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*Continued on p. 399

THE
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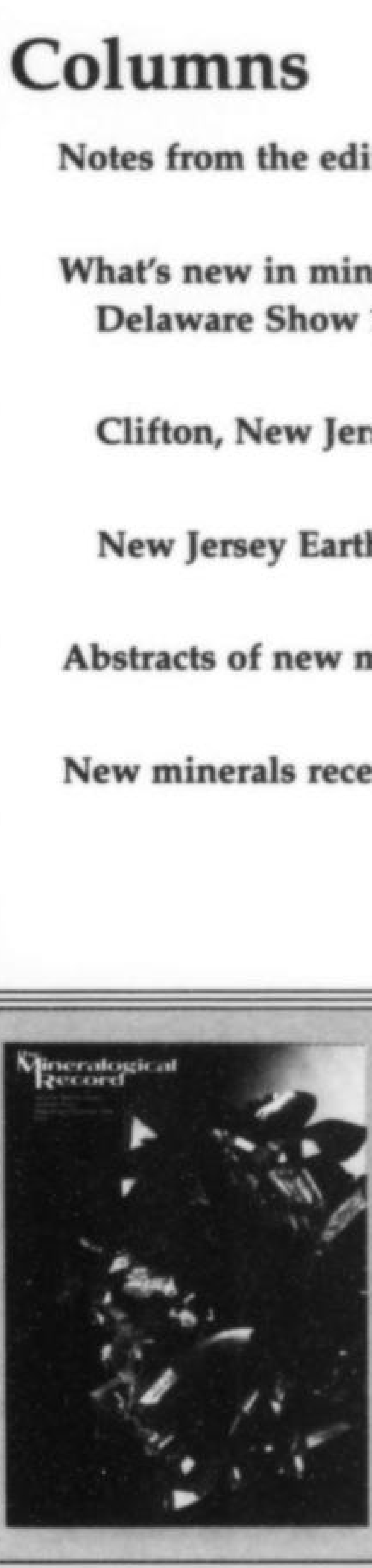
Articles

Columns



COVER: WULFENITE crystal group, 5 cm, from the famous Red Cloud mine in La Paz County, Arizona, collected in April 1996. See the article in this issue (p. 347) on the recent discoveries at this classic locality. Wayne Thompson specimen; Jeff Scovil photo.

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notes from the EDITOR

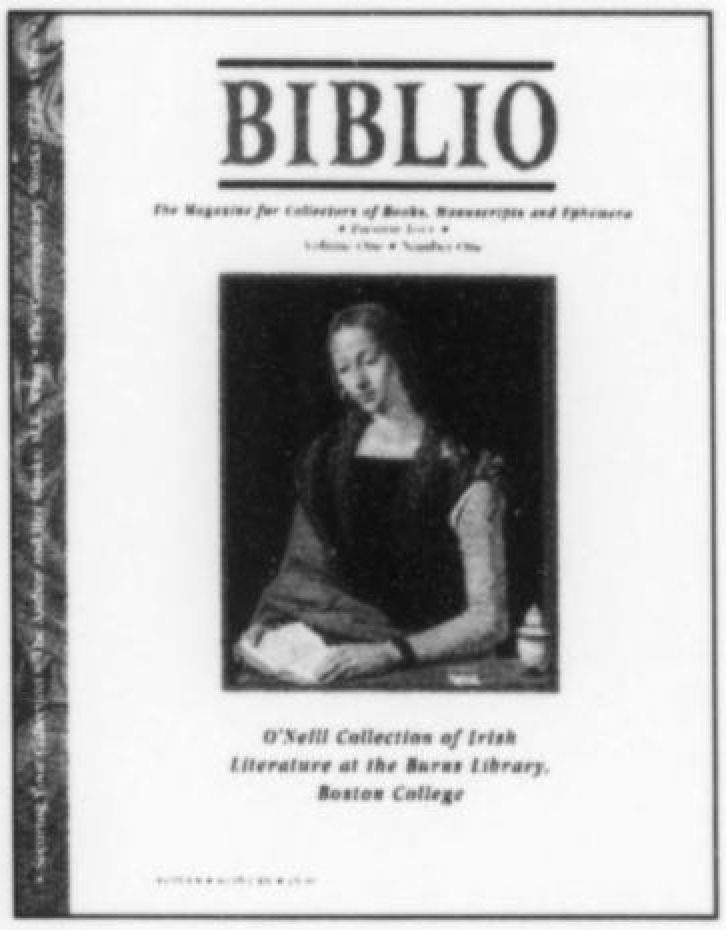
MINERAL CASES (III)

A while back we featured free-standing security vaults designed specifically for gun collectors but ideal for mineral storage as well. Those gun folks have some good ideas (or at least a lot of clout in the marketplace), and what works for them often works for us. Another example of this is the *Colt Collectables Showcase*, shown here. The pecan-finish pine cabinetry includes a locking lower wooden door and a locking glass display cabinet above, with three adjustable tempered-glass shelves. If you have a Western decor the etched Colt name and border design might fit in handsomely. With glass on three sides instead of just the front, this case should work well with only external lighting, but you could install lights under the roof panel if desired. Dimensions are 26 x 18.25 x 60.62 inches. The price is a remarkably reasonable $330 including shipping in the U.S. Order through your local gun shop or call Colt Blackpowder Arms at (718) 499-4678. The same case with plain glass is available for $395 + $62.50 shipping from Sugar Hill (1-800-344-6125); specify item #H8940181.

BRITISH CURATOR HONORED

Dr. Bob Symes, curator of minerals at The Natural History Museum in London, was recently awarded the prestigious O.B.E. (Order of the British Empire) for outstanding services to the Museum and to the science of mineralogy. Bob was presented with the medal by the Queen at an investiture ceremony last March. A former President of the Russell Society and incoming President of the Geologists Association, Bob will be retiring from his position at the Museum in October of this year but plans to continue writing books and papers on mineralogy.

Why doesn't the American government formally recognize the contributions of its leading curators and mineralogists like the British do? When was the last time you met a *decorated* American curator? Maybe there are some advantages to having a Queen after all.



BIBLIO

The Magazine for Collectors of Books, Manuscripts and Ephemera

O'Neill Collection of Irish Literature at the Burns Library, Boston College

MAGAZINE FOR BOOK COLLECTORS

The premier issue of a new magazine just for collectors of books and manuscripts recently came out. It's called *Biblio*, and it promises a lot of interesting features including in-depth examinations of specialty fields, price guides, auction reports, advice from experts, reviews of bookstores worldwide, tips and techniques for the new collector, evaluating, buying and selling rare books, care and preservation, profiles of collectors and collections, bookbinding, security measures and more. Of course, it will not deal entirely with mineral books or even natural history books; the publishers plan to cover *all* areas of book collecting, and, I suspect, will be looking to build a circulation far larger than that of the *Mineralogical Record*. Their introductory price for a 1-year, 12-issue subscription is just $25, fully refundable if you should find that the magazine does not suit your needs. Call toll-free 1-800-840-3810 (add $10 for delivery to Canada, Mexico, Latin America or the Caribbean; for European rates call the 800 number or 44-1-952-677-143 in the U.K.).

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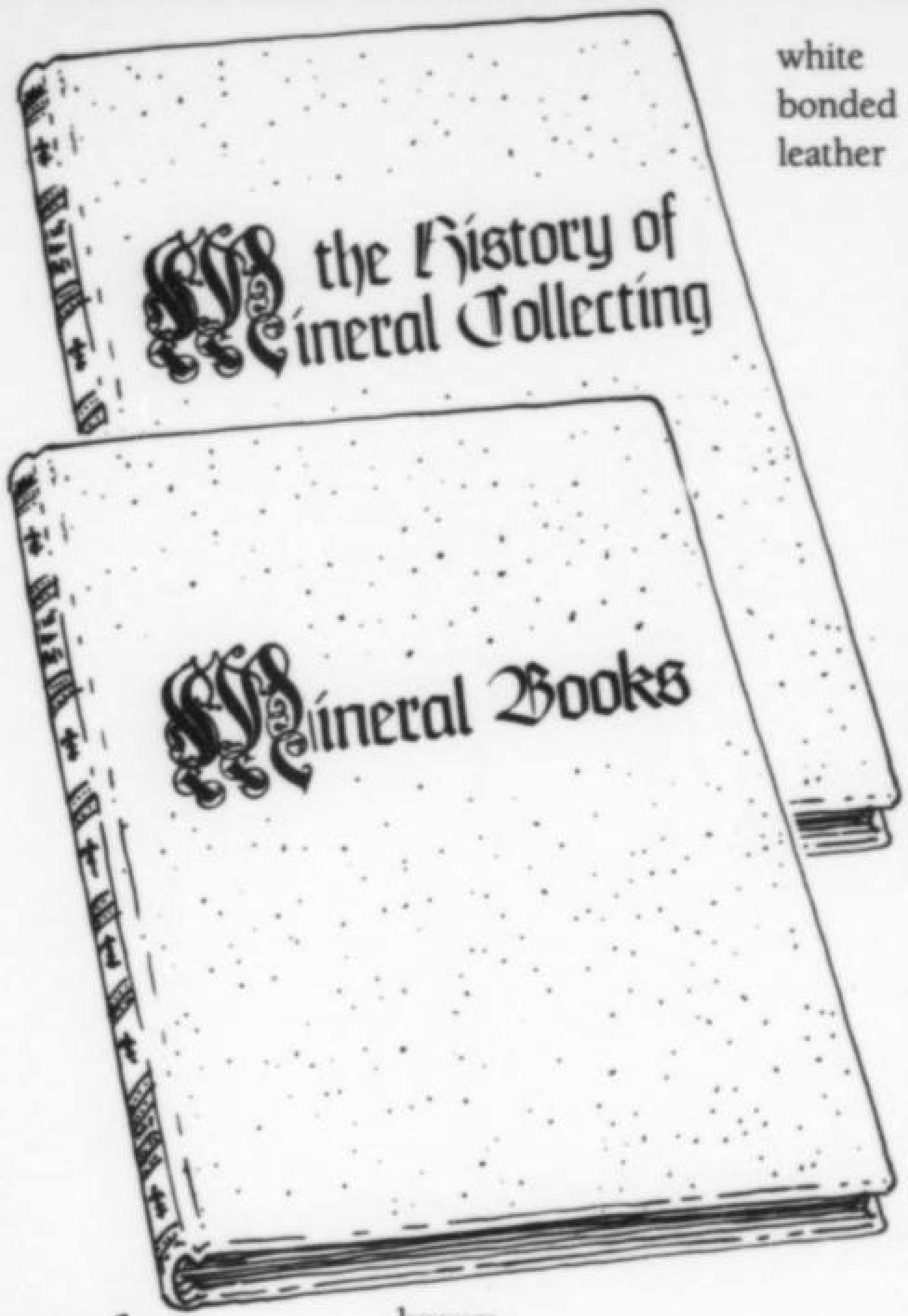
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THE HYALOPHANE OCCURRENCE AT ZAGRADSKI POTOK NEAR BUSOVAČA, BOSNIA AND HERCEGOVINA

Mirjan Žorž
Prešernova 53
1290 Grosuplje
Slovenia

The Zagradski Potok hyalophane occurrence has produced huge, lustrous, complexly twinned crystals which are easily the best known examples of the species. The occurrence, lost for some years in the forests of Bosnia, was rediscovered by collectors in 1978. A number of other minerals, including excellent faden quartz, have been found there as well.

INTRODUCTION

It was in the seventies and I had just finished a course on crystallography at Ljubljana University. As I showed extraordinary interest in the minerals, I was given permission to freely examine the mineral collection of the faculty. It took me several days to get through the complete collection; this was the first time that I had been able to take mineral specimens in my hands, which for years had adorned only the showcases. I had never seen so many before.

In the very last cabinet I pulled out a drawer full of excellent crystals, slightly yellow in color. Some of them measured more than 10 cm across. I had not seen anything like that previously. Some of them showed pagoda-like habits and were beautifully perched on the dark brown matrix. I was astonished by their complex shapes, brilliant faces and unique appearance. They were *hyalophanes* from Bosnia and Hercegovina. No one could tell me, at that time, why they were so complex and how they had developed in their native environment. I was told finally that there was a professor Ljudevit Barić at the Croatian Mineralogical and Petrographic Museum in Zagreb who might be able to tell me more about these crystals.

I managed to visit him together with my friend Gregor Kobler in 1979. At that time he was still working cheerfully on minerals. He was widely known among crystallographers, mineralogists and collectors as well, for his extraordinary work over many decades. The mineral *baricite* was named in his honor in 1976. That was one of those visits I would like to make again. He was very happy to see two young men interested in one of his most beloved topics. He gave us his reprints on hyalophane and some specimens, not knowing that one of them would prove to be the key to the solution of their structure and development.

Being told that the locality itself where the hyalophanes were found had been destroyed by the construction of a road over it was the only bitter disappointment. But since we were young and enthusiastic, we promised ourselves during the way back home to find the location in spite of what we had learned from the old professor.

It was not until 1981 that I first tried to visit the location with an old second-hand car together with my soon-to-be-wife on our way to the Adriatic Sea. The visit was intended to be only a site inspection. The road was bad; some parts were almost completely overgrown. The rotting timbers of badly damaged bridges were not really safe enough to drive over, but I was stubborn and drove further until the road turned away from the creek in a sharp turn. I looked around, but there was nothing but dense forest, mud and water. I could not find anything like hyalophane, and had to give it up that day, but with the firm resolution to come back again.

The next time was in 1983; G. Kobler and I came equipped with

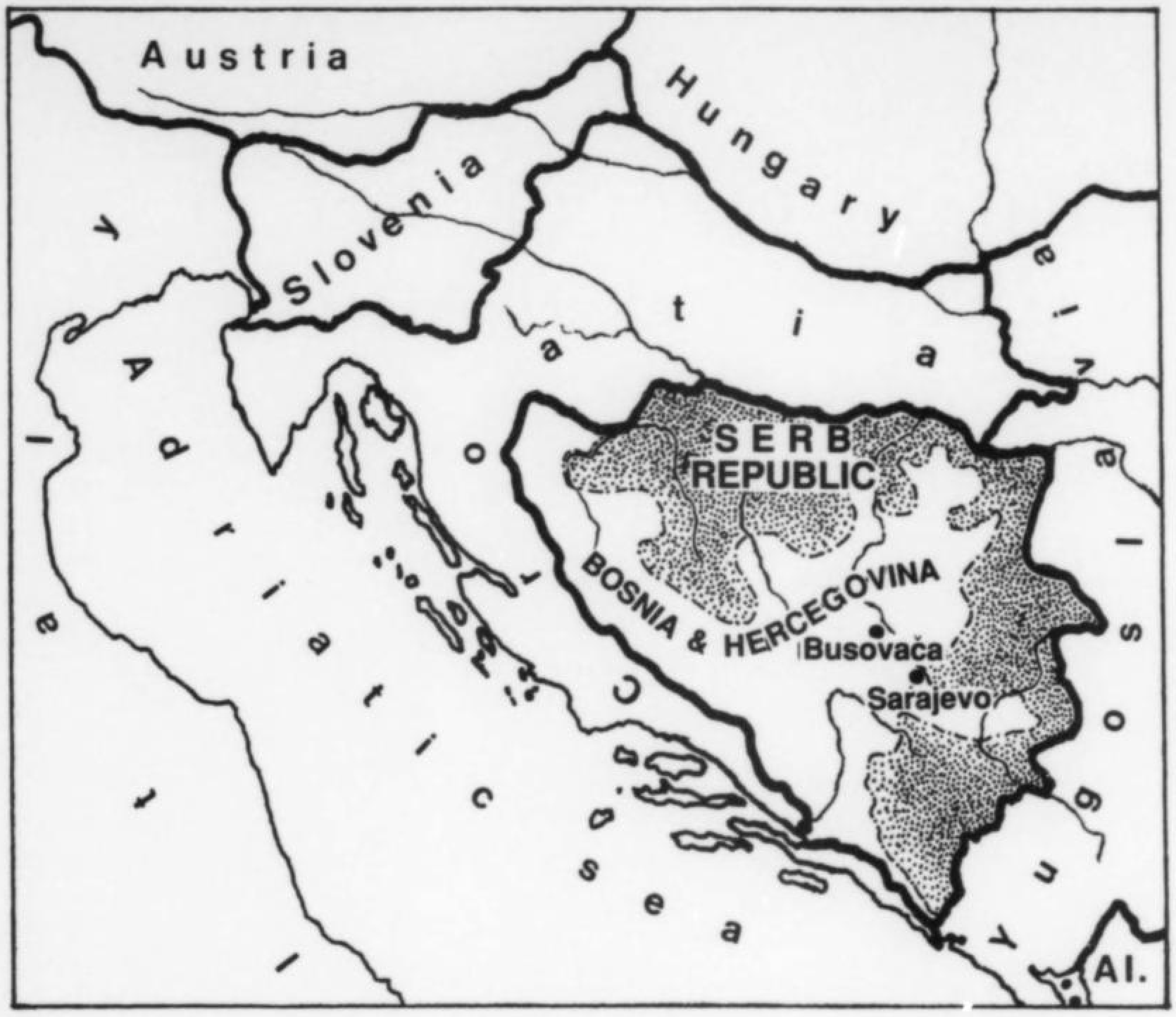

Figure 1. **Map showing the geographical position of the hyalophane locality in Bosnia and Hercegovnia. (All drawings by M. Žorž, unless otherwise stated.)**

maps, compass, altimeter and assorted ironware packed in our knapsacks. But what an amazing difference there was when we drove the same road as I had two years ago. It was now a normal forest road in quite good condition. The car scraped only once against the ridge between the ruts caused by heavy trucks conveying timber from the surrounding hills to Busovača.

I easily recognized the sharp turn where I had to stop two years ago. There was a nice parking place there, too. Zagradski Potok (potok = "creek") was running nearby, and almost everything was as described by Professor Barić (who had passed away some time before).

Kobler soon discovered what appeared to be a hole surrounded by large leaves of the "colt's foot" plant. We could see that there were animal skulls and bones scattered in it and, since we knew that the location was in the creek we concluded that it was probably some kind of animal burrow.

With our heavy knapsacks we walked upstream and downstream along Zagradski Potok and found nothing but some white pieces of massive quartz. Was the professor right in saying that the location had been filled in? We climbed to some nearby peaks, looked at the maps and tried to locate the site, but without success.

It was around 3 p.m. when we decided to rest for a while on the creek bank in the vicinity of the hole. While I was eating a sandwich and drinking a beer, complaining about timber-road builders and rummaging between the pebbles, I saw a reflection on a brown piece of stone. It was covered with sticky mud, so I washed it in the creek water. Razor-sharp, bladed crystals emerged on a dark brown carbonate matrix—hyalophane in person! It was a good specimen, still in my collection today. Finally a good sign. "The location must be here!" I shouted to my friend. "Give me that lamp!" he answered, and immediately jumped into the hole. The light beam revealed something else shiny and I asked him to hand it to me. It turned out to be an extremely good hyalophane fourling with Carlsbad twin attached. I jumped in too, heedless now of the scattered cow bones.

We were finally certain that we had found the hyalophane occurrence when we saw underground workings. Stopes were high enough to walk around in only slightly bowed. And to our great surprise, we found out that we were not the first visitors that year. Someone must have been there before us because we found several burned candles, long iron hooks and newspapers bearing a month-

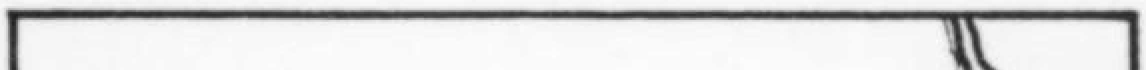

Figure 2. **Hyalophane locality at Zagradski Potok near Busovača.**

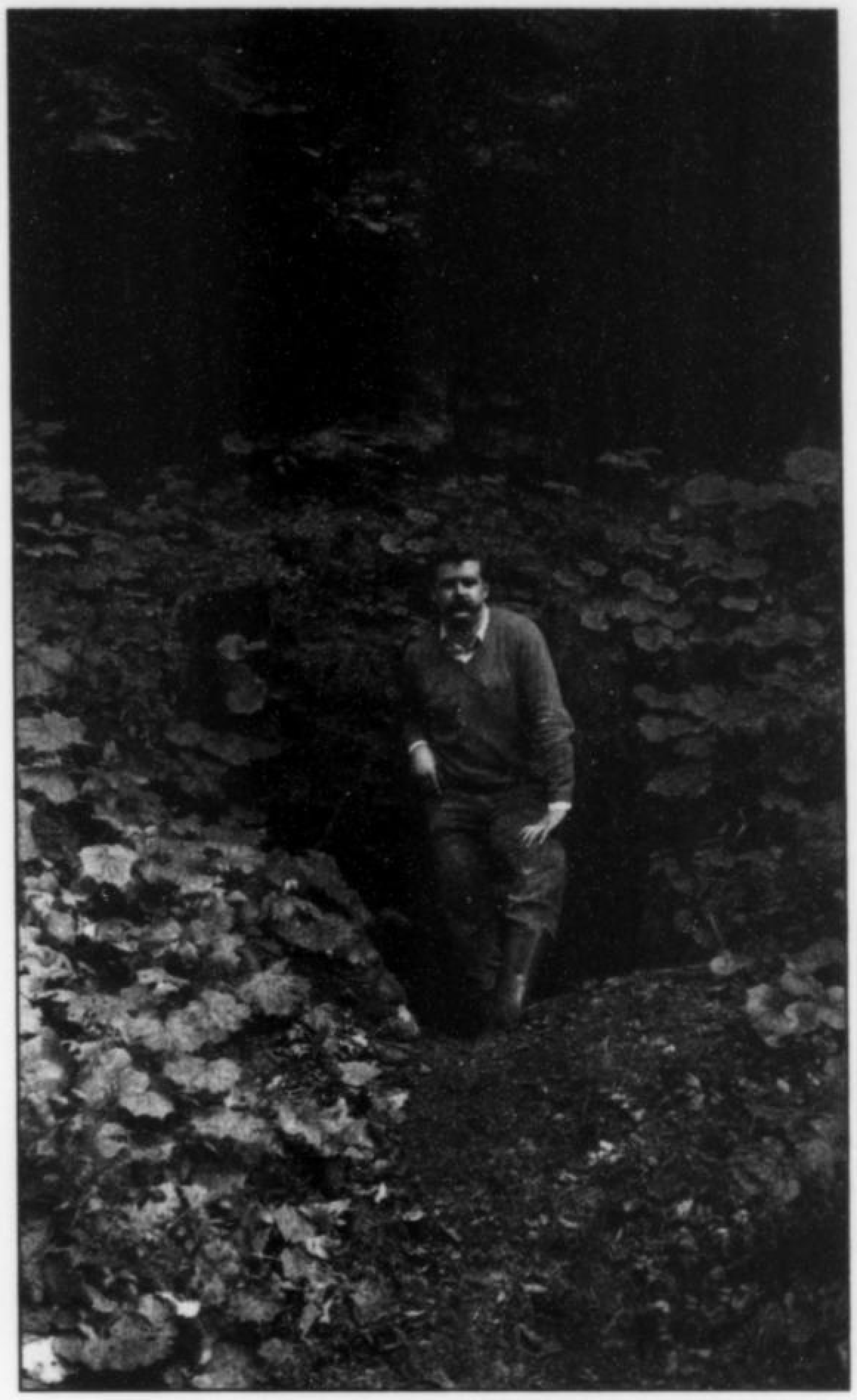

Figure 3. **R. Vidrih in front of the entrance to the underground workings at the hyalophane location near the Zagradski Potok. V. Mikuž photo.**

old date. In spite of this we found a lot of good material during the time we spent there.

I and my friends visited the location many times in the years since then. We recognized some people from the local area and became good friends. We encouraged them to begin searching for minerals not only at this location but also round about. We had had good days there in friendly atmosphere, with excellent barbecues, not to mention the constant temperature around 8° C in the pits, utilized as a perfect refrigerator for the beer.

It required only 5 or 6 hours by car from Slovenia to reach the locality. Our base was a restaurant positioned 3 km from the site. Surrounded by dense woods and with the only noise coming from the nearby Zagradski Potok, it was the best place in the world for the mineral collector, at least for a time.

HISTORY

Bosnia and Hercegovina had been geologically mapped under the Austro-Hungarian reign by the scientists of the then Royal Imperial institutions. The area surrounding the hyalophane location was geologically less interesting, but was quite attractive because of the dense forests. A narrow-gauge rail line was constructed from Busovača through the valley of Zagradski Potok for more efficient removal of the timber wealth. After the two world wars (one of which was initiated not far away), the line was abandoned. One can still see the remnants today in the form of rotten bridges and overgrown traces of the old layout. A cable-way was constructed instead and was also later abandoned. Only a bad gravel road connected Busovača with the scattered huts in the surrounding hills, owned by locals and visited only by foresters and hunters.

In the 1950's quartz became very important for different purposes, including its piezoelectrical properties which made it a strategic raw material for the electronics industry. For that reason geological surveys were again conducted in the region. A number of quartz veins had been found during the 1950's (Ilić, 1954 and Varićak, 1971). One of them was situated in the riverbed of the Zagradski Potok and was incompletely filled with quartz and crystals of what was at that time a (locally) unknown feldspar mineral. The discoverer was geologist V. Simić, who came across the site in 1953. At the end of 1954 mineralogist M. Ristić collected a number of quartz and feldspar specimens from the same locality. It was realized soon after that the Ba-rich member of the feldspar family, *hyalophane*, was present (Divljan, 1954).

The Yugoslav electronics industry developed an economic interest in the Bosnian quartz at that time. This interest culminated in 1956 when enough financial resources were provided to open an prospect pit at the Zagradski Potok site. More than 500 kg of quartz crystals were mined during the operation. The collected material was studied scientifically over the next two years, but the results were of no significant value and the material was unfortunately lost. This outcome definitely ended all activities related to piezoelectric quartz in Yugoslavia (Varićak, 1971).

Besides the quartz, more than 500 kg of hyalophane crystals were found. This material was divided between some Yugoslav institutes, universities and museums; a part of it also found its way into private collections. The great majority of the hyalophane specimens was packed in some wooden boxes and stored at the Geological institute in Sarajevo. These boxes caused problems there because of the space shortage, and it was eventually decided to discard them. The material, excepting some specimens which were rescued on the "You can take what you like!" basis, was thrown on the Sarajevo city dump.

The location itself was no longer attractive for quartz mining. Some surface pits and the entrance to the underground workings were filled in with dump material. The original vein in the riverbed of Zagradski Potok was covered with concrete to support the newly constructed road.

That was the situation known to Professor Barić, as he related it to us in the late 1970's. The road was in bad condition at the beginning of the 1980's. But at that time some localities for massive quartz (used for the production of special silicate bricks for metallurgical work in the nearby Busovača plant) were opened in the surrounding hills. The road was reconstructed and the hyalophane location thereby also became more easily accessible.

Around 1978 a group of Croatian collectors began collecting at this site. It is not known exactly how the entrance to the underground pits came to be opened. Perhaps the material that covered the entrance settled slowly over time, or perhaps wild animals dug the entry; or maybe collectors themselves widened the entrance. In any case, the entrance was large enough to permit one to creep in at the time when we first discovered it. The location has been subsequently visited by different groups of mineral collectors.

The best specimens were, naturally, recovered during the active period of the mine. The first private collectors, at the end of the seventies, must also have been very successful, since they found intact veins that had been left by miners. It was obvious that the workers did not extract the minerals from the intersecting small

Figure 4. **The author working in a vein in the stope in 1987. G. Kobler photo.**

veins but only from the main veins that were followed directly. The group from the Croatian Museum had good luck there at the beginning of the 1980's. Carlsbad hyalophane twins were reported by them for the first time. This material is now the basis of the Zagradski Potok collection of the Croatian Museum. Next to come were some Slovenian collectors who were lucky at least twice. They opened a parallel vein to the main pit and found many excellent hyalophane fourlings, some Carlsbad twins and a complete assemblage of species. Local collectors at the end of the 1980's searched for minerals in the already very exhausted veins. One of them opened a vein containing some of the best quartz crystals and probably the best double fourling of hyalophane ever seen.

In the year 1991 another reconstruction of the road took place; this time seriously endangering the location. The sharp bend in the road near the location was broadened and enlarged because of vehicular requirements, and access to the location became limited. The entrance to the pits remained open but there were serious intentions on the part of the roadbuilders to fill it.

At the time of my last visit (and it was absolutely one of the very last) the existing veins were "polished to a high luster," meaning that the chance to find something was by then very slim. Collecting had already been reduced to the combing of dump material on the bottom of the pits. There, one can still occasionally find something interesting. The final visits to the location were made by local collectors at the end of 1991. I have no information on what has happened since that time.

The literature describing the location, its geology and paragenesis is relatively abundant. Quartz veins in this region were described by Herbich (1880), who even mentioned quartz crystals longer than 20 cm that were used between Busovača and Kiseljak as a material for the gravel roads. Katzer (1924) described some locations around the Busovača. The quartz veins around Busovača were mentioned in 1954 by Ilić, who predicted the possible potential of the exposed quartz veins in the region around Busovača. It was Divljan in 1954 who first published the Zagradski Potok location. He described some hyalophane crystal forms and mentioned pagoda-like fourlings. He noted also some crystallographic forms appearing on the quartz crystals and recognized Dauphiné as well as Brazil-law twins. More data on hyalophane crystallographic forms were published by Barić (1955, 1961, 1972), Trubelja and Barić (1979) and Zebec (1978, 1988). Barić (1972), Gay and Roy (1968) and Roy (1965) published data on chemical and physical measurements made on hyalophane crystals. A series of articles describing hyalophane twins and paragenesis were published in the eighties beginning with an article on anatase (Zebec, 1980/1981) followed with the articles on apatite (Zebec and Zagorščak, 1983), oriented growth of hyalophane and albite (Zebec and Bermanec, 1985) and the oriented growth of rutile and hematite (Bermanec and Zebec, 1987). Mineral paragenesis has been described in two articles, one of which was published by Zebec and Šoufek in 1986 and another by Žorž *et al.*, in 1988. The first attempt to describe the complex structure of the hyalophane fourlings was made in the articles published by Zebec and Šoufek in 1986 and subsequently by Zebec in 1987/88. Carlsbad and Cunnersdorf twins were mentioned for the first time in these two articles, as well as parallel growths of the hyalophane crystals. A theory describing the formation, growth and structure of the hyalophane parallel growths, Carlsbad and Manebach twins, different types of fourlings and double fourlings was published in 1993 (Žorž).

GEOLOGY

Hyalophane appears in alpine veins emplaced in old Paleozoic schists. There are many ore deposits (mostly iron) found in this series. This region is therefore called also the Central Bosnian Schist mountains. The local series is composed of the metamorphic rocks, mostly sericite-phyllites, chloritic and amphibolitic schists. Layers up to 450 meters thick of dolomite and marble limestone layers occur within these schists. Carbonate rocks have been paleontologically determined as lower and middle Devonian. It has been concluded, on the basis of superposition, that the lowermost parts of the metamorphic paleozoic series are Silurian, followed by Devonian, Carboniferous and Permian strata. Rhyolites are most commonly represented in the series, and are partially metamorphosed into a meta-quartz-porphyry. Rhyolites are by formation subvolcanic intrusions and effusions that appeared in the Silurian, within the internal between lower Carboniferous and upper Permian and in the Permotriassic. The Paleozoic metamorphic series is placed tectonically in a region of divergent faulting. Variscan faulting axes generally trend northeast-southwest and are therefore perpendicular to the normal faulting axes of the Dinarides. Variscan tectonic activity has formed Silurian, Devonian and lower Carboniferous strata as well as those of rhyolitic masses that were intruded within these strata at that time.

Of interest to us is only a narrow region surrounding Busovača, or, to be precise, the west limb of the Busovača fault zone, that was formed in the Miocene and has the Dinaric direction (i.e. northwest-southeast). This is the region of the Variscan Zahor Anticline, composed of Silurian-Devonian chloritic-sericitic, quartz-sericitic and graphitic schists and rhyolites. Tremolitic schists are partially imbedded within this series and are metabasites by the origin.

The location itself consists of a series of a parallel quartz veins, emplaced within the Paleozoic metamorphosed sericite-phyllite schists. The schists strike southeast and dip 20° to 30° northwest. Insignificant ore mineralization is present in these schists, consisting of magnetite, pyrite, chalcopyrite and some magnetite alteration products, i.e., martite, limonite and lepidocrocite. Well-developed magnetite octahedrons up to 5 mm can be found within sericitic schists. Veins, completely or partially filled with quartz, are frequent in the series. The veins intersect the schists perpendicular to their stratigraphic plane and are north-south oriented. The walls of the lens-shaped veins dip 80° west. These walls, however, can sometimes be completely parallel and the veins there have a rectangular cross section. Some of the veins are reported to be more than 50 meters long. A few of them can also be traced on the left bank, but are mostly under the creek. The veins can be up to 1 meter in diameter. They are mainly incompletely filled, leaving enough room for the crystallization of well-developed crystals.

Ilić (1954) was of the opinion that these veins are the remnants of a sulfide orebody, swept away by erosion and leaving only quartz roots. The typical orientation of the veins, perpendicular to the schist strata, and the mineral paragenesis in them, confirm that they are in fact of the alpine-type, connected with hydrothermal crystal development (Barić, 1972). It is evident that the adularia (in this case the Ba-analog, hyalophane) is the only mineral of the alkali-feldspar series that can be present in the hydrothermal veins and that crystallizes at temperatures between 300° and 500° C. According to Divljan (1954) the temperature of formation here should have been less than 570° C.

It is also evident from the paragenesis that the hyalophane crystallized after the quartz. In the last stage of deposition the veins were filled with limonite (or ankerite later oxidized to limonite). The hydrothermal nature of the paragenesis can also be confirmed by the porosity and appearance of the rocks surrounding the veins themselves. The rock at such points is soft and brittle, because some minerals were leached out by hydrothermal fluids under elevated pressure and temperature. The color differs from that of the original unleached schist and can be almost white. There are no well-crystallized minerals near such zones, but they can be found in considerable quantities in the lower parts of the vein. Such veins must therefore be younger than the surrounding host rock. They were developed during the same orogenesis that caused the upheaval of the Alps. The African continental plate shifting toward the European continental plate caused the rise of the Central Bosnian schist mountains. Accompanying tectonic forces caused the opening and widening of the veins. As the erosion gradually swept away overlying rocks, they came slowly to the surface, where they were finally exposed by the waters of Zagradski Potok.

The absolute age of the mineral assemblage was determined on the hyalophane crystals by means of K-Ar analysis. Hyalophane was not metamorphosed and for that reason is suitable for age determination. The absolute age was determined to be around 60 ±6 million years (Barić, 1972).

Morphological structures of quartz, hyalophane and some other minerals are typical for an environment of slowly widening veins. This process causes thread (faden) crystals. The appearance of the crystals and the visible threads within them confirm the long, slow, steady widening of the veins. The final result of the vein-forming tectonic forces are the detached crystals lying freely in the veins and forming well developed "floaters." Such veins are of so-called ripe-type and are ranked among the best sources of excellent crystal specimens of all species present in the alpine-type veins.

Figure 5. **Map of the underground workings in 1991, incorporating data from D. Varićak (1971).**

MINE WORKINGS

Mining operations opened a series of more than 70 nearly parallel veins. The workings followed the veins that were visible along Zagradski Potok to a length of at least 10 meters on the surface. The workings continued after that underground, following the main veins. The rock was stable enough to allow excavation of stopes without the use of pillars. They are still stable today and show no tectonic deformation. There were originally around 80 meters of stoping along veins, of which some 50 meters were accessible during the second period of mineral collecting. Others were filled in after commercial mining had finished. The stopes were dry except in one section of about 5 meters that was constantly flooded. The stopes form something like a circle, with several off-shoots in the form of shorter prospect tunnels that were positioned in such a way that some of them intersect the veins radially. Only the minerals from the directly (axially) intersected veins and main veins were extracted during the active period, leaving, fortunately, a lot of material for later collectors in the veins to the left and right of the main stopes. The veins were filled with limonite mud full of tiny crystals and fragments of broken crystals. Not all of them were filled with crystals, at least not along the whole length, because of hydrothermal leaching.

Three methods were used for collecting mineral specimens at this site during the non-commercial collecting period. The first method utilized heavy tools. The rock was chiseled away and the vein was opened. This was the best method, producing superb undamaged specimens. It could seldom be used because only limited sections of the stopes hosted parallel vein extensions. The best two finds were made in this way. It is worth mentioning that this technique produces a lot of rubble which can completely fill the stope unless it is carried out. Hammering in the confined spaces, where one cannot even stand up straight, is extremely exhausting.

Another widely used technique was the *scraping* of crystals from veins that perpendicularly intersected the stopes. A variety of hooks were used; the longest were more than 3 meters in length. It was a fairly good technique unless there were obstructions or narrowings inside the veins (boudinages) that hampered the work. It was also surprising that the hyalophane crystals in particular were usually as wide as the vein itself, causing a lot of problems during their extraction. It was sometimes frustrating seeing good crystals that could not be reached by any means. The consequence of this technique was normally some damage to the crystals, especially on their edges. But some "floaters" were collected in superb condition. The fact that the veins are of the ripe-type explains the relative lack of matrix specimens. They were normally recovered only when the first technique was used. Large hyalophane matrix specimens are therefore extremely rare. In spite of the facts mentioned, all accessible veins have been completely worked out.

The "bucket" technique was the last, almost desperate, way of collecting at this location. It was widely used in the last few years before the outbreak of war. Shoveling of the dump material into the buckets and its transportation out of the pits was not very successful, but at least some good undamaged miniatures were recovered in this way.

HYALOPHANE

Hyalophane, (K,Ba)Al(Si,Al)Si_2O_8, is the barium analog of orthoclase and intermediate between orthoclase and celsian. Its name was derived from the Greek words *hialos* = glass and *phainethai* = to appear (Strübel and Zimmer, 1991). The results of chemical analyses of hyalophane from Zagradski Potok, given by Barić (1972), Gay and Roy (1968), and Roy (1965) show that it is composed of 35–41 mole % celsian, 38–49 mole % orthoclase, 14–21 mole % albite and 1–2 mole % anorthite. As hyalophane is by definition orthoclase with more than 5 mole % of the celsian component, it can be concluded that in this case a true intermediate link between orthoclase and celsian is present.

The quality, quantity and dimensions of the hyalophane specimens found at Zagradski Potok exceed all other localities worldwide. Exceptionally well developed crystals reach dimensions of over 20 cm; and crystals in the 5–10 cm range are not unusual here. Crystal faces have excellent brilliance and luster. Gemmy sections of some crystals are suitable for cutting. Many crystals are of a dark gray or green color, and are full of hematite inclusions. They often include oxidized ankerite crystals that have been incorporated during hyalophane crystal growth. Rutile needles are found only rarely as inclusions close to the crystal surfaces.

Hyalophane crystals normally overgrow quartz crystals, confirming that they grew later. Quartz crystals, on the other hand, can sometimes be found imbedded in hyalophane crystals. In this case the already formed crystals had fallen down onto the hyalophane surfaces where they were afterwards overgrown and thus incorporated within the hyalophane crystals.

Hyalophanes from Zagradski Potok are always slightly yellow in color due to numerous cracks filled with limonite. Crystals have been found everywhere in the veins, mostly in the form of floaters. Matrix specimens are very rare. Combinations with dark brown ankerite matrix and quartz crystals can be ranked among the most sought after specimens of this alpine-type paragenesis.

***Figure 6.* Hyalophane (001)- Manebach-Baveno combination twin (fourling), 6.1 x 6.9 cm, from Zagradski Potok near Busovača in Bosnia and Hercegovina. M. Žorž specimen; photo by Dragan Arrigler.**

Complex Manebach-Baveno combination twins (referred to here as "fourlings") are the largest hyalophane specimens ever found. The biggest is a combination of many fourlings that were intergrown after they had been detached from the vein walls. The fourlings on this specimen reach a maximum size of about 22 cm in diameter, whereas the whole specimen is about 35 cm. A second large fourling is about 20 cm in diameter. A photo of this specimen was published in *Lapis* (Zebec and Šoufek, 1986). However, fourlings over 7 cm in diameter are very rare, especially those which are completely developed. Fourlings under 5 cm are not rare. The most abundant are those with dimensions around 1 or 2 cm. There were hundreds of them in some veins.

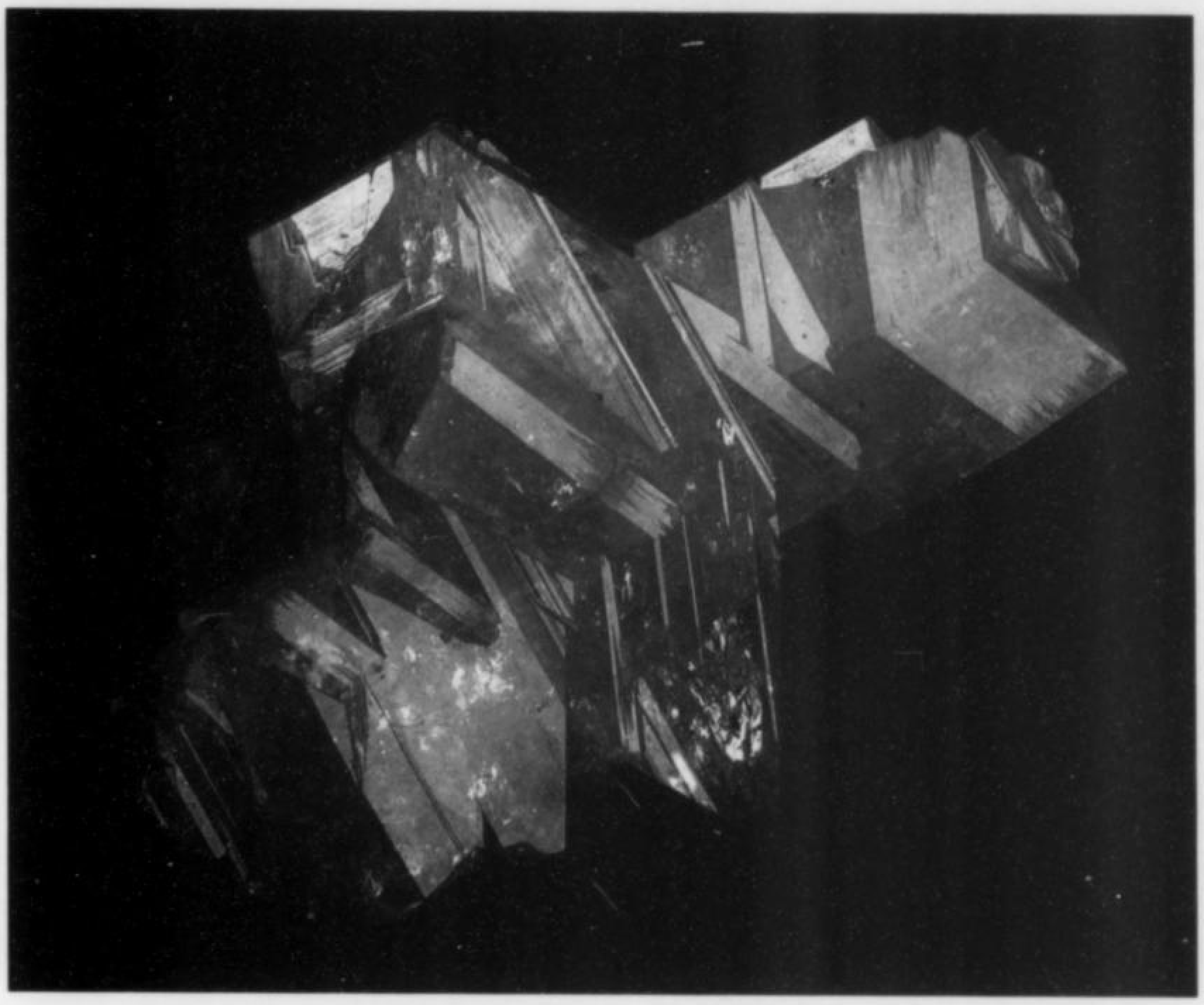

***Figure 7.* Hyalophane (001)-($\bar{0}\bar{1}\bar{0}$)-double Manebach-Baveno combination twin (fourling) with smoky quartz, 6.6 cm, from Zagradski Potok near Busovača in Bosnia and Hercegovina. The primary (001)-Manebach-Baveno combination twin is on the left-hand side. Gregor Kobler specimen; photo by Dragan Arrigler.**

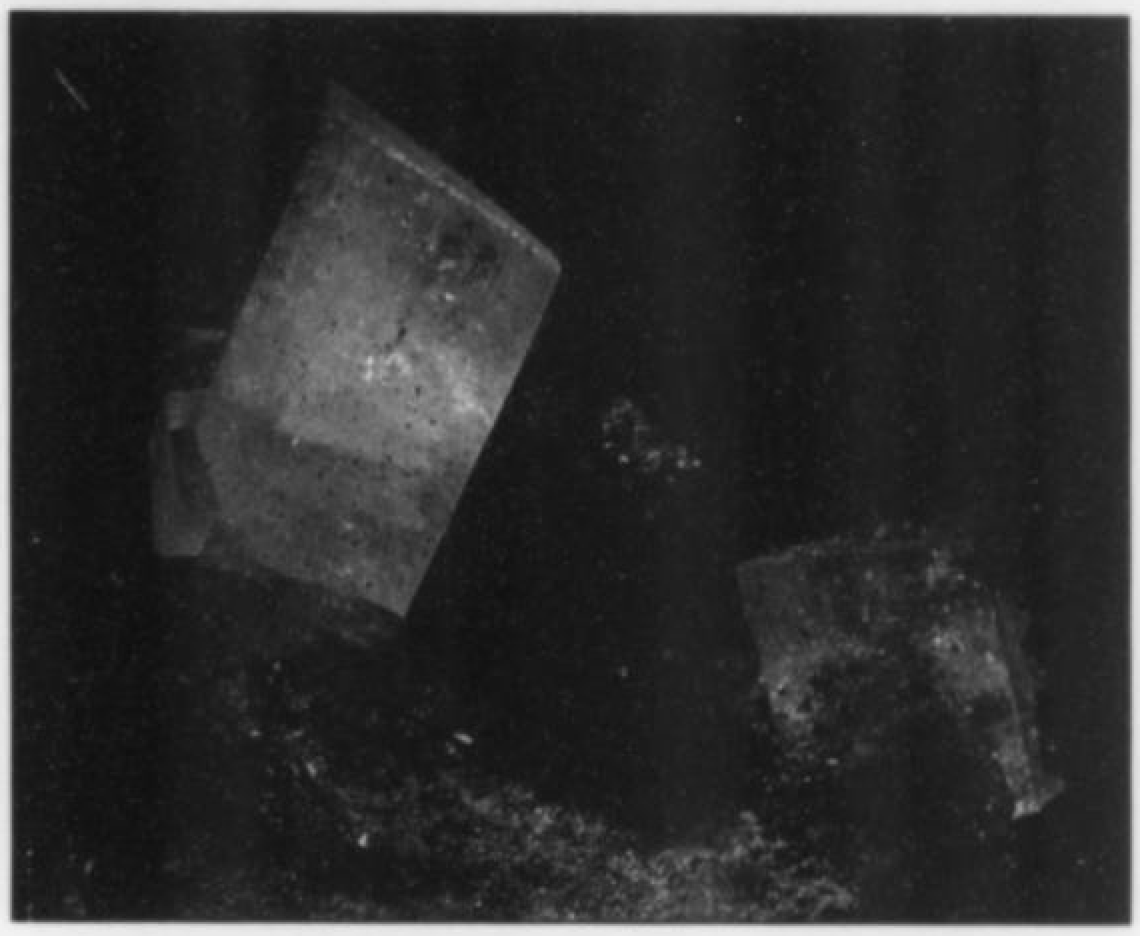

***Figure 8.* Hyalophane crystals up to 1.9 cm in length on matrix, covered with rutile and oxidized ankerite crystals. M. Žorž specimen and photo.**

A unique habit at Zagradski Potok is the double fourlings. Extremely complex twins can reach up to 15 cm in length. They are always found in the form of floaters, with the undeveloped side touching the matrix. Only a few symmetrical, well-developed, double fourlings have been found, whereas those with only one side well developed are not especially rare. All fourlings can be divided into the four different types that will be described further in the text. Fourlings usually have dimensions that correspond exactly to the width of the vein. This means that they were quickly deformed or broken if the vein diameter contracted or if the veins themselves were deformed in any way. Many broken and deformed fourlings that were afterwards rehealed have been found.

Single crystals are not as interesting, unless they are not elongated in any particular direction. The resulting parallel growths make very nice specimens. Single crystals are scattered over the matrix along with other minerals. Their dimension reach up to 2 cm in length and exceptionally up to 6 cm. Parallel growths, however, can reach considerable dimensions. Curved and twisted aggregates are common. It can be concluded that the growth of the fourlings occurred at a faster rate than that of the single crystals (which were probably even dissolved during the growth of the fourlings), and that their nucleation was favored in comparison to that of the single crystals. The majority of the single crystals were formed at the end of the crystallization sequence, mostly from broken crystal particles.

Manebach twins have been found in crystals up to 10 cm in length, but are quite rare. The habit of the individuals comprising the twins is interesting. The single crystals are longer in the *c*-axis direction than in the *b*-axis direction, in a ratio of about 12:1, resulting in a prismatic habit. Manebach twins have a ratio around 11:3 and are therefore flattened with short prism faces. Many Manebach twins can be observed on the fourlings but their origin is different (and will be described below under the different types of fourlings).

Baveno twins are rare as independent crystals (Barić, 1972). They are probably only overgrowth twins that form on the fourlings.

Zebec (1987/88) mentioned Cunnersdorf twins that are rarely described in the literature (Smith, 1974), but it is questionable

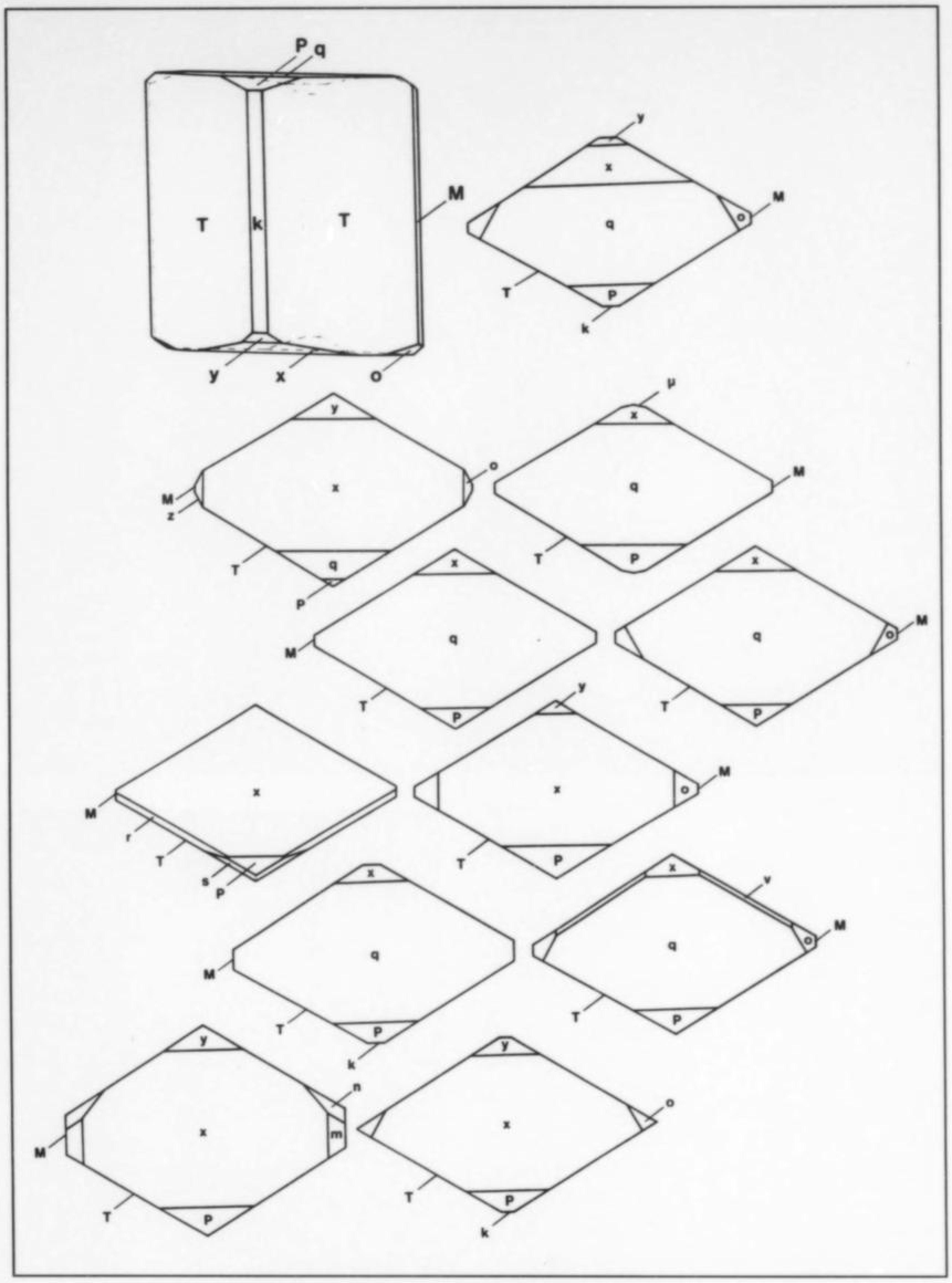

Figure 9. **Single hyalophane crystals (front view and terminations);** ***M*{010}, *P*{001}, *T*{110}, *x*{$\bar{1}$01}, *y*{$\bar{2}$01}, *q*{$\bar{2}$03}, *o*{$\bar{1}$11}, *z*{130}, *k*{100}, *μ*{310}, *s*{111}, *r*{011}, *m*{$\bar{2}$13}, *n*{$\bar{3}$23}, *v*{$\bar{3}$13}. Designed by S. Rečnik with Shape.**

whether they really exist here. All crystals that have been ascribed to this twinning type have proven to be Manebach twins.

The most unusual occurrence at Zagradski Potok is the presence of hyalophane Carlsbad twins, first mentioned by Zebec in 1984. They are extremely rare; only about 30 well-developed Carlsbad twins have been found. They look just like normal single crystals but with two distinguishable (001) cleavages at right angles to (010) but having opposite slopes relative to their common *c*-axis. An obvious twinning suture is present on typically alternating (001) and ($\bar{1}$01) termination faces. The result of this alternation is a jagged apex perpendicular to the *c*-axis. For that reason such crystals show pseudorhombohedral symmetry. They are typically elongated along the *c*-axis and sometimes narrow in step-like structures toward the terminating (001) and ($\bar{1}$01) faces. They are almost always transparent at the edges parallel to the (010) plane and are milky along the *c*-axis.

