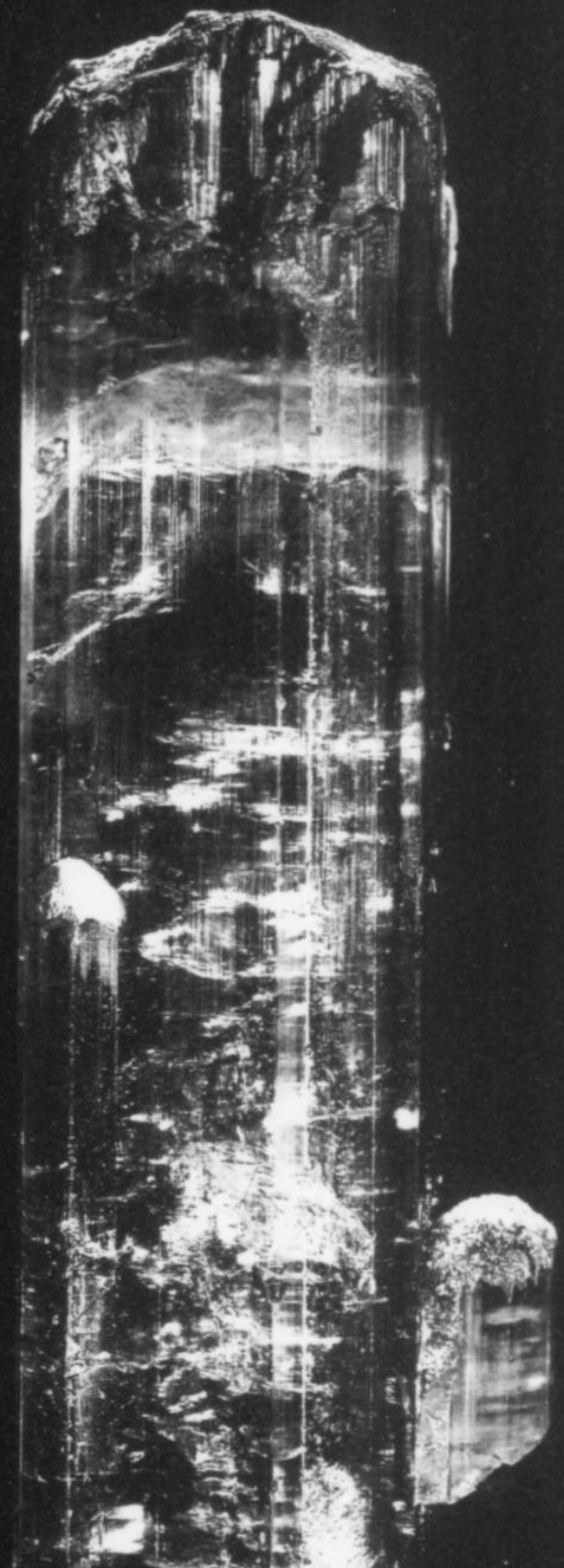

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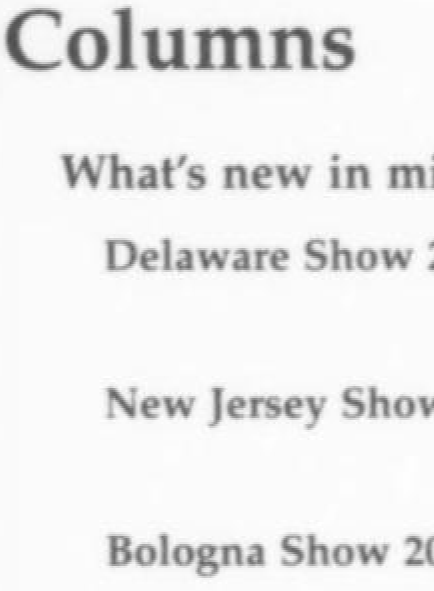
*Continued on p. 535

THE MINERALOGICAL RECORD

November–December 2000 Volume Thirty-one, Number Six

MOZAMBIQUE!

Columns



COVER: ELBAITE crystal, 7.3 cm, from the Alto Ligonha district, Mozambique. American Museum of Natural History collection, New York; photo by Jackie Beckett and Olivia Bauer courtesy of the AMNH.

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AFRICA
in *The Mineralogical Record*

In this issue we present our first article on mineral occurrences in Mozambique, but certainly not the first to deal with African localities and mineralogy. Over the years the *Mineralogical Record* has given considerable coverage to Africa, including major occurrences in Egypt, Malawi, Madagascar, Morocco, Namibia, South Africa, Zaire (Congo) and Zambia. And more such articles are currently "in the pipeline," so be sure to maintain your subscription. For quick reference, the Africa-related articles from past issues are listed below, demonstrating the value of maintaining a complete set of back issues. These articles contain, in addition to the usual historical and geological information, data on specimens collected which have been preserved nowhere else in the mineralogical literature. Though we haven't yet documented King Solomon's mines, the occurrences listed below and in the current issue are truly an African treasure chest worthy of H. Rider Haggard and Allan Quatermain.

Ed.

A Special Thanks

from the Mineralogical Record to **Philip Rust** and **Randy Rothschild** for donations which have financed the color photography in this issue and other issues in 2000.

Famous mineral localities:

THE ALTO LIGONHA PEGMATITES MOZAMBIQUE

Manuel Bettencourt Dias
Matos Lima
8100-308 Loulé, Portugal

Wendell E. Wilson
The Mineralogical Record
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The Alto Ligonha pegmatite field was an important producer of fine crystallized pegmatite minerals during the 1930's to 1970's. Though it has been less productive in the 1980's and 1990's, it is currently enjoying a revival phase. Specimens continue to be produced, and superb examples of elbaite, beryl, stibiotantalite, ferrotantalite, microlite, topaz, zircon and other species are preserved in museums and private collections worldwide.

INTRODUCTION

Alto Ligonha (pronounced "Lig-own'-yah") is the name of an administrative post founded during the period of pacification of the tribes of northeastern Mozambique, which ended around 1895. The name refers to the *upper* ("Alto") course of the Ligonha River.

Pegmatites of varied mineralization occur over a broad area, the heaviest concentrations being near the town of Alto Ligonha. There seems to be some confusion as to the actual extent of the Alto Ligonha district proper, some believing that it must refer primarily to the first and most important mine in the district, the Muiane. For the purposes of this article, however, we will follow the broader usage of most authors (DeKun, 1965; DSGM, 1974; etc.) and include the entirety of what might be called the northern Mozambique pegmatite province, that is, an area within approximately a 200-km radius of Alto Ligonha. This encompasses almost every pegmatite in Mozambique except those in or near the Mozambican panhandle (e.g. Tete), which are more closely related to the geology of nearby Malawi, Zambia and Zimbabwe.

The area is within the East African Monsoon Belt, at an average altitude of about 400 meters; temperatures are moderately hot in the summer and pleasantly cool in winter. There are two seasons: the cool, dry season (April to October) when the Monsoon blows eastward, and the rainy season (November to March) when the Monsoon reverses itself and blows across the Indian Ocean from India to Mozambique. Rainfall averages 100 to 120 cm per year.

***Figure 1.* Primitive mining operations at the Muiane mine in 1955. M. Bettencourt Dias photo.**

Access to the Alto Ligonha area is either (1) by air to Nampula—whose airport is served regularly by Mozambique Airlines—and from there by car to Murrupula and thence to Muiane, or (2) by air to Quelimane, then by rail or car to Mocuba, and from there onward to Alto Molocue, Alto Ligonha Post, and Muiane. The former route is the preferable one.

The best time of the year to visit Alto Ligonha is June to October, after the rainy season has ended and the roads have been repaired. For travel during the rainy season, a vehicle with four-wheel drive is a must, and information on the condition of roads and bridges should be obtained from local authorities before heading out.

Mineralogists and mineral collectors visiting the area should always check in beforehand with the Geological Survey of Mozambique headquarters in Maputo. They are very helpful in explaining regulations that apply to taking mineral specimens out of the country, and can advise on the best routes to the mines.

Although Alto Ligonha has a pleasant climate and is free of sleeping sickness, it must be remembered that since the country gained its independence from Portugal in 1975, malaria and other tropical diseases which had been nearly eradicated have come back in more virulent forms. While hunting laws prior to 1975 protected the native animals, widespread destruction of local species occurred thereafter. As a result, the proliferation of man-eaters among the population of big cats has become alarming. In consideration of these dangers, visitors should take antimalarial medicines (not generally available in Mozambique), should avoid being bitten by mosquitoes, and should assume that no water is safe to drink until it has been boiled. No stream is safe to wade in due to the possible presence of crocodiles and the certainty that it will be infected with *bilharzia*, the carrier of schistosomiasis. As for safety from wild animals, the best protection is to avoid going into the bush without a local resident as guide, and to follow his advice implicitly.

HISTORY

Toward the end of the 19th century, conflicts erupted between the Portuguese (who controlled the ports) and local potentates allied with Indian and Arabian slave traders. The slavers were defeated, opening up the interior for the first time to Europeans (who traded European goods in return for gold dust). During the first World War, the German East African Army marched through Mozambique, engaging British, Portuguese and South African forces at the Alto Molocue, Alto Ligonha, and Mamala military posts which were under Allied control.

Attached to the Portuguese Army units that took the brunt of the German offensive were convicts serving sentences for crimes committed in Portugal. Many of these convicts saw their sentences pardoned for acts of bravery in combat; after the end of hostilities they settled down as farmers, traders and prospectors. Alluvial gold and gem-grade tourmaline were first produced as a result of their work in the area.

Rubellite (red to pink tourmaline) was the first gemstone to be found in the Alto Ligonha area. It occurred in the eluvial rubble on the north slope of the Muiane pegmatite, where crystals were dug out by the first prospectors. One of those prospectors (so the story goes) showed the crystals to the captain of a German merchant ship docked at Mozambique Island. The captain correctly identified the specimens, concluded that they would bring a good price in Germany, and purchased the lot. A steady trade developed through individuals in the German merchant marine which lasted until the outbreak of World War II.

In 1936 one of us (MBD) saw a lot of those early, prospector-dug

Figure 2. **Large beryl crystal embedded in the inner intermediate zone of the Muiane pegmatite. The pocket behind the miner was filled with gem aquamarine on clevelandite, and later also yielded abundant green elbaite. Danilo S. Picolo photo, ca. 1956.**

Figure 3. **Hammering timbers in place at the Muiane mine ca. 1956. Danilo S. Picolo photo.**

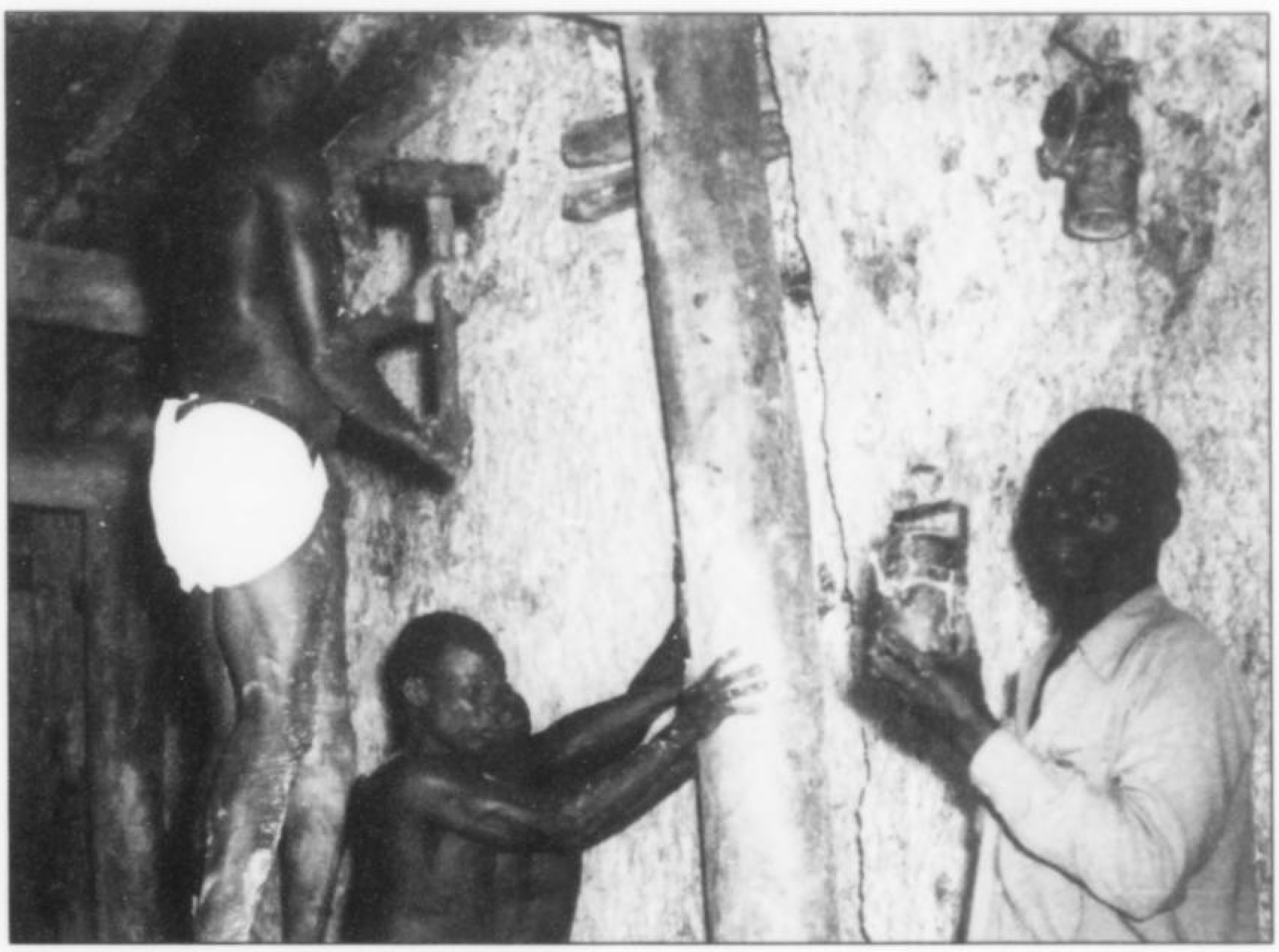
stones which someone had put away on Mozambique Island. There were nearly two dozen prismatic crystals of various sizes from about 1 x 2 cm up to 4 x 10 cm. All were perfectly gemmy and flawless, although the terminations (typically fracture-filled) had been cobbed off. All were a deep pink, except for the rare wine-red examples.

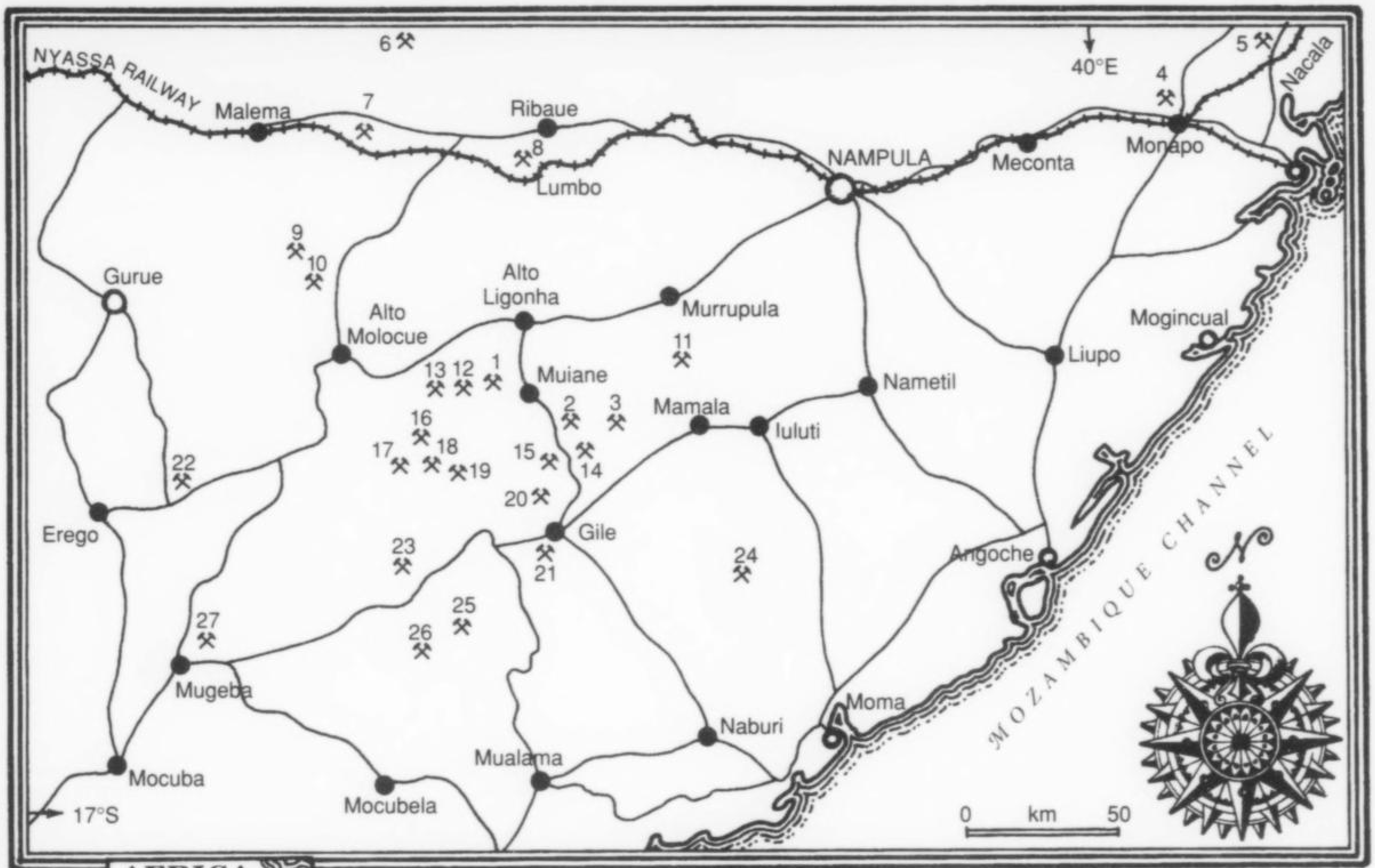
Pegmatites in the Alto Ligonha area were first actively mined around 1926, and continued in operation for several decades thereafter. The district was under the administration of the Nyasa Company until 1929, when it was taken over by the government. The best-known pegmatite is probably still the Muiane, which was operated by Empresa Miniera do Alto Ligonha, and which has produced many collector specimens now in museums.

In 1930 a report on the mineral potential of northern Mozambique was prepared for the Mozambique Department of Mines by Antonio J. Freitas, a distinguished mining engineer and first director of the Department. During the 1940's extensive prospecting[1] by the Mines and Geology Department located alluvial gold deposits in the valleys of the Cocone, Metuisse and Namirroe Rivers. It was also during this time that the first geological map of the area, on a scale of 1:250,000, was completed by Alexandre Borges and Arthur F. Nunes. In 1949 the American mining engineer and mineral collector Mark Chance Bandy (1900–1963) visited the Alto Ligonha district for several days and was impressed by the superb quality of crystals being found there. His report was published in 1951.

A geological reconnaissance by the American firm E. J. Longyear Company was conducted under contract to the Portuguese government during 1953 and 1954, while an investigation of economic potential was done by R. W. Hutchinson and R. J. Claus for the Union Carbide and Carbon Corporation. From 1954 to 1962 additional (unpublished) reports were produced by M. Bettencourt Dias, G. Myers, Lopes da Silva, J. Sabot, E. Mendelson, J. Browne and Alexandre Borges. An article by Bettencourt Dias on the

[1] Ed. Note: Author MBD was a part of those investigations, described in his memoir, *An African Name*, published in 1999 by Peanut Butter Publishing of Seattle, Washington. (ISBN # 0-89716-867-4)





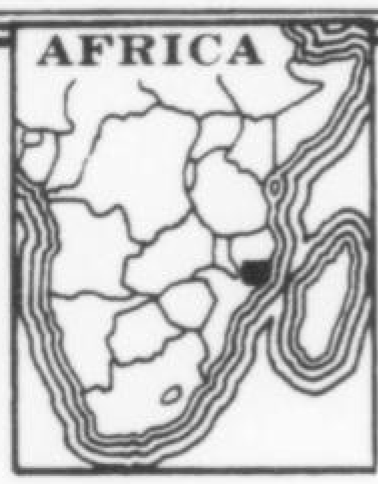


***Figure 4.* The Alto Ligonha pegmatite area. Numbers indicate the locations of the most important groups of pegmatites, as listed in Table 1 (Compiled from *Carta de Jazigos e Ocorrencias Minerais (1974)*, published by the Direcção dos Servicos de Geologia e Minas, (DSGM), Mozambique.)**

pegmatites of Alto Ligonha was published in 1961 as Bulletin no. 27 of the Geology and Mines Service of Mozambique. In 1962, Fernando Freitas, a mining engineer, published an explanatory notice to Geological Sheet Sul-D-37/U, Alto Ligonha-Murrupula, in Bulletin no. 28 of the Geology and Mines Service, including geologic maps of the pegmatites then in operation which had been prepared by himself and Bettencourt Dias. Since that time, many mineralogical reports on individual species have been published by many authors including Th. G. Sahama, M. Lehtinen, O. von Knorring, J. M. Correia Neves, J. E. Lopes Nunes, E. Saari, R. Quadrado, and others.

In April of 1974 a revolution took place in Portugal, led by Marxist-leaning elements of the military. They handed over independent authority in Mozambique to Russian-trained guerrilla leaders who had tried unsuccessfully for years to gain power there. Immediately the traditional authorities were persecuted; many of the most respected chiefs were hanged, and the Achirima tribe, one of two principal ethnic groups in the Alto Ligonha area, was treated with special brutality. The Achirima were artists, music lovers and intellectuals, and consequently were marked for extermination in a kind of "cultural revolution" similar to that suffered by China.

At the mines, work was suspended daily so that workers could attend political indoctrination sessions. Salaries were raised almost every month but (lacking significant production) were never paid. The production crisis was blamed on the pre-independence staff, who were arrested, tried, given fines too heavy to pay, and assigned jail sentences. The jails, however, were already jammed with non-communist prisoners and there were no funds made available for feeding them, so many prisoners were simply released.

In order to finance the communist party (called "Frelimo," Frente de Libertação de Mozambique, which is still in power), workers were encouraged to dig intensively for gem minerals such as tourmaline, aquamarine and emerald. This gem material was then sold by party leaders to Tanzanian black marketeers.

In the 1980's the Central Committee brought in Russian advisors and so-called "mining experts" from Romania and East Germany to improve production and stop illegal sales. Unfortunately the highly paid "experts" were innocent of any real mining or geological knowledge, and the only result was an increase in general starvation among the local population. What few specimens were found were sold on the black market as usual. Eventually the Party became disenchanted with the East European "experts" and expelled them. Some degree of free-market competition was subsequently allowed, and private investors were encouraged to return.

The Mines Department was reorganized and a new discipline was enforced, significantly reducing the level of contraband. The Department was placed in charge of the Alto Ligonha mines, and there is now a limited production of gems and mineral specimens being sold through government-owned shops. The Mines Department is currently said to be very interested in seeing the mines

Table 1. **The most important pegmatite mines in the Alto Ligonha area, and the most notable minerals found at each pegmatite (see map for locations of the numbered groups). Data compiled from DSGM (1974) *Carta de Jazigos e Ocorrençias Minerais*, and other sources.**

Group 1: *Mines:* Muiane, Naipa, Maridge, Nanro, Nacuissupa, Nihire.
Minerals: Tourmalines, beryl gems (1), beryl, manganotantalite, stibiotantalite, lithium minerals (2), mica, bismutite, bismuth, bismuthinite, monazite, stibiomicrolite, cassiterite, quartz gems (3), garnet, topaz, zircon, cookeite, samarskite.

Group 2: *Mines:* Ingela, Murrapane, Namicaia.
Minerals: Beryl gems, beryl, mica, ferrotantalite-ferrocolumbite, cassiterite, bismutite, topaz, quartz gems.

Group 3: *Mines:* Piteia Nahia, Mirrucue.
Minerals: Ferrotantalite-ferrocolumbite, quartz, quartz gems, topaz, lithium minerals, bismutite, mica, monazite, cassiterite, fluorite, fluorapatite, orthoclase.

Group 4: *Mines:* Monapo, Carapira.
Minerals: Amazonite, beryl gems.

Group 5: *Mines:* Tulua, Marengo.
Minerals: Tourmalines, cassiterite.

Group 6: *Mines:* Leonora, Mueterere, Namacala
Minerals: Tourmalines, beryl, amazonite, allanite.

Group 7: *Mines:* Niesse, Isabela.
Minerals: Beryl, mica, zircon, scapolite, allanite, corundum.

Group 8: *Mines:* Boa Esperança.
Minerals: Kaolin, beryl, ferrotantalite-ferrocolumbite, xenotime, samarskite, monazite, euxenite.

Group 9: *Mines:* Guiherme, Comua, Muetia, Giline, Culahipa.
Minerals: Euxenite, monazite, xenotime, allanite.

Group 10: *Mines:* Ehiale, Namovela, Massive, Horta.
Minerals: Betafite, euxenite, samarskite.

Group 11: *Mines:* Macotaia, Mtomotiti.
Minerals: Ferrotantalite-ferrocolumbite, monazite, bismutite, samarskite.

Group 12: *Mines:* Muhano, Majamala, Cochiline.
Minerals: Beryl, ferrotantalite-ferrocolumbite, bismutite, tourmalines, monazite, zircon.

Group 13: *Mines:* Murropoci, Nuaparra, Namirrapo, Mucholone.
Minerals: Beryl, beryl gems, tourmalines, mica, bismutite, ferrotantalite-ferrocolumbite, microlite, lithium minerals, kaolin, xenotime.

Group 14: *Mines:* Macula, Nahaji.
Minerals: Beryl, ferrotantalite-ferrocolumbite, rutile.

Group 15: *Mines:* Mocachaia, Alata, Intotcha, Nahora.
Minerals: Beryl, ferrotantalite-ferrocolumbite, bismutite, beryl gems, tourmalines, monazite, mica, lithium minerals, zircon, pollucite.

Group 16: *Mines:* Namacotcha, Conco, Napire, Nassupe, Munhamola, Moneia.
Minerals: Beryl gems, beryl, lithium minerals, microlite, zircon, tourmalines.

Group 17: *Mines:* Lice, Malolo.
Minerals: Beryl, ferrotantalite-ferrocolumbite, bismutite, amazonite, black beryl, beryl gems, ferrotapiolite.

Group 18: *Mines:* Maria, Uelele, Namarrela, Mecassa.
Minerals: Beryl, beryl gems, tourmalines, ferrotantalite-ferrocolumbite, microlite, bismutite, monazite.

Group 19: *Mines:* Maria III.
Minerals: Emeralds, molybdenite.

Group 20: *Mines:* Namivo, Tomeia, Nampoça.
Minerals: Beryl, ferrotantalite-ferrocolumbite, thorianite, bismutite, monazite, microlite, zircon, samarskite, euxenite, beryl gems, black beryl, xenotime.

Group 21: *Mines:* Niane.
Minerals: Emeralds.

Group 22: *Mines:* Ile.
Minerals: Betafite, euxenite, allanite, monazite, bismuthinite.

Group 23: *Mines:* Morrua.
Minerals: Microlite, manganotantalite, beryl gems, beryl, bismutite, lithium minerals, pollucite, monazite, rutile.

Group 24: *Mines:* Naiume.
Minerals: Beryl, ferrotantalite-ferrocolumbite, cassiterite, bismutite.

Group 25: *Mines:* Melela, Namarripa.
Minerals: Beryl, emeralds, ferrotantalite, bismutite, monazite, rutile.

Group 26: *Mines:* Marropino.
Minerals: Microlite, lithium minerals, bismutite, kaolin, manganotantalite, beryl and beryl gems, zircon.

Group 27: *Mines:* Mugeba, Bere, Enluma, Maria, Muacotaia, Namagoa.
Minerals: Ferrotantalite, euxenite, samarskite, monazite, fergusonite, uraninite, beryl.

[1] Beryl gems include gem-grade blue-green (aquamarine), pink (morganite), golden yellow (heliodor) beryl and green beryl.
[2] Lithium minerals include lepidolite, petalite, amblygonite, spodumene (green and lilac).
[3] Quartz gems include colorless, smoky, rose and citrine quartz of gem quality.

Figure 5. **The 7-km narrow-guage railroad constructed in 1956 by the senior author, connecting the Muiane pegmatite (white gash on the far hillside) with a washing plant on the Metuisse River. Danilo S. Picolo photo.**

Figure 6. **Contact zone between the quartz core (right side) and intermediate zone of the Mocachaia plagioclase–spodumene–quartz pegmatite. The senior author is kneeling (center) to examine morganite crystals coming from the contact, as the men at left pick up loose morganite fragments. Danilo S. Picolo, ca. 1956.**

reopened on a larger scale under competent management. Time will tell whether conditions and production will continue to improve, but today the outlook is brighter than it has been in many years.

Table 2. **Production from the Alto Ligonha pegmatite field, 1937–1962 (Kun, 1965).**

	Production 1937–1958	*Production 1962*
Beryl	7,300 tons	440 tons
Columbite-Tantalite	570	110
Tourmaline	1.4	?
Lithium ore	10,300	200
Other micas	150	1
Samarskite	20	?
Bismutite	20	15
Monazite	15	?
Kaolin	650	?

GEOLOGY

The pegmatite district lies within the Gneiss-Migmatite Complex, a huge area of metamorphic rocks and granitic intrusions of pre-Karoo age. These rocks are part of the Mozambique Belt, which has yielded rich mineral and gem wealth from Mozambique through Kenya and Tanzania. The most important geological units are (1) the regional gneisses, the oldest series, probably of Archaean age; (2) the metasediments, primarily schists, paragneisses and quartzites of varied compositions, probably of Proterozoic age; (3) the granites, consisting of several intrusions which have invaded the metamorphic rocks and emitted pegmatite bodies striking radially outward into the country rock; they are Proterozoic or younger; and (4) the basic and ultrabasic dikes which cut across older units.

Pegmatites are quite common throughout the Precambrian rocks of Mozambique. However, with the exception of scattered bodies in the Tete, Niassa, Moçambique and Manica districts, it is in Zambezia that they are most spectacular, not only in number but in size and the wealth and variety of their mineralization. An inventory carried out in an area not especially rich in pegmatites

Figure 7. **Access trench to the Third level of the Naipa mine, ca. 1955. M. Bettencourt Dias photo.**

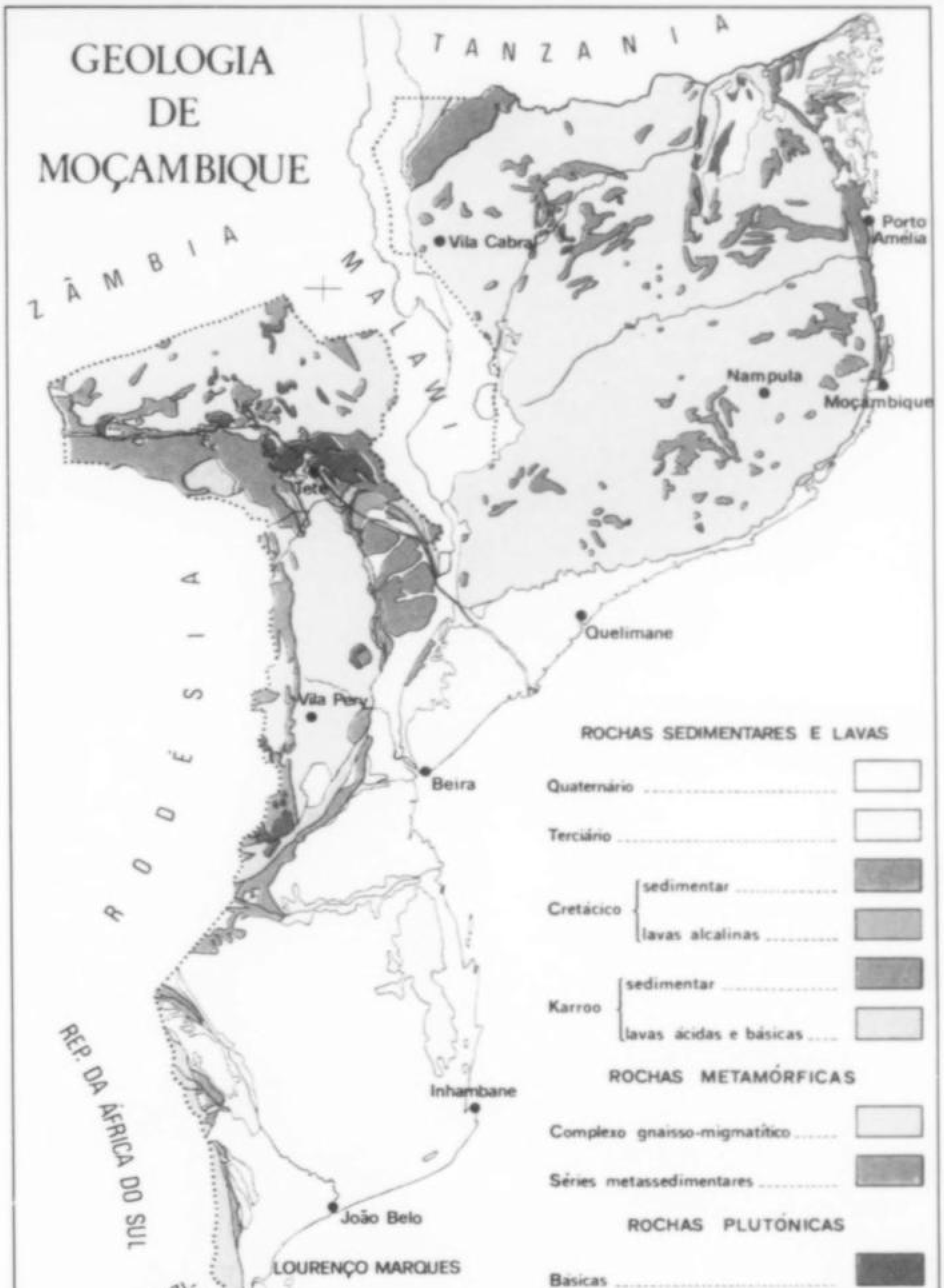


Figure 8. **Geologic map of Mozambique published in the 1960's by the Geological Survey of Mozambique.**

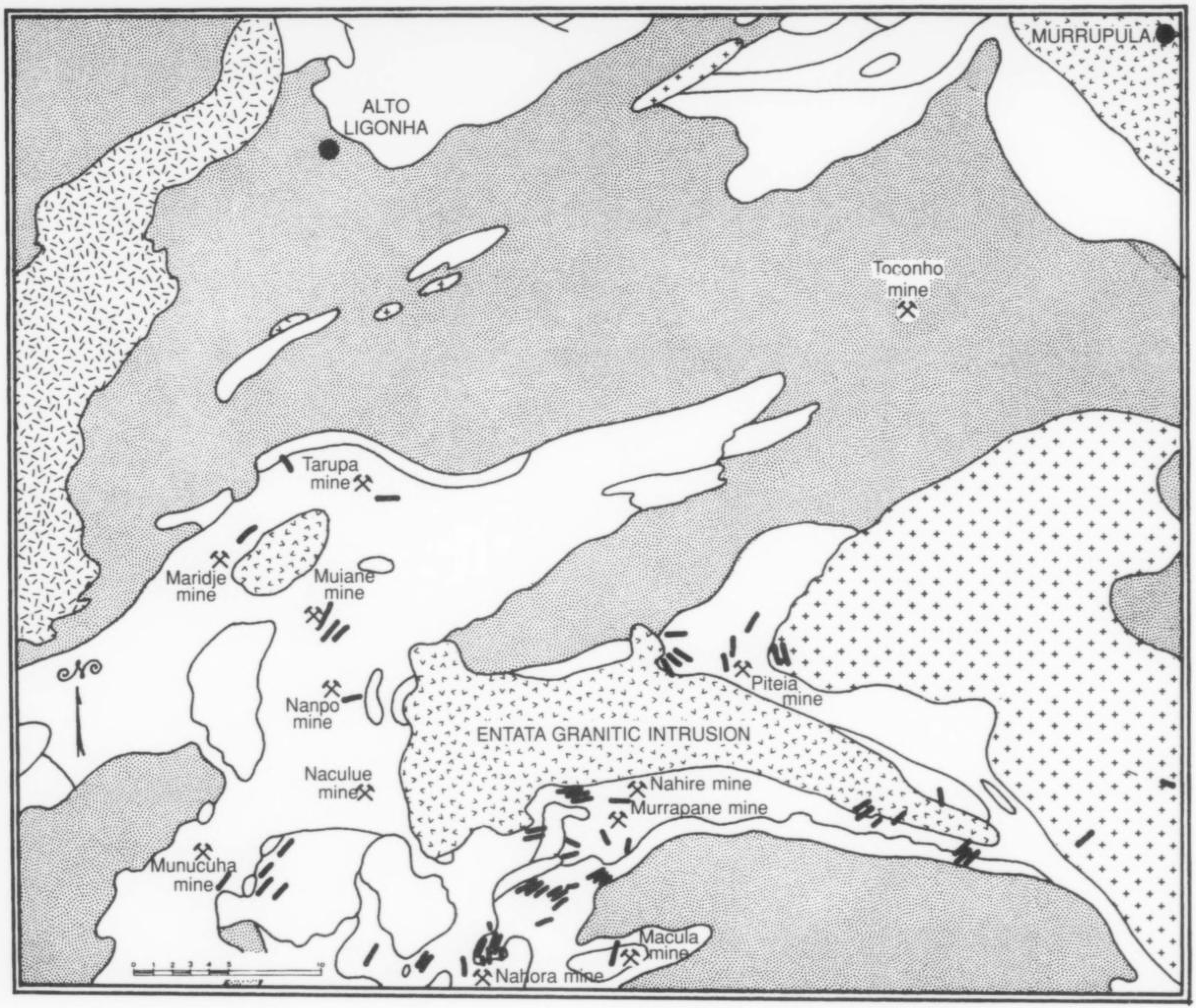


Figure 9. **Geologic map of the central Alto Ligonha district showing major pegmatite mines. The gray unit is undifferentiated Archaean gneiss. The white units are Proterozoic schists and gneisses. Heavy lines indicate pegmatites and pegmatite swarms. (From sheet SUL-D-35/U, Geological Survey of Mozambique.)**

(Gouveia, 1974) revealed over ten pegmatite outcrops per 100 square kilometers, of which 3.4% were economically exploitable.

In the Alto Ligonha area the pegmatites occur in fine-grained gneiss, schist, granulite, migmatite and basic to ultrabasic rocks. In form they range from long and vein-like to egg-shaped, and from vertical to flat horizontal. In size they may be a few tens of meters long and less than 10 meters wide, or up to several kilometers in length. The Muiane pegmatite, perhaps the most important specimen producer, is 400 meters wide and a full kilometer long!

The richest pegmatites have a well-developed concentric zoning, usually with very large quartz cores, and have been subjected to deep albitization. In most of the best deposits, intense kaolinization of the feldspars and abundant lithium mineralization is common. The detailed geochemistry of these pegmatites has yet to be thoroughly studied, but the influence of the host rocks on the composition, and the concentration of tantalum-niobium minerals and gem crystals in zones of albitization and lithium enrichment is conspicuous. Hutchinson and Claus (1956) have observed that pegmatite bodies containing ferrocolumbite, beryl, lepidolite, bismuth and presumably the other accessory minerals of complex pegmatites are restricted to the schists, whereas the pegmatites emplaced in granitic rocks are simple. They also detected a regional zoning in the district based on the presence or absence of lithium minerals.

Cotelo Neiva and Correia Neves (1960) determined the following sequence[2] of crystallization for pegmatite minerals at Alto Ligonha: (Note: not all species are present in every pegmatite.)

(1) Rutite → Zircon → Monazite → Ilmenite → Magnetite → Spessartine → Biotite → Muscovite → Oligoclase → Orthoclase → Quartz
(2) Lepidoite + Quartz
(3) Microcline → Quartz
(4) Monazite + Fluorapatite + Amblygonite + Quartz
(5) Topaz + Lepidolite + Quartz
(6) Albite + Spodumene + Muscovite + Quartz

[2] The arrow (→) indicates "followed by"; the plus (+) indicates "simultaneous with."

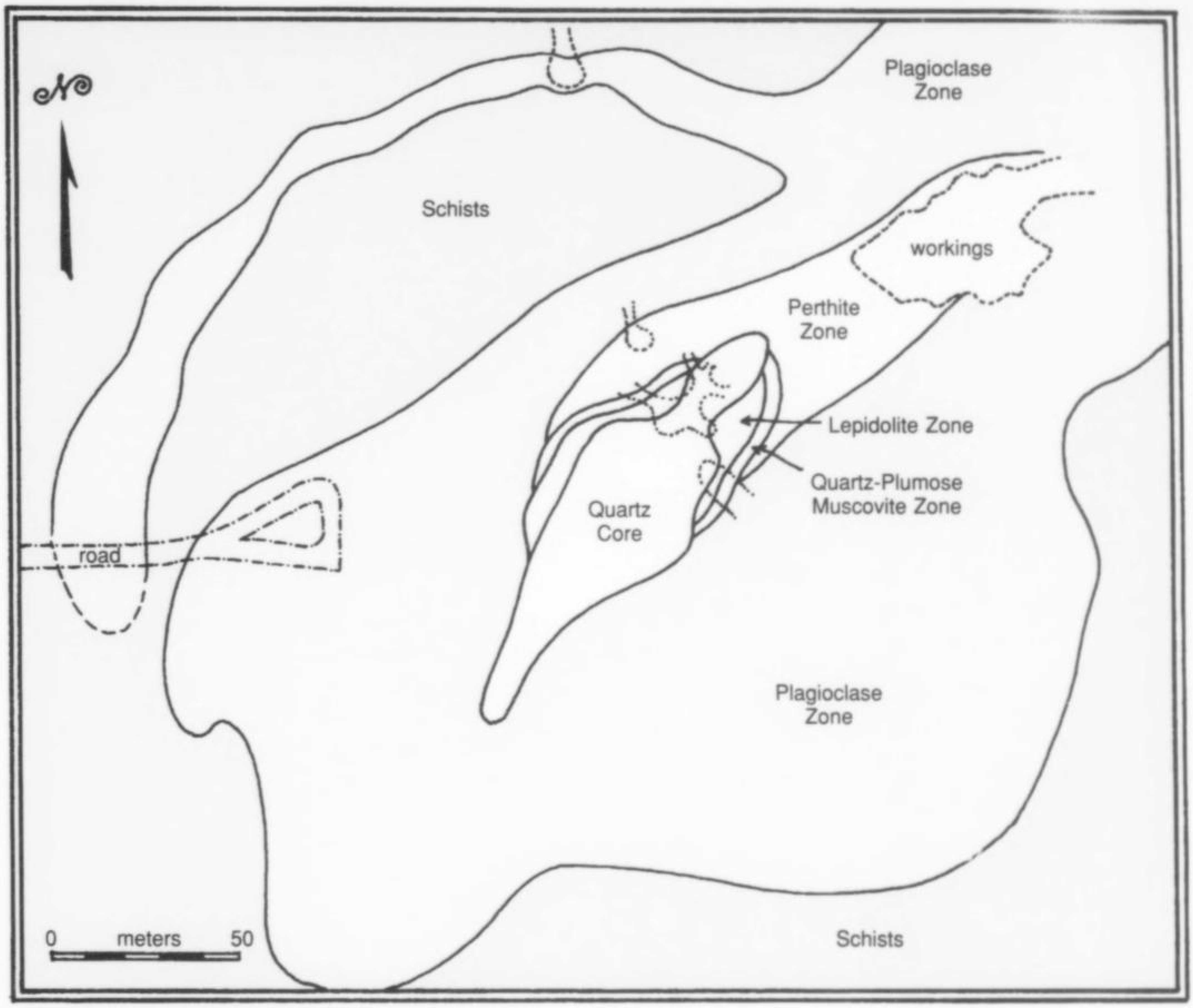


***Figure 10*. Geologic map of the Muiane pegmatite (after Hutchinson and Claus, 1956). The Lepidolite zone contains primarily lepidolite, quartz, plagioclase, and spodumene. The Plagioclase zone consists of plagioclase, quartz, muscovite and perthite. The Perthite zone, where most of the gem minerals and niobotantalites are found, consists of massive perthite, quartz, plagioclase and muscovite.**

(7) Tourmaline + Quartz
(8) Beryl + Gadolinite + Quartz
(9) Albite + Lepidolite + Muscovite + Quartz
(10) Ferrotantalite-Ferrocolumbite + Stibiotantalite + Samarskite + Pyrochlore + Thorogummite + Quartz
(11) Albite + Lepidolite + Muscovite + Quartz
(12) Tourmaline + Quartz
(13) Cassiterite + Lepidolite + Muscovite + Quartz
(14) Fluorite
(15) Muscovite + Quartz
(16) Chalcopyrite + Pyrite
(17) Cookeite + Sericite + Quartz
(18) Kaolinite + Montmorillonite + Bismutite + Quartz

The accompanying map of the Alto Ligonha district shows 27 different groups of pegmatites, each of roughly similar mineralization and morphology, all of which were being actively mined as of 1970. Mines that had previously been worked out and closed down (of which MBD himself supervised over 50) are not shown.

Table 1 lists the major mines and the most important mineral species found at each. Comparing the characteristic mineralization of each group of pegmatites to the host rock lithology gives clues which may aid in prospecting for additional deposits. It must be remembered that the hundreds of pegmatite bodies already mined represent only a small fraction of the district's potential. Bandy (1951) wrote:

> Due to the vegetation and lateritic soil, the only pegmatites known to date are those with quartz cores that [crop out prominently] or those containing relatively large amounts of mica with shallow cover of soil. So many pegmatites have been found in this way that there has been no need for systematic prospecting. Should modern geophysical prospecting methods be employed, many new pegmatites could be found.

MINERALS

Albite $NaAlSi_3O_8$

Albite occurs as typical pegmatitic "cleavelandite," glassy white crystal plates up to 15 cm, at the Cavala mine. Attractive clusters with quartz and orthoclase measuring over 75 cm across have been collected there (Bandy, 1951). The cleavelandite habit is also common at other pegmatites, including Muiane, where it shows the forms {010}, $\{1\bar{1}0\}$, {110}, $\{\bar{1}01\}$, {001}, {130} and $\{1\bar{3}0\}$. Correia Neves and Lopes Nunes (1966 a,b) made a detailed geochemical study of feldspars in the Alto Ligonha district, noting

Figure 11. **A tongue of pegmatite intruding darker amphibolite schist at the Muhano mine, ca. 1955. M. Bettencourt Dias photo.**

that the Ca-content of albite is very low, as are the K and Rb contents.

Allanite-(Ce) $(Ce,Ca,Y)_2(Al,Fe^{2+},Fe^{3+})_3(SiO_4)_3(OH)$

Allanite is known to occur in at least four different pegmatite groups: the Leonora-Mueterere-Namacala group, the Niesse-Isabela pegmatites, the Guilherme-Comua-Muetia group, and the Ile pegmatite. Associations include betafite, euxenite, monazite and xenotime-(Y) (DSGM, 1974).

Amblygonite $(Li,Na)Al(PO_4)(F,OH)$

Amblygonite and other lithium-bearing minerals are reported to occur in seven different pegmatites and pegmatite groups including the Muiane-Naipa group, the Piteia-Nahia-Mirrucue group, the Murropoci-Nuaparra group, the Morrua pegmatite and the Marropino pegmatite (DSGM, 1974).

Andalusite Al_2SiO_5

Cotelo Neiva and Correia Neves (1960) reported rare, rectangular crystals of andalusite showing {110}, {001} and {011} at the Muiane mine.

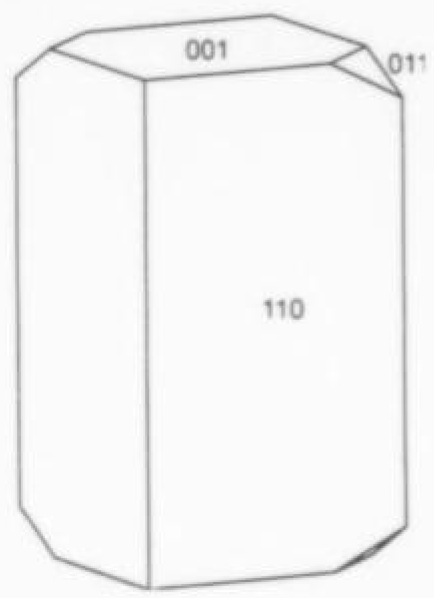


Figure 12. **Andalusite crystal drawing (Muiane mine) by R. Peter Richards, based on measurements reported by Cotelo Neiva and Correia Neves (1960).**

Bermanite $Mn^{2+}Mn^{3+}_2(PO_4)_2(OH)_2 \cdot 4H_2O$

Correia Neves and Lopes Nunes (1968) described bermanite, eosphorite, variscite, phosphosiderite, hureaulite, montebrasite, fluorapatite, amblygonite, and triplite from Alto Ligonha pegmatites.

