the Mineralogical Record

Volume Eleven, Number Six
November-December 1980 $3

affiliated with the Friends of Mineralogy

the Mineralogical Record

(USPS 887-700)

Volume Eleven, Number Six
November-December 1980

Articles

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COVER: ELBAITE on quartz from Minas Gerais, Brazil. The crystal is 8.5 mm in width. Photo by Olaf Medenbach.

address
The Mineralogical Record
P. O. Box 35565
Tucson, Arizona 85740

published
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Special Second Class postage
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famous mineral localities:

the Broken Hill mine Zambia

by **C. W. Notebaart**
Stadhoudersplein 25 C
3039-ER Rotterdam
Netherlands

and **S. P. Korowski**
Nchanga Consolidated Copper Mines Limited
P. O. Box 906
Kitwe, Zambia

HISTORY

The Broken Hill lead-zinc mine is located near the town of Kabwe, 140 km north of Lusaka, the capital of Zambia, on the main route to the Copperbelt (Fig. 1). The ore deposit was discovered in 1902 by T. G. Davey, a consulting engineer with the Rhodesia Copper Company, who was searching for old copper workings reported to exist in the area. One day he observed a prominent rounded hill in the distance (Fig. 2), called a kopje in Southern Africa, and decided to divert from his planned course. Later he wrote, "On reaching the kopje, I commenced to map the stone as I ascended. At first—that is, about the base of the kopje—I discovered a little limestone as well as hematite, but it was not long before I broke a heavy piece of stone which was perfectly white and which I at once recognized as cerussite or carbonate of lead. From this point to the summit of the kopje, I did not cease to find both carbonate and sulphides of lead as well as carbonates of zinc." Knowledge of the famous Broken Hill mine in Australia led Davey to name his discovery as the *Rhodesia-Broken Hill*. The name was changed to *Zambia-Broken Hill* after independence in 1964. The nearby town, however, has always been known as Kabwe, a name which had been used by Africans for the vicinity. It means "place of smelting," referring to the pre-European smelting of high-grade iron ore in the area.

The excitement of the discovery, prompted no doubt by visions of another Australian Broken Hill, resulted in the railway being extended from Livingstone to Kabwe, a distance of 600 km. When the railway men eventually reached Broken Hill, the largest hut which they found in the little town accommodated the local bar.

The Rhodesia Broken Hill Development Company was formed in 1904. The first high-grade zinc ore was mined in 1906 and calcined locally. Operations were discontinued in 1907 due to the high cost of transport of the calcine to the smelter. In that period the famous bone cavern in No. 1 kopje was discovered. This cavern contained a large accumulation of animal bones which were cemented together by rare zinc phosphates associated with cerussite. Evidence of human occupation was provided by primitive stone implements.

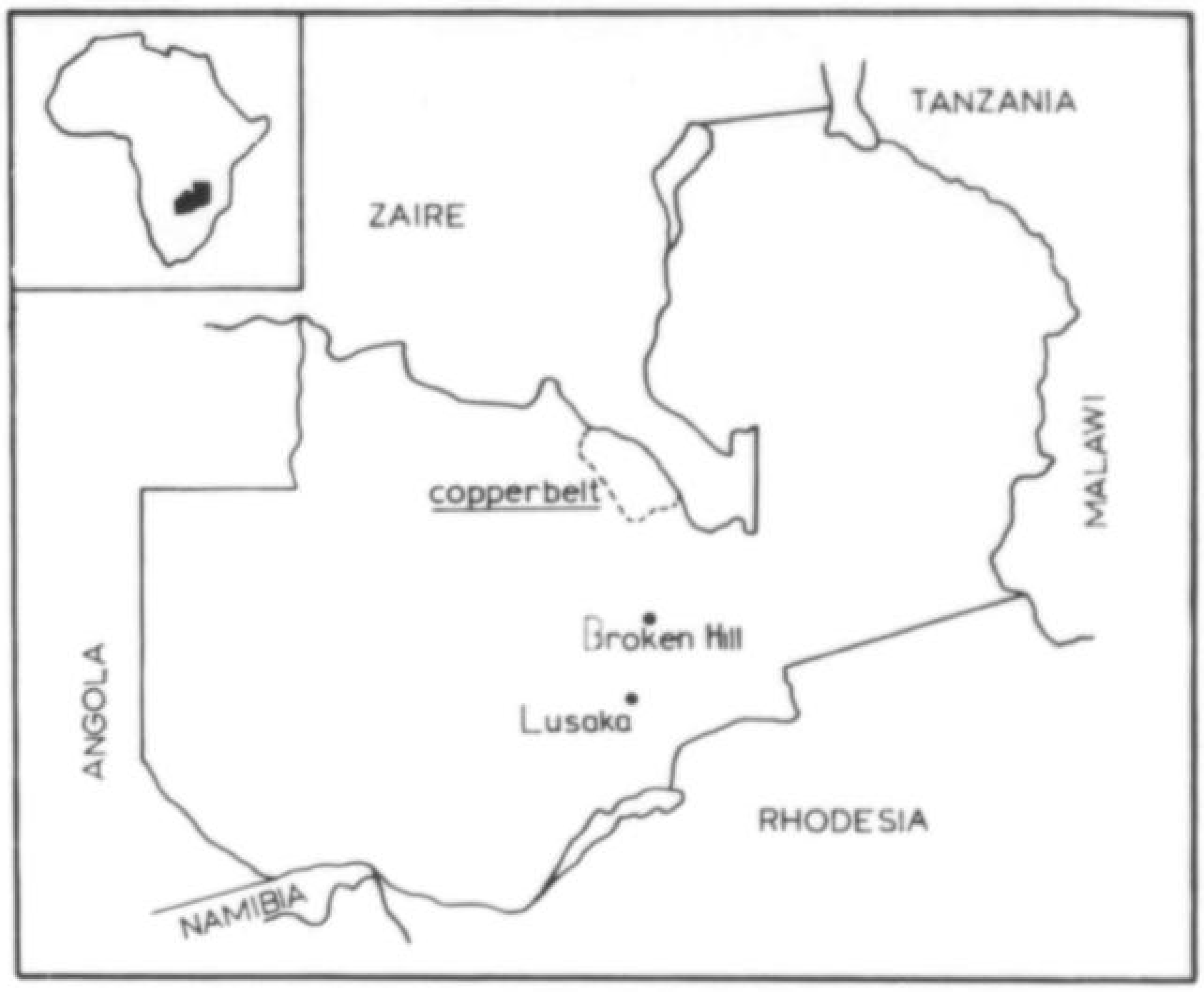

Figure 1. **Location map.**

No. 1 kopje is also the place where the famous Broken Hill man or Homo Rhodesiensis was found. This happened in 1921, when mining had progressed to the lower levels of the cave deposits, some 24 meters below the surface of the plain. On an afternoon shift, when the European shift boss and his African miners returned to the working face after blasting, they saw a skull (Fig. 3) peering at them from the pile of broken rock. The superstitious miners took to their heels and only after the skull had been displayed on a stake for several days were they prepared to start work again. Fortunately their supervisors realized the importance of this find and the skull is

Figure 2. **A view of No. 1 kopje. (Photograph courtesy of the Institution of Mining and Metallurgy.)**

now the proud possession of the British Museum. The estimated age of the skull was 40,000 years although recent investigations would indicate a middle Pleistocene date, possibly well over 125,000 years.

It is interesting to speculate what the Broken Hill cave people may have thought of their glittering surroundings. They certainly had an opportunity to be among the world's first collectors of rare minerals and fine crystal specimens! (They also had the opportunity to be poisoned by all of the soluble lead carbonate surrounding them. Ed.)

Figure 3. **The first mineral collector? Skull of Homo Rhodesiensis, found in No. 1 kopje during mining operations in 1907. The estimated date is 40,000 BP, but may be as early as 120,000 BP. (Photograph of a replica by the Livingstone Museum, Zambia.)**

Following the temporary suspension of operations in 1907 it was decided to build a full metallurgical treatment plant at Broken Hill for the production of lead bullion from high grade ore mined in No. 1 kopje. Continuous operations started in 1915 after commissioning a small lead blast furnace (Fig. 4). Subsequently, additional blast furnaces were built and in 1917 lead production was 4780 tonnes.

In 1920 a process was developed for the treatment of zinc silicate ores, using leaching and electro-winning. A full scale zinc electro-winning plant, the first of its kind, started production in 1928. After the ores which could be mined by open pit methods had been virtually exhausted, underground mining started in the late 30's. A differential lead/zinc flotation plant, hearth furnaces to treat the lead sulfide concentrate and a sphalerite roaster were commissioned in 1946. Over the years, facilities have been added to recover other metals as by-products: vanadium oxide was first produced in 1931, followed by cadmium in 1956 and silver in 1958. A new lead blast furnace and a sinter plant were built in 1954 but were closed down five years later. In 1962 an Imperial smelting furnace and a new sinter plant were commissioned. To treat the large, high-grade oxide dumps a Waelz kiln plant was constructed and became operational in 1975. At present, the mine produces 14,000 tonnes/year of lead and 46,000 tonnes/year of zinc. A very detailed account of the history of the metallurgical operations has been given by Barlin (1970).

GEOLOGY

The geology of the Broken Hill mine has been described by Pelletier (1930), Taylor (1954), Coles (1959), Whyte (1966) and Kortman (1970); the following summary is largely based on these publications. The ore deposits occur in a series of Precambrian dolomite rocks which are flanked by shales and phyllites. Originally it was thought that the dolomite rocks formed the center of a synform, but more recent data (Kortman, 1970) indicate that the argillaceous rocks on both sides of the dolomite zone cannot be correlated stratigraphically. It is thus probable that the dolomites and argillaceous rocks are part of a steeply inclined series which strikes to the northwest and dips to the northeast. Argillaceous layers also occur within the dolomites and the contact between one such layer and the ore can be seen in the No. 2 orebody, where it forms the hanging wall of the ore. Outcrops of conglomerate and

Figure 4. **A view of the first furnace in operation, as seen from No. 1 kopje. (Photograph courtesy of the Institution of Mining and Metallurgy.)**

sandstone are present to the northeast of the mine. Granitic rocks east of Kabwe are probably older than the dolomite series (Taylor, 1954).

Originally seven outcrops existed which were numbered 1 through 7. Later, three other orebodies were discovered and these were designated 8, E and X. It was subsequently shown that Nos. 3–4 and 5–6–7 formed only two distinct orebodies, reducing the total to seven. The No. 1, 3–4 and 5–6 orebodies have irregular pipe-like to vein-like shapes, dip steeply northwards and generally plunge east-northeast. The 5–6 orebody extends to the deepest level of the mine, 470 m below the surface, and is the largest of the seven orebodies with a strike length of around 800 m. The lens-shaped No. 2 orebody, located along the contact between the dolomite and an argillaceous series, is 100 m long, 20 m thick and extends 250 m below the surface. No. 8 orebody, which is also lens-shaped, does not outcrop and extends between the 230 m and 360 m levels and is, in fact, a series of small pipe-shaped deposits in mutual contact with each other.

MINERALOGY

The orebodies typically consist of a sulfide core surrounded by an oxidation zone containing secondary lead and zinc minerals. No. 2 orebody is virtually completely oxidized. The sulfide mineral assemblage consists of medium-grained pyrite, sphalerite and galena with very minor quantities of chalcopyrite, bornite, covellite, chalcocite and tetrahedrite. Pyrite was the first mineral to crystallize, followed by sphalerite and galena. Kortman (1970) notes an antipathetic relationship between galena and pyrite; i.e. the sulfide ore consists either of galena and sphalerite with very minor pyrite or of sphalerite and pyrite with little galena.

In the transition zone between the primary ore and the oxide zone galena is partially converted to cerussite or is replaced by smithsonite. Secondary galena occurs here as veinlets surrounding and replacing grains of pyrite and sphalerite. These galena veinlets often have a central core of smithsonite and willemite and are evidently of supergene origin. The associated pyrite is partially altered to goethite.

The ore in the inner regions of the oxidation zone is usually massive and fine-grained, whereas in the outer regions the texture ranges from massive through boxwork to cavernous. This ore varies in color from light gray to brown due to iron oxides and frequently shows color banding. The main ore minerals in the oxidation zone are willemite, smithsonite and cerussite. The vanadium minerals, descloizite, vanadinite and mottramite are concentrated in the outer zones of the orebodies. The most likely source of this vanadium is the argillaceous country rock which contains, on the average, 120 ppm vanadium.

In the following individual mineral descriptions, emphasis has been placed on the secondary lead and zinc minerals of interest to collectors.

Pyrite, FeS_2

Pyrite was the first sulfide mineral to crystallize. It occurs as subhedral grains associated mainly with sphalerite.

Sphalerite and Wurtzite, ZnS

Sphalerite is found in anhedral grains associated with pyrite or galena, but also occurs in large pure masses. Massive sphalerite is transparent and has a greenish or yellowish brown color. It is intimately intergrown with wurtzite. The iron content of the medium-grained sphalerite ranges from 0.7 percent to 1.1 percent iron and that of massive sphalerite from No. 8 orebody from 0.3 to 0.4 percent iron (Kortman, 1970). Sphalerite is replaced by galena and, in the transition zone between the oxide and sulfide ores, by smithsonite and willemite.

Galena, PbS

Galena is the main source of lead. It occurs mostly as anhedral grains, replacing the earlier deposited pyrite and sphalerite. Occasionally, well-formed cubes are found in open spaces and are in some cases overgrown by sphalerite. The occurrence of secondary galena veinlets has been mentioned above. The galena contains on the average 0.06 percent silver and 0.02 percent selenium (Kortman, 1970).

Copper Sulfides

The copper sulfides occur in very small quantities and are of no importance as ore minerals or specimen material.

Copper, Cu; **Cuprite,** Cu_2O

Native copper is present in very small amounts in the inner oxidation zone and is associated with malachite, cuprite and chalcocite. Cuprite occurs as small octahedral crystals.

Smithsonite, $ZnCO_3$

Smithsonite is often associated with willemite and these two minerals contribute by far the major part of the total zinc in the oxide ore. It is generally massive, fine-grained and intimately intergrown with other oxide minerals. In No. 2 kopje open pit massive botryoidal smithsonite (Fig. 5) with a concentrically banded structure and a light blue color can be found. The surface is covered by a layer of small, colorless hemimorphite crystals,

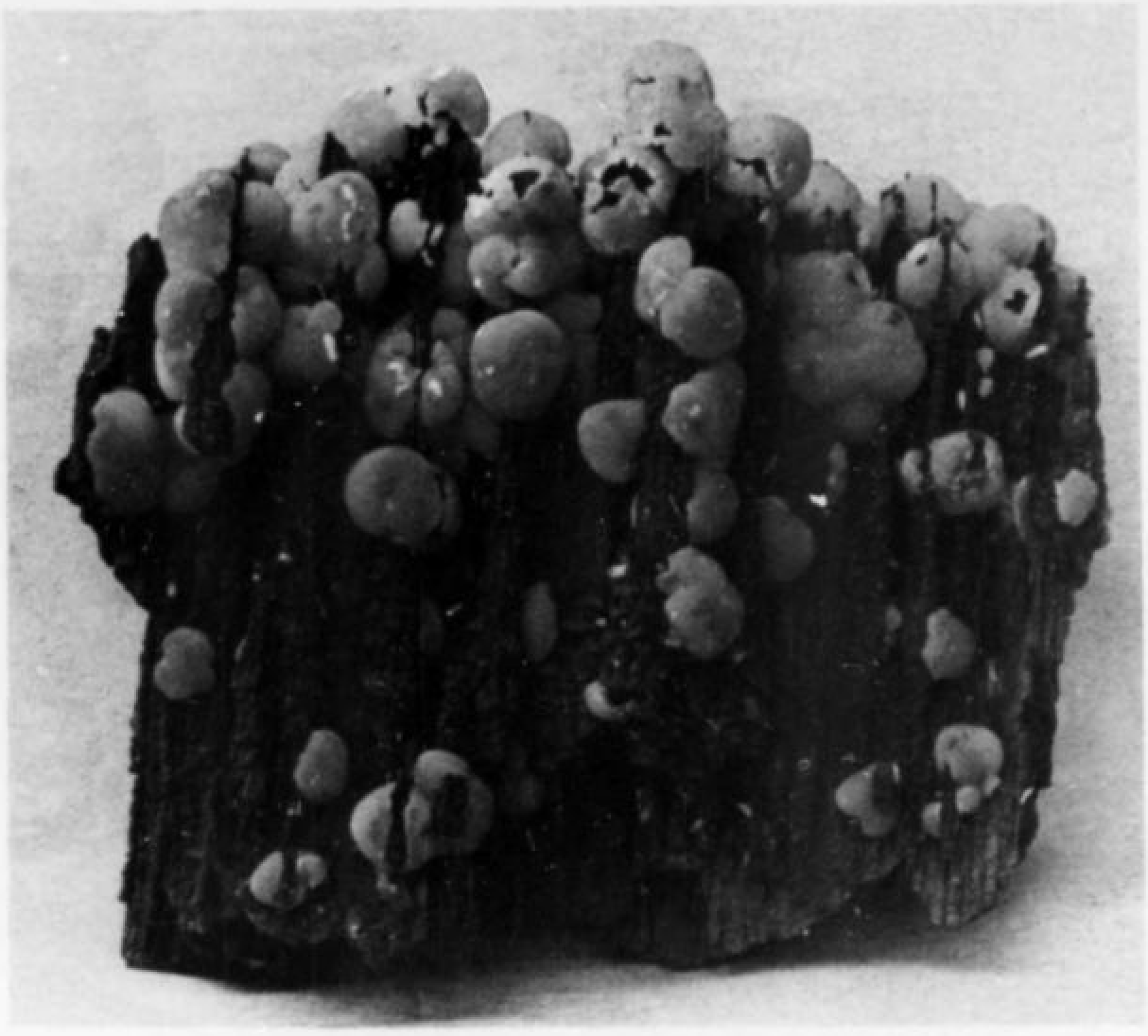

Figure 5. **Bluish white smithsonite balls (1 cm across) on columnar goethite. Collection of the Broken Hill Division of Nchanga Consolidated Copper Mines Ltd.**

sometimes stained brownish by iron oxide minerals. Spencer (1908) mentioned massive, mammillary smithsonite, partially or completely replaced by tarbuttite which appears on the surface as crystals. Associated with these tarbuttite crystals are acicular, pale yellowish crystals of smithsonite. Good smithsonite crystals can still be collected, both underground and in the No. 2 open pit.

The following crystal habits have been observed:

(1.) Simple rhombohedral crystals up to 2 cm in length (Fig. 6).

(2.) Acicular scalenohedral crystals. In recent finds from under-

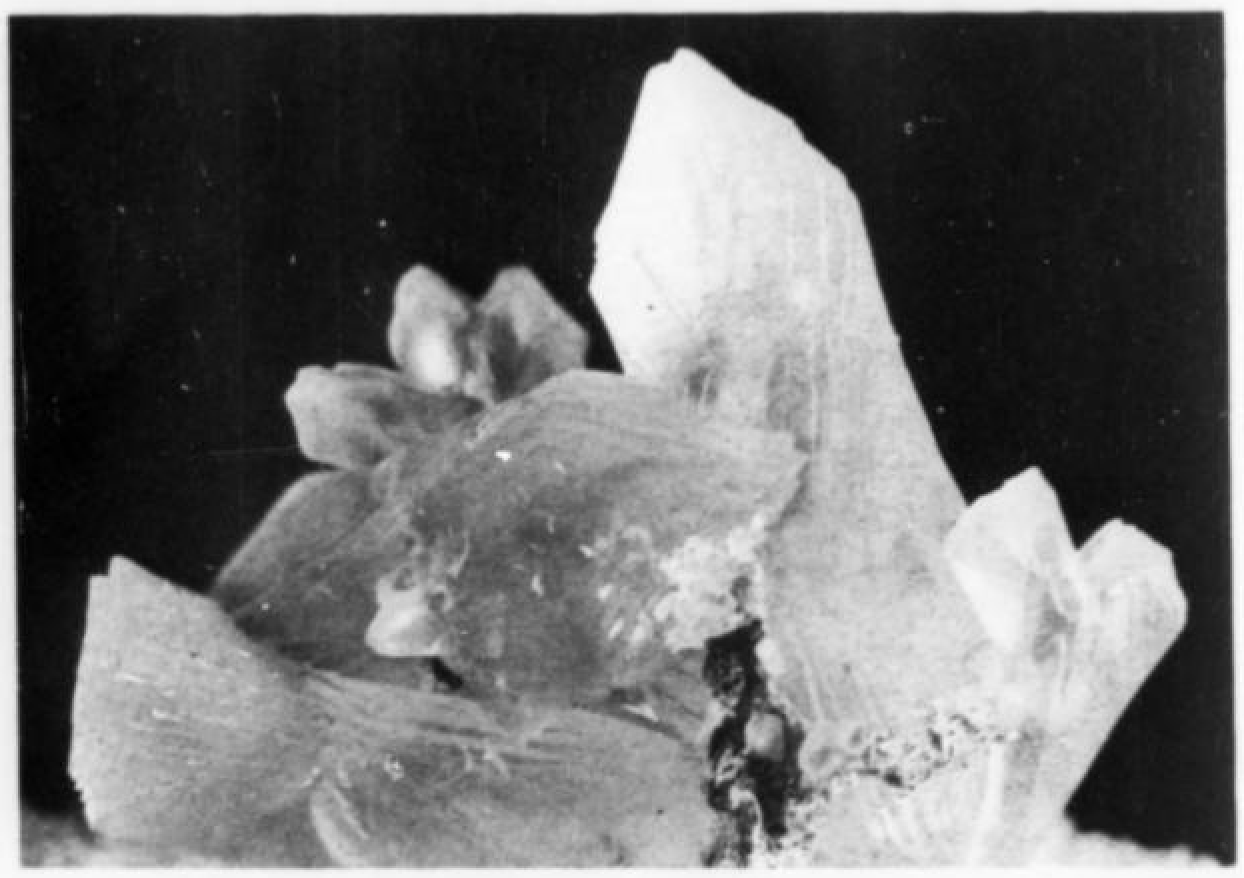

Figure 6. **Smithsonite crystals with a typical bow-tie shape. The longest crystal measures 2 cm. Collection of S. P. Korowski.**

ground, colorless crystals of this type occur up to 2 cm long and lining cavities or joints in dolomite (Fig. 7). As mentioned above, Spencer found this type on massive smithsonite, showing the scalenohedron {$21\bar{3}1$} and the rhombohedron {$05\bar{5}1$}.

(3.) Scalenohedral crystals as found by Hurlbut (1954) on a specimen from the Harvard collection. These crystals show large scalenohedral faces {$12.8.\overline{20}.1$}, smaller scalenohedron faces {$21.7.\overline{28}.12$} and {$21\bar{3}1$}, and the rhombohedrons {$10\bar{1}1$} and {$0\bar{2}21$}.

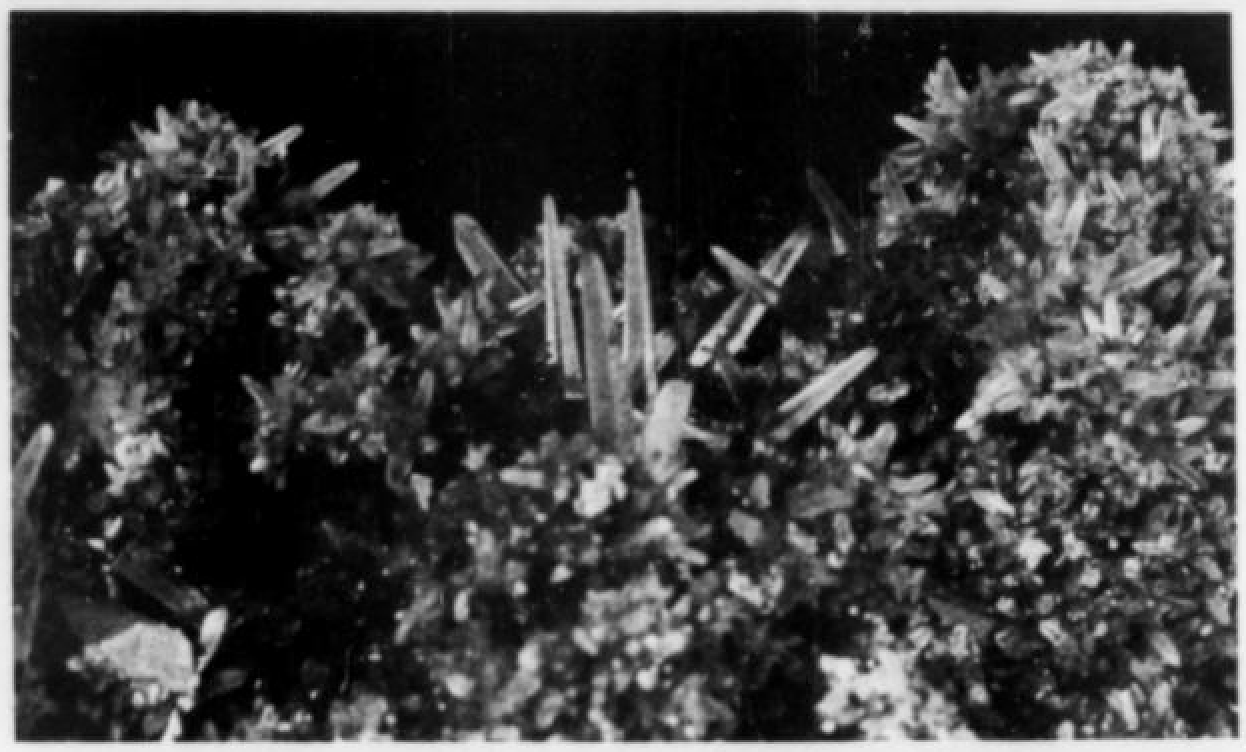

Figure 7. **Acicular scalenohedral smithsonite crystals up to 1.5 cm long. Collection of S. P. Korowski.**

(4.) Scalenohedral crystals with {$25\bar{7}3$} as the dominant form (Hurlbut, 1954).

Cerussite, $PbCO_3$

This was the first ore mineral to be identified in the outcrop and the early mining was due largely to its abundance in the outer zones of the orebodies. It is usually massive and finely intergrown with willemite and smithsonite. Direct replacement of galena by cerussite occurs in the transition zone between the sulfide and oxide ore. Well-developed colorless crystals up to 7 cm long have been found in cavities (Fig. 8), the largest crystals often being covered with microcrystals of hemimorphite.

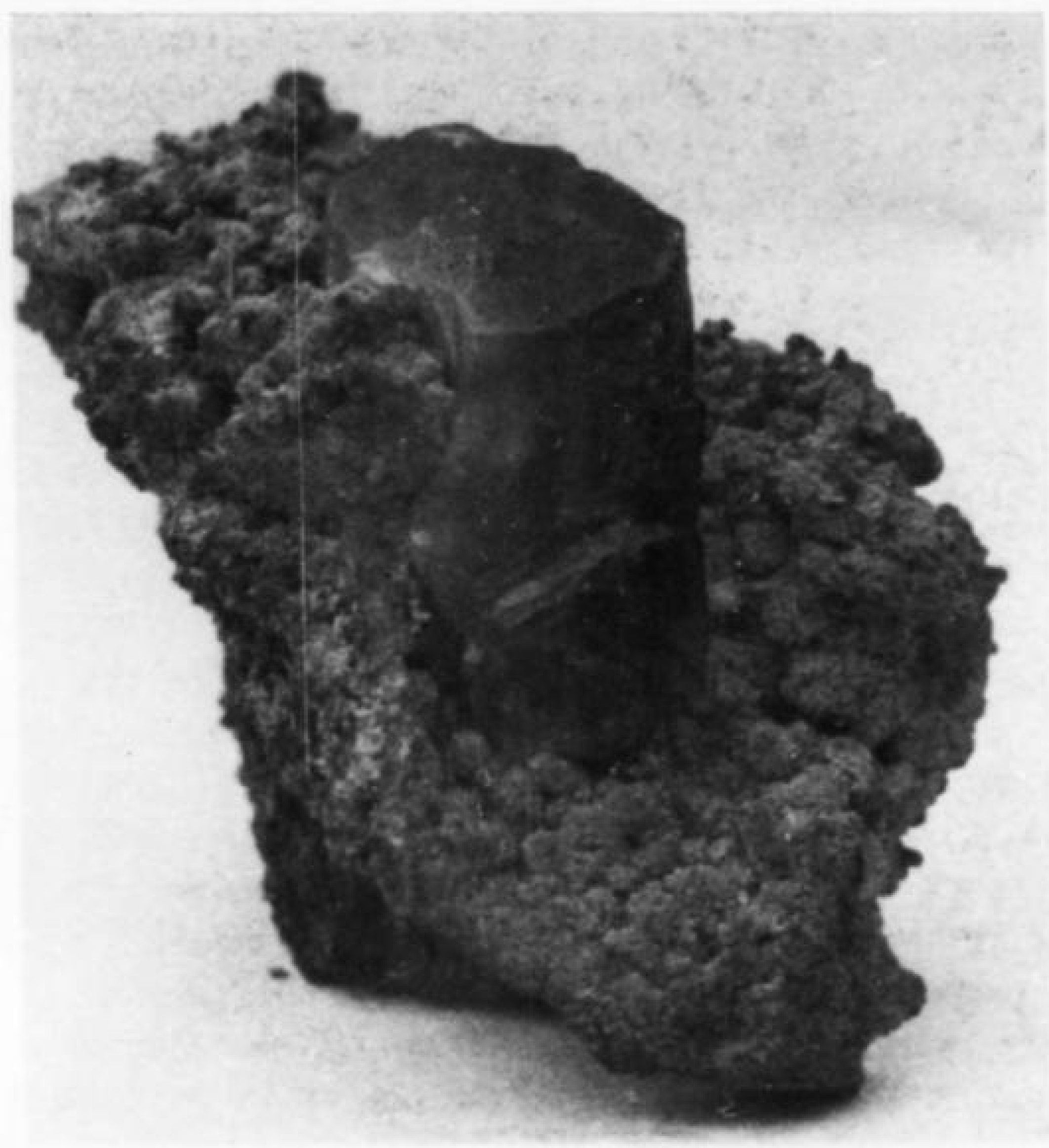

Figure 8. **A large cerussite crystal (3 cm long). Collection of the Broken Hill Division, Nchanga Consolidated Copper Mines Ltd.**

Cerussite crystals are elongated along the *a* axis and are prismatic or tabular parallel to the pinacoids {010} or {001}. Multiple twinning (Fig. 9) forms the characteristic six-rayed groups. Spencer (1908) mentioned the occurrence of stalactitic growths up to 6 cm long on the walls of the bone cavern in No. 1 kopje. These stalactites did not show the characteristic concentric banding but consisted of a mass of distinct needle-shaped microcrystals. In recent years good cerussite crystal specimens from Broken Hill have become rare.

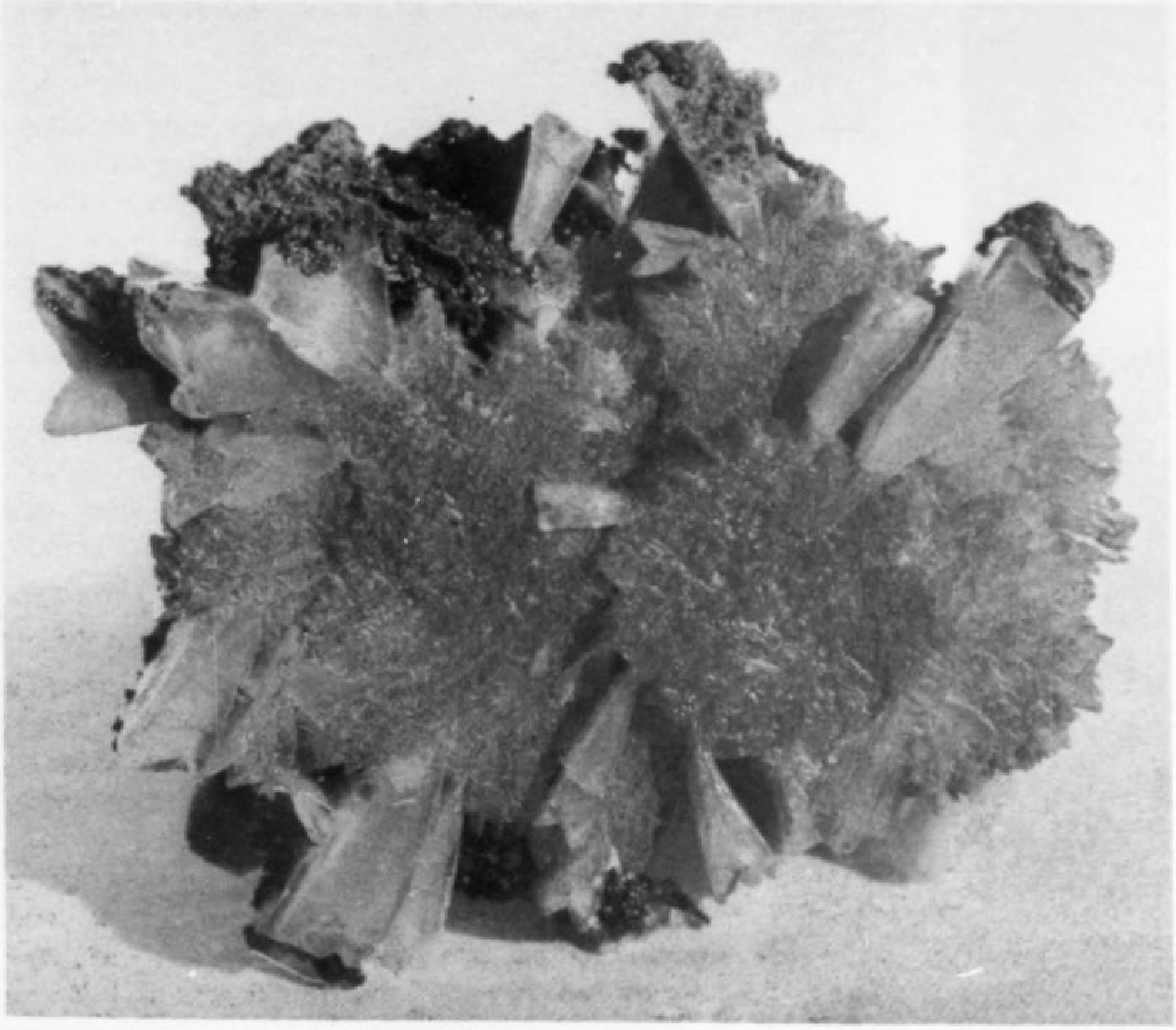

Figure 9. **An aggregate of cream-colored cerussite twins. The specimen measures 15 cm across and is from the collection of J. Salmon.**

Malachite, $Cu_2(CO_3)(OH)_2$; **Rosasite,** $(Cu,Zn)_2(CO_3)(OH)_2$

Malachite is the most common of the secondary copper minerals at Broken Hill. Even so, it is only rarely observed during the present underground mining operations. The presence of lead and zinc has resulted in the formation of two interesting malachite varieties: plumbian malachite and zincian malachite, the latter in association with rosasite.

