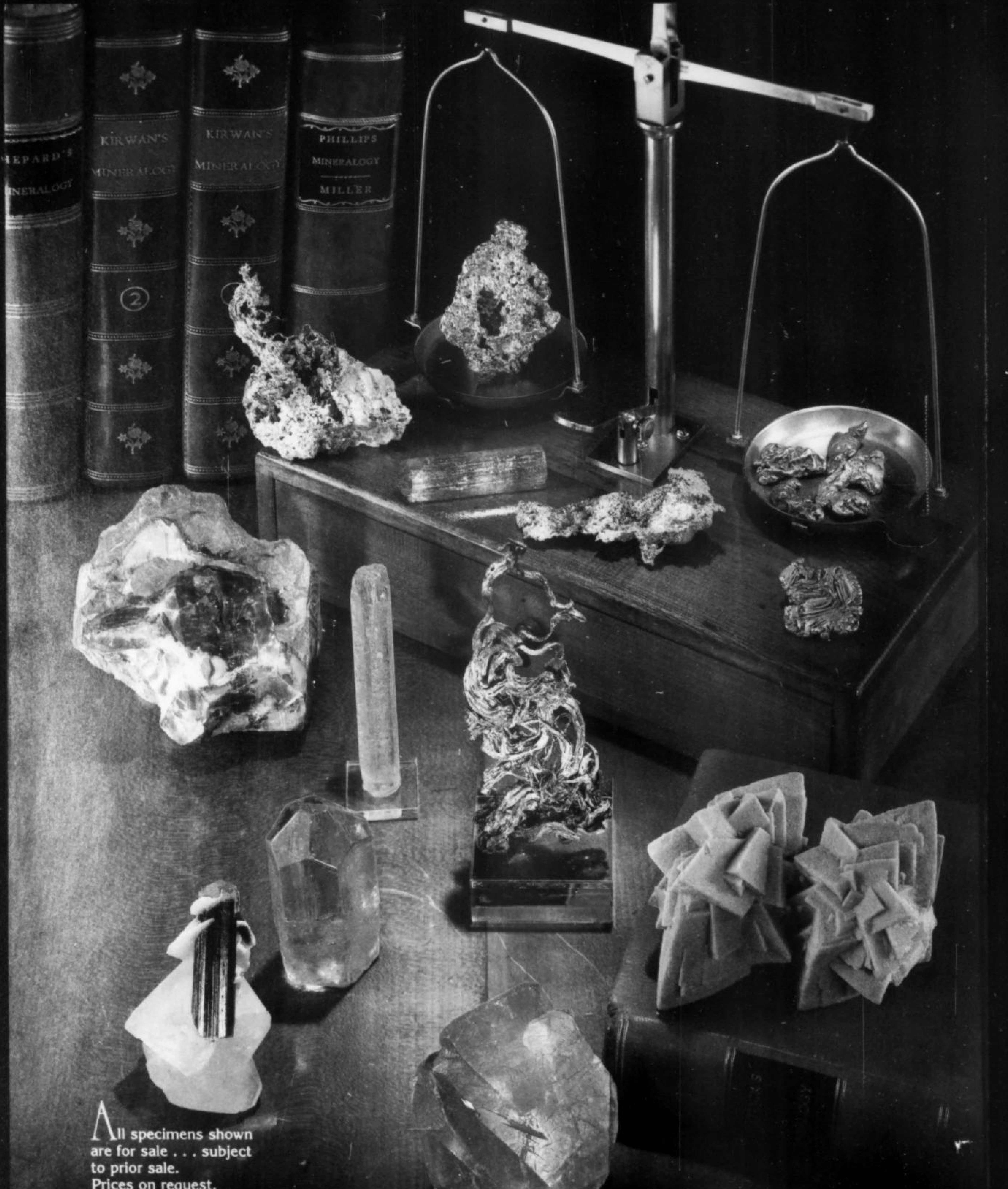
the
Mineralogical
Record

Volume Fifteen, Number Five
September-October 1984 $5.00


HEPARD'S
INERALOGY
KIRWAN'S
MINERALOGY
2
KIRWAN'S
MINERALOGY
PHILLIPS
MINERALOGY
MILLER

# the Mineralogical Record

September–October 1984
Volume Fifteen, Number Five

## Articles

## Departments

**The Mineralogical Record Inc. is a non-profit organization**
The Mineralogical Record magazine (USPS-887-700) is published by the Mineralogical Record Inc., 7413 N. Mowry Place Tucson, Arizona 85741

**Subscriptions**
$23 per year, $43 for two years, $500 lifetime, domestic and foreign. Payment in U.S. dollars.

**Mailing addresses & phone nos.:**

**Circulation, back issues, reprints**
The Mineralogical Record
P.O. Box 35565
Tucson, Arizona 85704
602-297-6709

**Editing, advertising**
Wendell E. Wilson
Mineralogical Record
4631 Paseo Tubutama
Tucson, AZ 85715
602-299-5274

**Book sales**
P.O. Box 1656
Carson City, NV 89702
702-883-2598

**Special second class postage**
Paid at Tucson, Arizona, and additional offices. POSTMASTER: send address changes to:
7413 N. Mowry Place
Tucson, AZ 85741

**Foreign Payments**
Remittance may be made in local currency, at *prevailing exchange rates*, without surcharge, to the following people:

**Great Britain**
Simon Harrison
42 Lansdown Crescent
Cheltenham
Gloucestershire GL50 2LF

**Belgium:**
Paul Van Hee
Marialei 43
B-2120 Schoten

**Canada:**
Mrs. J. W. Peat
36 Deepwood Crescent
Don Mills, Ontario M3C 1N8

**Italy:**
Renato Pagano
Via S. Anna 1/B
I-34074 Monfalcone

**South Africa:**
Horst Windisch
30 Van Wouw Street
Groenkloof, Pretoria

**West Germany**
Christian Weise Verlag
Oberanger 6
D-8000 München 2

**Contributed Manuscripts**
Contributed manuscripts are welcome. Acceptance is subject to the approval of the editor.

**Suggestions for authors**
See Vol. 15, no. 4, p. 195, or write for copy.

**Replacement copies**
Availability of replacement copies usually extends for several months following publication, but is not guaranteed. Requests for replacements should be made as soon as possible.

**Back Issues**
Write to the Circulation Manager for a list of issues still in print. For **out-of-print issues** contact *Mineralogical Research Co.*, 704 Charcot Avenue, San Jose, CA 95131. A list of other dealers in back issues is available on request.

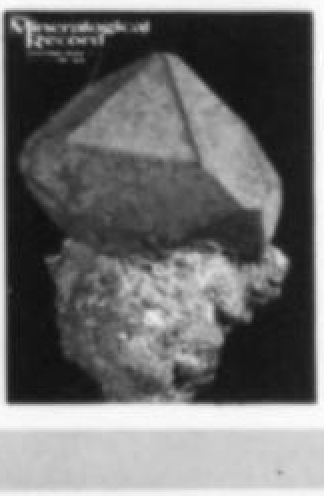
**Advertising Information**
All advertising in the Mineralogical Record must be paid in advance of the closing date. Discounts apply when more than two ads are paid for at a time. Telephone orders not accepted. Write to the editor for rates.

**Closing dates:**

| | |
|---|---|
| Jan.-Feb. issue . . . . . . . . | Oct. 15 |
| March-April issue . . . . . . | Dec. 15 |
| May-June issue . . . . . . . | Feb. 15 |
| July-Aug. issue . . . . . . . . | April 15 |
| Sept.-Oct. issue . . . . . . . | June 15 |
| Nov.-Dec. issue . . . . . . . | Aug. 15 |

An additional 30 days past the closing date are allowed in which advertisers may make changes (excluding size changes) in ads already paid for.

**Affiliated with the Friends of Mineralogy,** an independent, non-profit organization devoted to furthering amateur and professional interests in mineralogy. For membership information contact Ron Bentley, 309 Irvin Drive, Midland, Texas 79701.



COVER: CUPRITE crystal coated with malachite, 5 cm across, from the Onganja mine, Namibia. Collection of the Sorbonne, University of Paris; photo by Nelly Bariand. See vol. 5 (1974), p. 78, for a discussion of the find.

# notes from the EDITOR

### BROKEN HILL BOOK TO GO OUT OF PRINT

Readers who have been putting off ordering a copy of the big book on Broken Hill (available from the Mineralogical Record Book Department . . . see ad) should be advised that it may not be available for much longer. We recently ordered another batch of copies from the publisher in Australia; the order will be filled, but the publisher informed us that: "Unfortunately, this will have to be our last shipment to you, as our stock is now down to the last 150 copies. We do not envision having another print run."

### CONGRATULATIONS . . .

. . . to our *Microminerals* columnist Dr. William A. Henderson, Jr., after whom a new mineral species has recently been named. Willhendersonite is a zeolite mineral isostructural with chabazite. It was first noticed by Bill on a specimen from the San Venanzo quarry, Terni, Umbria, Italy, and was later recognized from the Eifel district in Germany as well.

PEACOR, D. R., DUNN, P. J., SIMMONS, W. B., TILLMANNS, E., and FISCHER, R. X. (1984) Willhendersonite, a new zeolite isostructural with chabazite. *American Mineralogist,* **69**, 186–189.

. . . and to Dr. John Sinkankas, long-time advertiser (*Peri Lithon Books*) and well-known author, after whom a new mineral species has also been recently named. Sinkankasite is a hydrated manganese aluminum phosphate formed as an alteration product of triplite and apparently unrelated to other known species. The type locality is the Barker pegmatite near Keystone, South Dakota.

PEACOR, D. R., DUNN, P. J., ROBERTS, W. L., CAMPBELL, T. J., and SIMMONS, W. B. (1984) Sinkankasite, a new phosphate from the Barker pegmatite, South Dakota. *American Mineralogist,* **69**, 380–382.

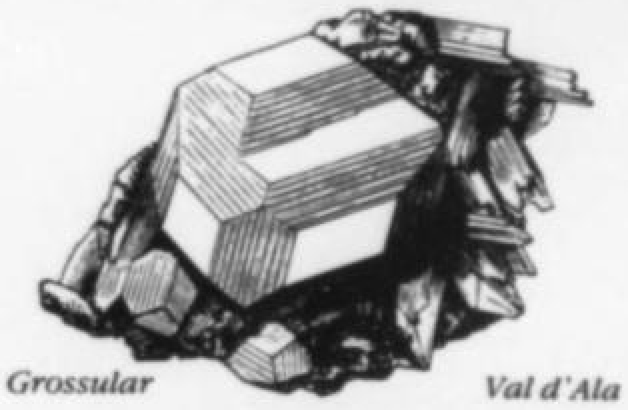
### NOTICES

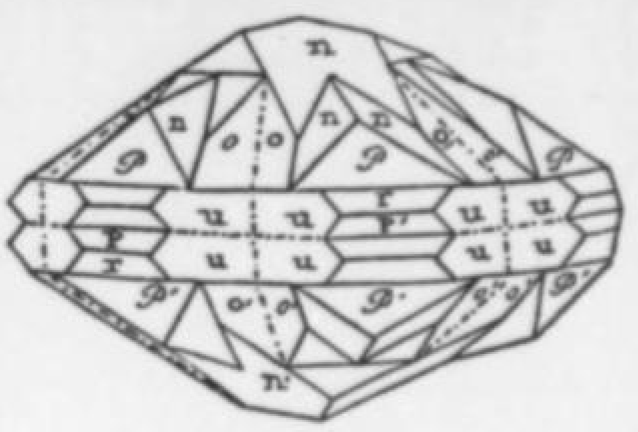
**Died, Arthur W. Johnson, 74,** in Butte, Montana. Arthur Johnson and his wife, June, supplied many fine Butte specimens to collectors, major museums and universities through their business (*Trevellion Johnson Gems*) and shop in Butte. Johnson started the business in his home in 1950 and expanded to a shop in 1964. He began collecting while studying mineralogy at the Montana School of Mines (1929–1932). In addition, he taught lapidary classes; two of his students won national awards. Art always considered himself fortunate that his chosen hobby was also his livelihood.

Marshall Koval

**Died, James Eric Johnson, 66,** in South Australia. Jim Johnson was a well-known South Australian collector, self-taught mineralogist, author, miner, lecturer and founding member of the Mineralogical Society of South Australia. At the age of 25 he donated his extensive and valuable collection of Australian minerals to the South Australian Museum; it was the largest single mineral collection ever presented to the museum at that time. He worked in many of the most highly mineralized mines in Australia, including Broken Hill, and in 1972 was appointed Honorary Associated in Mineralogy at the South Australian Museum. His list of publications consists of at least 57 titles, including *Catalogue of South Australian Minerals – 1983* (which he coauthored with R. J. Noble and J. Just, and which was published shortly after his death). A trust fund has been created in his name by the Mineralogical Society of South Australia.

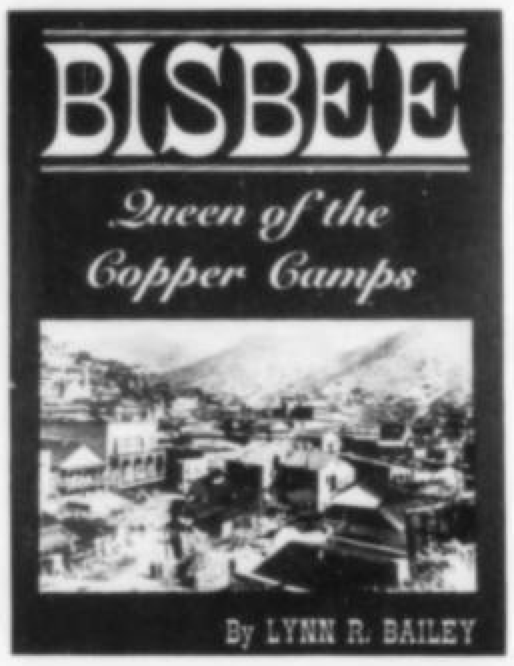
W.E.W.

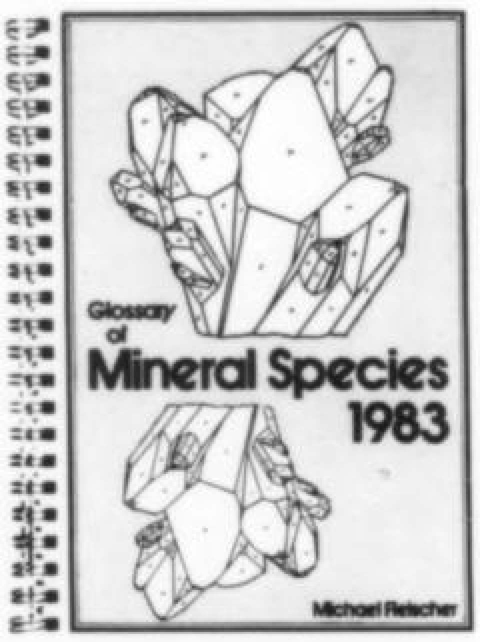


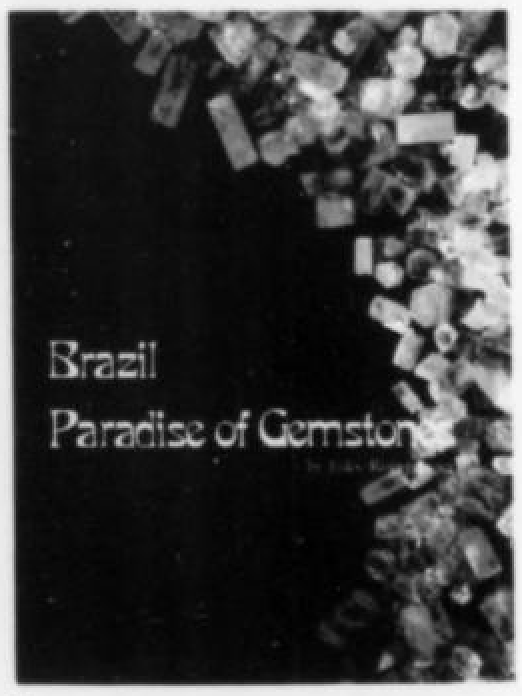


n
p
o
r
u
n'


MINERALS OF
BROKEN HILL


BISBEE
Queen of the
Copper Camps
By LYNN R. BAILEY


Glossary
of
Mineral Species
1983
Michael Fleischer


Brazil
Paradise of Gemston


CATALOGUE OF
SOUTH AUSTRALIAN
MINERALS-1983

# THE
# JACUPIRANGA
# MINE

## *São Paulo, Brazil*

**Luiz Alberto Dias Menezes, Jr.**
Rua Maria Dick, 65
04709 São Paulo, São Paulo, Brazil

and
**Joaniel Munhoz Martins**
Caixa Postal 5
Jacupiranga, 11940 São Paulo, Brazil

***The Jacupiranga carbonatite, located in the Brazilian state of São Paulo, is among Brazil's most interesting mineral deposits. It is the type locality for zirkelite, and has yielded over 40 other species including the finest known crystals of manasseite and calzirtite.***

## INTRODUCTION

The Jacupiranga[1] mine is located 230 kilometers southwest of the city of São Paulo, in the Ribeira de Iguape River Valley, São Paulo state, Brazil. Local topography consists of low hills once covered by dense jungle, but the rapid development of agriculture during the last 20 years has eliminated jungle vegetation in favor of bananas, tea, cocoa and palms.

The mine has been developed near the center of an alkaline intrusion measuring about 7 by 10 km; the original surface expression of the carbonatite[2] orebody was an unusually high hill (180 meters in an area where other hills rarely exceed 80 m) measuring about 400 by 1200 m.

## HISTORY

The alkaline intrusion was first described by Derby (1881); Derby gave the name *jacupirangite* to the principal igneous alkaline rock type composed mainly of titanian augite and magnetite with accessory phlogopite, olivine and nepheline.

A few years later the area was visited by Hussak (1892, 1895 and 1904) who made a detailed examination of the heavy minerals found in the weathered soil near the contact between the jacupirangite and what he described as a limestone. There he found apatite, magnetite, perovskite, baddeleyite and some flattened and twinned octahedrons which he first described as spinel but later recognized to be a new zirconium-niobium-titanium oxide. He subsequently named the new mineral *zirkelite* after Ferdinand Zirkel, 1838–1912, German petrographer.

The natural concentration of magnetite in the weathered cover of the orebody was investigated in the early 1900s as a possible iron ore but was revealed to be uneconomical due to the high phosphorous and titanium content. In the beginning of the 1940s Serrana S.A. de Mineração negotiated a lease of the mine with the São Paulo State Government, and in 1946 began mining and concentration of apatite. The process was simple: the weathered ore was first washed to remove clay and limonite, and then submitted to low and medium intensity magnetic separation to remove the magnetite;

---

[1] Pronounced "Hah'-coo-per-ahng'-gah."

[2] (Ed. note:) Verwoerd (1967) defines carbonatite as a granular rock consisting primarily of calcite, dolomite (including ankerite) or other rock-forming carbonates as principle constituents, usually with subordinate apatite, magnetite, silicates and accessories, and exhibiting primary features of intrusive rocks, e.g., transgressive contacts and/or flow structure. Heinrich (1966) notes that carbonatites are generally closely associated with alkaline igneous rocks, and that their apparently igneous origin has been a subject of some debate.

*Figure 1.* **Open cut workings of the Jacupiranga mine. Photo by the author.**

from this an apatite concentrate of up to 90% purity was obtained.

Because the origin of the ore was incorrectly interpreted as being due to contact metamorphism between limestone and jacupirangite, the reserves of the rich weathered ore were overestimated. By the end of the 1950s unweathered carbonatite had been exposed at several points and the life of the mine was re-estimated to be only eight more years. Serrana then began an intensive geological investigation while simultaneously working to develop an oredressing process capable of separating calcite from apatite (until that time an unsolved technological problem for such low-grade ore, average only 13% apatite).

The first study, conducted by Geraldo C. Melcher, concluded that the primary ore was an igneous carbonatite instead of a contact metamorphic product of jacupirangite and limestone. An intensive drilling program proved out reserves of 40 million tons of ore averaging 5% $P_2O_5$.

The second study resulted in the development of an original flotation process by Serrana's engineering staff in Jacupiranga; it proved capable of economically concentrating apatite from the crushed ore. The flotation plant was built and in 1969 the mining and concentration of the primary carbonatite ore began. Later in 1972 a cement plant was built to utilize the calcite tailings of the flotation plant as its raw material. Finally, in 1974 a sulphuric/phosphoric acid plant was built to solubilize the apatite concentrate close to the mine site.

## GEOLOGY

The alkaline intrusion is composed of a variety of rock types including nepheline syenites, pyroxenites, jacupirangite, ijolite, dunite and carbonatite. Its age is estimated at around 130 million years, contemporary with several other alkaline intrusions which extend from the southern state of Santa Catarina (the Anitapolis mine) through the north, passing into the states of Paraná (Cerro Azul mine) and São Paulo (Ipanema, Serrote and Jacupiranga mines), then turning northwest into Minas Gerais state (Araxá, Tapira and Salitre mines) and ending in the central state of Goias (Catalão mine). Most of these intrusions have carbonatites but in almost all cases the rocks are more deeply weathered then at Jacupiranga and so the carbonatite can only be seen in drill cores. Many of these areas are now being mined for phosphate (Araxá, Tapira and Catalão) and niobium (Araxá and Catalão); important projects for titanium (anatase) are presently under development at Araxá, Calatão and Salitre; other phosphate projects are planned to come on line during this decade (Anitapolis, Serrote and Ipanema).

The Jacupiranga carbonatite is oval in shape and has near-vertical contacts with the jacupirangite. It was formed by at least two successive intrusions which are separated by a contact zone composed mainly of jacupirangite intercalated with veins and xenoliths of carbonatite.

The South orebody is cut by a fault zone which divides it into a homogeneous southern body (zone 1) with low MgO (less than 4%) and medium $P_2O_5$ (around 5.5%) content, and a heterogeneous northern area composed of two distinct zones: the first consists of a carbonatite with high MgO (around 9%) and 5.5% $P_2O_5$, called zone 2, and the other consists of a rock with a lower $P_2O_5$ (4.5%) and medium MgO grade (around 5%) called zone 3. The North orebody is composed of two areas, both with a higher $P_2O_5$ content (around 6%). The first is in contact with the central jacupirangite and has medium MgO grade (around 5%), while the second extends into the border and has a very high MgO grade (16%). These last two zones are respectively referred to as zones 4 and 5, and the central jacupirangite as zone 6.

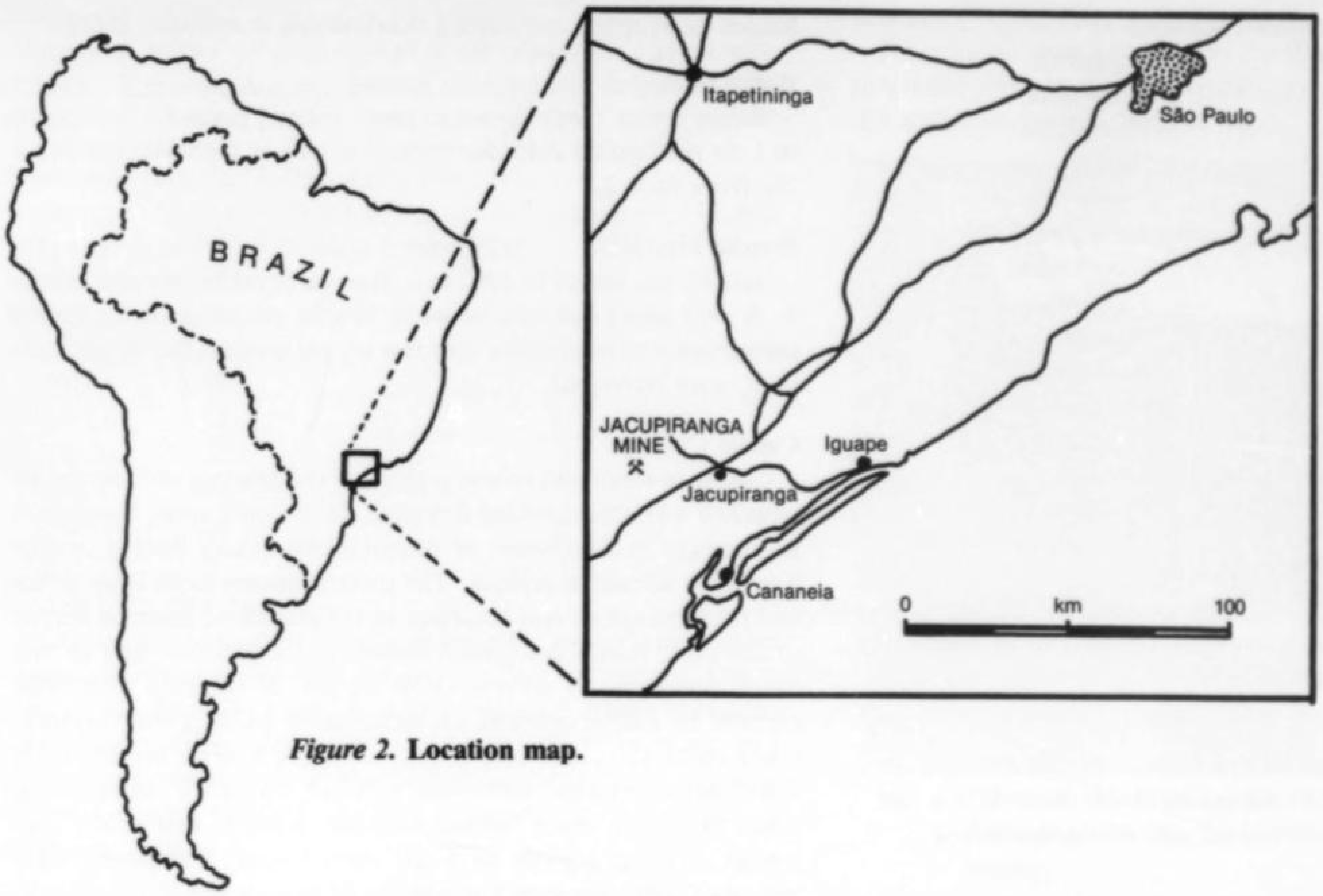


*Figure 2.* **Location map.**

The average mineral content of the orebodies is as follows:

| | |
|---|---|
| Fluorapatite: | 13% |
| Calcite: | 55% |
| Dolomite: | 22% |
| Magnetite: | 6% |
| Phlogopite: | 1% |
| Others: | 3% |

The rock is coarse-grained, with distinct flow texture. Contacts between the several zones are not sharp. Xenoliths are common, and are almost all near vertical in their orientation. The high-MgO carbonatite tends to widen with depth.

Compared to other famous carbonatites, Jacupiranga is relatively small in size. It has a very simple relationship with the surrounding alkaline rock, with very few reciprocal interpenetrations. Other singular characteristics include the relatively high $P_2O_5$ grade and the low content of silicates and barite.

The measured reserves suitable for open-pit mining total 90 million tons of ore with 5.3% $P_2O_5$ and 4.8% MgO, sufficient for 20 years of mining at the current production rate.

## MINERALOGY

The minerals of the deposit can be divided into two groups: those found as constituents of the carbonatite and those from the jacupirangite. The whole list consists of 42 species, as follows:

**Carbonatite Minerals**

Ancylite
Aragonite (secondary)
Baddeleyite
Barite
Brucite
Calcite (primary and secondary)
Chalcopyrite
Clinohumite (titanian)
Dolomite
Fluorapatite
Forsterite
Galena
Geikielite
Ilmenite (magnesian)
Magnetite
Manasseite
Phlogopite
Pyrite
Pyrrhotite
Quartz (secondary)
Serpentine
Strontianite
Uranpyrochlore
Valleriite

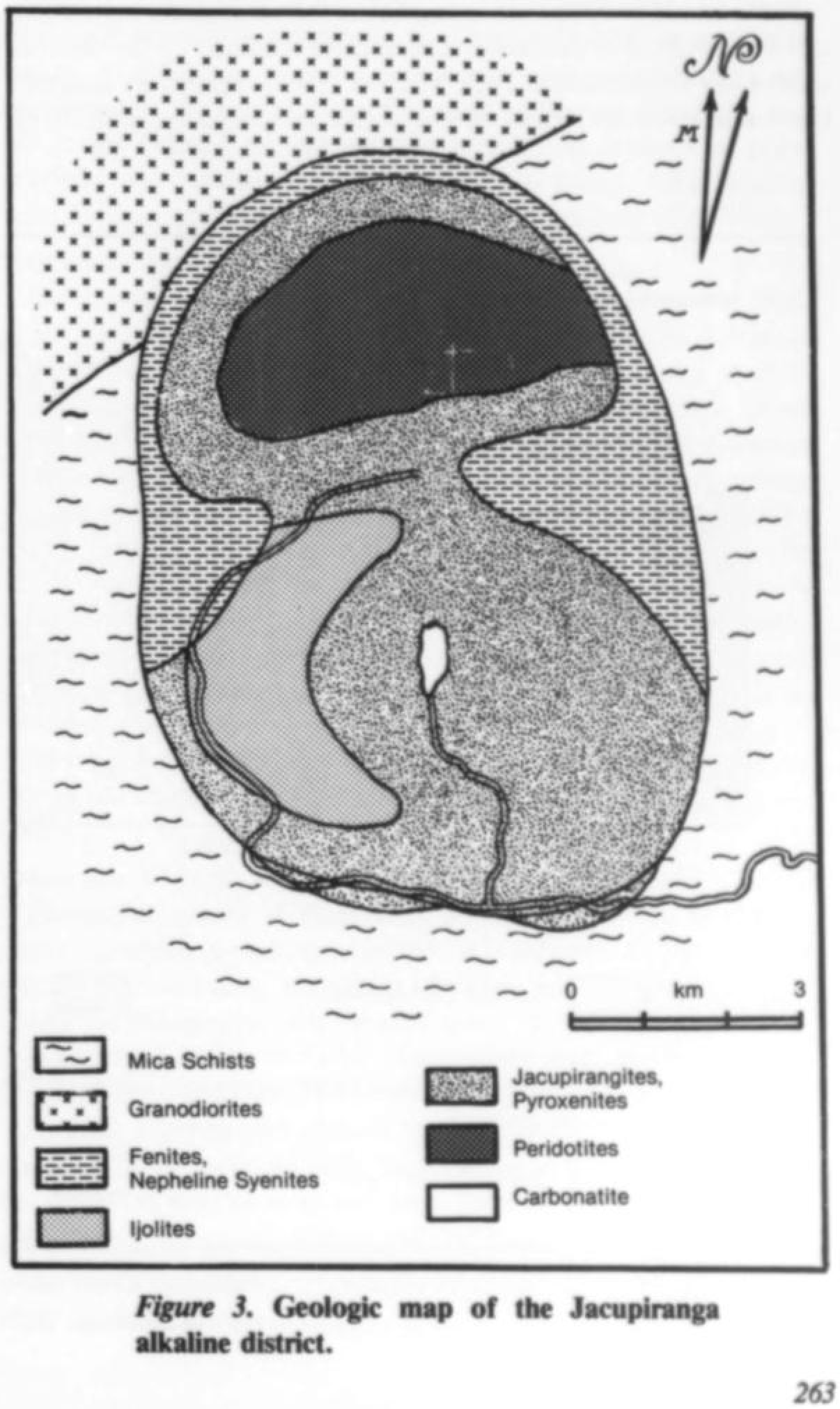


*Figure 3.* **Geologic map of the Jacupiranga alkaline district.**

**Jacupirangite Minerals**

Andradite (titanian)
Augite (titanian)
Barite
Calcite
Calzirtite
Diopside
Dolomite
Edingtonite
Fluorapatite
Forsterite
Hornblende
Ilmenite (magnesian)
Magnetite
Natrolite
Nepheline
Perovskite
Phlogopite
Pyrite
Pyrrhotite
Richterite
Schorlomite
Tazheranite
Titanite
Tremolite
Vesuvianite
Wollastonite
Zircon
Zirkelite

### *Carbonatite Minerals*

**Ancylite** $SrCe(CO_3)_2(OH) \cdot H_2O$

Ancylite was found in 1982 as tiny tan crystals up to 3 mm on dolomite crystals in vugs in zone 2.

**Aragonite** $CaCO_3$

Aragonite is found as groups of light yellow crystals covering the walls of small cavities and fractures, most of them in the old weathered part (now completely mined out) of the fault zone.

**Baddeleyite** $ZrO_2$

Baddeleyite occurs as small prismatic crystals measuring from 1 to 7 mm. It is dark brownish red, and is found very rarely in the carbonatite. It is difficult to recognize in the carbonatite matrix but can be identified in the heavy concentrates obtained by the dissolution of the carbonates in HCl. Melcher (1965) found very interesting baddeleyite specimens in the heavy concentrates: thin, gray blades intercepting pyrochlore octahedrons in epitaxial growth.

**Barite** $BaSO_4$

Barite is very rarely found as clear, yellow, prismatic crystals up to 1 cm perched on dolomite crystals in vugs in high-MgO carbonatite from zone 2.

**Brucite** $Mg(OH)_2$

Brucite was found in 1982 in a large carbonatite boulder in zone 2. A very small quantity of white brucite grains (showing typical resemblance to talc) and a very few crystal groups, the largest 1 cm long, were recovered.

**Calcite** $CaCO_3$

Calcite is white and coarse grained in the primary ore, always intermixed with finer grained dolomite. In the fault zone, however, it is common to find veins of recrystallized calcite having cavities lined with attractive crystals. The most common habit is the prism and rhombohedron combination. In the weathered cover at the top of this zone (today completely mined out) it was common to find caves, some up to several cubic meters in volume, with walls covered by calcite crystals, or more rarely by aragonite crystals. Some caves produced nice groups of white to pale yellow, short scalenohdral crystals, sometimes twinned on $(10\bar{1}0)$. Most of the caves produced white coraloid crystal groups, and many nice groups of long crystals to 5 cm were found. The largest cave measured approximately 2 m wide by 30 m long and 10 m high; the walls were almost completely covered by botryoidal calcite and aragonite crystal groups, in addition to many stalactites and stalagmites, the largest measuring 4 m in height.

In some recrystallized fractures in the dolomitic carbonatite of zone 2 yellowish brown radiating masses of calcite can be found which are suitable for carving and polishing.

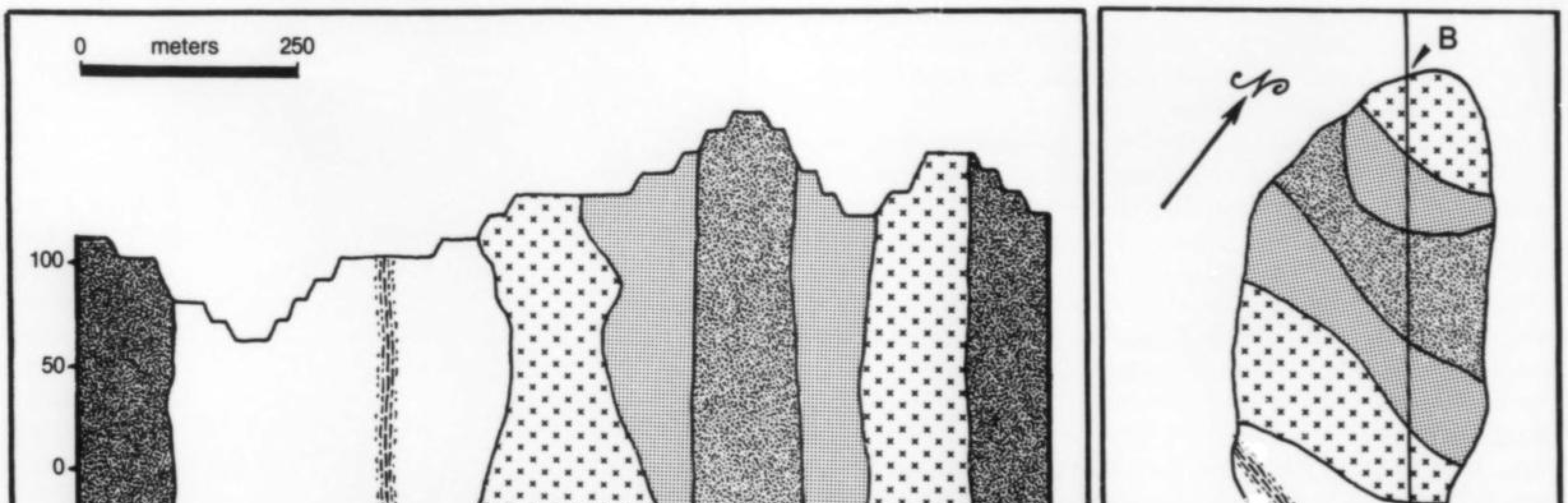


***Figure 4.* Cross section (left) and plan view of the Jacupiranga carbonatite orebody.**

**Chalcopyrite** $CuFeS_2$

Iridescent masses of chalcopyrite occur, rarely associated with pyrrhotite. It represents about 10% of the total sulfide contained in the ore.

**Clinohumite** $(Mg,Fe,Ti)_9(SiO_4)_4(F,OH)_2$

A titanian variety of clinohumite occurs at Jacupiranga; Mitchell (1978) determined the following composition:

$SiO_2$: 38.12%
$TiO_2$: 3.10
$Al_2O_3$: 0.00
FeO: 3.99
MnO: 0.51
MgO: 53.32
CaO: 0.00
$Na_2O$: 0.08
$K_2O$: 0.00
Total: 99.12%

Its most common occurrence is as irregular rims at the contact between forsterite grains and the surrounding carbonates. Clinohumite is also found in zone 6 as crude, complete crystals imbedded in carbonatite. More rarely it is found as relatively large (up to 1 cm) deep red crystals imbedded in serpentine, or as tiny (3 to 8 mm) polysynthetically twinned crystals attached to magnetite or phlogopite crystals.

**Dolomite** $CaMg(CO_3)_2$

In the low-MgO ore dolomite occurs as fine plates intergrown with calcite. In the high-MgO ore it is also normally fine grained, with a light yellow color. In zone 2 there are some areas of coarser grained dolomite with a pale gray color, sometimes as rhombohedral crystals measuring up to 1 cm on the walls of small vugs.

**Fluorapatite** $Ca_5(PO_4)_3F$

The most common habit for fluorapatite at Jacupiranga is radiating aggregates of thin, pale yellowish green, prismatic crystals widely dispersed in carbonate masses. The average crystal size is 1 by 5 mm, but can be smaller, as in the north orebody where 2 mm is the maximum, or also much larger, reaching up to 5 by 20 mm in some parts of zones 1 and 3. In the weathered ore, where the carbonates were completely dissolved, it was possible to find pale tan crystals and crystal groups associated with magnetite crystals.

**Forsterite** $Mg_2SiO_4$

Olivine from the Jacupiranga carbonatite has approximately 52% MgO and only 6% FeO, corresponding very closely to the forsterite end-member. In zone 1 it occurs as large, translucent, rough crystals showing a light to dark greenish gray color and reaching 5 cm in size. Forsterite also occurs as small (3 to 6 mm), sharp, pale gray, doubly terminated crystals thickly imbedded in apatite aggregates in carbonatite close to large jacupirangite blocks in zone 6. These apatite aggregates are fragile and the forsterite crystals can be easily separated; among these crystals some interesting twins have been found.

It is common to find forsterite grains surrounded by irregular and discontinuous rims of titanium-rich clinohumite. In the fault zone the forsterite grains are partially to wholly altered to serpentine.

**Galena** PbS

Galena has been identified by Melcher (1965) in heavy concentrates obtained by the dissolution of carbonatite in dilute HCl.

**Geikielite** $MgTiO_3$

Geikielite is the magnesium end-member of a series going to ilmenite, $FeTiO_3$. Mitchell (1977) obtained analyses of 15 to 24% MgO corresponding to 60–80% geikielite.

**Ilmenite** $(Fe,Mg)TiO_3$

Ilmenite occurs as exsolution lamellae covering and penetrating magnetite crystals. Several crystals from zones 1 and 3 analyzed by the authors contain 9 to 13% MgO.

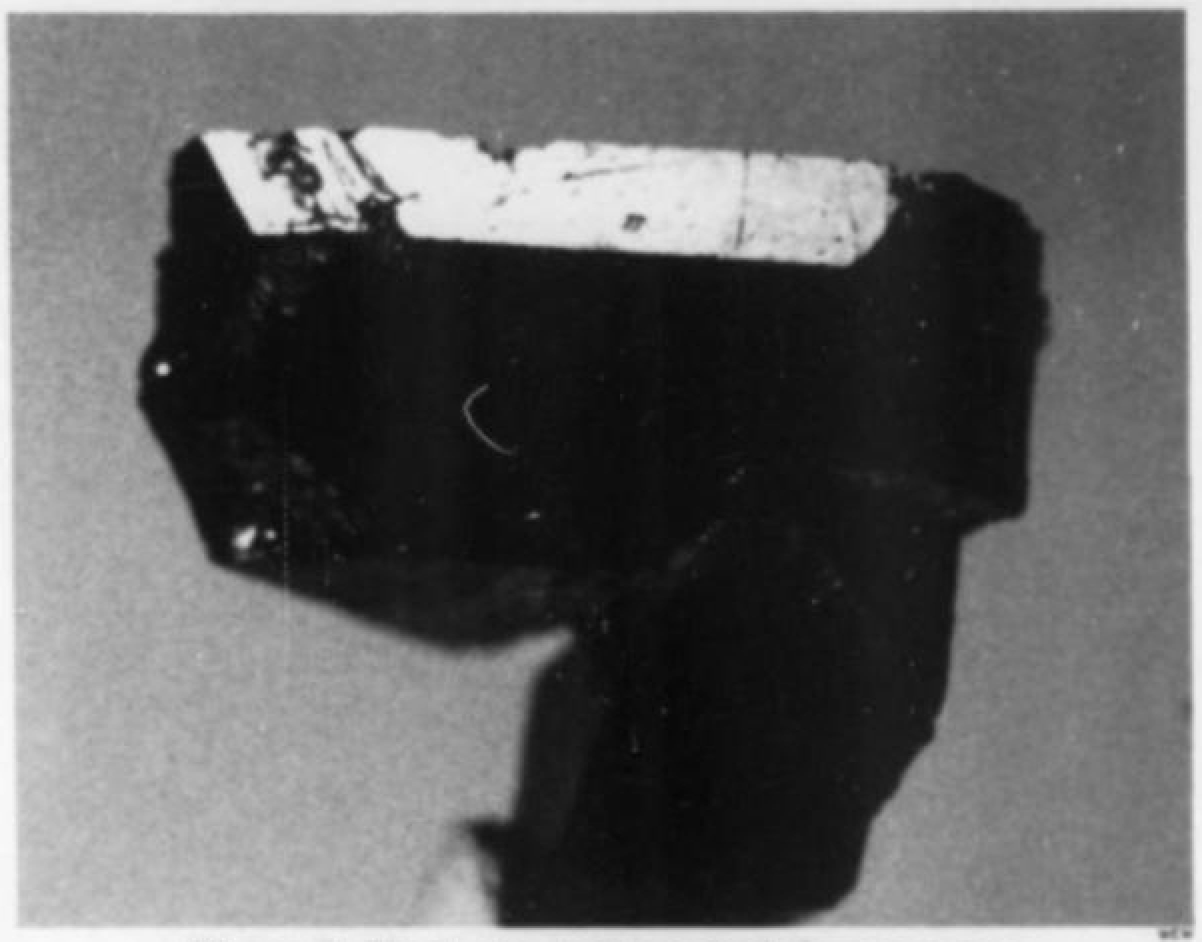


*Figure 5.* **Black magnetite twin 1.3 cm across. All specimens are from the collection of the author.**

**Magnetite** $Fe_3O_4$

Magnetite is present in all zones. It is normally found as bright octahedral crystals measuring up to 5 cm, imbedded in carbonate masses. Combinations of the octahedron and dodecahedron are also common. In zone 2 it can be found as flattened crystals, and also in very unusual spinel-law twins up to 2.5 cm in size. One polysynthetic twin consisting of 6 individuals was found. All magnetite from Jacupiranga has a relatively high MgO content (2 to 5%).

