the Mineralogical Record

Volume Thirty-one,
Number Four
July–August 2000
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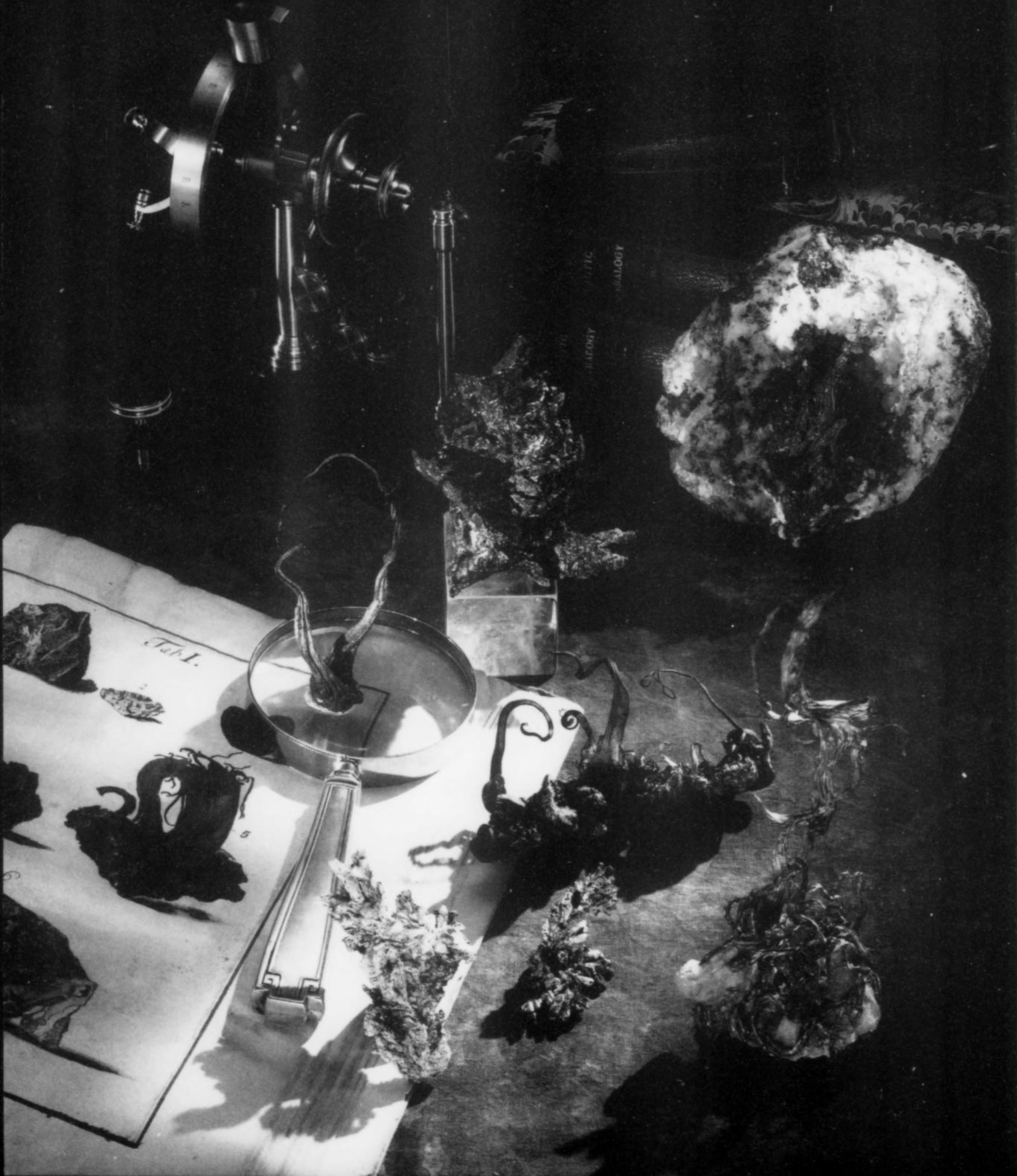
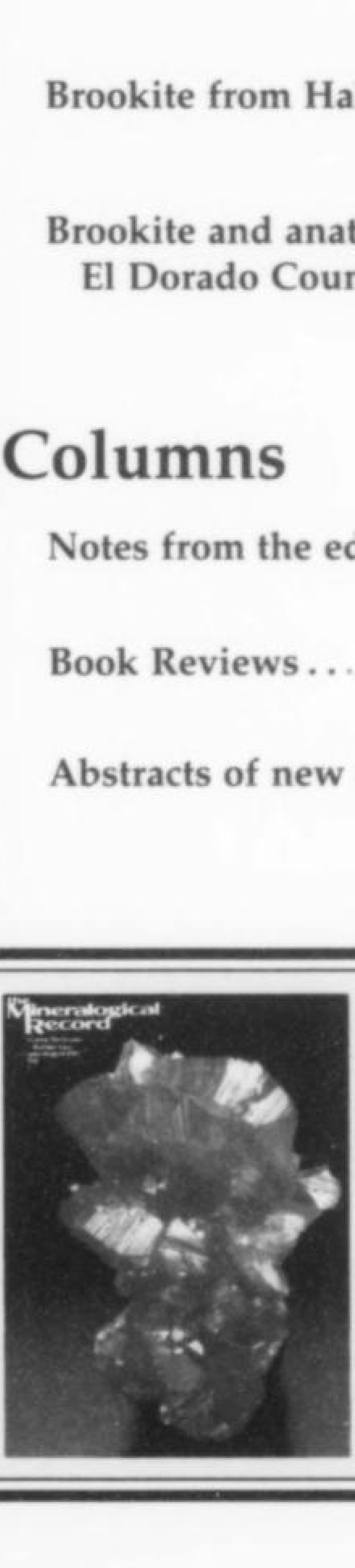

Tab. I.

THE MINERALOGICAL RECORD

July–August 2000 Volume Thirty-one, Number Four

Articles

Columns



COVER: ORPIMENT crystal cluster, 9.6 cm, from the Mega pit, Twin Creeks mine, Humboldt County, Nevada. Mined by Collector's Edge Minerals, Inc.; now in the Azurite Corporation collection. See the article beginning on page 311. Photo by Jeff Scovil.

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*Continued on p. 375

notes from the EDITOR

1909–12/31/1999

Died, Arthur Montgomery, 90, American mineralogist, mineral collector, mineral dealer, educator and author. Born in 1909, Arthur Montgomery was first introduced to minerals by his mother in 1928; she had traveled as a writer to Russia, and brought back for him a box containing a selection of Russian minerals. It was love at first sight. As he later wrote, "There was just a latent spark of tremendous interest, which struck fire the instant I saw those little bits of rock and mineral matter." Soon he was invading the American Museum of Natural History in New York to study specimens, reading mineral books for more data, collecting his own specimens while on summer vacation in the Adirondacks, and had become a member of the New York Mineralogical Society.

That same year, 1928, he attended an exhibition and sale of minerals held by Ward's Natural Science Establishment in a hotel near the American Museum; the thousands of specimens offered were the spoils of an extensive buying trip undertaken by a then-elderly George L. English, a man who had long been one of the most famous mineral dealers in the world, and was now working as chief mineralogist for Ward's. It was an exciting, frantic sale where, at the sound of a bell, collectors young and old scrambled to put their names on specimens chosen during a previous inspection-only period. Despite being a rank beginner, Montgomery acquired a number of fine specimens that day, including a yellow vanadinite from Tasmania and a cluster of water-clear anglesite crystals from Tunisia.