About six years ago, mining produced many specimens of well-crystallized cerussite covered with small globules (Fig. 10) and coatings of a dull grey-green malachite, which appeared to replace the former. X-ray powder photographs showed significant line shifts as compared to normal malachite. Unfortunately the presence of abundant inclusions of cerussite has so far prevented a detailed chemical analysis. However, microchemical tests on optically-selected malachite fragments show the presence of lead which could not be attributed to microscopically visible cerussite.

During the same period geologists have submitted to the authors several specimens of silicified and iron-stained dolomite, containing layers and rounded masses of malachite. These show dark green cores, lighter green middle layers and blue-green outer shells (Fig. 11). X-ray analysis confirmed the sequence malachite-zincian malachite-rosasite, passing from the core to the outer layer.

Azurite, $Cu_3(CO_3)_2(OH)_2$

Mentioned by Mennell (1920), but not found in recent years.

Aurichalcite, $(Zn,Cu)_5(CO_3)_2(OH)_6$

Mennell (1920) described aurichalcite as pale bluish green, hair-like crystals lining cavities in the oxide ore. It has not been identified in recent times.

Tarbuttite, $Zn_2(PO_4)(OH)$

Tarbuttite was first discovered at this locality by Spencer (1908) who named the mineral after P. C. Tarbutt, a director of the Broken Hill Development Company and a mineral collector. For a very long time the Broken Hill mine remained the only locality

Figure 10. **Small globules of dark green plumbian malachite on a cerussite twin crystal. Collection of S. P. Korowski.**

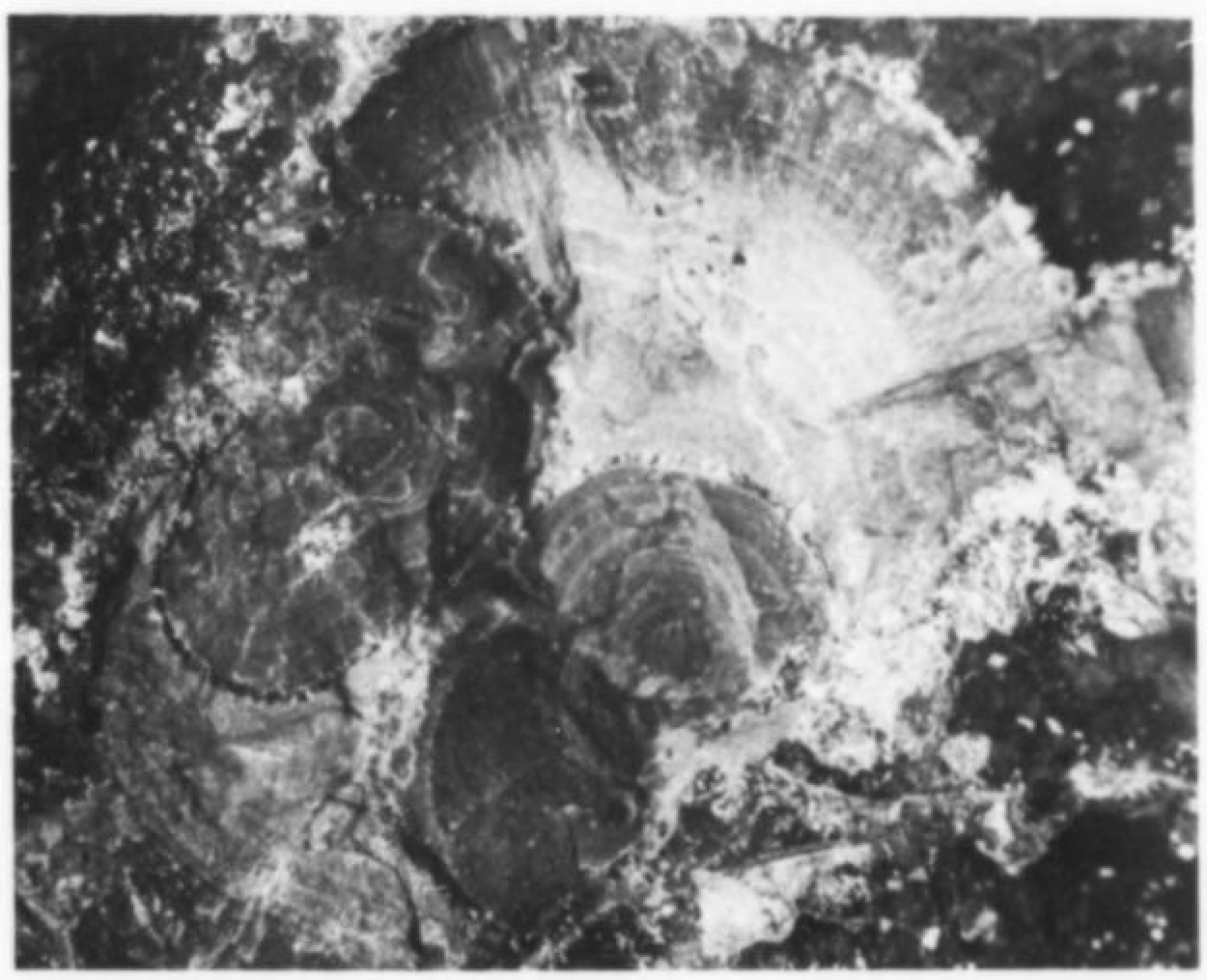

Figure 11. **Concentric layers of malachite, zincian malachite and rosasite. Collection of S. P. Korowski.**

Figure 12. **Tarbuttite crystals (up to 1 cm) in porous goethite. Collection of J. Salmon.**

where this mineral was found although a second occurrence was recently discovered at Reaphook Hill in the Flinders Range, South Australia (Hill and Milnes, 1974; Johnston and Hill, 1978).

The most important occurrence is at the No. 2 kopje, where it can be collected in the open pit or, more conveniently, from a small dump 100 meters to the east. It occurs here as well-defined, colorless crystals scattered profusely in cellular masses of goethite (Fig. 12). Less often, the tarbuttite is associated with rosettes of lath-shaped hemimorphite microcrystals. On a small heap of tarbuttite ore near the edge of the open pit a specimen was found with pale yellow, elongated, 2-cm-long tarbuttite crystals associated with globular beudantite (?). Tarbuttite also occurred in No. 1 kopje as thin crusts of microcrystals, together with hopeite on the bone breccia.

The tarbuttite crystals (Fig. 13) are triclinic with {001}, {010}, {100}, $\{\bar{2}\bar{2}1\}$, $\{\bar{1}01\}$ and $\{\bar{2}11\}$ as the most common forms out of a total of 17 identified by Spencer (1908). A perfect cleavage is developed parallel to (001) and cleavage surfaces show a characteristic pearly luster which allows easy identification. This luster is also shown by the (001) crystal plane itself, although less pronounced.

Tarbuttite was one of the last minerals to be formed. Pseudomorphs of tarbuttite after botryoidal smithsonite have been found in both the No. 1 and No. 2 kopje orebodies (Spencer, 1908). Massive smithsonite was replaced at the surface by a layer of finely crystalline anhedral tarbuttite, which itself was covered with microcrystals. Spencer also described hollow tarbuttite pseudomorphs after descloizite crystals, up to 1 cm across.

Hopeite, $Zn_3(PO_4)_2 \cdot 4H_2O$

Hopeite was first found 160 years ago on a few specimens from the old lead-zinc mine of Altenberg near Moresnet (north of Liege) in Belgium and was recognized as a new mineral by Brewster (1822, 1824). It was named after Dr. Thomas Charles Hope (1766–1844), Professor of Chemistry at Edinburgh University.

Its abundance at the Broken Hill mine during the early mining period is in contrast with its scarcity at the type locality, and numerous attractive crystal specimens from Broken Hill have found their way to museums and private collections all over the world. Its associations and relationships with other rare zinc and lead phosphates, carbonates and vanadates are of great mineralogical interest. A unique feature of Broken Hill hopeite is the direct association with its source of phosphorous. In the famous cavern in No. 1 kopje, hopeite replaced animal and human bones, the latter associated with stone implements (White, 1908). These bone fragments (Fig. 14) occurred in layers mixed with various proportions of sand and clay in the central part of the kopje (Mennell and Chubb, 1907) and had gradually filled up the large cavern which, at the onset of mining operations, was no longer connected with the surface.

The bones belonged to various animals including elephants, lions, hyenas, antelopes, rats and birds (Chubb, 1908). Some of the

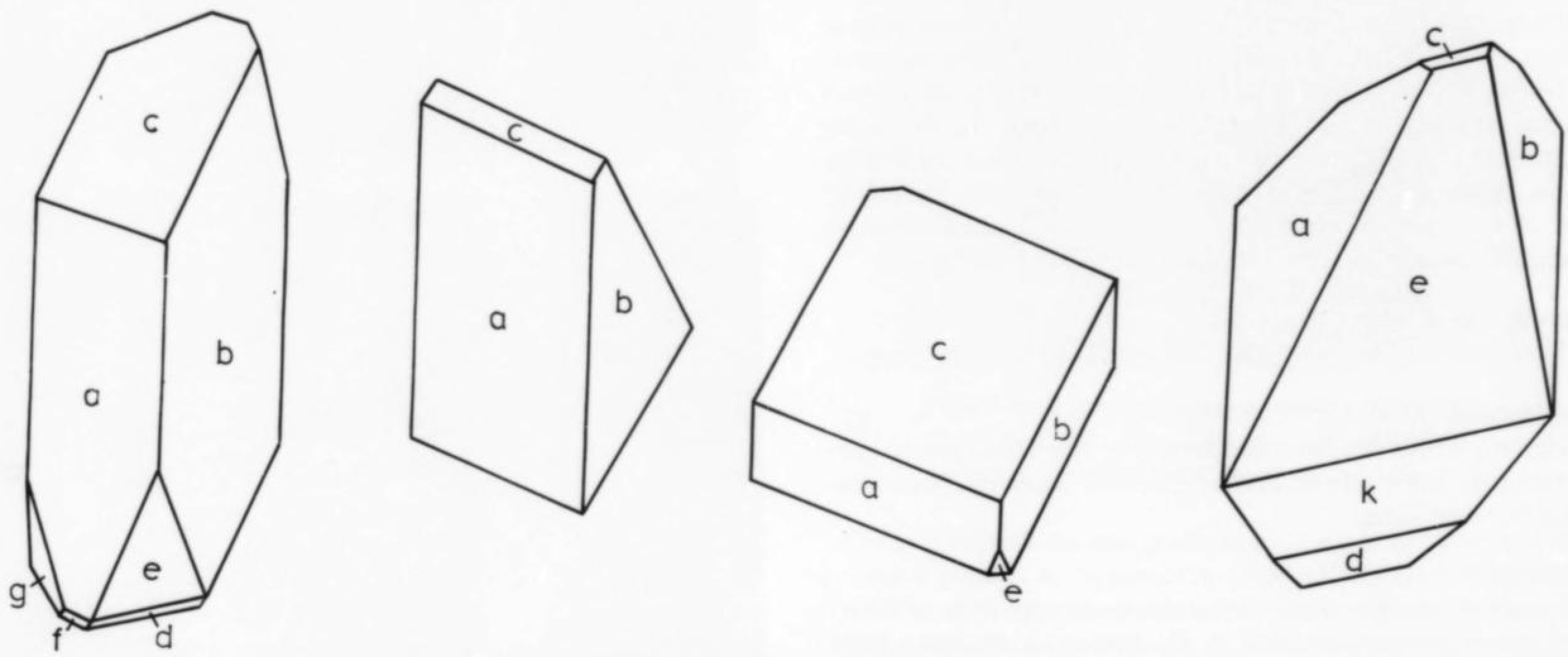

Figure 13. **Tarbuttite crystal drawings showing the forms** *a*{**100**}, *b*{**010**}, *c*{**001**}, *d*$\{\bar{2}\bar{2}3\}$, *e*$\{\bar{2}\bar{2}1\}$, *f*$\{\bar{1}01\}$, *g*$\{\bar{2}11\}$, *k*$\{\bar{1}\bar{1}1\}$. **Reproduced from Spencer (1908) with permission of the Mineralogical Society.**

Figure 14. **Bone breccia from No. 1 kopje. Collection of the Broken Hill Division of Nchanga Consolidated Copper Mines Limited.**

bones showed tool markings—others appeared to have been gnawed by hyenas. The bones are partially replaced by hopeite. Perfect colorless crystals occurred in open spaces within the breccia and grew on a thin layer of vanadinite or on crusts of hemimorphite, tarbuttite, smithsonie or mixtures of these (Spencer, 1908). Some specimens consist of massive hopeite, covered with fine crystals.

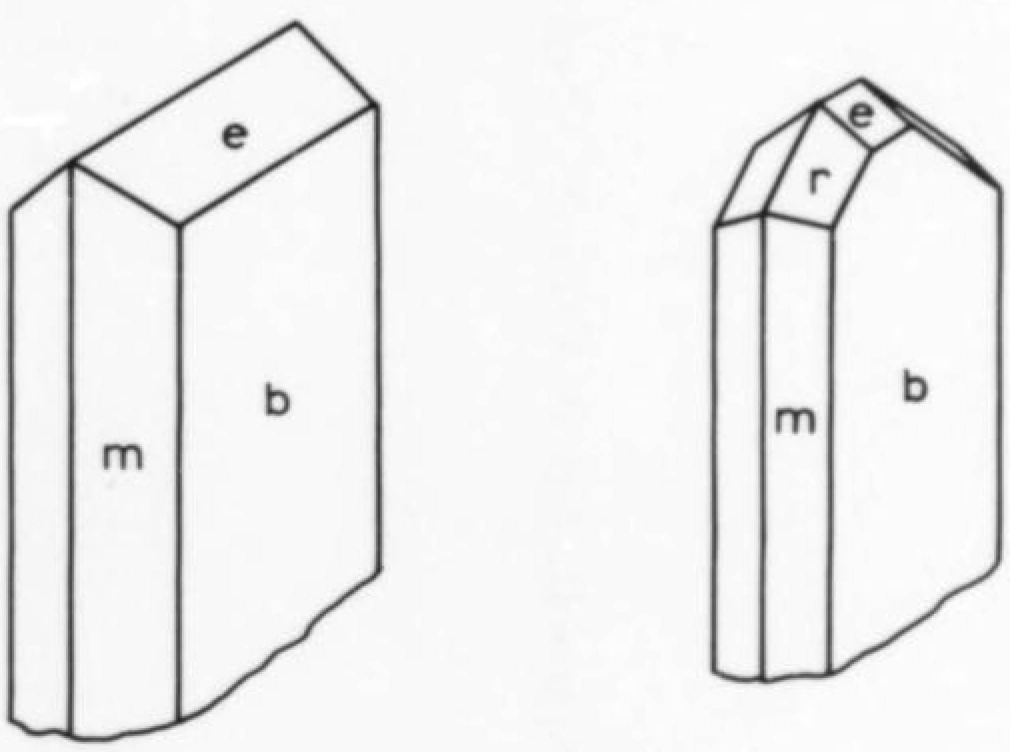

Figure 15. **Hopeite crystal drawings showing the forms *a*{100}, *b*{010}, *e*{031}, *m*{110}, *r*{131}.**

The crystallography of Broken Hill hopeite was first studied by Spencer (1908), with further data provided by Wolfe (1940). Hopeite is orthorhombic and the crystals generally show few forms (Fig. 15), the most common being {100}, {120}, {010}, {101} and {111}. Cleavage directions are parallel to the three axial planes, in order of perfection: (100), (010) and (001). Spencer noted a zonal structure, consisting of two apparently different substances which he designated α- and β-hopeite. This zonal structure can be most easily observed on sections parallel to the large (010) plane. The α-hopeite has a higher birefringence and a larger optic axial angle ($2V = 36°$) as compared to β-hopeite ($2V = 20°$). In β-hopeite the optic axial plane is sometimes orientated parallel to (001) and sometimes perpendicular to (001). The β and γ refractive indices of β-hopeite are slightly lower than those of α-hopeite. No difference in chemical composition could be detected.

Figure 16. **Colorless hopeite crystal, 1 cm long, from No. 2 open pit. Collection of J. Salmon.**

Figure 17. **A view of the hopeite collecting area on the steep slope of No. 2 open pit.**

Well-formed hopeite crystals (Fig. 16) can still be collected along a few joints in the dolomite of No. 2 open pit (Fig. 17). Crystals are often semi-transparent to opaque, due to iron staining, but still make attractive specimens. Recently, perfect colorless hopeite crystals up to 1 cm long have been found in small cavities in a limonitic dolomite. On weathered specimens pseudomorphs of fibrous parahopeite after hopeite crystals, sometimes coated in turn with minute tarbuttite crystals, have been encountered. In some cases the parahopeite was leached after crystallization of the tarbuttite, resulting in hollow crystals with thin tarbuttite walls, but still clearly showing the crystal shape of the original hopeite. Although pseudomorphs of parahopeite after hopeite are not uncommon, unaltered hopeite is only rarely associated with separate crystals of parahopeite. Some years ago an interesting vein was discovered, containing the whole sequence from unaltered, colorless hopeite crystals through pseudomorphs of parahopeite after hopeite (with or without tarbuttite), to separately crystallized, tabular parahopeite. Rounded masses of hopeite in vugs lined with tarbuttite crystals (Fig. 18) have been found recently.

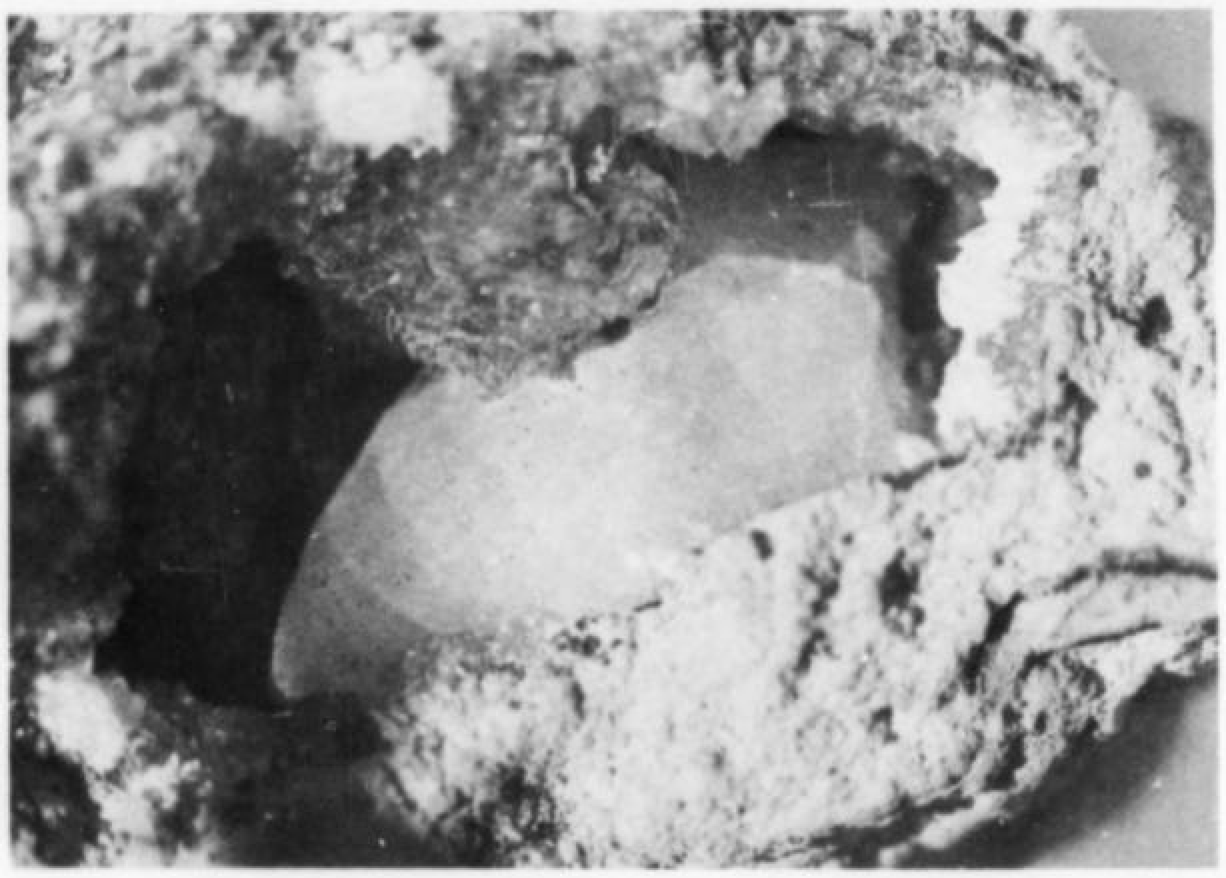

Figure 18. **A rounded mass of translucent hopeite in a vug, lined with tarbuttite crystals. The vug measures 4 cm across. Collection of C. W. Notebaart.**

Parahopeite, $Zn_3(PO_4)_2 \cdot 4H_2O$

Parahopeite, dimorphous with hopeite, was first found in the Broken Hill mine and was described in detail by Spencer (1908). It has been and still is much less common than hopeite. Crystals are colorless to creamy white, although often lightly stained by iron oxides. Various crystal habits have been observed; the most common in recent finds is tabular (Fig. 19). Ledoux *et al* (1919) described a prismatic habit (Fig. 20) and on weathered hopeite specimens an acicular variety occurs.

The association of parahopeite with the two other rare phosphates (hopeite and tarbuttite) has been described above.

Parahopeite can still be found sporadically in No. 2 open pit. Some years ago one of the authors (CWN) found here an attractive vug (12 cm across), lined with colorless tarbuttite crystals and scattered spherical clusters of cream-colored, tabular parahopeite crystals.

Pyromorphite, $Pb_5(PO_4)_3Cl$

Beautiful specimens with green and brown hexagonal prismatic pyromorphite crystals up to 3 cm long were recovered during the early mining period. (One of these is shown in color in *Encyclopedia of Minerals,* 1974, by Roberts, Rapp and Weber; color page 98. Ed.) Small crystals of yellow pyromorphite associated with tarbuttite, descloizite and limonite have been reported from the No. 2 kopje orebody. Very common at this location is the association of minute white pyromorphite crystals, perched on tarbuttite crystals. Large groups of divergent golden yellow crystals have been found recently underground (Fig. 21).

Libethenite, $(Cu,Zn)_2(PO_4)(OH)$

Zambia has an obvious speciality in unusual libethenites. The occurrence of individual libethenite crystals of exceptional size in two open pits on the Copperbelt has been described recently (Korowski and Notebaart, 1978). Little known is the occurrence of a unique zincian variety at the Broken Hill mine. This material was first found as minute, greenish blue crystals in the underground workings at No. 1 kopje during the early mining operations and was subsequently described by Mennell (1920) as veszelyite, $(Cu,Zn)_3(PO_4)(OH)_3 \cdot 2H_2O$. Many years later Guillemin (1956), made a detailed study of copper arsenates, phosphates and vanadates; he obtained a sample of this material from the British Museum and proved it to be a zinc-bearing libethenite. In 1971, while on a visit to the No. 2 pit, one of the authors (SPK) found greenish blue globules (< 2 mm) and encrustations in tarbuttite ore. The mineral was copiously present, but restricted to an area of only one meter across, near the rim of the eastern side of the pit. An X-ray powder photograph showed a pattern identical to that of normal libethenite but micro-chemical tests indicated the presence of both zinc and copper. This material is evidently similar to the zincian libethenite studied by Guillemin. It would appear that a solid solution exists between libethenite and a yet undiscovered zinc end-member.

Figure 19. **Tabular parahopeite crystals on tarbuttite crystals. The specimen measures 3 cm across and was found in No. 2 open pit. Collection of C. W. Notebaart.**

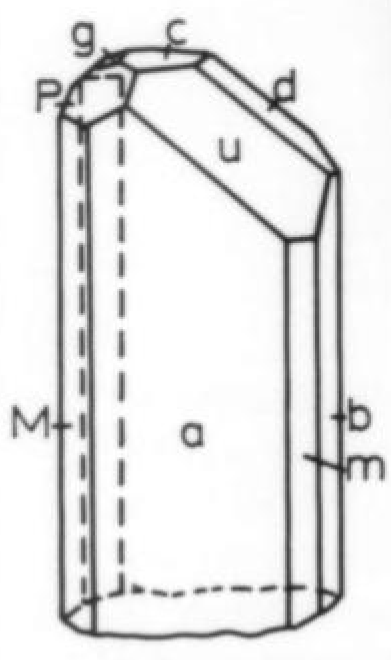

Figure 20. **Parahopeite crystal drawing showing the forms $a\{100\}$, $b\{010\}$, $c\{00\bar{1}\}$, $d\{011\}$, $g\{0\bar{1}2\}$, $m\{110\}$, $u\{322\}$, $M\{1\bar{1}0\}$, $P\{1\bar{1}1\}$. Reproduced from Ledoux *et al.* (1919) with permission of the Mineralogical Society.**

Figure 21. **A group of divergent, golden yellow pyromorphite crystals (7 x 5 cm). Collection of J. Salmon.**

The zincian libethenite has been formed by copper-bearing solutions replacing tarbuttite, and is therefore late in the paragenetic sequence.

Scholzite, $CaZn_2(PO_4)_2 \cdot 2H_2O$

Scholzite was recently identified on specimens submitted for identification by the Broken Hill mine geology department. This mineral has not been recorded previously for this locality. The specimens consist of porous, boxwork goethite with minute sprays of scholzite needles and thin, colorless plates of parahopeite, generally not more than 0.5 cm long. These parahopeite plates are coated with radiating clusters of colorless scholzite needles, up to 1.0 mm long. Magnification under the stereomicroscope shows slender prisms with well-developed terminations.

Figure 22. **Large blades of white anglesite, up to 15 cm long; collection of the Broken Hill Division of Nchanga Consolidated Copper Mines Ltd.**

Descloizite, $Pb(Zn,Cu)(VO_4)(OH)$; **Mottramite,** $Pb(Cu,Zn)(VO_4)(OH)$

A complete isomorphous series exists between the pure zinc and copper end members. The name descloizite is used for all compositions in which zinc predominates, whereas mottramite is applied to the other half of the series. At Broken Hill, descloizite is not only dominant but has contributed most of the vanadium that the mine has produced. It is still readily picked up around old dumps and along roadsides, attesting to its abundance during early mining.

Descloizite occurs as crystalline masses with dark brown crystals projecting into open spaces (Fig. 23). Spencer distinguished three common habits—pyramidal, prismatic and tabular—and measured 5 to 8 forms on each with {100}, {111}, {110} and (011) generally being dominant. In the experience of the authors with both old-time and recent specimens from underground workings, crystals are typically spear-shaped with rough surfaces.

A very simple habit of descloizite has been observed recently on dolomitic rock from the No. 2 open pit. This dolomite is partially replaced by iron oxides and contains small cavities, lined with colorless smithsonite crystals, from which bright metallic prisms of black descloizite project. The prisms are square (or nearly so) in cross-section and have flat basal pinacoids.

Mottramite bears no resemblance to descloizite. Much subordinate to descloizite, but still relatively common, it is found most typically as dull yellow or yellowish green masses in iron-stained dolomite. The mottramite almost always contains minute inclusions and thin veinlets of rosasite.

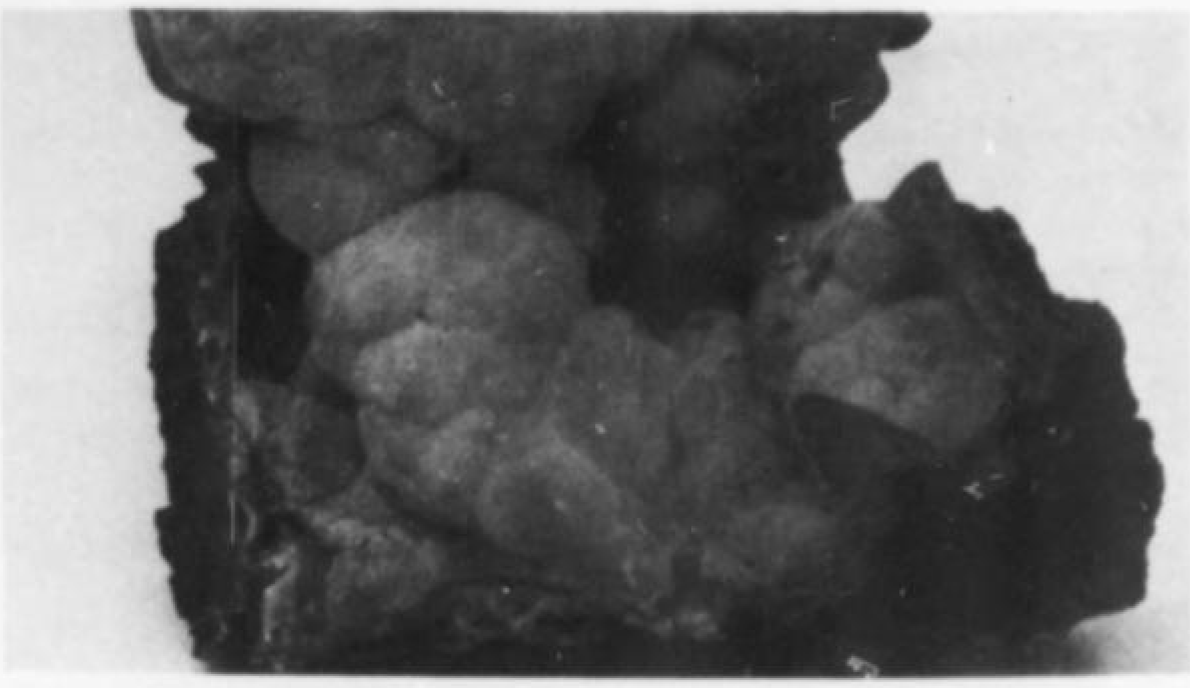

Figure 23. **Botryoidal vanadinite. The surface has a yellow color and the interior is yellowish brown. Collection of the Broken Hill Division of Nchanga Consolidated Copper Mines Ltd.**

Vanadinite, $Pb_5(VO_4)_3Cl$

This mineral, which is known from many other localities in the world as well-developed, hexagonal crystals, occurs in Broken Hill almost exclusively in a unique botryoidal form (Fig. 23). About six years ago a cavern several meters in diameter was discovered on the 430-m level of the mine. The walls of this cavern were heavily encrusted with botryoidal and stalactitic vanadinite, up to 10 cm thick. The outer layers of this vanadinite are solid whereas the inner zone, near the wall of the cavern, is usually porous with open spaces accounting for about half the total volume. The porous vanadinite frequently contains minute descloizite crystals which project into the cavities. Sometimes, vugs with small quartz crystals or cerussite crystals up to 1 cm are found. The concentric layers of the massive botryoidal vanadinite alternate between yellow and light to dark brown in color.

Spencer (1908) mentioned the occurrence of small globules of light brown vanadinite, forming branching aggregates on the bone breccia in No. 1 kopje. It was formed later than the thin crusts of hemimorphite and tarbuttite but earlier than the hopeite. According to Spencer, this vanadinite is similar to that from Wanlockhead in Scotland.