**Manasseite** $Mg_6Al_2(CO_3)(OH)_{16}\cdot 4H_2O$

Manasseite was found for the first time at Jacupiranga in 1976, as a very few specimens of bright orange-red grains in dolomitic carbonatite from bench 140, zone 2. In 1980 it was found again at bench 130, and fortunately it was possible to collect a larger amount of it, including several vugs containing small dolomite crystals partially covered by well-formed, transparent, pale orange to deep orange-red manasseite crystals measuring 2 to 6 mm. The habit appears to be a hexagonal trapezohedron modified by a prism and a basal pinacoid; the crystals are typically equant but some elongated habits have been found, as well as some tabular crystals. The basal cleavage is perfect. When bench 120 passed through zone 2 recently the rubble from each blast was carefully searched but no manasseite was found.

An interesting feature of manasseite is that it is the only known species belonging to the $P6_3/mmc$ structure group of the hexagonal system.

**Phlogopite** $KMg_3Si_3AlO_{10}(F,OH)_2$

Phlogopite occurs as thin, dark green, transparent, hexagonal plates imbedded in carbonate masses. It is common as disseminated crystals in pulverulent aggregates of short, thin apatite crystals, in which the phlogopite shows longer prism faces (the normal size is around 5 by 5 mm) and visible pleochroism (dark green parallel to the *c* face and brownish red perpendicular to it).

In zone 3 phlogopite crystals measure up to 4 cm. A very few unusually zoned crystals were found showing a bright red color in the center of the hexagon and dark green at the border. Crystals with several successive bands of red and green have been recovered; in 1976 a marvellous 5-cm crystal section showing this alternating banding was found.

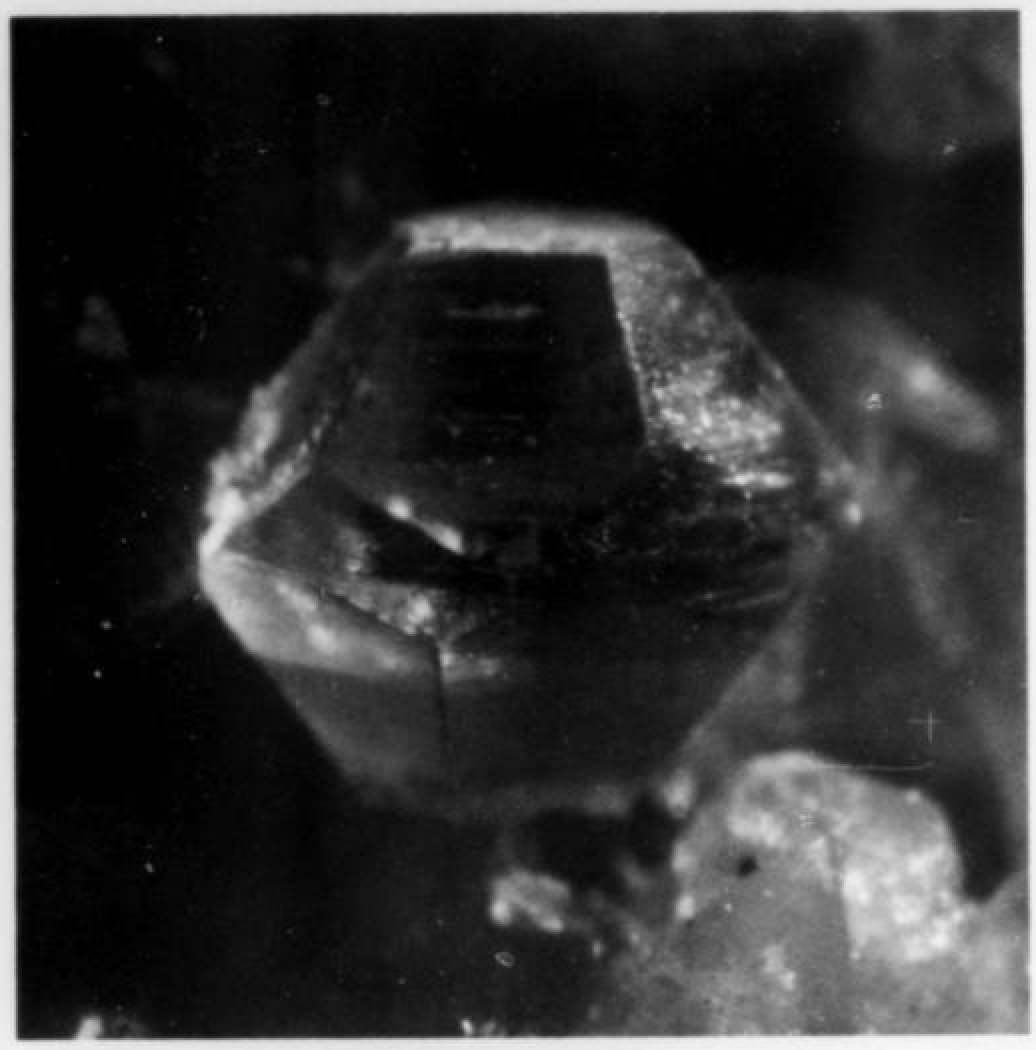


*Figure 6.* **(top) A 2-mm crystal of manasseite from the Jacupiranga mine. Julius Weber photo. Lou Perlof specimen.**

**Uranpyrochlore** $(U,Ca,Ce)_2(Nb,Ta)_2(O_6(OH,F)$

Until 1981, uranpyrochlore had been found only as small octahedrons measuring not more than 1 mm, and normally only detectable in the heavy concentrates following acid treatment. In 1981 it was found in a very restricted area in zone 2 as dark brown crystals measuring up to 2 cm.

**Valleriite** $4(Fe,Cu)S \cdot 3(Mg,Al)(OH)_2$

Boctor and Svisero (1978) described valleriite aggregates of radial crystals found at the interfaces between pyrrhotite or chalcopyrite and carbonate minerals, and as an interstitial phase between pyrrhotite and magnetite. In 1981 and 1982 the authors found valleriite as tufts of dark, greenish black, acicular crystals measuring up to 3 mm, attached to dolomite crystals in vugs in high-MgO carbonatite in zone 2. R. V. Gaines (personal communication) studied the material and determined that the X-ray diffraction pattern is identical to that of an unnamed member of the valleriite group described by Harris and Vaughan (1972) as having the composition $2FeS \cdot 0.84(CaCO_3 \cdot H_2O)$. This material is currently under study.

*Figure 7.* **Orange manasseite crystals to 4.5 mm.**

**Pyrite** $FeS_2$

Aggregates of small pyrite grains are typically associated with apatite. In zone 2 pyrite occurs as micro (up to 2 mm) cuboctahedral crystals on dolomite crystals filling small vugs in high-MgO carbonatite.

**Pyrrhotite** $Fe_{1-x}S$

Aggregates of rough plates and grains of pyrrhotite measuring from 5 mm to 3 cm occur imbedded in carbonate masses. Pyrrhotite represents about 60% of the total sulfide content of the carbonatite (less than 1%).

**Quartz** $SiO_2$

Quartz is very rarely found as tiny secondary crystals covering calcite crystals in vugs in partially altered carbonatite.

**Serpentine group**

Green pseudomorphs of a serpentine mineral after forsterite have been found in partially alterated carbonatite and also in fresh carbonatite in the fault zone.

**Strontianite** $SrCO_3$

Strontianite was found associated with ancylite in 1982; it occurs as tiny white globules (up to 2 mm) partially covering dolomite crystals.

*Figure 8.* **Orange manasseite crystal, 2.5 mm.**

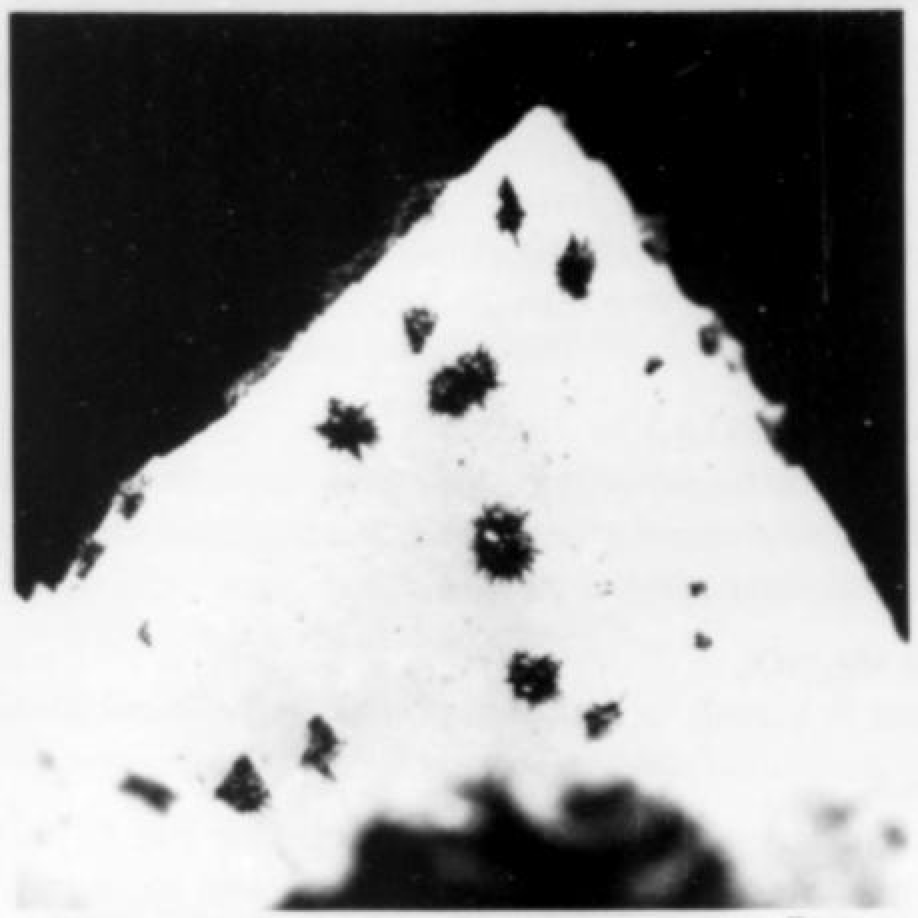


*Figure 9.* **Valleriite (?) sprays on a 7-mm dolomite crystal.**

### *Jacupirangite Minerals*

Jacupirangite rock is found at the Jacupiranga mine as surrounding country rock, as xenoliths in carbonatite (found more often near the borders of the orebody and near the contact between zone 3 and the jacupirangite zone), and in the central jacupirangite zone.

To date only the deeply weathered portions of the surrounding jacupirangite have been exposed so no interesting hand specimens have been found there. However, some very rare minerals including tazheranite and zirkelite can be separated as micro crystals from concentrates obtained after heavy liquid separation and magnetic separation.

Jacupirangite xenoliths found inside the carbonatite orebody measure from 0.5 to more than 10 m in diameter; their contacts with the carbonatite can be very sharp, but in most cases there is a thin transition zone (rarely more than 20 cm thick) composed of several alternating layers of carbonates and dark minerals (mainly phlogopite). In the xenoliths, as in the central jacupirangite zone, it is possible to find some very interesting specimens of several minerals, especially in a coarse grained jacupirangite exposed in the eastern part of zone 6. The rock there is coarse and vuggy, and the pocket walls are commonly covered by crystals of several minerals; some pockets are completely filled with crystalline calcite which must be dissolved away in order to expose the crystals.

Minerals identified from the jacupirangite are as follows.

**Andradite** $CaFe_2(SiO_4)_3$

Olive-green, translucent, dodecahedral crystals of andradite measuring 1 to 5 mm have been found in association with vesuvianite lining vugs in a jacupirangite xenolith.

**Augite** $(Ca,Na)(Mg,Fe,Al,Ti)(Si,Al)_2O_6$

Augite is the most common constituent of the vugs, occurring as sharp, dark green crystals measuring up to 3 cm, commonly associated with fluorapatite and phlogopite crystals.

**Barite** $BaSO_4$

White tabular barite crystals up to 5 mm occur perched on titanite crystal groups.

**Calcite** $CaCO_3$

Calcite is found as colorless to white crystals up to 3 cm; it is normally the last mineral formed in the vugs.

**Calzirtite** $CaZr_3TiO_9$

Dark reddish brown to brownish green crystals of calzirtite showing a very complex habit and measuring up to 5 mm have been

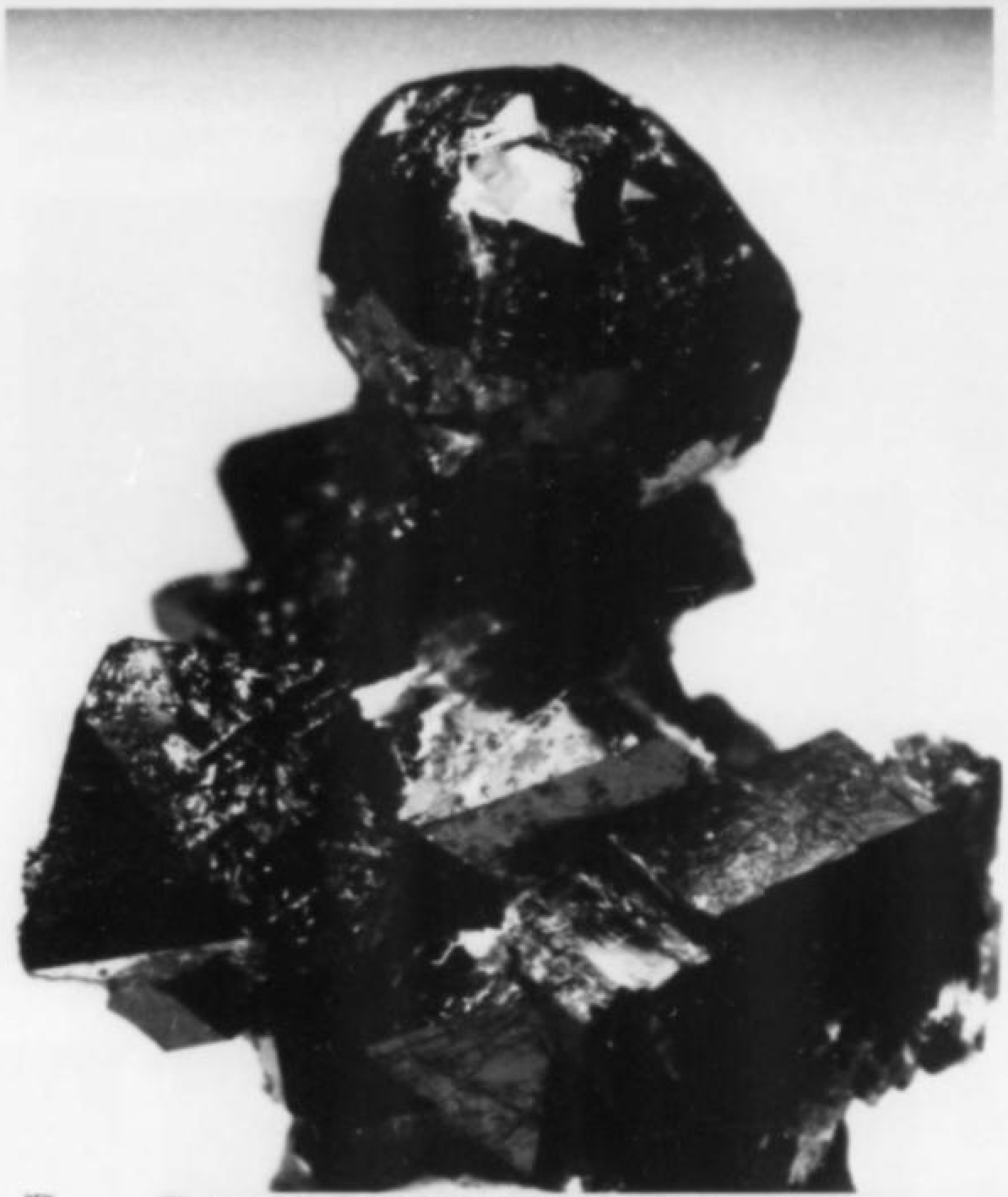


*Figure 10.* **Complex, twinned, black calzirtite crystal (top) on black magnetite crystals.**

*Figure 11.* **Roughly textured black calzirtite crystal, 5 mm.**

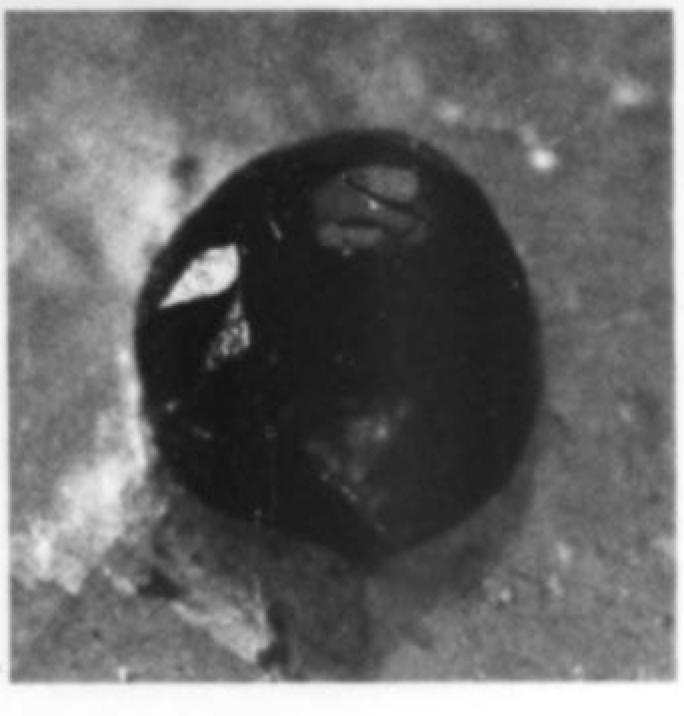


*Figure 12.* **Black, 1.5-mm calzirtite crystal on dolomite.**

found very rarely. They occur associated with augite, phlogopite, magnetite and perovskite crystals in vugs; calzirtite is also found as round, black crystal aggregates on augite crystals in vugs.

**Diopside** $CaMgSi_2O_6$

Pale green, translucent, crude diopside crystals up to 5 mm have been found associated with augite crystals.

**Dolomite** $CaMg(CO_3)_2$

Dolomite has been found as colorless to white crystals to 3 cm; it is typically the latest formed mineral in a pocket.

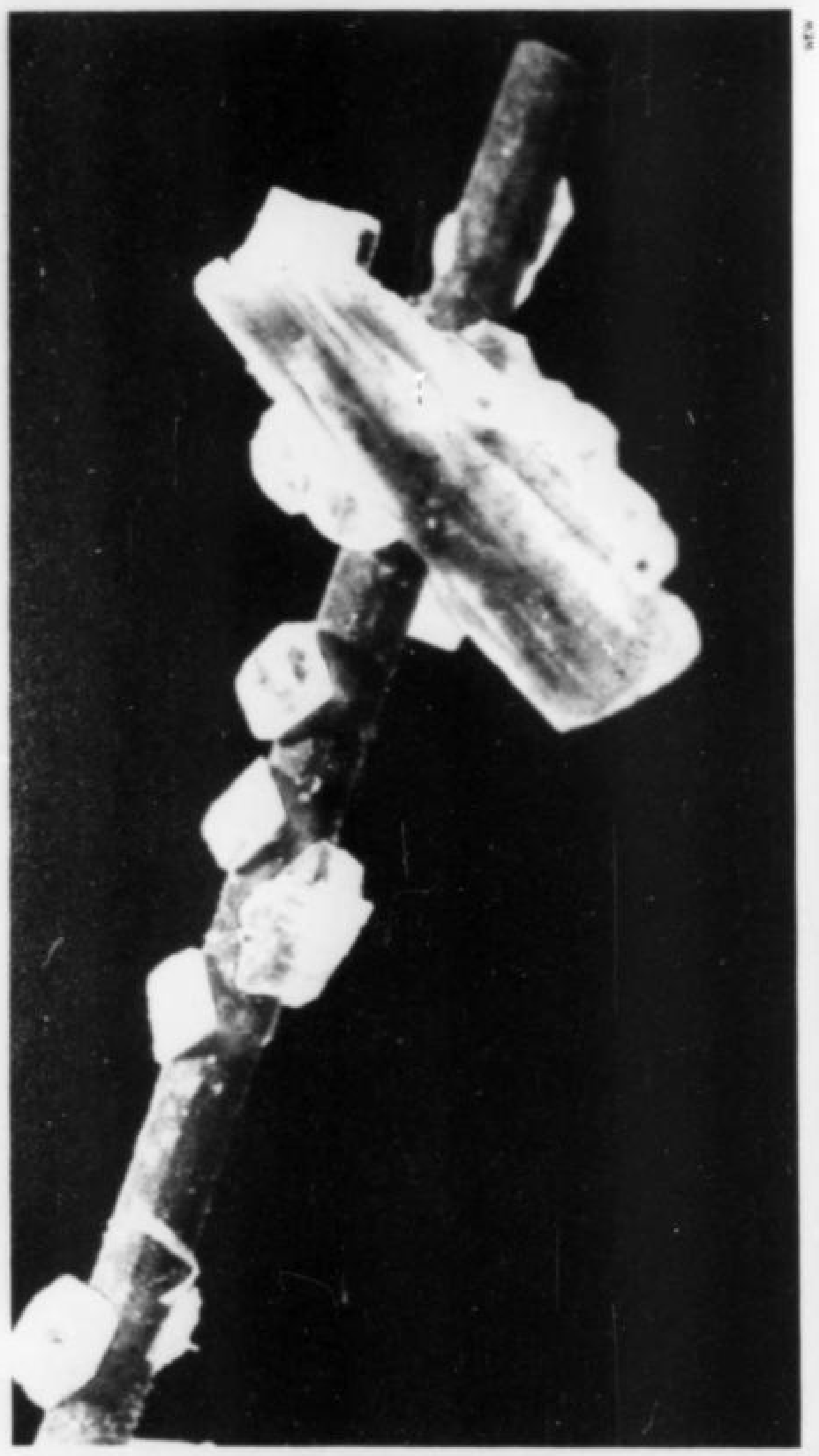


*Figure 13.* **White, 3-mm edingtonite crystal perched on a dark green needle of hornblende.**

**Edingtonite** $BaAl_2Si_3O_{10}\cdot 4H_2O$

Tiny, equidimensional, colorless edingtonite crystals showing the typical hemimorphic habit have been found attached to tufts of natrolite crystals or, more rarely, to hornblende crystals, calcite or phlogopite crystals. It was found only once, in a restricted area, when several hundred fine micromounts and miniature specimens were recovered.

**Fluorapatite** $Ca_5(PO_4)_3F$

Fluorapatite is found as thin, pale green crystals, measuring up to 7 cm but unfortunately very fragile. Crystals perched on augite crystals in vugs are typical.

**Forsterite** $Mg_2SiO_4$

Forsterite is a minor constituent of massive jacupirangite.

**Hornblende**

In coarse-grained jacupirangite rock hornblende can be found as large grains showing perfect cleavage surfaces and measuring up to 10 cm. It can also be found as thin, black crystals in vugs, commonly associated with calcite and natrolite crystals.

**Ilmenite** $(Fe,Mg)TiO_3$

Bright, flattened crystals of ilmenite measuring up to 1 cm have been found associated with natrolite and richterite crystals in vugs.

*Figure 14.* **White natrolite spray 1.6 cm across on brown phlogopite.**

*Figure 15.* **Small, white edingtonite crystals on white natrolite sprays; the group is 7 mm across.**

Chemical analyses indicate that the MgO content varies from 7.5 to 13.0%, lower than in ilmenite from the carbonatite.

**Magnetite** $Fe_3O_4$

Magnetite is found as octahedrons, as combinations of octahedron and dodecahedron and, more rarely, of octahedron and trapezohedron. Crystal size varies from 1 mm to 5 cm.

**Natrolite** $Na_2Al_2Si_3O_{10}\cdot 2H_2O$

Natrolite is found as tufts of white prismatic crystals up to 1 cm, associated with phlogopite crystals or with calcite, hornblende and titanite crystals in vugs. It can also be found as small crystals attached to long, green richterite needles.

**Nepheline** $(Na,K)AlSiO_4$

Nepheline is a minor constituent of massive jacupirangite.

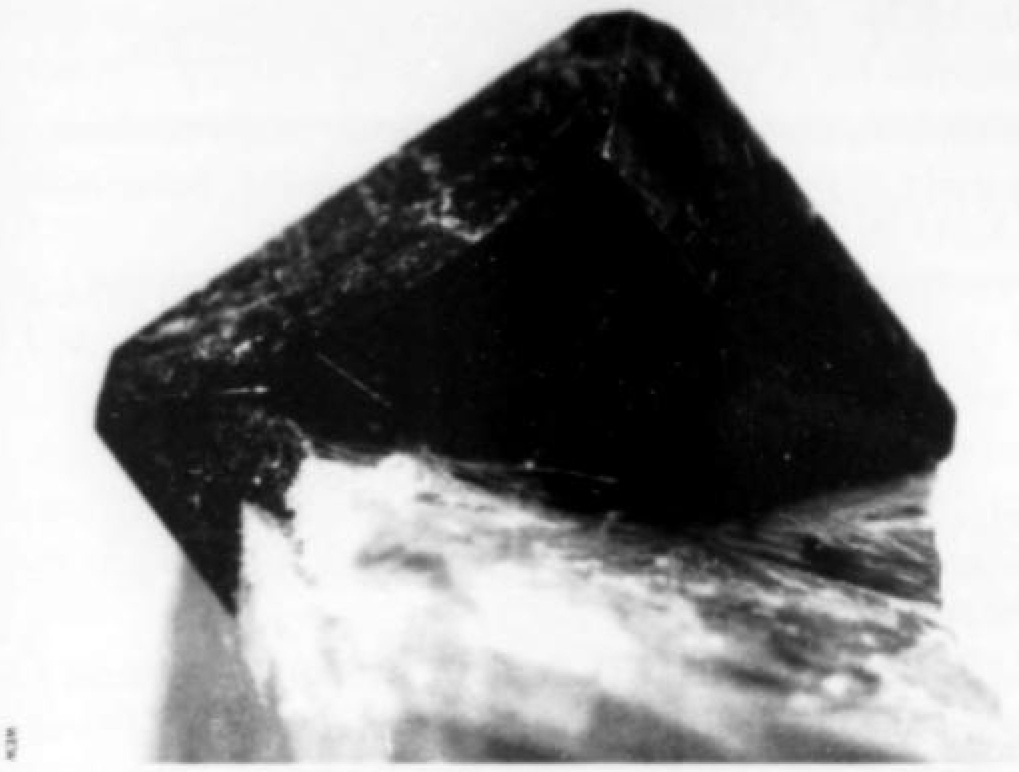


*Figure 16.* **Black perovskite crystal 7 mm across.**

**Perovskite** $CaTiO_3$

Perovskite, undoubtedly one of the most interesting items from Jacupiranga, occurs as sharp, bright, black crystals normally measuring 2 to 10 mm, but in exceptional cases reaching up to 4 cm. The habit is pseudocubic, sometimes with pyramidal modifications on the corners of the "cubes." It has also been found as dypyramidal crystals with prismatic modifications (resembling combinations of octahedron and cube), and even as complete dypyramidal, pseudo-octahedral crystals. The crystals may occur with augite, phlogopite and magnetite in vugs, or as incrustations on phlogopite crystals from the phlogopite veins.

**Phlogopite** $KMg_3Si_3AlO_{10}(F,OH)_2$

Phlogopite is found as dark brown to black prismatic crystals attached to the walls of vugs, and as veins composed of large (up to 10 cm) crystals; they are normally barrel shaped or thin and elongated, with a large hexagonal base narrowing to a small top.

**Pyrite** $FeS_2$

Pyrite is found in vugs as cubic crystals up to 1 cm.

**Pyrrhotite** $Fe_{1-x}S$

Pyrrhotite occurs rarely as crude, platy crystals to 8 mm.

**Richterite** $Na_2Ca(Mg,Fe)_5Si_8O_{22}(OH_2)$

Green acicular needles of richterite up to 2 cm have been found as radiating aggregates in vugs in jacupirangite.

**Schorlomite** $Ca_3(Fe,Ti)_2(Si,Ti)_3O_{12}$

Schorlomite has been found as black, solid masses measuring up to 3 cm, at the contact between weathered jacupirangite and ijolite, 2 km from the carbonatite orebody.

**Tazheranite** $(Zr,Ti,Ca)O_2$

Brownish green crystals of tazheranite measuring less than 1 mm

**Titanite** $CaTiSiO_5$

Pale yellow to deep orange, translucent to transparent crystals of have been found in one of the fractions obtained by high-intensity magnetic separation of heavy concentrates from weathered jacupirangite.

*Figure 17.* **Pale yellow titanite crystal 1.7 cm across on dark brown phlogopite crystals.**

titanite are normally associated with natrolite crystals or phlogopite crystals. Crystal size varies from 5 to 25 mm.

**Tremolite** $Ca_2(Mg,Fe)_5Si_8O_{22}(OH)_2$

Tremolite has been found as aggregates of light to dark green crystals imbedded in calcite grains or in vugs, partially covered by natrolite crystals and associated with magnesian ilmenite and zircon.

**Vesuvianite** $Ca_{10}Mg_2Al_4(SiO_4)_5(Si_2O_7)_2(OH)_4$

Very unusual, radiating aggregates of thin, brownish red vesuvianite crystals to 5 mm occur perched on crystals of green andradite in vugs in jacupirangite. Only one occurrence has been discovered, in a xenolith in zone 3; the small vugs were completely filled with massive natrolite which had to be removed with HCl in order to expose the crystals.

**Wollastonite** $CaSiO_3$

Long, white, radiating fibers up to 5 cm as fracture fillings in jacupirangite.

**Zircon** $ZrSiO_4$

Zircon occurs as brown, prismatic crystals measuring 3 to 10 mm, associated with groups of tremolite and natrolite crystals.

**Zirkelite** $(Ca,Th,Ce)Zr(Ti,Nb)_2O_7$

Zirkelite was described by Hussak (1894) from a heavy concentrate obtained from a weathered jacupirangite. In 1982 it was found in a small pocket as sharp crystals measuring 1 to 5 mm, attached to phlogopite crystals. The crystals are prismatic, and show typical striations due to polysynthetic twinning.

## CONCLUSIONS

The Jacupiranga carbonatite is one of the principal carbonatite bodies presently under large scale mining exploitation. As mining is expected to continue for 20 more years, many other interesting mineral specimens will probably be found, especially when fresh, unaltered parts of the surrounding jacupirangite are reached in the lower benches.

**ACKNOWLEDGMENTS**

The authors are grateful to Richard V. Gaines and Eugene Foord for several of the mineral identifications, and to Wendell E. Wilson and Julius Weber for the specimen photographs.

## BIBLIOGRAPHY

BOCTOR, N. Z., and SVISERO, D. P. (1978) Iron-titanium oxide and sulfide minerals in carbonatite from Jacupiranga, Brazil. *Annual Report of the Director, Geophysical Laboratory, Carnegie Institution, 1977–1978.*

BORODIN, L. S., NAZARENKO, I. I., and RICHTER, T. L. (1956) Zirconolite, a new mineral complex oxide $AB_3O_7$. *DAN U.S.S.R.* Issue 110, no. 5.

BULAH, A. G. (1963) Zircolites and zirconolites from the carbonatites of the Kola Peninsula. *Memoranda of the All-Union Mineralogical Society,* Issue 6, part 92.

BULAH, A. G., ILIINSKY, G. A., and KUHARENKO, A. A. (1960) Zircolite from the deposits of the Kola Peninsula. *Memoranda of the All-Union Mineralogical Society,* Issue 3, part 89.

DERBY, O. A. (1891) The magnetite ore districts of Jacupiranga and Ipanema, Sao Paulo, Brazil. *American Journal of Science,* series 3, **41**, 311–321.

GAIDUKOVA, V. S., and ZDORIK, T. B. (1962) Minerals of the rare elements in carbonatites. *Symposium on the Geological Deposits of Rare Elements, Gosgeolkohizdat,* Issue 17.

HARRIS, D. C., and VAUGHAN, D. J. (1972) Two fibrous iron sulfides and valleriite from Cyprus, with new data on valleriite. *American Mineralogist,* **57**, 1037–1052.

HEINRICH, E. W. (1966) *Geology of Carbonatites.* Rand McNally, 555 p.

HUSSAK, E. (1892) Ueber Brazilit, ein neues Tanta (Niob) Mineral von der Eisenmine Jacurpiranga. *Neues Jahrbuch fur Mineralogie, Geologie und Paleontologie,* **2**, 141–159.

HUSSAK, E. (1895) Ueber den Baddeleyite (syn. Brazilit) von der Eisenmine Jacupiranga in Sao Paulo. *Tschermaks Mineralogische und Petrologische Mitteilungen,* 395–411.

HUSSAK, E. (1904) Ueber die Mikrostruktur einiger brasilianischer Titanmagneteisenstein. *Neues Jahrbuch fur Mineralogie, Geologie und Paleontologie,* **1**, 94–113.

MELCHER, G. C. (1965) *O Carbonatito de Jacupiranga.* Boletin 282, Geologia no. 21, Sao Paulo, Brazil.

MITCHELL, R. (1978) Manganoan magnesian ilmenite and titanian clinohumite from the Jacupiranga carbonatite, São Paulo, Brazil. *American Mineralogist,* **63**, 544–547.

PIATENKO, U. A. (1971) The derivation of stoichiometric formulas for crystalline phases structurally related to fluorite. *News from the Academy of Science of the U.S.S.R.,* **7**, no. 4.

PUDOVKINA, Z. V., and PIATENKO, U. A. (1966) X-ray pattern study of zirconolite and its artificial analog. *Symposium on the X-ray Patterns of Mineral Ores,* issue 4.

PUDOVKINA, Z. V., and PIATENKO, U. A. (1966) Zirconolite and its crystallographic characteristics. *Symposium on New Information about the Minerals of the U.S.S.R.,* Issue 17.

VERWOERD, W. J. (1967) The carbonatites of South Africa and South West Africa. *Handbook 6, Department of Mines, Geological Society of the Republic of South Africa,* Pretoria and Capetown, p. 13.

WYLLIE, P. J., and TUTTLE, O. F. (1960) The system CaO-$CO_2$-$H_2O$ and the origin of carbonatites. *Journal of Petrology,* **1**, 1–46.

---

# Denver area Dealers

** by appointment only, except as noted*

*M. P. Abel Minerals*
P.O. Box 440356
Aurora, CO 80044
303-695-7600
Superb Worldwide Specimens

*B & W Minerals*
5609 North Pike
Golden, CO 80403
303-278-2936
Fine Colorado Minerals

*Collector's Stope*
Jim & Patti McGlasson
7387 S. Flower Street
Littleton, CO 80123
303-972-0376
Species & Display Minerals

*Crystal-Linn International*
Martin Zinn
P.O. Box 2433
Evergreen, CO 80439
303-670-1960
Fine Minerals, Tourmaline

*Eldorado Enterprises*
Don & Dee Belsher
P.O. Box 219
Eldorado Springs, CO 80025
303-494-7785
Wholesale, Appraisals

*Geology Museum & Shop*
Colorado School of Mines
Golden, CO 80401
303-273-3823
Mon-Sat 9-4, Sun 1-4

*Golden Minerals*
Don E. Knowles
13030 West 6th Place
Golden, CO 80401
303-233-4188
Largest Stock in Colorado

*Kalin*
3650 Berkley Avenue
Boulder, CO 80303
303-499-2452 or 278-7053
Cabinet Specimens, Fluorescents

*L & T Creations*
Tag & Lee McKinney
6780 S. Logan
Littleton, CO 80122
303-794-7803
Colorado-Utah Minerals

*Resource Enterprises*
R. Ted Hurr
P.O. Box 115
Wheat Ridge, CO 80033
303-421-3893

*Rough & Ready Gems*
Steve Green
P.O. Box 10404
Denver, CO 80210
303-758-2022
Mexican Amethyst

*St. James Collections*
C. R. & Elizabeth Williams
7707 W. Chestnut Place
Littleton, CO 80123
303-973-1865

*Tavernier*
3355 S. Wadsworth, G123
Lakewood, CO 80227
303-973-1865
Fine Minerals & Gems

*Williams Minerals*
Keith & Brenda Williams
P.O. Box 1599
Idaho Springs, CO 80452
303-567-4647
Colorado Minerals & Mounts

*Worldwide Resources*
Dennis O. Belsher
P.O. Box 636
Golden, CO 80402
303-494-7785
South American Minerals

*Shows:*

*Denver Council Gem & Mineral Show, Denver Merchandise Mart, Sept. 7-9, 1984*
*Denver Satellite Show, Holiday Inn North, Sept. 5-8, 1984*


Yew should take thet thar thang to the Pasadena Show!
I b'lieve I will!

# THE JENSEN QUARRY

## *Riverside County, California*

**Fred DeVito**
1406 Norwich Avenue
Thousand Oaks, California 91360

and
**Al Ordway Jr.**
9385 Church Street
Bloomington, California 92316

***Shrouded in relative obscurity for decades, the Jensen quarry has produced nearly 90 species including excellent tourmaline, ferro-axinite, epidote, muscovite and a host of rare minerals.***

## INTRODUCTION

The Jensen quarry, located near Route 60 about 8 kilometers west of the city of Riverside, California, is one of the most underrated mineral localities in the United States. This is probably due to several factors, the most significant of which is its close proximity to the famous Crestmore locality less than 5 km to the northeast. Although Crestmore has produced more than twice the number of mineral species, the Jensen quarry, with a growing list of nearly 90 species, would be better known among most mineralogists and mineral collectors if it were not located in the shadow of Crestmore. A second reason for its obscurity is that specimens from the major find (a small lithium pegmatite which produced crystals of elbaite and schorl during the late 1940s) were scattered in a few different mineral collections, and the exact locality lost. And finally, the only comprehensive report ever written on the quarry is a 1955 Master's thesis by Robert Cooney which has remained unpublished. Several significant mineralogical finds have been made since 1955, and it seems appropriate now to bring this information together for publication.

## HISTORY

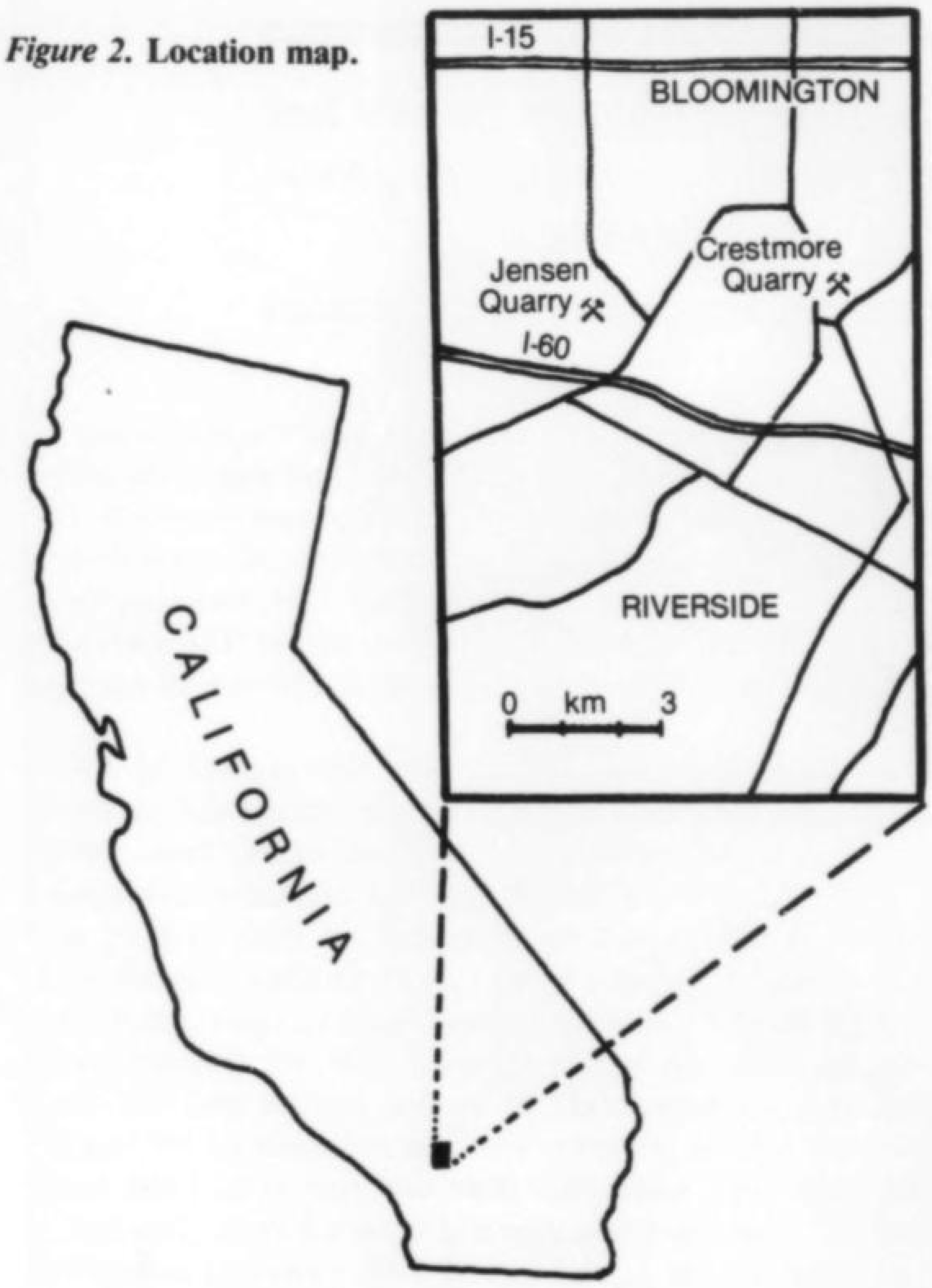
The Jensen quarry was first worked during World War I by the Riverside Cement Company, which was also working the nearby Crestmore deposit at Sky Blue Hill for cement-grade marble. During 1927 the Jensen quarry was shut down and remained so until 1948 when the Riverside Cement Company again worked the quarry and trucked the marble to Crestmore for processing. In 1955 the quarry again became inactive. During the early 1960s, Snow Rock Corporation leased the northeastern part of the property and worked dolomitic marble for roofing granules; the marble was too high in magnesium for cement production. This area of the quarry located at J100 and J101 (see quarry map) became inactive in 1971 when Snow Rock ceased quarrying operations. Riverside Cement again worked the quarry from 1974 through 1979, removing the remainder of the high quality cement-grade marble. The quarry has been inactive since 1979, and probably will not be worked again for marble.

The minerals of Jensen quarry were first studied by Joseph Murdoch, but apparently no papers were published with the exception of a report on geikielite (Murdoch and Fahey, 1949). During 1955 Robert Cooney studied the Murdoch collection and coupled Murdoch's data with his own comprehensive study of the quarry and its minerals. This work resulted in his excellent Master's thesis at the University of California at Los Angeles (Cooney, 1955). During the late 1960s the actively quarried J100 and J101 areas were studied and specimens collected by Joe Lavook and one of us (FDV). The lithium pegmatite was later rediscovered but was not worked until 1981 when Nick Rose and one of us (AO) began operations to recover tourmaline and other minerals. This find at J27, coupled with an axinite find at J103, produced several fine cabinet specimens. Both of these locations, however, have been exhausted and further recovery of specimens there seems unlikely.