Beryl $Be_3Al_2Si_6O_{18}$

Beryl at Alto Ligonha occurs mainly in the perthite intermediate zone, in crystals up to 900 kg, and also near the quartz core (Sinkankas, 1988). It is an important ore mineral at many mines in the district, over 100 tons of industrial-grade material having been produced before 1950. Ore beryl was typically an opaque, mottled green color, and crystals commonly exceeded a meter in diameter (Bandy, 1951). In fact, Mitchell (1959) describes one crystal exposed in a quarry wall that measured an astounding 2.44 meters in *diameter* and extended many meters into the pegmatite. Some of the rose-colored gem crystals can be quite large; Guillemin and Mantienne (1988) describe a crystal fragment weighing 7 kg as being only one-seventh of an original 50-kg crystal. Another rose-colored crystal they noted measured 9 x 25 cm with perfect faces.

Gem-grade beryl was also an important product, much of it hand-cobbed out of larger, partially opaque crystal sections. Roughly 60% of the district's production of gem beryl was aquamarine, and the rest was pink, golden yellow, dark blue, black, colorless, and even (at the Niane and Maria III pegmatites) deep emerald-green (DSGM, 1974; Bancroft, 1984).

Particularly unusual are the black beryls, which at the Muiane pegmatite display a pyramidal $\{40\bar{4}1\}$ habit. Bettencourt Dias (1961) attributes their color to inclusions; Behier (1957) agreed,

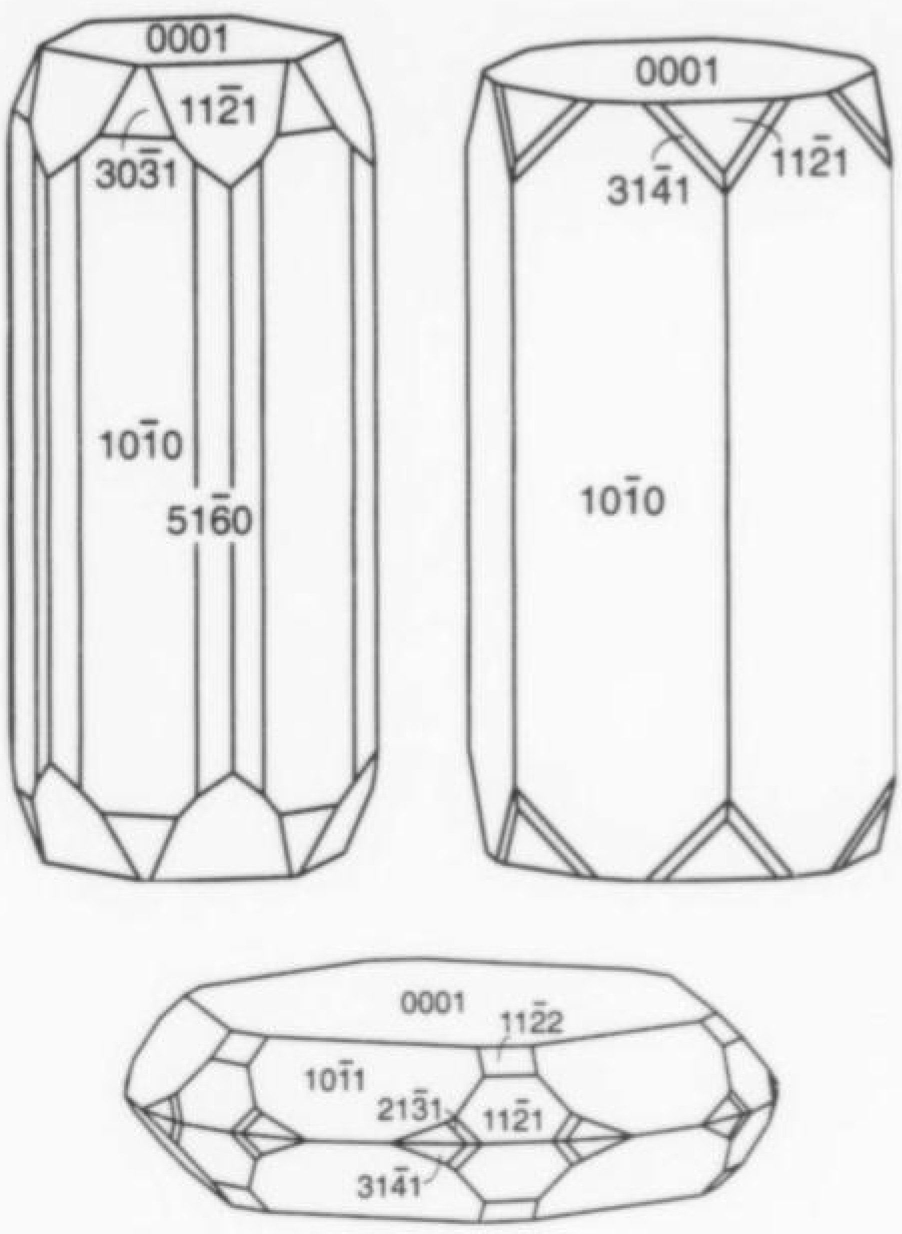


Figure 13. **Beryl crystal drawings (Alto Ligonha) by R. Peter Richards based in part on indices and habits reported by Sinkankas (1988).**

Figure 14. **Green beryl crystal, 12.8 cm, from Alto Ligonha. William Larson collection; Jeff Scovil photo.**

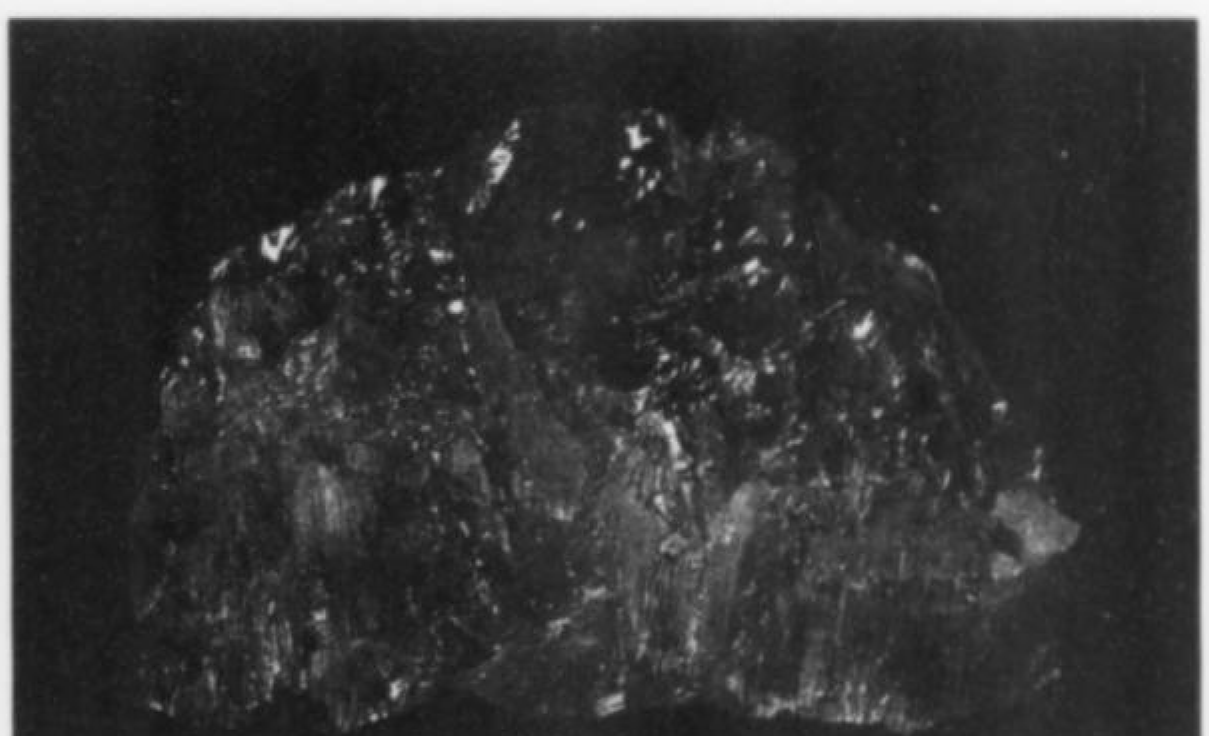


Figure 15. **Green beryl crystal, 10.4 cm, from the Nampula mine (1997). Desmond Sacco collection; Bruce Cairncross photo.**

Figure 16. **Beryl crystal, 8.1 cm, from Alto Ligonha. Gene Meieran collection; Jeff Scovil photo.**

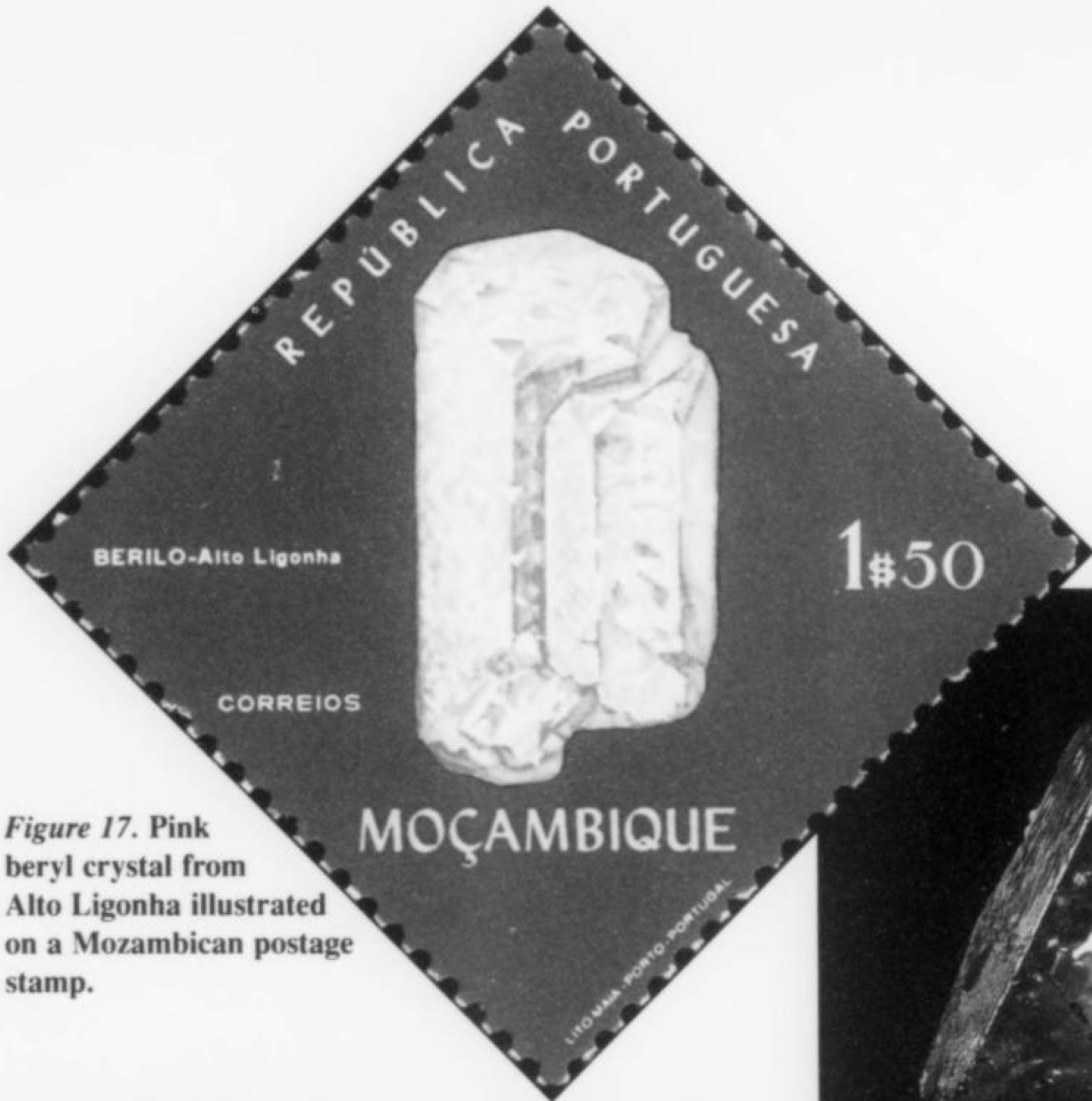


Figure 17. **Pink beryl crystal from Alto Ligonha illustrated on a Mozambican postage stamp.**

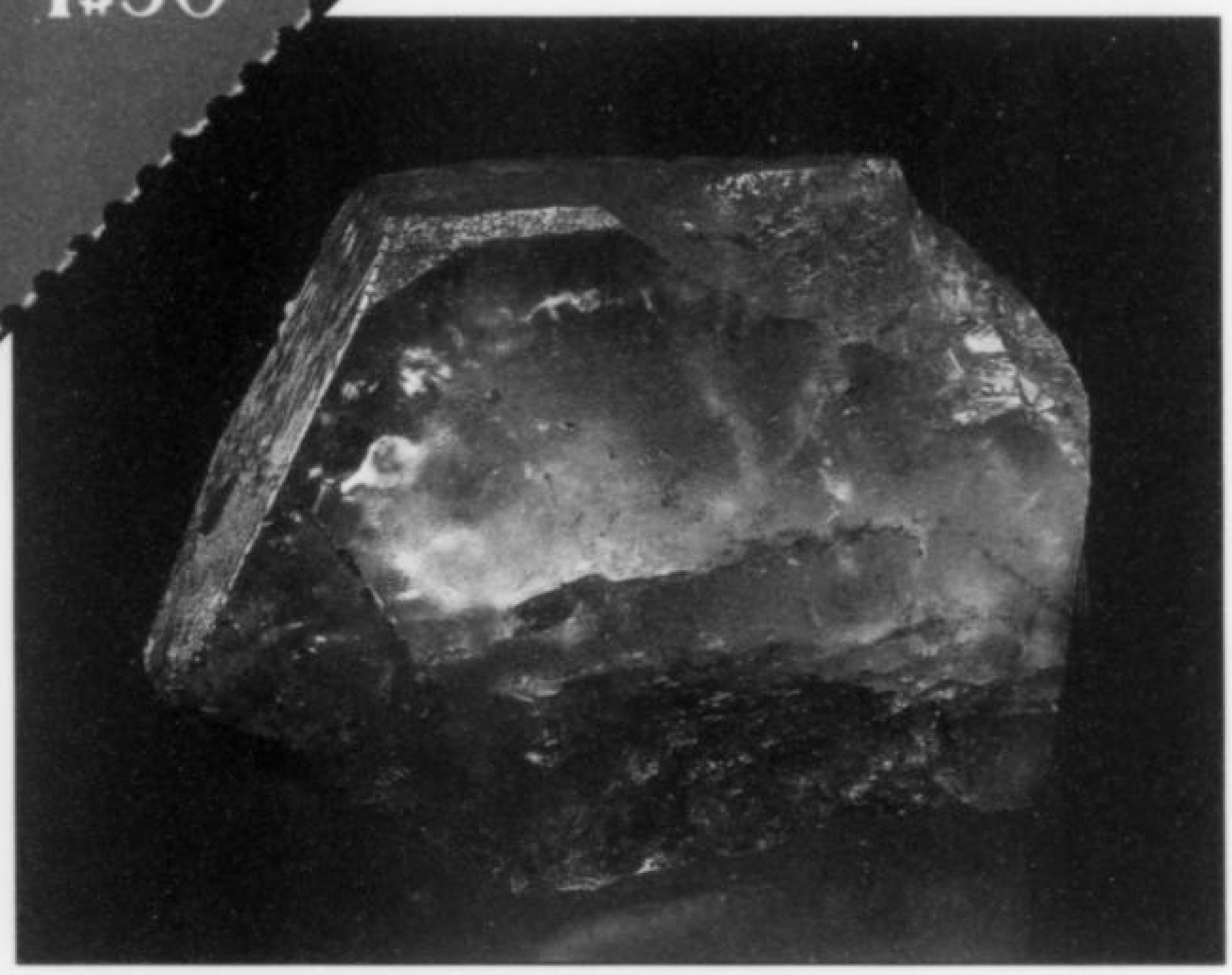
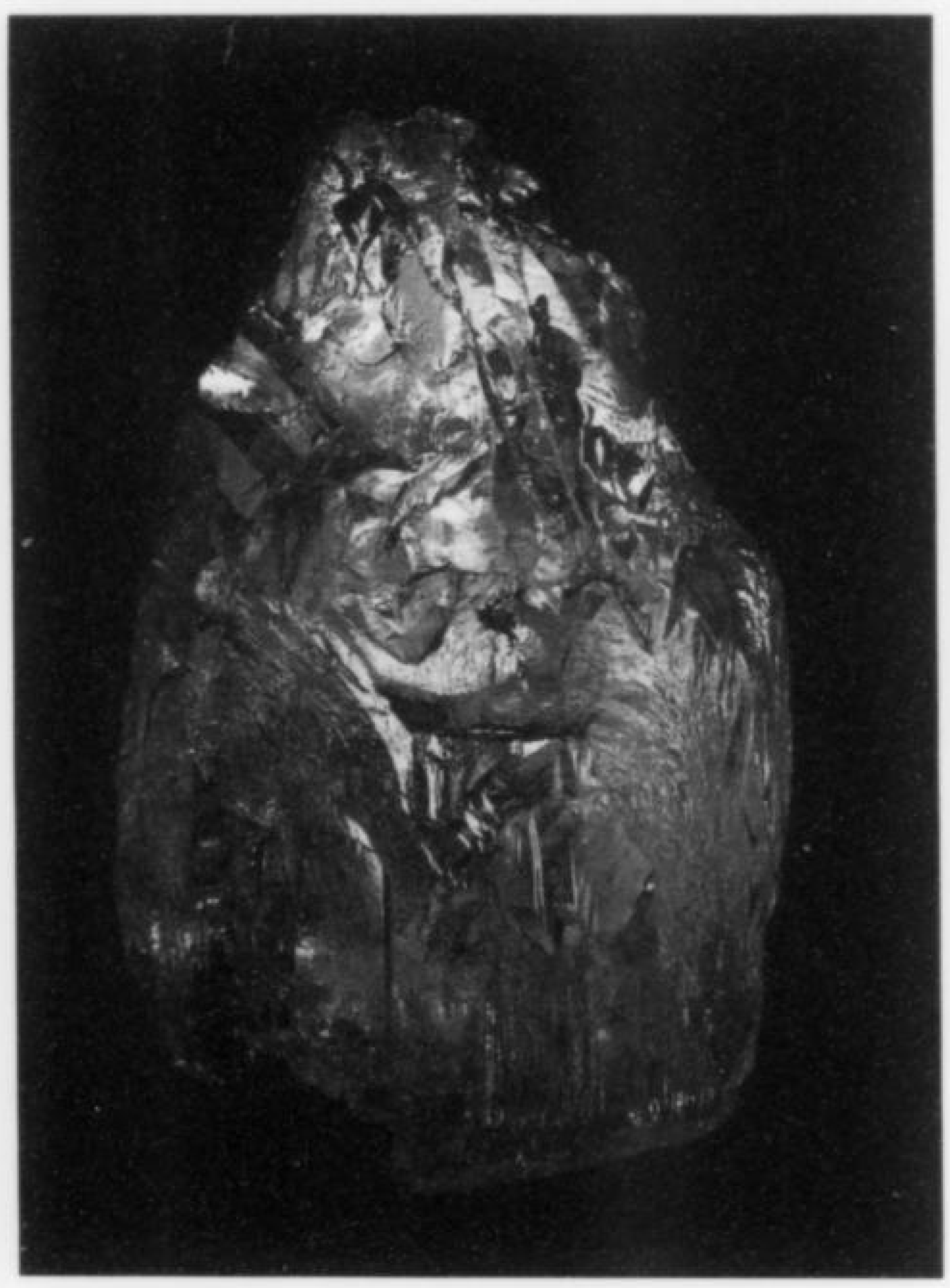


Figure 18. **Beryl (morganite) crystal, 10.2 cm, from Alto Ligonha. Jendon Minerals specimen; Jeff Scovil photo.**



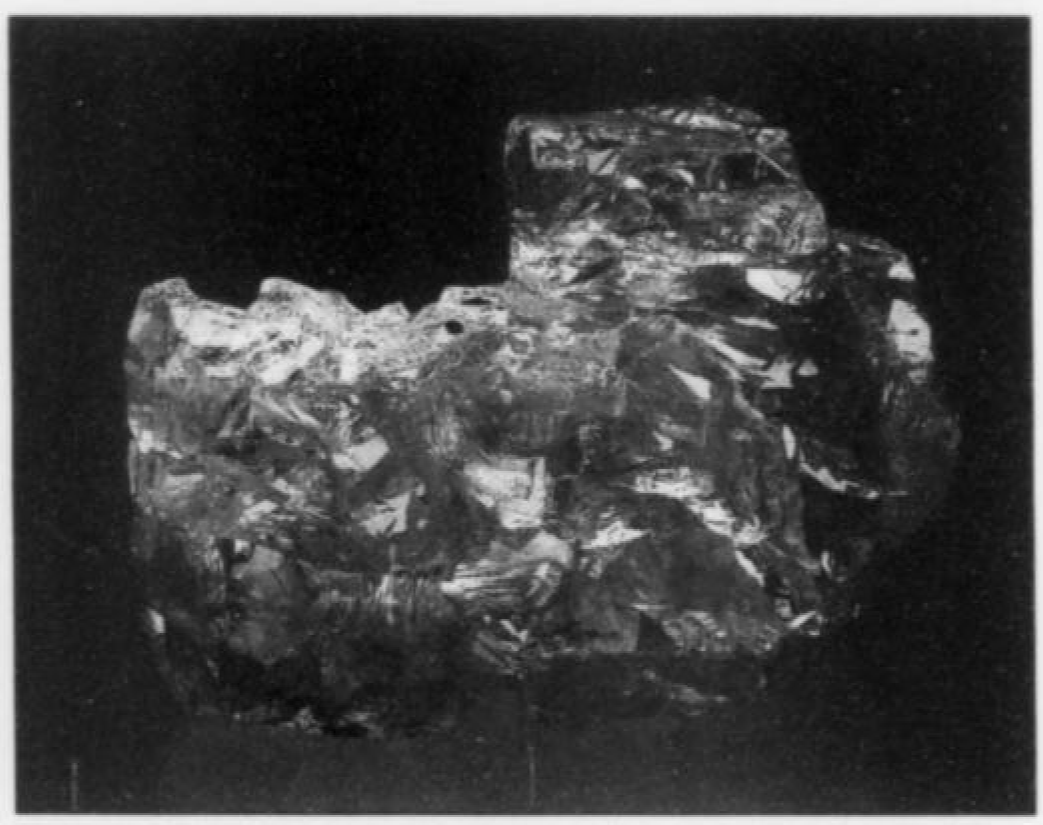


Figure 19. **Beryl crystal, 6.8 cm, showing corrosion surfaces, from Alto Ligonha. William Larson Collection; Jeff Scovil photo.**

Figure 20. **Beryl crystal, 7.1 cm, showing corrosion surfaces, from Alto Ligonha. William Larson collection; Jeff Scovil photo.**

suggesting that the crystals are basically aquamarine clouded by manganese oxides. Black beryl has been found also at the Maridge, Naipa, Muhano and Nahora pegmatites. Cotelo Neiva and Correia Neves (1960) described zoned crystals with black cores surrounded by green beryl, or with white to green cores and rims bracketing an intermediate zone of black beryl.

Morphologically most of the better crystals are composed of the pinacoid $\{0001\}$ plus $\{10\bar{1}0\}$, $\{11\bar{2}1\}$, $\{51\bar{6}0\}$, and $\{30\bar{3}1\}$. Beautiful rose-violet crystals are often tabular and gemmy, with $\{0001\}$, $\{10\bar{1}1\}$, $\{11\bar{2}1\}$, $\{21\bar{3}1\}$, $\{31\bar{4}1\}$, and rarely $\{11\bar{2}2\}$ and $\{1.0.\bar{1}.12\}$ (Sinkankas, 1988). Rose-red to salmon-pink crystals are often very gemmy and tabular with only the *c*-face being smooth; the numerous other forms present are typically very rough and corroded.

Many fine crystal specimens have been preserved in collections. A sharp, well-formed, 5 x 7.5-cm crystal of non-gem-quality

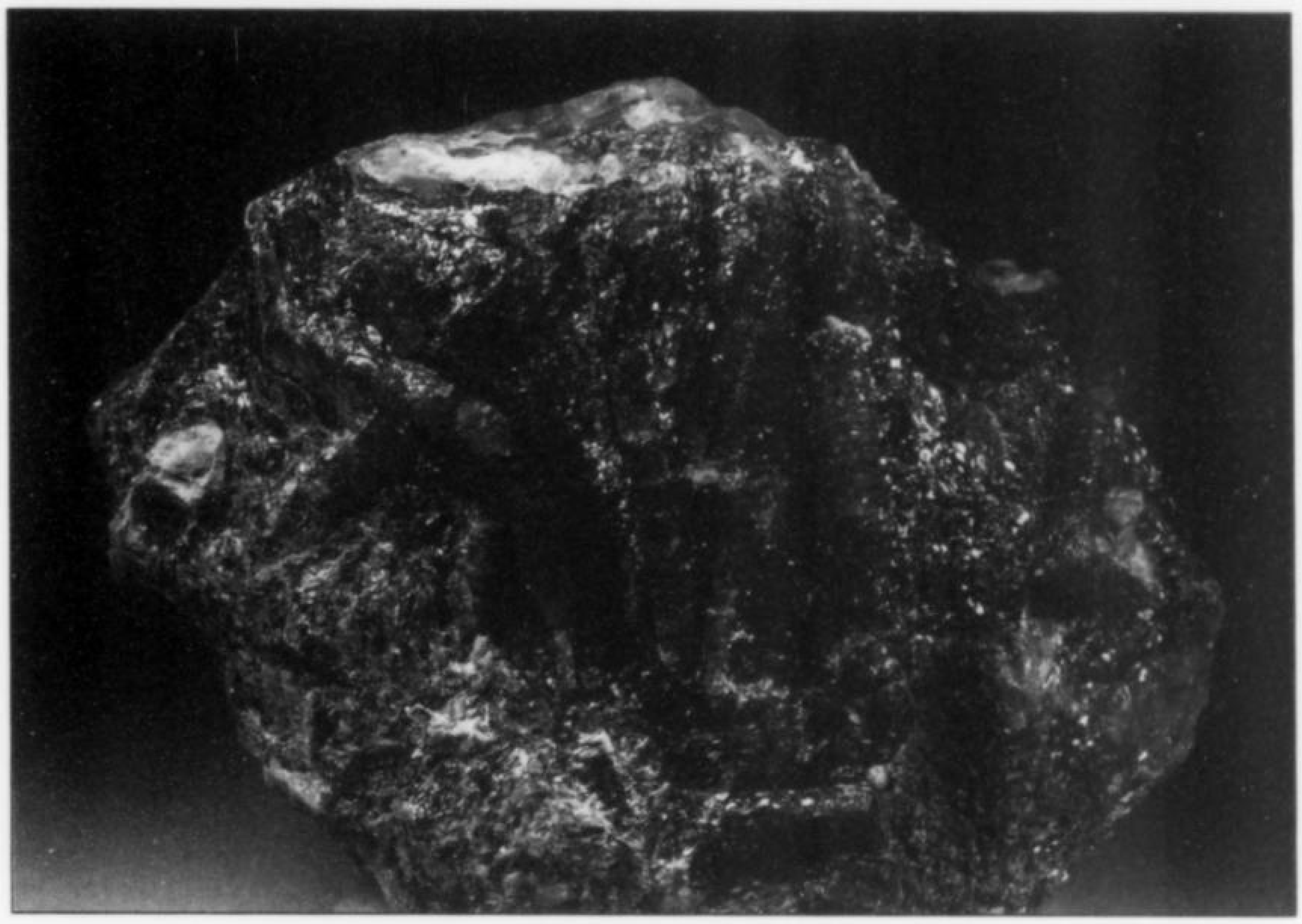


Figure 21. **Beryl (emerald) crystals in schist, 12.8 cm, from the Maria III mine. Lawrence Conklin specimen; Wendell Wilson photo.**

morganite from the Muiane mine is in the Smithsonian collection (Bandy, 1951). Behier (1957) mentions a 25 x 45-cm aquamarine crystal fragment of gem quality. Guillemin and Mantienne (1988) report that the Andrade Museum in Maputo, Mozambique, contains a perfect 45-cm beryl crystal from Alto Ligonha.

In all, at least 20 major pegmatites and pegmatite groups have produced noteworthy beryl at Alto Ligonha, especially those clustered around the Entata granitic intrusion. The Naipa pegmatite, for example, has produced beryl associated with gem elbaite, muscovite, lepidolite and other lithium-containing minerals. The Colina pegmatite yielded 40 tons of ore-grade crystals of which 0.1% were aquamarine. The Murrapane and Itaia pegmatites were also important producers (Borges, 1957; Bandy, 1951).

Betafite $(Ca,Na,U)_2(Ti,Nb,Ta)_2O_6(OH)$

Betafite has been reported from the Ile pegmatite, in association with euxenite, allanite and monazite, and from the Ehiale-Namovela-Massive-Horta group in association with euxenite and samarskite (DSGM, 1974).

Bismuth Bi

Approximately 3 tons of native bismuth, bismuth sulfide and bismuth alteration products were removed from two pegmatites (Bandy, 1951). These minerals came from the inner intermediate lithia zone and from the associated alluvium and eluvium (Kun, 1965). Masses of euhedral, well-developed crystals from the Muiane mine show the forms $\{10\bar{1}1\}$, $\{0001\}$, $\{01\bar{1}2\}$ and $\{02\bar{2}0\}$ (Cotelo Neiva and Correia Neves, 1960).

Bismuthinite Bi_2S_3

A single pocket in the Naipa pegmatite yielded over 450 kg (half a ton) of bismuthinite and a little native bismuth (Bandy, 1951).

Bismutite $Bi_2(CO_3)O_2$

The Naipa pegmatite has yielded pockets containing 45 kg of greenish bismutite and brownish bismuth ochre (Bandy, 1951). Bismutite also occurs as an alteration product of bismuth and bismuthinite, and is widespread throughout the district. Fifteen different pegmatites and pegmatite groups have reported the presence of bismutite (DSGM, 1974). At the Muiane pegmatite it forms amorphous masses which are white to greenish to lemon-yellow in color (Cotelo Neiva and Correia Neves, 1960). Aires-Barros (1966) made a detailed study of some occurrences of bismutite in the Alto Ligonha and Alto Molocué pegmatites. Sahama and Lehtinen (1968) made a regional study, describing acicular habits, ghostlike remnants and pulverulent masses of honey-yellow to dark gray or greenish bismutite.

In 1958 one of us (MBD) saw nearly 2 tons of bismutite pseudomorphs from the Malolo pegmatite. The pseudomorphs showed a hexagonal prismatic habit lacking terminations, apparently after beryl or quartz crystals; many were hollow or with quartz occupying the core of the pseudomorphs. "Crystal" sizes ranged up to 5 cm in diameter and 10 cm long, with most around 2 x 5 cm.

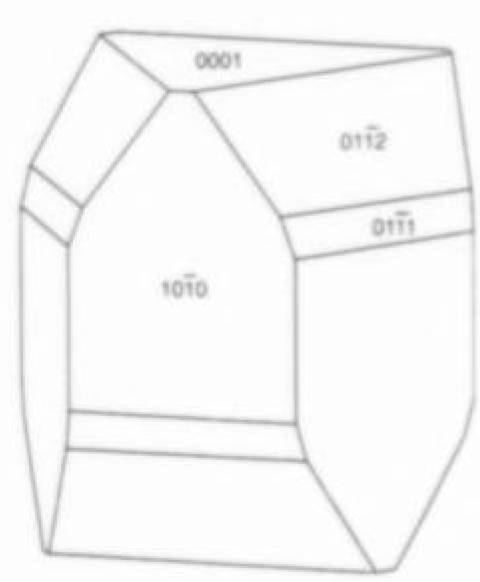


Figure 22 **Bismuth crystal drawing (Muiane mine) by R. Peter Richards, based on measurements reported by Cotelo Neiva and Correia Neves (1960).**

Cassiterite SnO_2

Cassiterite was reported from the Piteia pegmatite by Bandy (1951), although he admitted not having personally seen the specimens. It has also been reported from the Muiane-Naipa group, the Ingela-Murrapane-Namicaia group, the Tulua-Marengo group, and the Naiume pegmatite (DSGM, 1974).

Churchite-(Y) $YPO_4 \cdot 2H_2O$

Von Knorring (1977b) described specimens of churchite-(Y) from the Muiane pegmatite.

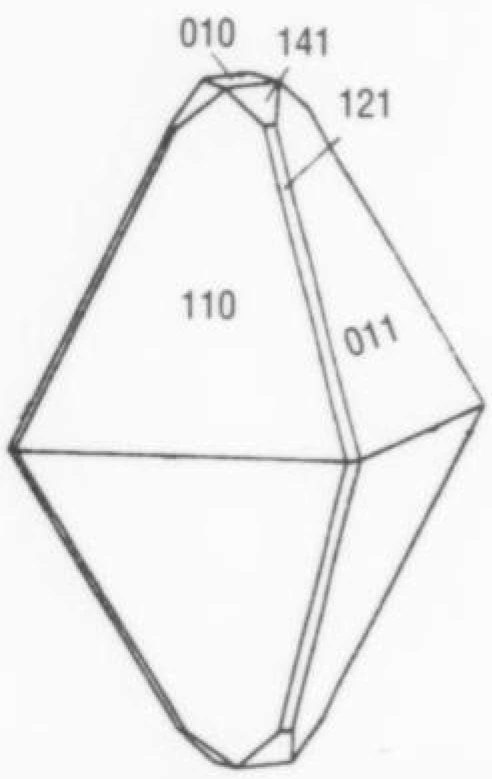


Figure 23. **Clinobisvanite crystal drawing (Mutala area) from Von Knorring *et al.* (1973).**

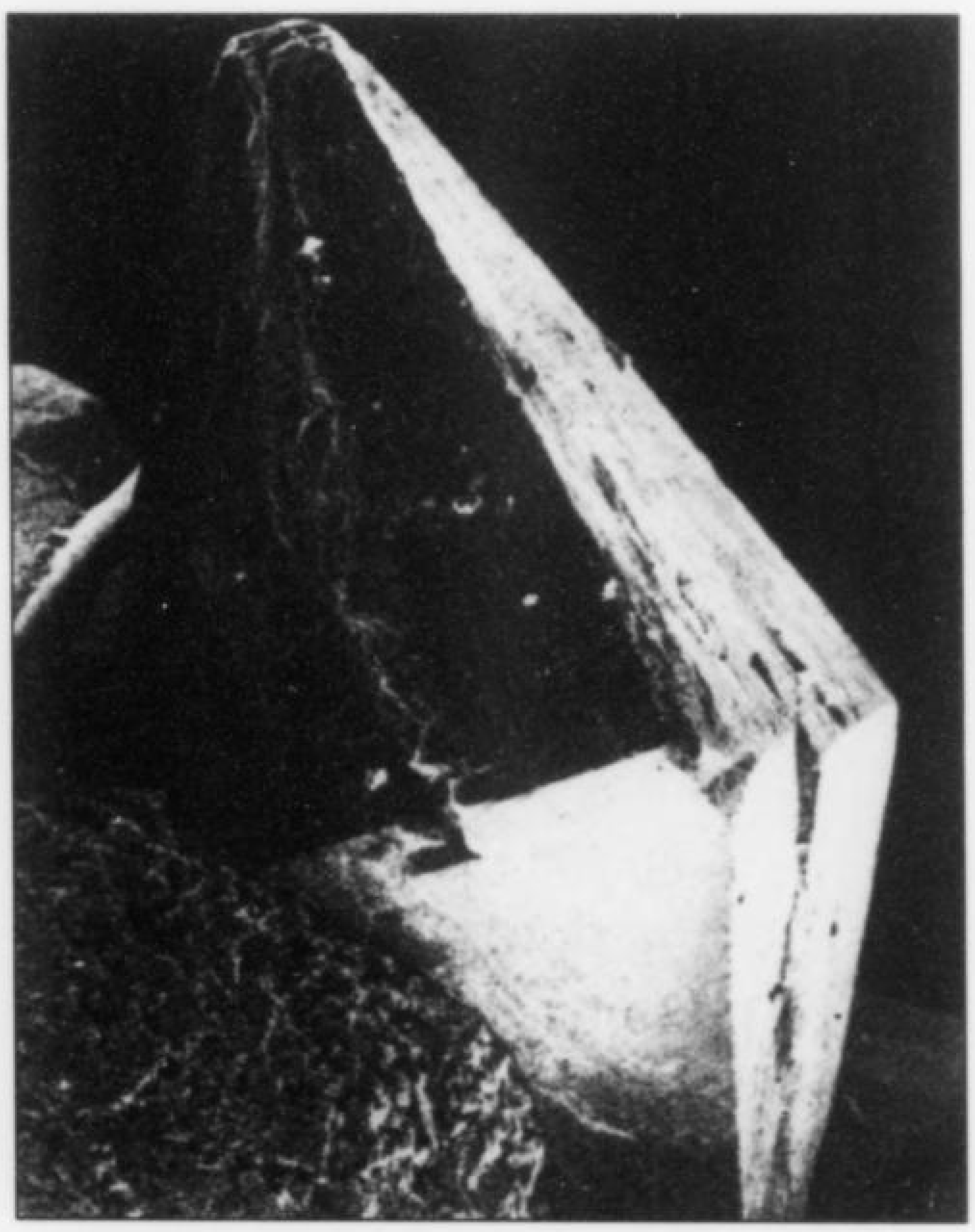


Figure 24. **Clinobisvanite crystal (SEM) from the Mutala area (from Von Knorring *et al.*, 1973).**

Clinobisvanite $BiVO_2$

Von Knorring *et al.* (1973) described pucherite and a monoclinic dimorph from the Mutala pegmatite. The orange, well-formed, 2-mm crystals resemble pyramidal scheelite in habit. Multiple twinning occurs on (101), and (010), with perfect cleavage on {010}. The monoclinic dimorph was officially named clinobisvanite by Bridge and Pryce (1974), based on specimens from Yinnietharra, Western Australia. Had Von Knorring *et al.* proposed a name, it would have had precedence, and Mozambique would instead have been the type locality.

Clinochlore $(Mg,Al)_6(Si_3Al)O_{10}(OH)_8$

Goñi and Guillemin (1964) observed iron-free clinochlore ("leuchtenbergite") as part of a suite of minerals (with microcline and muscovite) which have replaced tourmaline at Alto Ligonha. The clinochlore "locally forms a network in the microfissures of tourmaline crystals." The partially replaced tourmalines may also contain crystals of manganotantalite.

Cookeite $LiAl_4(Si_3Al)O_{10}(OH)_8$

Cookeite probably occurs at the same pegmatites where other lithium minerals are abundant. One documented specimen, from Muiane, is a remarkable 8-mm single crystal in the Andrade Museum, Maputo, Mozambique (Guillemin and Mantienne, 1988). It is sometimes found coating and partially replacing crystals of red elbaite, lepidolite and muscovite (Cotelo Neiva and Correia Neves, 1960). Sahama *et al.* (1968) described specimens from the Muiane mine: large rosettes crystallized in an open vug, consisting of thin, six-sided, transparent, yellowish flakes to 1 cm across.

Corundum Al_2O_3

Corundum was reported from the Niesse-Isabela mine area by DSGM (1974).

Elbaite $Na(Li,Al)_3Al_6(BO_3)_3Si_6O_{18}(OH)_4$

Magnificent red and green tourmaline crystals of the highest gem quality have been a hallmark of the district. Fine crystals in

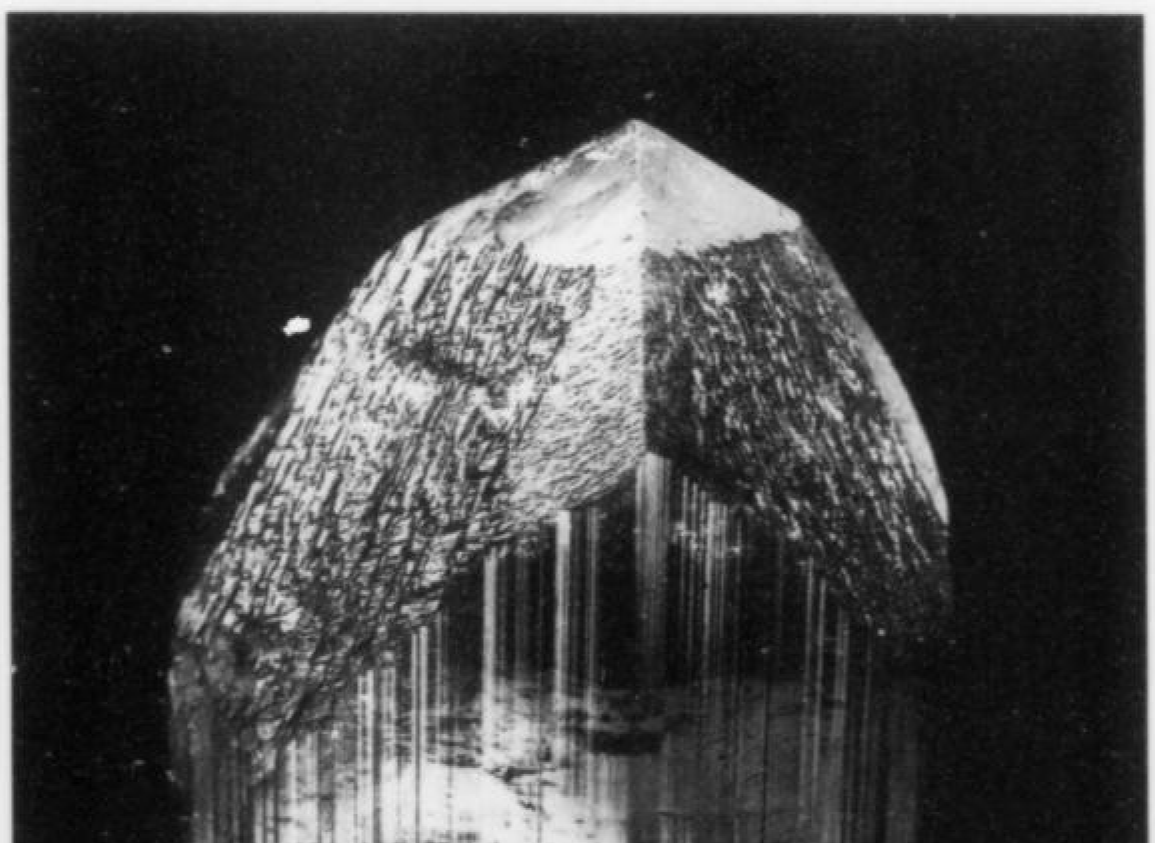


Figure 25. **Elbaite crystal, 8.1 cm, from Alto Ligonha. Jesse Fisher collection; Jeff Scovil photo.**

Figure 26. **Elbaite crystal, 7.8 cm, from Alto Ligonha. William Larson collection; Jeff Scovil photo.**

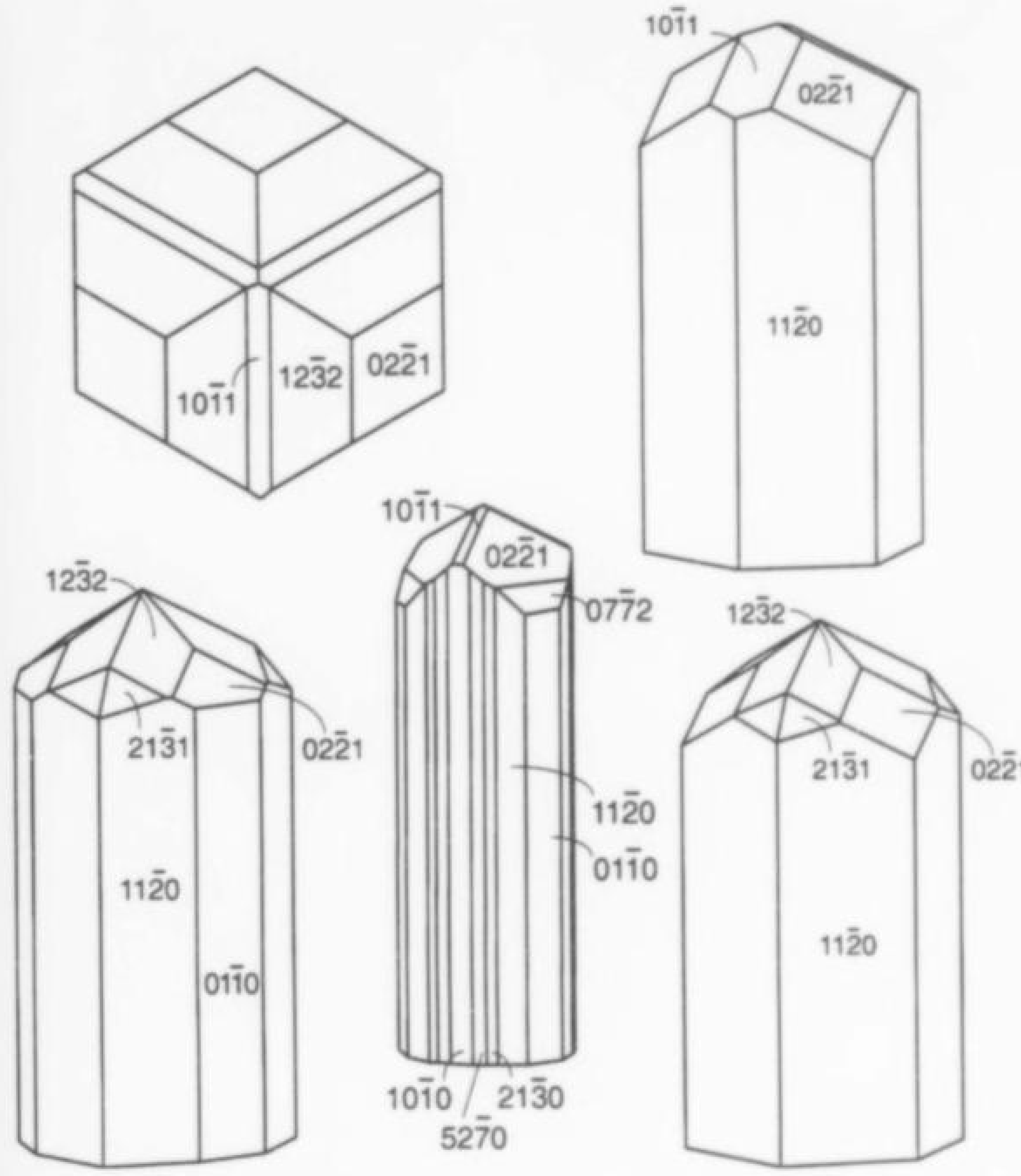


Figure 27. **Elbaite crystal drawings (from the Muiane and other mines) by R. Peter Richards, based in part on measurements reported by Cotelo Neiva and Correia Neves (1960), and in part on specimens studied by the authors.**