Anglesite, $PbSO_4$

Anglesite is one of the less common secondary lead minerals. It occurs as colorless, orthorhombic crystals up to 3 cm long with a prismatic habit, showing {100}, {102} and {011} as the dominant forms. Large platy crystals were found during the early mining period (Fig. 22).

Beudantite, (?) $PbFe_3(AsO_4)(SO_4)(OH)_6$

Small yellowish brown globules of a mineral belonging to the beudantite group have been found associated with tarbuttite on a specimen from No. 2 open pit. An X-ray powder photograph proved very similar to beudantite although some differences were noted. However the presence of arsenates would be unexpected at this locality. Unfortunately, insufficient sample was available for chemical analysis.

Goslarite, $ZnSO_4 \cdot 7H_2O$

This mineral is mentioned by Zealley (1912) as a white powdery material encrusting sphalerite in one of the lower drives of the No. 1 kopje.

Wulfenite, $PbMoO_4$

The occurrence of wulfenite in the Broken Hill mine has not been reported previously. It was found underground by the authors in a cavity as orange-red tabular crystals associated with quartz crystals.

Willemite, Zn_2SiO_4

Fine-grained massive willemite, intergrown with smithsonite and cerussite, occurs abundantly in the oxide zones of the orebodies. Columnar crystals, up to 1 cm in length, are less common. Unlike the spectacular willemite from Franklin, New Jersey, most of the Broken Hill willemite does not fluoresce under ultraviolet light though a rare grain yields a faint yellowish fluorescence.

Hemimorphite, $Zn_4Si_2O_7(OH)_2 \cdot H_2O$

Spencer (1908) describes hemimorphite as one of the most abundant zinc minerals. This may have been the case during the early mining period but is certainly not so at present. Hemimorphite occurs mainly as intimate intergrowths with cerussite and limonite in the massive oxide ore. In the early years of mining operations it was found as fibrous masses in crusts on the bone breccia in No. 1 kopje and as small, short-prismatic, yellow crystals, associated with tarbuttite and smithsonite on the surface of these crusts. Colorless, short prismatic crystals up to 1 cm long occur on the light blue, massive smithsonite from No. 2 kopje. Elsewhere, platy crystals showing the forms {010}, {110}, {101} and {001} have been found. Specimens of tarbuttite with small rosettes of hemimorphite platelets have been collected from a dump near No. 2 open pit.

Chrysocolla, $(Cu,Al)_2H_2Si_2O_5(OH)_4 \cdot nH_2O$

Chrysocolla is associated in very small quantities with other secondary copper minerals.

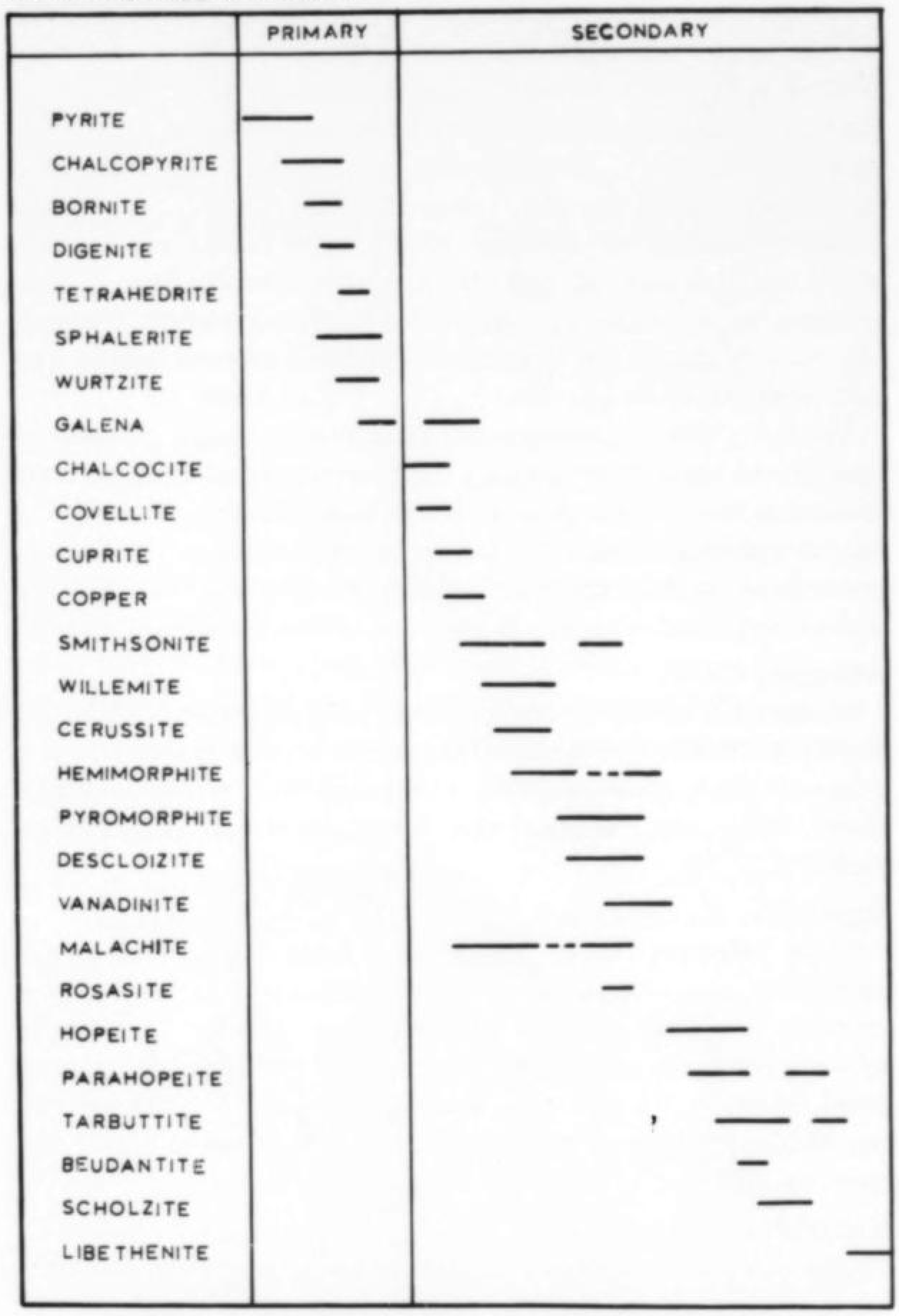

Figure 24. **Paragenesis of minerals at the Broken Hill mine.**

PARAGENESIS

The approximate paragenetical relationships are given in figure 24 and are based on observations by the authors and on data from the literature, in particular Taylor (1954).

ACKNOWLEDGEMENT

The authors wish to thank the Management of Nchanga Consolidated Copper Mines for permission to publish this paper.

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INTERVIEW: ALLAN CAPLAN

Recently we had the opportunity to talk with Allan Caplan about many things, including some of his experiences in Brazil. Caplan was the first to bring museum-quality mineral specimens out of Brazil, specimens which now grace famous public and private collections across the country. Today he is a dealer in precious stones, with an office at 10 Rockefeller Plaza, in New York City, and makes frequent buying trips to India and Sri Lanka. Although inactive for over 20 years as a mineral dealer, he has not lost his interest in quality specimens.

MR: You were dealing in minerals during your year at the Colorado School of Mines in 1937–1938. How long have you been interested in minerals?

CAPLAN: The natural sciences interested me since grade school, and while in high school I became interested in minerals and fossils. After high school, about 1933, I worked one summer for the Denver Museum of Natural History helping on the excavation of the Dent mammoth along the South Platte River.

While I attended the University of Colorado during the mid-thirties, my major was geology and mineralogy. I dealt in minerals and advertised in *The Mineralogist* and *Rocks and Minerals* magazines. My summers were spent traveling throughout different parts of the state looking for good mineral specimens.

MR: Did you go to places like Leadville and the other mining areas?

CAPLAN: Yes, I went to Leadville, Silverton, Cripple Creek, practically all the active mining areas which became well known to me, including Paradox Valley for uranium and vanadium minerals. Occasionally, a small advertisement would go in the Denver Post for minerals and collections. Replies offering material would be received, and weekend trips were made to visit people and make purchases. For example, the fine covellite with the large crystals from Sardinia in the U.S. National Museum was obtained from an estate of an assayer in Leadville, along with the other specimens from the mines of the area. How this assayer obtained the covellite wasn't known to the executors, although it would have been interesting to learn of its origin.

MR: Did you buy minerals from Pondorf's of Denver?

CAPLAN: No, I couldn't pay his prices, but visits were made from time to time. It was Pondorf and Hart of Manitou, Colorado, who bought the entire "original" pocket of Alma rhodocrosite. They divided the pocket, and everything was gone long before my time. Pondorf was an old man, and Hart had died some years before. Hart's two daughters were selling minerals in Manitou, and they had drawers of Canyon Diablo meteorites priced at 50¢ a pound, but no rhodocrosite.

MR: What made you decide to go to Brazil. Were you looking for greener pastures?

CAPLAN: Well, after graduating from the University of Colorado in 1937, I decided to go to the Colorado School of Mines for some geology courses and to think about what should be done in the future. I often visited the Denver Museum of Natural History, and saw the Pondorf collection of minerals and cut stones. It was a very small collection but I was impressed with the colorful tourmaline crystals from Brazil. I decided that the place to go was Brazil in order to continue doing what I liked best, and that was traveling and searching for minerals. As soon as school was over in June, I drove east with the minerals on hand and sold them to Dr. Hess at Princeton University, sold my car, and bought a round-trip ticket on a freighter to Rio de Janeiro.

MR: What did it cost to go round trip to Brazil in those days?

CAPLAN: About $400 on a freighter.

MR: Here we are forty years later and it doesn't cost so much more to fly down, you can still do it for around $500.

CAPLAN: Well, this was for a round trip and it took twelve days each way and boats were the only way to get to Rio. There was no regular plane service in those days, and

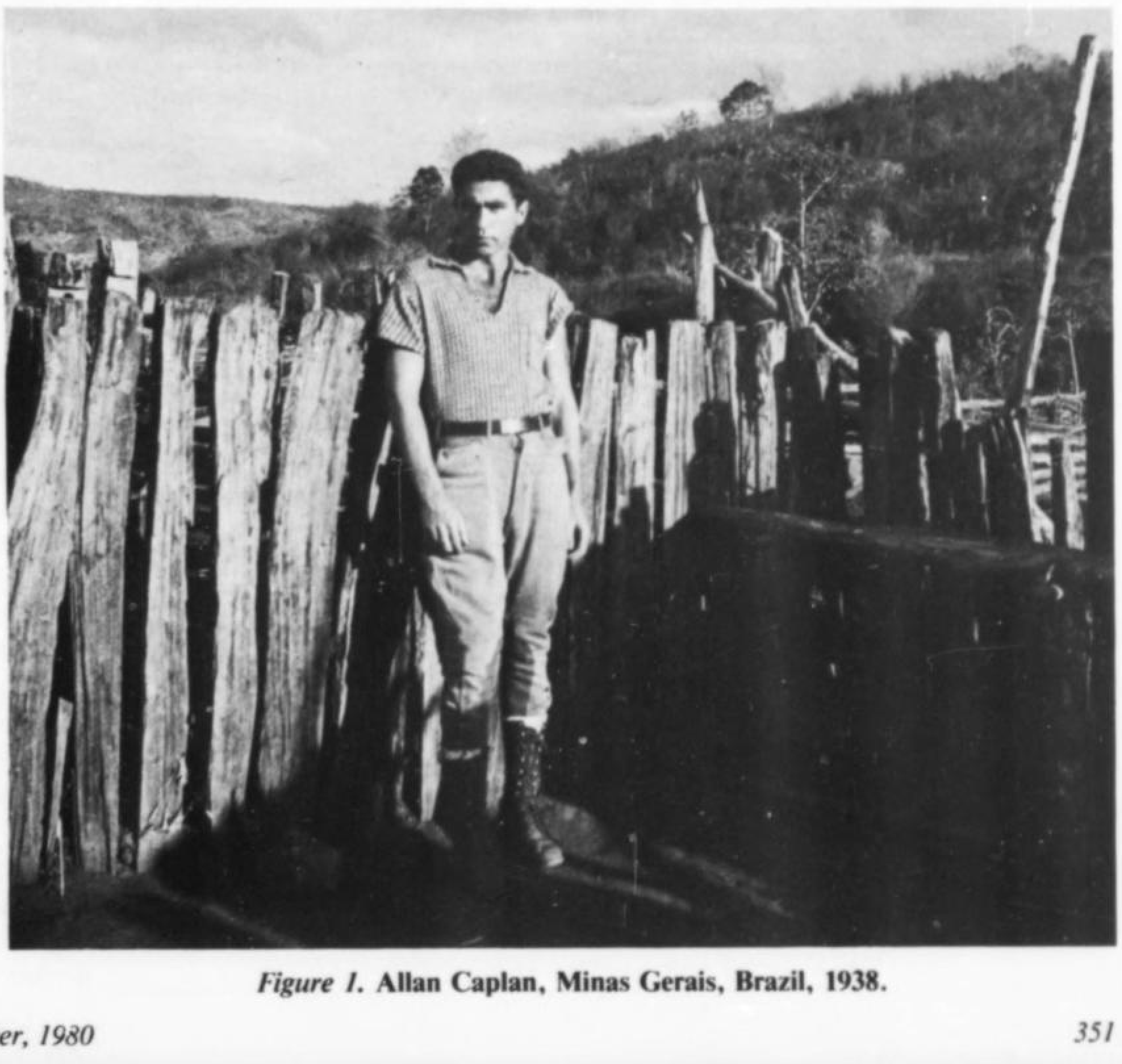


Figure 1. **Allan Caplan, Minas Gerais, Brazil, 1938.**

since there was no hurry nor obligations, time didn't matter, it was a great change and a new experience.

In all, I made about ten trips prior to World War II, and perhaps another dozen after the war when I was able to resume my trips for both gems and minerals. When plane service eventually did begin, my first flight back to New York took two days because there was no night flying at that time. By 1958, my interest developed for other sources and buying trips were made to Colombia and the Orient primarily for rough and cut gems for the jewelry trade. By that time, I was practically inactive in the mineral specimen field and with Brazilian material in general.

MR: Was it cheap living in Brazil in those days?

CAPLAN: Very cheap, even in Rio where you could get a good meal for $1.00 to $1.50 including filet mignon. The interior was cheaper still, but the living conditions were not very good and the food was bad. Today the situation is completely different since there is a high rate of inflation going on which started after World War II. The cost of living in Rio is much higher now, though still less than in New York. Living conditions in the interior have improved greatly and so has the food, but the costs are still lower than in Rio.

MR: When did you start traveling in the interior?

CAPLAN: Not right away. I had a small amount of capital to buy with, but plenty of time to look things over. It was necessary to obtain some knowledge of the country and the sources of minerals and of course the language with a Portuguese/English dictionary as a starter. My experience was mainly with the gold and silver minerals and other Colorado types. Brazil had completely different kinds of minerals to deal with. My experience in Colorado was of limited scope and I lacked a broad knowledge of the mineral market. It was necessary to go slow and buy whatever was obviously good. With each trip back to the states with minerals I learned more, and each return to Brazil was with more confidence, and more capital. Unfortunately, the market for specimens was small as few museums had money to buy minerals, and most collectors were limited in funds. The country was just coming out of the big depression and the large demand for good specimens at the high prices of today did not exist.

Finally, about September, I went on my first journey into Minas Gerais via a tedious overnight train trip to Belo Horizonte, and thence to Diamantina and the Serhina diamond mine where they used hydraulic jets for mining. I stayed overnight at the mine which was operated by an American named McCarthy who once worked in the African diamond fields. Later I visited the Drapers who also had African experience and were working a gold and diamond deposit at a place called Datas near Diamantina. They had pumped out the pool below a small waterfall and were working the gravel on bedrock with good results. It was possible to buy some "cangas," a conglomerate cemented with limonite, enclosing a diamond: my first purchase.

WEDNESDAY, JANUARY 31, 1940

225-Pound Topaz Found in Brazil

Gem Is 18 Inches In Diameter

By Science Service.

CAMBRIDGE, Mass., Jan. 31.—A giant topaz from Brazil, weighing 225 pounds and estimated to be about 100,000,000 years old, has been acquired by the Mineralogical Museum of Harvard University. Musuem officials say it is one of the largest and finest in the world.

An ordinary topaz weighs only a few ounces and is only an inch or so across. The Harvard topaz is 18 inches. It is white, with inclusions of dark manganese minerals in parallel streaks.

Harvard mineralogists who estimated its age, said its formation must have required extraordinarily stable conditions for a period of a million years or more for it to reach that size.

Topaz crystals are really formed by slow accretion of aluminum silicate from a hot solution. Ordinarily they are formed in pockets or hollow spaces in rock masses. A large crystal needs a large pocket to grow in and very stable external conditions. Temperature, for example, must remain constant within a few degrees.

Yellow is the most popular color for gem topazes, but other colors—white, gray, green, blue, red, straw-yellow and wine-yellow—actually are more common.

HUGE TOPAZ GOES TO SMITHSONIAN

WASHINGTON, D. C., Aug. 19.—The largest topaz crystal ever known—350,000 carats—has just been added to the mineral collection of the Smithsonian Institution. It was found in the course of mining operations for other gems in the Minas Geraes province of Brazil. The single crystal weighs 153 pounds. The ordinary topaz worn as a gem seldom would exceed four or five carats, according to Dr. William F. Foshag, Smithsonian curator of mineralogy.

While popular as a precious stone the topaz ranks considerably below the emerald, the ruby or the diamond. Many of the stores sold as topaz, Dr. Foshag says, actually are not this mineral at all, but a yellow-colored variety of quartz which is much more abundant. Many gem dealers actually do not know the difference.

The giant topaz obtained from Brazil has several large flaws but a great deal of it could be cut up into gem stones. The color ranges from a pale bluish on the outside to a pale sherry wine color on the inside.

O maior topazio do mundo

Encontrado em Minas e adquirido em Washington

WASHINGTON, 18 (Asciated Press) — O Institu- Smithsoniano adquiriu o aior topazio do mundo, ncontrado no Estado de Mis Gerais. A pedra, quasi m jaça, pesa 69 ramas e 300 gram erca de 350.000 qui O peso normal do t ara aneis ou alfine ravata é de cinco qu pedra internamente r de cereja palida e mente azul palido.

Um topazio do Brasil, de 225 libras

CAMBRIDGE, (Massachusetts), 31 (United Press) — O museu de mineralogia de Harward annunciou que adquirirá no Brasil um crystal de topazio pesando 225 libras, um dos maiores crystaes de topazio do mundo.

Foi declarado que este exemplar que tem um milhão de annos será exposto a partir da proxima semana.

TAGES-UMSCHAU

Ein Riesentopas.

Das Mineralogische Museum der nordamerikanischen Harvard-Universität gibt bekannt, dass es in Brasilien einen riesigen Topas im Gewicht von 225 Pfund erworben hat. Der Stein, der zu den grössten der Welt gehören dürfte, wird ab nächster Woche ausgestellt werden.

Figure 2. **The reaction in the newspapers to the first big topaz crystals brought out by Caplan. (The "153" pound topaz actually proved to weigh 156 pounds.)**

After a few days, I took the train back to Belo Horizonte and met Nelson Faria, who was buying the production of the Laranjaras aquamarine mine near a town then called Fortaleza, but since the war the name was changed to Pedra Azul (blue stone). The town has a number of high granite domes nearby, and I suppose this led to naming the place Fortaleza. Joã Almeida, a cattle rancher and influential resident of the town, was responsible for the new name since he owned the mine.

As Nelson was leaving on a buying trip to Pedra Azul, he invited me to go along and, of course, I gladly accepted. If I recall correctly, we went north to Montes Claros by train, and then east by car over very bad roads and trails with an overnight stop in Salinas. Upon arriving at Pedra Azul we stayed the night at Joã Almeida's ranch. The following morning the three of us went on horseback to the mine. It was a very large opening on a hillside with the decomposed pegmatite at least 50 or 60 feet wide. About 30 barefoot men were digging with picks and shovels. They were having a problem with production at the time, as they were not having results in certain areas. It was easy to see that some of the men were digging in the decomposed granite which, of course, was barren. After I showed them the difference between the pegmatite and the granite, they put all the men to work on the dike. Both the granite and the dike did look very similar with the reddish color caused by the decomposition of the surface rocks.

By just using picks and hauling away the waste in a wheel barrow they occasionally uncovered a good mass of deep blue aquamarine. Joã Almeida gave me a clean piece of gem rough the size of a walnut as a present to show his appreciation. Since that first trip, we became good friends, and I made several trips to visit him prior to World War II. After the war, and out of the service, my interests turned primarily to gemstones for the jewelry trade, and mineral specimens became of minor importance. I wrote Joã Almeida of my intention of resuming my trips to Brazil, and he asked me to bring him a portable typewriter, which I lugged all the way to Pedra Azul. Before leaving, I obtained a large piece of gem rough aquamarine on credit. They had very fine blue material from this dike, and it was the best source of gem material for many years. They found pieces up to two kilos and more fairly regularly. From what I've recently heard, Joã Almeida died some years ago, and the mine is not in operation.

MR: Pretty clean material?

CAPLAN: Not always, it sometimes had "chuva," rain-like inclusions. Most of the time it was clean but never in crystals. It was always found in etched masses. Sometimes, they would find an olive-colored beryl which would "burn" blue (heat treatment), and brought the same price per gram as the blue material. In those days the price was about $5 to $6 per gram, and good quality cut stones brought $5 to $10 per carat. On my last trip to Brazil about five years ago the same rough would've fetched $150 to $200 per gram, perhaps more, and cut stones would bring $200 to $300 per carat in the trade. I'm not familiar with the Brazilian market of today, but I've heard that current prices are much higher.

On that first trip into the interior, I left Nelson Faria in Pedra Azul and came back alone through a different route in order to see more country by way of Salinas, Itapore on the Rio Jequitinhonha, Aracuai and Teofilo Otoni. The problem was transportation since there were no real roads, and one was lucky to get a ride in a truck or anything that came along. In many cases there were trails originally made by wagons. It was the rainy season, and I was stuck some days in Teofilo Otoni, because the road to Governador Valadares was under construction with horse and wagon, pick and shovel through the jungle. It was a mass of mud, and travelers were afraid they would not get through. Finally, a driver decided he would try to make it to Governador Valadares and I went along as a paying passenger, but we had to struggle all the way. It took a full day of pushing in the mud and digging ourselves out. The automobile used was a Model "A" Ford touring car and the best type of car for the interior because of its light weight, power, and high axle clearance. This was before jeeps were known. Today, this same trip can be made in about an hour over an asphalt road through pasture land of grazing cattle, as the jungle has been completely cleared.

MR: When did you come across the big topaz crystals?

CAPLAN: It was on this first trip that I saw in Belo Horizonte a six-pound, transparent, colorless topaz crystal. I didn't buy it then as I didn't know its value, and thought the price too high. When I went back to the states and inquired about its value the response was that it was just another fish story. At the time, a large clear topaz with sharp crystal faces did not exist in any collection. It was obvious that the crystal was worth buying and so I purchased it on my return to Belo Horizonte. I sold it to Sam Gordon, curator, at the time, of the Academy of Natural Sciences in Philadelphia.

On the second trip to Brazil, when the topaz crystal was obtained, I met Antonio Carmo, a quartz crystal dealer in Rio who often traveled throughout the interior to make purchases. We became good friends, and it became a routine to drop around his office every day or so. He had boys working over quartz crystals, chipping off defective parts of small crystals for fusing quartz. They would be chipping away while we talked, and they taught me practical Portuguese.

On my third trip to Brazil, Carmo showed me two very large topaz crystals; one was 156 pounds, and the other a 100 pounder. By this time, their importance was obvious, considering the experience obtained with the six pounder. I had no hesitation in buying them right away, as the price was very reasonable. Photographs were taken and sent to Dr. Foshag at the U.S. National Museum, and I was surprised one day to get a cable offering for the larger one a bit less than what was asked, and I accepted. Later, I got a letter saying he could sell the 100-pounder for me, and this was sold to the Cranbrook Institute near Detroit. Sometime after this, while back in the states and visiting Harvard with minerals, Dr. Harry Berman, who was curator, said that he wanted first choice of any new topaz crystals. I agreed, hoping to get others. Then the American Museum wanted a crystal, and they were to get second choice.

This return trip to Brazil was on a passenger boat. Moore and McCormack Shipping Line had three passenger boats: the Brazil, Uruguay, and Argentina which left New York about every 12 days. Eventually, I made trips on all of them; they were pleasant and the food was very good. Trips back to the states on these boats were something to look forward to after a couple of months in the interior with the limited diet of beans and rice, tough chicken and "carne secca," sun dried meat, which I learned to avoid.

A couple of days before my departure for the states on about my fourth trip, I saw Antonio Carmo who just returned from a quartz buying trip in the interior. Quartz was big business then, prior to and during the war. Carmo stated that he had something good for me, and he showed me some prints of three large topaz crystals which were coming via freight train from the interior. It could take weeks for them to arrive, and I was set to leave. He told me that he had to wrap them with vines, because he had neither nails or lumber, and it was quite a job to get them to the railroad. The locality was not mentioned, nor did I ask for it. As the price for the three large crystals was reasonable in spite of all the publicity the earlier crystals received in the Brazilian press, I bought them from the photographs with a legal bill of sale, and I left for the states on schedule.

Then I sweated in New York hoping to hear about these crystals, but it was some months before I even got a letter from Carmo. He was having trouble getting official clearance to export them, because certain government officials said such rare items should not be exported. When the U.S. Na-

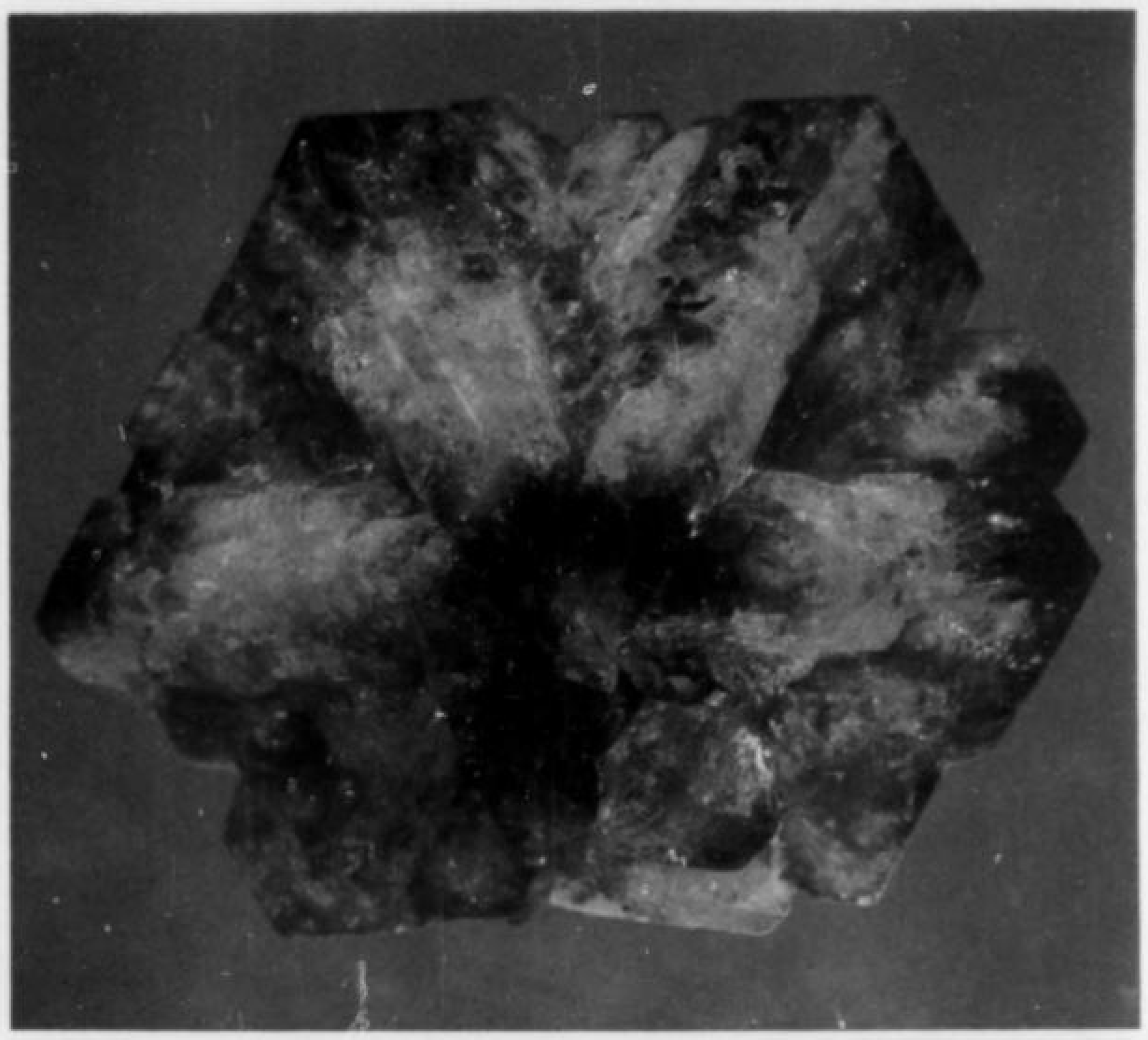


Figure 3. (left) **Chrysoberyl twin, about 2 inches across, from Itaguaçu, Espirito Santo, Brazil. American Museum of Natural History specimen G45385 acquired in 1942; photo by Christian H. Grube for the AMNH.**

Figure 4. (middle left) **A large Brazilianite crystal group measuring 5.5 by 4 inches, from near Conselheiro Pena, Minas Gerais. Smithsonian specimen C5759 purchased in 1945.**

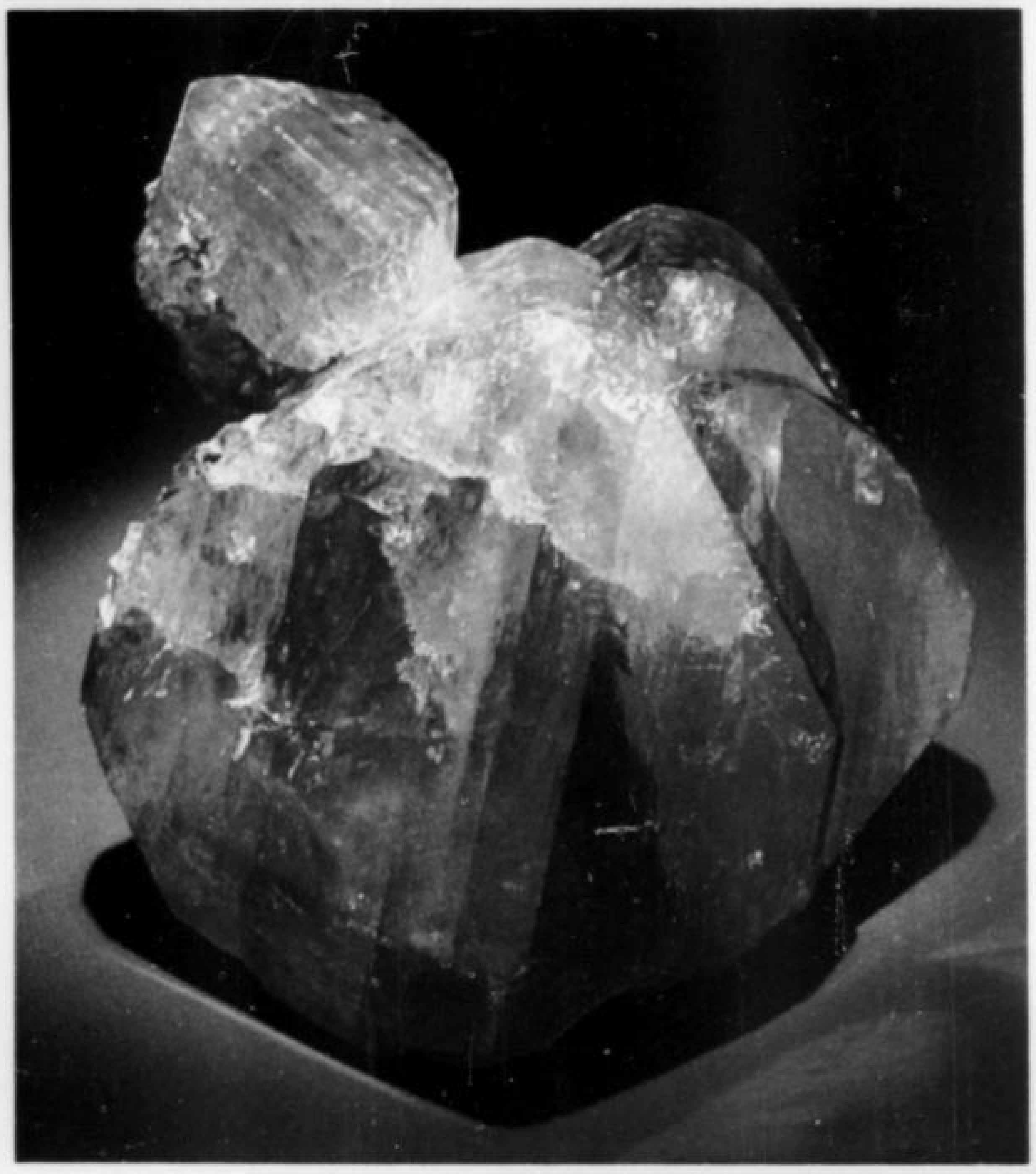
Figure 5. (bottom) **Chrysoberyl twins, the largest 3.8 inches across, from Itaguaçu, Espirito Santo, Brazil. Smithsonian specimens #123578 and #123590.**

