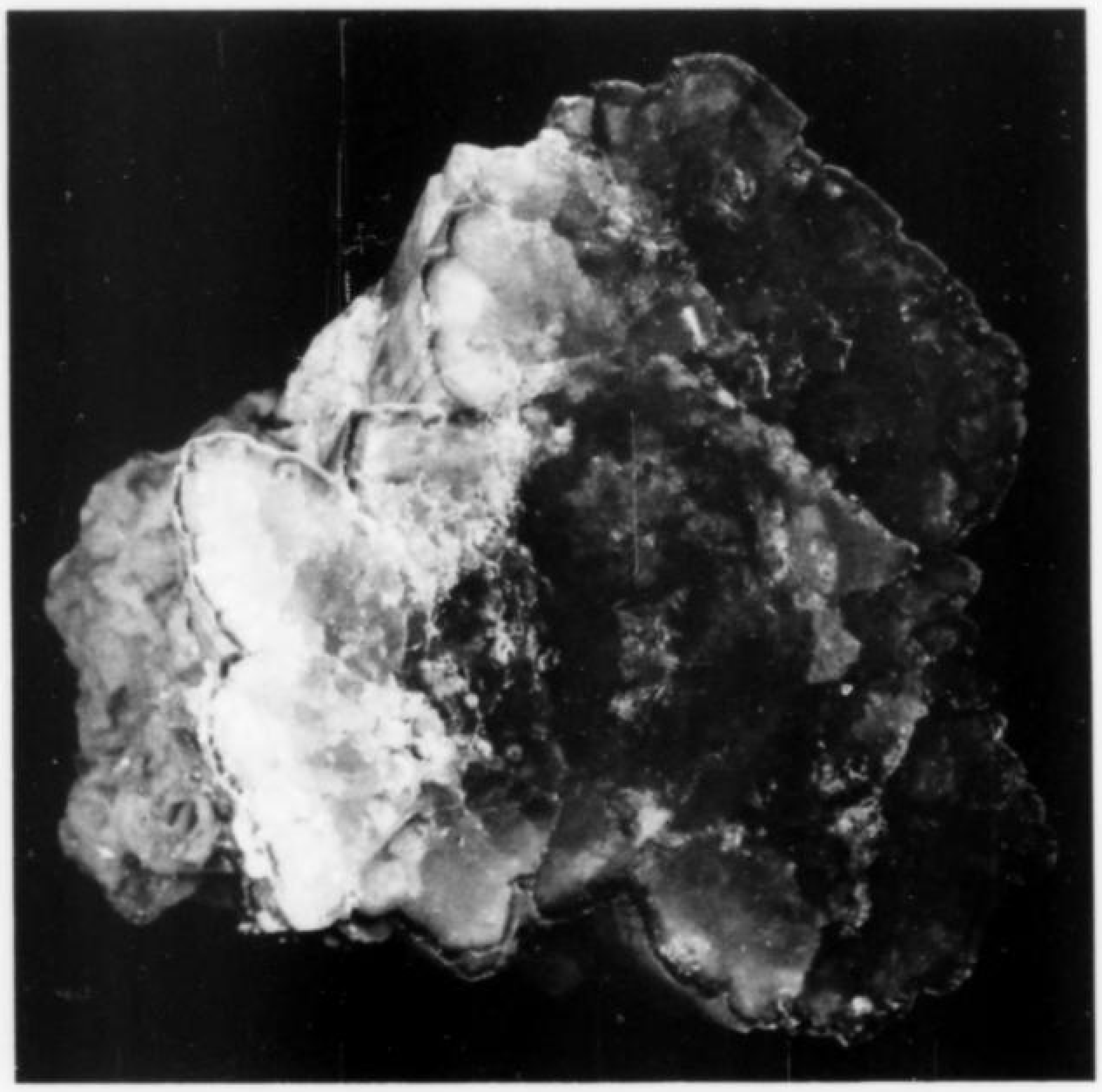


Figure 13. **Elbaite tourmaline, 21 by 15 cm, from Laghman, Afghanistan (Herb Obodda collection). Photo by WEW.**

Figure 14. **Top view of crystal shown in Figure 13. Photo by WEW.**

Figure 15. **Morganite beryl crystal 6 cm across on matrix with tourmaline, quartz and albite, from near Nuristan, Afghanistan (Herb Obodda collection). Photo by WEW.**



ACKNOWLEDGMENTS

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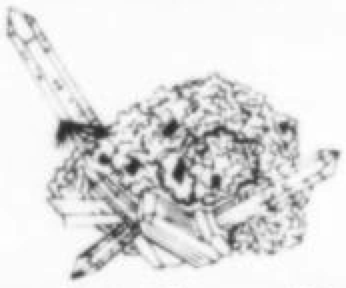

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Microminerals

Editor's note: Vi Anderson, who usually writes this column, will occasionally turn it over to a guest columnist as she has for this issue. Micromounters who would like their turn as guest columnist should contact the editor. Al Falster, this issue's guest columnist, is originally from Germany and now living in Wisconsin. Readers may recall his note on phenakite from Marathon, Wisconsin, in the September-October 1977 issue of the Record. Al has been a mineral and fossil collector for over 20 years, and a micromounter for 13. His collection currently numbers 13,000 mounts of 750 different species. Like many Europeans, he is an avid trader and has obtained much of his collection in this way.

Perhaps I should begin with practical matters and describe some of the techniques I have developed for my own micromounting, and some of my sources for supplies. I use standard plastic boxes for mounting specimens, in both clear and black plastic, which I obtain from a friendly dealer in Switzerland (**H.P. Mueller-Tieche,** Goldermattenst. 36, CH-6312 Steinhausen, Switzerland). **Sharon Cisneros** of *Mineralogical Research Company*, an advertiser in the *Record*, is now carrying plastic boxes of high quality, so you may wish to check with her too…see her ad. The Swiss dealer I mentioned carries various sizes of boxes, mounting putty and other supplies for micromounters. I'm particularly fond of his non-hardening mounting putty which I use for about 95% of my mounts. This putty has several advantages over ordinary mounting glue: (1) the specimen can be easily removed, (2) the specimen can be repositioned easily and quickly (this is especially convenient for photographers), (3) the putty acts as a shock-absorber if the mount is accidentally dropped, and (4) mounting is simple and fast. The putty should not be used on specimens having a porous matrix because the putty will not adhere well, and may discolor the matrix (for example, it will discolor the sugary dolomite from the Lengenbach quarry).

I keep a double record of my specimens, one as a continuous listing in a catalog book where the catalog numbers may be looked up in running order, and one as a file card system arranged alphabetically. Each specimen gets a number according to Hey's index, for example, 14.3.1 for phenakite, and my running numbers for both locality and specimen. Typical enties look like this:

14.3.1-6.1 *Phenakite, Beilke's quarry, Marathon Co., Wisc., found August 1977.*
14.3.1-6.2 *Phenakite, Beilke's quarry, Marathon Co., Wisc., found September 1977.*
14.3.1-7.1 *Phenakite, Lord Hill, near Stoneham, Maine, traded from R. DeMark, November 1977.*
14.3.1-8.1 *Phenakite, Rientallucke, Switzerland, traded from C. Vogel, November 1977.*

To house my specimens I use a color-coded system of plastic drawers (e.g. red for elements, blue for sulfides, etc.) manufactured by **Akro-Mills,** Dept. 10-2, P.O.Box 989, Akron, Ohio 44309. The model number for these drawers is 50-150. Office supply stores sometimes carry them or can order them. I like the system quite well, and can tell at a glance where my collection is strongest and where it needs work.

Another dealer specializing in micromounting equipment is **Dieter Haas**, Westring 22, D-6740 Landau/Pf., West Germany. He carries a large number of very handy tools, and has been a trading partner of mine for years. Through him I've acquired some very fine Eifel minerals, such as hematite, titanite, nepheline and several others. If you would like to do some exchanging for Eifel minerals you might also contact my friend **Karl O. Pakleppa**, Melanchthonst. 25, 4000 Duesseldorf 13, West Germany.

For applying a specimen number to the plastic box I use a marker designed for writing on freezer bags; it writes directly on the plastic. Don't forget to mark both the top and the bottom of the box!

Last summer I paid several visits to the "Copper Country" of upper Michigan, and have only recently had some time to look over the material brought back. The Osceola shaft #10 yielded quite a few different minerals. Most of the material I collected there consists of calcite-filled vesicles in basalt, but I watched for a light and dark green rim indicative of prehnite and epidote. To remove the calcite I use a 25% solution of acetic acid (with good ventilation!). Hydrochloric acid will gelatinize the prehnite; acetic acid has always worked best for me.

From material collected at the Osceola shaft #10 I have so far identified the following minerals: *Adularia*, in small, pink to white crystals lining small vesicles, sometimes associated with quartz and pumpellyite. *Chalcocite*, in small but beautiful, complex crystals on prehnite and more often as a dark, irregular crust on prehnite. *Copper*, in crystals of various habits, as irregular masses, in and on prehnite. *Datolite*, in clear crystals with bright inclusions of copper and associated chalcocite, epidote, pumpellyite and quartz…but so far I have found only one of these magnificent specimens.

Epidote is plentiful up there, on basalt or light green prehnite, and forms some of the finest epidote micromounts you are liable to see from any locality. Many crystals are perfectly clear and flawless. The color is not always the typical deep olive-green but may be a more pleasing medium olive-green. The *prehnite* from this locality occurs in light green aggregates like those found in New Jersey and elsewhere. *Pumpellyite* is very common in basalts, forming felty aggregates of dark green acicular crystals. *Quartz* is very abundant as well, and often contains inclusions of pumpellyite and other minerals. I have even found native *silver*, in a few crude crystals and wires, always on prehnite.

While in upper Michigan I also collected at the *kinoite* locality described by Marc Wilson in the November-December 1977 issue of the *Record*, p.519-520. I found a number of nice specimens; one is outstanding: a chunk of basalt, about fist-size, with a 3-cm vesicle lined with kinoite-loaded quartz crystals! This vesicle was originally calcite-filled.

In general I have found the following to be good advice for collecting in the copper country of Michigan. Look for calcite-filled vesicles with a light or dark green rim of prehnite and epidote, and don't bother with the open, calcite-free vesicular basalt. The open vesicles rarely contain good micromount material; rather you will probably find only dull, corroded and fractured crystals. Most collectors will only go after those open vesicles, and will discard the best samples just because they are "gift-wrapped" by nature!

Before visiting Michigan be sure to order a copy of *The Mineralogy of Michigan* by Heinrich (available for $3 from Publications Room, Geological Survey Division, Department of Natural Resources, P.O.Box 30028, Lansing, Michigan 48909; reviewed in the *Record*, September-October 1977, p. 415). It contains much information on Michigan minerals and localities although it is lacking maps.

If you own a camera you should consider photographing your best specimens or favorite locality for an evening slide show at your local mineral club. I've done several of them already, co-produced with *Record* associate editor Eric Offermann. Programs with slides of micromounts have been, in my experience, the best method of showing micromounts to a large audience…in fact it's the only way to do it short of lining them all up at microscopes. Thus far we have produced programs on the following subjects: "The technique of micromounting," "The beauty of micromounts," "Alpine minerals" (a particular favorite with audiences), "The mineral system," "The Wausau pluton," "Minerals of the oxide zone of lead-zinc-copper deposits" and several others. Why not consider picking up your camera and giving it a try. Several articles on the technique of mineral photography have been published by Wendell Wilson in earlier issues of the *Record* and, if you will be at this year's Detroit Show, you can see one of Eric Offermann's slide shows (with background music and Dr. Offermann's own voice on tape) which Dr. Wilson will be showing in conjunction with his own lecture. If you prefer not to produce your own show you can obtain completed slide programs with accompanying tape and impulse unit for completely automatic programs from Eric Offermann (Lettenweg 16, CH-4144 Arlesheim, Switzerland).

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LETTER from EUROPE

Europe's early 1978 spring *bourses* (shows), with one sensational exception, did not produce any "stunners" this year, at least from the American point of view, and most of the offerings were either leftovers from last year or specimens the European dealers acquired during their now annual great pilgrimage to the Tucson Show in February. A record-breaking 123 overseas dealers checked into the wholesale area at Tucson, many accompanied by their assistants or wives. The "leftovers" included a lot of good minerals not previously mentioned in my column but I will eventually get to some of these.

At Lausanne, Switzerland, however, a number of fine semi-gemmy matrix specimens of alexandrite, a variety of chrysoberyl, were to be seen. The stubby, well-formed, orthorhombic crystals ranged to an inch (2.5 cm) in diameter and the specimens were labeled simply "Rhodesia." They have appeared sporadically for over a year now and, though expensive, are a fine addition to any advanced collection. The specimens were sent to a Swiss dealer by a relative living in Rhodesia; this is the way a good many small collections of the more unusual (or valuable) minerals reach Europe. The minerals are air-mailed in small, under-valued packages as "petite paquet" (under 2.2 pounds) and usually clear customs without any problems. The packages are mostly shipped from countries with "soft" currencies or strict money export regulations, and once the specimens are sold the hard currency is then deposited in a European bank or held for the sendee's eventual return.

One of the finest specimens to be shown at Lausanne was a huge, gemmy, dark green vivianite crystal 11 by 5 by 4 cm, this by a Brazil-roaming Swiss dealer. The sharply terminated, blocky crystal had a number of attached pale yellow, semi-gemmy, 1 to 2-cm amblygonite crystals plus a small group of rich brown eosphorite crystals—truly attractive. The specimen came from a commercial amblygonite mine near the village of Galileia, some 50 km east of Governador Valdares in Minas Gerais. The dealer also reported some very fine 1 to 2-cm blue-green crystals of ludlamite, some associated with mica, had been found in the same district. The vivianite was priced at 4500 Sf—about 2400 dollars, but, although a super specimen, it remained unsold.

European collectors were generally delighted this spring, however, as many a dealer's table offered a wide selection of "new" material, mostly acquired by the 100-plus European dealers doing the rounds at Tucson's hotels and then the main show from early morning to late at night in February. Displayed were fine examples of Peruvian pyrite, those fabulous Washington pyrite scepter quartz groups (Ed. note: article coming in the next issue!), Wah Wah Mountain red beryl (now coming into reasonable price range in Europe) (Ed. note: article coming soon on this locality too.), fine Mexican legrandite, Thomas Mountain topaz (the best ever now, I think), South African rhodocrosite (who ever dreamed so much of it would appear), Black Hills purple apatite (really sleepers in my opinion), and a good but expensive assortment of Brazilian material. Incidentally, I have seen no mention of those fairly recent Santa Eulalia, Mexico, rhodocrosites in any of the periodicals, but some of the thumbnail and miniatures I have seen are superb and are much more moderately priced than their big brothers from South Africa.

Switzerland's Lausanne and St. Gallen bourses as well as Germany's Heidelberg bourse were well attended and business was generally brisk, indicating, we all hope, the end of Europe's long recession and the start of a new mineral era over here. There are a number of summer resort area bourses coming up, France's big St. Marie Aux Mines bourse for one, but for the most part, things will not get hectic until the big fall ones get underway, starting with Altdorf, Switzerland (Sept. 3-4). Then follow Brussels, Belgium (Sept. 16-17), Stuttgart and Cologne, Germany (Sept. 23-24), Geneva, Switzerland (Oct. 7-8), Nürnberg, Germany (Oct. 14-15), London, England (Oct. 21-22), Münich, Germany (Oct. 27-29), Hannover, Germany (Nov. 24-26), Düsseldorf, Germany (Dec. 2-3), and Bremen, Germany (Dec. 9-10). There are several other major shows yet to be announced, also a host of other minor shows taking place in Europe, at least one or two nearly every week of the fall and early winter. I'll try to update this list in the next column.

Once again the snows remained late in the Alps and the Swiss *strahlers* will have a short summer season to search out their high altitude minerals, such as hematite "eisenrosen," pink octahedral fluorite, rich smoky quartz and Cavradischlucht rutilated hematite. However, a host of other less publicized but highly desirable minerals, such as titanite, adularia, anatase, purple apatite, axinite, milarite and pericline, are found at lower altitudes and each year small quantities of these minerals continue to appear at the spring and summer bourses on a somewhat regular basis. Actually over 200 different minerals have been found in Switzerland yet, strangely enough, this does not include any significant quantities for two of the world's most common collector minerals, pyrite and amethyst. Visiting collectors tend to turn up their noses at both the price and quality of these two Swiss minerals, but, because the minerals are very rare in Switzerland, they are highly prized by Swiss collectors. Amethyst has been found recently in the Grimsel region, the upper part of the canton Tessin in Val Canaria and Valle Del Lucomagno, and in the Tavetsch area, including the famous bladed hematite locality of Cavradischlucht. The crystals are usually small and, for the most part, only tipped with a violet color but do occur in interesting forms, commonly being sceptered or skeletal in habit.