Hyalophane crystals are quite rich in crystallographic forms. Barić (1972) observed 12 different forms. Zebec (1987/88) added some other forms with higher {hkl} indices. The most common are: *p*{001}, *M*{010}, *k*{100}, *T*{110}, *x*{$\bar{1}$01}, *y*{$\bar{2}$01}, *o*{$\bar{1}$11}, *z*{130}, *u*{$\bar{2}$21}, *μ*{310} and *q*{$\bar{2}$03}. Some additional crystallographic forms were observed and reconstructed by means of the "Shape" program, i.e. *m*{$\bar{2}$13}, *n*{$\bar{3}$23}, *r*{011} and *s*{111} (Žorž, 1993). The most highly developed forms are: *T*, *p* and *x*, which together determine the overall crystal habit. Form *M* is lustrous, unstriated, and narrow or missing on single crystals, but can be

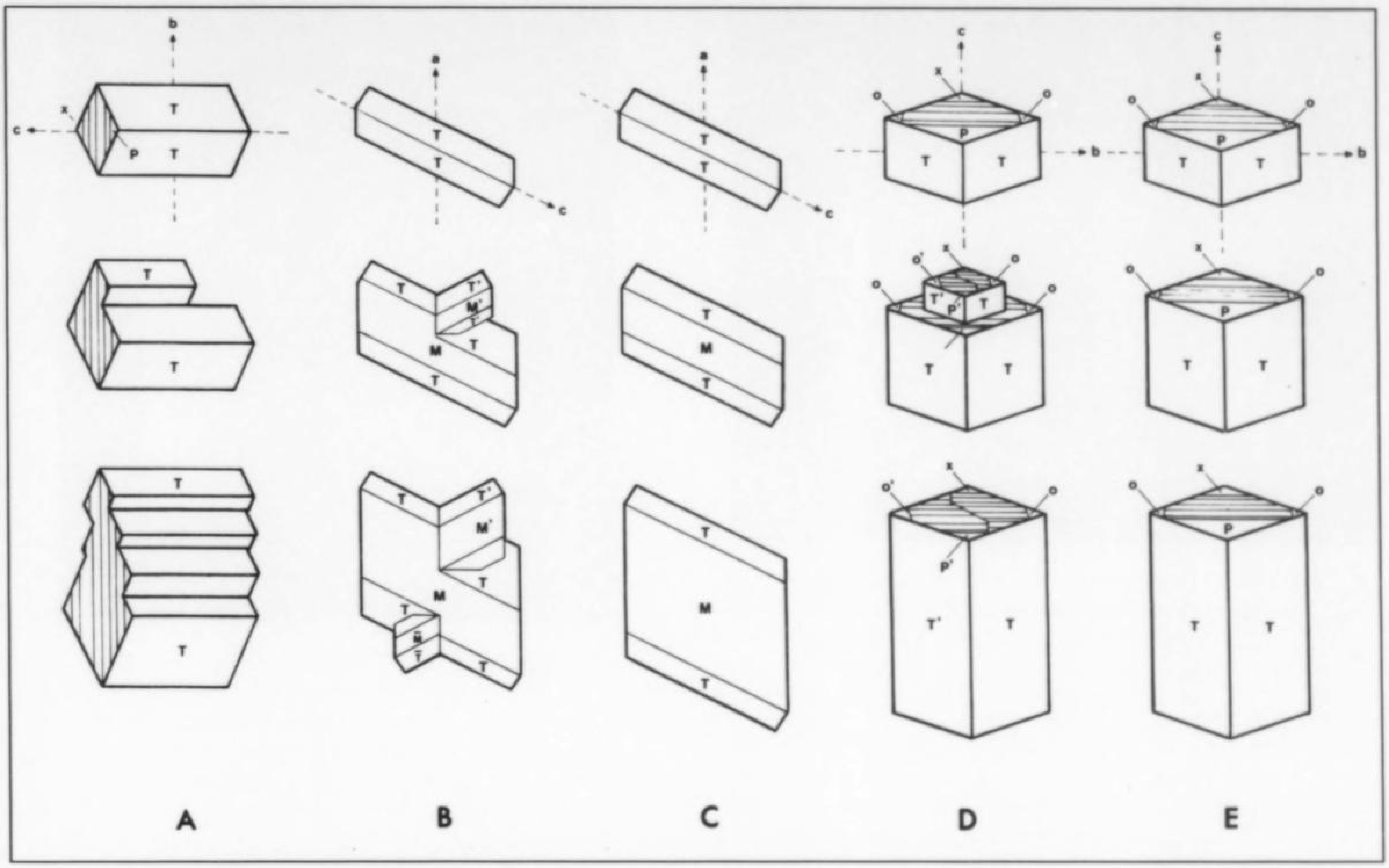

Figure 10. **Typical hyalophane elongations and twinnings showing the results of stretching between the fissure walls. (A) Elongation of a single hyalophane crystal in the *b*-axis direction; formation of parallel growths. (B) Elongation of a hyalophane crystal in the direction of the *a*-axis; formation and inversion of the Manebach twin. (C) Elongation of a hyalophane crystal in the direction of the *a*-axis; formation of an elongated crystal of so-called "Fibbia" habits. (D) Elongation of a hyalophane crystal in the *c*-axis direction; formation of a Carlsbad twin. (E) Elongation of a hyalophane crystal in the *c*-axis direction; formation of an elongated crystal.**

found extremely well-developed and always etched or striated on the fourlings. Form *o* is characteristic of the Carlsbad twins and is of diagnostic importance in their determination. Form μ is found at the apex structure of the fourlings. All faces are shiny except ($\bar{2}21$), which is dull and has a layered appearance. Also interesting are the special compensation figures (actually vicinal faces) which are present on the fourling ($\bar{1}01$) and (001) faces. They take the form of flat pseudohexagonal pyramids. Etch figures on (001) and ($\bar{1}01$) faces are also very characteristic of the hyalophane crystals from Zagradski Potok, in addition to those mentioned on the (010) faces.

Morphogenesis

All hyalophane crystals show some morphological aspects which can be explained by the stretching process and faden formation (Žorž, 1993). Hyalophane possesses excellent cleavage parallel to the (001) face, and less pronounced cleavage parallel to the (010) face. For that reason hyalophane crystals are typically penetrated by a network of visible cleavage planes, which made the faden invisible. Only a few specimens with visible faden have been found.

The elongation direction of a hyalophane crystal can be described as a vector: $\mathbf{E} = \mathbf{xa} + \mathbf{yb} + \mathbf{zc}$, where **xa** is the component of the vector in the *a*-axis direction, and likewise for the other two components. If two components are equal to zero, the elongation leads in the direction of only one crystallographic axis. If one component equals zero, the translation of a particular plane occurs, which results in parallel growth.

Some extreme elongation examples are: $\mathbf{E} = \mathbf{xa}$, $\mathbf{yb} = \mathbf{zc} = \mathbf{0}$, translation in the direction of the *a*-axis; formation of elongated crystals, formation and inversion of Manebach twins; $\mathbf{E} = \mathbf{zc}$, $\mathbf{xa} = \mathbf{xb} = \mathbf{0}$, translation in the direction of the *c*-axis; formation of elongated crystals, formation of Carlsbad twins; and $\mathbf{E} = \mathbf{yb}$, $\mathbf{xa} = \mathbf{zc} = \mathbf{0}$, translation in the *b*-axis direction, formation of elongated crystals in parallel growth.

If component **xa** is equal to zero, then the (010) face is narrow or missing. The typical parallel striations on the (010) faces are thus the result of infinitesimal stretching, the breaking and rehealing of the crystal between the fissure walls. These faces are therefore prone to etching and are frequently deeply etched.

All orientations of the vector **E** are possible, and thus so are all elongated structures. The rotation of this vector results in the twisted and curved structures that are frequently found at Zagradski Potok.

Manebach Twins

Translation in the *a*-axis direction yields the so-called "Fibbia" habit, with extremely well-developed (010) faces. This habit is rare here. Manebach twinning is more common, where a crystal is broken along the (001) plane. The (001) face is thus exposed. Such a crystal can be twinned with another two-crystal individual. In this way a "penetration" Manebach twin is formed, but actually it consists of one connecting individuals and two twinned individuals. This process is well manifested on (010) faces, which have

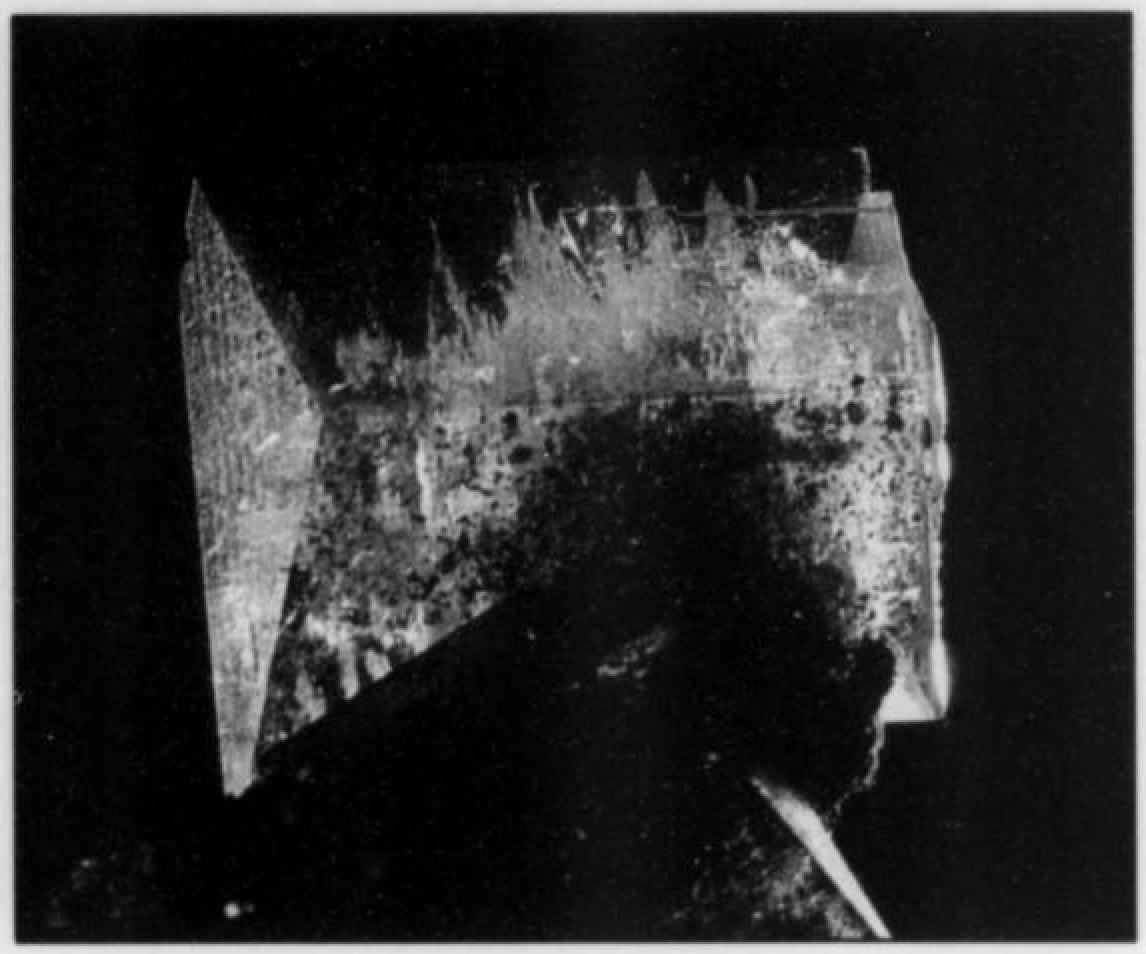

Figure 11. **Single hyalophane crystal, 1.7 cm, elongated in the direction of the *b*-axis. Cleavages along (001) can be seen, as well as hematite inclusions. M. Žorž specimen and photo.**

Figure 12. **R-(001)-Carlsbad hyalophane twin, 2.6 cm, with oxidized ankerite crystals. Note the typical opposing cleavages along (001) of both twinned individuals. Lower part of the crystal is not twinned; note uniform cleavage along (001) throughout the crystal. M. Žorž specimen and photo.**

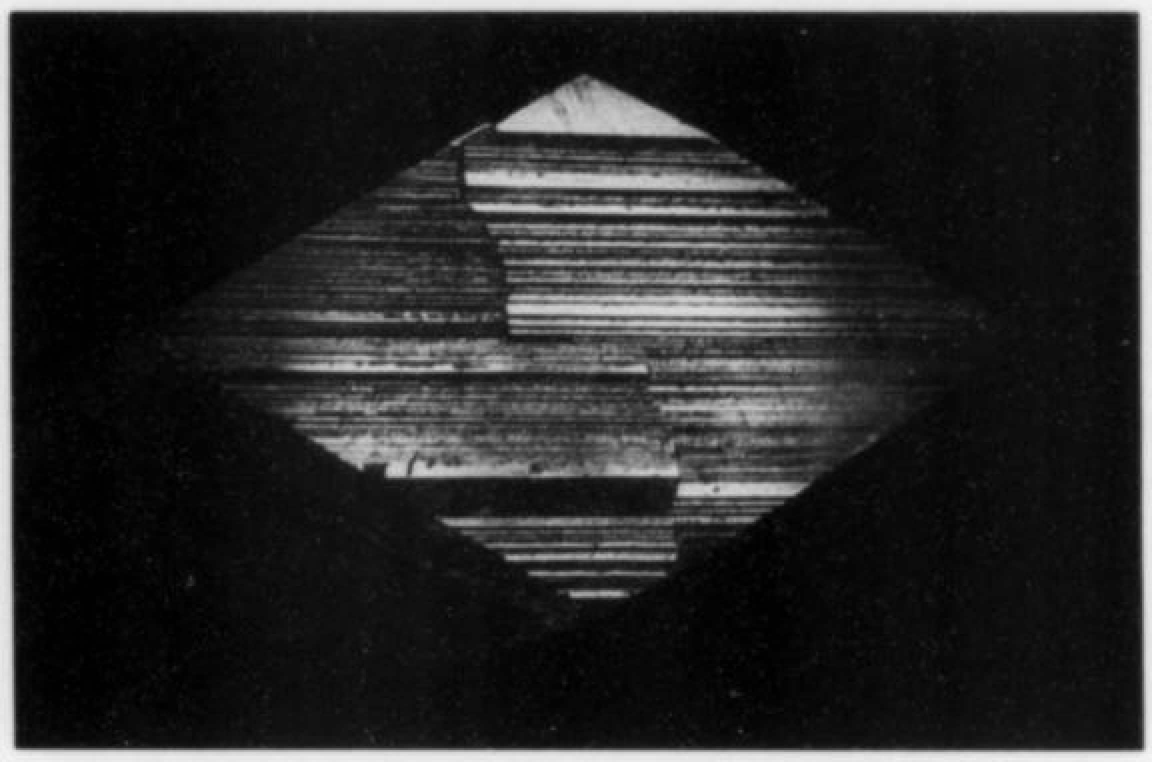

Figure 13. **Top view of the R-(001)-Carlsbad hyalophane twin from the previous Figure. A typical S-shaped twinning suture can be seen, as well as alternating (001) and $(\bar{1}01)$ faces. Note the position of the terminating (001) faces of each twinned individual. M. Žorž specimen and photo.**

typical striations and twinning sutures. This is in fact the inversion of the Manebach twin, which plays an important role in the formation of double fourlings. Manebach twin formation depends upon growth conditions during the translation process, and can take a relatively long time. In this case the (010) face of the primary individual is broad. The process can be observed only on the secondary Manebach fourlings that are present on the original fourlings. "Real natural" twins, which have not undergone the translation process, are found in the already mentioned forms with narrow or absent (010) faces.

Carlsbad Twins

Translation in the *c*-axis direction results in elongation of the crystal and formation of a Carlsbad twin. In this case the hyalophane crystal is broken along the (010) plane; the (010) face is exposed, and a Carlsbad twin can be formed. The proof of this Carlsbad twin process can be seen in the specimens that are not twinned in their lower parts, but at a particular point along the crystal the Carlsbad twinning begins to form. This is demonstrated by a cleavage that runs throughout the lower part of the crystal and is reversed in its upper part, where two reversed cleavages are observed.

Primary Structure of Carlsbad Twins

Both left and right orientations of two individuals forming a Carlsbad twin are possible. Both orientations are present equally on the Zagradski Potok Carlsbad twins. They can easily be recognized because of the two distinctive cleavages running in opposite directions from the (010) plane, and the typical orientations of $(\bar{1}11)$ faces.

Secondary Structure of Carlsbad Twins

A distinction can be made between penetration and non-penetrating Carlsbad twins, and both types have been found. Non-penetrating twins are formed in such a way that both twinned individuals can be easily recognized by the straight suture on the alternating top (001) and $(\bar{1}01)$ faces. Both individuals are equally developed on each side of the (010) plane and are easily distinguishable. Penetration twins, however, can be mistaken for single crystals. They are sometimes twinned so perfectly that both individuals merge to make what appears to be a perfectly developed single crystal. The most distinguishable cleavage as well as the uneven twinning suture on alternating (001) and $(\bar{1}01)$ faces are diagnostic.

Tertiary Structure of Carlsbad Twins

This structure is characterized by the appearance and positions of (001) and $(\bar{1}01)$ faces on both individuals, but only in the case of non-penetrating twins. Left and right combinations (not enantiomorphism) are possible. The situation is different with penetration twins. Twinned crystals develop in such a way that only (001) or $(\bar{1}01)$ faces of the twinned individuals are present. This fact

Figure 14. **A (010)-hyalophane fourling, 2.6 cm. Secondary Manebach twins are centro-symmetrical aligned. M. Žorž collection and photo.**

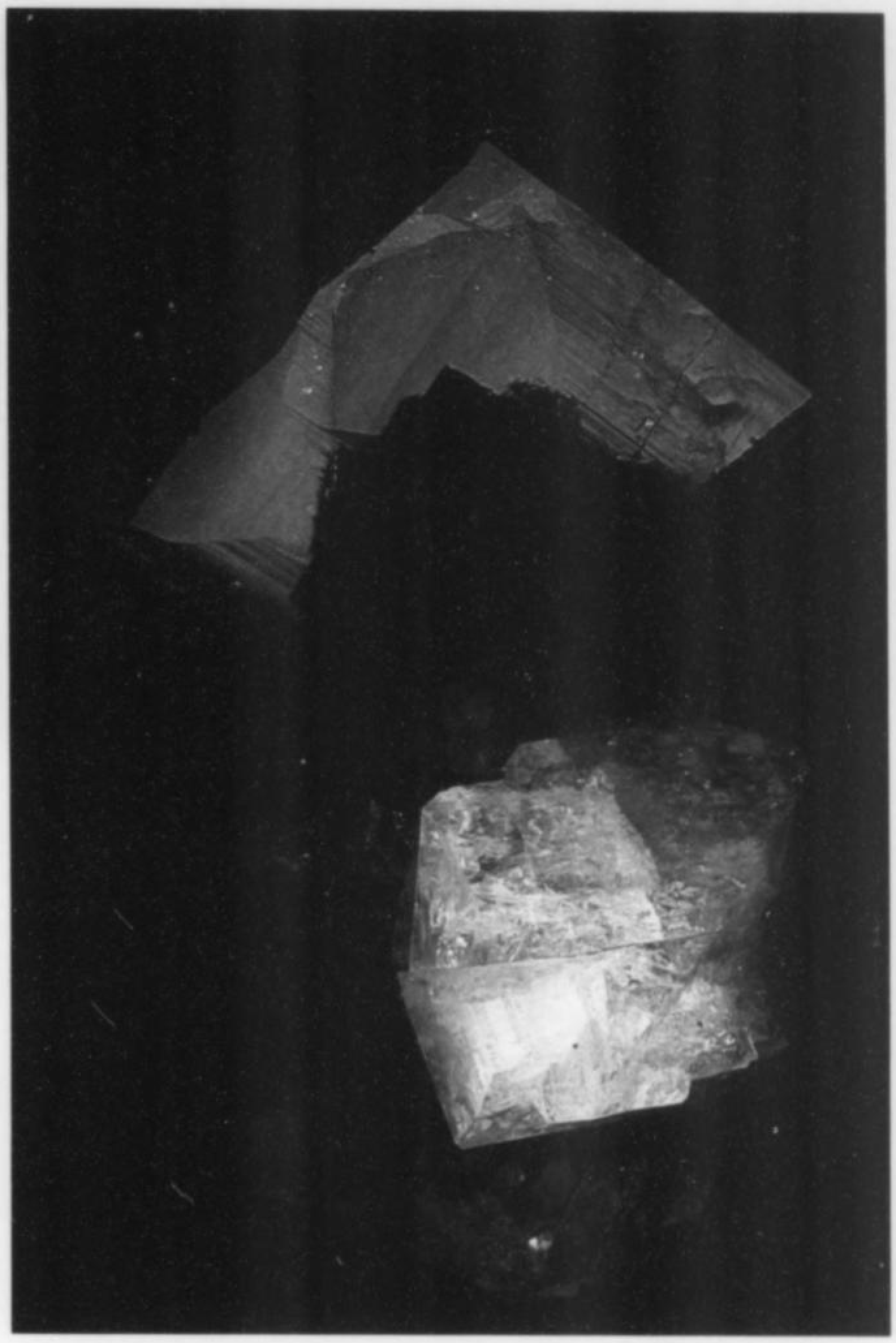

Figure 15. **A (010)-hyalophane fourling on matrix, 9.5 cm. An over-developed (110) face of another (010)-fourling with typical surface features can be seen as well. Both crystals are tectonically cracked. M. Žorž specimen and photo.**

increases the number of possible combinations by four, i.e. L-(001)-twin and L-$(\bar{1}01)'$-twin as well as their right-hand analogs. Six combinations are possible in single Carlsbad twins. All of these combinations have been found in about equal numbers.

Double Carlsbad Twins

It is quite possible that the stretching process can be repeated on the other side of an already twinned crystal, as occurs in the case of double fourlings, and therefore double Carlsbad twins can be formed. The ends of these twins have different primary structures; one end shows the left-hand structure and the other the right-hand structure. Taking into consideration secondary and tertiary structures, nine combinations are possible. Out of these, six are penetration twins, two are mixed and one is non-penetrating. The probability of a Carlsbad twin forming is low at the Zagradski Potok site, and therefore formation of a double twin even less likely. One double non-penetration Carlsbad twin has been found so far.

Manebach-Baveno Fourlings

Fourlings constitute the largest part of the whole mass of hyalophane found at Zagradski Potok. The presence of the Manebach twins around the fourlings, and their gradual narrowing in the direction of a common fourfold twinning *a*-axis, results in a pagoda-like aspect. The fourlings are the result of two twinnings that developed simultaneously, i.e. Baveno and Manebach twinning, producing a structure where all four *a*-axes coincide in a common fourfold *a*-axis. Normals to (001) and (021) hyalophane faces thus close at an angle of 44°50′, and normals to (010) and (021) faces at an angle of 45°10′ (Barić, 1972). This twinning can be described as two Manebach twins that are twinned according to Baveno law into a fourling.

Primary Structure of Fourlings

Few people realize that *two* orientations of the two Manebach individuals prior to their twinning, are possible. The result is two types of fourlings. Some authors (Grammaccioli, 1975) use the terms "Manebach-Baveno" and "Baveno-Baveno" fourling, whereas others are not aware of the two types (Barić, 1972; Linck, 1923; Philipsborn, 1967; Ramdohr and Strunz, 1978; Roesler, 1980; Schwarzman, 1977; and Weibel, 1990). In addition to other features, these two fourlings are distinguished by the faces whose normals are perpendicular to the common fourfold twinning *a*-axis, i.e. (010) and (001). Let the first type be defined as a *(010)-Manebach-Baveno* combination twin or a *(010)-fourling*, and the second type as a *(001)-Manebach-Baveno* combination twin or a

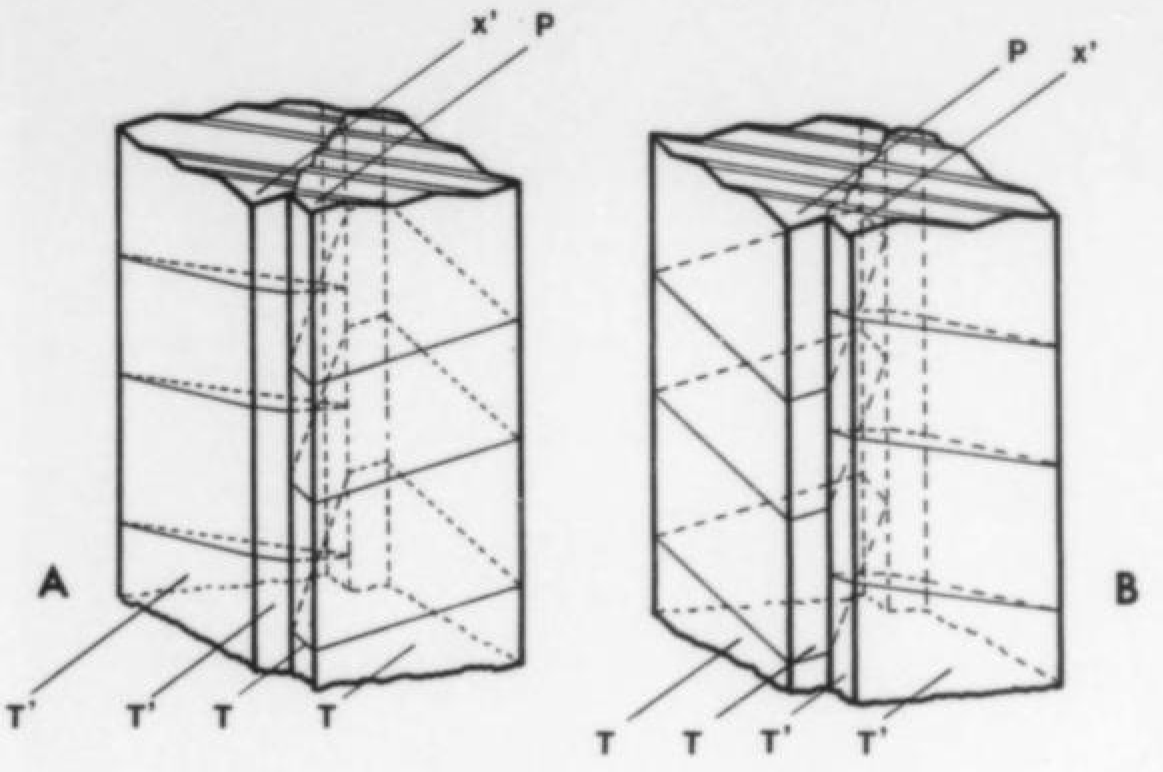

Figure 16. **Non-penetrating Carlsbad twins. (A), L-Carlsbad twin and (B), R-Carlsbad twin. Modified after V. Zebec (1987/88).**

(001)-fourling. It is evident that both fourlings are twinned according to both the Manebach and Baveno laws, acting simultaneously, and also that the different halves of the two Manebach twins are twinned into a fourling according to the Baveno law. The (010) and (001) faces have a significant influence on the morphology of fourlings.

Secondary Structure of Fourlings

Typical of both fourling types are secondary Manebach twins positioned around the fourlings. These positions are different, and are diagnostically important for the determination of particular fourling types.

(1.) (010)-Fourlings. This type of fourling is present in crystals up to several centimeters, which are combinations of alternating and narrowing *M, T, P, x, d* and *z* forms. The neighboring secondary Manebach twins can sometimes be twinned into a Baveno twin, forming a secondary (010)-fourling. The (010) faces are separated from other secondary Manebach twins by (001) and $(\bar{1}01)$ faces, resulting in a shape where single Manebach twins protrude out of (001) and $(\bar{1}01)$ faces. This type of fourling is relatively "closed." The distribution of the aforementioned secondary Manebach twins is uneven on the four fourling sides. All secondary Manebach twins are symmetrically intersected along their twinning (001) planes by two fourling planes of symmetry. Each fourling, regardless of its type, has four symmetry planes that are parallel with its common four-fold *a*-axis. Two of these planes are parallel with the {001} and {010} faces of the fourling. The other two symmetry planes are identical to the Baveno twin planes {021}. The first two of these planes are discussed later in the text as the fourling symmetry planes. This is clearly visible on the striated Manebach twin faces whose junctions make a visible twinning suture along their (010) twinning planes. This is also the direction of the fourling cleavage. A (001) face is always well-developed and striated. It sometimes stretches over the entire side of the fourling, but never on all sides simultaneously. This type of fourling ends in a conical apex structure. The apex is rarely perfectly formed because of the presence of secondary Manebach twins that also contribute to its formation.

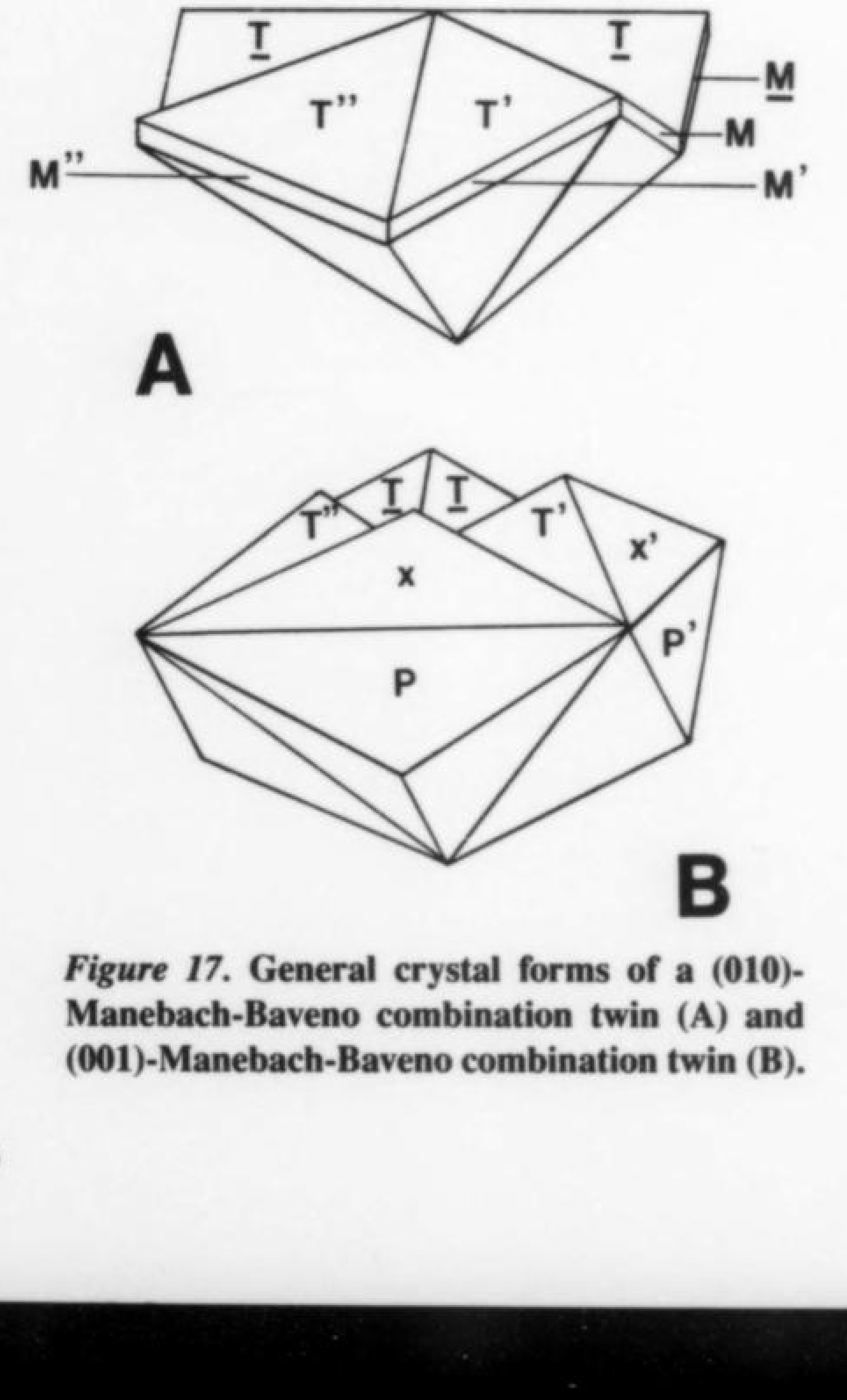

Figure 17. **General crystal forms of a (010)-Manebach-Baveno combination twin (A) and (001)-Manebach-Baveno combination twin (B).**

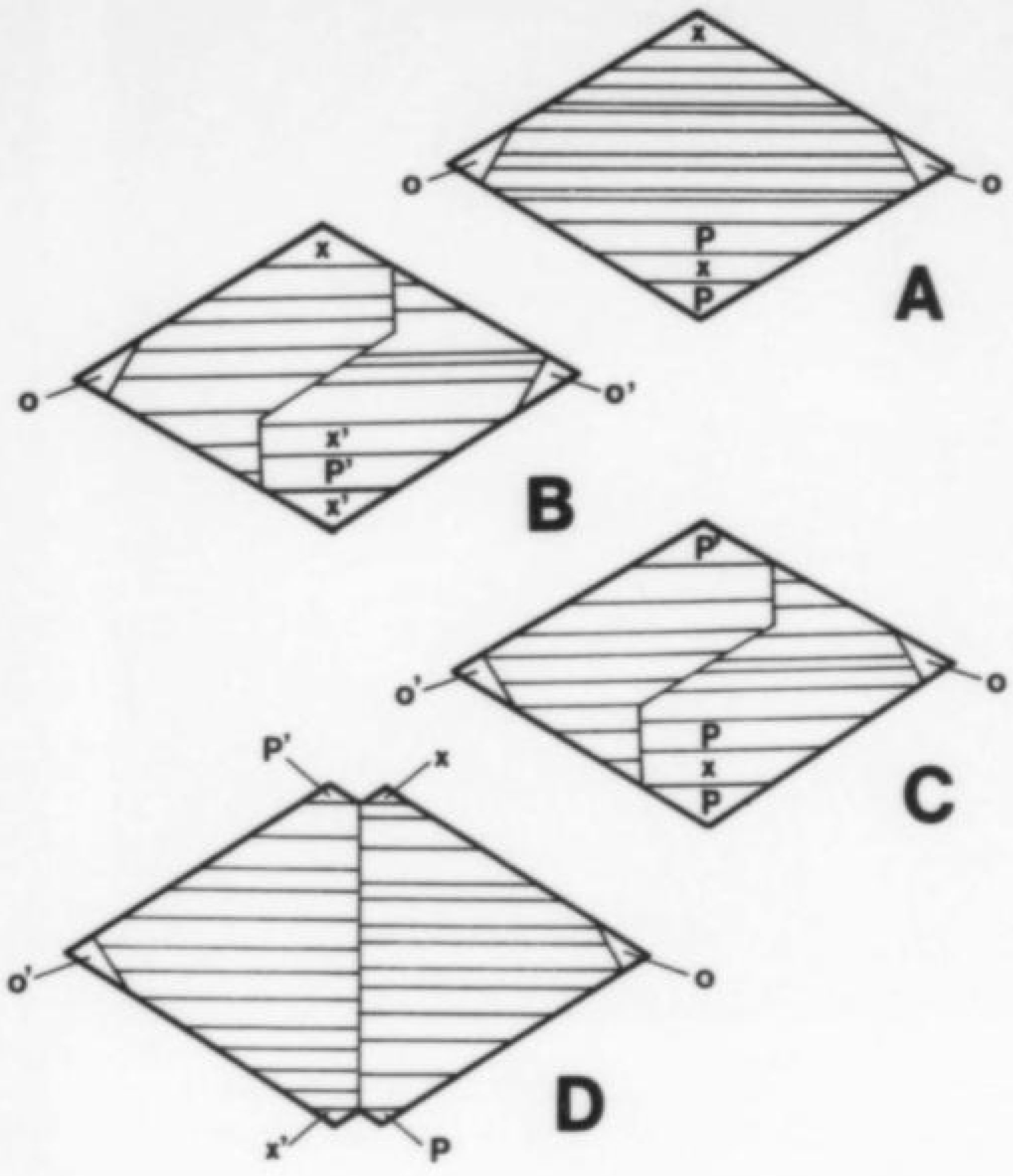

Figure 18. **Terminations of different Carlsbad twin types. Single crystal (A), R-($\bar{1}$01)′-penetration twin (B), L-(001)-penetration twin (C) and L-non-penetrating Carlsbad twin (D).**

Such morphology can be described by the translation of this fourling in the direction of its common fourfold axis. The fourling is broken and rehealed (as described under quartz crystals). Two (001) Manebach twinning planes intersect the fourling parallel to its common *a*-axis, and these two planes, the (001) and (010), are at the same time two out of the four planes of fourling symmetry. The secondary Manebach twin can be formed at the point where the crystal is broken in the (001) twinning plane. This secondary Manebach twin grows outwards from that point in the secondary phase. It becomes more and more developed with (001) and $(\bar{1}01)$ faces. These faces are then developed to the extent where they

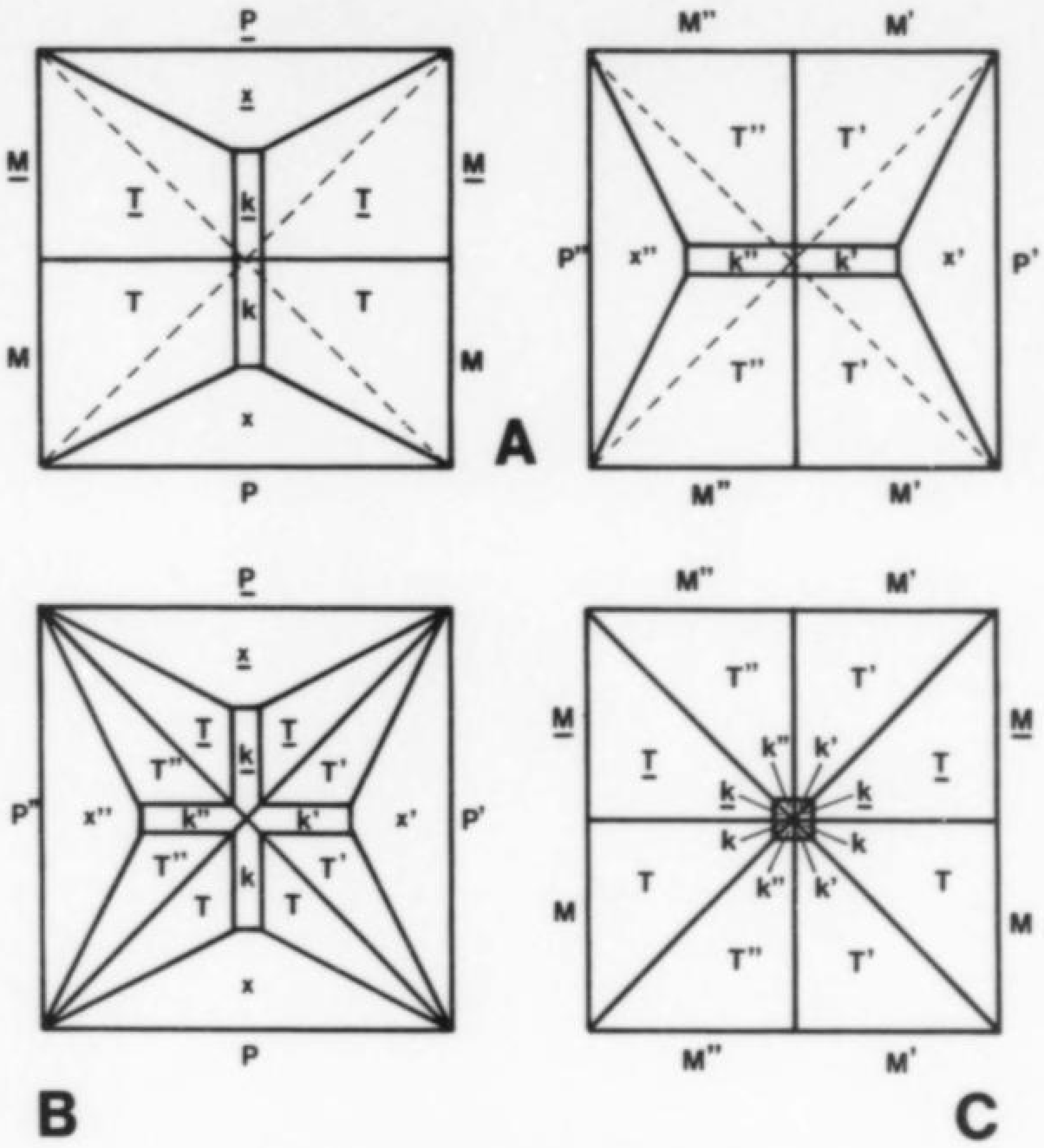

Figure 19. **Positions of particular Manebach twins prior to their twinning according to the Baveno law (A). Terminations of the (001)-Manebach-Baveno combination twin (B) and (010)-Manebach-Baveno combination twin (C).**

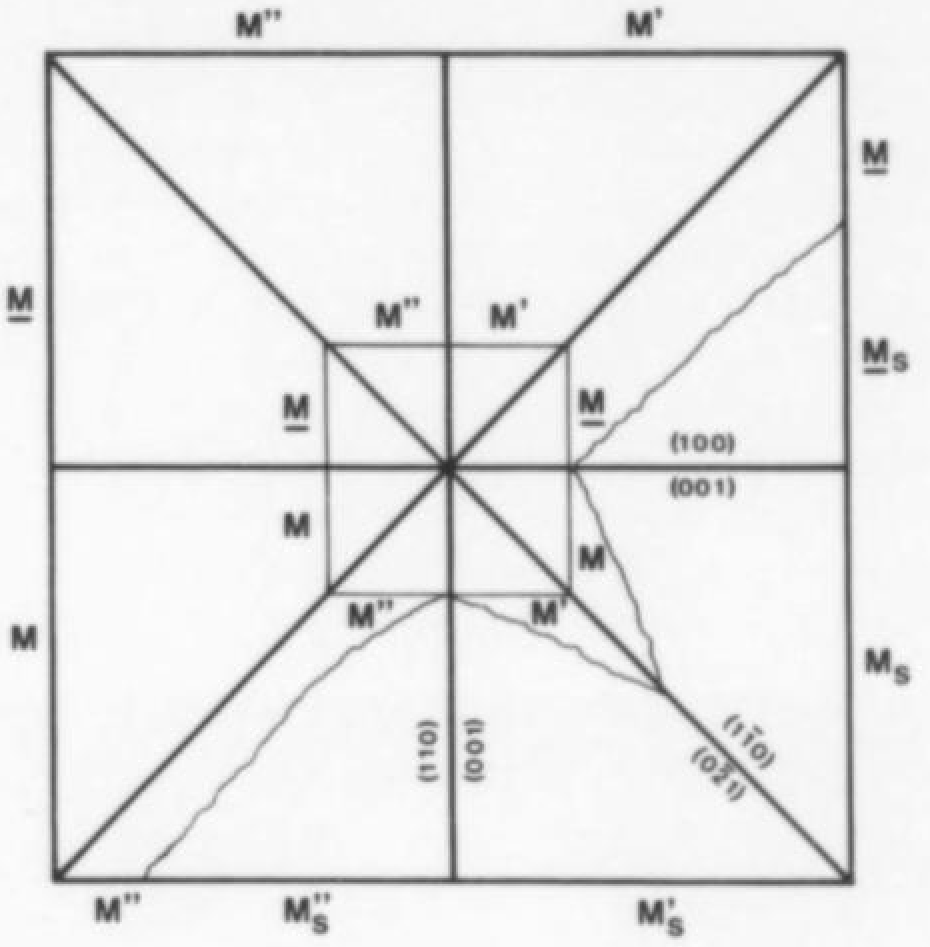

Figure 20. **Drawing of a (010)-Manebach-Baveno combination twin (fourling) cross-section normal to four-fold *a*-axis, with the formation of secondary Manebach twins. Index *s* denotes secondary faces.**

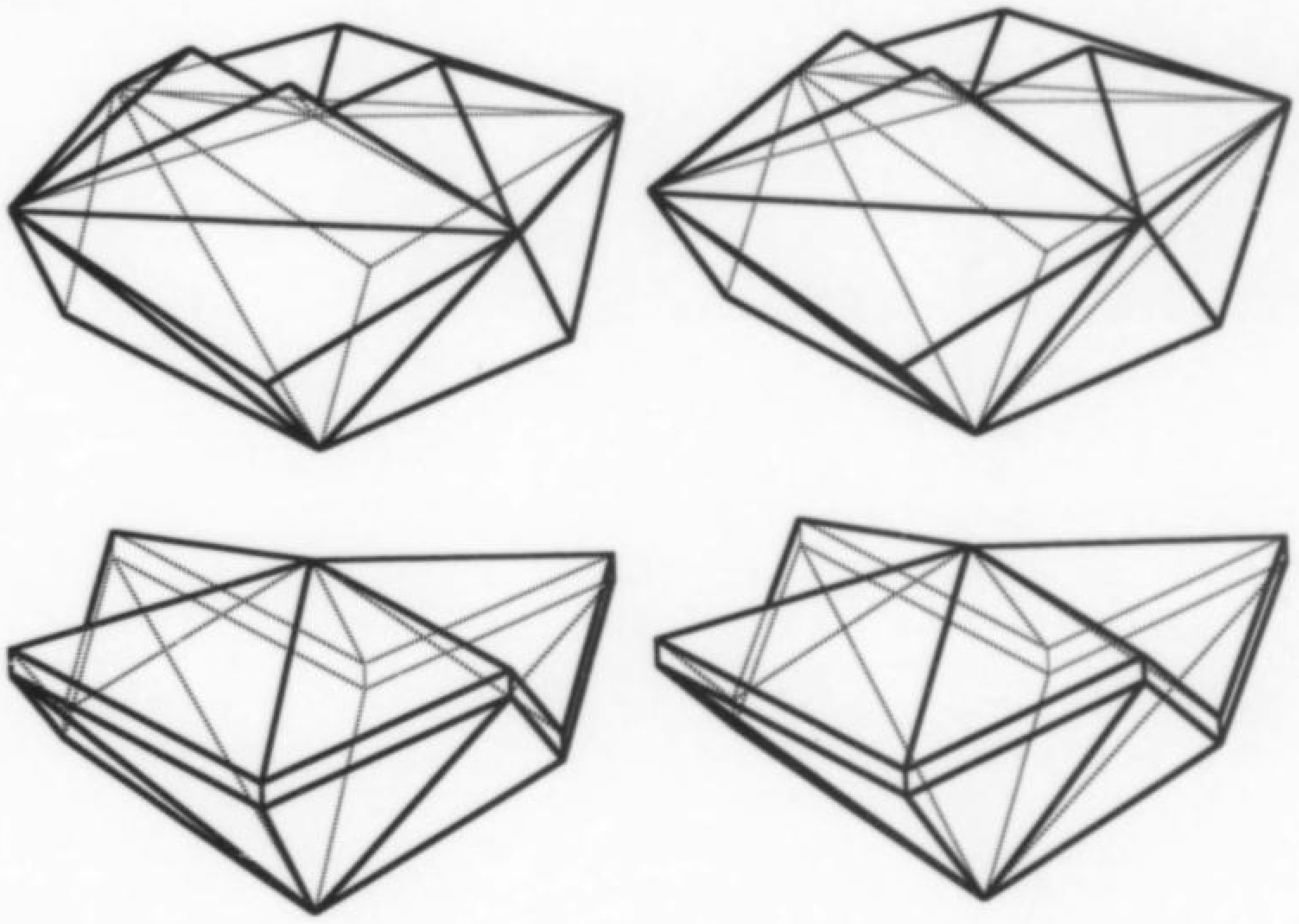

Figure 21. **Stereopair drawing of a (001)-Manebach-Baveno combination twin (top) and (010)-Manebach-Baveno combination twin (courtesy of R. P. Richards).**

completely overgrow the faden, thus producing a fourling with well-developed (001) and ($\bar{1}$01) faces that are protruded randomly by a primary (010)-fourling faden structure, i.e. the (010) faces.

The Manebach twinning around a broken faden can begin at any time, but this does not necessarily occur on all four sides simultaneously. As the faden grows, more secondary Manebach twins are formed. The lower and older individuals have more time to develop than the upper and younger ones, therefore a structure with a conical pagoda-like shape is developed. The growth of the secondary Manebach twin, as well as the outward growth of the faden, is spatially limited because all of them grow simultaneously outwards around the faden, thus encountering each other sooner or later. The whole structure of such a crystal is held together by a common faden, as well as by penetration of certain secondary Manebach twins. This structure can be compared to that of a pine cone where particular scales grow from a common kernel.

(2.) (001)-Fourlings. These fourlings are the largest. They are not always square in cross-section (perpendicular to their common fourfold *a*-axis), but are usually more or less rectangular. The most common forms are: *M, P, T, x, y, o, z, d, μ* and *k*. A typical concave apex structure is formed on the top of such a fourling. It is sometimes perfectly developed, but usually not, because of the secondary Manebach twins that also contribute to its formation. Diameters of the apex hollows depend on the dimensions of the fourling itself as well as on growth conditions. They can reach up to 8 cm in size. The secondary Manebach twins are, in comparison to those on (010)-fourlings, positioned equidistantly to the left and right of the (010) and (100) fourling planes of symmetry. The distance between the (010) twinning planes of the secondary Manebach twins on one fourling side is more or less constant and is approximately equal to the apex hollow diameter. The distribution of the secondary Manebach twins around a fourling is random. These fourlings act more openly than those of the (010)-type.

***Figure 22.* A (001)-hyalophane fourling, 2.8 cm. Secondary Manebach twins are positioned left and right from the crystal symmetry plane. M. Žorž specimen and photo.**

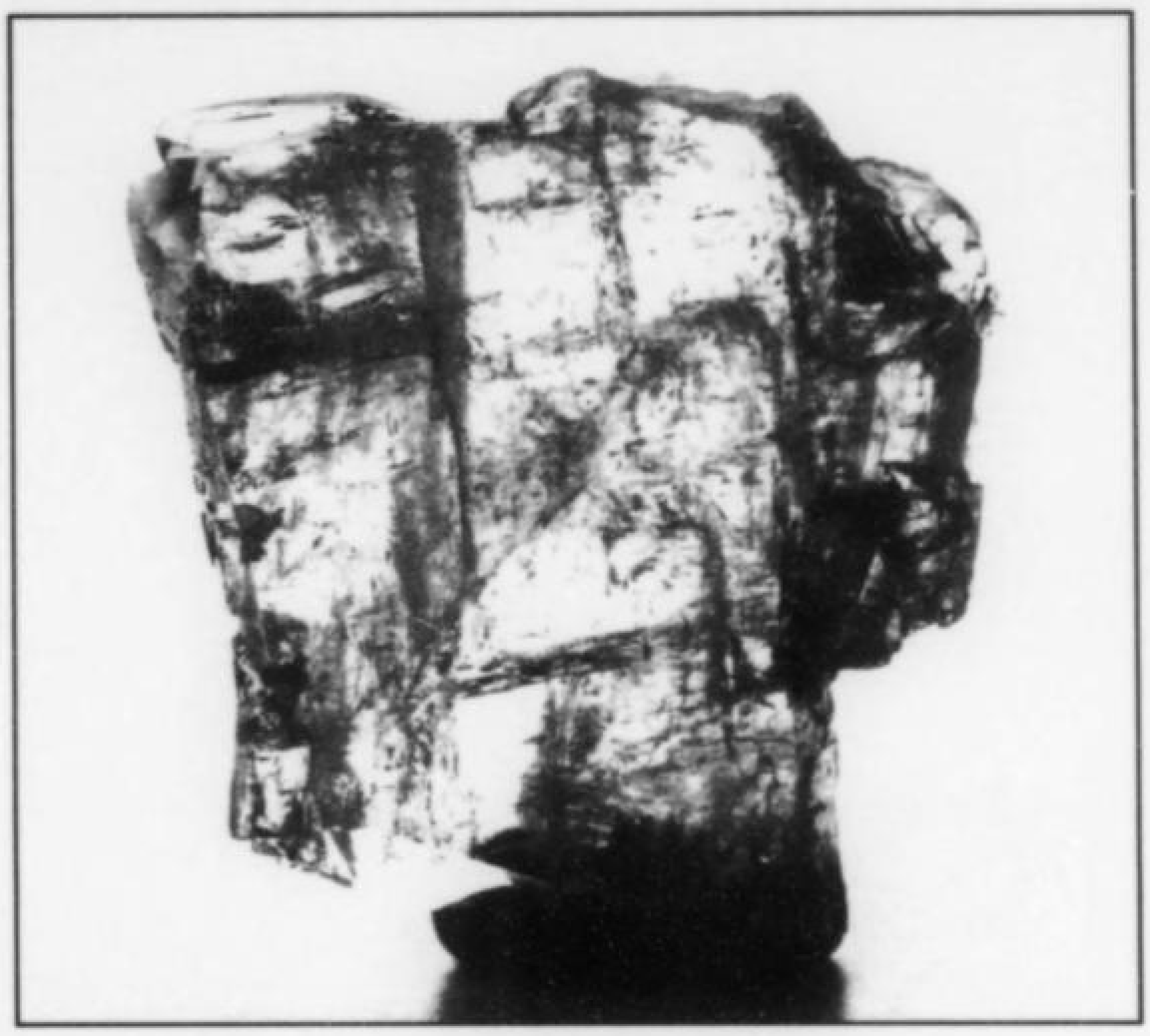

***Figure 23.* Hyalophane (001)-cross section, 3.7 cm, of a (001)-fourling. Note the formation of the secondary Manebach twin in its upper left part. D. Arrigler photo.**

***Figure 24.* Redrawing of Figure 23 showing the formation of the secondary Manebach twin at the edge of the faden.**

The translation of this fourling-type in the direction of its *a*-axis results in a structure that is different from that of the (010)-fourling. It also has four symmetry planes that are parallel to the fourfold axis, yet it has no (001) Manebach twinning plane. In this case, this plane is contracted to a line identical to the fourfold axis. Two secondary Manebach twins can be formed at the points, where the fourling is broken in the (021) twinning plane. The (001) face of each twinned individual is exposed. At that point the crystal can be twinned into a secondary Manebach twin. As two such points exist on each fourling side, two parallel secondary Manebach twins can be formed simultaneously on each fourling side.

The distance between the (001) twinning planes of both secondary Manebach twins is exactly the diameter D_f of the faden at that point. Due to the growth conditions and spatial limitations, parallel secondary Manebach twins are rarely formed. More frequent are the alternating secondary twins on both sides of the (001)-fourling symmetry plane. From one such point two secondary Manebach twins can grow outward simultaneously. They are both in the Baveno twinning position at the same time. The result is a secondary (010)-fourling (the inversion of the (001)- to (010)-fourling) which plays an important role in the formation of the double fourlings. The apex is concave and, if the faden-building process is really the reason for crystal growth, a hollow faden would be possible. Crystals with a channel in the center of the faden have indeed been found. If the faden is narrow, these two types are difficult to distinguish because with the (001)-fourling, secondary Manebach twins are almost aligned, thus imitating the secondary Manebach twins of a (010)-fourling, where they are aligned. The difference lies in the apex structure.

Tertiary Structure of Fourlings

This structure is defined by the two possible combinations of two types of fourlings. Assuming that a crystal could be broken alternately on both sides and rehealed, a fourling with a double conical form would develop. This is the case at Zagradski Potok.