Figure 6. (facing page, top) **A 6.7-inch aquamarine crystal from Marambaia, Minas Gerais. Below that, a 5-inch aquamarine crystal from Aqua Preto, Minas Gerais. Both Smithsonian specimens, R7937 and R7948, purchased in 1939.**

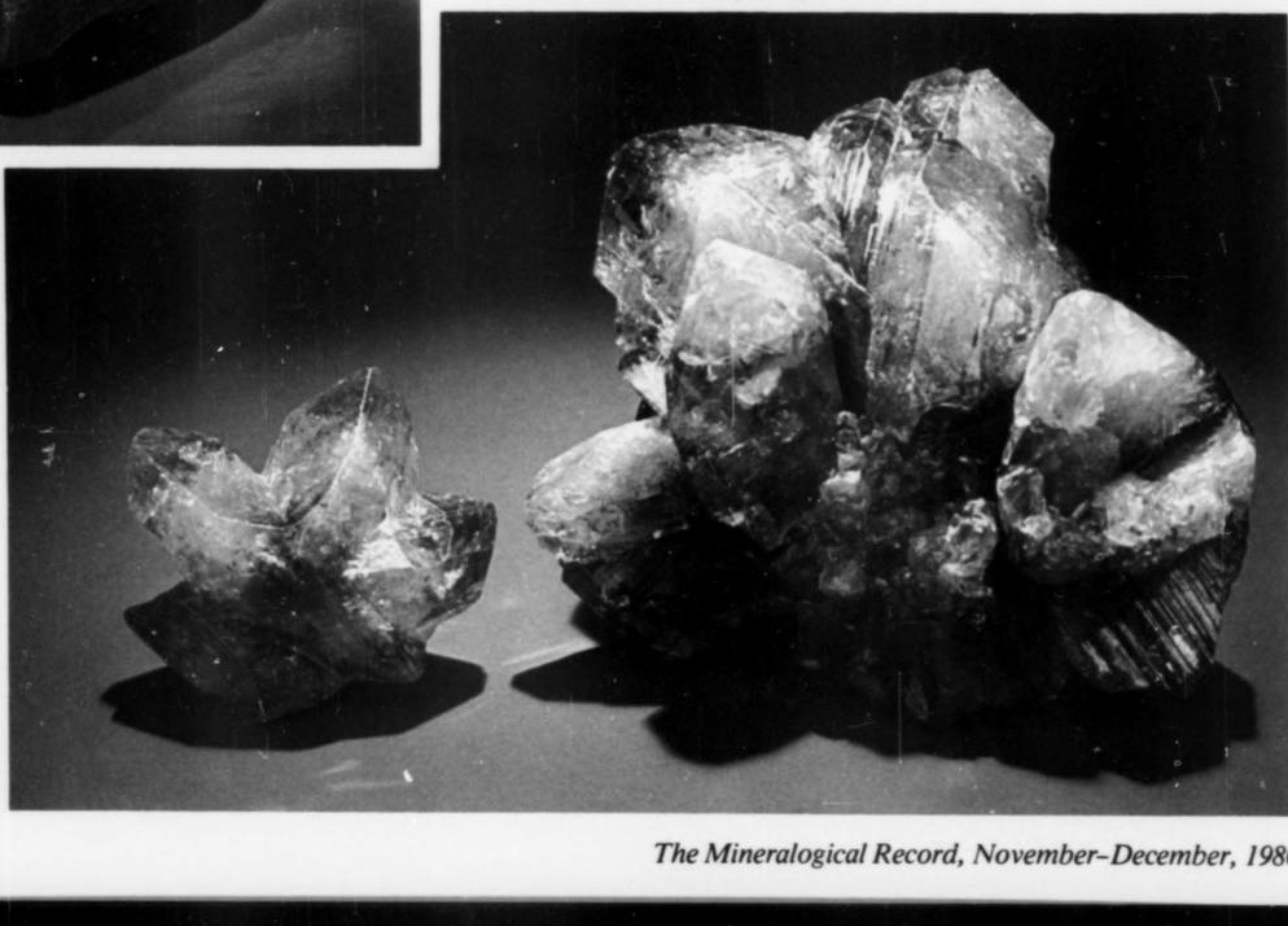
Figure 7. (facing page, center) **A 5-inch aquamarine crystal weighing 400 grams, from Aqua Preto, Minas Gerais. Smithsonian specimen, purchased in 1939.**

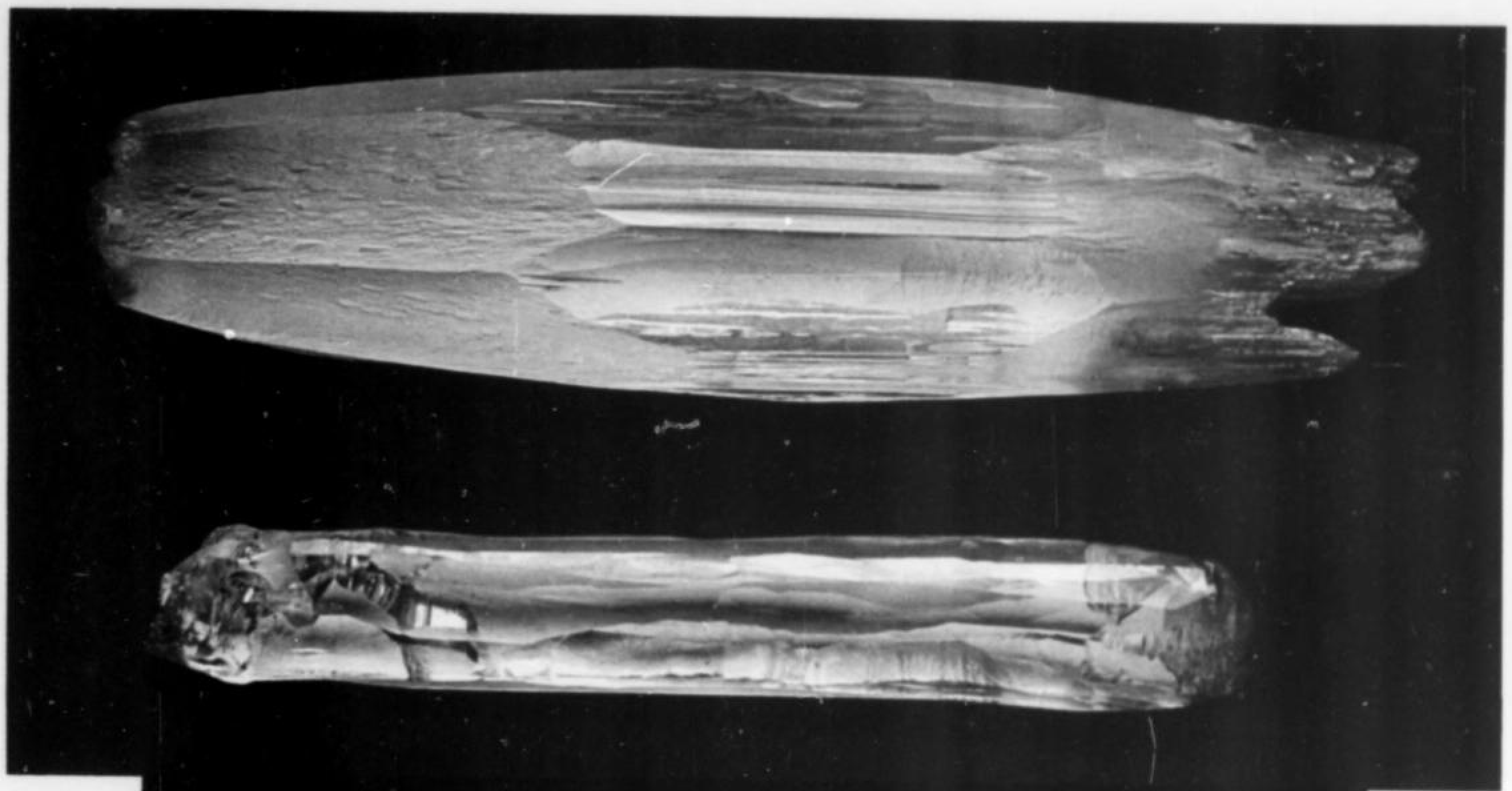
Figure 8. (facing page, below left) **An etched beryl crystal 5 inches tall, from Fazenda da Posse, Brejauba district, Minas Gerais. Smithsonian specimen R8098, purchased in 1941.**

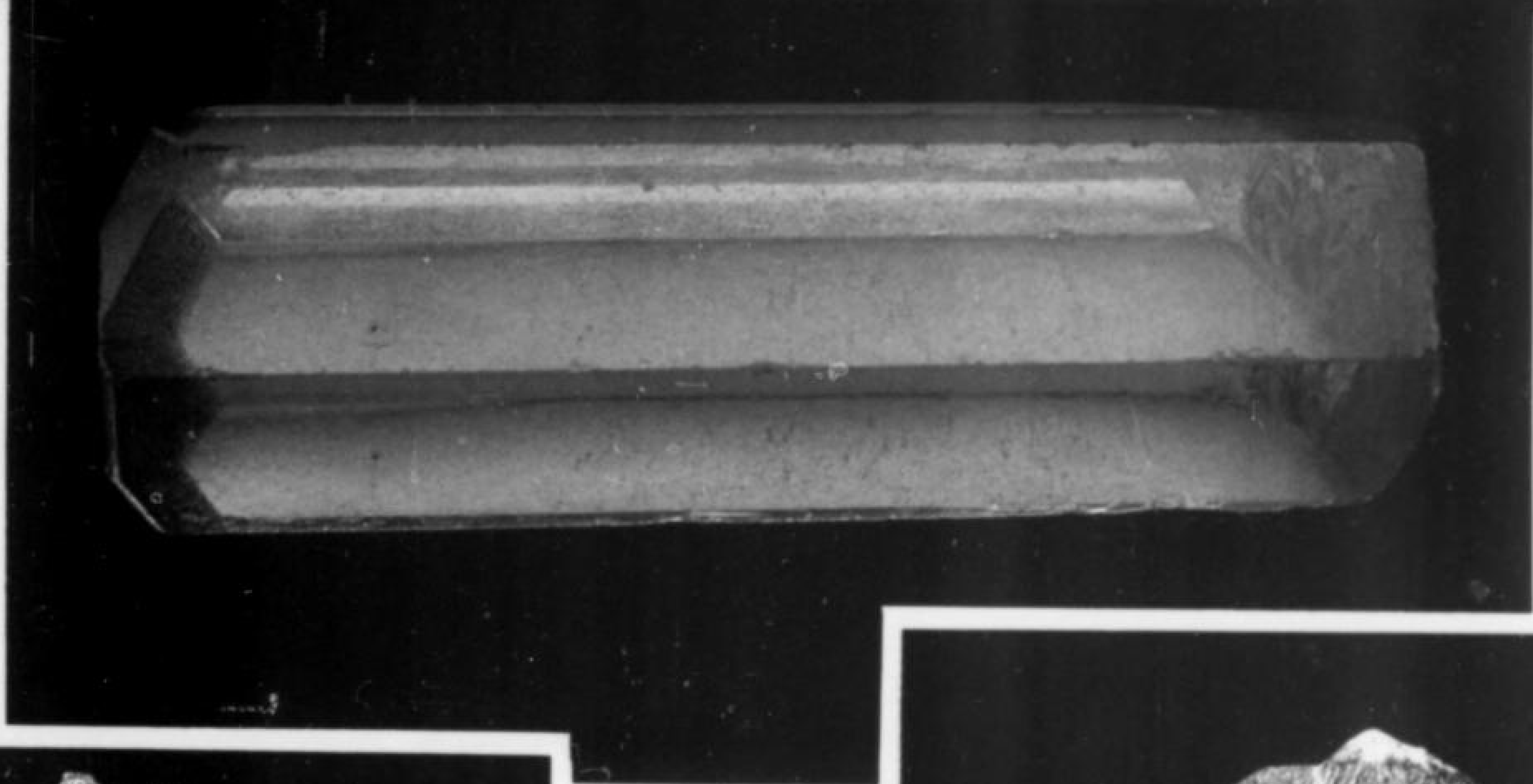
Figure 9. (facing page, below right) **A 6.3-inch, 1820-gram beryl crystal with interpenetrating muscovite crystals (back side) from Fazenda do Funil, Minas Gerais. Smithsonian specimen C5867, purchased in 1947.**



NOTE: **All specimens illustrated in this interview were acquired by Allan Caplan, and are now in various collections. Color photos by Dane Penland, except Figure 3.**







tional Museum bought their 156-pounder, they made a splash in the newspapers, which also was published in the Rio papers. Fortunately, we had a legalized bill of sale, and Carmo explained that the property was sold and he was obliged to export them. Finally permission was granted, and six more weeks went by before they arrived. They weighed 596, 225, and 300 pounds, and the latter crystal, although tall, had a damaged termination.

Finally they arrived and I had the crates opened at the customs office. I was shocked to find that the big crystal had no termination; it was just a big, 596-pound cleavage! And I thought, well, I really got clipped here. Permission was given to move the crates to the basement at the American Museum, and I was a lot happier when I opened them this time, *right side up.* There I saw the termination and realized that the crate had been opened up-side down at customs. So I felt pretty good.

Dr. Berman was notified and came to New York with Dr. Palache from Harvard to look over the crystals. There was no doubt in my mind that they would pick the large crystal, but to my surprise they preferred the 225-pound crystal because of its slightly better quality. So the American Museum got the 596-pounder, the one they wanted in the first place.

After Harvard received their crystal, Dr. Berman suggested that other minerals associated with the topazes should be obtained. On one of my next trips I did come back with a large smoky quartz crystal, doubly terminated, with parallel growth, weighing 150 or 200 pounds, and some very large amazonite crystals 12 to 15 inches tall. After all the trouble of getting them they weren't wanted by Harvard, so I gave the large smoky quartz crystal and a thick topaz cleavage weighing over 100 pounds to the Colorado School of Mines.

During the war I served in Italy as a photo interpreter with the 15th Airforce and, when the war was over in 1945, it was possible to visit the University of Florence where the head of the mineral department, if I recall correctly, was Professor Carrobi. After I told him about the 300-pound crystal stored in the basement of the American Museum, we discussed a swap. At the time, they had drawers of anglesite and large phosgenite crystals from Sardinia and a fair selection was put aside and held for me until my return to the states. The topaz was eventually sent by freighter to Florence and they were very happy with it. They sent the specimens which were put aside for me and I sold them to Schortmann's Minerals.

MR: Didn't you obtain a very large cassiterite from the same mine?

CAPLAN: Yes, that's now in the U.S. National Museum, and perhaps the largest cassiterite crystal known. It is associated with muscovite and has some small topaz crystals attached. It's illustrated in Bancroft's book *The World's Finest Minerals and Crystals,* (page 138. Ed.) and came out of the same pocket which produced the large smoky quartz, amazonite and topaz crystals.

Figure 10. **The 596-pound topaz crystal from Fazenda do Funil, now in the American Museum of Natural History in New York. (This is the crystal that was originally unpacked up-side down.) Photo courtesy of the AMNH.**

MR: When did you first visit the locality?

CAPLAN: Eventually, when all deals were completed Carmo gave me the location of the Fazenda do Funil topaz source in Minas Gerais. It was some miles north of Santa Maria Do Itabira which was a well known locality for fine but small aquamarine. The place called Fazenda do Funil was just a small farm. It was on this first trip to the locality that I obtained the large smoky quartz crystal and topaz cleavage which I gave to the Colorado School of Mines.

On that trip I met Gladstone Drummond, the owner of the property, for the first time. With a name like that, I expected to find a conservative Englishman but, although of English descent, he didn't speak English. He was beefy and rugged with a heavy black beard, very jovial and friendly and went about barefoot; he even rode his horse barefoot. Although my Portuguese was far from good, we got along very well. We walked up to the diggings, just a small cut in a hillside on his land. His hope in digging was to find quartz crystals, and it is amazing that so many important specimens came out of that small hole in the ground. When they first found the topaz pocket, they couldn't lift them out. They cut a small tunnel about eight feel long through the hillside which they lined with very large amazonite cleavages, like paving stones, and slid the large topaz crystals out across them. The tunnel and amazonite cleavages were still there when I visited the mine.

After the war, I visited the Fazenda do Funil again and had a friendly reunion with Drummond. After some negotiating, I was able to buy an entire pocket of aquamarine crystals he had uncovered. There were about 50 or 60 crystals ranging in size from 10 grams to over 3 kilos Some were over 12 inches in length with a variety of colors from pale blue, and chartreuse, to golden. A good part of it was cutting quality. Total weight of the crystals was about 20 kilos. Those crystals are scattered throughout many collections. The U.S. National Museum has a golden crystal weighing 1820 grams, about 3 by 6 inches with mica crystals attached. Until recently, they also had a pale blue one 1218 specimens but very desirable. Twins and small trillings, which I bought very cheaply. At the same time, he informed me that they had come from *another* town, down the road, perhaps 20 or 30 miles from Santa Tereza. So it was necessary to stay overnight in the hotel. The next morning I got a ride on a loaded open truck with other travelers, going deeper into Espirito Santos to the town of Itaguaçu, which was very isolated and about the end of the road. On arrival I asked around, using the crystals I'd bought as samples. A man riding horseback told me he knew where they came from and led me a few miles from town to a small white cottage where a woman and some children appeared. When shown some of my crystals, they led me to the back of the house through some coffee trees to a small hillside containing a small hole no larger than 5 feet square, and *this* was the source of the chrysoberyls.

Figure 11. **The Fazenda do Funil diggings, Ponte do Reis, Santa Maria de Itabira, in Minas Gerais, 1940. Photo by Allan Caplan.**

Figure 12. **Gladstone Drummond, owner of the Fazenda do Funil in 1940. Photo by Allan Caplan.**

grams, about 11 by 2 inches and clean, for the most part, which was recently traded off and cut into a very large, long stone which will go back into some museum collection; personally, I don't like such over-rated large stones. To me, they are not gems, because if reduced to practical sizes for jewelry they are seen to be generally of very poor quality.

From what I've heard recently, Drummond is still living and is approaching 90 years. It would be fun to see him again.

MR: What about the chrysoberyls?

CAPLAN: After selling those large topazes I went again to Brazil. Dr. Foshag had told me that if any of those chrysoberyl trillings were brought back they would be worth a thousand dollars. So I decided to look for them at the first opportunity.

MR: Even back in those days they were worth a thousand dollars?

CAPLAN: That's what I sold them for, but today a good one would bring $10,000 or more. The locality was called Colatina, in the state of Espirito Santo. On one of my earlier trips I saw a book in Rio, in English, and it mentioned that the original source of the chrysoberyls in the U.S. National Museum was a Mr. Otto Richard. I met the man, a German supplier for Idar-Oberstein, about 70 years old, spoke good English and a very nice person. He also said the locality was called Colatina. Years earlier he had sent two very good crystals to Idar-Oberstein, which were bought by a New York gem dealer named Lucien Zell, who either sold them to Roebling or the U.S. National Museum, although I have not checked this out. Anyway. that's how the "locality" of Colatina originated. Richard was never at the source; he bought them from someone from the interior, and later exported them to Idar-Oberstein.

To reach Colatina it was necessary to go by train on the Valley Rio Doce Railroad which started from Belo Horizonte and went on to Governador Valadares (formerly named Figueira), to Conselheiro Pena (formerly called Lajoá) and eventually to Colatina, which wasn't much of a town. No one in the place knew anything about chrysoberyls until a man from Santa Tereza told me that a hotel owner in *his* town had some of the things I was looking for. I left my suitcase at the railroad station and got a ride in a small truck going to Santa Tereza, about 20 or 25 miles away to the south.

At the hotel in Santa Tereza I explained to the owner what I wanted and he brought out a cigar box full of chrysoberyls, not *great*

I started digging with my hands in the red decomposed pegmatite, and here and there was a hunk of quartz or a piece of beryl, but also chrysoberyls and I just started digging them out, crystals from ½ inch to 2 inches in size. They were quite abundant, and after an hour of digging I went back to the cottage where the woman brought out a box full of crystals which I promptly bought. She told me of a farmer who had a large crystal, and I hiked along a trail looking for this farmer and getting instructions from the local farmers who were of Polish extraction, descendants of immigrants who came to Brazil many generations ago. They spoke a dialect no one else understood, which sounded like a combination of Portuguese and Polish, and it was surprising to find a group of blonde, blue-eyed people settled in

Figure 13. **Several crystals of aquamarine from the Fazenda do Funil. The largest crystal weighs 7.4 pounds (3350 grams). Photo by Allan Caplan.**

Figure 14. **A 5-inch cassiterite group from the Fazenda do Funil. Smithsonian specimen C5698, photo by Dane Penland.**

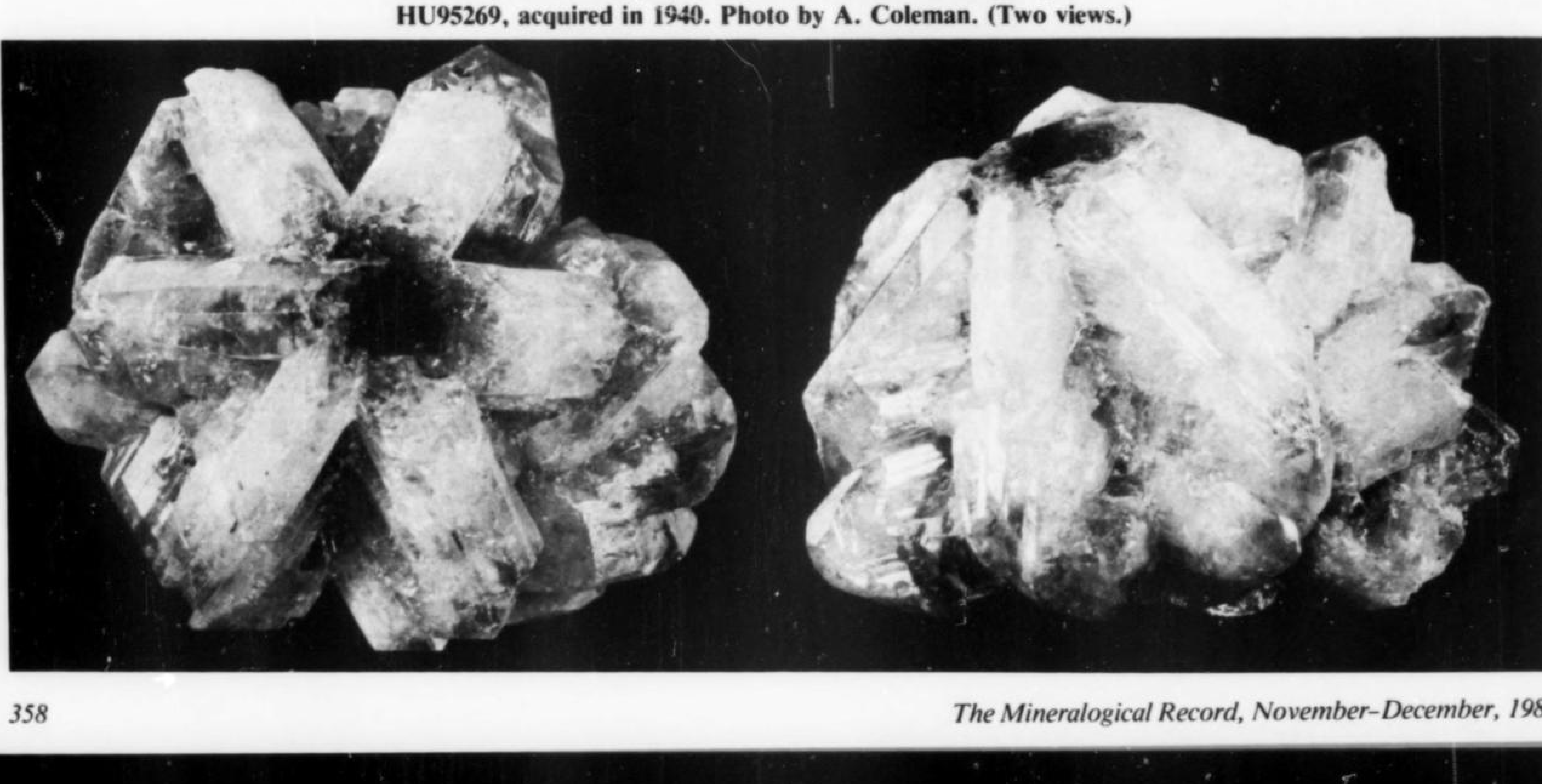
the interior. I found the farmer, and purchased the crystal. It was the best one of a successful day. Before nightfall I had half a grain sack of crystals and located a place to stay for the night. The food was the minimum, just some beans and rice and coffee.

The next morning, I hitched a ride back to Santa Tereza in a small truck, and was surprised to find a cluster of people around the hotel getting vaccinated. Members of the Rockefeller Foundation, American and Brazilian doctors and assistants were vaccinating as many people as possible. They explained to me that there were many cases of people dying of yellow fever in the area. They anticipated an outbreak in the area because they had been tracing it for some years, as the epidemic was moving eastward about 200 miles every year, and estimated that in another year or so, it would reach the coast and disappear. Most of the infected people worked in the forests cutting trees or were burro packers, since the transmitting mosquitos lived in this type of habitat and carried the disease from infected monkeys. A doctor explained that the vaccinating team was able to anticipate the path taken by the epidemic by finding dead monkeys at the foot of trees. Well, they vaccinated me too.

That same day, an American doctor had to go to Colatina and I obtained a ride back with him. Three days later, I arrived in Rio by train via Governador Valadares and Belo Horizonte with the sack of chrysoberyls stuffed in my suitcase. It was the only way to return to Rio as there were no roads either to Belo Horizonte or Rio.

Without my knowing it, my activities in the hotel at Santa Tereza were observed by a Brazilian named Gregorio Azevedo. He was very curious about this foreigner coming all

Figure 15. **A classic chrysoberyl sixling twin about 2 inches in diameter, from Itaguaçu, Espirito Santo. Harvard specimen HU95269, acquired in 1940. Photo by A. Coleman. (Two views.)**



the way from the United States to look for crystals, and he assumed they must be very valuable. He knew the area very well, and also went on to Itaguaçu after I left Santa Tereza. Being in a small place it was easy for him to learn of my activity.

Some weeks later while in Rio and walking in the Rua Ouvidor, I was stopped by Azevedo who introduced himself and revealed his observations of some weeks before. He warned me not to go back into the area because a "fiscal," a tax collector, would be after me, because of my failure to declare the stones and pay the state taxes. On the other hand, I wasn't even legalized to buy stones. This didn't bother me, as there was no intention of going back in view of the large quantity of chrysoberyls in my possession, not to mention the numerous other localities I wanted to visit. Eventually I learned the facts, and realized that there was no truth to his statements. He was just interested in getting control of the source and didn't want me returning to Itaguaçu.

He did get control of the property and put people to work looking for gem material, but all he found was a quantity of very good specimens. On one of my trips, shortly before we entered the war, he offered me a large trilling and I had to pay $600. There was no doubt I'd get $1,000 for it, but I wasn't happy over the price paid since originally I'd bought them for very low prices.

Later I had it at the American Museum, where it was being cleaned to get the red mud out, and the crystal split in half; it had been glued along a smooth cleavage. As I was expecting to go into the Army very soon, it was sold for cost, and it's now on display in the museum collection.

After the war, while in Rio and visiting Gregorio, I mentioned the glued chrysoberyl and he explained that the specimen was glued with the white of an egg and covered with mud without his knowing, before he took possession of it in Itaguaçu. Gregorio and I began working together for a number of years, and his cooperation and help were considerable. We're still good friends to this day.

MR: What was the best crystal that came out?

CAPLAN: The American Museum has this large one, but I don't know if it was the best. I sold Arthur Montgomery a couple of my best and also some smaller ones. They're now in the National Museum collection. Many of the chrysoberyls from this locality in collections today must be from this one and only trip to Itaguaçu.

MR: What about those aquamarine specimens from near Conselheiro Pena that you tried so hard to get?

CAPLAN: The locality is now called Palmital, but at that time, we had no name for the place. Three trips to the site were made without success. Palmital was a new mica discovery on a jungle-covered hillside, about an hour and a half by horseback on the opposite side of the Rio Doce from Conselheiro Pena. During the war, it became an important source for mica.

The first time I went there was with a rough-gem buyer I knew from Rio, named Otto Veeck. We met in Conselheiro Pena by chance, and he asked me if I wanted to go along with him to this new area. Of course I agreed, and we obtained horses and crossed the Rio Doce on a raft and rode along a trail through the densely wooded area to a shack in a small valley. There were a couple of fellows there in this shack, and on the wall was a cabinet made of some old boards with a wooden lid which was locked. By pulling the lid back, you could see about half a dozen good aquamarine clusters with crystallized mica and albite. The aquamarine crystals were long and terminated, with a pale blue-green milky color.

The source of these specimens was a large pegmatite dike a couple of hundred yards from the shack on a hillside in a densely wooded area with thick foliage and hanging vines. It was truly a jungle. The outcrop was white albite, and some men were sitting on the edge of this outcrop peeling off large books of mica and stacking them. The books were thickly scattered throughout the albite outcrop. The foliage was so dense, there wasn't enough sunlight to get a decent photograph.

The outcrop, by right of possession, belonged to a man named Massias who was considered an outlaw. He had killed some people over some land and was wanted by the police. It was never clear in my mind who the police were in the interior, because I never saw any, but I believe they were part of the military. As Massias was always on the move by horseback, it was difficult to meet up with him. He had a partner in Conselheiro Pena named Mansur who made all the transactions. The two boys in the shack were Mansur's younger brothers, who were looking after the new mine. They told me it was necessary to deal with Massias over the specimens, but they never knew when he would show up. Otto and I went back to Conselheiro Pena (and it was on this trip I went down to Colatina, via the Rio Doce railroad, in search for the chrysoberyls). Within a period of a year or two, I made two solitary trips by horseback to Palmital hoping to find Massias, but never had the luck. Each time, I'd stay overnight, sleeping on the floor and leaving in the morning.

It was during the war that the military finally caught up with Massias and killed him. I am told they surrounded a house, and promised him safety if he surrendered, and when he came out unarmed they shot him down.

After the war, the collection was in the hands of Mansur in his office in Conselheiro Pena. I tried to buy the lot from him but couldn't meet his price. Right after the war the cruzeiro was very strong, but inflation took hold, and one was able to get more cruzeiros for the dollar and everything began to get low priced with dollars. Being in the interior Mansur never realized what was happening to exchange rates and kept a firm price in cruzeiros for the collection. Unfortunately for me, a Brazilian firm came along, at the right time, and bought the collection. Possibly at less than half the amount of dollars it would have cost me when I first tried to negotiate. The specimens were eventually sold in the states; the best one was sold to the U.S. National Museum and is illustrated in Bancroft's book (page 78, Ed.).

MR: Were they hauling a lot of iron ore on the Valley Rio Doce Railroad?

CAPLAN: Yes, after the war one of the large American mining companies brought in large gondolas to haul the ore to Vitoria Bahia on the coast for export, and they had to improve the tracks. The railroad runs parallel to a large ridge of pure hematite. I recall hiking around the outskirts of Belo Horizonte and every rock was pure hematite. Near Itabira where there is a large smelter and steel works, there is a small town where all the streets are cobbled with pure hematite. I really don't know about the extent of the mining of iron ore which has taken place in recent years. The iron deposit didn't interest me very much, although I did get some large rosettes of hematite from a place called Burnier.

MR: What was traveling on the trains like?

CAPLAN: The main means of transportation in this part of Minas Gerais was the Valley Rio Doce Railroad which started in Belo Horizonte and stopped at the major gem producing towns along the Rio Doce, such as Governador Valadares and Conselheiro Pena, and then went on to Vitoria Bahia on the Atlantic Coast. The passenger trains were all wooden types of the late 19th century with wooden seats, and wood-burning locomotives. There were plenty of trees growing along the tracks and stacks of wood would be piled along the way where the train would stop to load up.