Strangely enough, with all its minerals, Switzerland has never been a commercial mining country and the few attempts in the past have been, for the most part, unprofitable. Some of the sedimentary oolitic iron-manganese ore deposits in the Jura Mountain and Gonzen areas were temporarily mined during World War II, but have generally been abandoned. To the visiting collectors this means there are virtually no mine dumps to scrounge in, but if one wants to "take to the ropes," the alpine clefts do offer better opportunities—and thrills. This sort of thing is for the experienced mountain climbers only! Try France, Italy, Spain, Germany, or even England for some simpler digging. Check with local clubs, mineral shops or dealers for locality information, restrictions and advice. But communication can be a problem if you do not speak the local language. Also bear in mind that in many countries you are required to have a "patent" to dig minerals (much like a fishing license) and in Switzerland the cost in some cantons can be several hundred dollars or more. Many areas of most countries do not have such regulations, however, but check it out as fines can be very stiff.

I think what I am saying is that the best bet for short term visitors is to hit the local bourses, mineral shops and mineral clubs—the latter particularly for trading. Some museums do trade, a few sell minerals (mostly the private museums), but these are of most interest to the sophisticated collector. Incidentally, a few clubs run field trips in conjunction with their bourses, Heidelberg for one—as with some of the summer French and Italian bourses. Use the phone book "yellow pages" (they are green in some countries) to locate mineral shops and you will find virtually every major city has several—Paris has over 20, for example. The word for minerals in German is *mineralien*, in French it is *mineraux*, in Italian *minerale*, but don't look for "rockshop" (except in England) for (with one exception, Stockholm, Sweden) the term is never used over here. One of the best bets is to pick up a copy of the local mineral magazine—it is simple to read an advertisement in any language—and with it you can seek out the smaller dealers in other towns, or traders who advertise, and do much better costwise. Paris shops, for example, can be horrendously expensive.

For those of you carrying over minerals for trading purposes (Europeans love to trade) it is best to have a list of them and their approximate value. The best trick is to state the value on a per-pound basis, including specimens, and $5.00/pound is enough to satisfy most customs inspectors (with such things as gold, silver, the precious minerals such as tourmaline and topaz being excluded, naturally). Customs no. *9905.01* is the international duty-free reference for minerals for *collection* only, but do not try to bring in minerals to sell under this number. Such material is automatically subject to a sales tax, usually very high, in each country you enter, and the situation can get very complicated. Also cut and polished or faceted material is not allowed under the above number and is similarly complicated to import into most countries.

You will find the badly depreciated dollar will not go far in Europe, this coupled with some very high European inflation rates. Some countries are a better choice than others, particularly those with the weaker currencies such as Italy, England, and Spain. France is not too bad, particularly outside of Paris, but Switzerland, Germany and the Scandinavian countries will hit your pocketbook very hard. Bear in mind it is possible to pick up a mineral bargain anywhere, including even in the U.S.A.

For those of you heading for Europe this summer, here is a partial list of bourses that could be worth seeking out. **France:** St. Marie-Aux-Mines (July 1-2); Realmont (July 13-14) (usually); Millau (July 22-23); Chamonix (Aug. 5-6), Alpe-D'Huez (Aug. 11-13), Aix-Les Bains (Aug. 26-27). **Germany:** Freudenstadt (Aug. 20). There are virtually no summer bourses in Germany. **Switzerland:** Zuoz (July 22-23); Martigny (Aug. 26-27). **England:** Portsmouth (July 7-10); N. Yorkshire (Aug. 26-28). **Italy:** Riccione (July 1-2); Lanzo (July 8-9) (usually); Aosta (July 15-16) (usually). There are a few others yet to be announced, and be sure to check out those marked "usually" above before going, since dates are subject to change. Good luck to those of you fortunate enough to go, and watch out for those glued specimens!

Back to this past spring in Europe and that "sensational exception" mentioned earlier. Brazil has done it again and this time with an unbelievable discovery of elbaite which has been baptized "cranberry tourmaline." The crystals and groups of this new find are simply gorgeous, with the best being those groups on which the richly colored, deep violet-red tourmaline crystals are perched on large, pure white albite crystals or are surrounded by intricate clusters of small, pink, very gemmy lepidolite. The gemmy lepidolite is a rarity in itself. Some specimens have been found with the cranberry tourmaline crystals perched on beautiful groups of lustrous, sharply terminated, rather clear quartz crystals, these up to 5 or more cm (2 inches) in diameter by 10 to 15 cm (4-6 inches) in length. The tourmaline crystals range in size from slim needles to one giant reportedly 25 cm (10 inches) in diameter and 75 cm (30 inches) tall which is nearly completely gemmy!

This huge crystal was removed intact along with a number of smaller, attached, gemmy crystals on a matrix of crystallized albite and weighs a total of 320 kg—over 700 pounds! A second albite and quartz matrix specimen weighing over 80 kg (175 pounds) with a single, all-gemmy, cranberry-red tourmaline 12.5 cm (5 inches) in diameter by 50 cm (20 inches) in length was also removed from the same pocket. Both specimens remain with the mine's owner and are "not for sale," although the larger one has been valued at over a million dollars and the smaller one nearly half that amount. They certainly must be ranked among the world's best specimens and, with luck, I hope to have color photographs of them for a future issue of the *Record*.

The story behind the find is indeed intriguing. The "mine," a *garimpo* only a few kilometers from Minas Gerais' famous Conselheiro Pena area, has for a number of years sporadically produced only green tourmaline, usually associated with albite. In mid-April, however, the *garimpieros* hit a large pocket containing only cranberry red rubellite tourmaline and the estimates on the amount of it seem to vary from "quite a bit" to "a great deal." It seems to depend somewhat on the point of view, i.e. the gem material content or the mineral specimen content. Factually, however, over $3 million (wholesale) worth of gem rubellite was extracted, most of which has already been disposed of in a hungry rubellite gem market. In Europe, faceted top-quality rubellite stones bring exceptionally high prices and the problem has always been supply, not demand. According to the experts, the color and richness of the cranberry tourmaline exceeds even that of the famous Alta Ligonia, Mozambique, rubellite of 20-some years ago. It is these facts that make cranberry tourmaline a tough nut pricewise for the collector.

According to several European dealers who hit Brazil this spring, the specimen prices were just too high and most passed it up. Roger Titieux of France and a couple of German dealers "took the chance" and brought back a few pieces which were quickly swallowed up by top European collectors. One Swiss dealer passed them up saying "there is plenty around and prices should fall in the future." One American dealer reportedly brought a few groups to the U.S.A. Miniature to large cabinet size specimens are retailing from 500-5000 dollars or more and semi-gemmy specimen crystals from around 5-15 dollars per gram. This would put the retail price of a well-terminated, quite gemmy crystal perhaps 1 by 4 cm (0.4 x 1.6 inches), weighing about 7 grams, at about $75. That is somewhat expensive by "old standards," but then again this is a "new standard" and, what with the current weakness of the dollar and rubellite's current value as gem cabochon or slabbing material, I doubt if the price of cranberry tourmaline collector specimens would fall much in the future. Rather I believe the problem for the avid tourmaline collector (like me) will not be price, but simply to lay his hands of one of these real beauties. Time will tell. (Ed. note: See André Lallemant's description of this find in the *What's New in Minerals?* column elsewhere in this issue.)

As usual the snows were deep and the days short and cold up in Norway this past winter—actually well into late spring—but the spirit of the Norwegian mineral collectors continues to amaze me no matter what the season. As an example, I quote from a letter received from friend Torgeir Garmo at the end of April: "Spring has slowly moved into Norway, melting the snow away and uncovering the thrilling rock surface once again. I have heard about few finds this winter. Only yellow phantom calcites on zeolite matrix from new tunnels in the west. Vestlandet consists entirely of

Precambrian gneisses and has, up to quite recently, only been known for peridot and eclogites. In cracks and faults in the gniess, however, nice zeolites have been formed, mainly heulandite and stilbite, but also mesolite etc., often covered with calcite. Up to now, no one cared to take out these minerals but the tunnel workers now and then bring out excellent samples.

"Myself, I have only been out mineral hunting once this winter. The pegmatites of the high Jotunheimen area are easiest accessible on skis and often they are protected behind cracked glaciers. Froydis and I visited one 2100 meter high (about 6,800 feet altitude), a complex pegmatite unfortunately mostly covered by snow this year. Near the core zone I got out a few terminated thulite crystals, pale rose and with light shining through, like kunzite. Very small crystals however. I also picked spessartines with strange forms in druses, together with albite crystals. This pegmatite is in the middle of the next national park and has never been explored. Most of the area pegmatites are quite simple and only carry clinozoisite/schorl in any abundance, but a few are complex and certainly hide nice minerals. None have ever been blasted." Torgeir, by the way, has one of the finest collections in Norway, many specimens self-collected and, like most Norwegians, he is a year-round outdoor and camera enthusiast.

Another letter recently received from Knut Eldjarn of Norway indicates that the Norwegians are jumping on the bandwagon and will have their first mineral show in Honefoss, just outside of Oslo, about mid-August. Check with one of the several mineral/tourist shops in Oslo for the exact dates should you be up that way. Knut, by the way, is a medical doctor—the kind you would love to have, as he much prefers to talk minerals—like until 3 a.m. the last time I visited with him! Knut is also president of Norway's federation of 10 regional mineral clubs and is presently deeply embroiled in trying to combat what they believe is a backward philosophy (e.g. the guest editorial in vol. 8, no. 4) with respect to minerals in their country.

Apparently the English had similar problems many years back and I just love the quote on the subject given by Roger Harker in the preface of his Lythe Minerals (Leicester, England) catalog. With his permission I quote, "No one has created minerals; they do not belong to any person in particular, but to the people as a whole; only that which has been created by labour can be claimed by individuals, and that which has been created by nature belongs to all equally. J. Keir Hardie (England) 14 November 1890." Amen!

Knut Eldjarn is an avid prospector and is the person primarily responsible for salvaging a small quantity of very fine, rare ktenasite that a road building crew hit into late last year. The micro-sized monoclinic crystals were a typically bluish green color and were associated with very small, clear gypsum crystals. One of the matrix specimens yeilded a 2½-cm crystal of the very rare yttrium silicate, thalenite. Many of the specimens had showings of a copper-aluminum sulfate yet to be identified or baptized by the Oslo museum's research staff. So much for Norway, one of my favorite friendly countries.

Want something to think about over the next couple of months? How about blood-red gemmy anatase crystals up to 20 mm (½ inch) from you-guess-where! I'll tell you about it in my next letter. Until then have a good summer and don't forget to think young.

Cheers,

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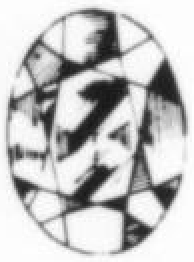

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CHUQUICAMATA
Chile

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Awesome is perhaps the best general description of Chuquicamata. This single word in many ways describes the wide distribution of Chuquicamata mineral specimens in private and museum collections; the locality's climate and terrain; the size of the mine, supporting mill and smelter complex; and, most importantly, the current specimen producing potential.

INTRODUCTION

The following article is intended to generally acquaint the reader with Chuquicamata and to review pertinent facts about those Chuquicamata mineral species which he is most likely to encounter in his collecting endeavors. Much of the information contained herein is compiled from generally available professional articles updated and augmented by the author's observations and experience at Chuquicamata in December, 1976.

LOCATION AND SETTING

The Chuquicamata copper deposit is in the northern Chilean province of Antofagasta, within the northeastern part of the Atacama Desert approximately 250 km northeast of the port city of Antofagasta and 19 km north of Calama (Figs. 1 and 2). Paved highways connect Chuquicamata with major cities and a spur of the Antofagasta and Bolivia Railroad services the mine. Commercial airline service is maintained between various cities and Calama.

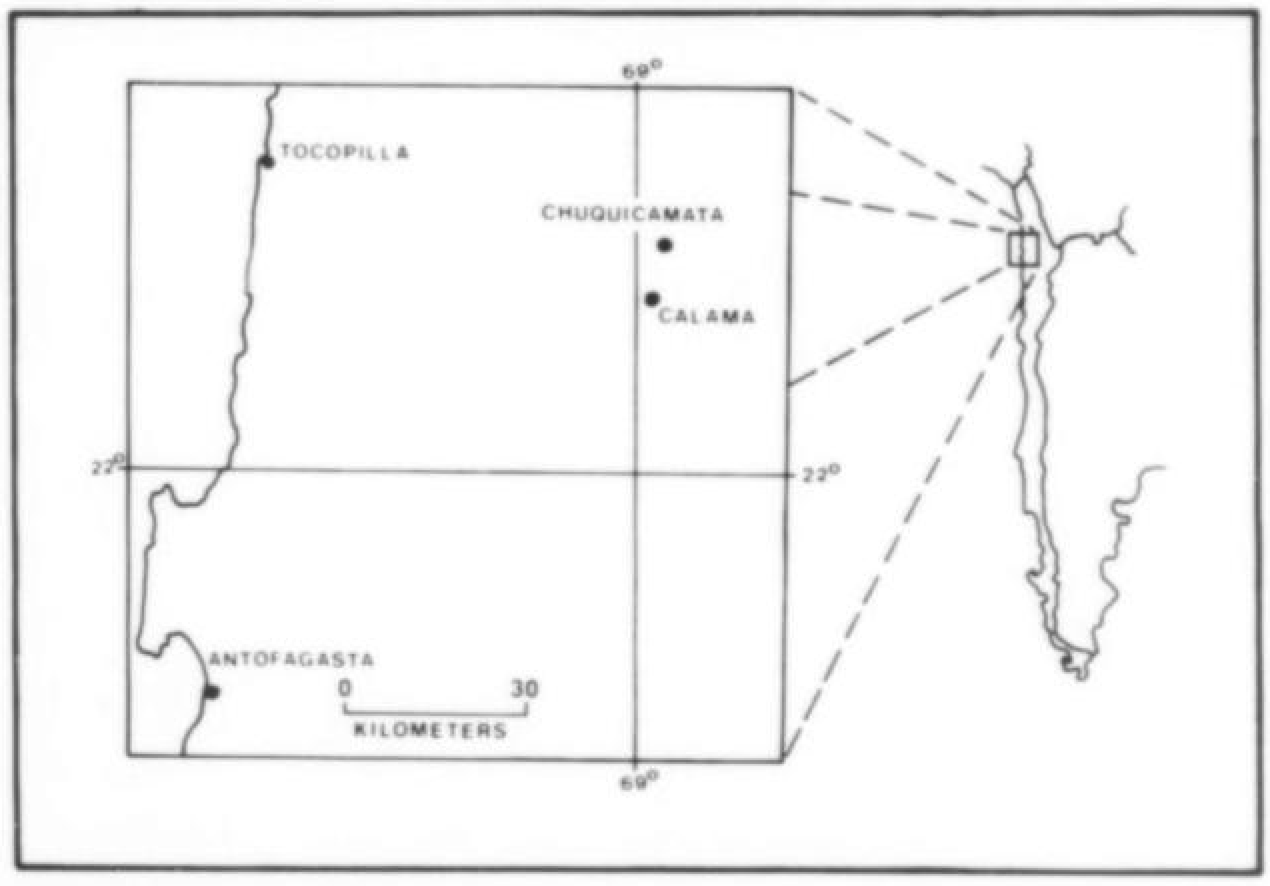

***Figure 1*. Location map.**

The deposit is situated in rugged terrain at an altitude of approximately 2830 m (approximately 9300 feet) within the foothills of the main Andes Mountains (Fig. 2). Although Chuquicamata is located within the tropics, rain is extremely rare. Calama has been listed in the *Guiness Book of World Records* as the dryest spot on Earth. Vast portions of the Atacama Desert in the general vicinity of Chuquicamata are without visible plant life. Were it not for this extreme aridity, many of the soluble mineral species for which Chuquicamata is famous would be much less abundant or absent in the deposit.