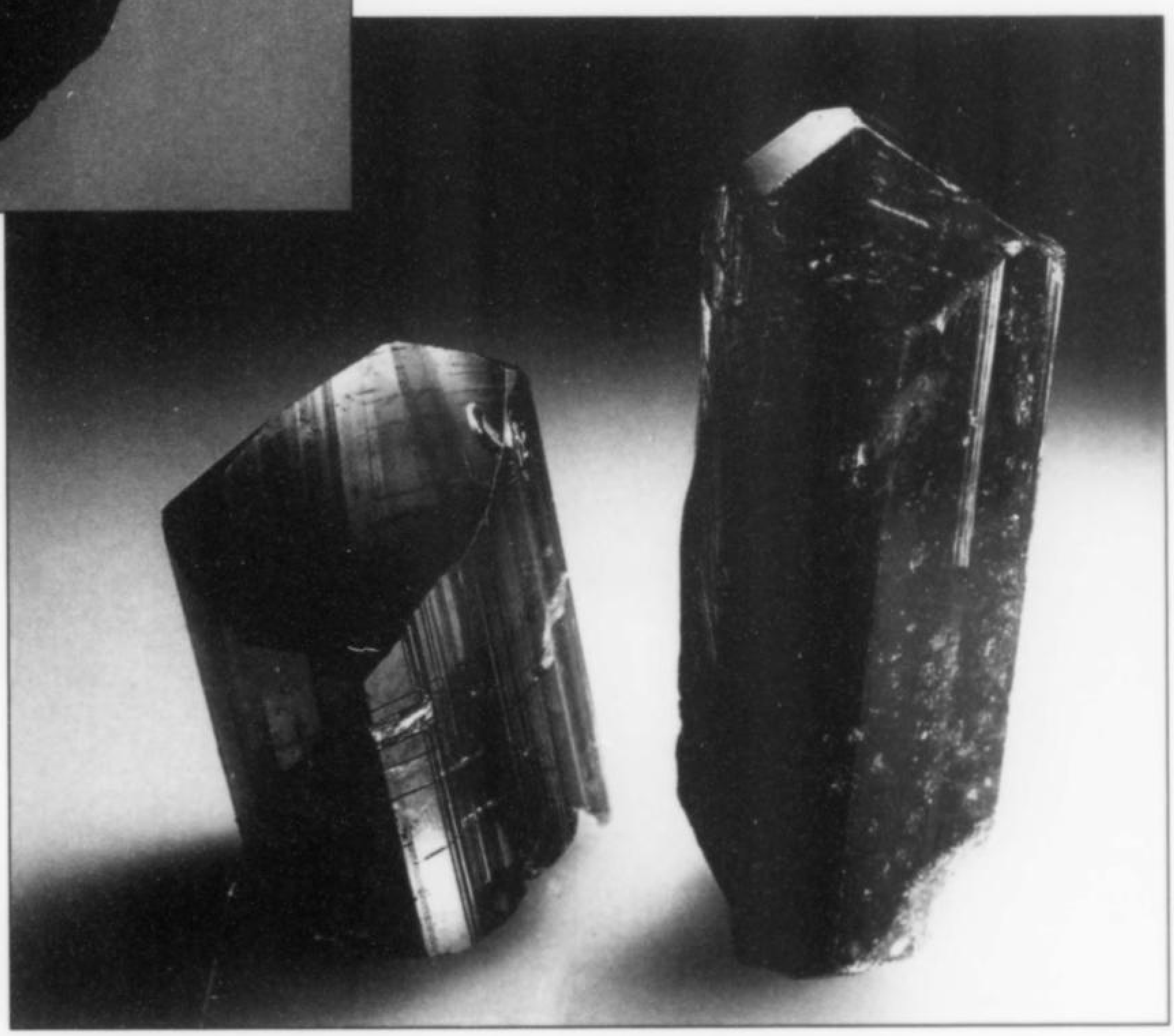


Figure 28. **Elbaite crystals to 7.7 cm, from Alto Ligonha. Harvard collection; Wendell Wilson photo.**

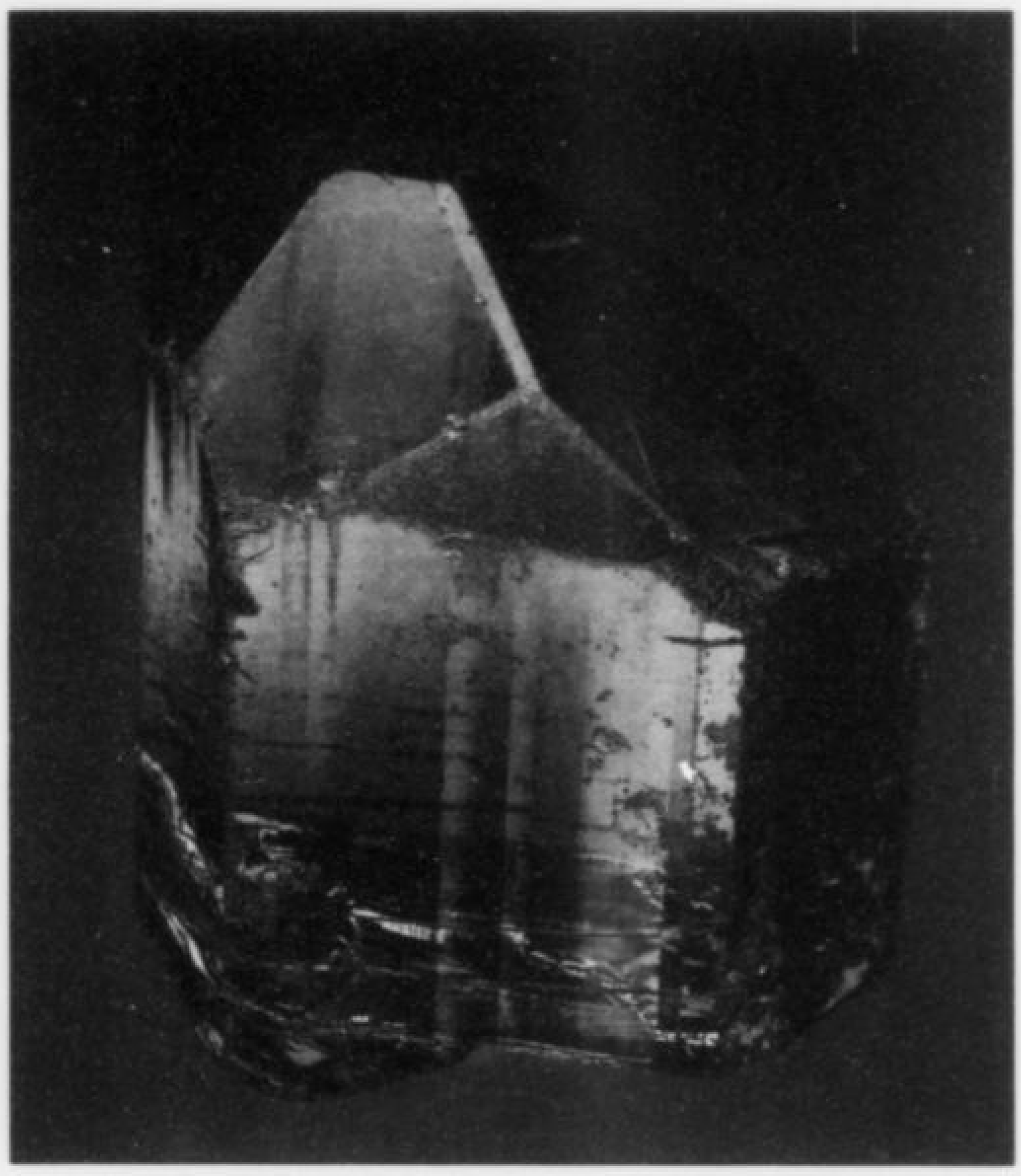


Figure 29. **Elbaite crystal, 7.7 cm, from Alto Ligonha. William Larson collection; Jeff Scovil photo.**

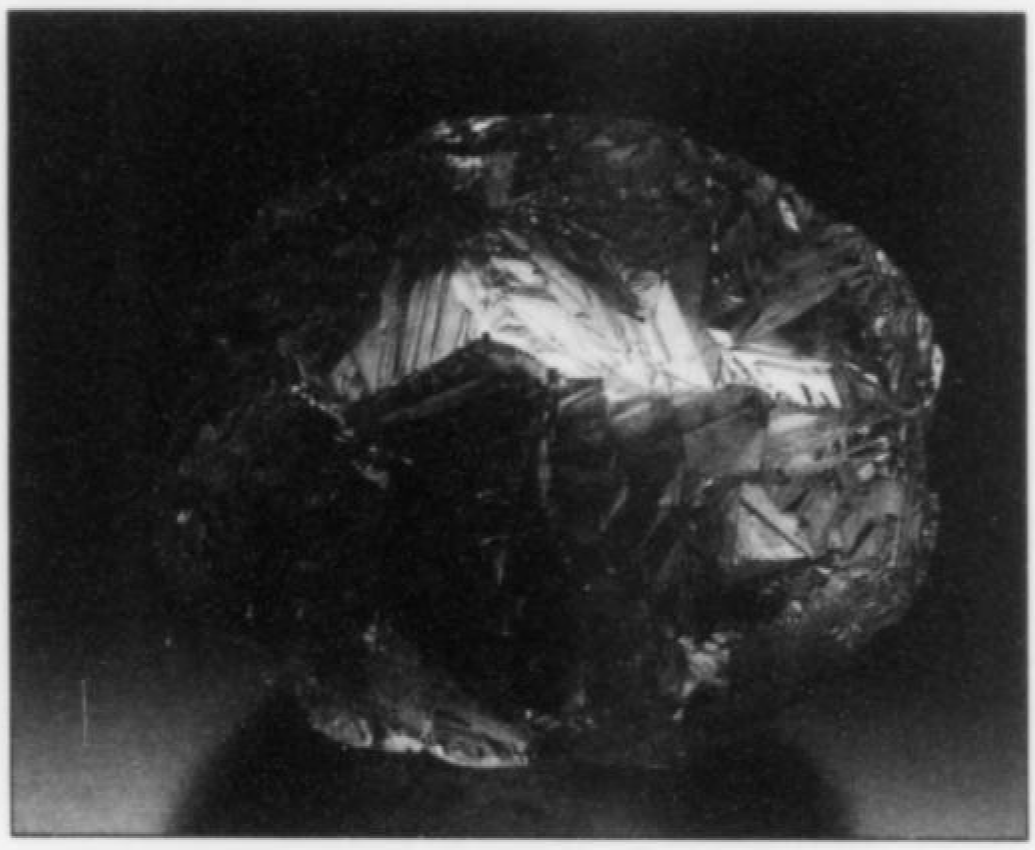


Figure 30. **Elbaite crystal, 3.1 cm, showing corrosion surfaces, from Alto Ligonha. William Larson collection; Jeff Scovil photo.**

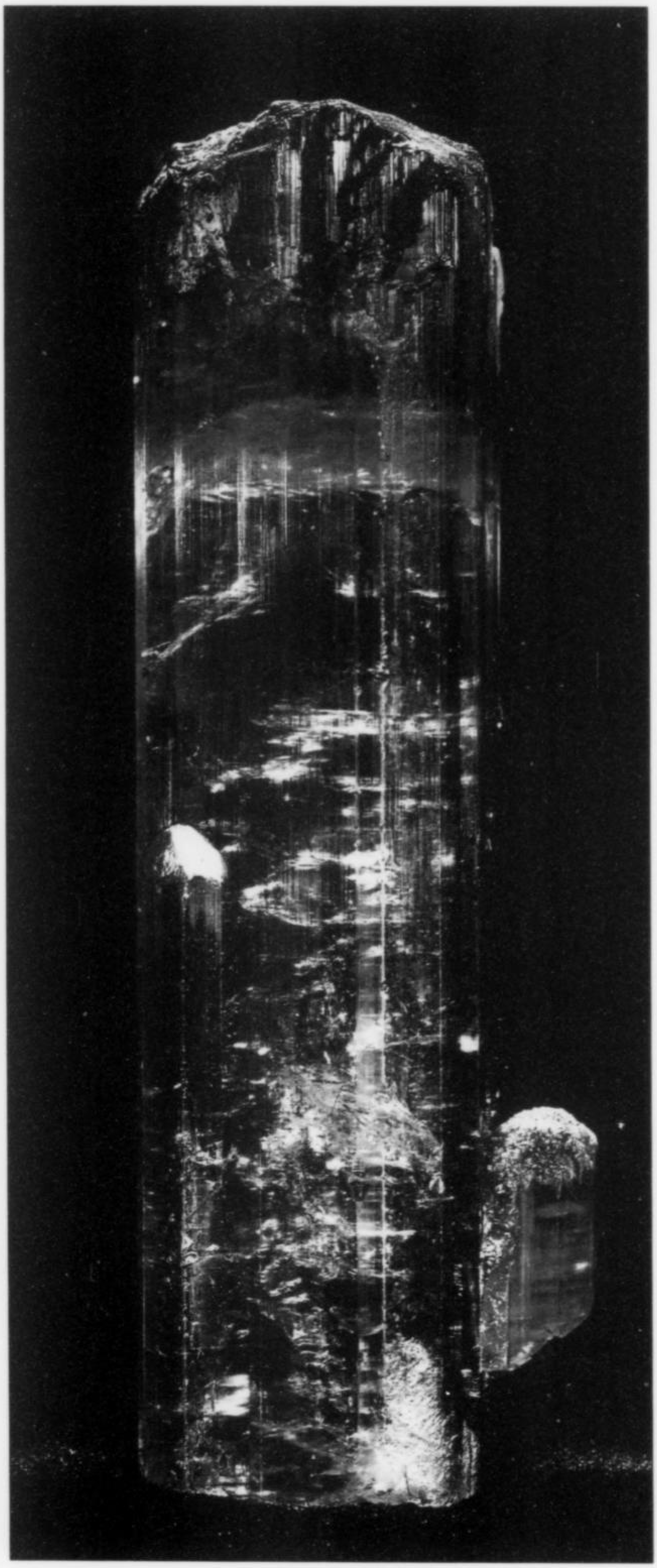


Figure 31. **Elbaite crystal, 7.3 cm, from Alto Ligonha. American Museum of Natural History collection; photo by Jackie Beckett and Olivia Bauer courtesy of AMNH.**

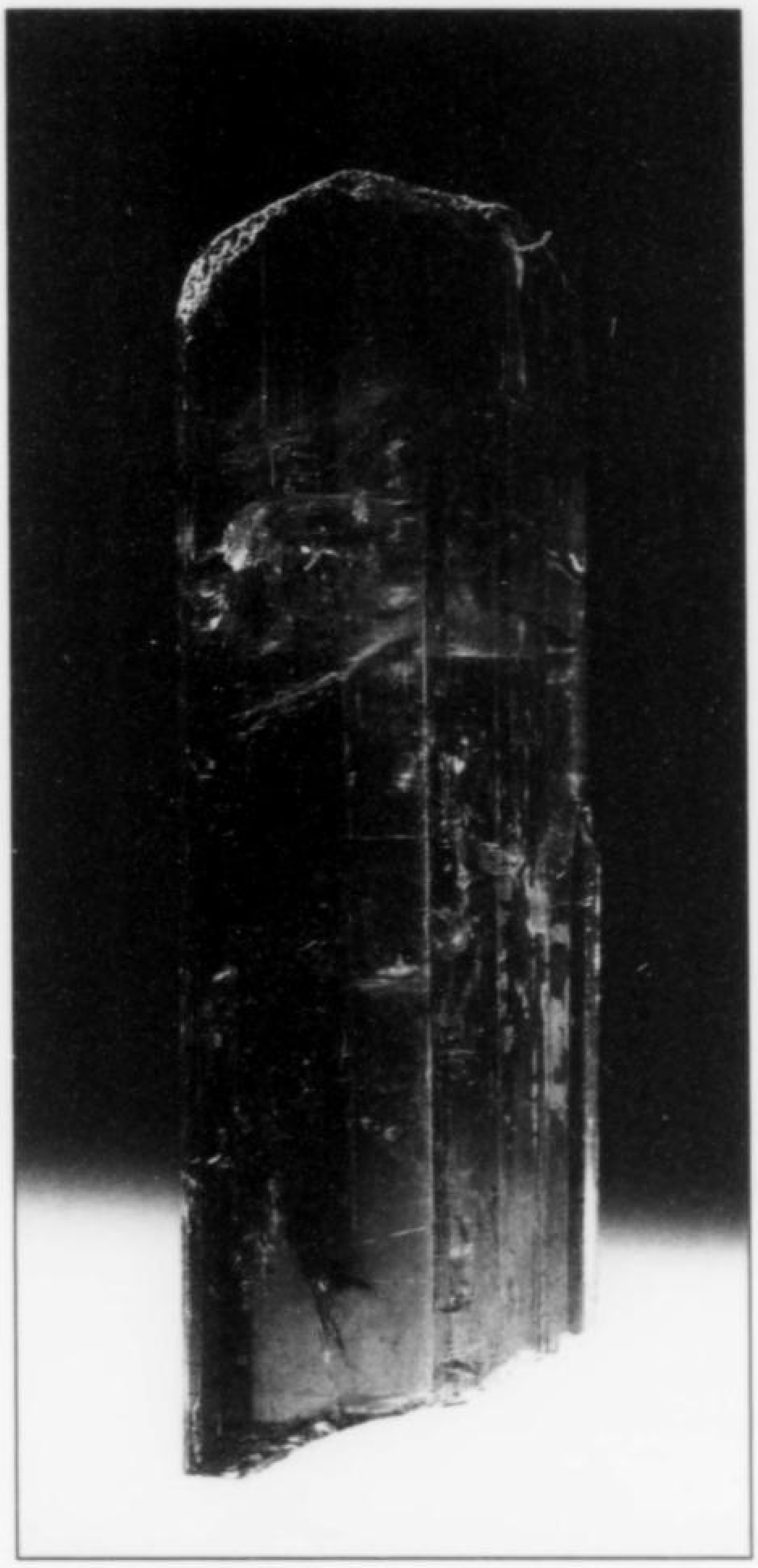
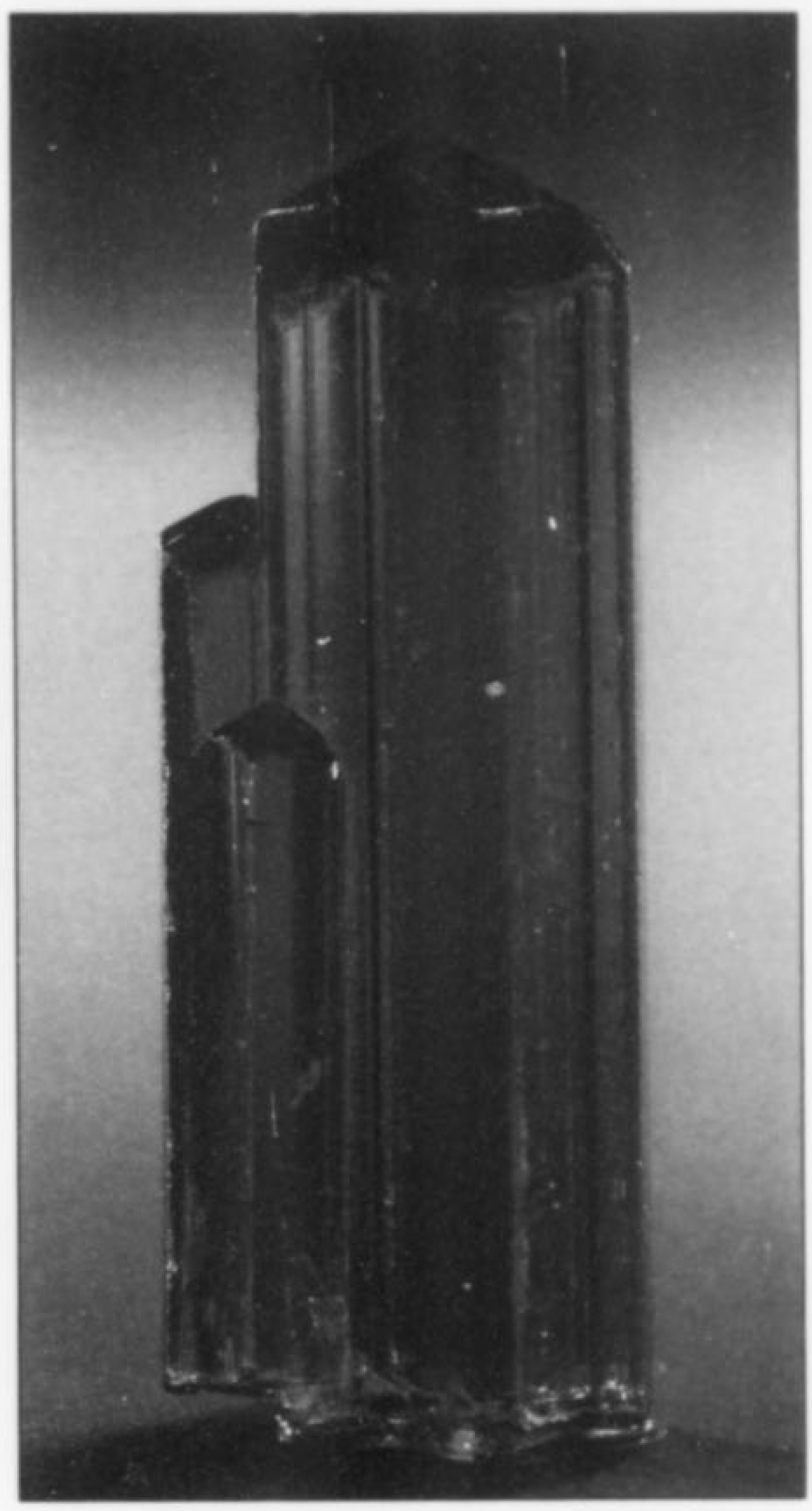


Figure 32. Elbaite crystal, 5.4 cm, from Alto Ligonha. Karl Hartmann photo courtesy of Traudel Sachs.

Figure 33. Elbaite crystal, 6 cm, from Alto Ligonha. F. John Barlow collection; photo by Malcolm Hjerstedt courtesy of F. John Barlow.

Figure 36. Elbaite, 3 cm, from the Muiane mine. William Larson collection; photo by Harold and Erica Van Pelt.



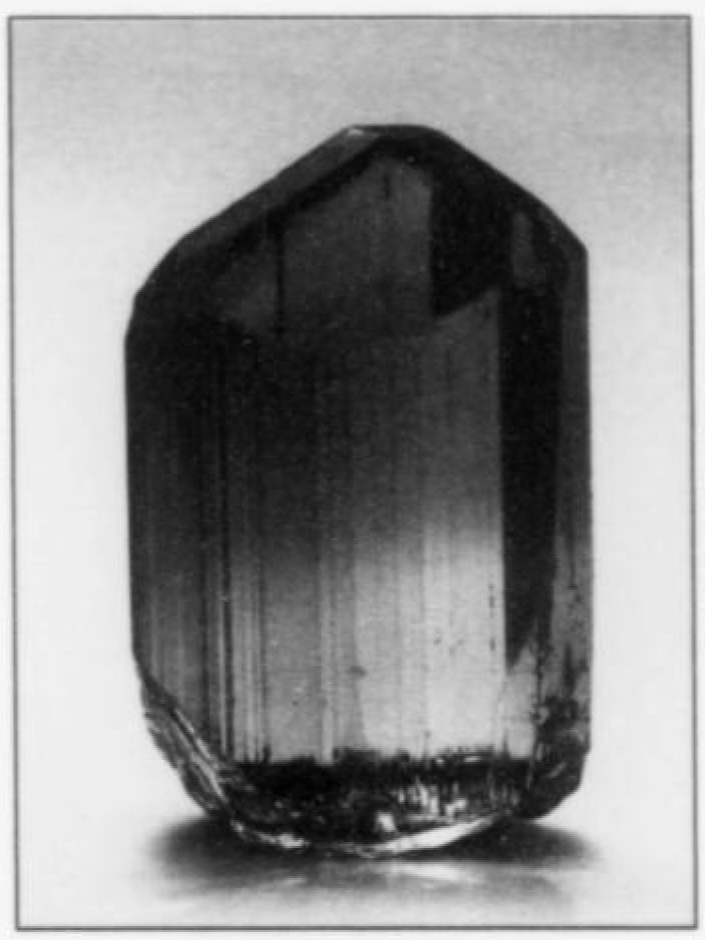


Figure 34. Elbaite crystal, 2.8 cm, from Alto Ligonha. Sorbonne collection; photo by Nelly Bariand.

Figure 35. Elbaite crystal, 4.2 cm, from Alto Ligonha. Karl Hartmann photo courtesy of Traudel Sachs.

Figure 37. **Green Elbaite ("verdelite") from Alto Ligonha, as illustrated on a Mozambican postage stamp.**

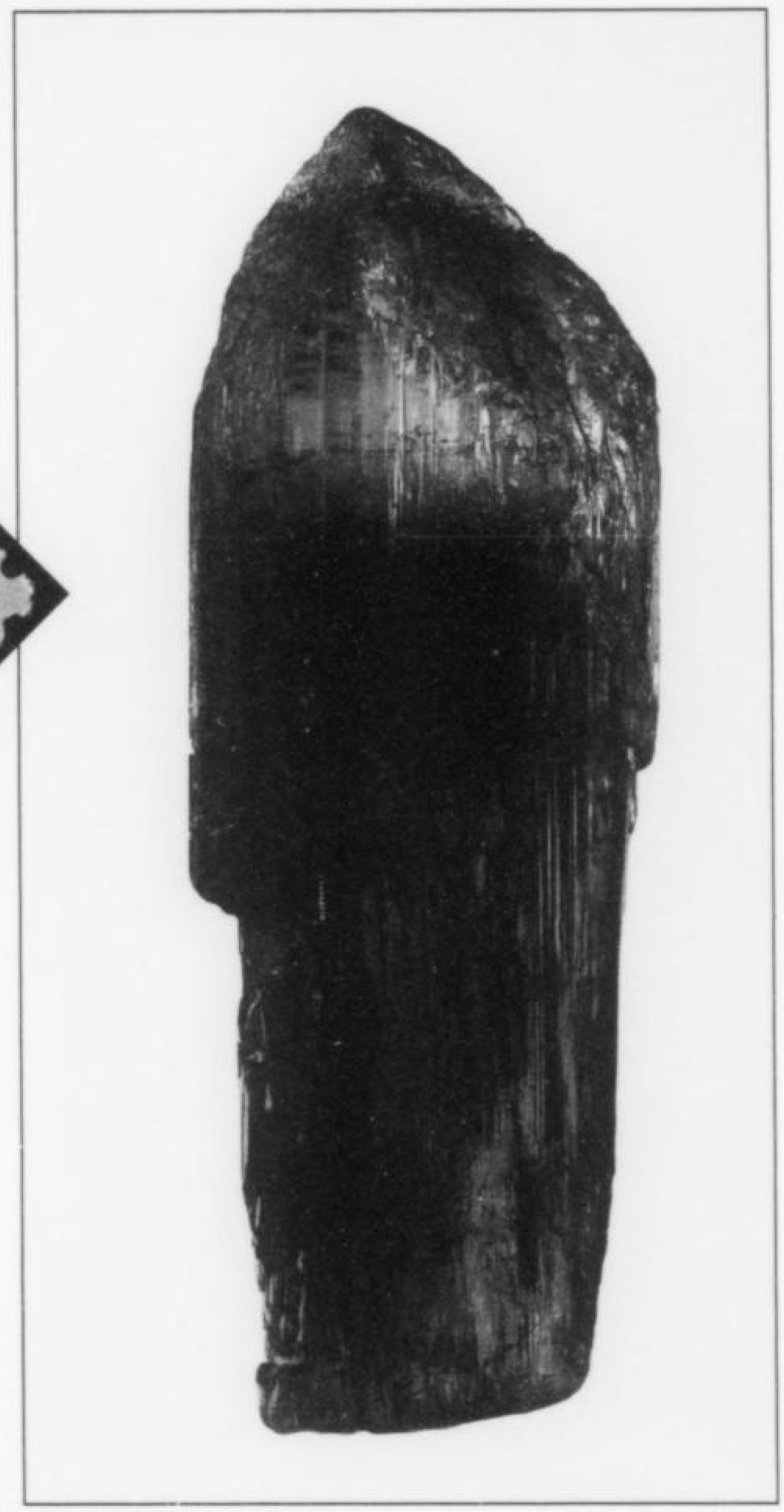


Figure 38. **Elbaite crystal, 5 cm, from Alto Ligonha. Karl Hartmann photo courtesy of Traudel Sachs.**

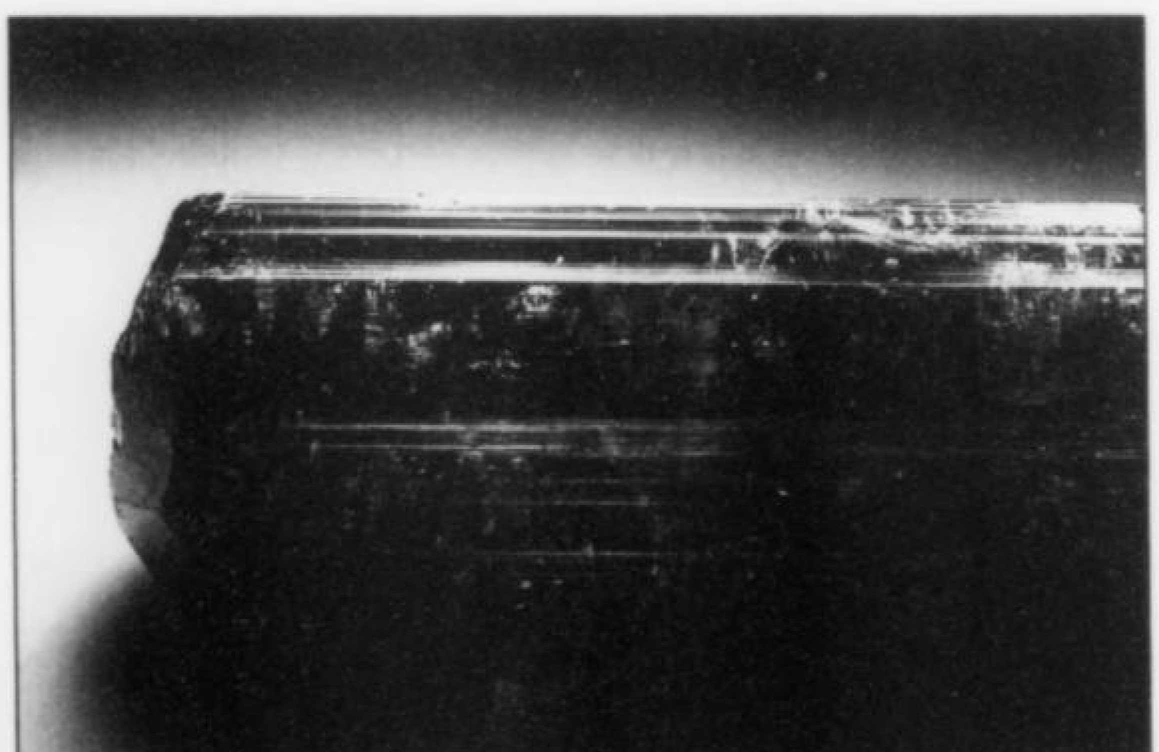


Figure 39. **Elbaite crystal, 16 cm, from Alto Ligonha. Harvard collection. Wendell Wilson photo.**

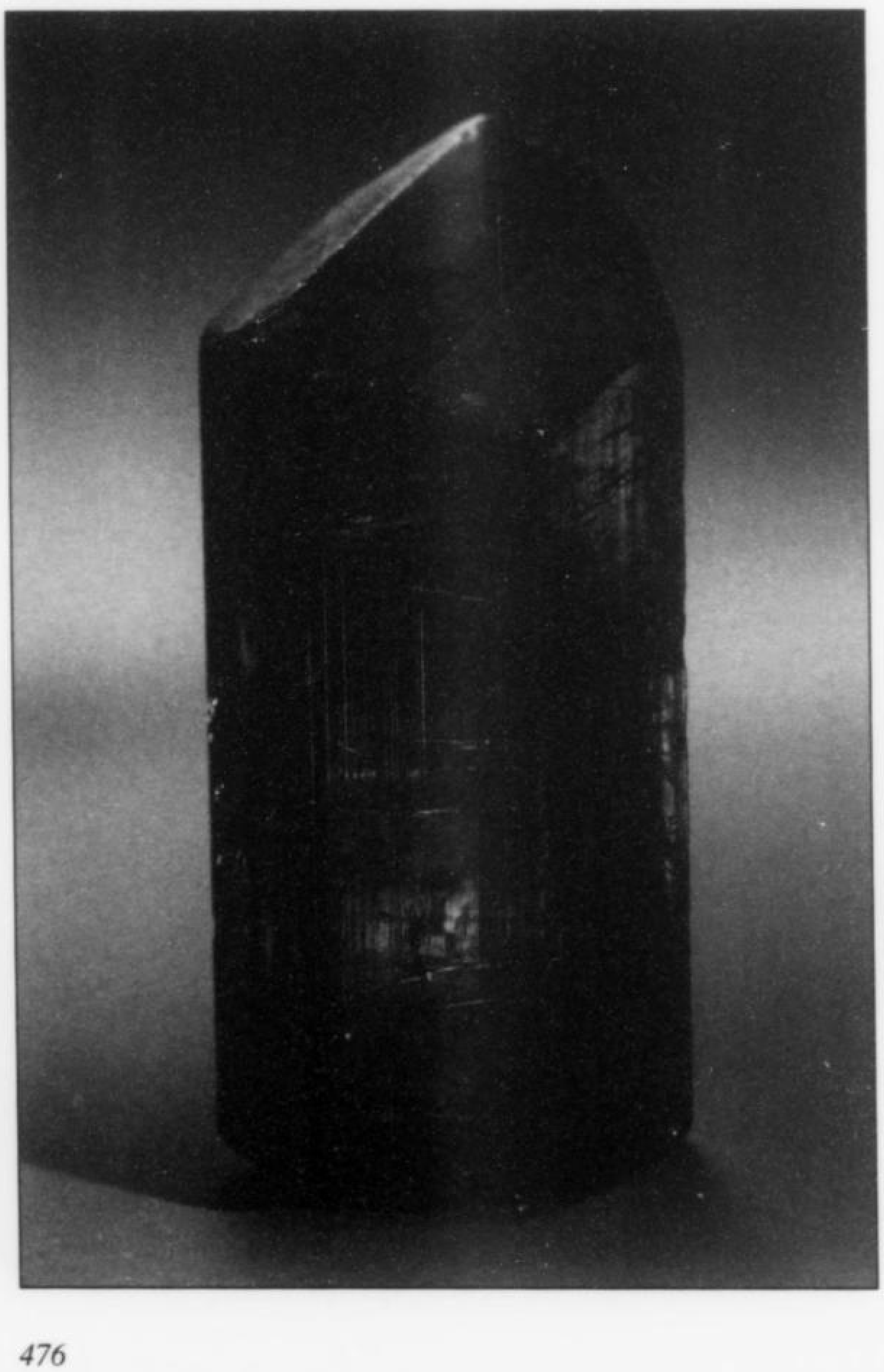


Figure 40. **Elbaite crystal, 7.2 cm, from Alto Ligonha. Keith Proctor collection; photo by Harold and Erica Van Pelt.**

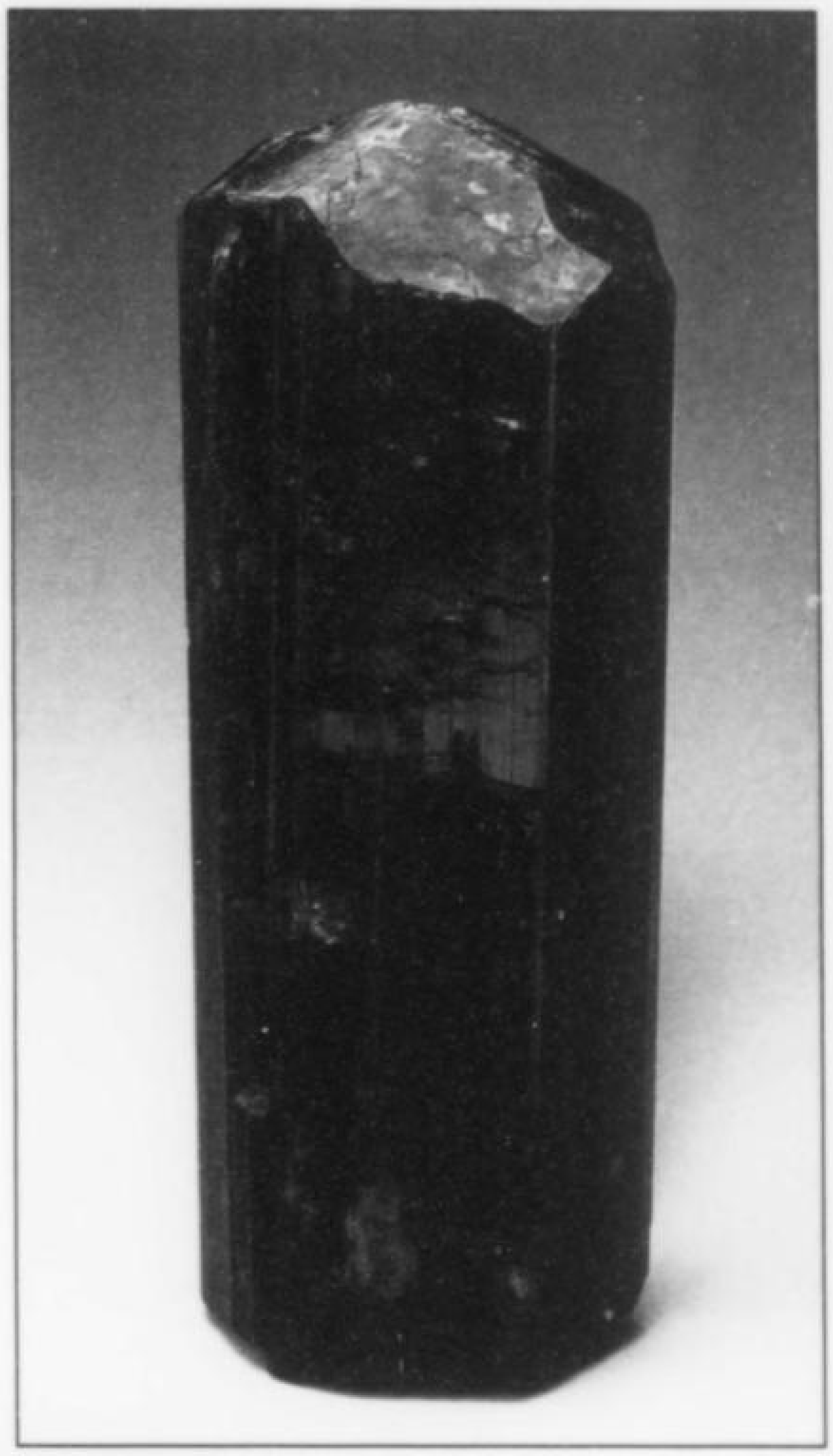


Figure 41. Elbaite crystal, 16 cm, from Alto Ligonha. Smithsonian specimen (NMNH #112913) and photo; gift of Mark Chance Bandy in 1957.

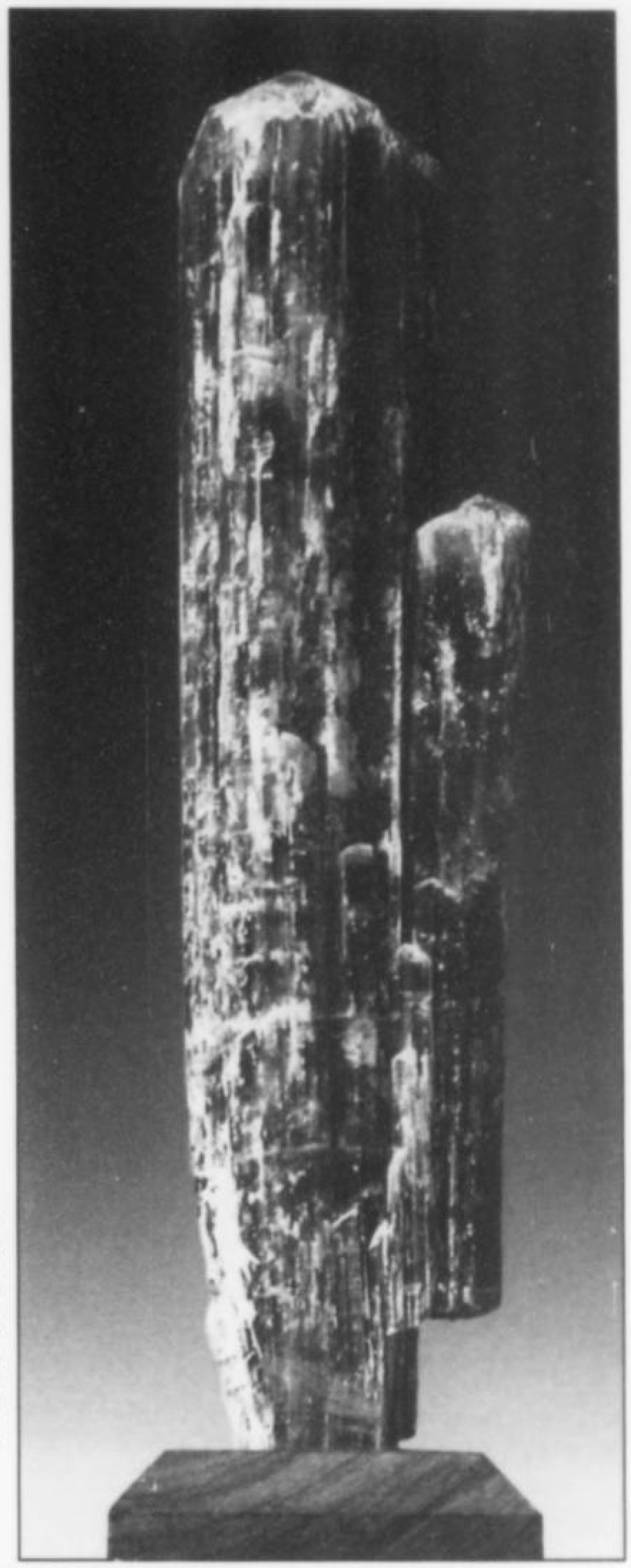


Figure 43. Elbaite crystal, 46 cm (7.5 kg), from the Muiane mine, Alto Ligonha. Collection of the Alto Ligonha Mining Company at Muiane; photo by M. Bettencourt Dias.

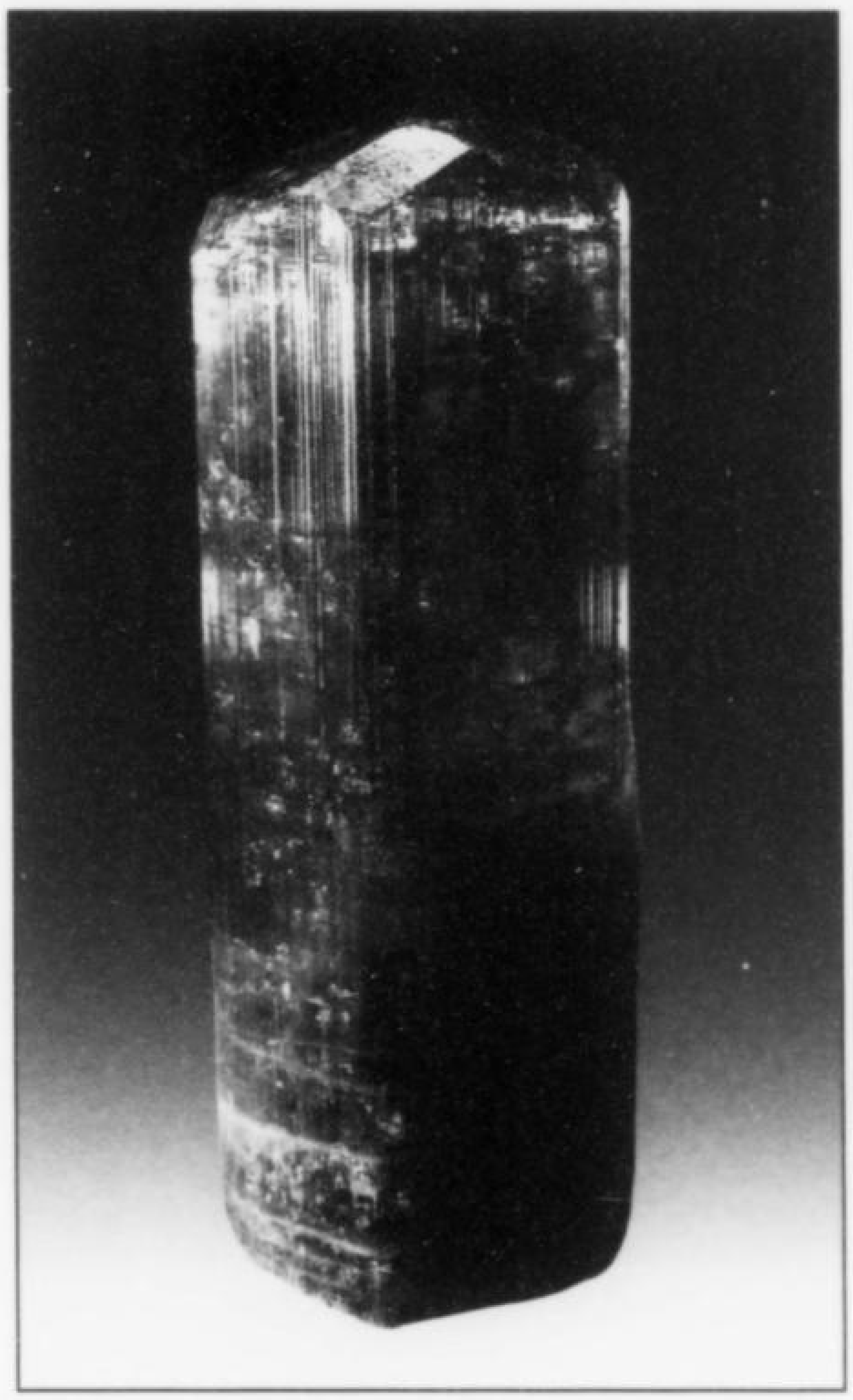


Figure 42. Elbaite crystal, 17.5 cm, from Alto Ligonha. Collection of the Natural History Museum of Los Angeles County (gift of Ed Harrison in 1983, from the Sol Shalevitz collection, 1962); A. Kampf photo.

Figure 44. Elbaite crystal, 8.2 cm, from Alto Ligonha (identity confirmed by electron microprobe analysis). Jack Halpern collection; Wendell Wilson photo.