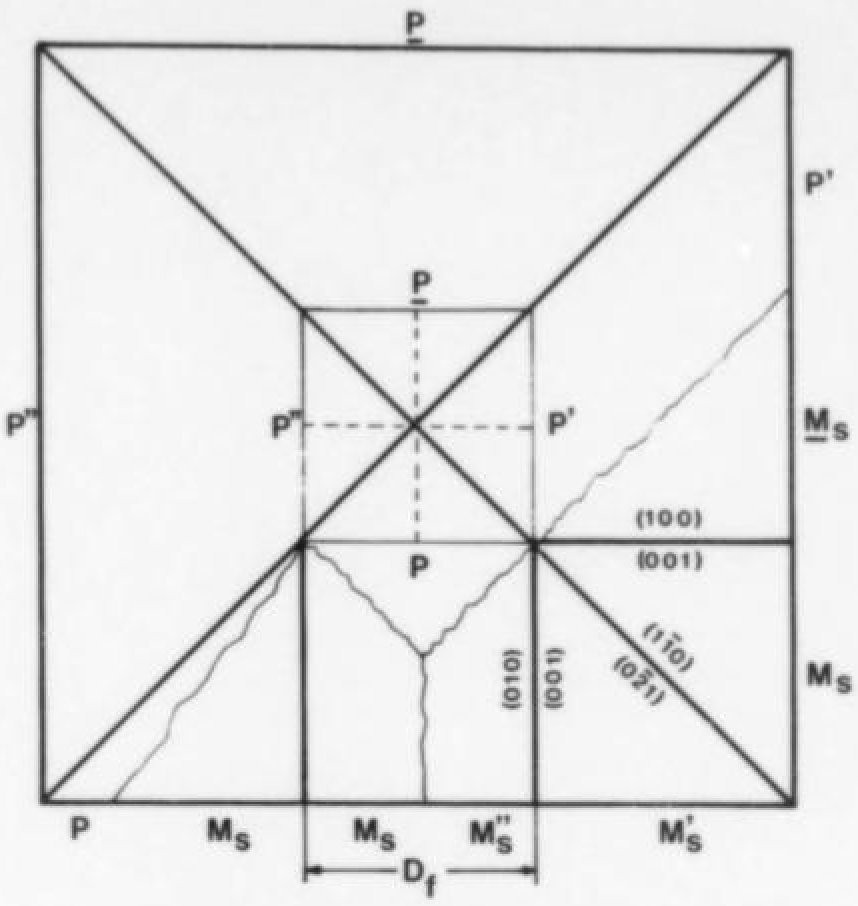

Figure 25. Drawing of a (001)-Manebach-Baveno combination twin (fourling) (001)-cross-section with the formation of secondary Manebach twins and their inversion to a (010)-Manebach-Baveno combination twin. D_f is the distance between the secondary Manebach (001) twinning planes and the diameter of the faden at that point. Index *s* denotes secondary faces.

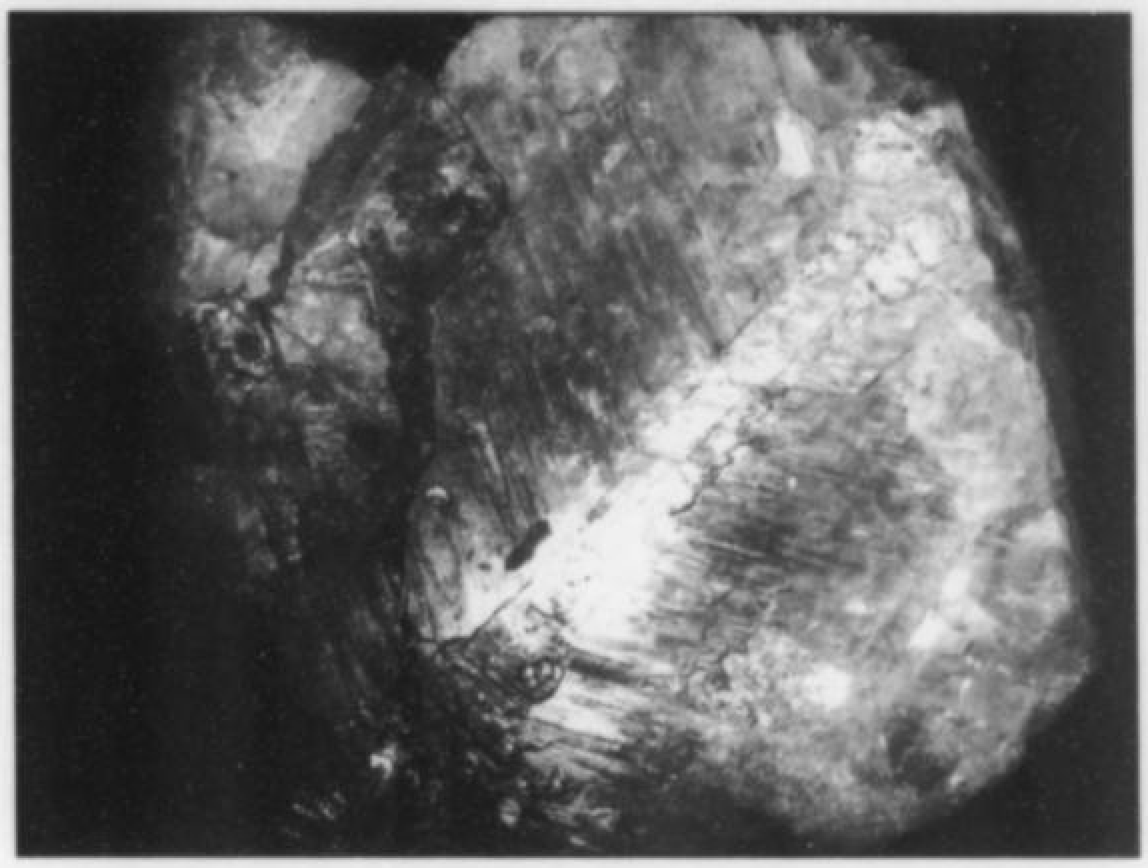

Figure 26. Cross-section of a hyalophane (001)-fourling, 8.4 cm, parallel to its (100) plane of symmetry. The faden, as well as secondary Manebach twin can be seen on its edge. M. Žorž specimen and photo.

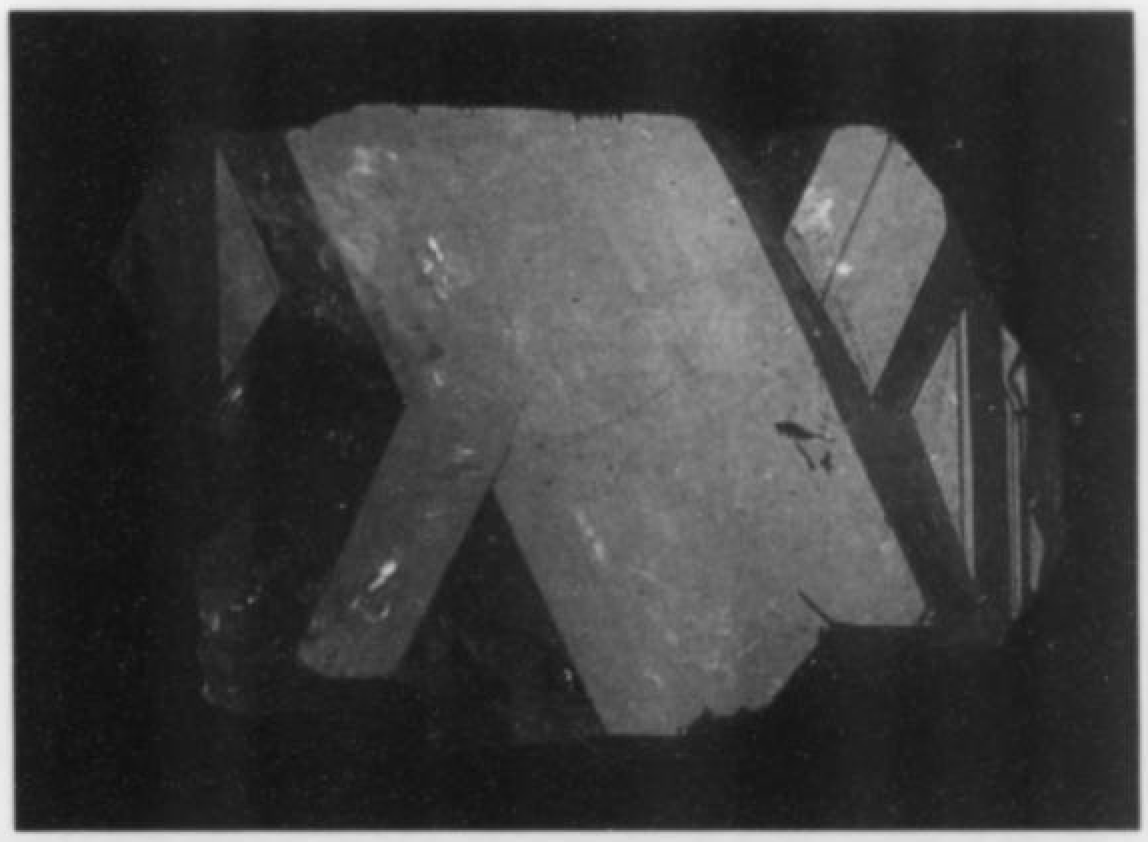

Figure 27. Hyalophane specimen, 4 cm, showing excellent inversion of the secondary Manebach twin, as well as of the (001)-fourling to a (010)-fourling, forming a (001)-($\overline{010}$)-double fourling. Note the (010) faces and positions of the secondary Manebach twins on the right side of the crystal, broad (010) face of the inverted secondary Manebach twin, (001) and ($\bar{1}$01) faces, and the position of the secondary Manebach twin on the left-hand side of the crystal. M. Žorž specimen and photo.

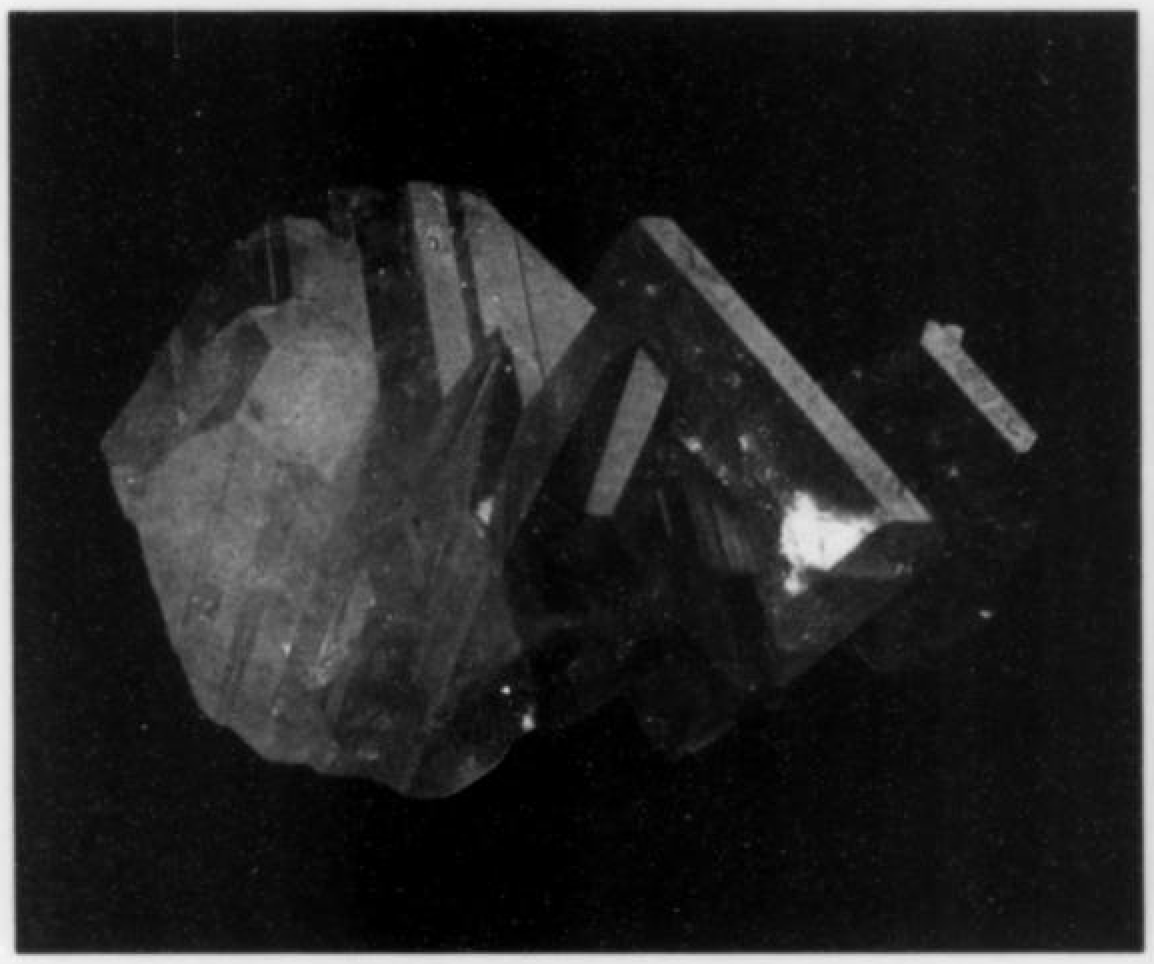

Figure 28. A (010)-($\overline{010}$)-double hyalophane fourling, 3.4 cm. M. Žorž specimen and photo.

Figure 29. Hyalophane twin, 5 cm, showing a "theoretically" developed (001)-($\overline{010}$)-double fourling lying on the matrix together with faden quartz and ankerite crystals. Alternation of the secondary Manebach twins on the left-hand side and centrosymmetrically positioned secondary Manebach twins on the right-hand side can be seen. M. Žorž specimen and photo.

Such fourlings are characterized by the positions and orientations of the secondary Manebach twins, as well as by different apex structures on each side. These crystals are neither symmetrical nor pseudosymmetrical in the planes normal to their common four-fold *a*-axes, but they will be described as such in order to distinguish among them.

(1.) (010)-($\overline{010}$)-Fourlings. This type of double fourling is characterized by secondary Manebach twins that are symmetrically intersected by (010) and (100) fourling planes of symmetry. A typical feature is the inversion of the lower most secondary Manebach twin, which yields to the formation of a similar fourling on the other side of the fourling plane, perpendicular to the common fourfold axis. The two apex structures are equal. The translation of the lowermost Manebach twins (which can be, at the same time, twinned into a secondary (010)-fourling) results in the inversion of the secondary (010)-fourling. If this secondary fourling is translated, the same structure develops as on the primary side, yet with the secondary Manebach twins pointing towards the apex of the secondary fourling. Quasi-symmetrical (010)-($\overline{010}$)-fourlings result.

(2.) (001)-($\overline{010}$)-Fourlings. This type of double fourling is characterized by the two different apex structures: one is of the (001)-fourling type and the other of the (010)-fourling type. Also characteristic are the positions of the secondary Manebach twins equidistant from the fourling planes of symmetry on the side with (001)-fourling apex structure. These Manebach twins are intersected by the same planes of symmetry on the side with (010)-fourling apex structure. It is evident that a double fourling composed of both types is present.

The existence of such double fourlings confirms that two inversions of secondary Manebach twins took place. It has been pointed out that two neighboring secondary Manebach twins on a (001)-fourling form a secondary (010)-fourling. If it is assumed that the lowermost secondary (010)-fourling can be translated in the opposite direction, as mentioned in the case of a (010)-($\overline{010}$)-fourling, the inversion of secondary Manebach twins occurs. The result is the (010)-fourling translated in the opposite direction. Both semi-fourlings are connected via secondary Manebach twins that are inverted in the common (001) plane of both fourlings. This is neither the symmetry plane nor the pseudosymmetry plane, but only the plane where the inversion of secondary Manebach twins occurs. Hence it follows that the (010)-fourling is in fact the inversion of the (001)-fourling, or the "negative" form of it; (001) and ($\bar{1}01$) faces of the (001) fourling are protruded with (010) faces of the secondary Manebach twins. The (001) planes of symmetry of these secondary Manebach twins are positioned left and right of the (010) plane of symmetry of the (001) and ($\bar{1}01$) fourling faces. The distance between them is the diameter of the faden D_f.

The situation is completely opposite with the (010) fourling, where its (010) faces are protruded with (001) and ($\bar{1}01$) faces of secondary Manebach twins. The (010) planes of symmetry of these secondary Manebach twins are positioned left and right of the (001) plane of symmetry of the (010)-fourling faces. The distance between them is the diameter of the faden D_f. It can be concluded that mostly three crystallographic forms, i.e. (001), ($\bar{1}01$) and (010) contribute to the final appearance of the fourlings. The (010) form is normally not present on hyalophane crystals, or is very narrow. This form is the product of the hyalophane crystal stretching process. If such a fourling acquires much substance during its growth, then this form disappears, as can especially be seen on the adularia fourlings which are of exactly the same morphogenesis and show the same forms.

Hyalophane probably exhibits the most complex twinning of any species.

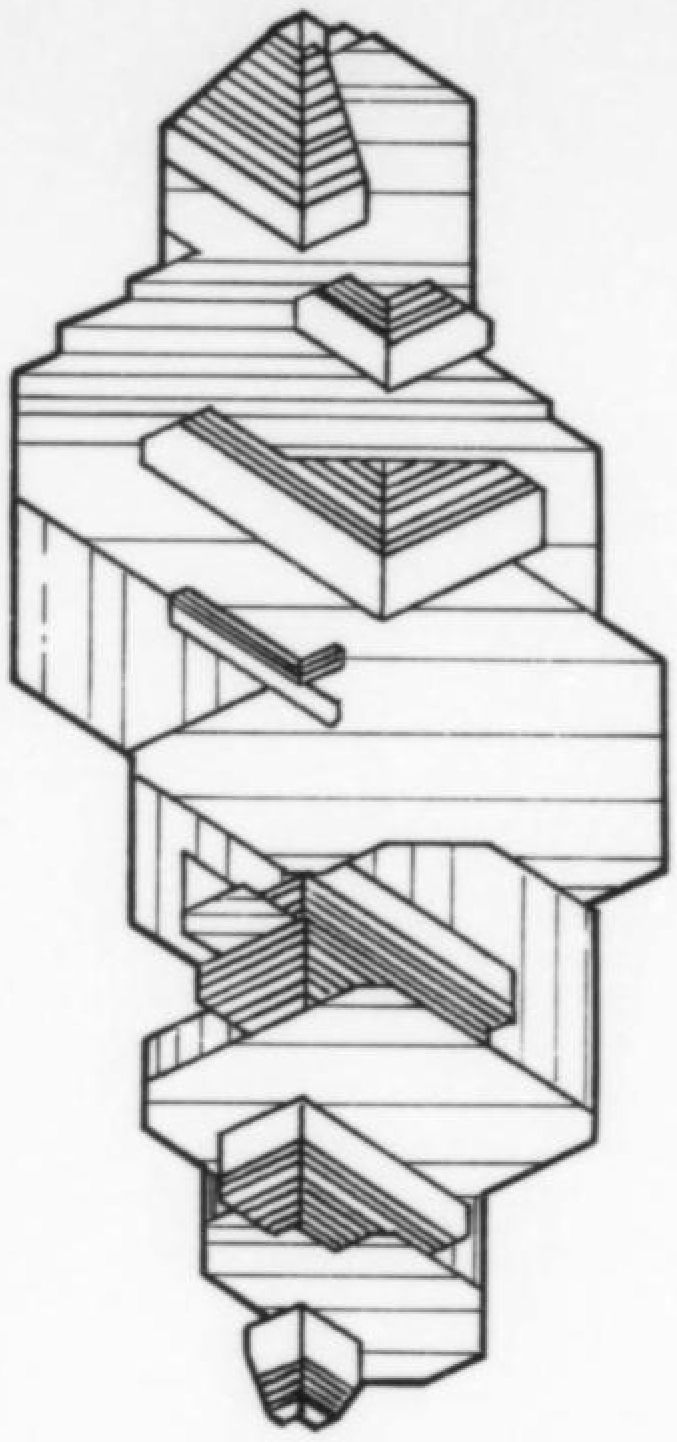

Figure 30. **Redrawing of a (001)-($\overline{010}$)-double-Manebach-Baveno combination twin (fourling) from Figure 16. Note the left and right positions of the (010) and (110) faces of the secondary Manebach twins protruding from (001) and ($\bar{1}01$) faces on the primary upper part of the fourling, and the left and right positions of the (001) and ($\bar{1}01$) faces of the secondary Manebach twins protruding from (010) and (110) faces on the secondary lower fourling. The connecting, inverted and less-pronounced, secondary Manebach twin is in the middle of the crystal.**

Distribution of Fourlings

All fourlings can be classified according to the four aforementioned groups. Out of more than 350 fourlings studied from this location, about 53% have proven to be of the (001)-type, 33% of the (010)-type, 7% of the (010)-($\overline{010}$)-type and 7% are of the (001)-($\overline{010}$)-type. It seems that the nucleation of the (001)-type was favored in comparison with the (010)-type. If the mass percentage is considered, then the proportion of (001)-type twins is over 95%. This type is present in much larger crystals than the (010)-type. Double fourlings of the (001)-($\overline{010}$)-type are therefore larger and better developed than those of (010)-($\overline{010}$)-type.

ASSOCIATED MINERALS

Two groups of associated minerals are present at Zagradski Potok. The first consists of minerals in the host rock and small ore mineralizations within it. The second consists of the vein assemblage. The minerals from the first group were, to some extent, mentioned in the geological section and will not be discussed here in detail, unless they are also members of the vein assemblage.

Twelve minerals have been discovered thus far in the veins. It is surprising that, other than the abundant hyalophane, no barium-containing minerals have been found. The following descriptions of the minerals associated with hyalophane are given alphabetically.

Albite $Na(AlSi_3O_8)$

Albite is one of the earliest-formed minerals of the paragenesis at Zagradski Potok. It is quite rare, and mostly found in insignificant crystals not exceeding 1 cm in length. Crystals are tabular, colorless and sometimes transparent. They grew prior to the hyalophane, and show deep etching unless they are overgrown by hyalophane crystals. Sometimes only casts in the hyalophane crystals can be identified. Individual albite crystals (not common) are combinations of {001}, {010}, {110} and some other forms as determined by Zebec and Bermanec (1985).

More common are the oriented growths of hyalophane on albite crystals. The (010) faces and *c*-axis of the albite crystal are parallel with the (010) faces and *c*-axis of the hyalophane crystal. If the initial albite is twinned according to the Carlsbad law (as is typical), then the later hyalophane crystal is, in fact, in parallel orientation with one individual of the albite twin and in the Carlsbad twinning position with the other.

Albite crystals were probably more abundant during the early crystallization stages but were afterwards dissolved. They are normally found in the vicinity of the hyalophane crystals, if not actually imbedded in them.

Anatase TiO_2

Reddish brown crystals of anatase are quite rare at Zagradski Potok, and are always accompanied by rutile. Anatase crystals can sometimes be completely covered with a rutile layer composed of tiny needles. Anatase crystals with rutile crystals growing from their faces have also been found. In some cases they are attached to quartz crystals of the transition habit. This means that both minerals grew simultaneously where anatase could have had some preference.

The crystals can be transparent with a high luster on some of their faces. Typical also are stair-step structures present on the bipyramidal faces, giving them a terraced appearance. Some faces can also be skeletal. Two habits of crystals, rich in different crystallographic forms, are present. One is distinguished by steep bipyramids and the other by a flatter habit. Both types are present in equidimensionally developed crystals, rarely exceeding 3 mm. Fifteen different crystallographic forms have been determined by Zebec (1980/81). The most common are {001}, {017}, {012}, {035}, {011}, {010}, {112} and {233}.

Ankerite $Ca(Mg,Fe)(CO_3)_2$

Barić (1972) and Zebec (1984) mentioned "siderite" from Zagradski Potok, but since there were some doubts connected with the chemical composition I decided to conduct some additional chemical analyses by atomic adsorption coupled with ICP technique. Only unaltered samples with different habits were taken from the different parts of the veins. The results for all samples analyzed are almost identical. The average mole % is 0.482 Ca, 0.263 Mg, 0.244 Fe, 0.044 Mn, 0.004 Ba, 0.001 Sr and 0.001 Na. It can be concluded, therefore, that ankerite with the ideal formula $Ca_2MgFe(CO_3)_4$ is present. One sample that was taken from the lower layers of the vein rock showed different composition, resulting in an ideal formula of $Fe_3Mg(CO_3)_4$ corresponding to magnesian siderite.

Ankerite is present everywhere in the veins and forms the matrix of most specimens. Crystals are well developed and can reach up to 8 cm in size. Unaltered crystals are transparent and of an oil-green color. Due to the strong oxidation to goethite, only cores of the larger crystals and some small crystals remain unaltered and show original composition. Unaltered crystals can be found in narrow, closed vugs that were preserved from oxidation. Their faces are iridescent with a golden hue. Oxidation of the ankerite results in dark brown, dull-lustered faces giving them an appearance resembling chocolate. Some oxidized crystals with dull luster look remarkably like small chocolate candies.

Ankerite is one of the earliest members of the present paragenesis. It is frequently found in quartz crystals, forming faden in their interior. It can be observed that in all such cases the particles imbedded in quartz crystals are not oxidized. This means that ankerite oxidation did not take place at least during the stage of the quartz faden formation. On the other hand, ankerite crystals that are included within hyalophane crystals are always oxidized, having been overgrown following oxidation. The small Ba content also confirms that ankerite was formed before the hyalophane itself. Faden ankerite structures were also found in the form of the strings of simple or elongated rhombohedrons. Faden in such structures cannot be seen because of the opaqueness or the oxidation of ankerite. Quartz faden sometimes include unoxidized ankerite in elongated crystals clearly showing a typical faden line. Such imbedded ankerite crystals are flat and elongated in sawtooth-like structures, typical of simple rhombohedrons that have undergone a stretching process. Ankerite and quartz faden crystals were therefore formed simultaneously. Crystals are the combinations of the predominant rhombohedrons, prisms and pinacoid. Twinned crystals with a (0001) twinning plane are very common.

Aragonite $CaCO_3$

Aragonite, the youngest species at Zagradski Potok, can be found covering everything in the vugs. (This is, however, not very common.) Botryoidal coatings of aragonite are frequently brown in color, and can sometimes be fan-shaped, especially on the quartz crystals. Coatings show a silky luster. Less common are idiomorphic crystals in the form of acicular aggregates composed of white, translucent or transparent needles. Aggregates can reach about 5 mm in diameter. Lath-like crystals up to 1.5 cm long can sometimes be found on matrix; such crystals usually have some terminal faces.

Muscovite group

Barić (1972) mentioned muscovite at Zagradski Potok. Two types of mica crystals can be found. The first type consists of tiny, silvery, hexagonal plates that sometimes form prismatically bounded tablets not more than 1 mm thick. The other type is represented by emerald-green crystals, mostly imbedded in quartz crystals. These crystals can be completely transparent, in the form of hexagonal platelets or worm-like structures typical of chlorite. Green crystals are frequently included in the quartz faden structure or in the parts of quartz floaters touching the matrix and thus incorporating the mica crystals. Combinations of clear quartz crystals with emerald-green mica crystals are quite remarkable but rare. This suggests that they were formed as early as quartz or even earlier. Muscovite is ranked for that reason among the earliest minerals appearing at Zagradski Potok. The absence of chlorite is somehow surprising, since it is well known that the chlorite group frequently crystallizes at the *end* of the alpine-vein paragenesis, coating all minerals present.

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

As is typical for alpine-vein assemblages, fluorapatite is rare here. Crystals can be exceptionally well shaped, completely transparent and with brilliant luster on their faces. This holds true for crystals smaller than 2 mm, whereas larger examples show fewer

Figure 31. **Anatase crystals, 2 mm, and rutile crystals on matrix with a hyalophane crystal in the background. M. Žorž specimen and photo.**

Figure 32. **LL′-Dauphiné quartz twin, 11 cm, of the transition habit with phantom hematite inclusions. Note the abrupt change in crystal habit. M. Žorž collection and photo.**

Figure 33. **RR′-Dauphiné quartz twin, 7.2 cm, elongated in the direction of the *c*-axis, with two parallel faden containing unoxidized ankerite cleavage rhombohedrons and quartz particles. Some hyalophane and oxidized ankerite crystals are attached. M. Žorž specimen and photo.**

Figure 34. **RR′-Dauphiné smoky quartz twin, 5.6 cm, elongated in the direction perpendicular to its prism face. Green muscovite crystals are included in the faden and are also imbedded in the lower part of the crystal. M. Žorž specimen and photo.**

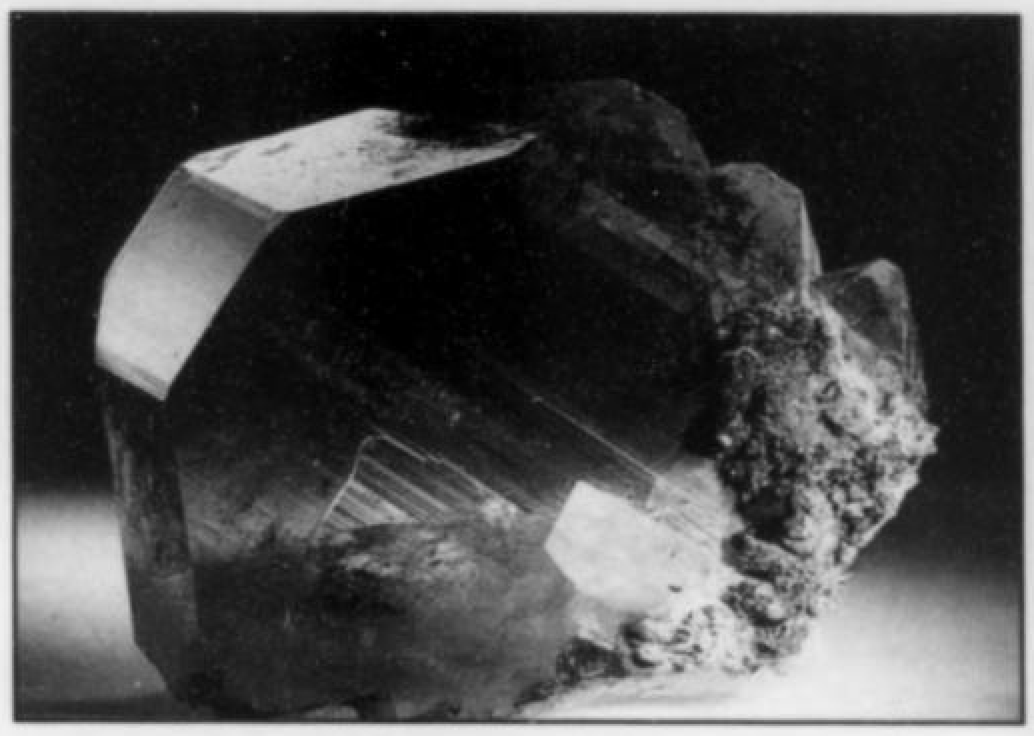

Figure 35. **RR′-Dauphiné smoky quartz twin, 6.2 cm, elongated in the direction of the *a*-axis. Typical damascence on the rhombohedron faces can be seen. Attached are a hyalophane crystal and oxidized ankerite crystals. Tiny black hematite crystals are included in the upper part of the crystal. M. Žorž specimen and photo.**

Figure 36. (right) **Faden structure: finger-post (8.1 cm) of five morphologically and sterically different quartz crystals. The morphological orientation of a particular crystal from the lower most crystal towards the uppermost is as follows: RR′-, LL′-, RR′-, RR′-, and RR′-Dauphiné twin. M. Žorž specimen and photo.**

Figure 37. **Quartz gwindel (4 cm) with hyalophane crystals attached. Twisting angle 17°. S. Rečnik collection; M. Žorž photo.**

Figure 38. **Apatite crystal, 4 mm in length, on oxidized ankerite. M. Žorž specimen and photo.**

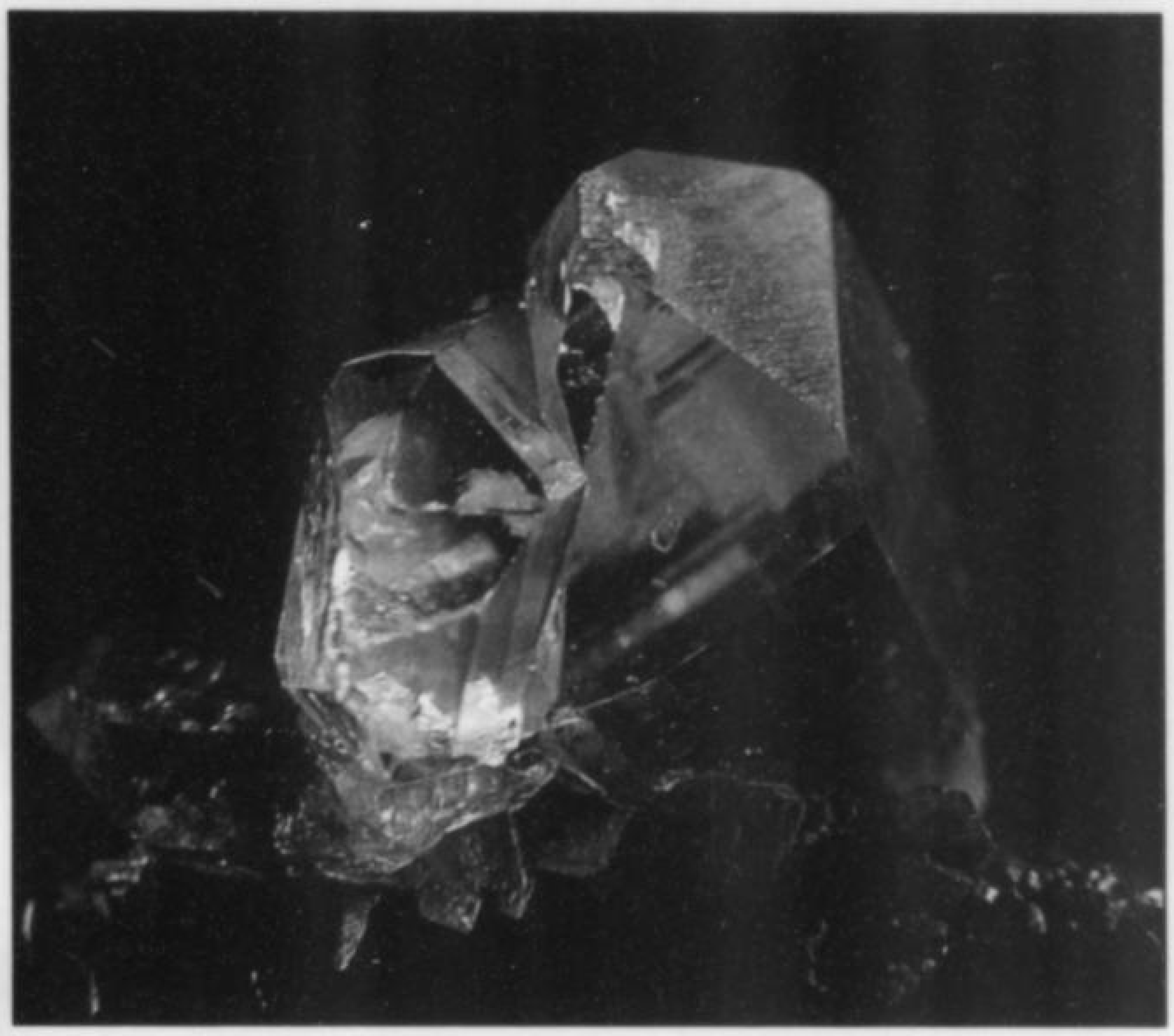

Figure 39. **Quartz on oxidized ankerite crystals; 3.7 cm. The largest crystal, an LL′-Dauphiné twin, is elongated in the direction perpendicular to the prism face and shows the typical diamond-shaped habit. A faden, composed of crumbled ankerite particles, can be seen in its interior. Parallel etchings extending from the rhombohedron's lower right-hand side up to its left-hand side can be seen as well. G. Kobler collection; M. Žorž photo.**

forms and have faces that possess typical luster but are not even because of the many vicinal faces. Such crystals are only translucent. Size ranges up to 5 mm in diameter. The habit is typically tabular or, less commonly, prismatic. Some elongated faden aggregates were found up to 2 cm in length, without visible faden but with typical elongated and curved morphology showing this type of the crystal morphogenesis. Apatite crystals are always associated with ankerite. The dark brown matrix of oxidized ankerite makes for a good contrast with the white glittering apatite crystals. Unfortunately, such specimens are very rare. Apatite crystals are sometimes overgrown by ankerite crystals, and in other cases ankerite crystals are found attached to them within the upper crystal layers. It can be concluded, therefore, that both formed simultaneously.

Apatite crystals are rich in forms. Zebec and Zagorščak (1983) mentioned 12, among them $\{0001\}$, $\{10\bar{1}0\}$, $\{10\bar{1}2\}$ and $\{10\bar{1}1\}$ being the most frequent. They mentioned, on the basis of optical measurements, that the apatite from this locality is fluorapatite.

Goethite α-FeOOH

As already mentioned, goethite is present everywhere in the veins as pseudomorphs after ankerite. It can be found quite rarely in the form of conical radiating structures of divergent fan-shaped crystals up to 5 mm in length. This habit resembled elongated trigonal cones balancing on their tips. Crystals are of a dark brown color. Chemical analysis has shown almost pure FeOOH with small amounts of Mg, Mn and Ni.

Hematite and **Rutile** Fe_2O_3, TiO_2

It is interesting that many hematite crystals can be seen included in quartz and hyalophane crystals but they almost never occur as freely developed crystals. Individuals do not exceed 5 mm in diameter. The tiny black and glossy tabular crystals form phantoms in quartz crystals and zones in hyalophane. Some extremely thin hematite crystals are red in transmitted light.

Hematite layers are diagnostic for particular quartz or hyalophane crystal orientations during growth. Crystal faces that were exposed to the hematite "crystal rain" are covered with these crystals, forming multilayered structures in the interior of the crystals. This must have happened several times during the growth of the quartz and hyalophane crystals because one can see many parallel layers within the crystal. Some of them are pronounced, and some can hardly be seen. This means that the precipitation of the hematite from the vein solution was sometimes quite substantial, followed by interruptions or reductions in the crystallization of hematite. The crystallization ended just shortly before the final crystallization stages of the quartz and hyalophane crystals.

Five different crystallographic forms appearing on the hematite crystals have been reported (Bermanec and Zebec, 1987). The pinacoid has absolute predominance, resulting in an extremely flattened crystal habit.

The substitution of rutile for hematite can be seen on some hematite crystals from Zagradski Potok. Intact, deeper lying hematite crystals can frequently be seen imbedded in hyalophane, and especially in the quartz crystals. But those closer to the surface are partially replaced by oriented rutile overgrowths. Those hematite crystals that are close to the surface or even exposed are completely replaced or overgrown by the rutile, leaving only sagenite-like structures in the outward shape of the primary hematite crystals. This is probably the cause of the scarcity of free-growing hematite crystals, whereas the sagenitic rutile has been found quite frequently. The orientation of the rutile crystal on the hematite crystal is such that the rutile *c*-axis is parallel to one of the hematite *a*-axes, and the (100) face of the rutile crystal is parallel to the (0001) face of the hematite crystal. This oriented growth can be seen especially on partially replaced hematite crystals. Rutile replacing hematite is red in color with a prismatic crystal habit on which some crystallographic forms can be seen. Seven different forms have been observed on prismatic crystals (Bermanec and Zebec, 1987).

Sagenitic rutile nets of transparent red, acicular crystals that sometimes cover surfaces of about 1 cm^2 are quite typical. It is in some cases evident that the crystallization nucleus must have been hematite because of the special hexagonal star-like arrangement with a dense center and only a few crystal rays stretching out of it.

Another type of rutile crystal is the extremely thin, golden or straw-yellow needles that can reach several centimeters in length. They can be found enclosed close to the surface of the quartz crystals or sometimes covering several square centimeters with felt-like coverings. As already mentioned, it can sometimes be found growing out of anatase crystals.

Rutile formation clearly occurred in the last crystallization steps of the quartz and hyalophane crystals. This means that it was formed after hematite had precipitated, and that its growth was completed just prior to the end of the quartz and hyalophane crystallization. Anatase, on the contrary, has never been found completely intergrown within quartz or hyalophane crystals. Rutile was therefore preferentially formed before the anatase only on the hematite crystals which served as the crystal matrix, thereby accelerating its formation. After the replacement of the hematite had been completed, simultaneous precipitation and growth of anatase and rutile occurred.

Pyrite FeS_2

Pyrite is present at Zagradski Potok in crystals that can reach up to 5 mm on an edge. The predominant form is the cube, modified by small octahedron faces. They occur scattered over ankerite matrix, and are quite rare. Crystals are typically covered with a coating of brown limonite and only occasionally show golden striated faces. Unoxidized pyrite crystals can frequently be found within quartz crystals but they do not form faden. Such crystals show deformed, drop-like and flattened shapes with some faces. They can also reach about 5 mm in length. The octahedral habit is extremely rare. A few other forms have also been noticed. Crystals found are partially imbedded in quartz crystals. Pyrite must have formed slightly earlier or at the same crystallization stage as rutile and anatase.

Quartz SiO_2

A variety of habits, crystal forms, etchings, inclusions, morphological features, twins and colors makes quartz specimens from Zagradski Potok so unique that they can immediately be distinguished from all other known world quartz occurrences.

It is a fortunate circumstance that the veins here are incompletely filled with quartz, allowing it to crystallize freely in exceptionally well developed crystals, mostly in the form of floaters. Crystallization of quartz at this location can be divided into three phases:

In the **first phase,** the randomly oriented quartz nuclei in the wall rock began to develop crystal faces. Since the vein is still narrow during that phase, the crystals quickly bridge the gap to the opposite wall. Vein widening causes fractures in the quartz crystals, which then reheal. The process repeats many times, producing crystal bridges connecting both walls, formed out of the elongated quartz crystals.

In the **second phase** the "bridges" are getting heavier because of the increasing mass of quartz. The crystallization rate falls to the point where the vein widening rate exceeds that of crystal re-

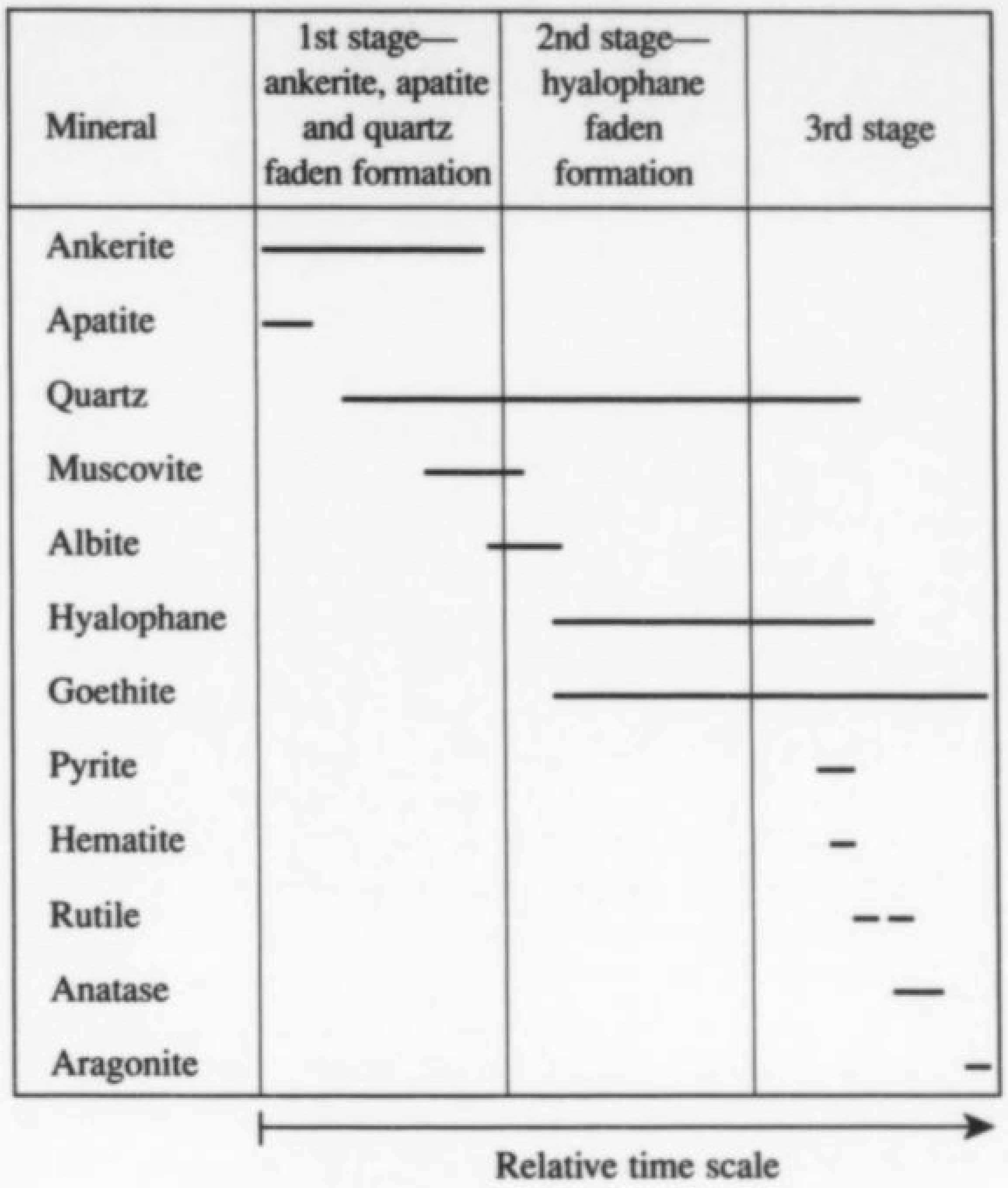

***Figure 40.* Paragenetic diagram showing the relative time and duration of crystallization for the mineral species present at Zagradski Potok.**

growth. At that particular time the formation of the crystal bridge (or, in other words, faden) is completed. The crystal acquires more substance, becomes heavier and finally detaches from the wall in response to the same tectonic forces that cause the vein widening.

At this time the **third phase** begins, where crystals grow further as "floaters." Broken faces are rehealed, and the crystals become idiomorphically well developed (Laemmlein, 1946; Richards, 1990 and personal communication; Rykart, 1989; Žorž, 1992).

All three phases are associated with processes that leave some special, diagnostic features. The most interesting is the stretching of the crystal. In this case the process was very smooth. This means that the faden were formed very slowly, in minute steps, during a very long period. This is manifested by tiny faden that can be almost invisible. One cannot easily observe the parallel faden lines that are so obvious in crystals from other locations. The faden width can be only a tenth of a millimeter, but may in some cases reach over three centimeters. The lengths of the faden range between a few millimeters and 10 cm.

Faden typically include broken particles of the other minerals present at the time of their formation. These particles are crushed from the already crystallized minerals and accumulate in the faden. At Zagradski Potok these include unaltered ankerite (also faden structured), muscovite and quartz. If the faden-containing crystal is properly oriented, one can see those inclusions like different objects on a shelf. This gives us the original orientation of the "crystal bridge" between the widening walls. Quartz faden from this location are sometimes full of crumbled ankerite and quartz particles. Muscovite faden inclusions are quite rare but make a nice contrast with the transparent quartz.

The original crystallographic orientation of the seedling quartz nucleus dictates the habit of the quartz crystal in the second crystallization phase. Assuming that all quartz particles in the wall rock are randomly oriented, all orientations should be equally represented. Since the growth rates of particular quartz faces are different, however, the probability of any particular faden orientation is altered. This is especially true in the case where the elongation is in the direction perpendicular to a prism face. This is the direction of slowest growth. Growth is most rapid in the direction of the *c*-axis, and less in the direction of an *a*-axis (Richards, 1990). Growth rate effects cause mostly the formation of faden that are close to the direction of the highest growth rate. Crystals elongated in the *c*-axis direction show quite normal habits, unless they are not much elongated. This habit is present at Zagradski Potok but is not very common. Such crystals have been found, but it seems that this was not the preferred orientation of the quartz nuclei. They were formed in the veins with high widening rates and are therefore always filled with crumbled ankerite and quartz.

Crystals elongated in the direction of the *a*-axis are very common at this location. They can be perfectly developed in the form of crystals tabular on a prism, with two highly developed prism faces. Such crystals can reach 6 cm in length. Their prism faces are sometimes even without the striations, giving them a unique smoothness. This is the most common orientation of the quartz faden at Zagradski Potok.

The most surprising fact is the abundance of quartz crystals with their faden oriented in the direction of the prism face. This elongation results in the diamond shape, where four of the crystal prism faces are dominant and the other two much less so. This gives the crystal a strange but very nice appearance. Such quartz crystals are the "trade mark" of this location. The largest specimen preserved is more than 12 cm high and some 15 cm long, with extremely good, divergently shaped faden. The many crystals of this type confirm the slowness of the vein-widening process. In this direction crystals still had enough time to reach the opposite wall. If all three orientations are taken into account, it can be concluded that the layered schistose wall rock has a preferred orientation to the quartz grains, those with *c*-axes parallel to the plane of schistosity and the vein walls. Naturally, all other orientations are still possible; and, indeed, all have been found, sometimes in the form of peculiarly developed elongated quartz crystals. The vein-widening process is not always straight. It can also describe a curve. The result is curved faden and crystals. Twisted and curved faden within quartz crystals and twisted quartz crystals as well, are nothing special here.

Not very common, but extremely interesting, are faden quartz crystals that are in the form of a multi-directional sign-post. They really do have many pointing "fingers" along the faden, like a string of crystals. All such crystals have the same faden but can have different chirality (left or right-handedness). Chirality of the strung crystals alternates. And, what's more, the *c*-axes of these crystals are not oriented in the same direction. This may be explained in the following way. A broken quartz particle is positioned on the top of the crystal at the time when the broken part of the crystal is exposed. This particle grows forth and is rehealed and broken according to the aforementioned scenario. Since it has a different *c*-axis orientation or even a different chirality, a sequential faden aggregate with differently oriented crystals and different structural orientation is developed. These aggregates can reach up to 8 cm in height.

The third phase causes the additional growth of the already detached quartz faden crystals. If there was enough silica in the solution, all broken parts will have been rehealed. Well-developed floaters have been formed in that way. If really large amounts of quartz have been deposited, then the elongation of the crystal morphology can be completely compensated for, resulting in an almost "normal" crystal but with visible faden in its interior. Such crystals are quite common. The intergrowth of the neighboring floaters results in the formation of aggregates that can reach up to 20 cm in diameter and are composed of several crystals with differently oriented faden. Curvatures and twisted faces are also compensated for in this way. The final result of all three stages is exceptionally well-developed faden quartz crystals with smooth faces that are sometimes covered with crystals of other minerals that are present in the particular vein.

Most of the quartz matrix specimens are in fact only detached crystals that have fallen down onto the matrix and continued their growth there.

Quartz at Zagradski Potok is a typical representative of the alpine vein. It is always present as crystals of the Friedländer type, characterized by prismatic crystals with typical sutures or macromosaic structures on the prism faces (Rykart, 1989). A variation of this type are crystals of the so-called transition habit. The first subtype is distinguished by prism faces that are only slightly modified by steep rhombohedrons. The second subtype has prism faces which are more highly modified. Prism faces are, in this case, much more striated and therefore unevenly developed. Such crystals are rounded in the section where prism faces traverse into rhombohedrons. This subtype is less common and is normally not associated with faden formation. Anatase crystals are predominantly found on such crystals. A common morphological feature associated with Friedländer-type quartz is twisted or so-called *gwindel* quartz. I predicted the present of the gwindels at this location. The probability should, in theory, be low because of more probable faden formation. Gwindels should only be able to grow in directions in which they cannot touch the opposite wall. This is sometimes possible. On the basis of this prediction S. Rečnik managed to find excellent gwindel quartz in 1990, with hyalophane crystals attached. The twist angle was calculated according to the mathematical expression $\varphi_a = \mathbf{kh/d}$, where the twisting constant $\mathbf{k} = 3.98°$, $\mathbf{d}$ is the diameter of the terminal prism face and $\mathbf{h}$ is the height of the elongated and twisted side prism face (Žorž, 1993 and 1994). The calculated twisting angle around the *a*-axis is 17.5° (17° measured). This is in good agreement with the equation, meaning also that there is no difference between this gwindel and others of different provenances. If faden development had not been so predominant, there would have certainly been many more gwindels found at this location.

Another typical feature of Friedländer-type quartz is Dauphiné twinning. All quartz crystals found at Zagradski Potok are twinned according to this law. Diagnostic for the determination of this twinning are trapezohedron faces that are always present in the Dauphiné twinning positions. They are well developed and always show typical etchings. Even all of the faden crystals show well-developed trapezohedrons. This type of twinning can also be distinguished by the typical presence of differential etching on some of the crystal faces. It can be observed especially on the rhombohedrons and less so on the prism faces in the form of randomly scattered dull spots with uneven but straight boundaries. These spots are in fact twinning domains that correspond to one of the individuals comprising the Dauphiné twins. Most typical is the presence of many parallel etch lines, observed within such spots on the rhombohedrons only. These lines enable the determination of the chirality of the particular crystal. They run with the morphologically left-handed crystal under the angle of about 50° from the lower right corner of the rhombohedron face to its upper left, pointing toward the direction of the *c*-axis, and vice versa with the right-handed crystals. These lines distinguish quartz crystals from Zagradski Potok from all other locations. They are the result of the extremely slow etching process that happened during their growth. The figures cannot be observed, however, if the spots are too deeply etched.

Crystals frequently show traces of dissolution, resulting in some cases in "terraced" faces with bevelled edges. Divljan (1954) reported Brazil-law twins. Morphologically developed crystals confirming this type of twinning have not been found. Yet some crystals show limited domains with V-shaped etch figures typical for these twins.

Crystallographic forms present are prism $m\{10\bar{1}0\}$, rhombohedrons $r\{10\bar{1}1\}$ and $z\{01\bar{1}1\}$, bipyramid $s\{11\bar{2}1\}$, trapezohedrons $x\{51\bar{6}1\}$ and $u\{31\bar{4}1\}$, negative trapezohedrons $-x\{15\bar{6}1\}$ and steep rhombohedrons $M\{30\bar{3}1\}$ and $e\{50\bar{5}1\}$. All faces are normally well-developed, with high luster, except the already mentioned damascence and dull trapezohedrons. Vicinal faces typical for quartz crystals are frequently present.

Crystals are normally completely transparent with only a slight hint of smoky color. Crystals of the transition type are colorless. Milky crystals are also present and are usually deformed due to the tectonic forces. Quite rare are the intensely colored smoky quartz crystals. Their color can be compared to those from the Swiss Tavetsch region. Most interesting is the fact that extremely dark-colored crystals can be found in a vein where all other crystals are only slightly colored. It can be seen on some of them that the faden itself is made of colorless quartz and that some of them are covered with smaller, detached, colorless quartz crystals. Such crystals must have incorporated higher concentrations of the Fe ions in their crystal structures. All deeply colored crystals have faden in their interiors.

CONCLUDING REMARKS

In 1991 I visited the location for the last time, not knowing what was going to happen there later. Once again I crept into the hole and once again I found a few nice things. But I was soon forced to leave the place by the local armed waterwell keeper. The warlords were already preparing themselves for the dismemberment of the republic, once known for its colorful history, architecture, picturesque nature and numerous member nations. I still have rare contacts with some people there, but I am not quite sure whether it will be possible to visit the location again, considering all that has happened and not knowing when there will be real peace again in this country.

For the time being it may be concluded that the hyalophane location at Zagradski Potok is closed for many years to come. The existing material that has been collected during recent years is preserved in the Mineralogical and Petrographic Museum in Zagreb (currently not accessible to the public because of safety precautions), in a few private collections of Slovenian and Croatian collectors, and scattered throughout private and museum collections around the world. The Land Museum in Sarajevo, with its well-preserved collection of fine Bosnian mineral specimens, arranged in the well-known Royal Imperial manner, has been severely damaged by shelling. The invaluable mineral and other collections were transferred to secure and hidden places where they are waiting for better times.

In most recent times, aside from some battles during the early part of the war which destroyed the nearby military warehouse, gas station and hotel, there has been relative peace in the Busovača area. The people have suffered mostly from shortages of food and energy. Some local residents traded their remaining hyalophane specimens to soldiers of the United Nations Protection Force for badly needed fuel. Armed waterkeepers still patrol the area, and are extremely impatient with outsiders.

(continued on page 361)

BONANZA AT THE RED CLOUD MINE

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The world's most famous wulfenite occurrence is again yielding specimens, this time in unprecedented quantities. The current recovery operation, however, may eventually mean the end of this classic locality.