HISTORY

Copper at Chuquicamata was known prior to Spanish colonization in the early sixteenth century. In 1443 the Incas invaded Chile, bringing primative copper smelting techniques. Copper ornaments have been found in graves of local Indians pre-dating the Spanish conquest, and worked turquoise has been found along outcrops. The Spanish conqueror Don Diego de Almagro (an associate of Francisco Pizarro) used Indian-smelted Chuquicamata copper to shoe the horses of his expedition for their return across the Atacama Desert to Cuzco in 1536. The name Chuquicamata means "territory of the Chuco Indians," whom the conquistadors observed wearing copper jewelry (anonymous, 1922). Sporadic and minor exploitation of the associated high-grade veins by Spanish and Bolivian groups occurred between 1560 and 1879. The earliest appreciable mining was by English and Chilean companies between 1879 and 1912. Open pit mining began in 1915. During the first 59 years of open pit mining (through May 1974) 857 million tons of ore and 518 million tons of waste were removed. Exploration data indicate that an additional 1.4 billion tons of ore will be produced through the year 2010 with a gradual decrease in grade from approximately 2% copper to approximately 1% copper. The current pit dimen-

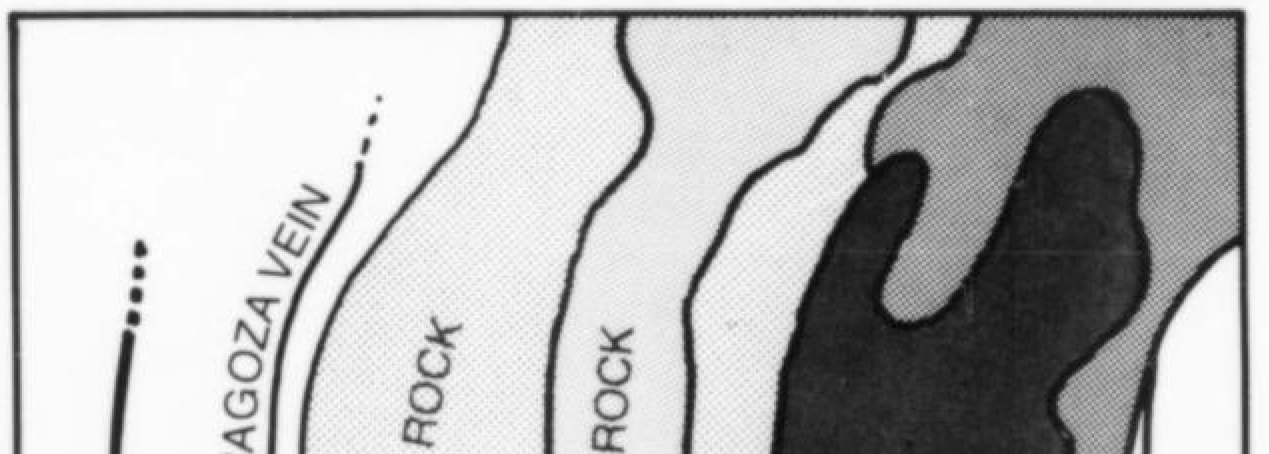

Figure 2. (above) **Aerial view of Chuquicamata looking southwest across the pit to the mill and smelter complex, and beyond to the town of Chuquicamata (December, 1976). The outskirts of Calama are in the extreme left-center portion of the photograph. Areas of current specimen production are at K (kröhnkite and chalcanthite), C (chenevixite) and A (antlerite). Dump areas containing specimen-grade material are in the lower right corner and at wing tip.**

Figure 3. (left) **General geology of the Chuquicamata mine. The open pit is a violin-shaped area, narrow on the south, covering most of the area between the West fissure and the transition rock. (After Bateman, 1951, and Perry, 1952.)**

sions are 3.5 km by 1.6 km by 0.4 km deep (Figs. 2 and 3). Approximately 70,000 tons of ore per day are processed, including a substantial amount of ore stockpiled in previous years. Production of finished copper including blister and wirebar is 1100 tons per day.

GEOLOGY

Aspects of Chuquicamata's geology have been dealt with by a number of authorities (Hendricks, 1922; Taylor, 1935; Lopez, 1939; and Perry, 1952). The deposit is discussed in the textbook *Ore Deposits* (Park and MacDiarmid, 1964) as an example of mesothermal porphyry copper deposits. A concise annoted bibliography of Chuquicamata appears in Geological Society of America Memoir 131 (Ridge, 1972). Voluminous additional information is contained in private reports and other generally unavailable forms generated during the many years that the deposit was controlled by The Anaconda Company and later by the current operator, CODELCO, the Chilean national copper company.

Chuquicamata is classified as a porphyry copper by economic geologists. It is characterized by enormous volumes of ore composed predominantly of altered and fractured plutonic rock containing more or less evenly disseminated sulfide mineral grains and innumerable mineralized veins and veinlets. As with many porphyry copper deposits, the ore body is enhanced by various zones of enrichment formed by leaching and redeposition of copper, generally by the action of downward-migrating surface water.

The intrusive igneous complex hosting, and apparently responsible for, the Chuquicamata deposit is a portion of one of many similar batholithic masses characteristic of the Andes. The deposit occupies a quartz monzonite pluton known as the Chuquicamata porphyry. A major fault of regional extent, the West fissure (Fig. 3), bounds the deposit on the west. Detailed published studies of the Chuquicamata porphyry indicate that extensive alteration and fracturing took place prior to the emplacement of much of the mineralization. It appears that the West fissure is a boundary and a zone of weakness along which the Chuquicamata porphyry was intruded, as suggested by Perry (1952). Subsequently (considering the intense fracturing and veining to the east of the fissure), it would appear that the mineralizing channels tapping hydrothermal solutions at depth in the cooling porphyry magma were largely independent of the West fissure and well inside the boundaries of the porphyry body.

A unique feature of the deposit is the thick blanket of oxidized waste which overlayed the zone of strongest sulfide mineralization. This blanket resulted from oxidation of the very pyritic primary sulfide assemblage causing strong acid conditions and preventing precipitation of secondary copper minerals. Thus, in mining, it was found that oxidized waste of about 0.02% copper was in almost knife-edge contact with the top of the zone of high grade secondary enrichment sulfide ores (15 to 20% Cu).

After formation of the secondary enrichment zone a drastic and apparently sudden increase in aridity abruptly lowered the water table, leaving the blanket-like enrichment zone stranded at an abnormally high elevation in the deposit. Continued, though much slower, leaching of near-surface enriched ore and redeposition of copper as a second supergene enrichment zone at the new, deeper water table resulted in the anomalous presence of two such zones. The formation of the unusual suite of sulfate minerals for which Chuquicamata is famous is the result of this slow leaching and recombination of sulfate, generated by the decomposition of pyrite, with various cations supplied from preexisting sulfides, sulfates and perhaps silicates. Although much of the higher-grade oxidized ore has been depleted, the grade of the underlying, primary sulfide zone is sufficient to sustain the operation for many decades.

MINERALOGY

The unusually complex mineralogy of the Chuquicamata oxide zone was suspected early in the development of the present open pit. However, it was not until the landmark paper by Mark C. Bandy (1938) that an overall picture of this extraordinary occurrence became available. Bandy's work was augmented somewhat by later investigations by Jarrell (1939 and 1944) which included the recognition of marshite in the ores. In addition to those described by Bandy, new mineral species such as lindgrenite (Palache, 1935), leightonite (Palache, 1938), bellingerite (Berman and Wolfe, 1940) salesite (Palache and Jarrell, 1939) and sampleite (Hurlbut, 1942) were first identified in Chuquicamata ores. Natrochalcite, leightonite, bellingerite, salesite, ungemachite and clinoungemachite have been found nowhere else in the world.

Recent publications concerning the mineralogy of Chuquicamata have dealt most with the refinement of data concerning minerals of particular economic significance in the deposit, not in the search for and identification of additional species. A thorough, though unpublished, study of the sulfide mineralization in a portion of the deposit was conducted by Denison (1969). The works of Denison (1969) and Bandy (1938) collectively give the most comprehensive overview of Chuquicamata mineralogy.

The accompanying tabulation of 114 mineral species and groups occurring at Chuquicamata (Table 1) is presented in the format[1] of Dana's *System of Mineralogy*, volumes I and II (Palache, Berman and Frondel; 1944, 1951) in deference to Dana collectors and as an aid in classification. Although the tabulation is incomplete, it includes those species which have been adequately described in the English literature. Approximately 40 additional species have been identified by personnel of The Anaconda Company and CODELCO.[2] Sulfate minerals are discussed individually or in closely related groups due to their relative importance in the mineralogy of the deposit. Crystal drawings are presented as an aid to identification and distinction between morphologically similar species.

Elements

The native elements gold, copper and sulfur have been reported from Chuquicamata but are uncommon and, in the case of gold, of questionable occurrence. Ancient workings immediately north of the Chuquicamata pit are thought to have been for gold. Repeated attempts to substantiate the presence of gold in this area by panning local gravel and assaying crushed quartz were unsuccessful (Bandy, 1938).

Native copper is uncommon at Chuquicamata. It occurs within cuprite and as small irregular masses with abundant hematite (specularite). Copper is thought to occur in a transition zone where ores dominated by sulfates give way to those characterized by silicates, oxides, and chlorides.

Minute though unusually complex crystals of sulfur are described by Bandy (1938). One crystal, less than a millimeter in diameter, was found to have 120 faces. Two crystals on the same specimen exhibited 26 individual crystal forms. Associated species are pisanite, chalcanthite, natrojarosite and kröhnkite.

Sulfides

Although sulfide minerals are abundant at Chuquicamata, it appears that specimen-quality material is rare. Covellite and chalcocite occur as supergene sulfides but rarely, if ever, in well crystallized masses. Supergene chalcocite has been mined to depths of over 200 m. Bornite in small cubic crystals associated with chalcocite was reported by Bandy (1938). Covellite, bornite and chalcopyrite also occur as primary ore minerals within the unoxidized portion of the deposit. Pyrite is quite abundant and has apparently formed during several mineralizing episodes. Brilliant pyrite cubes up to 1.3 cm on edge associated with euhedral quartz are occasionally found near the ends of enargite-bearing veins. Very minor sphalerite and galena have been reported. In his years at Chuquicamata, Bandy was never able to definitely identify sphalerite in any of the material he studied. Molybdenite occurs in quartz veinlets and constitutes an economically important by-product.

A comprehensive study of sulfide mineralization along a central section of the Chuquicamata ore body (Denison, 1969) resulted in a detailed description of the occurrence of digenite, djurleite, idaite and marcasite. These sulfides (several of which were unknown at the time of Bandy's research) are of paragenetic and mineralogical significance but have not yet afforded material of interest to collectors.

Sulfosalts

Enargite is probably the most important primary copper mineral in Chuquicamata ore currently being mined. Locally it occurs in coarse, bladed masses in veins exceeding a meter in width, although it is generally in disseminated grains and in narrow veinlets throughout the central portions of the porphyry. Crystals are infrequently encountered and show only the common forms. Significant enargite specimens appear to be quite rare and Chuquicamata will not, in all likelihood, produce material of the quality and abundance of some of the other well known Andean occcurrences. Tennantite, colusite and possibly famatinite (or luzonite?) (Denison, 1969) are present in only minor quantities and generally as very fine-grained constituents complexly intergrown with the more common sulfides.

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[1] Exclusive of silicates.

[2] Attempts to secure a complete listing have been unsuccessful as of this writing.

Oxides

Chuquicamata does not boast an extensive array of oxide minerals. Of the copper oxides, only cuprite and tenorite are important. Cuprite is occasionally encountered in specimen-grade material. Fibrous cuprite was once relatively common (Wittke, 1960). Crystalline cuprite after native copper in simple cubes with minor octahedral and dodecahedral faces was described by Bandy (1938). Exceptional specimens of cuprite were once obtained from veins around the northeast margin of the porphyry.

Pitch-like masses composed essentially of tenorite and various manganese oxides were once abundant in the upper portions of the deposit. Cracks and vugs through these masses were commonly coated with antlerite crystals. In veins containing cuprite, tenorite-rich material typically formed shells about individual cuprite masses.

Hematite, magnetite and presumably goethite occur locally, both within the Chuquicamata porphyry and in associated vein-like masses near its margin. Specular hematite is abundant in parts of the deposit and has locally been replaced by magnetite. Bandy (1938) described exceptionally striking specimens of hydrated iron oxides after "stringy stalactitic masses" of gypsum. Other oxides such as rutile and ilmenite are minor constituents of the host porphyry.

Halides

A small but significant suite of halide minerals occurs at Chuquicamata. Halite was reported by Bandy (1938) as widespread in the surface material about the deposit where it occurs in grains, crystals and aggregates. It is also reported from local occurrences within the pit. Halite is thought to be the source of chlorine that has combined with copper to form atacamite and paratacamite.

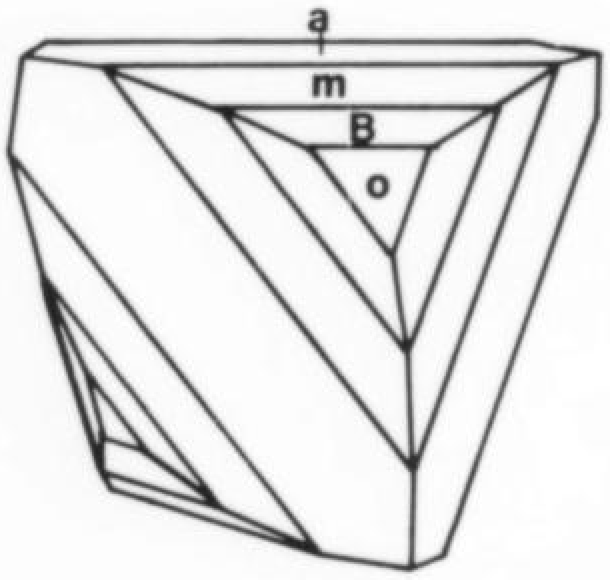


***Figure 4*. Marshite: *a* {100}, *o* {111}, *m* {113} and *B* {223}. (Redrawn from Jarrell, 1939.)**

Marshite was described from Chuquicamata by Jarrell in 1939. A detailed study of Chuquicamata marshite was presented in 1969 by Trash. Originally, specimens were recovered only from the south end of the open pit within 24 m of the original surface. Marshite occurred there intimately associated with atacamite lining fractures in altered porphyry. Marshite crystals penetrate atacamite and perch upon it. Most crystals are small, ranging up to several millimeters across, and are typically composed of the cube and tetrahedral forms (Fig. 4). When first found, the crystals are colorless to light honey-yellow although exposure to humid conditions reportedly causes a gradual color change to salmon or red. The physical resemblance of Chuquicamata marshite to iron-deficient sphalerite is striking. Malachite pseudomorphs after marshite are also known. Marshite fluoresces deep red under ultraviolet light...the only fluorescent Chuquicamata mineral.

Atacamite was once locally abundant in the upper 35 m of the deposit. Thousands of Chilean atacamite specimens, many of them from Chuquicamata, have been disseminated over the years into mineral collections worldwide. Although atacamite is erratic in its distribution at Chuquicamata, it was most commonly found in the upper oxidized portions of the more massive sulfide veins. Typically it occurs in maroon-colored iron oxide matrix as chisel-shaped crystals, masses of long acicular crystals, or as matted masses of minute prismatic crystals (Fig. 5). Its occurrence is generally restricted to areas characterized by a relative deficiency in sulfate and may, in fact, replace antlerite in the paragenetic sequence. Atacamite typically occurs in intimate association with kröhnkite and natrochalcite. Veinlets of atacamite cut turquoise and occur on crystals of leightonite (Bandy, 1938). It is commonly associated with chrysocolla and generally appears to be the earlier-formed mineral. Exceptional specimens of atacamite are currently encountered during the reworking of older dump material and in abandoned areas of the uppermost portion of the deposit, particularly in the northeast end of the pit.

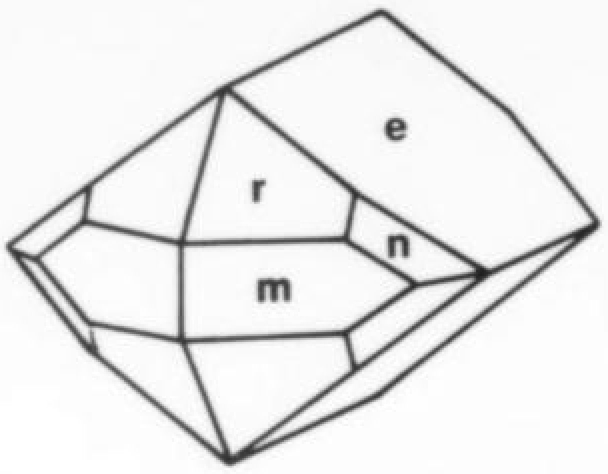


***Figure 5*. Atacamite; *m* {110}, *e* {001}, *r* {111} and *n* {121}. (Redrawn from Palache, *et al.*, 1951.)**

The similar mineral paratacamite is reported by Jarrell (1944) as occurring at Chuquicamata although details are not given. The mineral has not been positively identified in material collected by the author.

Carbonates

Carbonate minerals are uncommon and generally unimportant at Chuquicamata. Calcite, dolomite, and magnesite have been identified as gangue constituents of sulfide veins in the northwestern portion of the deposit. Cerussite was described by Bandy (1938) as occurring in rare pockets in the central-northwest portion of the mine in crystals ranging up to 3 mm associated with fibrous masses of antlerite.

Malachite and azurite are quite uncommon and are found only in areas that are sulfate-deficient. Bandy (1938) mentioned the occurrence of azurite in an outlying, though genetically related, copper occurrence, the Flor de Bosque mine. Specimens of the copper carbonates thus far discovered at Chuquicamata are less than inspiring and at best are composed of fibrous malachite with brochantite and azurite. A 5-cm veinlet of quartz with a 1-cm center of rhodochrosite was encountered in one of the east crosscuts off the drainage tunnel (Lester Zeihen, pers. communication).

Nitrates

The nitrate minerals darapskite, niter, and soda niter have been reported from the extreme upper portions of the deposit and from alluvium surrounding the deposit. Of these, soda niter is perhaps the most abundant, occurring locally in massive aggregates associated with atacamite, bloedite and altered mirabilite (Bandy, 1938). Soda niter was considered by Bandy to be of volcanic origin .