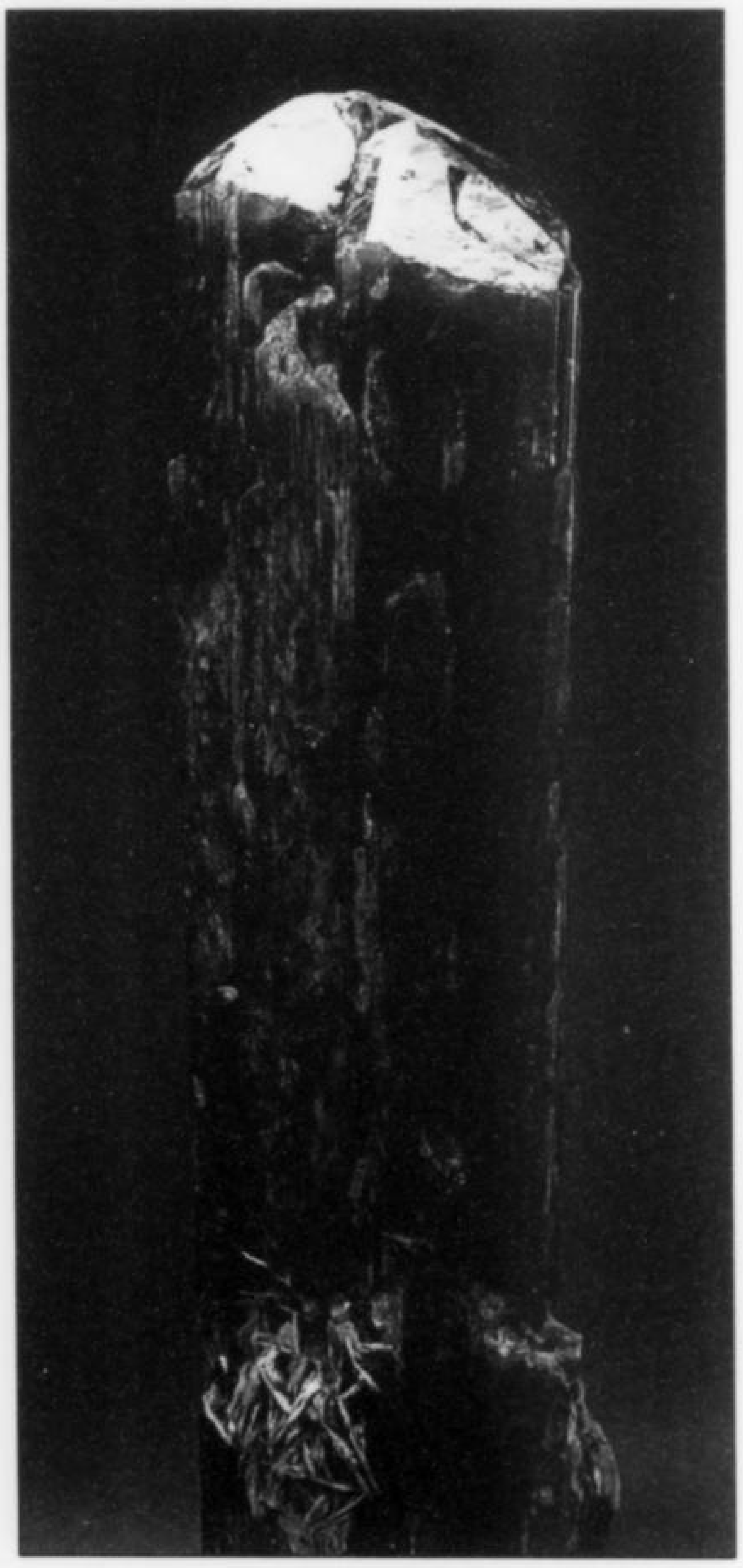


Figure 45. **Elbaite crystal, 55 cm, from Alto Ligonha. Smithsonian specimen (NMNH #R9436) purchased from Martin Ehrmann in 1955; NMNH photo.**

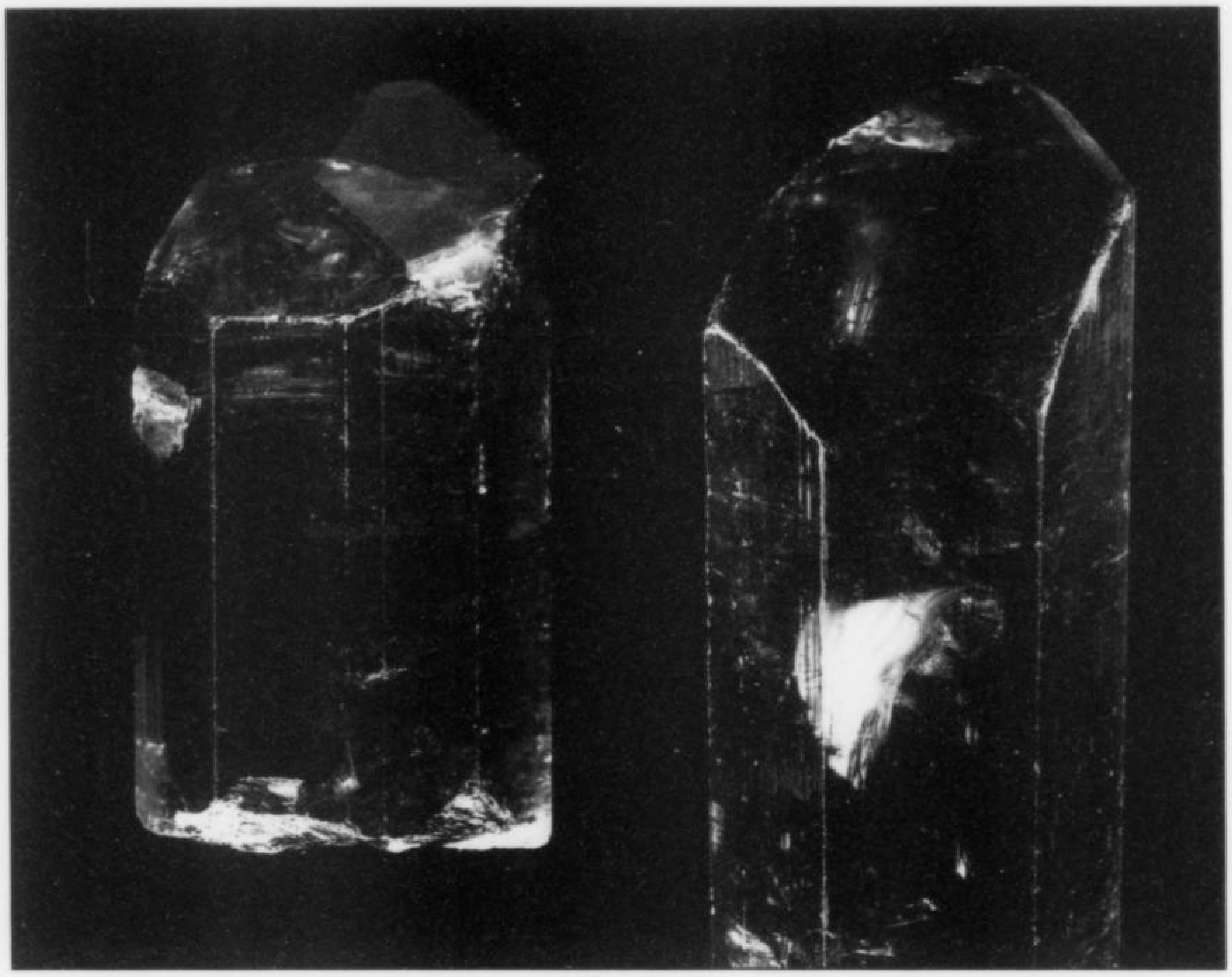


Figure 46. **Elbaite crystals from Alto Ligonha: *(left)* 6 cm, Sorbonne collection; *(right)*: 15 cm, Gerhard Becker collection; photo by Nelly Bariand.**

shades of blue, violet, brown, orange and yellow, even "tea-color" and "ecru," have also been found. Eight of the 27 principal mines and mine groups have produced significant tourmaline (DSGM, 1974), including the much-admired rubellite form Muiane, and beautiful green to blue-green crystals from Naipa. Many of the large red crystals have a green termination (Bandy, 1951).

Generally the green crystals are smaller, rarely over 4 cm, whereas the red to raspberry crystals can be quite large. A particularly large, terminated, rose-red crystal from Muiane measuring 42 cm is in the Andrade Museum, Maputo, Mozambique. A 10 x 30-cm red crystal is in the collection of the American Museum of Natural History in New York. A fine green crystal measuring 12 x 35 cm is held by the Smithsonian Institution (Guillemin and Mantienne, 1988), along with a remarkable 50-cm rubellite crystal from Muiane.

Crystal forms observed on Alto Ligonha tourmaline include $\{11\bar{2}0\}$, $\{10\bar{1}0\}$, $\{21\bar{3}0\}$, $\{52\bar{7}0\}$, $\{41\bar{5}0\}$, $\{71\bar{8}0\}$, $\{01\bar{1}0\}$, $\{0001\}$, $\{02\bar{2}1\}$, $\{07\bar{7}2\}$, $\{10\bar{1}1\}$, and $\{01\bar{1}2\}$ (Cotelo Neiva and Correia Neves, 1960).

An electron microprobe analysis of a large rubellite crystal in the Jack Halpern collection was performed by Terry Wallace (University of Arizona); the mineral is confirmed as elbaite, with an Na:Ca ratio of 5:1.

Eosphorite $Mn^{2+}Al(PO_4)(OH)_2{\cdot}H_2O$

Correia Neves and Lopes Nunes (1968) described eosphorite, variscite, phosphosiderite, hureaulite, montebrasite, fluorapatite, amblygonite, triplite and bermanite from Alto Ligonha pegmatites.

Euclase $BeAlSiO_4(OH)$

Von Knorring *et al.* (1964) described euclase crystals from the Muiane pegmatite. Crystal forms observed include {010}, {210}, {120}, {111} and {211}.

Euxenite-(Y) $(Y,Ca,Ce,U,Th)(Nb,Ta,Ti)_2O_6$

Euxenite has been reported from six principal mines and mine groups (DSGM, 1974).

Fergusonite $(Ce,Nd,La,Y)NbO_4$

Fergusonite has been reported from the cluster of pegmatites that includes the Mugeba, Bere, Enluma, Maria, Macotaia and Namagoa bodies (DSGM, 1974).

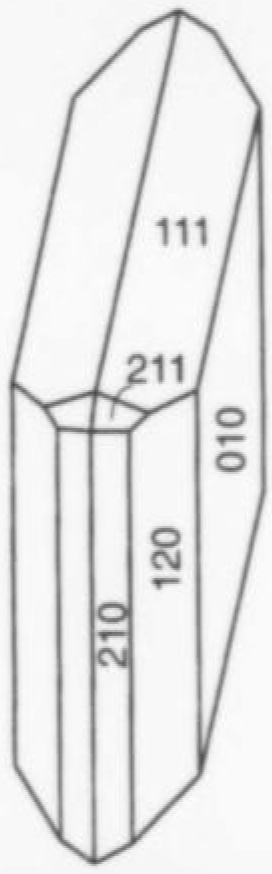


Figure 47. **Euclase crystal drawing (Muiane mine) by R. Peter Richards, based on measurements by Von Knorring *et al.* (1964).**

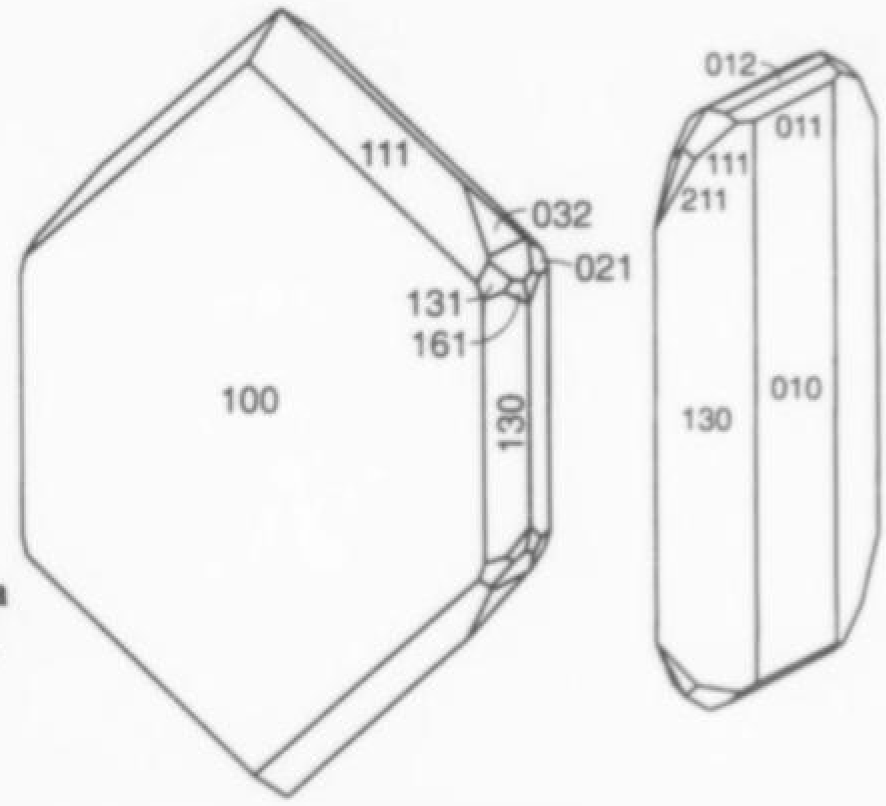


Figure 48. **Ferrotantalite crystal drawings (Alto Ligonha) by R. Peter Richards, based on measurements by Cotelo Neiva and Correia Neves (1960).**

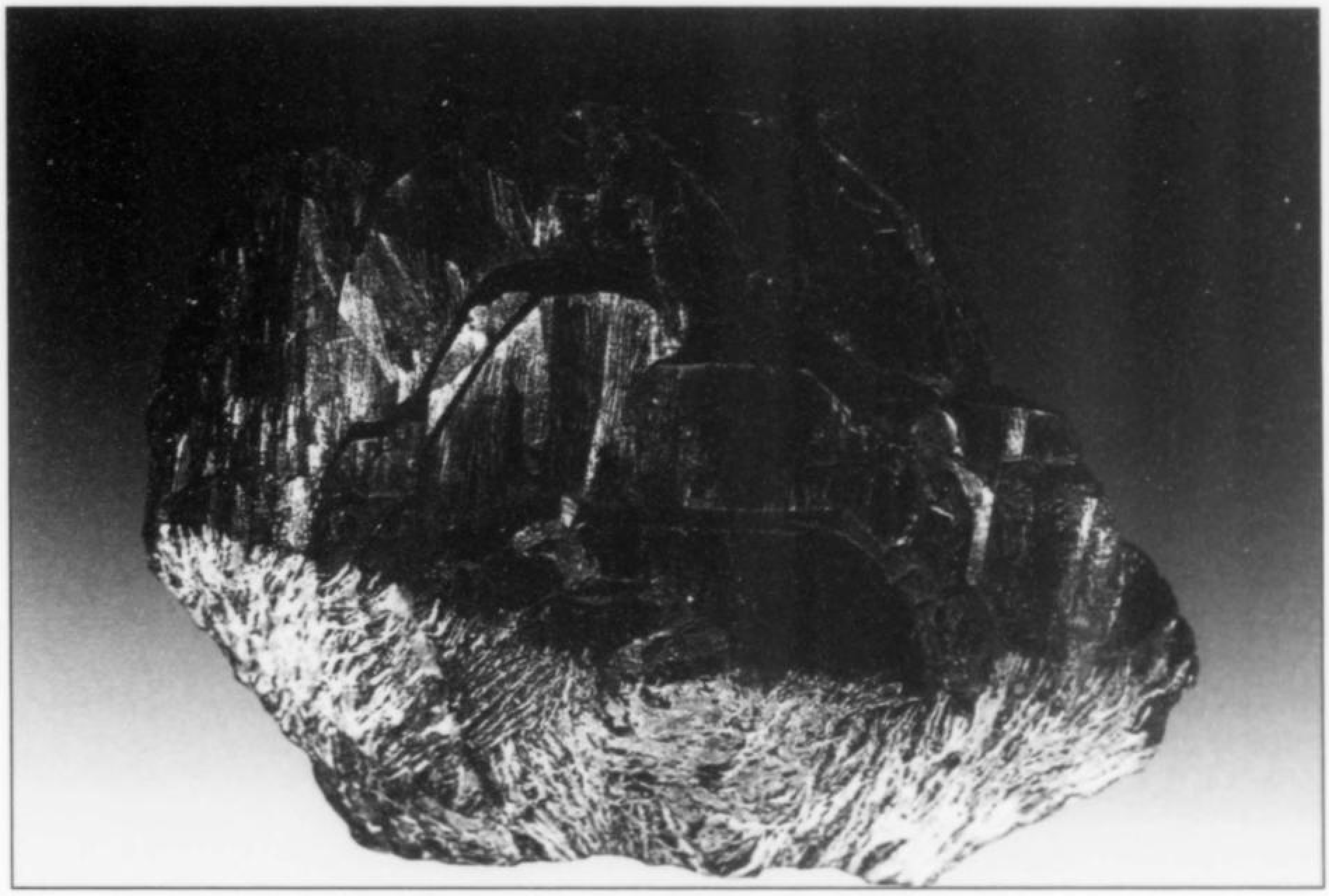


Figure 49. **Ferrocolumbite crystal group, 15 cm, from the Morrua mine. Collection of the Natural History Museum of Los Angeles County (#15440; purchased from Martin Ehrmann in 1962); A. Kampf photo.**

Ferrocolumbite $Fe^{2+}Nb_2O_6$

Ferrocolumbite was a commercial product at a number of pegmatites. Ferrocolumbite and ferrotantalite, both black and visually indistinguishable, came out in the concentrates at the Muiane processing facility. The ferrocolumbite was then magnetically separated from the non-magnetic ferrotantalite. According to Kun (1965), crystals from the perthite zone tend to be large, whereas crystals from the albite-lithia zone are smaller, fan-like, tabular grains.

Ferrotantalite $(Fe,Mn)Ta_2O_6$

Over 100 tons of what was then referred to loosely as "columbite-tantalite" or "columbotantalite" was produced from the district in the 1940's (Bandy, 1951). Most of this material generally had a Ta:Nb ratio of about 4:1, making it ferrotantalite by today's nomenclature. It was found in almost every complex pegmatite, and in commercial quantities in ten of the larger orebodies.

The crystals vary from rough to quite sharp, and from small grains to crystal masses weighing 1 kg or more. Fine crystals measuring 2.5 x 2.5 x 5 cm, from mines in the southern part of the district show a variety of interesting crystal forms. The best crystals came from the contact area between the mica and feldspar zones.

Cotelo Neiva and Correia Neves (1960) report crystals of "tantalite-columbite" having the following forms: tabular on {010} or instead on {100}, {130} on all crystals; to a lesser extent also {012}, {011}, {032}, {021}, {111}, {211}, {221}, {201}, {131} and {161}. Some crystals are twinned on (201) and others on (203); parallel aggregates are common.

Ferrotapiolite $(Fe,Mn)Ta_2O_6$

Fine crystals of black ferrotapiolite to 8 kg have been reported from the Muiane pegmatite (Gaines *et al.*, 1997). Ferrotapiolite is also known from the Malolo-Lice pegmatites (DSGM, 1974).

Florencite $(Ce,La,Nd)Al_3(PO_4)_2(OH)_6$

A massive chunk of florencite from the Naipa pegmatite was collected by Mark Bandy and came later into the collection of the Los Angeles County Museum of Natural History. The mottled, cream-colored mass was identified by X-ray diffraction, therefore the exact species (florencite-(Ce), florencite-(Nd) or florencite-(La)) is not known.

***Figure 50.* Florencite specimen, 7 cm, from the Naipa pegmatite. Collection of the Natural History Museum of Los Angeles County (Mark C. Bandy collection, #19864); A. Kampf photo.**

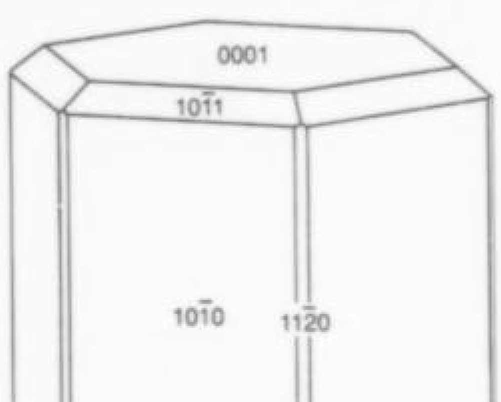


***Figure 51.* Fluorapatite crystal drawing (Alto Ligonha) by R. Peter Richards, based on measurements by Correia Neves and Lopes Nunes (1968).**

Fluorapatite $Ca_5(PO_4)_3F$

Altered fluorapatite crystals occur at many pegmatites in the district, especially at Nahia where white crystals 30 cm across and 15 cm tall and blue-green 15 x 15-cm crystals were found (Bandy, 1951). Short prismatic crystals showing $\{10\bar{1}0\}$, $\{0001\}$, $\{10\bar{1}1\}$ and $\{11\bar{2}0\}$ were reported by Cotelo Neiva and Correia Neves (1960). Some fluorapatite is unusual in containing 0.21% Cd (Correia Neves and Lopes Nunes, 1968).

Fluorite CaF_2

According to Bandy (1951), about 5 tons of fluorite concentrate were shipped from the Piteia pegmatite, where it occurred with other fluorine-containing minerals such as fluorapatite, topaz and lepidolite. It was found in deep green masses; 10-cm cleavage octahedrons were broken out by the miners. Cuboctahedral crystals were reported by Cotelo Neiva and Correia Neves (1960) from the Muiane mine.

Gadolinite $(Ce,La,Nd,Y)_2Fe^{2+}Be_2Si_2O_{10}$

Cotelo Neiva and Correia Neves (1960) report the occurrence of rare gadolinite at the Muiane mine. They do not specify whether it is gadolinite-(Ce) or gadolinite-(Y), but the presence of other Ce-Nd-La-containing minerals at Alto Ligonha makes gadolinite-(Ce) the more likely choice. It occurs as massive grains and prismatic crystals of a dark greenish brown color.

Garnet

Bandy (1951) reported that red to black non-gem garnets, massive and in crystals, had been found at several pegmatites in the district, especially at Naipa. Sinkankas (1981) also refers to garnet, as a component of the Muiane pegmatite. (See spessartine.)

Gibbsite $Al(OH)_3$

Correia Neves *et al.* (1969) identified gibbsite as a principal weathering product of microcline-perthite in the pegmatites of the Zambézia district.

Gold Au

Surprisingly, over 90 kg of native gold have been recovered from district pegmatites and the alluvial/eluvial deposits associated with them. A 75-gram specimen was reportedly taken from a quartz vein or pegmatite at Locuir (Bandy, 1951).

Most gold probably came from eluvial accumulations resulting from the breakdown of small quartz veinlets common throughout the schists, in close proximity to pegmatites. Weathered material from the two rock types can become mixed near the contact; for example, eluvial deposits of ferrocolumbite on the south slope of the Muiane pegmatite contain some gold from the schist. Gold is visible in the schist itself, and in the eluvium layer directly in contact with the schist, but never higher up in the depositional sequence.

Hafnon $HfSiO_4$

In 1974, "zircon" crystals from tantalum-bearing pegmatites of the Morro Conco, Moneia and Muiane mines were shown to be the hafnium analog. Analyses yielded 69.78% HfO_2, sufficient to designate the material as a new species given the name *hafnon*. The crystals are zoned, with higher Hf content near the surface. Associations include cookeite and cleavelandite. The crystals, which have the same habit as zircon, are euhedral to irregular and occur in sizes up to 1 cm. They range in color from colorless to orange-red and brownish yellow. The mineral occurs in pegmatites enriched in Ta and Nb minerals, especially where the enrichment favors ^{72}Hf-^{73}Ta over ^{40}Zr-^{41}Nb (Correia Neves, *et al.*, 1974).

Holmquistite $(Li_2Mg_3Al_2)Si_8O_{22}(OH)_2$

Barros (1972) reported the presence of holmquistite in the border zone of the Morrua pegmatite.

Hübnerite $(Mn,Fe^{3+},Fe^{2+},Ti,Sn)(W,Nb,Ta)O_4$

Saari *et al.* (1968) described niobium and tantalum-rich hübnerite from the Nuaparra pegmatite. Crystals are opaque, dark gray to

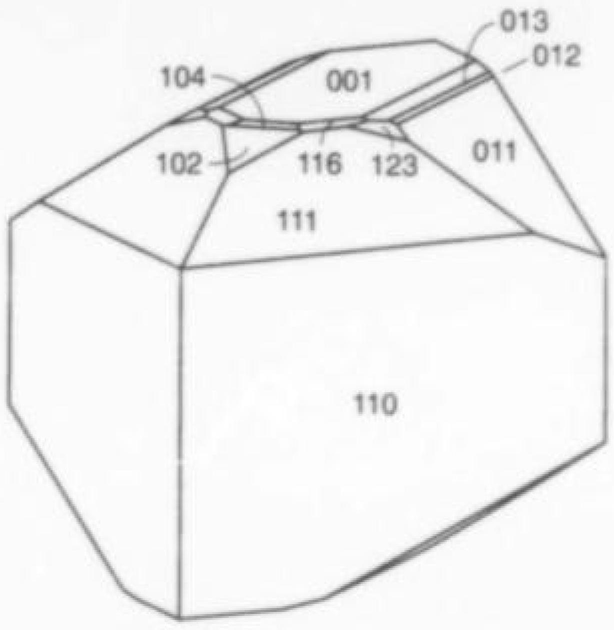


Figure 52. **Herderite crystal drawing (Naipa mine) by R. Peter Richards, based on measurements by Correia Neves and Lopes Nunes (1965).**

black, prismatic and poorly developed, with a semi-metallic luster, in sizes up to 3 cm.

Hureaulite $Mn_5^{2+}(PO_4)_2[PO_3(OH)]_2 \cdot 4H_2O$

Correia Neves and Lopes Nunes (1968) described hureaulite, montebrasite, fluorapatite, amblygonite, triplite, phosphosiderite, variscite, eosphorite and bermanite from Alto Ligonha pegmatites.

Hydroxylherderite $CaBe(PO_4)(OH,F)$

Correia Neves and Lopes Nunes (1965) described herderite crystals from the Naipa pegmatite. Principal forms include {110}, {011}, {111}, {001}, {012}, {013}, {102}, {$\bar{1}$04}, {123}? and {$\bar{1}$16}. Lacking analyses, it must be assumed to be hydroxylherderite.

Ilmenorutile $(Ti,Nb,Fe^{3+})_3O_6$

Ilmenorutile and its tantalum analog, strüverite, were described from the Nampoça pegmatite by Lima de Faria and Quadrado (1966). Crystals sometimes show a microscopic intergrowth with columbite.

Figure 53. **Scandian ixiolite in hemispherical crystal aggregates to 1.4 cm, from the Nanro pegmatite. Richard V. Gaines collection (courtesy of John S. White); Wendell Wilson photo.**

Ixiolite $(Fe^{2+},Fe^{3+},Ta,Nb,Sc,Ti,Sn,Zr,Mn)_4O_8$

Borisenko *et al.* (1969) analyzed a scandium-bearing tantalo-niobate from Mozambique and found it to be scandium-titanium-zirconium-bearing ixiolite. It occurs in rounded grains to over 1 cm, having a dull gray-black color. Von Knorring *et al.* (1969) described what is apparently the same material, specifying the locality as the Naquissupa pegmatite. The locality is currently known as Nanro, and continues to yield black hemispheres of ixiolite.

Kaolinite $Al_2Si_2O_5(OH)_4$

A large percentage of the pegmatites in the district are deeply kaolinized. Especially large quantities have been found in the Boa Esperança, Murropoci, Nuaparra, Namirrapo, Mucholone and Marropino pegmatites (DSGM, 1974).

Figure 54. **Lepidolite (spherical crystal aggregate), 14 cm, from the Naipa mine. University of Arizona collection; Wendell Wilson photo.**

Lepidolite Li-Mica

After muscovite, lepidolite was the most important ore mineral in the district. It was found in masses of high purity at several pegmatites; the Naipa pegmatite, for example, contained a bed of almost pure lepidolite measuring 3 meters thick, and 11 meters across.

Bandy (1951) reports lepidolite with a fine lavender color, in interlocking books, radiating columns and large, tapering crystals. At the Naipa mine these individual crystals reach 18 cm in length and 5 x 10 cm across. Cleavages 36 cm across were found at the Muiane mine, and 30 cm across at the Piteia mine. Cotelo Neiva and Correia Neves (1960) report large cleaved slabs to 60 cm across from the Muiane mine. Crystals show {001}, {110} and {010}. It is sometimes found in cylindrical masses of crystals 13 to 40 cm across and 20 to 80 cm long, rounded over the top, as if having once encrusted a large, now-gone crystal. At the Naipa mine it was found as spherical, radial aggregates to over 14 cm.

Magnetite $Fe^{2+}Fe_2^{3+}O_4$

Coarsely crystalline magnetite is the only accessory mineral in the barren, simple pegmatites of the granitic terranes (Hutchinson and Claus, 1956).

Manganotantalite $(Mn,Fe)(Ta,Nb)_2O_6$

Fine and sometimes large, tabular to blocky crystals of manganotantalite have been reported from the Morrua, Muiane and Marropino pegmatites; some specimens show sharp, transparent twins (Gaines *et al.*, 1997). The V-shaped twins, of which we have

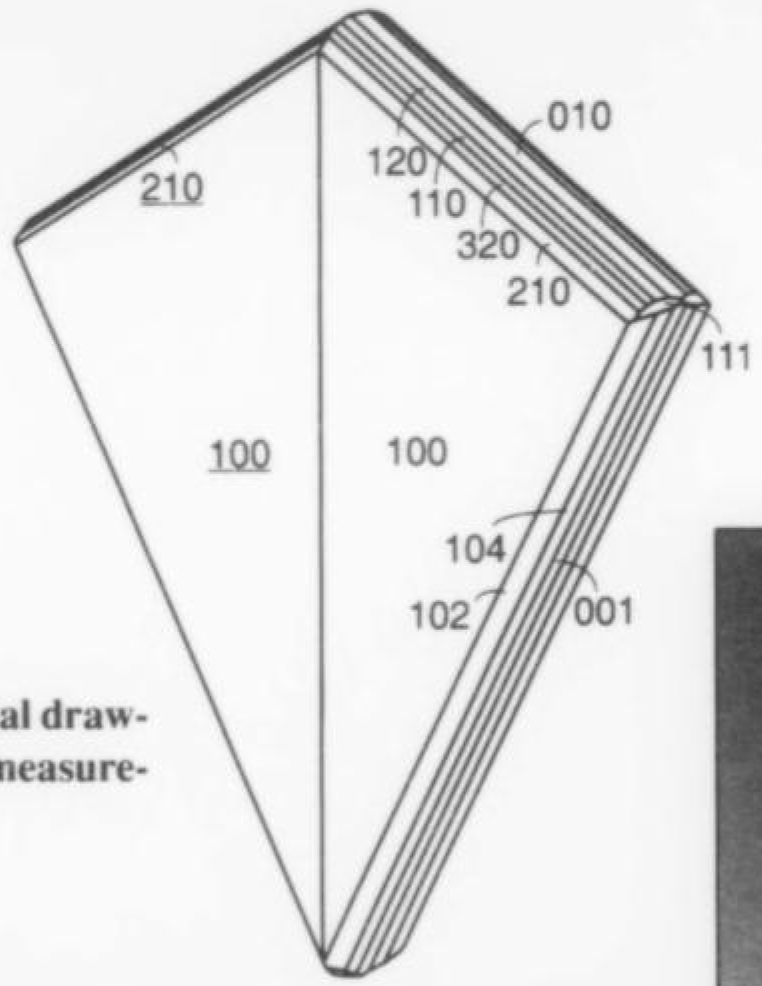


Figure 55. Manganotantalite twin crystal drawing by R. Peter Richards, based on measurements by Wendell Wilson.

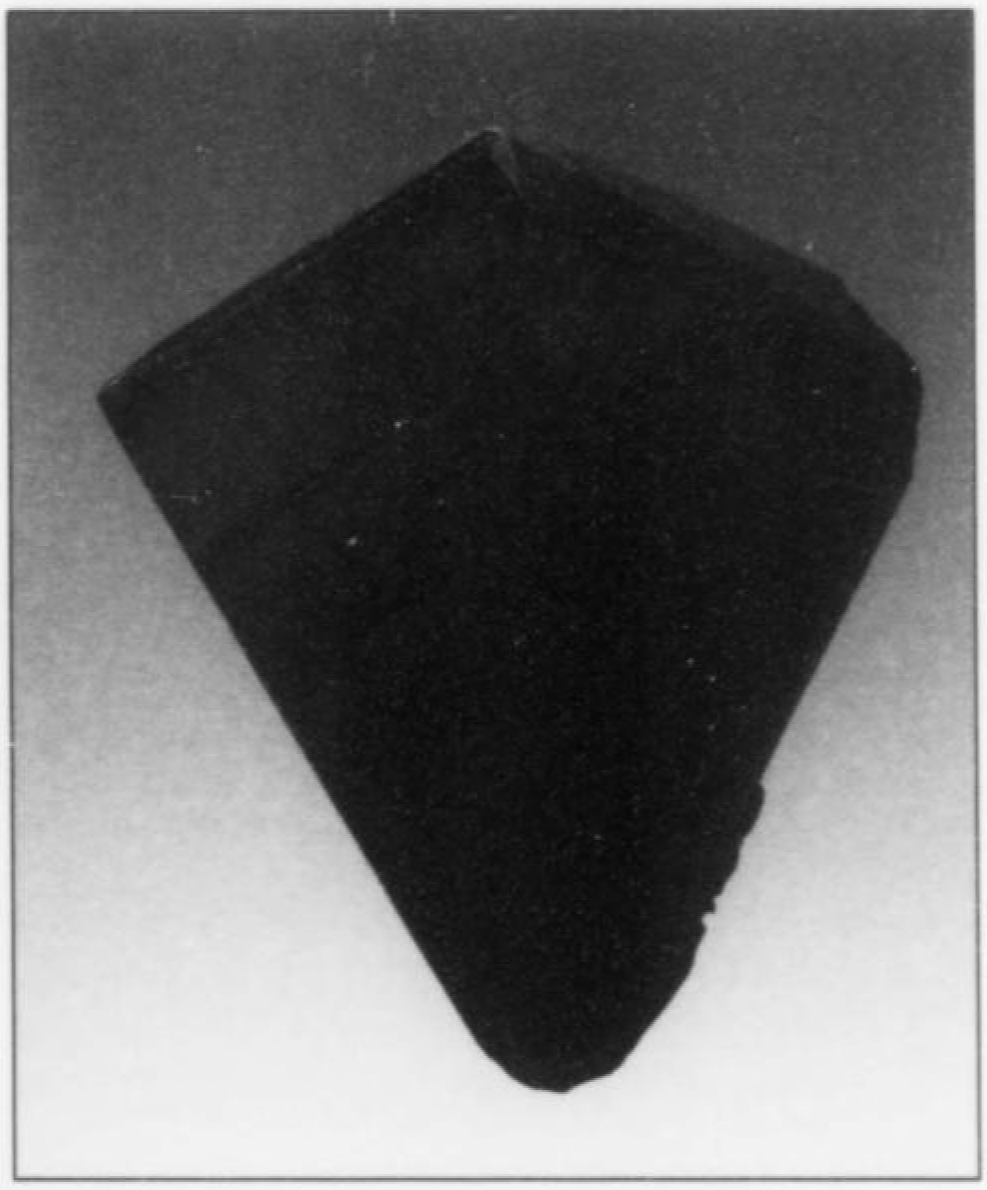


Figure 56. Manganotantalite twin (021), 1.5 cm, from Alto Ligonha. Richard V. Gaines collection (courtesy of John S. White); Wendell Wilson photo.

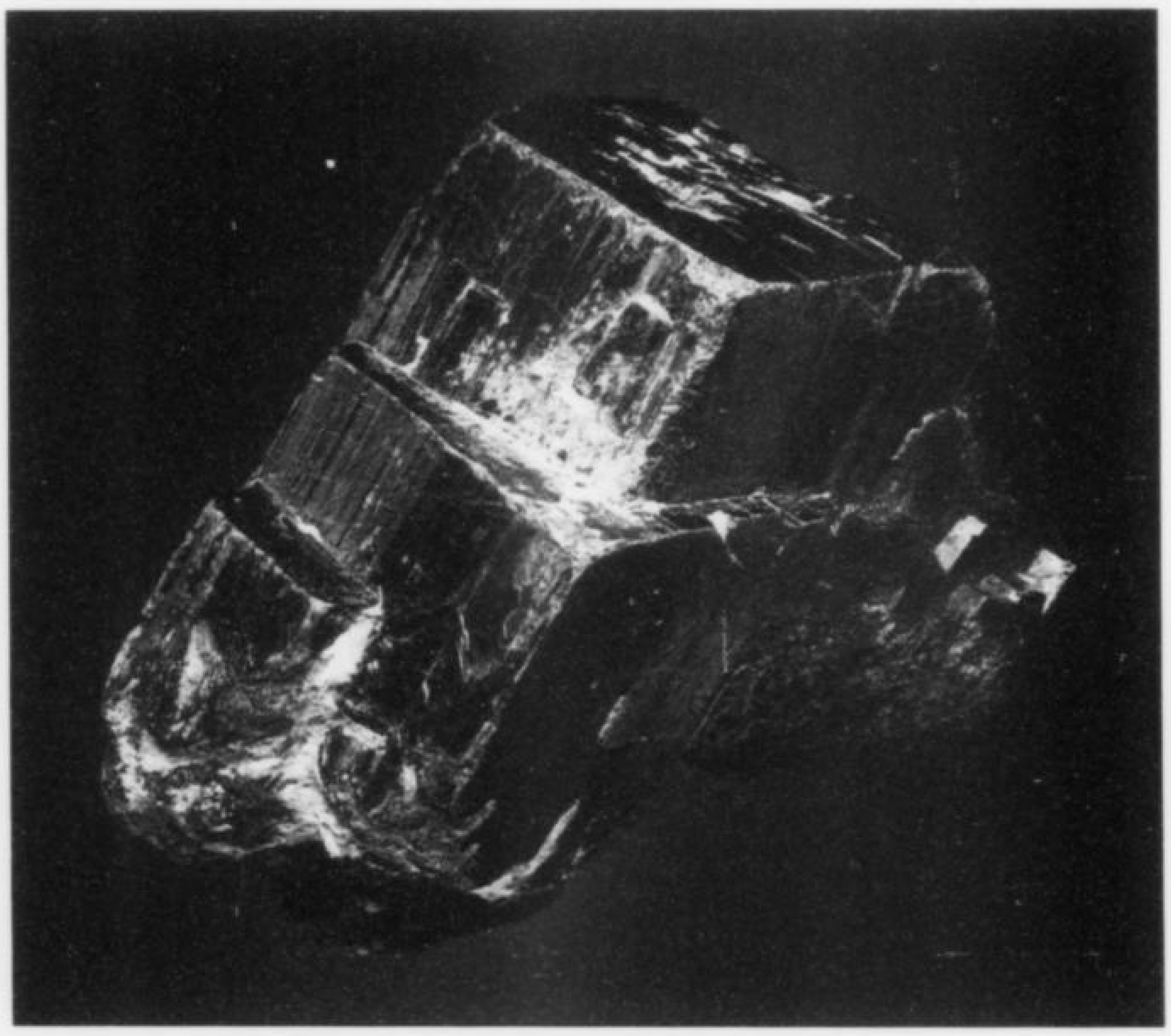


Figure 57. Manganotantalite crystal, 9 cm, from Alto Ligonha. Herb Obodda specimen; Jeff Scovil photo.

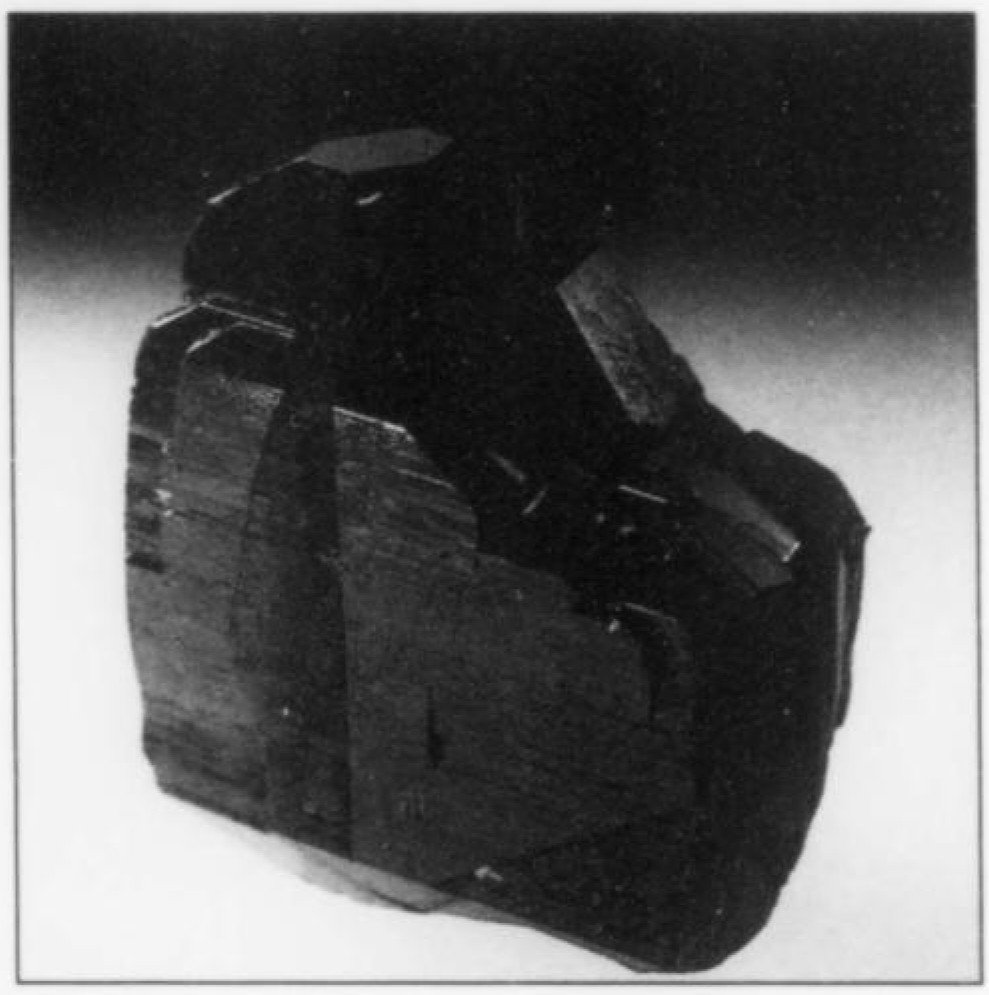


Figure 58. Manganotantalite crystal, 2.7 cm, from the Naipa pegmatite. José Rodriquez Rosa specimen; Wendell Wilson photo.

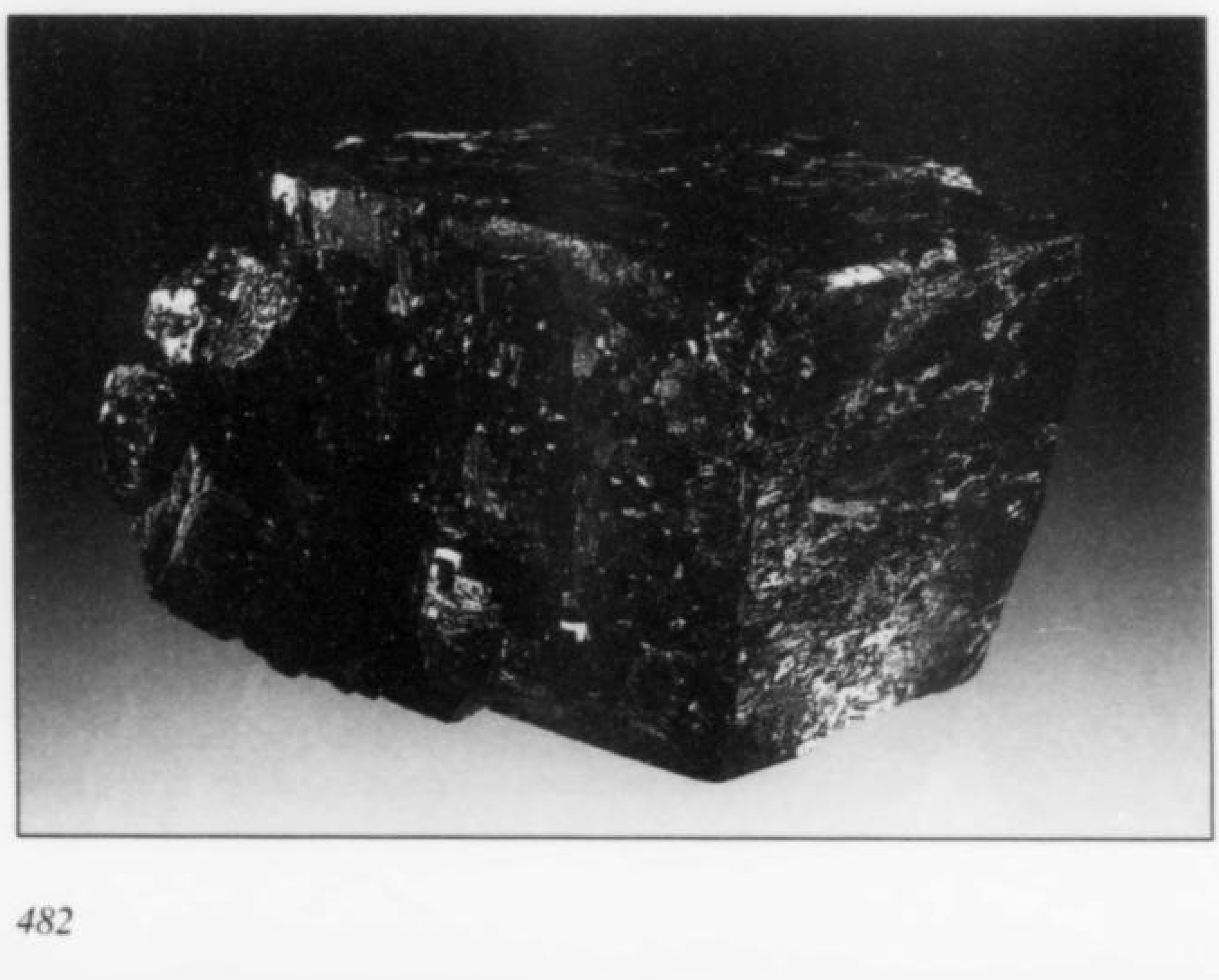


Figure 59. Manganotantalite crystal, 14.5 cm, from the Naipa mine. Desmond Sacco collection; Bruce Cairncross photo.

seen several, are dark red and measure about 1.5 cm. They have a broad {100} face in common, are striated parallel to {001}, and are twinned on (021). On the specimen we measured the bordering faces include {010} and {001}, with *different* modifications on the left-hand member of the twin ({101}, {201}, {120}) vs. the right-hand member ({102}, {301}, {140}). An excellent Morrua-mine crystal measuring 7 cm is in the collection of the Natural History Museum, London (Guillemin and Mantienne, 1988). Von Knorring *et al.* (1966) analyzed crystals from the Morrua mine and found them to be the closest yet known to having an ideal formula (Ta:Nb = 99:1, Mn:Fe = 97:3). A 9.8 x 10-cm "floater" crystal from the Cunco pegmatite, and an 11 x 14 x 14.5-cm euhedron (7 kg) from the Naipa pegmatite are in the Desmond Sacco collection.

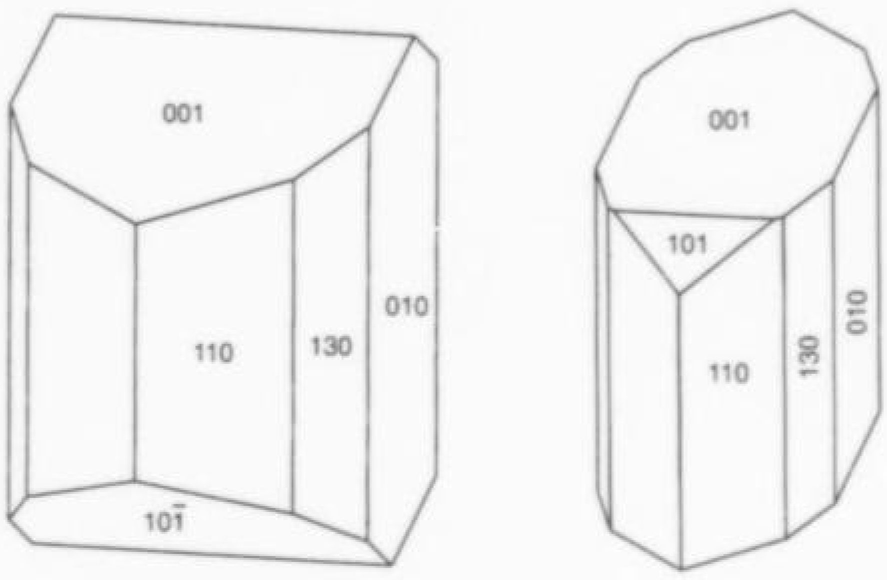


Figure 60. **Microcline crystal drawings (Alto Ligonha) by R. Peter Richards, based on measurements by Cotelo Neiva and Correia Neves (1960).**

Microcline $KAlSi_3O_8$

Amazonite, the bluish green variety of microcline, has been reported from the Monapo, Carapira, Leonora, Mueterere, Namacala, Lice and Malolo pegmatites (DSGM, 1974). Cotelo Neiva and Correia Neves (1960) described a 1-meter crystal showing {001}, {010}, {110}, {1$\bar{1}$0}, {$\bar{1}$01} and {1$\bar{3}$0}.

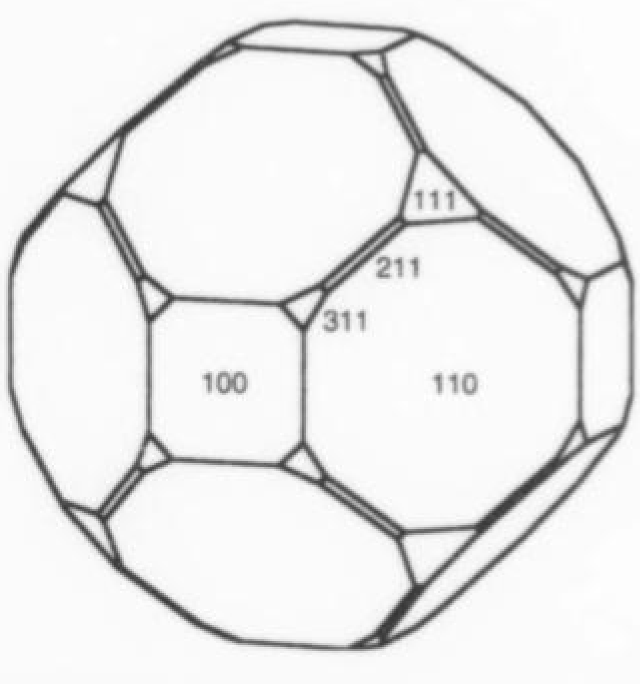


Figure 61. **Microlite crystal drawing by R. Peter Richards, based on a José Rodriquez Rosa specimen from the Munhamola pegmatite.**

Microlite $(Ca,Na)_2Ta_2O_6(O,OH,F)$

Microlite has been reported from six major pegmatites and pegmatite groups including the Marropino, Morrua, Nampoça, Napir and Munhamola pegmatites (DSGM, 1974). At the Munhamola pegmatite near Alto Molocue, microlite occurs as sharp, lustrous crystals to 2.5 cm, associated with tabular lepidolite crystals exceeding 1 cm across the cleavage face. The microlite crystals are nearly black in overall appearance, but are actually a very dark, translucent yellow as revealed by internal fractures. The habit is a combination mainly of the dodecahedron and cube, modified by small octahedron faces and very small faces of two trapezohedron forms.