INTRODUCTION

Wulfenite from the Red Cloud mine in the Silver district, La Paz County, Arizona, is widely regarded as the world's best because of its stunning red color, in combination with high luster, attractive morphology, good crystal size (to over 5 cm), and transparency. Top-quality matrix specimens larger than thumbnail (2.5 cm) or miniature size (5 cm) have traditionally been rare, but specimens have been reaching the market sporadically since Philadelphia mineral dealer A. E. Foote visited the site ca. 1880, and Benjamin Silliman first wrote about it in 1881. For sheer size, beauty and rose-red color, the specimens found by Ed Over in 1938 have been worshipped as the best-of-the-best by wulfenomaniacs worldwide.

HISTORY

The Red Cloud mine was first opened as an open cut in the 1860's or 1870's, and during the early 1880's yielded over $30,000 in lead/silver (at 1880's prices, of course . . . about $1 per ounce of silver). By 1890 this production is thought to have reached $1 million, by which time the workings had reached approximately the extent at which they stand today, save for the minor burrowings of collectors since then. The history of the claim in recent years has been complex, but in 1995 a group headed by Wayne Thompson (including Les Presmyk, Graham Sutton, Bob Johnson and others) obtained clear ownership of the patented claim.

GEOLOGY

The Red Cloud fault is bounded on the hanging wall by andesite and on the footwall by monzonite. Between these walls the vein matter composed of mineralized, brecciated andesite, varies in thickness from about 7 to 11 meters. Wulfenite is found lining vugs and fracture surfaces throughout the workings.

The rock of the Red Cloud vein gives no indication when a wulfenite pocket is near; so, for more than a century, collectors have gone underground and dug in places chosen more or less at random, hoping to luck into a crystal-lined vug or fracture. Because the potentially productive volume of the vein measures at least 5 to 6 meters thick by 100 meters down-dip and 100 meters along strike, there were originally at least 50,000 cubic meters of potentially productive ground. As it turns out, however, the vein may actually be up to 11 meters thick, but only the 2 or 3 meters directly adjacent to the hanging wall were stoped by the early miners. This probably means that the pods of argentiferous galena were preferentially situated near the hanging wall. However, wulfenite mineralization appears to penetrate all the way to the footwall (the most recently found pocket ended right at the footwall). Based on this finding, the productive volume may well have exceeded 100,000 cubic meters, less than a quarter of which has already been mined.

CURRENT OPERATION

Wayne Thompson, and his associates (1723 E. Winter Dr., Phoenix, AZ 85020; tel. 602-678-0156) have been engaged in a major specimen-mining operation at the Red Cloud mine. The mine, incidentally, is situated on the same fault as the North Geronimo mine featured elsewhere in this issue. The new operation at the Red Cloud began in January of 1996.

Rather than contribute further to the honeycomb of underground stopes, passages and crawlways, Thompson's group has decided to mine the entire volume of the vein, from hangingwall to footwall, in horizontal strips beginning at the surface. This eliminates to some extent the luck factor in that, if a pocket exists in that layer,

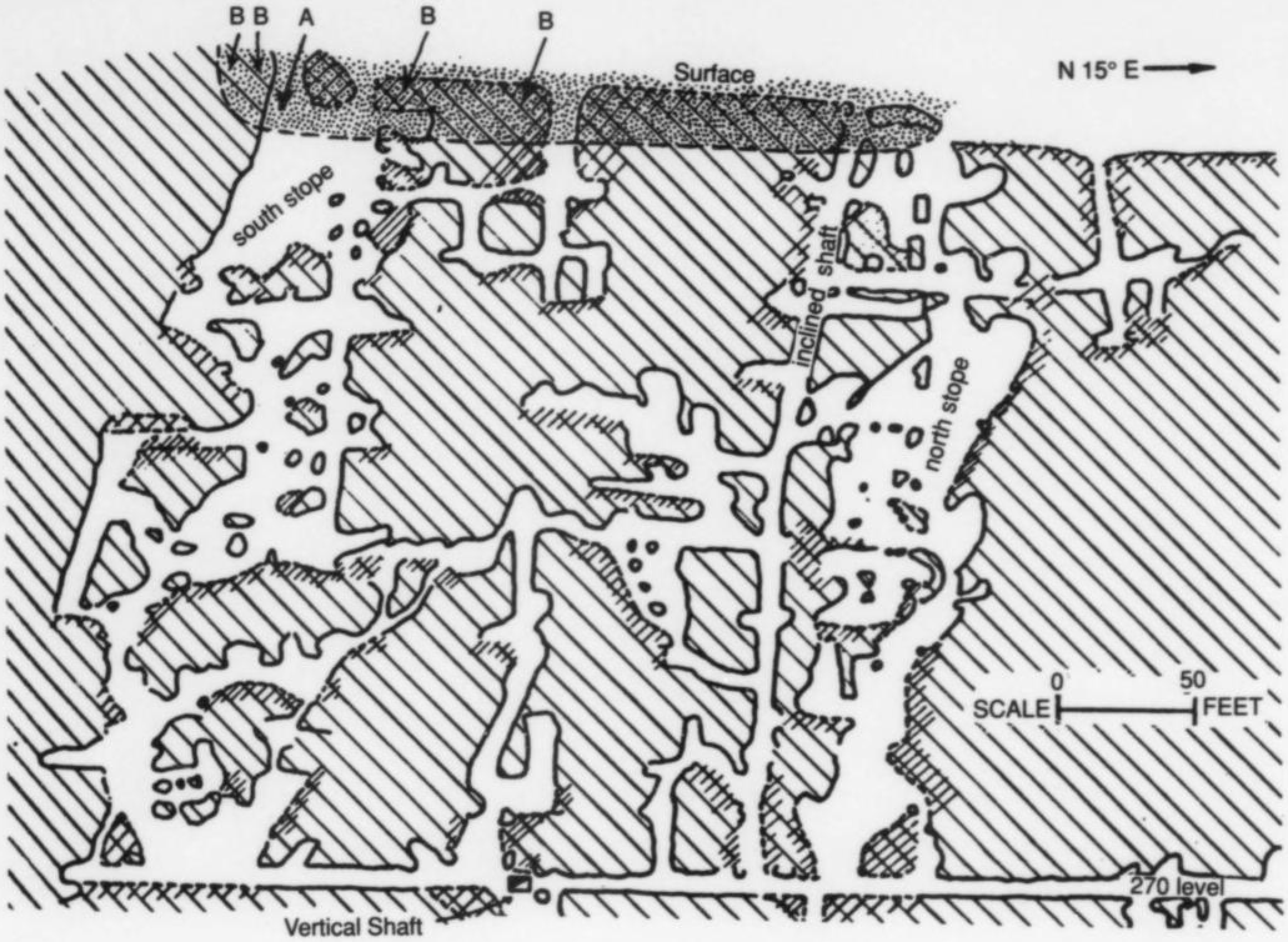


Figure 1. **A section along the plane of the vein showing early workings in the Red Cloud mine, and also the area removed by the current operation (stipled). Ore was originally concentrated in two parallel zones (the south stope and the north stope); it remains to be seen how much wulfenite mineralization exists in the relatively unmined area between them. (Modified from Wilson, 1933.) A = large pocket of April 1996; B = smaller pockets.**

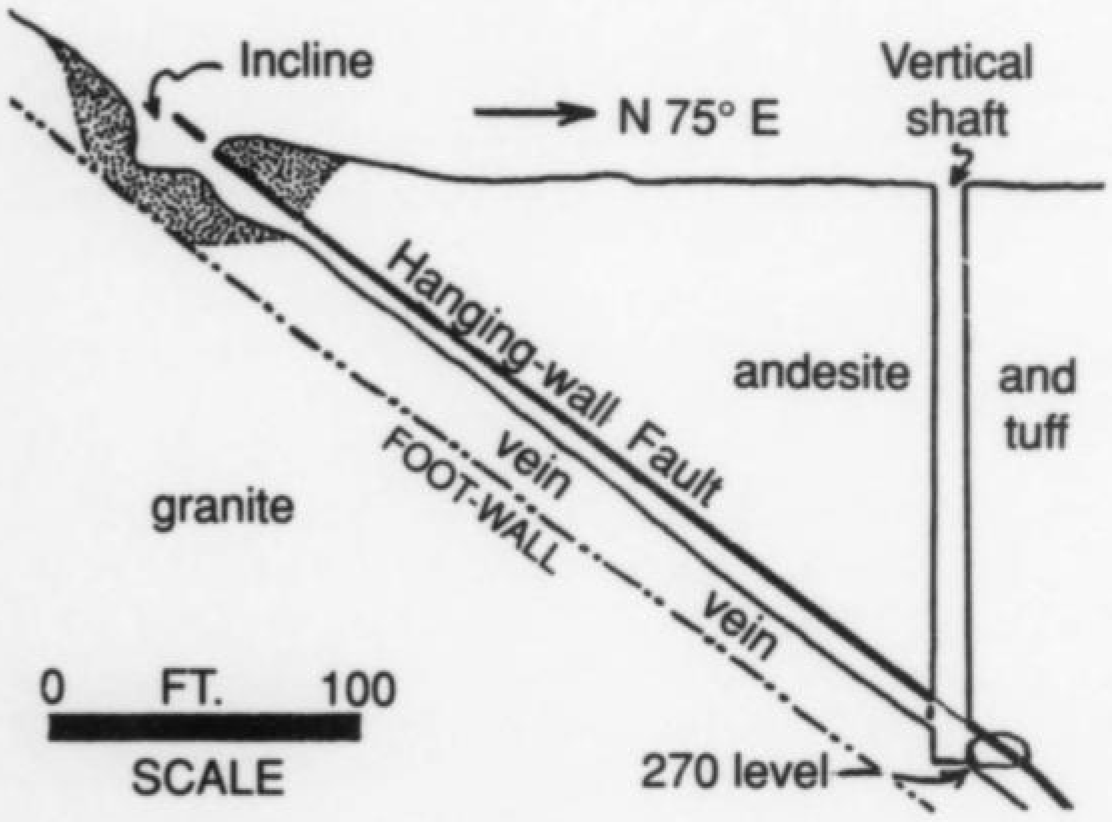


Figure 2. **Vertical section view through the Red Cloud mine perpendicular to the vein, showing the inclined shaft and new workings (shaded) (modified from Wilson *et al.*, 1951).**

they will find it. The only question is whether they will find *enough* in each strip to pay the increasing cost of overburden removal to expose the next few meters of vein. So far they've done well, and are now down 10 meters along the fault from the surface (early miners stripped the first 4 meters of the vein before resorting instead to stoping in selected areas).

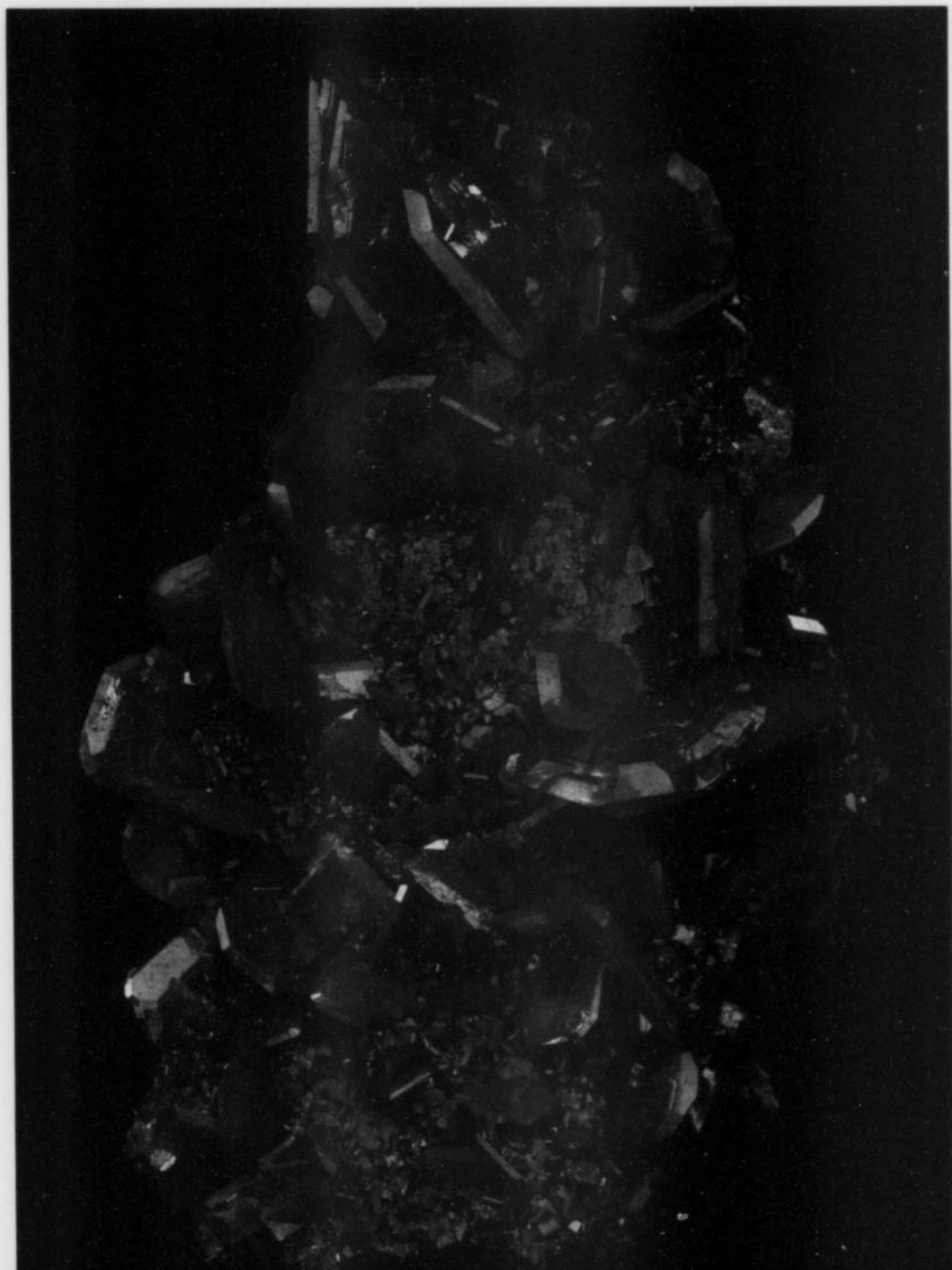
In April of 1996, they hit their biggest strike so far: a crystal-lined open vein 10 cm wide, and 1 by 4 meters across! From that one pocket they have recovered large quantities of lower-grade material plus dozens of exceptional specimens from miniature to large cabinet size. Particularly amazing are the large cabinet specimens which are unlike anything ever removed from the Red Cloud mine. This success will finance the next stripping phase; with continued discoveries they hope eventually to remove the entire vein for at least 50 meters down-dip by this open-pit method. From there down, based on what they will have learned about wulfenite distribution, they will stope only the potentially richest areas.

So far, despite the large number of superb specimens recovered with crystals well over an inch, nothing found has equalled the 2-inch-plus size of the best Ed Over crystals. Nevertheless, the material taken out so far (as the accompanying photos show) is clearly among the finest *other than* the few Over pieces, and the sheer quantity is unprecedented.

When the operation ceases, that is, when they can no longer afford to go deeper, government regulations will force them to fill in the pit, sealing whatever remains at a depth relatively inaccessible to future collecting. The pit is expected to take in the vertical shaft which now provides access to the lower reaches of the vein, so even that route of approach will probably be gone. At that point the mine will quite effectively be closed for the foreseeable future. Consequently we can only hope that the operation will remain profitable for as long as possible, so that the maximum number of specimens can be recovered.

10.3 cm ↑

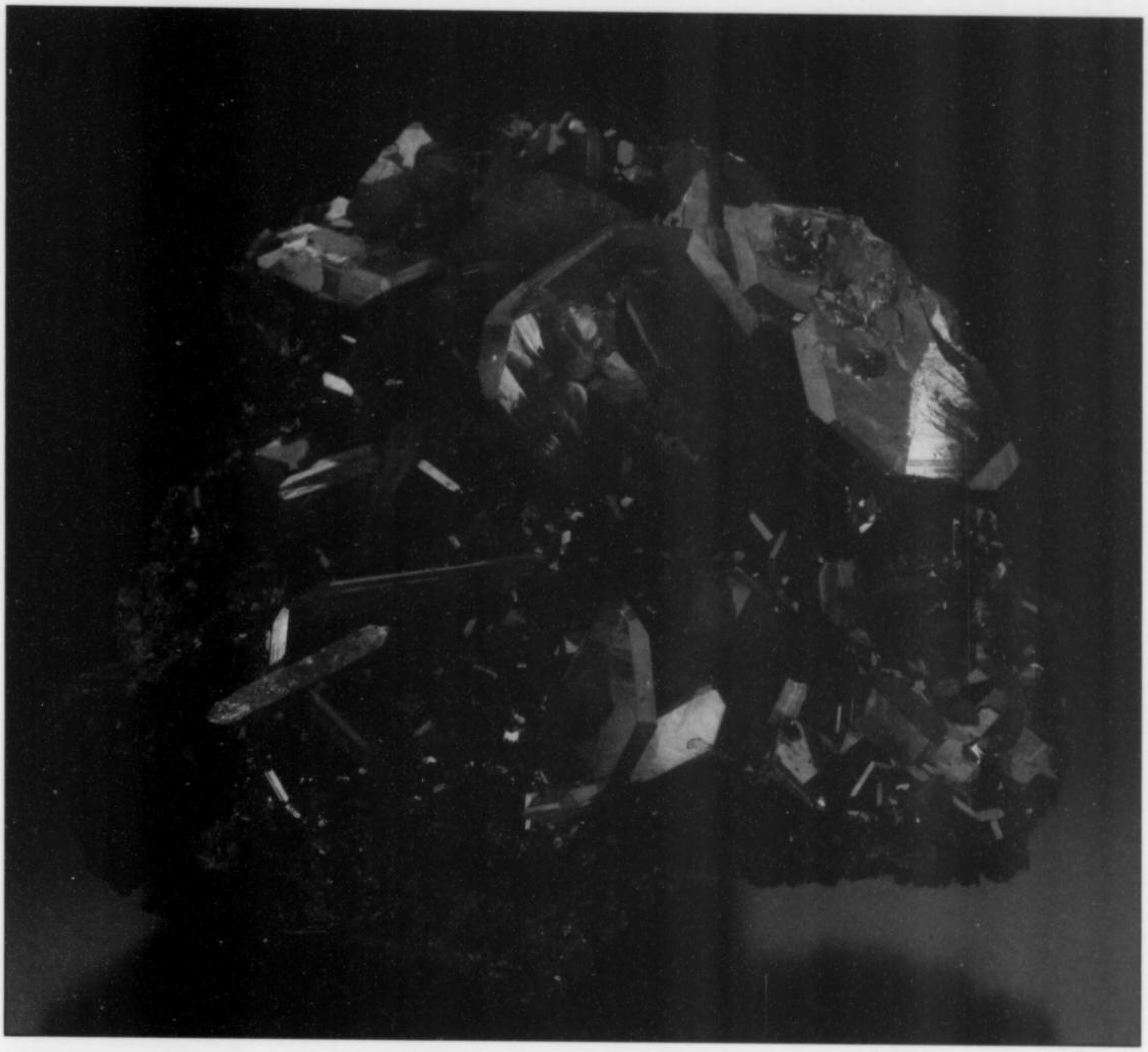
10.7 cm



15.0 cm

4.6 cm ↓

7.0 cm

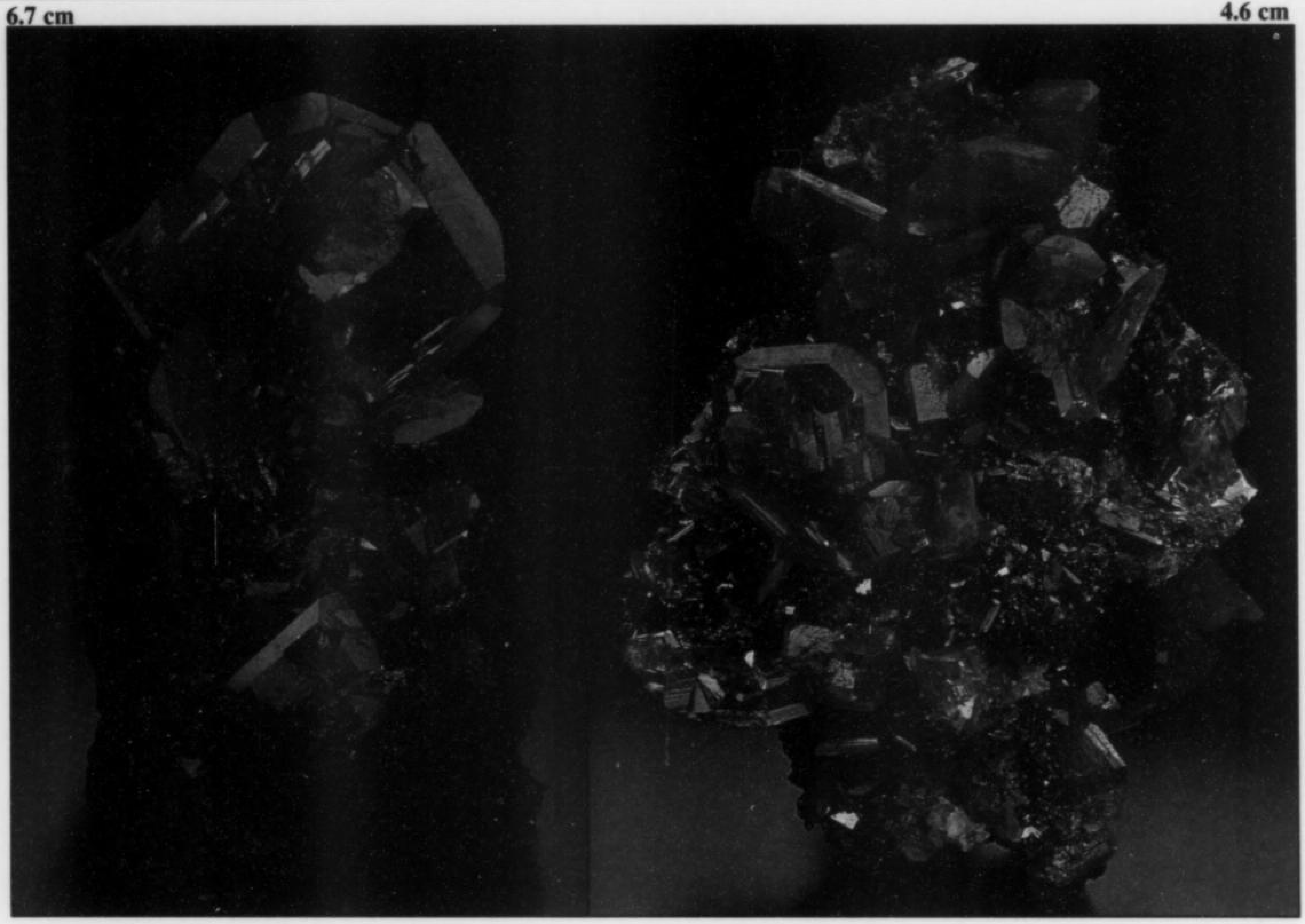


6.3 cm ↓

6.2 cm ↑

6.7 cm

4.6 cm

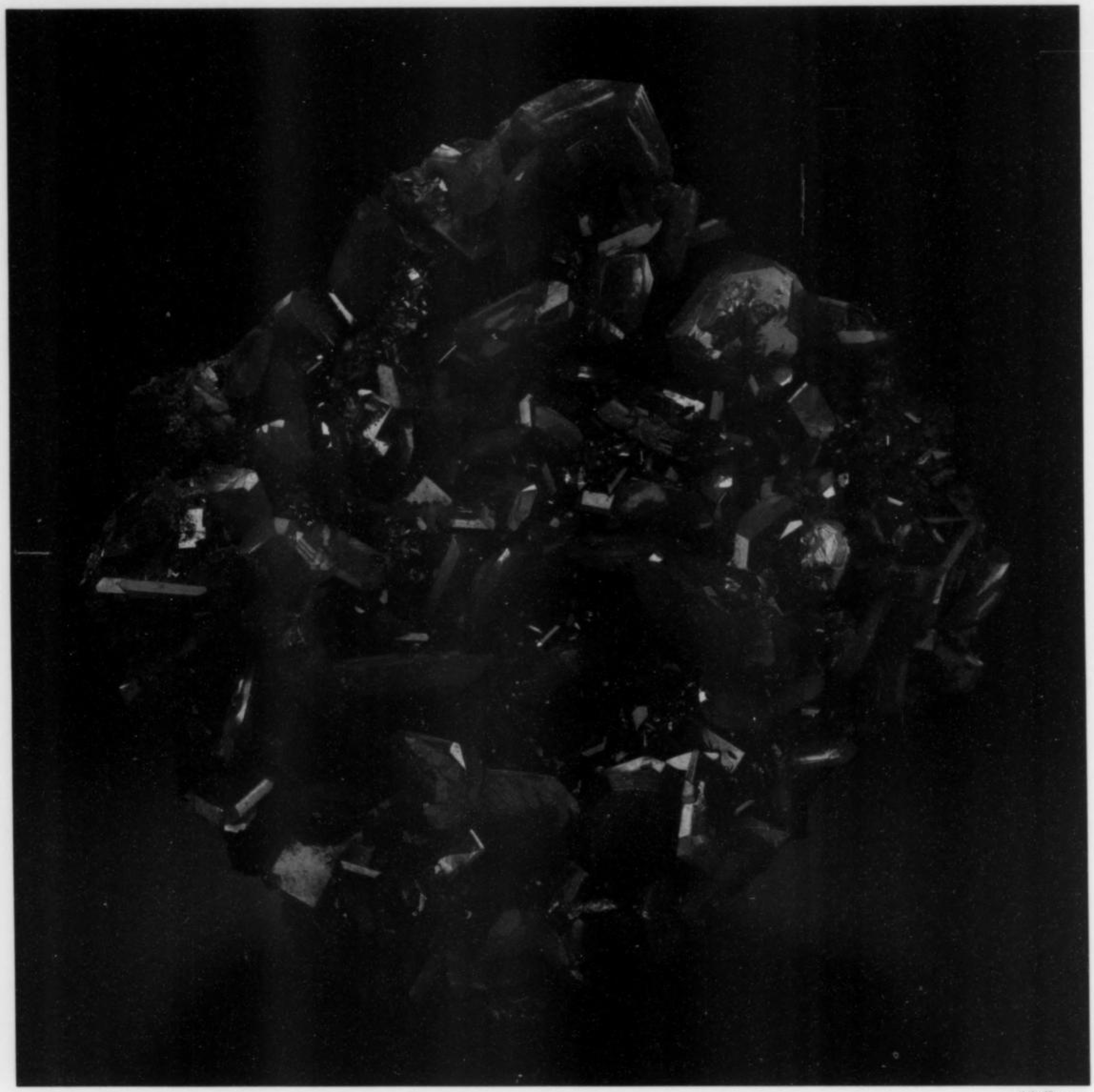


5.5 cm

10.0 cm

12.5 cm

10.3 cm



10.7 cm

ACKNOWLEDGMENTS

All specimens shown are from the April 1996 pocket; many are now in private collections. All of the photos are by Jeffrey A. Scovil, provided to the *Mineralogical Record* courtesy of Wayne Thompson. (Sizes indicated are maximum dimensions of the specimen as a whole.)

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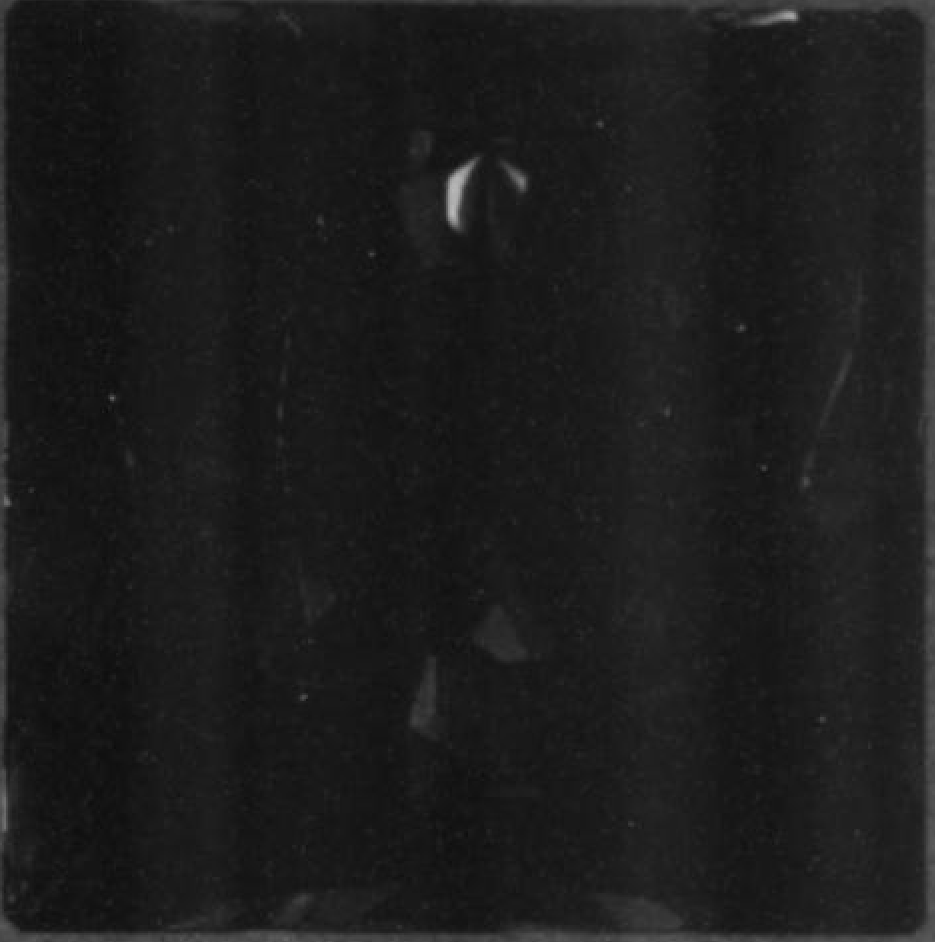

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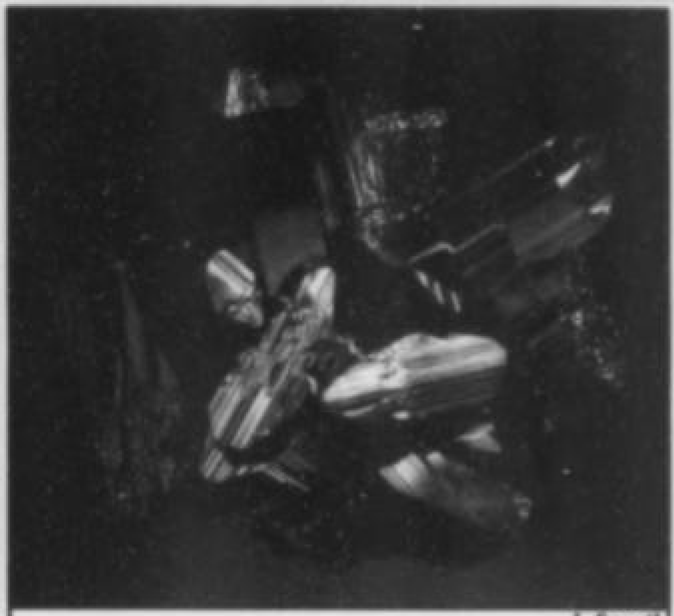

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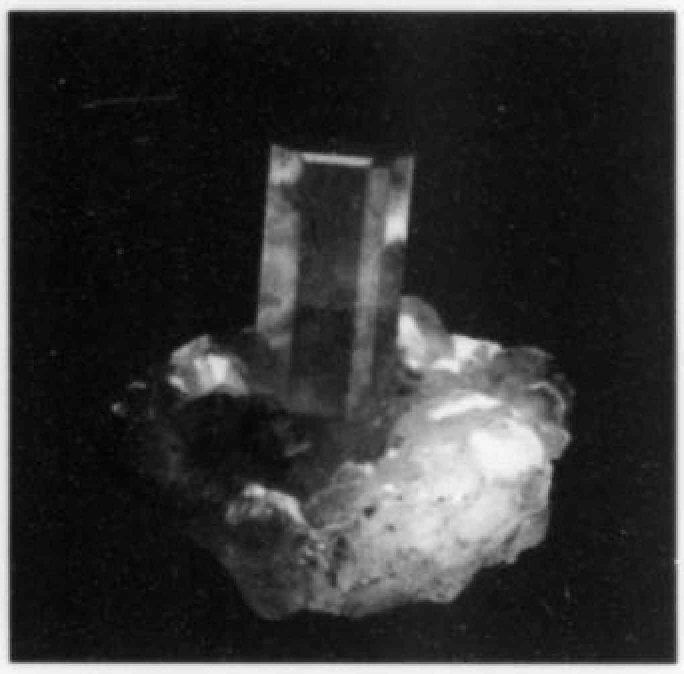

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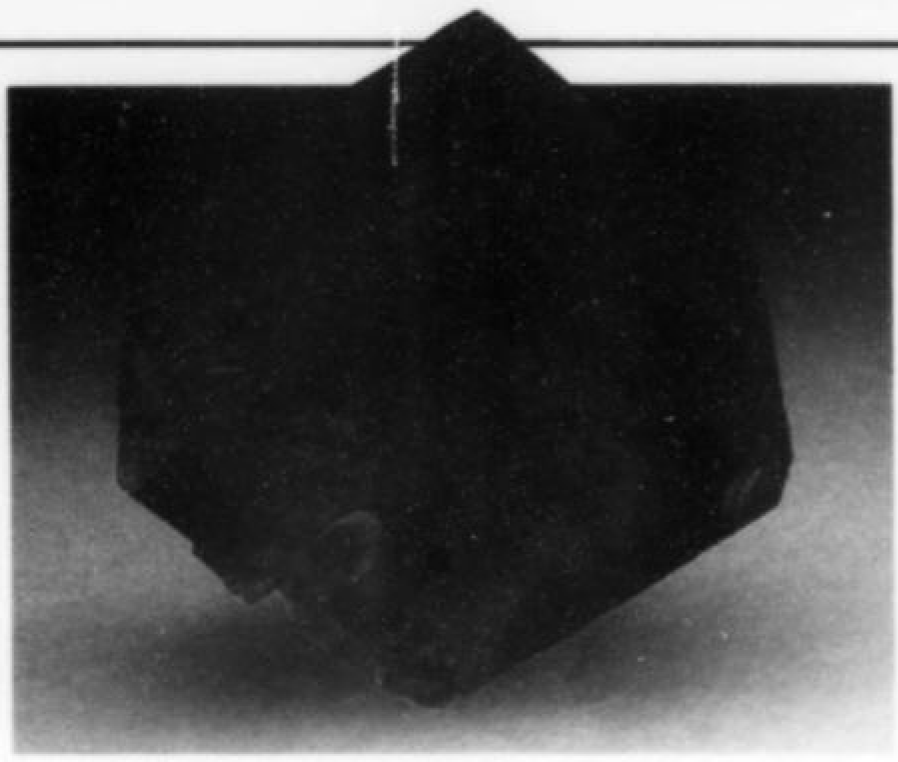

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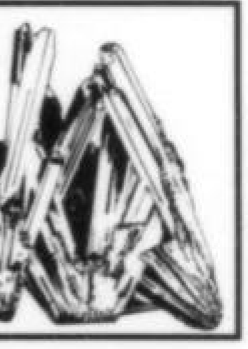

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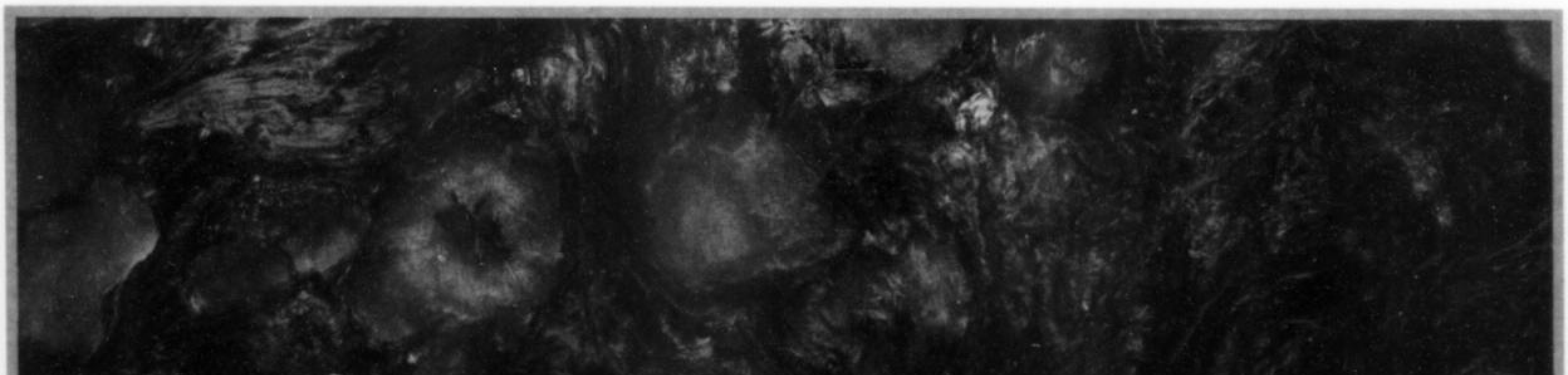

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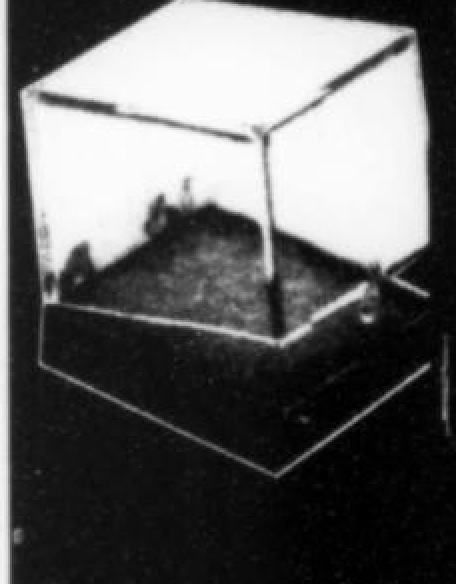

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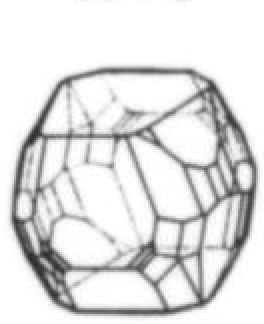

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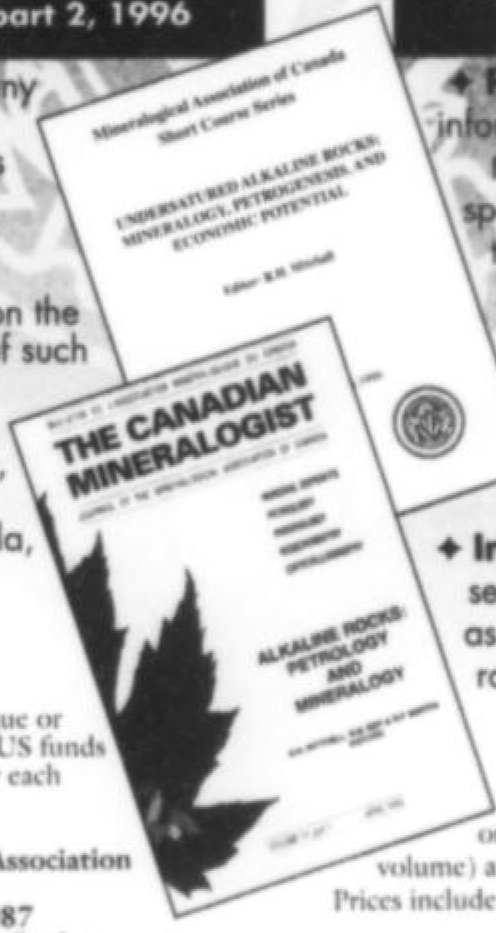

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Hyalophane (continued from p. 346)

ACKNOWLEDGMENTS

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INTRODUCTION

Arizona's most famous vanadinite occurrences include the Apache mine in Gila County (Wilson, 1971), the Old Yuma mine in Pima County (Jones, 1983), the J. C. Holmes claim in Santa Cruz County (Novak and Besse, 1986), and the Mammoth-St. Anthony mine in Pinal County (Bideaux, 1980). All of these mines have yielded fine crystals from 5 mm to 5 cm or more in length, the larger ones typically being rather hoppered.

The Hamburg mine in the Silver district (Shannon, 1980) has yielded nice crystals up to 1.5 cm or so, and is suspected of being identical to an early claim called the "Romaldo Pachecos" claim, which was at one time represented by a whole drawer full of vanadinite specimens in the U.S. National Museum of Natural History. No one today is quite sure, however, where the Romaldo Pachecos claim actually was located, beyond the general designation of "Silver district, Yuma County," given by U.S.G.S. geologist William F. Hillebrand (1853–1925) when he donated the specimens to the Smithsonian in 1894. Since the early 1970's when one of us (WW) saw those specimens in Washington, most of them were traded away to Tucson mineral dealer Gene Schlepp by the late Paul Desautels, and only a few now remain there for examination; several (if not most) of those traded are now in private Arizona collections. Silliman (1881) cited the Hamburg mine as the source of the best vanadinite in the district. But no one is sure of the locality for Zepharovich's "Yuma County" vanadinite (1889), a parallel grouping of larger hoppered crystals.

Another locality in the district has lately been producing what are probably the finest Silver district vanadinites found in modern times: the North Geronimo mine. The specimens, which are as good as or better than anything ever produced by the Apache and Old Yuma mines, may well identify the North Geronimo as the most likely site of the Romaldo Pachecos mine, and perhaps also Zepharovich's source.*

---

*The Zepharovich reference is obscure. The illustration appears in the sixth edition of *Dana's System of Mineralogy*, labeled "Yuma County, Arizona," without a referencing footnote. On the same page the form $\{10\bar{1}3\}$ is reported, with reference to a footnote stating "Zeph., Yuma Co., Arizona, Lotos, 1889." Presumably this is also the source of the drawing. The text regarding localities for vanadinite mentions "the Hamburg, Melissa, and other mines in Yuma Co." According to the On-line Computer Library Center (OCLC), a journal named *Lotos* was published in Prague from 1851 until 1875, beginning anew in 1907 and running until 1942. Apparently it continued beyond 1875 in its first series, but no library in the United States has a copy. Interestingly enough, the drawing was overlooked by Goldschmidt, who failed to include it in his *Atlas der Krystallformen*; but it was reproduced in the 1932 edition of Dana's *Textbook of Mineralogy*. If any reader can locate the original *Lotos* article, we (and the authors of *Mineralogy of Arizona*) would greatly appreciate a photocopy.

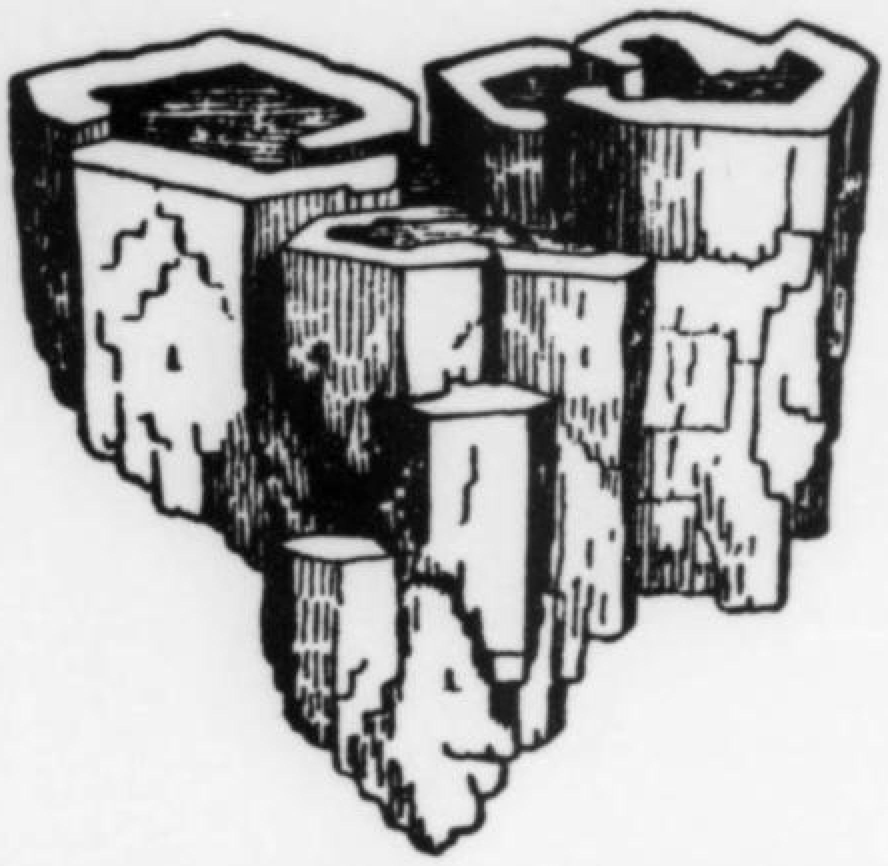


Figure 1. **A drawing of vanadinite from "Yuma County, Arizona," probably the N. Geronimo mine, published by V. R. von Zepharovich in 1889.**

The North Geronimo has been known to mineral collectors for many years, and has long been suspected of being the Romaldo Pachecos mine. Grant (1989) wrote:

> Over the past three years there has been increased interest in the North Geronimo, and many bright red vanadinites have been collected. One reason for this interest is the idea that this mine is the lost Romaldo Pachecos mine (see *Mineralogical Record,* **11**, 139–140). But other mines in the area have also been determined to be this lost mine . . . the vanadinites from this locality are no bigger than those from any other locality in the Silver district.

Grant's last statement is no longer true, now that crystals to 3.7 cm (about 1.5 inches) have been recovered from the North Geronimo mine.

The North Geronimo remains under claim, and specimen recovery work takes place there on a regular basis. Collecting by people other than the claim holder is currently not permitted, but that condition may eventually change.

LOCATION

The North Geronimo mine is situated about a half-mile north of the Melissa mine in Section 34, T3S, R23W. It is indicated as an unnamed shaft on the U.S.G.S. 7½-minute quadrangle *Picacho, Arizona/California*, but the claim map shown by Wilson (1933) clearly identifies it as the "N. Geronimo." The claim is the northernmost of a series which follows the prominent Red Cloud fault, including also (in order from north to south) the South Geronimo, Cochise, Black Eagle No. 2, Red Cloud No. 1, Red Cloud Extension, Red Cloud, R.C. Frac, Papago, and Lone Star State.

Access is by way of Yuma, Arizona, proceeding north for 16 miles on U.S. Highway 95 to the Martinez Lake turnoff, then west 10.2 miles on a paved road to a point just past the Yuma Proving Grounds Airfield. From there a gravel road branches off to the right (north) for 2.1 miles, then forks (to the right) at a gravel road marked "Red Cloud Road." This road, rugged but usually passable, winds for 12.9 miles to the Black Rock mine and then the Red Cloud mine 1.3 miles further on, then to the Melissa mine about 1.2 miles beyond that, and finally to the North Geronimo about a half mile due north of the Melissa.

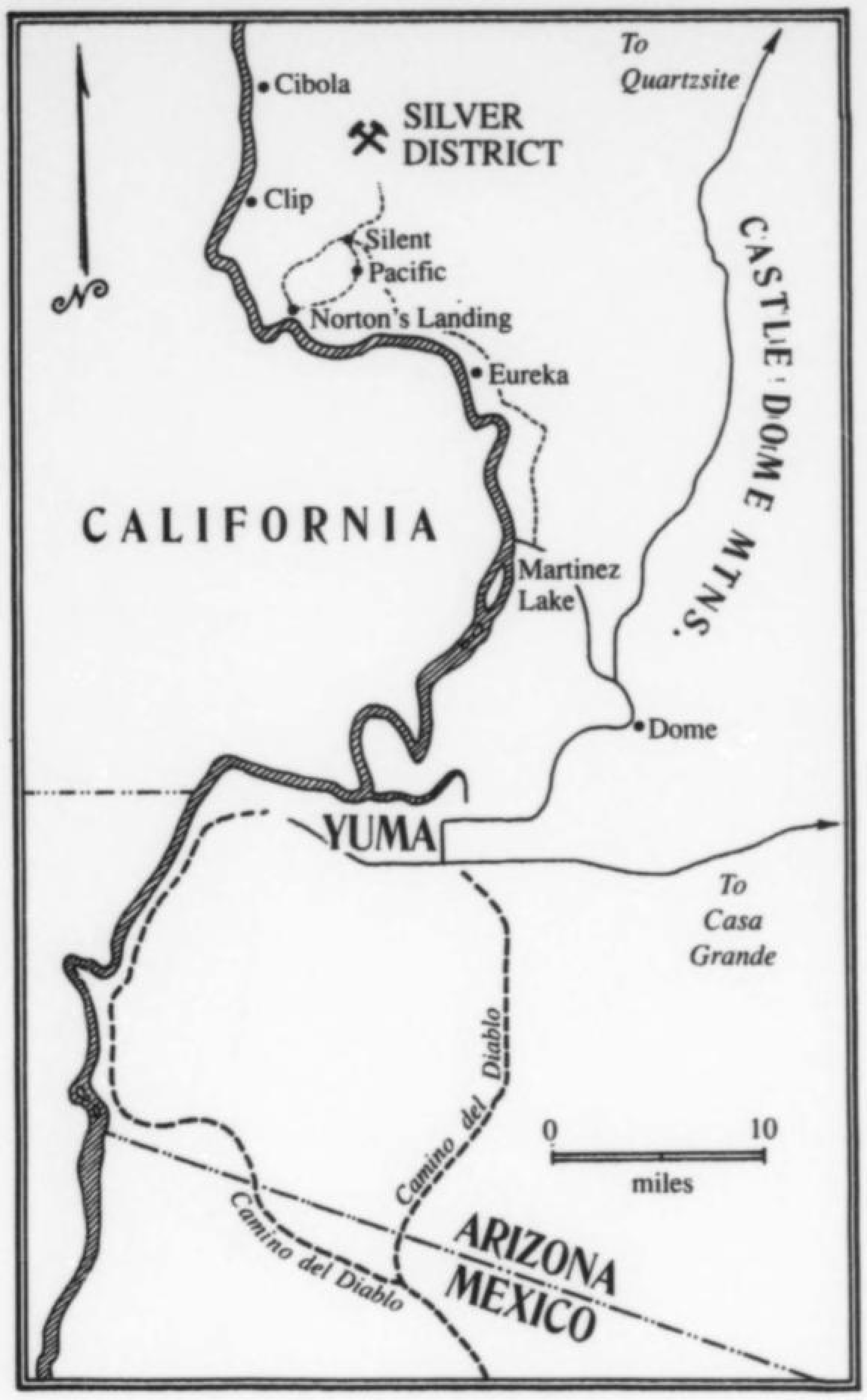


Figure 2. **Location map.**

It should be noted for labeling purposes that the entire district, originally located in Yuma County, has since 1982 been part of the newly formed La Paz County.

HISTORY

The history of mining in the Silver district has been reviewed by Bancroft and Bricker (1990). Ore was first discovered in the Trigo Mountains in 1863, though not immediately exploited. The Black Rock and Pacific mines were claimed in 1877, and the Red Cloud mine in 1878. The Silver district was officially established by a group of miners a year later.

The early history of the Geronimo claims is unknown, but they probably date back to the 1880's when most of the claims along the Red Cloud fault were first filed. As of 1933 the North Geronimo mine claim was held by the Neal Mining Company, and it has occasionally been reclaimed since that time, but never with any significant mining accomplished. As of about ten years ago the New Jersey Zinc Company held all but the Red Cloud claim; since then the ownership situation of claims in the Silver district has been complex. The Geronimo claims have been open to collecting for a number of years, until recently. Bancroft and Bricker wrote:

> At the [North Geronimo] claim's northern edge a 25-foot shaft was dug. At the 25-foot level, two short drifts lead [left and right] to vugs containing abundant wulfenite and vanadinite crystals.

Figure 3. **North Geronimo mine (Pure Potential claim); the entrance to the vertical shaft is near the small headframe just to the right of the vehicle. (Arrow)**

In 1994 one of us (GG) filed a new claim on the mine, calling it the "Pure Potential" claim. Assessment and development work has been kept up, and a steel ladder has been installed which descends down the vertical portion of the shaft for about 25 feet, and from there down an incline for the next 60 or 70 feet. Short drifts proceed left and right from the 25-foot level, and also from the 70-foot level. Many hundreds of attractive specimens have been removed, albeit through a great deal of work. In 1995 over 80 flats (boxes) of specimens were removed from a pocket on the 70-foot level (now under the loading platform, marked "A" on the mine diagram), and in May of 1996 approximately 60 flats of good to excellent specimens were recovered from a man-size pocket ("B") at the north end of the 70-foot level. Wulfenite with red mimetite has been found at the locations marked "C," near the hanging wall. Vanadinite mineralization is visible all along the incline, and is probably abundant in the unmined vein material between the 25-foot and 70-foot levels.