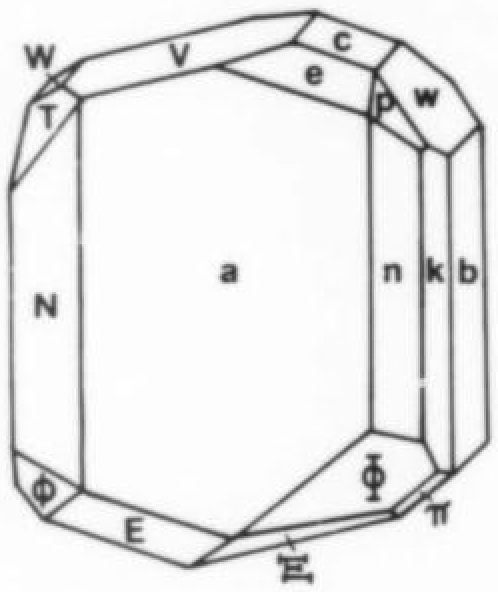


***Figure 6*. Bellingerite: *c* {001}, *b* {010}, *a* {100}, *k* {120}, *n* {210}, *N* $\{2\bar{1}0\}$, *w* {011}, *V* $\{0\bar{1}2\}$, $\underline{\Xi}$ $\{\bar{1}\bar{1}2\}$, $\underline{\pi}$ $\{\bar{1}\bar{1}1\}$ and $\underline{\Phi}$ $\{\bar{2}\bar{1}1\}$. (Redrawn from Berman and Wolfe, 1940.)**

Iodates

Chuquicamata is the type locality for the rare copper iodates bellingerite and salesite. The species were first described by Berman and Wolfe (1940) and Palache and Jarrell (1939), respectively. Bellingerite is found sparingly as a secondary mineral in tiny, prismatic to somewhat tabular, light green crystals usually associated with leightonite and gypsum (Fig. 6). The best specimens of bellingerite came from benches D-1, D-2 and E-1 on the northwest end of the pit. Narrow veinlets of bellingerite in altered porphyry are also known. The crystal chemistry of bellingerite has recently been determined by Ghose and Wand (1974).

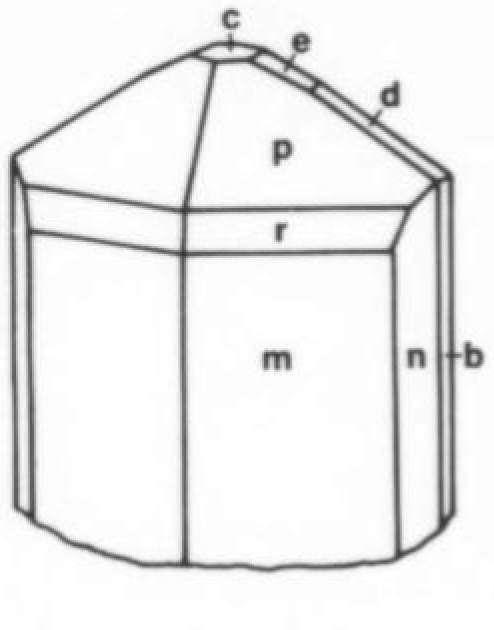


***Figure 7.* Salesite: *c* {001}, *b* {010}, *n* {130}, *m* {110}, *e* {023}, *d* {011}, *p* {111} and *r* {552?}. (Redrawn from Palache and Jarrell, 1939.)**

Bluish-green salesite, similar in color to caledonite, occurred infrequently in the oxide zone as small stout prisms with pyramidal terminations (Fig. 7). The crystal structure of salesite was determined by Ghose in 1962. Neither mineral is found in appreciable quantities today, although samples of bellingerite with associated leightonite may still be collected. Salesite is found in portions of the old oxide dump and in areas where dump material is being recovered for mill feed.

In the past, iodine mineral(s) in appreciable concentrations were occasionally encountered. Dramatic evidence was provided when explosive charges produced clouds of smoke colored purple by liberated iodine (pers. communications from R.V.Gaines and Lester Zeihen). Much limonite, especially the irridescent specimens, gives an iodine odor, although no iodine mineral has ever been identified in this material.

Borates

Bandy (1938) described ulexite in alluvium at Chuquicamata where it occurs associated with gypsum and halite in loose masses of silky fibers. The borate-chloride bandylite occurs at its type location, the Quentena mine, a short distance from Chuquicamata.

Sulfates

The publication of Bandy's now classic treatise on Chuquicamata mineralogy in 1938 resulted in worldwide recognition of this locale as a source of exotic and unique sulfate minerals. Today, no less than 45 individual sulfate species have been recorded from the pit and immediately adjacent areas. Various species such as leightonite and ungemachite were first described in Chuquicamata ores. It is the only major copper deposit in which such minerals as antlerite, kröhnkite and chalcanthite constituted important ore minerals. Perhaps not surprisingly, and certainly in testimony to Bandy's thorough work, only a handfull of sulfates have been added to his original list. Several of these are species initially identified by Bandy at the nearby Quetena and Alcaparrosa deposits and later identified at Chuquicamata. Although some of the sulfate minerals characteristic of Chuquicamata are unstable in climates more humid than the Atacama desert, the sulfates collectively are a source of great interest and enthusiasm among both species collectors and micromounters.

Thenardite: Thenardite occurs as a fine-grained white powder formed by the alteration of mirabilite. It is always found near the original surface of the deposit. Complete pseudomorphs after mirabilite have been reported.

Anhydrite: Anhydrite is an uncommon constituent of alluvium surrounding the deposit. Thick beds of anhydrite are reported from the Rio Loa valley several kilometers away. Significant specimen material is unknown.

Mirabilite: Mirabilite was relatively common though sporadic in occurrence within the upper 20 m of the deposit. It was found associated with bloedite and occurs almost exclusively along the western side of the deposit in rocks characterized by sericitic alteration. Even in the extremely arid climate of the deposit, freshly broken surfaces of mirabilite require less than a minute for the dehydration product thenardite to form (Bandy, 1938).

Kröhnkite: Kröhnkite constitutes an ore mineral in portions of the Chuquicamata deposit. Crystals are common although the most well known form is in cross-fiber veins commonly exceeding several centimeters in width. Particularly attractive specimens consist of dark blue cross-fiber veins in light grey porphyry. A single kröhnkite crystal in the Bandy collection, measuring 7 cm in greatest dimension, was described by Jones (1973).

Kröhnkite was once common in the northern end of the deposit where it was locally replaced by antlerite. Kröhnkite associated with atacamite and natrochalcite is still encountered today along the western side of the deposit near the West fissure. In the southern part of the deposit, early bloedite replaced by kröhnkite was once common. Masses and aggregates of kröhnkite crystals exceeding 10 cm in diameter were observed by the author in freshly blasted ore in the west-central portion of the pit. This kröhnkite was locally associated with chalcanthite and extremely finegrained atacamite.

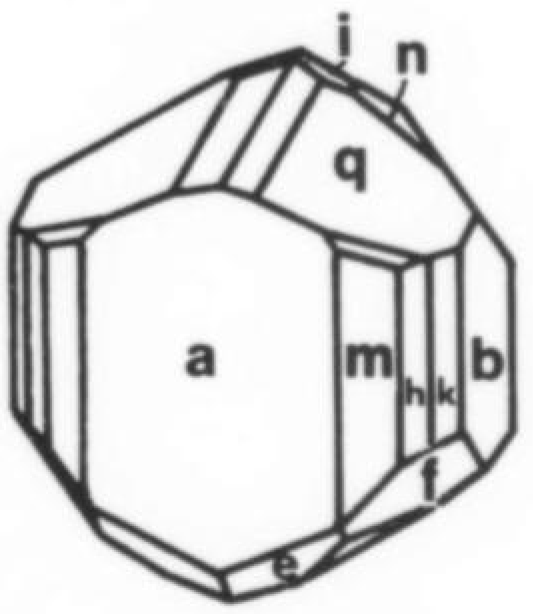


***Figure 8.* Krohnkite: *a*{100}, *q*{011}, *n*{132}, *i*{123}, *m*{110}, *h*{120}, *k*{130}, *b*{010}, *f*{131} and *e*{111}. (Redrawn from Palache, *et al.*, 1951.)**

Bloedite: Bloedite was once a common mineral at Chuquicamata, particularly in the southwest end of the deposit within approximately 25m of the surface. Its typical occurrence was in fibrous or granular veins and crust. Good crystals had not been reported as of Bandy's writing nor were any observed by the author in 1976. Typical associated minerals are mirabilite, thenardite, soda niter and atacamite. Locally, bloedite is replaced by kröhnkite and leightonite.

Picromerite: Picromerite occurs in crusts of white glistening crystals giving the appearance of a late secondary mineral that has formed by dehydration. Commonly associated minerals are hohmannite, metavoltine and metasideronatrite.

Ferrinatrite: Aggregates of pale amethystine ferrinatrite associated with metasideronatrite and metavoltine are described in detail by Bandy (1938). The mineral typically forms fibrous crusts of prismatic, deeply striated crystals. Pseudomorphs of metasideronatrite after ferrinatrite have been reported.

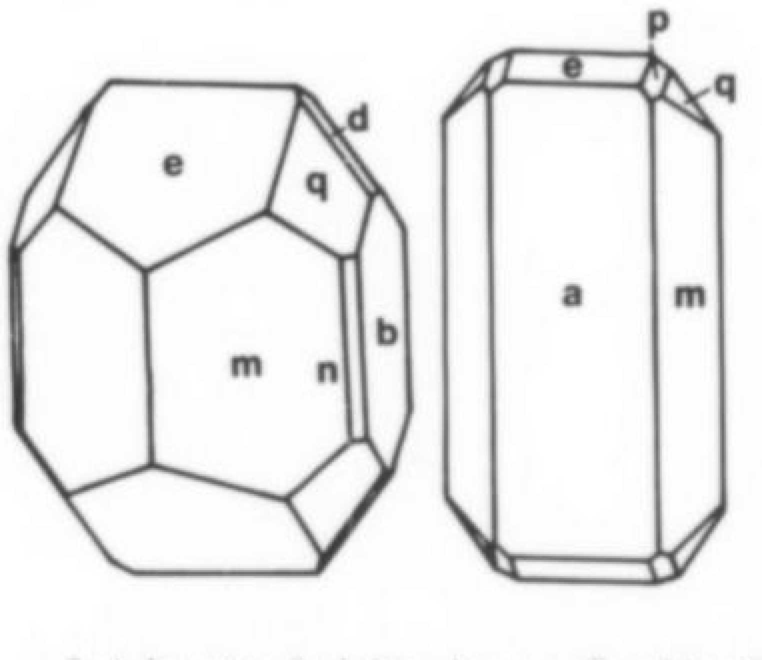


***Figure 9.* Leightonite; *b*{010}, *a*{100}, *m*{110}, *e*{101}, *p*{111} and *q*{131}. (Redrawn from Palache, 1938.)**

Leightonite: Leightonite was first identified in ores of Chuquicamata by Palache (1938). It was once relatively abundant near the south end of the pit as networks of crystals cementing rock fragments, light blue to bluish green individual crystals up to 1 cm in length (Fig. 9), and in cross-fiber veins similar in occurrence to kröhnkite. It was limited in

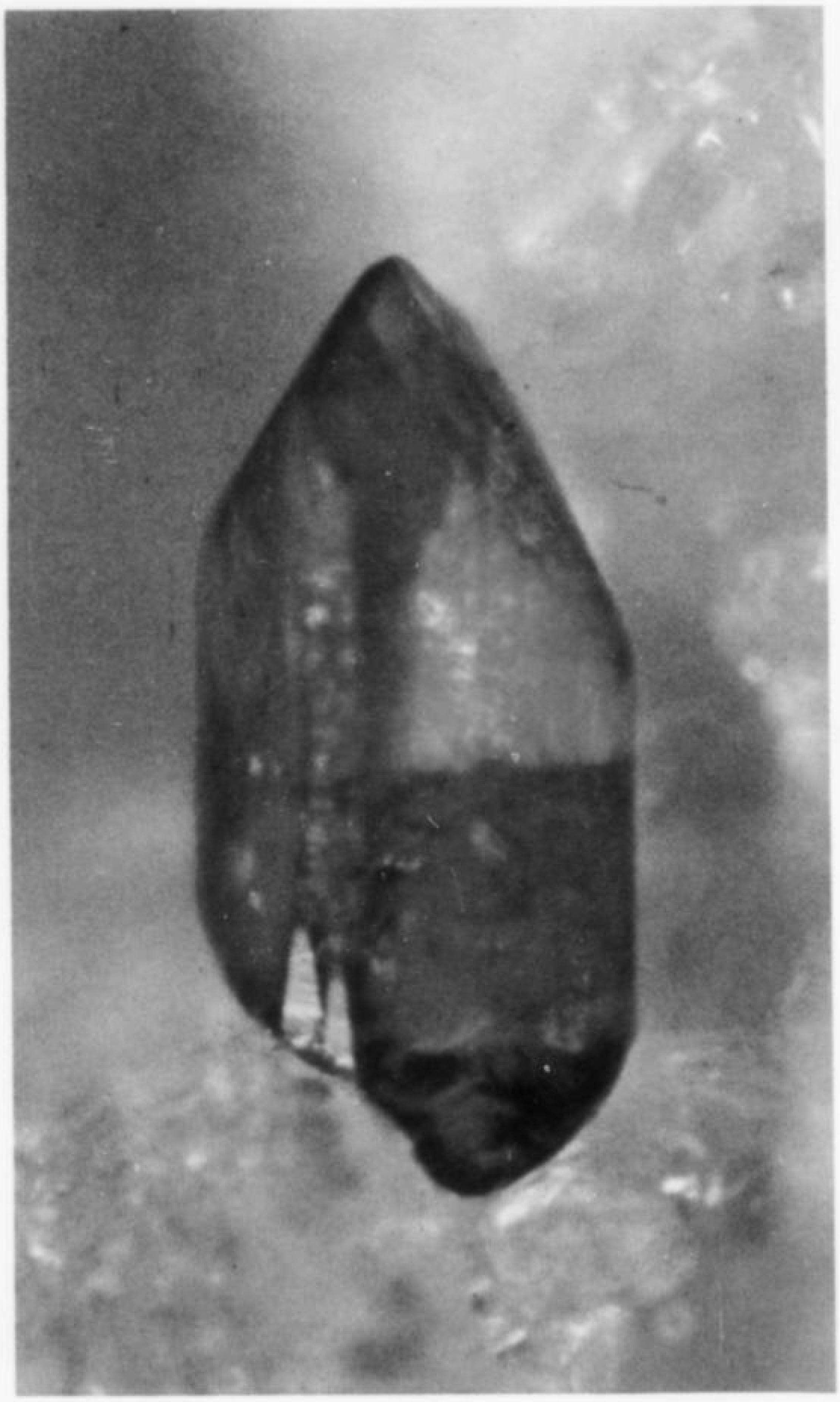


Figure 10. Salesite from Chuquicamata. Photo by Julius Weber; specimen, collection of Lou Perloff.

Figure 11. Malachite pseudomorph after marshite from Chuquicamata. Photo by Julius Weber; specimen, collection of Lou Perloff.