Montgomery enrolled at Princeton, and studied mineralogy under Professor Alexander Phillips, who set him firmly on the road to becoming a professional mineralogist. Following graduation in 1931, however, Montgomery did not feel capable of immediately tackling graduate studies; that would come later. Instead he spent a year in Europe, then worked for a time at Ward's, under George English, to become familiar with the commercial side of mineral collecting.

In the summer of 1933 Montgomery left New York and traveled west with his friend R. C. Vance (also a Ward's employee). They headed for the Thomas Range in Utah to dig for topaz, then proceeded on to the Virgin Valley, Nevada, opal fields where they collected for the remainder of the summer season. In October Montgomery returned once again to Utah, without Vance, but with the assistance of a local guide, and together they rediscovered the lost bixbyite type locality. It had remained unknown since Maynard Bixby's original description of it as "35 miles southwest of Simpson Springs" in 1895; the location given by Bixby was deliberately misleading. Montgomery found it deep in the rugged and then-nearly-inaccessible Thomas Range.

Back in New York, Montgomery heard one day from a friend that Tiffany's, the famous jewelry firm on 34th Street, had minerals for sale. Investigation revealed that there was indeed a storeroom with big skylights at the top of the building, and that part of it was turned over to a series of dusty glass-topped cases containing hundreds of fine mineral specimens gathered for Tiffany's many years before by George F. Kunz. It was a rare opportunity to find the old specimens for sale, and Montgomery added many fine pieces to his collection as a result.

Sometime during the early 1930's, Montgomery was introduced, by Dr. Charles Palache of Harvard, to a talented field collector named Edwin Over. Montgomery and Over soon formed a partnership in which Over dug mineral specimens and Montgomery marketed them. It was during the winter of 1937 that Over set out for Arizona and ultimately made fabulous discoveries of wulfenite at the Red Cloud and Hilltop mines. Montgomery kept the best five "Ed Over Red Clouds" in his personal collection for many years; they remain the finest known specimens of the species, their large size and striking color achieving near-legendary status among later generations of collectors.

Among Over and Montgomery's first project together was the Devil's Head, Colorado, topaz locality in the summer of 1934. They prospected and dug together, bringing out superb, colorless, blocky topaz crystals up to 11 cm across.

In 1935 they leased the San Diego mine in the Mesa Grande pegmatite field, in southern California. It was located just around the hill from the famous Himalaya mine, source of gorgeous red elbaite tourmaline crystals. Unfortunately, they found only a few small crystal pockets.

Montgomery also collected quartz "Pecos diamonds" in central New Mexico, quartz crystals in Madagascar, and epidote at Green Monster Mountain on Prince of Wales Island, Alaska (1936), among many other localities.

Returning from Prince of Wales Island, Alaska, in 1936, Montgomery and Over stopped at an abandoned mine near Fairfield, Utah. There they found substantial numbers of variscite nodules containing not only green variscite but also small, fine crystals of a range of interesting minerals. Among them were two new species ultimately named in their honor: *overite* and *montgomeryite*.

In 1939 Montgomery accompanied Over to the mountains of central Idaho near Boise. There they found a gem pegmatite that yielded beautiful, blue, gem-grade aquamarine crystals to 15 cm long and 2.5 cm across.

In 1942 Montgomery took an interest in a New Mexico pegmatite property, the Harding mine, and during the next few years produced industrial-grade tantalum, lithium and beryllium minerals for the U.S. government. The mine was inactive for a few years following the war, but in 1949 Montgomery's old mine foreman, Flaudio Griego, suggested they reopen the mine; within a few months hundreds of tons of industrial grade beryl were removed. The deposit proved to be one of the most remarkable pegmatites in the American Southwest. Montgomery later turned it over to the University of new Mexico in 1979 as a historic site worthy of permanent preservation and study.

Montgomery returned to university studies in the late 1940's and in 1951 was awarded a PhD in mineralogy from Harvard. He taught mineralogy at Lafayette College in Easton, Pennsylvania, from 1951 to 1975, and published many articles in professional journals and amateur publications. He was particularly devoted to the task of describing Pennsylvania quarries, mines and mineral occurrences, and published his *Mineralogy of Pennsylvania 1922–1965* in 1969. He also wrote a biography of Samual Gordon which was later serialized in the *Mineralogical Record.*

In 1970 Montgomery was instrumental in founding the Friends of Mineralogy and also made donations to cover the start-up costs of the *Mineralogical Record.*

In the late 1970's Montgomery began to divest himself of his personal wealth and his mineral collection. Disavowing commercialism, he donated many specimens to other collections (Richard A. Bideaux, for example, received ten fine specimens of his own choosing including a superb Ed Over Red Cloud wulfenite crystal). Montgomery devoted the remainder of his life to humble service to others.

Arthur Montgomery is a legend among mineral collectors, and stands as a significant figure in the mineralogy of Pennsylvania, Arizona, Utah and other states. His work and his creations, along with the many students he influenced over the years, will carry his name forward into the 21st century.

Readers may be interested in obtaining a copy of Arthur Montgomery's memoirs, *Reminiscences of a Mineralogist,* published in 1997 by the Pennsylvania Chapter of the Friends of Mineralogy and by the Matrix Publishing Company, Inc. (Jay Lininger), Dillsburg, Pennsylvania. The price is $23 postpaid. (See following page.)

Wendell E. Wilson

The Friends of Mineralogy, Inc.

Who We Are:

Vol 1, No 1, Mineralogical Record, Spring 1970

The *Friends of Mineralogy* was founded in Tucson, Arizona, on February 13, 1970. Its objectives were to promote better mineral appreciation, education and preservation. The chief aims and activities of *FM* include:

* Compiling and publishing information on mineral localities, and important mineral collections.

* Encouraging improved educational use of mineral specimens, collections, and localities.

* Support a semi-professional journal of high excellence and interest designed to appeal to mineral amateurs and professionals, through which *FM* activities may be circulated.

* Operating informally in behalf of minerals, mineral collecting, and descriptive mineralogy, with voluntary support by members.

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

Co-Sponsor, with the Tucson Gem & Mineral Society and the Mineralogical Society of America, of the Annual Tucson Mineralogical Symposia.

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Chapter Symposia
Annual chapter symposia schedules are available through each chapter's contact person, listed on this page.

Tucson TGMS-MSA-FM Symposium 2001

The twenty-second annual Mineralogical Symposium will be held on February 10, 2001 at the Tucson Gem and Mineral Show. It is cosponsored by Friends of Mineralogy, the Tucson Gem and Mineral Society, and the Mineralogical Society of America. The topic of the symposium is **Minerals of Russia**—the Tucson Show's theme for 2001. Papers on descriptive mineralogy, paragenesis, classic and new locations and related subjects about the minerals of Russia are welcome. An audience of amateur and professional mineralogists and geologists is expected.

Anyone wanting to present a paper should submit a 200 to 300-word abstract to Raymond W. Grant, Mesa Community College, 1833 W. Southern Avenue, Mesa, AZ 85202; Tel: (480) 461-7008; Fax: (480) 461-7234; e-mail: rwgrant@mail.mc.maricopa.edu.

Presentations will be twenty minutes in length, followed by a period for questions. Abstracts must be submitted by September 10, 2000. The abstracts will be published in the January/February 2001 issue of *The Mineralogical Record*.