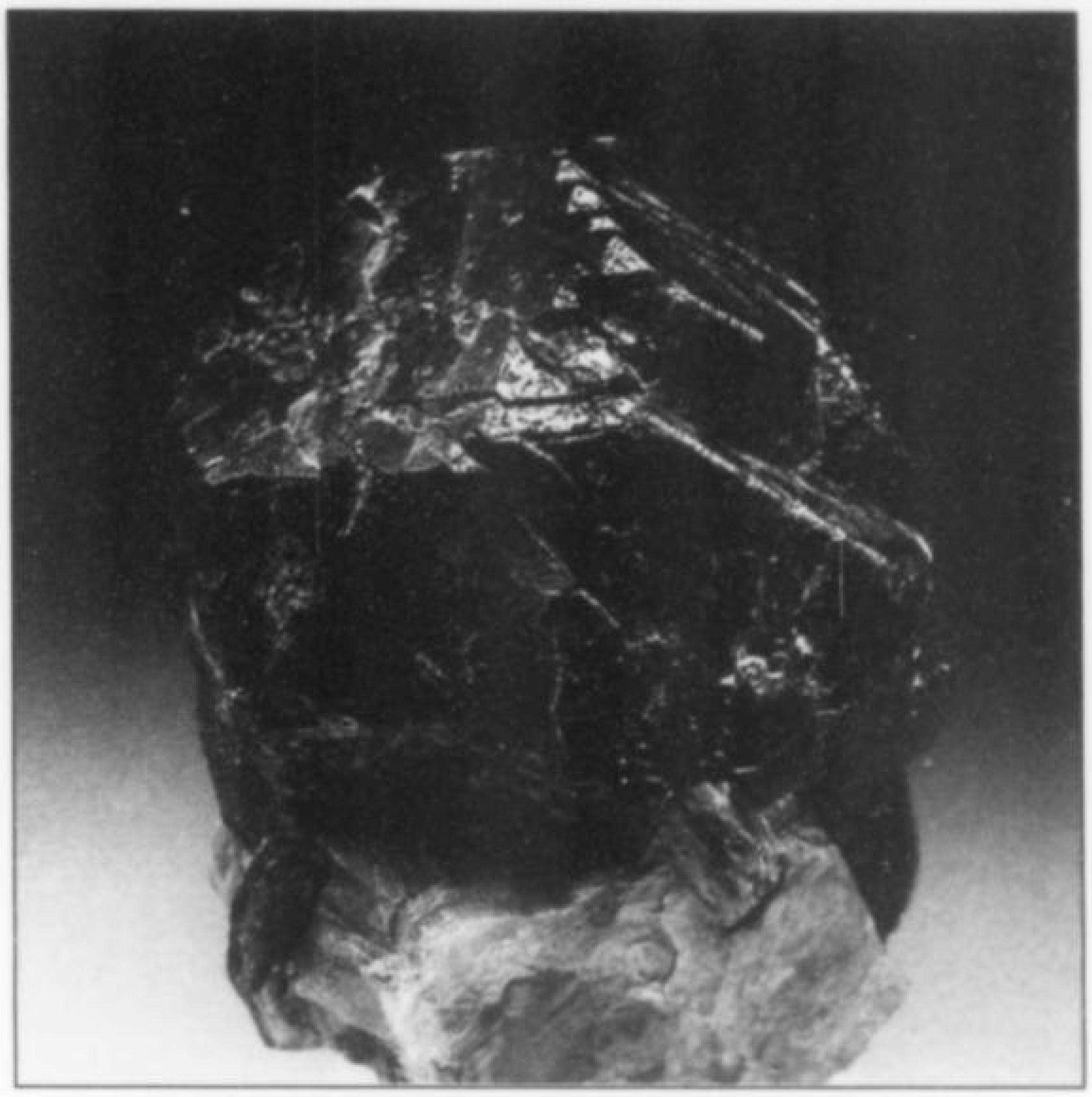


Figure 62. **Microlite crystal, 2.5 cm, from the Munhamola pegmatite, Alto Molocue. Richard V. Gaines collection (courtesy of John S. White); Wendell Wilson photo.**

Molybdenite MoS_2

Molybdenite has been reported from the Maria III pegmatite (DSGM, 1974).

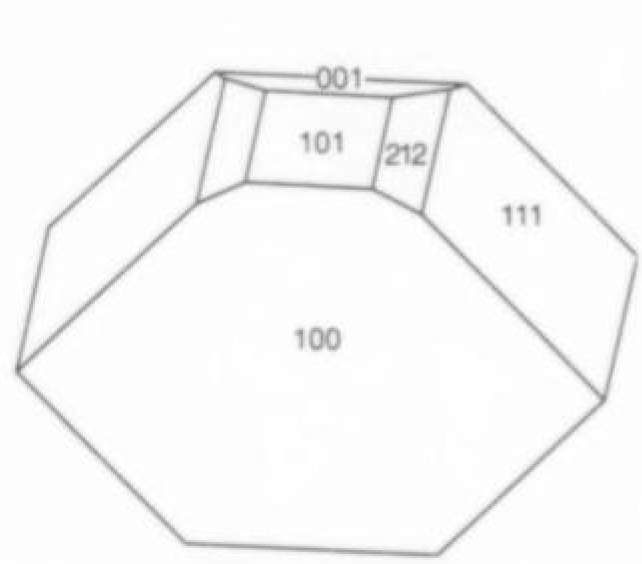


Figure 63. **Monazite crystal drawing (Alto Ligonha) by R. Peter Richards, based on measurements by Cotelo Neiva and Correia Neves (1960).**

Monazite $(Ce,La,Nd,Th)PO_4$

Over 680 kg of monazite have been produced in the Alto Ligonha district, especially at Muiane, with allanite and samarskite (Bandy, 1951). It is a common mineral, noted from a dozen different pegmatites and pegmatite groups (DSGM, 1974). Cotelo Neiva and Correia Neves (1960) found crystals only very rarely, in a tabular habit on {100}, with {100}, {$\bar{1}$01}, {$\bar{1}$11}, {001}, and {$\bar{2}$12}. Bancroft (1984) described crystals up to 10 cm in size (1), but said the mineral usually occurs in irregularly shaped masses and as tiny crystals with allanite.

Montebrasite $LiAl(PO_4)(OH,F)$

Correia Neves and Lopes Nunes (1968) described montebrasite, fluorapatite, amblygonite, triplite, hureaulite, phosphosiderite, variscite, eosphorite and bermanite from Alto Ligonha pegmatites.

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

Montmorillonite clay was reported as rare flesh-colored masses at the Muiane mine (Cotelo Neiva and Correia Neves, 1960).

Muscovite $KAl_2AlSi_3O_{10}(OH)_2$

Muscovite was for many years the principal ore mineral in the district, over a thousand tons having been produced as of 1951 (Bandy, 1951). Most of the early production came from the Murrapane and Bõa Esperanza mines. Books measuring over 30 cm across were not uncommon.

Various colors of mica were recovered, including a gemmy red variety known as "ruby mica." Black and brown micas assumed to be biotite and phlogopite were found as well (but definitive analyses are lacking).

Tabular and occasionally prismatic crystals have been described by Cotelo Neiva and Correia Neves (1960) from Muiane. Forms observed include $\{001\}$, $\{110\}$, $\{010\}$, $\{\bar{1}01\}$, $\{023\}$ and $\{043\}$. "Curious spherical concentrations" are sometimes found surrounding a crystal of green elbaite, schorl or beryl. Neiva (1978) described a barian, chromium-bearing variety from Alto Ligonha.

Oligoclase $(Na,Ca)(Si,Al)_4O_8$

Cotelo Neiva and Correia Neves (1960) reported cleavable masses and pale gray crystals of oligoclase from Muiane; crystal forms include $\{001\}$, $\{1\bar{1}0\}$, $\{110\}$, $\{010\}$ and $\{130\}$. It was found also as inclusions in microcline, and also, with its own rare inclusions of euhedral zircon.

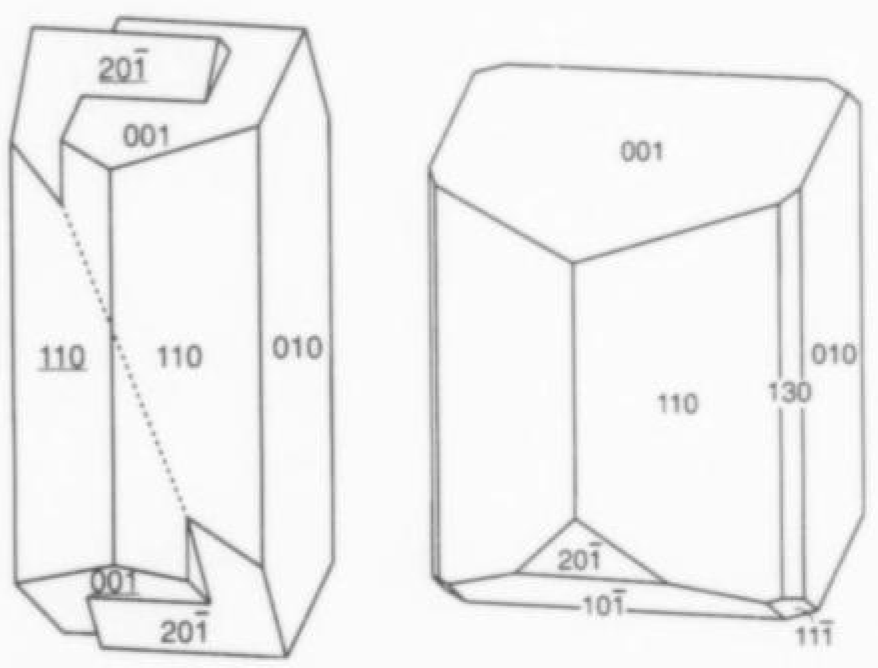


Figure 64. **Orthoclase crystal drawings (Alto Ligonha) by R. Peter Richards, based on measurements by Cotelo Neiva and Correia Neves (1960).**

Orthoclase $KAlSi_3O_8$

Orthoclase occurs in cleavable masses up to 76 cm across in some of the simple pegmatites. Fine, sharp crystals of pink to cream color measuring up to 10 cm were found at Piteia (Bandy, 1951). Carlsbad twins are common. Crystal forms observed include $\{001\}$, $\{010\}$, $\{110\}$, $\{130\}$, $\{\bar{1}01\}$, $\{\bar{2}01\}$ and $\{\bar{1}11\}$ (Cotelo Neiva and Correia Neves, 1960). Thousands of tons of massive orthoclase, microcline and albite were stockpiled as of 1949.

Petalite $LiAlSi_4O_{10}$

Petalite is reported as one of several lithium-bearing minerals (including also lepidolite, amblygonite and spodumene) known to occur at seven pegmatites and pegmatite groups (DSGM, 1974).

Phosphosiderite $Fe^{3+}PO_4 \cdot 2H_2O$

Correia Neves and Lopes Nunes (1968) described phosphosiderite, hureaulite, montebrasite, fluorapatite, amblygonite, triplite, variscite, eosphorite and bermanite from Alto Ligonha pegmatites.

Plumbomicrolite $(Pb,Ca,U)_2Ta_2O_6(OH)$

Plumomicrolite has been reported from the Naipa pegmatite by Leal Gomes (1999a); it contains 25.03 wt. % PbO.

Pollucite $(Cs,Na)[AlSi_2O_6] \cdot nH_2O$

Pollucite has been reported from the Morrua, Mocachaia, Alata, Intotcha and Nahora pegmatites (DSGM, 1974). Khalili and Von Knorring (1977) described specific examples.

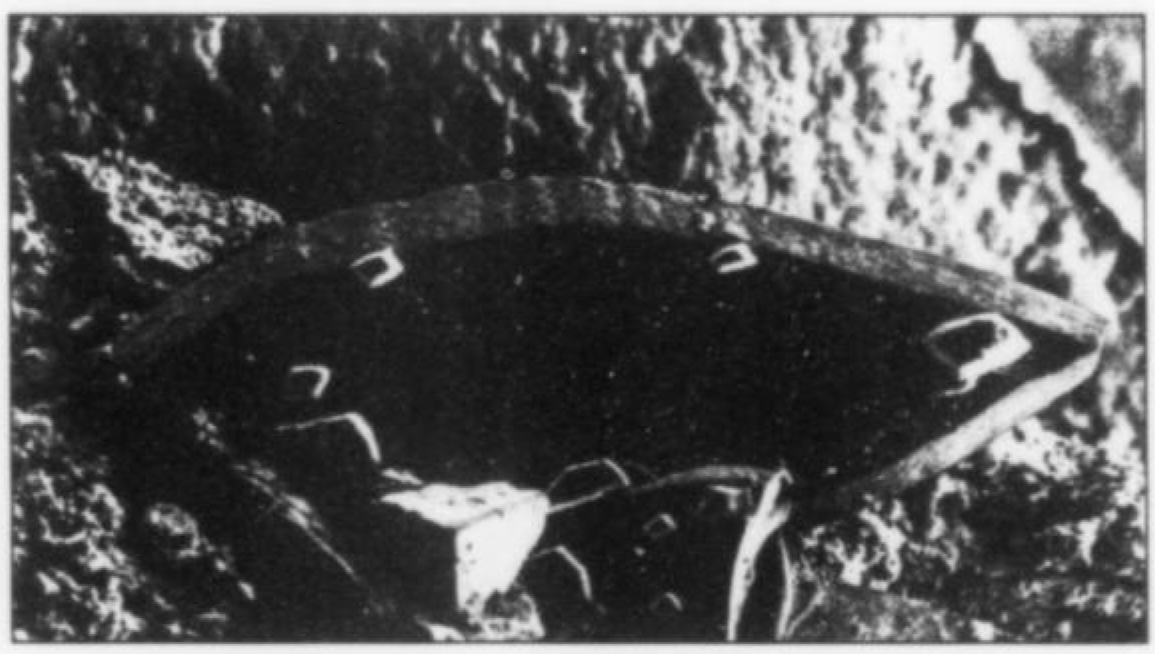


Figure 65. **Pucherite crystal (SEM), Mutala area, from Von Knorring *et al.* (1973).**

Pucherite $BiVO_4$

Von Knorring *et al.* (1973) described two types of $BiVO_4$ occurring as orange, well-formed crystals to 2 mm in bismutite from the Mutala pegmatite. The orthorhombic phase was identified as pucherite; the monoclinic phase was a new species but remained unnamed until Bridge and Pryce (1974) described the same material from Western Australia, naming it clinobisvanite.

Pyrochlore $(Na,Ca)_2Nb_2O_6(OH,F)$

Pyrochlore crystals, octahedral and yellowish brown in color, were reported from the Mocachaia pegmatite (Cotelo Neiva and Correia Neves, 1960). It appears to be partially pseudomorphically replaced by an unknown black mineral.

Quartz SiO_2

Although notable quartz crystals are rare in most pegmatites in the district, magnificent crystals to more than a meter were found at Nahia, and fine crystals 15 cm in diameter were discovered at Cavala. In some vugs, fine crystals of quartz and orthoclase or albite were found. Rose quartz (massive) came from Macula.

The well-zoned Muiane pegmatite contained large masses of lepidolite and large quartz crystals, some of fine specimen quality, up 1.8 meters and 900 kg (Sinkankas, 1981). The color ranges from black to pale brown, colorless, milky and rose. Parallel crystal aggregates are common. Large scepters of smoky quartz on colorless quartz are also known. Forms generally include $\{10\bar{1}1\}$, $\{10\bar{1}0\}$, $\{01\bar{1}1\}$, plus occasionally $\{10.0.\overline{10}.1\}$, $\{0.11.\overline{11}.1\}$, $\{40\bar{4}1\}$, $\{50\bar{5}1\}$, $\{05\bar{5}1\}$, $\{2\bar{1}\bar{1}1\}$, $\{11\bar{2}1\}$, $\{5\bar{1}41\}$, $\{13\bar{4}7\}$ and $\{10\bar{1}2\}$. Brazil-law twins are common (Cotelo Neiva and Correia Neves,

Figure 66. **Quartz crystals with cleavelandite albite, ca. 30 cm, from the Muiane mine. M. Bettencourt Dias photo, ca. 1970.**

1960). Included species noted: zircon, rutile, muscovite and tourmaline. Fluid inclusions were also fairly common in Muiane quartz.

Rutile TiO_2

Superb, sharp, lustrous crystals of rutile to over 5 cm in diameter have been reported from the Ribaue area (Bandy, 1951). Examples have also been recorded from the Macula, Nahaji, Morrua, Melela and Namarripa pegmatite (DSGM, 1974).

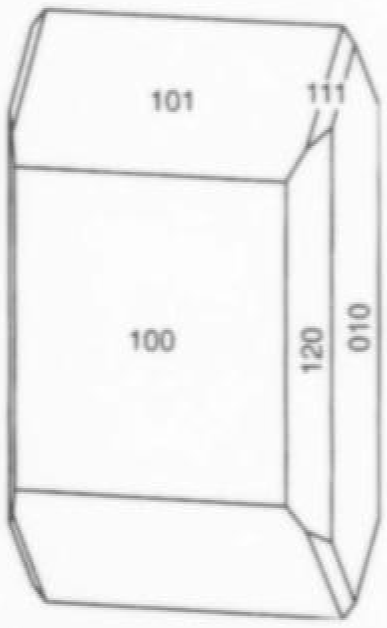


Figure 67. **Samarskite crystal drawing (Ingela pegmatite) by R. Peter Richards, based on measurements by Cotelo Neiva and Correia Neves (1960).**

Samarskite-(Y) $(Y,Ce,U,Fe^{3+})_3(Nb,Ta,Ti)_5O_{16}$

Eight tons of samarskite, a remarkable quantity, were produced from three pegmatites (Bandy, 1951). Excellent, sharp crystals to

Figure 68. **Smoky quartz scepter on white quartz, about 50 cm, from the Muiane mine. M. Bettencourt Dias photo.**

about 2 cm were found at Macotaia (where it constituted the only commercially valuable mineral), and some larger ones came from Muiane. Other occurrences include the Bõa Esperança, Ehiale, Namovela, Massive, Horta, Mtomoti, Namivo, Tomeia, Nampoça and Mugeba pegmatites (DSGM, 1974). At the Ingela and Mirrucué pegmatites it was found as euhedral crystals showing well-developed {100}, {010} and {101} with minor {120} and {111}. Some crystal clusters are fan-shaped. The mineral appears to be metamict (Cotelo Neiva and Correia Neves, 1960). Bancroft (1984) reported sharp crystals of samarskite to 4 cm from the Macotaia pegmatite. Alto Ligonha samarskite has been isotopically age-dated at 408 to 465 million years (Kun, 1965).

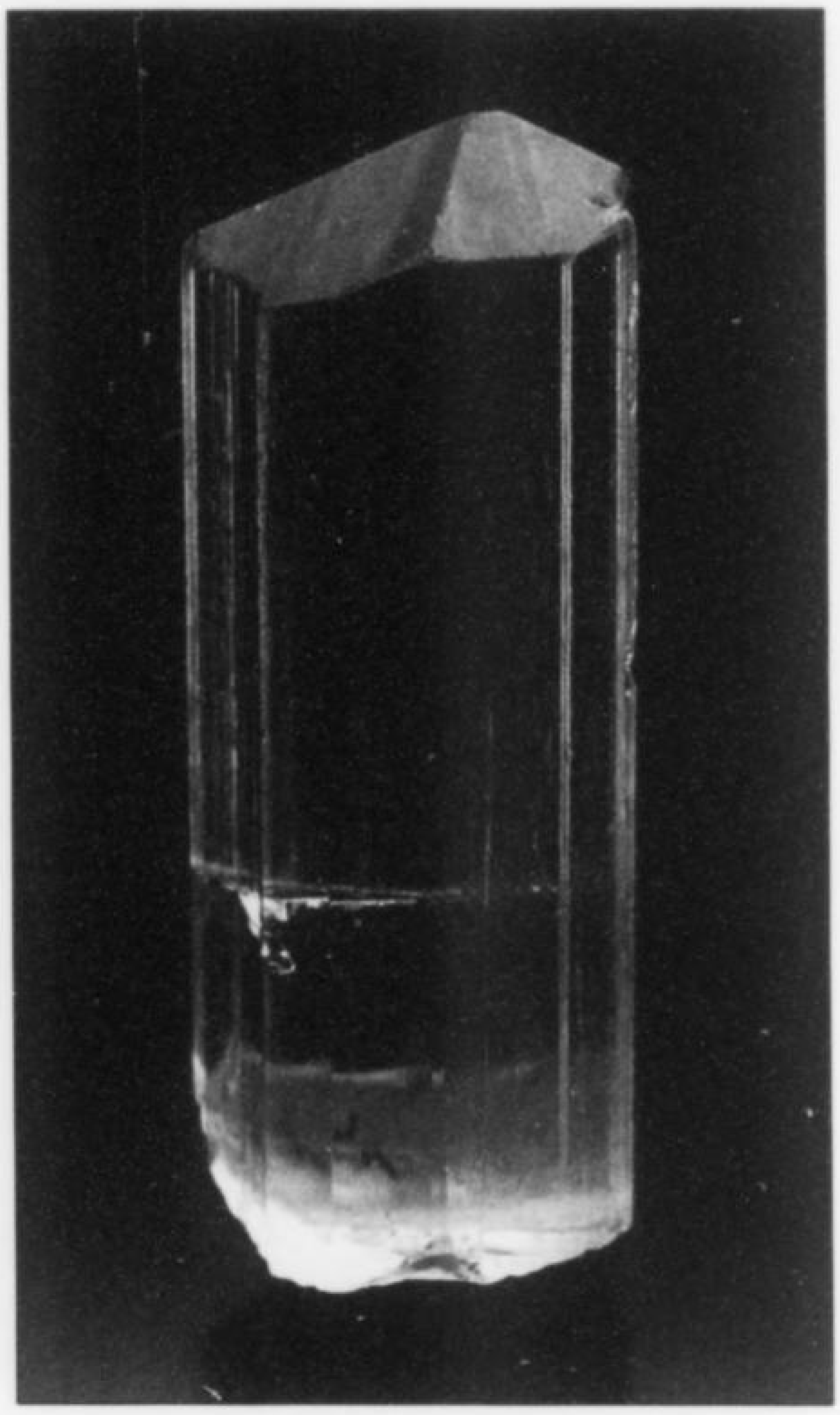


Figure 69. **Scapolite crystal, 2.8 cm, from Alto Ligonha. William Larson collection; Jeff Scovil photo.**

Scapolite $3NaAlSi_3O_8 \cdot NaCl$

Scapolite (not specified as marialite or meionite) was reported from the Niessa-Isabela pegmatites (DSGM, 1974). There is a fine, gemmy, terminated crystal of pale tan color, measuring 2.8 cm, in the William Larson collection.

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

Small, black tourmaline crystals, presumably schorl, have been found embedded in mica and feldspar along the border zone of simple and mica-rich pegmatites (Bandy, 1951). Attractive, deep black crystals penetrating quartz crystals occur at the Muiane mine.

Spessartine $Mn^{2+}_3Al_2(SiO_4)$

Cotelo Neiva and Correia Neves (1960) report euhedral crystals of red-brown spessartine from the Muiane mine. Forms include {110} and {211}.

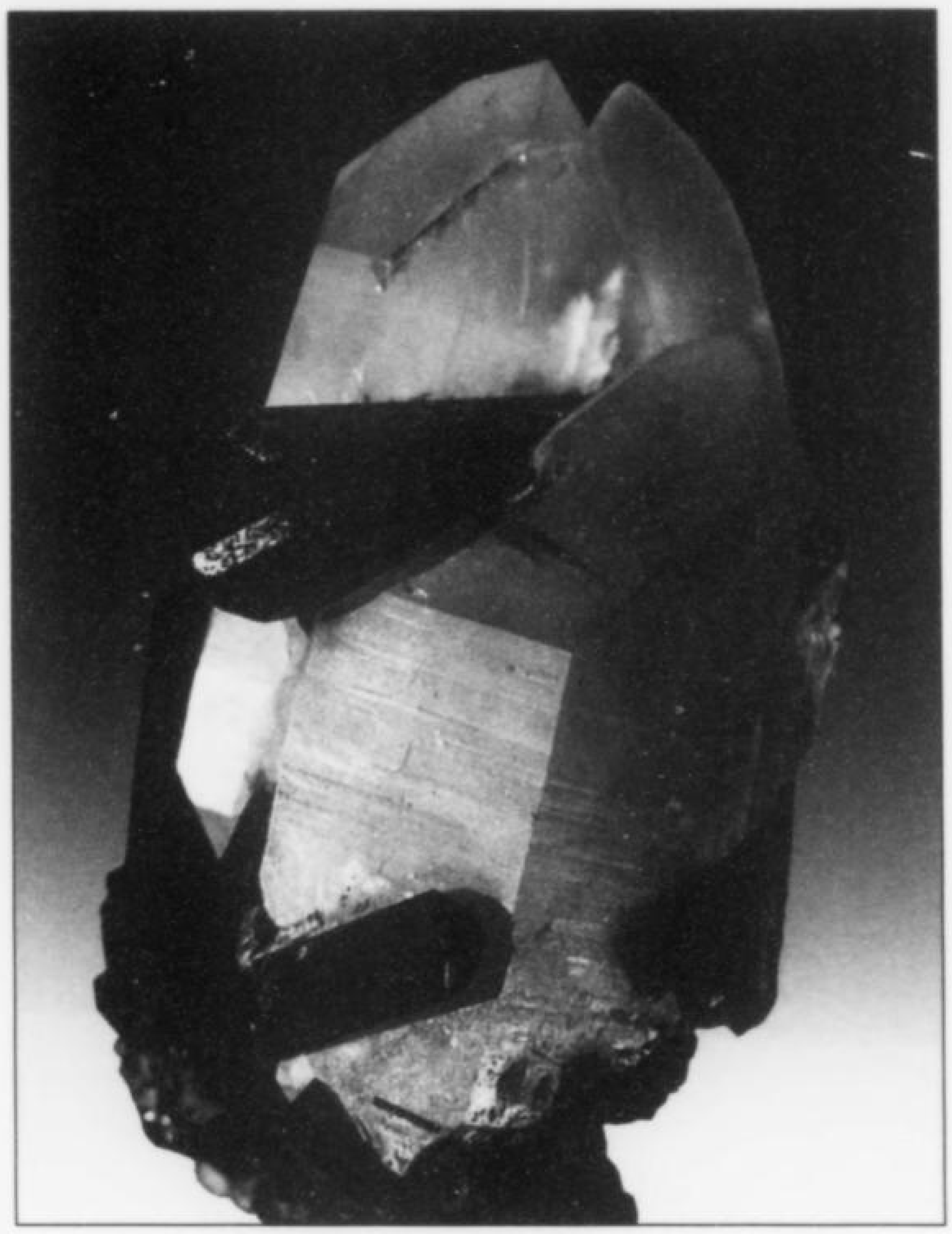


Figure 70. **Schorl crystals on a quartz crystal, about 17 cm, from the Naipa mine. Collection of the Museum Freire de Andrade, Geological Survey of Mozambique; photo by M. Bettencourt Dias.**

Spodumene $LiAlSi_2O_6$

Spodumene, including the varieties hiddenite and kunzite, as well as other lithium minerals such as lepidolite, petalite and amblygonite, have been reported from seven major pegmatites and pegmatite groups (DSGM, 1974), including the Muiane pegmatite (Sinkankas, 1981). It occurs in large, prismatic crystals dominated by {100}. Quadrado and Amorós (1965) described spodumene from the Namacotche pegmatite as being colorless and transparent with a prismatic habit and showing etch figures on the {110} faces. Associated species include beryl, albite, lepidolite and bismuth minerals.

Stibiomicrolite $(Sb,Ca,Na)_2(Ta,Nb)_2O_7$

The Naipa pegmatite appears to be the first known occurrence of well-crystallized (that is, at least subhedral, macroscopic) stibiomicrolite. The two known specimens are rather tabular due to restricted growth in the interstices between albite plates.

One specimen, 3.5 cm across and about 8 mm thick, appears to be flattened perpendicular to the 2-fold axis (i.e., on the dodecahedron). On one end it shows lustrous and sharp octahedron faces with narrow dodecahedron modifications. Most of the crystal is blackish in color but gemmy areas seen through the good crystal faces are demantoid-green. The second crystal, 2.9 cm across, is also contacted over much of its surface but appears to show octahedron and dodecahedron faces on one end. The color is a similar dark green, but the crystal is flattened roughly perpendicular to the 4-fold axis.

The two crystals were collected by José Rodriguez Rosa and identified by electron microprobe at the Universidade do Minho in Braga, Portugal.

Figure 71. **Stibiomicrolite, 3 cm, from the Naipa pegmatite; one of only two known crystals of the species. José Rodriquez Rosa specimen (self-collected); Wendell Wilson photo.**

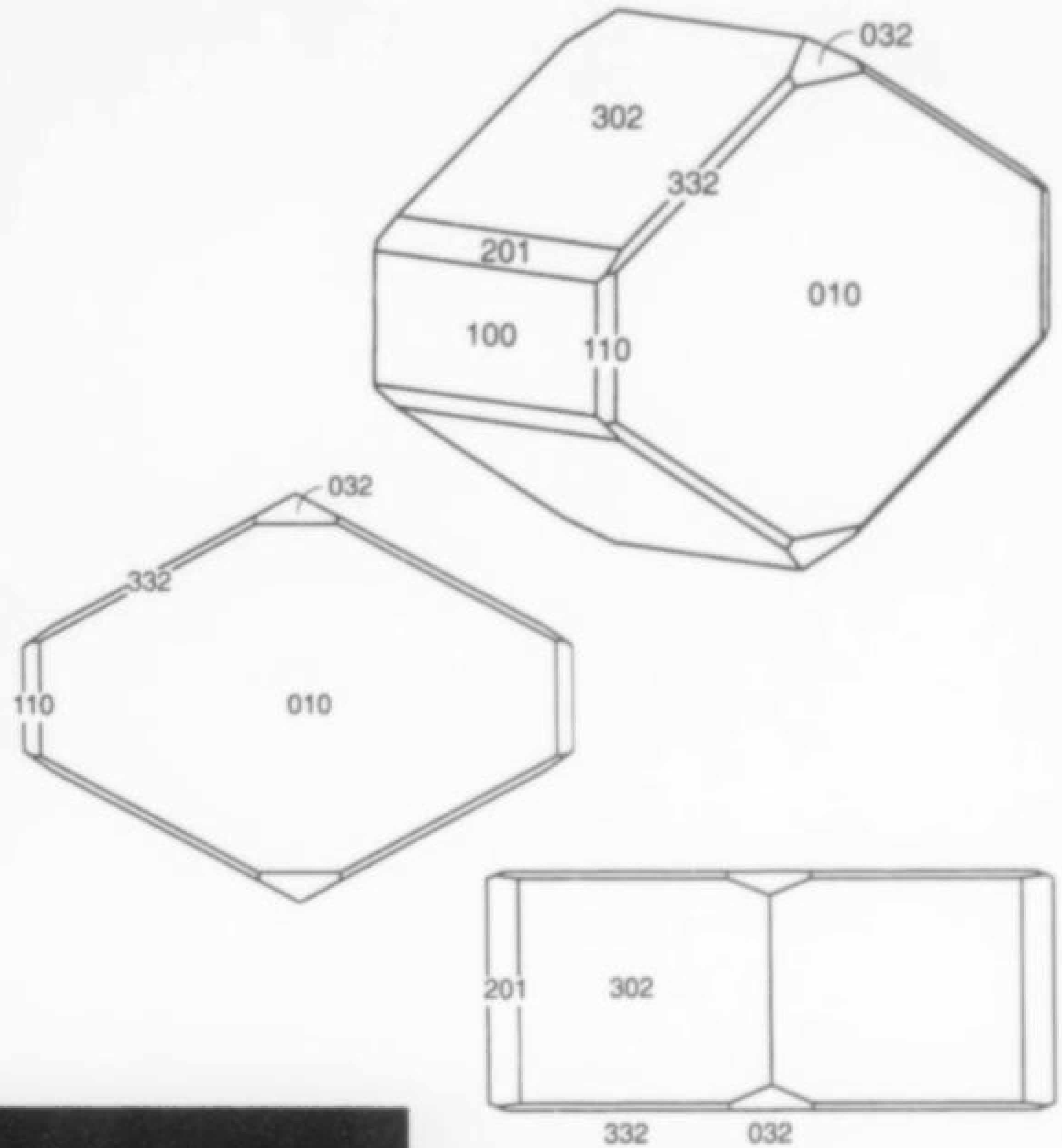
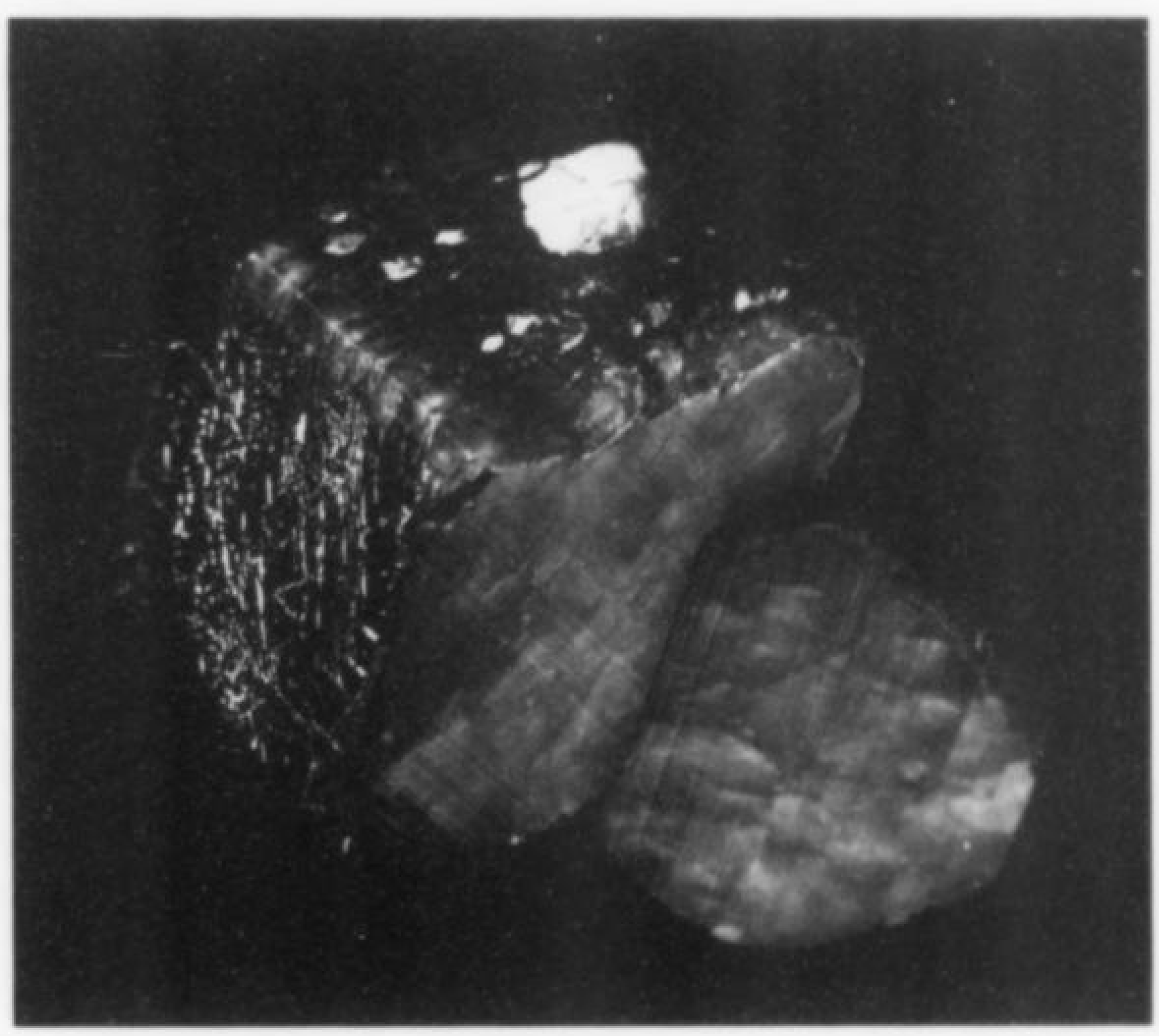


Figure 72. **Stibiotantalite crystal drawings (Maridge pegmatite) by R. Peter Richards, based on measurements by Wendell Wilson.**

Figure 73. **Stibiotantalite crystals to 2.3 cm, from the Maridge pegmatite. Richard V. Gaines collection (left, courtesy of John S. White) and Thomas Moore collection (right); Wendell Wilson photo.**

Figure 74. **Stibiotantalite crystal, 2.7 cm, from the Maridge pegmatite. Desmond Sacco collection; Bruce Carncross photo.**



Stibiotantalite $(Sb,Bi)(Ta,Nb)O_4$

Bandy (1951) reported that most stibiotantalite crystals from Alto Ligonha are rather small, 1 cm or less, but the largest known crystal (a sharp but damaged, blocky crystal in the Smithsonian) is 10 x 10 cm. A 10 x 10.5-cm crystal, partially gemmy, from the Morrua pegmatite is in the Desmond Sacco collection. This crystal and many other smaller examples came from the Muiane pegmatite. Another Muiane crystal, this one weighing 2 kg, is in the collection of the Andrade Museum, Maputo, Mozambique (Guillemin and Mantienne, 1988).

Some of the small crystals are gemmy and colorless to pale brown; larger crystals are blackish to opaque with translucent to transparent zones. At Muiane it occurs with red elbaite, pink beryl and manganotantalite (Gaines *et al.*, 1997).

Crystal forms noted on stibiotantalite from the Muiane mine include {010}, {110},{101}, plus occasionally {111}, {130}, {170}, {150}, {012} and {332}. Some are twinned on (010) (Cotelo Neiva and Coreia Neves, 1960).

Stibiotantalite crystals from the Maridge pegmatite are a grayish

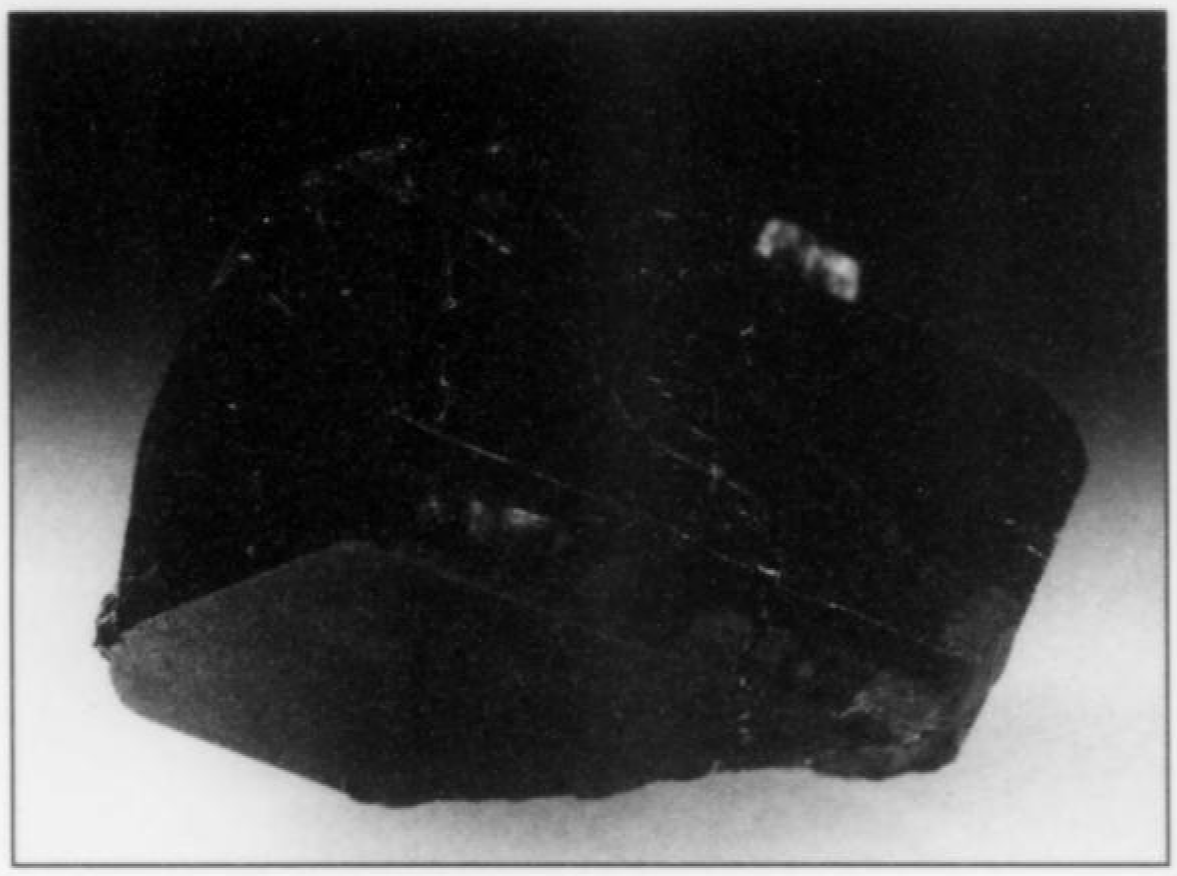


Figure 75. **Stibiotantalite crystal, 5.2 cm, from the Maridge pegmatite. José Rodriquez Rosa specimen; Wendell Wilson photo.**

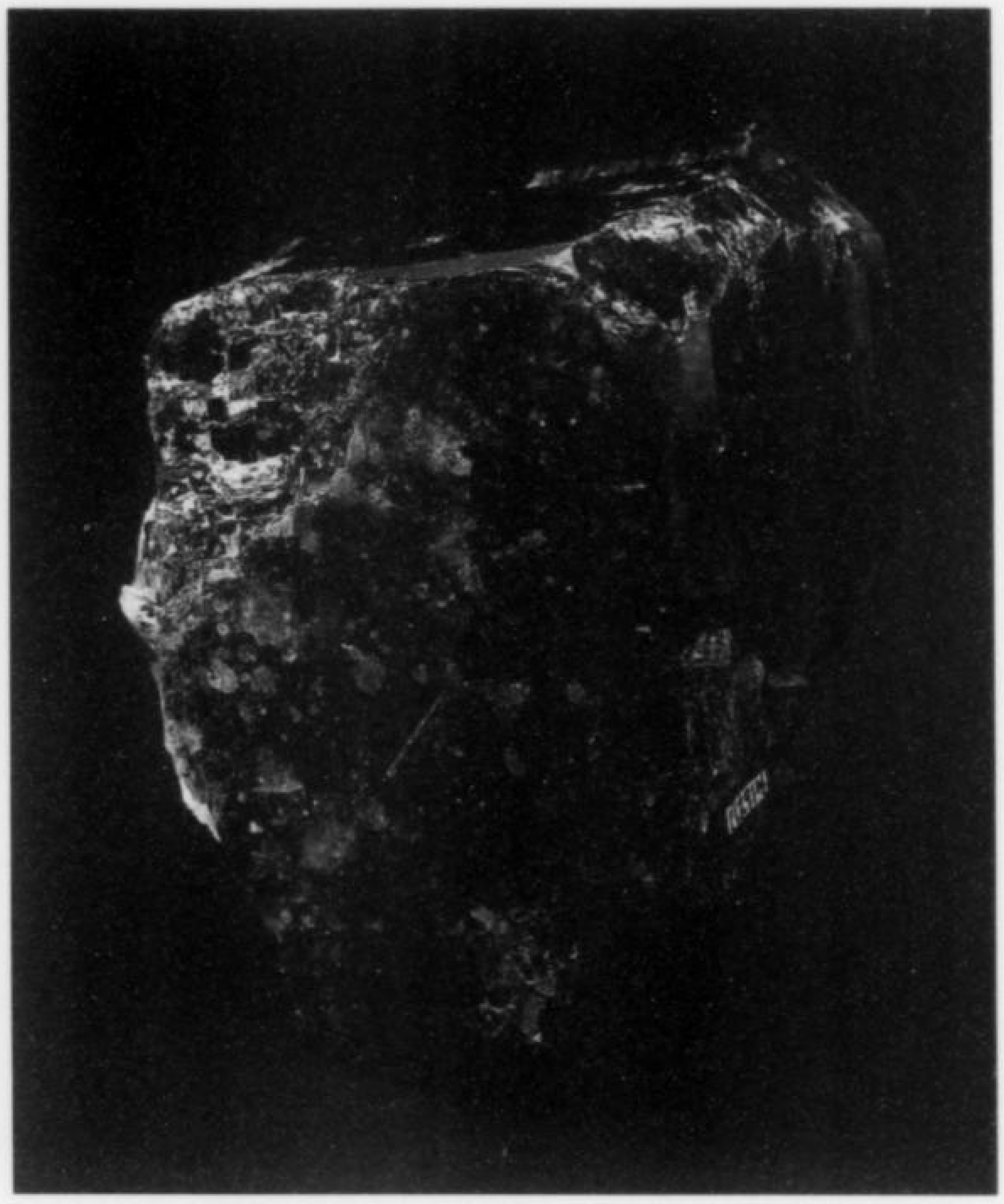


Figure 77. **Stibiotantalite crystal, 20 cm, from Alto Ligonha. Smithsonian collection (NMNH #112914, donated by Mark C. Bandy in 1957); NMNH photo.**

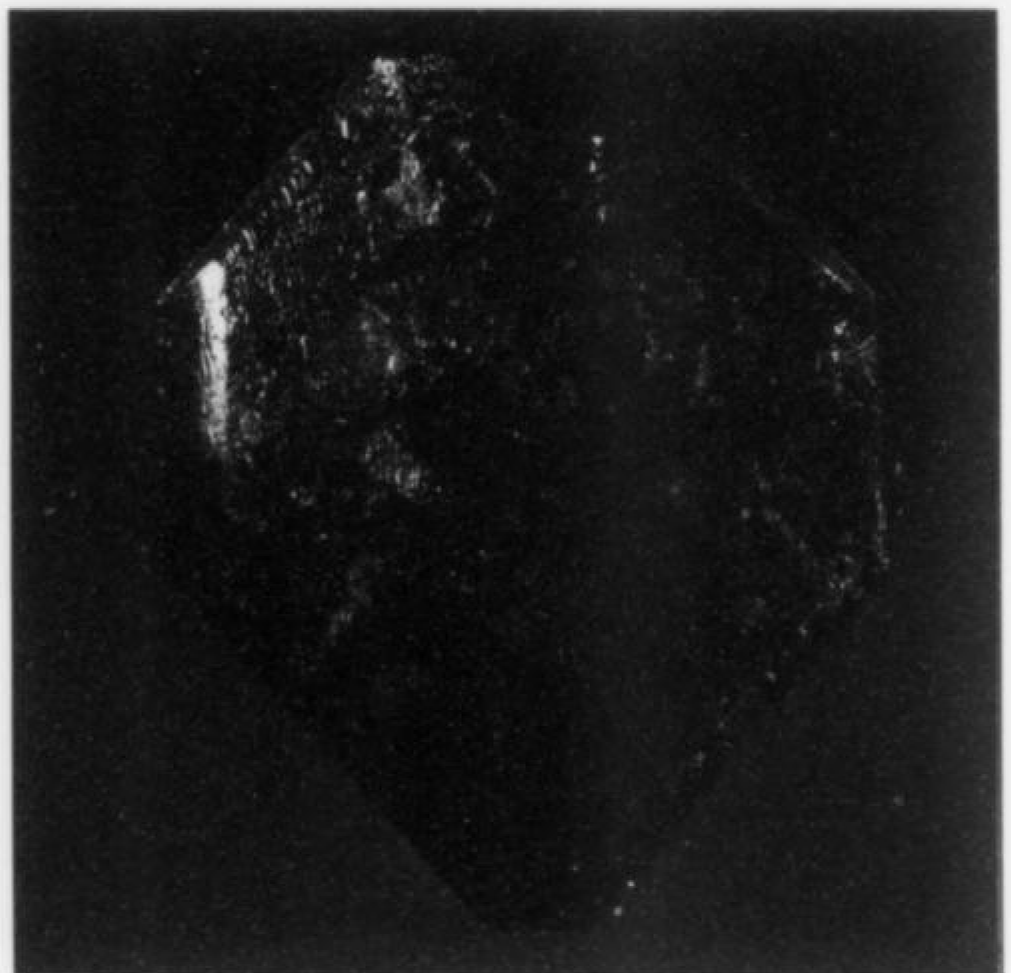


Figure 76. **Stibiotantalite crystal, 10.5 cm, from the Morrua mine. Desmond Sacco collection; Bruce Cairncross photo.**