GEOLOGY

The geology of the district has been reviewed by Edson (1980). In brief, the Red Cloud fault, which runs northwesterly from the Red Cloud mine to the Geronimo claims, is bounded primarily by monzonite and quartz monzonite on the west (footwall) and andesitic/rhyolitic rocks on the east (hanging wall). Epithermal vein mineralization took place intermittently along the fault during the Tertiary period, depositing galena. Breccia zones and high-

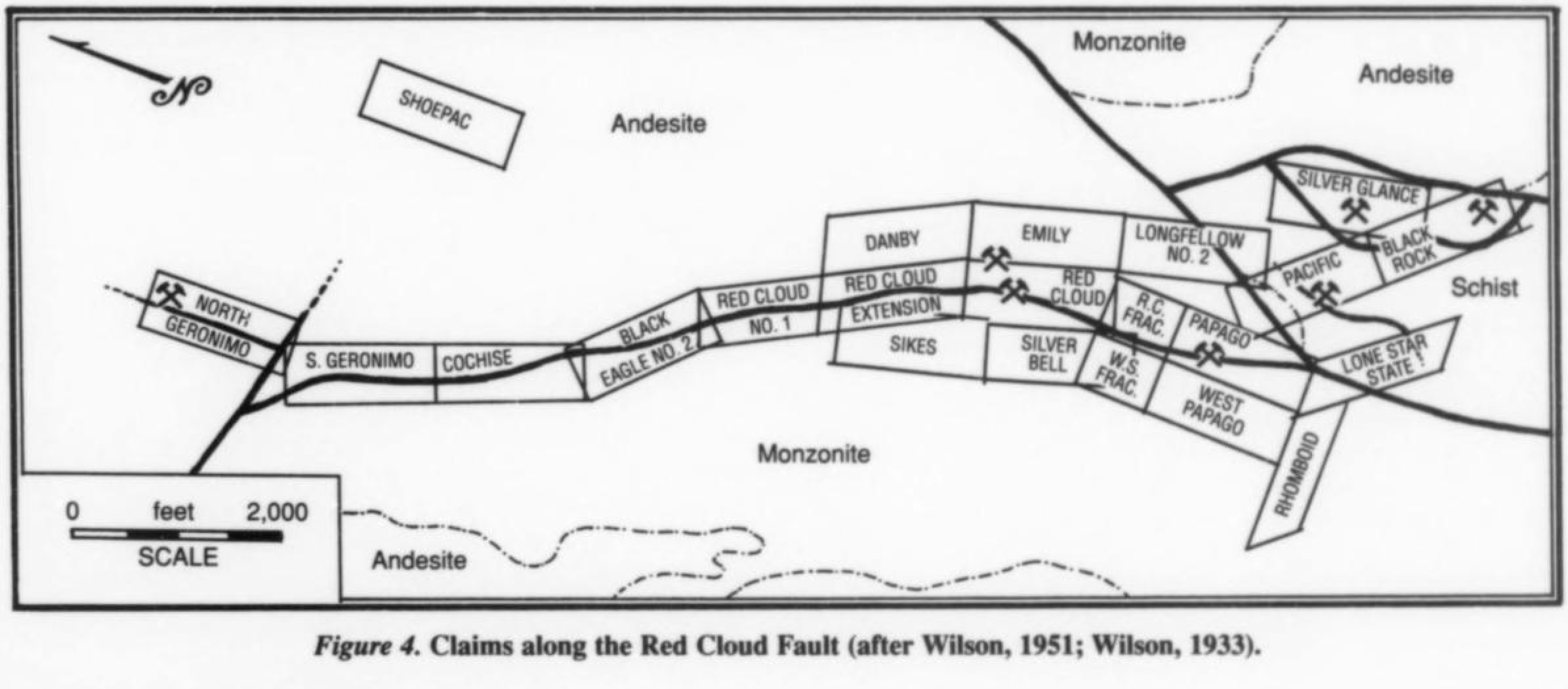


Figure 4. **Claims along the Red Cloud Fault (after Wilson, 1951; Wilson, 1933).**

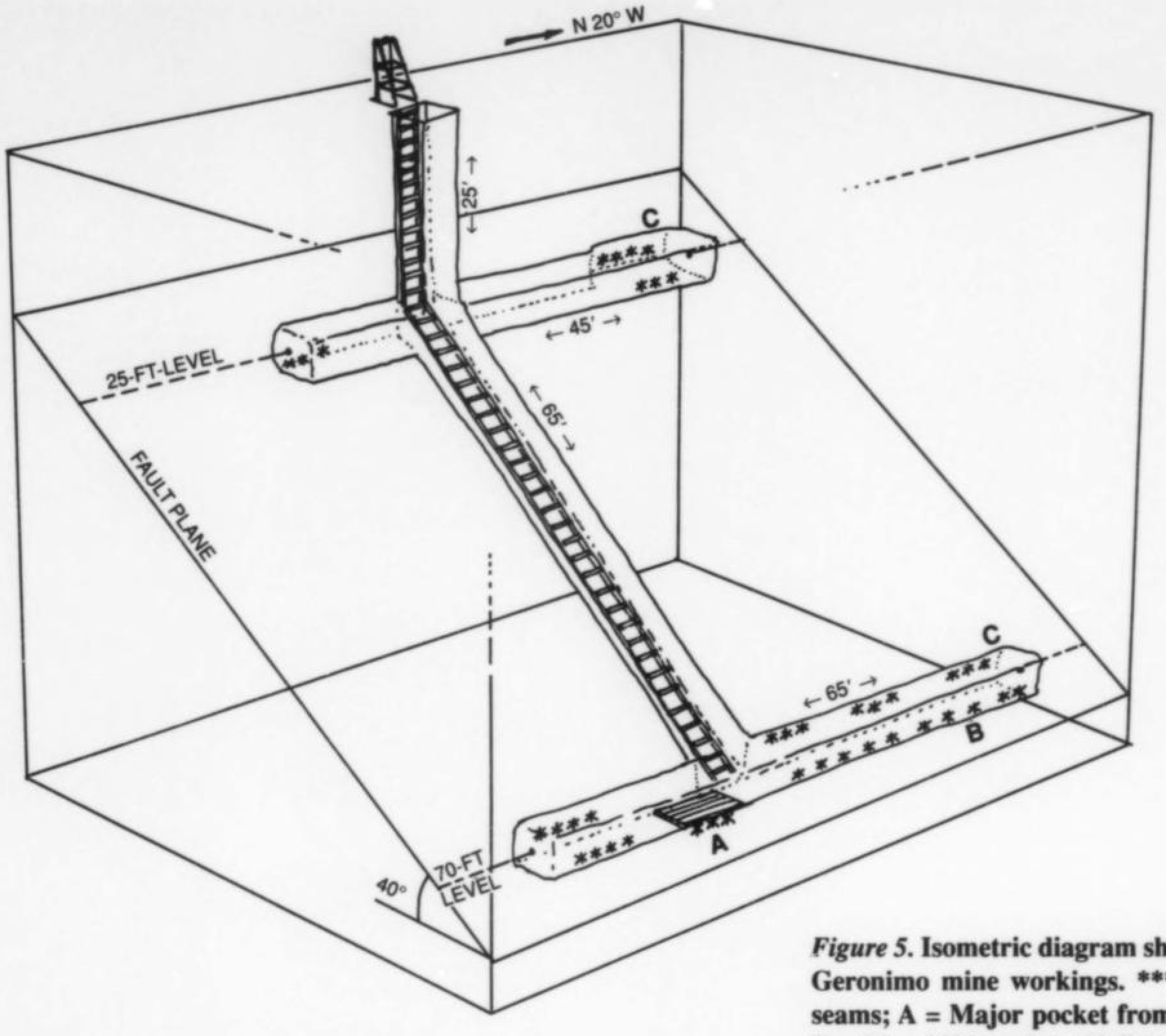


***Figure 5.* Isometric diagram showing the North Geronimo mine workings. *** = Mineralized seams; A = Major pocket from 1995 (80 flats); B = May 1996 pocket (60 flats); C = Wulfenite and mimetite occurrences (always at hanging wall).**

angle tension gashes intersecting the fault zone enhanced permeability for the deposition of galena and for the later oxidation of the veins.

The northernmost end of the Red Cloud fault is offset eastward by an unmineralized transverse fault for a distance of several hundred feet, the result being that the terminal section (almost entirely within the North Geronimo claim boundary) is enclosed by andesitic rocks on both the hanging wall and the footwall. The vein here is irregular and up to perhaps a few feet in width; the hanging wall boundary is quite distinct but the footwall is often less clear, and the actual thickness of the vein is not clearly discernible. The ore, galena and secondary minerals, averaged 6% lead and 8 ounces of silver per ton (Wilson, 1933).

MINERALS

The vein consists primarily of hematite and limonite with fluorite, calcite and quartz gangue. Near the footwall a few streaks and nodules of remnant galena can still be seen, partially altered to massive anglesite, cerussite and powdery yellow massicot. Other secondary minerals line vugs and coat breccia fragments in the vein. Trace amounts of lead, zinc, copper and silver have been identified in the gangue minerals (Parker, 1966); gold also shows up, as a trace constituent, in the adjacent South Geronimo claim.

Calcite $CaCO_3$

Calcite crystals, in rhombohedrons to 5 cm, colored dark gray and brown by manganese inclusions, have been found completely covered by red drusy vanadinite. The effect is similar to a large, sparkly rhodochrosite crystal.

Fluorite CaF_2

Greenish, highly modified fluorite crystals to about 6 mm are commonly found, some of them covered by drusy quartz.

Mimetite $Pb_5(AsO_4)_3Cl$

Hexagonal prismatic crystals of red to yellow mimetite to nearly 1 cm in size occur in association with wulfenite. The red crystals, visually distinguishable from vanadinite by their barrel-shaped habit, are translucent to transparent (like vanadinite), whereas the yellow crystals are opaque. (Identity was confirmed by electron probe microanalysis.)

Quartz SiO_2

Drusy quartz and small isolated crystals commonly coat fractures and vugs in the workings, and make an attractive matrix for the other minerals. The specimens identified with the "Romaldo Pachecos" claim in the Smithsonian nearly all consisted of vanadinite crystals on drusy quartz covering a manganiferous matrix, exactly as at the North Geronimo, suggesting that the two claims may be one and the same.

Vanadinite $Pb_5(VO_4)_3Cl$

The vanadinite from the North Geronimo is blood-red, about midway in color between the slightly orange-red of Old Yuma mine vanadinite and the pure, almost ruby-like pigeon's-blood color of fresh Apache mine vanadinite. Crystals up to 6 or 8 mm are typically simple hexagonal prisms capped by pinacoids and having roughly equant to somewhat elongated proportions. The larger crystals (up to about 3.7 cm in length) tend to develop stepped and hoppered shapes involving some pyramid faces, and typically taper to a rather small point where they are attached to the matrix. This unfortunately means that nearly all large crystals break off from the matrix at the first vibration from hammering. But the resulting

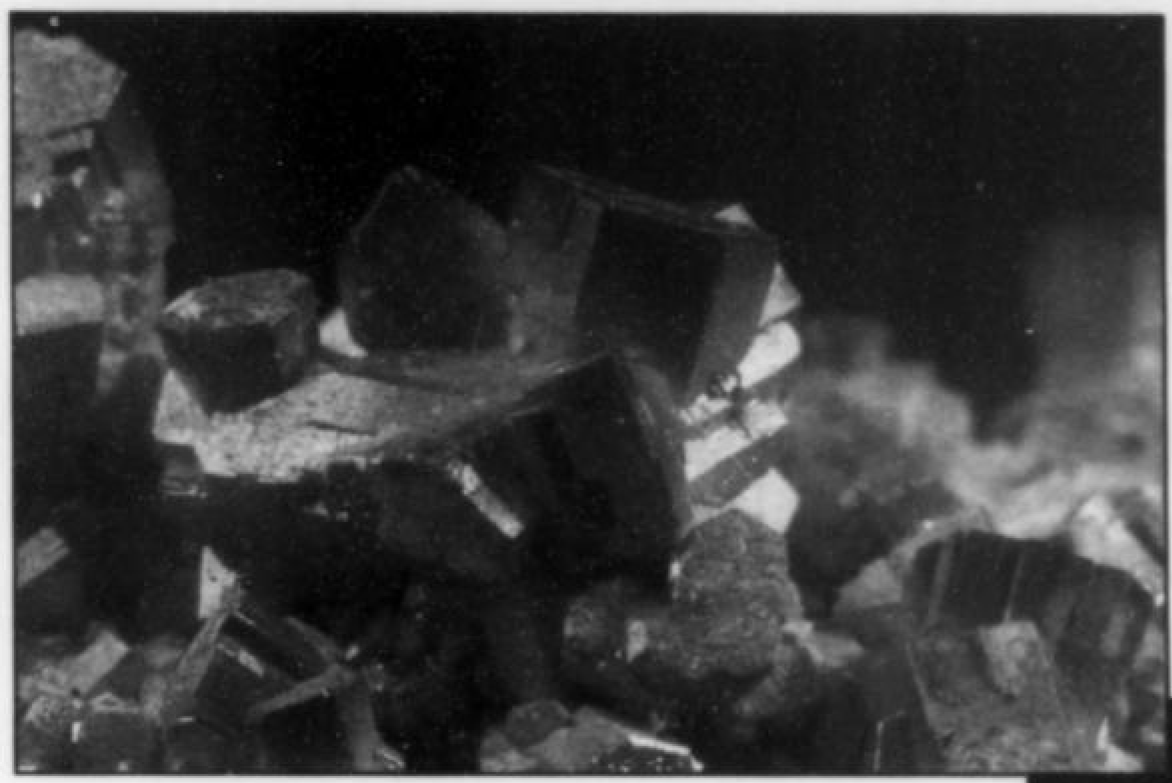


Figure 6. **Yellow mimetite crystals to 1 cm. Godas specimen; Wilson photo.**

Figure 7. **White barite crystal group, 4.7 cm, with vanadinite microcrystals. Godas specimen; Wilson photo.**

Figure 8. **Vanadinite druse on pale green fluorite crystal group, 8 cm. Godas specimen; Wilson photo.**

Figure 9. **Vanadinite group of parallel crystals, 1.3 cm. Godas specimen; Wilson photo.**

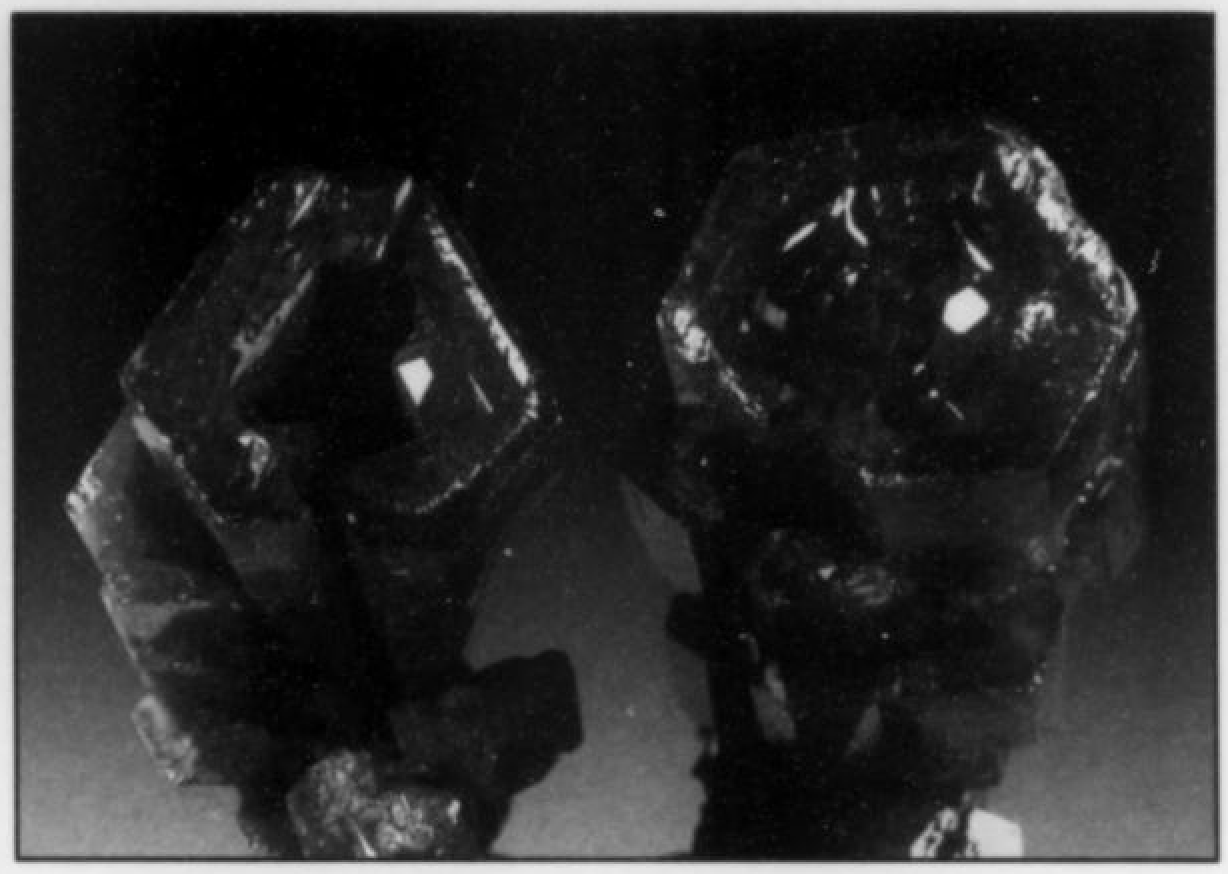


Figure 10. **Vanadinite crystals showing cavernous growth, 2 cm. Godas specimens; Wilson photo.**

Figure 11. **Vanadinite crystal group, 2 cm. Godas specimen; Wilson photo.**

Figure 12. **Vanadinite crystals showing parallel growth, 2.4 cm. Godas specimens; Wilson photo.**

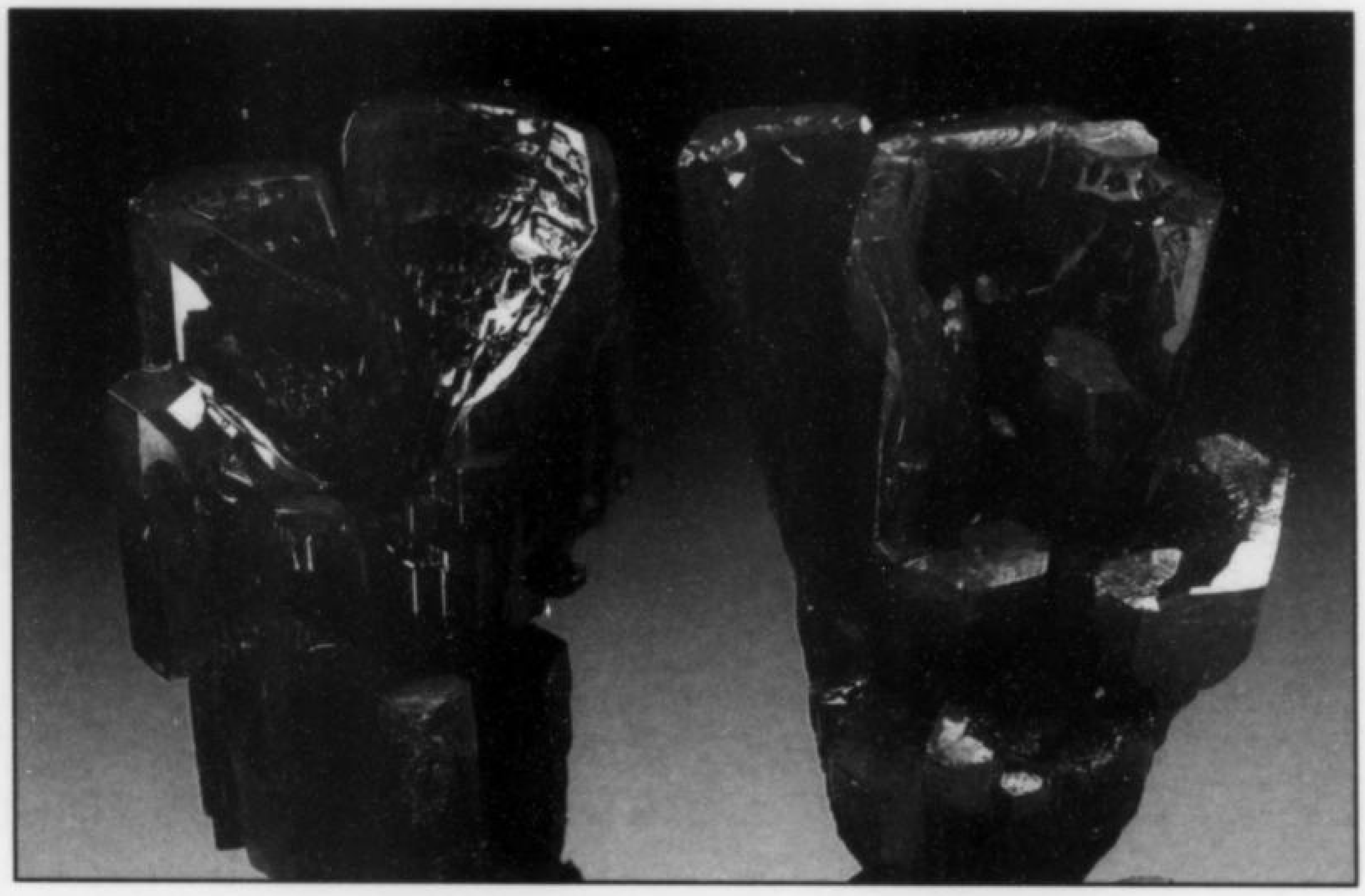


Figure 13. **Vanadinite crystals showing "hopper" growth, 2.4 cm. Godas specimens; Wilson photo.**

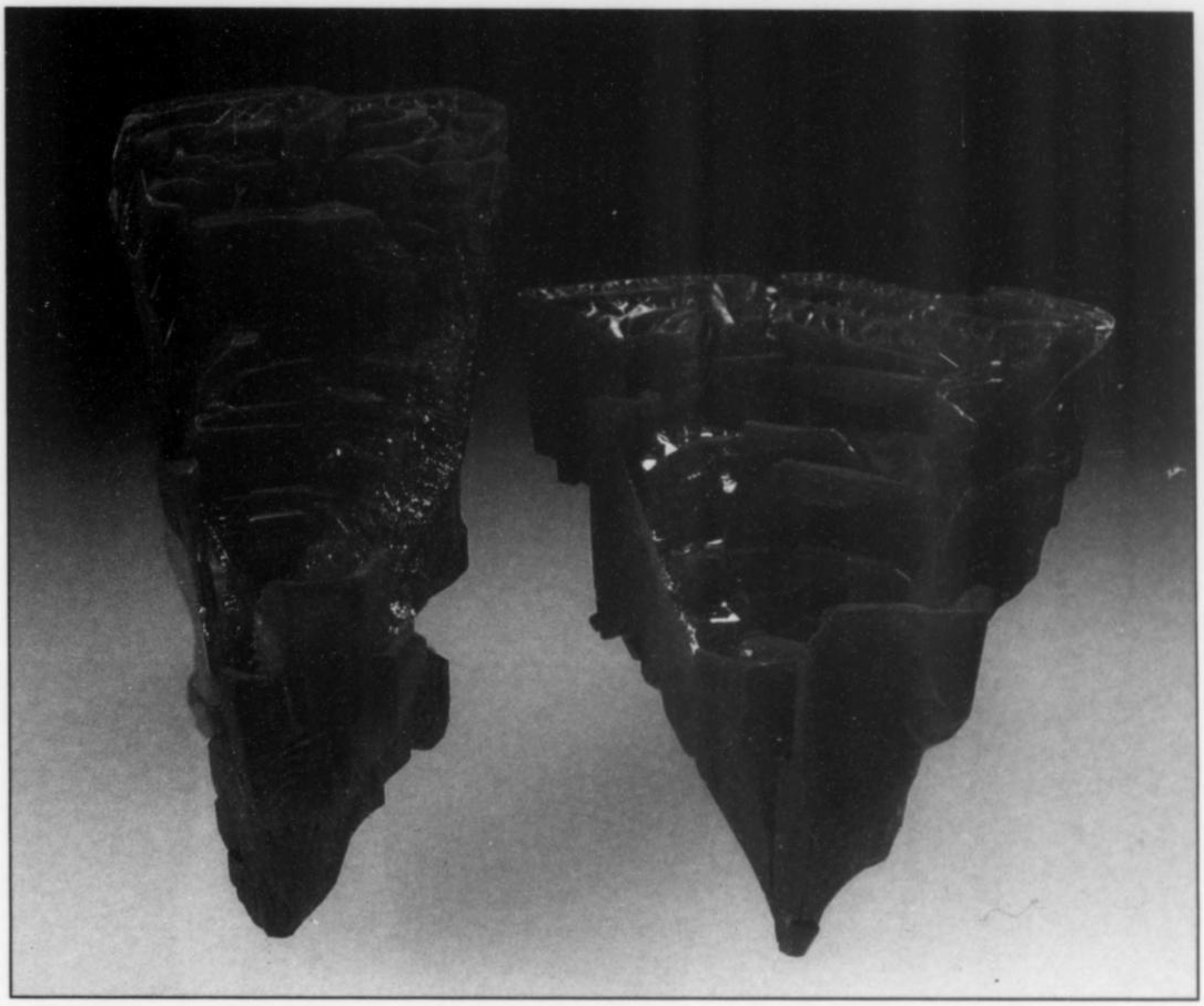


Figure 14. **Vanadinite crystals showing "hopper" growth, 3.7 cm and 3.2 cm. Godas specimens; Wilson photo.**

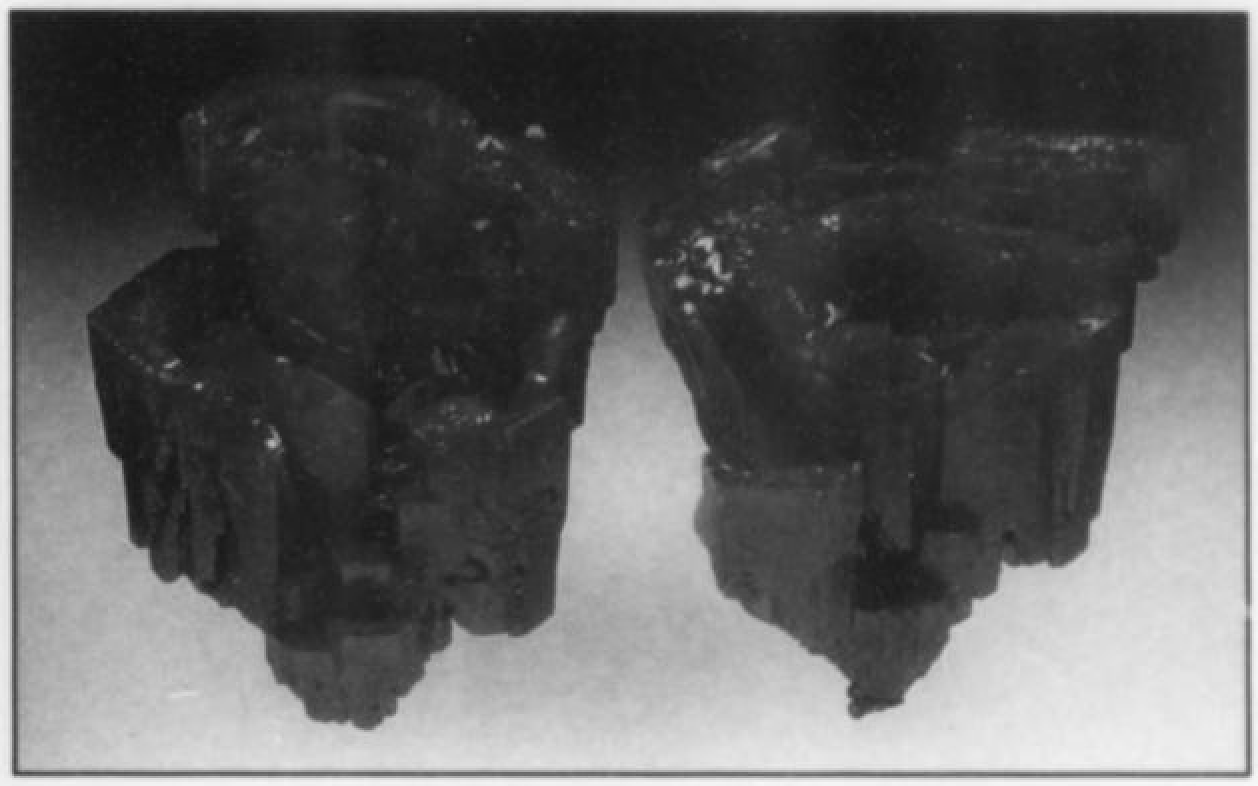


Figure 15. **Vanadinite crystals showing "hopper" growth, 2.6 cm. Godas specimens; Wilson photo.**

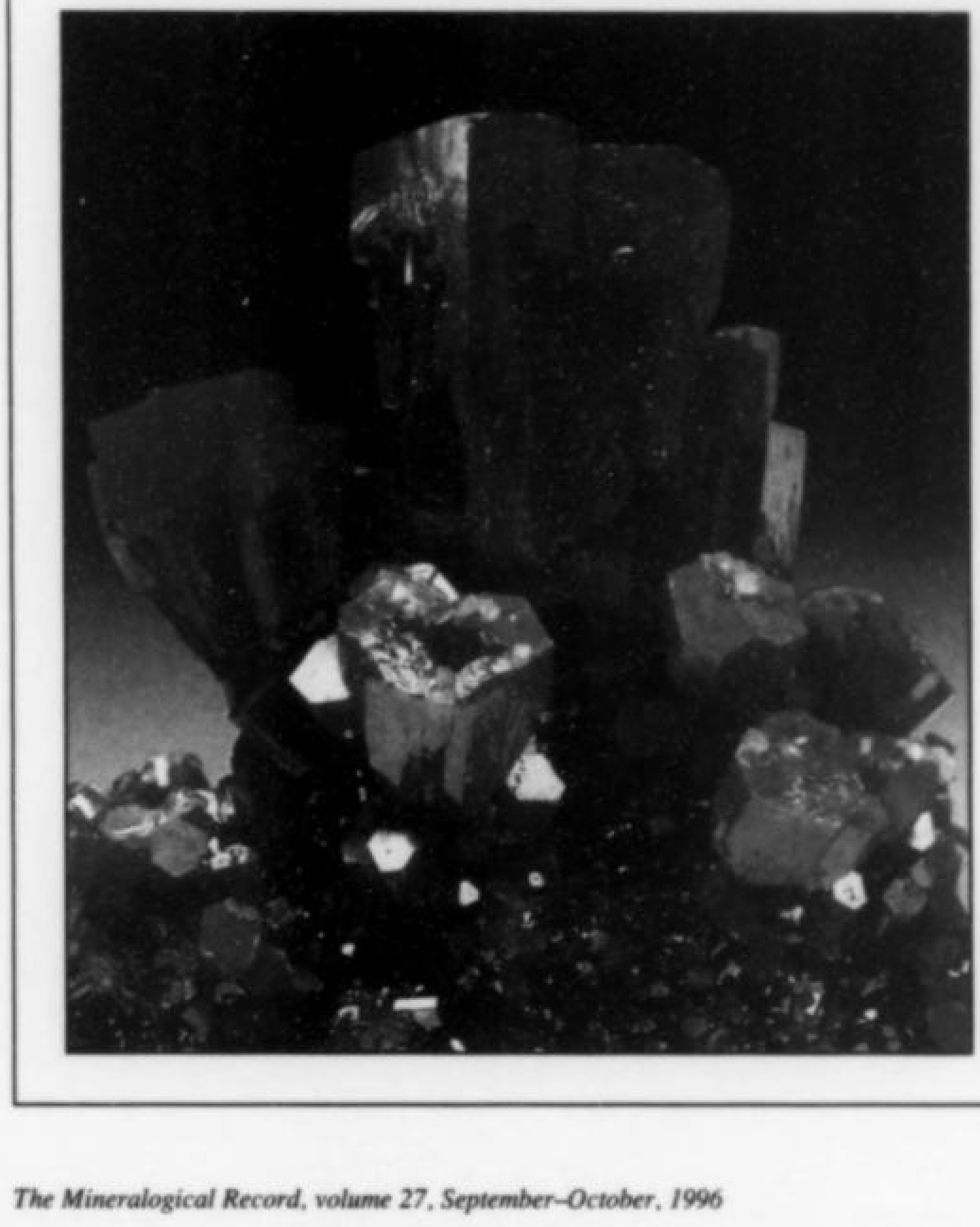


Figure 16. **Vanadinite crystals to 1.2 cm. Godas specimen; Wilson photo.**

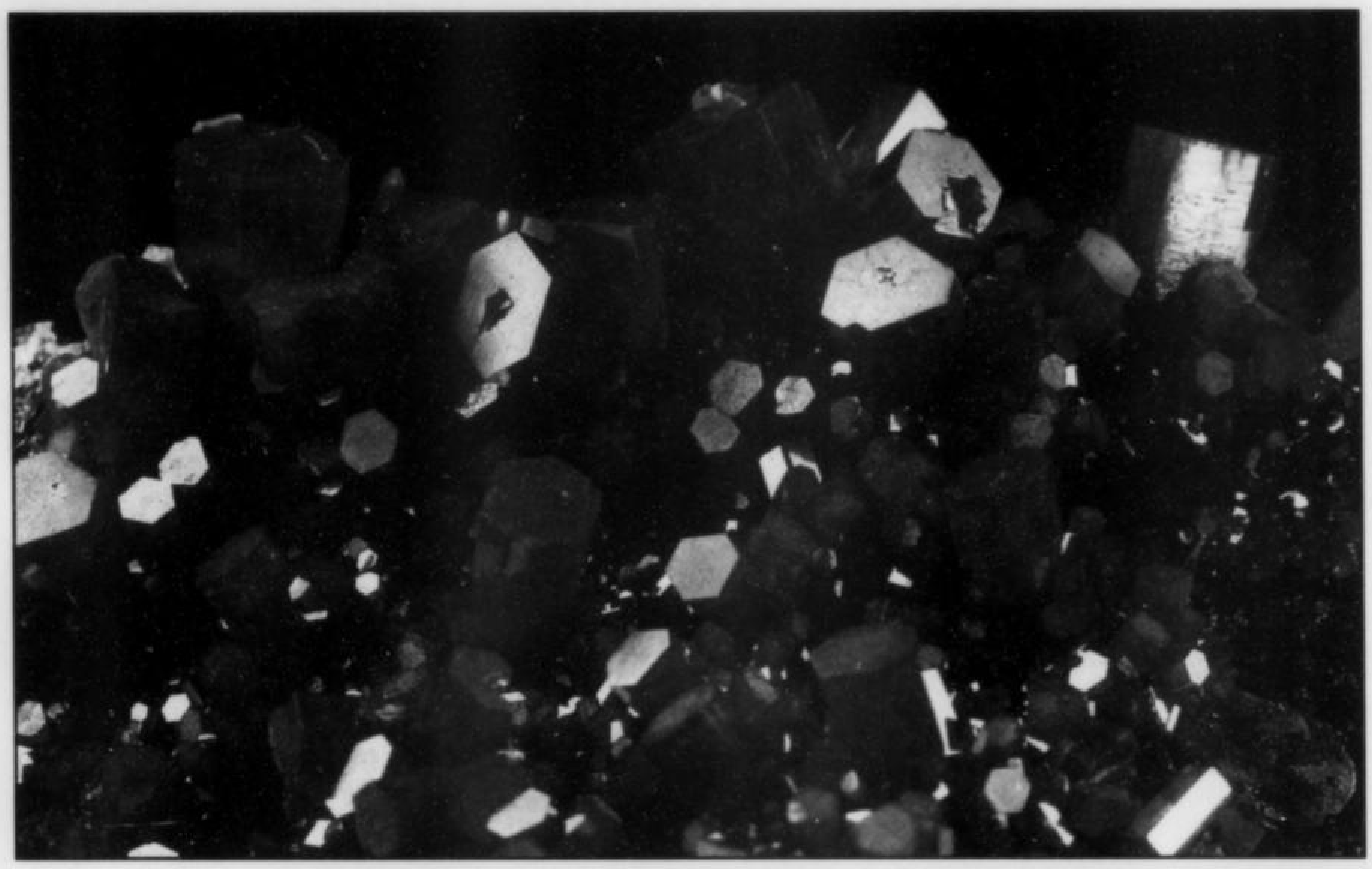
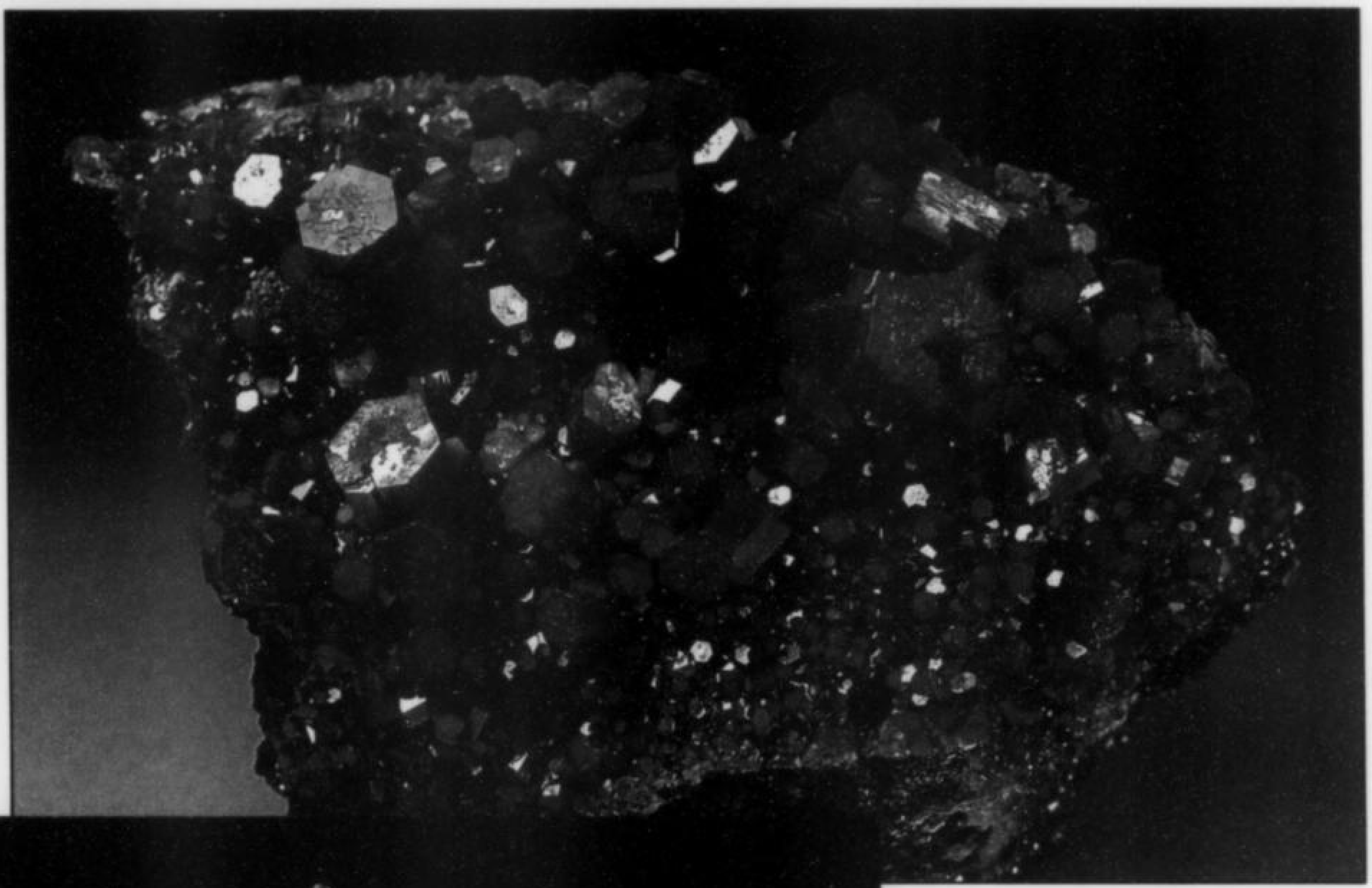


Figure 17. **Vanadinite crystals to 7 mm. Godas specimen; Wilson photo.**

Figure 18. **Vanadinite crystals on matrix, 6 cm. Godas specimen; Wilson photo.**



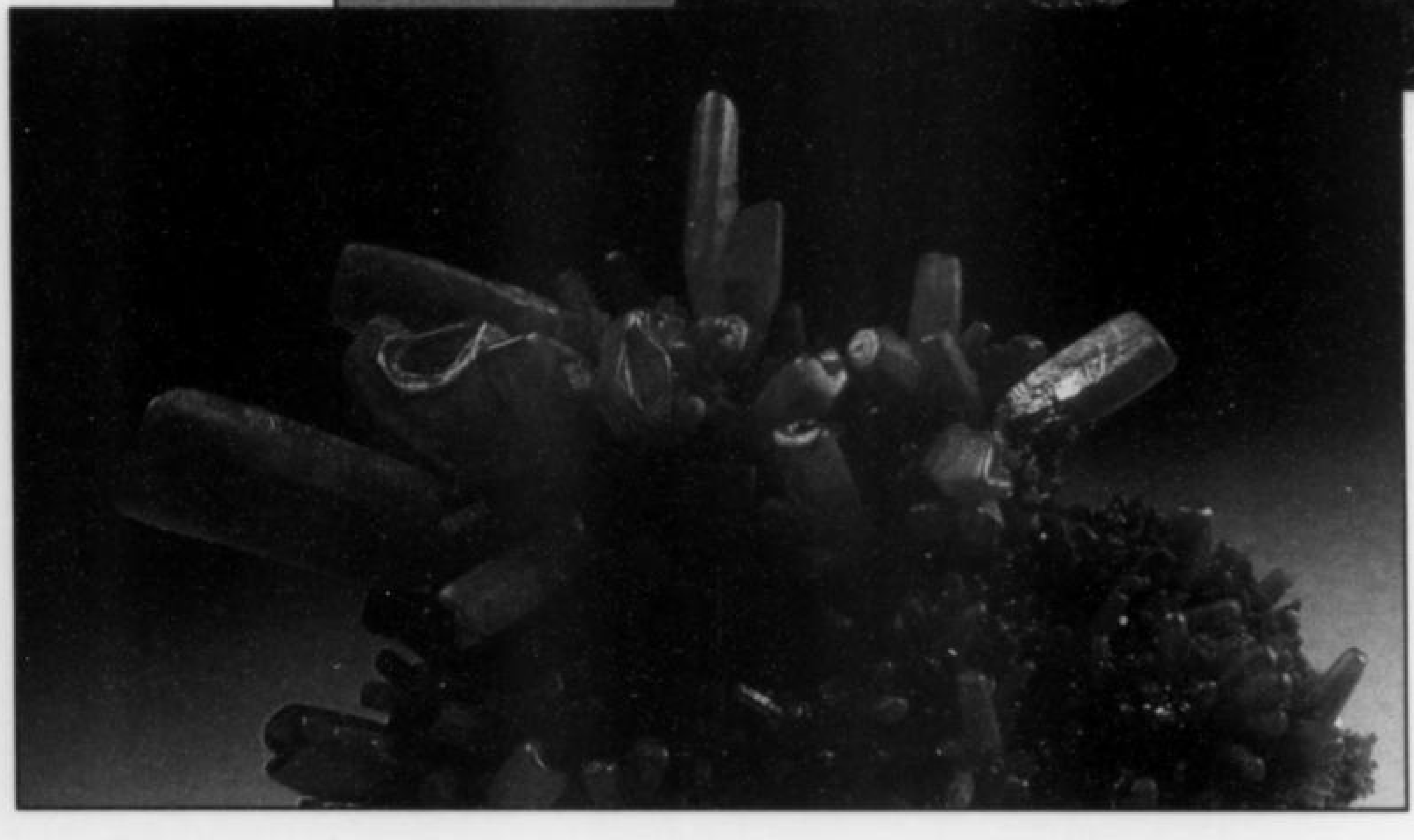


Figure 19. **Vanadinite crystal group, 3.6 cm, showing elongate habit. Godas specimen; Wilson photo.**

Figure 20. Vanadinite crystal group, 3.6 cm. Godas specimen; Wilson photo.

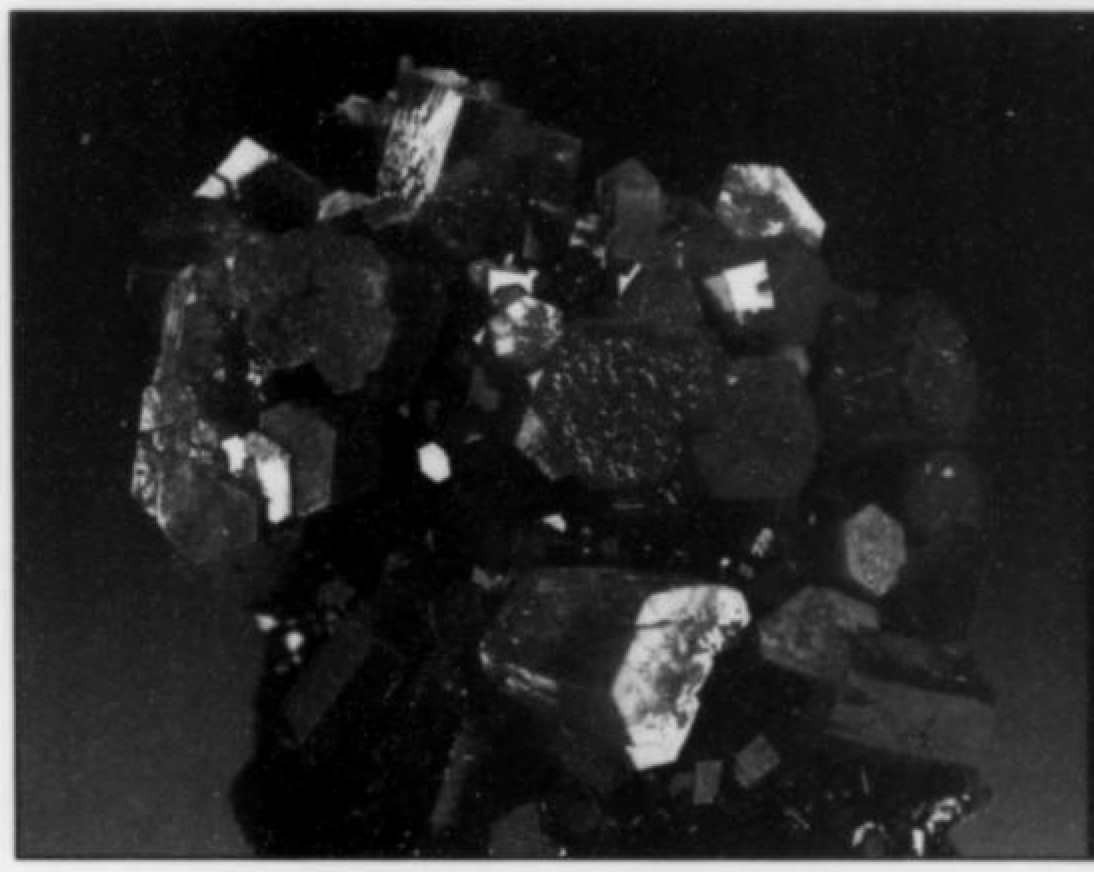


Figure 21. Vanadinite crystal group, crystals to 1 cm. Godas specimen; Wilson photo.

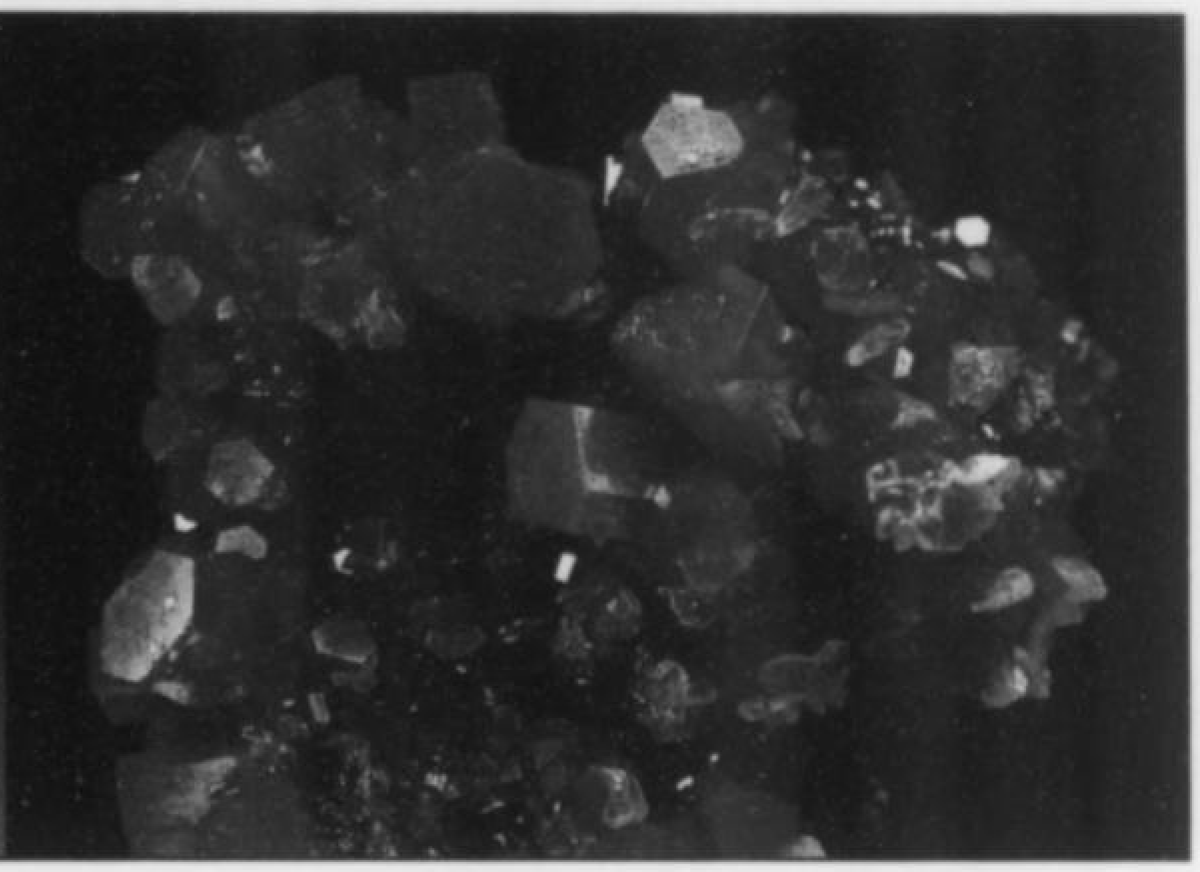


Figure 22. Vanadinite crystal group, 3.8 cm. Godas specimen; Wilson photo.

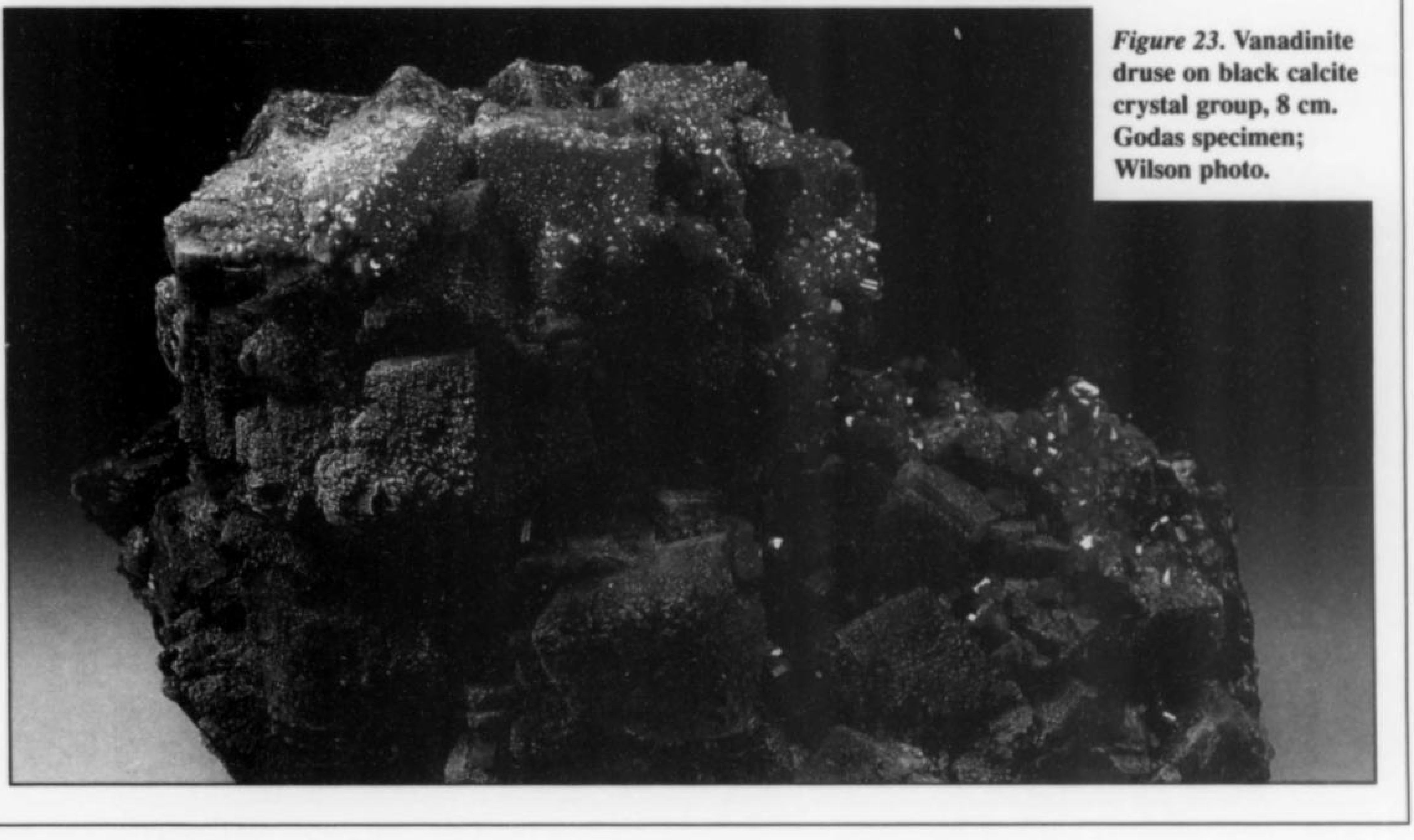


Figure 23. Vanadinite druse on black calcite crystal group, 8 cm. Godas specimen; Wilson photo.