JUANITAITE

A NEW MINERAL FROM GOLD HILL, UTAH

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ABSTRACT

Juanitaite, $(Cu,Ca,Fe)_{10}Bi(AsO_4)_4(OH)_{11}\cdot 2H_2O$, is a new mineral from the Gold Hill mine, Tooele County, Utah. The name is for Juanita Curtis who found the mineral. Juanitaite occurs at one occurrence as square crystal plates with rounded corners in sheaf-like subparallel aggregates and rosettes associated with conichalcite and mixite, scattered over fracture surfaces on limonitic matrix, and in another occurrence with connellite, tyrolite and azurite on quartz. The mineral formed from the oxidation of tennantite in quartz veins.

Juanitaite is olive-green to grass-green with a pale greenish yellow streak and resinous to dull luster. It is translucent and non-fluorescent. Crystals are tabular on {001} and also exhibit the forms {110} and {310}. Twinning was not observed. Plates are flexible, but not elastic. Cleavage is perfect on {001} and {110} and good on {100}. Fracture was not observed. The specific gravity measured by sink-float in Clerici solution is 3.61(5) g/cm^3. The calculated density is 3.56 g/cm^3. Crystals are uniaxial (–), ω 1.785(5), ε 1.705(5) (white light), but subparallel aggregates yield an anomalous biaxial figure ($2V \cong 20°$). No dispersion was observed. Pleochroism: O = olive-brown, E = olive-green.

Juanitaite is tetragonal, space group $P4_2/nnm$, $a = 9.961(3)$, $c = 29.19(2)$ Å, $V = 2896(2)$ Å^3, $Z = 4$. EMP analyses provided: CaO 8.64, FeO 2.32, CuO 35.97, Bi_2O_3 14.82, As_2O_5 29.35, H_2O (8.90) (by difference), total (100.00) weight %. Water was confirmed by IR. Juanitaite has a close chemical relationship with mixite, $Cu_6Bi(AsO_4)_3(OH)_6\cdot 3H_2O$. The six strongest powder diffraction lines are [d(Å)(I)(hkl)] 14.6(100)(002), 7.04(50)(110), 6.34(70)(112), 5.07(50)(114), 3.146(60)(310,303), 2.535(50)(228).

INTRODUCTION

In September of 1971, a group of four collectors, Juanita and Charles (Bob) Curtis, Wayne Leicht and Fred Croad, visited the Gold Hill mine. On the dump immediately west of the 30-foot level adit (see Kokinos and Wise, 1993, Fig. 2), they noticed weathered fragments of limonitic gossan bearing a green mineral that they took for malachite (but which was later determined to be mixite). Juanita noticed native gold in the matrix, which spurred Wayne and Bob to venture through a crawl hole into the shallow inclined adit. Here they found similar material in place in the walls. They collected approximately two flats of this material.

A couple of weeks later, while examining the material more closely, Juanita noticed dark spots resembling pepper scattered on many of the specimens. Under the microscope she observed these to be clusters of olive-green plates with bronzy reflections. They didn't match anything that she had seen before from Gold Hill, so she sent them to one of the authors (WSW) for identification. X-ray powder diffraction and chemical analysis indicated that the mineral

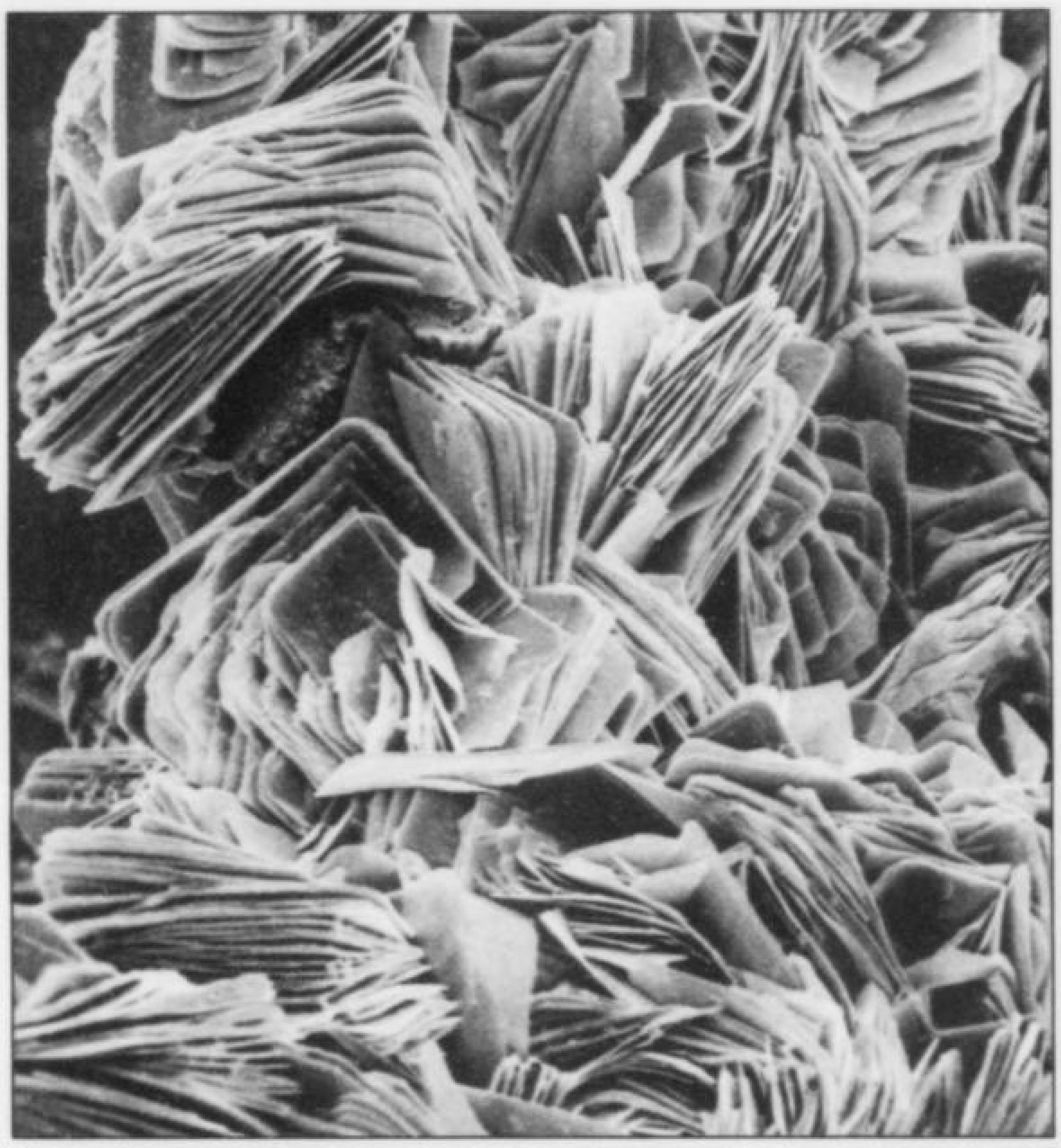

Figure 1. (top) **Dense surface coating of sheaf-like subparallel aggregates and rosettes of juanitaite plates; field of view is approximately 125 µm.**

Figure 2. (bottom) **Several groups of diverging juanitaite plates, about 35 µm across.**

Figure 3. (top) **A sheaf-like subparallel aggregate of juanitaite plates, about 35 µm across.**