I enjoyed riding on these trains because the pace was slow, the scenery and towns interesting and the people friendly. All the trips were in the daytime, I don't recall making any night trips. It wasn't unusual at one of the stops to see a man get on carrying his saddle, and later getting off at another stop to continue his trip by horseback to a ranch, a mine or some other destination. Often a man would be packing a gun but there rarely

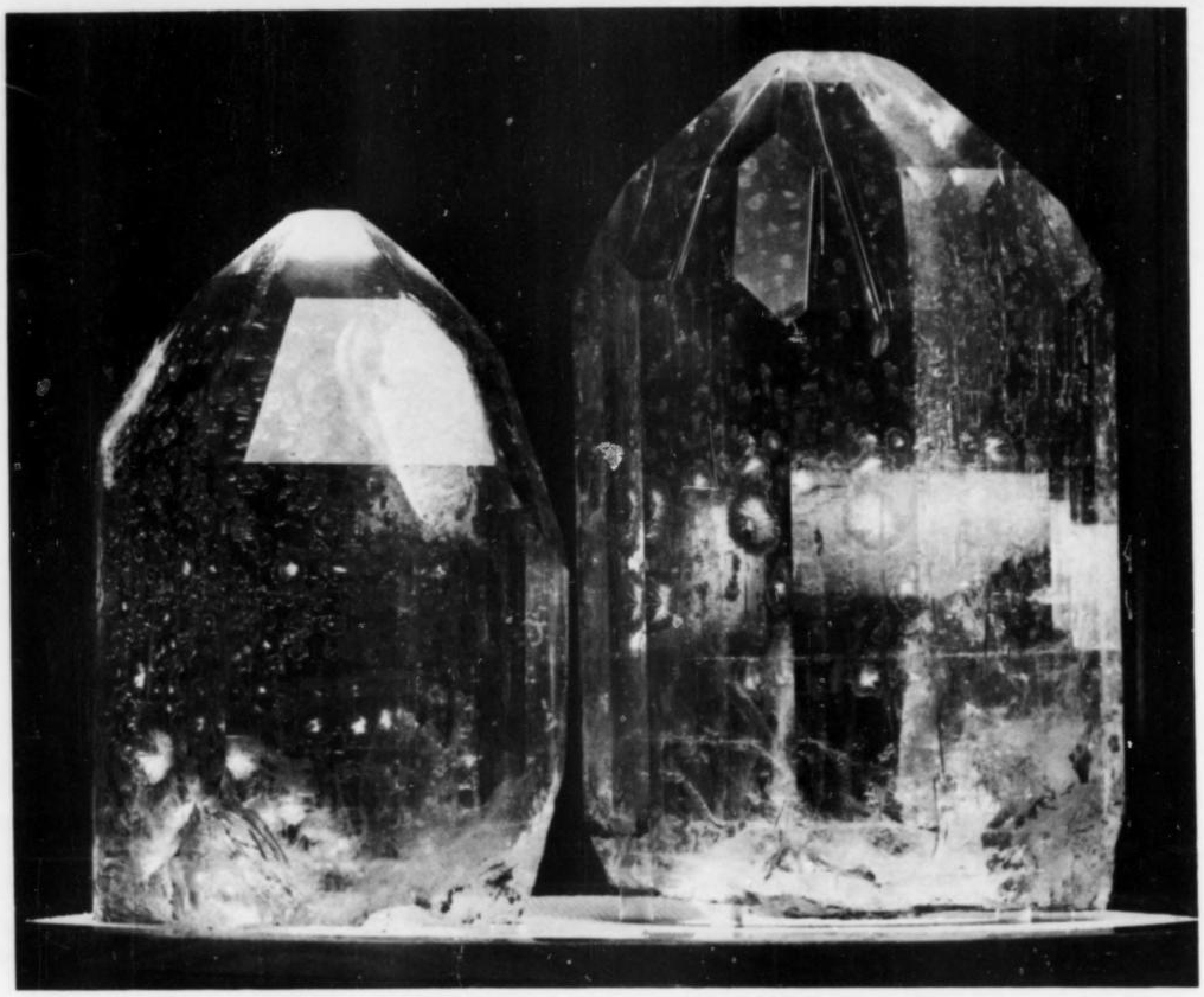


Figure 16. **Two large, colorless topaz crystals, the largest nearly 2 feet tall and weighing 111 pounds. The smaller crystal weighs only 70 pounds. These came from the Teofilo Otoni area, Minas Gerais. Collection of Dr. and Mrs. Andrew Kulin; photo courtesy of the Smithsonian Institution, where the crystals are currently on display.**

was any trouble at all, like you see in Colombia today where it seems *everybody's* packing a gun. I made over twenty trips to Brazil, traveling to many parts of the country, and never had trouble of any kind worth mentioning. The Brazilians, and especially the people in the interior were always helpful and friendly, especially on my early trips when I didn't know the language. A young American traveling alone with a pocket dictionary was something of a novelty. Today, a foreigner traveling in the interior is a common event. With plane travel and good roads opening the country and a great migration of foreigners settling in the interior, the atmosphere is not the same. The gem business has expanded, involving a great many people, many of whom originated in other countries.

MR: Wasn't that area which is now grassy hills all forest in those days?

CAPLAN: The road between Governador Valadares and Teofilo Otoni, which was under construction on my first trip to Brazil, was cut through a very densely wooded area. The trees were tall and the vines climbed everywhere; it was a jungle.

A few years back I went to Brazil, following an absence of about 15 years, to visit friends and see the changes in the interior. I was surprised to see the forests gone and, in their place, the rolling grassy hills with grazing cattle. Where once there were no roads, two-way asphalt roads were winding through the hills carrying buses and trucks. Far different than in early trips when there were few roads, no buses, some so-called hotels and bad food. Governador Valadares had few houses, mud streets, a clap-board shack of a hotel called the Grande where the soup always had a fly or two for flavor. Today, it's a busy town with paved streets, good shops and restaurants, and an important gemstone center, with a population approaching 100,000 people.

MR: Do you think there are many undiscovered things in Brazil?

CAPLAN: Sure, Brazil is just full of stuff, tremendous areas that haven't been scratched and, of course, in places where the vegetation covers outcrops. Anything is liable to be found in Brazil.

MR: If you consider these pegmatites that have produced the fine aquamarine, topaz and tourmaline, very few of them have been exploited to a depth of more than 100 feet, and that you might say is surface skin. There is no reason why there shouldn't be more material at greater depth.

CAPLAN: Well, one reason why so much stuff has been found in Brazil is the decomposition of many of the pegmatites, and this makes easy digging by pick and shovel. If hard rock is encountered it might be necessary to use blasting, but I don't know of any gem-bearing pegmatites that have been worked to any significant depth. Searching for gem pockets in hard rock is difficult and risky. There will be many new gem producing pegmatites found all the time, and important gem strikes from time to time, such as that recent rubellite ("cranberry" tourmaline) discovery near Governador Valadares. The most important factor in the wealth of gem material from Brazil is the simple fact that she has been blessed. Pegmatites are scattered over the world, but most of them are barren, and Brazil is fortunate in having a wealth of gem-producing dikes. There is no end to what will be found in the future.

the Cruzeiro mine past and present

by **J. P. and J. O. Cassedanne**
Federal University of Rio de Janeiro and
National Research Council (C. N. Pq.)
Rio de Janeiro, Brazil

and **D. A. Sauer**
Cia Itabras de Mineração & G. G. Amsterdam-Sauer
Rio de Janeiro, Brazil

The Cruzeiro pegmatite mine, in the state of Minas Gerais, Brazil, is world-famous. Murdock et al. (1944) refer to it as "the principal mine of the region and one of the larger in the world." Huge production during World War II was only in strategic mica, and mining decreased abruptly thereafter. However, the subsequent discovery of magnificent, large, gemmy and flawless elbaite crystals of outstanding size contributed to the increased fame of this exceptional deposit.

LOCATION, ACCESS, PHYSIOGRAPHY AND LOCAL GEOLOGY

The Cruzeiro mine is located northwest of Governador Valadares, west-southwest from Teofilo Otoni and northeast from Belo Horizonte, in the eastern center of the state of Minas Gerais. It belongs to Santa Maria do Suaç_i township, Poaiá district.

Access is by way of Frei Inocêncio (elevation 150 m), at kilometer 590 of the paved highway that joins Rio de Janeiro to Salvador. From Frei Inocêncio a good dirt road, passing a fork to the right at 26.8 km, goes toward São José da Safira at 52.5 km. Leaving this little town (elevation 220 m) a small road runs to Poaiá. The narrow, steep Cruzeiro trail, only passable by four-wheel-drive vehicles, forks to the right at an elevation of 400 m, 3 km after Sao José, and climbs up for 9 km to the mine offices (elevation 1085 meters), passing a first escarpment at the level of 900 m.

Access is also possible from the Santa Maria do Suaçui road, passing Cristalina, Grama and Poaiá. This way is presently almost abandoned.

The deposit is near the top of the Serra da Safira, whose highest summits are between 1,100 and 1,500 m in altitude. This is a long north-south mountain range whose western slope is very abrupt (Poainha escarpment), serving as a prominent landmark which extends for several kilometers north of the village of Poaiá. The eastern slope, where the workings are located, is less steep.

The Serra da Safira is the dividing ridge between the Rio Suaçui Grande and its tributary, the Rio Urupuca, and overlooks gently undulating hills and broad flat valleys. Thus, the difference of level between the Cruzeiro mine and Santa Maria is 600 m, and between the same and Poaiá is 800 m.

The area immediately east and west of the Poainha escarpment is underlain by a metamorphic sequence several hundred meters thick, composed of beds of quartzite, sericitic and ferruginous quartzite, phyllites and quartziferous or ferruginous phyllites (Complexo Fundamental = Basement of the former authors). The escarpment itself is held up by a quartzite unit a few hundred meters thick which is best exposed at the Cruzeiro mine. Ottoni *et al.* (1942) has referred to this quartzite as equivalent to the Itacolomy series of Proterozoic age (now the upper part of the Minas supergroup). Presently, the whole is mapped as "undivided granite gneiss basement" of Archeozoic age, according to the Geological Map of the State of Minas Gerais (1/1,000,000 scale).

Several erosion levels may be seen, particularly one on the summit of the Serra da Safira, where flat lateritic outcrops are frequent near the mine offices.

The valleys are occupied by pastures whereas the hills are covered by thick, high grass. A luxuriant tropical forest with many palm trees grows in the deep mountain torrent valleys that cut the fern-covered slopes of the Serra da Safira. The top of the mountain is bald with some "canelas de ema" *(Vellosa variabilis)*, a typical bush tree of the quartzitic mountains.

Figure 1. **The No. 1 vein (dark depression in the center of the photo). On the right, white dumps are from adit 1 D. View looking north. (All photos except Fig. 4 by J. P. Cassedanne.)**

Figure 2. **Dumps from Adit 1 J and 1 I. Coeruleolactite was found in the dumps on the right.**

Figure 3. **Waste of mica sheets near the mine offices.**

Water is abundant in the valleys, where the population is concentrated in villages and small towns, whereas population is very scattered in the ranges, in little settlements near the deposits.

GEOLOGY OF THE DEPOSIT

Three elongated, sub-parallel pegmatite lenses, running N20°W and dipping sub-vertically or deeply to the southwest, were mined and are known as the No. 1, No. 2 and No. 3 veins, the first being the main one. They compose today the bulk of the Cruzeiro property, where workings are between the 980 and 1110-meter levels (see geological map).

Several other parallel fractures with pegmatite occur on both sides, but they are of lesser importance. The main ones are:

Campinho, Safirinha, Rio Preto,
Forattini deposit (500 meters to the east),
Jazida do Oliveira (on a gently dipping lens).

The pegmatites are veins, frequently of only a few meters width (adit 2 B—1,085 m, for instance), but with many widenings where a quartz core is generally present.

During World War II, the known dimensions of the pegmatites were quoted, in meters, as follows (Pecora *et al.*, 1950):

	Maximum thickness	*Exposed strike length*	*Vertical range of exposure*	*Deep length explored*
Cruzeiro 1	50	1,000	70	40
Cruzeiro 2	4	900	120	85
Cruzeiro 3	6	1,200	115	20
Cruzeiro 4	4	600	70	20
Forattini	50	600	85	10

Contact with the wallrock—quartzite (2 and 3 veins and "Capa"), schists (partially "Lapa" 1) or amphibolites—is always sharp. Numerous refractions and protuberances are visible in the gently dipping quartzite wallrock.

The main wallrock, unusual for this region, is a white to light buff or pinkish medium grained quartzite, with thin muscovite beds and coarse grained lenses. Irregular sedimentary features cause some small undulations. A partial recrystallization may be seen under the microscope, appearing as corrosion of the larger grains, the smaller remaining unchanged.

Mica schists are essentially composed of biotite, quartz and oligoclase or andesine with graphitic, chloritic and amphibolitic varieties. Their outcrops, always weathered, are purple and their residual soil is very ferruginous.

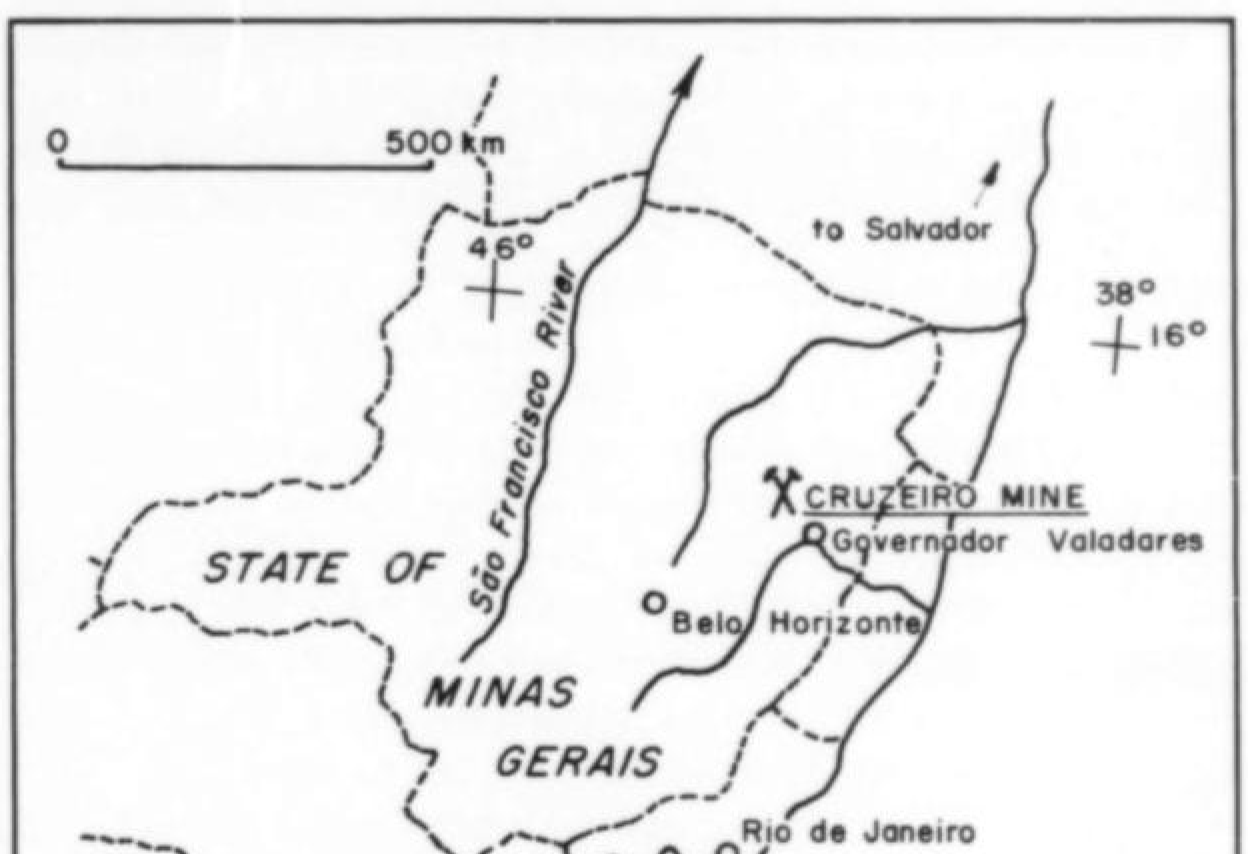
The amphibolite that does not crop out, and is partially decomposed in the adits, forms a mappable, lens-shaped unit, and is composed of olivine, serpentine, pyroxene, hornblende, fibrous amphibole, biotite, chlorite, quartz and calcite. Garnets are locally abundant (adit 1 D).

Irregular masses of amphibolite in quartzite are interpreted as a product of the metamorphism of an ultrabasic rock that was intruded into sedimentary layers prior to the principal period of metamorphism and prior to the intrusion of the mica-bearing pegmatites (Pecora *et al.*, 1950).

Almost all the pegmatite veins present a symmetrical, well developed zonation that may be schematized as follows, from the wallrock to the quartz core:

—Light, thin bed of coarse grained mica in contact with the wallrock.

—Rock of granitic texture, quartz and feldspar with some graphic granite known as *sal grosso* (coarse salt) by the *garimpeiros*.



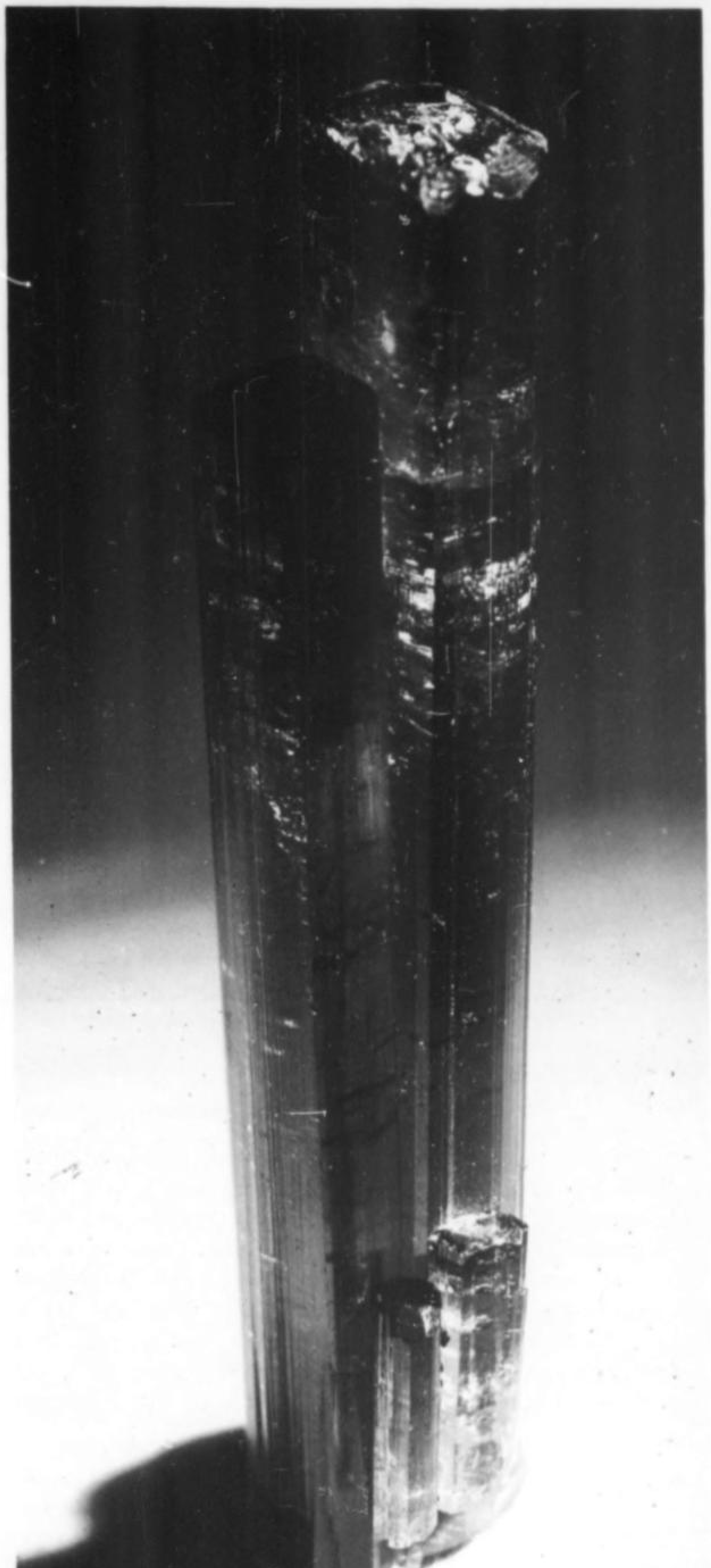
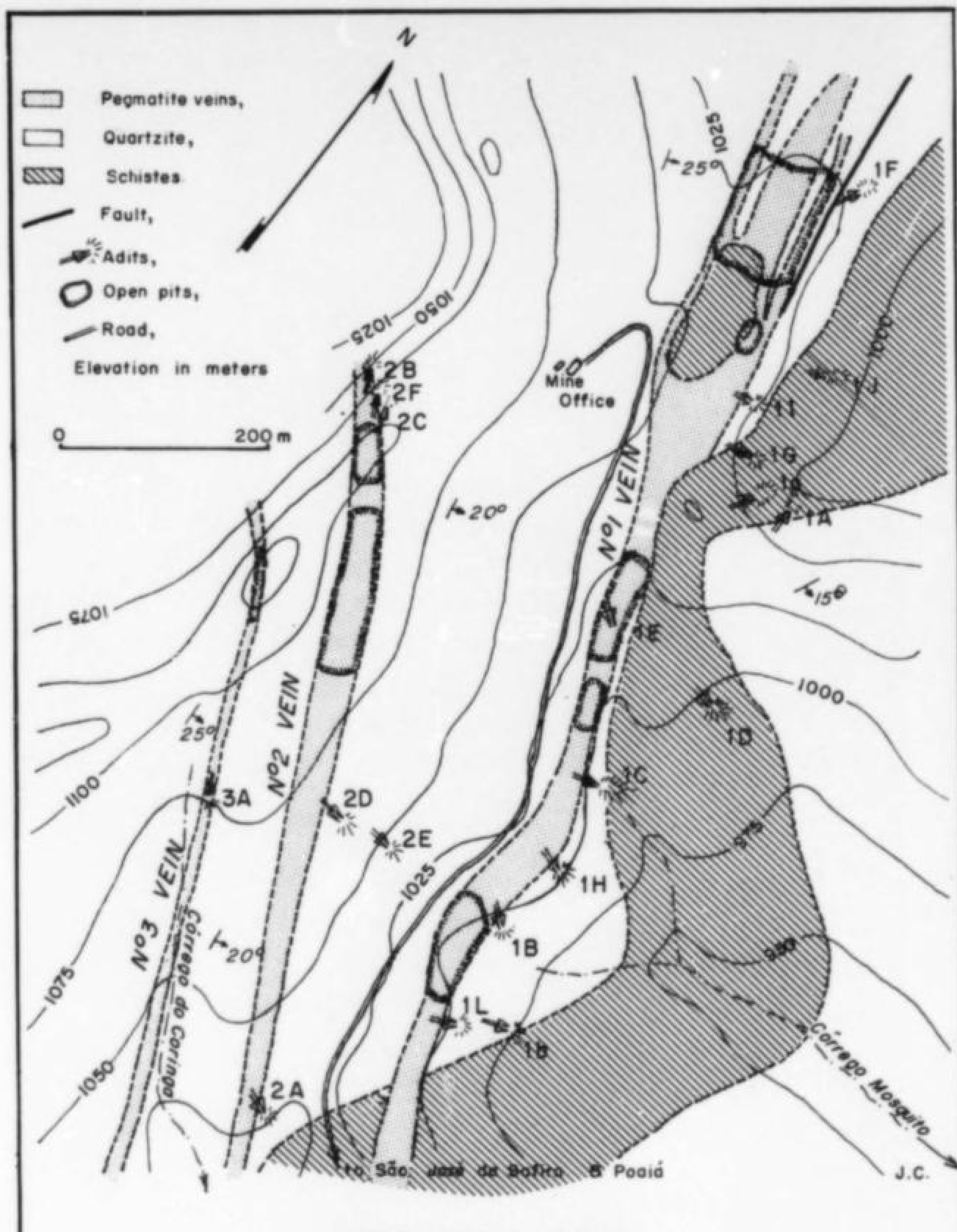


Figure 4. **A large, polychrome green-pink elbaite crystal. The specimen, found in the No. 1 vein in 1970, is 26 cm in length. (J. R. Sauer collection, photo by D. Sauer.)**

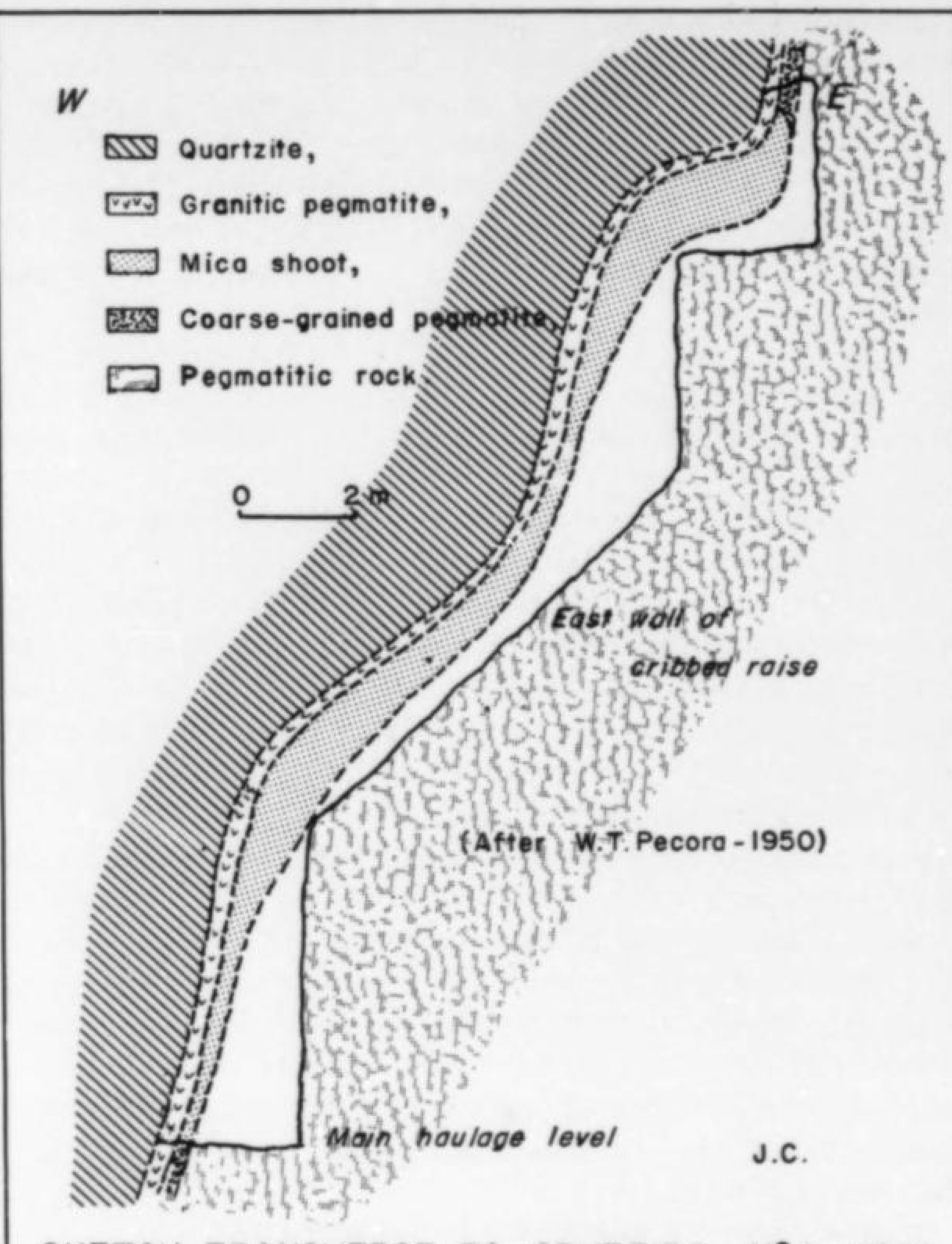
—Outer intermediate zone, locally exceptionally rich in muscovite books, or coarse granitic texture.

—Inner intermediate zone, essentially composed of potassium feldspar locally albitized.

—Central zone: coarsely crystalline quartz and potassium feld-



GEOLOGIC MAP



SKETCH TRANSVERSE TO CRUZEIRO Nº2 VEIN

(Relation of mica shoots to arches in the hanging wall)

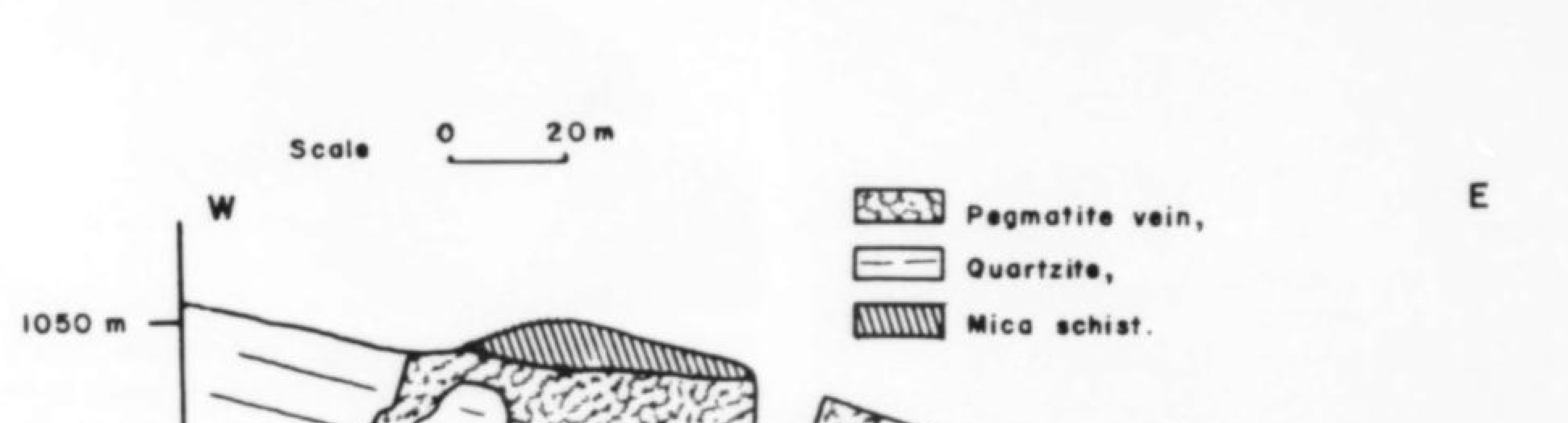
spar with albite druses containing tourmaline and large spodumene crystals.

—Sometimes a quartz core.

In border zones that are granitic in texture, muscovite books comprise 2 to 10 percent of the rock, but only rarely are the books large enough to yield sheet mica. The most extensive and highly concentrated border-zone deposit of the Minas Gerais mica belt was in the Cruzeiro No. 1 vein, in contact with a roof-like pendant of amphibolitic schist. This outstanding mica shoot was 325 m long, 10 to 50 m wide and 0.5 to 2 m thick, and appeared as a curved sheet that was concave upward, pitching about 15°S, and was located where the contact with roof rock was essentially horizontal or gently inclined. In this deposit, mica books suitable for trimming formed 7 to 15 percent of the rock by weight.

Zonation has been previously emphasized by Pecora *et al.* (1950) during their study of the Cruzeiro mica mine. This is presently a true mole-hill of tortuous small adits running without preferential direction and largely caved in. Some main adits are perpendicular to the pegmatite veins (1 and 2), parallel to these (2 and 3) or variable.

It is possible to divide the history of the deposit into two phases: one period of intensive mining during World War II (summarized below), and a more recent period of smaller-scale mining activity focusing only on tourmaline; mica is now only a by-product.



CROSS SECTION PASSING BY 1 J ADIT

THE MICA PERIOD

Two meridian mica-bearing belts may be recognized in the state of Minas Gerais. The first, to the west of the Rio-Bahia highway, begins near Chonim and extends towards the north beyond São José da Safira. The second runs from Resplendor to Mantena via Conselheiro Pena (Sapucaia and Boa Vista pegmatites among others). The Cruzeiro mine is located to the north of the first belt (Barbosa, 1944).

A few mines were worked for mica at the beginning of the 20th century. The small production prior to World War II came from the Governador Valadares region and from the Espera Feliz zone, more to the southeast.

During the conflict, 90 percent of the Brazilian production came from Minas Gerais; 12 percent of the whole came from the Santa Maria do Suaçui township where the Cruzeiro mine is located. This appears to have been discovered in August of 1915. In 1916 the concession was granted to Antônio Nunes de Almeida and Miguel Liebmann. Prior to World War II, official reports are missing. By decree number 10,632 on 15/10/42 the *lavra* (mine) of Cruzeiro (present property and Mosquito, Coringa and Maquiné deposits) was granted to Dilermando Rodrigues de Mello, who sub-leased the mine to the firm Vieira and Neto. This firm, once more, sub-leased the several deposits and prospects to *garimpeiro* groups which were required, by contract, to sell them the whole production. Profit of Vieira and Neto was the price difference between purchase to *garimpeiros* and sale to exporters, the Irmãos (Brothers) Algranti, during this time.

Six hundred to 800 *garimpeiros* worked in the district where more than 40 mining fronts were in operation during World War II.