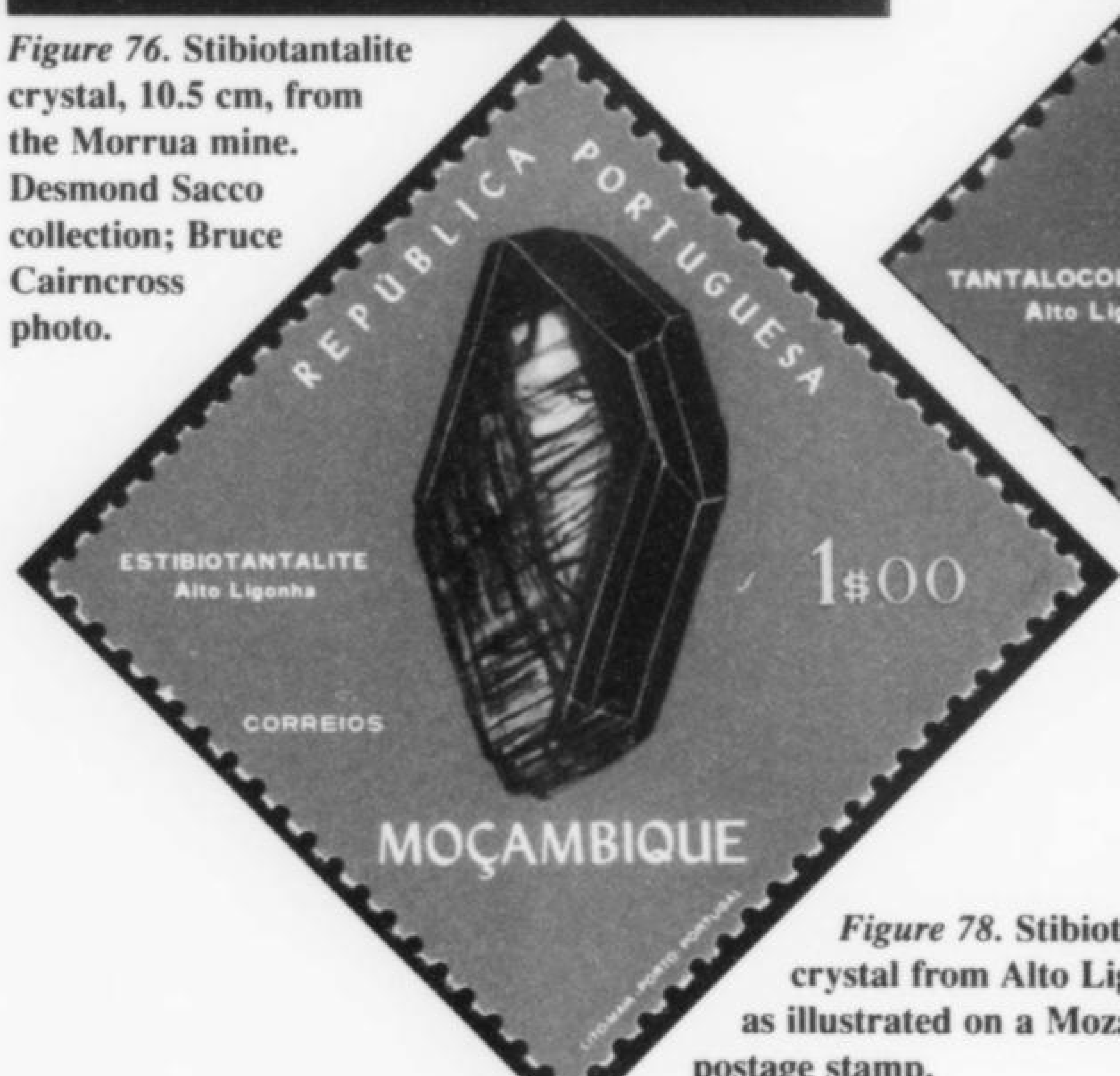


Figure 78. **Stibiotantalite crystal from Alto Ligonha, as illustrated on a Mozambican postage stamp.**

Figure 79. **"Tantalocolumbite" crystal (presumably columbo-tantalite) from Alto Ligonha, as illustrated on a Mozambican postage stamp.**

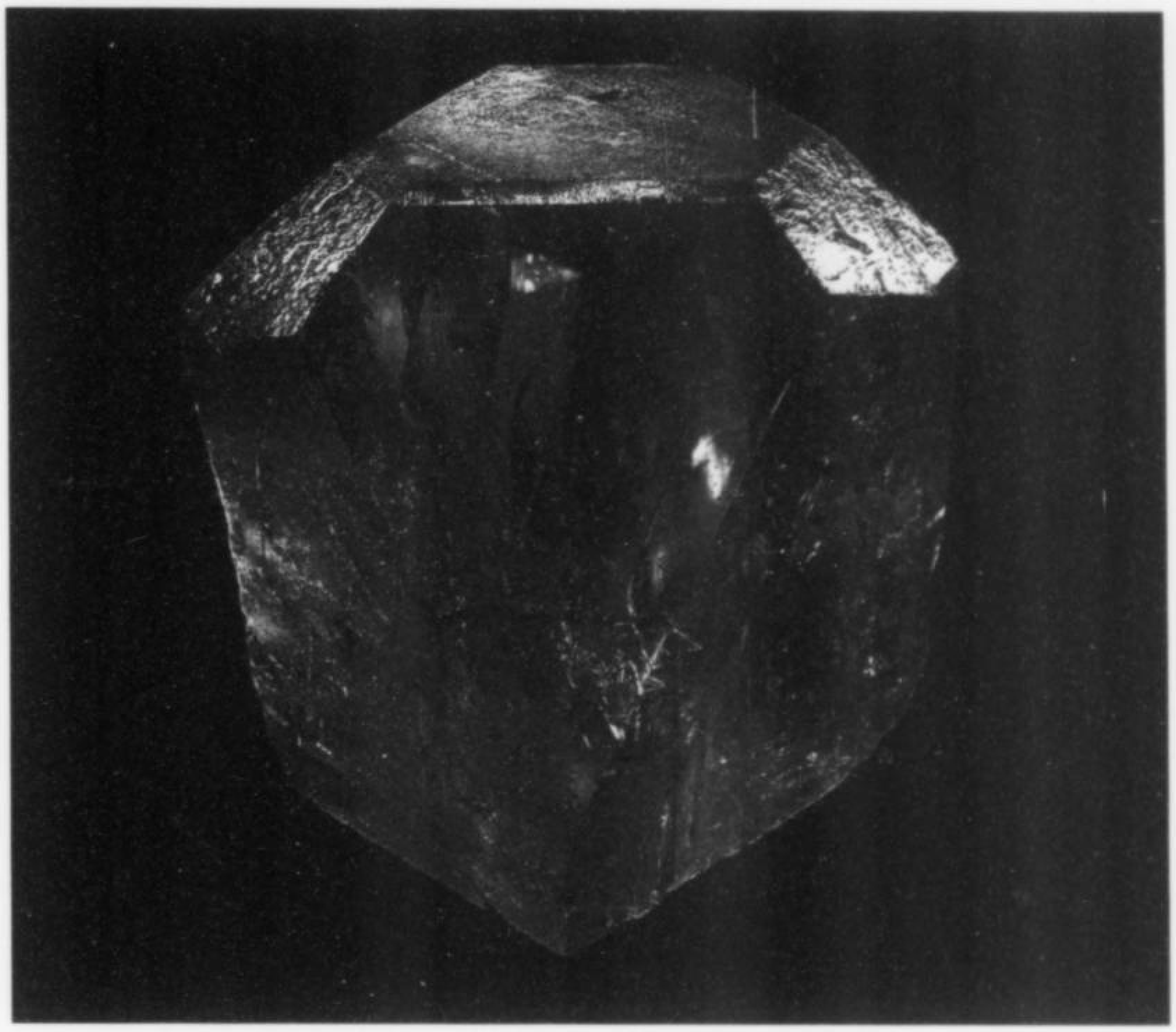


Figure 80. **Topaz crystal, pale blue, 20 cm (9.7 kg), collected in the late 1950's at the Namirrapo pegmatite. Desmond Sacco collection; Bruce Cairncross photo.**

yellow in color and quite translucent. They occur in sharp, blocky crystals dominated by {010}, {100} and {302}, and measuring 1 to 5.2 cm. The {010} faces are striated parallel to *c*, and the {302} and {201} faces are commonly preferentially coated by a thin, epitaxial layer of a black, opaque mineral, presumably manganotantalite or ferrotantalite. The only other association visible is lepidolite.

Strüverite $(Ti,Ta,Fe^{3+})_3O_6$

Strüverite and its niobian analog, ilmenorutile, were described from the Nampoça pegmatite by Lima de Faria and Quadrado (1966).

Thorianite ThO_2

Thorianite has been identified from the Namivo-Tomeia-Nampoça group of pegmatites (DSGM, 1974).

Thorogummite (?) $(Th,REE,U)(Si,Al)O_4(OH)_4$

Cotelo Neiva and Correia Neves (1960) reported a new mineral from Muiane which they named *mozambikite*. The description stated that the mineral is yellow-brown, occurring in octahedral crystals with a specific gravity of 5.24. A preliminary chemical analysis yielded ThO_2 = 58.80%, V_3O_8 = 6.04%, R_2O_3 rare earth oxides = 8.60%, Al_2O_3 = 4.40%, SiO_2 = 11.00%, and H_2O = 5.33%, plus less than a percent of CaO and Fe_2O_3. A more complete study was promised but never published; the description as it stood was unanimously rejected by the International Mineralogical Association. It is probably a variety of thorogummite.

Topaz $Al_2SiO_4(F,OH)_2$

Topaz crystals to more than a meter long and 25 cm wide have been found at Piteia; they are opaque white to yellowish white and rough. Smaller colorless, translucent crystals were found at the same mine (Bandy, 1951). The mineral is also recorded from the Ingela-Murrapane-Namicaia group of pegmatites (DSGM, 1974), and occurred in fine crystals at the Muiane pegmatite (Sinkankas, 1981). Muiane crystals tend to be colorless to gray and prismatic, with dominant {110} and {001}, and minor {120} and {021} (Cotelo Neiva and Correia Neves, 1960).

Topaz crystals were also found at the Gelo pegmatite in the 1970's, some weighing 2 to 4 kg; they were colorless and partially gemmy.

In 1967, while visiting the Muiane mine treatment plant, one of us (MBD) saw sky-blue topaz crystals from Mirrucue being bagged for shipment as industrial beryl. When the superintendent was informed that the blue material was actually topaz worth many times the value of beryl, he vigorously disputed the identification. "We've shipped more than 5 tons of this kind of beryl to the U.S.," he said, "and the buyers have never complained!"

Triplite $(Mn^{2+},Fe^{2+},Mg,Ca)_2(PO_4)(F,OH)$

Triplite and other manganese minerals are reported to occur at two pegmatites and perhaps others (Bandy, 1951). Correia Neves and Lopes Nunes (1968) later reported triplite and other phosphates from Alto Ligonha pegmatites.

Uraninite UO_2

Uraninite, in association with ferrotantalite, fergusonite, euxenite, samarskite and monazite, is known from the cluster of pegmatite bodies that includes the Mugeba, Bere, Enluma, Maria, Muacotaia and Namagoa pegmatites (DSGM, 1974).

Uranmicrolite $(U,Ca,Ce)_2(Ta,Nb)_2O_6(OH,F)$

Uranmicrolite has been reported from the Naipa pegmatite by Leal Gomes (1999a); it contains 10.47 wt.% UO_2.

Variscite $AlPO_4 \cdot 2H_2O$

Correia Neves and Lopes Nunes (1968) described variscite, phosphosiderite, hureaulite, montebrasite, fluorapatite, amblygonite, triplite, eosphorite and bermanite from Alto Ligonha pegmatites.

Xenotime-(Y) YPO_4

Xenotime-(Y) has been reported from a number of pegmatites

Table 3. **Pegmatite minerals of the Alto Ligonha district.**

Elements	
Bismuth	Bi
Gold	Au
Sulfides	
Bismuthinite	Bi_2S_3
Molybdenite	MoS_2
Fluorides	
Fluorite	CaF_2
Oxides, Hydroxides	
Cassiterite	SnO_2
Corundum	Al_2O_3
Gibbsite	$Al(OH)_3$
Hematite	Fe_2O_3
Magnetite	$Fe^{2+}Fe^{3+}_2O_4$
Rutile	TiO_2
Thorianite	ThO_2
Thorogummite (?)	$(Th,REE,U)(Si,Al)O_4(OH)_4$
Uraninite	UO_2
Carbonates	
Bismutite	$Bi_2(CO_3)O_2$
Silicates	
Albite	$NaAlSi_3O_8$
Allanite-(Ce)	$(Ce,Ca,Y)_2(Al,Fe^{2+},Fe^{3+})_3(SiO_4)_3(OH)$
Andalusite	Al_2SiO_5
Beryl	$Be_3Al_2Si_6O_{18}$
Clinochlore	$(Mg,Al)_6(Si_3Al)O_{10}(OH)_8$
Cookeite	$LiAl_4(Si_3Al)O_{10}(OH)_8$
Elbaite	$Na(Li,Al)_3Al_6(BO_3)_3Si_6O_{18}(OH)_4$
Euclase	$BeAlSiO_4(OH)$
Gadolinite-(Ce)	$(Ce,La,Nd,Y)_2Fe^{2+}Be_2Si_2O_{10}$
Hafnon	$HfSiO_4$
Holmquistite	$(Li_2Mg_3Al_2)Si_8O_{22}(OH)_2$
Kaolinite	$Al_2Si_2O_5(OH)_4$
Lepidolite	Li-mica
Microcline	$KAlSi_3O_8$
Montmorillonite	$(Na,Ca)_{0.3}(Al,Mg)_2Si_4O_{10}(OH)_2 \cdot nH_2O$
Muscovite	$KAl_2AlSi_3O_{10}(OH)_2$
Oligoclase	$(Na,Ca)(Si,Al)_4O_8$
Orthoclase	$KAlSi_3O_8$
Petalite	$LiAlSi_4O_{10}$
Pollucite	$(Cs,Na)[AlSi_2O_6] \cdot nH_2O$
Quartz	SiO_2
Scapolite series	$3NaAlSi_3O_8 \cdot NaCl$
Schorl	$NaFe^{2+}_3Al_6(BO_3)_3Si_6O_{18}(OH)_4$
Spessartine	$Mn^{2+}_3Al_2(SiO_4)_3$
Spodumene	$LiAlSi_2O_6$
Topaz	$Al_2SiO_4(F,OH)_2$
Zircon	$ZrSiO_4$
Niobates, Tantalates	
Betafite	$(Ca,Na,U)_2(Ti,Nb,Ta)_2O_6(OH)$
Euxenite-(Y)	$(Y,Ca,Ce,U,Th)(Nb,Ta,Ti)_2O_6$
Fergusonite	$(Ce,Nd,La,Y)NbO_4$
Ferrocolumbite	$(Fe,Mn)Nb_2O_6$
Ferrotantalite	$(Fe,Mn)Ta_2O_6$
Ferrotapiolite	$Fe(Ta,Nb)_2O_6$
Hübnerite	$(Mn,Fe^{3+},Fe^{2+},Ti,Sn)(W,Nb,Ta)O_4$
Ilmenorutile	$(Ti,Nb,Fe^{3+})_3O_6$
Ixiolite	$(Fe^{2+},Fe^{3+},Ta,Nb,Sc,Ti,Sn,Zr,Mn)_4O_8$
Manganotantalite	$(Mn,Fe)(Ta,Nb)_2O_6$
Microlite	$(Ca,Na)_2Ta_2O_6(O,OH,F)$
Plumbomicrolite	$(Pb,Ca,U)_2Ta_2O_6(OH)$
Pyrochlore	$(Na,Ca)_2Nb_2O_6(OH,F)$
Samarskite-(Y)	$(Y,Ce,U,Fe^{3+})_3(Nb,Ta,Ti)_5O_{16}$
Stibiomicrolite	$(Sb,Ca,Na)_2(Ta,Nb)_2O_7$
Stibiotantalite	$SbTaO_4$
Strüverite	$(Ti,Ta,Fe^{3+})_3O_6$
Uranmicrolite	$(U,Ca,Ce)_2(Ta,Nb)_2O_6(OH,F)$
Yttrocolumbite-(Y)	$(Y,U,Fe^{2+})(Nb,Ta)O_4$
Phosphates, Vanadates	
Amblygonite	$(Li,Na)Al(PO_4)(F,OH)$
Bermanite	$Mn^{2+}Mn^{3+}_2(PO_4)_2(OH)_2 \cdot 4H_2O$
Churchite-(Y)	$YPO_4 \cdot 2H_2O$
Clinobisvanite	$BiVO_4$
Eosphorite	$Mn^{2+}Al(PO_4)(OH)_2 \cdot H_2O$
Florencite	$(Ce,La,Nd)Al_3(PO_4)_2(OH)_6$
Fluorapatite	$Ca_5(PO_4)_3(F,OH)$
Hureaulite	$Mn^{2+}_5(PO_4)_2[PO_3(OH)]_2 \cdot 4H_2O$
Hydroxylherderite	$CaBe(PO_4)(OH,F)$
Monazite	$(Ce,La,Nd,Th)PO_4$
Montebrasite	$LiAl(PO_4)(OH,F)$
Phosphosiderite	$Fe^{3+}PO_4 \cdot 2H_2O$
Pucherite	$BiVO_4$
Triplite	$(Mn^{2+},Fe^{2+},Mg,Ca)_2(PO_4)(F,OH)$
Variscite	$AlPO_4 \cdot 2H_2O$
Xenotime-(Y)	YPO_4

and groups including the Bōa Esperança, the Guilherme-Comua-Muetia group, the Murropoci-Nuaparra group, and the Namivo-Tomeia-Nampoça group (DSGM, 1974). Sahama *et al.* (1973) analyzed xenotime from the Morrua pegmatite and found that it occurs in two distinct generations, has an unusually high ratio of yttrium to lanthanides (78:22), and is strongly enriched in gadolinium.

Yttrocolumbite-(Y) $(Y,U,Fe^{2+})(Nb,Ta)O_4$

Yttrocolumbite was described by Lepierre (1937) as a new mineral from an unspecified pegmatite in Mozambique. Considering the abundance of other rare earth minerals in the Alto Ligonha district, it is likely that the type locality is in this area. The mineral is black with a brilliant luster, and is said to resemble ampanagabite.

Zircon $ZrSiO_4$

Zircon has been reported from the Niesse-Isabela pegmatites, in association with beryl, scapolite, allanite and corundum (DSGM, 1974). Cotelo Neiva and Correia Neves (1960) report reddish brown, well-formed zircon from the Muiane mine, showing the form {111} (dominant) with {100}, {001} and {311} (minor).

Unknowns

Cotelo Neiva and Correia Neves (1960) reported several unknown or unidentified species, including:

(1) "Mineral A," in well-developed, black, orthorhombic crystals with resinous luster. It was presumed to be a tantalate of some kind (strongest x-ray lines: 2.495 (10), 1.470 (10), 2.060 (4), 1.675 (3) and 1.600 (3)).

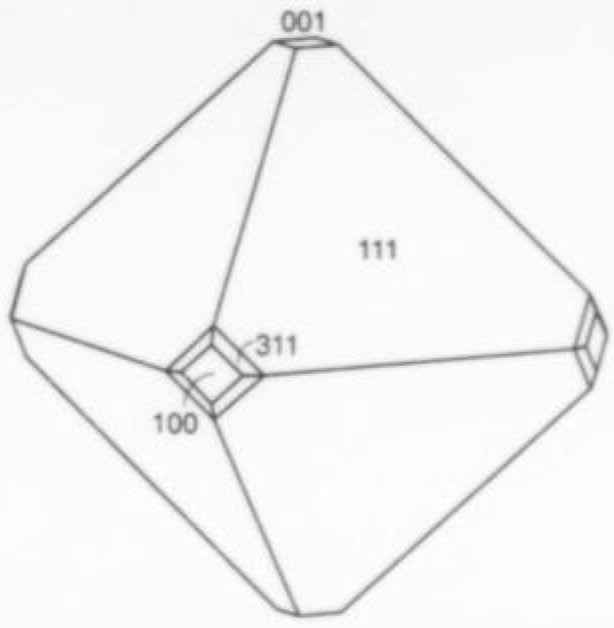


Figure 81. **Zircon crystal drawing (Muiane mine) by R. Peter Richards, based on measurements by Cotelo Neiva and Correia Neves (1960).**

(2) "Mineral B," in black, apparently orthorhombic crystals dominated by {001}, {100} and {110}. It looks like columbite-tantalite but has differing principal X-ray powder diffraction lines (2.72 (10), 4.20 (6), 1.70 (5), 1.458 (5)).

(3) Alteration product of stibiotantalite, yellow and powdery (strongest X-ray lines: 2.95 (10), 1.625 (8), 2.75 (4), 2.14 and 1.94 (4)).

(4) A black, octahedral, cubic-isotropic, radioactive mineral with a_0 = 8.18Å; it occurs surrounding a core of pyrochlore from the Mocachaia pegmatite.

CURRENT STATUS

There is currently much activity going on in the Alto Ligonha pegmatites. The government has issued a number of concessions to people willing to work various pegmatites, and is encouraging development in the district.

Alexander Dikov, a Bulgarian geologist (P.O. Box 66, 1404 Sophia; e-mail: dikov@mail.techno-link.com), has the Nuapara II concession, consisting of five small pegmatites collectively referred to as **Nuaparra**. Attractive, large quartz crystals with green elbaite are among its products.

Operating under the company name of *Intergeoresource Ltd.*, Dikov distributes specimens from his own concession and also from other Alto Ligonha pegmatites currently in operation. These include the main pegmatite at **Muiane** (red elbaite in coarse-textured lepidolite, pale yellow cookeite, and yellow microlite crystals to 6 mm), **Nacuissupa** (citrine quartz crystals, green elbaite in a sheaf-like habit to over 10 cm, and dark smoky quartz crystals), **Manica** (blackish, thick tabular stibiotantalite crystals to 3 cm), **Nanro** (the sole locality for the black hemispheres of ixiolite to 1 cm, as well as green elbaite and large colorless/citrine zoned quartz crystals), **Mutala** (quartz crystals on albite, pale pink beryl crystals in thick tabular habit to more than 10 cm), **Namacotcha** (pale green elbaite crystals with pink tips, blackish green elbaite with steep rhombohedral terminations and indicolite-blue interiors, to 10 cm), **Conco** (black beryl, schorl crystals and acicular schorl inclusions in quartz crystals) and **Nahora** (green to black elbaite crystals on quartz, spodumene in magenta, green and colorless crystals, "watermelon" tourmaline crystals).

Two Portuguese nationals, José and Sebastian Rodriguez Rosa (brothers), have the concession on the Naipa and Namacoche pegmatites. They operate under the company name *Geofil Ltda.* (Alto da Bela Vista 2-A, 2750 Cascais, Portugal).

The **Naipa** has lately been particularly prolific, yielding large and spectacular clusters of blue-green tourmaline crystals, as well as interesting crystals of yellow microlite octahedrons to 2 cm, blackish yellow microlite cuboctahedrons to 3 cm, black stibiocolumbite and manganocolumbite crystals to 4 cm, and flattened, dark green stibiomicrolite crystals to 3.5 cm. During 1998 and 1999 the Naipa mine was the leading producer of pegmatite minerals (mostly niobium-tantalum concentrates, gem beryl, gem elbaite, microlite, manganocolumbite and herderite) in Mozambique (A. A. Leal Gomes, pers. comm.). The deposit is the focus of new studies on pegmatite structure and paragenesis, and on Nb-Ta minerals, being undertaken by the Earth Science Department of Minho University, Portugal (see Leal Gomes, 1999a, 1999b).

From **Namacotcha** some attractive pink beryl crystals have recently appeared. They measure up to 10 cm across and are rather flattened perpendicular to the *c* axis (in the typical pink beryl habit).

Tabular crystals of reddish black manganotantalite to 10 cm have also been coming lately from **Morrua** and **Muiane**. Active mining continues at many sites, and more specimens should be forthcoming.

CONCLUSIONS

The Alto Ligonha pegmatite field is clearly among the most mineralogically interesting pegmatite areas in the world, and has yielded a substantial quantity of collector-quality crystal specimens. Many small pegmatite bodies surely remain unworked or undiscovered, and others continue to be mined on a small scale. Specimen production is likely to continue on a limited and sporadic basis indefinitely.

MEMOIRS OF ALTO LIGONHA[3]

by M. Bettencourt Dias

I had worked in Mozambique during the 1930's and 1940's but during the years of World War II I was kept busy with the exploration and evaluation of gold and graphite deposits which kept me away from Alto Ligonha. As soon as travel became possible again I left Africa for a time and attended the Colorado School of Mines. In 1952 I returned to Alto Ligonha.

My wife Chris and I boarded the *Principe Perfeito*, a luxury liner on her return trip from Europe. These ships sailed from Lisbon, went around the African Continent, up to Nacala—the last modern port in Mozambican territory—and then turned around stopping at Beira, Lourenço Marques, Cape Town (in South Africa), Luanda (in Angola), Funchal (the capital of the Island of Madeira) and back to Lisbon. From Lisbon to Lourenço Marques they were always booked solid, but lots of passengers left before the ship stopped in Beira and, since the Geological Survey valued its geologists enough to pay for a first class ticket, I had no trouble getting a berth for the two-day trip to Lourenço Marques.

We were installed in a double-bed cabin with private bath, were served breakfast in bed, spent the daylight hours lounging around a lovely swimming pool and retired to our cabin to dress for dinner, which was served to the accompaniment of a live orchestra and followed by dancing until the wee hours.

[3] Extracted from the author's forthcoming books: *An African Name* and *An African Career.*

The day after we landed in Lourenço Marques I reported to Alexandre Borges at the survey office. All the geologists were in town but most were on vacation and the office was quiet. Borges said that I could turn in my report in two weeks, and then go on a month's vacation before the next field assignment. I asked where I would go next. He answered that Lisbon had lost interest in the uranium of Tete. It had not turned out to be the kind of deposit that the central government could use to show how well they were "developing the *colonies*." He did not expect that the uranium investigations would continue. We might even be left to ourselves, in which case we might get down to some "honest geological investigations instead of work to satisfy the egos of politicians."

The Director had not yet asked him for suggestions, but when that came to pass he was thinking of proposing the continuation of the geological mapping of the Manica Gold Belt. I handed in my report, titled *The Limestone Deposits of the Cheringoma Plateau*, long before the end of the two weeks he had given me and then took a vacation. We could not go anywhere for we had no money. So we concentrated on getting our home organized. I assembled bookshelves and kitchen shelves, organized the garage so that it could house the car and assorted trunks and boxes. We did some gardening. Chris trained an African man to maintain the house and to clean and wash our clothes. The month went so fast that I had the impression that the vacation was over a couple of days after it had started.

Back at work the rumors were that Lisbon had indeed lost interest in the "immense mineral wealth" of Mozambique. The geologists and engineers who had come from Lisbon convinced that they could, with their "superior knowledge," make a few trips to the interior and find ore deposits worth millions, had already returned home. I busied myself with the petrographic microscope. It seemed that I was always behind in getting my rock collections ready to be stored in the museum. Borges was very strict making his geologists back up their written reports with collections of rocks and minerals properly classified and accompanied by microscope slides. Only after he had personally checked them were the collections sent to the museum for safekeeping. The museum in Maputo had been founded with the specimens collected in the field before the end of the 19th century by A. A. Freire de Andrade, geologist and mining engineer (who was also the most distinguished Governor General the country had).

We only owned one petrographic microscope, kept in the mezzanine of the mineralogical museum. It was such a prized treasure that it rated an office all to itself while most geologists had to share a cramped space with a colleague. You had to wait your turn to use the microscope.

It soon developed that, although I was an employee of the Geological Survey, I was being "drafted" to go and work for the Alto Ligonha Mining Company. The Company was in difficulty, and 51% of it was owned by the government. So the Governor General was in a position to insist that I go (at twice my usual salary) and try to improve the operations.

Ten days later I flew to Nampula. His Excellency had agreed to a preliminary fact-finding visit of no more than two weeks. There was a car driven by the manager of the mines awaiting my arrival at the airport in Nampula. The trip to the mines took four hours. The only interruption was the crossing of the Ligonha River on a pontoon after passing through Murrupula (from where I had started out on foot to look for Borges, in 1943. See *An African Name*). After we crossed the river I recognized many of the places where I had then built bridges with local timber and bamboo. They were all made of concrete now. The manager told me that a permanent bridge over the Ligonha, to be located where the pontoon still operated, was already under study.

We arrived at Muiane, the headquarters of the mining company, before dark. The last time I had come this way was nearly ten years ago. That trip from Lourenço Marques to join Borges who was camped at Murrapane, just a few tens of kilometers to the south, had taken two weeks by ship, two days by train, one evening on a Thorneycroft truck, and six days walking with a retinue of nearly three dozen porters through uninhabited jungle. Now, I had done it all in the same day.

Muiane had changed as well. It now had one ample building where the administrative offices were housed; there was a modern hospital; a school house; houses for the employees; a store and a bar; workshops and warehouses occupied one whole side of a street. It looked clean and well taken care of. The mine management had also established a small company museum where they had preserved occasional outstanding mineral specimens. By that time the main sources of revenue for the company were beryl and ferrotantalite; tourmaline was recovered as a by-product from the occasional pockets encountered. I was so impressed by several of the specimens in their little museum that I took them out into the sunlight and photographed them. There were four elbaite specimens, all from the Muiane mine. The first is a slightly divergent parallel crystal group terminated by the pedion. It is a true "watermelon" tourmaline: pink in the middle with a green rind, and measuring about 6 cm tall. The second is a cluster of fractured elbaite crystals, mainly white in color, with a green rind at the base, and measuring 15 cm across. The fractured crystals appear to be partially to almost completely replaced by albite. The third specimen is a typical broken elbaite crystal showing a gem nodule of flawless tourmaline emerging from the center. Usually at Alto Ligonha these are red but I have seen a couple of pale green examples. And the fourth is a perfectly terminated elbaite crystal composed mostly of that rarest of all Mozambican colors: "tea." The tea-colored tourmaline, having a delicate color similar to pale honey or yellowish smoky quartz, was only found at the Muiane mine and was not seen even there after the early 1960's. (See Fig. 28, p. 473.)

The raw production from the various pegmatite mines was delivered by truck to the Muiane plant for upgrading to meet the specifications required by the buyers. Beryl was the most important product. In the 1950's the world production of this mineral was less than one million tons per year with Brazil leading in exports; Nigeria was the second world producer. Either Mozambique, Southwest Africa, or Madagascar usually came third.

The run-of-the-mine beryl was washed with jets of water to remove clay and then dumped on metal-covered tables where it was inspected by pickers of the Achirima and Lomwe tribes; they seemed to have a high natural ability to remove pieces of quartz, felspar, topaz and some lithium minerals that are look-alikes for beryl. Each sorter had a small container in which he saved any gems he found mixed with the run-of-the-mine beryl ore. These were usually tourmaline (green, red, blue, rarely yellow), topaz (blue, white and smoky), aquamarine (sky-blue, rarely deeper shades), kunzite spodumene (light purple), morganite beryl (pink or peach-colored), quartz (transparent, rose-colored, smoky or citrine, rarely amethyst). Bonuses were given to the lucky sorters who found valuable gems (the bonuses were aimed at sharpening their eyes; the question of honesty didn't come into play: both the Achirima, as well as the Lomwe, have very high moral standards and were not in the habit of keeping back stones). Following the sorting the beryl was dried in the sun and packed in 50-kg bags ready for export to the U.S.A. where it brought about $550 per ton.

Next in economic importance came two very dense, dull-black minerals which occurred in the same zones of the pegmatites that produced beryl. They are members of a mineralogical series which has columbium-rich minerals at one end and grades into tantalum-rich minerals at the other end. Really they should be called columbo-tantalites but are named columbite or tantalite according to the predominant element. [Ed. note: Today the accepted names are ferrocolumbite and ferrotantalite.] Our columbite obtained an average price of approximately $8,500 per ton while our tantalite sold at nearly $23,000 per ton. Both minerals were found in the residues from washing beryl as well as in pockets associated with cassiterite and bismutite in the beryl zone of the pegmatites. They were very dense and similar, except bismutite which was tan in color, while the others were black. Bismutite was hand-picked. The rest was crushed, mixed with water and put over shaking tables to separate the cassiterite from the other two. After drying, tantalite was separated from columbite because the latter was magnetic enough to be pulled out in a magnetic separator. Each fraction was dried separately and bagged for export in especially heavy-duty bags.

Lithium minerals occurred in the intermediate zones of the pegmatites either by themselves or mixed with beryl, columbium and tantalum minerals, as well as the tourmaline gems of the most beautiful shades of green and red (including the highly priced rubellite). There was a separate shed in which lithium-bearing minerals were processed. Lepidolite (a lavender-colored lithium mica) was so characteristic that it was hand-sorted and shipped in bulk. Spodumene occurred in long, flat, lavender-colored crystals and was easily separated by hand. The residues were washed, checked over for gems, crushed and passed over shaking tables where microlite (another tantalum mineral of very high value), tantalite and bismutite were recovered.

Each section of the plant had an African overseer who moved from place to place issuing advice, showing the other workers how to perform their tasks to his satisfaction and occasionally conducting the singing with gestures like an orchestra conductor. Every task was performed to the rhythm of improvised African songs. Although the system was definitely labor-intensive, one had the impression that every worker knew what he was doing and enjoyed doing it.

The most interesting section was the "mica building." It was apart from the rest of the plant. We entered it through a wide patio with a brick floor where truckloads of bulk mica were piled at regular intervals in heaps of approximately five tons each. Workers wielding pitchforks and shovels attacked the heaps and spread the material into layers of about one foot in thickness which were then hosed with water. The water, loaded with clay and other impurities, ran towards an iron grill where it disappeared to be pumped to the shaking tables for removal of heavy minerals, leaving behind the washed mica which was now shiny and reflected the sunlight like pieces of glass. After it dried in the sun it was loaded into wheelbarrows and carried inside the building where it was spread over a large table from which pickers took the largest "books" of mica to be distributed to the cutters. After the pickers had removed all the good quality mica, the residue was shoveled into wheelbarrows and taken to an enormous pile located under a shed at the back of the patio. This was sold in bulk to be crushed for paints and other uses.

"Cutting" mica is an art that was developed in India (at the time the world's major producer of the commodity). The impurity-free mineral is used as a dielectric substance which reduces the weight of electrical equipment. This is why it has to be cut by hand into sheets about 1 mm thick, taking advantage of the fact that the mineral has perfect cleavage and can be separated into flat sheets of any thickness. The cutters use a sharp knife which is kept fixed while the thin sheet of cleaved mica is pulled against the blade. All impurities, discolorations and inclusions are removed by the cutters. The final product is graded by type (the most common types were "ruby mica," biotite, muscovite, phlogopite and "black spotted") and by size. It was packed between sheets of Kraft paper inside sturdy handmade wooden boxes. Good, red "ruby mica" of large sizes brought in the 1950's hundreds of dollars per pound.

During the visit I noticed various operations whose efficiency could be improved. The main problem with these operations was their high labor costs. But in Africa one had to think carefully before rushing into mechanization. When you are isolated in the interior, with extremely unreliable communications and transportation; when you have no other electric power than what your generator will produce; when parts for mechanical equipment have to be ordered from representatives that are thousands of miles away and seldom have them in stock; when your fuels and lubricants have to travel weeks on the high seas and more weeks on roads that become impassable for half of the year: you live with the nightmarish fear of what will happen to your expensive, highly sophisticated mechanical devices and to your operation should you receive a telegram reading: "REGRET TO INFORM PARTS ORDERED NOT IN STOCK STOP ORDERING TODAY STOP ETA APPROXIMATELY NINETY DAYS."

On the other hand your mining operation is surrounded by villages where the people have no other opportunity to obtain jobs from which they can make enough money to buy clothes and other necessities except by working for you; their children come to study at the mine school; any urgent medical treatment is performed at the mine hospital before they can get to the Government Hospital which is located at the Posto, maybe a couple of days walking distance. Furthermore the tribal people in Mozambique turned out to be excellent workers capable of performing tasks such as sorting and cutting mica far better than any mechanical devices could. Such considerations came out in sharp focus in the beneficiation plant at Muiane.

During the following months I worked at modernizing the Muiane treatment plant and reorganizing the mining operations at many of the pegmatites. It was not uncommon to find amid the concentrates nice crystals of gem minerals, stibiotantalite, microlite, and cassiterite as well as occasional nuggets of native bismuth up to 50 grams in size. The Muiane picking table was a collector's dream.

One of the most striking specimens I saw at Muiane was shown to me on my first visit in 1944. The mine was already famous for excellent gem rubellite and green tourmaline, and was also being worked for ferrotantalite. What they showed me was a very lustrous crystal of stibiotantalite measuring 2.5 x 6 cm and weighing over a pound. At that time it was the largest such crystal in the world, and in addition had real quality going for it, with well-developed basal pinacoid faces and sharp prism and pyramid faces around the sides. The color graded beautifully from colorless to pale beige to honey-yellow and pale brown, with some of the prism-zone faces a rich dark brown. It was later donated to the Freire d'Andrade Museum in Maputo.

A few years later an even larger crystal was found at Muiane, this one measuring 11 cm along one edge and weighing 2 kg (four times the weight of the earlier crystal). It, too, was donated by the mine management to the Andrade Museum, where presumably they are both still preserved.

Stibiotantalite, as I said, was not an uncommon mineral at Muiane, and usually showed up in association with rubellite tourmaline and clusters of cleavelandite albite. At one time I got to wondering whether the Naipa mine about 5 km away might simply be an extension of the same pegmatite, because stibiotantalite was found there, too, usually inside spherical nodules of lepidolite. The ground between the two mines is an uninterrupted mantle of pegmatitic regolith, and prospecting pits which were sunk along the trace connecting the two mines found abundant eluvial ferrotantalite.

One day I received instructions to have a road cut through the jungle so that cars could reach the old abandoned Nahia mine. I recruited a crew composed of a few dozen local tribesmen and we set to work. The men, equipped with bush knives, axes, picks and hoes, cleared a path wide enough for a truck, and smoothed it over by removing rocks and stumps here and there as necessary. Big trees and large boulders we went around, so the road was not exactly straight.

Figure 82. **Man-size quartz crystals as discovered in a clearing at Nahia in 1944. M. Bettencourt Dias photo.**

The scouting group that checked the ground ahead for obstacles was led by an old tribesman who knew (more or less) where the abandoned mine was. When we were getting close to our goal, one of the scouts came back to see me where I was working with the "engineering brigade." He was excited, and wanted me to come and see a strange sight they had come upon: "large pieces of water rock sticking out of the ground." This phenomenon, he said, was right in the path of the road, and the old tribesman leading the scouts wanted to know whether we wanted to remove the obstacles or curve the road around them.

I followed the scout and came to a clearing where the ground was littered with broken chunks of transparent quartz of all sizes, as well as five magnificent crystals of quartz, almost as tall as I am, protruding from the earth! One of them, standing vertically, was totally water-clear and a pale amber color. The others were milky to partly transparent and leaned at various angles. They were all well-formed and terminated, weighting perhaps three-quarters of a ton each.

I learned that the local language (Achirima) did not have words for "quartz," "transparent, " "smoky color," or "crystal," so they had just done the best they could in describing the crystals as "water rock." This description seemed appropriate and sensible to me, so I adopted the term from then on.

Ultimately I concluded that the remarkable forest of quartz crystals was the exposed quartz core of a large pegmatite, perhaps even an extension of the nearby Nahia pegmatite. I ordered the road to be driven in a wide loop around the occurrence and had it cleared of underbrush. I instructed the men sternly not to take away any specimens—not that they would have considered such foolishness anyway; only white men are crazy enough to collect rocks!

The quartz crystal outcrop was later threatened when the mine came under new ownership. The new owners devised a scheme for getting the rough mine road I had built improved at no cost to themselves: they donated the crystals to the Geographic Society of Lisbon. The catch was that the Society had to come get them, and that meant the Society would be forced to invest in a program of road building. The project was begun, but the Society ran out of money halfway before reaching the crystals, and abandoned the project. They never did take the crystals away; as far as I know, they are still where we found them.

At the time I worked there the Alto Ligonha Pegmatite District was only known to a few serious collectors of rare minerals. Its rubellite was highly prized (and already highly priced) by gem cutters at Idar-Oberstein and in the Far East. Very few people in the United States had heard of the district. Cut stones, especially those from the Muiane mine, were sold as Brazilian because buyers associated beautiful tourmaline, aquamarine and morganite with that country. The sellers could charge more by letting the buyers think that way.

I remember some geologists who, even after they had visited the mines and seen what they were producing, insisted on telling me that only Brazil could be considered as a serious producer of beryl, columbite and tantalite. From a few to whom I tried to convey the idea of the enormous potential of the field, I received looks of disbelief and veiled remarks about the dangers of being in the bush too long! But at least three visitors understood what I was saying. Martin L. Ehrmann (see Smith and Smith, 1994) of California, who visited the mines in 1955, became a regular purchaser of stones and specimens; Dr. E. N. Cameron tried to interest a large American corporation to invest in exploration and development and sent two geologists to study the alluvial deposits of columbite-tantalite; Dr. Erland Grip, chief geologist of the Boliden Mining company, of Boliden, Sweden, spent some time with me in the field and later sent a group of representatives of his company to investigate the possibilities of investment in Mozambique. But when they contacted the directors of the Alto Ligonha Company to discuss the formation of joint ventures to develop the district, they found not the faintest interest. Any association with large companies made the directors suspicious of being replaced by competent management. And that they did not want.

When the so-called "independence" took place under the Marxists in 1975, I knew that my days were numbered. I sold my mineral collection to a South African dealer before the government could get around to confiscating it. Then I went around to small post offices where I was not known and mailed off in many small packages what I had left (mostly gem rough) to the Colorado School of Mines; I did not give a sender's name or return address, hoping that the School would guess the packages were from an alumnus on the run. About half of the packages got through, and the School lived up to my hopes, saving everything for me until I showed up to claim it. Arriving in Colorado at the age of 55, with only $100 in my pocket, I was grateful to find that cutting material waiting for me.

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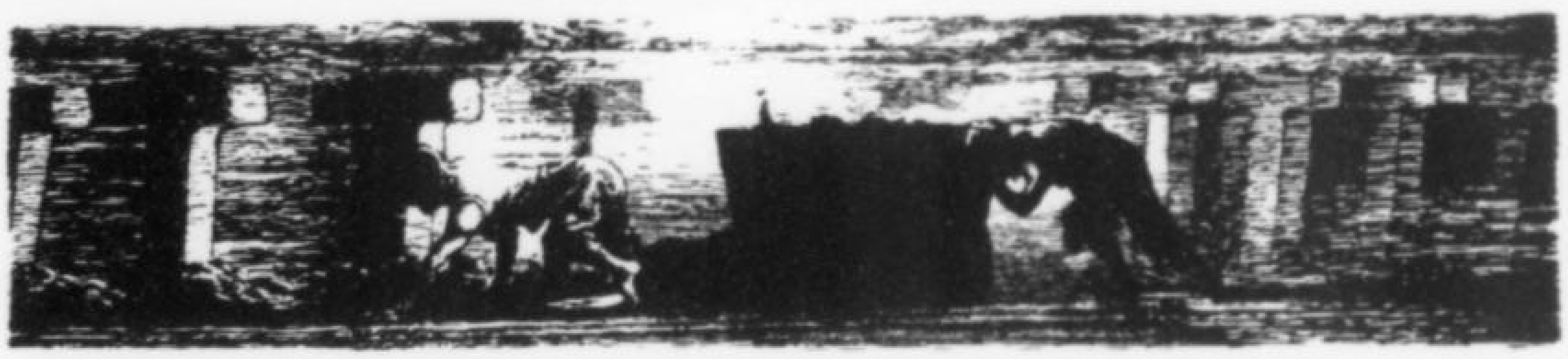

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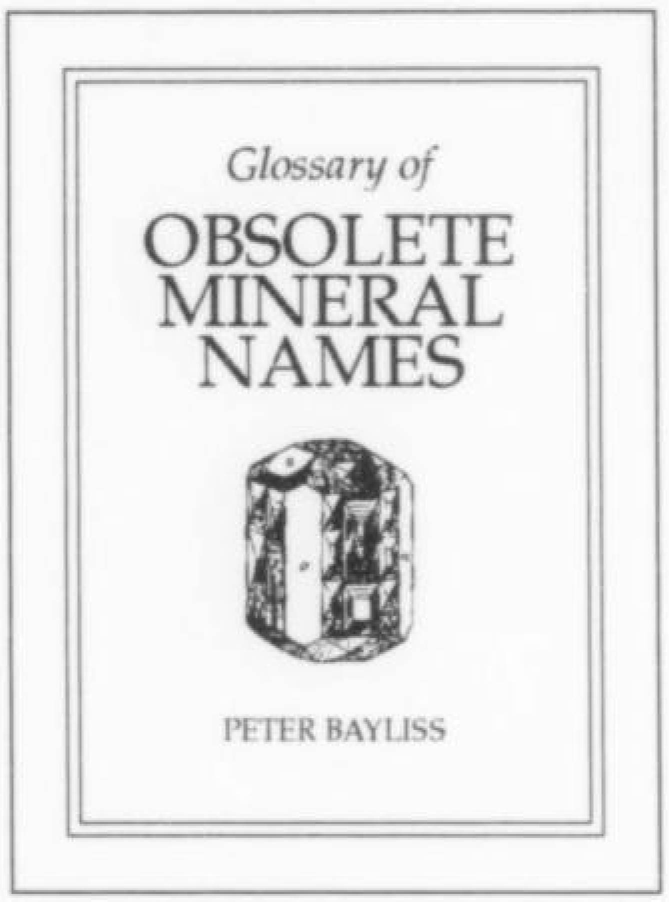

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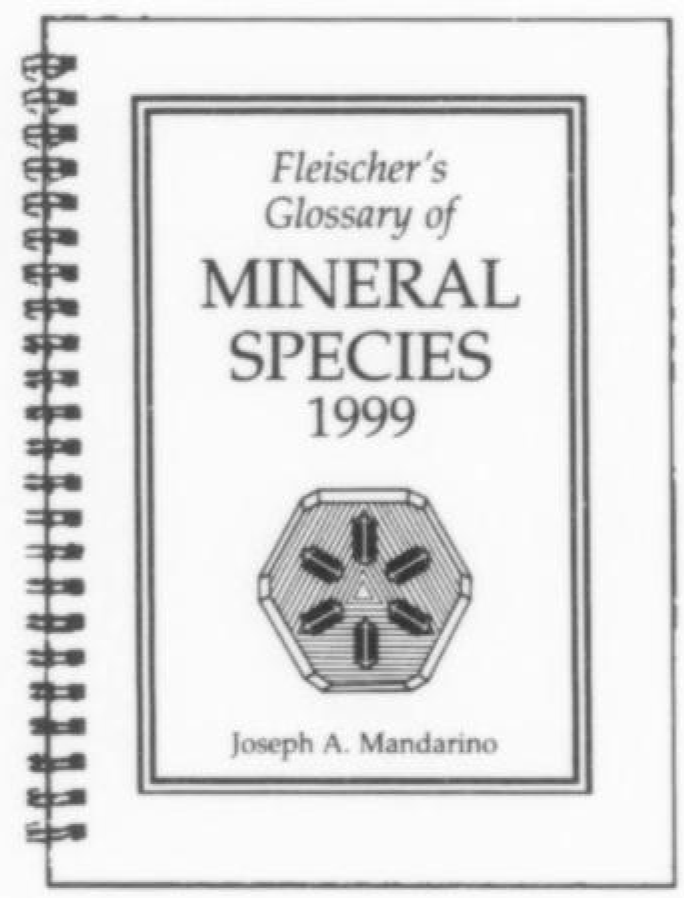

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Vol 1, No 1, Mineralogical Record, Spring 1970

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* Compiling and publishing information on mineral localities, and important mineral collections.
* Encouraging improved educational use of mineral specimens, collections, and localities.
* Support a semi-professional journal of high excellence and interest designed to appeal to mineral amateurs and professionals, through which *FM* activities may be circulated.
* Operating informally in behalf of minerals, mineral collecting, and descriptive mineralogy, with voluntary support by members.

The Mineralogical Record has agreed to an affiliation with the Friends of Mineralogy whereby it will publish its written material and news of its activities. The *Friends of Mineralogy* will support the *Mineralogical Record*, since the aims of both are similarly educational and directed toward better coordination of the interest and efforts of amateurs and professionals.

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What's New in Minerals

Delaware Show 2000

by Joe Polityka

[March 4]

The Delaware Show is held in Claymont, Delaware, each year. This year *Broken Back Minerals* of Newark was disbursing a collection of Pennsylvania minerals from classic locations; they had a good selection of **almandine** crystals to 2 cm on mica and feldspar from the now-extinct old pegmatites of Delaware and Chester Counties, and some excellent native **copper** specimens from the mines and prospects near Mount Hope, Adams County. The coppers, from miniature to large cabinet size, consist of branching masses on greenschist matrix. No actual crystals of copper are visible, but some specimens show a dusting of malachite microcrystals.