Although there is a "no trespassing" policy in effect, permission for our exploratory work was obtained from the Riverside Cement Company. X-ray and microprobe analyses for this study, except as noted, were performed by William Wise at the University of California, Santa Barbara.

*Figure 1.* **The Jensen quarry (center) in the Jurupa Mountains. The J100-J101 area is on the right, and the J103-J104 cut is on the left. The view is facing northwest. Photo by FDV.**

*Figure 2.* **Location map.**



## GEOLOGY

The Jensen quarry is situated in the southeast corner of the Jurupa Mountains, an 11-km-long series of hills composed of crystalline rocks and located about 72 km east of Los Angeles. The Jurupa Mountains represent the extreme northern end of the Peninsular Range geologic province, which extends southward through San Diego County and into Baja California, Mexico. This small, isolated range consists of Paleozoic gneisses, schists, marbles and quartzites which have been intruded by Cretaceous rocks ranging from gabbros to granodiorites (Cooney, 1955). Pegmatite dikes are abundant throughout the crystalline rocks, particularly around the northwestern flanks of Jensen quarry.

The Jensen quarry geology is dominated by the intimate association of magnesian marble with siliceous metamorphic rocks, conspicuous tonalite intrusives and granitic pegmatites. The marble bodies appear to reach a maximum thickness of 60 meters (McKevett, 1951). The mineral-producing areas of the quarry are in the pegmatites, along the marble contacts with tonalite and pegmatite and in the marble body itself. Within the marble many of the minerals occur in banded predazzite (a brucite-rich marble) which is silica deficient but very rich in magnesium minerals. These zones contain large quantities of brucite pseudomorphs after periclase, which apparently formed from two-stage dedolomitization of pure dolomitic rock, i.e. dolomite → periclase, periclase → brucite (Williams, Turner, and Gilbert, 1954). It is interesting to note that these zones found at the Jensen quarry and in surrounding areas are nearly identical to the predazzite which occurs at Predazzo, Italy. Many of the associated minerals are also common to the two localities.

## MINERALOGY

The following discussion of Jensen quarry mineralogy is divided into four subsections: minerals of the southwest contact zones, the northeast contact zones, the marble and the J27 pegmatite. Although only the species of greatest collector interest are dealt with in detail, all species known from Jensen are listed in Table 1 at the end of this article.

### *The Southwest Contact Zones*

There are two contact zones at the south end of the Jensen quarry which are separated by Bonsall tonalite. The contact zone at the east end of the separation (J1) was revealed by deep quarrying operations and is traceable for about 160 m before disappearing

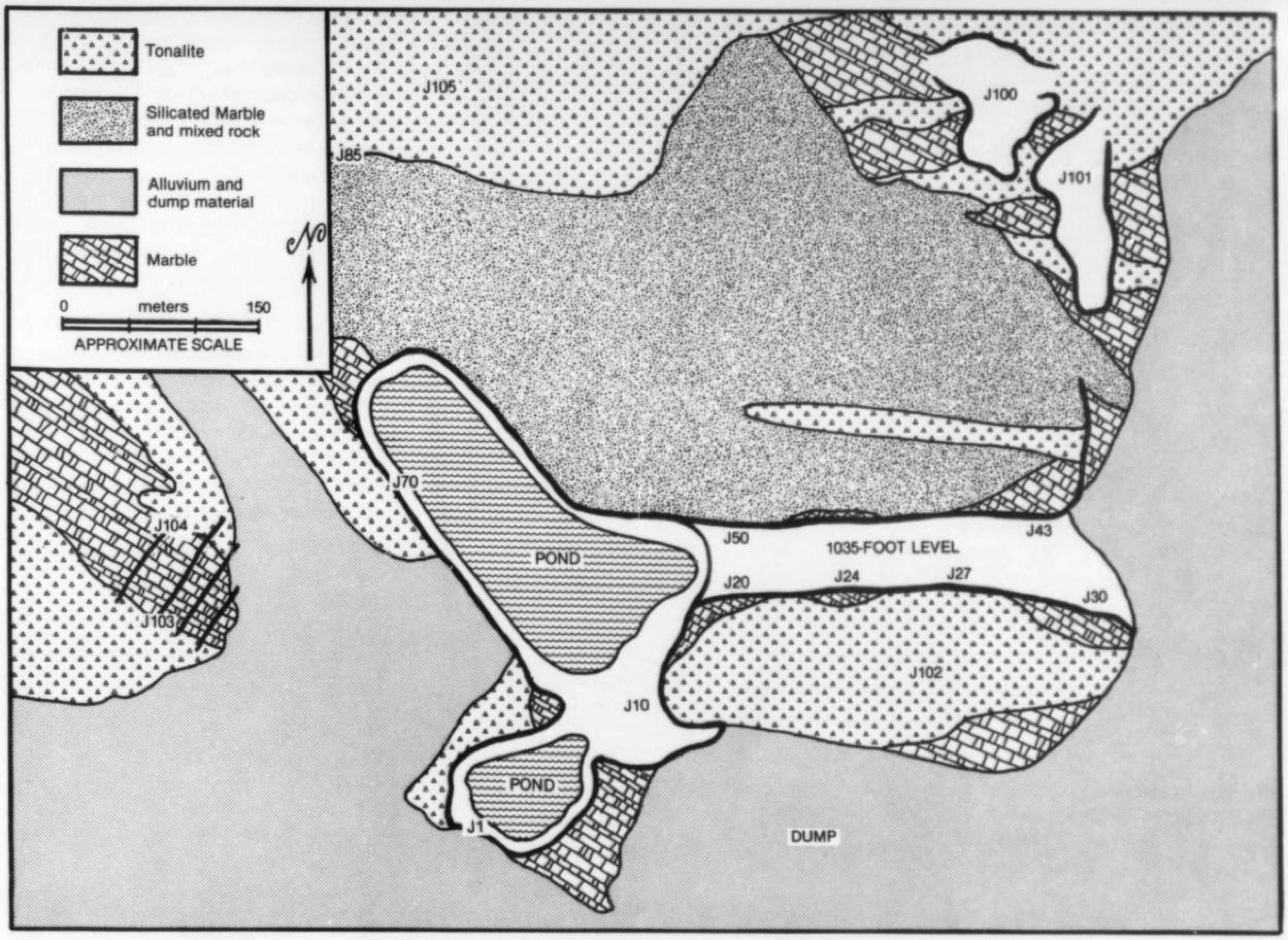


*Figure 3.* **Geology and collecting sites at the Jensen quarry (modified from Cooney, 1955). Heavy lines are the quarry walls and benches; quarry floors are shown in white. J-numbers are those used by Cooney (1955) except for the new numbers J100 through J105.**

*Figure 4.* **The main pit of the Jensen quarry, facing east. The arrow indicates the rubble pile at the base of the J27 pegmatite. The main quarry wall is at left. Photo by FDV.**

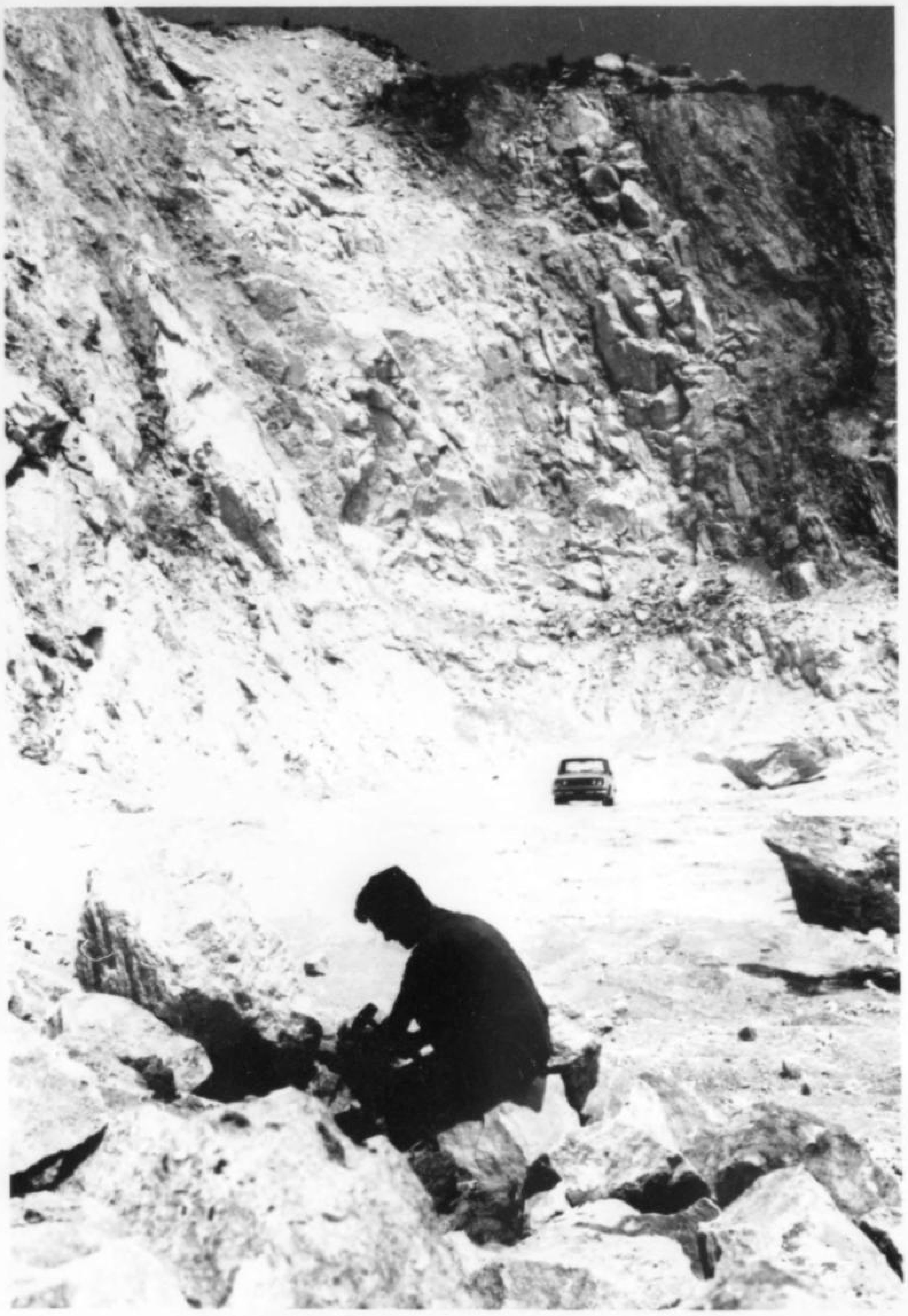


*Figure 5.* **The J101 area in 1969. Photo by FDV.**

under alluvium to the east and terminating to the west. The minerals of this zone are mainly grossular, epidote and quartz, and they occur at various areas on and at the base of the quarry cut. This zone is highly fractured and most of the garnet and epidote are recoverable only as small chunks in a friable mass. Where there are lenses and large masses of quartz, the garnet tends to be less fractured and good crystal groups can be etched out of calcite-filled vugs. Sharp epidote crystals have been found in the garnet-quartz vugs and scheelite masses and crystals to 1 cm have been found in granular garnet lenses at the contact of the marble and the garnet-quartz masses. Late fracture filling by calcite is common, and occasionally crevices filled with opaque amber-colored scalenohedrons can be found.

On the west side of the tonalite separation the contact surfaces as a zone of gouge and is nearly devoid of mineralization. This zone continues to the west and becomes concealed beneath blocks of diopside-wollastonite rocks which form the southerly slope of a prominent limestone outcrop. Where exposed, the contact strikes approximately west and dips nearly vertically. There is a small area along this zone (J103) where the contact arcs 5 m into the tonalite for about 9 m along the strike. Isolated limestone blocks lie within this arc and are surrounded by a skarn zone of varying character. A general cross section drawn from north to south through this arc would show limestone, coarse garnet rock, coarse garnet-epidote rock, limestone blocks, friable garnet-epidote rock, a thin, discontinuous pocket zone of quartz-epidote-axinite-actinolite, friable garnet-epidote rock and decomposed tonalite. the coarse garnet-epidote rocks commonly contain small lenses and pods of quartz and calcite encasing crystals of epidote and sometimes axinite. The encased crystals are quite fractured and very few specimens can be recovered through etching of the calcite.

The main epidote-axinite pocket zone was exposed a few years ago when a road was cut near J103 for quarrying the adjacent limestone. Scatterings of quartz crystals, epidote and axinite along the bulldozer tracks led a couple of Riverside collectors (Tom Hill and Jerry Brem) to exploit this area with excellent results. A couple of epidote crystals 12 cm in length, and at least one 8 cm axinite cryatal were recovered from this small area. Recent investigation over the last few months produced a few small vugs and a couple of pockets of epidote and axinite. The largest pocket was tubular in form and 1 meter in length, but the contents were completely shattered. Piecing together some of the crystal fragments indicated that this pocket could have been the source of some of the finest epidote and axinite ever found; however, nature subsequently destroyed what she had meticulously created. Very large fragments of epidote and axinite in this pocket were cemented with calcite and prehnite and much of the cemented material was also ruptured. Two large boxes of material came from this pocket, but only one 7-cm epidote crystal had survived natural destruction. Two other pockets within a meter of this one were characteristically different in that they contained abundant axinite, a radiating type of epidote, some titanite and considerable actinolite (*amianthus*). There was also little evidence of rupturing, as most specimens were in place.

**Actinolite** $Ca_2(Mg,Fe)_5Si_8O_{22}(OH)_2$

Amphiboles are scattered throughout this area as blackish sprays of needles in the course garnet-epidote rocks and as soft green mats along the pocket zone. Samples from one pocket showed a continuous range from masses of course green actinolite to the delicate variety called amianthus. These fibers filled most of the voids and are usually associated with many interesting and excellent microscopic (1–2 mm) crystals of prehnite and/or axinite.

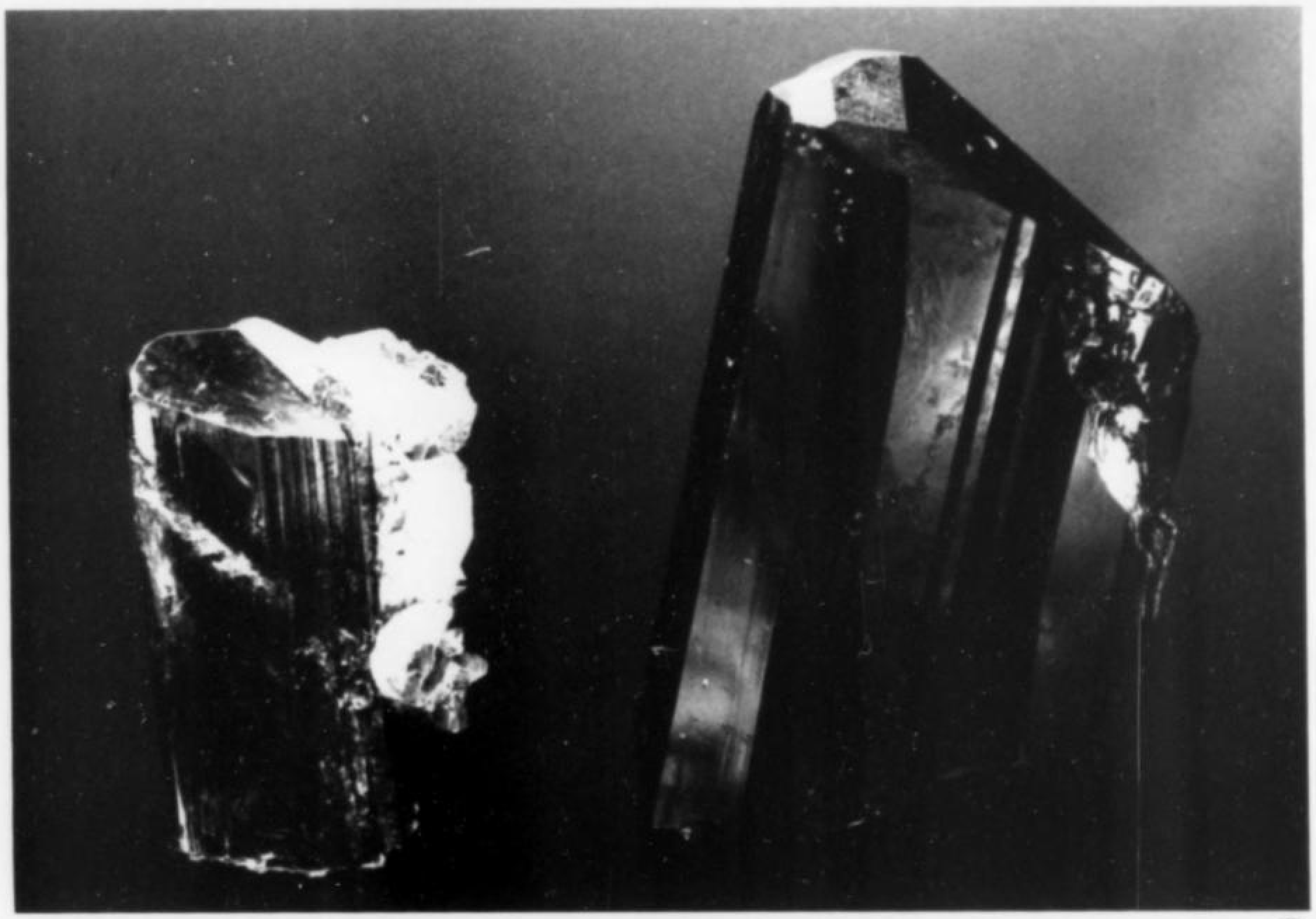


***Figure 6.*** **Gemmy, reddish brown epidote crystals, the largest measuring 3.7 cm. Ordway collection.**

**Epidote** $Ca_2(Al,Fe)_3(SiO_4)_3(OH)$

Lustrous, dark green, translucent to transparent crystals of epidote are among the most noteworthy finds at Jensen. Though crystals as long as 13 cm were found, most of the specimens recovered are single or twinned crystals less than 4 cm in length. Most of the smaller specimens came from stringers of small vugs filled with a soft calcareous material. Larger pockets first encountered by the collectors from Riverside yielded the bulk of the larger crystals found. The epidote crystals formed as extensions from thick cleavable masses of epidote forming the sides and bottoms of the pockets, but when found the crystals were completely detached from the host mass. Well crystallized epidote diminished further down the dip as axinite became more prominent. Instead of occurring as sharp, prismatic crystals, the epidote took on the form of crude crystalline masses and sprays of tiny needles growing parallel to the sides of the pockets.

**Ferroaxinite** $Ca_2FeAl_2BSi_4O_{15}(OH)_2$

Axinite was formerly abundant in the pocket zone, and also very abundant as large masses beneath the pockets. The axinite crystals penetrating the pockets were unusually large (up to 15 cm), perhaps too large, as most of these crystals grew from wall to wall, eliminating terminal faces. Smaller (1–2 cm), well formed crystals grew from the faces of these larger crystals and represent the majority of good crystals found. Axinite appears to have formed in two stages: larger crystals and masses covered in part by prehnite and as 1–2 mm crystals scattered on the prehnite. This latter occurrence was also noted on epidote, larger crystal sections of axinite and as complete, single crystals within the amianthus masses. As with the micro prehnite crystals (see below), the axinite is penetrated by delicate hairs of amianthus. The larger axinite crystals are moderately to highly fractured and were usually in contact with the pocket walls or covered with prehnite and/or calcite. On a couple of occasions, fine quality terminations of these large crystals were found protruding into unobstructed voids. The finest axinite found measures 9 cm in length and is a "floater," having no visible point of attachment.

**Prehnite** $Ca_2Al_2Si_3O_{10}(OH)_2$

Prehnite has been found in massive form and as colorless to pale green crystals to 5 mm in a couple of the larger pockets. It appears

***Figure 7.*** **Cross-section sketch of a 25-cm axinite-epidote pocket. Epidote shown black, ferroaxinite dark gray, quartz pale gray, with botryoidal prehnite and acicular amianthus sprays.**

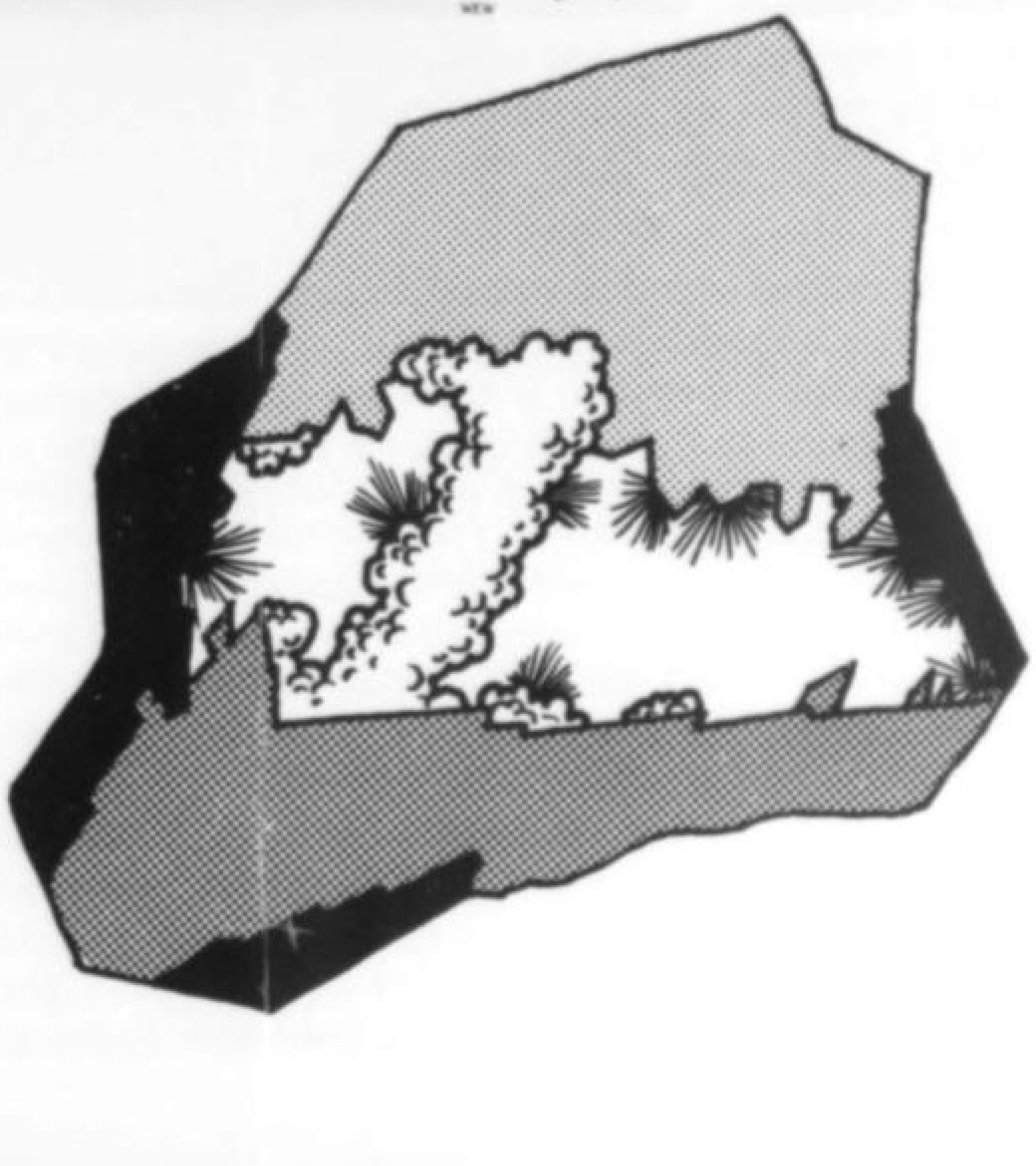


**Figure 8. Large, brown ferroaxinite crystal measuring 9 cm. Ordway collection.**

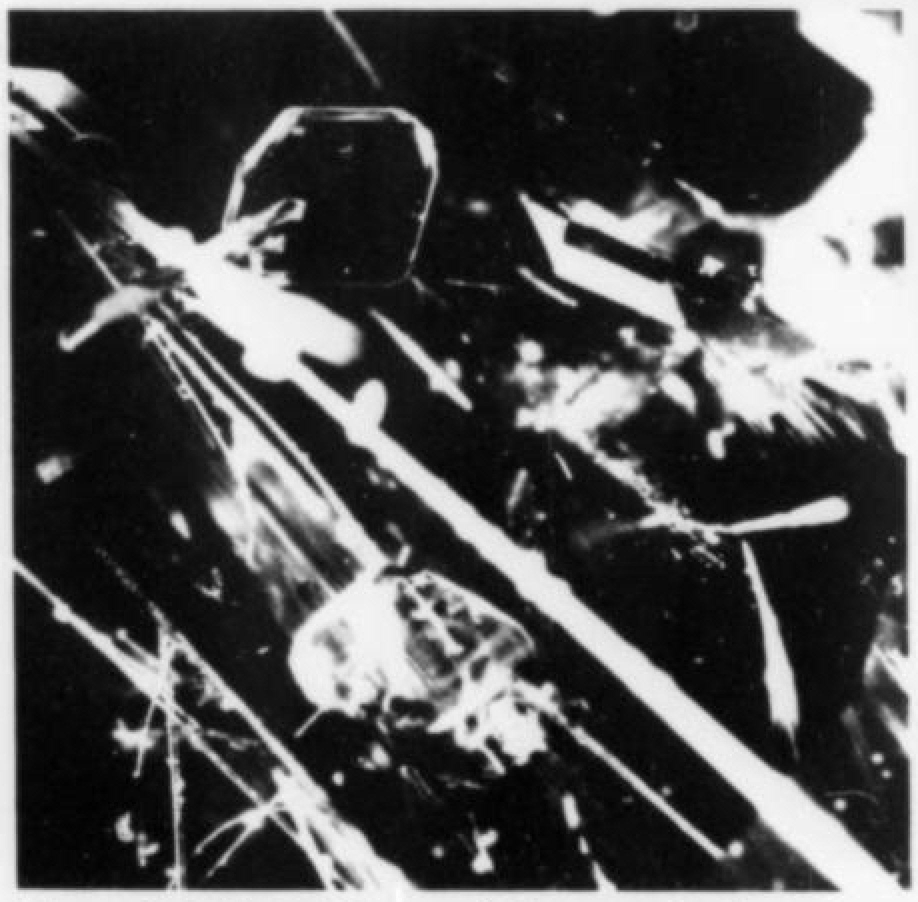


**Figure 9. Euhedral ferroaxinite crystals about 1 mm in size perched on amianthus fibers from the J103 contact area. Photo and specimen: FDV.**

**Figure 10. Pale green, transparent prehnite crystals to 3 mm perched on dark brown axinite crystals. Mike Moore photo. Ordway specimen.**

to have crystallized later than the epidote, quartz, and most of the axinite. These minerals were found lightly coated or completely encased in prehnite. Amianthus is abundant on the crystalline surfaces of prehnite, and contains hundreds of sharp, single microscopic prehnite crystals scattered through it, many of which are speared by the amianthus.

**Titanite** $CaTiSiO_5$

Several peach-colored crystals of titanite were found in the soft actinolite masses lining portions of the lowermost axinite pocket and along the edges of epidote associated with these masses. The crystals are quite small, averaging about 5 mm in length along the *b* axis, which has a ratio of about 3:1 over the normally longer *c* axis.

### *The Northeast Contact Zones*

Although the major contact minerals have been found at the southwestern end of the Jensen quarry (at J1 and J103), many unusual species have been found along the other contacts which are numerous throughout the quarry. The contacts at the northeastern end of the quarry at J100 and J101 were particularly productive when Snow Rock Corporation worked the area for dolomitic marble. Some of the more significant finds at these contacts are discussed below.

**Apophyllite** $KCa_4Si_8O_{20}(F,OH)\cdot 8H_2O$

At location J101 loose apophyllite crystals to 12 mm were found in clay near a tonalite-marble contact. The crystals are white and show prominant {111} faces. Near the same location, sharp apophyllite crystals elongated along *c* were found in cavities in granular grossular with laumontite, stilbite, prehnite and calcite. At J24 Cooney (1955) reported simple, clear crystals with wollastonite in seams in diopside-wollastonite hornfels. No analytical work has been done to determine the F:OH ratio of the Jensen quarry apophyllite.

**Clinozoisite** $Ca_2Al_3(SiO_4)_3(OH)$

At location J20 clinozoisite is found in the contact as small, clear, brilliant, striated, micro crystals growing out from larger clinozoisite crystals of lesser quality. Many of the finer crystals are included in calcite but can easily be exposed by removing the calcite with hydrochloric acid.

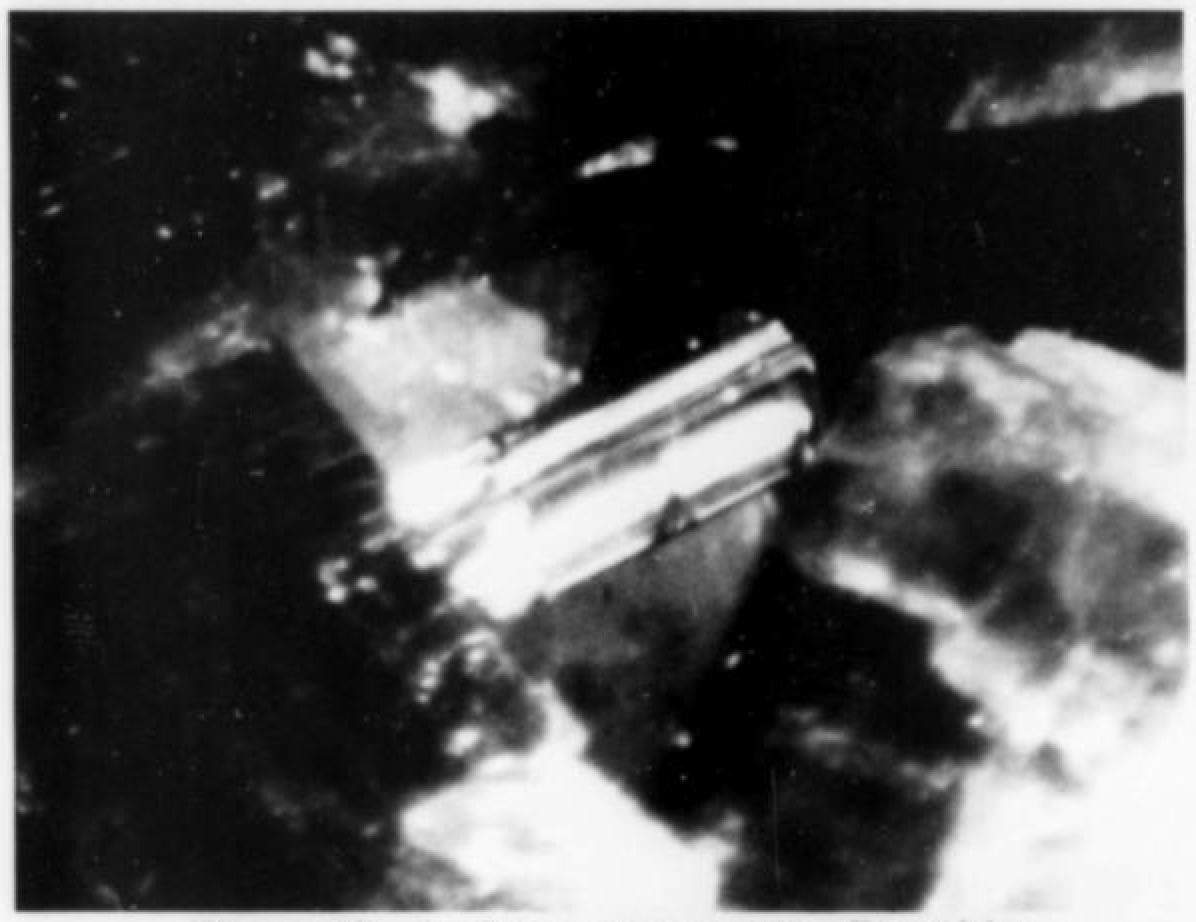


***Figure 11.* A sharp, transparent clinozoisite crystals about 2 mm long on clinozoisite. Specimen and photo: FDV.**

**Grossular** $Ca_3Al_2(SiO_4)_3$

Pale lavender grossular crystals occurring with blue ellestadite were found in the worked out 1035-foot level of the quarry (Cooney, 1955).

Clear, pale amber-colored crystals of grossular with a lavender hue were found at J101 in a tonalite-marble contact zone during Snow Rock's blasting of the magnesian marble. The crystals are small, up to 1 cm, and are brilliant, striated and reminiscent of those from Asbestos, Quebec. Small cavities in massive grossular contained sharp crystals of grossular associated with prehnite, calcite, stilbite, laumontite and clear botryoidal opal.

**Laumontite** $CaAl_2Si_4O_{12}\cdot4H_2O$

Laumontite is common in a tonalite-marble contact at J101 where it occurs as small, white, terminated, single crystals to 5 mm and masses of intergrown crystals to 4 cm in massive grossular. This laumontite is very stable, unlike the *caporcianite* variety which occurs at Crestmore. Jensen quarry laumontite appears to be the last mineral to have formed in the grossular cavities with the exception of minor opal which, in a few cases, completely envelops the laumontite crystals. Laumontite is found on calcite, stilbite, prehnite, apophyllite and grossular.

**Pargasite** $NaCa_2(Mg,Fe)_4Al(Si_6Al_2)O_{22}(OH)_2$

Sharp, prismatic, brilliantly terminated pargasite crystals to 8 cm occur in calcite-filled cavities in massive pargasite. Several of the pargasite masses found were 3 meters across and were uncovered during Snow Rock's removal of dolomitic marble near a tonalite-marble contact at J100. Dark amber-colored to brown, doubly terminated crystals to 1 cm are revealed when the calcite is dissolved away. Common forms are *a*{100}, *m*{110}, *b*{010} and brilliant *r*{011}.

**Phlogopite** $KMg_3Si_3AlO_{10}(F,OH)_2$

Although relatively common throughout the marble in the quarry, at locations J100 and J101 phlogopite occurs as sharp, golden brown, pseudohexagonal crystals to 3 cm across and as intergrown crystal masses to 8 cm. The phlogopite crystals are reminiscent of those from the Franklin limestone in New Jersey. Associated minerals include pyrrhotite, graphite and spinel. The largest crystals are found at J100 where many show bicoloration across the cleavage plates. Part of the plate is golden brown and the remainder is green. The green coloration appears to be due to oxidation of an included sulfide mineral. At location J101 the crystals are small but clear and well crystallized pyrrhotite occurs included within the phlogopite and occasionally growing on the phlogopite prism faces.

***Figure 12.* Brown pargasite crystal group with black graphite, 8 cm across, from the J100 contact area. Specimen and photo: FDV.**

***Figure 13.* Sketch of a doubly terminated pargasite crystal from the J100 contact area; *a*{100}, *b*{010}, *m*{110}, *r*{011}.**

**Prehnite** $Ca_2Al_2Si_3O_{10}(OH)_2$

Large, pale green crystals to 1.5 cm have been found at J101 with laumontite on grossular. Many of the larger crystals are completely covered by laumontite. Small, clear, barrel-shaped crystals were found in vugs in the prehnite-grossular matrix. Prehnite was the first mineral to form in these cavities after the grossular, and serves as the matrix for stilbite, apophyllite, calcite, and opal as well as laumontite. The J101 prehnite crystals exhibit *c*{001}, *a*{100} and almost no *m*{110} development, unlike the prehnite found at J103 which showed elongated and steep *m*{110} development and minor *a*{100}.

Large specimens of green prehnite up to 15 cm with crystals to 2 cm were found in 1926 at the old Sunnyslope Ranch near the western edge of the quarry. The matrix contains imbedded epidote crystals. Whether or not the exact location is presently within the quarry boundary is not known at this time (Riverside City Museum file data).

**Stilbite** $NaCa_2Al_5Si_{13}O_{36} \cdot 14H_2O$

Stilbite was found as small, clear, colorless crystals of the *epidesmine* habit with laumontite and prehnite in massive grossular along a contact zone at J101. The crystals appear to be simple and tabular with characteristic epidesmine $f\{20\bar{1}\}$ and *b* and *c* faces, although close examination shows the typical twinning.

### *The Marble*

The minerals in the marble areas near the contacts are predominantly silicates, and good crystals of diopside, wollastonite, grossular, phlogopite and actinolite are common. The predazzite zones in the marble contain abundant brucite, spinel, graphite, pyrrhotite, hydromagnesite and, more rarely, geikielite and unaltered periclase. The banded predazzite zones near the silica-rich contact regions contain chondrodite, phlogopite and forsterite in addition to the species mentioned above.

**Brucite** $Mg(OH)_2$

Reported from Jensen quarry for decades, brucite is still very common and widespread throughout the magnesium-rich predazzite marble. It occurs as complete replacements of crude periclase octahedrons to over a centimeter in size. The brucite is waxy, scale-like, and varies in color from white through gray, pink, red and yellow to black. Common associations are spinel, pyrrhotite and hydromagnesite. Residual periclase is occasionally found in the brucite as clear cores showing good cleavage in contrast with the waxy, onion-skin habit of brucite. Alteration of brucite with resultant residual limonite leaves bands of numerous reddish pits in the marble. These pitted zones are very conspicuous and many are several meters in length.

**Clinohumite** $(Mg,Fe)_9(SiO_4)_4(F,OH)_2$

Clinohumite is common in the marble at J104 where it occurs as well formed, clear, yellow to yellow orange crystals to 5 mm although crude crystals and masses much larger have been found. It is associated with spinel, brucite, graphite and pyrrhotite. The identity of clinohumite at this location was verified by both optical and X-ray methods. Its occurrence at other locations in the quarry must yet be confirmed in order that it not be mistaken for chondrodite, which is also found in the marble throughout the quarry.

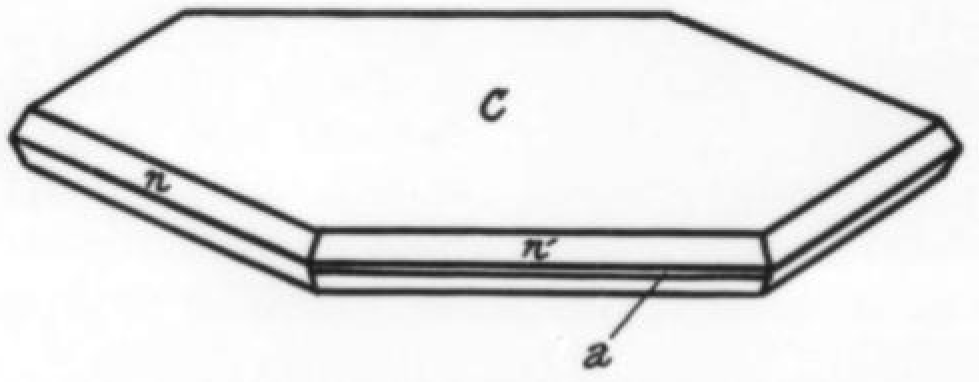


*Figure 14.* **Sketch of a geikielite crystal from the J21 marble area; *c*{0001} (brilliant), *a*{1120}, *n*{2243}.**

**Geikielite** $MgTiO_3$

Although geikielite has subsequently been reported from a number of other localities,* the Jensen quarry was the world's second location for this rare mineral and was the first locality in which it was found in place and in well developed crystals (Murdoch and Fahey, 1949). Although the crystals are small, usually 1 mm in size, they occur as deep ruby-red hexagonal plates with brilliant {0001} faces associated with lavender spinel crystals in the marble. Geikielite is one of the most elusive minerals at the quarry because of its size and its occurrence in the massive marble. It can be confused with dark colored, flattened spinel octahedrons. However, spinel is usually 10 to 20 times the size of the geikielite and the color of the spinel diminishes as the crystals become smaller. Optically the spinel is isotropic with $n = 1.7–1.8$ in the magnesium-rich banded zones. The geikielite is uniaxial with indices greater than 1.95. It is found at J13, J20 and J101 where it occurs with spinel, brucite, pyrrhotite and forsterite.

**Magnesite** $MgCO_3$

Although long suspected at the Jensen quarry, magnesite was confirmed only recently. It was found at J100 in large quantities in 1969, where it occurs as 6- to 8-cm chalky white masses of intergrown nodules in dolomitic marble. X-ray powder diffraction indicates that these nodules are magnesite admixed with some dolomite. The magnesite appears to make up more than 80% of the nodules. Slickensidal surfaces through some of the magnesite give it the appearance of sepiolite.

**Spinel** $MgAl_2O_4$

Spinel is very common in the marble and occurs as small, sharp, simple octahedrons, although crude crystals to 2 cm have been found. The spinel color is variable although lilac appears to be the most common color. Deep blood-red crystals have been found in the worked-out 1035-foot level with phlogopite, graphite and tourmaline (Cooney, 1955). Green octahedrons were found at J10 and clear pink octahedrons to 5 mm are still found at J20 with pyrrhotite and forsterite. Sharp, dark blue octahedrons to 1 cm were found just south of J101 (Mel Larson, personal communication, 1982).

### *The J27 Pegmatite*

Pegmatites in and around the Jensen quarry have produced many common pegmatite minerals such as feldspars, allanite, micas, schorl, quartz and almandine. One pegmatite, located at J27, is unique among these in that it is a lithium pegmatite rich in bismuth and rare-earth elements. This pegmatite lies in a tongue of the Bonsall tonalite that has a near-vertical contact with the marble to the north and has an obscure marble contact to the south. The pegmatite strikes perpendicular to the northern contact and varies in dip from 60° W at the top of the cliff to 70° W at the bottom of the 25-meter cut. Evidence at the foot of the cut shows that the pegmatite intruded the marble.

The lower portion of the pegmatite is fine grained but has elongated blades of biotite to 4 cm near the outer edges. The pegmatite here is about 2 meters thick and becomes progressively thicker up the side of the cliff. About half-way up the cliff this pegmatite braids around a septum of the tonalite, then begins to flatten in dip. The aplitic texture changes abruptly here with the appearance of a coarse-grained central unit. This unit is composed of massive quartz, microcline and a scattering of schorl. Many vugs were found between the massive quartz and microcline; they contained euhedral crystals of quartz, microcline, schorl and albite. This main pocket zone is traceable for about 3 meters, then splits into two smaller pocket zones eventually separated by 1 to 2 meters of finer-grained pegmatite. The pegmatite in this section is about 3 meters thick. Erratic placements of thin, discontinuous, vuggy areas were found within this finer grained pegmatite and are parallel to and/or nearly perpendicular to the two main pocket zones. The sequence of crystallization within this area is difficult to determine since pockets of schorl were found centimeters from

---

*Ed. note: Coincidentally, geikielite is reported from another locality, the Jacupiranga carbonatite, elsewhere in this issue.

*Figure 15.* **Working in the upper pocket zone of the J27 pegmatite. Photo by Nick Rose.**

elbaite vugs, and both of these tourmaline occurrences had common associated minerals of cleavelandite, calcite, stilbite and sometimes stibiotantalite.

Where the pocket zone has split in two, the lower pocket zone is not as well developed as the upper and main zones and has produced very little euhedral material. Near the top of the cliff, the pegmatite narrows to 2 meters in thickness and the two smaller pocket zones converged again, forming one large altered core zone about 1 meter thick. In this area, the quartz has been leached out of the graphic granite and the potassium feldspars have become extremely corroded. Soft masses of green microcrystalline muscovite filled about half of this zone and secondary crystals of quartz were found admixed with this mica. With the exception of some needles of schorl, no tourmaline was found in this altered zone. The tourmaline-producing zones below this area were probably more extensive and better developed nearer the mined-out marble but are now gone; the remaining pocket zones pinch out abruptly southward along the strike of the pegmatite.