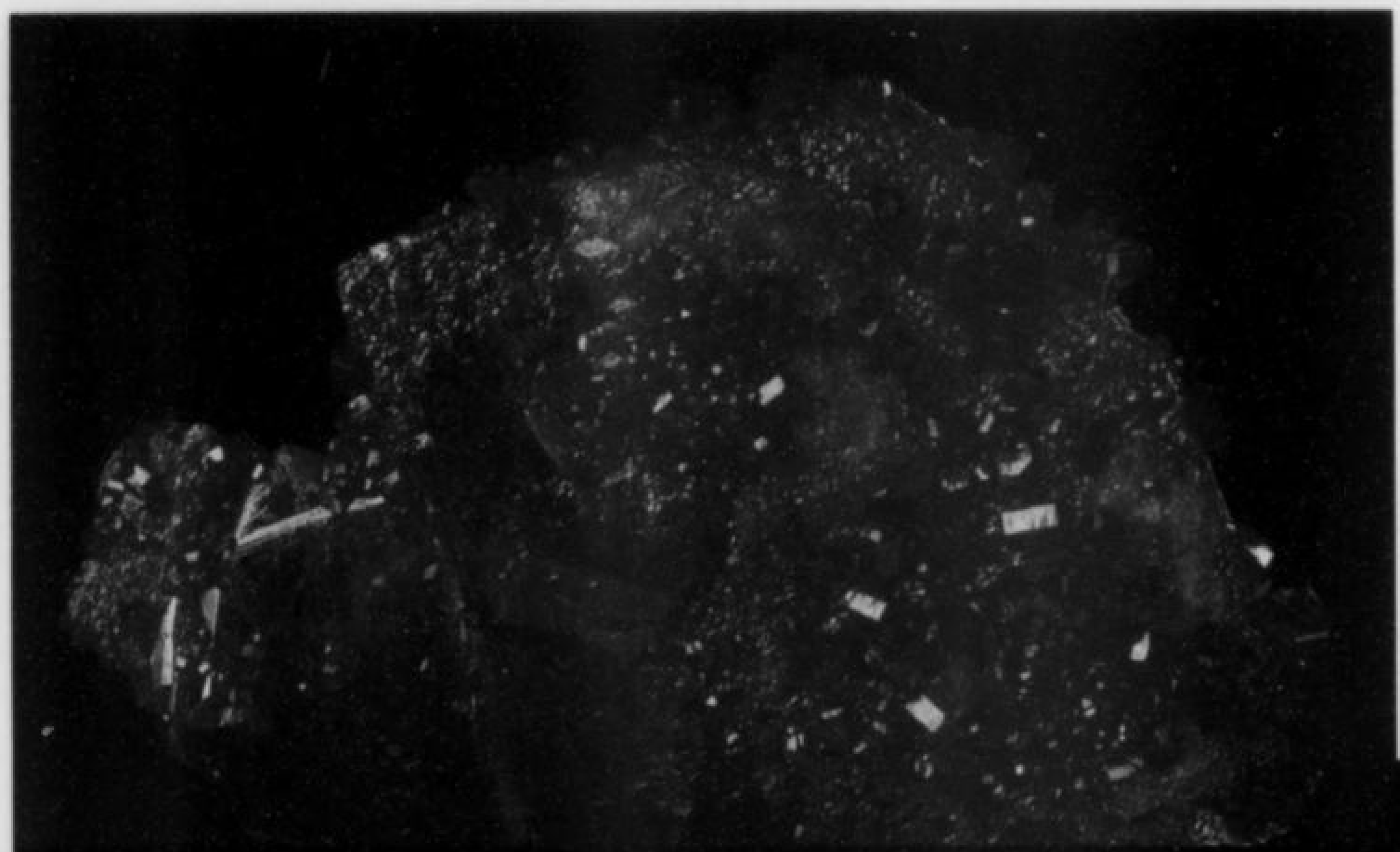


Figure 24. (left) **Red mimetite crystals on wulfenite crystal, 3.5 cm. Godas specimen; Wilson photo.**

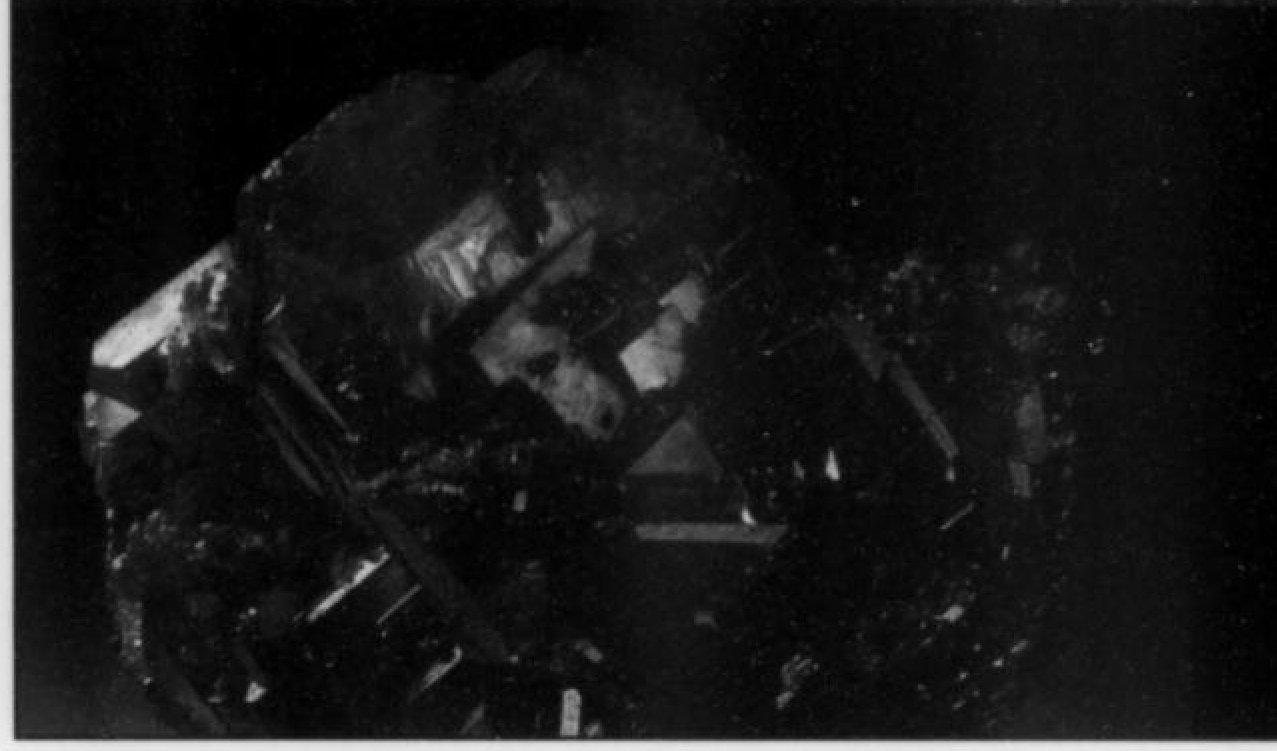


Figure 25. (below left) **Red mimetite crystals on a wulfenite crystal, 2.5 cm. Godas specimen; Wilson photo.**

Figure 26. (below) **Red mimetite crystals on wulfenite crystal, 2.4 cm. Godas specimen; Wilson photo.**

loose singles and parallel-growth crystals make superb thumbnail and miniature specimens. Top-quality, recently collected crystals and groups qualify the North Geronimo as one of Arizona's premier vanadinite localities.

Wulfenite PbM_0O_4

Red to red-orange wulfenite is common where the vein is bounded by the hanging wall. Crystals to over 2 cm have been recovered here which are more or less identical to crystals found at the Red Cloud mine. Much of the wulfenite is associated with red mimetite crystals and on a few specimens the wulfenite is even associated closely with vanadinite crystals to 6 mm, an unusual combination. Apparently the chemical conditions conducive to the deposition of wulfenite and vanadinite overlap hardly at all, because these two species (widespread in Arizona) almost never occur on the same specimen.

ACKNOWLEDGMENTS

We would like to thank Thomas Garvin of the Arizona Geological Survey, Karen Bolm of the Earth Science Information Center, and Ken Phillips of the Arizona Department of Mines and Mineral Resources for assistance with the historical research. Richard A. Bideaux and Dr. Anthony R. Kampf reviewed the manuscript, and Dr. Terry Wallace (University of Arizona, Tucson) provided the mimetite and vanadinite analyses.

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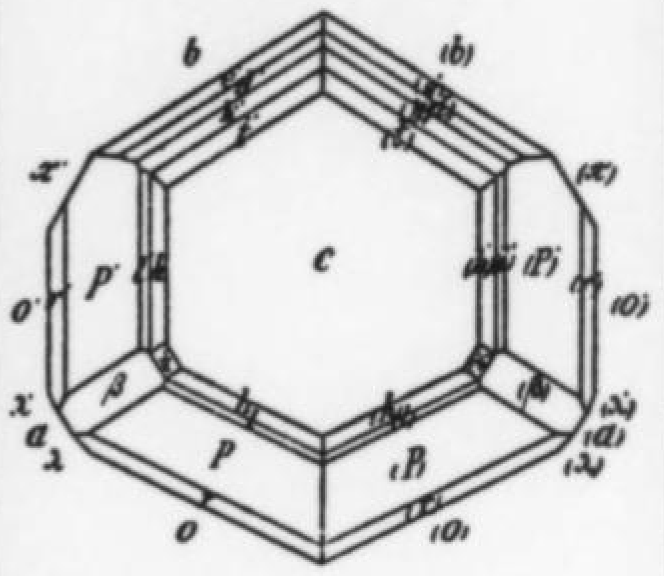
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AUSROX

MIMETITE AND WULFENITE FROM THE KINTORE OPENCUT, BROKEN HILL, NEW SOUTH WALES

Peter Elliott
1282 Greenhill Road
Carey Gully, South Australia 5144
Australia

During the seven years that the Kintore Opencut was worked, the list of species from Australia's famous Broken Hill deposit and the knowledge of the Broken Hill orebody were greatly expanded. Two of the many oxidized minerals found, mimetite and wulfenite, occurred in a variety of colors and crystal habits that may be unsurpassed at any other locality.

INTRODUCTION

Mimetite and wulfenite have long been considered rare in the oxidized zone at Broken Hill, New South Wales, and specimens are highly prized by collectors. Mining operations at the Kintore Opencut between 1984 and 1991 exposed a large suite of minerals, currently numbering about 120 species, and have resulted in many mimetite specimens and a lesser number of wulfenite specimens being recovered (Birch and van der Heyden, 1988; Birch 1990). A wide variety of colors and crystal habits is exhibited by the two species.

MIMETITE

Although mining at the Kintore Opencut has shown mimetite to be abundant in some areas of the Broken Hill oxidized zone, Broken Hill mimetite specimens have always been quite rare in collections. The scarcity of mimetite specimens recovered during early mining operations is probably not surprising, considering the often inconspicuous appearance of the species compared to the more spectacular specimens that were recovered of many other minerals for which Broken Hill is famous, such as pyromorphite, smithsonite, cerussite and anglesite. A number of mimetites of different color and habit have previously been described by Birch *et al.* (1982) and Birch and van der Heyden (1988).

Occurrence

Of the arsenates identified from the Kintore Opencut, mimetite is the most abundant. It has been found in direct association with at least 20 other species. The most common associates are minerals related to beudantite and plumbogummite, with compositions occurring in several solid solution series. The "end members" of series thus far identified are beudantite, corkite, hinsdalite, hidalgoite, plumbogummite, philipsbornite and two new species for which the Kintore Opencut is the type locality, segnitite and kintoreite (Birch *et al.*, 1992; Pring *et al.*, 1995). A number of these species are frequently found replacing mimetite, ranging from an overgrowth on the faces of still complete mimetite crystals, through partial replacement to complete replacement. These pseudomorphs are generally cavernous shells, retaining the form of the original mimetite crystal. Coronadite is occasionally also seen replacing mimetite crystals. Some of the other more common associates of mimetite are bayldonite crystals, olivenite crystals in a variety of habits, white to gray smithsonite, and cerussite.

Color

Mimetite from the Kintore Opencut shows a wide variety of colors. Crystals colored pale orange to deep orange and orange-red provide the most spectacular specimens, especially when associated with yellow and green segnitite-beudantite and plumbogummite-like minerals. The most impressive specimens have orange to orange-red crystals to 5 mm richly scattered on coronadite and quartz-rich rocks. Matrix specimens exceeding 30 cm were recovered. Orange crystals commonly show color zoning, with pyramid and pinacoid faces, and sometimes also the second-order prism

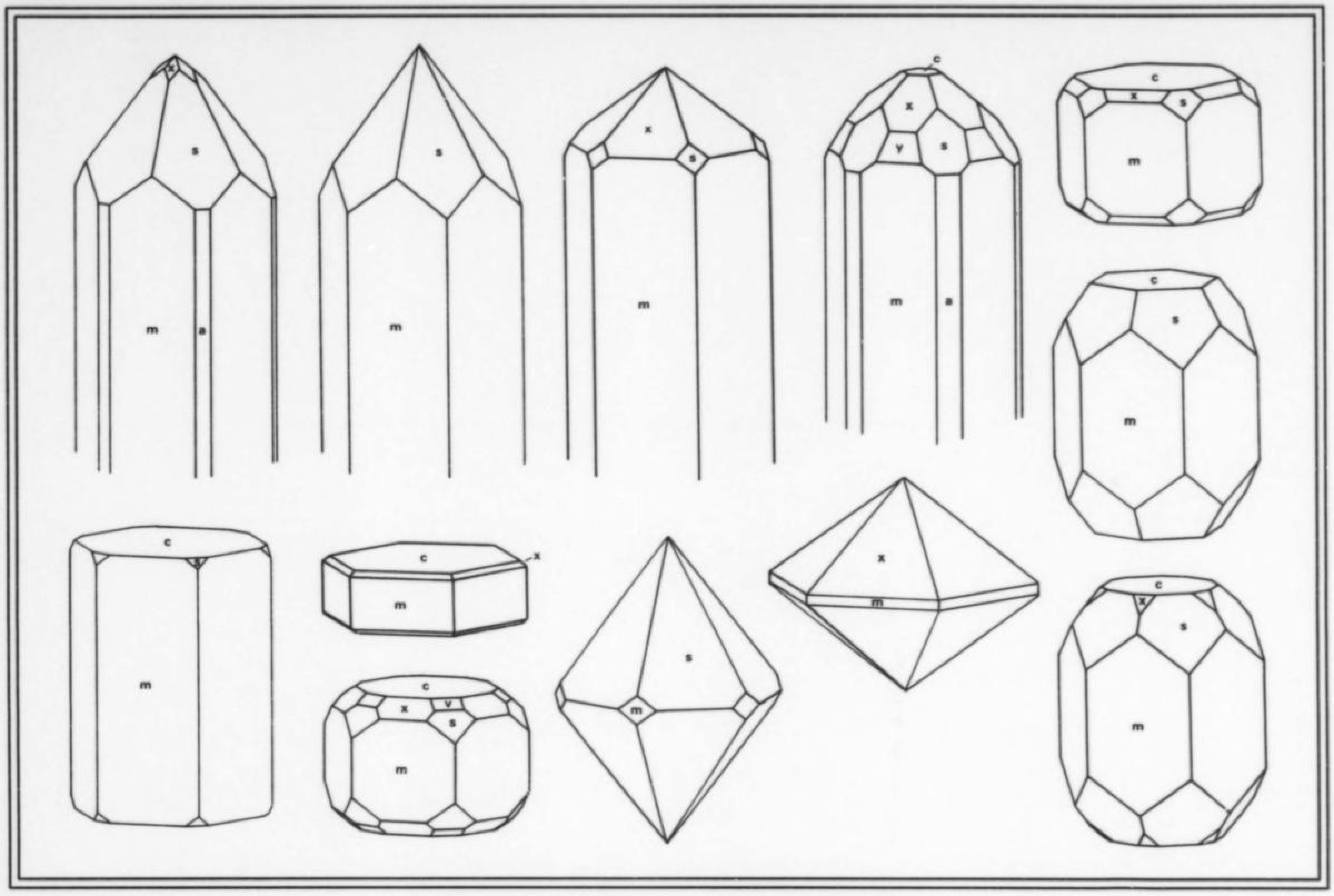

***Figure 1.* Crystal drawings of mimetite showing the range of habits from the Kintore Opencut. Forms shown are $c\{0001\}$, $m\{10\bar{1}0\}$, $d\{11\bar{2}0\}$, $x\{10\bar{1}1\}$, $y\{20\bar{2}1\}$, $s\{11\bar{2}1\}$ and $v\{11\bar{2}2\}$.**

faces, being yellow or white. Attractive specimens of yellow mimetite were also found; the crystals do not reach the same size and are not as common as the orange crystals, but they still provide excellent specimens. Again there is a variety of shades from a very pale, pastel yellow to more vivid colors. Some of the best specimens have gemmy, transparent crystals scattered on goethite matrix, and resemble a smaller version of those from Tsumeb. Some crystals are a brilliant "electric" yellow, and are exceptionally transparent and lustrous. Green is perhaps the most uncommon color for Kintore Opencut mimetites. Transparent crystals to 3 mm ranging in color from yellow through yellow-green to a bright apple-green occur very rarely on garnet sandstone associated with beudantite.

Colorless crystals are also common, and many are water-clear and very lustrous. Opaque, milky white crystals, some of which are skeletal and consist of only a very thin shell, occur on goethite matrix. Mimetite is also found in varying shades of cream, gray, brown and tan, some of which are also bicolored, with white pyramid and pinacoid faces.

Morphologies

Mimetite crystals are usually found as scattered individuals or as random intergrowths of two or more crystals, but sprays of radiating crystals also occur, as do crusts of drusy crystals. The most common habit is short to long prismatic, and although crystals to 8 mm in length were found, they are typically 3 mm or less in size. The majority of the Kintore Opencut mimetite crystals are elongated prisms with the first-order prism $\{10\bar{1}0\}$ as the predominant form, occasionally accompanied by the second-order prism $\{11\bar{2}0\}$. Prismatic crystals are generally terminated by the first-order pyramid $\{10\bar{1}1\}$ or second-order pyramid $\{11\bar{2}1\}$, with both frequently being present on a single crystal, often modified by the pinacoidal base $\{0001\}$. More rarely seen are the first-order pyramid $\{20\bar{2}1\}$ and second-order pyramid $\{11\bar{2}2\}$. Many prismatic crystals show multiple terminations with numerous pyramid faces or with what appears to be a single prism branching out at both ends to become a group of radiating individuals, resulting in sheaf or dumbbell shaped groups (see Wilson and Miller, 1971, for discussion of this same habit from the Rowley mine, Arizona). Tabular, yellow and bright orange to orange-red crystals occur scattered on coronadite matrix. The prism $\{10\bar{1}0\}$ and the base $\{0001\}$ are the predominant forms with small $\{10\bar{1}1\}$ faces also sometimes present. The $\{0001\}$ faces often appear frosted due to the development of many $\{10\bar{1}1\}$ faces across the surface. Crystals on which a prism is not a dominant face are very rare. Orange bipyramidal crystals which have small $\{10\bar{1}0\}$ faces accompanying the pyramid $\{10\bar{1}1\}$ occur on quartz and kaolin-rich rocks associated with smithsonite. Orange bipyramids with the second-order pyramid $\{11\bar{2}1\}$ modified by small $\{10\bar{1}1\}$ faces are associated with pale green hinsdalite.

Compositions

Microprobe analysis of several mimetites from the Kintore Opencut were published by Birch and van der Heyden (1988). Most of those analyzed were near end-member composition but a few had intermediate compositions, being phosphatian mimetite.

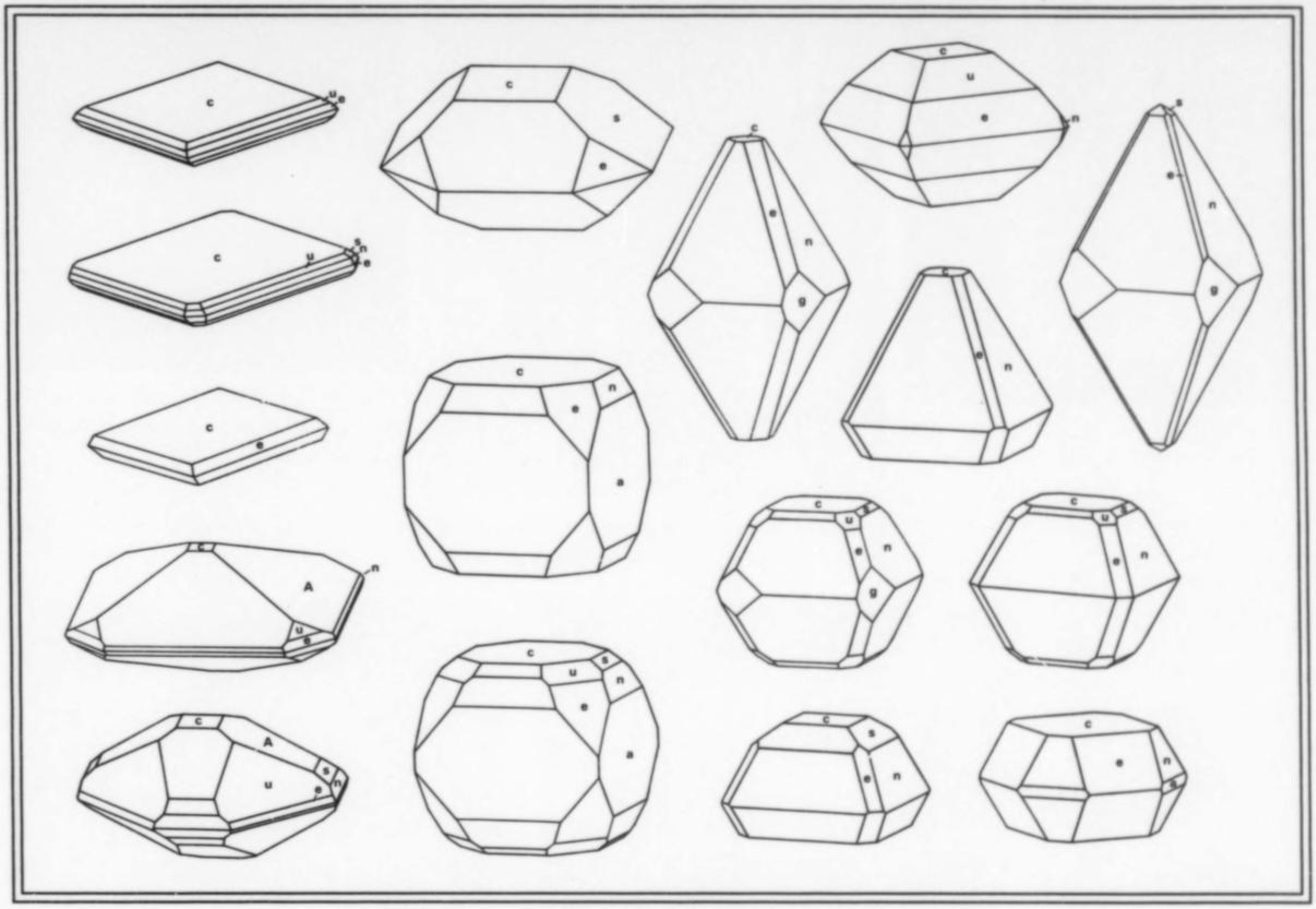

Figure 2. **Crystal drawings of wulfenite showing the range of habits from the Kintore Opencut. Forms shown are *c*{001}, *a*{010}, *g*{120}, *A*{015}, *s*{013}, *n*{011}, *u*{114} and *e*{112}.**

WULFENITE

Wulfenite specimens from Broken Hill have always been highly prized by collectors. There have previously been only two finds outside of the Kintore Opencut, both from one area of the 45-meter level of the Junction mine. The first of these was in 1890, when very few specimens were saved, and the second was in 1924 when more specimens were collected. The crystals are orange bipyramids modified by prism and pinacoid faces (Birch *et al.*, 1982).

Wulfenite from the Kintore Opencut does not show the same wide variation in color as mimetite, but it does occur in a variety of crystal habits. The finest examples were found in mid-1986 when specimens up to 20 cm across with orange to orange-red crystals on garnet-rich sandstone were collected. The crystals are typically less than 4 mm, with some reaching 8 mm. They are associated with drusy yellow to orange mimetite and white cerussite crystals. The crystals are generally transparent, and vary from paper thin and tabular with dominant {001} faces modified by small pyramid faces, to more equant habits showing similar development of {001} and two or more pyramids.

Apart from these very rich specimens, wulfenite crystals have tended to occur as small isolated individuals and were thus easily overlooked. Tabular orange crystals to 1.5 mm, with a more complex habit, occur on iron-stained and manganese-stained quartz associated with pale yellow mimetite crystals. The dominant faces are the pyramids {114} and {015} with smaller {011}, {013}, {112} and {001} faces. Yellow to orange cuboid crystals to 2 mm occur on quartz, associated with malachite and mimetite. The crystals show dominant second-order prism faces {010} modified by the pyramids {011} and {112} and sometimes also {013} and {114}. The prism is sometimes elongated to form a short prismatic habit. Yellow 1-mm crystals which show the rarely seen hemimorphic character of wulfenite occur on "limonite" gossan; the {013} faces are absent from one half of the crystal. Yellow crystals with a bipyramidal habit occur on quartz and kaolin-rich rocks associated with chlorargyrite. In addition to the dominant second-order pyramid {011} and lesser {013} and {112} faces, a prism, probably {120} is also present. The crystals also sometimes show small {001} faces. The color of these crystals is a bright lemon-yellow or, in rare instances, gray.

PARAGENESIS

Birch and van der Heyden (1988) and Birch (1990) have suggested four broad associations as occurring at the Kintore Opencut, with the arsenate-rich series being the most complex and diverse. All three associations have their origin in ground water dissolution of the primary sulfides galena, sphalerite and chalcopyrite. Local concentrations of arsenopyrite would yield arsenic-rich solutions and small amounts of molybdenite may be the source of molybdenum for wulfenite.

Mimetite and pyromorphite, which form under acidic conditions, were possibly the most abundant minerals during the early

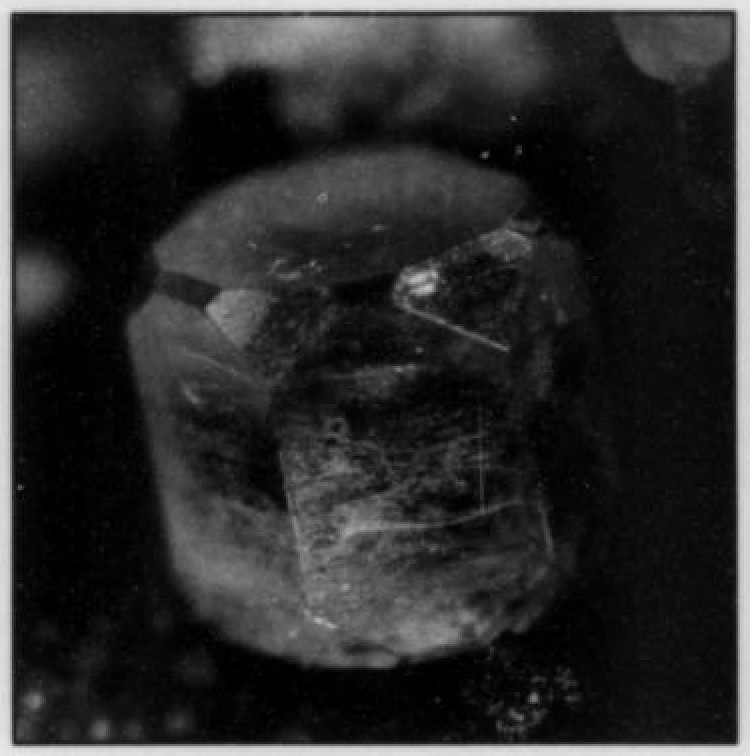

Figure 3. Mimetite crystal, 1.3 mm, on goethite. Author's specimen and photograph.

Figure 5. Mimetite crystal, 2 mm in length, on beudantite. Author's specimen and photograph.

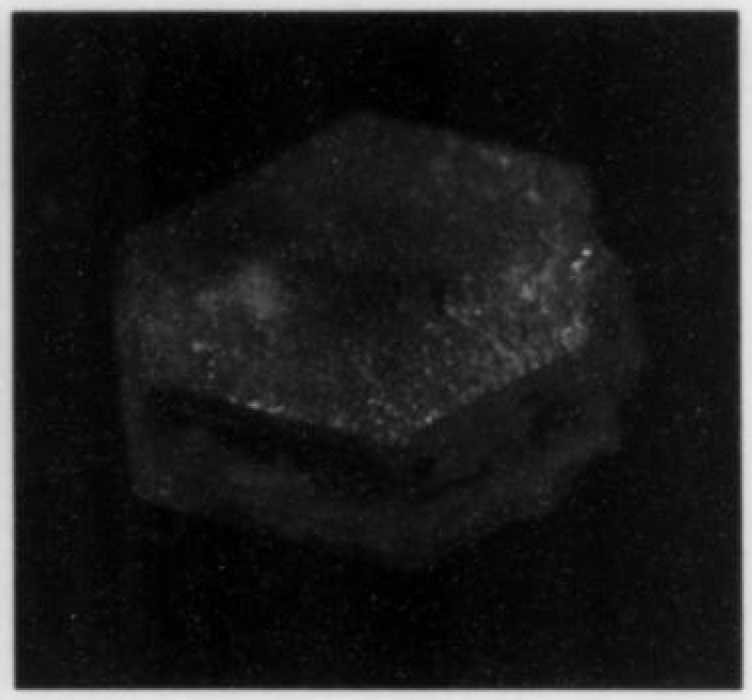

Figure 6. Tabular mimetite crystal, 1.3 mm in width, on coronadite. Author's specimen and photograph.

Figure 4. (below) Mimetite crystals to 2 mm on beudantite. Author's specimen and photograph.

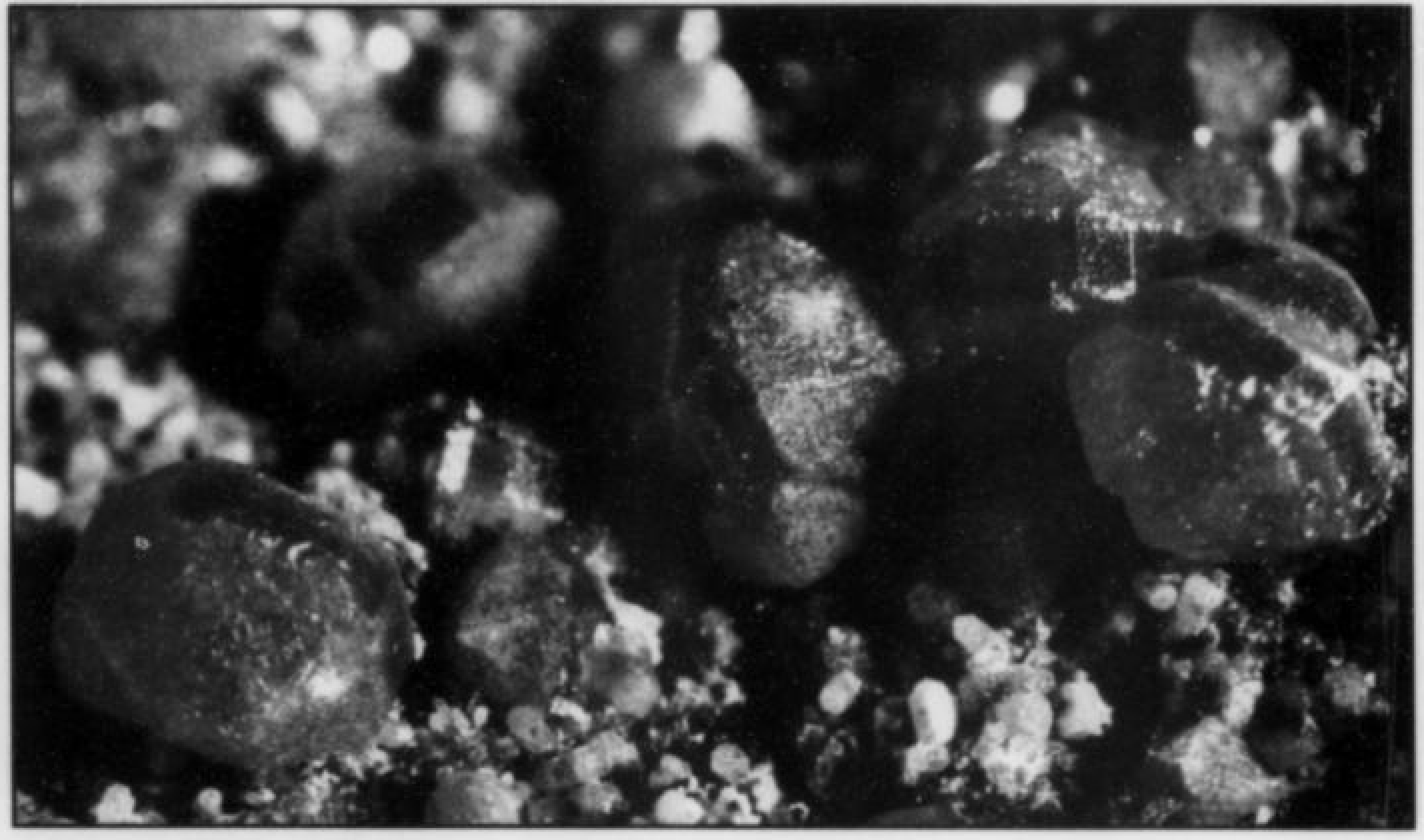

Figure 7. (below) Mimetite crystal, 1 mm in length, on beudantite. Author's specimen and photograph.

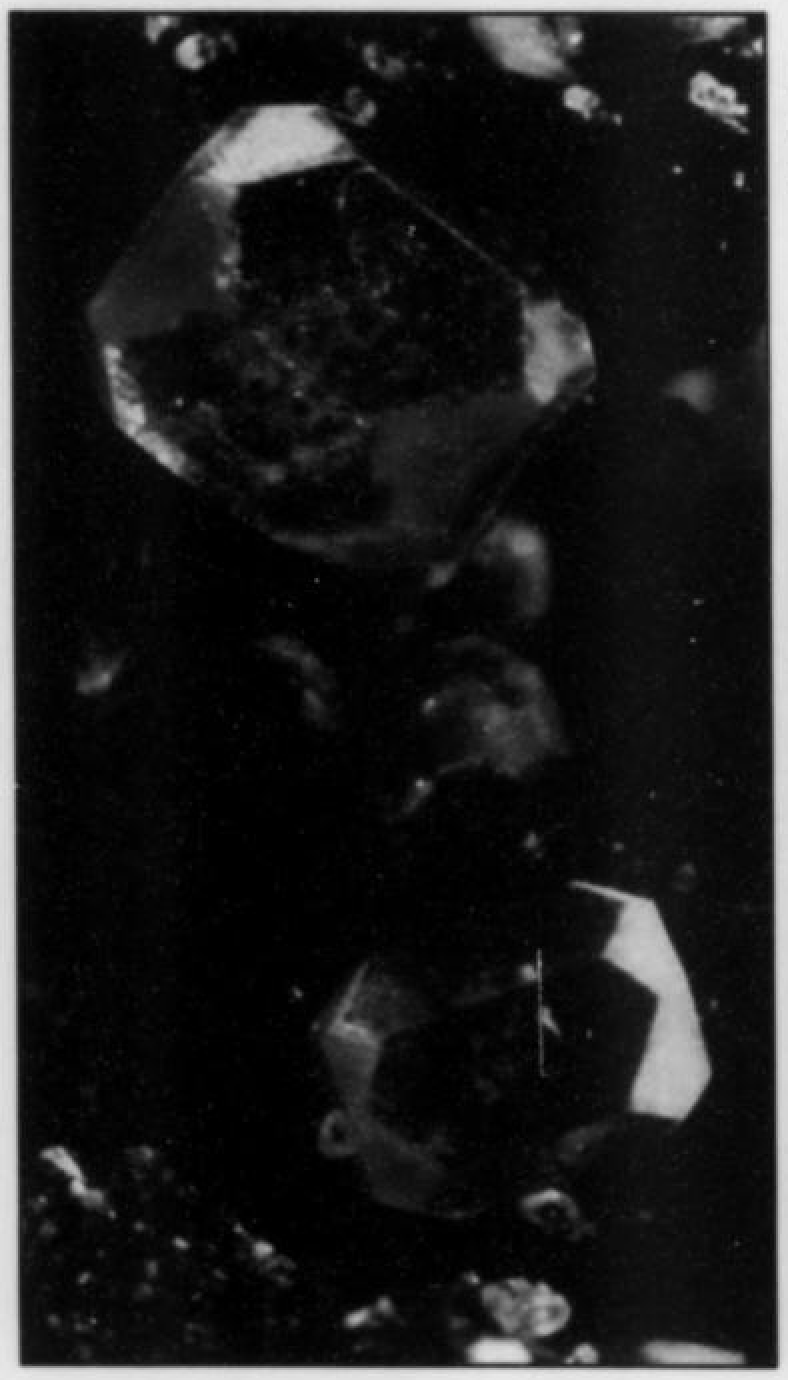

Figure 8. (left) Mimetite crystals to 1 mm on goethite. Author's specimen and photograph.

Figure 9. (below) Mimetite crystals to 4 mm, on goethite. Author's specimen and photograph.

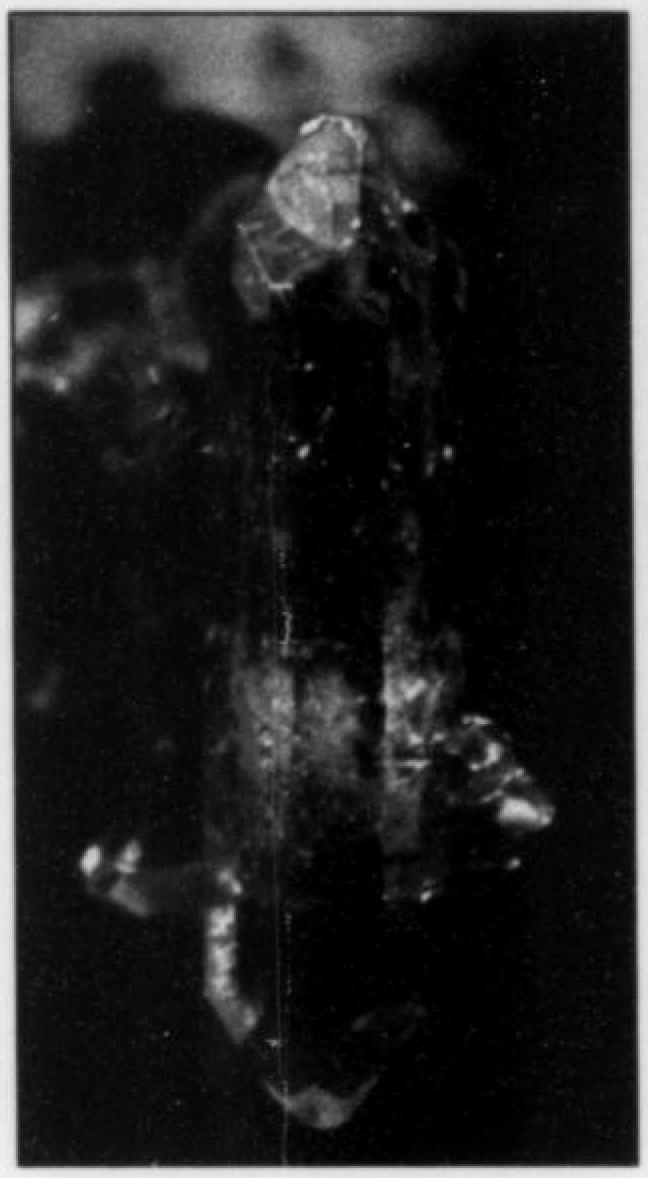

Figure 10. **Mimetite crystal, 1 mm in length, on goethite. Author's specimen and photograph.**

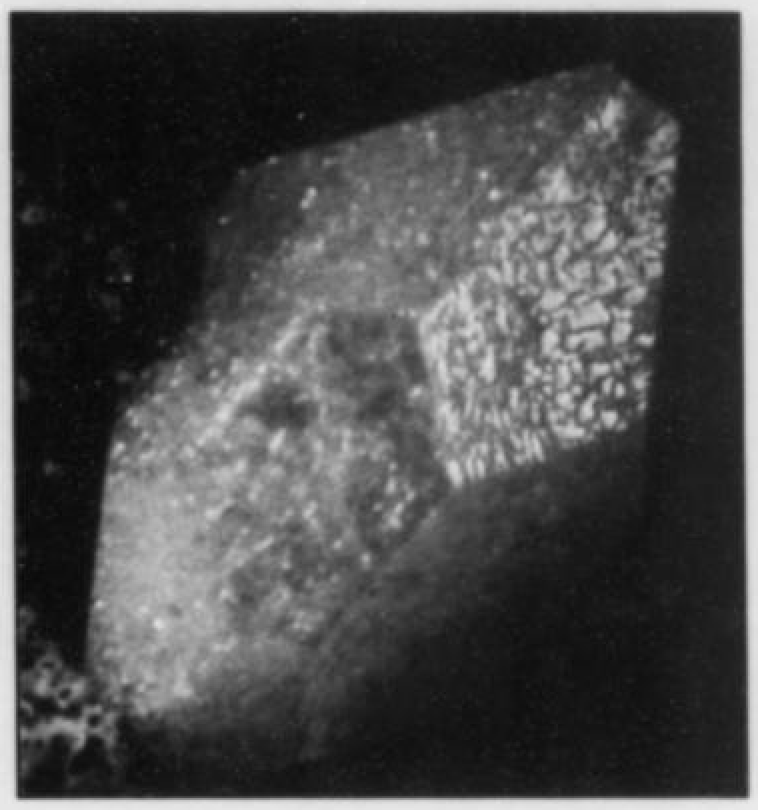

Figure 11. **Mimetite crystal, 1 mm in length, on goethite and kaolin. Author's specimen and photograph.**

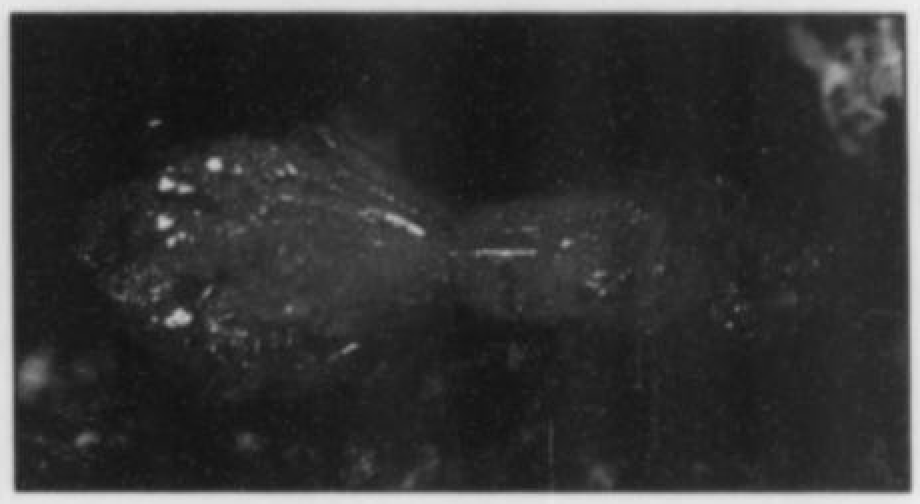

Figure 12. **Mimetite crystal group, 2 mm across, on coronadite. Author's specimen and photograph.**

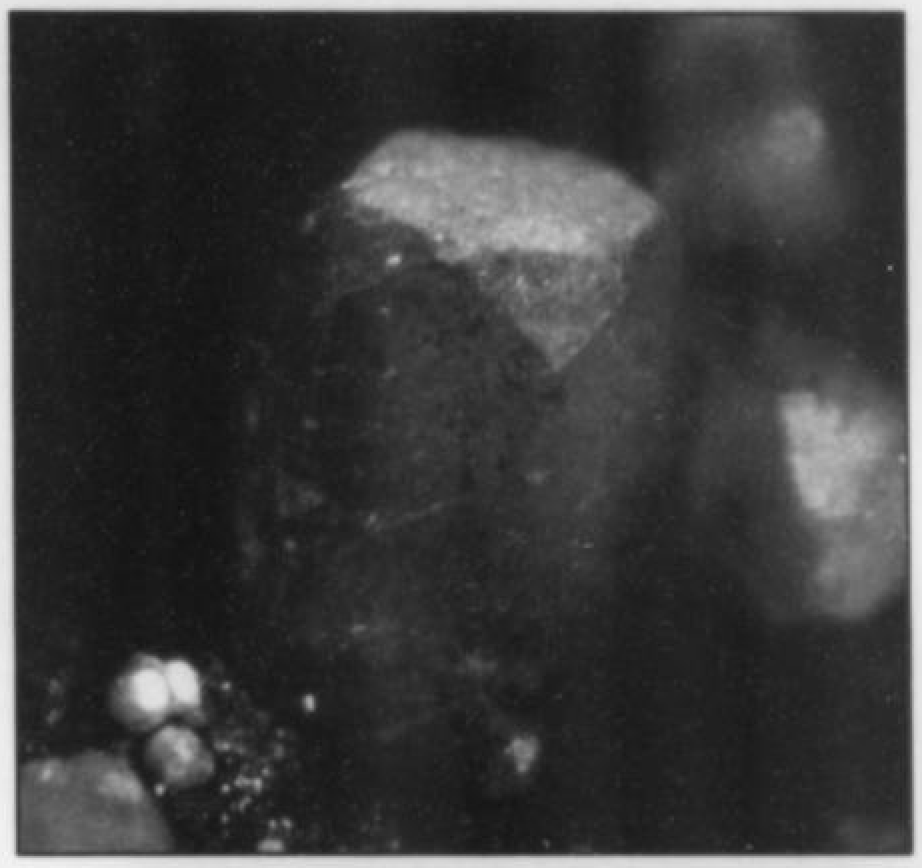

Figure 13. **Mimetite crystals to 1.5 mm, on goethite. Author's specimen and photograph.**

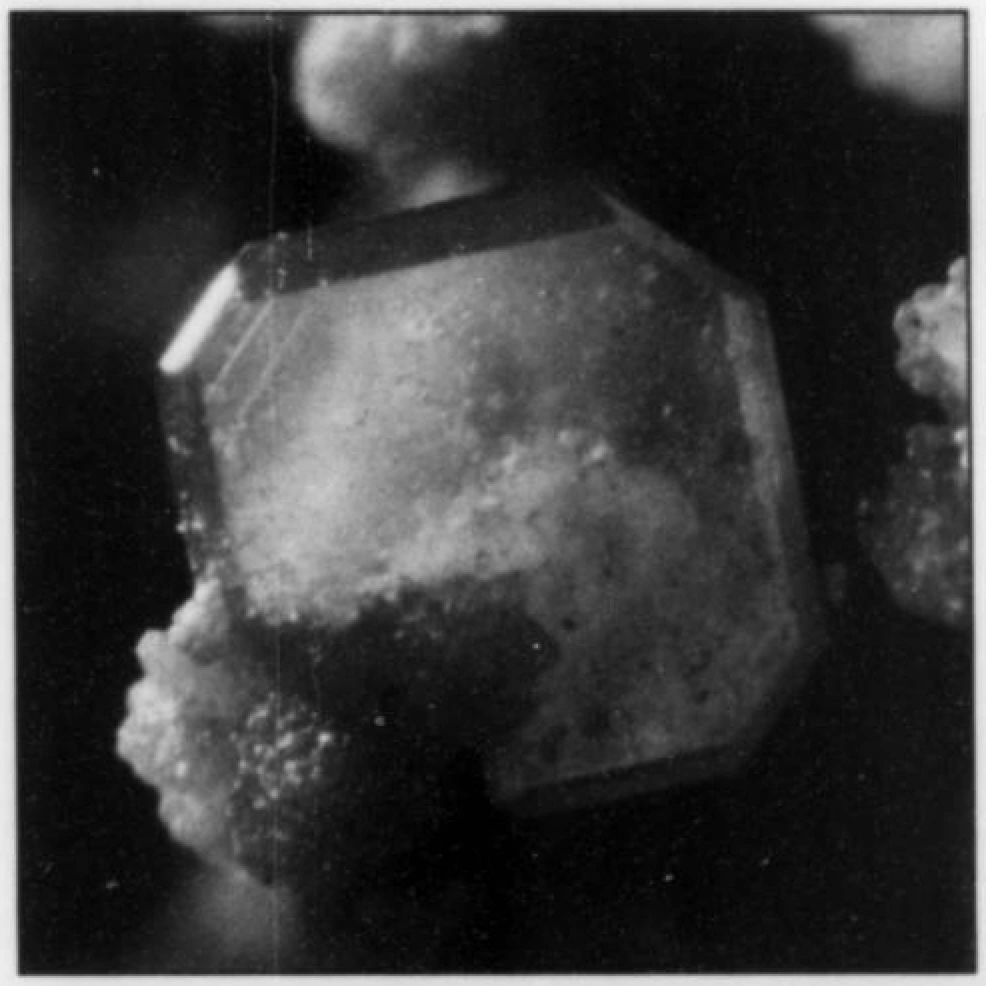

Figure 14. **Tabular wulfenite crystal, 1 mm, with mimetite. Author's specimen and photograph.**

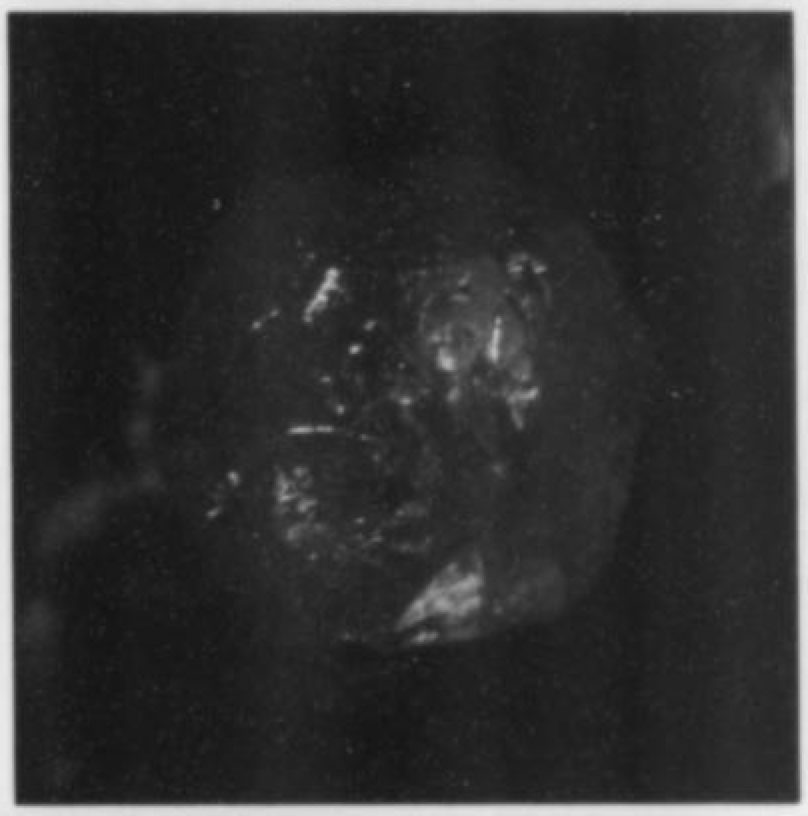

Figure 15. **Wulfenite crystal, 1 mm, with malachite and quartz. Author's specimen and photograph.**

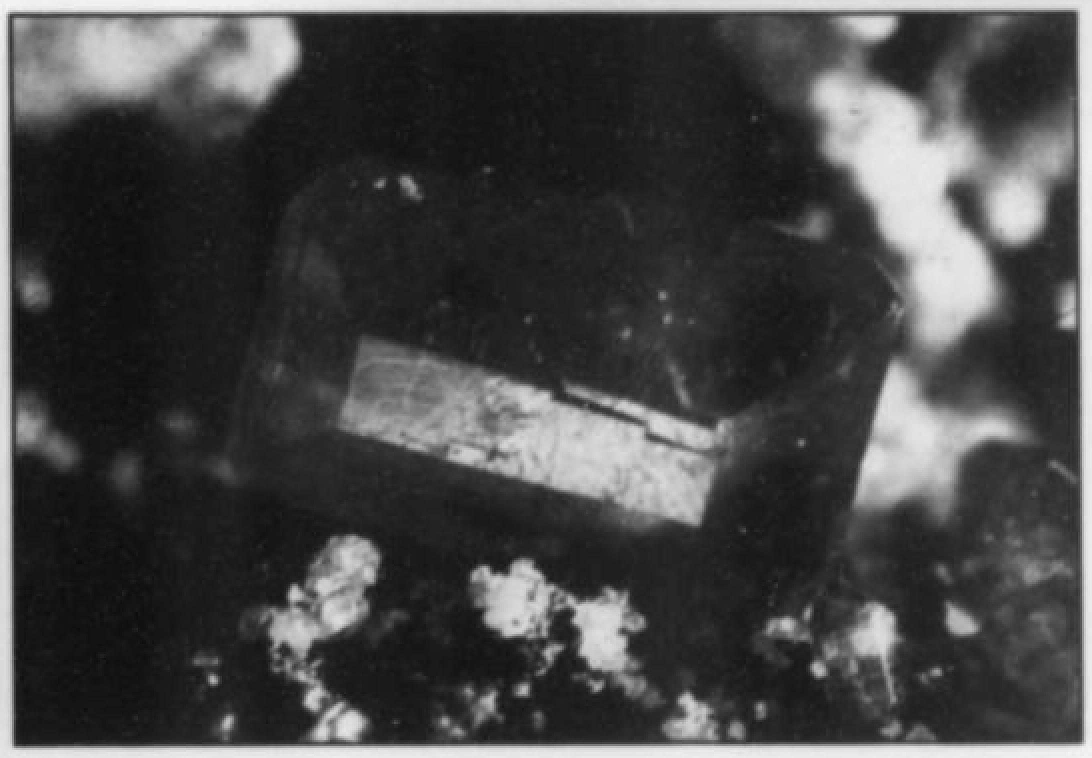

Figure 16. **Wulfenite crystals, 2 mm in width, with mimetite. Author's specimen and photograph.**

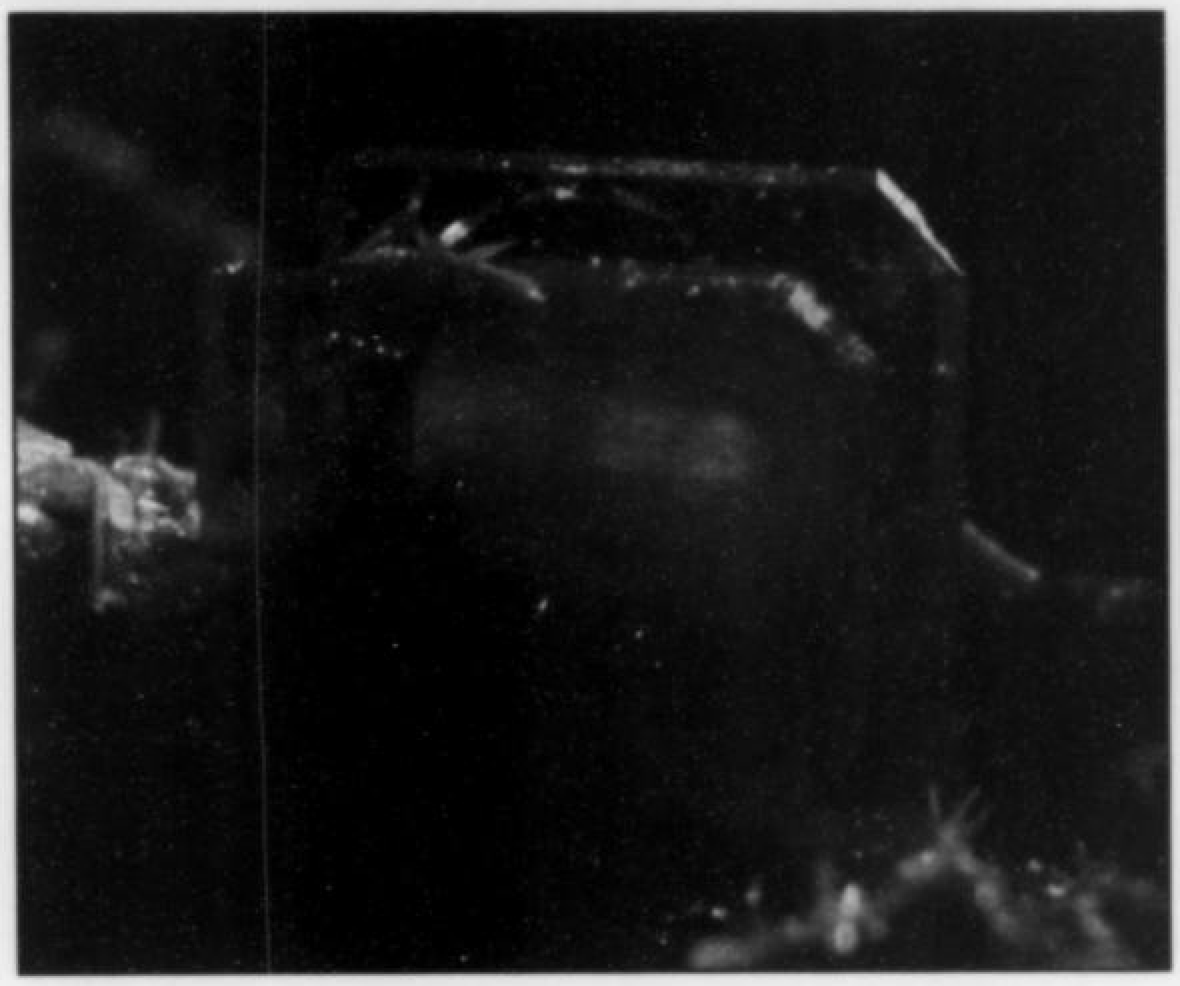

Figure 17. **Tabular wulfenite crystal, 1.5 mm, with mimetite. Author's specimen and photograph.**

stages of oxidation. Finely crystalline corkite-beudantite and plumbogummite may also be among the earliest precipitated minerals, forming directly onto the garnet sandstone or alternately, rich solutions may have attacked and dissolved mimetite and pyromorphite forming pseudomorphs and replacement shells.

ACKNOWLEDGMENTS

The author wishes to thank Brian Beyer, Jack Leach, John Toma and Robert Wehr, who provided specimens, and Bill Birch for some useful suggestions.