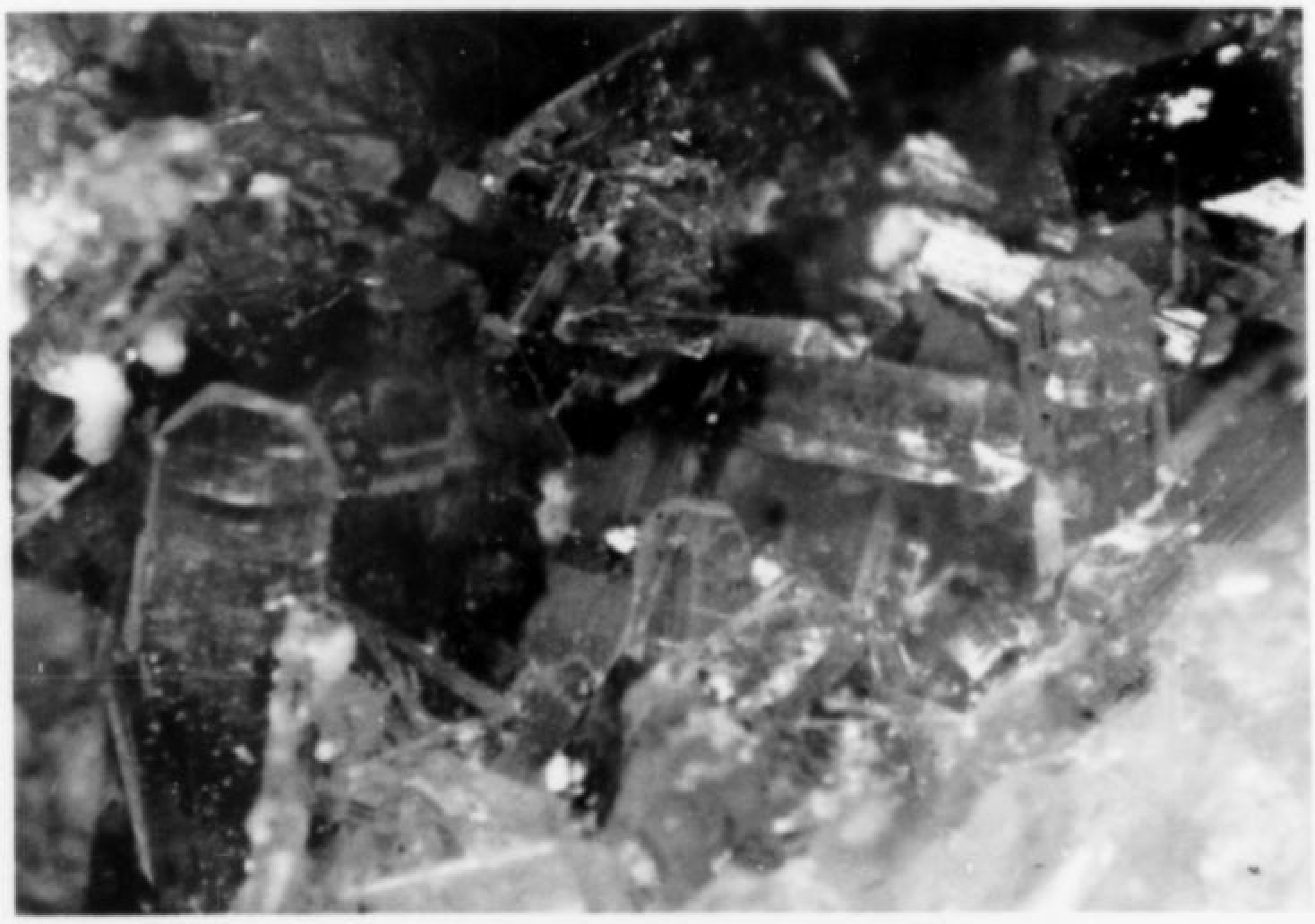
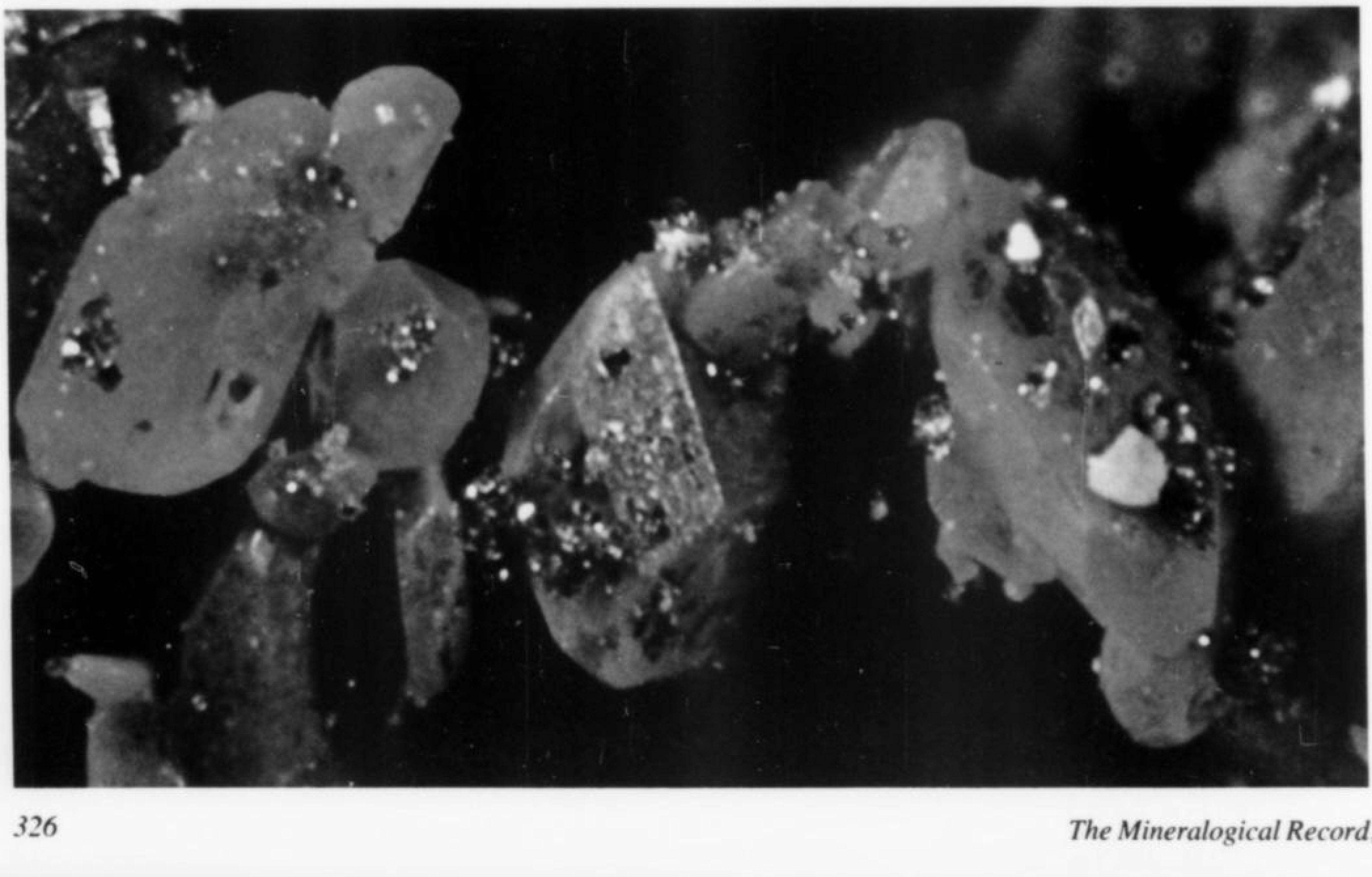


Figure 12. Leightonite from Chuquicamata. Specimen and photo: Julius Weber.

Figure 13. Kröhnkite from Chuquicamata. Specimen and Photo: Julius Weber.



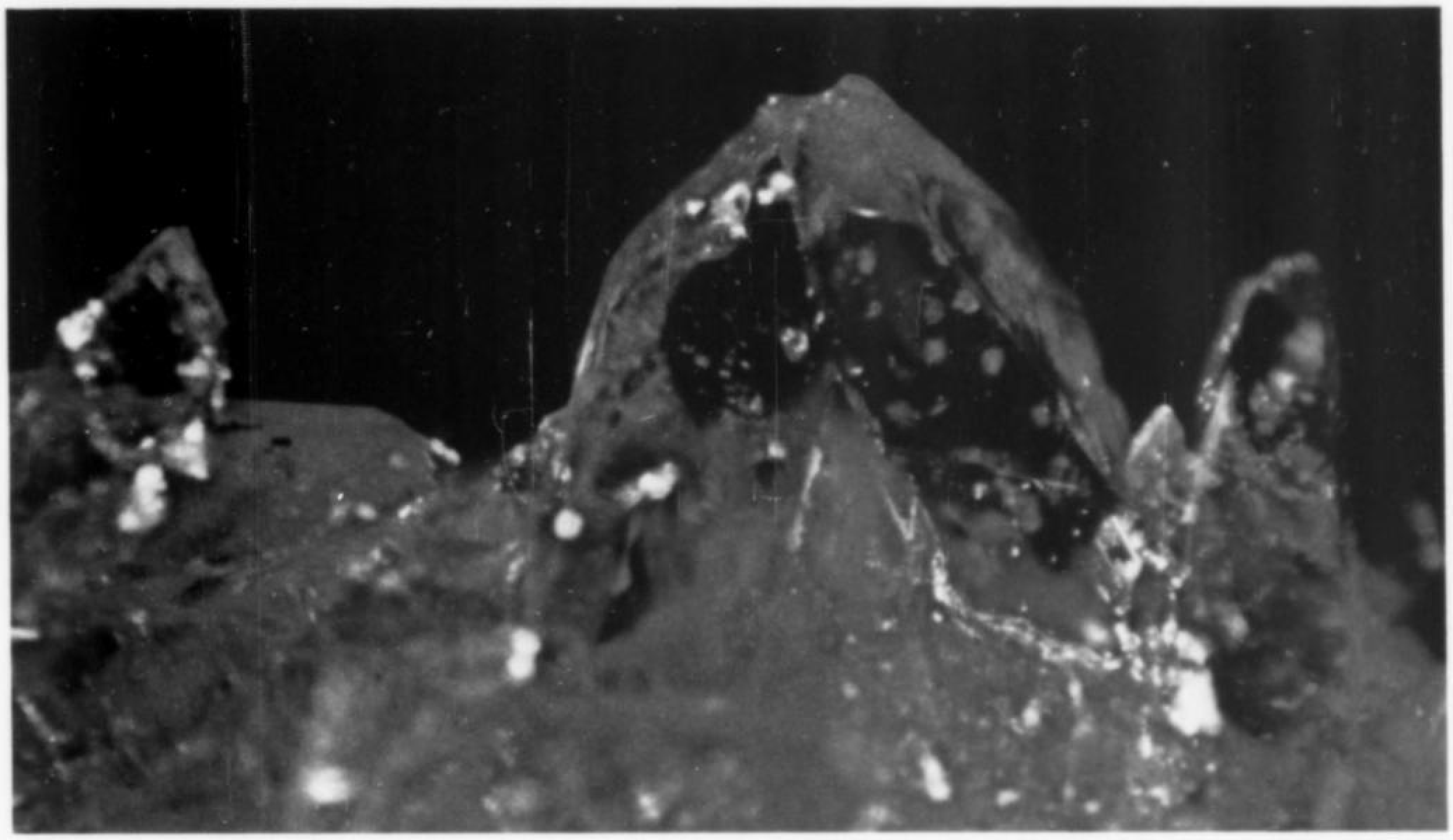


Figure 14. Natrochalcite on kröhnkite from Chuquicamata. Photo by Julius Weber; specimen, collection of Lou Perloff.

Figure 15. Atacamite from Chuquicamata. Photo by Julius Weber; specimen, collection of Lou Perloff.

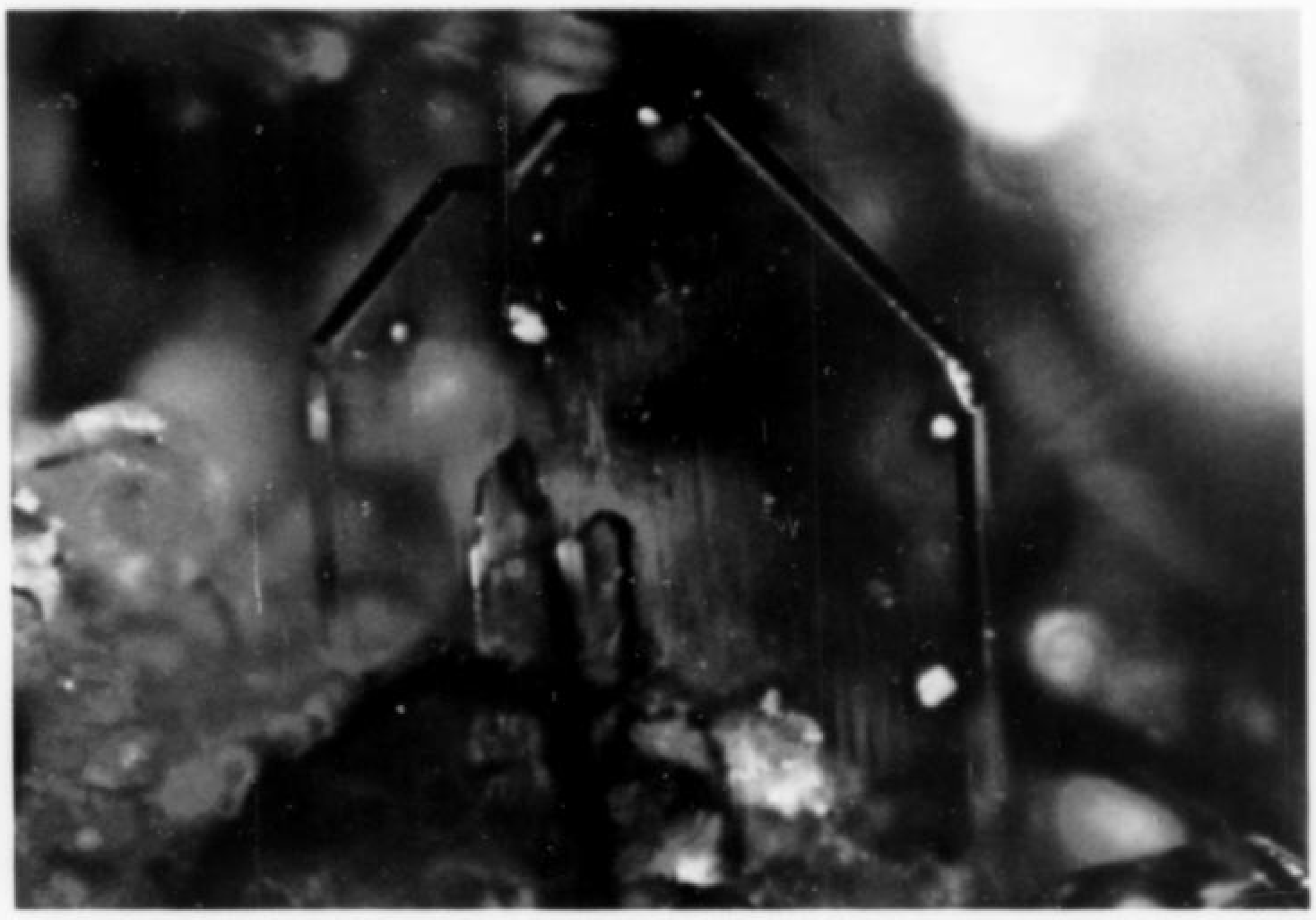


Figure 16. Antlerite from Chuquicamata. Photo by Julius Weber; specimen, collection of Lou Perloff.