Collecting was done with the aid of ropes and by blocking out steps down the pegmatite. Several tons were removed by hand to obtain the few good specimens recovered. The more interesting minerals from the J27 pegmatite are described below.

**Beyerite** $(Ca,Pb)Bi_2(CO_3)_2O_2$

Beyerite occurs abundantly as yellowish smears and massive coatings on microcline and albite, and is associated with dendritic manganese oxides. It occurs much less commonly in small vugs in the feldspars as pale yellow, botryoidal groups of minute, plate-like crystals coating crystals of albite, quartz and stilbite. Beyerite is intimately associated with clinobisvanite and vanadinite. These minerals have been identified by X-ray diffraction.

Although secondary bismuth minerals have been found in this pegmatite, only one suspected primary source of bismuth has been noted. Twisted, grey, metallic hairs accompanied by straw-yellow hairs of the same character were found included in some quartz crystals. Though not yet confirmed, the grey mineral is believed to be bismuthinite intergrown with its alteration products.

**Calcite** $CaCO_3$

Calcite is quite abundant in some pockets, especially the lower pocket zone. The crystals are most commonly thin and bladed, but crude rhombs have also been found. Fractures through the pegmatite show little evidence of having served as conduits for carbonate-bearing solutions percolating from the adjacent limestone. It appears instead that the calcite formed at the very last stage of pocket crystallization, as evidenced by calcite blades included within the outer margins of some quartz crystals.

**Clinobisvanite** $BiVO_4$

Clinobisvanite occurs in cavities in microcline and albite. It is found as pale orange to deep reddish orange rosettes of plate-like crystals occurring with bright yellow needles of vanadinite, and sometimes with yellow balls of beyerite crystals. This occurrence is quite unlike the type locality in Western Australia, where the clinobisvanite was found in a beryllium-rich pegmatite and was associated with bismutite, bismutoferrite and pucherite (Bridge and Pryce, 1974). Very attractive microspecimens of reddish orange clinobisvanite rosettes perched on yellow acicular vanadinite coating albite have been found. The clinobisvanite has been identified by X-ray diffraction and verified by energy dispersive analysis. This occurrence appears to be the first known in California and possibly the United States. The find was made during the early part of 1983.

**Danburite** $CaB_2(SiO_4)$ and **Hambergite** $Be_2BO_3(OH)$

Pale green danburite was found in one pocket in the main pocket zone and consists of fragments and two partial crystals, one of which measures 6 cm across the termination. Associated with the danburite were good sharp crystals of schorl, other typical pocket

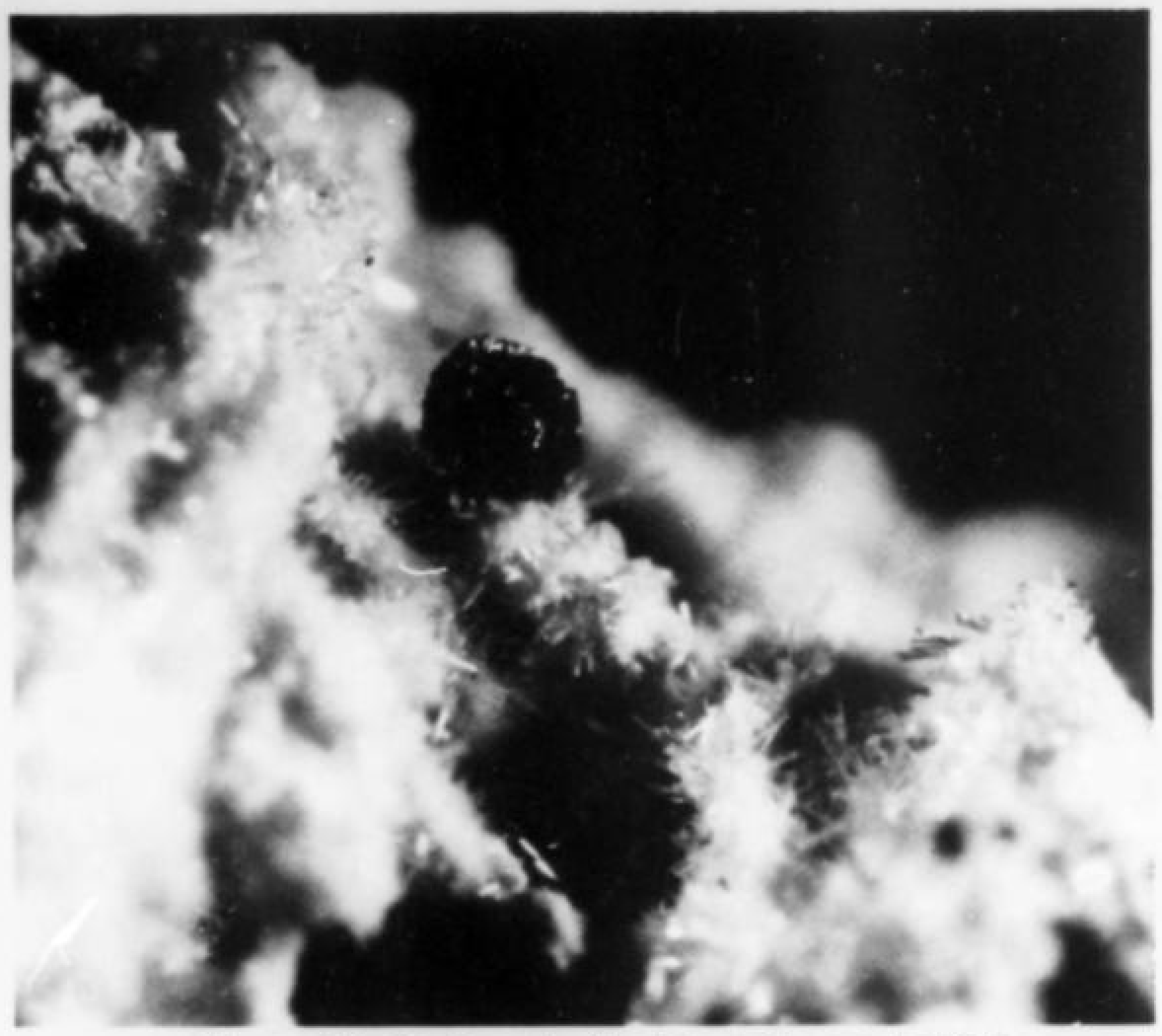


*Figure 16.* **Dark red clinobisvanite crystal 0.5 mm across on yellow vanadinite druse from the J27 pegmatite. Specimen and photo: FDV.**

*Figure 17.* **Danburite crystal 10 cm across. Specimen and photo: A.O.**

*Figure 18.* **White hambergite crystal 2.5 cm long from the J27 pegmatite. Specimen and photo: A.O.**

minerals and a small patch of hambergite. Several cleavage pieces and a few crystals of hambergite were found associated with danburite, schorl and elbaite within the main pocket zone. The crystals are porcelain white and average about 2 cm in length. The finest specimen found is a doubly terminated crystal 3 cm wide and 8 cm in length.

**Feldspars**
**Microcline** $KAlSi_3O_8$
**Albite** $NaAlSi_3O_8$

White to cream-colored microcline occurs as subhedral crystals as large as 20 cm within massive quartz and was found as sharp euhedral crystals in most of the J27 pockets. The pocket microcline is generally in the form of untwinned crystals up to 5 cm in length and shows light to moderate etching. The microcline in the altered zone has undergone extensive corrosion and was found as pumice-like remnants of larger crystals.

Albite was found as tiny prismatic crystals in the lower pocket zone and as blocky, incomplete crystals on corroded microcline in the altered zone. A pocket of albite crystals up to 8 cm in length was found close to the stilbite "bow tie" location noted here under stilbite. The variety *cleavelandite* was prominent in the tourmaline pockets as rosettes and individual bladed crystals to 2 cm across.

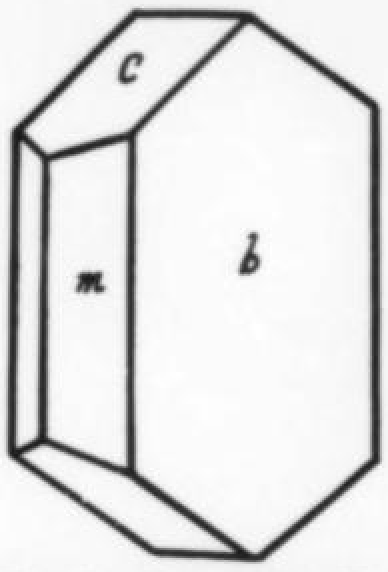


*Figure 19.* **Sketch of a hellandite crystal from the J27 pegmatite; *b*{010}, *c*{001}, *m*{110}.**

**Hellandite** $(CaY)_6(Al,Fe)Si_4B_4O_{20}(OH)_4$

Although found at several European locations and in Canada, this may be the first U.S. occurrence for hellandite. It is not uncommon at Jensen, where it occurs as blackish brown, vitreous, resinous masses to 2 cm in schorl-rich quartz and microcline pegmatite. Most of the massive hellandite has a greenish white to pale pink alteration rim which gives an X-ray diffraction pattern rich in nontronite. Very few crystals were found. They are tabular, monoclinic, and have a broad *b*{010} face and much smaller *m*{110} faces. The crystals are small, less than 5 mm, and are firmly bonded to the quartz matrix. An insufficient number of crystals have been found for a complete morphological description. Other associations include zircon, monazite, albite and manganese oxides. It is interesting to note the absence of gadolinite and the abundance of hellandite in the beryllium-deficient J27 pegmatite; an absence of gadolinite was also noted in an Italian pegmatite rich in hellandite (Gandolfi, 1966).

The Jensen quarry hellandite was identified by X-ray diffraction methods and verified with energy dispersive analysis. It was first found at the Jensen quarry in 1982.

**Micas**
**Biotite** $K(Mg,Fe)_3(Al,Fe)Si_3O_{10}(OH,F)_2$
**Muscovite** $KAl_2(Si_3Al)O_{10}(OH,F)_2$

Biotite is found as long, narrow, bronze-black crystals in the outer edges of the J27 pegmatite and as smaller, equant crystals and flakes throughout the rest of the pegmatite. Biotite did not occur within the pockets, though heavy concentrations were found nearby.

Muscovite crystals occur mainly within the pockets and as large crystalline masses within the altered zone. It is a common constit-

*Figure 20.* **Multicolored elbaite crystal 9 mm wide on quartz from the J27 pegmatite. Ordway collection.**

uent in the lower pocket zone but surprisingly rare in the other pocket units. Muscovite crystals are best developed in the altered zone. Individual crystals, and those comprising crystalline masses, are mostly microscopic in size (1–2 mm), though larger crystals to 8 mm are common within the interstices of the leached graphic granite bordering the muscovite masses. A typical mineral association with muscovite within these interstices is: albite, clear quartz crystals with red almandine inclusions and stilbite.

**Microlite** $(NaCa)_2Ta_2O_6(O,OH,F)$

Microlite and other members of the pyrochlore group occur as small octahedral crystals to 5 mm in albite and quartz. The crystals are golden-green, transparent and, in many cases, metamict. They show quartz intergrowth lines along the edges of the octahedron. Many of the pyrochlore group minerals are metamict and, although not uncommon, must be chemically evaluated and subjected to elaborate X-ray analysis for species confirmation.

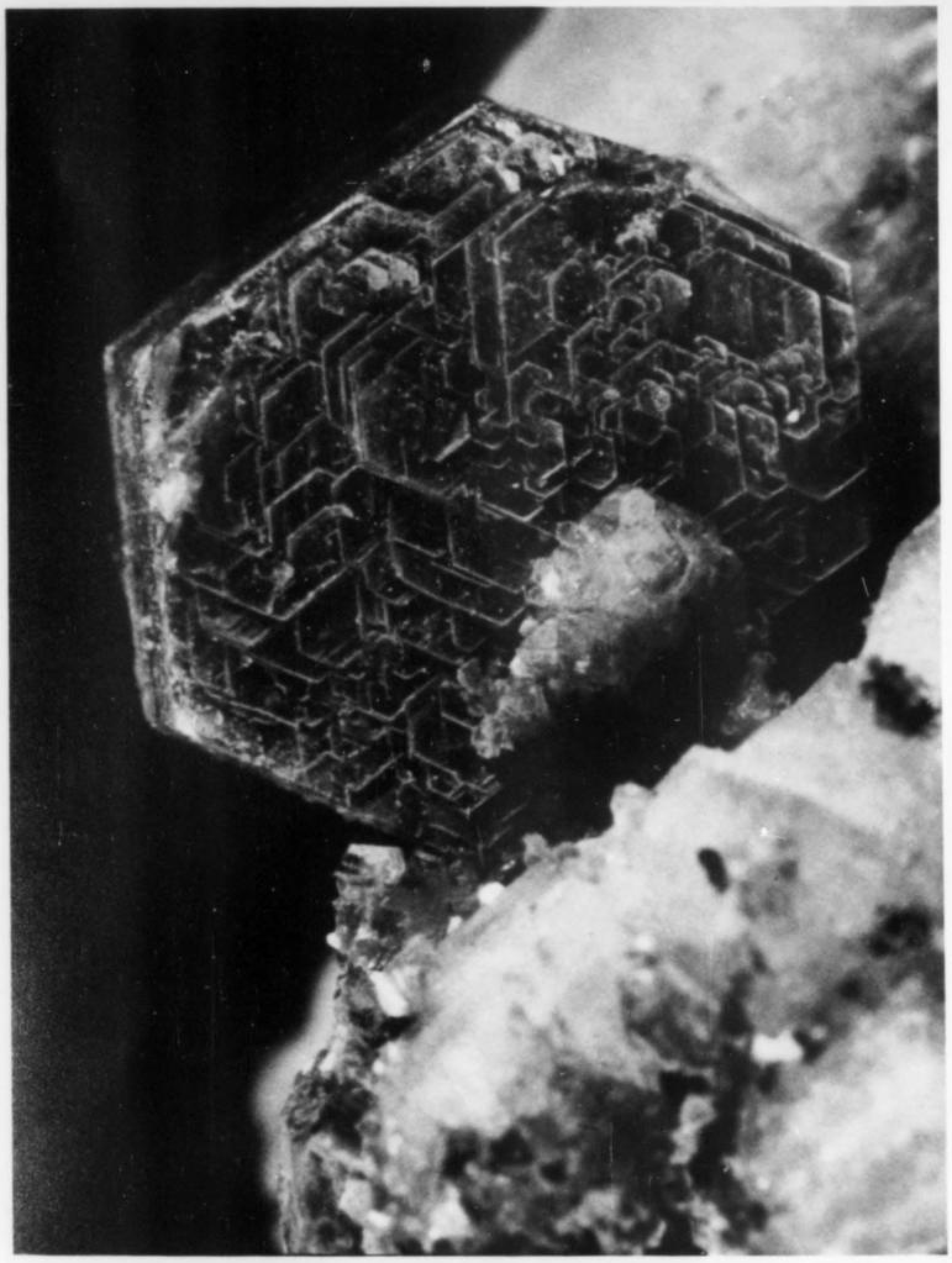


*Figure 21.* **Muscovite crystal 4 mm across on stilbite from the altered zone of the J27 pegmatite. Mike Moore specimen and photo.**

*Figure 22.* **Sketch of a monazite crystal from the J27 pegmatite;** ***a*****{100},** ***m*****{110},** ***w*****{101}.**

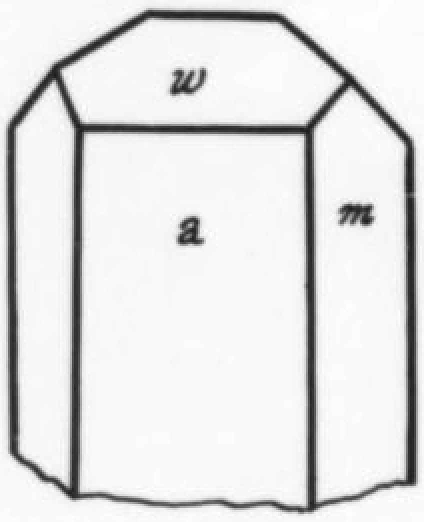


*Figure 23.* **Red-orange stibiotantalite crystals with cleavelandite from the J27 pegmatite. Mike Moore photo; A. O. specimen.**

**Monazite** $(CeLaNdTh)PO_4$

Resinous, orange, 2- to 3-mm crystals of monazite have been found in schorl and quartz. Some of the crystals are sharp, transparent and show good development of prism and termination faces. The monazite was identified by X-ray diffraction and electron microprobe analysis.

**Pyrochlore** $(NaCa)2Nb_2O_6(OH,F)$

Dark yellow-green crystals of pyrochlore have been found in gray quartz. This discovery is presently limited to a few 5-mm crystals, but more may be found as the rock is broken up by mineral collectors. Though the few found are imbedded in quartz, octahedral faces are visible. Identification was made by X-ray diffraction and electron microprobe analysis.

**Quartz** $SiO_2$

Quartz crystals have been found in all pockets and within the altered zone. The crystals are typically less than 5 cm in length and are colorless to slightly smoky. Those from the pockets have rhombohedral terminations typical of pegmatitic occurrences. The crystals found in the micaceous masses of the altered zone are characterized by long tapering prism faces and very minute pyramidal terminations.

**Stibiotantalite** $SbTaO_4$

Bright, striated, straw-yellow crystals of stibiotantalite up to 5 mm in length were a minor constituent of the main, upper and lower pocket zones. They are usually found deep in the interstices of cleavelandite blades, but have also been noted on quartz, schorl and elbaite.

*Figure 24.* **Pale peach-colored stilbite crystals on feldspar; the specimen is 5.8 cm tall. Nick Rose collection.**

**Stilbite** $NaCa_2Al_5Si_{13}O_{36}\cdot 14H_2O$

Tan-colored stilbite has been found in all pockets and in the altered zone as drusy crystals covering all other pocket minerals and their broken surfaces. Though stilbite was one of the latest minerals to form, it is covered by beyerite and/or vanadinite in some vugs. The largest crystals of stilbite are about 1 cm in length, though "bow ties" as large as 2.5 cm were found in what is believed to be a segment of the J27 pegmatite outcropping on the east side of the tonalite tongue at J102.

**Synchysite** $(CeLa)Ca(CO_3)_2F$

Small, waxy, yellow-orange, hexagonal crystals of synchysite have been found in clay-filled vugs in altered albite by Veryle Carnahan (personal communication, 1983). The crystals are bipyramidal, elongated and striated. Many show significant parting along (0001) due to alteration. The crystals occur either singly or as groups of many randomly oriented crystals in vugs. They are found near the upper part of the pegmatite and occur with schorl, almandine, albite, stilbite and muscovite. The presence of much xenotime in the pegmatite suggested that an electron microprobe determination for yttrium would be advisable to establish whether the synchysite might be synchysite-(Y), but no yttrium was found. An electron microprobe scan also showed the synchysite to be relatively pure with no bastnaesite present. This may be the first California occurrence for synchysite.

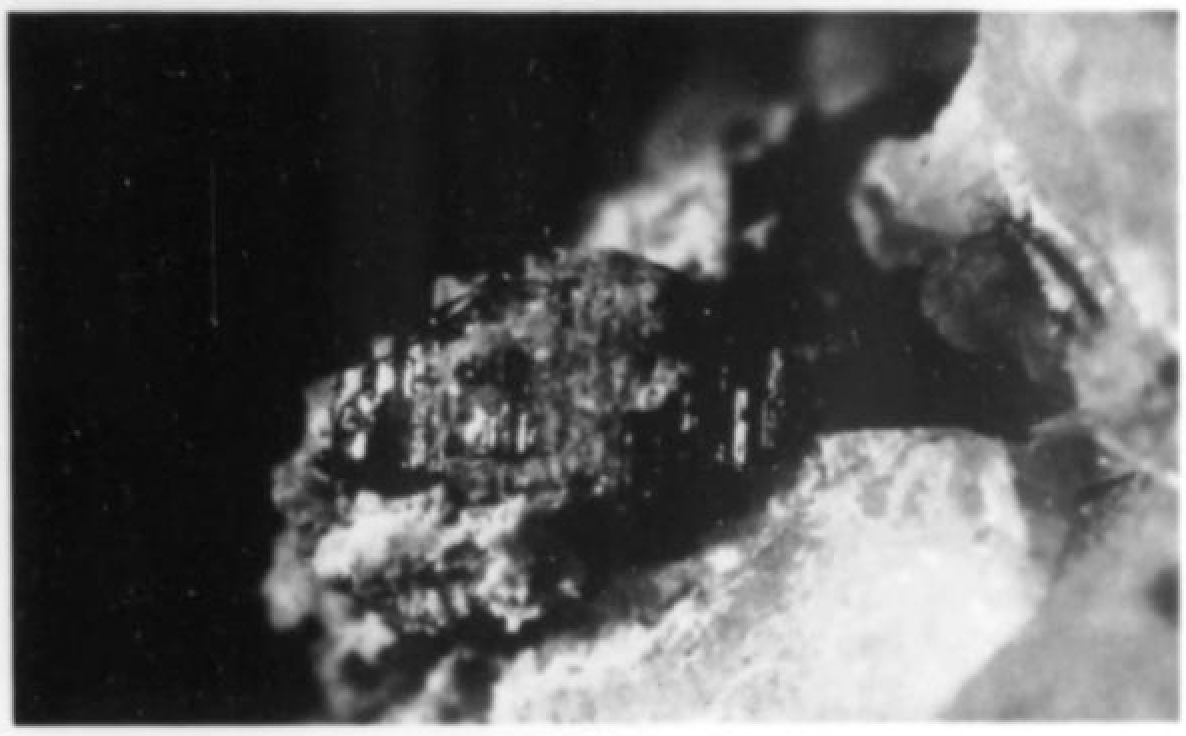


*Figure 25.* **Dark orange synchysite crystal 2 mm long on albite from the J27 pegmatite. Specimen and photo: FDV.**

### Tourmaline

**Schorl** $NaFe_3Al_6(BO_3)_3Si_6O_{18}(OH)_4$
**Elbaite** $Na(Li,Al)_3Al_6(BO_3)_3Si_6O_{18}(OH)_4$

Lustrous, euhedral crystals of schorl are common in the main and upper pocket zones. The crystals are typically 2 to 7 cm in length and are sharply terminated, with either the basal pedion or rhombohedron faces predominating. Very few schorl crystals were found still attached to matrix; most were found loose in pocket debris consisting of broken crystal fragments, kaolin and bluish clay. Tourmalines typically grow inward from the hanging wall of a pocket pegmatite, but most of these schorls protruded into the voids at low angles radiating from schorl masses beneath the pockets.

A series of vugs in the upper pocket zone contained some tourmaline in compact groups of purplish needles growing out from single bases. A small, isolated pocket of colored tourmaline was found by Nick Rose in 1982 within a section of the pegmatite that extended out the furthest from the cliff face. A series of elbaite vugs was encountered a few months later as work progressed deeper along the strike of this pegmatite. Though the vugs and the isolated pocket were separated by about 5 meters of schorl-bearing pocket pegmatite, the color zoning of the elbaite occurring in two of the vugs is identical to that seen in Rose's isolated pocket.

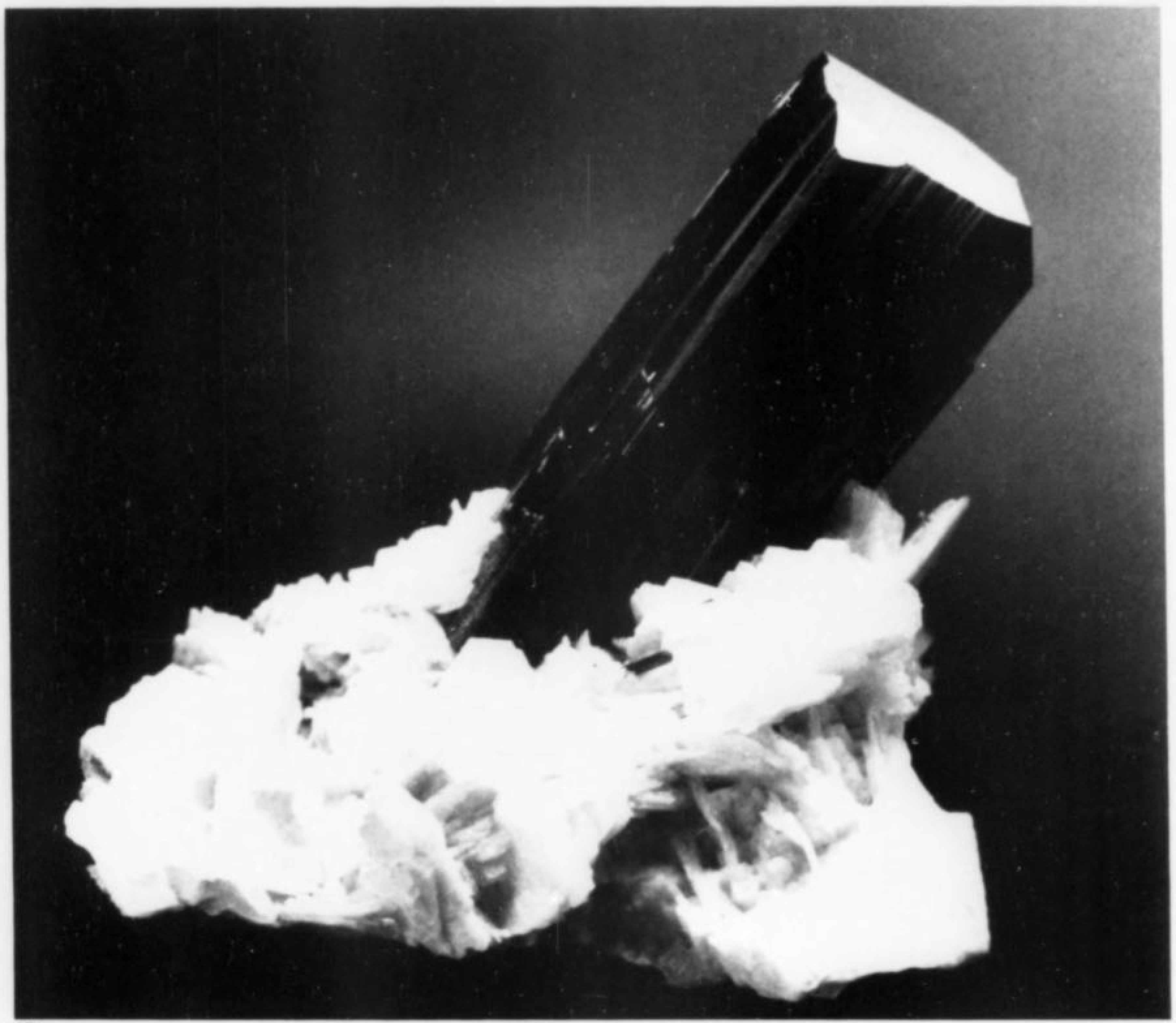


*Figure 26.* **Magnificent schorl crystal 5.8 cm long on white albite from the J27 pegmatite. Nick Rose collection.**

Very few of the lithium-bearing tourmalines were found during the mining of this pegmatite. Those that were found average less than 2 cm in length but exhibit excellent color zoning. Beginning at the base, the color zoning goes from colorless to pale pink, deep pink, orange and bright green at the pedion.

Though this pegmatite is partially encased in marble, spectrographic analysis by Eugene Foord indicates that the calcium and magnesium content of the elbaite is too low for it to be liddicoatite. However, lanthanum, tin and lead were detected in unusually large amounts (200, 150 and 700 ppm respectively).

### Vanadinite $Pb_5(VO_4)_3Cl$

Brilliant yellow, acicular crystals of vanadinite have been found coating albite and occasionally stilbite in cavities. It is intimately associated with clinobisvanite and beyerite in this unusual occurrence. Although the vanadinite, beyerite and clinobisvanite formed at approximately the same time, some specimens show the clinobisvanite on vanadinite which is covering beyerite. The vanadinite was identified by X-ray diffraction.

### Xenotime $YPO_4$

The J27 pegmatite has yielded numerous, small, pale green flattened bipyramidal crystals of xenotime in cavities with albite and schorl. Other associations include almandine, monazite and zircon.

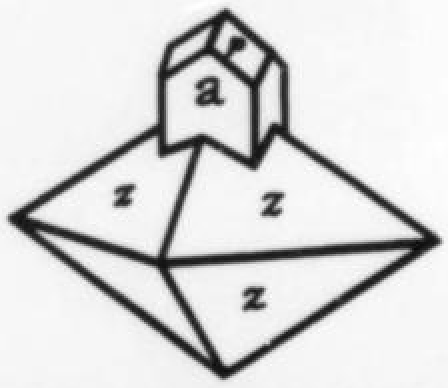


*Figure 27.* **Sketch showing epitaxial growth of a xenotime crystal around a zircon crystal; xenotime $x\{001\}$, zircon $a\{100\}$, $p\{111\}$.**

Apparently epitaxial overgrowth of xenotime on zircon crystals is relatively common at J27; the habit is very similar to that shown in Ford (1932).

### Zircon $ZrSiO_4$

Zircon is found in many of the quarry pegmatites but many small crystals were recently found in the J27 pegmatite. The crystals are

*Figure 28.* **Zircon crystal 2.5 mm long from the J27 pegmatite; note brilliant $p\{111\}$ face.**

generally smaller than 7 mm, are well developed and colored brown, amber, and rarely green. The matrix is usually quartz or feldspar and the associated minerals include xenotime, almandine and hellandite. The crystals are elongated along *c* and exhibit good terminations. Common forms are $a\{100\}$ and $p\{111\}$. In areas where there is contact with xenotime, the zircon is epitaxially overgrown by xenotime as noted above.

## CONCLUSIONS

The Jensen quarry is indeed a unique and interesting collecting site. Many minerals remain unidentified and the list of species from this quarry will certainly continue to grow. The nearby Henshaw marble quarry, the marble quarries at Riverside and the Sky Blue Hill quarries at Crestmore are subjects for later reports, but they have similar geology and mineralogy and are located within a 5-km area. Taken together, the list of species from these quarries is matched by few other localities in the world.

*Figure 29.* **Crystallization sequence of principal minerals in the J27 pegmatite (modified from Cooney, 1955).**

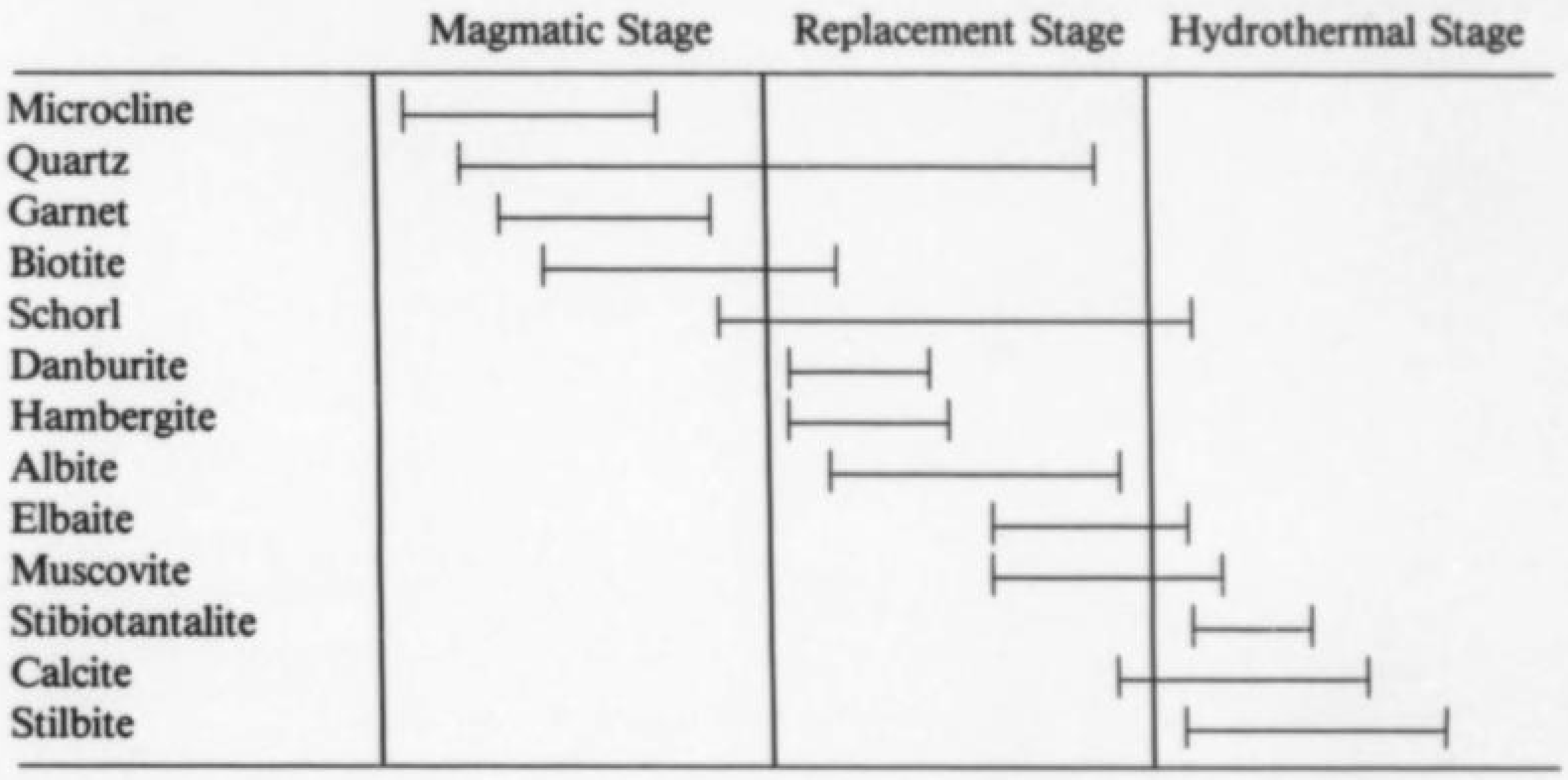


*Table 1.* **Minerals of the Jensen quarry, Riverside, California.**

| Species | Best Locations | Descriptions and references |
|---|---|---|
| Actinolite | Contacts J1, J20, J103 | Green, fibrous with clinozoisite (1). Thick crystals with axinite (3). Green blades with biotite (4). |
| Allanite | Pegmatite J70 | Black euhedral crystals to 2 cm in white feldspar (2). |
| Almandine | Pegmatite J27, J105 | Sharp red crystals in feldspars and quartz (1). Small clear red crystals in microcline (4). |
| Apatite | Contacts J85 | 5-mm colorless prisms with brucite and hydromagnesite in calcite (1). |
| Apophyllite | Contacts J24, J101 | Clear crystals on wollastonite (1). White and colorless crystals on grossular with laumontite (4). |
| Aragonite | Marble J101 | Small prismatic crystals on marble (4). |
| Arsenopyrite | Marble 1035 level | Prismatic crystals to 5 mm with brilliant $n\{101\}$ faces. Mixed sulfide association (1). |
| Augite | Tonalite and Contacts | 1-cm needles with golden titanite (1). Small crystals in tonalite (5). |
| Azurite | Contacts J70 | Deep blue coatings with malachite, schorl and diopside on contact rock (1) |
| Beryl | Pegmatite J85 | Rare; 1-cm green and blue crystals in pegmatite (1). |
| Beyerite | Pegmatite J27 | Yellow botryoidal coatings on albite and stilbite (4). |
| Biotite | Pegmatite J20, J27 | Thin blades to 8 cm in pegmatite (1). Common in many pegmatites (4). |
| Bornite | Contacts J70, 1035 | 1-cm masses with chalcopyrite (1). Small masses with ludwigite and spinel (1). |
| Brucite | Marble widespread | Pseudomorphous after octahedral periclase crystals (2, 4). Small plates to 4 mm (1). |

| Species | Best Locations | Descriptions and references |
|---|---|---|
| Calcite | Widespread<br>All zones | Good steep rhombs in marble (1). Thin wafers in pegmatite (3). Blue, green and black masses (4). |
| Chalcocite | Contacts<br>J71 | Small masses and veins with bornite, diopside and secondary copper minerals (1). |
| Chalcopyrite | Pegmatite<br>J24, 1035 | Small masses and veinlets in pegmatite (1). |
| Chlorite group | Pegmatite<br>widespread | After muscovite with marialite (1). Chlorite schist containing tourmaline (1). |
| Chondrodite | Marble<br>widespread | Yellow to orange grains and crystals with spinel and brucite in banded marble (1). |
| Chrysocolla | Pegmatite<br>J20, J70 | Blue-green coatings on chalcopyrite (1). Coating bornite (1). Coating grossular hornfels (4). |
| Clinobisvanite | Pegmatite<br>J27 | Orange crystal rosettes on vanadinite and beyerite in albite cavities (4). |
| Clinohumite | Marble<br>J104 | Sharp yellow to orange crystals with graphite in marble (4). |
| Clinozoisite | Contacts<br>J1, J20 | Pale brown to green crystals with axinite and allanite (1). Sharp, terminated, gray-green crystals (4). |
| Clintonite | Contacts<br>1035 level | Small green crystals with spinel and diopside in marble; rare (2). |
| Corundum | Contacts<br>1035 level | Lavender to pale blue grains with pink spinel, phlogopite and tourmaline (2). |
| Danburite | Pegmatite<br>J27 | Gray-green crystals to 2 cm (1). Light green crystals to 6 cm with hambergite (3). Rare. |
| Diopside | Contacts<br>J20, J30 | Green crystals to 1 cm with wollastonite and apophyllite (1). Emerald-green crystals in marble (4). |
| Dolomite | Marble<br>J10, J100 | Thin layers on Mg-marble (1). Admixed with magnesite in large nodular masses (4). |
| Dravite | Marble<br>J20 | Yellow-green masses to 2 cm in marble (1). Green needles and masses in marble near contact (4). |
| Elbaite | Pegmatite<br>J27 | Bicolored and tricolored crystals (1). 2.5-cm crystals with albite, stilbite and stibiotantalite (3). |
| Ellestadite | Marble<br>J30, 1035 | Yellow masses and grains in marble (2). 1-cm blue pods with grossular and diopside (2). |
| Epidote | Contacts<br>J1, J103 | Crystals with allanite and zircon (1). Crystals to 13 cm with axinite (3). 3.5-cm crystals with scheelite (4). |
| Ferroaxinite | Contacts<br>J103, 1035 | Pink masses with bornite (1). Large, sharp crystals with prehnite and amianthus (3). Micro crystals (4). |
| Forsterite | Marble<br>J10, J30 | Yellowish grains with spinel in banded marble (1). Colorless grains with titanite (2). |
| Galena | Marble<br>J70 | 1-cm masses in brucite marble; rare (1). |
| Gersdorffite | Marble<br>banded zone | Sharp tin-white crystals with spinel and rutile in marble (1). |
| Geikielite | Marble<br>J10, J20 | Red hexagonal plates with spinel and pyrrhotite in banded marble (1, 4, 6). |
| Goethite | Pegmatite<br>J27 | Small reddish balls of fine crystals on albite crystals (4). |
| Graphite | Marble<br>widespread | Shiny, black, hexagonal crystals to 3 mm with wollastonite (1, 2). Masses to 2 cm (4). |
| Grossular | Contacts<br>J1, J100, 1035 | Cinnamon-brown crystals to 3 cm (1, 4). Pale lavender crystals with ellestadite (1). Clear striated crystals (4). |
| Gypsum | Contacts<br>J43 | Satin spar fracture fillings in serpentine; rare (2). |
| Hambergite | Pegmatite<br>J27 | White, terminated prismatic crystals to 4 cm with danburite and schorl; rare (3). |
| Hellandite | Hellandite<br>J27 | Brown, resinous, vitreous masses to 2 cm in microcline; crystals rare (4). |
| Hornblende | Tonalite<br>J50 | Small crystals and cleavage masses in tonalite with augite; rare (1). |
| Hydromagnesite | Marble<br>J24, J101 | Thin, bladed crystals on marble (1, 5). Radiating masses on Mg-marble (4). |
| Kaolinite | Pegmatite<br>J27 | Soft, white masses in albite vugs (1). |
| Laumontite | Contacts<br>J85, J101 | Masses with zoisite in pegmatite (1). Small, sharp crystals with prehnite and grossular in contact (4). |
| Ludwigite | Marble<br>J24 | Small, black prisms in calcite near contact zones; rare (1). |
| Magnesite | Marble<br>J100 | White, chalky nodules to 6 cm admixed with dolomite in Mg-marble (4). |
| Magnetite | Marble<br>banded zone | Small, perfect octahedrons in marble; rare (1). |
| Malachite | Contacts<br>J70 | Thin crusts and tuffs on fine crystals with azurite and tourmaline; rare (1). |
| Marialite | Contacts<br>J10, J50 | Very sharp crystals with pyrrhotite (1). Small, terminated crystals with diopside and titanite (1). |
| Microcline | Pegmatite<br>J27, J70, J85 | Well formed crystals to 5 cm in cavities (3). Intergrown crystal masses to several meters across (3). |
| Microlite | Pegmatite<br>J27 | Small, clear, golden-green octahedral crystals in quartz and albite (4). |
| Monazite | Pegmatite<br>J27 | Small, sharp, resinous orange crystals with schorl and quartz in albite (4). |
| Monticellite | Marble<br>1035 level | Brown, granular masses to 6 cm with pyrrhotite and chalcopyrite (2). |
| Muscovite | Pegmatite<br>J27, J70 | Masses with pink zoisite (1). Small sharp pseudo-hexagonal crystals with albite and stilbite (3, 4). |
| Nontronite | Pegmatite<br>J27 | Pale green alteration rims around hellandite masses in microcline and quartz (4). |
| Opal | Contacts<br>J27, J85<br>J101 | Colorless, botryoidal hyalite in pegmatite (1). Coating laumontite and axinite in contacts (4). |

| Species | Best Locations | Descriptions and references |
|---|---|---|
| Orthoclase | Pegmatite<br>J27 | Cream-colored crystals usually showing some corrosion (1). |
| Pargasite | Contacts<br>J100 | Sharp, brown, prismatic crystals to 8 cm with graphite and phlogopite in calcite (4). |
| Periclase | Marble<br>J20, J30 | Brucite replacement very common. Residual periclase clear with cubic cleavage; rare (1, 4). |
| Phlogopite | Marble<br>J30, J100, J101 | Small, excellent crystals near J30 (2). Large golden crystals to 6 cm with spinel near contact (4). |
| Plagioclase | Pegmatite<br>J27, J85, J102 | Andesine (1). Oligoclase (2). Stubby albite crystals with schorl and thin bladed cleavelandite (3). |
| Prehnite | Contacts<br>J101, J103 | Small, sharp crystals with axinite (3). Sharp barrel crystals with laumontite and grossular (4). |
| Pyrite | Pegmatite<br>Widespread | Common in pegmatites as well as contact zones. Most pyrite replaced by limonite (1, 5). |
| Pyrochlore | Pegmatite<br>J27 | Dark yellow-green cubic crystals and small masses in quartz (4). |
| Pyrrhotite | Marble<br>J10, J50, J101 | Masses to 3 cm and flat hexagonal crystals with forsterite (1). Masses with pargasite and graphite (4). |
| Quartz | Pegmatite<br>J27, J70, J101 | 5-cm colorless and smoky crystals in pegmatite and contacts (3). Drusy crystals on 6-cm-thick chalcedony (4). |
| Rutile | Marble<br>J50, 1035 | Small, prismatic crystals and cyclic twins with corundum and occasionally stibnite (2). |
| Scheelite | Contacts<br>J1 | 1-cm crystals with grossular (3). Small, white crystals in epidote cavities (4). |
| Schorl | Pegmatite<br>J27, J50 | Brilliant, black, terminated crystals to 7 cm in cavities with feldspars (1, 3, 4) |
| Serpentine group | Contacts<br>J50, J101 | Green fibrous vein fillings (1). 5-cm-thick seams with chalcedony in marble (4). |
| Sphalerite | Marble<br>1035 level | Small crystals to 5 mm with other sulfides in calcite (2). Amber-colored grains with monticellite (2). |
| Spinel | Marble<br>J20, J30, 1035 | Pink, octahedral crystals to 2 cm with tourmaline and phlogopite (1). Red-violet crystals to 5 mm in calcite (4), |
| Stibiotantalite | Pegmatite<br>J27 | Straw-yellow, prismatic, adamantine crystals in cavities with schorl and stilbite (3, 4). |
| Stibnite | Marble<br>1035 level | Tarnished blades with pyrrhotite (1). Fan-shaped aggregates with spinel and chalcopyrite (1). |
| Stilbite | Pegmatite<br>J27, J102 | Pale brown sheaves common (1, 3, 4). Clear epidesmine with laumontite and prehnite (4). |
| Synchysite | Pegmatite<br>J27 | Yellow, waxy, bipyramidal crystals with stilbite, albite and muscovite in clay-filled vugs (4). |
| Talc | Pegmatite<br>J27 | Late-forming, pale yellow masses to 4 cm in albite cavities (1). |
| Titanite | Contacts<br>J20, J70, J103 | Perfect crystals with allanite and zircon (1). Peach-colored with actinolite (3). Crystals to 4 cm (4). |
| Tremolite | Marble<br>1035 level | Near contacts, elongated green crystals with corundum (2). Terminated crystals with sphalerite (2). |
| Vanadinite | Pegmatite<br>J27 | Bright yellow, acicular crystals with clinobisvanite and beyerite in albite cavities (4). |
| Vesuvianite | Marble<br>1035 level | Near contacts, yellow grains to 5 mm with spinel, rutile and corundum in marble (1). |
| Wollastonite | Contacts<br>J20, J30 | Near contacts, terminated, colorless, 5-mm crystals (1). Bladed crystals (1). Phosphorescent, saccharoidal (4). |
| Xenotime | Pegmatite<br>J27, 1035 | Small crystals with marialite (2). Green, bipyramidal crystals with zircon in albite (4). |
| Zircon | Pegmatite<br>J27, J50, 1035 | Crystals in marble with corundum (1). Elongated brown crystals with xenotime in albite (4). |
| Zoisite | Pegmatite<br>J85 | Small, pink needles of thulite with white laumontite in granite pegmatite (1). |

---

(1) Cooney, 1955
(2) Murdoch; reported by Cooney, 1955
(3) Found by Ordway
(4) Found by DeVito
(5) MacKevett, 1951
(6) Murdoch and Fahey, 1949

The following species have been reported from the Jensen quarry but confirmation is needed: Antigorite, Bismuthinite, Cassiterite, Chrysotile, Clinochlore, Datolite, Fergusonite, Hydrogrossular, Hydrotroilite, Lepidolite, Manganaxinite, Manganite, Plumbomicrolite, Pyrolusite, Sillimanite, Spessartine, Tenorite.