In order to increase the production as a war effort, the primitive, manual workings were improved by supervision of U.S. technicians from the U.S. Geological Survey, Foreign Economic Administration and U.S. Purchasing Commission.

Mining was by cut-and-fill stopes with cribbed raises at 20-meter intervals, with some stopes timbered and filled.

Mica occurrence in the pegmatite veins

Exceptional concentrations of mica books or "mica shoots" that occur in a well defined border zone of the pegmatite have been the most profitable sources of mica for mining.

According to Pecora *et al.* (1950), 6 of the 15 principal mica shoots of the Minas Gerais State were located in the Cruzeiro property, and structurally controlled by local arches in the hanging wall, as follows:

—Cruzeiro No. 1 vein, a mica shoot known as the Roof Pendant shoot. See description and size above. Estimated content of mine crude mica in metric tons: 4,500. Estimated percent mined to September 1, 1945: 60. Exploration incomplete in north and south parts. Central part mined out.

—Cruzeiro No. 1 vein, West Arch shoot. Essentially pod-shaped, pitching about 12°S and dipping west. Dimensions in m: length 275, average breadth 8, average thickness 1.5. Content: 1,500 tons; 90 percent mined out. The south end exposed and eroded. Central part completely mined out.

—Cruzeiro No. 1 vein, East Arch shoot. Identical to the preceding but dipping east. Dimensions in m: 80 x 8 x 1.5; content: 300 tons, 50 percent mined out. Extension of ore shoot below main haulage level offers future reserves.

—Cruzeiro No. 2 vein, Charles Gomes shoot. Irregular sheet composed of several pod-shaped shoots, all pitching about 12°S and dipping west. Dimensions: 250 x 25 x 1.5. Content: 2,500 tons; 90 percent mined out. Extension of ore shoot below main haulage offers future reserves. The shoot is controlled by a series of local arches in the hanging wall that are off-set *en échelon* to the south.

—Cruzeiro No. 3 vein, Coringa shoot. Essentially lath-shaped, pitching south. Dimensions in m: 350 x 6 x 1. Content: 1,200 tons, 90 percent mined out. South end exposed and eroded.

—Cruzeiro No. 3 vein, Aricanga shoot. Essentially pod-shaped, pitching south. Dimensions in m: 150 x 6 x 1. Content: 450 tons, 90 percent mined out. Extension of the north end offers future reserves.

Type of mica

Many of the large mica books from the pegmatite veins in the Cruzeiro district were valueless because of the abundance of tourmaline crystals intergrown with the mica, or because the mica was buckled or twisted. Mica books that have been contorted or twisted into sharp flexures are referred to as "buckled mica." It was especially common in the hanging wall mica zone of the Cruzeiro No. 3 vein. The buckling has probably resulted from tectonic movement within the pegmatite.

Mica books that yield sheet mica with a wavy instead of a flat surface were in high proportion in the mine and significantly reduced the commercial value of the ore. Waviness was more pronounced in the weathered parts of the pegmatites. In contrast, ruled mica at the Cruzeiro mine is a rare feature (Murdock *et al.*, 1944).

Near the surface, mica books were also frequently stained with brown limonite patches between the sheets or by organic compounds, as may be seen presently in the No. 2 vein outcrops.

THE TOURMALINE PERIOD

Presently the stopes and adits driven during World War II in search of mica are caved or filled with waste. Of the workings made to gather gems, only a few are now accessible.

Surveys and geological mapping of the caved adits during the last 15 years will not be reported in detail here (see Sauer, 1975).

From a prospecting point of view, gemmy concentrations seem to be localized where pegmatites show widenings, that is to say in the most differentiated parts of the deposits. These are frequently controlled by local arches in hanging wall as seen for mica as well (adits 1 A, 1 D, 1 E and 1 J with a 7 kg gem pink sample).

The Itabras Minerãçao, owner of the property, has exclusive right to gem mining. The company maintains, however, a leasing system with *garimpeiros* for the non-gem material recovered, and each hand-carved adit is named according to its operator as follows: 1 b and B = João de Matos; 1 H = Osório; 1 A = Jacy; 1 J = Toquinho; 2 A = Raimundo; 2 D = Louro and 2 E = Dodo.

As a result of our recent investigations, a list of the principal minerals that may be recovered is given below.

Elbaite. The worldwide fame of the Cruzeiro mine comes from the beautiful, large, green or pink gem crystals extracted here. Black tourmaline is also common, as in the other pegmatites of the neighborhood, but is without mineralogical interest.

Gems occur in the central zone of the pegmatite, surrounded by large feldspar in a coarse granitic texture, which is frequently associated with multidecimetric altered spodumene blades and patches of lepidolite. Gem elbaite is generally perched on cleavelandite blades that coat druses of variable size. The crystals, almost always well developed, are multicentimetric, frequently reaching more than 10 cm in length. They are in unoriented groups, generally opaque, and are actively sought after by collectors; or they occur isolated, with large gemmy portions. Habits are diversified: elongated, doubly terminated crystals, needle-shaped, rounded or short, large flat-terminated crystals similar to those from Pala (California). Some of these latter, mainly gem, several kg in weight, are the pride of important Brazilian jewellers (J. Sauer in Rio de Janeiro and E. Rohrmann in Belo Horizonte for instance) and museums (see Keller *et al.*, 1977).

Color is varied: light to dark green in the opaque specimens, with a shade of blue in the gemmy crystals. Some other crystal groups, frequently opaque, are light pink. Short, flat gem specimens are

(continued on page 370)

dark rose to almost red, with a magnificent, famous tint. No other gemstone has a wider color spectrum that elbaite, and the finds of this stone in the Cruzeiro mine are probably the most outstanding proof of this statement. It is almost impossible to divide the gem specimens into narrow different categories because in a single crystal can be encountered not only different color hues but sections ranging from decomposed to totally flawless. *Cromolites, indicolites* and *rubellites,* to mention the three most valuable color hues, have been found in multicentimetric crystals. Bi-colored elbaites are common, either with one end green and the other rose or with a combination of various color patterns concentric to the *c* axes ("melancia" or "watermelon" tourmaline), typical of the Cruzeiro mine. Both *watermelon* and *rubellite,* however, rarely occur without heavy inclusions whereas the green and blue varieties are often at least eye-clean.

An important pocket of multicolored, banded tourmaline was found under an arch formed by the contact of the pegmatite with the mica schist in No. 1 vein (see cross section). The largest crystal, more than 20 cm, is shown here in color.

Irregular, small, gemmy fragments and broken crystals are sold for tumbled stones and fancy jewelry.

It must be emphasized that, although relatively rare in Brazil, green elbaite does occur in an asbestos-like habit. These samples are actively sought after by collectors and produce a magnificent "cat's eye" effect when cut in cabochon forms.

Quartz. It occurs near the quartz core in multidecimetric milky crystals, frequently doubly terminated, and in druses; but samples are not exceptional.

Fine, bladed, translucent specimens several decimeters in length are sporadically recovered. With a pegmatitic habit they are actively sought by collectors.

Smoky quartz is uncommon, and occurs sparingly in the No. 1 vein. It must be noted that some milky and smoky quartz samples are rich in H_2S which is released when broken.

Feldspar. Some large, platy, bladed cleavelandite specimens from the druses occurring near the quartz core are easily recoverable in the dumps. However, most generally either potassium feldspar or albite occur as large, unattractive, coarse masses; only good granitic texture samples may be collected.

Micas. The large, abundant books of muscovite do not offer outstanding specimens, although sheets of several square decimeters may be obtained by splitting. The color varies from a light ruby to light buff. Staining is common.

Lilac-pink lepidolite, fine grained, is sporadically abundant (Adit 1 D near the quartz core). Always of industrial quality, it is commonly associated with black tourmaline and locally with smoky quartz.

Lithian muscovite is sometimes associated with lepidolite.

Beryl. Industrial beryl is scattered in the pegmatite veins, but does not occur as attractive mineral specimens (adits 1 D, 1 b and 1 C).

Garnet. Some cataclastic, opaque, orange-brown to brown garnets are disseminated near the quartz core (north of No. 1 vein). Gem fragments or euhedral crystals are not known.

Spodumene. Locally, huge crystals more than 1 meter in length occur near the core (Adit 2 B). They are commonly altered and pseudomorphosed to kaolinite (X-ray determination). In the weathered zone, pink, earthy, compact or banded masses appear sporadically, called hard or soft "soapstone" by the *garimpeiros.* They are, in fact, montmorillonite (X-ray determination) with some lithia.

Amblygonite. Massive, dull white or creamy with a good cleavage, or saccharoidal, it is locally common (adit 1 I). Crystals have never been found in the Cruzeiro mine.

Cassiterite. Rare, it is in centimetric, irregular patches in the feldspar.

Figure 5. **Asbestos-like tourmaline from No. 1 vein. The specimen is 4 cm in length.**

Columbotantalite. Specimens up to 10 cm in length are sporadically collected. Crystals are always cracked or with only a few good faces (adit 1 b and No. 2 vein).

Coeruleolactite. Very rare, it occurs in cryptocrystalline veinlets crossing earthy amblygonite (adit 1 J). Color is very light green, and it does not occur as good specimens or cutting fragments.

Manganese oxides and Fe-Mn phosphates. They are very common near the surface as dark or brown thin coatings on quartz of the core. Specific determination of the phosphates was not carried out (adits 1 b, 1 B, 1 C and 1 E).

Torbernite in small crystals and **phosphuranylite** in thin coatings are scattered in gray fetid quartz (adit 1 C).

CONCLUSION

After the end of World War II, mining activity practically ceased in the Cruzeiro property, and the mine, like many others, would today be only a glorious remembrance if outstanding gem elbaite had not been found there after the war.

Presently mica production supports the workings. *Garimpeiros* work in leased areas with hand-blasting and haulage to search out the scarce and famous gem.

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First Discovery of Ruby in Australia

by **D. H. McColl** and **R. G. Warren**
Canberra College of Technical and Further Education
Constitution Avenue
Canberra City, A.C.T. 2601
Australia

In 1978 the first commercially significant discovery of ruby in Australia was made in the Harts Range, Northern Territory. The ruby occurs as sharp crystals of good color, but to date little material of value for faceting has been found. The prospective area is extensive and further discoveries are likely. The host rock is an amphibolitic complex, interpreted as a development from a terra rossa soil profile formed on a limestone contaminated with pyroclastics and interlaminated with lavas and tuffs.

INTRODUCTION

The Precambrian Arunta inlier of central Australia has produced occasional specimens of corundum from various sites within the Harts Range for several years (Joklik, 1955). Most of this is of no gem significance, being almost opaque and ranging in color from cream and pale greenish grey to pink or pale reddish tints, but previously the bright red variety colored by chromium, known as ruby, had not been found.

During the latter part of 1978, J. R. Bruce of Alice Springs observed that corundum crystals excavated from subsurface outcrops in the vicinity of Mount Brady were pinker than any previously recovered. Exploratory bulldozer trenching was carried out on various areas held under lease or exploration license by Hillrise Properties Pty. Ltd. of Melbourne. Several hundred kilograms of red corundum were recovered from these initial excavations, which are nowhere deeper than 5 meters. Chelsea filter examination of these specimens showed the presence of appreciable chromium.

Pink and lilac shades of gem sapphires have been known as a rarity in the alluvial deposits of the Great Dividing Range in Eastern Australia (Oughton, 1973), and a reddish corundum was recently noted at a site in the Harts Range only 25 km distant from the new find (Males, 1976), but most so-called Australia "rubies" have actually been almandine garnets (Rennie, 1889), and Australia has been regarded as deficient in true ruby. This discovery is the first ruby deposit recorded in Australia, having commercial significance. It is located 6 km southeast of Mount Brady in the eastern Harts Range (Lat. 23°05'S Long. 135°02'E). This is about 250 km by road from Alice Springs, and is on the northeastern corner of the Illogwa Creek 1:250,000 sheet area.

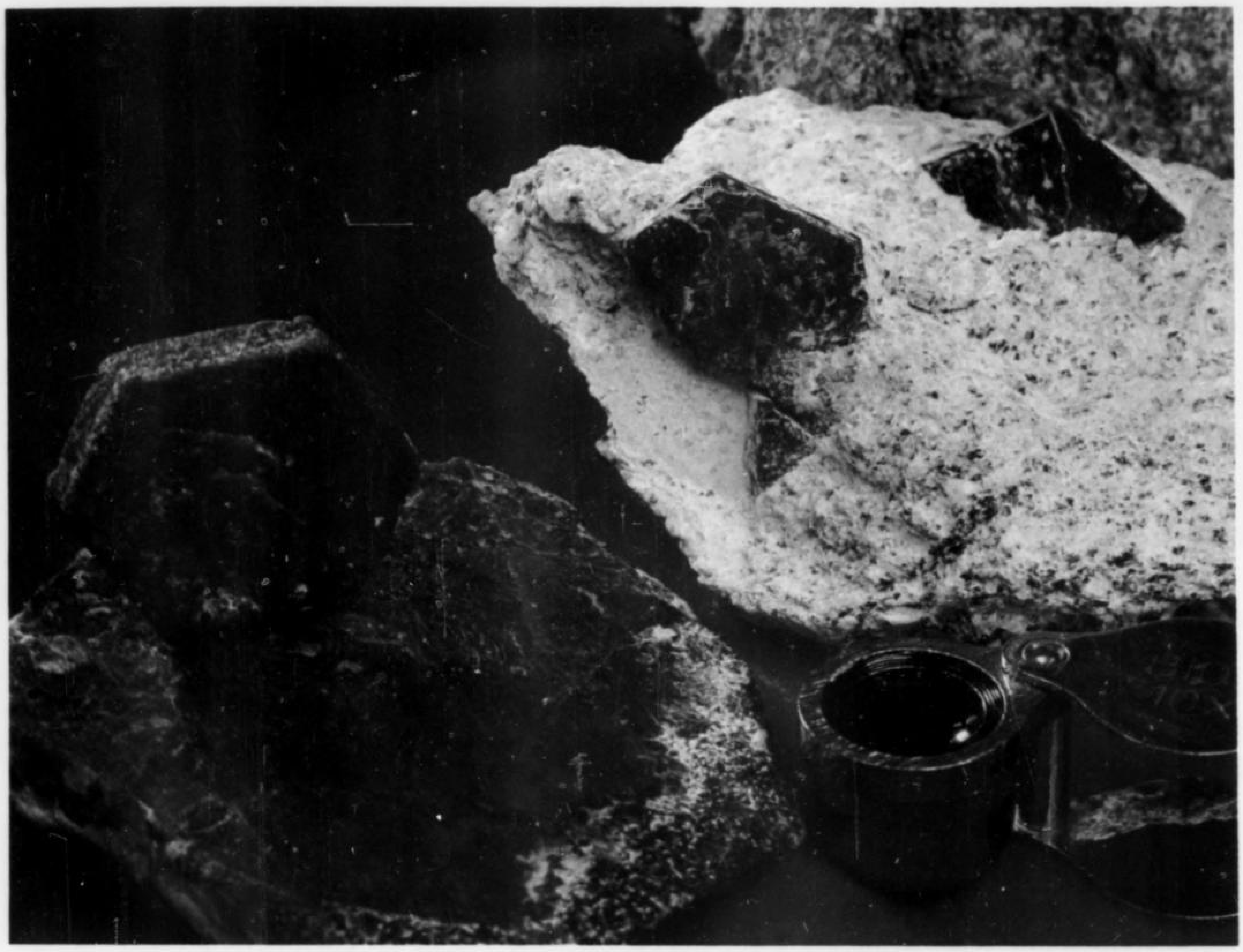
MINERALOGY

The ruby occurs either as well formed, hexagonal, tabular crystals up to 5 cm in diameter and 1 cm thick, or as roughly ovoid masses up to 12 cm long, which are anhedral single crystals. The smaller discrete crystals generally show the best ruby color. The larger pieces are hexagonally zoned in shades of red and are generally more opaque. The largest single fragments recovered weigh about half a kilogram. Very little fully transparent ruby has been found; the small to medium size crystals are commonly translucent, but the larger pieces are grossly clouded with fine gas-filled fissures roughly following the rhombohedral parting directions. Scarce mica flakes (phlogopite?) and accessory rounded subhedral zircons are present as inclusions in the peripheral zones of some crystals.

The refracive indices measured on a polished crystal are 1.760–1.768. The specific gravity is 3.98, which is slightly lower than usual—possibly due to the gas-filled fissures. The optical transmission spectrum shows a typical chromium pattern, with a fluorescent line at 6935Å, broad absorption band from 5200Å to 6000Å, dark lines at 6590Å, 4780Å and 4710Å, and almost total absorption of the violet. The Chelsea filter reaction is strong.

Chemical analysis of a representative sample of cleaned ruby crystal fragments gave the following minor components content (Amdel, 1979).

Element	Percent
Fe —	1.93
Si —	0.33
Cr —	0.31
Ti —	0.02



This is comparable to ruby from other countries, although the higher iron content contributes a faint bluish or purplish tint, which is regarded as a disadvantage. The titanium content is very low by comparison with most foreign rubies and Australian sapphires, and implies that asterism will probably not be seen. The high iron content also accounts for the very weak ultraviolet fluorescence.

In lapidary trials cabochons have been cut from ruby crystals of good color with quite pleasing results. The quality of the polish is excellent and the inclusions do not result in appreciable pitting or undercutting of the surface unless more prominent fractures are present, which may have been caused in part by near-surface weathering and mining shocks.

REGIONAL GEOLOGY

The ruby is found in a distinctive layer of greenish gneiss of very unusual composition within the Riddock amphibolite. The Riddock amphibolite is a prominent ridge-forming member of the Irindina gneiss, part of the Harts Range group (Joklik, 1955) of Precambrian age. The group is approximately 1,800 million years old (Shaw and Langworthy, in prep.).

The Irindina gneiss generally consists of garnet, biotite, feldspar and quartz. It is the host for the now-abandoned mica mines of the Harts Range. Scapolitic marbles interlayered with the Irindina gneiss suggest it was deposited in an intermittently arid climate.

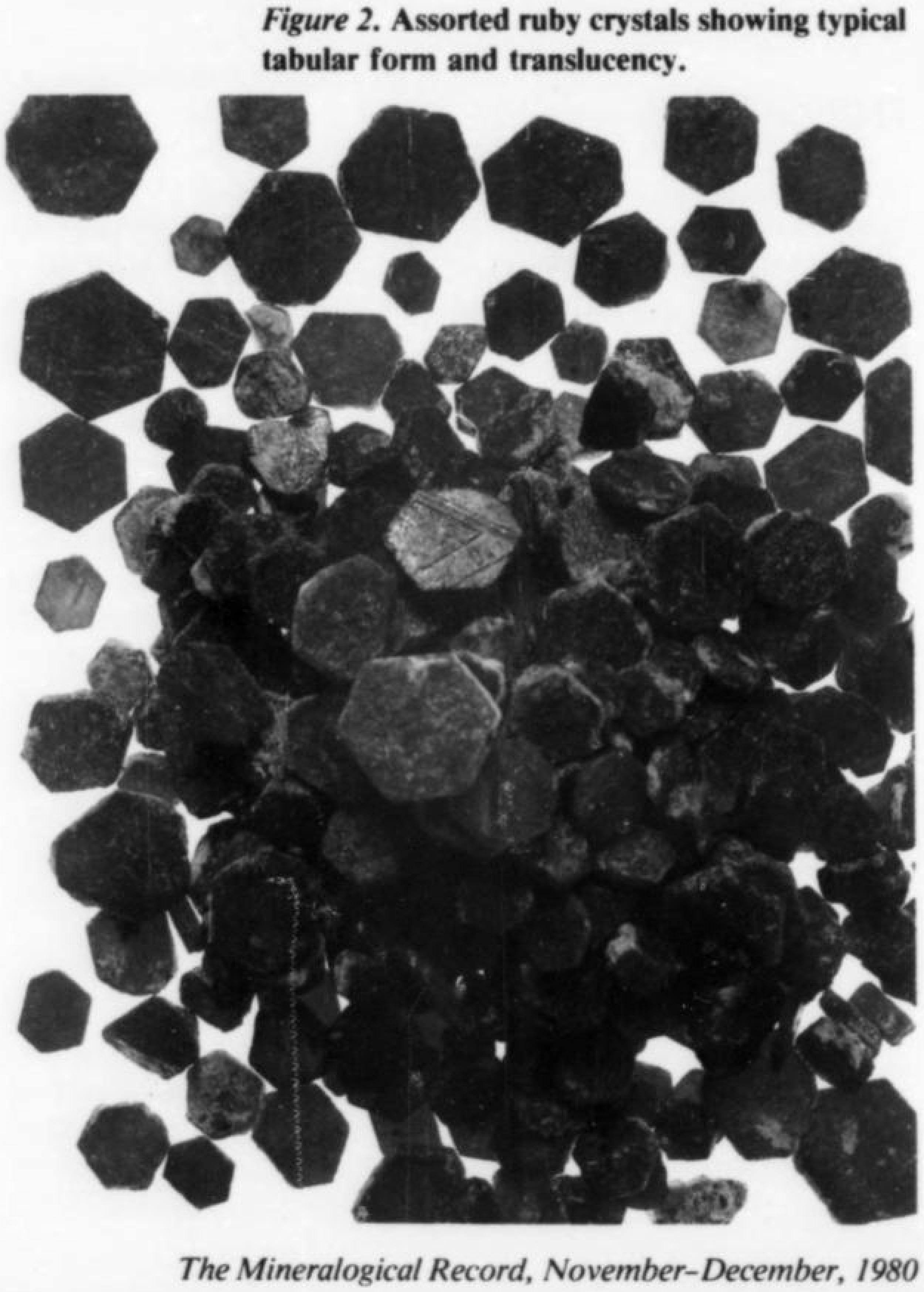
The Riddock amphibolite is a layered sequence interpreted as a succession of mafic lavas, sills, tuffs and minor sediments. In the Harts Range it is up to 1000 m thick, but thins out to the north and east. The analysis given by Joklik (1955) is of a typical basic igneous rock, but a later analysis also of a massive amphibolite (Shaw, unpublished data) suggests that some weathering or introduction of carbonate affected parts of the unit prior to metamorphism.

GEOLOGY OF THE RUBY-BEARING LAYER

At the ruby occurrence the Riddock amphibolite contains a persistent light-colored para-amphibolite (metamorphosed impure

Figure 1. **Hexagonal tabular crystals of ruby in anorthite-hornblende gneiss from the new discovery.**

Figure 2. **Assorted ruby crystals showing typical tabular form and translucency.**



limestone) which contains lenses of greenish gneiss which in turn are the actual ruby host. The para-amphibolite is about 50 m thick and is fairly well exposed as a flat-lying band, along a strike of 15 to 20 km, all of which is considered prospective for ruby. The greenish gneiss layers are quite different from the enclosing amphibolite and are sharply bounded against it. They are commonly grossly lenticular, swelling from a thickness of a centimeter or so to as much as 4 m within a strike length of only 10 m. A schematic cross-section of one such lens is shown in Figure 3. The lenses are sporadic in distribution, but appear always to lie concordantly within the enclosing amphibolite, despite minor distortions effected by later tectonism.

Figure 3. **A general view of the main exposure at the ruby locality.**

The greenish gneiss consists of magnesian common hornblende, anorthite (An 95), chlorite (clinochlore?), magnesian chromium spinel, and ruby corundum (Table 1). Minor amounts of a brown mica also occur along sheared surfaces. This may be phlogopite or a variant of the chlorite seen in thin sections. The best ruby crystals occur mainly in lenticular, somewhat dislocated leucocratic bands in which the proportion of anorthite may exceed 90 percent. The larger ovoid ruby masses occur toward the base of the gneiss lens as irregular segregations. Pods of massive crystalline tourmaline also occur intermittently near this lower lens boundary, often in close proximity to the corundum. Immediately below the lens boundary

Figure 4. **Drilling holes for blasting during exploratory trenching at the ruby locality in the Harts Range.**

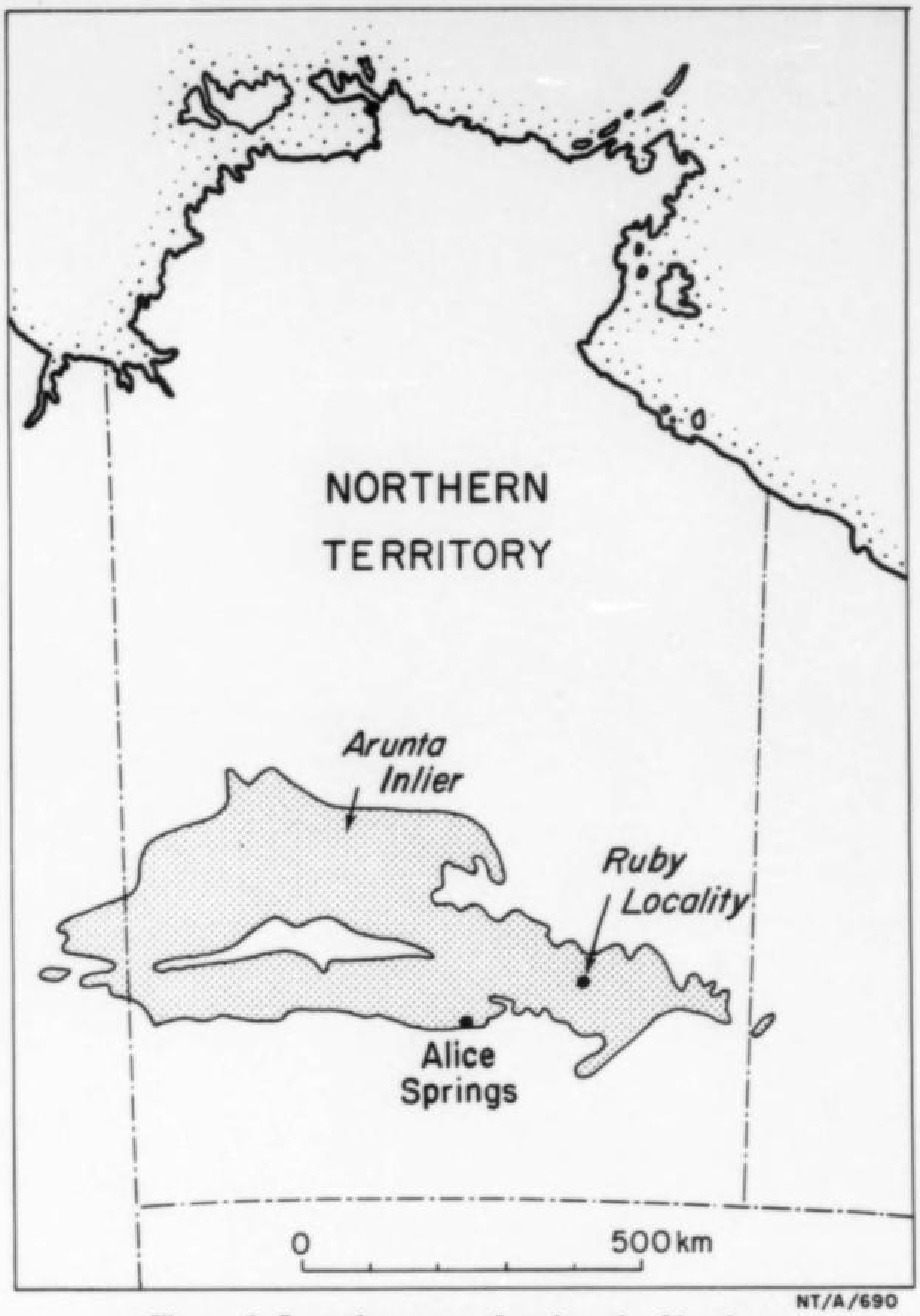


Figure 5. **Location map showing the Northern Territory of Australia, the Arunta inlier, and the new ruby locality.**

a few coarse, similarly ovoid masses of garnet occur within the amphibolite.

Retrogressive alteration of all the rocks in the region has accompanied later mild tectonism, in which thin transgressive quartz and pegmatite veins have cut across the lens and the amphibolite. Some fracturing of ruby crystals has resulted and thin coatings of sericite now cover the crystals (or fragments). When chromium is especially abundant the bright-green chromium mica, fuchsite, has also formed.

ORIGIN OF THE DEPOSITS

The high calcium content of the ruby-bearing layer suggests that calcite was a dominant component in the protolith. The present aluminum content is also high for a normal clay. It is therefore considered that aluminosilicates in the protolith were in part converted to gibbsite before the ruby-forming metamorphism took place.

We believe that the following stages have been involved:

(i) The para-amphibolite developed from a chemically deposited shallow-water marine limestone, which was heavily contaminated with volcanic detritus or wind-borne pyroclastics.

(ii) During subsequent regression, weathering and erosion of this limestone developed a partial karst topography with hollows or possibly caves becoming infilled by a lateritic "terra rossa" soil profile and layers of near-surface calcrete. These pockets of gibbsitic clays could form during seasonal drying of the profile, alternating with leaching of sodium and soluble salts. Effectively this would cause an enrichment in lime, magnesia, alumina, iron and chromium.

(iii) Preservation of these basin fills by subsequent transgression coupled with deposition of further pyroclastics.

Metamorphism of soil profiles such as these suggested could lead to formation of the rock types observed in the greenish gneiss lenses. The chromium would be derived from the volcanics which

Figure 6. **A diagrammatic sketch of a cross section through a ruby-bearing lens.**

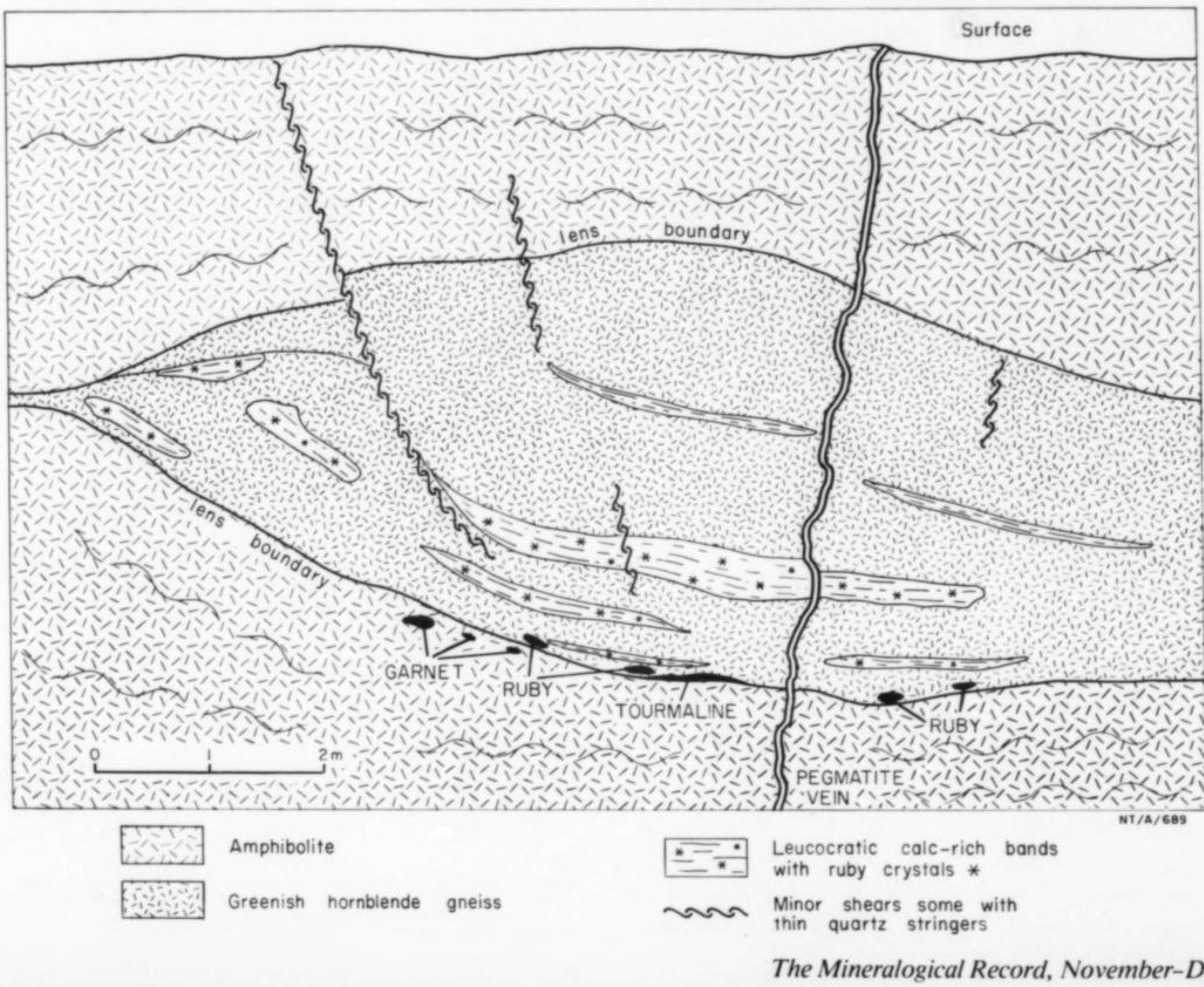


Table 1. **Microprobe analyses of minerals from ruby-bearing rock.**

	Plagioclase	Plagioclase	Plagioclase	Amphibole	Amphibole	Spinel**	Spinel**
SiO_2	43.72	43.79	44.18	41.79	44.63	—	—
TiO_2	—	—	—	.15	.15	—	—
Al_2O	35.70	35.70	36.00	18.35	16.18	43.18	40.02
Cr_2O_3	—	—	—	1.00	.85	20.84	23.77
FeO*	—	—	—	6.03	6.73	27.65	26.11
MnO	—	—	—	.00	.11	.36	.41
MgO	—	—	—	12.47	15.31	7.75	8.97
CaO	19.34	19.46	19.61	13.74	11.85	—	—
K_2O	—	—	—	.21	.28	—	—
Na_2O	.65	.69	.41	1.38	1.70	—	—
Total	99.42	99.64	100.20	95.12	97.80	100.98	100.12
	An 94.3	An 93.9	An 96.3			**ZnO = 1.56	ZnO .92

FeO* Total iron expressed as FeO.
The chlorite could not be satisfactorily analyzed. However it is very aluminous, and magnesian and contains traces of Cr_2O_3 and NiO.

generally have a content of 200 ppm. This content would need to be enhanced by a factor of 10 to 20-fold in the ruby-bearing horizon.