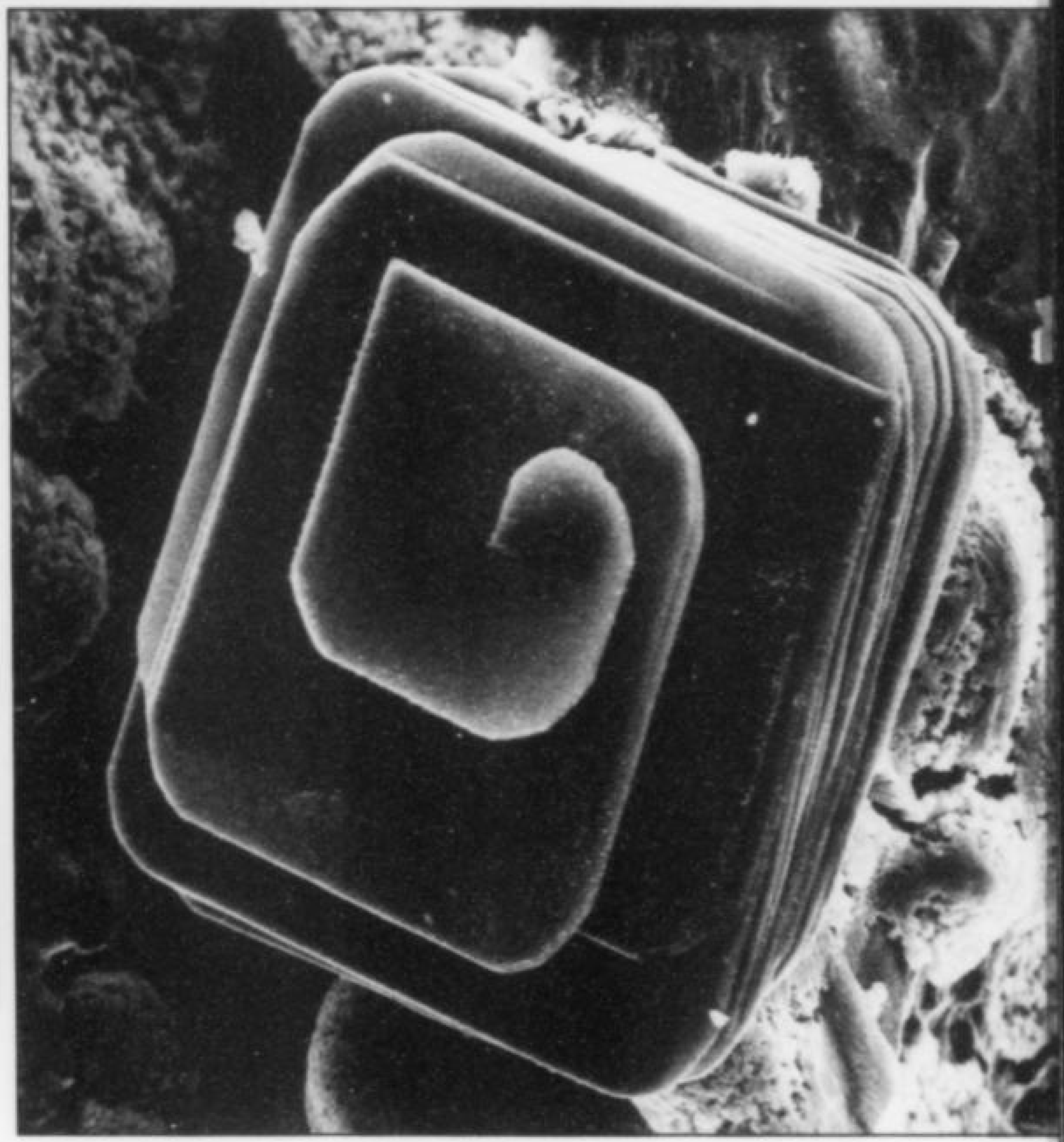

Figure 4. (bottom) **Stack of juanitaite plates, about 30 µm across, showing spiral growth on {001}. Note that each rounded corner is composed of two faces that are estimated to correspond to the form {310}.**

was new, but it was not until recently that crystals of sufficient quality to complete the description were located in the original material.

The new mineral is named "juanitaite" for Juanita Curtis. This name was chosen rather than "curtisite" because the latter was originally applied to a mineral described in 1926, which in 1975 was determined to be a mixture of hydrocarbons. The mineral and name have been approved by the Commission on New Minerals and Mineral Names, IMA. Specimens LACMNH #45266 and #45267 are designated as cotypes and are deposited in the collection of the Los Angeles County Museum of Natural History.

OCCURRENCE

The Gold Hill mine in western Tooele County, Utah, is well known to collectors for its vast array of well-crystallized secondary zinc, iron, lead, copper and bismuth arsenate minerals. Kokinos and Wise (1993) reported on the mineralogy of the deposit and referred to juanitaite as an "unnamed Cu-Bi arsenate." The juanitaite from the 30-foot level is found coating surfaces and filling thin fractures in gossan. It is associated with Ca-rich mixite, conichalcite, chrysocolla, azurite, gold and quartz. In the early 1990's, juanitaite was found by Les Cubit in quartz veins underground on the 150-foot level. Here it forms fine-grained coatings on cavity walls and is associated with connellite, tyrolite and azurite.