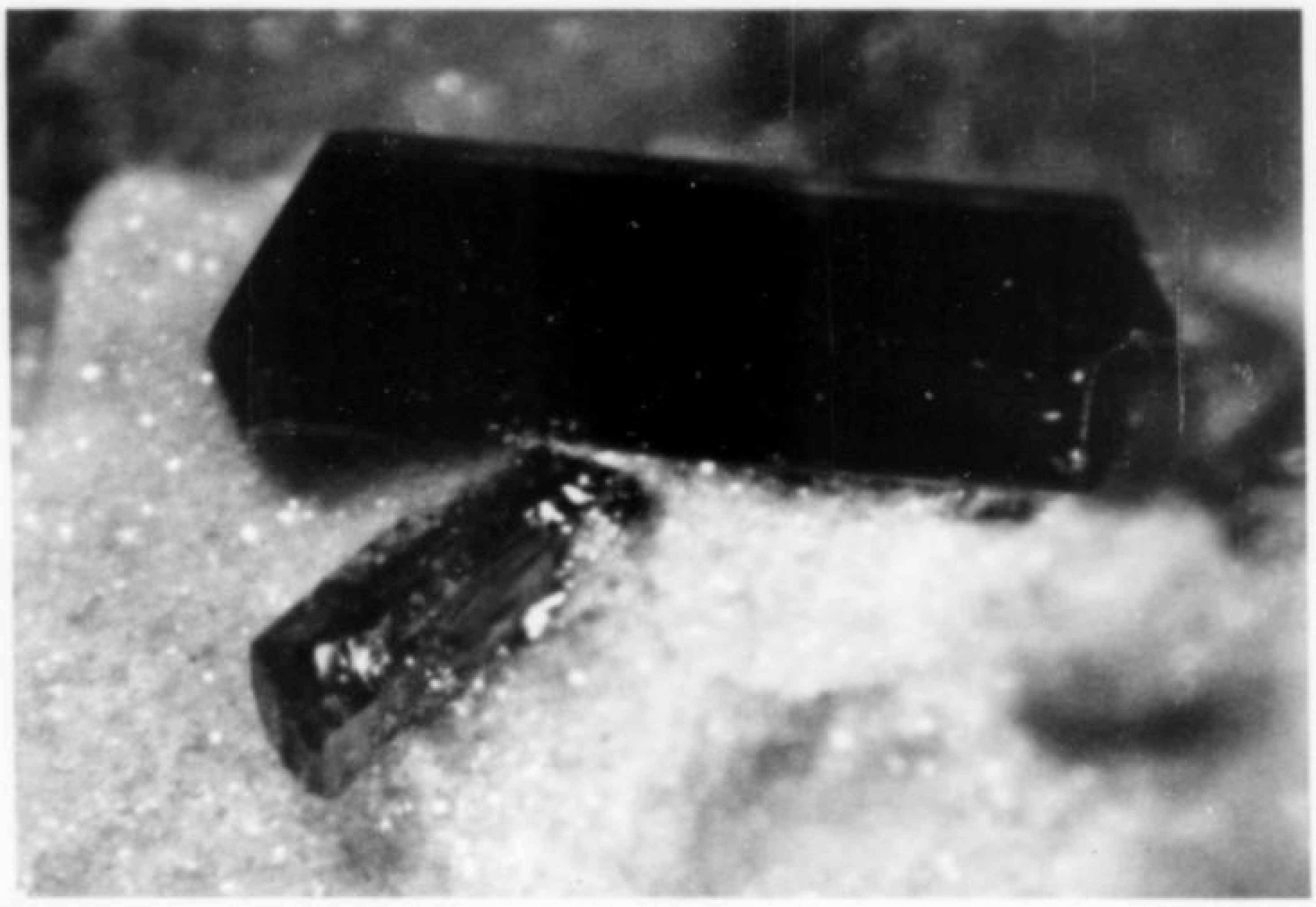
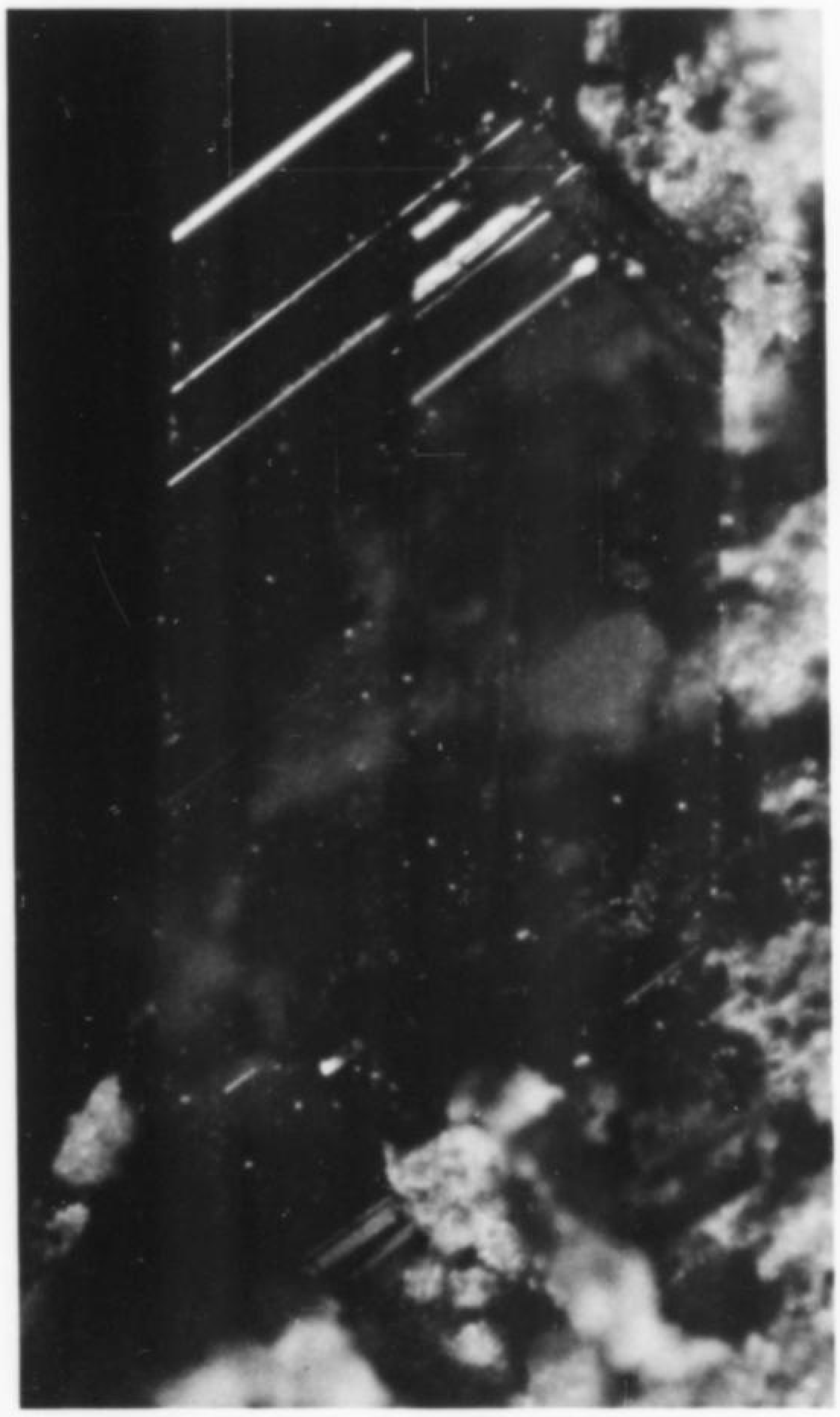


Figure 17. Lindgrenite from Chuquicamata. Photo by Julius Weber; specimen, collection of Lou Perloff.



vertical extent to within approximately 40 m of the original surface. Chief associated minerals were atacamite and kröhnkite; never atacamite. More recently, small crystalline aggregates of leightonite intimately associated with bellingerite have been collected by the geological staff of CODELCO.

Voltaite: Voltaite is uncommon at Chuquicamata and is confined to areas of more massive pyrite veins. It is commonly associated with coquimbite and it has been shown by Bandy (1938) to be paragenetically later than this mineral. Well formed crystals are particularly rare and the mineral is best distinguished by its lack of cleavage, conchoidal fracture, resinous luster, and greenish black to dark olive-green color.

Tamarugite: Tamarugite is restricted in occurrence to the upper portions of the deposit and appears to be paragenetically later than ubiquitous associated alums (Bandy, 1938). The mineral occurs as fine-granular masses or as fibrous crusts. Rarely, colorless tabular crystals have been collected.

Mendozite, kalinite and potash alum: Mendozite, kalinite and potash alum have been found intermittently in the near-surface portions of the deposit. Mendozite is perhaps most common and in all instances the minerals are paragenetically late. Significant crystalized specimens are not known.

Gypsum: Gypsum beds up to 30 cm are relatively common in alluvium in the immediate vicinity of the pit. Generally, the mineral is fibrous although small, uninteresting crystals have been reported. Gypsum occurs locally within the ore deposit and is typically stained deep blue by chalcanthite and kröhnkite.

Chalcanthite: Chalcanthite once constituted an important ore mineral in the upper portions of the deposit, particularly within a blanket zone characterized by the occurrence of both supergene sulfide minerals and sulfates. Fibrous veins up to 5 cm wide, crystal-lined pockets and small individual crystals were not uncommon. Two new crystal forms for chalcanthite were identified on Chuquicamata material by Bandy (1938). At the time of the author's visit, chalcanthite in moderately good specimens could still be collected near the West fissure in the central portion of the pit.

Pisanite: Pisanite is reported but its occurrence and distribution have not been described in detail, probably due to the difficulty in distinguishing it visually from poorly crystallized chalcanthite.

Epsomite: Epsomite is a relatively common mineral both within the upper portions of the deposit and with other salts in nearby alluvium. Epsomite beds 10 to 20 cm thick were described by Bandy (1938) west of the deposit. Epsomite associated with the deposit proper typically forms white pulverulent masses and fibrous aggregates.

Roemerite: Roemerite is a relatively rare mineral at Chuquicamata. In almost every instance, it is closely associated with coquimbite and is restricted in vertical extent to the near-surface portions of the deposit.

Halotrichite: Colorless to light green fibrous aggregates of halotrichite were described from near-surface ores by Bandy (1938). Individual, though unterminated, crystals up to approximately 2 mm thick in a granular mass of pyrite, sericite and aluminum sulfate were mentioned. The mineral is typically associated with partially oxidized pyrite and a variety of other iron sulfates. Larger crystals are commonly hollow.

Pickeringite: The first precise crystallographic measurements for pickeringite were presented by Bandy (1938) for material collected near Chuquicamata at Quetena. A similar occurrence is mentioned at Chuquicamata by Jarrell (1944). The mineral occurred in long acicular tufts, felted masses, closely packed cross-fiber veinlets, and as massive aggregates. The most typical color is white to very light yellow although at times brown pickeringite has been observed. Associated minerals are matrix jarosite, chalcanthite and fibroferrite.

Coquimbite: Coquimbite is surprisingly uncommon at Chuquicamata with respect to its general abundance in other Chilean sulfate deposits. It is typically pale violet and occurs in relatively small crystals. Its occurrence is restricted to the near-surface portions of the deposit.

Alunogen: Granular alunogen associated with blue, partially dehydrated chalcanthite, yellow sideronatrite, and yellow-green copiapite has been described at Chuquicamata by Gordon (1940).

Brochantite: Brochantite is a comparatively rare mineral at Chuquicamata, although for many years it was thought to be the main ore mineral of the oxide zone (rather than antlerite). Brochantite occurs near the margins of the deposit and is associated typically with gypsum and chrysocolla. It also occurs in carbonate veins along the northwestern portion of the deposit. Brochantite was not identified in samples collected by the author and material so labeled from Chuquicamata should be examined for confusion with antlerite or acicular atacamite.

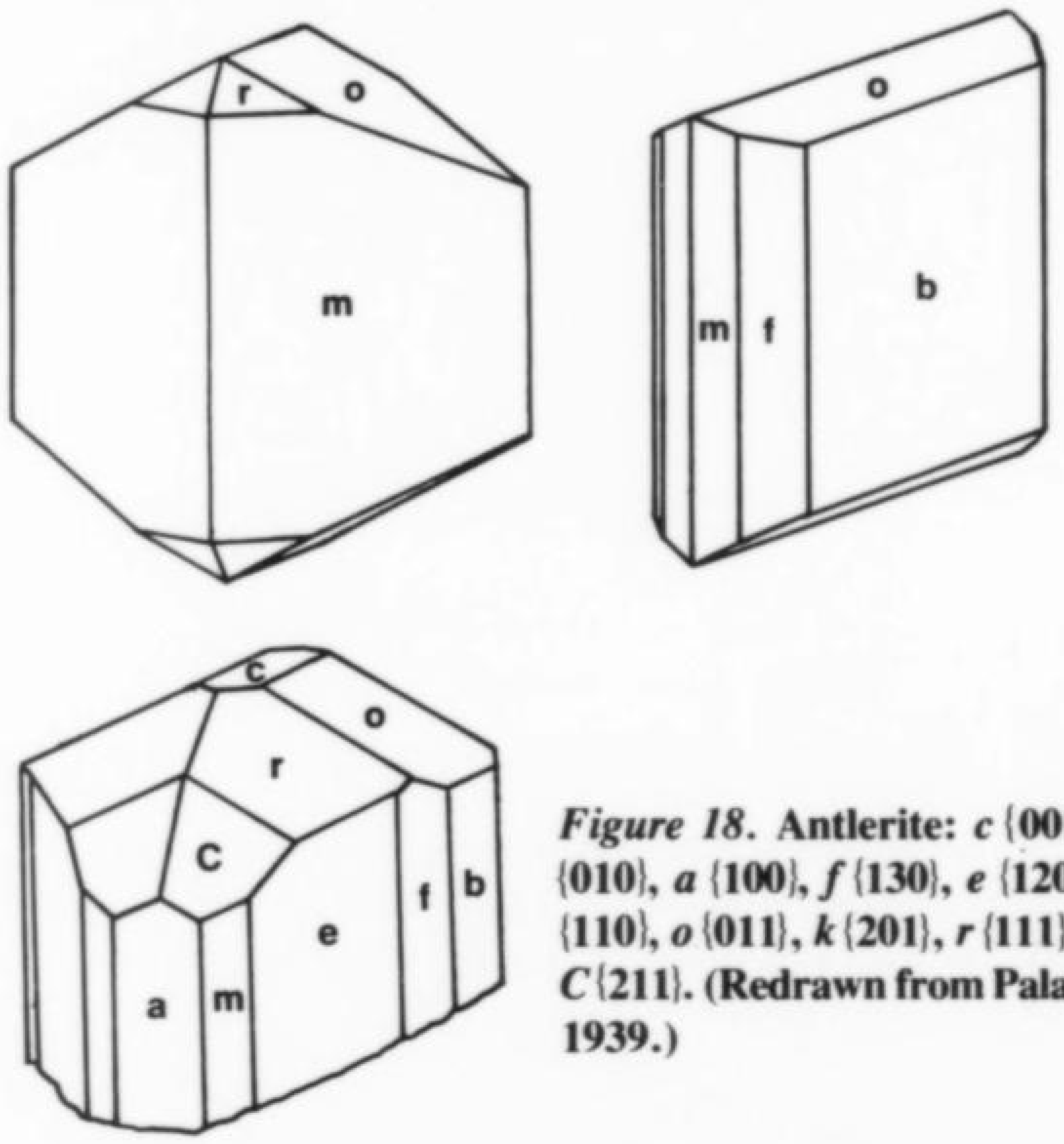


***Figure 18.* Antlerite: *c* {001}, *b* {010}, *a* {100}, *f* {130}, *e* {120}, *m* {110}, *o* {011}, *k* {201}, *r* {111} and *C* {211}. (Redrawn from Palache, 1939.)**

Antlerite: Antlerite was the main ore mineral of the oxide zone at Chuquicamata. Bandy (1938) considered antlerite to represent the last stage in copper mineralization and determined the vertical range to be as great as approximately 330 m. A detailed study of antlerite was presented by Palache (1939) which included excellent crystallographic drawings of Chuquicamata crystals (Fig. 18).

The most common occurrence of antlerite is in fibrous veinlets up to several centimeters thick cutting silicified, chalcocite-rich porphyry. Exceptional single crystals and aggregates are relatively common in open spaces within fractured and altered porphyry. Crystals as large as 5mm in greatest dimension were relatively abundant in dump material being used as mill feed in 1976. Fibrous veinlets of chantoyant, deep green antlerite up to 3 cm thick can still be found in abandoned portions of the pit along its northeast margin. Older Chuquicamata specimens labeled "stelznerite" and "heterobrochantite" are probably actually antlerite.

Alunite and Natroalunite: Alunite and natroalunite have been described from Chuquicamata as supergene minerals occurring in the oxidized portions of pyrite-rich veins. Occasionally, the minerals are found in veins associated with antlerite and are locally associated with jarosite. The minerals are typically quite fine-grained and mechanically combined with other constituents so that precise distinction between the potassium and sodium species is difficult.

Jarosite: Fibrous and massive aggregates, and minute tabular crystals of jarosite were relatively common in the upper portions of the ore body, typically in the central, more massive portion. Jarosite pseudomorphs after alunite or natroalunite preserving the "hopper crystals" were described by Bandy (1938).

Natrojarosite: Small brilliant crystals of cinnamon-brown natrojarosite associated with chalcanthite, kröhnkite and sulfur have been described in detail by Bandy (1938). Chuquicamata natrojarosite afforded the first material suitable for detailed crystallographic study.

Trillings with the twin plane (110) were common and explain previously reported anomalous optical behavior. Natrojarosite was not observed during the author's visit in 1976 although good specimens are still encountered.

Plumbojarosite: Plumbojarosite is mentioned by Jarrell (1944) as occurring at Chuquicamata although details are not given. The mineral was not observed by the author.

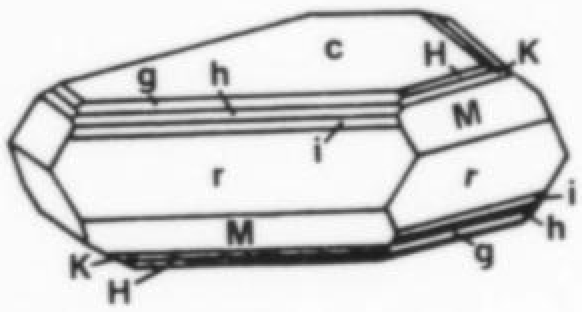


***Figure 19*. Ungemachite: *c* {0001}, *g* {1017}, *h* {1014}, *i* {2025}, *r* {1011}, *H* {0115}, *K* {0227} and *M* {0112}. (Redrawn from Peacock and Bandy, 1938.)**

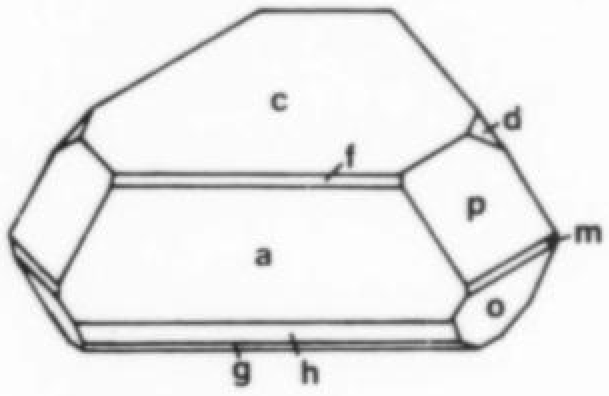


***Figure 20*. Clinoungemachite: *c* {001}, *a*{100}, {110}, *d* {012}, *f* {101}, *g* {102}, *h* {101}, *p* {111} and *o*{111}. (Redrawn from Peacock and Bandy, 1938.)**

Ungemachite and Clinoungemachite: Ungemachite and clinoungemachite were described as new minerals by Peacock and Bandy (1938) from material collected at Chuquicamata. Ungemachite occurs as granular vein filling and rarely as individual, colorless to yellow crystals less than 1 mm in diameter lining small vugs in massive jarosite and metasideronatrite. The description of clinoungemachite was based on the discovery of six minute crystals originally thought to be ungemachite but determined goniometrically to be monoclinic (pseudo-rhombohedral). The crystals were found intimately associated with ungemachite in massive jarosite.