While geological study of the Harts Range ruby deposit is still continuing, the similarity of this deposit to that which is already being mined at Hunza in Kashmir is noted, and a similar genetic origin seems likely (Okrusch, Bunch and Bank, 1976).

ACKNOWLEDGEMENTS

The authors wish to thank N. and T. Crowley, T. Sloggett and J. R. Bruce of Hillrise Properties Pty. Ltd. for continual assistance with this investigation, and for provision of specimen materials. Two of the photographs were provided by Hillrise Properties Ltd. and were taken by W. Leo Russell of Melbour.·:.

Microprobe analyses were carried out at the Research School of Earth Sciences, Australian National University, with assistance from N. G. Ware.

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a new find of crystallized Rose Quartz in minas gerais

by **J. P. and J. O. Cassedanne**
Federal University of Rio de Janeiro, C. N. Pq. & FINEP
Instituto de Geociências, Cidade Universitária
Rio de Janeiro, Brazil

The Taquaral-Itinga region in the Jequitinhonha Valley, Minas Gerais, is known worldwide for crystallized rose quartz from the Lavra da Ilha pegmatite (Cassedanne and Cassedanne, 1973). A nearby new prospect on the mainland has recently produced magnificent, richly colored samples of crystallized rose quartz.

LOCATION AND ACCESS

The prospect, known as *Laranjeira* ("orange tree") or *pegmatito do Ademar* ("Ademar's pegmatite") lies in the Taquarai district, township of Itinga, in the neighborhood of Laranjeira Creek, on the right side of the Jequitinhonha River (see location map).

Access is by way of Itaobim (km 846.5; elevation 220 m) on the paved road that joins Rio de Janeiro to Salvador. From Itaobim a good dirt road goes toward Araçuai passing Itinga (31 km from the highway) and Taquaral (47 km from the same). At 6.4 km before Taquaral, a jeep road forks to the left which leads in 300 meters to the prospect at an elevation of 250 meters.

The region is gently undulating with low bush vegetation and small patches of dry forest.

DESCRIPTION OF THE PROSPECTS

Workings started in early 1979 at the top of a small, low, wooded hill, 30 meters above the level of Laranjeira Creek. Numerous small excavations in the buff-colored clayey-sandy eluvium, irregularly scattered in a subcircular-shaped area approximately 600 meters in diameter, were dug in search of gem tourmaline. The hand-dug pits, roughly square, from 2 x 2 to 10 x 10 meters, are sunk in the soil, the thickness of which reaches up to 6 meters. In May of 1979 a deeper pit encountered the unexpected pegmatite, covered by eluvium. Presently the pegmatite is mined in five prospects, small tortuous adits diverging from the bottom of the pits, and reaching down to 10 meters in depth from the surface. Only one 20-meter adit is driven horizontally to the south *(galeria do Ademar)*. The white dumps from the pegmatite contrast with the buff-colored ones from the eluvium.

The pegmatite runs northwest-southeast with a northeasterly dip of approximately 20°. It is heterogeneous with large grain size but superficially kaolinized. Near the quartz core there are irregular vugs *(caldeiroes)* that contain the crystallized rose quartz *(canga rosa)*. The sizes and shapes of these vugs are variable, but in some cases they reach up to ! meter in length.

DEPOSIT LOCATION IN THE STATE OF MINAS GERAIS

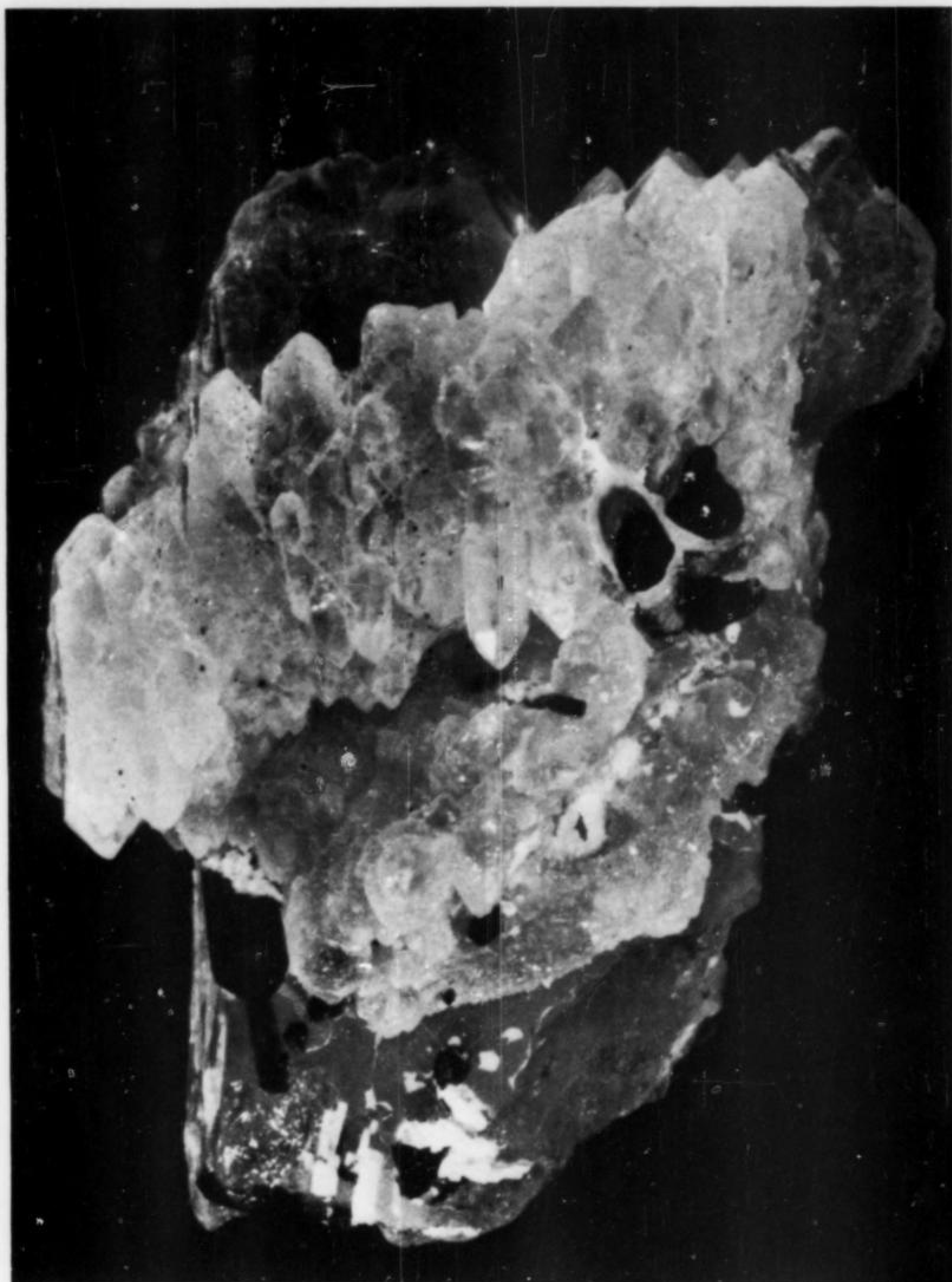

Figure 1. **A crown of crystallized rose quartz around a milky quartz crystal. The black material is elbaite. The specimen is 8 cm tall.**

Figure 2. **White quartz with a cluster of crystallized rose quartz. The specimen is 7 cm tall.**

The pegmatite, approximately 100 meters in length, has a relatively small thickness which is at present not accurately determinable.

Regional rocks belong to the Macaubas group of Upper Precambrian age. These are mainly quartz-mica schists with biotite, sericite and accessory cordierite, garnet and andalusite. The schist runs northeast-southwest with a regional northwesterly dip (Da Costa and Romano, 1976). The group is 650 million years old with intrusive granites (520 m.y.) and pegmatites less than 500 m.y. old (Sá, 1977).

CRYSTALLIZED ROSE QUARTZ

Crystallized rose quartz is always found in the vugs occurring close to the quartz core. These vugs are filled by a beige clayey material and lined by quartz crystals with stepped faces. They are commonly transparent, reaching up to 20 cm in length and terminated by a 3-faced rhombohedron.

The rose quartz occurs either as a partial or whole crown around quartz crystals, transparent or milky, sometimes fetid when broken, or it fills up the interstices between the translucent quartz crystals.

Crowns are the most spectacular specimens. Their axis of symmetry may be the same as that of the supporting quartz, or they may be undulating. Some specimens display a cluster of crystals lying upon a face of a milky quartz crystal, reminding one of the "quartz flowers" occurring in the southern Brazil amethyst region. Small crowns of crystallized rose quartz around tourmaline crystals are known but are uncommon.

The crowns are made of interpenetrating small prisms and rhombohedrons whose axes are subparallel or divergent to the surface; the result is dazzling. Growth figures on the crystal faces are common as repeated "scepter" forms. A thin coating of powdered white quartz sporadically covers the rose quartz groups.

Color ranges from light pink to purplish pink, reminding one of the famous old samples from the Sapucaia mine in the same state. The crystals are transparent to translucent with, on the whole, a relatively homogeneous coloration. However light variations of shade may be observed with a lens.

Black or green-blue to water-green elbaite, sometimes with chatoyancy, is commonly associated with the rose quartz, but crystallized phosphates never occur. This observation permits easy distinction from the samples produced at the nearby Lavra da Ilha pegmatite.

The crystallization sequence is: feldspar—tourmaline—transparent to milky quartz—rose quartz.

The bulk of the production is sold in Taquaral, mainly by José Batista Coitinho (José da Estrada), a mineral dealer. But some good pieces also may be purchased directly from the *garimpeiros* at the mine. The most valuable samples are long, transparent, terminated quartz crystals with a dark rose crown of crystallized rose quartz.

OTHER MINERALS

Other minerals identified through our visits are:

Quartz. Milky and massive, it also appears in transparent or translucent multidecimetric prisms and pyramids in the vugs.

Feldspar. Beige to cream-colored, potassium-feldspar is very common, sometimes in multidecimetric crystals *(galeria do Ademar),* or with cleavelandite vugs partially filled with clay.

Muscovite. Frequently twinned in multicentimetric crystals, it is abundant in the dumps.

Elbaite. Always broken in rounded or subangular pieces in the eluvium, it is green, green-blue or rose, frequently of gem quality. In the pegmatite it appears as elongated crystals or parallel groups with some chatoyancy. Crystals in the matrix are frequently broken and slightly twisted. Elbaite is molded by or embedded in the rose quartz.

Amblygonite. Milky to beige, it is always of fine grain size.

Lepidolite. Scarce, it occurs as centimetric lilac-colored plates.

Beryl. Milky to translucent, cracked, it is uncommon, in small irregular crystals.

Spodumene. Chalky, partially altered, it occurs sparingly.

Cassiterite and tantalite are scattered in small disseminated patches.

Frondelite. Irregular buff to brown-colored cavernous nodules are sparsely disseminated in the feldspars. They result from the decomposition of primary phosphates not yet found, and are mainly limonite with manganese oxides, quartz and feldspar fragments. Some needles and radial clusters of red-brown to orange-brown frondelite (X-ray determination and Fe_2O_3/MnO ratio of 48.94/10.76 percent with 0.84 percent FeO) occur sporadically through these nodules.

Wardite. Very fine transparent crystals less than 2 mm in length, with smooth faces are frequent in the vugs of the hydrothermally altered feldspar. This is partially pseudomorphosed to kaolin, which allows the phosphate crystals to be easily separated. Excellent micromounts of single crystals or groups perched on milky cleavelandite, in small vugs, may be easily collected in the dumps (ϵ = 1.582; ω = 1.590, both $\pm$ 0.001).

Garnet and sulfides were not observed.

Noteworthy is the lack of crystallized phosphates (eosphorite, roscherite, wardite; Cassedanne and Guillemin, 1971) in association with rose quartz and the lack of crystallized translucent amblygonite, in contrast to the nearby world-famous Lavra da Ilha deposit.

Although the production is just beginning, the important valuable material already extracted, from micromount to museum size and quality samples, guarantees that the Laranjeira prospect will become in the future, a world-renowned occurrence of fine crystallized rose quartz.

ACKNOWLEDGMENTS

Thanks to our colleague Richard V. Gaines who kindly revised the English manuscript.

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TUCSON 1981

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What's New in Minerals?

WHAT'S *OLD* IN MINERALS?

Since the last installment of this column in the September–October issue, nothing new has come to the fore. So, for a change, this installment will look back on some previously mentioned items, and also on some old occurrences which never did get mentioned in earlier columns due to lack of space. Rifling through the *Record*'s old file of unused photos was quite a pleasure, and more photos than those shown here could certainly have been chosen, but these make an interesting enough selection. Rather than attempt to discuss or re-discuss them here in the text, I've put all of the appropriate information into the figure captions.

As this is reaching readers the annual Pasadena Show should be underway, and the famous Detroit Show will have recently passed into history for another year. The next issue will carry a report on these shows.

W.E.W.

Figure 1. (right) **This unique ivory carving was made in mainland China and depicts miners at work. Well, not all of them are at work . . . some are simply holding up their little books of the sayings of Chairman Mao. The carving is about 8 inches tall and was offered for sale by one of the dealers on the ground floor of the Holiday Inn during the 1976 Detroit Show.**

Figure 2. (below left) **A year or two ago Jack Hannahan, of Belmont Abbey College in North Carolina, sent us this enormous crystal of rutile to be photographed. The large crystal measures about 5 inches and is perched with another large crystal on a very friable matrix. The specimen is from Graves Mountain, Georgia.**

Figure 3. (right) **This remarkable collection of fine blue aquamarine crystals is from the well-known locality in northern Espirito Santo, Brazil. The group of specimens was offered by Oceanside Imports at the 1978 Intergem Show in Washington, D.C.**

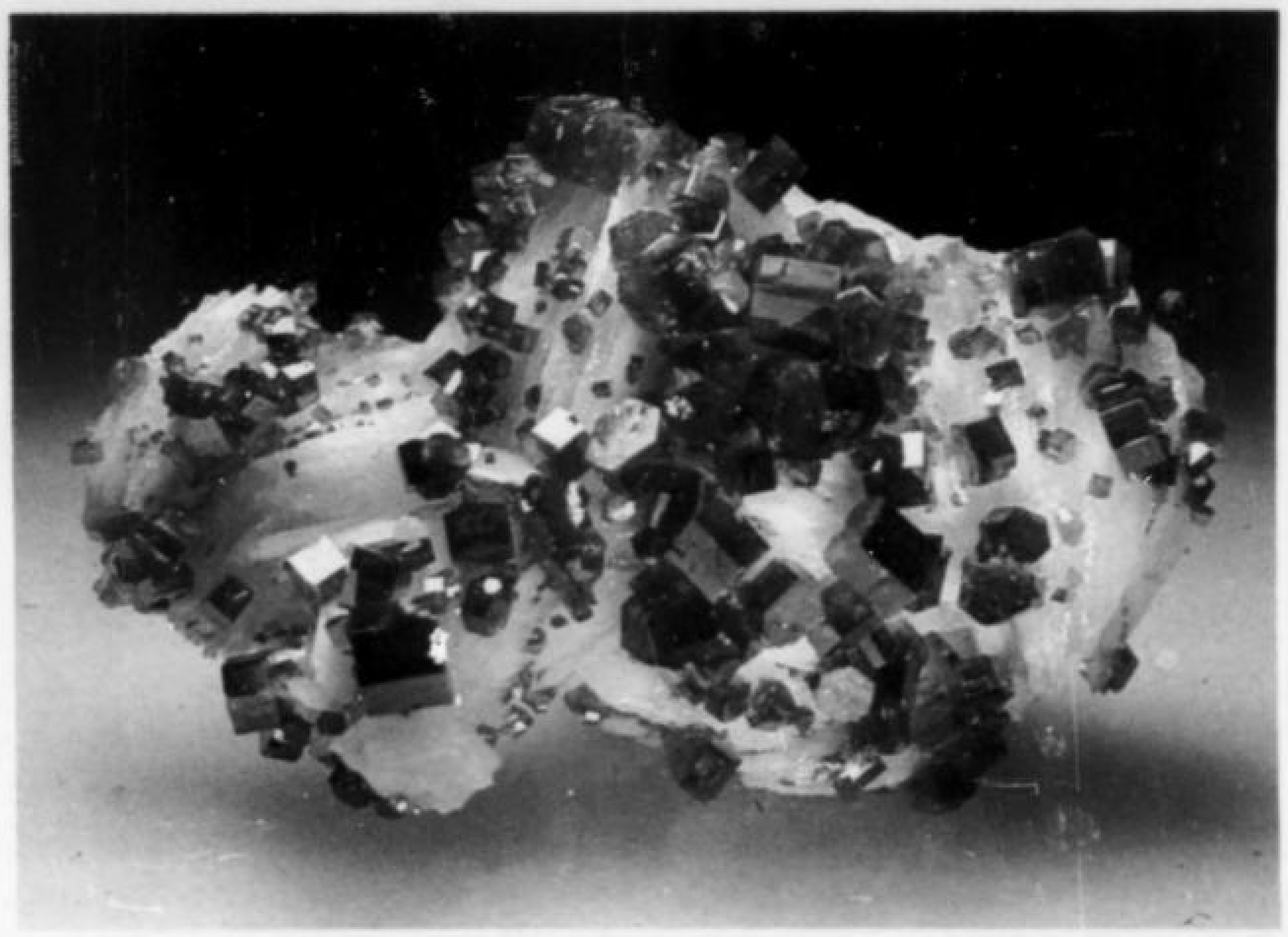


Figure 5. Here is one of the recently found vanadinite specimens with white barite matrix. The crystals reach about 0.3 inches. Victor Yount specimen.

Figure 4. Shown above is one of the giant rubellite crystals (this one is 22 inches tall and nearly 7 inches in diameter) from the Minas de Jonas, Itatiaia district, Minas Gerais. These remarkable crystals have been described earlier in the *Record* (9, 298; 9, 317; 10, 33), but this is the first of the really large crystals to be photographed. Some estimates have indicated that as much as 4 *tons* of fine rubellite have been removed from the mine.

The specimen shown here has, through the assistance of friends, been acquired by the Smithsonian and will soon go on public display. It is doubly terminated and shows almost no damage. The crystal, a rich cranberry red, could yield tens of thousands of carats of fine gems so that its value is easily several million dollars. Value aside, it is certainly one of the most extraordinary specimens that a collector might ever have the opportunity to see. Photo by Dane Penland.

Figure 6. Sharp and well formed as originally reported, this specimen is from the lot of cinnabar obtained from Kweichow province in mainland China. Russell Behnke specimen. The large crystal is about ½-inch across.

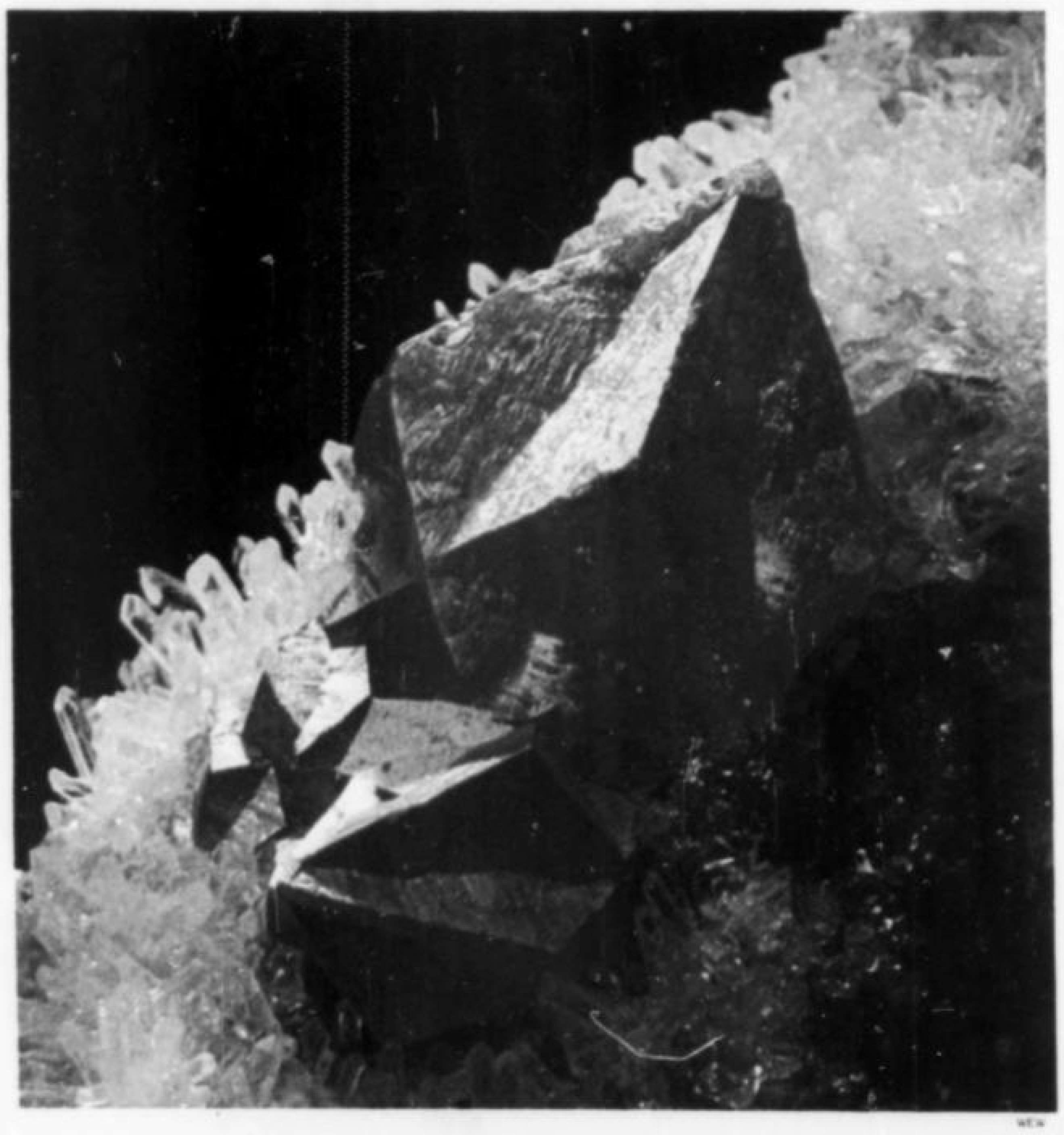
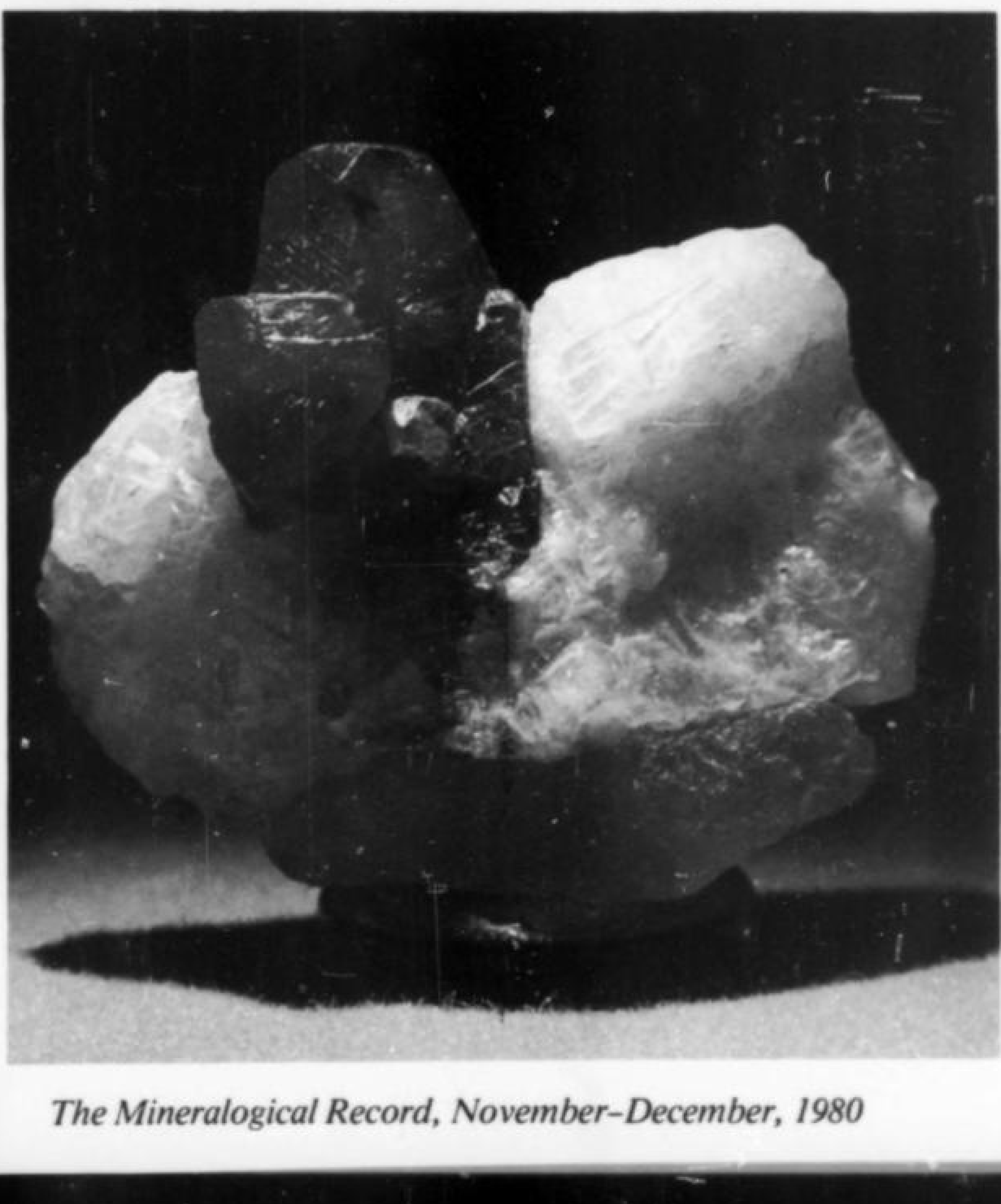


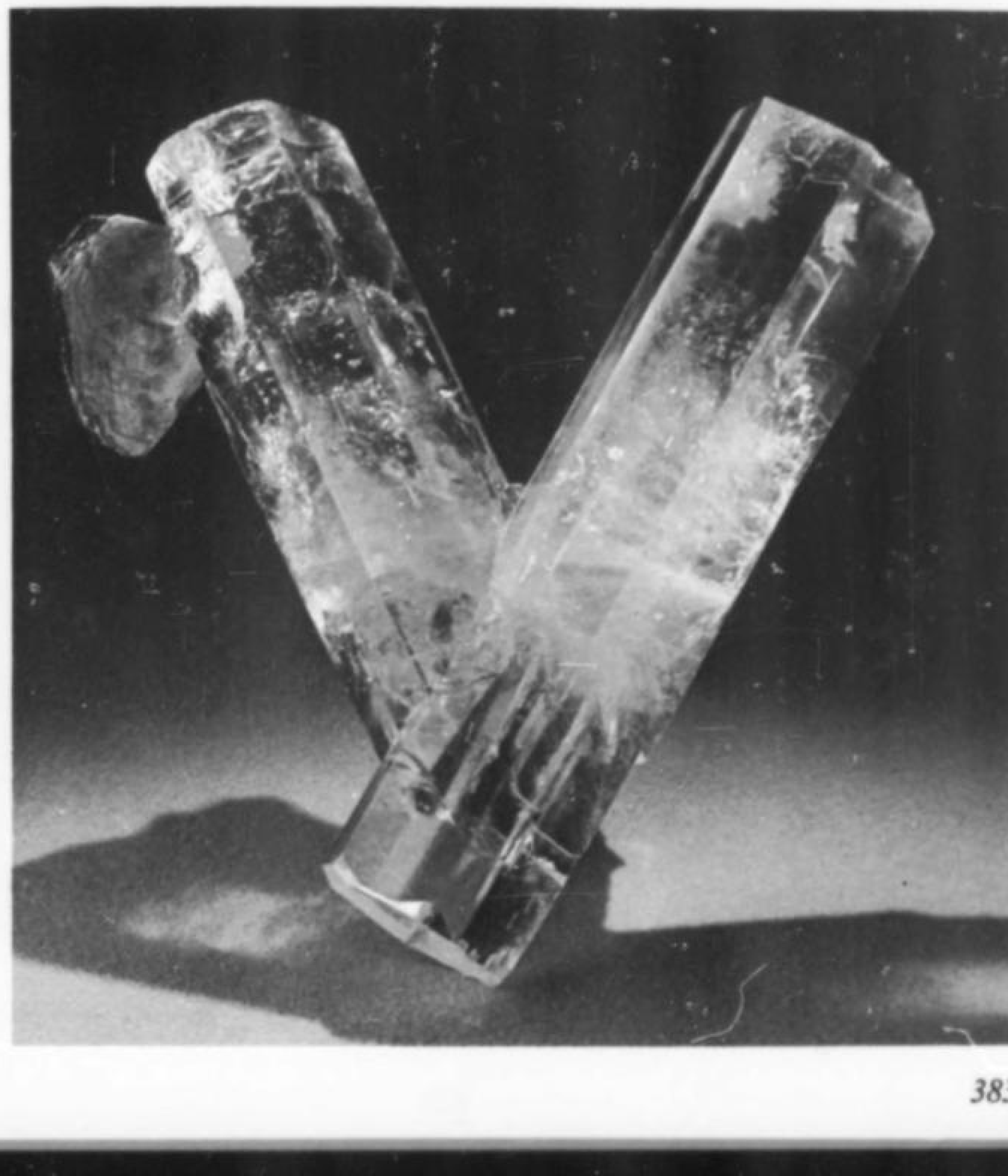
Figure 7. (left) A pale yellow anglesite crystal on matrix from Morocco. The crystal is about 1 inch long. Pala Properties specimen.

Figure 8. (below) A superb kunzite crystal with white albite matrix and short green elbaites from Afghanistan. This and the next two specimens are from the lot which David Wilber recently obtained through Herb Obodda. The crystal is about 2.7 inches tall. Photo by Gem Media, copyright 1979.

Figure 9. (below right) Perhaps the most esthetic Pakistan aquamarine yet found, this magnificent crystal group measures about 3 inches on the longest crystal. David Wilber specimen. Photo by Gem Media, copyright 1979.

Figure 10. (below left) A group of finely colored ruby crystals 0.8 inches tall on white matrix from Jegdalek, Afghanistan. David Wilber specimen. Photo by Gem Media, copyright 1979.