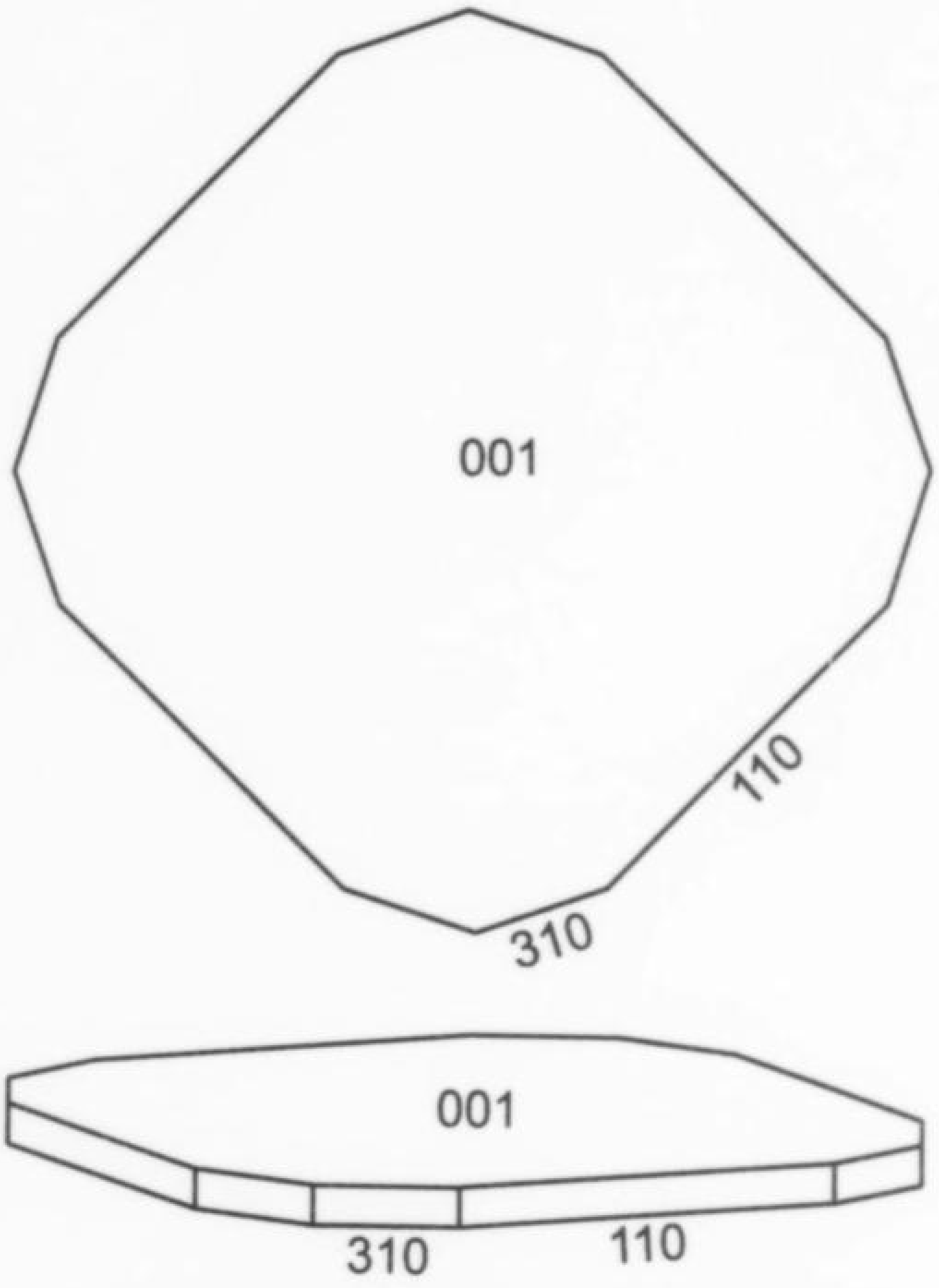

Figure 5. **Crystal drawings of juanitaite: above: looking down the *c* axis; and below: clinographic projection.**

PHYSICAL and OPTICAL PROPERTIES

Juanitaite crystals are square crystal plates (25 to 150 micrometers across and 1 micrometer thick) with rounded corners. Sheaf-like subparallel aggregates and rosettes of juanitaite plates are scattered over fracture surfaces. Crystals are tabular on {001} and are bounded by the forms {110} and {310}; the latter were estimated from SEM images. No twinning was observed.

The color of juanitaite is olive-green to grass-green and the streak is pale greenish yellow. Reflections from the {001} faces often appear bronzy. No fluorescence under ultraviolet light was detected. The luster is resinous to dull. Crystals are very soft, with Mohs hardness estimated at about 1. Crystals are flexible, but not elastic. No fracture was observed. The specific gravity measured by sink-float in Clerici solution is 3.61(5). The calculated density is 3.56 g/cm^3.

Juanitaite is uniaxial negative, but subparallel aggregates yield an anomalous biaxial figure with $2V \cong 20°$. The indices of refraction measured in white light are ω 1.785(5) and ε 1.705(5). No dispersion was observed. Pleochroism: O = olive-brown, E = olive-green.

CHEMICAL COMPOSITION

Seven chemical analyses were carried out by means of an electron microprobe using the following standards: clinoclase for Cu and As, hematite for Fe, Bi metal for Bi and wollastonite for Ca. Because of the paucity of material and the sparse distribution of the small, thin plates, it was impossible to separate a sufficient quantity of pure material for determination of water; however, the presence of water in juanitaite is supported by infrared spectroscopy (see below). In the analysis presented here, water is calculated by difference.

The mean analytical results (and ranges) are: CaO 8.64 (8.51–8.80), FeO 2.32 (1.46–2,44), CuO 35.97 (35.36–36.87), Bi_2O_3 14.82 (13.76–14.99), As_2O_5 29.35 (28.85–31.11), H_2O (8.90), total (100.00) weight %. The empirical formula (based on O = 29) is: $(Cu_{7.03}Ca_{2.39}Fe_{0.50})_{\Sigma 9.92}Bi_{0.99}(AsO_4)_{3.97}(OH)_{10.90}\cdot 2.22H_2O$ and the ideal formula is $(Cu,Ca,Fe)_{10}Bi(AsO_4)_4(OH)_{11}\cdot 2H_2O$. The ideal formula (with Cu:Ca:Fe = 7.09:2.41:0.50) requires: CaO 8.65, FeO 2.30, CuO 36.09, Bi_2O_3 14.91, As_2O_5 29.41, H_2O 8.65, total 100.00 weight %. Juanitaite is soluble in weak acids.

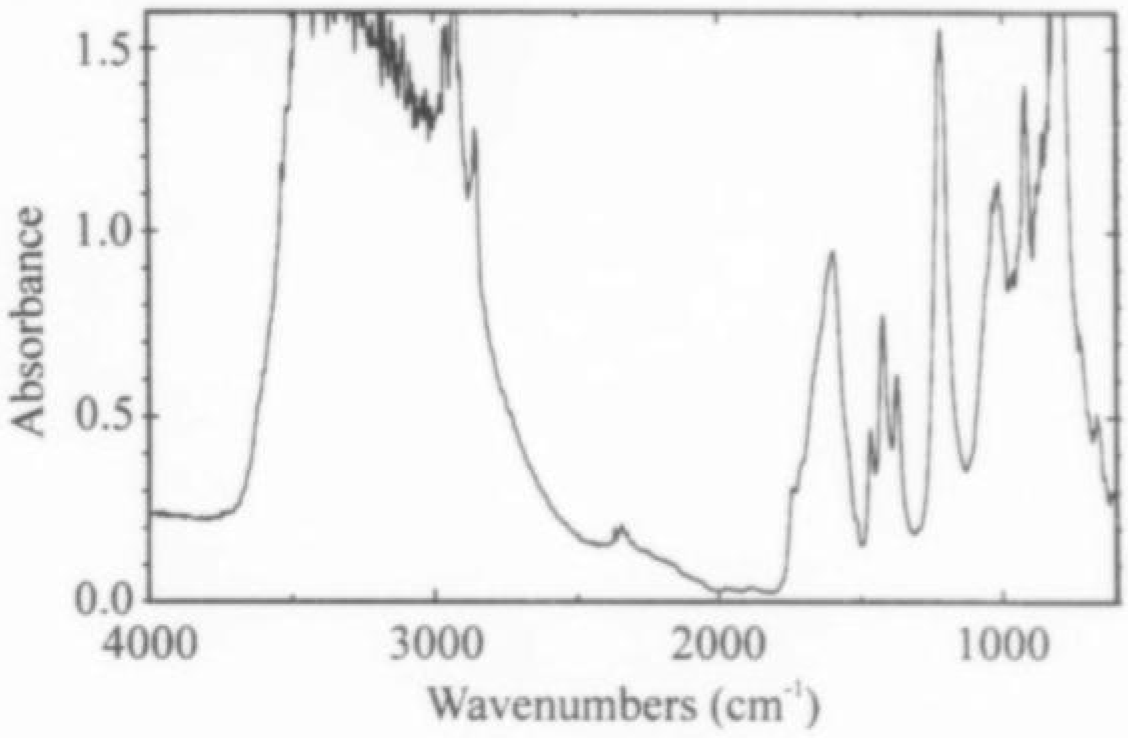

Figure 6. **Infrared absorption spectrum of juanitaite.**

INFRARED SPECTROSCOPY

Infrared absorption spectroscopy was conducted on an approximately 0.01 mm thick single juanitaite flake using an infrared microscope. An unpolarized spectrum was recorded at room temperature with light propagating down the *c*-axis. The presence of H_2O in juanitaite is supported by the IR spectrum. Absorption bands at 3440 cm^{-1} and 1600 cm^{-1} are assignable to H_2O. The lack of a band specifically corresponding to OH may be due to masking of that band by the very large band at 3440 and/or to extensive hydrogen bonding between and among OH and H_2O. The amount of absorbance attributable to H_2O is consistent with the weight % H_2O calculated by difference. The juanitaite spectrum is very similar in general features to the mixite spectrum reported by Miletich *et al.* (1997).