Aluminite: Aluminite was mentioned by Bandy (1938) as occurring at Chuquicamata although details of occurrence and associations were not given. The mineral was not observed by the author.

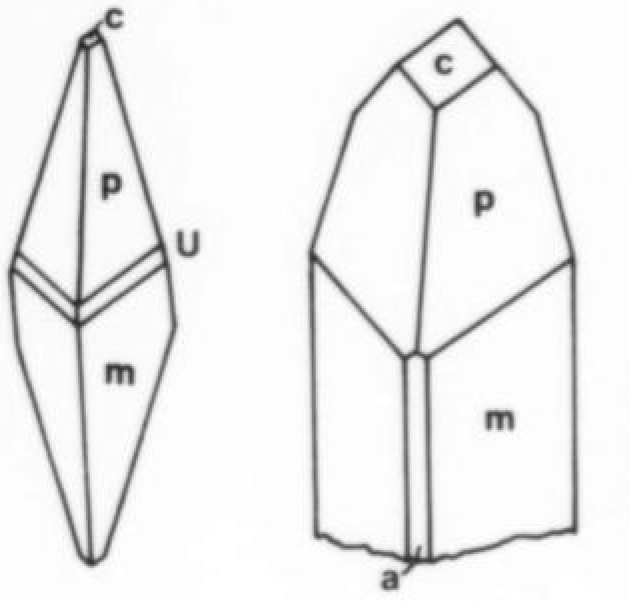


***Figure 21*. Natrochalcite: *c* {001}, *p* {111}, *m* {10} and *U* {221}. (Redrawn from Palache and Warren, 1908.)**

Natrochalcite: Natrochalcite is today an exceptionally uncommon mineral originally described from Chuquicamata. It was limited to the uppermost portions of the deposit and was considered rare at the time of Bandy's work, although in 1936-1937 it was a moderately important ore mineral. Excellent specimens consist of bright emerald-green crystals lining fractures in altered porphyry or crystalline natrochalcite crusts on kröhnkite and atacamite. Natrochalcite-filled vugs in fibrous kröhnkite reportedly were the origin of the finest specimen material. In 1940 there was abundant specimen material available, consisting of cross-fiber veinlets to 1 cm thick in kröhnkite. Natrochalcite was not encountered during the author's visit and specimens of this mineral should be considered a rarity today.

Metasideronatrite: Metasideronatrite was described as a new mineral from Chuquicamata ores by Bandy (1938). It is generally thought to be a dehydration product of sideronatrite. The typical occurrence of metasideronatrite is in coarse to fine-grained, yellow to straw-yellow crystalline aggregates exhibiting perfect cleavage and silky luster. Common associated minerals are metavoltine, ferrinatrite, ungemachite, alums and natrojarosite. The mineral is limited to the uppermost portions of the deposit.

Sideronatrite: Although sideronatrite was not identified by Bandy, several sideronatrite samples from Chuquicamata are in the U. S. National Museum collections. One of these specimens contains sideronatrite associated with metavoltine.

Metahohmannite: Orange powdery metahohmannite was described by Bandy (1938) as a dehydration product of hohmannite. Although identical material had been described previously by various authors, Bandy (1938) was the first to apply the name metahohmannite to the mineral.

Butlerite: Butlerite was not described from Chuquicamata ores by Bandy, although he identified for the first time the analogous compound, parabutlerite. The presence of butlerite is mentioned in Dana's *System of Mineralogy*, Volume II (Palache, Berman and Frondell, 1951), apparently in reference to work by Samual Gordon.

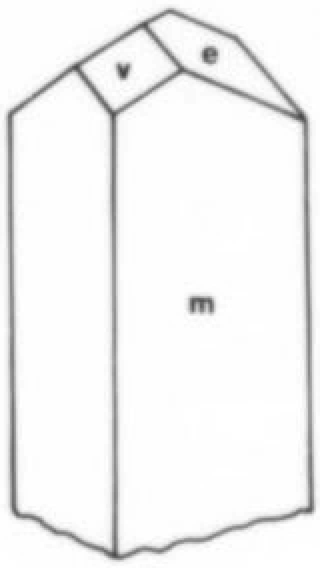


***Figure 22*. Parabutlerite: *m*{110}, *e*{011}, *s*{012} and *p*{111}. Redrawn from Bandy, 1938.)**

Parabutlerite: Parabutlerite was described as a new mineral species by Bandy (1938) from material collected at Chuquicamata. Parabutlerite occurs closely associated with copiapite (from which it alters) and jarosite. Crystals are typically small and prismatic (Figure 7), and vary in color from light orange to a light orange-brown. The mineral has been observed only in the upper portions of the deposit.

Amarantite: Superb though small crystals of amarantite have been found from time to time at Chuquicamata. The first detailed crystallographic and optical description for this mineral was presented for Chuquicamata material by Bandy (1938). Amarantite typically occurs in small, amaranth-red, transparent crystals associated with hohmannite and fibroferrite along the walls of small sulfate veins in the oxidized portions of massive quartz-pyrite veins. In addition, small acicular amarantite crystals have been described in chalcanthite or pisanite.

Hohmannite: Hohmannite occurs as small, brilliant, light amaranth-red to chestnut-brown crystals associated with chalcanthite and picromerite. The mineral is best distinguished from amarantite by optical properties and is extremely unstable, particularly in arid climates, readily dehydrating to metahohmannite. As with many of the preceding sulfate species, hohmannite was almost entirely limited in occurrence to the upper, depleted portions of the ore deposit.

Fibroferrite: Fibroferrite occurred in the upper portions of the Chuquicamata porphyry as greyish white efflorescent crusts or silky greenish grey material associated with chalcanthite, amarantite and hohmannite. The mineral dehydrates rapidly upon exposure to air.

Botryogen: Botryogen was once quite common at Chuquicamata as light orange to dark orange-red prismatic crystals and masses associated with hohmannite and amarantite. Bandy (1938) showed that material labeled "quetenite," "rubrite," "idrizite" and "palachite" are identical with botryogen and should be so relabeled.

Metavoltine: Metavoltine was tentatively described for Chuquicamata ores by Bandy (1938) and positively identified by Gordon (1940). Bandy described the mineral as occurring in six-sided plates and scales of peculiar vitreous to oily luster and olive-green to greenish brown color. It is always associated with metasideronatrite and locally with kalinite, pickeringite, tamarugite, ungemachite and jarosite. In Gordon's samples, metavoltine occurred as granular masses with alunogen, blue dehydrated chalcanthite, yellow sideronatrite and yellowish green copiapite.

Copiapite: Copiapite was relatively common in the upper portions of the deposit where it occurred as aggregates of well developed though small tabular crystals with pearly luster and a yellow to greenish yellow color. Copiapite may still be found on portions of the older dumps.

Cuprocopiapite: Cuprocopiapite was relatively common at Chuquicamata where it was always associated with copiapite and commonly with parabutlerite, chalcanthite and jarosite. Cuprocopiapite is characteristically less well crystallized than copiapite, commonly occurring in rounded masses and aggregates of greenish grains.

Phosphates and Arsenate

Members of the phosphate family are poorly represented at Chuquicamata, the only species previously described being libethenite, sampleite and turquoise. Metatorbernite was identified around 1950 but the identification was not published (Lester Zeihen, pers. communication). Jarrell (1939) reports that a few specimens of dark olive-green libethenite crystals perched on white, extremely kaolinized granodiorite have been found. The crystals are distinctive in that they are composed only of prismatic and pyramidal faces, domes so characteristic of crystals from other localities being entirely absent (Fig. 23). Sampleite was identified from Chuquicamata as a new mineral species by Hurlbut (1942). Sampleite occurs as small, flattened, micaceous aggregates of light blue tabular crystals (Fig. 24) on altered porphyry. It is distinguished by a well defined pearly luster on cleavage faces. Associated minerals are gypsum, atacamite, libethenite, jarosite, and goethite. Sampleite is still to be found on older portions of the oxide dumps. Turquoise was first identified at Chuquicamata in 1931 by Bandy. It is not an uncommon mineral and deep blue gem-grade material is known, although most is light blue, chalky and occurs in narrow veinlets. Common associated minerals are atacamite and antlerite. Turquoise may still be found in the upper portions of the deposit in the northeast end of the pit.

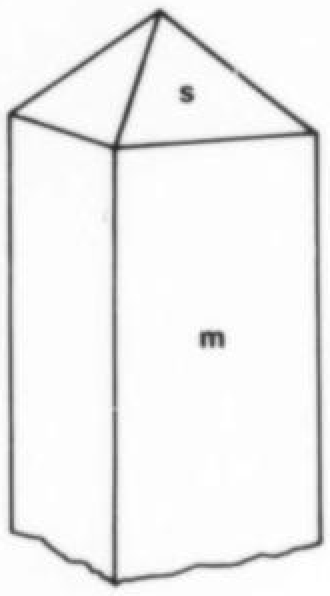


Figure 23. **Oliventie: *m* {110}, *v* {101} and *e* {011}. (Redrawn from Jarrell, 1939.)**

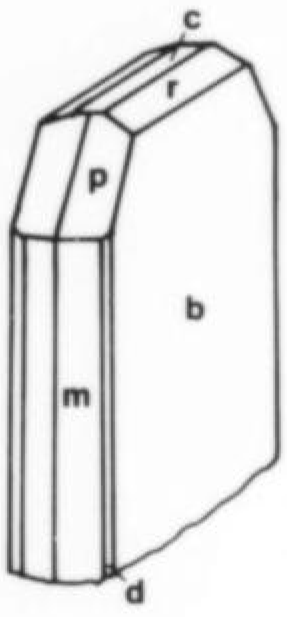


Figure 24. **Libethenite: *m* {110} and *s* {111}. (Redrawn from Jarrell, 1939.)**

The arsenate suite of minerals is represented by chenevixite, olivinite, scorodite and pharmacosiderite. Only chenevixite is locally abundant, occurring in light green to lime-green microcrystalline masses formed by the oxidation of enargite. Chenevixite masses measuring several tens of centimeters in diameter are still encountered in the central portion of the pit near the West fissure. The mineral is of interest to collectors due to its generally pleasing color and rarity. Olivinite is infrequently encountered in small though well formed crystals (Fig. 25) embedded in porous aggregates of chenevixite (Jarrell, 1939). Scorodite and pharmacosiderite are reported from chenevixite-rich zones although exceptional specimens are apparently unknown.

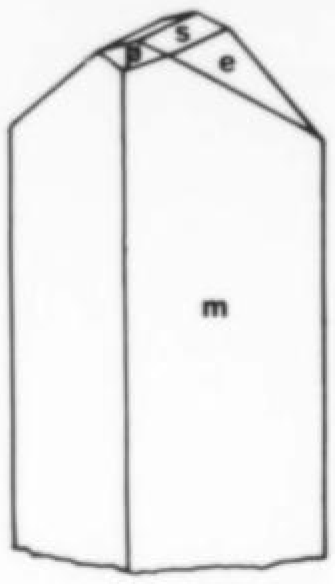


Figure 25. **Sampleite: *c* {001}, *b* {010}, *m* {110}, *d* {150}, *r* {021} and *p* {111}. (Redrawn from Hurlburt, 1942.)**

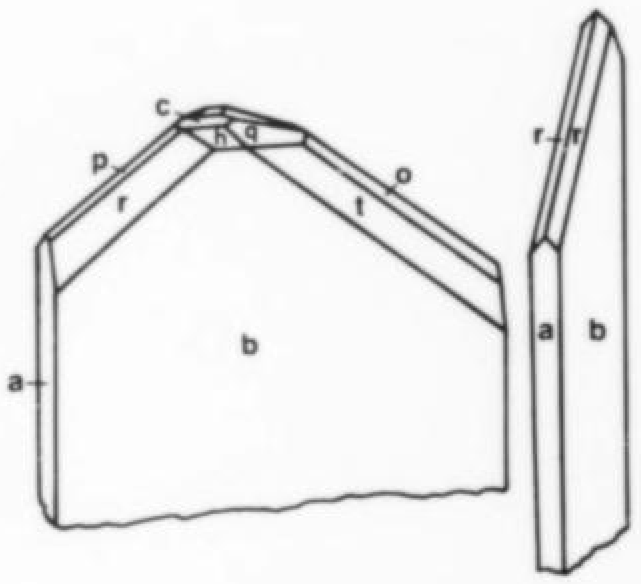


Figure 26. **Lindgrenite: *a* {100}, *b* {010}, *c* {001}, *r* {021}, *t* {130}, *o* {110}, *h* {111}, *q* {211} and *p* {011}. (Redrawn from Palache, 1935.)**

Molybdates

The oxidation of primary molybdenite has resulted in the formation of only three secondary molybdates: wulfenite, lindgrenite and ferrimolybdite. Lindgrenite was originally identified by Palache (1935) in type material collected at Chuquicamata by Bandy. It occurs in transparent tabular crystals (Fig. 26) of deep green to yellow-green color. Most crystals are less than 4 mm in maximum dimension and exhibit brilliant, well-formed faces. Associated minerals are antlerite and iron oxides. Lindgrenite specimens are uncommon at Chuquicamata today. Dark grey, massive wulfenite associated with fine-grained antlerite was reported from an isolated location in the mine (Jarrell, 1939). The specimens were found in the immediate vicinity of molybdenum mineralization in which most of the molybdenum had been fixed in lindgrenite during oxidation. Minor galena occurs as a fine-grained constituent of ores in this section of the pit. Ocherous ferrimolybdite has been reported at intervals from Chuquicamata although specimens worthy of note are unknown.

Silicates

Although silicate family minerals are of utmost importance at Chuquicamata in as much as they are the primary minerals comprising the Chuquicamata porphyry and related alteration assemblages, they are, for the most part, of little interest to the connoisseur of mineral specimens. Quartz, plagioclase and potassium feldspars, and micas are the dominant silicate minerals in unaltered portions of the porphyry. Kaolinite, chlorite and muscovite (sericite) constitute various phases of the altered portions of the pluton. Tourmaline occurs locally as small radiating needles filling cracks in the porphyry as well as in veins near the central portion of the pluton. Small, cinnamon-brown titanite crystals were described by Bandy (1938) in tourmaline-albite-titanite pegmatites immediately north of the deposit.

Chrysocolla has been described by various authors in both the Chuquicamata porphyry proper and associated alluvium and gravels (Newberg, 1962). At least three individual minerals are mentioned but not specified as being generally grouped with chrysocolla (Bandy, 1938). Chrysocolla typically occurs in botryoidal cryptocrystalline masses in the southeast portion of the deposit. The most commonly associated copper mineral is atacamite. In local areas that appear to be deficient in copper, chrysocolla grades into opal.

The Exotica mine, actually a southward extension of the oxidized copper deposit of the Chuquicamata pit, contains a variety of copper silicates, oxides and halides deposited downhill from the main sulfide ore body by weathering solutions.