The Rocksmiths had gray-brown **scheelite** crystals to 2 cm with pale green **fluorite** cubes to 2 cm on edge, from Dongsang, Hunan, China.

M. Phantom Minerals of Columbus, Ohio, had some **quartz** scepters from Sichuan province, China. The gemmy, Herkimer-like crystals to 2.5 cm sit on transparent stems about half that width. Large thumbnail to toenail sizes were available. Chris and Neal Pfaff of *M. Phantom* also had some interesting **gold** specimens in miniature sizes from Berezovsk Yekaterinburg Oblast, Russia. The pieces show branching, flattened masses of gold on quartz matrix.

The following week I was in Clifton, New Jersey, for their annual show. Although little was new there to report on, I was impressed by the selection of New Jersey zeolites and associated minerals in the booth of James Zigras (201-444-9864). James has obtained legal access to the old Prospect Park quarry near Paterson, New Jersey, and has collected some excellent specimens there during the past year. He had for sale mostly small cabinet-size specimens of **heulandite**, red **stilbite**, **datolite**, **amethyst**, **greenockite** and **calcite** (but very little prehnite).

New Jersey Show 2000

by Joe Polityka

[April 29–30]

The annual New Jersey Earth Science Show was held at the Littell Community Center and the Hardyston Township School. The two facilities sit on opposite sides of Route 23, but buses were available to shuttle people back and forth. About 50 tailgaters were also set up in conjunction with the show.

The theme this year was **GOLD.** The American Museum of Natural History displayed their famous Newmont gold specimen next to five cases of gold from private collections. Penn State exhibited a case of minerals, and there were cases of Franklin fluorescent minerals and general minerals from private collections.

A total of 40 dealers set up in the two buildings, giving collectors plenty to look at. *Mountain Minerals International* had their usual selection of gem crystals, and also some unusual **enstatite** single crystals from Mpwa-Mpwa, Tanzania. The rectangular, thumbnail-size crystals are root beer-brown in color with partial transparency, some being facetable. These crystals are rather dark, but are certainly far better for the species than any I have ever seen. Dan Weinrich also had some of them.

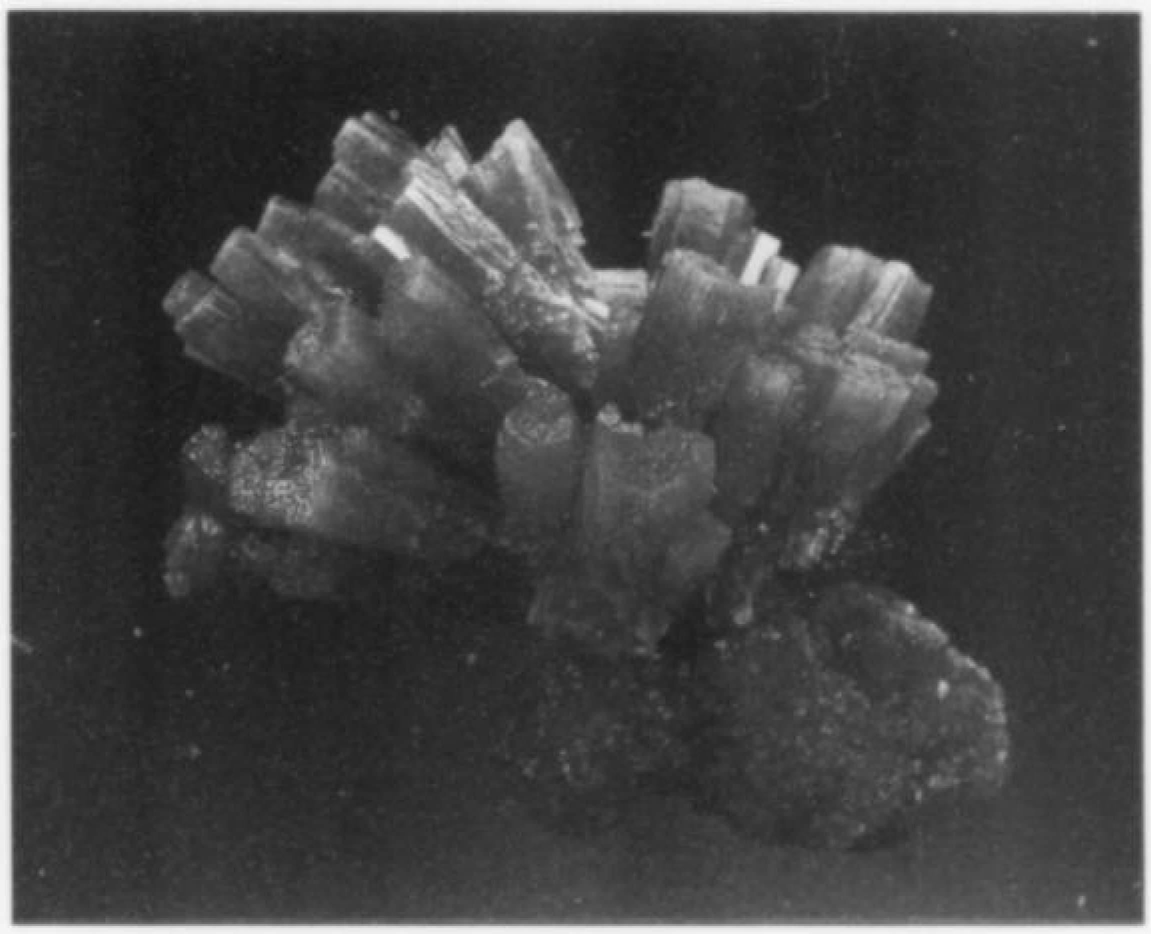


Figure 1. **Pyromorphite, 4.2 cm, from Gulin, Guanjshi prov., China. Dan Weinrich specimen; Jeff Scovil photo.**

In addition, Dan Weinrich had a selection of the **pyromorphite** specimens from Gulin, Guanjshi province, China, as did Dave Bunk and Chris Wright. Thumbnail to cabinet sizes were available, with yellow-green to apple-green crystals up to 1 cm in size. Some of the specimens resemble pyromorphite from Spain, whereas others look like Bunker Hill mine, Idaho, specimens or old-time North Carolina pieces. Danny Trinchillo also came up with a flat of exceptionally fine examples. Prices, however, were not for the faint-hearted.

The Rocksmiths had some amethyst scepters from Andilamena, Madagascar. Imagine a 2.5-cm crystal (like those from North Carolina) perched on a stem of Arkansas-like quartz. I thought these were the sleepers of the show, as many folks seemed to be in a pyromorphite-induced stupor (which is understandable).

Coisas Preciosas of Newark, Delaware, had specimens of **silver** from Cobalt, Ontario. Most are matrix miniatures with flattened silver leaves, although I saw several specimens with distinct wires on matrix that could easily have been mistaken for Kongsberg specimens.

Next year's show will focus on children and young collectors, with many exhibits and features designed for the young folks.

Bologna Show 2000 by Jeff Scovil

[March 10–12]

Escaping the heat of a Phoenix summer to attend a mineral show is something anyone can understand. But to leave in early March when the desert is blooming and the weather is gorgeous—what could make an otherwise sane mineral photographer do that? The answer is the 31st Bologna (Italy) Mineral and Fossil Show. Many consider it to be the finest show in all of Italy, and with 240 dealers from around the world, it is also good-sized.

The show takes up five halls of the Palazzio dei Congressi, a large complex in northern Bologna. I was quite impressed with its organization and the quality of the dealers. The focus is on minerals and fossils, with cut stones allowed but no jewelry. Dinosaurs are as popular in Italy as in the rest of the world, so there were two life-size dinosaur replicas in one of the halls. And I found that gold panning is not just an American phenomenon; the show had hands-on demonstrations available for young and old alike.

And what would a mineral show be without exhibits? One hall was entirely devoted to exhibits, most of which came from the Regional Museum of Natural Science in Turin. I am always amazed at the wealth of minerals from European localities that we seldom get to see here in the United States. From Italy there were some real eye-openers on display, such as 7-cm scheelites, chlorite crystals to 9 cm, and dolomite twins to 10 cm, all from Traversella; gold from Brusson, Val d'Aosta; plates of albite to 35 cm across with 4-cm crystals from Val Varaita, Piemonte; and cuboctahedral galenas to 3 cm and pyrite octahedra to 4 cm on magnetite in specimens to 45 cm from Brosso. Of course there were the Baveno-twinned, pink orthoclase crystals from Baveno, Piemonte, and the famous grossular garnets to 2 cm across with diopside from Val d'Ala, Piemonte. There were also several fine cases of fossils from the Museum of Paleontology, University of Bologna.

Unfortunately, there was little that was truly new in the way of minerals, what with the show following so closely on the heels of Tucson. *Laplandia Minerals* had been busy during August of 1997 collecting on the Khibiny Massif, Kola Peninsula, Russia. There

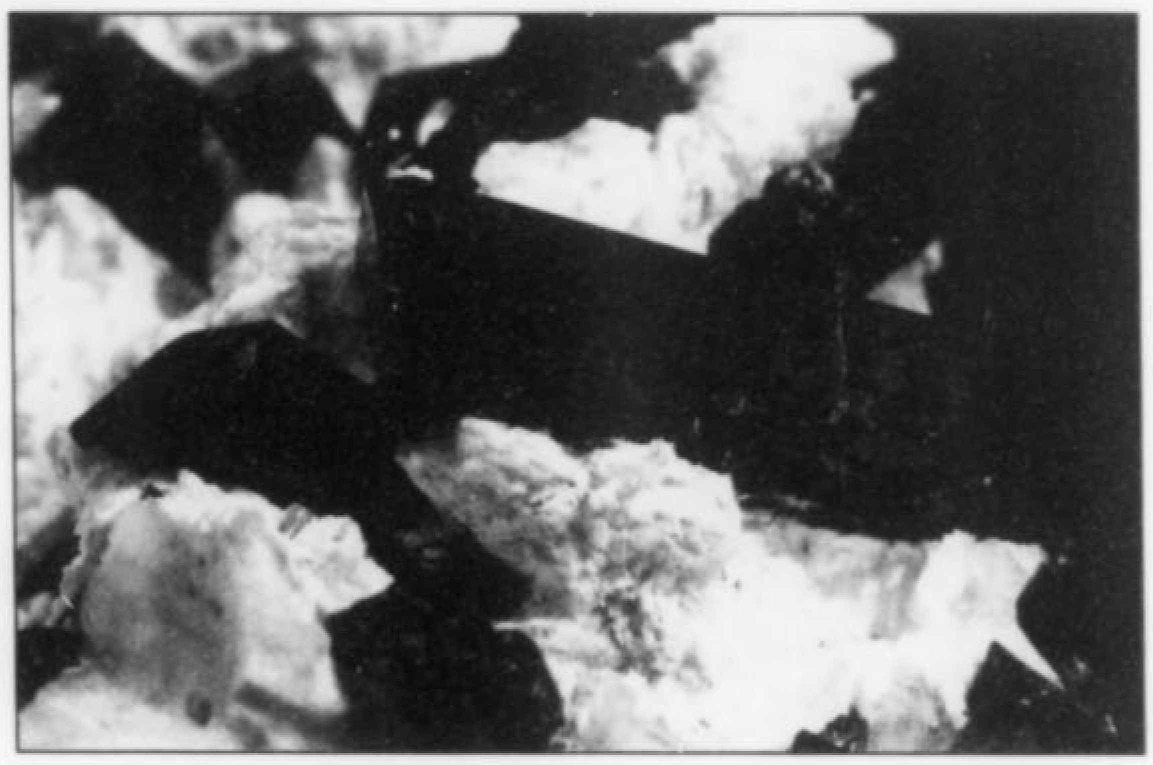


Figure 2. **Mangan-neptunite crystals to 2 cm, from the Khibiny massif, Kola Peninsula, Russia. Laplandia Minerals specimen; Jeff Scovil photo.**

they found some superb **mangan-neptunite** crystals to over 2 cm long. The Italians are heavily connected with mining in Madagascar and so numerous large and fine crystals of **rhodizite** were available, especially from Lino Caserini, and **liddicoatites** (some on matrix) from Enio Prato. A recent find was made of wonderful **anatase** and gorgeous **brookites** from Monte Bregaceto, Genova, Italy, with the bright orange brookite crystals up to 1.6 cm long.

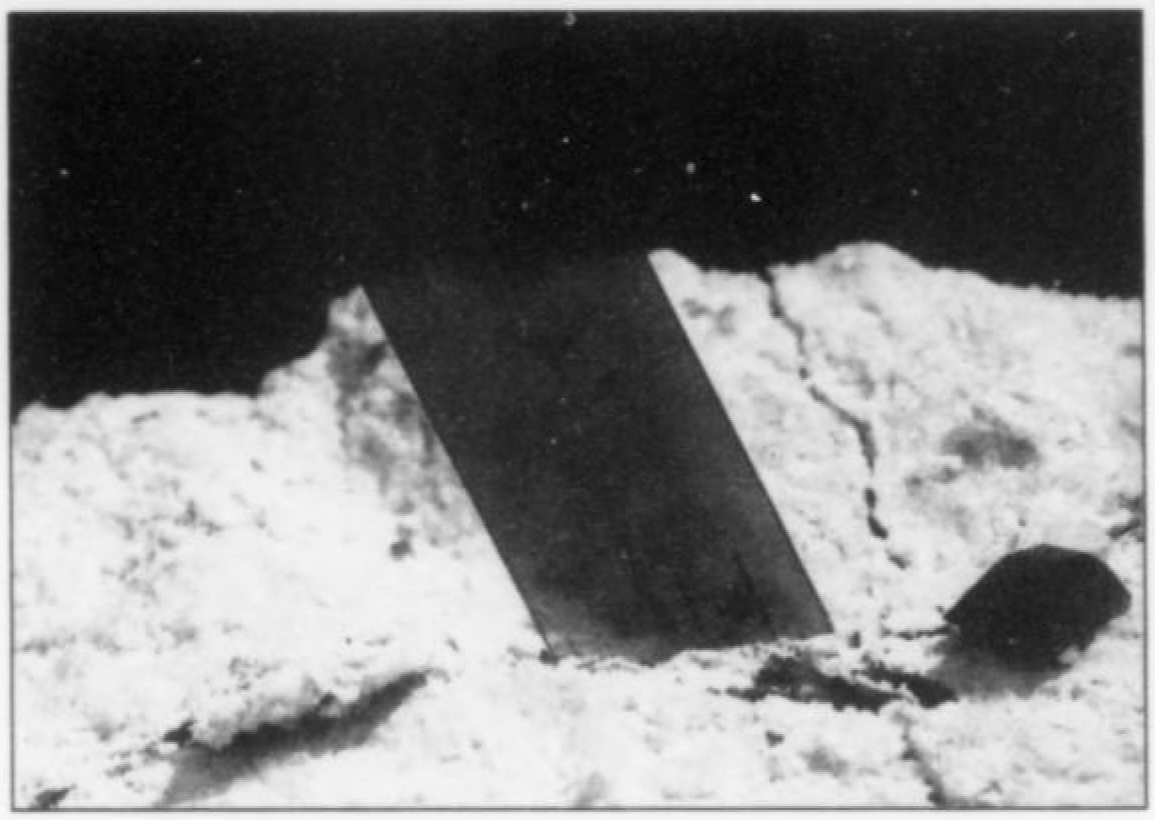


Figure 3. **Brookite (1.6 cm) with anatase, from Monte Bregaceto, Genova, Italy. Pregi Gemme specimen; Jeff Scovil photo.**

These were available from *Pregi Gemme*. Franco Granai operates one of the famous marble quarries in Carrara, Italy, and had a nice selection of the minerals from there including herkimer-like **quartz**, **sulfur**, **dolomite** and **wurtzite**.

Besides minerals, Italy is known for its food. Every night was a gastronomic adventure, whether it was a local restaurant or the party put on by the show organizers. I quickly realized that anything resembling a diet would be impossible on the trip, so I went with the flow. Just when you thought the meal was over (with your tablemates insisting you have seconds on everything), another course would be placed on the table. I spent another week touristing in Tuscany after the show, and it might safely be said that I ate my way across the country.

In closing, I must note that my final stop was in Milan. Besides seeing the newly restored, famous fresco by Leonardo da Vinci, *The Last Supper*, I spent some time at the Civic Museum of Natural History in Milan. Our gracious hosts were curator Frederico Pezzota and assistant curator Alesandro Guastoni. In their short tenure, these two have done a marvelous job of redoing the exhibits, and updating them with the finest minerals in the Museum's collection. The cases are modern and well-lighted with not just classic Italian specimens, but also fine minerals from around the world. The rest of the museum is impressive too, with a very strong showing in paleontology. When in Milan, the Museum is a must-see.

Spring Shows 2000 by Jeff Scovil

For me, the spring show schedule starts with the Rochester Mineralogical Symposium. While not actually a show, it does have a number of fine dealers who often come up with new things. The Symposium was held April 13–16 and boasted 41 dealers all on one floor of the hotel. Dudley Blauwet of *Mountain Minerals International* had been tramping about Pakistan, India and Sri Lanka as usual. From the one locality of Kollona, Embrilipitiya, Uva Province, Sri Lanka, he had several interesting items. The first were sharp, black, slightly modified octahedra of **spinel** in a calcite matrix. The crystals are up to about 5 cm across, but the smaller ones are generally sharper. A well-crystallized associated mineral is **forsterite** in very tabular, clean, dark green crystals that reach sizes of 6 or 7 cm. To round out this locality collection, he had nice tabular **pargasites** of a dark greenish black color that could be over 8 cm across.

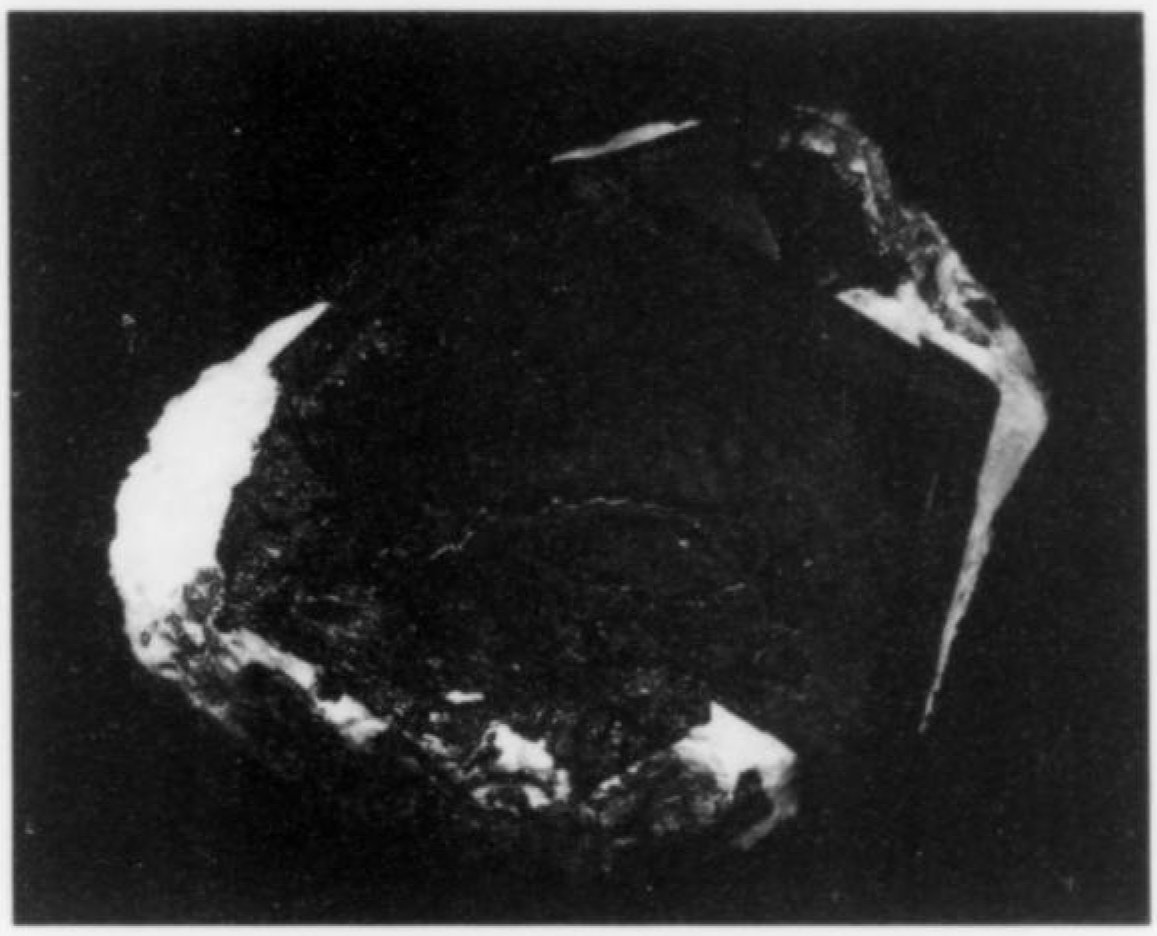


Figure 4. **Pargasite crystal, 8.4 cm, from Kollona, Embrilipitiya, Sri Lanka. Mountain Minerals International specimen; Jeff Scovil photo.**

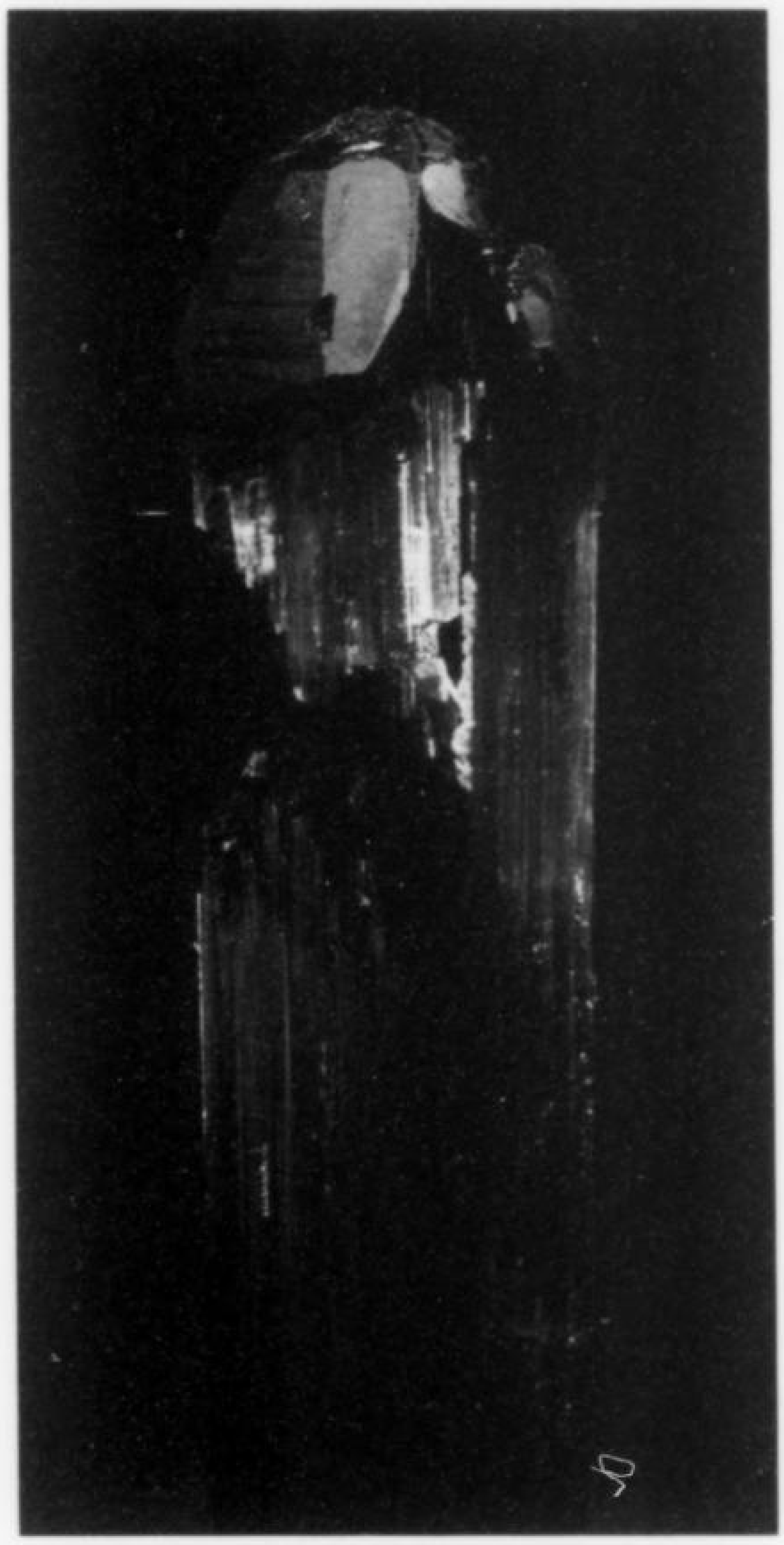


Figure 5. **Elbaite, 2.5 cm wide, from the Mutuca mine, Minas Gerais, Brazil. Hawthorneden specimen; Jeff Scovil photo.**

The Melansons (*Hawthorneden*) divide their time between eastern Europe and Brazil when it comes to buying trips. Recently there have been some very nice, primarily green **elbaites** to come out of the Mutuca mine, Santa Rosa Malacacheta, Minas Gerais, Brazil. This is the same property that hosts the famous Santa Rosa mine. Frank managed to buy up the "weirdos" of the recent find—elbaites to over 20 cm long, that are etched in strange ways just shy of the termination.

Chris Tucker always manages to come up with interesting minerals from a state that doesn't seem to be high on most collectors' hit parade list—Montana. The Southwest does not have an exclusive on **vanadinite** and wulfenite any more. The former comes as bright red micro crystals from near Johnny Gulch, Broadwater County, Montana, up to 1 mm across. From Lone Mountain in the same county, Chris had **wulfenites** with crystals up to 5 mm. Neither of those sound very big, but they are nice, and whoever heard of them coming from Montana?

Jonathan Levinger hails from Montreal and was selling some nice groups of pale yellow "dogtooth" **calcite** from the LAB mine, Black Lake, Quebec. They are associated with what looks like stilbite but has yet to be tested. Just a bit to the southwest in Felch, Dickinson County, Michigan, New Mexico expatriate Ray DeMark found some pretty nice cockscomb **marcasite** associated with octahedral pyrite microcrystals in a road cut.

Figure 6. **Marcasite, 1.7 cm across, from Felch, Dickinson County, Michigan. Ray DeMark specimen; Jeff Scovil photo.**

The next weekend (April 21–23) this wandering photographer was at the *Spring Show in the Rockies*. It is held at the same Holiday Inn in Denver as Marty Zinn's fall show, and across the street at what is now a Best Western. The only thing I saw there that was new (to me) was a batch of **morganite** from Alto Ligonha, Mozambique, being sold by Beau Gordon of *Jendon Minerals*. The etched crystals had been recently mined and are fairly gemmy with a pleasing peach color. Beau had about a half dozen of them. I finally had an opportunity to photograph some of the **marcasite** "worms" that have been coming out of the Da Chang ming, Guang Xi, China. Jim McEwen of *Lehigh Minerals* had a nice selection of these glittery, snaky things at very reasonable prices. For the pseudomorph aficionados, Jim also was selling some very nice, sharp, black **tennantite after enargite** from the Julcani mine, Angaraes Province, Huancavelica, Peru. I believe that these first turned up at the last Tucson Show.

May 13 to 14 found me in Cincinnati for the fine show there. The show had moved from the Cincinnati Gardens, where it has been held for some years, back to its old home downtown at the Cincinnati Convention Center. The facility is a much nicer venue but with the disadvantage you have to pay for parking. One plus, though, is that if you do not like the food at the concessions, you have lots of restaurants to choose from within a short distance. This show was much better than usual for new things or just better older things. The beat-up Chinese **pyromorphite** I had first seen a year earlier at the St. Marie-aux-Mine show has improved dramatically. A number of dealers had specimens but the best were to be found in the booth of *Dave Bunk Minerals*. The color is a beautiful grass-green and they are no longer beat-up. The locality is given as Gulin, Guangjshi, China. Dan Weinrich had not the largest, but probably the best that I have seen to date. Dave Bunk also had the best **halite** I have seen yet, associated with the attractive amber-colored **gypsum** crystals from Las Salinas, Paracas, Pisco, Ica Department, Peru. The piece is 10.1 cm high and actually worth having for the halite itself instead of the attached selenite crystals (though they did add to its aesthetics).

For really new things, *Jeff & Gloria's Minerals* took the prize. Just before leaving for the show, they had received a new shipment from Dal'negorsk. The hottest specimens were the stalactitic, pale green **"beta" quartz** from the Second Sovietskiy mine. The stalactites are up to 17 cm long and looked as if they had been delicately glued together from loose, doubly terminated crystals, with the last few at the tip being nearly colorless and opalescent. There were also a few plates with individual crystals to nearly 8 cm across. Most of these pieces were snapped up quickly, and a number of collectors went home with empty, wringing hands. Evidently from the same pocket, were **ilvaite** crystals with divergent terminations, occasionally with attached pale green quartz crystals. Also from the Second Sovietskiy were oddly flattened, elongated **sphalerites** partially coated with drusy quartz and calcite. The real oddballs were the brilliant apple-green **cuprian adamite** hemispheres on a gossan matrix from the Verchniy mine at Dal'negorsk. Supposedly, some miners went into some of the old, upper workings to collect them. You may recall that at the 1998 Tucson Show, Jeff and Gloria had a lot of superb orange quartz crystals from the Second Sovietskiy mine that sold quickly. Since then there has only been a trickle of them and of not nearly as good quality. There were several specimens of this **orange quartz** in this new shipment but with the difference that the tips of the crystals are white, making for very attractive specimens.

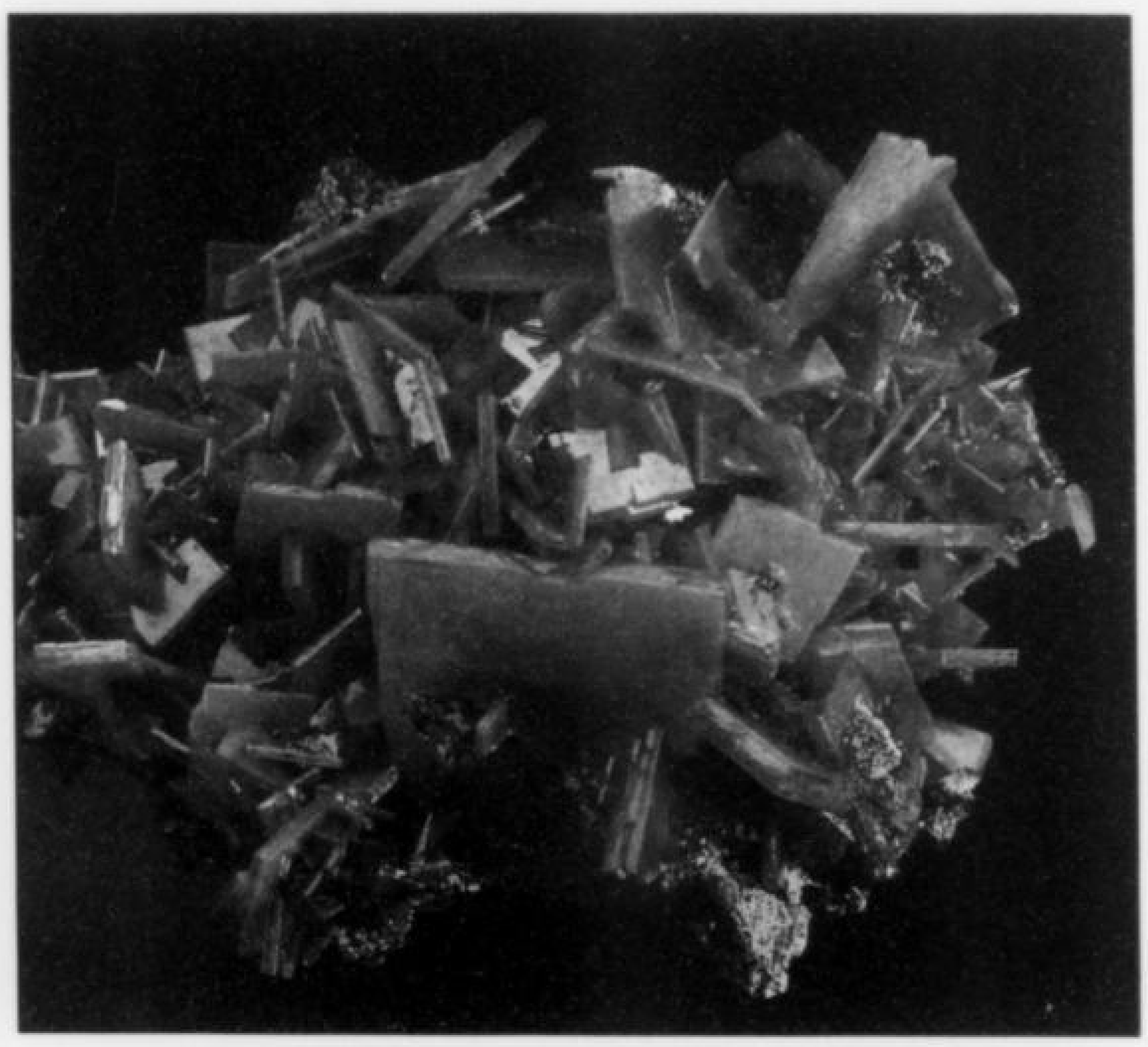


Figure 7. **Wulfenite crystals to 2.1 cm, from the La Aurora mine, Cuchillo Parado, Chihuahua, Mexico. Blue Sky Mining specimen; Jeff Scovil photo.**

My final stop on the Spring Rock Tour was Costa Mesa, California, from May 19 to 21. Ken Gochenour had relocated an old **corundum** locality in the San Jacinto Mountains, Riverside County, California. Preparation of these extremely elongated, pale blue crystals is a bear, as they are locked in a hard gneiss. Most were on matrix and up to 20 cm long. The La Aurora mine, Cuchillo Parado, Coyama, Chihuahua, Mexico, continues to produce better and better **wulfenite**. The crystals, which could easily be mistaken for Los Lamentos, are being sold by Dan Belcher of *Blue Sky Mining* in a variety of sizes. Dan was also one of two dealers (the other being *Great Basin Minerals*) selling the delicate **wire gold** that has recently been coming from the 6030 level, 813 Pit, Olinghouse mine, Washoe County, Nevada. They range from individual, rather long wires to masses that look like gold pseudomorphs after a steel wool pad.

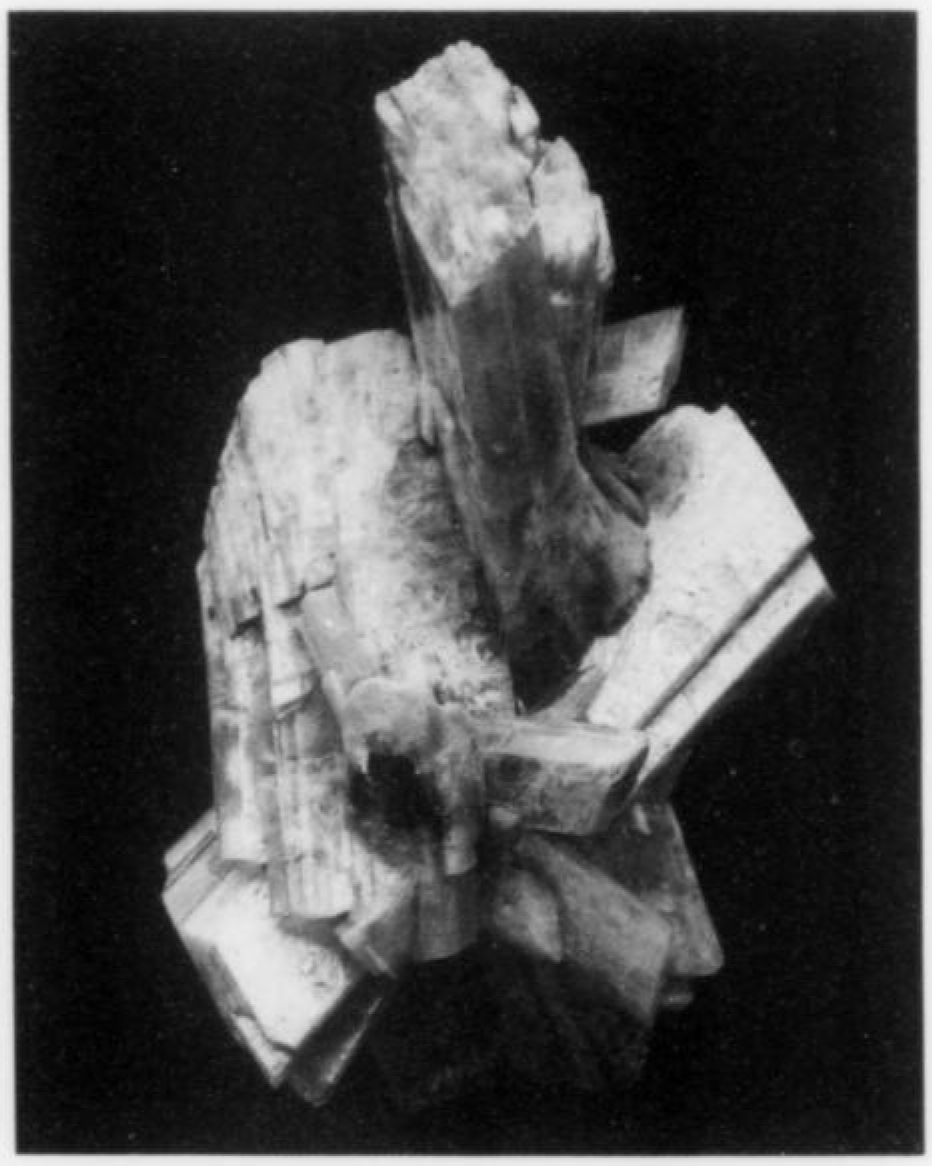
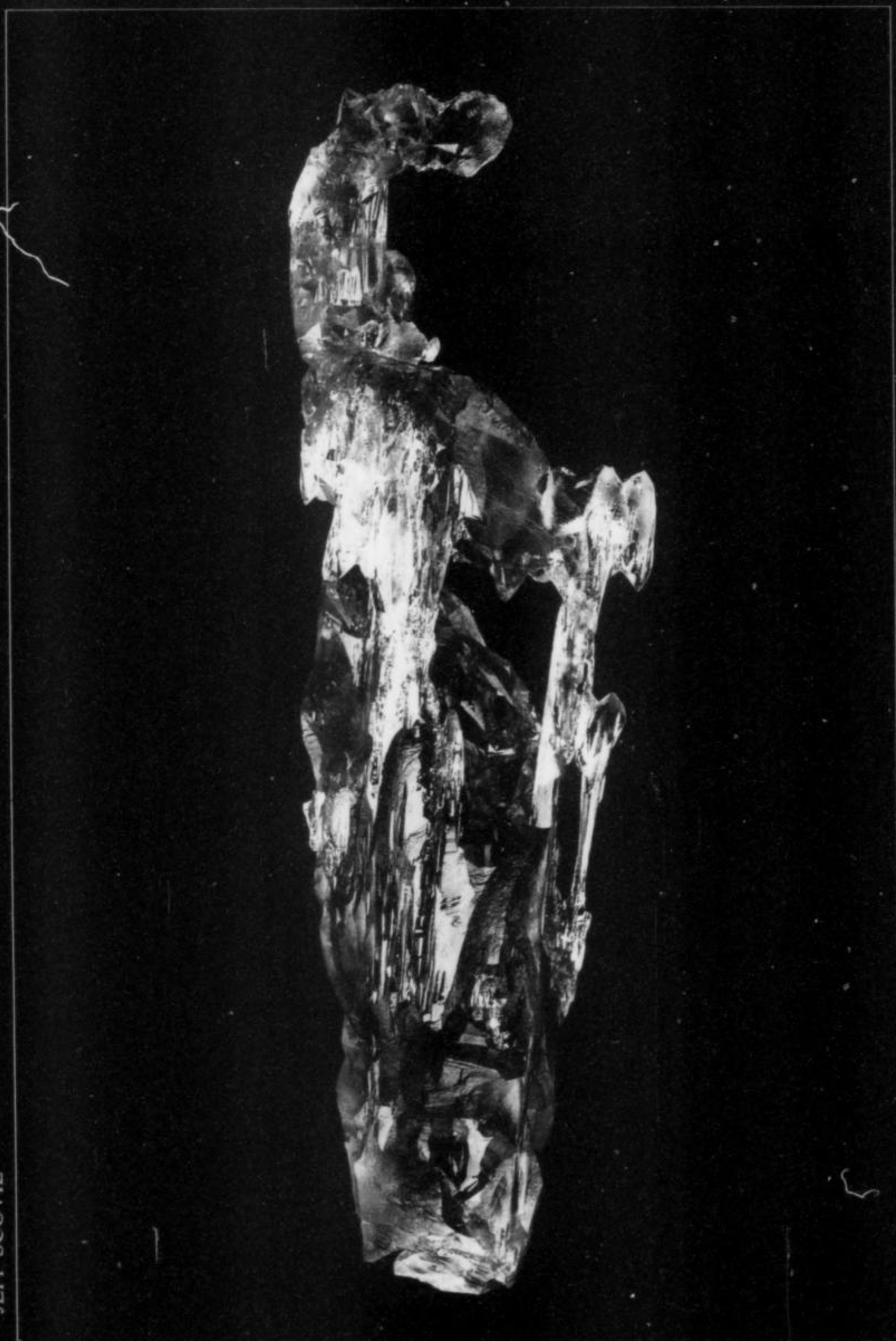


Figure 8. **Paravauxite, 3.7 cm, from the Siglo Veinte mine, Llallagua, Bolivia. Alfredo Petrov specimen; Jeff Scovil photo.**

There was a recent find of rather large (for the species) crystals of **paravauxite** from the Siglo Veinte mine, Llallagua, Bolivia. The crystals up to 2 cm long were being sold by, who else—Alfredo Petrov. The Murray mine, Elko County, Nevada, continues to produce fine **stibnite** and some very fine, blocky, white **barite** crystals with a sugar frosting of drusy quartz on a dark gray, brecciated matrix. Many of these very attractive specimens came out of the Sugar Bowl Pocket, Zone 4, Level 175, Drift 13 and are being offered by *Geoprime*. Last, but not least, I saw some superb **calcite** from Nan Jing, Hunan, China, in the possession of Irv Brown and Stuart Wilensky. The hexagonal prisms terminated by a low rhombohedron look for all the world like the finest to come out from Cumbria, England, but with even brighter luster and clarity.

I decided to skip France this year and try to catch up on a little work at home as well as attend a high school reunion. I am not sure if it was worth the trade-off, but I had a good time. That's it for the spring line-up; see you at the next show!


JEFF SCOVIL

"The Ice Dragon" Aquamarine, Minas Gerais, Brazil, 22.5 cm. Acq..1999.