X-RAY DIFFRACTION STUDY

A single-crystal X-ray precession study using MoKα radiation showed juanitaite to be tetragonal, space group $P4_2/nnm$, a = 9.961(3), c = 29.19(2) Å, V = 2896(2) Å^3, Z = 4. The cell parameters were refined from the powder diffraction data using all uniquely indexed lines between 4.50 and 1.70 Å with intensities ≥5. The powder diffraction data are provided in Table 1. The small size, thinness, softness and flexibility of the plates, and their occurrence in sheaves, make the selection of a single crystal suitable for atomic structure determination impossible.

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

I	$d_{meas.}$	$d_{calc.}$	*hkl*
100	14.6	14.595	002
10	9.4	9.427	101
50	7.04	7.043	110
70	6.34	6.343	112
50	5.07	5.068	114
5	4.405	4.404	211
10	4.258	4.261	212
25	4.112	4.114	204
5	4.006	4.003	116
5	3.646	3.649	008
40	3.518	3.522	220
40	3.494	3.496	221
15	3.425	3.423	222
5	3.285	3.285	216
5	3.235	3.240	118
60	3.146	3.150, 3.142	310, 303
10	3.079	3.079	312
<5	2.917	2.919	0•0•10
40	2.855	2.853	226
30b	2.761	2.750, 2.772	321, 315
5	2.718	2.714	322
30	2.657	2.658	323
5	2.603	2.597	307
50	2.535	2.534	228
20	2.491	2.490	400
20	2.456	2.455	402
30	2.391	2.402, 2.386	326, 229
10	2.321	2.318	332
10	2.250	2.247	2•2•10
10	2.236	2.235	334
10	2.143	2.141	3•1•10
5	2.119	2.114	336
<5	2.057	2.057	408
<5	2.001	2.006	3•2•10
30	1.956	1.954	510
5	1.946	1.949	511
5	1.929	1.936	512
10	1.897	1.895	4•0•10
10	1.856	1.853	515
5	1.817	1.813	516
5	1.789	1.793	524
10	1.762	1.761, 1.758	440, 441
25	1.746	1.748	442
15	1.718	1.712, 1.722	444, 518
5	1.704	1.708	530
<5	1.684		
<5	1.653		
20	1.602		
<5	1.577		
20	1.548		
5	1.526		
25	1.502		
20	1.474		
10	1.450		
5	1.430		
15	1.409		
5	1.386		
5	1.374		
5	1.352		
10	1.349		

(Recorded with CuKa radiation using a 114.6 mm diameter Gandolfi camera.)

STRUCTURAL CONSIDERATIONS

Chemically juanitaite is most closely allied to mixite, $Cu_6Bi(AsO_4)_3(OH)_6\cdot 3H_2O$. Minerals of similar chemistry that occur in intimate association, as do juanitaite and mixite, often possess similar structural components. Miletich *et al*. (1997) noted that the basic structural units in mixite are infinite chains of edge-sharing CuO_5 square pyramids. These chains are aligned parallel to the *c*-axis of mixite. The cell of juanitaite does not seem capable of accommodating such a chain. Although the *c*-axis of juanitaite (29.19 Å) is almost exactly five times the length of the *c*-axis of mixite (5.913 Å), that would suggest a chain with ten square pyramids in each unit cell repeated along *c*, which is inconsistent with the space group symmetry of juanitaite. Other orientations of edge-sharing or, for that matter, corner-sharing chains of CuO_5 square pyramids also appear inconsistent with the juanitaite cell.

The empirical formula of juanitaite provides another structural quandary. If Cu is accommodated in square pyramidal (5-coordinated) sites in juanitaite as it is in mixite, where do Ca and Fe go? It is unlikely that either could be accommodated in significant quantity in a square pyramidal site and it is unusual for Ca and Fe to share the same site. The ideal formula could be written $Ca_{10}Fe_2Cu_{28}Bi_4(AsO_4)_{16}(OH)_{44}\cdot 8H_2O$, reflecting the contents of the unit cell ($Z = 1$), with Ca, Fe and Cu segregated into separate sites. However, apportioning cations between hypothetical structural sites must, by necessity, take space group special position multiplicities and symmetries into consideration. This ideal formula requires that Fe exist at a site with 2-fold multiplicity. The only such site in space group $P4_2/nnm$ has site symmetry $\overline{4}2m$, which is not consistent with the octahedral (6-fold) coordination typical for Fe^{2+}. This, of course, assumes full site occupancies, which need not be the case. Fe could statistically half occupy a site with 4-fold multiplicity. In space group $P4_2/nnm$ such sites have *mm*, *2/m* or 222 symmetry, all of which are compatible with octahedral coordination about the Fe.

PARAGENESIS

Kokinos and Wise (1993) noted that the orebody of the Gold Hill deposit was emplaced in three stages, each with a different set of primary minerals. Oxidation of each set yielded a different suite of secondary minerals. Juanitaite is found in the suite designated as the *copper arsenate and sulfate assemblage*, which originated from the oxidation of tennantite, chalcopyrite and pyrite and consequent fluid remobilization of ions. The contributors to the constituents of the secondary minerals found in this assemblage include the groundwater (carbonate and chloride), limestone host rock (calcium and carbonate), tennantite (Cu, Bi, arsenate and sulfate), chalcopyrite (Cu, Fe and sulfate) and pyrite (Fe and sulfate). Specific associations, such as juanitaite-mixite-conichalcite or juanitaite-connellite-tyrolite-azurite, are attributed to unique local cation and/or anion concentrations.

Juanita Curtis

ACKNOWLEDGMENTS

We wish to very gratefully acknowledge Juanita Curtis, not only for providing specimens of the new mineral and details concerning its occurrence, but also for her many years of dedicated service to the amateur and professional mineralogical community.

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MILETICH, R., ZEMANN, J., and NOWAK, M. (1997) Reversible hydration in synthetic mixite, $BiCu_6(OH)_6(AsO_4)_3 \cdot nH_2O$ ($n \le 3$): hydration kinetics and crystal chemistry. *Physics and Chemistry of Minerals*, **24**, 411–422.