## ACKNOWLEDGMENTS

This report would have lost much of its scope and magnitude were it not for considerable help from William Wise, who gave much of his valuable time determining many of the species new to the Jensen quarry and to the state of California. His valuable suggestions and his help with the analytical work, photographs and manuscript review will always be appreciated.

Our thanks also go to John Sinkankas and Eugene Foord for the identification of hambergite; Eugene Foord again for the identification of stibiotantalite and for his help in reviewing this article; Anthony Kampf for his identification of the unusual titanite crystals; Ruth Kirkby for the stilbite find at J102; and to collectors Bill Fuko, Millard Maynard, Jack Nieburger and Joe Lavook for their contributions. We are especially grateful to Nick Rose for his work and observations while mining the J27 pegmatite and to Mike Moore and Wendell Wilson for their fine specimen photography.

Finally, our thanks to the Riverside Cement Company for allowing us to enter their property and collect specimens and data for this report.

## REFERENCES

BRIDGE, P., and PRYCE, M. (1974) Clinobisvanite, monoclinic $BiVO_4$, a new mineral from Yinnietharra, Western Australia. *Mineralogical Magazine,* 39, 847–849.

COONEY, R. (1955) *The Mineralogy of the Jensen and Henshaw Quarries near Riverside, California.* Masters thesis. University of California at Los Angeles, 59 p.

FOORD, E. E. (1977) The Himalaya dike system, Mesa Grande district, San Diego County, California. *Mineralogical Record,* **8**, 461–474.

FORD, W. E. (1932) *Dana's Textbook of Mineralogy.* Fourth edition, p. 195. John Wiley and Sons, New York.

GANDOLFI, G. (1966) Distribution and significance of heavy metals of Predazzo Granite (North Italy). *Mineralog. Petrog. Acta,* **12**, 215–238.

MACKEVETT, E. (1951) Geology of the Jurupa Mountains, San Bernardino and Riverside Counties, California. *California Division of Mines and Geology Special Report 5,* 14 p.

MURDOCH, J., and FAHEY, J. J. (1949) Geikielite, a new find from California. *American Mineralogist,* **34**, 835–838.

POHL, D., GUILLEMETTE, R., SHIGLEY, J., and DUNNING, G. (1982) Ferroaxinite from New Melones Lake, Calaveras County, California. *Mineralogical Record,* **13**, 293–302.

WILLIAMS H., TURNER, F., and GILBERT, C. (1954) *Petrography.* 406 p. Freeman & Co., San Francisco.

---

---

---

---

**RIVISTA MINERALOGICA ITALIANA**
3 - 1983

**Rivista Mineralogica Italiana**
Museo Civico di Storia Naturale
C.so Venezia 55
20121 MILANO, ITALY

**Keep informed** on new finds and research on Italian and other European localities through this quarterly magazine devoted entirely to mineralogy.

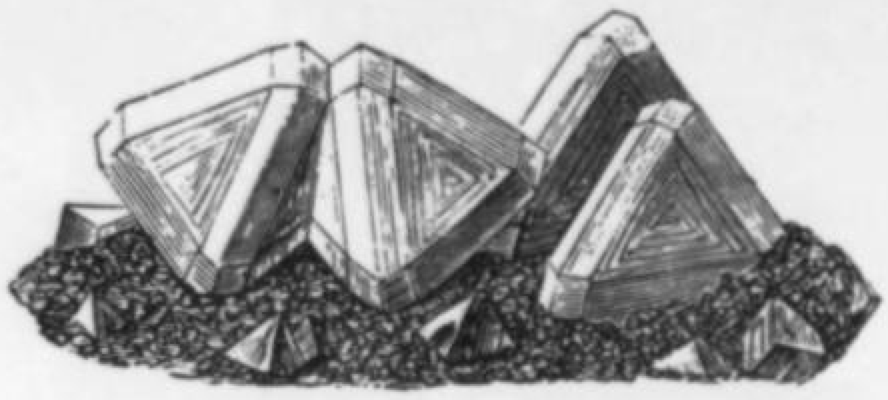
Subscription rate: 15 US $ for one year,, surface mail postpaid.
R.M.I. publications available (in Italian):
- Val Codera Mineralogical Routes: 14 US $.
- Minerals in the Carrara Marble: 11 US $.
- The minerals of Franklin & Sterling Hill: 9 US $.

The Society welcomes as members individuals who are interested in mineralogy, crystallography, petrology, or related sciences. Membership applications can be obtained from the business office at the address below. Membership is for the calendar year, and the annual dues are $20 for all except students, who pay only $6.

**The American Mineralogist** is a bimonthly, technical publication of the Society and emphasizes the latest scientific aspects of modern mineralogy, crystallography, and petrology. A price list for other publications of the Society may be obtained from the business office.

**Mineralogical Society of America**
2000 Florida Avenue N.W.
Washington, D.C. 20009
Telephone: (202) 462-6913

**Abel Minerals**



*Tetrahedrite · Cornwall · 1864*

Fine worldwide specimens. Showroom by appointment only. See us each year at the Denver Satellite Show (Hol. Inn) and Tucson Show (Desert Inn-247). Write or call for list.

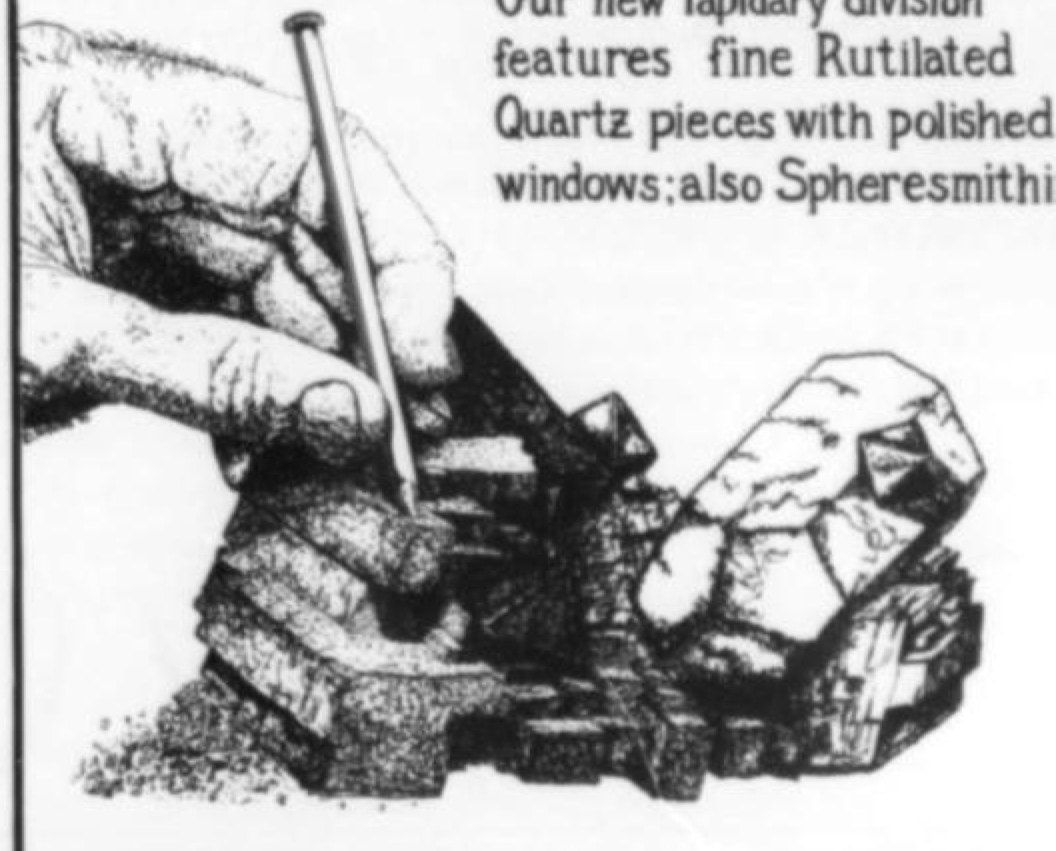
Mitch & Barb Abel
P.O. Box 440356, Aurora,
Colorado 80044 – (303) 695-7600

**JIM'S GEMS, INC.**

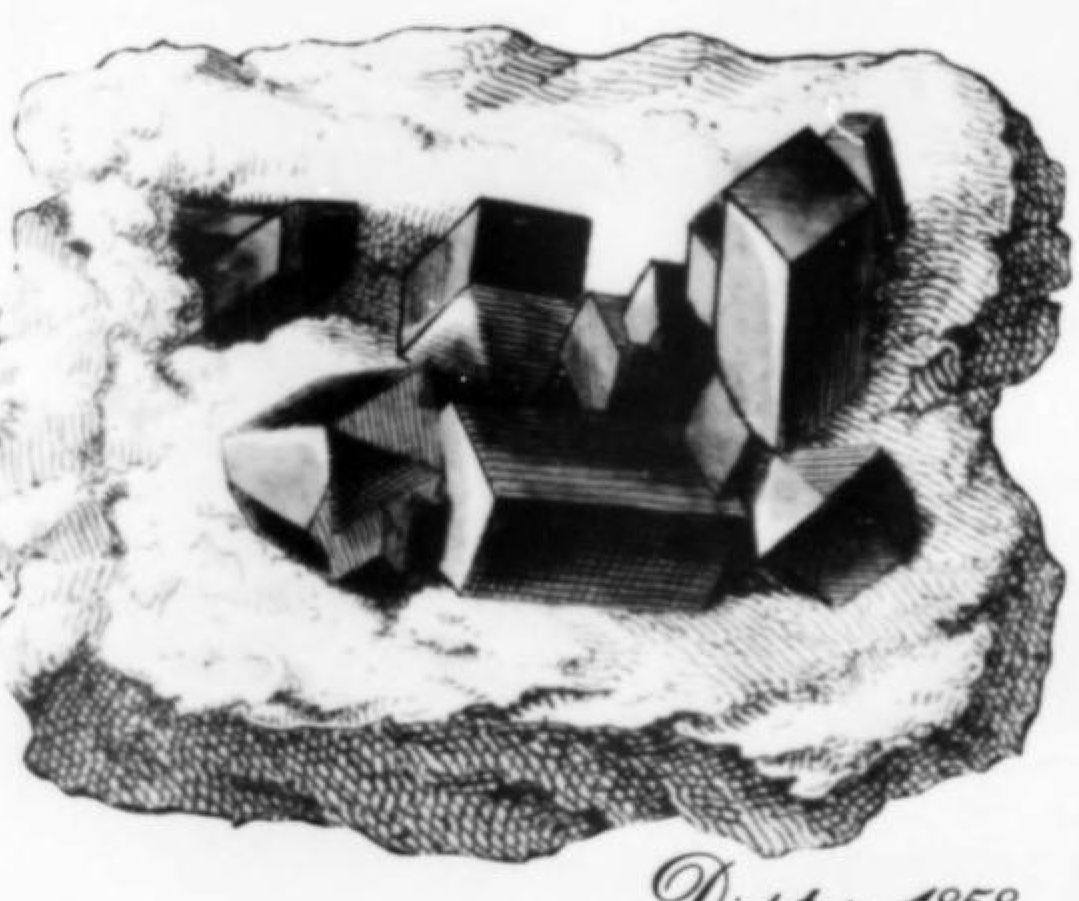
***Always trying to uncover NEW THINGS***

Franklin-Sterling Hill mines well represented in our stock of fine minerals and fossils

Our new lapidary division features fine Rutilated Quartz pieces with polished windows; also Spheresmithing



**1581 Rt. 23, Wayne, N.J. 07470 (201) 628-0277**



# *Secondary Uranium Minerals of the*

# CUNHA BAIXA MINE

**R. Vochten** and **M. Van Doorselaer**
Laboratory for Chemical and Physical Mineralogy
University of Antwerp
Middelheimlaan 2, B-2020 Antwerp, Belgium

***A number of secondary uranium deposits have been discovered recently in Portugal's Sierra da Estrel Mountains. One of these, the Cunha Baixa mine, has yielded a variety of fine specimens of uranyl phosphates including the largest known crystals of saleeite.***

## INTRODUCTION

The geological evolution of the Iberian Peninsula has given rise to some very important ore deposits in Spain and Portugal. The northern and central parts of Portugal are well known for wolframite and cassiterite orebodies. At Carthagena, in the southern part of Spain, galena has been mined for its high silver content since ancient times. The exploitation of these mines continues even today. Almaden, a small town in central Spain, is known throughout the world for its high-grade mercury ore, consisting primarily of cinnabar and native mercury. Other ores, including sphalerite and pyrite, are found abundantly in the region of Picos de Europe in northern Spain and in Rio Tinto, Huelva, in southern Spain. More recently, uranium-bearing granites were discovered both in Spain and in Portugal.

The main uranium-bearing region of the Iberian Peninsula is dominated by the northeast-southwest trending Sierra da Estrel mountain range. The range is geographically situated within and towards the western side of the Iberian Meseta, which consists mainly of Hercynian granites with a southeast-southwest orientation (Geffroy and Sarcia, 1954). The most important uranium deposits accordingly are situated in the north-central and southeastern parts of Portugal, namely in the provinces of Beira Litoral, Beira Baixa and Beira Alta.

In 1980, we had the opportunity to visit the open pit mine at Cunha Baixa* in the province of Beira Alta. Samples were collected which contain the various uranium minerals representative of the paragenesis. These samples were more closely examined in the laboratory where chemical and mineralogical analyses were performed.

## PARAGENESIS

At the Cunha Baixa mine only the oxidation zone of the deposit is mined. Secondary uranium minerals belonging to the uranyl phosphate series are the principal ore minerals. They formed from primary pitchblende, either by direct oxidation and hydrothermal alteration *in situ,* or at various distances from the orebody after migration of the very soluble and mobile uranyl ion.

In addition to the finely disseminated primary ore, the following secondary minerals have been found: torbernite, metatorbernite, meta-autunite, saleeite and phosphuranylite. This assemblage is not unique to Cunha Baixa, but is also characteristic of most uranium deposits in the region. The large and fully hydrated crystals of saleeite, however, are quire remarkable and possibly unique to this deposit.

The occurrence of marcasite pseudomorphs after pyrrhotite is characteristic at Cunha Baixa, and most of the secondary uranium minerals are associated with this iron mineral. According to Ramdohr and Strunz (1978), this pseudomorphism is very common; due to variations of pH and temperature of the mineralizing solutions, pyrrhotite may become thermodynamically unstable and transform into the more stable marcasite phase.

The marcasite matrix shows many cracks and holes, which are the preferred sites for crystallization of the uranium minerals from circulating solutions.

## MINERALOGY

In the set of samples we collected, torbernite, metatorbernite and meta-autunite were easily recognized. Other crystals, however, show rather uncommon morphologies; these were examined by X-ray diffraction.

---

* Pronounced "Coon-ya By-cha."

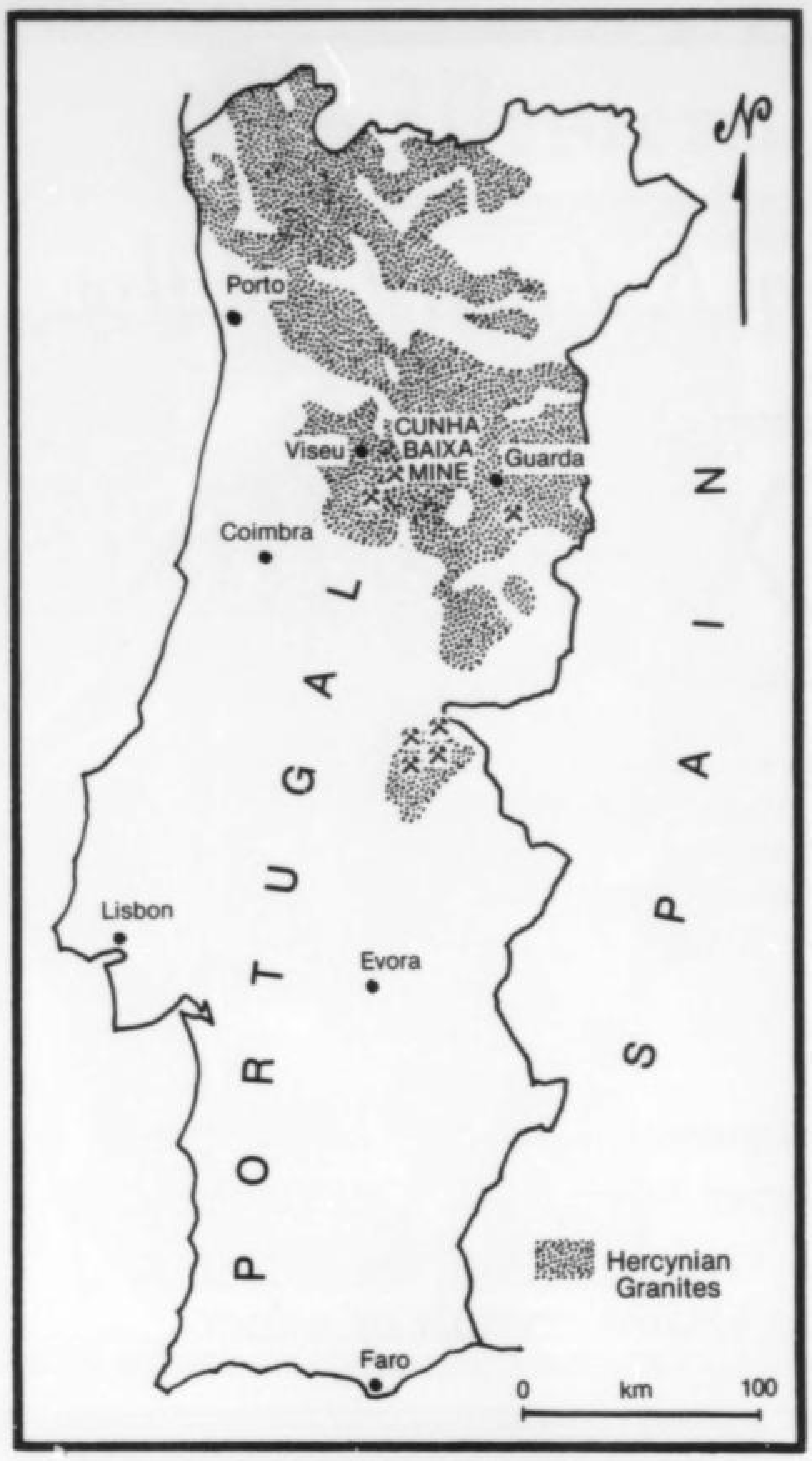


*Figure 1.* **Location of the most important uranium deposits in Portugal.**

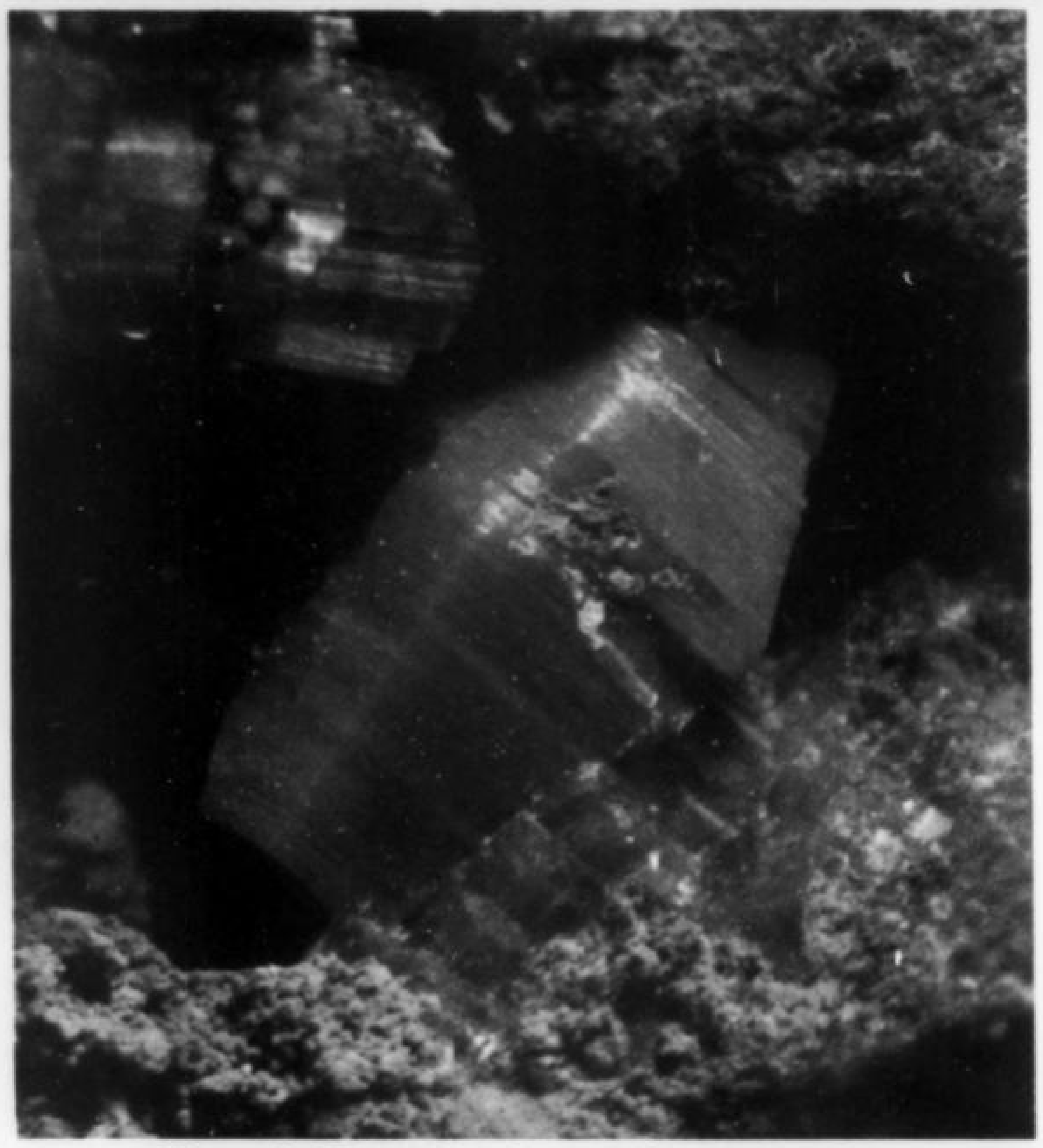


*Figure 2.* **Metatorbernite pseudomorphs after torbernite, 4 mm tall, from Cunha Baixa. Vochten collection.**

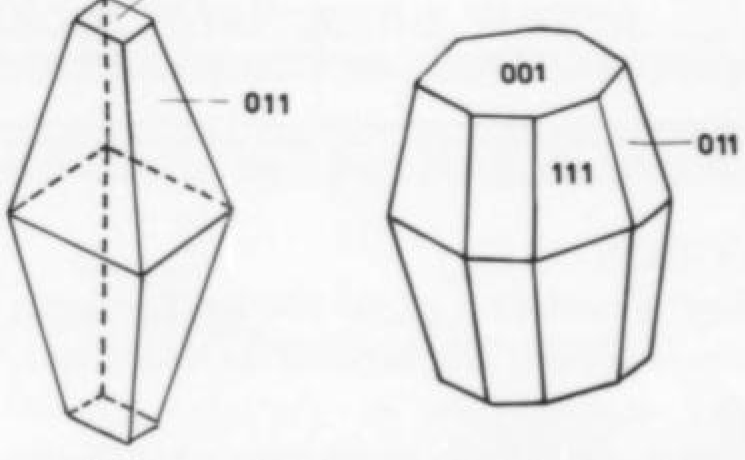


*Figure 4.* **Bipyramidal crystal habit of torbernite and metatorbernite from Cunha Baixa.**

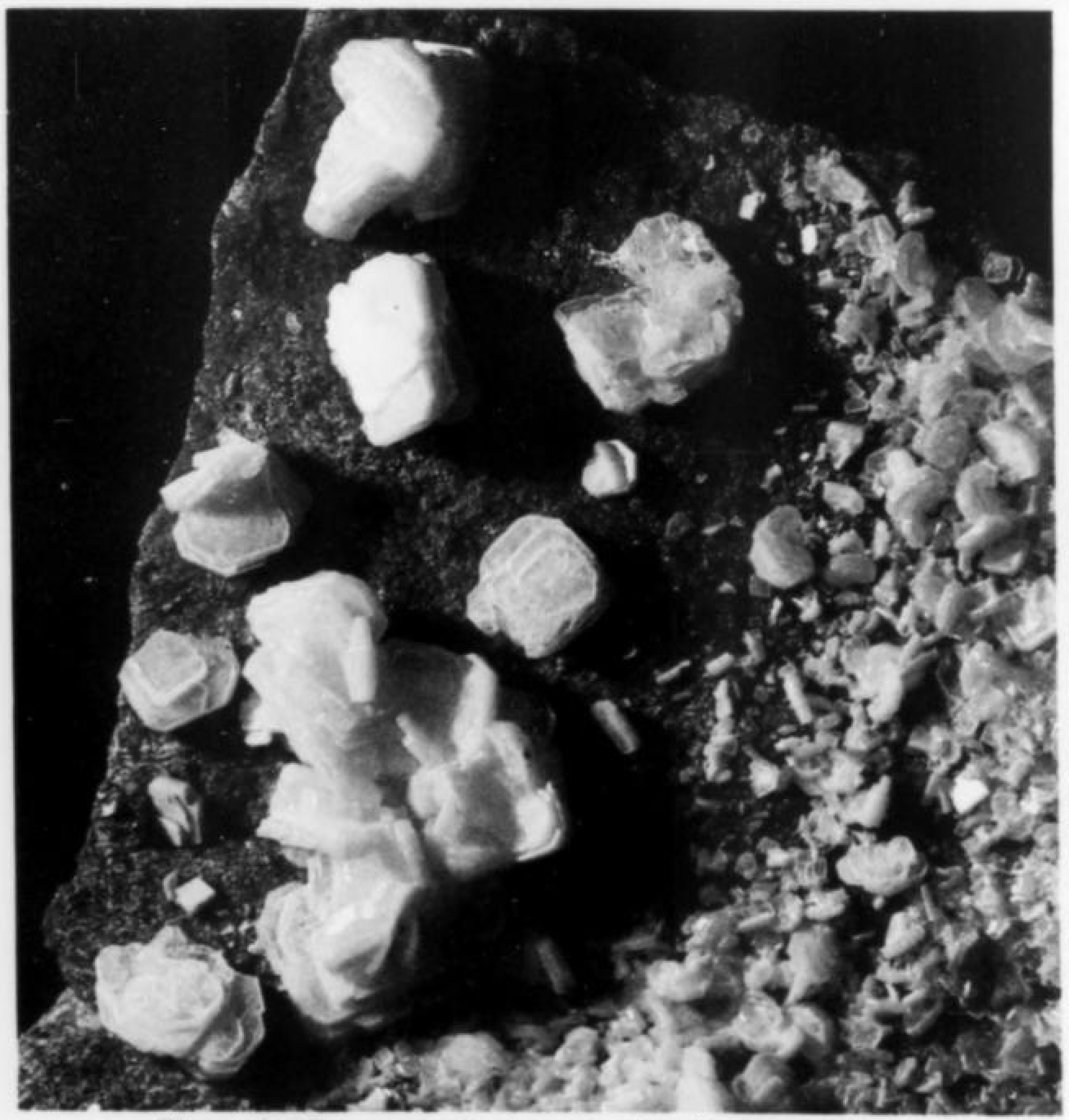


*Figure 3.* **Meta-autunite crystals, 4 to 8 mm, on matrix from Cunha Baixa. Vochten collection.**

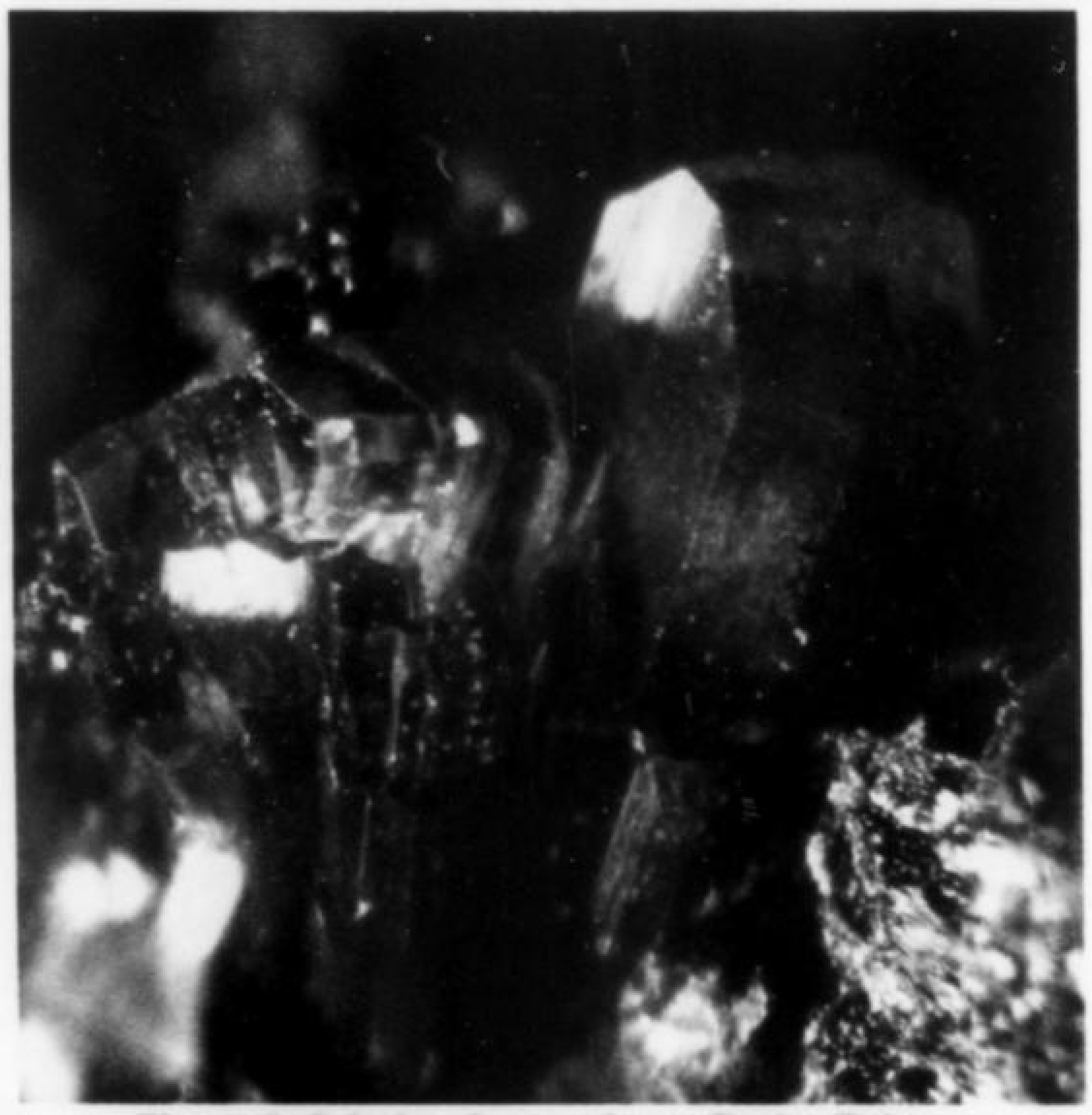


*Figure 5.* **Saleeite, 8 mm, from Cunha Baixa. Vochten collection.**

*Figure 6.* **Meta-autunite crystals to 8 mm from Cunha Baixa. Vochten collection. Note subparallel growths which are characteristic of minerals in the uranyl phosphate series.**

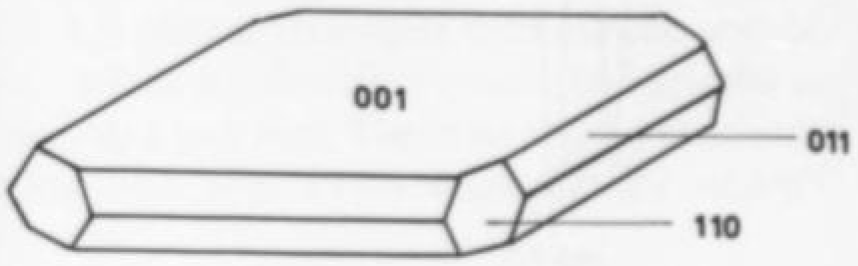


*Figure 7.* **Crystal habit of meta-autunite from Cunha Baixa, with corners truncated by the form {110}.**

*Figure 8.* **Crystal habit of tabular saleeite from Cunha Baixa, defined by the forms {001}, {012} and {112}.**

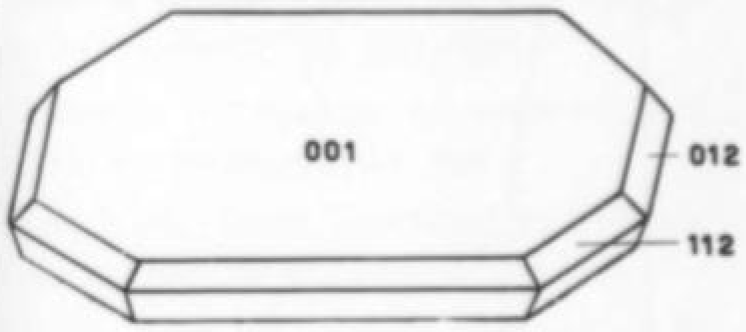


*Figure 9.* **Saleeite crystal, 8 mm, from Cunha Baixa, showing a color transition from yellow-green to grass-green. Vochten collection.**

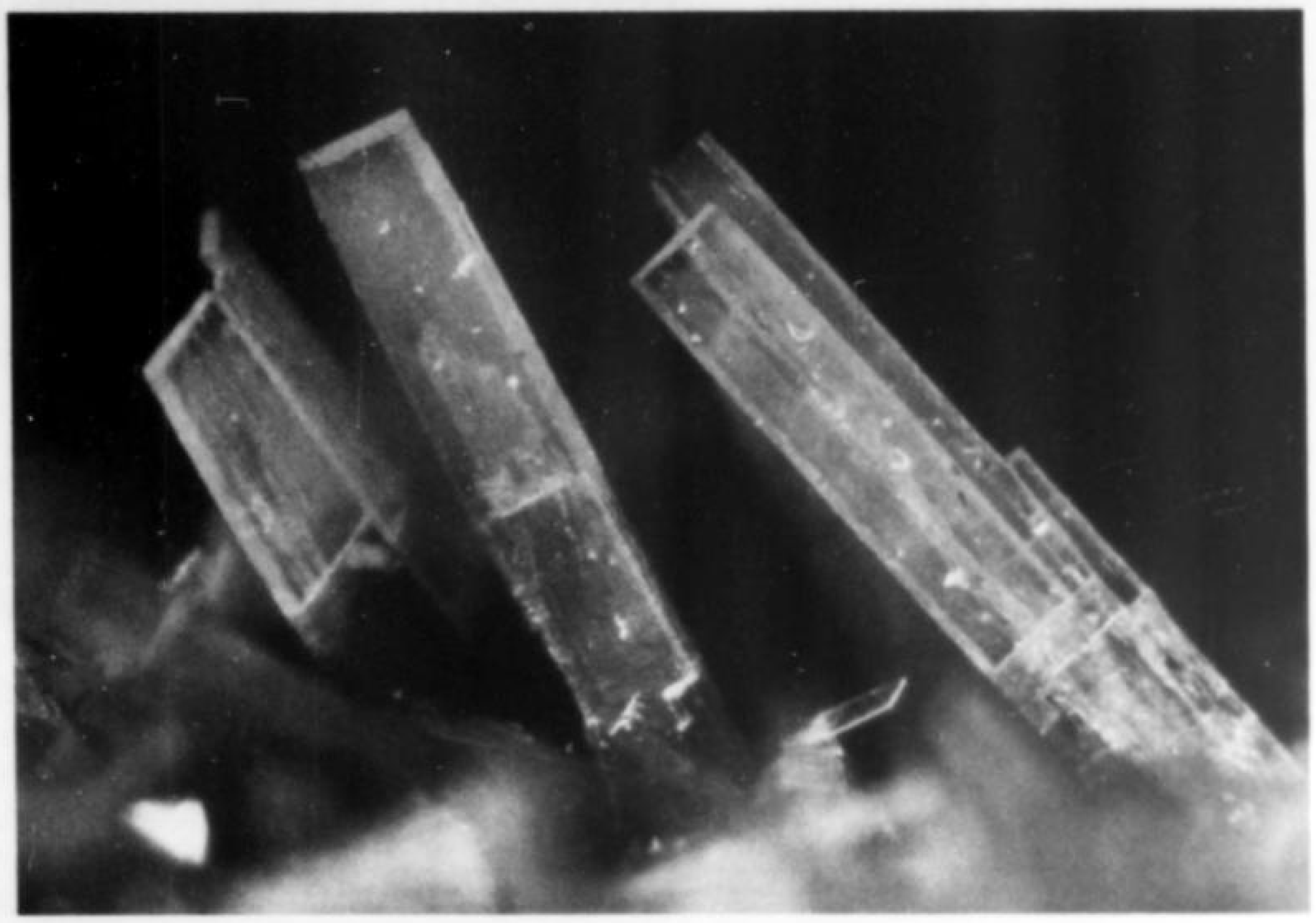


*Figure 10.* **Phosphuranylite crystals, 1 to 2 mm, from Cunha Baixa. Vochten collection.**

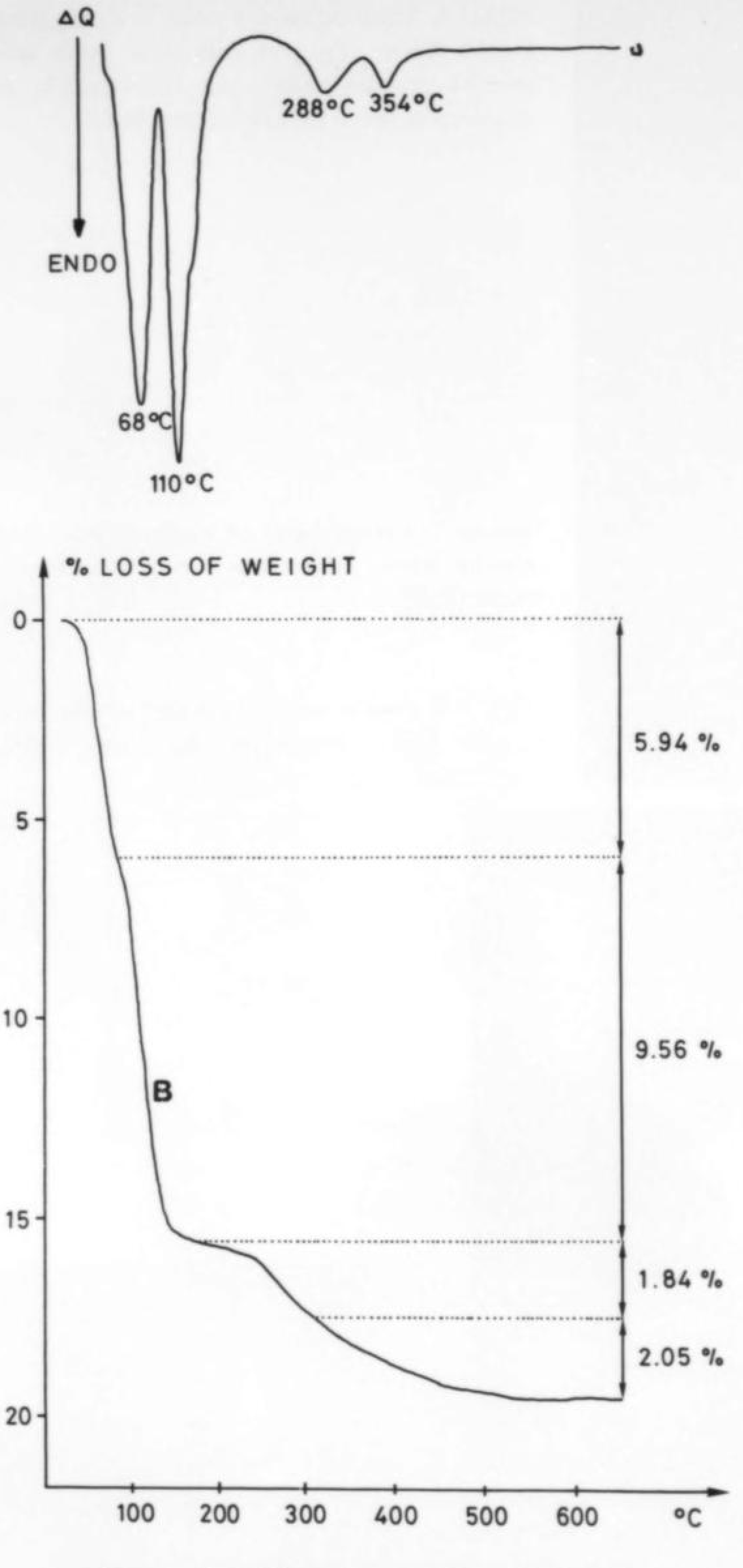


***Figure 11.*** **Differential scanning calorimetric curve (A) and thermogravimetric curve (B) of saleeite from Cunha Baixa.**

***Table 1.*** **Chemical analysis and crystal-chemical formula of saleeite from Cunha Baixa.**

| | Weight % | Atomic ratio (anion) | Atomic ratio (cation) | coefficient |
|---|---|---|---|---|
| MgO | 4.43 | 1099 | 1099 | 1.03 |
| $UO_3$ | 61.72 | 2158 | 6474 | 2.02 |
| $P_2O_5$ | 14.87 | 2095 | 5238 | 1.96 |
| $H_2O$ | 19.39 | | | 10.05 |
| Total | 100.41 | | | |
| Crystal-chemical formula | $Mg_{1.03}(UO_2)_{2.02}(PO_4)_{1.96} \cdot 10.05H_2O$ | | | |

X-ray diffraction data were obtained at 40kV and 20mA, using copper radiation ($CuK\alpha_1$ = 1.5406Å) and a high-resolution Guinier-Hägg camera (diameter 100 mm). In order to obtain $d_{hkl}$ values with a precision of ±0.0005Å, silicon powder (X-ray diffraction standard, NBS-640) was used for internal calibration. The relative intensities of the diffraction lines were measured by means of a Carl Zeiss Jena MD-100 microdensitometer.