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VANADINITE
FROM THE GERTY MINE, BADAJOZ, SPAIN

Miguel León* and **María Jesús Liso**
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The Gerty mine, abandoned since the post-war years, is one of the rare occurrences in Spain where collector-quality vanadinite can be found. The gray to yellowish and greenish crystals may be freely collected from an ore stockpile at the site.

INTRODUCTION

During the last several years the Department of Crystallography and Mineralogy at the University of Extremadura has been dedicating itself to the preparation of a mineralogical inventory of the region (consisting of the Spanish provinces of Caceres and Badajoz). Extremadura is one of Spain's most important mineral-producing areas, in terms of both quality and quantity of specimens.

Our doctoral research at the University has focused on the phosphates, arsenates, vanadates, molybdates and other secondary minerals in the oxidation zones of Pb-Zn-Fe-Cu orebodies in Extremadura; thus far we have studied and sampled over 40 such deposits, and have identified a sizeable number of mineral species, including many not previously reported from this area. Among the most interesting of these occurrences is the Gerty mine, one of the few commercial vanadium deposits in Spain. The presence of collector-quality specimens of vanadinite is the reason for this article.

LOCATION

The Extremadura region is located in west-central Spain on the border with Portugal. The Gerty mine is situated a short distance from the village of Azuaga, about 145 km east-southeast of Badajoz. Access is by way of Route 432 just east of Azuaga, where a secondary road (C-4211) branches off and proceeds due north; at a point about 5 km from the turn-off, the mine is visible about 100 meters off to the left (west) of the road.

The climate in this part of Spain is relatively arid, with annual rainfall of less than 500 mm (20 inches), and average temperatures around 22°C (72°F); during the long, hot dry season from May to October temperatures usually reach 40°C (104°F). The countryside is relatively flat, with scarce vegetation except for crops associated with dry farming (e.g. grapevines and cereal grains).

HISTORY

The vicinity around Azuaga has long been known to host Pb-Zn-Fe-Cu deposits containing vanadium, the Gerty mine being historically the largest producer. The deposit was first exploited in 1928 (IGME, 1949) by an open pit 20 meters deep in the northwest area of the property. Mining there ceased in 1936 due to a lack of market demand for vanadium. In 1940, however, vanadium was recognized as a strategic metal, and the Spanish government supported mining there until the mid-1940's.

Due to periodic flooding of the pit, work shifted to trenching operations above the water table in the southwestern part of the mine area. Seventy metric tons of ore averaging 10 to 12 weight % V_2O_5 were recovered.

In 1949 the ground water level rose to within 7 meters of the surface, flooding most of the underground and surface workings. The underground workings are sealed and inaccessible, and the trench is now nearly completely filled over. Today the mine still stands abandoned, with a nearby reserve stockpile of 7 metric tons of ore containing abundant collectible specimens of vanadinite. There are no apparent restrictions on collecting at the mine, a pleasant circumstance considering how rare vanadinite is in Spain, and how interesting it is to collectors.

---

*Current address: Mineral Resources Division, Instituto Tecnológico y Geominero de España, Rio Rosas 23, 28003 Madrid, Spain.

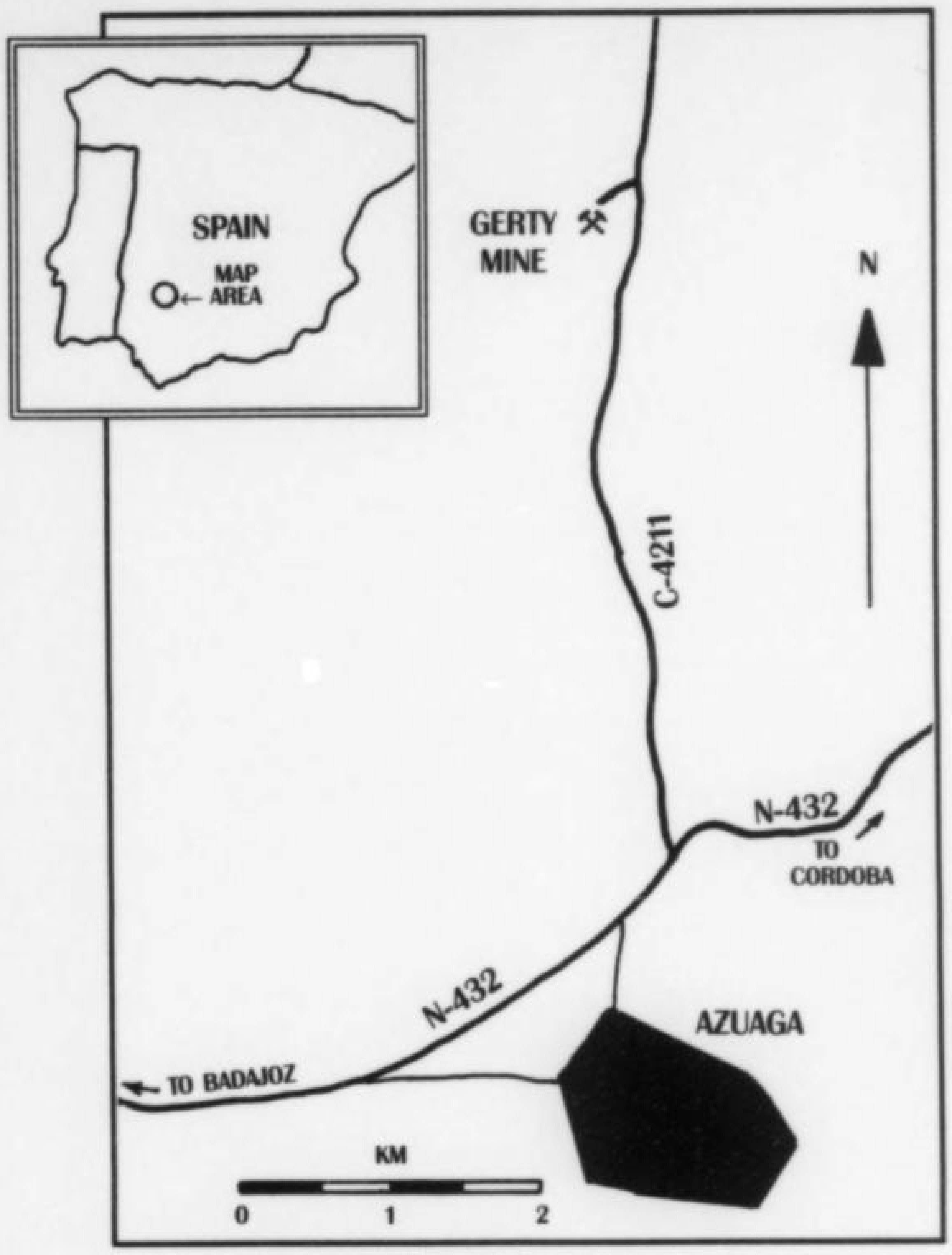

Figure 1. **Location map.**

Figure 2. **Gerty mine headframe, 1940's.**

Figure 3. **View of the ruins of the mine buildings, 1995.**

GEOLOGY

The country rock in the Gerty mine area consists of gneisses, amphibolites and quartzites of the Upper Proterozoic Azuaga Gneiss Formation (Delgado Quesada, 1971), which is cut by subparallel east-west faults of Hercynian age. A number of Pb-Zn-Fe-Cu deposits are associated with these faults, each varying in width and lateral extent. The most common sulfide minerals are galena, sphalerite and pyrite in a gangue of quartz, carbonates and barite (Apalategui *et al.*, 1983). Overburden consists of 5 to 10 meters of carbonate-rich Neogene detrital material.

At the Gerty mine there is almost no evidence of remaining, unaltered primary ore; only minor fragments of galena and pyrite have been identified. The gangue minerals are quartz and carbonates. The surrounding rock shows a sometimes dense network of microfractures which are filled primarily with calcite and dolomite, and with minor cerussite near the ore veins. Within the veins vanadinite and cerussite are common as crystals coating fracture surfaces, filling cavities and occasionally forming crusts over relict galena.

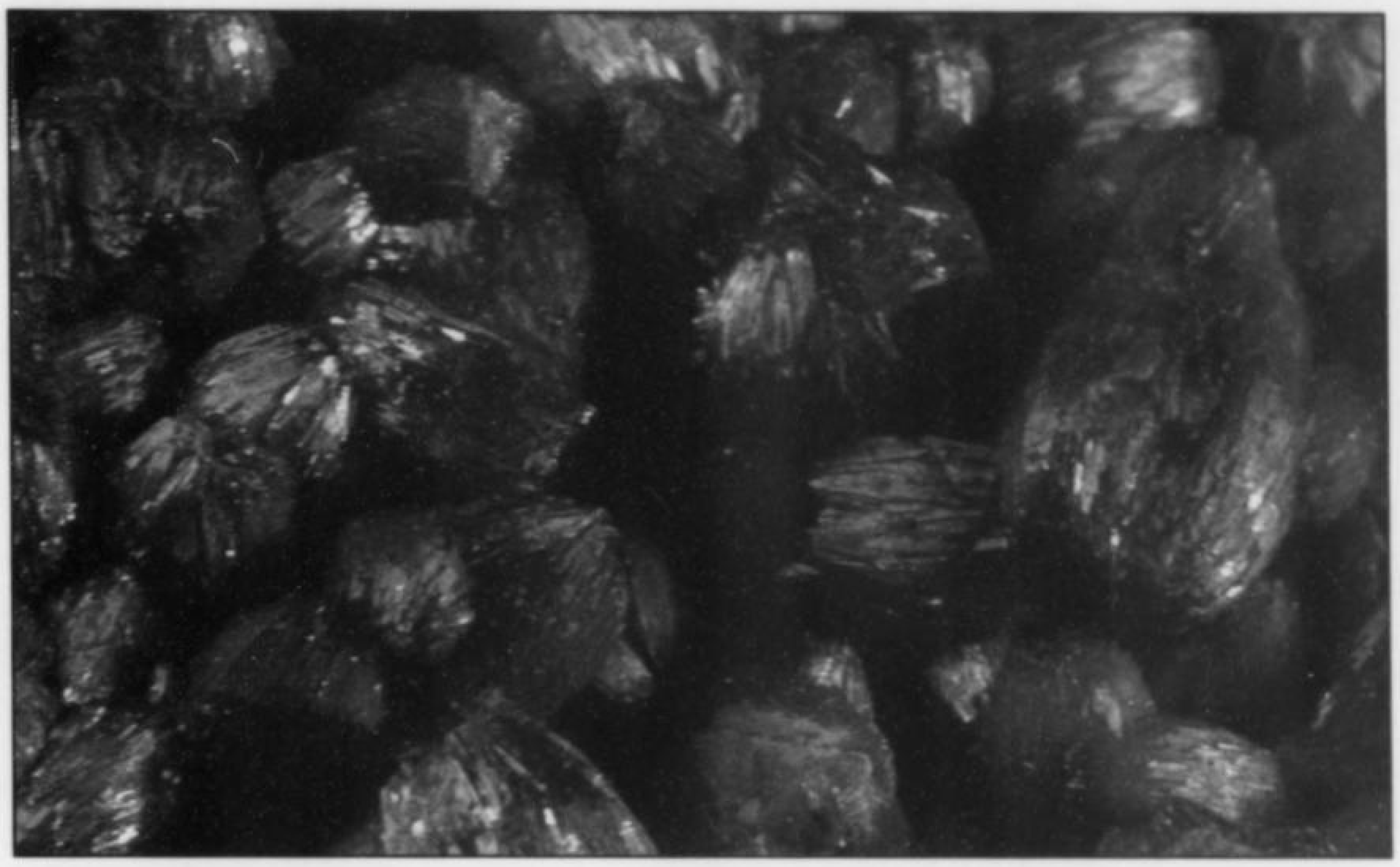

Figure 4. **Barrel-shaped vanadinite crystals to 3 mm. M. León collection.**

Figure 5. **Barrel-shaped vanadinite crystals to 3 mm. M. León collection.**

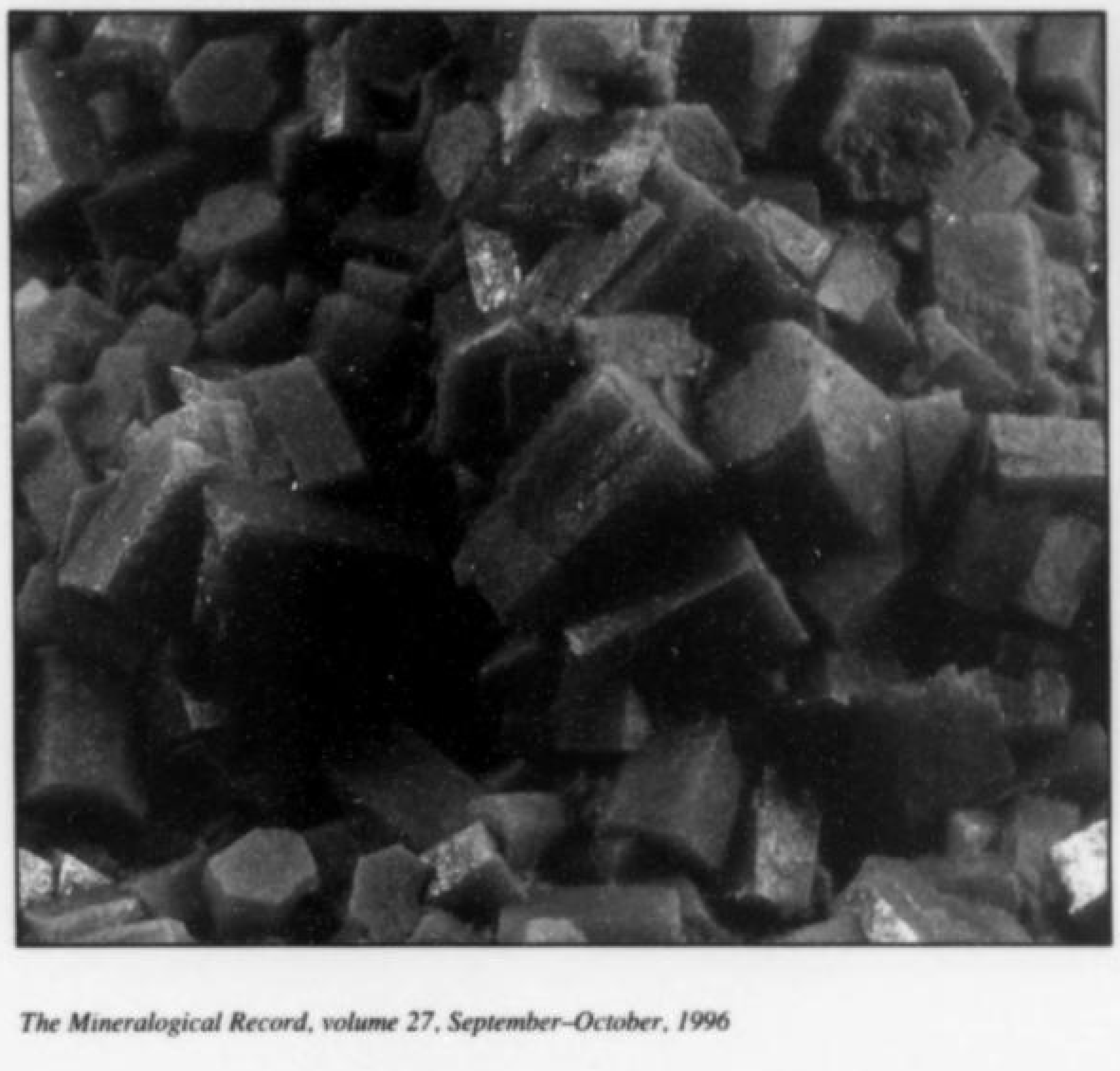

Figure 6. **Prismatic vanadinite crystals (to 1 mm) on matrix. M. León collection.**

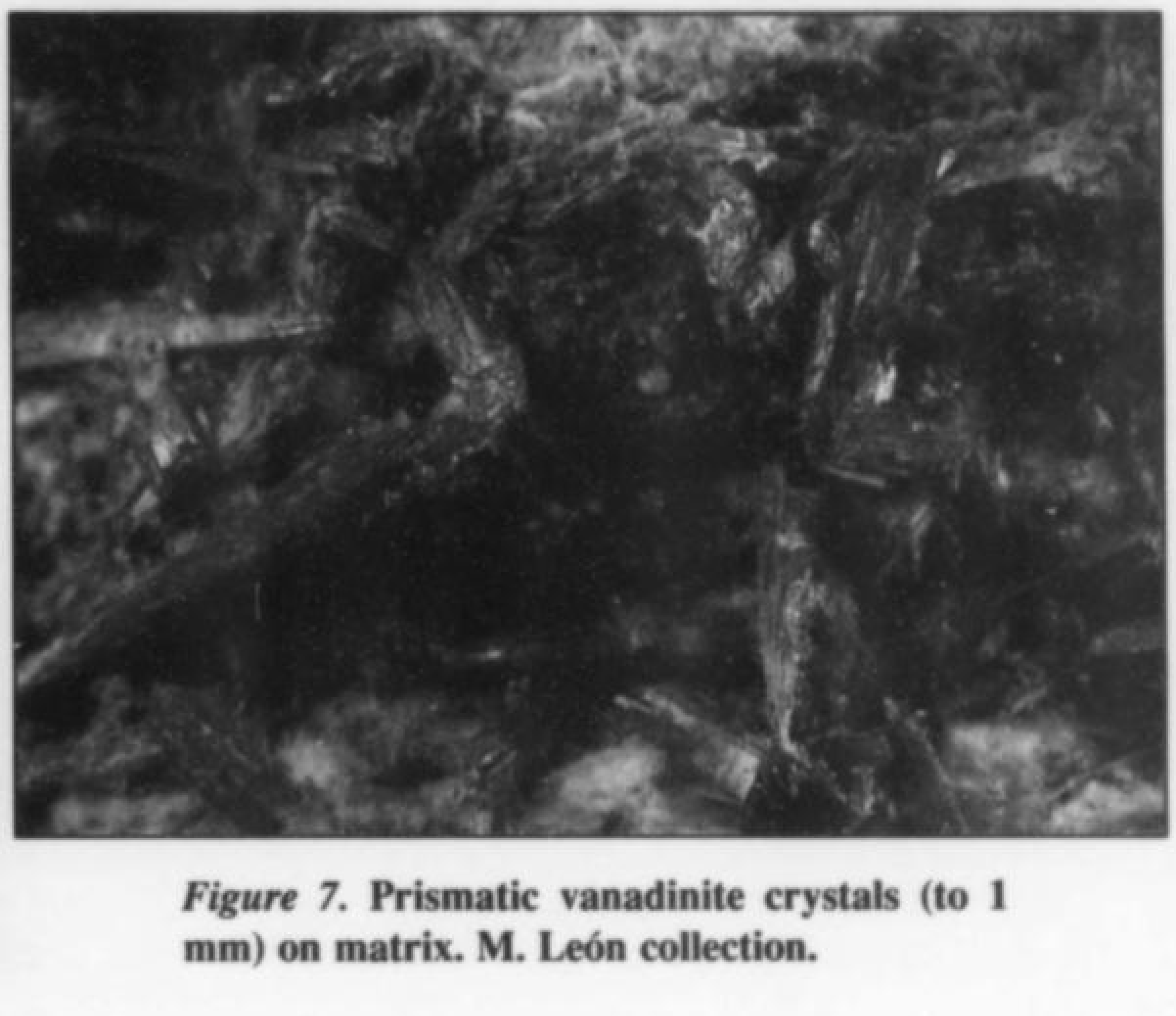

Figure 7. **Prismatic vanadinite crystals (to 1 mm) on matrix. M. León collection.**

The formation of vanadinite is attributed to the supergene alteration of galena in combination with groundwater leaching of vanadium from the neighboring amphibolitic country rocks. Because Pb is relatively immobile, vanadinite formed very near the galena during oxidation, as groundwater carried in the necessary vanadium. This is the typical interpretation of such deposits elsewhere in the world, as, for example, in the American Southwest.

VANADINITE

Vanadinite [$Pb_5(VO_4)_3Cl$] occurs at the Gerty mine in simple crystals consisting only of the *c* pinacoid and the hexagonal *m* prism. Habits range from virtually acicular to stout, barrel-shaped crystals and all gradations in between. The barrel-shaped crystals show some convex curvature of the prism faces. They reach about 5 mm in size, commonly as part of randomly oriented aggregates and crusts to 10 cm across coating fractures and filling cavities. The more elongated crystals tend to be a bit smaller, usually 3 to 4 mm. Color ranges from gray to grayish green, pale yellow and greenish yellow, with a greasy or resinous to subadamantine luster.

The vanadinite was identified by X-ray diffraction and qualitative infrared spectroscopy, indicating a rather pure vanadinite with only minor arsenic and phosphorus in substitution.

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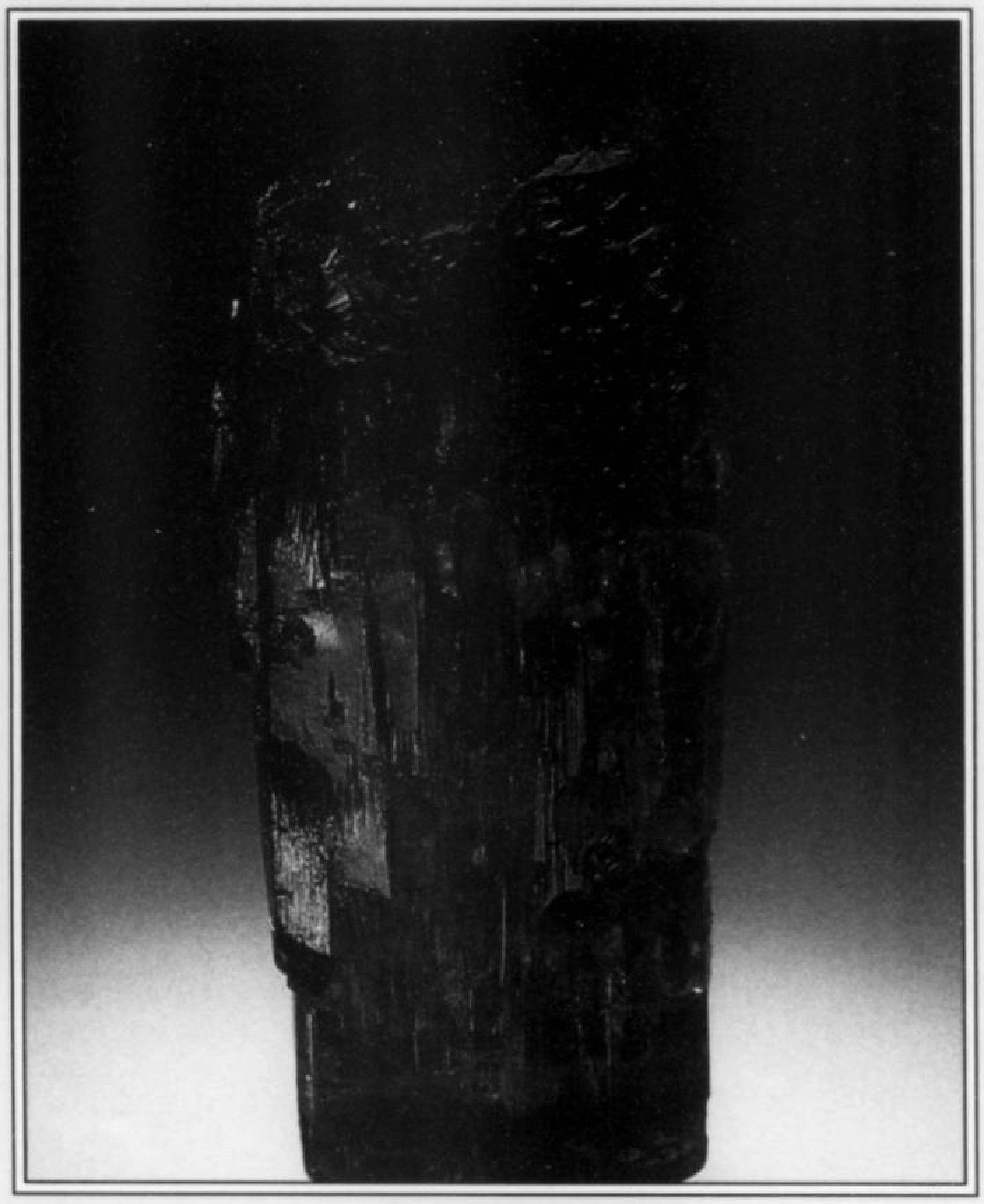

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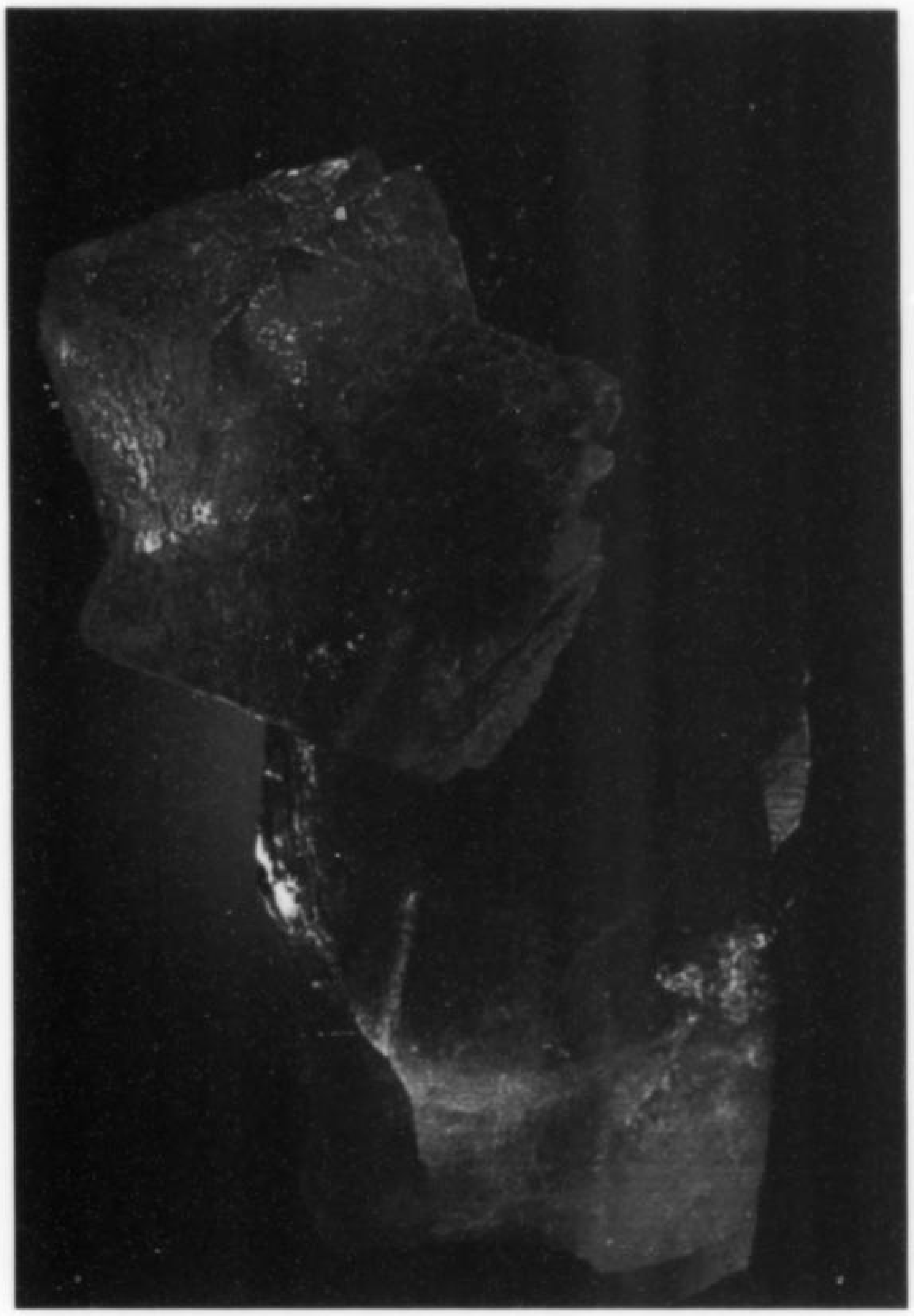

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What's New in Minerals

Delaware Show 1996

by Joe Polityka

[March 9–10]

Someone once said "time is too precious a commodity to wish away." Under normal circumstances this is true. However, three broken snow shovels, 50 pounds of calcium chloride, two sore backs, and assorted pulled deltoids and biceps later, I am happy the winter of 1995 has ended. I have had my fill of crystals (ice crystals that is) and I hope I never again have to do such a detailed study of crystal deposition. What bothered me the most was the possibility that I might miss two of my favorite Winter shows: The Delaware Mineral Club Show on March 9th and 10th and The Clifton, New Jersey, Club Show on March 16th and 17th.

Getting to Clifton was no problem, the weather was fine; but the drive down the New Jersey Turnpike to Claymont, Delaware, was another matter. Obviously, I made it and survived the ordeal to write this report. The Delaware Show gets my vote for the "Best Small Show" award. The club goes out of its way to accommodate collectors, young and old alike. The exhibits are superb (this year's theme was lead minerals), the lectures are top quality and the kids' sales table goes well beyond the "grundge and gravel" theme of some shows.

This show is the first East Coast show of consequence after Tucson, so the mineral dealers have lots of "fresh" minerals in their inventory. Chris and Neal Pfaff (*M. Phantom Minerals*, Columbus, Ohio) had just returned from their annual one-month stay in Tucson and had a variety of choice specimens for sale. **Epidote** from Ica, Peru, was the order of the day; the epidote is superb and, in my opinion, can be placed into the "instant classics" category. When found, the epidote was heavily covered with a layer of silicates and, to quote Neal Pfaff, was "aesthetically impaired." ("Ugly" for those of us not into political correctness.) Only after a soaking in highly corrosive solvents and careful removal of the silicate residue was its true beauty revealed. The specimens are fan-like sprays of singly terminated, lustrous crystals up to 8 cm in length. The crystals closely resemble the Austrian classics but without the associated byssolite and quartz. These associations are what keep the Austrian crystals at the top of the epidote "pecking order."

Neal and Chris also had a large selection of minerals from the Soviet Union and former territories, including **bornite** crystals from Mine 57, Dzezkazgan, Kazakhstan, with sharp (for the mineral) faces. Some crystals reach about 8 mm and sit on drusy quartz crystals, a nice contrast. In addition, they had **galena** crystals with the usual associated sulfides from Dal'negorsk, Russia; **titanite** (some twins) from the Dodo deposit in the Polar Urals and **calcite** crystals in thumbnail and toenail sizes, with twins to 2.5 cm. (Some supplier finally woke up and realized there are folks who collect calcite thumbnails.)

The Rocksmiths had their usual variety of worldwide specimens, including a fresh batch of minerals from Russia and China. Their cabinet specimen of 3-cm **scheelite** crystals on mica matrix from Xue Bao Diang Mountain, Chendgdu, China, got my attention. I should have asked my wife for some money or told her I was buying the specimen for "her collection." Unfortunately, if I took this approach, she could, legitimately, go out and buy some diamonds for herself and tell me they are for "my collection."

Broken Back Minerals (Newark, Delaware) had more of the Fred Keidel collection of oxide-zone minerals. Most notable are the **cerussite** crystals, in miniature to small cabinet sizes, from Tsumeb, Namibia. It's been a long time since I have seen so many oxide-zone lead minerals in one place. They recently sold a cabinet-sized specimen of **cerussite** from Davidson County, North Carolina (an almost impossible-to-get classic), formerly in Fred's collection. Speaking of the late Fred Keidel, the museum at the University of Delaware recently dedicated a special exhibit of miniatures from Fred's collection. If you are in the area during weekdays, stop in and drool over the minerals, especially the new museum-size, high-quality, Kongsberg, Norway, **silver** specimen. Every specimen on display is exceptional for the species, so this museum deserves a special visit. [Ed. note: See the article on this museum in vol. 14, p. 369–375, written by Curator Peter Leavens.]

Clifton, New Jersey, Show

by Joe Polityka

[March 16–17]

The Clifton, New Jersey, Show came off without a hitch. The temperature was in the 60's and the show was a nice diversion from the NCAA basketball games I had watched the previous week. This show has no exhibits but, like any mineral show with fine dealers, is worth a visit.

Dan Weinrich had a flat of blue **corundum** from the Ilmen Mountains, Russia. These opaque crystal to 2 cm contrast nicely with the white massive matrix and were a bargain at ten dollars. Dan also had sharp **pyrochlore** crystals to 8 mm from Vein #140, Vishnevogorsk, Chelyabinsk Oblast, Russia. The dark reddish brown crystals sit on a white drusy quartz and granite matrix. One toenail specimen of **anatase** on a gemmy quartz crystal caught my eye. This specimen, from the Lapcha deposit in the Polar Urals, Russia now occupies a spot in my (wife's?) collection. Lastly, Dan had purchased about 40 specimens (from an old collection, of course) of Bisbee, Arizona, **azurite/malachite.** This was a mixed lot of crystallized and massive pieces.

North Star Minerals (West Bloomfield, Michigan) offered a collection of one-of-a-kind English classics. Electric-green **fluorite** in thumbnail to small cabinet sizes, from Weardale, Cumbria, England, sold quickly; a singular miniature of **hematite on quartz** from Cleator Moor (ex. Viktor Hoffman, Berlin, Germany) now resides in my collection. This piece was mined in the 1890's. Ross

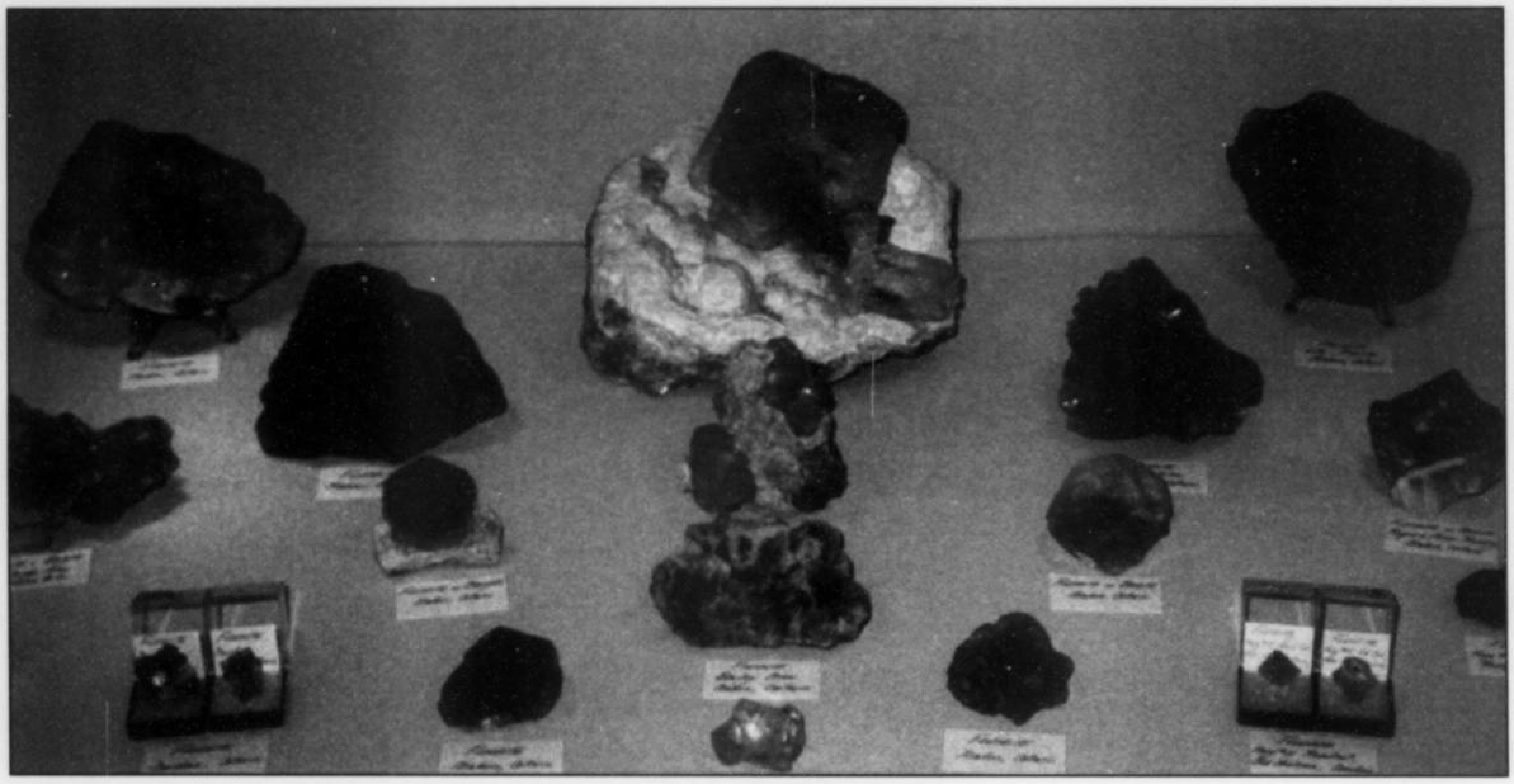

Figure 1. **Wendy and Frank Melanson's exhibit of Canadian fluorite specimens (photo by J. Polityka).**

also had his usual inventory of **fluorite, calcite and associated minerals** from Southern Illinois. However, with the closing of the mines his supply has dwindled over the last few years. In addition, as old hordes are released by his suppliers, the prices are always higher. This situation reminds me of what has happened to the supply of minerals from Mexico over the years and what is sure to happen with the supply of choice specimens from the Soviet Union. Do you remember when we could get a cabinet specimen of Los Lamentos wulfenite or Mapimi adamite for the equivalent of the price of a meal in a good restaurant? Today those specimens would cost you the price of about ten meals at the same restaurant.

Carter Rich had a slew of East Coast classics from an old college collection. Many specimens were available from classic New York and New Jersey locations. Carter has the instincts of a "bloodhound" when it comes to finding "antique" minerals.

New Jersey Earth Science Show 1996

by Joe Polityka

[April 27–28]

Alas, I did not exhibit this year, so I was unable to enjoy the great pre-show Friday-night dinner. I did, however, wake up at the crack of dawn on Saturday and made it to the Westfield, New Jersey, Armory right before the 9:00 a.m. opening bell. While gazing across the armory, I did a quick check of the show program and noticed that 38 dealers were set up in the large, open room of the armory. There were 50 exhibits, ten of which were dedicated to fluorescence. At that moment, nostalgia overtook me and I started thinking about my Navy days and the "yer-left-right-left" barkings of my old drillmaster. This is a feeling only military veterans can, or want, to understand. Hey, be nice! Some people cry at weddings; I cry in armories.

The ubiquitous Dave Bunk, making the most of his youthful energy, was well-stocked with the good stuff! Dave had lots of one-of-a-kinders, the most noble of which was a large museum-size (and quality) **ludlamite** from the Huanuni mine, Oruro, Bolivia. The specimen consists of undamaged 1-cm, lime-green crystal aggregates on a contrasting tan matrix (with associated **vivianite**) about 15 cm across. If this specimen were a thumbnail it would be exceptional; to see a large piece, in such perfect condition, is quite an experience (almost like seeing Sophia Loren, Vanessa Williams and Cindy Crawford enter a room at the same time . . . almost). Unfortunately, the decimal point was too many places to the right; so I turned my attention to more humble but still desirable specimens. By the way, one of the links in my grapevine tells me this specimen was later sold at the Cincinnati Show.

Dave also had two **danburite** single crystals from Dal'negorsk, Russia. The unusual feature of both crystals is their color: a transparent, maple-syrup-brown, not the usual white you see in most crystals of this species. Another attractive specimen was a 2.5-cm hemispherical aggregate of **creedite** from Mine #2, Akchatau, Kazakhstan, with 1-cm purple crystals. Dave also had about eight flats of thumbnail-size **wulfenite** single crystals from the Red Cloud mine, La Paz County, Arizona. A good thumbnail was going for about $40.00. [See the article elsewhere in this issue, beginning on p. 347.]

Hawthorneden had about two flats of pale green **fluorite** crystals from Madoc, Ontario, Canada. These are not from a new find but are from Frank and Wendy Melanson's personal collection. In fact, these were mined by Frank and Wendy about 25 years ago, before the mine closed. The largest and best specimen, a 10-cm cluster of crystals (on display in their exhibit case) was found, undamaged, under a large pile of fluorite cleavages in the mine owner's basement.

Mountain Minerals International had their usual large selection of **zeolites** from India and **pegmatite minerals** from Pakistan. Dudley Blauet showed me something new, however—**spessartine on quartz and clevelandite** from Sabir, Rondu District, Gilgit-Skardu Road, Pakistan. If someone showed me these specimens without locality information, I would have guessed Ramona,

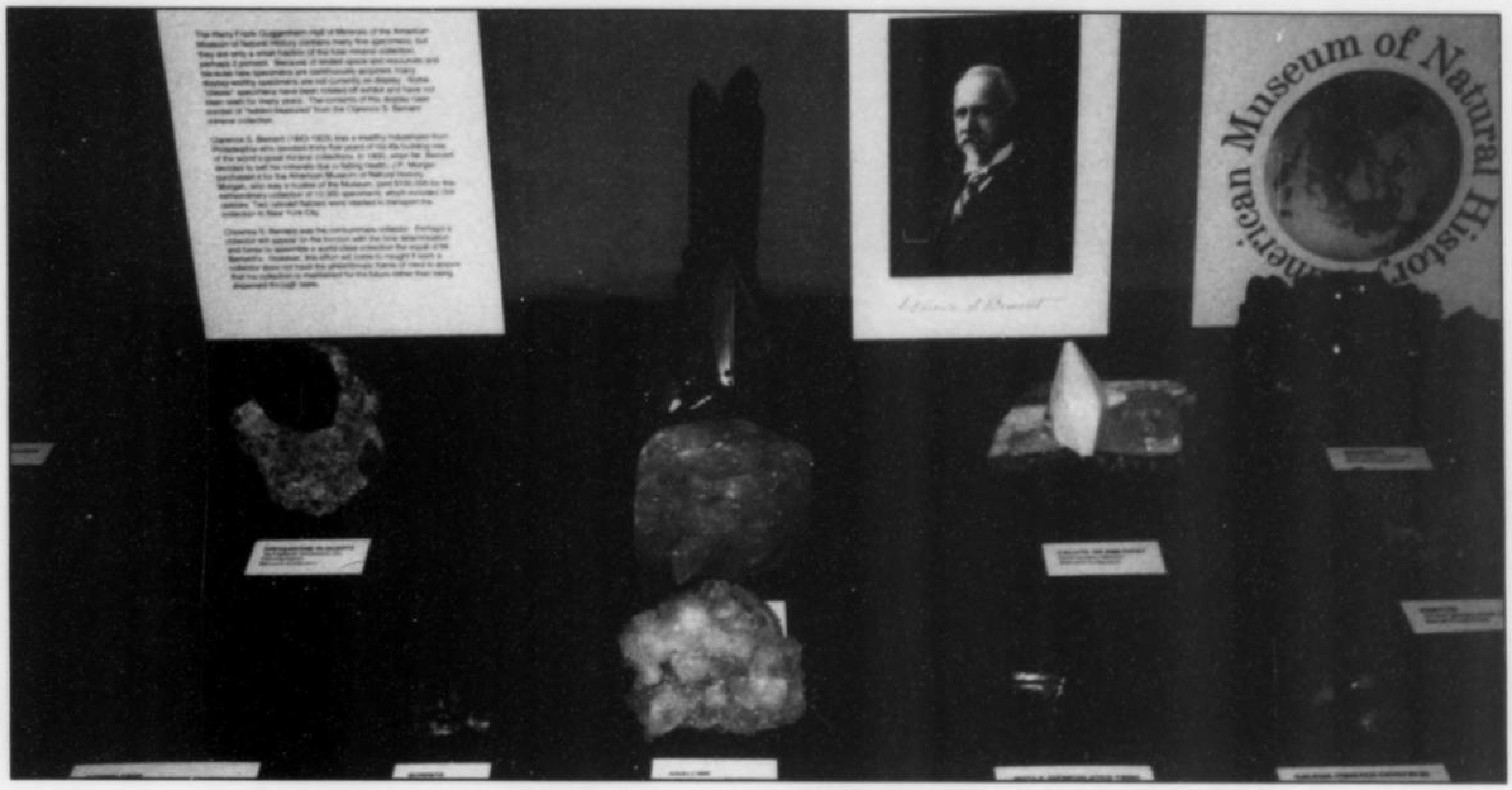

Figure 2. **The American Museum of Natural History exhibit (photo by J. Polityka).**

California. Dudley also had large **hausmanite** crystals with stepped octahedral faces to 1.8 cm from the N'chwaning mine, Kuruman, South Africa, and several pink **fluorite** cubes with **hematite** from Ishkapal, above Sassi, Gilgit-Skardu Road, Pakistan. The single crystals reach about 2 cm in size and have the frosted faces typical of specimens from an Alpine-type deposit.

Dennis Beals was sharing Dudley's booth and had a fresh collection of minerals from Mexico, in miniature to cabinet sizes. His **datolite** from the La Aurora mine, Charcas, Mexico, was very attractive (clusters of pale green, lustrous 1-cm crystals, some with pyrite). The **aguilarite** thumbnails from the La Serena mine, Guanajuato, Mexico, were a popular item. Dennis also showed me some **adamite** from a new locality in Oaxaca, Mexico. The drusy lime-green coatings are found with small (about 2 mm) **hemimorphite** crystals. Who knows what the future holds for this locality?

Willis' Earth Treasures (Stewartsville, NJ) had a nice section of Franklin-Sterling Hill, New Jersey, **fluorescent minerals** and crystallized **franklinite and willemite.** They also had several flats of old-time Paterson, New Jersey, **zeolites.** They had an exceptional plate of **amethyst**, about 10 by 10 cm in size, from the Upper New Street quarry in Paterson, New Jersey.

Williams Minerals (now located in Rio, WV) had five specimens of thumbnail **sphalerite** twins from Talcville, New York. The color of the crystals ranges from transparent lemon-yellow to butterscotch-brown. By the way, if you ever need quality plastic bases for your minerals or blue tack for mounting, Keith Williams is the man to see.

The Emerald City Gem Shop, Spruce Pine, NC, had clear **quartz** crystals with acicular **rutile** inclusions from their emerald-mining operation at Hiddenite, North Carolina. These single quartz crystals reach about 7 cm and have a small amount of rutile visible in each crystal. For you gem collectors out there they had **cats-eye garnets** with four-ray stars from Morganton, North Carolina. The gems I saw were cut in typical cats-eye fashion and had a nice x-shaped star.

The American Museum of Natural History, New York City, gave an encore presentation of its Tucson show exhibit. This exhibit was recently mentioned by Tom Moore in his Tucson Show report (May–June issue). All I can say is wow! My favorites are a 3-cm **hiddenite** (on matrix) from Alexander County, North Carolina; a 10-cm geniculated twin **rutile** crystal from Parkesburg, Pennsylvania; a cabinet specimen of **mimetite** crystals to 6 mm from Johanngeorgenstadt, Germany; and an 8-cm **spessartine** in matrix from Springfield, Pennsylvania. If I had a dollar for every stone I picked up myself in the Springfield, Pennsylvania, area on field trips of my youth, I would have enough money to buy Dave Bunk's ludlamite specimen. Come to think of it, I wish I had found one specimen of *anything* on those field trips! Today, Springfield, Pennsylvania, like most classic localities, is covered by shopping malls and housing developments. The only hope for the collector is to be "Johnny-on-the-spot" when a construction project is started. Otherwise, we have to be content with admiring these old classics at mineral shows and museums.

The hot topic this year at the lectures was amber. Dr. Peter Grimaldi and Paul Nash of the American Museum of Natural History both spoke on the subject. New Jersey figured prominently in the discussions because many rare specimens have been found there within the past year. In fact, the *New York Times* and other publications have published articles on the find, and the New Jersey collectors who located the deposit. The amber is found in Cretaceous sediments near Sayreville. Finding specimens requires digging down about 3 meters through sandy soil until a carbonaceous layer is reached. The amber is found in, or near, this layer. The area is quite swampy, therefore, holes can quickly fill with water, creating a hazard for collectors. The caveats that apply to all collecting trips also apply here: never go collecting alone, and go fully prepared!

Next year's show on April 25–27 will be the Association's Silver Anniversary Celebration. Mark your calendar, buy your plane, train or bus ticket, or tune up your car and point it toward Interstate 95—great things are going to happen at the New Jersey Earth Science Show.

Jeff Scovil

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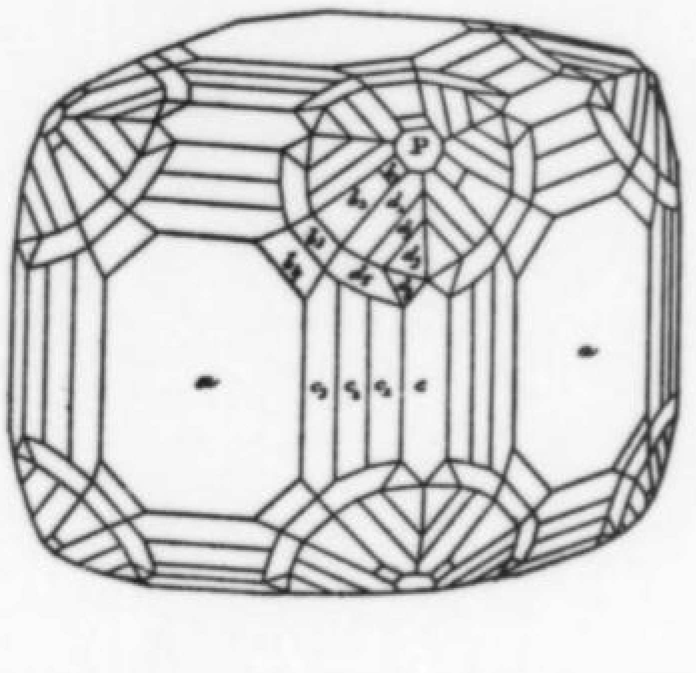
ABSTRACTS OF NEW MINERAL DESCRIPTIONS



J. A. Mandarino
Chairman Emeritus of the Commission on
New Minerals and Mineral Names
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and
Curator Emeritus
Department of Mineralogy
Royal Ontario Museum
100 Queen's Park
Toronto, Ontario, Canada M5S 2C6

Bechererite — Hexagonal (trigonal)

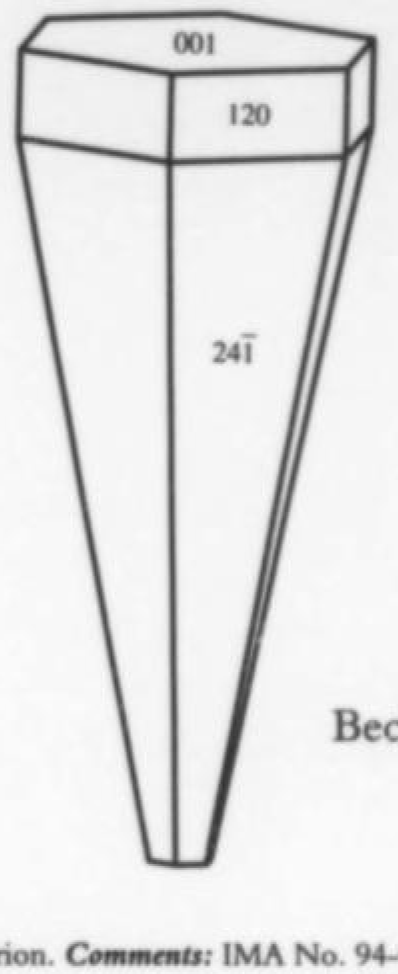
$(Zn,Cu)_6Zn_2(OH)_{13}[(S,Si)(O,OH)_4]_2$

Locality: The dump of the Tonopah-Belmont mine, Osborne silver-gold district, Maricopa County, Arizona, U.S.A.

Occurrence: An alteration product. Associated minerals are: willemite, rosasite, hydrozincite, smithsonite, paratacamite, and boleite.

General appearance: As druses and hemispheres of trigonal acicular crystals (maximum length of 250 µm and diameter of 40 µm).

Physical properties: *Luster:* vitreous. *Diaphaneity:* transparent. *Color:* light green. *Streak:* white. *Luminescence:* non-fluorescent. *Hardness:* 2–3. *Tenacity:* brittle. *Cleavage:* {001} perfect. *Fracture:* not mentioned. *Density:* 3.45 g/cm³ (meas.), 3.49 g/cm³ (calc.). ***Crystallography:*** Hexagonal (trigonal), $P\bar{3}$, a 8.322, c 7.376 Å, V 442.4 Å³, Z 1, c:a = 0.8863. Morphology: forms {001}, {120}, {241}, {24$\bar{1}$}. Twinning: none observed. ***X-ray powder diffraction data:*** 7.37 (100), 3.623 (25), 3.282 (30), 2.724 (30), 2.556 (50), 1.572 (20). ***Optical data:*** Uniaxial (-), ω 1.705, ε 1.611, nonpleochroic. ***Chemical analytical data:*** Means of five sets of electron microprobe data: CuO 8.6, ZnO 60.6, SO_3 9.5, SiO_2 6.1, H_2O 15.20 (by difference from 100.0), Total 100.0 wt.%. Empirical formula: $(Zn_{4.93}Cu_{1.01})_{\Sigma 5.94}Zn_{2.00}(OH)_{13.00}(S_{1.10}Si_{0.95})[O_{5.30}(OH)_{2.70}]_{\Sigma 8.00}$. ***Relationship to other species:*** The crystal structure is related to that of spangolite. ***Name:*** For Dr. Karl Becherer (1926-), of the University of Vienna, in recognition of his contributions to the mineralogy of spangolite from Lavrion. ***Comments:*** IMA No. 94-005. A minor amount of the data given in this abstract was taken from the original IMA proposal. The crystal drawing which appears in the paper does not conform to the symmetry given for the mineral nor does it display the form {241}. The symmetry of the drawing is more compatible with crystal class 6 with forms {001}, {00$\bar{1}$}, {120}, and {241}. I have corresponded with Dr. Giester and he agrees that the morphological class should be 6 or even 3; the latter class would require *two* trigonal prisms and *two* trigonal pyramids. The problem appears to be with the meagre intensity data obtained from the very small crystals during the X-ray diffraction study. Dr. Giester hopes to resolve the problem with better material or measuring time with a more efficient X-ray source.



Bechererite

GIESTER, G. and RIECK, B. (1996) Bechererite, $(Zn,Cu)_6Zn_2(OH)_{13}[(S,Si)(O,OH)_4]_2$, a novel mineral species from the Tonopah-Belmont mine, Arizona. *American Mineralogist* **81**, 244–248.

Fluor-ferro-leakeite — Monoclinic

$NaNa_2(Fe^{2+}_2Fe^{3+}_2Li)Si_8O_{22}F_2$

Locality: The Canada Pinabete pluton, Questa, New Mexico, U.S.A.

Occurrence: In a mildly peralkaline porphyry. Associated minerals are: quartz, alkali feldspar, aegirine (given as "acmite"), ilmenite, and zircon.

General appearance: Anhedral crystals elongated parallel to [001] up to 1 mm long.