TABLE 1. Minerals of Chuquicamata

A = Country rock minerals B = Hydrothermal alteration minerals
C = Oxide zone minerals and supergene sulfides D = Primary ore minerals

NAME	FORMULA	CHARACTERISTIC OCCURRENCE
ELEMENTS		
Gold	Au	(?)
Copper	Cu	C
Sulfur	S	C
SULFIDES		
A_2X Type		
Digenite	Cu_9S_5	D
Djurleite	$Cu_{1.96}S$	D
Chalcocite	Cu_2S	C,D
A_3X_2 Type		
Bornite	Cu_5FeS_4	C,D
AX Type		
Galena	PbS	D
Sphalerite	ZnS	D
Chalcopyrite	$CuFeS_2$	D
Covellite	CuS	C,D
Idaite	Cu_5FeS_6	D
AX_2 Type		
Pyrite	FeS_2	D
Marcasite	FeS_2	C,D
Molybdenite	MoS_2	D
SULFOSALTS		
A_3BX_3 Type		
Tennantite	$(Cu,Fe)_{12}As_4S_{13}$	D
A_3BX_4 Type		
Colusite	$Cu_3(As, Sn, V, Fe)S_4$	D
Famatinite	Cu_3SbS_4	D
Enargite	Cu_3AsS_4	D
OXIDES		
A_2X Type		
Cuprite	Cu_2O	C
AX Type		
Tenorite	CuO	C
A_2X_3 Type		
Hematite	Fe_2O_3	A,B,C,D.
Ilmenite	$FeTiO_3$	
AX_2 Type		
Rutile	TiO_2	A
Pyrolusite	MnO_2	C
AB_2X_4 Type		
Magnetite	Fe_3O_4	A,C,D.
Hydroxides, etc.		
Manganite	MnO(OH)	C
Goethite	FeO(OH)	C
Birnessite	$(Na,Ca)Mn_7O_{14} \cdot H_2O$(?)	C(?)
HALIDES		
AX Type		
Halite	NaCl	A,C
Marshite	CuI	C
$Am(O,OH)_pX_q$ Type		
Atacamite	$Cu_2Cl(OH)_3$	C
Paratacamite	$Cu_2(OH)_3Cl$	C
CARBONATES		
$A(XO_3)$ Type		
Calcite	$CaCO_3$	B,C,D
Magnesite	$MgCO_3$	C
Cerussite	$PbCO_3$	C
$AB(XO_3)$ Type		
Dolomite	$CaMg(CO_3)_2$	C,D
$Am(XO_3)pZp$ Type		
Malachite	$Cu_2(CO_3)(OH)_2$	C
Azurite	$Cu_3(CO_3)_2(OH)_2$	C
NITRATES		
$A(XO_3)$ Type		
Soda Niter	$NaNO_3$	A,C
Niter	KNO_3	A,C
Misc.		
Darapskite	$Na_3(SO_4)(NO_3) \cdot H_2O$	C
IODATES		
$A(XO_3)_2 \cdot xH_2O$, etc.		
Bellingerite	$Cu_3(IO_3)_6 \cdot 2H_2O$	C
Salesite	$Cu(IO_3)(OH)$	C
BORATES		
Ulexite	$NaCaB_5O_9 \cdot 8H_2O$	A
SULFATES		
A_2XO_4 Type		
Thenardite	Na_2SO_4	C
AXO_4 Type		
Anhydrite	$CaSO_4$	A,C
$A_2(XO_4) \cdot xH_2O$ Type		
Mirabilite	$Na_2SO_4 \cdot 10H_2O$	C
$A_2B(XO_4)_2 \cdot xH_2O$ Type		
Kröhnkite	$Na_2Cu(SO_4)_2 \cdot 2H_2O$	C
Bloedite	$Na_2Mg(SO_4)_2 \cdot 4H_2O$	C
Picromerite	$K_2Mg(SO_4)_2 \cdot 6H_2O$	C
$AmBn(XO_4)p \cdot xH_2O$ Type		
Ferrinatrite	$Na_3Fe(SO_4)_3 \cdot 3H_2O$	C
Leightonite	$K_2Ca_2Cu(SO_4)_4 \cdot 4H_2O$	C

NAME	FORMULA	CHARACTERISTIC OCCURRENCE
$AB(XO_4)_2\cdot xH_2O$ Type		
Voltaite	$K_2Fe_5^{+2}Fe_4^{+3}(SO_4)_{12}\cdot 18H_2O$	C
Tamarugite	$NaAl(SO_4)_2\cdot 6H_2O$	C
Mendozite	$NaAl(SO_4)_2\cdot 11H_2O$	C
Kalinite	$KAl(SO_4)_2\cdot 11H_2O$	C
Potash Alum	$KAl(SO_4)_2\cdot 12H_2O$	C
$A(XO_4)\cdot xH_2O$ Type		
Gypsum	$CaSO_4\cdot 2H_2O$	A,C
Chalcanthite	$CuSO_4\cdot 5H_2O$	C
Pisanite	$(Fe,Cu)SO_4\cdot 7H_2O$	C
Epsomite	$MgSO_4\cdot 7H_2O$	A,C
$A_2B(XO_4)_4\cdot xH_2O$ Type		
Roemerite	$Fe^{+2}Fe_2^{+3}(SO_4)_4\cdot 14H_2O$	C
Halotrichite	$Fe^{+2}Al_2(SO_4)_4\cdot 22H_2O$	C
Pickeringite	$MgAl_2(SO_4)_4\cdot 22H_2O$	C
$A_2(XO_4)_3\cdot xH_2O$ Type		
Coquimbite	$Fe_2(SO_4)_3\cdot 9H_2O$	C
Alunogen	$Al_2(SO_4)_3\cdot 18H_2O$	C
$Am(XO_4)pZq$ Type		
Brochantite	$Cu_4(SO_4)(OH)_6$	C
Antlerite	$Cu_3(SO_4)(OH)_4$	C
Alunite	$KAl_3(SO_4)_2(OH)_6$	C
Natroalunite	$NaAl_3(SO_4)_2(OH)_6$	C
Jarosite	$KFe_3(SO_4)_2(OH)_6$	C
Natrojarosite	$NaFe_3^{+3}(SO_4)_2(OH)_6$	C
Plumbojarosite	$PbFe_6^{+3}(SO_4)_4(OH)_{12}$	C
$(AB)_2(XO_4)Zq\cdot xH_2O$ Type		
Ungemachite	$Na_8K_3Fe^{+3}(SO_4)_6(OH)_2\cdot 10H_2O$	C
Clinoungemachite	$Na_9K_3Fe(SO_4)_6OH_39H_2O(?)$	C
Aluminite	$Al_2(SO_4)(OH)_4)\cdot 7H_2O$	C
$A_3(XO_4)_2Zq\cdot xH_2O$ Type		
Natrochalcite	$NaCu_2(SO_4)_2(OH)\cdot H_2O$	C
Metasideronatrite	$Na_4Fe_2^{+3}(SO_4)_4(OH)_2\cdot 3H_2O$	C
Sideronatrite	$Na_2Fe^{+3}(SO_4)_2(OH)\cdot 3H_2O$	C
$A(XO_4)Zq\cdot xH_2O$ Type		
Metahohmannite	$Fe_2(SO_4)_2(OH)_2\cdot 3H_2O$	C
Butlerite	$Fe^{+3}(SO_4)(OH)\cdot 2H_2O$	C
Parabutlerite	$Fe^{+3}(SO_4)(OH)\cdot 2H_2O$	C
Amarantite	$Fe(SO_4)(OH)\cdot 3H_2O$	C
Hohmannite	$Fe_2^{+3}(SO_4)_2(OH)_2\cdot 7H_2O$	
Fibroferrite	$Fe^{+3}(SO_4)(OH)\cdot 5H_2O$	C
Botryogen	$MgFe^{+3}(SO_4)_2(OH)\cdot 7H_2O$	C
Metavoltine	$(K,Na,Fe)_5Fe_3^{+3}(SO_4)_6(OH)_2\cdot 9H_2O$	
Copiapite	$Fe^{+2}Fe_4^{+3}(SO_4)_6(OH)_2\cdot 20H_2O$	C
Cuprocopiapite	$CuFe_4(SO_4)_6(OH)_2\cdot 20H_2O$	C
PHOSPHATES AND ARSENATES		
$A(XO_4\cdot xH_2O$ Type		
Scorodite	$Fe(AsO_4)\cdot 2H_2O$	C
$AB(XO_4)Zq$ Type		
Chenevixite	$Cu_2Fe_2(AsO_4)_2(OH)_4\cdot H_2O$	C
$A_2(XO_4)Zq$ Type		
Olivenite	$Cu_2(AsO_4)(OH)$	C
Libethenite	$Cu_2(PO_4)(OH)$	C
$(AB)m(XO_4)pZq\cdot xH_2O$ Type		
Sampleite	$NaCaCu_5(PO_4)_4Cl\cdot 5H_2O$	C
Turquoise	$CuAl_6(PO_4)_4(OH)_8\cdot 5H_2O$	C
Pharmacosiderite	$Fe_3^{+3}(AsO_4)_2(OH)_3\cdot 5H_2O$	C
$A(UO_2)_2(XO_4)_2\cdot xH_2O$ Type		
Metatorbernite	$Cu(UO_2)_2(PO_4)_2\cdot 8H_2O$	
MOLYBDATES		
$A(XO_4)$ Type		
Wulfenite	$PbMoO_4$	C
$A_3(XO_4)_2Zq$ Type		
Lindgrenite	$Cu_3(MoO_4)_2(OH)_2$	C
$A_2(XO_4)_3Zq$ Type		
Ferrimolybdite	$Fe_2(MoO_4)_3\cdot 8H_2O(?)$	C
SILICATES		
Quartz	SiO_2	A,B,C,D
Plagioclase (undifferentiated)	$(Na,Ca)Al(Al,Si)Si_2O_8$	A,B,D
Orthoclase	$KAlSi_3O_8$	A,B,D
Muscovite	$KAl_2(AlSi_3)O_{10}(OH)_2$	A,B,D
Biotite	$K(Mg,Fe)_3(Al,Fe)Si_3O_{10}(OH,F)_2$	A,B,D
Kaolinite	$Al_2Si_2O_5(OH)_4$	B
Chlorite (undifferentiated)		B
Zoisite	$Ca_2Al_3(Si_3O_{12})(OH)$	A,B
Epidote	$Ca_2(Al,Fe)_3Si_3O_{12}(OH)$	A,B
Tourmaline (undifferentiated)		A,B
Titanite	$CaTiSiO_5$	A
Chrysocolla	$(Cu,Al)_2H_2Si_2O_5(OH)_4\cdot nH_2O$	C
Opal	$SiO_2\cdot nH_2O$	C

CONCLUSIONS

Indications are that Chuquicamata will continue to be a source of good to excellent specimens of peculiar and exotic mineral species for some time to come. This specimen-producing potential is the result of the exposure of oxide zone material in older dumps now being reworked to supplement mine production and the good accessibility of currently inactive, upper portions of the open pit. It does not appear that any significant effort is being made to consistently collect specimen material by employees of the current operator, CODELCO, probably due to a general lack of incentive.

Species presently available in moderate quantity, either within the pit or in dump material, are antlerite as both cross-fiber vein filling and excellent individual crystals, atacamite, kröhnkite, chenevixite, sampleite, bellingerite and leightonite. A good selection of the less spectacular iron sulfates is no doubt available to those interested in such species.

Chuquicamata is of atypically easy access to the visiting mineralogist or collector. Accommodations in Chuquicamata are available at a single clean hotel. Other accommodations exist in the nearby city of Calama. CODELCO maintains an excellent public relations service complete with guided tours of the surface facility. Unfortunately, such tours do not include the opportunity to collect minerals. In recent years, Chuquicamata has become an unusually frequented tourist stop and, as such, company policy has become increasingly strict with respect to access of pit and dump areas. Those wishing to collect at Chuquicamata should in all instances make tight, previous arrangements with CODELCO to insure that a long trip does not end in disappointment.

Significant mineralogical research remains to be conducted at Chuquicamata. Data contained in the classic papers dealing with Chuquicamata mineralogy could be expanded by restudying the various unique and rare species with such modern equipment as the electron microprobe. In addition, careful study will probably bring to light additional species not reported at Chuquicamata but found in similar environments at other locations in Chile. Undoubtedly many of these species have already been found at Chuquicamata but have not been described in the available literature. Others such as specific sulfate and halogen-bearing minerals have perhaps been overlooked or misidentified as other species. Let us hope that the publication of this article and its admittedly incomplete listing of Chuquicamata minerals will prompt those persons with access to unpublished data to respond in such a manner that a complete list can be furnished at a future date.

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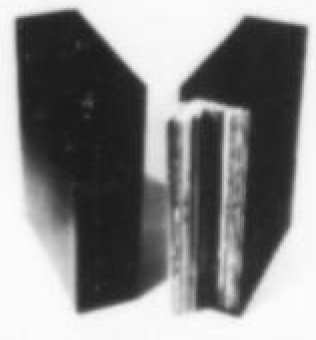

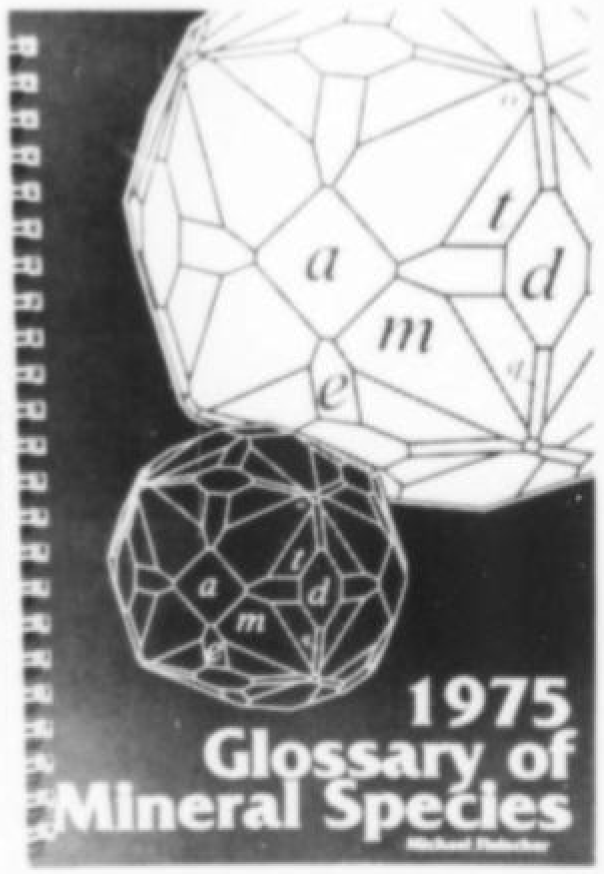

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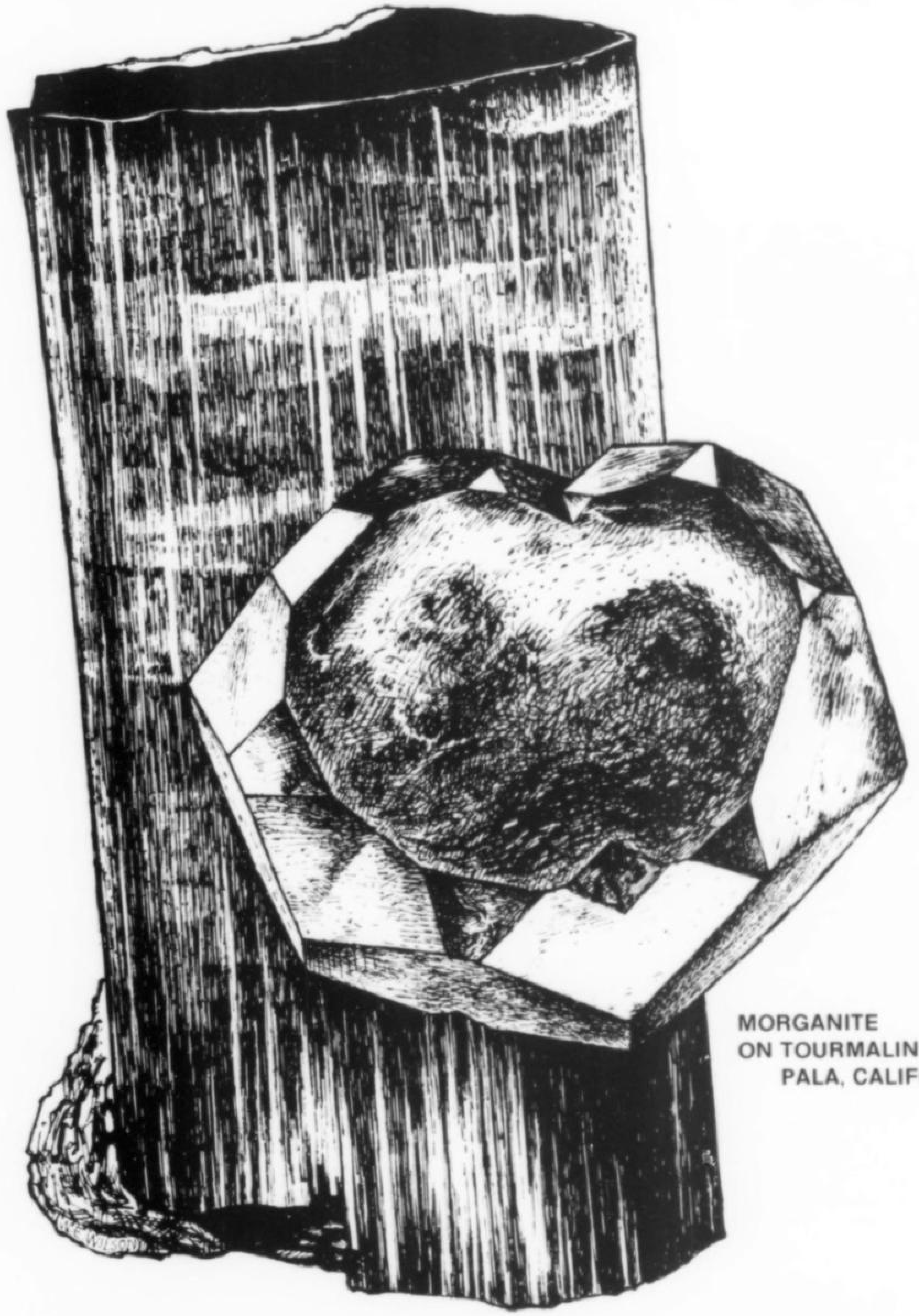

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