Because saleeite can exist in several hydration states, a thermogravimetric study was performed on this mineral in order to calculate the exact chemical composition. This study was carried out with a Du Pont TGA-951 and DSC-910 apparatus.

**Torbernite** $Cu(UO_2)_2(PO_4)_2 \cdot 8\text{–}12H_2O$
**Metatorbernite** $Cu(UO)_2)_2(PO_4)_2 \cdot 8H_2O$

Torbernite with $12H_2O$ is the fully hydrated modification of copper uranyl phosphate, occurring as grass-green crystals. When torbernite crystals are exposed to a relatively dry atmosphere, they rapidly lose some of their water molecules, thereby transforming into metatorbernite with only eight molecules of water instead of the original twelve. During this transformation, the vitreous luster of torbernite from this locality turns dull, and the transformed crystals become turbid and cracked.

At Cunha Baixa, both torbernite and metatorbernite occur as crystals from 1 to 4 mm in size. The habit is definitely bipyramidal, in some cases showing both first and second-order bipyramids. The latter habit is well known from localities in the Cornwall region. Both habits are terminated by small faces {001}. However, the tabular habit, which is most common for torbernite and metatorbernite at other localities, does not occur at Cunha Baixa.

**Meta-autunite** $Ca(UO_2)_2(PO_4)_2 \cdot 2\text{–}6H_2O$

Autunite, the calcium analog of torbernite, transforms to meta-autunite as a result of dehydration. To date, only meta-autunite has been found at Cunha Baixa. Crystal size ranges from 4 to 8 mm.

According to Frondel (1953), the crystal habit of autunite and meta-autunite is generally tabular with a rectangular outline or, less commonly, with an octagonal outline. The rectangular outline of these crystals is defined by the form {011} and {001}, with the corners truncated by the form {110}.

**Saleeite** $Mg(UO_2)_2(PO_4)_2 \cdot 10H_2O$

Saleeite has been described from a number of different localities. From the analyses given by Thoreau and Vaes (1932), the crystal-chemical formula of saleeite from Shinkolobwe, Shaba, Zaïre, is $Mg(UO_2)_2(PO_4)_2 \cdot 8.4(?)H_2O$.

Frondel (1951) examined specimens from the Mina da Quarta Feira, Sabugal County, Beira Alta Province, Portugal, and calculated their chemical formula as $Mg(UO_2)_2(PO_4)_2 \cdot 9H_2O$. These specimens were contaminated with 0.21% PbO and 0.37% $Al_2O_3$.

Recently, Piret and Deliens (1980) made a thorough study of saleeite from Shinkolobwe and determined the crystal-chemical composition of the fully hydrated phase to correspond to $Mg(UO_2)_2(PO_4)_2 \cdot 10(?)H_2O$. They also pointed out that saleeite can occur in different dehydration stages, or even as mixtures of fully hydrated and partially dehydrated modifications, resulting in variable X-ray diffraction data. Therefore, differential scanning calorimetric (DSC) and thermogravimetric (TGA) data are necessary.

The TGA curve of saleeite from Cunha Baixa indicates a total loss of water corresponding to 19.39%, which is equivalent to 10 moles of $H_2O$. This means that saleeite from Cunha Baixa can be identified as the fully hydrated phase. The DSC curve and the TGA curve suggest the following dehydration scheme:

$Mg(UO_2)_2(PO_4)_2 \cdot 10H_2O$
$- 3H_2O \quad \downarrow \quad$ 25–91° C
$Mg(UO_2)_2(PO_4)_2 \cdot 7H_2O$
$- 5H_2O \quad \downarrow \quad$ 91–193° C
$Mg(UO_2)_2(PO_4)_2 \cdot 2H_2O$
$- H_2O \quad \downarrow \quad$ 193–308° C
$Mg(UO_2)_2(PO_4)_2 \cdot H_2O$
$- H_2O \quad \downarrow \quad$ 308–590° C
anhydrous state

No traces of Pb or Al could be detected in the samples from Cunha Baixa, although Frondel (1951) found these elements in some specimens from Sabugal. Moreover, no traces of As or Fe are present in our samples, although De Lancastre (1965) suggested a variability in the chemical composition of saleeite regarding substitution of $PO_4^{-3}$ by $AsO_4^{-3}$ and $Mg^{+2}$ by $Fe^{+2}$.

From Table 1, which summarizes the chemical analyses of saleeite from Cunha Baixa, it is clear that the chemical composition corresponds to $Mg(UO_2)_2(PO_4)_2 \cdot 10H_2O$.

The X-ray diffraction data obtained for saleeite from Cunha Baixa differ from those of the MPDF data card 8-313, which represents the reflections of saleeite from Sabugal described by Frondel (1951). Piret and Deliens (1980) conclude that these saleeite specimens consist of a mixture of fully hydrated saleeite and one or more dehydrated phases. On the other hand, the X-ray diffraction data of saleeite from Cunha Baixa are identical with those found by Piret and Deliens (1980) for the holotype of saleeite from Shinkolobwe. Consequently, we may conclude that saleeite from Cunha Baixa is identical with the fully hydrated modification, a conclusion which is confirmed by TGA and chemical analyses.

According to Frondel (1953) and De Lancastre (1965), crystals larger than 0.5 mm are very rare. Saleeite crystals from Cunha Baixa, however, are as large as 8 mm! While Frondel (1953) describes saleeite as crusts or as porous, interlocking aggregates of thin plates and scales, crystals from Cunha Baixa are well formed and highly transparent, with a yellow-green color and a bright luster. Some of these crystals clearly show a color transition from yellow-green to dark grass-green in the lower part of the crystals, which can be explained by a diffusion-controlled exchange of $Mg^{+2}$ against $Cu^{+2}$. Moreover, some torbernite crystals are overgrown with saleeite.

**Phosphuranylite** $Ca(UO_2)_4(PO_4)_2(OH)_4 \cdot 7H_2O$

Phosphuranylite differs from the above described minerals by the presence of OH groups in its crystal lattice. Its presence in the samples from Cunha Baixa was confirmed by X-ray diffraction.

In this paragenesis, it is mostly associated with saleeite and occurs in distinct forms, including pulverulent masses and acicular or lath-like crystals as large as 1 to 2 mm. The latter show a characteristic rectangular outline with large {100} faces and are strongly elongated along the *c*-axis.

## ACKNOWLEDGMENTS

The authors are indebted to Karel Van Springel and Myriam Vochten for technical assistance.

## REFERENCES

DE LANCASTRE, J. (1965) Contribuiçao para o estudo dos minerais secundarios de uranio Portugueses. *Communicaçoes dos Serviços Geologicos de Portugal LXIX, Lisboa.*

FRONDEL, C. (1951) Studies of uranium minerals: IV. Saléeite and novacekite. *American Mineralogist,* **36**, 680–686.

FRONDEL. C. (1953) Systematic mineralogy of uranium and thorium. *U.S. Geological Survey Bulletin 1064,* 400 p.

GEFFROY, J., and SARCIA, J. A. (1954) Contribution à l'étude des pechblendes françaises. *Sciences de la Terre,* **2**, 1–157.

PIRET, P., and DELIENS, M. (1980) Nouvelles données sur la saléeite holotype de Shinkolobwe. *Bulletin Minéral.,* **103**, 630–632.

RAMDOHR, P., and STRUNZ, H. (1978) *Klockmann's Lehrbuch der Mineralogie.* Ferdinand Enke Verlag, Stuttgart.

THOREAU, J., and VAES, J. F. (1932) La saléeite, nouveau minéral uranifère. *Societe belge geology Bulletin,* **43**, 96–100. ⊠

The 21st annual

MUNICH

Mineral, Gem & Fossil Show

**October 26, 27, 28**
Friday, Saturday, Sunday 9-6

**ALPINE '84**
**SUPER-STRAHLER-SHOW**

Three great days in the Exhibition Centre of Munich & more than 320 top dealers & spectacular exhibits of mineral specimens from dealers, museums and private collections & old classic localities & the best assortment of high quality Europe minerals and fossils & new discoveries from the international market & great competitive show-exhibits & rare geological literature & demonstrations and meetings . . . it's an event!

**EUROPE'S TOP SHOW!**

**INFORMATION**
**MINERALIENTAGE MÜNCHEN**
P.O. Box 60
D-8024 Oberhaching
West Germany

Tel.: 0 89 / 6 13 47 11

★ TOURS ★

*Especially for Mineral Collectors*

| | | |
|---|---|---|
| Munich Show | Oct. '84 | Oct. '85 |
| Minas Gerais | | '85 |

• ADVENTURE CENTER •
Betty Lee, Sales Rep.
31 Krestview Lane
Golden, Colorado 80401
Tel. (303) 526-9291

Mineralogical Record

*Show Schedule*

| | |
|---|---|
| Denver | Sept. 7-9 |
| Houston | Sept. 7-9 |
| Pacific NW Symp. | Sept. 28-30 |
| Detroit | Oct. 12-14 |
| Munich | Oct. 26-28 |
| Pasadena | Nov. 3-4 |

*See Us There!*

Wright's
ROCK SHOP

**★ NEW CATALOG $2 ★**

**★ NEW MINERALS:**
Amethyst, Mexico; red Dravite, Brazil; Ettringite/Sturmanite, South Africa; Tourmaline, California

**★ SHOW SCHEDULE:**
Sept. 7-9: Houston, Texas
Sept. 14-16: Winston-Salem, N. Carolina
Oct. 12-14: Detroit, Michigan

ROUTE 4, BOX 462, HIGHWAY 270 WEST
HOT SPRINGS, ARK. 71913 ★ 501-767-4800

# a highly magnesian Alleghanyite from sterling hill, new jersey

**Ole V. Petersen** and **J. Bollhorn**
Geology Museum, University of Copenhagen
Copenhagen, Denmark

**Pete J. Dunn**
Department of Mineral Sciences
Smithsonian Institution
Washington, D.C. 20560

## SUMMARY

A highly magnesian alleghanyite from Sterling Hill, Sussex County, New Jersey, is monoclinic, $P2_1/b$, with $a = 4.827$, $b = 10.613$, $c = 8.116$ Å, and $\alpha = 108.65°$, Z = 2. Microprobe analysis yields $SiO_2$ 26.7, FeO 0.4, MgO 15.0, ZnO 3.5, MnO 50.0, F 3.1, $H_2O$ [2.5], less O = F 1.3, sum = 99.9 weight percent. This is one of the most highly magnesian alleghanyites reported, and has a calculated formula, based on Si = 2 atoms, $(Mn_{3.17}Mg_{1.68}Zn_{0.19}Fe_{0.02})_{\Sigma 5.06}Si_{2.00}O_{8.07}(OH_{1.25}F_{0.73})_{\Sigma 1.98}$.

## INTRODUCTION

A small hand-specimen, acquired in 1982 by the Geological Museum, Copenhagen, Denmark, was labeled alleghanyite from Sterling Hill, Ogdensburg, Sussex County, New Jersey. It consists of coarse-grained white calcite, 1–2 mm rounded willemite crystals, and 2–5 mm franklinite crystals. One side of the specimen, obviously the surface of a fracture in the ore, is covered by a thin crust of manganoan dolomite, a profusion of 0.1–1.0 mm very well formed and lustrous secondary franklinite crystals, and a few groups of 0.05–0.1 mm incomplete brown transparent crystals of what proved to be a highly magnesian alleghanyite. Inasmuch as very little is known of the intermediate compositions in the alleghanyite-chondrodite series, we subjected these crystals to a detailed characterization, the results of which are presented here.

## PHYSICAL and OPTICAL PROPERTIES

The alleghanyite from Sterling Hill shows no apparent cleavage. The luster is vitreous on fracture surfaces. The specific gravity measured by suspension in heavy liquids is 3.75 (±0.05), compared with the calculated value of 3.82 g/cm³ derived from the empirical formula. This value, as would be expected in the case of Mg-for-Mn substitution, is lower than that of end-member alleghanyite. As summarized by Ribbe (1982), indices of refraction are not useful criteria for distinguishing the various members of the homologous series of humites, except for the Mg-member, norbergite. However, we did prepare a thin section, cut parallel to (101) for examination using the universal stage. This magnesian alleghanyite is biaxial, negative, with $2V_\alpha = 65° (\pm 2°)$, slightly lower than that calculated from the data of Rogers (1935) for Bald Knob, North Carolina, alleghanyite, which is near end-member composition (Winter *et al.*, 1983). The orientation of the indicatrix relative to the unit cell was determined to be $\alpha \wedge c = 20° (\pm 2°)$, $\beta = b$, and $\gamma = a$.

## CRYSTALLOGRAPHY

### Morphological Crystallography

With the exception of two fairly complete crystals of this magnesian alleghanyite, all the others show little more than two or three crystal faces. The best developed of the two crystals was measured on the two-circle goniometer. Orientation was determined by use of oscillation diagrams which showed the two most prominent zone axes of the crystal to be 8.1 Å (the *c* axis) and 10.6 Å (the *b* axis). This procedure also established that the crystal is untwinned and greatly facilitated the identification of the forms by comparison with a stereographic projection of possible forms constructed using the unit cell parameters. The forms present are: {010}, {100}, {110}, {120}, {101}, {111} and {112}. Transformation matrix of face indices from this setting to the conventional one for monoclinic crystals is: 001/100/010. Figure 1 shows a drawing of an idealized crystal having a distinct prismatic habit; in this drawing, the faces are indexed in the conventional manner. Figures 2 and 3 show crystal drawings of the same crystal using the axial orientation for humite group minerals discussed below, and adopted here. Figures 4 and 5 are SEM photomicrographs of more complexly formed magnesian alleghanyites from similar secondary assemblages at Sterling Hill.

### X-ray Crystallography

X-ray diffraction studies, including Weissenberg single-crystal methods, showed this highly magnesian alleghanyite to be monoclinic, $P2_1/b$, with unit cell parameters $a = 4.827$, $b = 10.613$, $c = 8.116$ Å, and $\alpha = 108.65°$, $V = 393.9$ Å³, Z = 2. We adopt here, for X-ray data, the convention of Jones (1969) wherein alpha is the unique angle, so as to facilitate comparison of these data with those of other recent investigators, all of whom have adopted this convention for humite-group minerals. These values were obtained by least-squares refinement using the indexed powder pattern, and the program REFBASE written by E. S. Leonardsen. The powder data (Table 1) were obtained with a Guinier-Hägg camera, utilizing quartz as an internal standard and Cu*K*α X-radiation ($\lambda = 1.54051$ Å). In Table 2 we compare the unit cell of this magnesian alleghanyite with the unit cells of end-member alleghanyite and chondrodite. From this table it is evident that the volume of the unit cell of this magnesian alleghanyite falls between the volumes of end-member alleghanyite and chondrodite.

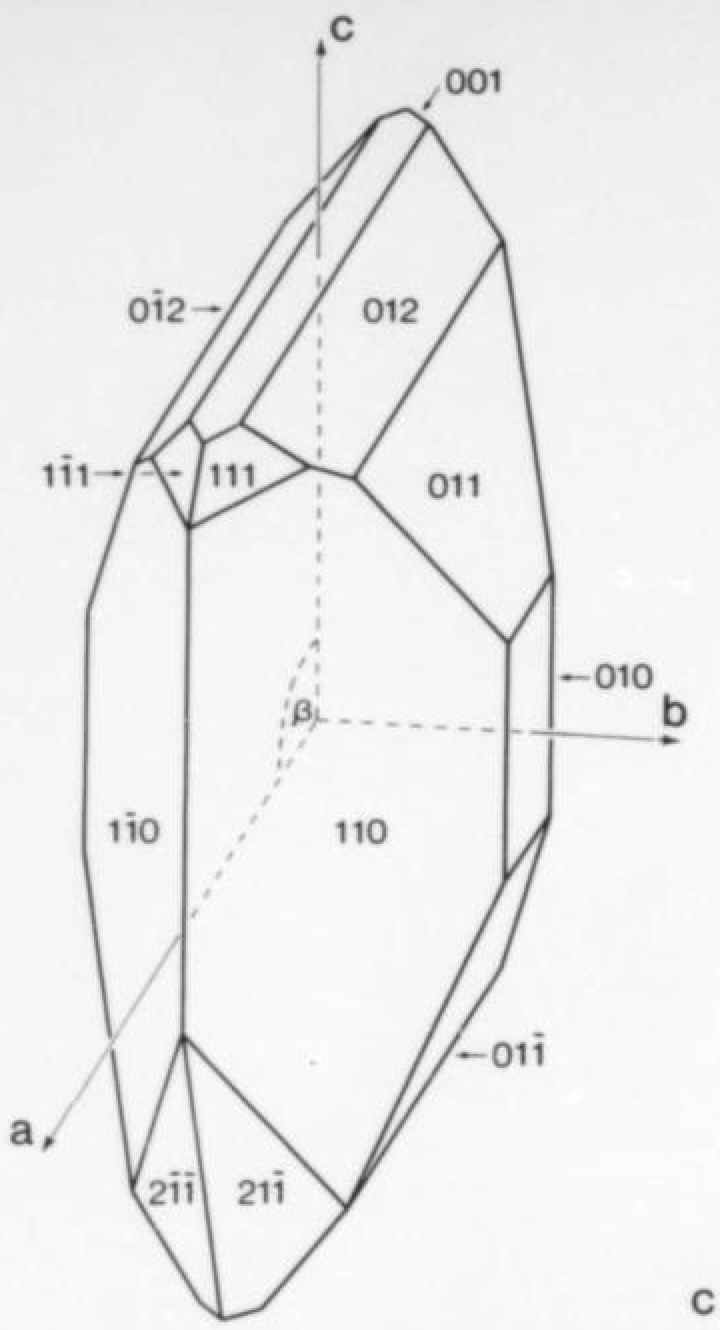


*Figure 1.* Drawing of an idealized crystal of magnesian alleghanyite, in conventional setting.

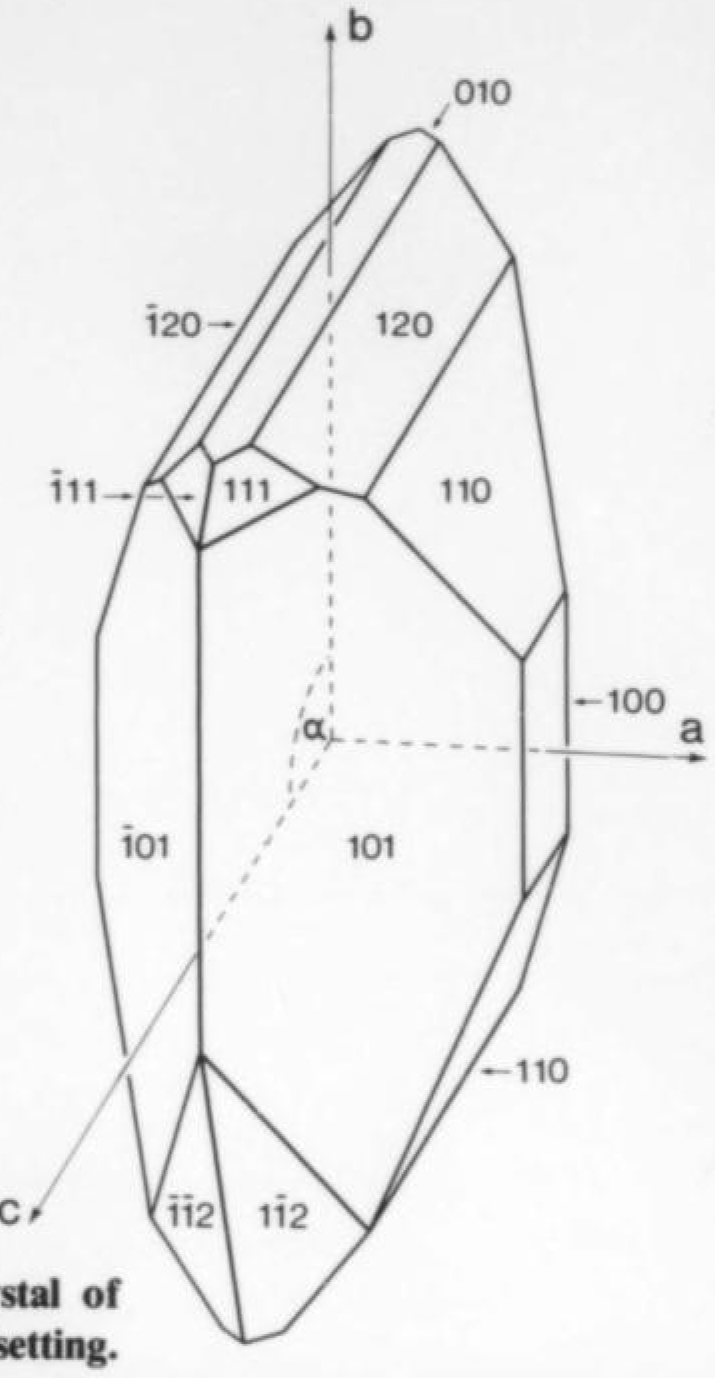


*Figure 2.* Drawing of an idealized crystal of magnesian alleghanyite in the newer setting used for humite-group minerals.

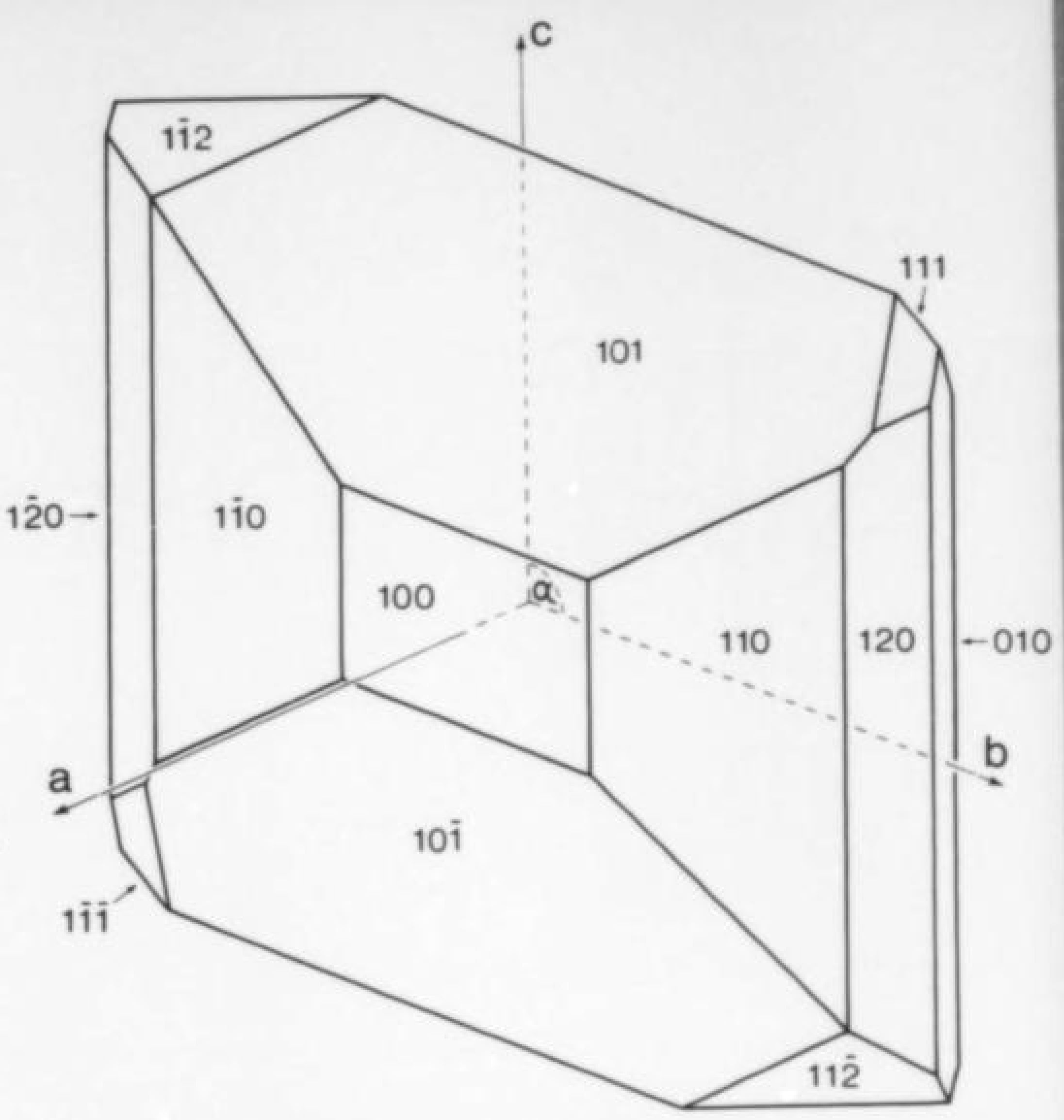


*Figure 3.* Drawing of an idealized crystal of magnesian alleghanyite, employing the same setting used in Figure 2, but showing the crystal in a different orientation. This projection aptly demonstrates the *in situ* appearance of many of the crystals on preserved specimens.

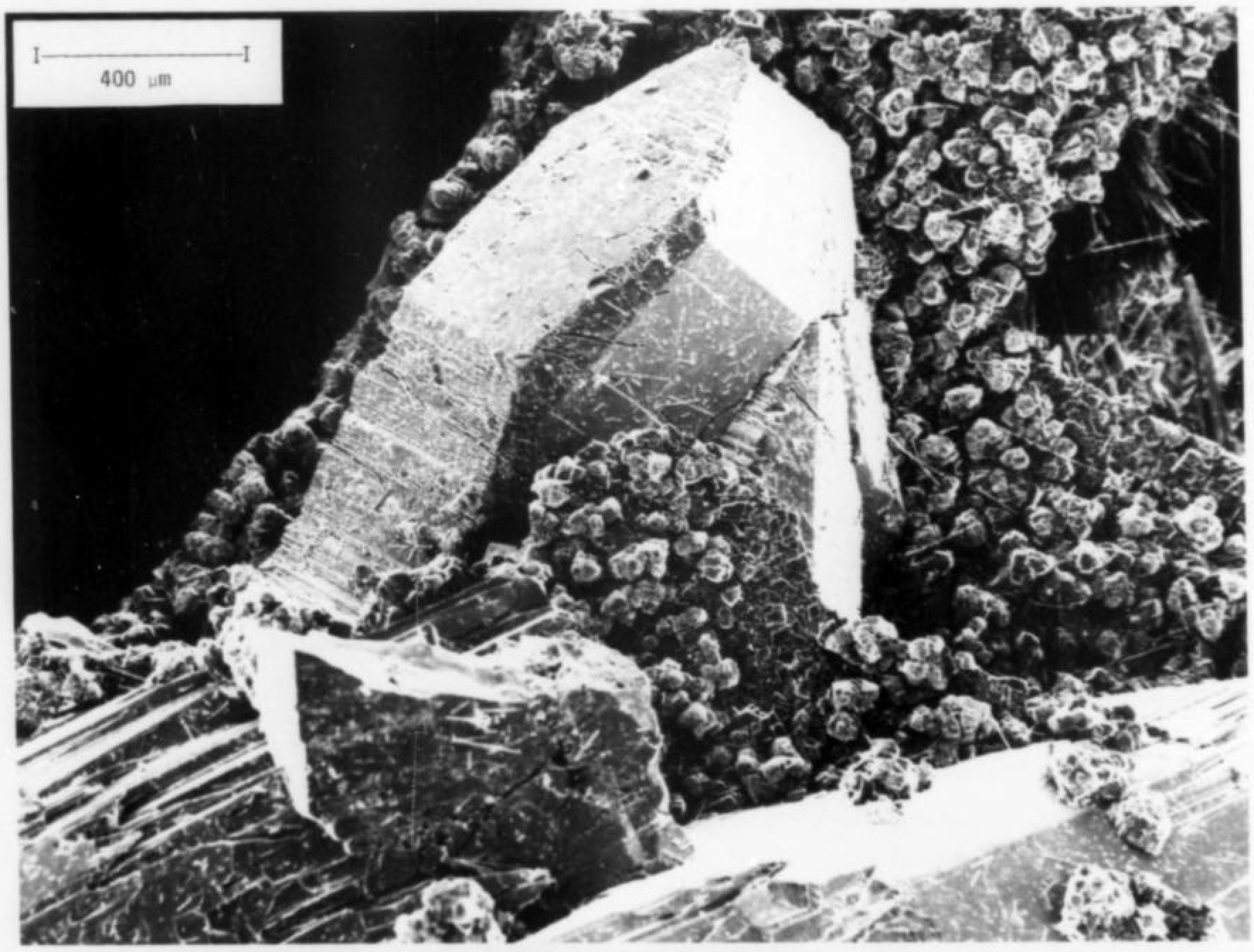


*Figure 4.* SEM photomicrograph of magnesian alleghanyite from a different assemblage.

## CHEMICAL COMPOSITION

A crystal of this magnesian alleghanyite was chemically analyzed using an ARL-SEMQ electron microprobe with an operating voltage of 15 kV and a sample current of 0.025 μA, measured on brass. The standards used were synthetic tephroite (Mn,Si), synthetic ZnO (Zn), fluorapatite (F) and hornblende (Mg,Fe). The crystal was found to be homogeneous at the microprobe level. The

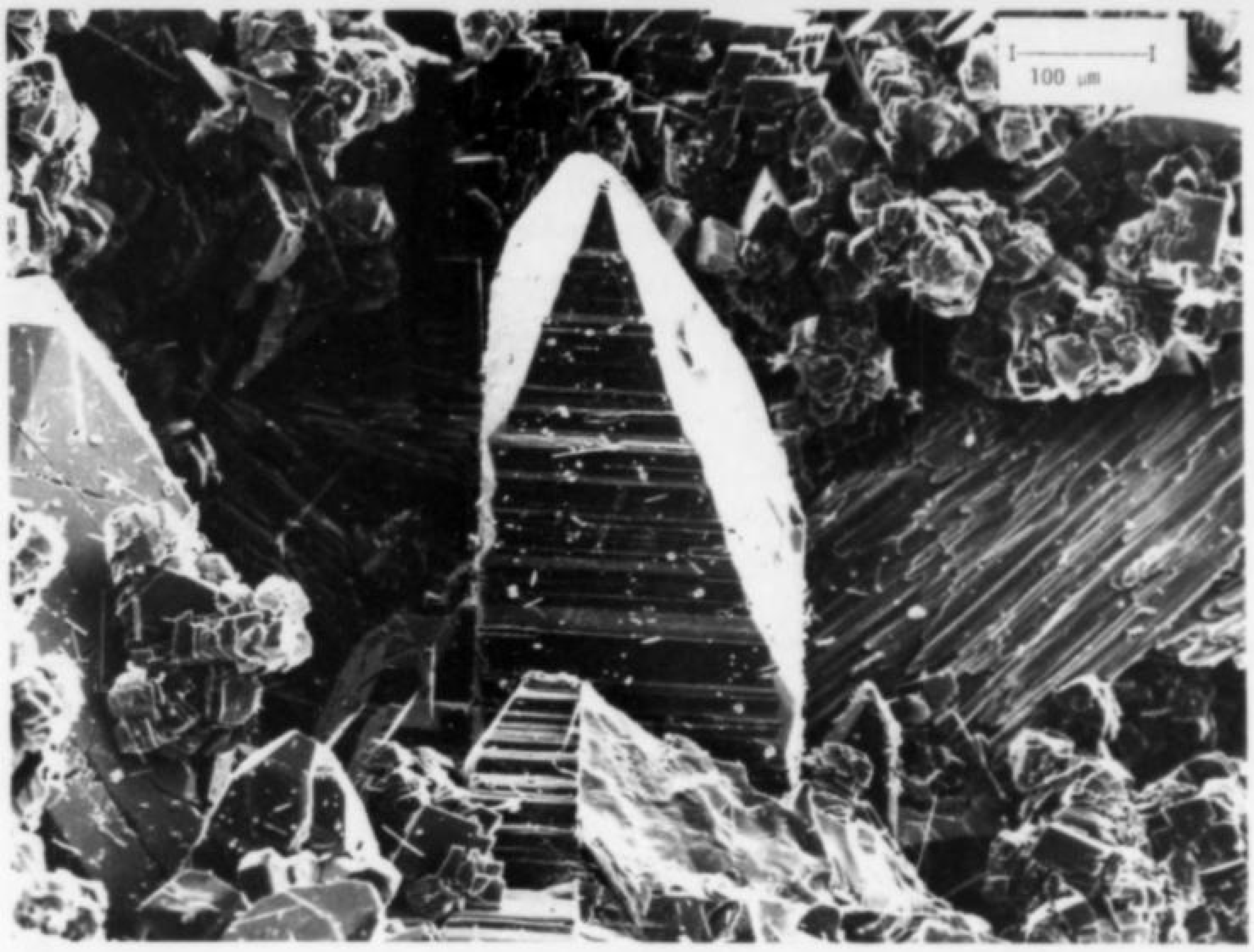


*Figure 5.* **SEM photomicrograph of magnesian alleghanyite from a different assemblage.**

*Table 1.* **X-ray powder diffraction data for magnesian alleghanyite.**

| *d* (obs) | I/Io | *hkl* | *d* (calc) |
|---|---|---|---|
| 7.68 | 3 | 001 | 7.689 |
| 5.00 | 1 | $02\bar{1}$ | 5.004 |
| 4.083 | 1 | 101 | 4.088 |
| 4.039 | 2 | $11\bar{1}$ | 4.034 |
| 3.850 | 1 | 002 | 3.845 |
| 3.671 | 1 | $02\bar{2}$ | 3.673 |
| 3.579 | 3 | 111 | 3.581 |
| 3.473 | 1 | $12\bar{1}$ | 3.474 |
| 3.104 | 10 | $11\bar{2}$ | 3.102 |
| 2.937 | 1 | 121 | 2.937 |
| 2.840 | 7 | $13\bar{1}$ | 2.840 |
| 2.753 | 4 | 130 | 2.753 |
| 2.702 | 4 | 112 | 2.702 |
| 2.667 | 2 | 022 | 2.670 |
| 2.651 | 1 | $04\bar{1}$<br>$02\bar{3}$ | 2.653<br>2.652 |
| 2.585 | 4 | $13\bar{2}$ | 2.583 |
| 2.501 | 2 | $04\bar{2}$ | 2.502 |
| 2.416 | 1 | 200 | 2.414 |
| 2.400 | 3 | 131 | 2.400 |
| 2.354 | 2 | $11\bar{3}$ | 2.356 |
| 2.335 | 1 | 122 | 2.336 |
| 2.325 | 5 | $14\bar{1}$<br>$12\bar{3}$ | 2.325<br>2.325 |
| 2.294 | 1 | 211 | 2.293 |
| 2.202 | 1 | 211 | 2.199 |
| 2.176 | 1 | $04\bar{3}$<br>220 | 2.176<br>2.176 |
| 2.087 | 2 | 113 | 2.086 |
| 2.070 | 1 | $21\bar{2}$ | 2.073 |
| 2.021 | 1 | 221 | 2.022 |
| 1.907 | 1 | $15\bar{2}$ | 1.907 |
| 1.856 | 2 | 150<br>$11\bar{4}$ | 1.856<br>1.857 |
| 1.791 | 6 | 222 | 1.790 |
| 1.787 | 6 | 104<br>$24\bar{1}$<br>$22\bar{3}$ | 1.786<br>1.785<br>1.785 |
| 1.758 | 1 | $0\bar{6}1$<br>203 | 1.759<br>1.757 |
| 1.737 | 1 | $24\bar{2}$ | 1.737 |
| 1.671 | 1 | 213<br>133 | 1.670<br>1.670 |
| 1.588 | 1 | 310 | 1.589 |
| 1.562 | 1 | 043 | 1.562 |
| 1.552 | 1 | $04\bar{5}$<br>$22\bar{4}$ | 1.551<br>1.551 |
| 1.537 | 3 | 061<br>005 | 1.538<br>1.538 |

resulting analysis, with $H_2O$ calculated to sum (OH + F) to 2.0, yields: $SiO_2$ 26.7, FeO 0.4, MgO 15.0, ZnO 3.5, MnO 50.0, F 3.1, $H_2O$ [2.5], less O = F 1.3, sum = 99.9 weight %. The accuracy of the data is ±3% of the amount present for major elements, ±15% of the amount present for F.

The formula for this alleghanyite, calculated on the basis of Si = 2.0 atoms, yields: $(Mn_{3.17}Mg_{1.68}Zn_{0.19}Fe_{0.02})_{\Sigma 5.06}Si_{2.00}O_{8.07}(OH_{1.25}F_{0.73})_{\Sigma 1.98}$, which is in very good agreement with the structural formula for alleghanyite, $Mn_5(SiO_4)_2(OH,F)_2$. This alleghanyite has one of the highest Mg contents ever reported in alleghanyite. Subsequent to our study, we learned that similar magnesian alleghanyite from Sterling Hill had been subjected to crystal structure analysis (Francis, in press), and the Mg was found to be ordered in the structure.

*Table 2.* **Unit cell data for alleghanyite and chondrodite.**

| | Alleghanyite Bald Knob Rentzeperis (1970) | Alleghanyite Sterling Hill Present study | Chondrodite Finland Gibbs *et al.* (1970) |
|---|---|---|---|
| *a* | 4.8503 Å | 4.827 Å | 4.7284 Å |
| *b* | 10.7198 | 10.613 | 10.2539 |
| *c* | 8.2747 | 8.116 | 7.8404 |
| α | 108.64° | 108.65° | 109.059° |
| V | 416.3 Å³ | 393.9 Å³ | 359.3 Å³ |
| Space Group | $P2_1/b$ | $P2_1/b$ | $P2_1/b$ |

Data for Rentzeperis (1970) reset to new convention with alpha as the unique angle.

## ACKNOWLEDGMENTS

Thanks are due to E. S. Leonardsen who performed the single-crystal X-ray studies. PJD thanks the Trustees of the Franklin Mineral Museum for their continued assistance. This project was supported, in part, by a grant from Mrs. E. Hadley Stuart, Jr., for which PJD expresses gratitude.

## REFERENCES

FRANCIS, C. A. (1985) Crystal structure refinement of magnesian alleghanyite. *American Mineralogist,* **70**, in press.

GIBBS, G. V., RIBBE, P. H., and ANDERSON, C. P. (1970) The crystal structures of the humite minerals. II. Chondrodite. *American Mineralogist,* **55**, 1182–1194.

JONES, N. W. (1969) Crystallographic nomenclature and twinning in the humite minerals. *American Mineralogist,* **54**, 309–313.

RENTZEPERIS, P. J. (1970) The crystal structure of alleghanyite. *Zeitschrift für Kristallographie,* **132**, 1–18.

RIBBE, P. H. (1982) The humite series and Mn-analogs. *Reviews in Mineralogy,* **5**, 2nd edition, 231–274.

ROGERS, A. F. (1935) The chemical formula and crystal system of alleghanyite. *American Mineralogist,* **20**, 25–35.

WINTER, G. A., ESSENE, E. J., and PEACOR, D. R. (1983) Mn-humites from Bald Knob, North Carolina: mineralogy and phase equilibria. *American Mineralogist,* **68**, 951–959.

# Paulkerrite

## a new titanium phosphate from arizona

**Donald R. Peacor**
Department of Geological Sciences
University of Michigan
Ann Arbor, Michigan 48109

**Pete J. Dunn**
Department of Mineral Sciences
Smithsonian Institution
Washington, D.C. 20560

**William B. Simmons**
Department of Earth Sciences
University of New Orleans
New Orleans, Louisiana 70148

### ABSTRACT

Paulkerrite is a new mineral from near Hillside, Yavapai County, Arizona, having the ideal composition $KTi(Mg,Mn)_2(Fe^{+3},Mg,Al,Ti)_2(PO_4)_4(OH)_3 \cdot 15H_2O$. It occurs as an alteration product of triplite associated with bermanite and minute crystals of leucophosphite, phosphosiderite and strengite. It is orthorhombic, space group *Pbca*, with $a = 10.49(7)$, $b = 20.75(13)$, $c = 12.44(2)$ Å, $Z = 4$. The name is in honor of Professor Paul Kerr, former Professor of Mineralogy at Columbia University.

### INTRODUCTION

As part of a description of bermanite, Hurlbut (1936) gave partial descriptions of some unidentified phosphates which occur as microcrystals associated with bermanite, but which occur in such small quantities as to preclude their identification with the methods then available. A re-examination of bermanite by Leavens (1967) provided identifications for some of the unknown phosphates. Of particular interest to us was the light brown and most abundant of these minutely crystallized species, which Hurlbut had referred to as *unidentified phosphate #2.* Our examination of this mineral indicated it was probably a new species and our subsequent study has verified this initial observation.

We are pleased to name this new titanium-bearing phosphate *paulkerrite* in honor of the late Professor Paul F. Kerr of Columbia University, in recognition of his voluminous contributions to mineralogy and the education of mineralogists. A biography of Paul Kerr was published by Holmes (1965) in a *Festschrift* in the *American Mineralogist,* upon Professor Kerr's retirement. Holotype material is preserved in the Smithsonian Institution. The mineral and the name were approved by the I.M.A. Commission on New Minerals and Mineral Names. Type material is preserved at the Smithsonian Institution (cat. no. NMNH R7778 and NMNH 120405).