Physical properties: *Luster:* vitreous. *Diaphaneity:* opaque. *Color:* bluish black to black. *Streak:* bluish grey. *Luminescence:* non-fluorescent. *Hardness:* about 6. *Tenacity:* brittle. *Cleavage:* {110} perfect. *Fracture:* irregular. *Density:* 3.37 g/cm³ (meas.), 3.34 g/cm³ (calc.). ***Crystallography:*** Monoclinic, C 2/m, a 9.792, b 17.938, c 5.3133 Å, β 103.87°, V 906.0 Å³, Z 2, a:b:c = 0.5459:1:0.2962. Morphology: no forms observed. Twinning: none observed. ***X-ray powder diffraction data:*** 8.426 (45), 4.481 (54), 3.404 (57), 2.985 (38), 2.710 (100), 2.585 (38), 2.536 (92). ***Optical data:*** Biaxial (+), α 1.675, β 1.683, γ 1.694, 2V(meas.) 87°, 2V(calc.) 81°; dispersion not visible because of the strong absorption; pleochroism X = very dark indigo blue, Y = grey blue, Z = yellow green; X ^ c = 10° (in obtuse β), Y = b. ***Chemical analytical data:*** Means of ten sets of electron microprobe data: Li_2O 0.99, Na_2O 9.22, K_2O 1.19, MgO 2.02, CaO 0.15, MnO 4.51, FeO 8.87, ZnO 0.57, Al_2O_3 1.13, Fe_2O_3 16.73, SiO_2 51.12, TiO_2 0.68, H_2O (0.60), F 2.87, sum (100.65), less O = F 1.21, Total 99.44 wt.%. Li was determined by ion microprobe. H_2O was calculated to give F + OH = 2.00. Empirical formula: $(K_{0.23}Na_{0.76})_{\Sigma 0.99}(Na_{1.97}Ca_{0.03})_{\Sigma 2.00}(Mg_{0.46}Fe^{2+}_{1.13}Mn^{2+}_{0.58}Zn_{0.06}Fe^{3+}_{1.92}Ti_{0.08}Li_{0.61})_{\Sigma 4.84}(Si_{7.80}Al_{0.20})_{\Sigma 8.00}O_{22.00}[F_{1.39}(OH)_{0.61}]_{\Sigma 2.00}$. ***Relationship to other species:*** It is a member of the amphibole group. ***Name:*** For the relationship to leakeite. ***Comments:*** IMA No. 93-026. The subscripts in the empirical formula differ slightly from those given here. Some of the data given in this abstract were taken from the original IMA proposal.

HAWTHORNE, F. C., OBERTI, R., UNGARETTI, L., OTTOLONI, L., GRICE, J. D., and CZAMANSKE, G. K. (1996) Fluor-ferro-leakeite, $NaNa_2(Fe^{2+}_2Fe^{3+}_2Li)Si_8O_{22}F_2$, a new alkali amphibole from the Canada Pinabete pluton, Questa, New Mexico, U.S.A. *American Mineralogist* **81**, 226–228.

Tungstibite Orthorhombic

$Sb_2O_3 \cdot WO_3$

Locality: The Clara Mine, near Oberwolfach, central Black Forest, Germany.

Occurrence: Associated minerals are: quartz, barite, fluorite, "fahlore" (tetrahedrite-tennantite series), chalcopyrite and cervantite.

General appearance: Globular aggregates (up to 1 mm in diameter) composed of thin, tabular crystals (up to 0.1 mm long and a few µm thick).

Physical properties: *Luster:* dull, in part pearly. *Diaphaneity:* translucent to opaque. *Color:* green to dark green. *Streak:* greenish. *Luminescence:* non-fluorescent. *Hardness:* about 2. *Tenacity:* not given. *Cleavage:* {001} perfect. *Fracture:* irregular. *Density:* could not be measured, but that of synthetic material is 6.69 g/cm³; 6.91 g/cm³ (calc.). ***Crystallography:*** Orthorhombic, Probably $P22_12_1$, a 8.59, b 9.58, c 6.12 Å, V 503.6 Å³, Z 4, a:b:c = 0.8967:1:0.6388. Morphology: only {001} was observed. Twinning: none observed. ***X-ray powder diffraction data:*** 3.32 (10), 3.06 (10), 2.98 (4), 2.73 (6), 2.46 (5), 1.919 (4). ***Optical data:*** Biaxial (+), α 2.285, β 2.40, γ 2.58, 2V could not be measured, 2V(calc.) 82°, dispersion r << v; pleochroism X = dark green to brownish green, Y = dark green, Z = pale green to yellowish; Z = c. ***Chemical analytical data:*** Means of 3 sets of electron microprobe data: Sb_2O_3 55.5, WO_3 43.6, Total 99.1 wt. %. Empirical formula: $Sb_{2.01}W_{0.99}O_{6.00}$. ***Relationship to other species:*** none mentioned. ***Name:*** For the chemical composition. ***Comments:*** IMA No. 93-059. Some of the data given in this abstract were taken from the original IMA proposal. The calculated density given here is very slightly different from that given in the paper.

WALENTA, K. (1995) Tungstibit, $Sb_2O_3 \cdot WO_3$—ein neues Mineral von der Grube Clara bei Oberwolfach im mittleren Schwarzwald (Deutschland). *Chemie der Erde* **55**, 217–224.

Ungarettiite Monoclinic

$NaNa_2(Mn^{2+}_2Mn^{3+}_3)Si_8O_{22}O_2$

Locality: The abandoned Hoskins manganese mine, 3 km west of Grenfell, New South Wales, Australia.

Occurrence: In manganese silicate and oxide rocks. Associated minerals are: serandite, rhodochrosite, norrishite, clinopyroxene, braunite, quartz and albite.

General appearance: Prismatic grains (up to 1 mm long).

Physical properties: *Luster:* vitreous, but the high indices of refraction require the luster to be adamantine. *Diaphaneity:* transparent. *Color:* cherry red to very dark red. *Streak:* pale pinkish white. *Luminescence:* non-fluorescent. *Hardness:* about 6. *Tenacity:* brittle. *Cleavage:* {110} perfect. *Fracture:* irregular. *Density:* 3.52 g/cm³ (meas.), 3.43 g/cm³ (calc.). ***Crystallography:*** Monoclinic, C2/m, a 9.89, b 18.04, c 5.29 Å, β 104.6°, V 912 Å³, Z 2, a:b:c = 0.5482:1:0.2932. Morphology: no forms were observed. Twinning: none observed. ***X-ray powder diffraction data:*** 8.426 (45), 4.481 (54), 3.404 (57), 2.985 (38), 2.710 (100), 2.585 (38), 2.536 (92). ***Optical data:*** Biaxial (-), α 1.717, β 1.780, γ 1.800, 2V(meas.) 51°, 2V(calc.) 57°, dispersion r < v; pleochroism X = orange red, Y and Z = very dark red; Y = b, Z ^ c = 17° (in obtuse angle β). The mineral is stated to be biaxial (+), but the indices of refraction show that it is biaxial (-). ***Chemical analytical data:*** Means of ten sets of electron microprobe data (Li by ion microprobe): Li_2O 0.02, Na_2O 9.13, K_2O 0.76, MgO 1.46, CaO 0.18, MnO 12.42, Mn_2O_3 24.35, Fe_2O_3 0.50, SiO_2 50.66, Total 99.48 wt. %. OH was not detected by IR spectroscopy; F and Cl were below detection limits. Empirical formula: $(Na_{0.83}K_{0.15})_{\Sigma 0.98}(Na_{1.97}Ca_{0.03})_{\Sigma 2.00}$–$(Mn^{3+}_{2.93}Mn^{2+}_{1.66}Mg_{0.34}Fe^{3+}_{0.06}Li_{0.01})_{\Sigma 5.00}Si_{8.00}O_{22.00}O_{2.00}$. ***Relationship to other species:*** A member of the amphibole group without F, Cl or OH. ***Name:*** For Prof. Luciano Ungaretti (1942–), Universitá de Pavia, Pavia, Italy. ***Comments:*** IMA No. 94-004. Some of the data given in this abstract were taken from the original IMA proposal. The calculated density given here is slightly different from that given in the paper. The empirical formula given in the abstract of the paper shows $Zn_{0.01}$ instead of $Li_{0.01}$ and $(Si_{7.99}Al_{0.01})$ instead of $Si_{8.00}$; the correct empirical formula is given here.

HAWTHORNE, F. C., OBERTI, R., CANNILLO, E., SARDONE, N., GRICE, J. D., and ASHLEY, P. M. (1995) A new anhydrous amphibole from the Hoskins mine, Grenfell, New South Wales, Australia: Description and crystal structure of ungarettiite, $NaNa_2(Mn^{2+}_2Mn^{3+}_3)$-$Si_8O_{22}O_2$. *American Mineralogist* **80**, 165–172.

Vicanite-(Ce) Hexagonal (trigonal)

$(Ca,Ce,La,Th)_{15}As^{5+}(As^{3+}_{0.5}Na_{0.5})Fe^{3+}Si_6B_4O_{40}F_7$

Locality: Vican (Vico lake) volcanic complex at Tre Croci, Vetralla (north of Rome), Latium, Viterbo province, Italy.

Occurrence: Inside a volcanic ejectum from a pyroclastic formation. Associated minerals are: zircon, thorite, thorian uraninite, betafite, thorian hellandite, titanite, antimonian asbecasite, "apatite," stillwellite-(Ce), and other unidentified phases.

General appearance: Anhedral grains and euhedral crystals (up to 0.3 mm).

Physical properties: *Luster:* vitreous, but the high indices of refraction indicate that it should be adamantine. *Diaphaneity:* transparent. *Color:* yellowish green. *Streak:* white. *Luminescence:* non-fluorescent. *Hardness:* estimated as 5 to 6. *Tenacity:* not given. *Cleavage:* none. *Fracture:* conchoidal. *Density:* could not be measured, 4.73 g/cm³ (calc.). ***Crystallography:*** Hexagonal (trigonal), R3m, a 10.795, c 27.336 Å, V 2758.8 Å³, Z 3, c:a = 2.5323. Morphology: forms, a "prism" and a "pyramid" were observed. Twinning: sometimes present giving a pseudocubic habit. ***X-ray powder diffraction data:*** 7.70 (50), 4.42 (50), 3.13 (50), 2.993 (100), 2.950 (70), 2.698 (50), 1.839 (50), 1.802 (50), 1.686 (50), 1.572 (50). ***Optical data:*** Uniaxial (-), ω 1.757, ε 1.722, nonpleochroic. ***Chemical analytical data:*** Means of about 40 sets of electron microprobe data: Na_2O 0.14, CaO 17.07, B_2O_3 5.27, Al_2O_3 0.16, Fe_2O_3 1.66, As_2O_5 3.76, As_2O_3 1.26, La_2O_3 12.01, Ce_2O_3 14.41, Pr_2O_3 2.77, Nd_2O_3 1.79, SiO_2 13.82, TiO_2 0.14, P_2O_5 0.38, ThO_2 18.24, UO_2 1.96, F 7.50, sum 102.34, less O = F 3.16, Total 99.18 wt. %. Empirical formula: $(Ca_{8.03}Ce_{2.32}La_{1.95}Th_{1.82}Pr_{0.44}Nd_{0.28}U_{0.19})_{\Sigma 15.03}(As^{5+}_{0.86}P_{0.14})_{\Sigma 1.00}(As^{3+}_{0.34}Na_{0.12})_{\Sigma 0.46}(Fe^{3+}_{0.55}$–$Al_{0.08}Ti_{0.05})_{\Sigma 0.68}Si_{6.07}B_{4.00}(O_{36.58}F_{10.42})_{\Sigma 47.00}$. ***Relationship to other species:*** The cell parameters are very close to those of okanoganite-(Y). ***Name:*** For the locality. ***Comments:*** IMA No. 91-050.

MARAS, A., PARODI, G. C., DELLA VENTURA, G., and OHNENSTETTER, D. (1995) Vicanite-(Ce): A new Ca-Th-REE borosilicate from the Vico volcanic district (Latium, Italy). *European Journal of Mineralogy* **7**, 439–446.

Wupatkiite Monoclinic

$(Co,Mg,Ni)Al_2(SO_4)_4 \cdot 22H_2O$

Locality: On the walls of a shallow open cut 8 miles ESE of Gray Mountain, Coconino County, Arizona.

Occurrence: As veins in a concrete-like crust. The primary ores of U-Co-Ni-Mo are colloidal black material cementing grits of the Shinarump member in the upper Chinle Formation. Associated minerals are: quartz, pickeringite and moorhouseite. Other minerals not directly associated with wupatkiite are: nickel-boussingaultite, hydrohonessite, magnesiocopiapite and ilsemannite.

General appearance: Fibers 5–10 µm in diameter and up to 8 mm long.

Physical properties: *Luster:* silky. *Diaphaneity:* transparent. *Color:* empire rose. *Streak:* white. *Luminescence:* not mentioned. *Hardness:* 1½. *Tenacity:* delicate. *Cleavage:* one oblique to the fibre axis. *Fracture:* not mentioned. *Density:* 1.92 g/cm³ (meas.), 1.87 g/cm³ (calc.). ***Crystallography:*** Monoclinic, $P2_1/c$ (by analogy with halotrichite), a 6.189, b 24.23, c 21.20 Å, β 100.33°, V not given, but calculated by the abstractor as 3128.7 Å³, Z 4, a:b:c = 0.2554:1:0.8750. Morphology: no forms observed. Twinning: none observed. ***X-ray powder diffraction data:*** 6.03 (22), 4.790 (100), 4.295 (27), 4.106 (22), 3.945 (26), 3.768 (33), 3.494 (92). ***Optical data:*** Biaxial (sign unknown), α 1.477, γ 1.484, 2V and β could not be measured, dispersion weak; pleochroic, pink with the strongest color parallel to the length; Z ^ fiber length up to 12°. ***Chemical analytical data:*** Chemical analysis by AAS, ICP.ES, colorimetry, gravimetry and Penfield (for H_2O) gave the following data: MgO 1.63, CaO 0.10, MnO 0.17, FeO 0.15, CoO 3.41, NiO 0.52, CuO 0.12, Al_2O_3 11.30, SO_3 35.97, H_2O 42.26, Total 95.63 wt. %. Empirical formula: $(Co_{0.42}Mg_{0.37}Ni_{0.06}Mn_{0.02}Fe_{0.02}Ca_{0.02}Cu_{0.01})_{\Sigma 0.92}Al_{2.04}S_{4.14}$–

$O_{16.40}\cdot 21.60H_2O$. ***Relationship to other species:*** It is the cobalt-dominant member of the halotrichite group. ***Name:*** For the prehistoric pueblo dwelling near the locality. ***Comments:*** IMA No. 94-019.

WILLIAMS, S. A. and CESBRON, F. P. (1995): Wupatkiite from the Cameron Uranium District, Arizona, a new member of the halotrichite group. *Mineralogical Magazine* **59**, 553–556.

Yuanjiangite Hexagonal

AuSn

Locality: In sandy gravel in the middle course of the Yuanjiang River, near the town of Yuanlin, Hunan Province, People's Republic of China (Lat. 28°25′37″ N, Long. 110°22′49″ E).

Occurrence: In a placer deposit. Associated minerals are: gold, platinum, osmium, diamond, cassiterite, cinnabar, realgar, pyrite, zircon, rutile, etc..

General appearance: Crystalline aggregates (grains < 5 µm) interlocked with gold. A few somewhat larger hexagonal prisms were observed in cavities.

Physical properties: *Luster:* metallic. *Diaphaneity:* opaque. *Color:* silver white. *Streak:* black. *Hardness:* VHN_{25} 215 kg/mm^2, Mohs H 3½–4. *Tenacity:* slightly ductile. *Cleavage:* not observed. *Fracture:* not observed. *Density:* 11.7 to 11.9 g/cm^3 (meas.), 11.82 g/cm^3 (calc.). ***Crystallography:*** Hexagonal, $P6_3/mmc$, a 4.316, c 5.510 Å, V 88.88 Å^3, Z 2, c:a = 1.277. Morphology: hexagonal prisms and other forms (not specified) were observed. Twinning: not mentioned. ***X-ray powder diffraction data:*** 3.726 (34), 3.087 (38), 2.218 (100), 2.159 (57), 1.546 (31), 1.257 (25), 1.162 (18). ***Optical data:*** In reflected light: white, with a light yellow tint; anisotropism, clear, polarization colour light yellow with a brown tint; bireflectance, faint; pleochroism, unclear. $R_{max.}$ & $R_{min.}$: (67.1, 66.7 %) 480nm, (76.1, 74.3 %) 540nm, (79.9, 77.4 %) 580nm, (83.1, 79.6 %) 660nm. ***Chemical analytical data:*** Means of 7 sets of electron microprobe data: Au 62.73, Sn 37.06, Pb 0.09, Ag 0.09, Total 99.97 wt. %. Empirical formula: $Au_{1.01}Sn_{0.99}$. ***Relationship to other species:*** It is isostructural with nickeline, NiAs. ***Name:*** For the locality. ***Comments:*** IMA No. 93-028. Some of the data given in this abstract were taken from the original IMA proposal.

CHEN LICHANG, TANG CUIQING, ZHANG JIANHONG, and LIU ZHENYUN (1994): Yuanjiangite—A New Auriferous and Stanniferous Mineral. *Acta Petrologica et Mineralogica* **13(3)**, 232–238.

Zdenekite Tetragonal

$NaPbCu_5^{2+}(AsO_4)_4Cl\cdot 5H_2O$

Locality: The Cap Garonne mine, near Le Pradet, 12 km east of Toulon, Var, France.

Occurrence: In a tennantite-bearing horizon near the contact with a lead-bearing horizon in pillars 78, 78b and 80 in the northern part of the mine. There are two groups of associated minerals: (1) tennantite, covellite, anglesite, a Cu-Fe-Pb-As mineral of the tsumcorite group and olivenite; (2) covellite, antlerite and geminite.

General appearance: Individual tabular tetragonal crystals (up to 0.1 mm) or spherulites and aggregates (up to 0.3 mm in diameter).

Physical properties: *Luster:* vitreous. *Diaphaneity:* translucent. *Color:* turquoise blue. *Streak:* pale blue. *Luminescence:* non-fluorescent. *Hardness:* could not be determined because of the soft and fragile nature of the mineral. *Tenacity:* fragile. *Cleavage:* {001} perfect. *Fracture:* irregular. *Density:* 4.1 g/cm^3 (meas.), 4.08 g/cm^3 (calc.). ***Crystallography:*** Tetragonal, $P4_122$ or $P4_322$, a 10.066, c 39.39 Å, V 3991.41 Å^3, Z 8, c:a = 3.9132. Morphology: forms, {001}, {100} and {110}. Twinning: none mentioned. ***X-ray powder diffraction data:*** 9.83 (100), 4.925 (60), 4.482 (50b), 3.132 (90), 2.772 (40), 2.515 (50), 1.778 (40). ***Optical data:*** Uniaxial (-), ω 1.770, ε 1.710; pleochroism strong, O = turquoise blue, E = pale blue to light green. ***Chemical analytical data:*** Means of sixteen sets of electron microprobe data (H_2O by TGA): Na_2O 2.92, CaO 0.62, PbO 16.79, CuO 32.97, As_2O_5 36.66, H_2O 7.2, Cl 3.54, sum 100.70, less O = Cl 0.80, Total 99.90 wt. %. Empirical formula: $(Na_{1.15}Ca_{0.14})_{\Sigma 1.29}Pb_{0.92}Cu_{5.08}(AsO_4)_{3.91}Cl_{1.22}O_{0.24}\cdot 4.90H_2O$. ***Relationship to other species:*** The tetragonal lead analog of lavendulan, $NaCaCu_5^{2+}(AsO_4)_4Cl\cdot 5H_2O$, which is orthorhombic. ***Name:*** For Dr. Zdenek Johan (1935–), mineralogist and Director of Scientific Affairs of the Bureau de Recherches Géologiques et Minières, France. ***Comments:*** IMA No. 92-037. The empirical formula given here is in a different form from that given in the paper. The indices of refraction indicate that the luster should be adamantine rather than vitreous.

CHIAPPERO, P-J. and SARP, H. (1995): Zdenekite, $NaPbCu_5(AsO_4)_4Cl\cdot 5H_2O$, a new mineral from the Cap Garonne mine, Var, France. *European Journal of Mineralogy* **7**, 553–557.

Zlatogorite Hexagonal (trigonal)

$CuNiSb_2$

Locality: Zlatoya Gora deposit, near Karabasch, Middle Urals, Russia.

Occurrence: In altered schistose rock (listwenite). Associated minerals are: antimony, calcite, cuprostibite, nisbite, seinäjokite, ullmannite, galena, gudmundite, and lead.

General appearance: Round grains and short prismatic crystals (up to 0.3 mm) and as monomineralic aggregates (up to 2 mm).

Physical properties: *Luster:* metallic. *Diaphaneity:* opaque. *Color:* silver-white. *Streak:* light silver-grey. *Hardness:* VHN_{50} 283 kg/mm^2, Mohs 4–4½. *Tenacity:* not given. *Cleavage:* {001} imperfect. *Fracture:* unknown. *Density:* 8.21 g/cm^3 (meas.), 8.27 g/cm^3 (calc.). ***Crystallography:*** Hexagonal (trigonal), $P\bar{3}m1$, a 4.0489, c 5.1358 Å, V 72.91 Å^3, Z 1, c:a = 1.2685. Morphology: no forms observed. Twinning: none. ***X-ray powder diffraction data:*** 2.901 (100), 2.572 (10), 2.074 (65), 2.026 (51), 1.660 (11), 1.539 (8), 1.449 (8), 1.284 (10). ***Optical data:*** In reflected light: light yellow to pinkish yellow, distinct anisotropism, weak bireflectance, nonpleochroic. R_O & R_E: (59.3, 52.4 %) 470nm, (63.0, 56.8 %) 546nm, (65.5, 60.9 %) 589nm, (68.6, 64.9 %) 650nm. ***Chemical analytical data:*** Means of twenty-four sets of electron microprobe data: Cu 17.31, Ni 16.02, Fe 0.23, Co 0.18, Sb 65.22, As 0.84, Total 99.80 wt.%. Empirical formula: $Cu_{0.99}Ni_{0.99}Fe_{0.01}Co_{0.01}Sb_{1.95}As_{0.04}$. ***Relationship to other species:*** none apparent. ***Name:*** For the locality, *Zlatoya Gora*. ***Comments:*** IMA No. 94-012. Some of the data given in this abstract were taken from the original IMA proposal.

SPIRIDONOV, E. M., SPIRIDONOV, F. M., KABALOV, Y. K., KOROTAEVA, N. N., and SOKOLOVA, E. V. (1995) Zlatogorite $CuNiSb_2$—a new mineral from the listwenite in rodingite at the Zlatoya Gora deposit (Middle Ural). *Vestnik Moskovskolo Universiteta* **Ser. 4 (5)**, 57–64.

ERRATA

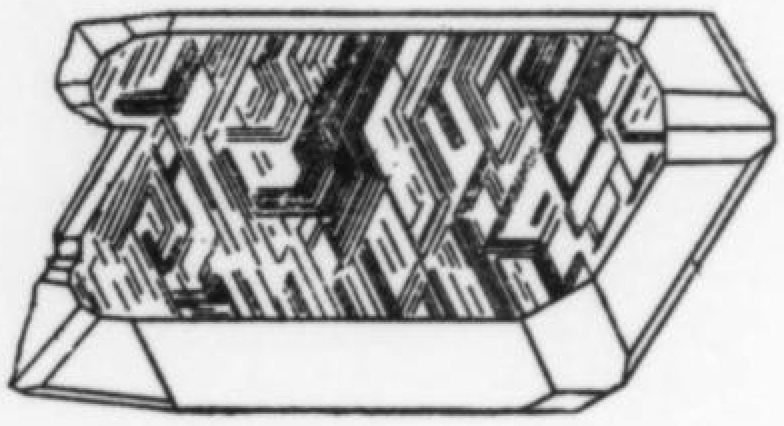
The optical orientations of three minerals were omitted from the first set of abstracts published in the March-April 1996 issue of this journal. Please add the following information.

Alumoklyuchevskite: Z = b

Artroeite: X ∧ c = 10° (in acute angle β), Y ∧ a = 42° (in acute angle γ), Z ∧ b = 50° (in obtuse angle γ)

Vanadomalayaite: orientation not given

New Minerals Recently Approved



BY THE COMMISSION ON NEW MINERALS AND MINERAL NAMES INTERNATIONAL MINERALOGICAL ASSOCIATION

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Commission on New Minerals and Mineral Names
International Mineralogical Association

The information given here is provided by the Commission on New Minerals and Mineral Names, I.M.A. for comparative purposes and as a service to mineralogists working on new species.

Each mineral is described in the following format:

Chemical Formula

Any relationship to other minerals

Crystal system, space group. Unit cell parameters. Color; luster; diaphaneity. Optical properties. Strongest lines in the X-ray powder diffraction pattern. IMA No.

The names of these approved species are considered confidential information until the authors have published their descriptions or released information themselves.

NO OTHER INFORMATION WILL BE RELEASED BY THE COMMISSION.

1995 PROPOSALS

$SrFe^{3+}_3(PO_4)_2(OH,H_2O)_6$

A member of the crandallite group

Hexagonal (trigonal): $R\bar{3}m$. a 7.28, c 16.85 Å. Yellow, brown; vitreous to resinous; transparent to translucent. Uniaxial (-), ω 1.872, ε 1.862. 5.88 (10), 3.65 (6), 3.06 (9), 2.96 (5), 2.81 (5), 2.53 (5), 2.25 (6), 1.969 (5), 1.820 (5). IMA No. 95-001.

$(H_2O,K)_2Ti(Mn^{2+},Fe^{2+})_2(Fe^{3+},Ti^{4+})_2$-$(PO_4)_4(O,F)_2 \cdot 14H_2O$

The Mn^{2+} and (O,F) analogue of paulkerrite

Orthorhombic: Pbca. a 10.561, b 20.858, c 12.516 Å. Greenish-yellow, sometimes light brown; vitreous; transparent. Biaxial (+), α 1.612, β 1.621, γ 1.649, 2V(calc.) 59.9°. 10.40 (90), 7.50 (80), 6.28 (100), 5.22 (40), 3.97 (40), 3.77 (50), 3.13 (100), 2.88 (40). IMA No. 95-002.

$Cu(Pt,Ir)_2S_4$

Cubic: Fd3m. a 9.940 Å. Steel grey; metallic; opaque. In reflected light: white with greenish tint, isotropic, no bireflectance or. pleochroism. R: (37.3 %) 470nm, (37.7 %) 546nm, (38.1 %) 589nm, (38.6 %) 650nm. 5.72 (4), 2.98 (6), 2.48 (5), 1.90 (7), 1.75 (10), 1.29 (5), 1.014 (5). IMA No. 95-003.

$(Sr,Ba,K)Mn_8O_{16}$

The strontium end-member of the cryptomelane group

Monoclinic: $P2_1/n$. a 10.00, b 5.758, c 9.88 Å, β 90.64°. Black; submetallic; opaque. In reflected light: grey, strong anisotropism, grey-blue to white bireflectance, pleochroism strong. $R_{max.}$ & $R_{min.}$: (34.2, 26.0 %) 470nm, (31.7, 24.4. %) 546nm, (30.6, 23.4 %) 589nm, (27.9, 22.3 %) 650nm. 3.15 (100), 3.13 (80), 2.409 (80), 2.229 (40), 2.170 (60), 2.170 (60), 1.556 (50). IMA No. 95-005.

$AgInS_2$

The silver analogue of roquesite in the chalcopyrite group

Tetragonal: $I\bar{4}2d$. a 5.880, c 11.21 Å. Havana brown; metallic; opaque. In reflected light: brownish grey; abundant red internal reflections; strong anisotropism in oil from red brick with orange tint to bluish-grey and purplish; pleochroism weak, brown to clear brown-grey in oil. $R_{max.}$ & $R_{min.}$: (29.3, 27.8 %) 460nm, (27.5, 25.9 %) 540nm, (27.65, 25.6 %) 580nm, (27.4, 27.5 %) 660nm. 3.351 (100), 2.941 (80), 2.082 (75), 2.030 (75), 1.767 (80), 1.188 (40). IMA No. 95-006.

CoSbAs

Probably belongs to the marcasite group

Orthorhombic: space group unknown. a 3.304, b 6.092, c 10.26 Å. White; metallic; opaque. In reflected light: silver-white, weak to distinct anisotropism, weak bireflectance, nonpleochroic. R_2 & R_1: (58.2, 55.5 %) 470nm, (56.8, 55.6 %) 546nm, (55.8, 55.5 %) 589nm, (55.0, 55.5 %) 650nm. 2.63 (10), 2.53 (8), 1.942 (10), 1.730 (4), 1.640 (4), 1.3963 (4), 1.1182 (8). IMA No. 95-007.

$PtSe_2$

The natural analogue of synthetic $PtSe_2$

Hexagonal (trigonal): P3m1. a 3.730, c 5.024 Å. Silvery lead grey; metallic; opaque. In reflected light: white; anisotropism moderate to strong with tints from. pinkish-yellow to dark-grey-lilac; strong bireflectance; pleochroism: $R_{max.}$ light-yellow, R_{min} light-lilac. $R_{max.}$ & $R_{min.}$: (48.4, 35.1 %) 470nm, (48.3, 35.0 %) 546nm, (49.1, 35.3 %) 589nm, (50.8, 36.5 %) 650nm. 5.04 (3), 2.72 (10), 1.983 (5), 1.859 (5), 1.747 (3), 1.360 (4). IMA No. 95-009.

$Cu(Mg,Cu,Fe,Zn)_2Te^{6+}O_6 \cdot 6H_2O$

Hexagonal (trigonal): P3. a 5.305, c 9.693 Å. Pale yellow to pale orange-yellow; vitreous; transparent to somewhat translucent. Uniaxial (-), ω 1.803, ε 1.581 (calc.). 9.70 (100), 4.834 (80), 4.604 (60), 2.655 (60), 2.556 (70), 2.326 (70), 1.789 (40). IMA No. 95-011.

$Cu[AsO_3OH] \cdot 2H_2O$

Triclinic: $P\bar{1}$. a 6.020, b 7.632, c 11.168 Å, α 74.43°, β 89.32°, γ 86.55°. Turquoise blue; vitreous; transparent. Biaxial (-), α 1.615, β 1.660, γ 1.700, 2V(meas.) 82°, 2V(calc.) 84°. 7.35 (100), 5.239 (50), 4.440 (60), 3.936 (60), 3.302 (40), 3.008 (50), 2.840 (35). IMA No. 95-012.

$Pb_2(Zn,Fe)[(As,S)O_4]_2 \cdot H_2O$

The zinc analogue of arsenbrackebuschite

Monoclinic: $P2_1$ or $P2_1/m$. a 8.973, b 5.955, c 7.766 Å, β 112.20°. Pale olive green with streaks of white; adamantine; transparent. In reflected light: pale brownish grey; abundant colorless to very pale yellow. internal reflections; anisotropism not detectable by eye; bireflectance measurable but not noticeable by the eye; nonpleochroic. R_{min} & R_{max}:. (11.2, 11.5 %) 470nm, (10.8, 10.9 %) 546nm, (10.7, 10.8 %) 589nm, (10.7, 10.8 %) 650nm. 4.85 (50), 3.659 (30), 3.246 (100), 2.988 (60), 2.769 (60), 2.293 (30), 2.107 (50), 1.889 (30). IMA No. 95-013.

$Ca_2FeCl[B_9O_{13}(OH)_6] \cdot 4H_2O$

Monoclinic: $P2_1$ a 11.64, b 9.38, c 8.735 Å, β 98.40°. Pale yellow; vitreous; transparent. Biaxial (+-), α 1.550, β 1.554, γ 1.592, 2V(meas.) 36.6°, 2V(calc.) 32.6°. 8.65 (3), 7.29 (10), 5.32 (2), 4.50 (2), 2.958 (3), 2.744 (2), 2.113 (3). IMA No. 95-014.

$Ca_5(SiO_4)_2SO_4$

Orthorhombic: Pnma. a 6.863, b 15.387, c 10.181 Å. Bright blue; vitreous; transparent. Biaxial (-), α 1.630, β 1.637, γ 1.640, 2V(meas.) 63.3°, 2V(calc.) 66.2°. 3.198 (27), 3.042 (32), 2.853 (40), 2.830 (100), 2.617 (32), 2.565 (57), 1.9612 (26), 1.8924 (27). IMA No. 95-015.

$Mn_2V(V,As)O_7 \cdot 2H_2O$

Monoclinic: $P2_1/n$. a 7.809, b 14.554, c 6.705 Å, β 93.25°. Orange-red; vitreous; transparent. Biaxial mean n 1.82, 2V small. 5.32 (80), 3.436 (50), 3.260 (50), 3.039 (100), 2.723 (60), 2.573 (50b), 2.441 (50), 1.592 (60). IMA No. 95-016.

$FeNb_3S_6$

The natural analogue of synthetic $FeNb_3S_6$

Hexagonal: $P6_322$. a 5.771, c 12.190 Å. Dark grey to black; metallic; opaque. In reflected light: grey; distinct to strong anisotropism from blue-grey to dark-brown; distinct bireflectance; pleochroism, light grey to grey. R_{max} & R_{min}: (36.3, 29.5 %) 470nm, (36.6, 29.4 %) 546nm, (36.1, 28.9 %) 589nm, (34.7, 28.1 %) 650nm. 6.11 (8), 3.04 (6), 2.88 (5), 2.606 (8), 2.096 (10), 1.665 (8), 1.524 (6). IMA No. 95-017.

$K(Fe^{2+},Mg)(Fe^{3+},Al)Si_4O_{10}(OH)_2$

A member of the mica group (compare 95-019)

Monoclinic: C2/m. a 5.270, b 9.106, c 10.125 Å, β 100.27°. Blue green; earthy; translucent in thin section. Complete optical data could not be measured, mean n 1.640. 3.65 (52), 3.358 (86), 3.321 (100), 3.090 (60), 2.584 (50). IMA No. 95-018.

$K(Fe^{2+},Mg)(Al,Fe^{3+})Si_4O_{10}(OH)_2$

A member of the mica group (compare 95-018)

Monoclinic: C2/m. a 5.270, b 9.106, c 10.125 Å, β 100.27°. Blue green; earthy; translucent in thin section. Complete optical data could not be measured, mean n 1.625. 3.65 (52), 3.358 (86), 3.321 (100), 3.090 (60), 2.584 (50). IMA No. 95-019. **NOTE:** The minerals represented by 95-018 and 95-019 occur intimately mixed, have the same unit cell parameters, and give the same X-ray powder diffraction data. They differ in chemical composition.

$CaB_3O_4(OH)_3$

Monoclinic: Pc. a 7.234. b 8.130. c 8.378 Å. β 98.22°. Colorless to white; vitreous; transparent to translucent. Biaxial (-), α 1.580, β 1.605, γ 1.623, 2V(meas.) 63°, 2V(calc.) 80°. 4.30 (64), 3.379 (100), 3.169 (25), 3.122 (31), 2.151 (20), 1.919 (20), 1.846 (45). IMA No. 95-020.

$PbSb_2O_6$

The natural analogue of synthetic $PbSb_2O_6$

Hexagonal (trigonal): P31m. a 5.295. c 5.372 Å. Colorless to pale yellow; resinous; transparent. Uniaxial (-), ω 2.092, ε 1.920. 3.49 (VS), 2.648 (M), 2.110 (W), 1.887 (W), 1.651 (W), 1.531 (W). IMA No. 95-021.

$KFe_8^{3+}(PO_4)_6(OH)_7 \cdot 8H_2O$

Monoclinic: C2, Cm or C2/m. a 29.52. b 5.249. c 18.56 Å, β 109.27°. Yellowish brown, pale yellow, cream to white; vitreous to silky; translucent. Biaxial (+), α 1.780, β 1.785, γ 1.800, 2V(calc.) 60°. 9.41 (60), 4.84 (90), 4.32 (70), 4.25 (50), 3.470 (60), 3.216 (100), 3.116 (80). IMA No. 95-022.

$Sr_3Na(La,Ce)(PO_4)_3(F,OH)$

Hexagonal (trigonal): P3. a 9.647(1), c 7.170(1) Å. Bright yellow to greenish-yellow; vitreous; transparent. Uniaxial (-), ω 1.653, ε 1.635. 3.59 (87), 3.30 (65), 3.17 (32), 2.897 (100), 2.884 (100), 2.790 (54), 1.910 (36), 1.796 (36). IMA No. 95-023.

$NaNbO_3$

The cubic polymorph of lueshite and natroniobite

Cubic: $Pm\bar{3}$ or P23. a 3.911 Å. Brownish-black; adamantine; opaque. In reflected light: bluish; reddish-brown internal reflections; isotropic;. nonpleochroic. R: (15.75 %) 480nm, (15.00 %) 540nm, (14.70 %) 580nm, (14.35 %) 660nm. 3.915 (35), 2.765 (100), 1.953 (53), 1.747 (8), 1.594 (30), 1.380 (22), 1.234 (7). IMA No. 95-024.

$[Zn_{8-x}Al_x(OH)_{16}][(SO_4)_{x/2+y/2}Na_y(H_2O)_6]$

Hexagonal (trigonal) : P3. a 3.082, c 11.116 Å. Pale blue; vitreous to waxy, translucent. Uniaxial (sign unknown), ω 1.532, ε unknown. 11.12 (100), 5.549 (24), 3.704 (15), 2.595 (6), 2.408 (6), 2.167 (4), 1.926 (4). IMA No. 95-025.

$NaCaAl_3Si_{17}O_{40} \cdot 7H_2O$

A member of the zeolite group

Orthorhombic: Cmcm. a 9.747, b 23.880, c 20.068 Å. Colorless; vitreous; transparent. Biaxial (+), α 1.476, β 1.478, γ 1.483, 2V(meas.) 65°, 2V(calc.) 65°. 11.94 (40), 9.04 (33), 8.23 (29), 7.69 (29), 3.79 (100), 3.61 (40). IMA No. 95-026.

$Cu_5(VO_4)_2O_2 \cdot n(Cs,Rb,K)Cl$

Hexagonal (trigonal): P3. a 6.375, c 8.399 Å. Black; resinous-metallic; opaque. Reflectance measurements could not be made because the material is too fine. grained. 3.43 (7), 2.810 (4), 2.315 (10), 2.131 (3), 1.598 (4). IMA No. 95-027.

MnS

A hexagonal polymorph of alabandite

Hexagonal: $P6_3mc$. a 3.9817, c 6.4447 Å. Dark brown to black; resinous; opaque. In reflected light: steel- grey; brown-red internal reflections; anisotropism, 2.62. to 2.77; bireflectance, 0.15; nonpleochroic. R_{max} & R_{min}: (24.5, 22.1 %) 470nm, (22.6, 20.5 %) 546nm, (22.1, 20.0 %) 589nm, (21.6, 19.6 %) 650nm. 3.445 (89), 3.217 (72), 3.036 (66), 1.988 (82), 1.820 (100), 1.691 (63). IMA No. 95-028.

$MnSb_2S_4$

The Mn-analogue of berthierite

Orthorhombic: Pnam. a 11.47, b 14.36, c 3.81 Å. Black; submetallic; opaque. In reflected light: light grey; distinct anisotropism; faint bireflectance;. nonpleochroic. R_{max} & R_{min}: (35.0, 24.0 %) 470nm, (36.1, 23.9 %) 546nm, (36.9, 24.9 %) 589nm, (35.6, 25.7 %) 650nm. 4.46 (40), 3.69 (90), 3.23 (70), 3.05 (40), 2.90 (80), 2.65 (100), 2.18 (40), 1.906 (40), 1.813 (50). IMA No. 95-029.

$Zn_3Cu_2(SO_4)_2(OH)_6 \cdot 4H_2O$

Triclinic: $P\bar{1}$. a 5.415, b 6.338, c 10.475 Å, α 94.38°, β 90.08°, γ 90.24°. Greenish blue; vitreous; transparent. Biaxial (+), α 1.629, β 1.630, γ 1.637, 2V(meas.) 60°, 2V(calc.) 42°. 10.459 (61), 5.230 (74), 3.486 (40), 3.157 (6), 2.728 (6), 2.493 (7), 2.355 (7), 1.743 (9). IMA No. 95-030.

$(K,Na)_2(Nb,Ti)_2Si_4O_{12}(O,OH)_2 \cdot 4H_2O$

Monoclinic: Cm. a 14.692, b 14.164, c 7.859 Å, β 117.87°. White; vitreous; translucent. Biaxial (+), α 1.649, β 1.655, γ 1.759, 2V(meas.) 20°, 2V(calc.) 28°. 7.10 (9), 4.98 (6), 3.262 (10), 3.151 (8b), 2.956 (6), 2.549 (4), 1.723 (4), 1.591 (4b), 1.451 (4b). IMA No. 95-031.

(Fe,Os,Ru,Ir)

Hexagonal: $P6_3/mmc$. a 2.591, c 4.168 Å. Megascopic color unknown; metallic; opaque. In reflected light: white; weak anisotropism. R: (57.4 %) 470nm, (53.4 %) 546nm, (53.3 %) 589nm, (54.4 %) 650nm. 2.246 (5), 2.087 (6), 1.976 (10), 1.297 (6b), 1.180 (6b), 1.100 (5b). IMA No. 95-032.

$Na_6Mn(Ti,Nb)Si_{10}(O,OH)_{28} \cdot 4H_2O$

Monoclinic: I2/m. a 13.033, b 18.717, c 12.264 Å, β 99.62°. Yellow, pinkish-yellow or pink; vitreous to greasy; translucent to transparent. Biaxial (-), α 1.536, β 1.545, γ 1.553, 2V(meas.) 87°, 2V(calc.) 86°. 10.56 (100), 6.38 (50), 5.55 (45), 4.78 (40), 4.253 (40), 3.196 (80), 2.608 (50). IMA No. 95-033.

$Na_5(Y,Dy,Gd)(Ti,Nb)Si_6O_{18} \cdot 6H_2O$

Hexagonal (trigonal): R32. a 10.696, c 15.728 Å. Colorless; vitreous; transparent or cloudy. Uniaxial (-), ω 1.612, ε 1.607. 5.99 (60), 3.21 (100), 3.093 (40), 2.990 (85), 2.61 (40), 1.998 (55), 1.481 (44b). IMA No. 95-034.

$(Nb,Ta)C$

Cubic: Fm3m. a 4.45 Å. Bronze-yellow; metallic; opaque. In reflected light: yellowish- to rose-cream; no anisotropism, bireflectance or pleochroism. R: (33.9 %) 480nm, (38.5 %) 540nm, (45.1 %) 580nm, (52.8 %) 660nm. 2.56 (10), 2.22 (9), 1.574 (8), 1.343 (8), 1.289 (7), 1.115 (3). IMA No. 95-035.

$Na(Ca,Sr)_3Ce(PO_4)_3F$

The calcium-dominant analogue of belovite-(Ce)

Hexagonal (trigonal): P3. a 9.51, c 7.01 Å. Bright yellow; vitreous; transparent. Uniaxial (-), ω 1.682, ε 1.660. 3.51 (30), 3.12 (40), 2.84 (100b), 2.753 (40), 1.967 (30), 1.870 (30). IMA No. 95-036.

$Fe^{3+}_3PO_7$

The natural analogue of synthetic $Fe^{3+}_3PO_7$

Hexagonal (trigonal): R3m. a 7.994, c 6.855 Å. Brown to red brown; greasy; non-translucent. Optical data could not be obtained because of the small size of the domains. 4.86 (10), 3.09 (100), 2.446 (16), 2.078 (20), 1.997 (13), 1.845 (11), 1.623 (23), 1.545 (12), 1.440 (16). IMA No. 95-037.

$Fe^{3+}PO_4$

The natural analogue of synthetic $Fe^{3+}PO_4$

Hexagonal (trigonal): $P3_121$. a 5.048, c 11.215 Å. Brown to red-brown; greasy; non-translucent. Optical data could not be obtained because of the small size of the domains. 4.360 (19), 3.445 (100), 2.518 (7), 2.362 (14), 2.298 (7), 2.180 (10), 1.8846 (12), 1.5814 (8), 1.4214 (10). IMA No. 95-038.

$Cu_5Zn_3(Te^{6+}\underline{O}_4)_4(OH)_8\cdot 7H_2O$

Triclinic: P1 or $P\bar{1}$. a 8.794, b 9.996, c 5.660 Å, α 104.10°, β 90.07°, γ 96.34°. Pale blue to deeper blue-green; vitreous to pearly; transparent to translucent. In reflected light: very pale light brown; light emerald green internal reflections;. anisotropism unknown; slight bireflectance. R values could not be measured. with certainty. 9.638 (100), 8.736 (50), 4.841 (100), 2.747 (60), 2.600 (45). IMA No. 95-039.

$Ba_2Ce(CO_3)_3F$

Monoclinic: $P2_1/m$ or $P2_1$ a 13.396, b 5.067, c 6.701 Å, β 106.58°. Yellow; vitreous; transparent. Biaxial (-), α 1.584, β 1.724, γ 1.728, 2V(meas.) 16°, 2V(calc.) 18°. 4.000 (10), 3.269 (100), 2.535 (20), 2.140 (40), 2.003 (40), 1.635 (10), 1.373 (10). IMA No. 95-040.

In_2Pt

Cubic: $Fm\bar{3}m$, F42 or $F4\bar{3}m$. a 6.364 Å. Bright white; metallic; opaque. In reflected light: bright white with yellowish tint; no anisotropism, bireflectance or pleochroism. R: (49.3 %) 470nm, (60.6 %) 550nm, (68.5 %) 590nm, (80.1 %) 650nm. 2.25 (100), 1.92 (60), 1.59 (60), 1.299 (80), 1.125 (60), 1.076 (60), 1.006 (60). IMA No. 95-041.

$InPt_3$

Cubic: $Pm\bar{3}m$. a 3.988 Å. Bright white; metallic; opaque. In reflected light: bright white with yellowish tint; no anisotropism, bireflectance or pleochroism. R: (56.1 %) 470nm, (62.5 %) 550nm, (65.7 %) 590nm, (71.3 %) 650nm. 2.30 (100), 1.99 (60), 1.411 (40), 1.203 (80), 1.151 (40), 0.997 (20). IMA No. 95-042.

$Fe_2(Ta,Nb)$

Hexagonal: $P6_3/mmc$, $P6_3mc$ or $P\bar{6}2c$. a 4.87, c 7.76 Å. Greyish-yellow; metallic; opaque. In reflected light: greyish white; no anisotropism, bireflectance or pleochroism. R: (55.4 %) 460nm, (60.8 %) 540nm, (65.7 %) 590nm, (71.3 %) 660nm. 2.84 (7), 2.46 (6), 2.22 (9), 2.00 (3), 1.92 (4), 1.41 (3), 1.34 (8). IMA No. 95-043.

$Bi_{16}CrO_{27}$

The natural analogue of synthetic $Bi_{16}CrO_{27}$

Tetragonal: I4, $I\bar{4}$ or I4/m. a 8.649, c 17.24 Å. Orange-brown; adamantine; translucent. Uniaxial (+), ω 2.50, ε 2.55. In reflected light: greyish white to light orange; orange internal reflections; weak anisotropism; weak bireflectance; very weak pleochroism. R_E & R_O:. (21.46, 19.40 %) 470nm, (27.46, 25.22 %) 546nm, (29.80, 26.22 %) 589nm, (29.98, 25.96 %) 650nm. 3.19 (100), 2.730 (40), 1.980 (40), 1.715 (30), 1.655 (55), 1.124 (25), 1.054 (25). IMA No. 95-044.

$Li_2(Mg,Fe^{2+})_3Fe^{3+}_2Si_8O_{22}(OH)_2$

A member of the amphibole group

Monoclinic: C2/m. a 9.474, b 17.858, c 5.268 Å, β 101.88°. Black; vitreous; translucent. Biaxial (+), α 1.699, β 1.703, γ 1.708, 2V(meas.) 72°, 2V(calc.) 84°. 8.222 (61), 4.458 (19), 3.044 (100), 2.741 (53), 2.712 (14), 2.341 (14), 1.433 (46), 1.392 (14). IMA No. 95-045.

$Na_2(Sr,Ba)_{14}Na_2Al_{12}F_{64}(F,OH)_4$

Monoclinic: C2/m. a 16.046, b 10.971, c 7.281 Å, β 101.734°. Colorless to white; vitreous; translucent. Biaxial (-), α 1.436, β 1.442, γ 1.442, 2V(meas.) 0–5°, 2V(calc.) 0°. 7.844 (8), 3.643 (9), 3.453 (10), 3.193 (10), 3.112 (9), 2.989 (9), 2.220 (8), 2.173 (9), 2.001 (8). IMA No. 95-046.

IrBiS

Cubic: $P2_13$. a 6.164 Å. Steel black; metallic; opaque. In reflected light: bright white with yellowish tint, isotropic. R: (46.2 %) 470nm, (47.2 %) 550nm, (47.6 %) 590nm, (47.4 %) 650nm. 2.75 (70), 2.51 (60), 1.860 (100), 1.090 (50), 1.090 (50). IMA No. 95-047.

$Cu^{2+}(AsO_3OH)\cdot H_2O$

A polymorph of geminite

Triclinic: P1 or $P\bar{1}$. a 6.435, b 11.257, c 18.662 Å, α 79.40°, β 86.48°, γ 83.59°. Very light green to colorless; vitreous; transparent. Biaxial (+), α 1.602, β 1.642, γ 1.725, 2V(meas.) 70°, 2V(calc.) 73°. 18.3 (25), 11.00 (100), 3.171 (30), 2.952 (50), 2.920 (60), 2.816 (50), 2.492 (25). IMA No. 95-048.

$(Pt,Pd,Cu)_9Cu_3Sn_4$

The Pt-dominant analogue of taimyrite

Orthorhombic: Pmmm, Pmm2 or P222. a 7.89, b 4.07, c 7.73 Å. Pinkish lilac; metallic; opaque. In reflected light: pinkish lilac, distinct to moderate anisotropism, weak to distinct bireflectance, pleochroic from brownish pink to pinkish lilac. $R_{max.}$ & $R_{min.}$: (44.1, 42.8 %) 470nm, (50.0, 49.5 %) 546nm, (54.6, 51.8 %) 589nm, (56.8, 55.6 %) 650nm. 2.283 (10), 2.163 (4), 2.030 (2), 1.369 (3), 1.218 (2), 1.143 (2). IMA No. 95-049.

$Bi_2O(OH)VO_4$

The vanadium analogue of atelestite

Monoclinic: $P2_1/c$. a 6.973, b 7.539, c 10.881 Å, β 107.00°. Light brown; adamantine; transparent to translucent. Biaxial (+), α 2.26, β 2.27, γ 2.30, 2V(meas.) 65°, 2V(calc.) 61°. 6.667 (23), 6.102 (22), 4.279 (38), 3.267 (100+), 3.150 (62), 2.734 (36), 2.549 (21), 1.889 (21). IMA No. 95-050.

$Ca_4(Ca,Sr,K,Ba)_3Cu_3Al_{12}Si_{12}O_{48}(OH)_8\cdot\sim H_2O$

A member of the zeolite group

Cubic: Fm3m. a 31.62 Å. Light blue; vitreous; transparent. Isotropic: n 1.505. 18.34 (100), 15.82 (50), 9.69 (5), 4.43 (5), 3.87 (5), 3.47 (5). IMA No. 95-051.

$KCr_2[AlSi_3O_{10}](OH,F)_2$

A member of the mica group; the Cr-dominant analogue of muscovite

Monoclinic: C2/c. a 5.32, b 9.07, c 20.20 Å, β 95.6°. Emerald green; vitreous; transparent. Biaxial (-), α 1.619, β 1.669, γ 1.673, 2V(meas.) 31°, 2V(calc.) 31°. 9.94 (6), 4.52 (8), 2.60 (10), 2.40 (6), 2.15 (6), 1.519 (10). IMA No. 95-052.

$SrLa(CO_3)_2(OH)\cdot H_2O$

The lanthanum-dominant analogue of ancylite-(Ce)

Orthorhombic: Pmcn. a 5.072, b 8.589, c 7.276 Å. Light yellow to yellowish brown; vitreous; transparent. Biaxial (+), α 1.640, β 1.668 (calc.), γ 1.731, 2V(meas.) 70°. 4.36 (92), 3.738 (88), 3.705 (90), 2.955 (100), 2.664 (89), 2.358 (87), 2.092 (80). IMA No. 95-053.

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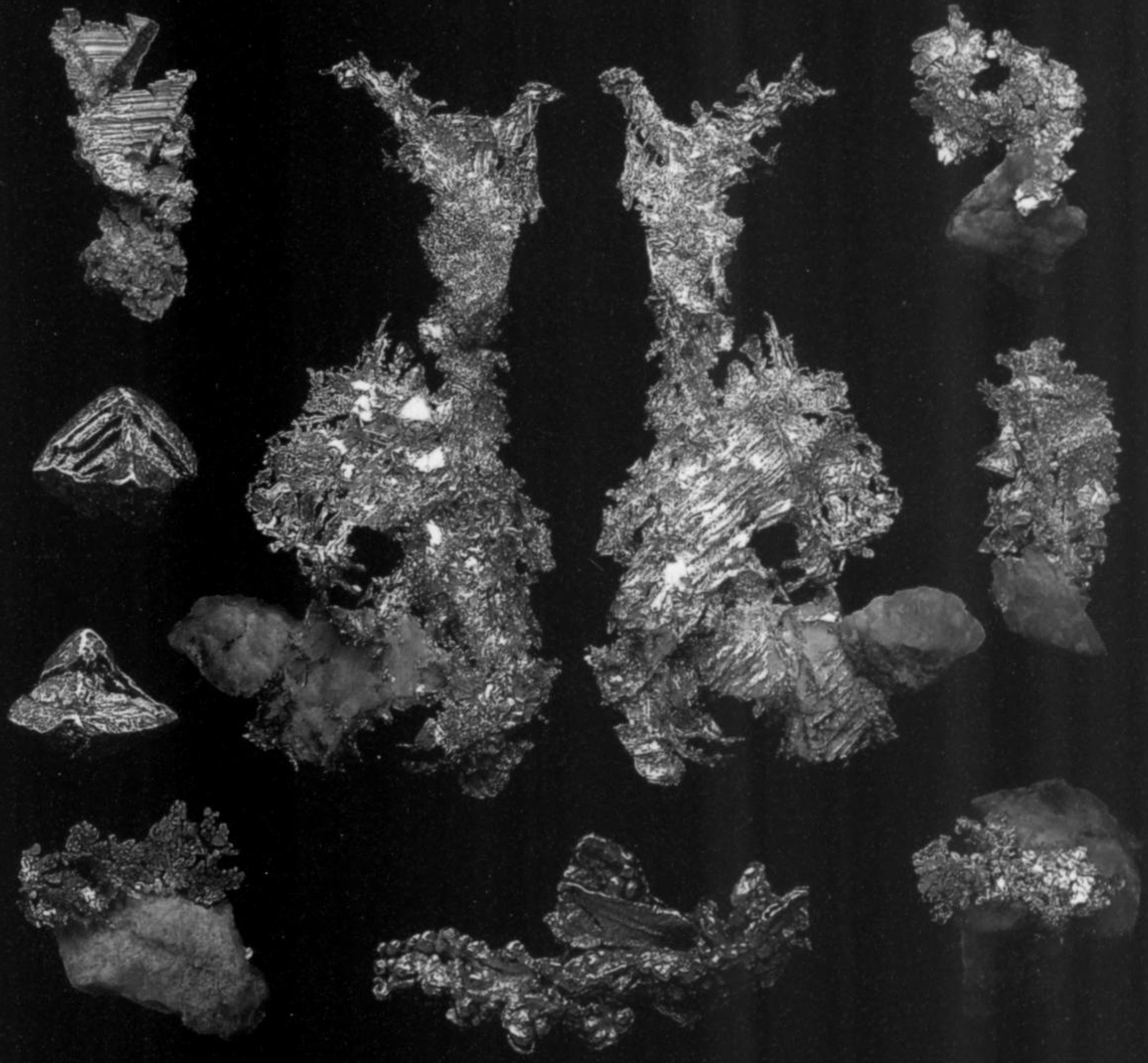

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