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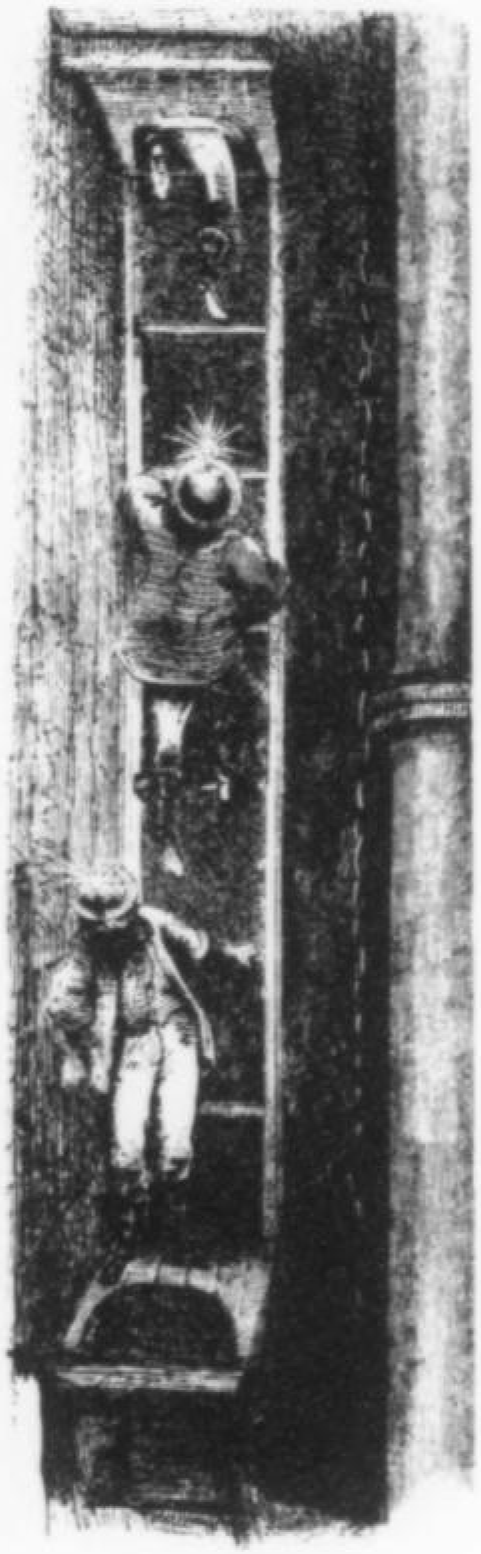

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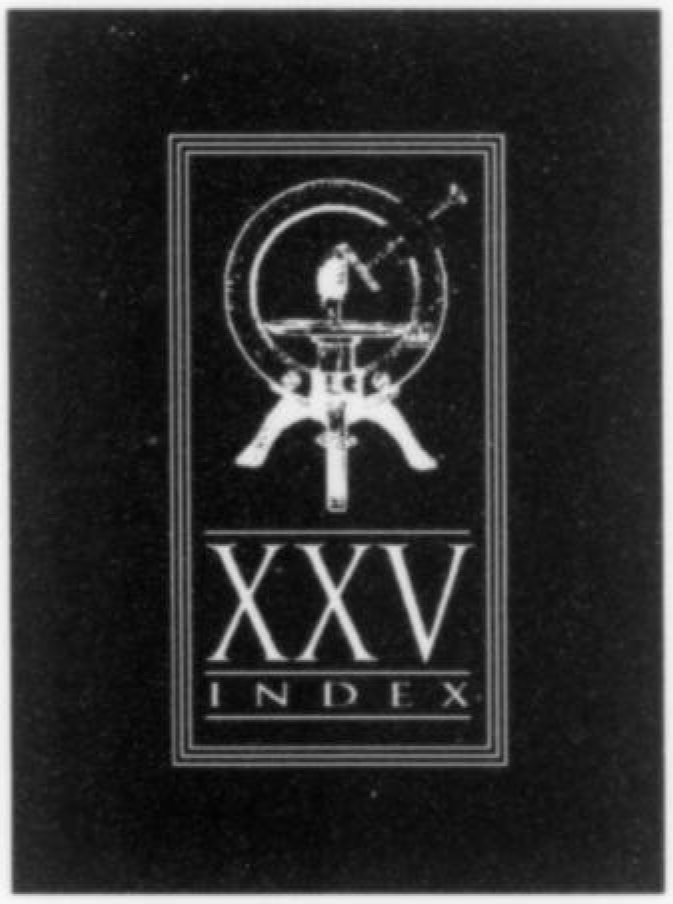

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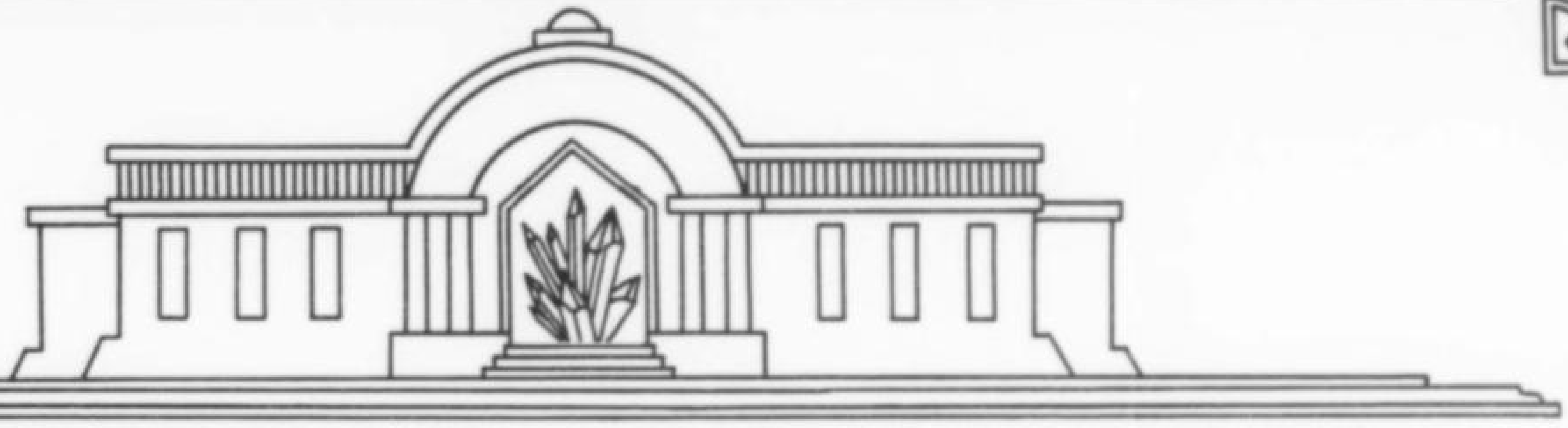

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ORPIMENT

FROM THE TWIN CREEKS MINE, HUMBOLDT COUNTY NEVADA

Bryan K. Lees
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P.O. Box 1169
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In early 1999 an extraordinary occurrence of beautifully crystallized orpiment was discovered during ongoing gold mining activities at Newmont Mining Corporation's Twin Creeks mine in Winnemucca, Nevada. Through partnership with a private specimen recovery firm, these magnificent specimens were saved from the crusher.

INTRODUCTION

The Twin Creeks mine lies approximately 40 miles northeast of Winnemucca, Nevada (Fig. 1). Prior to early 1999, mine geologists seldom saw specimen-quality minerals; microscopic gold was the only thing of interest to them. Then, in April, a fresh blast revealed a zone of yellow and orange smears. Upon close inspection, the zone was found to be full of small pockets lined with brightly crystallized orpiment.

Newmont geologists contacted Collector's Edge Minerals, Inc., and invited the company to come out and see the discovery. Soon after, an agreement was reached to recover and preserve the orpiment specimens. Between April and October, 1999, the entire orpiment zone was worked out and thousands of specimens were collected.

The orpiment is well crystallized and shows a range of bright colors, from reddish orange to orange to honey-yellow. Specimens are mostly large miniature to small cabinet in size. The color, high luster and pristine condition of the Twin Creeks' orpiment specimens render these among the best of species.