### PHYSICAL and OPTICAL PROPERTIES

Paulkerrite is light yellowish brown, grading to nearly colorless. It has a colorless streak. It is highly transparent and, due to the thinness of some crystals, it can easily be overlooked upon casual observation. However, the crystal habit, discussed below, is relatively invariant and permits easy identification, at least in all crystals that we have observed. The luster is vitreous on crystal faces and cleavage and fracture surfaces. Paulkerrite is not discernibly fluorescent in ultraviolet radiation. The hardness (Mohs) is approximately 3. There is a perfect {100} cleavage, which is easily produced. The fracture is even. The density, measured using heavy-liquid techniques, is 2.36(4) g/cm³, in excellent agreement with the calculated value of 2.36 g/cm³.

Optically, paulkerrite is biaxial negative, $2V \cong 80°$ (Hurlbut, 1936), but $\beta$ could not be determined on our crystals due to twinning, small size and mosaic texture. The indices of refraction are $\alpha = 1.598(4)$, $\beta = 1.624$(calc) and $\gamma = 1.643(4)$. Dispersion is strong, $r > v$; orientation is $X = c$, $Z = a$. Paulkerrite is non-pleochroic. These optical parameters compare well with those reported by Hurlbut (1936) ($\alpha = 1.591$, $\beta = 1.615$, $\gamma = 1.639$, $2V = 80°$, $r > v$) although all three indices are slightly higher. The differences may be due to slight variations in cation content or in the oxidation state of Fe and/or Mn.

### CHEMISTRY

Paulkerrite was chemically analyzed using an ARL-SEMQ electron microprobe utilizing an operating voltage of 15 kV and a beam current of 0.025 $\mu$A. After first being checked for homogeneity with a small beam-spot, the mineral was analyzed using a large-diameter beam-spot in order to minimize loss of $H_2O$ through volatilization. Standards used were hornblende (K,Ti), maricite (Fe), montgomeryite (Al,Mg,P), manganite (Mn) and fluorapatite (F). There was inadequate material for the direct determination of $H_2O$; it was calculated by difference. The oxidation state of Fe was determined by microchemical tests which showed $Fe^{+3}$ to be dominant and $Fe^{+2}$ to be present but subordinate in amount. Mn was assigned to $Mn^{+2}$ based on calculation of the Gladstone-Dale relationship, which for the formula with $Mn^{+2}$ gives $K_C = 0.270$, and for that with $Mn^{+3}$ gives 0.277, as compared with a value of $K_P = 0.263$ as calculated from values for physical properties.

A wavelength-dispersive microprobe scan indicated the absence of any additional elements with atomic number greater than 8. The resultant analysis yields: $K_2O = 4.4$, $Al_2O_3 = 1.6$, $Fe_2O_3 = 12.2$, $MnO = 7.1$, $MgO = 4.6$, $TiO_2 = 9.8$, $P_2O_5 = 29.4$, $F = 0.9$, $[H_2O] = 30.5$, sum = 100.4, less O = F = 0.4, sum = 100.0%. Calculation of unit cell contents, using the unit cell parameters and observed density, yields: $K_{3.59}Mg_{4.39}Fe^{+3}_{3.88}Al_{1.20}\,Mn^{+2}_{3.85}Ti_{4.72}P_{15.94}$

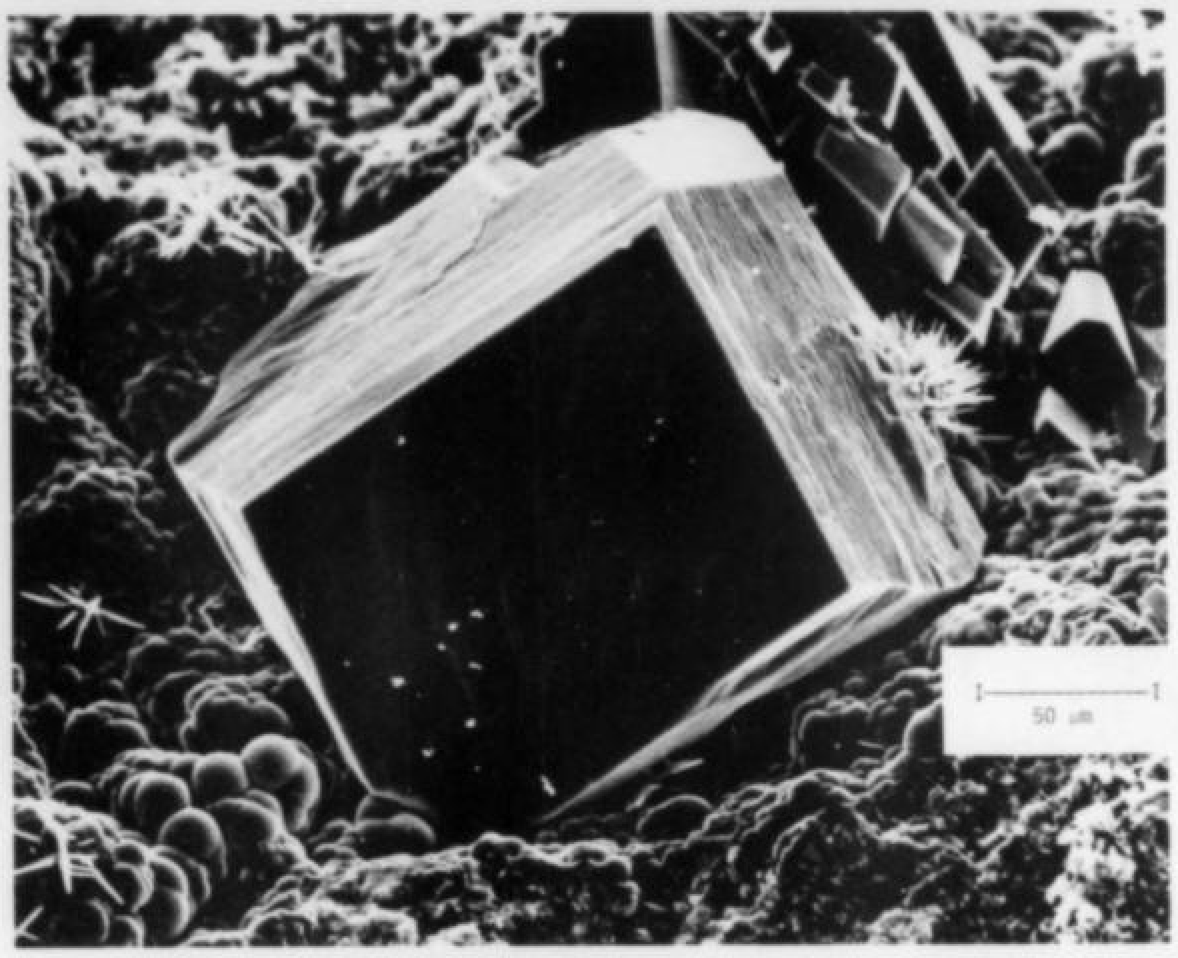


*Figure 1.* **Tabular paulkerrite crystal from Arizona.**

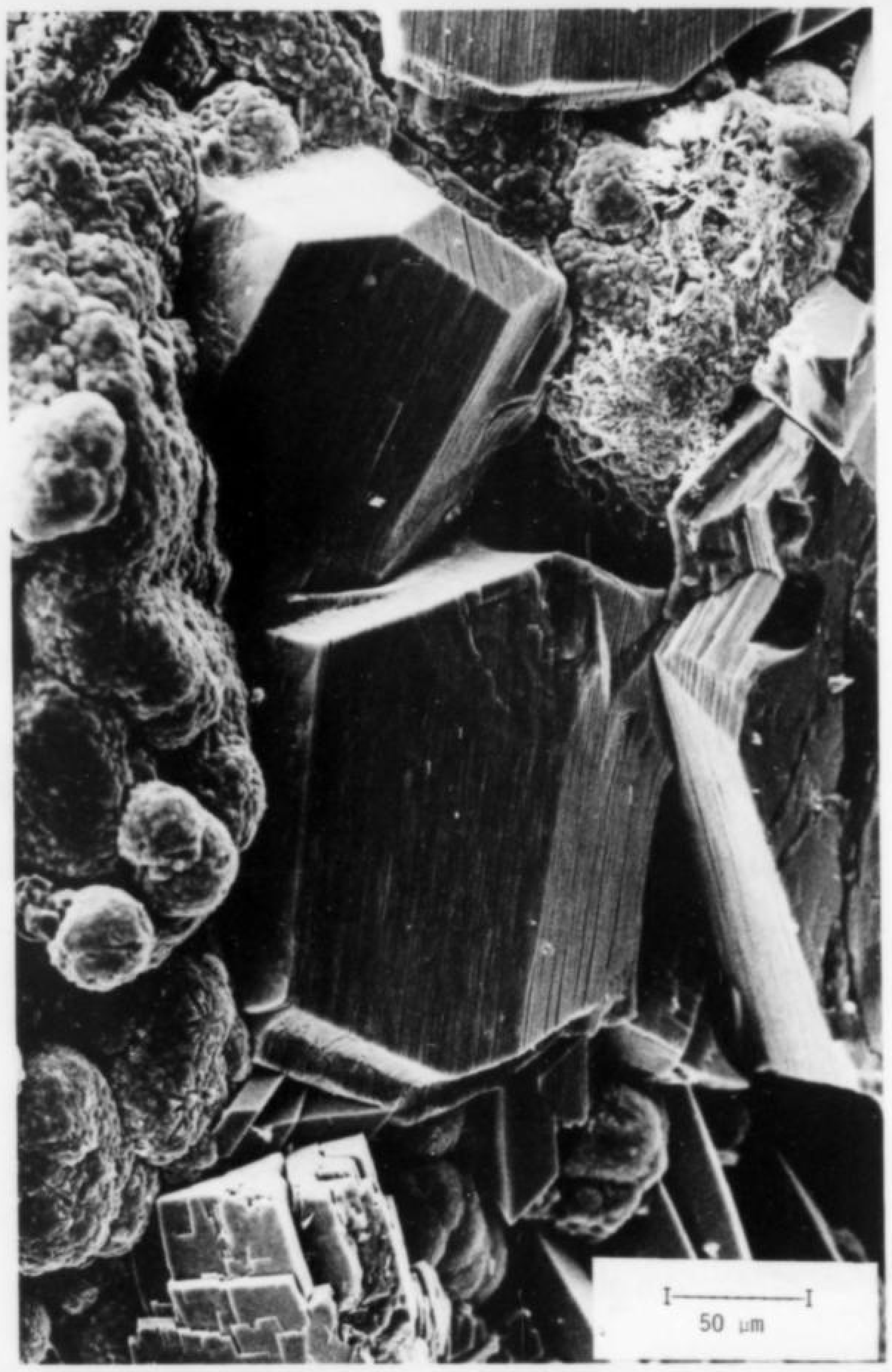


*Figure 2.* **Equant paulkerrite crystals showing traces of the perfect cleavage.**

$F_{1.82}H_{130.31}$, which we interpret as: $K_{3.59}Ti_{4.0}(Mg_{4.15}Mn^{+2}_{3.85})_{8.0}(Fe^{+3}_{5.88}Mg_{0.24}Al_{1.20}Ti_{0.72})_{8.04}(PO_4)_{15.94}(F_{1.82}OH_{10.55})_{12.37}\cdot 59.9H_2O$. The idealized formula of paulkerrite is $\mathbf{KTi(Mg,Mn)_2(Fe^{+3},Al,Ti,Mg)_2(PO_4)_4(OH)_3\cdot 15H_2O}$. This ideal formula is written so as to be compatible with the formula for the isostructural mineral mantienneite, $KMg_2Al_2Ti(PO_4)_4(OH)_3\cdot 15H_2O$ (Fransolet, in preparation).

The space group *Pbca* has only two special positions of rank 4 in addition to the general equipoint of rank 8. This formula assumes that K and Ti occupy those equipoints. Given only the chemical data for paulkerrite, it is not clear as to whether Ti, Mg or Mn occupy a special equipoint. We therefore have used the isostructural

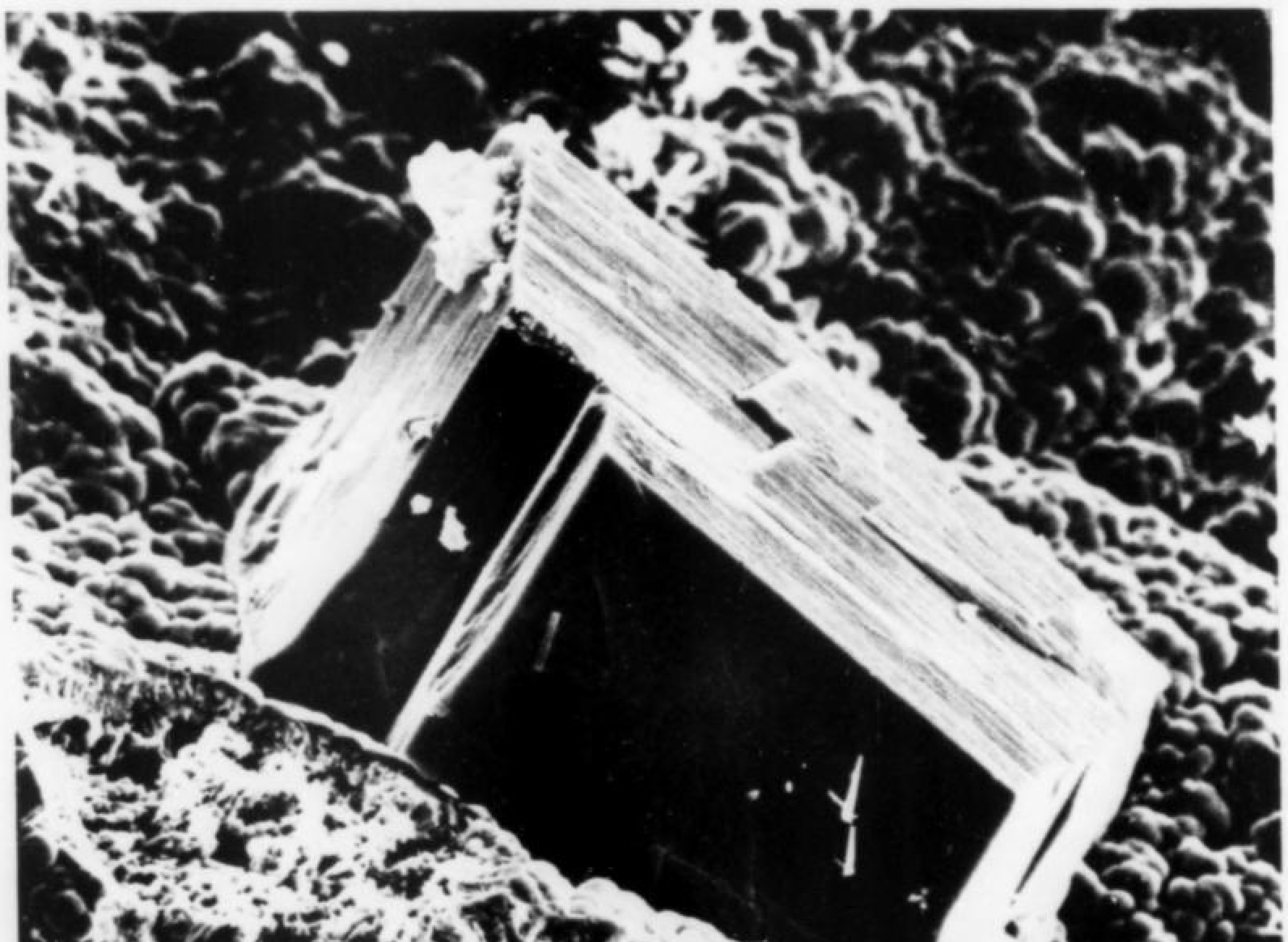


*Figure 3.* **Sharp, tabular paulkerrite crystals which lack the {100} pinacoid.**

relation with mantiennite, for which the special site occupancy of Ti appears to be clear-cut, as a reference for deriving site assignments for paulkerrite.

The sum of approximately 12 F+OH per cell requires some explanation, as it apparently requires that 4 OH occupy a special site of rank 4 and none are available. As with mantienneite (Fransolet, in preparation) we propose solid solution of some OH with $H_2O$, implying that at least some $H_2O$ is directly coordinated to an octahedrally coordinated cation. The hydrogen-containing portion of the formula might then be better written as $(OH,F)_2(OH,H_2O)_2\cdot 14H_2O$. This is an awkward expression, however, and we prefer to write the formula as above with the status of hydrogen being determined in the future through a crystal structure analysis.

Lastly, we note that the valence states for Fe and Mn are not precisely known. There is a small proportion of $Fe^{+2}$ and some Mn may be $Mn^{+3}$. The formula is affected only in small adjustments in the relative amounts of OH versus $H_2O$, when such adjustments in valence are considered. The overall form of the formula is unchanged.

## CRYSTALLOGRAPHY

### *Morphology*

Paulkerrite occurs as 0.2-mm euhedral crystals which are either equant or flattened on {010}. The crystals are elongate parallel to [001]. The forms present are {010}, {100} and {111}. Tabular crystals have large dominant {010} faces, as shown in Figure 1. More equant crystals, shown in Figure 2, have well-developed {111} dipyramids, giving the crystals a stouter habit. Growth features parallel to the {010} cleavage are well illustrated on the crystals shown in Figure 2, lending to them a layered aspect. The {100} pinacoid is not always present, as shown in Figure 3.

### *X-Ray Crystallography*

Weissenberg and precession photographs show that paulkerrite is orthorhombic, space group *Pbca*. Least-squares refinement of Gandolfi camera powder diffraction data, obtained using Si as an internal standard, and FeKα radiation, yielded the lattice parameters $a$ = 10.49(7), $b$ = 20.75(13), and $c$ = 12.44(2) Å. Reflections having $h + k + l = 2N + 1$ are generally very weak in intensity or not observable except for the reflection 111. The structure is therefore pseudo-body centered. In addition reflections parallel to $b^*$ are somewhat diffuse, indicating the presence of some kind of stacking disorder in that direction. Except for 111, indices are assigned to reflections in the powder pattern assuming that only reflections with $h + k + l = 2N$ are observable, by analogy with the single-crystal patterns.

*Table 1.* **X-ray powder diffraction data for paulkerrite.***

| $I/I_o$ | d (Obs) | d (Calc) | hkl | $I/I_o$ | d (Obs) | d (Calc) | hkl |
|---|---|---|---|---|---|---|---|
| 90 | 10.3 | 10.4 | 020 | 10 | 2.814 | 2.824 | 341 |
| 80 | 7.46 | 7.47 | 111 | 20 | 2.624 | 2.623 | 400 |
| 100 | 6.20 | 6.22 | 002 | 10 | 2.563 | 2.585 | 323 |
| 20 | 5.22 | 5.25 | 200 | 10 | 2.512 | 2.547 | 411 |
|  |  | 5.19 | 040 | 5 | 2.322 | 2.340 | 314 |
|  |  | 5.18 | 112 |  |  |  |  |
|  |  |  |  | 5 | 2.187 | 2.191 | 442 |
| 1 | 4.72 | 4.71 | 211 | 5 | 2.117 | 2.111 | 433 |
|  |  | 4.68 | 220 | 10 | 2.069 | 2.073 | 006 |
| 1 | 4.37 | 4.36 | 141 | 20 | 1.980 |  |  |
| 30 | 3.95 | 3.96 | 231 | 2 | 1.864 |  |  |
| 40 | 3.75 | 3.74 | 222 | 2 | 1.831 |  |  |
| 70 | 3.13 | 3.11 | 004 | 5 | 1.713 |  |  |
| 5 | 3.05 | 3.02 | 312 | 2 | 1.663 |  |  |
| 20 | 2.979 | 2.979 | 024 | 1 | 1.608 |  |  |
| 40 | 2.872 | 2.944 | 233 | 1 | 1.566 |  |  |

*Data obtained using a 114.6-mm diameter Gandolfi camera, FeKα radiation, and Si as an internal standard. Intensities visually estimated.

There are several aspects to the data, especially the X-ray diffraction data, which indicate that the cell parameters and/or formula may be subject to revision. The interpretation of the powder diffraction data is not entirely satisfactory in that the agreement between *d*(obs) and *d*(calc) is not as good as is generally true for other well-defined minerals. For example, the agreement for 233, 312, 323 and 411 is not especially good. Furthermore, the indexed powder data leads to lattice parameters with relatively high standard errors. In order to determine if this was due to some peculiar feature of the specific powder photograph, a second Gandolfi photograph, obtained using a different specimen, was obtained and measured, but without improved results. Furthermore, the diffuse nature of single-crystal diffraction patterns (parallel to $b^*$) coupled with the {010} cleavage and layered aspect of the crystals, implies that the structure is layered parallel to {010} and that there must be some sort of stacking disorder. Such disorder implies that there must be domains with cell parameters and symmetries different from those of the average crystal. In a general and unspecified way, the substructure-superstructure relation defined by pseudo-body centering and the near equality of $a$ and $b/2$ also imply the possibility of submicroscopic domains having a structure differing from the average. These data in turn imply that the composition, with cations distributed as consistent with equipoint requirements for space group *Pbca,* may not be entirely accurate if units of structure possess some other symmetry. We have examined the crystals and data carefully for additional features which might serve to provide a firmer basis for our concerns, but can find none. Further definition of these relations must await either a structure analysis (which may provide ambiguous results due to the disorder parallel to [010]) or high resolution transmission electron microscopy and electron diffraction data (which is difficult to obtain due to the small crystal size and good cleavage).

## OCCURRENCE

Paulkerrite occurs at the type locality for bermanite, the 7 U 7 Ranch, about 40 km west of Hillside, Yavapai County, Arizona. The dominant phosphate mineral at the locality is triplite, which was found in a pegmatite knot as described by Hurlbut (1936). The massive triplite, frequently weathered black by oxidation of the manganese, is dissected by numerous fractures which are lined with secondary phosphates, chiefly bermanite, $Mn^{+2}Mn_2^{+3}(PO_4)_2(OH)_2\cdot 4H_2O$, which occurs in crystals up to several mm in size. In addition to the rather abundant bermanite, a number of other secondary $Fe^{+3}$ and Mn phosphates occur in association, including light blue crystals of phosphosiderite, magenta-colored leucophosphite crystals, glassy pink strengite crystals, deep violet massive phosphosiderite, and colorless-to-white acicular sprays of switzerite as identified using powder X-ray diffraction techniques. Randomly distributed among these late-stage phosphates are paulkerrite crystals. Next to bermanite, they are the most abundant of the species listed here. Only bermanite and switzerite are younger than paulkerrite in this paragenesis. Paulkerrite crystals are evenly distributed on the fracture surfaces in triplite and show no preferential association with other species. The source of Ti is enigmatic. We know of no work on this pegmatite other than Hurlbut's description and no $TiO_2$ was reported in the analysis by Gonyer (*in* Hurlbut, 1936) of the host triplite. Other than paulkerrite, no titanium-bearing minerals were found in the specimens we examined. It is still possible that the triplite contains a very small amount of Ti which became concentrated in paulkerrite, or that the source of titanium may have been through supergene alteration of minerals of the country rock.

We have found paulkerrite crystals on many of the specimens labeled bermanite from the type locality which were available to us. Hence, it might be almost as abundant as bermanite at this locality, albeit in very small crystals.

## ACKNOWLEDGMENTS

We are indebted to Professor André-Mathieu Fransolet for providing us with data on the mineral mantienneite so that a comparison with data on paulkerrite could be made, and for reviewing the manuscript. We also thank Richard W. Thomssen and Abraham Rosenzweig for helpful reviews of the manuscript.

## REFERENCES

HOLMES, R. J. (1965) Paul Francis Kerr. *American Mineralogist,* **50**, 1519–1531.

HURLBUT, C. S. Jr. (1936) A new phosphate, bermanite, occurring with triplite in Arizona. *American Mineralogist,* **21**, 656–661.

LEAVENS, P. B. (1967) Reexamination of bermanite. *American Mineralogist,* **52**, 1060–1066.

*Mary & Gardner Miller*
*Missoula, Montana*

*Mineral Collectors*

**STAR MINERALS**
Aesthetic mineral specimens from worldwide localities. Send for our free list and unique photo service.
**Satisfaction Guaranteed**
P.O. BOX 144494, CORAL GABLES, FL 33114

***Silver Scepter Minerals***
*Fine Minerals . . . Oriental Carpets*
*** NEW BRUSHY CREEK CALCITES ***
*Shown by Appointment*
*P.O. Box 141605 Spokane, WA 99214*
*(509) 928-6407 or (509) 534-7467*

**Excalibur's 60,000 Specimens**

- **Rare Species** — New discoveries and type locality specimens from worldwide sources, thumbnail to cabinet sizes.
- **Microminerals** — Photographic quality specimens from the extensive reference collection of Julius Weber.
- **Bulk Minerals** — For researchers, universities, and foreign or domestic specimen dealers.

One dollar brings you our periodic lists for at least a year.
Please state your interests. Dealer inquiries invited. Satisfaction guaranteed.

**Excalibur Mineral Co.**

7 Grover Road
Dover, N.J. 07801

**Chilean Minerals**

HELMUT WEIDNER • CASILLA 3576, SANTIAGO, CHILE • TELEX 340-260

ATACAMITE
with Halloysite & Libethenite
AZURITE-MALACHITE
for cutting
CHRYSOCOLLA
large pcs. for decorating
CUPRITE on native copper
GOLD on Chrysocolla
GOLD on Boleite &
Paratacamite
LAPIS LAZULI
with Pyrite
TURQUOISE 3 mm to 12 mm
Best natural colors

German Address:
Hauptstrasse 81
D-6580 Idar-Oberstein
06781-44381

U.S. Agent
A. L. McGuinness
San Mateo, CA
415-345-2068


Silver
Georgetown, Colo.

Donald A. Zowader

Specializing in the finest thumbnails, miniatures and cabinet specimens for competition and display.

Write or phone for current list.

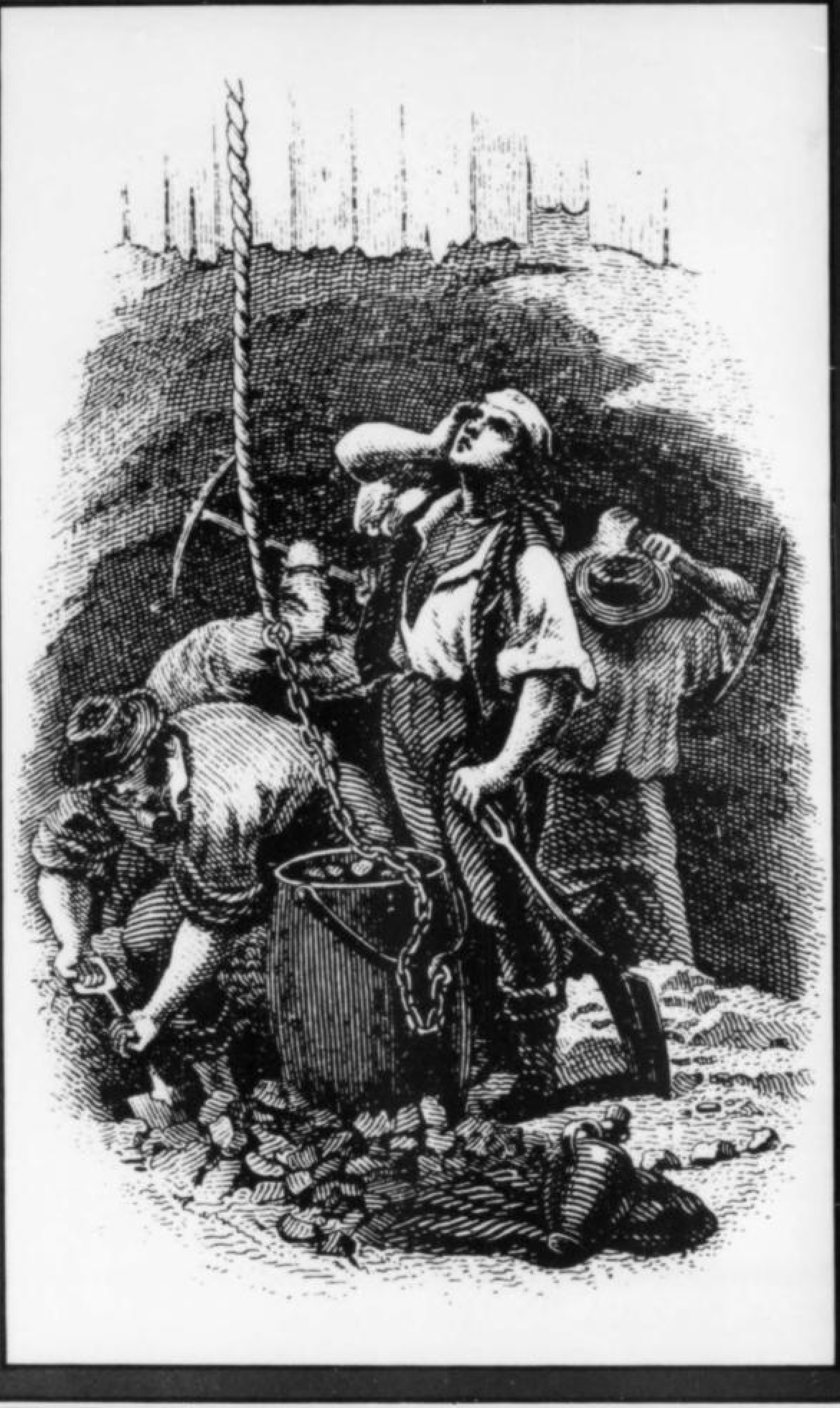
Individual requests invited.

**MOUNTAIN GEMS AND MINERALS**

**P.O. Box 25161 Portland. Oregon 97225 (503) 297-1928**

# California Mi

## Northern



**Maloney's Fossils**
Larry Maloney
P.O. Box 1053
Willows, California 95988
Tel: (916) 934-4536

**A. L. McGuinness**
Al McGuinness
4305 Camden Avenue
San Mateo, California 94403
Tel: (415) 345-2068

**Pathfinder Minerals**
Mary Jean & Larry Cull
41942 Via San Gabriel
Fremont, California 94538
Tel: (415) 657-5174

**Roberts Minerals**
Ken and Betty Roberts
P.O. Box 1267
Twain Harte, California 95383
Tel: (209) 586-2110

**Frazier's Minerals and Lapidary**
Si and Ann Frazier
2000 Centre Street, Suite 1177
Berkeley, California 94704
Tel: (415) 848-9541

**Galas Minerals**
Chris and Agatha Galas
P.O. Box 1803
10009 Del Almendra
Oakdale, California 95361
Tel: (209) 847-4782

**Kassionas**
John and Dolores Kassionas
P.O. Box 578
Alviso, California 95002
Tel: (408) 263-7784

**The Lidstrom Collection**
Margaret Lidstrom
P.O. Box 5548
Carmel, California 93921
Tel: (408) 624-1472

**Runners**
Bruce and Jo Runner
13526 South Avenue
Delhi, California 95315
Tel: (209) 634-6470

# neral Dealers

## Southern

**Bourget Bros.**
1636 11th Street
Santa Monica, California 90404
Tel: (213) 450-6556

**California Rock and Mineral Co.**
2587 Pomona Boulevard
Pomona, California 91768
Tel: (714) 594-7134

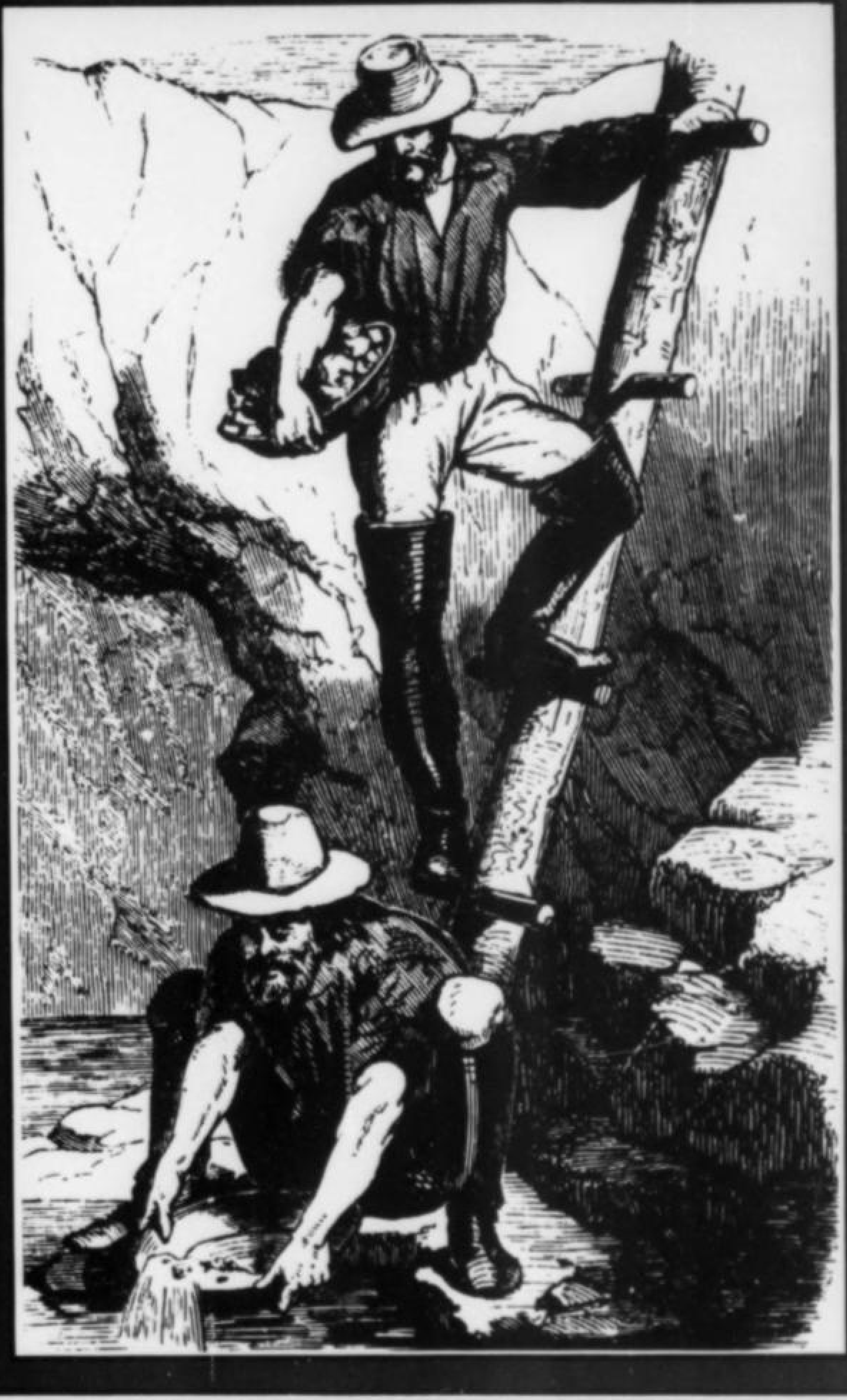
**Geoscience Minerals and Old Books**
Russ and Alix Filer
13057-MC California St.
Yucaipa, California 92399
Tel: (714) 797-1650

**Cal Graeber**
P.O. Box 47
Fallbrook, California 92028
Tel: (619) 723-9292

**Hamel Minerals**
6451 West 84th Place
Los Angeles, California 90045
Tel: (213) 645-1175

**Jewel Tunnel Imports**
Rock H. Currier
1212 S. Mayflower Avenue
Arcadia, California 91006
Tel: (213) 357-6338

**Kristalle**
332 Forest Avenue, #8
Laguna Beach, California 92651
Tel: (714) 494-7695



**Pala International & The Collector**
912 So. Live Oak Park Road
Fallbrook, California 92028
Tel: (619) 728-9121
US Wats 1-(800)-854-1598

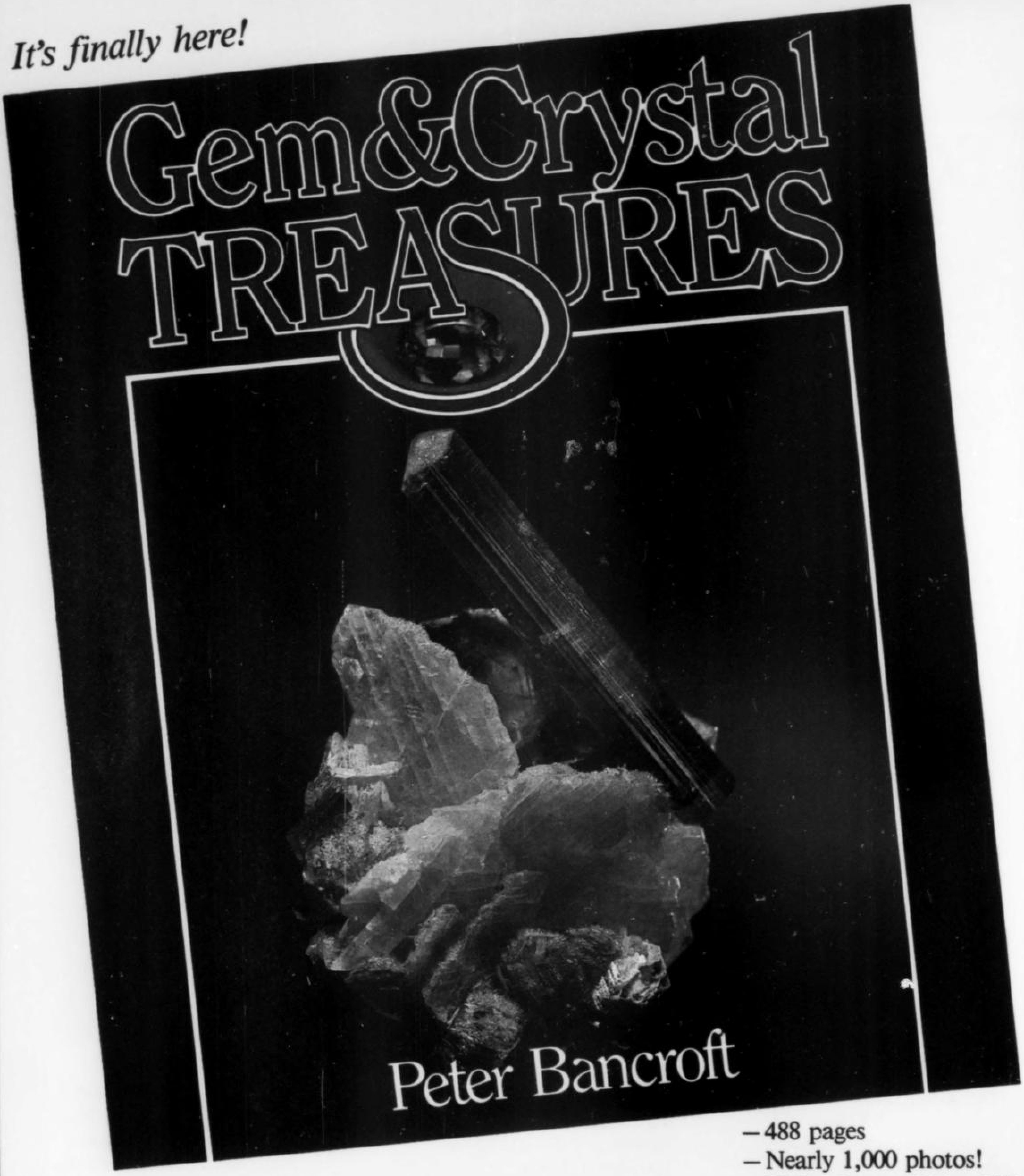
**Mark and Jeanette Rogers**
P.O. Box 1093
Yucaipa, California 92399
Tel: (714) 797-8034

**Schneider's**
13021 Poway Road
Poway, California 92064
Tel: (619) 748-3719

**Seibel Minerals**
20308 Sears Drive
P.O. Box 95
Tehachapi, California 93561
Tel: (805) 822-5437

**Weber's Minerals**
605 San Dieguito Drive
Encinitas, California 92024
Tel: (619) 436-4350

*It's finally here!*



- 488 pages
- Nearly 1,000 photos!
- 23.5 x 24 cm (9¼ x 11")
- Hardcover: $64 postpaid (U.S. and foreign)
- Leather Edition: $230 postpaid (foreign orders add $20)

Within these pages you will embark on 100 "field trips" to many of the world's most exotic gem and crystal mines. You'll relive the discovery and earliest days of each deposit, and meet those who worked in and about the mines—shopkeepers, sheriffs, miners, prostitutes, and bad men, all portrayed in 667 black and white illustrations and accompanying text.

Over 320 crystal and gemstone treasures gleaned from these deposits are depicted in full color. Each crystal has been selected as one of the choicest examples available. For the most part, specimens have been photographed in their entirety.

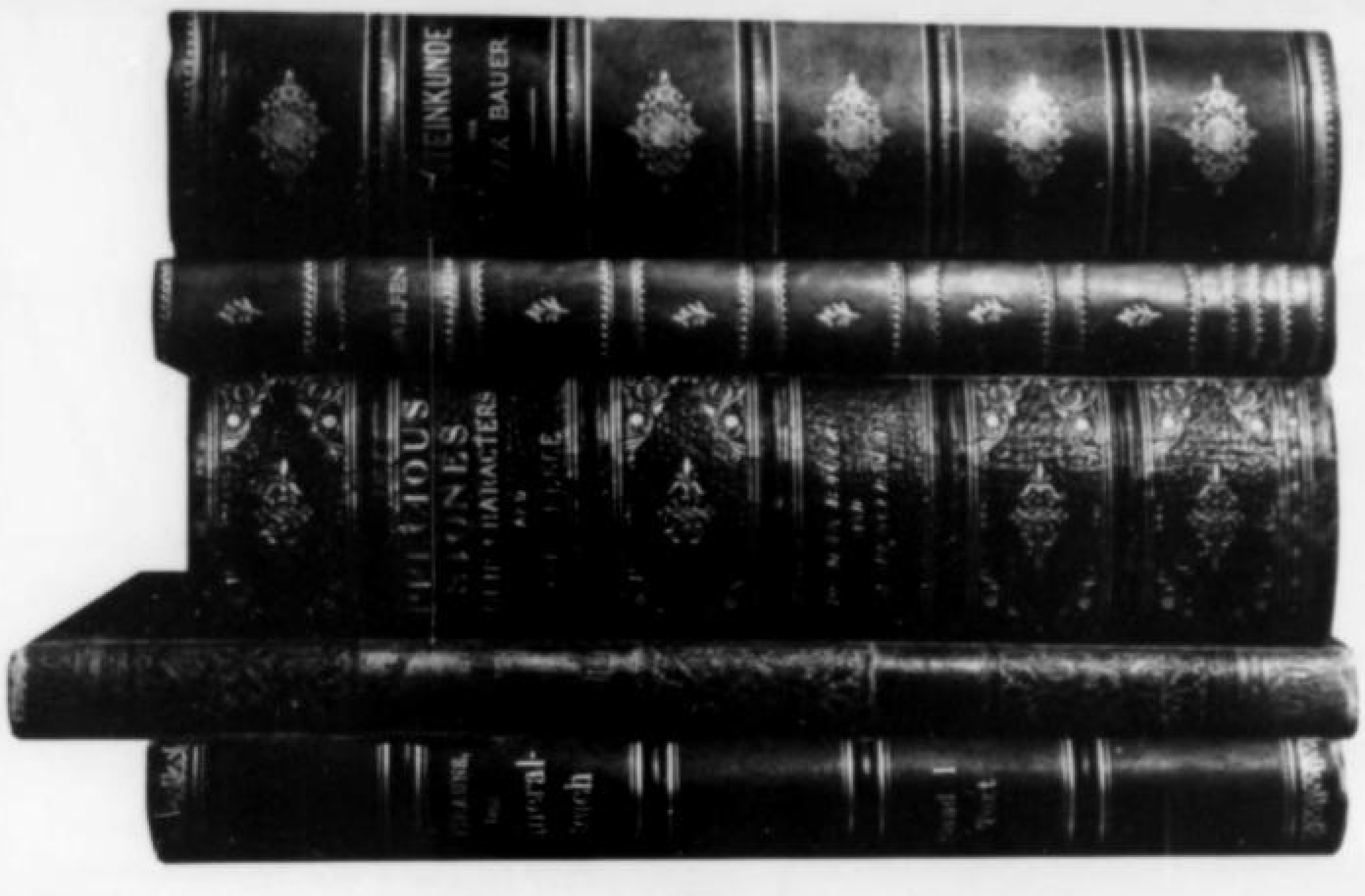
Dr. Peter Bancroft has assembled what may be the finest group of gemstone and crystal illustrations ever, augmented by photos of exquisite carvings, faceted gems, and stunning jewelry.