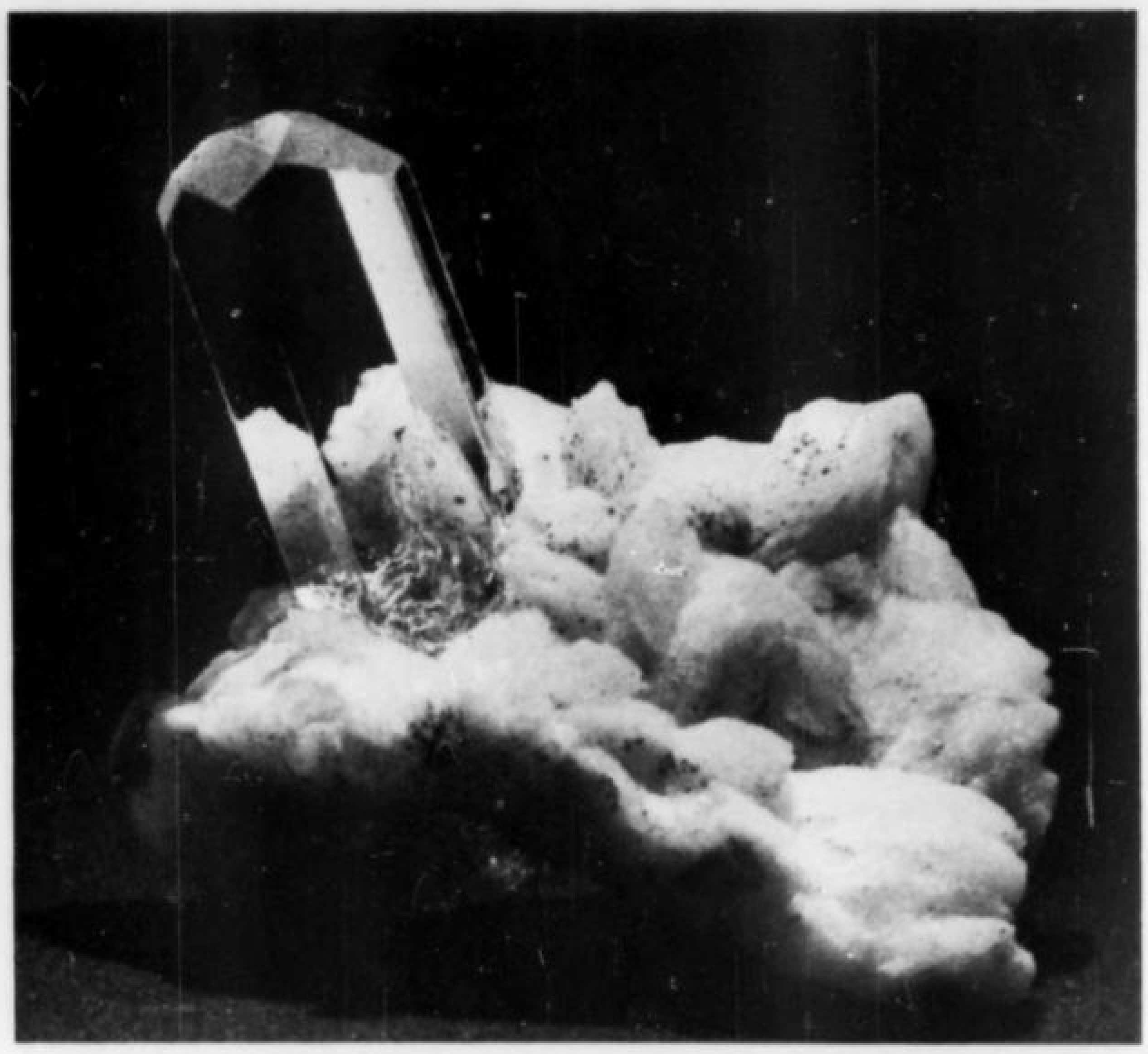


Figure 11. A perfectly water-clear, 1-inch, pale blue aquamarine crystal on white albite matrix from Pakistan. David Wilber specimen. Photo by Gem Media, copyright 1979.

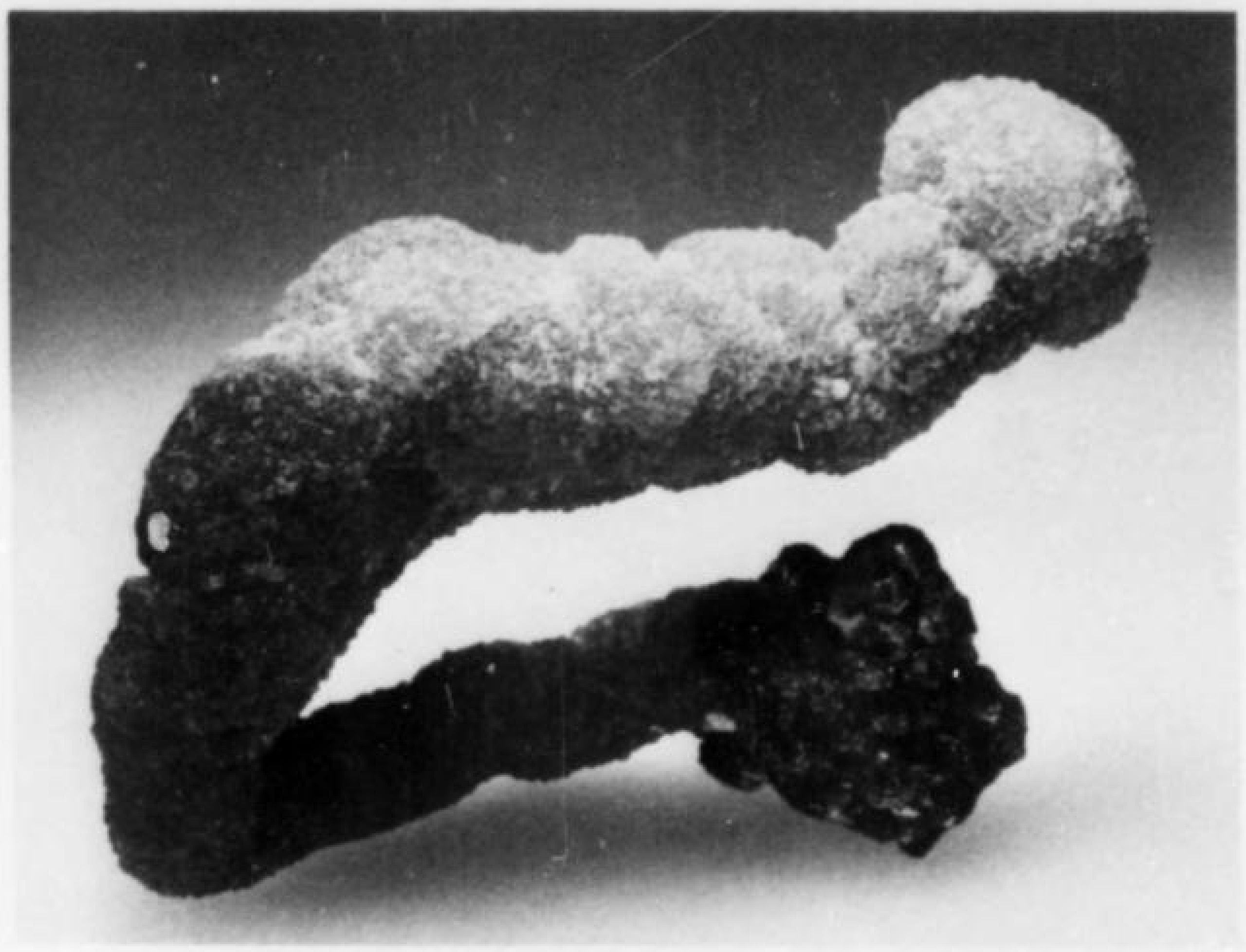
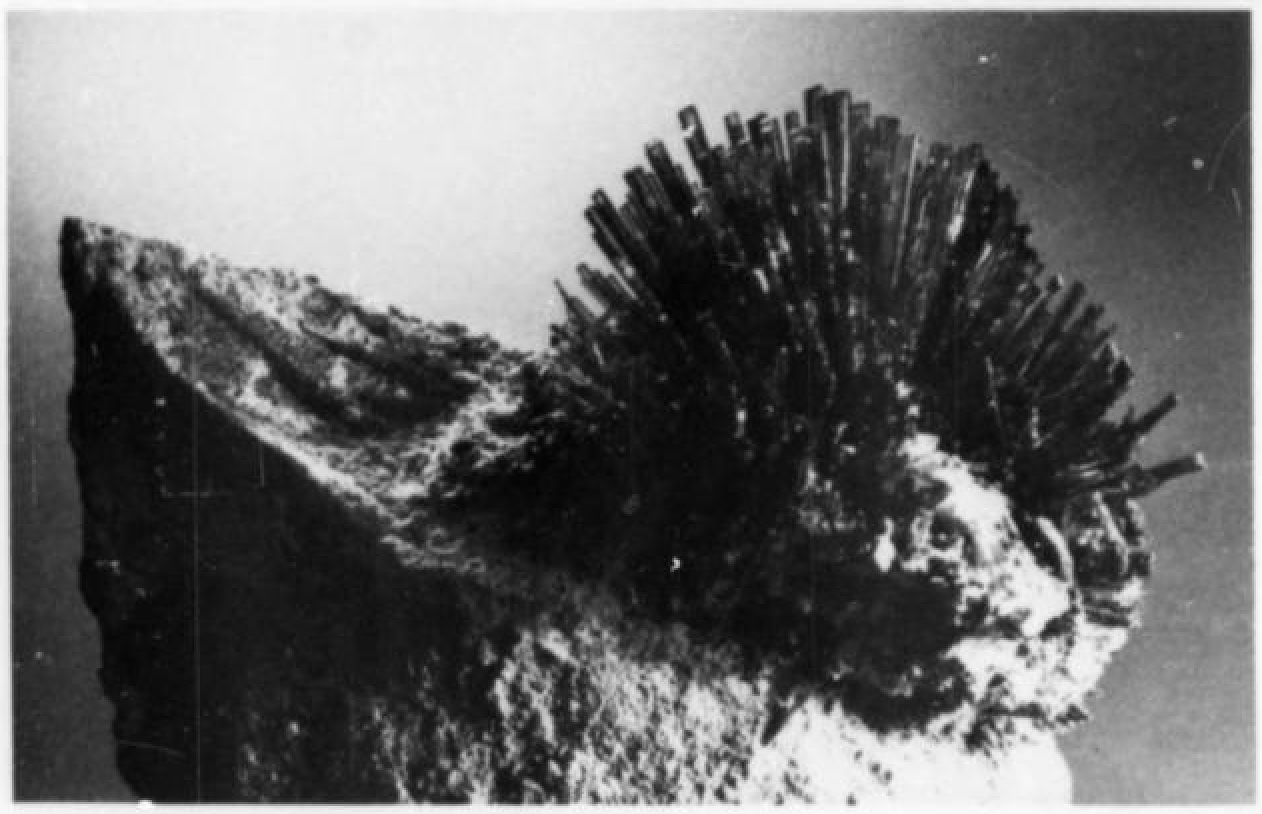


Figure 12. An interestingly shaped, deep rose rhodochrosite specimen from Santa Eulalia, Chihuahua, Mexico. The specimen is 4 inches across. Ken and Betty Roberts specimen, displayed in their booth at the 1979 Detroit Show.



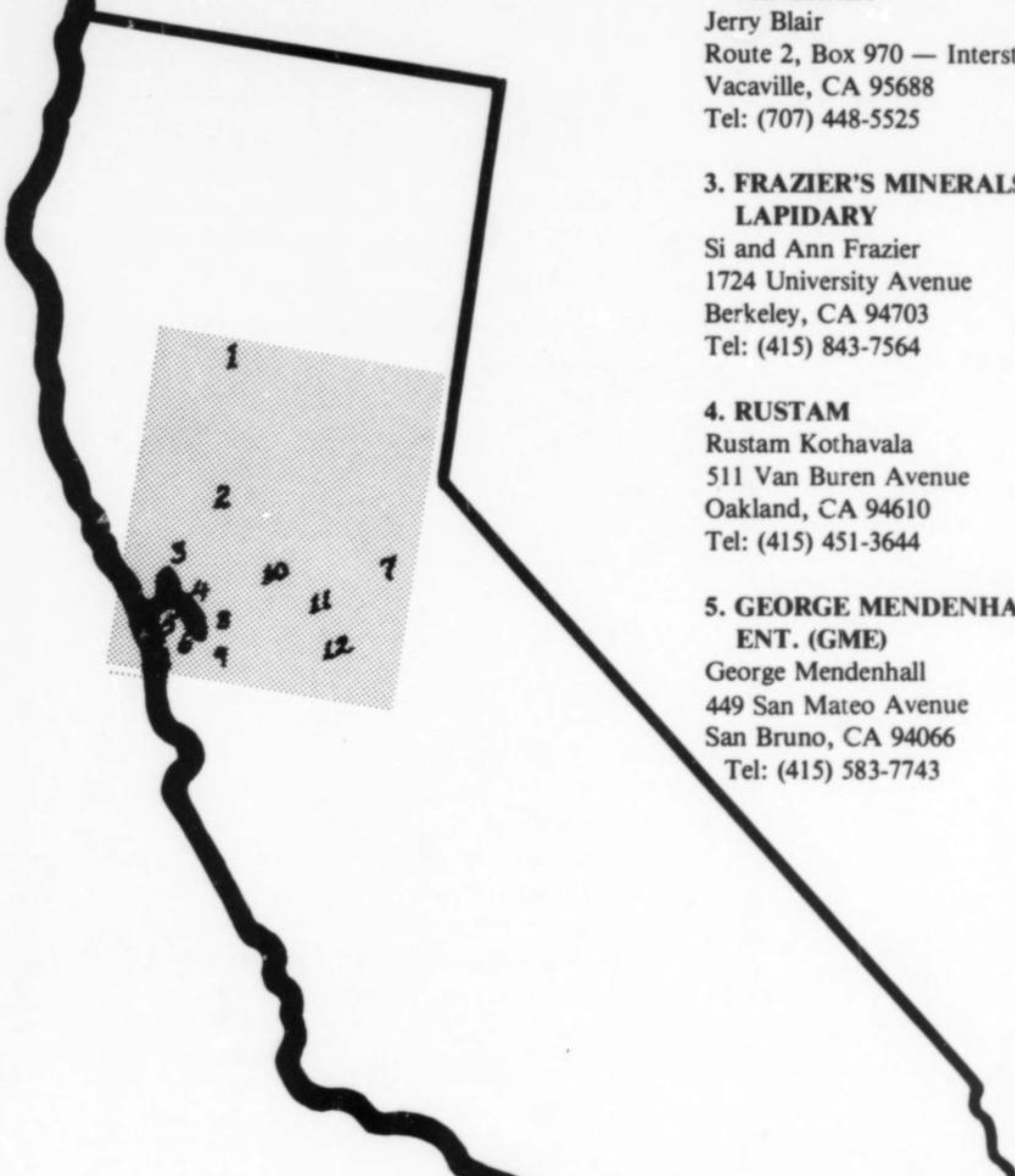
Note: See page 386 for notice of the annual slide competition.

Figure 13. Fine green vivianite crystals on matrix from Bolivia. The spray is about 2.5 inches across. Victor Yount specimen, photographed in 1978.

Figure 14. David Wilber beside his case of minerals at the 1974 Lincoln, Nebraska, federation show. You'd smile too with minerals like those.

Northern California Dealers

Northern California has many quality mineral dealers. Some are wholesale, some are both wholesale and retail, all give quantity discounts to dealers. Come and see us the next time you're in the West. (Appointments are encouraged, as travel for specimens often takes dealers away.)



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ANNUAL SLIDE COMPETITION

With the Tucson Show coming up in February it's time once again for all you mineral photographers to look through your files and send us your best two slides.

Rules:

1. The following information must be *on each slide*
   a. Mineral name and location
   b. Your name and mailing address
   c. "AM" for "amateur" or "PRO" for "professional." Only those who have never been paid for photography and have never won first place in the *Record* slide competition are "amateurs."

2. Maximum of two entries per person.

3. All slides must be original 35 mm transparencies in cardboard mounts.

4. Photos must be of minerals (not under ultraviolet light).

5. The entrant must be the sole owner of copyright for the entered slides and by entering grants the *Mineralogical Record* permission to publish the slides at no charge.

6. All entries should be mailed to **Dr. Arthur Roe, 3024 E. Sixth St., Tucson, Arizona 85716,** so as to be received before February 9. No return envelope is required and all entries will be returned.

Prizes: (Prize money once again contributed by Dr. Richard Webster)

Amateur category	*Professional category*
First prize: $100	First prize: $100
Second prize: $25	Second prize: $25
Third prize: $25	Third prize: $25

Twenty semi-finalist slides will be selected from the entries, and the Saturday night show audience will then select the winners by ballot.

Letters

BIG LEGRANDITE

Dear sir,

In Bob Sullivan's *Letter from Europe* column (vol. 11, no. 2, p. 113) covering the 1979 Munich Gem and Mineral Show, Bob neglected to mention our new legrandite specimen which was on display there. This specimen is one of several incredibly large crystallized legrandites discovered in November or December (1978) in a series of huge, interconnecting pockets at the Ojuela mine, Mapimi, Durango, Mexico. Our specimen is a slightly diverging spray of terminated yellow crystals 22.8 cm (9 inches!) long.

The legrandite will be on display in the American Museum shortly, along with the recently acquired Newmont azurite (pictured in the *Record* in vol. 9, no. 3, p. 192) and gold specimens. *Record* readers are invited to see these magnificent specimens the next time they visit New York.

Joseph J. Peters
American Museum of Natural History
New York, New York

BOSCH CODE

Dear sir,

I can supply some additional information backing up the letter from Jim Minette (vol. 11, no. 1, p. 56) regarding the labeling code used by Carl Bosch. I have helped log into the collection of the Cleveland Museum of Natural History a sizable collection of minerals put together over a period of more than 30 years by Frank R. Van Horn. In 1902 Horn bought a large number of specimens from two German dealers. Some of the original labels have prices marked in German currency, and the equivalent in dollars was recorded as well. This showed the exchange rate to be $1 = 4 DM in 1902. Both dealers (D. Blatz, Heidelberg Mineralein Comptoir, and K. S. Mineralein-Niederlage, Freiberg) used the decimal format in writing their prices, 2.50 for 2½ DM or -.40 for 40 pfennigs. The specimens typically ranged in price from 25 pfennigs to 2.50 DM, with the occasional specimen reaching 20 DM ($5.00). (Of course one must remember that $5.00 in 1902 was worth about $50.00 in today's money.) It seems reasonable that Carl Bosch could have purchased his stephenite and acanthite for 100 pfennigs ($2.50 today) and 90 pfennigs ($2.25 today), rather than 100 times that as would be the case if the notation was in marks instead of pfennigs. The matter could be proven once and for all if some Bosch labels are accompanied by labels from one of these two dealers, considering that their method of notation is known.

William R. Cook, Jr.
Cleveland Heights, Ohio

FOR THUMBNAIL COLLECTORS

Dear sir,

The "International Thumbnail Mineral Collectors" organization is presently conducting a membership drive. The organization is composed of members interested in various aspects of mineralogy and mineral collecting, with a common interest in thumbnail-size specimens.

A monthly newsletter, silent auctions and a membership directory are provided through the mail. The directory lists each member's individual interests, and therefore constitutes an aid to trading; the club has attracted many swappers throughout the United States, Canada, and overseas.

The newsletter is devoted mainly to information on collecting sites, shows, trading opportunities, and other items of interest to collectors in general.

Dues are $6 per year for North American members and $8 per year for overseas members. Those interested in joining the ITNMC may receive a sample newsletter, directory page, and membership application by contacting: Larry Rush, Treasurer, ITNMC, P.O. Box 1457, Guilford, Connecticut 06437.

Larry Rush

FOR FLUORESCENCE FANS

Dear sir,

Persons who collect, display, or study fluorescent minerals are invited to join the Fluorescent Mineral Society. This nationwide and international group has about 135 members from a total of 10 countries. The F.M.S. publishes a bimonthly newsletter and an annual journal containing original and reprinted articles about mineral fluorescence; past issues of the journal may be purchased from the Society (1979 was vol. 8). Other activities of the F.M.S. include occasional field trips, regional meetings (there is a particular concentration of members in California), and an annual "silent" mail auction of fluorescent specimens. Annual dues are $7.50 ($9.50 outside the U.S.) plus a one-time $1 membership fee. For membership applications or information please contact Paul Morris, Executive Secretary, 713 Kentucky St. #2, Vallejo, California 94590.

Peter J. Modreski
Littleton, Colorado

SUDBURY DISCOVERY SITE

Dear sir,

The historical site at Sudbury, Ontario, where the copper-nickel orebody was first discovered, was described in the *Mineralogical Record* (vol. 7, page 159) as part of a Friends of Mineralogy series on important mineral sites. The exact location was given, and the statement was made that collecting was still possible from the pieces of broken rock that resulted from highway construction.

Recently it became necessary to relocate both the historical plaque and a section of the adjacent highway because of the extension of the Murray mine pit. The plaque is now located on Ontario Provincial Highway #144, four miles north of Sudbury on the road from Sudbury to Timmins. There is a paved turn-off on the east side of the road, and the location is marked. Unfortunately for the rock collector, the area around the plaque has been grassed over and nicely landscaped.

However, those interesting in seeing the ore in place can get a good impression of this by parking and walking 150 feet north toward the new Canadian Pacific Railway cut. Here the orebody is revealed much as it must have been to the railway workers in 1883. On a recent visit to the site, it was possible to observe the rusty gossan (weathered pyrrhotite) and to find small pieces of broken rock adjacent to the railway track.

Louise S. Stevenson
Montreal, Canada

TOXIC MINERALS

Dear sir,

A matter I have been concerned with for some years is the present legalistic approach to toxic hazards of our technological society. The problem is that it is impossible to prove anything harmless, and that many actions (such as the recent lists of toxic chemicals and ores published by OSHA, NIOSH and the EPA, and reviewed in the article "Toxic minerals" by John H. Puffer, *Mineralogical Record,* vol. 11, p. 5) are legalistic rather than scientific in their approach. I fear Dr. Puffer has fallen into the trap, like many academic people, of believing superficial and incomplete surveys issued by OSHA and EPA to tighten legalistic controls. We need much better information and more scientific cooperation between government and industry that we now have, if the toxicities of minerals are to known with complete reliability. Neither the government regulatory agencies nor the mining and extractive industries are 100 percent right in their current claims about toxicity . . . it is certain that the former tend to exaggerate the risks, the latter to conceal them. The problem with Dr. Puffer's article is that it was not a *critical* review, and therefore gave an exaggerated picture of mineral toxicity.

I would like to correct some specific inaccuracies I noticed while reading through the paper. Many tests have shown barite to be essentially non-toxic, rather than "slightly toxic." Orpiment is insoluble in stomach acids and therefore harmless. Antimony is perhaps more toxic than suspected, especially in the form of stibiconite. Chromite (Baetjer, National Academy of Sciences, 1974) is not toxic or carcinogenic, although chromate minerals (lopezite, crocoite, tarapacaite, dietzite) are. Throughout the article, the product function of toxicity, probability of ingestion, and continued exposure for cumulative effect is treated most superficially, as is characteristic of EPA and NIOSH documents, which the article reflects all too faithfully. If you want a quite different and equally believable study, consult "Element concentrations toxic to plants, animals, and man," U.S. Geological Survey Bulletin 1466 (1979).

There are other dangers not mentioned in the article. Acid testing of sulfides such as sphalerite can liberate H_2S, a very toxic gas. And I wouldn't do blow-pipe tests of arsenic, mercury, zinc or cadmium minerals except in a well ventilated hood.

Collectors will virtually never be exposed to the same hazard levels as miners and quarrymen, and should consequently be far less concerned. I won't wear a respirator or rubber gloves when I go to work on my collection (which contains at least 60 toxic species), although I do keep my mercury specimen in a sealed bottle, and I would wear a respirator at a very dusty collecting locality.

Winslow H. Hartford
Belmont Abbey College

Winslow Hartford is Associate Professor Emeritus of Chemistry and Environmental Science at Belmont Abbey College, Belmont, North Carolina, and has worked for 47 years in the chemical processing of chromite. Ed.

POUGH-PEARL MIX-UP

Dear sir,

The Pough 4th edition now available is *The Field Guide to Rocks and Minerals,* not *Cleaning and Preserving Minerals.* That pearl is authored by Dr. Richard Pearl, and is presumably also now available in a fourth edition as reported in your *Letters* column letter from John Jaszczak (vol. 11, no. 1, p. 54). In any case, Dr. Pearl and I both appreciate the plug, but please try to keep the right author with the right title.

Frederick H. Pough
Reno, Nevada

BEMCO MINE TRITOMITE-(Y)

Dear sir,

Regarding the article by Vassiliou on the Bemco mine (vol. 11, no. 1, p. 39), readers may be interested to know that the rare mineral tritomite-(Y) (also known as *spencite*) occurs at the locality as well. Roberts, Rapp and Weber mention tritomite-(Y) in their *Encyclopedia of Minerals* as coming from a locality which is probably the Bemco mine, though they don't give a mine name. In a personal communication, Frank Warnett Sr., former owner of the Bemco mine, has reported the presence of *spencite* (tritomite-(Y)) in the ore.

Robert T. Price
Trout Run, Pennsylvania

EXCHANGES

I have many excellent specimens of brilliant black osumilite crystals to 1/8 inch, with tridymite on rhyolite matrix, in sizes to 5 by 5 inches. I wish to exchange for thumbnail-size mineral specimens.

Pani Fausto
Viale Merello, 87/A
09100 Cagliari, Italy

I have clear selenite gypsum, large Mexican geodes 3 to 8 inches across lined with beautiful quartz crystals. I would like to trade for fluorite, galena, quartz, rhodochrosite, or minerals from your area.

Mike Dawson
P.O. Box 272
Temple Bar, Arizona 86443

NO IMPLICATION

Dear sir,

In *What's New in Minerals* (Vol. 11, no. 3, p. 189) you discussed the discovery of more adamite at the Ojuela mine, and the expelling of a couple of unfortunate U.S. dealers by new occupants who invested little. In the next sentence you mentioned a dealer now carrying the material in the U.S. . . . is there an implication that this dealer was involved in the "expelling"?

Jolen Barnek
Kennewick, Washington

Not at all. According to my information, those who took over the mine are Mexican nationals who wholesaled the adamite to a number of U.S. dealers. Ed.

OBSOLETE LOCALITY NAMES

Dear sir,

When listing the country of origin on a mineral label, what is the accepted policy regarding use of country names which have been changed? Up to now I have been using the new name as soon as it becomes official, even for old specimens, but someone recently told me that the name in effect at the time the mineral was collected should be used on the label in perpetuity. Is there standard agreement on which to use?

Ralph Merrill
Mineral Unlimited

No, there is no standard agreement among people, simply because the question has never been put to an official vote. One finds labels done both ways. However, the prevailing majority opinion probably favors use of updated country names. Granted, some of the old names seem to be steeped in the exotic flavor which comes from long and loving use by collectors and curators. But old names eventually become obscure and a nuisance. Their place is on old labels dating from the time of collection, which should be saved for historical purposes. New labels should use current terminology, though if the date of collection or other history is known it should certainly be included. Ed.

BROOKLYN CHILDRENS MUSEUM

Dear sir,

Many mineralogists, some of them quite prominent, received their early impetus and training at the Brooklyn Childrens Museum. Will those who have done so, or who know of others who have, please communicate with me?

Martin J. Starfield
140 Camden Plaza West, Apt. 12F
Brooklyn Heights, New York 11201

GREY HORSE MINE

Dear sir,

I am the present owner of the Grey Horse mine about which Andrew Clark and Gary Fleck wrote in the Arizona-II issue (vol. 11, no. 4, p. 231). It is now listed as the Red Coral claim. Collectors are permitted, but they should first check with me; power equipment and explosives will not be allowed.

Lewis Heinle
512 E. Laurel Drive
Casa Grande, Arizona 85222

GOOD COLLECTING

Dear sir,

On July 4th we visited the Red Cloud mines in the Gallinas Mountains of New Mexico, which were described in the article by DeMark (vol. 11, no. 2, p. 69). I'm pleased to say that two days of collecting yielded micromount crystals of all of the species described except vanadinite. We were particularly pleased with the agardite we found. It shows that if one has good information and is content with micromounts, such trips can be successful. Many thanks to the *Record.*

Fred Bird
Ouray, Colorado

STATEMENT OF OWNERSHIP, MANAGEMENT AND CIRCULATION
(Required by 39 U.S.C. 3685)

1. *Title of publication:* Mineralogical Record
2. *Date of filing:* September 25, 1980.
3. *Frequency of issue:* Bimonthly
   a. *Number of issues published annually:* Six.
   b. *Annual subscription price:* Sixteen dollars.
4. *Location of known office of publication:* 12304 Welling Lane, Bowie, Prince George's County, Maryland 20715.
5. *Location of the headquarters or general business offices of the publishers:* 12304 Welling Lane, Bowie, Maryland 20715.
6. *Names and complete addresses of publisher, editor, and managing editor: Publisher:* John S. White, Jr., 12304 Welling Lane, Bowie, Maryland 20715. *Editor:* Wendell E. Wilson, 4631 Paseo Tubutama, Tucson, Arizona 85715. *Managing editor:* none.
7. *Owner:* The Mineralogical Record Incorporated, 12304 Welling Lane, Bowie, Maryland 20715. No stockholders.
8. *Known bondholders, mortgagees, and other security holders owning or holding 1 percent or more of total amount of bonds, mortgages or other securities:* none.
9. *For completion by nonprofit organizations authorized to mail at special rates (Section 132.122, PSM).* The purpose, function, and nonprofit status of this organization and the exempt status for Federal income tax purposes have not changed during the preceding 12 months.
10. *Extent and nature of circulation:*

	Average no. copies each issue during preceding 12 months	Actual no. copies of single issue published nearest to filing date
A. Total no. copies printed	9133	9200
B. Paid circulation		
1. Sales through dealers and carriers, street vendors and counter sales	1291	200
2. Mail subscriptions	6066	5981
C. Total paid circulation	7357	6181
D. Free distribution by mail, carrier or other means, samples, complimentary and other free copies	29	21
E. Total distribution	7386	6200
F. Copies not distributed		
1. Office use, left over, unaccounted, spoiled after printing	1747	3000
2. Returns from news agents	0	0
G. Total	9133	9200

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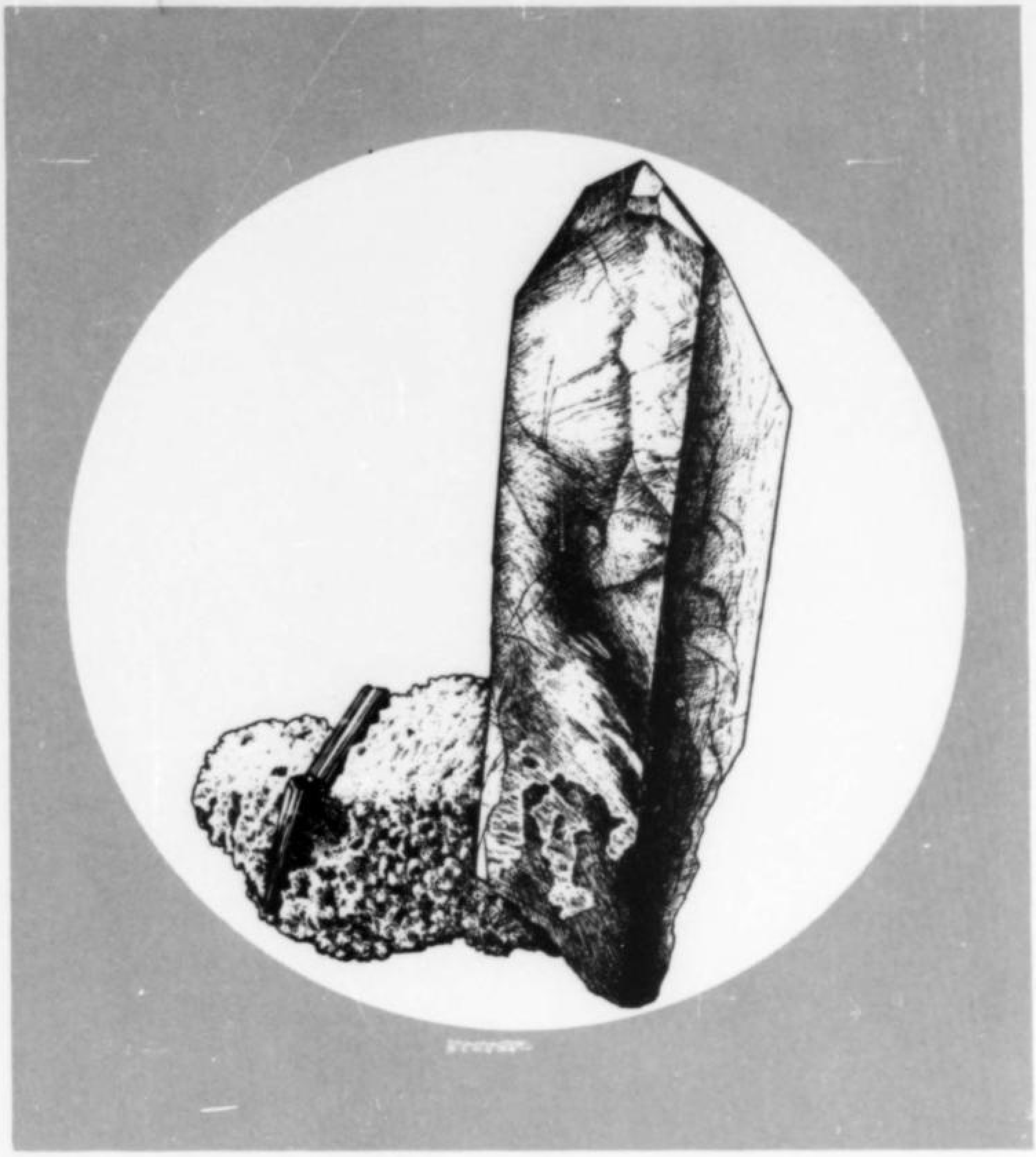

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