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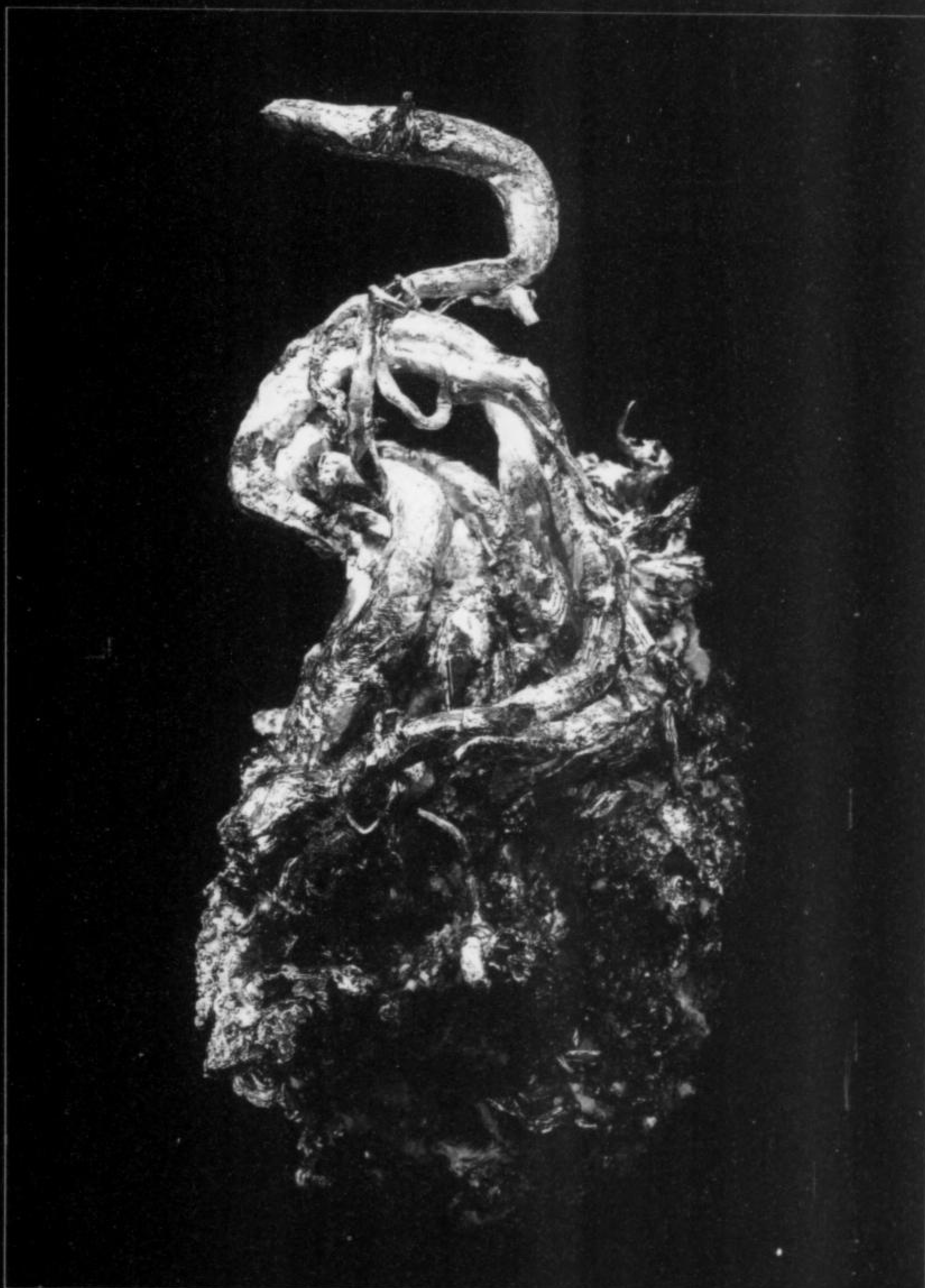
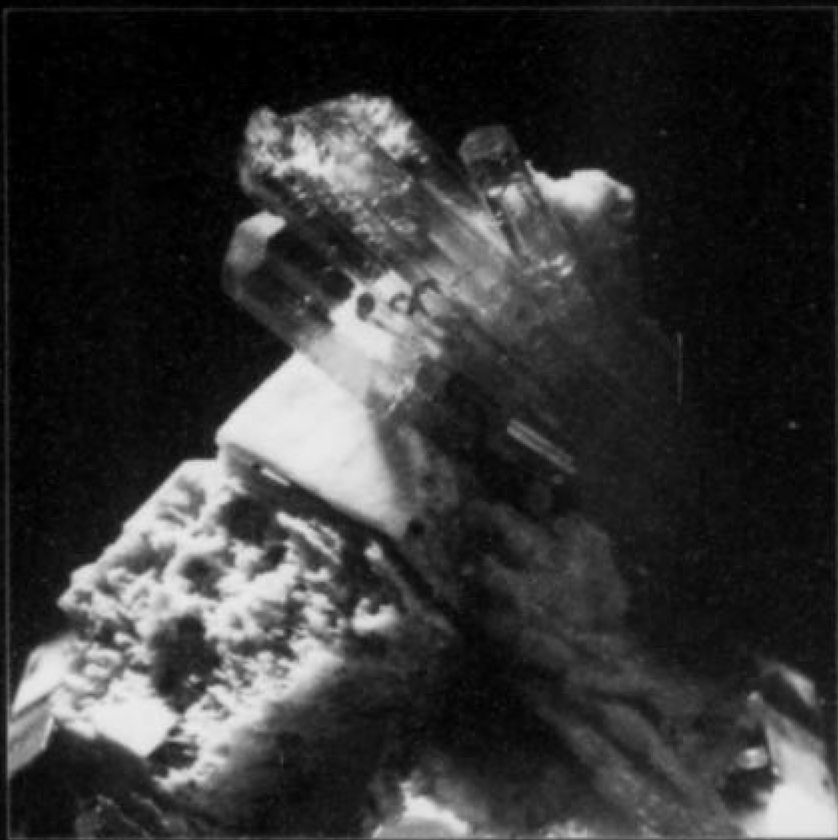
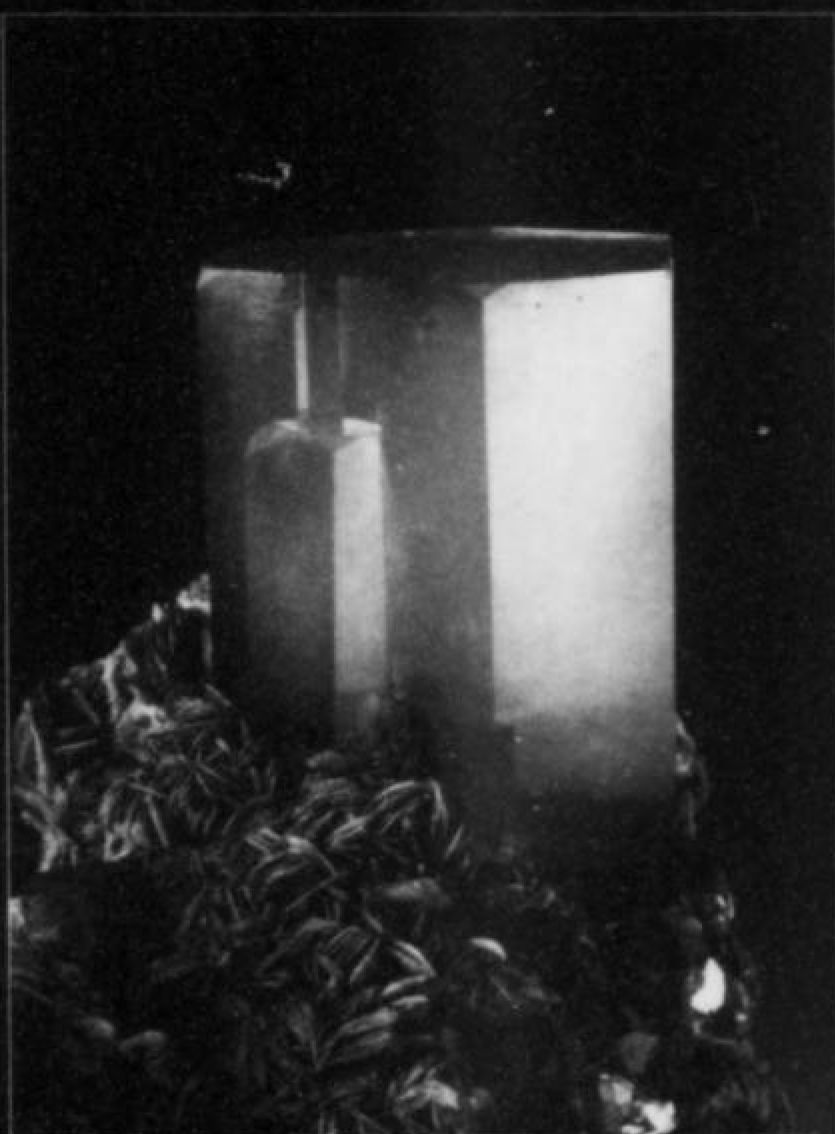
Ken Roberts-Acquisitions

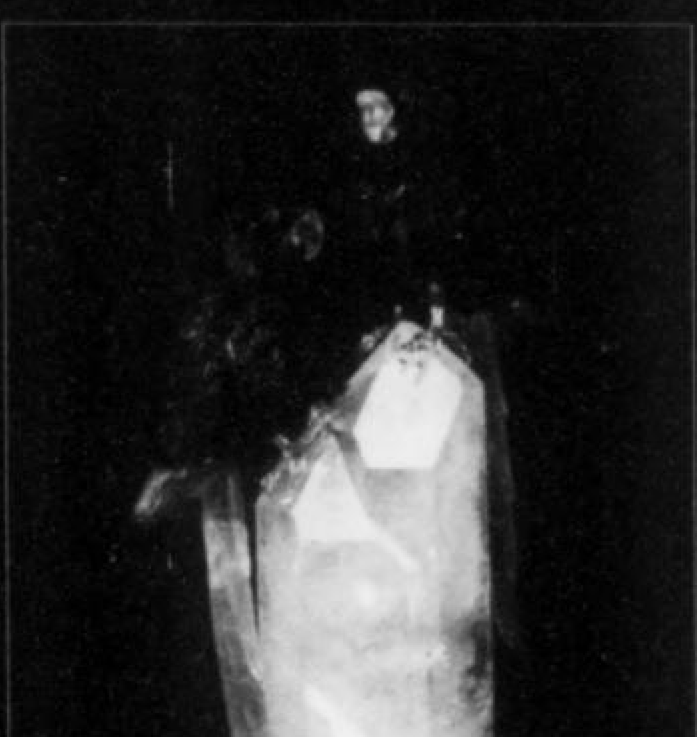
ken@collectorsedge.com

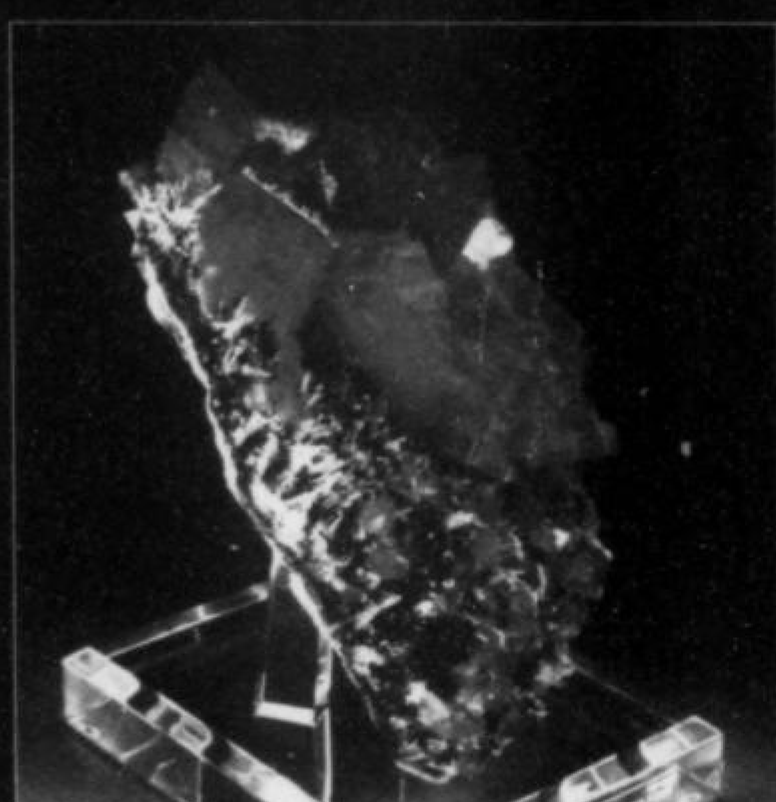


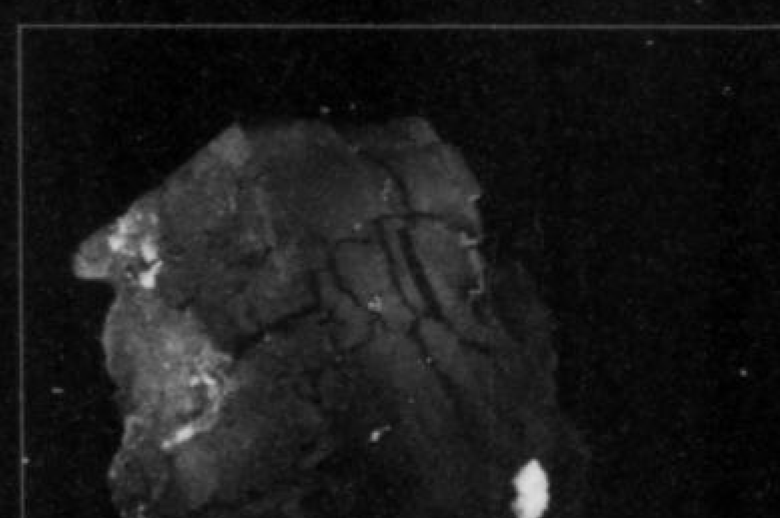
Silver, 15 cm, Kongsberg, Norway. Acq. 1999

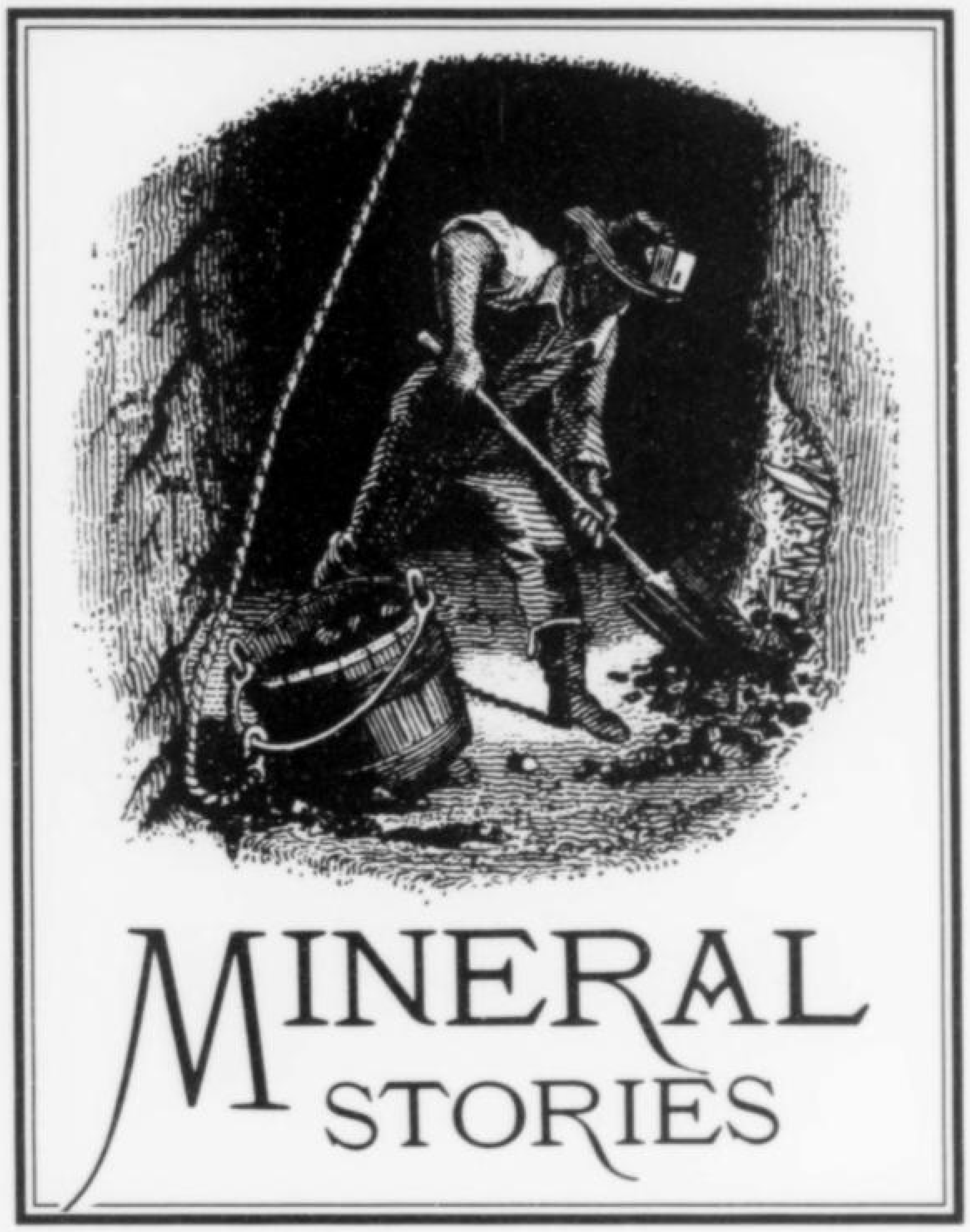









BARITE on FLUORITE
Elmwood Mine
Smith Co., Tennessee



A Language Lesson — by Tom Moore

This story is a cautionary tale concerning the snares and pitfalls of dealing in languages not one's own.

Some decades ago, at a time when my wife and I were just starting to set up shop as American expatriates in Germany, we set off one fine spring weekend to check out one of the German mineral shows. This was, in fact, the first mineral show of any kind to which I had taken (dragged) my wife. She knew almost no German then, and I knew only what I had picked up during 15 months as a G.I. ordering *ein Bier, bitte*, and perhaps also *noch ein* ("one more"). Still I felt fairly confident as I cruised through the show, chatting expertly (as I thought) with German dealers here and there.

At one dealer's stand we came across a batch of new specimens of the beautiful Turkish kämmererite (chromian clinochlore) which had just arrived on the European scene. It took only one fast eyestroke over the lot to locate "my" matrix thumbnail; a sharp, gemmy, 1.5-cm twinned crystal garlanded by smaller crystals. To my surprise, the price was within reason for my modest budget. And I found it endearing that the specimen's label (in addition to giving species and locality) proclaimed it to be "*UNBEDINGT SCHÖN!*" in large red letters. I knew, of course, that "*schön*" meant "beautiful." When my wife asked me what "*unbedingt*" meant, my imagination derived the obvious cognate: "undinged!" You know, no little *bedings* anywhere whatsoever on this specimen here. The phrase, therefore, clearly meant "undamaged and beautiful!"

Being under a little time pressure at that point, and trusting the dealer, I purchased the specimen then and there without examining it any more closely. For the rest of the show I enjoyed its presence in its little box in my pocket, affirming my good taste and wise on-the-spot decision-making.

At home that night I laid out my spoils from the show on my desktop. There, under the light of the desk lamp, an examination of the kämmererite with a hand lens revealed *numerous dings* on the small crystals surrounding the main big one. Some were cleaved off near the tip (so common with kämmererite) or disfigured by tiny white micaceous bruises. None of the minor damage was "fatal," and would not be noticed at all by the casual onlooker (e.g., me, earlier!) But now my glum puritanical eye could not help returning endlessly to the little wounds.

Right away I was angry, and felt betrayed by the dealer. The little specimen was not *unbedingt* after all! At least I had the honesty to chastise myself for inadequately inspecting the specimen before buying it. But that didn't help me feel any better.

I can't say what made me open my dictionary at last, but I confess it was a full year before I did so, and finally learned that *unbedingt* simply means "absolutely" or "emphatically." During that year I had nurtured my resentment of that dealer, whose shop I had avoided and whose overtures at several later shows I had rejected. He was most puzzled when I finally, clumsily tried to apologize to him for a linguistic misunderstanding which I was too embarrassed about to describe specifically. From then on he surely must have viewed me as a decidedly odd American whom a civilized European could not hope to fathom.

Neal Yedlin always used to say, "Buy and use a good mineral book." And when venturing abroad, a good language dictionary wouldn't hurt either.

A Highgrader's Story — by Al Ordway

As a new student of geology at Pasadena City College in 1959, I had been recently introduced to the field of mineralogy. And of all the minerals we were studying, the most fascinating to me were the tourmalines.

On December 31, two of my three collecting partners were at my house preparing for a trip to a "new" tourmaline mine in San Diego County (at least it was new to us). The third partner had yet to arrive with our source of transportation. We had heard about the "highgrader" hole on top of a hill that led into the old workings of the Himalaya mine. This was our target for New Year's Eve. The culprits were McCready Bob Bartsch, myself and Mr. X (a local professor today). The object was to enter the area as discretely as possible, hike across a glen to the highgrader hole, then enjoy an evening of searching for scraps of tourmaline. Those plans already began to falter when McCready arrived in a WWII military truck that was painted bright red! Not only was this a visual standout, but it must have had several holes in the muffler (if it even had a muffler!)

Nonetheless, we headed to Mesa Grande and arrived in the early afternoon. We had ample time waiting for nightfall, so we decided to check out the Esmeralda mine, once known for dark tourmaline and excellent morganite. This meant having to cross what was then the Alvord Ranch with its many gates and "keep out" signs. The truck belched its way through several of these gates, and we were nearly to the mine before being confronted by a chap in cowboy attire standing high atop the hood of his jeep. The side of his face bulged from a big wad of chewing tobacco and he was salivating profusely. His double-holstered 44's and shotgun were quite ominous!

"Yew better git outta here or I'll blow yer haids off!" . . . spitooey! . . . After failing to convince him that we were emissaries from the Smithsonian, we were "cordially" escorted off of the property. With the closing of the last gate, we headed towards the Angel Ranch (across the valley from the Himalaya mine). We hid on a high knoll amid scrub oaks and waited for darkness. None of us had been in this area before so we were not exactly sure where the mine was located. Our biggest concern was the many guards we'd heard about. A successful caper depended on absolute silence! Essentially, we planned to "glide" to our objective.

At last it became dark . . . very, very dark! We walked along the Angel Ranch road, then cut off across the pasture towards Gem Hill. We unexpectedly encountered mud holes, barbed wire fences, dung piles and irritable cattle (I thought cows were supposed to be docile!). We still didn't know how close we were to our objective once we crossed the glen, so we separated into two groups to search for the mine. Mr. X and I went to the right and up the hill and the others went left and up.

After crawling a long distance through thick growths of manzanitas, tall grasses and thorny plants, Mr. X and I were almost to the summit of the hill. The excitement mounted, as we knew we were nearly there! We could smell the tourmalines! Then we heard voices! Someone was approaching directly towards us and getting very close! It *had* to be the guards! Feeling we'd been discovered, Mr. X and I vaulted from our hiding place and raced down the hill as fast as we could. We could hear the "guards" crashing through the brush close behind us! Mud holes, cattle, cow paddies and barbed wire fences were no longer obstacles. Barbed wire hurdles, mud hole broadjumps and cattle stampeding were the highlights of these pasture "Olympics." We never looked back until we stumbled onto the road. Here came Bartsch and McCready running hard right behind us! When the dust settled, all four of us stood there trembling and exhausted. We peered into the darkness . . . all was still. So where were the guards? Nowhere to be seen!

We discovered that each group had heard the other and had assumed they were the fabled sentinels. Dirty, cut and dejected, we began walking back to the truck. Suddenly, there was a roar of a vehicle approaching! We dove into a row of bushes to hide without realizing that they were growing on the rim of a small ravine. Expecting to land immediately on terra firma, we found ourselves airborne before tumbling down a slope as one mass of frightened humanity. I had someone's boot in my face and a prybar punching my derriere. Hearts throbbing, we huddled together waiting for the approaching vehicle to pass. The roar got louder and louder until it seemed to be directly overhead. In fact, it *was* directly overhead: it was an airplane! After blaming each other for the sudden panic, we gathered our hard hats and whatever else spilled out of our packs, got back to the red truck, cranked up the muffler and headed out of the area.

We stopped at a restaurant in Rincon where New Year's Eve activities were being held. It was about 30 minutes before midnight. The four of us entered the establishment in torn coveralls with mud and dung zones up to our knees. Somehow, we drew attention as the crowd became suddenly silent. We were escorted away from the patrons to a private area that had been closed. It was probably because of our appearance; however, we prefer to think that we were V.I.P.'s. We had a bite to eat, rang in the New Year with a toast, then headed out for the tourmaline mines at Pala. Surely, we couldn't get into any trouble there! But that's another story.

Forgotten Emeralds? **by Hilton Freed**

My favorite line is, "I usually don't find anything good," but this time it was different. I met Earl and Jack in King's Mountain, North Carolina. I'd heard stories about large spodumene crystals from the famous Foote mine in Cleveland County, but it wasn't until I bumped into a local collector at the Schiele Museum and Gastonia Rock Club Show that I heard about *emeralds* from King's Mountain. The old prospector (and they are always old) said, "Ask Earl to show you his emeralds."

"Emeralds?" I said.

"He found them up at Foote. On the dump."

My heart began to pound, and in short order I was climbing a steep embankment bordered by thorny vines which finally brought Earl and me to the dump. The old lithium mine itself has been closed to the public, and to further mining, but the dump is wide open.

Unfortunately, Earl had *forgotten* where he found the emeralds so many years before.

"Earl," I said, "that's hard to believe!"

"Sorry," he said. "It was a long time ago."

Then Jack showed up; he was a former mining engineer at the Foote mine, now retired. I mentioned Earl's emeralds to him, and Jack said *he* had found an emerald here too! I was momentarily excited but, wouldn't you know it, Jack couldn't remember where he found *his* either! Jack had had a mineral named after him, and that's prestigious; but there is still no excuse for forgetting where emeralds were found!

Totally frustrated, I went about my business looking for specimens. After an hour or two pounding rocks with my sledge I sat down to rest. I looked down, and there were emeralds! I was sitting on them! The sledge hammers flew, and in short order we had reduced that boulder down to four or five nice specimens of emerald in matrix to take home. And I will never forget where that boulder was!

Ultimate Standard of Mineral Value **by Lawrence H. Conklin**

In the middle 1970's one hat that I wore was that of consultant on the restoration of early American houses. It was an amateur hat, of course, but one of which I was quite proud. I had finished restoring my own house by then (see "Beardsley House" in my biography at my web site WWW.LHCONKLIN.COM) and had volunteered to oversee the restoration of the 1740 saltbox of my late friend Fred Gardner. One of the stonemasons on the job was called Balthazar, and he knew a lot about rocks as old-time masons often do. It was not long before he found out what it was I did in my day job and asked me if I would look at a bunch of specimens that he had collected.

I, of course, said yes and looked forward to the event.

It was not too long before I was looking over about 100 pounds of totally valueless rock and informing their owner as to their lack of value. Balthazar refused to accept my appraisal of his specimens and stated emphatically that "they *must* be valuable—you have no idea how hard I worked to get them."

Editor's Note: Everybody has a story they like to tell. If it has something to do with minerals, why not share it with other Mineralogical Record *readers? Just write it up (we'll help with the editing) and send it to* ***Lawrence H. Conklin****, 2 West 46th Street, New York, NY 10036, or* ***Wendell E. Wilson****, The Mineralogical Record, 4631 Paseo Tubutama, Tucson, AZ 85750.*

KLEMKE ERZGEWINNUNG

Letters

MOGUL MINE

Stephen Moreton's article on the Silvermines district, County Tipperary, Ireland (vol. 30, no. 2) was most interesting; I can add some facts about the occurrence of galena and other minerals at the Mogul mine.

In late 1978 I spent a very pleasant couple of days with Dick Barstow, looking through hundreds of specimens from the find. It was a memorable experience. The overwhelming majority of specimens were combinations of galena and sphalerite, with or without drusy iridescent pyrite. Although the fine-grained pyrite looked (and in some cases smelled) suspect, and although some galena crystals had white coatings around their contact with the matrix, it appears in retrospect to be less susceptible to "pyrite disease" than one might have expected.

The sphalerite specimens, reaching 15 cm or so across, consisted of plates of matrix thickly covered with transparent, honey-brown, brilliantly lustrous crystals. Examples bearing reasonably good bournonite crystals were rare, although small and corroded crystals were not uncommon in association with the other minerals.

But it was the galena that I had really come to see, and 22 years later the experience is still vivid in my memory. The specimens were even more spectacular than Moreton's description. Crystals, ranging up to 5 cm (2 inches) or so were as dazzlingly mirror-bright as the smaller crystals. The very finest specimens, of which there were only a few, consisted of single galena crystals disposed on a granular, ivory-white dolomite matrix. Dick kept them in a separate cupboard, and it was easy to see why. I wheedled, cajoled and begged for one, but was too far down in the pecking order. They were destined for Dick's personal collection, for the British Museum, and for a few special customers.

One aspect of the galena not mentioned in Moreton's text (but shown in Fig. 6) is the prevalence of spinel-law twinning. These twins are not as obvious as the flattened twins from Peru, Dalnegorsk and Bulgaria; Mogul mine galena twins are blocky, with only a hint of a re-entrant angle on the twin plane. A few rare examples, such as the one in Figure 6, do show a parallel growth accompanied by some flattening. Barstow had only a handful of such pieces. In my own examples the twinning is clearly delineated by an abrupt change in cleavage angle visible on broken faces. Spinel-law twinned galena is otherwise extremely rare from the British Isles, the exception being the famous Herodsfoot mine in Cornwall, where slightly flattened twins were found in association with bournonite. Corroded bournonite also accompanies the flattened spinel-law galena twins from Castrovirreyna, Peru (is the association significant, I wonder?).

The beautiful dodecahedral sphalerite shown by Moreton in Figure 10 reminds me of one such in Barstow's personal collection. (It may actually be the same one; it's an amazing piece.) Combinations of high-grade galena with high-grade sphalerite were surprisingly uncommon and unsurprisingly expensive!

Michael P. Cooper
Nottingham, England

STOLEN TOURMALINES

Someone broke into an exhibit case at Colby College, Waterville, Maine, and stole many of their finest tourmaline crystals from the Berry-Havey quarry in Poland, Maine. These are superb, terminated, gemmy, emerald-green crystals 2 to 4 inches long, recovered during the early days of mining at Berry-Havey. A large and choice watermelon tourmaline from Newry (another old-timer) was also taken.

Please watch for these specimens in the marketplace, and report suspicious offerings to Prof. Donald Allen, Geology Department, Colby College, ME (tel.: 207-872-3249; e-mail: dballen@colby.edu). Images of similar tourmalines may be seen at: http://www.colby.edu/geology/.

SWEET HOME HISTORY

We debated for probably too long to respond to a portion of the Sweet Home Mine issue written by Steve Voynick on page 20, paragraph 7. The negative reference to Roger and Norm Bennett is both highly offensive and inaccurate. ["In January 1977, Norm and Roger Bennett snowmobiled to the Sweet Home mine on New Year's Day for a bit of underground high-grading. . . ."] The only thing correct in his description of what transpired is the spelling of our names. A simple telephone call by Mr. Voynick to us would have resulted in an accurate description of how we were involved in a tiny part of this mine's history.

To set the record straight: Norm went to the mine in August 1976 with Mr. Beach. It was on this visit that Norm discovered a nice pocket of rhodochrosite. This pocket was shared with Mr. Beach even though he had initially told Norm he could keep anything he found. Norm and I, along with Mr. Beach, returned on a second trip to try to finish the pocket with Mr. Beach present. Without proper equipment, we were unable to get to the back of the pocket. For reasons known only to Mr. Beach, he did not want to bother with us returning with the necessary equipment to finish Norm's original pocket and splitting 50-50 with him on anything else found. The mine was to be leased the following spring, and we felt it was not right to give the remainder of Norm's pocket to the lessee, so we did not.

Roger and Norm Bennett
Denver and Golden, CO

BEDFORD GEODES

Last summer I revisited the Bedford, Indiana, geode locality (see vol. 22, no. 5, p. 351–354) for the first time in several years. Collecting can still be carried out in the I-37 roadcut. I found no millerite, but did collect some nicely shaped geodes with clear, sparkling quartz crystals. Several also contain nicely developed, pale yellow calcite crystals with rhombohedral terminations. Over the course of about two hours, I and two other collectors gathered 40 to 50 geodes, about a dozen of which are good, keeper display-pieces.

A note of caution: be sure to wear a hardhat at this locality. Although it is aboveground, the productive area of the outcrop has been mined back on the northbound side of the highway, creating a significant overhang. Late winter and early spring freezing and thawing may make the limestone unstable because of cracks opened along joint planes. This will, of course, also render the rock more easily mined by geode-seeking collectors, but do watch your head (this is experience speaking here!).

Rick Ley
West Chester, PA

THE LILY MINE

We have received a number of enquiries regarding the atacamite and gypsum locality (May–June issue cover) known as the Lily mine. Please let your readers know that they can contact us at the mine by fax (51-1-449-8492), e-mail (faro@amauta.rcp.net.pe) or through our website (mineralrt.com/mineperu) (click on the atacamite and selenite).

Felix Rocha
The Lily mine, Peru

NUMBERING SPECIMENS

How should one best number his mineral specimens? I tried to do mine by the Yale and Dana systems but got lost. I asked some curators and dealers, and they said they simply number them sequentially. I have been assigning an arbitrary number to the species (e.g., #184 = Beryl), and then a number for the variety (e.g., #2 = Aquamarine), and finally a sequential number for that variety (e.g., #7 being the 7th aquamarine acquired). So that piece would be #184.2.7. Is there a better system?

Alfred Charman
West Suffield, CT

That depends on how much work you want the number alone to do for you. These days, with computers that can sort huge lists according to any of several data fields, you don't really need to pack so much information into the catalog number.

Cataloging photos of minerals is like cataloging the specimens themselves. I give each of my photos a two-part number, such as 99-10, meaning that it is the tenth photo taken in 1999. So the number carries only date information. But in my computerized database I also give species, variety, locality (in reverse order, e.g., country first, then district, then mine name), owner and specimen size. I could also add a chemical designation (e.g., arsenates). The whole file can be sorted by any of those aspects, whenever desired. So if I suddenly want to see all of the oxalates or all of the Mozambique minerals or all of the microlites I can do so immediately, with a few keystrokes. Complicated numbering systems are really a relic of the years before personal computers. Ed.

THE POETRY OF DECAY

While metallics were never my forte,
I've heard rumblings that cause me dismay,
concerning the nature of sulfides
when near other minerals abide,
causing atoms to and fro to stray.

Is all of this rumor really true,
that sulfur atoms add themselves to
or remove other elements from
minerals in close addendum?
Please inform me what to do.

Can I place galena on display
where non-sulfur minerals do stay?
Will pyrite or any sulfide
cause other mineral atoms to collide
and thus bring forth mineral decay?

Cliff Vermont
Brielle, NJ

There once was a man from Dzhezkazgan
who bought all the marcasite that cash can.
But the acid emitted
left his calcites all pitted
Now he's thrown everything
in the trash can.

As any curator of an old collection has found, some sulfides do decompose in the drawer, giving off sulfuric acid vapor which attacks nearby specimens and especially paper labels. The worst offenders are marcasite and, to a lesser extent, pyrite, particularly if fine-grained and porous instead of in big lustrous crystals. But even galena will slowly react with the air, as shown by the gradual loss of bright luster over the years.

Ventilation is a useful deterrent to acid vapor damage. If storage is in drawers or closed boxes it's best to keep the marcasites and pyrites segregated. Most other common sulfides probably decompose too slowly to cause a problem. Ed.

ABOUT PHOTOMACROGRAPHY

The article on the crystal morphology of the sodalite family minerals in your March–April issue presented an opportunity for readers interested in photomacrography to think again about techniques. Dan Behnke has pioneered the use of the Olympus Zuiko macro lenses in the United States. Like most American photographers, Dan uses Tungsten films while mineral photographers in Europe often prefer daylight film with blue filters and exposure times up to ten seconds.

I use Olympus equipment too. Vibrations are no problem with long exposures provided that:

(1) The axis bearing the rack of the bellows is supported from beneath. Stacked wood blocks and cartons of variable thickness can do the job. The thinnest cartons of variable thickness can do the job. The thinnest cartons can provide a rough focusing, the final adjustment being achieved with the lens focusing ring.

(2) The nylon gliding channel attached to the central metal track is not damaged. This is very important as the channel can be fissured near its corners where nylon is the thinnest.

When the bellows are extended, there is little space in which to manipulate the fiber-optic tubes for adequate lighting. Though frowned upon by purists, some photomacrographers (including myself) often employ a Vivitar teleconverter. The results can be satisfactory with sufficient practice.

During the last few years, French photomacrographers have developed techniques which yield good results at very high magnifications. Their photographs appear regularly in the French magazine *Le Règne Minéral*.

Joseph Lhoest
Liege, Belgium

ALUM CAVE BLUFF

It has come to my attention that samples of the new rare earth minerals discovered at Alum Cave Bluff ("The Minerals of Alum Cave Bluff, Great Smoky Mountains, Tennessee" by T. D. Coskren and R. J. Lauf, vol. 31, no. 2) have recently been offered for sale by at least one mineral dealer. I wish to remind readers that any materials collected within a National Park are property of the U.S. Government *in perpetuity*. In a case like this they are regarded as stolen property and would be subject to confiscation. I also wish to state for the record that neither I nor any member of the staff of Oak Ridge National Laboratory was the source of the Alum Cave Materials now in commercial channels.

R. J. Lauf
Oak Ridge National Laboratory

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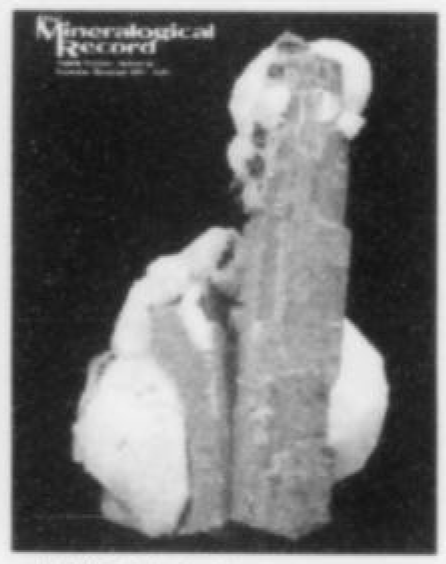

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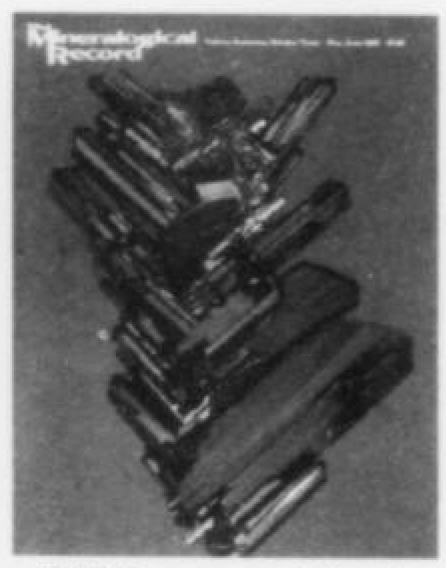

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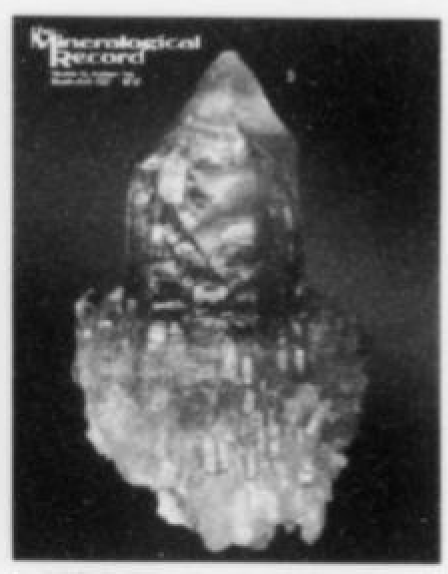

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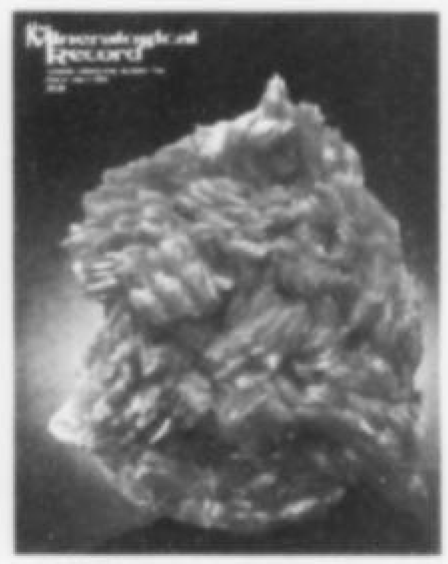

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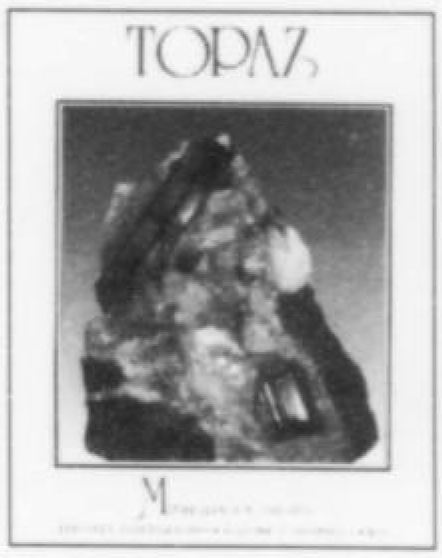

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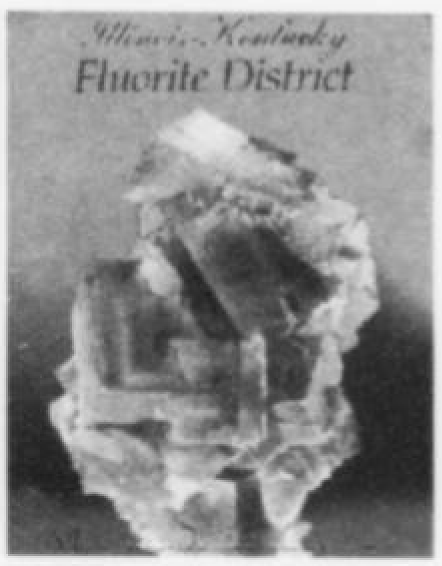

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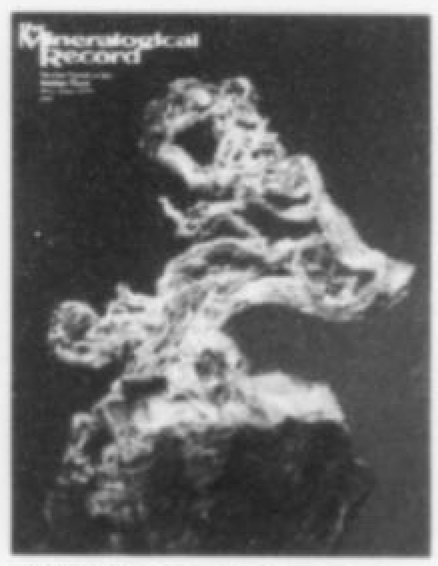

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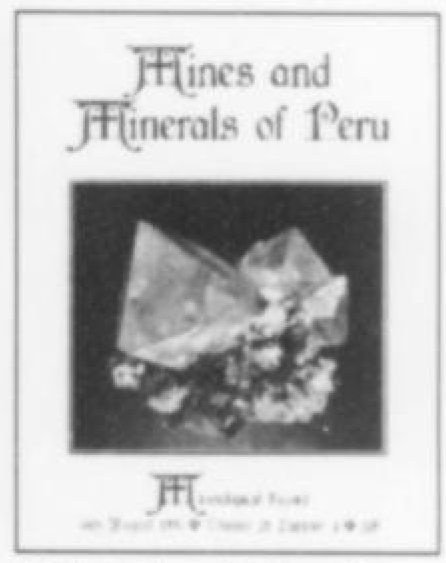

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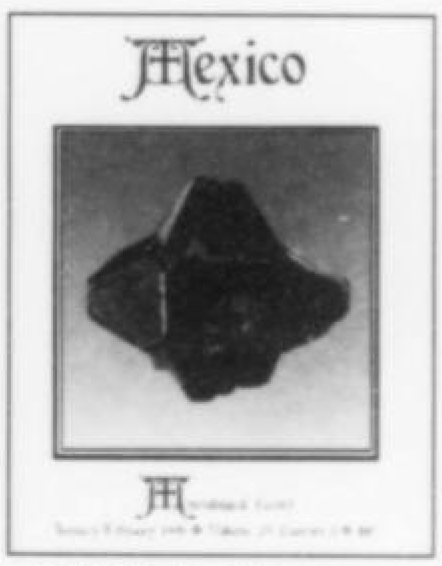

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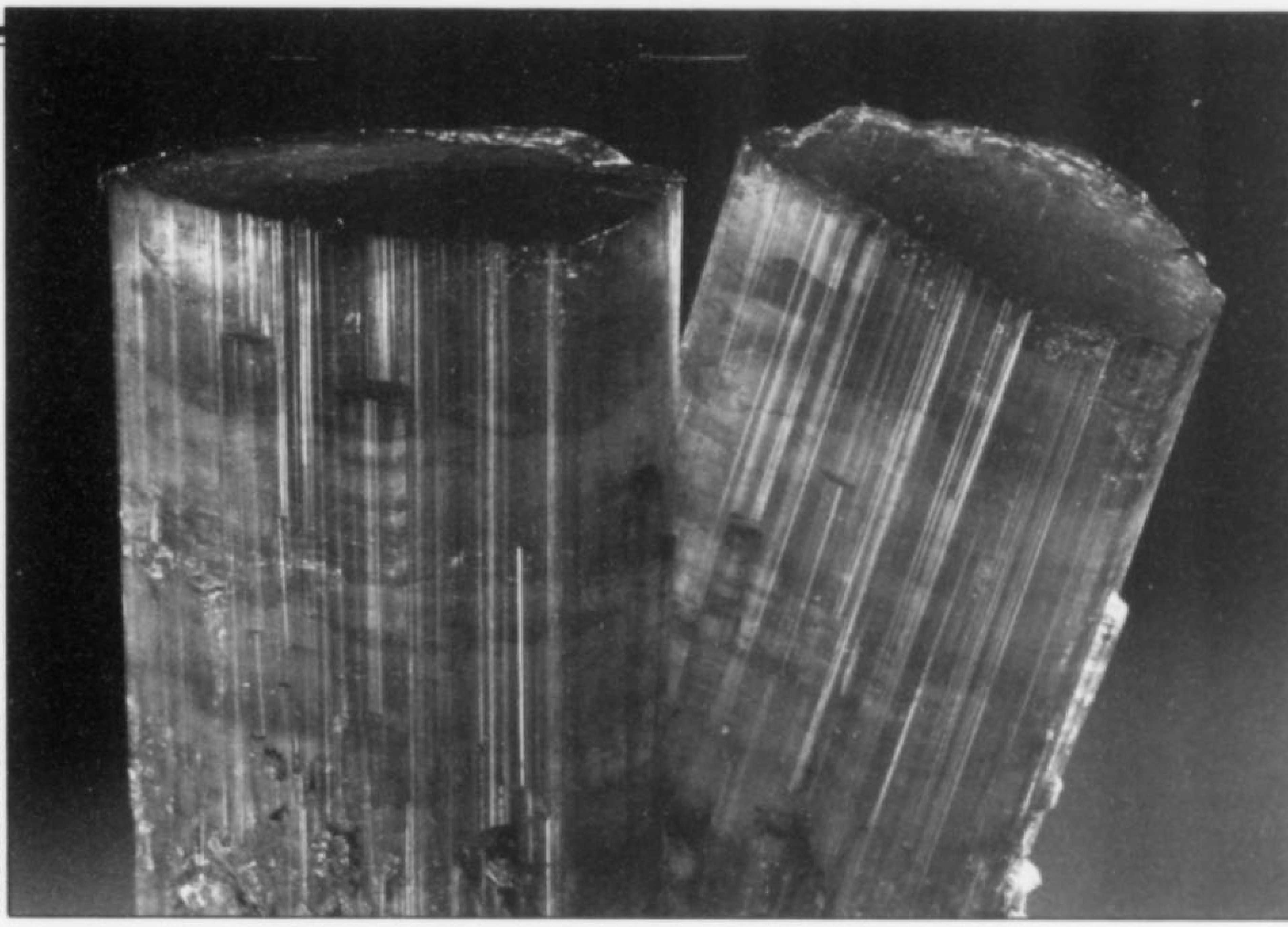

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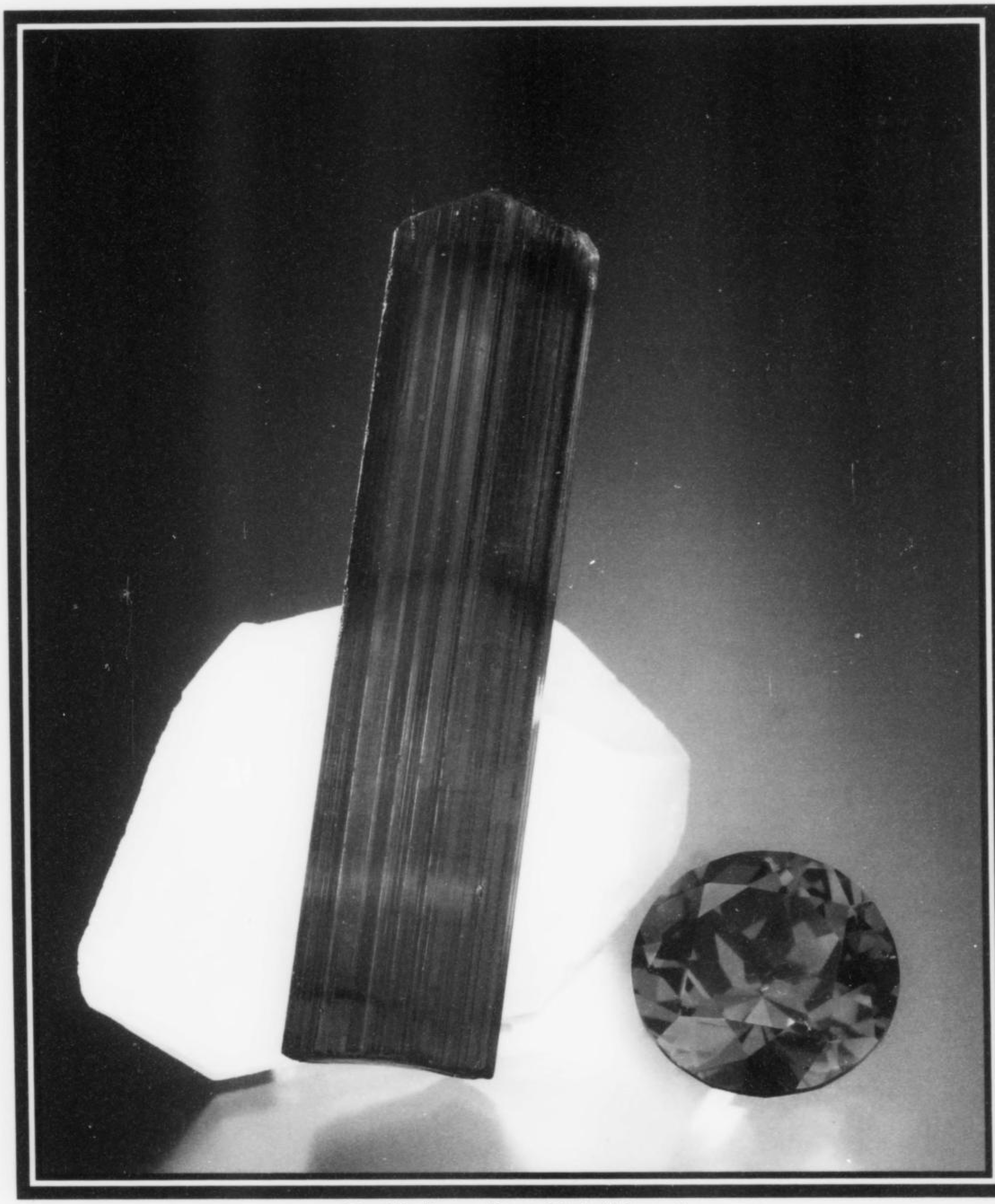

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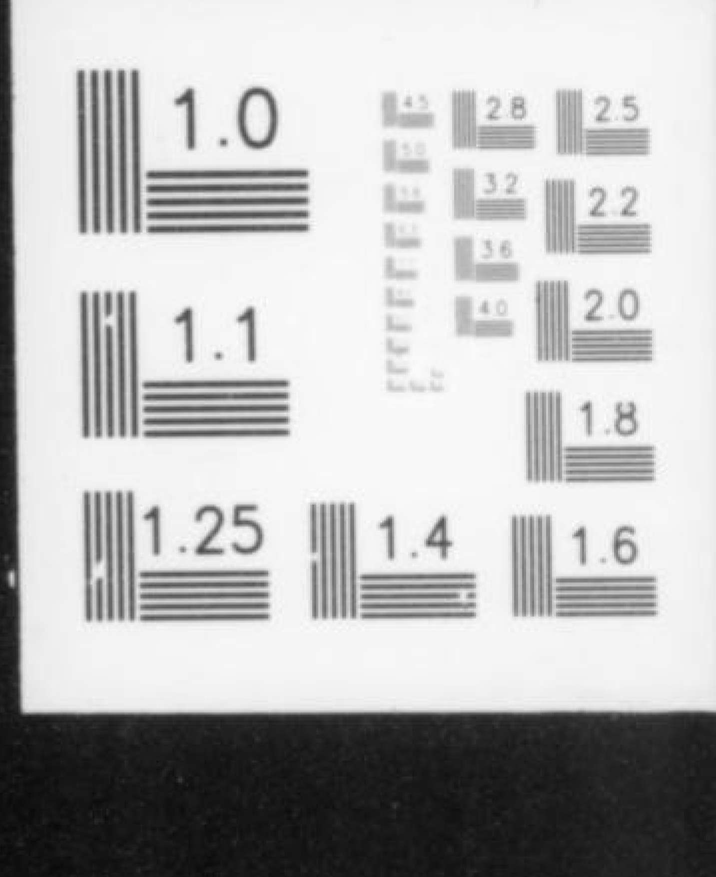
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