Step back in time and experience human drama as it was—incredible good fortune, stark tragedy, and every conceivable event inbetween. Marvel at a wealth of gemstones and naturally formed crystals—surely among God's greatest treasures.

* Prepaid
orders only,
except by
previous arrangement

*Mineralogical Record Book Dept.*

TEL.: 702-883-2598 P.O. BOX 1656, CARSON CITY, NEVADA 89702



# Book Reviews

***Brazil: Paradise of Gemstones*, by Jules R. Sauer. Published (1982) by J. R. Sauer, Rio de Janeiro, Brazil; available from Mineralogical Record Book Department, P.O. Box 1656, Carson City, Nevada 89702. Hardcover, 136 pages, 100 color plates, 18.5 x 26 cm, $24 postpaid.**

Given the importance of Brazil's extraordinary gem wealth in the international marketplace, it is surprising that until now no one book addressing the subject was available to the mineralogist. *Brazil: Paradise of Gemstones* is an excellent beginning to the filling of this void. While the book does not go into great detail on each of the various gem species found in Brazil, it does give the reader an adequate introduction. In addition, the book is beautifully illustrated with superb Harold and Erica Van Pelt photographs of crystal specimens and cut stones.

The text is divided by species; for each the author gives a brief description, including its possible color range, the derivation of its name, the causes of its color, and the like. Following this background, Sauer goes on to describe the major Brazilian deposits in which the material has been found, along with a brief history. This history may include detail on recent discoveries, such as the 1977 find of unprecedentedly large and fine rubellite crystals near Conselheiro Peña in Minas Gerais. The only distraction to the book, a minor one, is that the table of contents is in the rear; essentially doubling as a brief index.

*Brazil: Paradise of Gemstones* will be an important introduction for the casual reader, and delightful reading for the mineralogist, particularly as a reference for gem localities.

**Peter C. Keller**

(Reprinted by permission from *Gems & Gemology*.)

***Bibliotheca De Re Metallica; the Herbert Clark Hoover Collection of Mining & Metallurgy*, annotated by David Kuhner, cataloged by Tania Rizzo, introduction by Cyril Stanley Smith. Published (1980) by the Library of Claremont College, Claremont, California; printed at the Arion Press, San Francisco; hardbound in cloth, 221 pages, 17.8 x 28 cm, $125.**

The price of this book suggests that it is something special, and so it is: a fine example of quality book printing and binding. The cream-colored paper feels almost like hand-made, the printing is by individually set metal type, and the binding (a fine-textured, muted olive-colored cloth with gold stamping) has a luxurious feel. And finally, the limited press run (500 copies) makes this a rather exclusive offering.

Presentation aside, the contents of this book are valuable and fascinating indeed, especially for the book collector. It is an annotated catalog of the collection of 912 pre-1800 books on mining and metallurgy assembled by Herbert Hoover (mining engineer and later U.S. President) between 1908 and 1914. Hoover and his wife Lou had taken on the formidable task of translating Agricola's monumental *De Re Metallica* (1556) from Latin into English; the book collection provided valuable references and background material for that work. Hoover, it must be said, was infected with bibliophilia as well as academic motivation; although his translation was completed in 1912, it was two more years before he could bring himself to stop purchasing rare books related to the job.

The compilation (plus the informative annotations) is an excellent reference for modern-day collectors. And, for those not feeling compelled to own their own copies of such extremely rare and expensive books, it tells what is available for the use of visiting scholars at Claremont College, where the collection now resides.

**W.E.W.**

***Butte's Memory Book*, by Don James (1980). Published by Caxton Printers Ltd., P.O. Box 700, Caldwell, Idaho 83606; hardcover, 23 x 28 cm (9 x 11 inches), 295 p., $19.95 (postage free with prepaid orders).**

The mining town of Butte, Montana, built on "the richest hill on earth," is well known among mineral collectors as the source of many fine copper minerals. Over two billion dollars have come out of the ground here, through nearly 5,000 km of workings reaching a depth of well over a kilometer. Much has been written about Butte, but this book by Don James is the most profusely illustrated and the most evocative of the town's rich mining history. It is essentially a picture album of antique photos accompanied by minimal text. Most interesting is the first chapter, "The Mines," but the other two chapters, "The Town" and "The People," are fascinating in their own way and certainly worth the time of anyone interested in the history of famous mineral localities.

**W.E.W.**

## TITLES RECEIVED

***Mineralogical Studies on Guatemalan Jade*, by William F. Foshag. First published in English (1957) by the Smithsonian Institution as publication 4307, Smithsonian Miscellaneous Collections, vol. 135, number 5; 60 pages plus 8 black and white plates. Reprinted (1984) by the Smithsonian Institution Press. Available at no charge.**

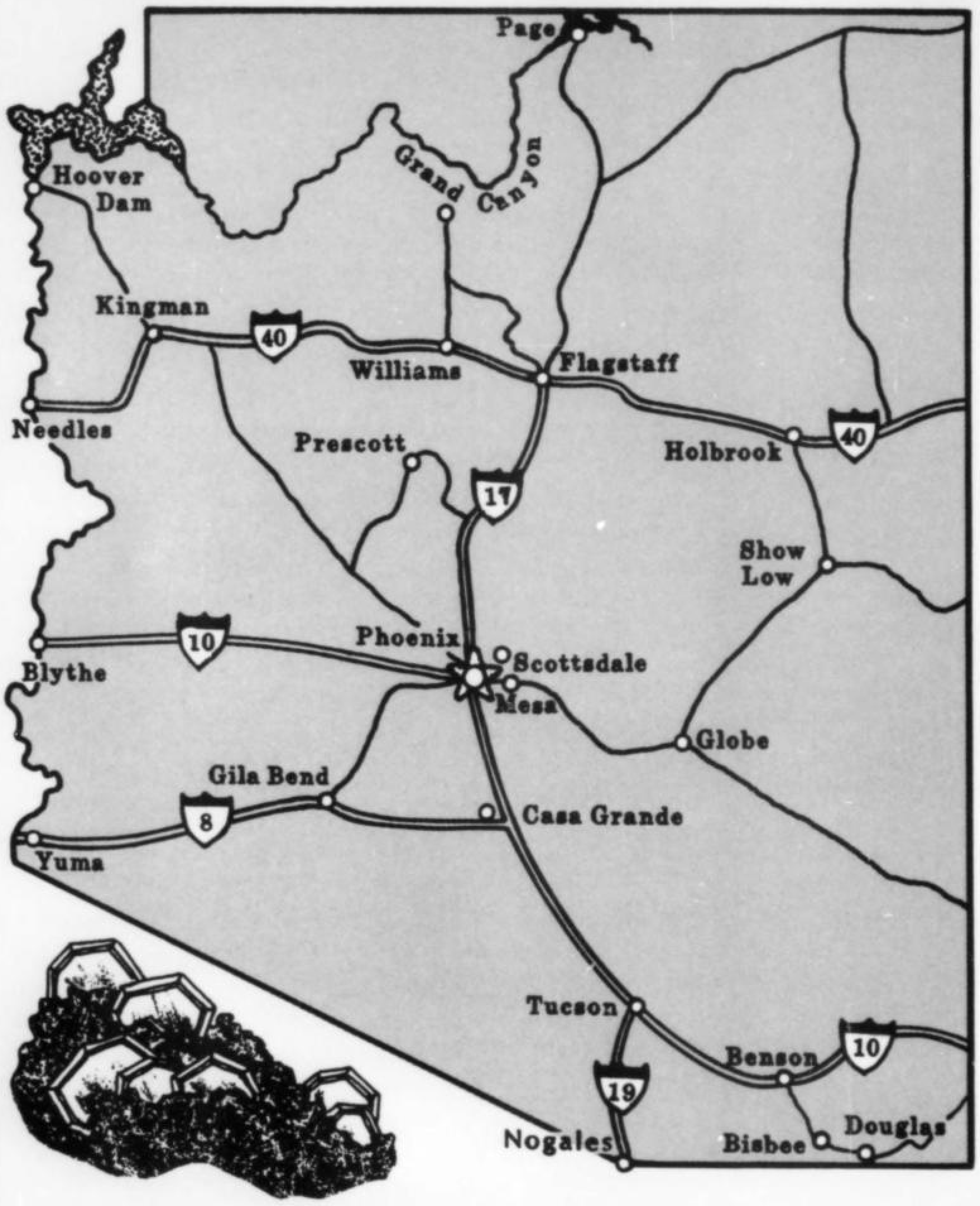
In his 1984 preface to this reprint, John S. White calls Foshag's work "a major contribution to the literature and a classic for its time," and concludes that Foshag's data are "precisely the type of fundamental research upon which subsequent, more sophisticated and often more specialized, studies depend."

***Gems and Minerals of Washington*, by Robert Pattie (1983). A brochure available at no charge from the Tourist Promotion Division, Department of Commerce and Economic Development, 101 G. A. Building, Olympia, Washington 98504.**

***The Field Description of Metamorphic Rocks*, by Norman Fry. Published (1984) by Halsted Press, John Wiley and Sons, One Wiley Drive, Somerset, New Jersey 08873. Paperback, 11.7 x 18 cm, 110 pages, $12.95 postpaid.**

# Arizona Mineral Dealers

*Arizona Is Fast Becoming The Center For Dealers of Minerals & Supplies!*



*Throughout Arizona there are numerous mineral dealers and field collectors who sell wholesale, retail or both. We encourage you to visit Arizona and our many fine dealers.*

*Below, a few of us are listed: Appointments prior to visits are recommended (dealers tend to travel often).*

**Bitner's, Inc.**
42 West Hatcher
Phoenix, Arizona 85021
(602) 870-0075

**Copper City Rock Shop**
John & Melba Mediz
566 Ash Street, Hwy. 60-70
Globe, Arizona 85501
(602) 425-7885

**Cureton Mineral Company**
Forrest & Barbara Cureton
P.O. Box 5761
Tucson, Arizona 85703
(602) 743-7239

**De Natura**
Les & Paula Presmyk
P.O. Box 2512
Mesa, Arizona 85204
(602) 830-1406

**49-er Minerals**
Jim & Joyce Vacek
1903 N. 74th Street
Scottsdale, Arizona 85257
(602) 994-9024

**Dr. David H. Garske**
Mineralogist
Brewery Gulch (P.O. Box 83)
Bisbee, Arizona 85603
(602) 432-3362

**Kino Rocks & Minerals**
6756 S. Nogales Highway
Tucson, Arizona 85706
9-11:15/Noon-5:30 (Closed Sun.)
(602) 294-0143

**Lesnicks West-Wholesale**
Beth & Stan Lesnick
P.O. Box 31074
Tucson, Arizona 85751
(602) 749-3435

**Panczner Minerals**
Div. Panczner Associates
640 N. La Cholla Boulevard
Tucson, Arizona 85745
(602) 624-0680

**David Riley Minerals**
529 W. Pepper
Mesa, Arizona 85201
(602) 898-0740

**David Shannon Minerals**
David & Rena, & Mike
1727 W. Drake Circle
Mesa, Arizona 85202
(602) 962-6485

**Southwest Geosupply**
Scott & Kelly Wendegatz
P.O. Box 5405
Mesa, Arizona 85201
(602) 898-3396

**Maudine & Bob Sullivan**
Geological Specimens Int'l.
3202 Saguaro West Trail
Tucson, Arizona 85745
(602) 743-0081
See us at the major shows only

# What's New in Minerals?

by Wendell E. Wilson

## SAN DIEGO FEDERATION SHOW

The big Federation show (AFMS-CFMS) on the West Coast this year was held in San Diego and was hosted by the 50-year-old San Diego Mineral and Gem Society. I realize that Federation shows move around from city to city and are supposed to be something special, but if this show could be duplicated *every* year it could develop a real reputation as one of the few shows having nationwide stature, like Detroit and Pasadena.* The three big criteria were met: good dealers, good displays and good lectures. And in each case the selection was strengthened by important out-of-state participation, further evidence of a high-quality show.

San Diego itself is a modern, affluent port city with a superb Mediterranean climate, no end of fine restaurants and interesting sights to see, and excellent convention facilities. Combine this with a large enough local population to draw on for attendance (including Los Angeles, which is within commuting distance), an enthusiastic local society to play host, and also the fact that San Diego County is the nation's most important gem pegmatite area, and you have all the ingredients for a first-rate show.

During the four days of the show, no fewer than 22 lectures were presented, at least half of them appealing to mineral collectors as well as gem folk. The speaker chairman was none other than Peter Bancroft, whose new book made its world-premier at the show (the book, as expected, was a hit, and Peter was pestered into writer's cramp by autograph hounds).

Orchestrating the displays, over 200 of them, must have been quite a job as well. Although too diverse to summarize briefly, there were certainly plenty of California's most famous products: pegmatite minerals and gold. And a large array of private collections was coaxed out of the woodwork . . . there are a great many such in California.

Getting down to dealer minerals: Washington still grudgingly gives up a few fine pyrite and quartz specimens from time to time (see vol. 9, no. 6, p. 349–358), but only to the most intrepid souls. Ken Roberts showed off some recently found examples which he collected himself. They are lustrous and beautiful, every bit as good as the earlier material, though nothing over small cabinet size and only about a dozen pieces total. The Roberts also had some extremely fine specimens of gemmy, golden brown siderite crystals in groups up to cabinet size (but also some nice miniatures too) from the famous Morro Velho mine in Brazil, and several groups of large (to 5 cm), well formed pyrrhotite crystals from the same locality (see vol. 4, no. 5, p. 224–229). About 40 siderites and three good pyrrhotites comprised the lot. Finally, here is a tip for the forthcoming Pasadena or Detroit shows: Ken has in storage a number of very fine pieces of green and dark purple fluorite from Namibia (labeled "Okaruso"). These still need careful cleaning, however, and will not be ready for sale for awhile. The one piece he had prepared for San Diego is a large cabinet specimen, perhaps 30 cm, and very esthetic.

Speaking of self-collecting dealers, John Seibel (P.O. Box 95, Tehachapi, CA 93561) continues to make major discoveries. Two separate occurrences worthy of more detailed description at a later date were brought forth for the show. The first is a remarkable find of creedite having a very rich, medium-purple color rather than the pale lavender (at best) of previous finds. The crystals are not exceptionally large, most of them ranging from 2 to 10 mm and are grouped in solid, sparkling crusts lining seams and vugs. But they are very lustrous, transparent and well formed. About 200 relatively good pieces and perhaps a dozen very fine ones were recovered. The locality is the Liberty mine near Tonopah, Nevada.

John's other big strike (with Harvey Gordon) was made at the Miracle Mountain mine near Volcano, Calaveras County, California, where they found huge epidote and axinite crystals. The epidote, in blocky crystals to 23 cm, is of major significance and compares well with specimens from Prince of Wales Island, Alaska. The crystals are characterized by flat, smooth faces and very few striated surfaces, giving them a recognizable personality all their own. A few crystals even show nice twinning. Associated, though unfortunately not attached, quartz crystals up to 45 cm in length are quite interesting as well; the prisms taper gracefully to a small rhomb termination with green byssolite inclusions. Palygorskite is found as loose masses in all the pockets. Axinite crystals to about 7 cm, in sub-parallel groups and sheaves, were found in nicely shaped groups but show some alteration. Consequently the color is an opaque, mottled tan. All in all, more than 100 good epidote specimens and just a few good axinites and quartz crystals were removed.

Herb Obodda and Dave Wilber brought back another even larger batch of beautiful tourmaline from the Gilgit-Skardu area of Pakistan. Their earlier lot of this material, brought out last February (see vol. 15, no. 3, p. 177), was a highlight of the last Tucson Show. The crystals are blackish green in the center zone, with medium green, pale green and colorless zones on each end. Some of the terminations have a pleasant purplish pink color. The interesting thing is the peculiar tendency these crystals have for doubly terminated development, with the crystals perched on or partially intergrown with attractive white cleavelandite.

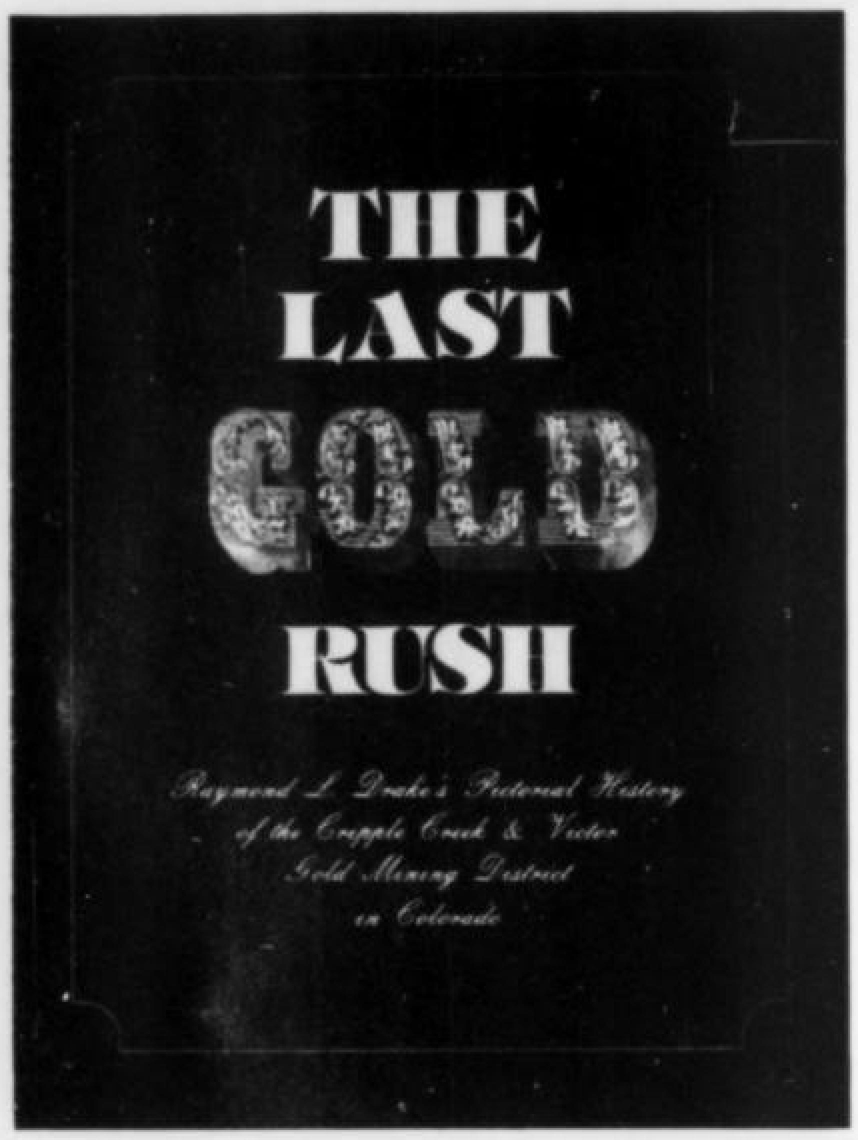
Miriam and Julius Zweibel (*Mineral Kingdom*) surprised everyone with a really striking selection of new green apophyllite from the Pashan quarry, Poona, India. The 27 specimens, most of which are cabinet size, have well-colored crystal groups and excellent transparency and luster rivalling anything previously seen in the long history of this classic occurrence.

A find of black andradite crystals was recently made in Mexico by Tom Palmer (*Crystal Cavern Minerals*). The locality is the Ojos Españoles mine near Ciudad Lazara Cardenas in Chihuahua. These crystals have a distinct feeling of quality about them which is difficult to describe. It must have something to do with the surface details of the lustrous, brilliantly black faces and sharp edges. The largest of the really fine crystals is about 4 cm across, though larger crystals of poorer quality were also found. They occur in intergrown but esthetic groups.

Of course, dazzling arrays of other minerals were layed out by the various dealers . . . only the relatively new finds are mentioned here. And, as usual, even a few of the gem dealers had nice uncut crystals for sale. Collectors who managed to satiate themselves with all this could make a short excursion up to Balboa Park and see the fine display of tourmaline at the San Diego Museum of Natural History, then visit the incomparable San Diego Zoo, or simply sprawl out on a pristine beach and watch the Pacific Ocean roll in. As I said . . . a great place for a mineral show!

---

*Tucson and Munich have *inter*national stature.



You can now order article reprints from the Mineralogical Record

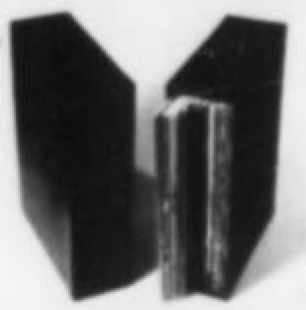
University Microfilms International, in cooperation with publisher of this journal, offers a highly convenient Article Reprint Service. Single articles or complete issues can now be obtained in their original size (up to 8½ x 11 inches). For more information please complete and mail the coupon below.

ARTICLE REPRINT SERVICE
University Microfilms International

☐ YES! I would like to know more about the Article Reprint Service. Please send me full details on how I can order.
☐ Please include catalogue of available titles.

Name ____________ Title ____________
Institution/Company ____________
Department ____________
Address ____________
City ____________ State ____________ Zip ________

**Mail to:** **University Microfilms International**
Article Reprint Service
300 North Zeeb Road
Ann Arbor, Michigan 48106



The Deluxe Magazine File

The Blade-Lock Binder

Record BINDERS

HOW TO ORDER:
Both the file boxes and the binders are 3 inches thick. **One box or one binder** will hold Volumes 1-4 (22 issues), Volumes 5-7 (18 issues), or Volumes 8-9 (12 issues). (You can see that the *Record* has grown consistently thicker over the years!)

**NOTE**: Each binder comes with 12 blades to hold 12 issues. **You must order extra blades** if you wish to put more than 12 issues in a binder. Extra blades come in packages of 12.
Please specify catalog number and "Mineralogical Record" when you order:
**Deluxe Magazine File**—Title: The Mineralogical Record
Black only (# **23-220A**) **$6.50** each postpaid
**$5.85** each for 3 or more
**Blade-Lock Binder**—Title card: The Mineralogical Record
Gray only (# **A52-572A**). **$17.75** each postpaid
Package of 12 extra blades
(# **A52-565A**). . $3.15 when ordered with binder;
$4.45 when ordered alone.

Send Order Directly To
(and make checks payable to)
**THE HIGHSMITH COMPANY**
**P.O. Box 25M**
**Fort Atkinson, WI 53538**
(a catalog of other items is available on request)

NATURE'S TREASURES
**P.O. Box 10136**
**Torrance, CA 90505**

We've moved but still have fine mineral specimens in all sizes and prices from world-wide localities,
✲ Rare minerals
✲ Museum pieces
✲ Single crystals
Always something new.
Send 25¢ for list.
Dealer inquiries invited.
No cutting materials.
✲ ✲ ✲ ✲

Hours by appointment
**(213) 373-3601**

**SOME SIMPLE FACTS:**

You may have noticed from our previous ad that we like to have fun with our copywriting. But the truth is, we take the business end of mineral collecting pretty seriously. Here are the facts:

- We have a good inventory of splendid mineral specimens from all over the world, from T/N to cabinet sizes.
- We offer very reasonable prices and a wide price range.
- We guarantee your satisfaction.
- We specialize in Australian, African and Indian minerals, things you may have had difficulty getting elsewhere.
- We want your business.

*For a list, please call or write:*

**GRAYSON LAPIDARY**
**5135 Washington Street Hillside, IL 60162**
**(312) 499-1399**

Overseas: Please send International Reply Coupon for list.

**Micros, TNs, Miniatures**
*free lists!*
**Hermann Eustrup**
Heiersstr. 15, D-4790 Paderborn
West Germany 05251/26649

LIDSTROM
COLLECTIONS,
INC.

WHOLESALE ONLY
BY APPT. ONLY

P.O. Box 5548, Carmel-by-the-Sea
California 93921—(408) 624-1472

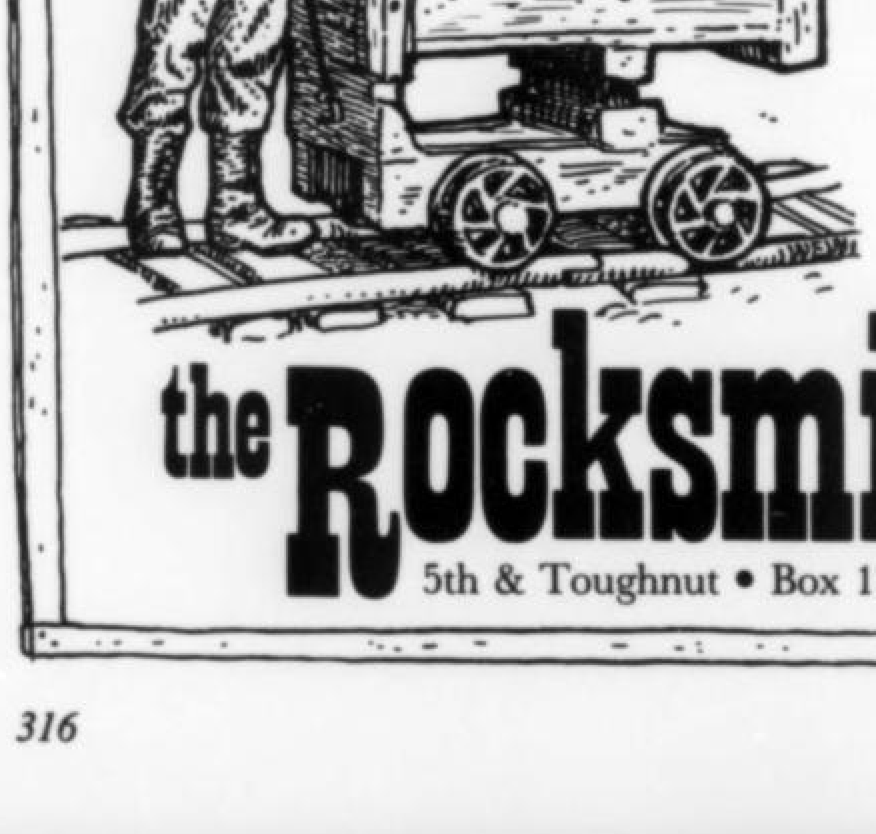
Complete Set of the
**Mineralogical Record**
available for purchase.
Excellent condition. Contact:
**Chet Pohl,** 101 Longwood,
Lafayette, LA 70508
(318) 989-0623 • (318) 269-7715

Bart Cannon

FEATURING A UNIQUE STOCK OF WESTERN NORTH AMERICAN MINERALS; MICROMOUNT THROUGH CABINET SIZE... DISPLAY AND RARE SPECIES. SULFOSALTS, SILICATES AND PSEUDOMORPHS ARE EMPHASIZED.

FREE ILLUSTRATED LIST

1041 N.E. 100 ST., SEATTLE, WA 98125 (206)522-9233



Fine Mineral Specimens
* New European
Acquisitions

**SHOWS**

| | |
|---|---|
| Oct. 6-7 | Franklin, NJ |
| Oct. 12-14 | Detroit, MI |
| Oct. 19-21 | Richmond, VA |
| Nov. 9-11 | St. Louis, MO |
| Nov. 10-11 | Dallas, TX |
| Nov. 14-15 | Austin, TX<br>Private showing |
| Nov. 16-17 | Houston, TX<br>Private showing |
| Nov. 24-25 | West Palm<br>Beach, FL |

**the Rocksmiths**

Eldon, Jean
& Jaye Smith
602-457-3691

5th & Toughnut • Box 157 • Tombstone, Arizona 85638

**A.G.A.B.**
Association des Geólogues
Amateurs de Belgique

**15. Intermineral**

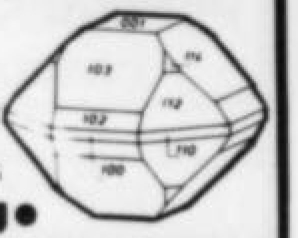
**the 15th Annual**
**Liége International Show**

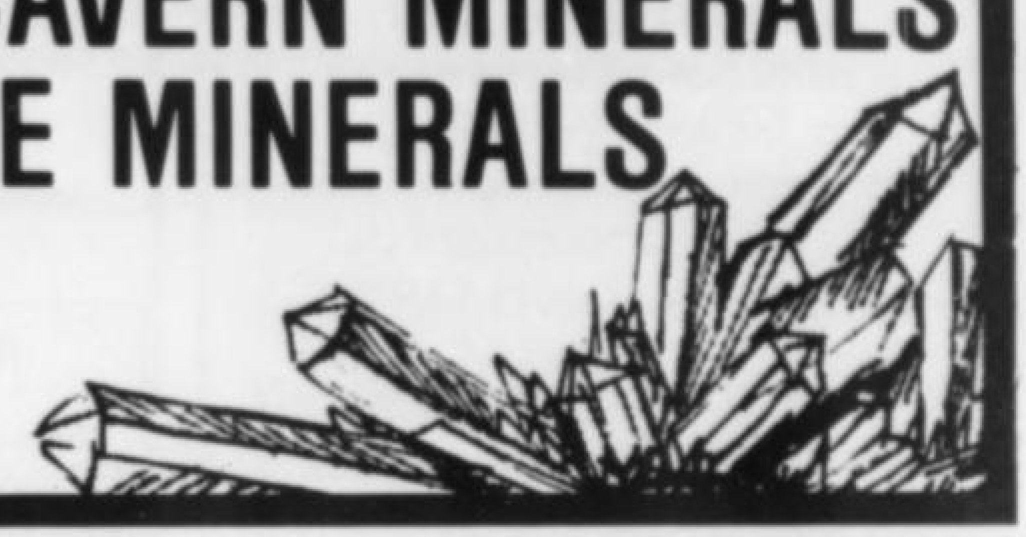
Lycée L. de Waha,
96 Blvd. D'Avroy
Liége, Belgium

**Nov. 24-25**

MINERALS – FOSSILS – GEMS

Dealer Chairman:
René Hubin
8 Heid du Moulin
B-4051 Neupré
Belgium


001
103
114
112
102
110
100



**TOPAZ-MINERAL EXPLORATION**
DEPT. M
1605 HILLCREST
GRAND HAVEN, MI. 49417
WORLD-WIDE MINERALS
PSEUDOMORPHS
LIST

**CRESTMORE / JENSEN QUARRY MINERALS**
75 Species, Crestmore Quarry
25 Species, Jensen Quarry
Sent $1 for catalog to:
**Jurupa Mtns. Cultural Center**
**7621 Granite Hill Drive**
**Riverside, CA 92509 (714-685-5818)**

*Mineral List Available*

**WHOLE EARTH MINERALS**
P.O. BOX 50008
RENO, NEVADA 89513

***W.D. Christianson, Minerals***
**200 NAPIER STREET, BARRIE**
**ONTARIO, CANADA L4M 1W8**
**TELEPHONE: (705) 726-8713**

- **Free Introductory List**
- **Mail Order For Over 20 Years**
- **New And Rare Species**
- **Beginner To Advanced Customers**
- **We Buy, Sell And Trade**

*Your guarantee of satisfaction*

**Mineralight® Lamps**
**with the**
**5000 hour filter**
Brilliant fluorescence that is brighter than our old lamps after 13 hours - a reversal of all previous experience. Only Mineralight lamps can make this claim. Send for a free catalogue.
**Ultra-Violet Products, Inc.**
is now: **UVP, Inc.**
5100 Walnut Grove Ave.
P.O. Box 1501
San Gabriel, CA 91778 U.S.A.
(213) 285-3123 • Telex: 688461

L.T. HAMPEL'S
**PRECIOUS EARTH COMPANY**

HAS
FINE
MINERAL
SPECIMENS

From World-Wide Localities
Including Beautiful Pieces
From Wisconsin & Michigan's
Iron, Copper & Lead Mines

For our latest list write or call
**TOLL FREE 1-800-558-8558**
Wis. Residents call 414-255-4564
Phones Answered Days and
Most Evenings and Weekends
**Your MasterCard or VISA**
**accepted for specimens on approval**

MasterCard VISA

SHOWROOM BY APPOINTMENT
**9940 Neptune Dr., Germantown, WI 53022**

**MONTEREGIAN MINERALS**
**MICROMINERALS AND RARE SPECIES**

Specializing in Mt. St-Hilaire and
other Canadian localities. List available.

**P.O. Box 2096, Dorval, Quebec**
**H9S 3K7 CANADA**

C. C. RICH
Buying/Selling Microminerals
— Satisfaction Guaranteed —
Frequent Free Mail Lists
115 Boot Road
Newtown Square, Penn. 19073

**GREGORY, BOTTLEY & LLOYD**
MINERALOGISTS & GEOLOGISTS - ESTABLISHED 1850

8-12 RICKETT STREET, LONDON SW6 1RU
**TELEPHONE 01-381 5522: TELEGRAMS METEORITES LONDON SW6**

Brian Lloyd looks forward to seeing you when you are next in London. We are open weekdays 9:30 to 5 pm — evenings and weekends by appointment.

***New for Arizona*** **. . . La Paz Co, Az**
**TOCORNALITE**
**Rare Silver Mercury Iodide**
**massive with Chlorargyrite xls**
Over 500 Mineral Specimens in Stock
send three stamps for complete listing
DAVID SHANNON MINERALS
1727-M W. DRAKE CIRCLE, MESA, AZ 85202 (602) 962-6485
**** COME SEE OUR DISPLAY ROOM & TALK "ROCKS"**

*Gold xls to 1 inch*

**Mineral Classics**

Minerals, Gems, Mining, Consulting. We offer superb quality mineral specimens and gems for advanced and discriminating collectors and museums, direct from our own mines and prospects in Colorado, including world-class amazonite. We also have an extensive stock of Bolivian minerals, Alpine minerals from Italy and Switzerland, and a comprehensive collection from worldwide localities. Inquiries invited. No list. Professional consulting and appraisal service available.

RICHARD A. KOSNAR
3113 Highway 46
Golden, Colorado 80403
(In scenic Golden Gate Canyon)
Tel: (303) 642-7556
Visits by appointment only!

**SALT MINERALS**

Worldwide Specimens
Free List

540 Beaverbrook St.
Winnipeg, Man. R3N 1N4
Canada

**New & Rare Species**

*free list*

HOWARD MINERALS
P.O. Box 56, Vanderveer Station
Brooklyn, NY 11210 (212) 434-8538

**"MINERALIEN"**

available in French edition.
Same 162 magnificent prints
from paintings by C. Caspari.

order "MINERAUX" $112.00 pp

FRANCIS PAUL
50 Church Street
Hoosick Falls, NY 12090
(518) 686-7986

**MICHIGAN COPPER COUNTRY MINERALS!**

**Decorative Copper ★ Copper and Calcite ★ Crystal Silver ★ Crystal Copper ★ Half Breeds ★ Fluorescent Datolite ★ Datolite ★ Mohawkite ★ Prehnite with Copper and Silver Wires ★ New find: Cuprite xls on Copper**

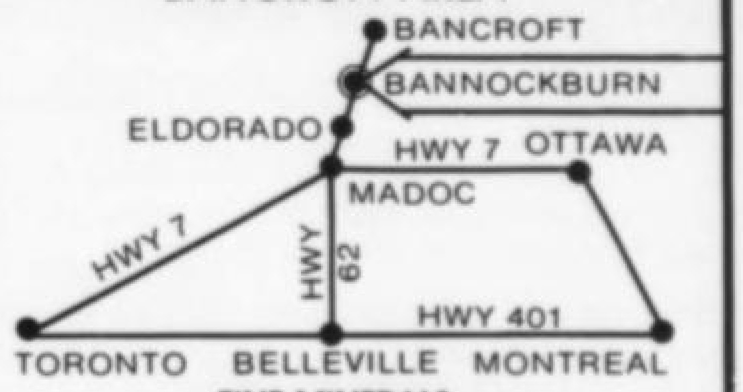
**DON PEARCE**
178 Calumet Ave.
Calumet, Michigan 49913
906-337-2093

**TETRAHEDRON MINERALS**

- We have been commissioned to dispose of a fine collection of 100 specimens in perfect condition, all crystallised, from worldwide localities. Many classics. Greatly reduced for a rapid sale as a single lot at $3,500. List available.
- SALE — Reference quality/massive items. Hundreds of unusual items all priced at under $2.00. Send for SALE listing.
- NZ MINERAL SLIDES & NZ GEOLOGICAL MAPS New listings are available.

**SEND YOUR WANT LISTS TO:-**
**P.O. BOX 226 PARAPARAUMU**
**NEW ZEALAND.**

BANCROFT AREA



**FINE MINERALS**
**HAWTHORNEDEN**
RR #1, Eldorado
Ontario, Canada KOK IYO
(613-473-4325) Frank & Wendy Melanson

**BRUSHY CREEK CALCITE**

**Irridescent chalcopyrite on calcite**

We once again have these famed crystals from the Brushy Creek Mine, Reynolds County, Missouri.

Specimens from 1" x 1" to 24" x 24", with crystals up to 15".

Other Missouri calcite, galena, pyrite, and marcasite specimens are also available.

Call or write for prices.

Retail and Wholesale

Bill & Julie Kepner

**B & J Rock Shop**
**620 Claymont Est. Dr.**
**Ballwin, MO 63011**
**Ph (314) 394-4567**

**BOOKS** OUT—OF PRINT

Send $1.00 for latest catalog listing 100's on minerals, mining, geology, fossils, gems.

**Tel.: 619-488-6904**
**PERI LITHON BOOKS**
P.O. Box 9996
5372 Van Nuys Court
San Diego, Calif. 92109

**DIAMONDS SPECIMENS DIAMONDS**

**Giant 100.00 cts. to Micros**

Cubes
Macles
Octahedrons
Dodecahedrons
Free Form Shapes
Conglomerate Crystals

**'The Rough Diamond Specialist'**
List $2.00 (Credit on order)
price, size, description, & drawings of specific stones

**Kenneth Glasser**
**P.O. BOX 1002, R.C.U., NY, NY 10185**
(212) 773-3471

**SCHNEIDER'S rocks & minerals**

**13021 Poway Road**
**Poway, California 92064**
**619-748-3719**

California benitoite,
tourmaline, spessartine,
morganite & minerals
from worldwide localities

NOW BY APPOINTMENT ONLY
OR SEE US AT THE SHOWS

**INDIAN MINERAL SPECIMENS.**

We offer 25 kgs of Okenite puffs specimens and Geodes OR 25 kgs mix mineral specimens, i.e. Apophylite, Stilbite, Heulandite, Okenite, Prehnite, Gyrolite, Calcite, Scolecite, Quartz, Laumontite, etc. by insured sea mail post for only US $180 CIF (Postage included). Send payment by TT to Grindlays Bank, 90 M.G. Road, BOMBAY - 400 023.

**ZEOLITES INDIA**
**D-311 Manju Mahal**
**35 Pali Hill Road, Bandra**
**BOMBAY - 400 050 INDIA**

**Metersky's Minerals**

MINIATURES & THUMBNAILS

*Affordable Minerals—Free List*
725 CHERYL DR., WARMINSTER, PENNSYLVANIA 18974

**A. L. McGuinness**

**WHOLESALE MINERAL SPECIMENS**

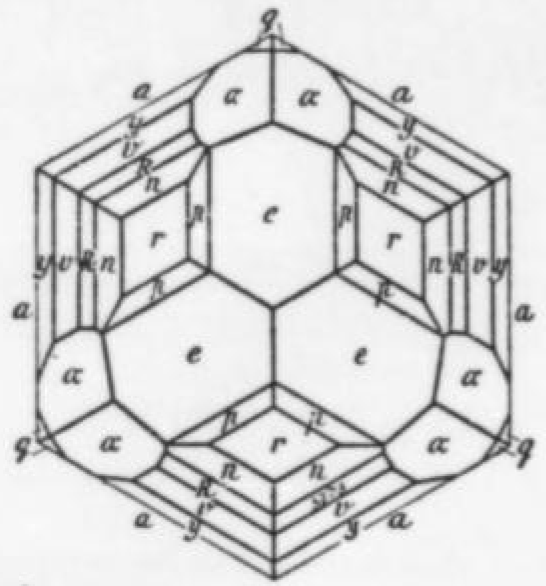
DEALER INQUIRIES INVITED
By Appointment Only — Lists $1.00
4305 Camden Ave., San Mateo, CA 94403
Tel: (415) 345-2068

**THE OUTCROP**

"MINERALS FOR THE COLLECTOR"
Send stamp for current list.
Satisfaction guaranteed.

PETE & NANCY OLSON (217) 787-6149
P.O. BOX 2171
SPRINGFIELD, IL 62705

*Searching the World*
*to bring you the finest in*
*Mineral Specimens*
*at competitive prices*



For your selection: Thumbnail, miniature & cabinet specimens

1. **FIRST QUALITY MINERAL SPECIMENS** for collection & display
2. **RARE SPECIES** for systematic collection, reference, research

**MINERAL LISTS:** Send for our bimonthly lists of thumbnail, miniature, and cabinet specimens. First quality mineral specimens for collection and display, plus rare species for systematic collection, reference, and research. Send 40¢ postage for lists, non-USA, send 80¢ or two International Reply Coupons.

**MICROMOUNT & SPECIMEN BOXES:** A separate listing is available detailing prices and sizes of micromount, Perky Boxes, plastic magnifier boxes, white cotton lined specimen boxes, etc. See the advertiser's index below for our other ad with prices, etc. Send 40¢ for our specimen box price list. Non-USA, send 80¢ or two International Reply Coupons.

**MICROSCOPES & OPTICAL GOODS:** Check our other ad in this issue for information and prices on stereo microscopes for gem and mineral use. Send 40¢ postage for complete microscope and optical goods catalog. Non-USA, send $1.50 postage or two International Reply Coupons.

**LOOK FOR OUR BOOTH AT MAJOR WESTERN U.S.A. SHOWS—SHOWROOM OPEN BY APPOINTMENT ONLY**

**MINERALOGICAL RESEARCH CO.**
A DIVISION OF THE NAZCA CORPORATION
**15840 E. ALTA VISTA WAY, SAN JOSE, CALIFORNIA 95127 U.S.A.**
**PHONE: 408-923-6800**

*Now dealing in out-of-print copies of the*
**Mineralogical Record**
★ Send us your want list
★ Let us know if you have copies to sell
★ Ask for listing of copies in stock

Upper Canada Minerals
**Specializing in Canadian Minerals**
**Patrick W. Collins**
**Madawaska House**
**Calabogie, Ontario, Canada K0J 1H0**
**Tel.: (613) 752-2201**
**Monday–Friday 9–5 by Appointment**

Wanted to Buy or Exchange
**METEORITES**
Correspondence Invited
**Jim DuPont**
391 Valley Rd., Watchung, NJ 07060

**WALSTROM**
**MINERAL ENTERPRISES**
Rare and fine mineral specimens
from worldwide locations. Specializing
in rare barium minerals.
**LIST AVAILABLE**
P.O. Box 583, Carson City, NV 89702

# ADVERTISERS INDEX