HISTORY and COLLECTING

The Twin Creeks orpiment occurrence, lying in the Getchell Trend, is one of the many Carlin-type gold deposits in west-central Nevada. Gold was first discovered in the Twin Creeks area in 1984 by the Goldfields Mining Company, followed by an additional discovery in the same area by the Santa Fe Pacific Gold Corporation in 1987. In 1993, the two companies merged and consolidated

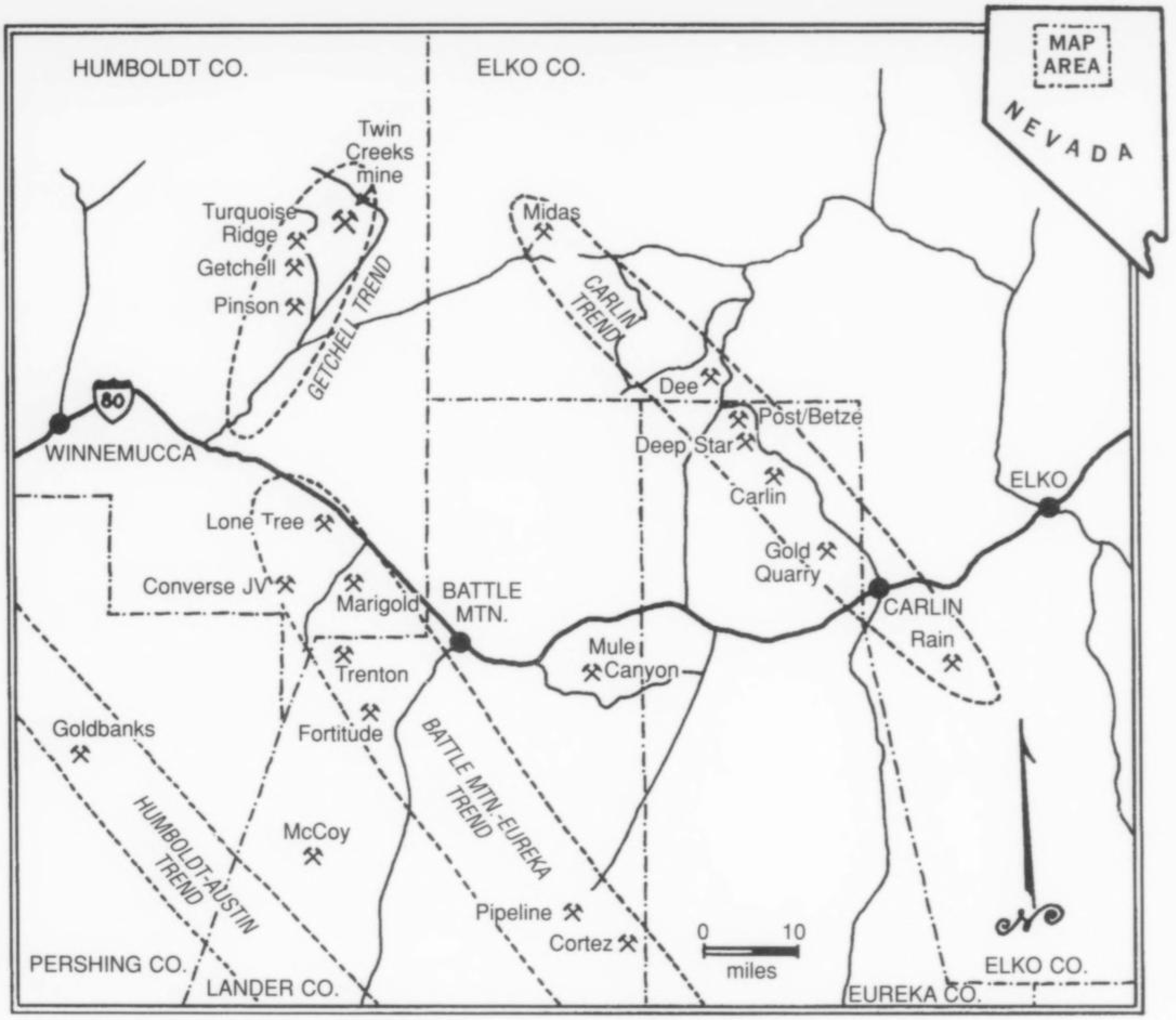


Figure 1. **Gold mine locations in north-central Nevada and their relationship to four major Carlin-type deposit trends. The Twin Creeks mine is at upper left, in the Getchell Trend, Humboldt County, just a few miles from the famous Getchell mine.**

their two mines to form the Twin Creeks mine. In 1997, Newmont Mining Corporation merged with Santa Fe Pacific, creating a relationship that exists today.

The Twin Creeks mine, currently the third largest gold producing mine in North America, is divided into two open pits: the Vista and Mega pits (Fig. 2). Annual gold production of nearly a million ounces is extracted from over 15 million tons of ore. Average production is over 40,000 tons per day, split between oxide and sulfide milling and oxide leaching operations. Over 700 people work at the facility on a 24-hour-per-day, 7-day-per-week schedule. The Twin Creeks mine accounts for over 22% of Newmont's worldwide gold production of over 4 million ounces per year.

Project Development

Signs of crystallized orpiment were observed in Cut 62 of the Mega pit by geologists in late 1998. The quality was superior to any seen in the past, and prompted Newmont geologist Leroy Schutz to contact Collector's Edge. A decision was made to keep close track of the orpiment production areas for signs of better specimens.

In January, 1999, mining in Cut 62 continued downward through increasingly better orpiment zones. Then, in March, incredible orange-colored orpiment was discovered by Newmont geologist Pat Donovan. Newmont regional mine geologist Ron Thoreson contacted Collector's Edge to set up an on-site evaluation. Ken Roberts, from the Collector's Edge, traveled to the mine for a 1-day inspection and ended up spending an entire week collecting the newly discovered pocket zone on the 4220 Bench of Cut 62. Unfortunately, the zone had severe blast damage and few top-quality specimens were collected, but the potential was clear; the orpiment was world-class.

By April, 1999, everyone was excited about the new orpiment, and finding a means of preserving the specimens became a high priority. Collector's Edge presented the Twin Creeks mine staff with a collecting and marketing proposal that suggested ways the two companies might work together. Newmont staff responded with an excellent plan to identify orpiment zones and protect them from harm during blasting work.

Ideas about collecting schedules, techniques and requirements were discussed in order to create a project model. The primary

Figure 2. Aerial photo of the Twin Creeks mine complex looking north-northeast (courtesy Newmont Mining Corporation).

project goal was to design a mineral collecting procedure that did not cause ore production slowdowns. After all, it was unheard of to consider altering the production schedule of a major mine in order to collect mineral specimens.

A collecting contract was completed by May. A mining crew, supervised by Graham Sutton, was borrowed from the Sweet Home mine, in Colorado, and sent to the Twin Creeks mine. Meanwhile, Randy Ford, Production General Foreman, and Lyle Avey, Drill and Blast General Foreman, designed ways to continue gold mining activities in and around the collecting crews without production disruptions.

By late May, 1999, the Collector's Edge crew was busy collecting orpiment on the 4200 Bench of Cut 62. During the next 5 months, the zone was worked to a depth of 100 feet and thousands of specimens were collected.

Collecting

Weather conditions in the Mega pit vary from blowing snow in March to 100+ degree days in August. Wide temperature fluctuations created challenges to specimen collecting. In springtime, cold fingers and stiff bodies made collecting difficult. During the still, 100+ degree days of August, the desert sun beat down relentlessly and care had to be taken to avoid heat exhaustion. Adding to the experience was the dust. After about 20 minutes of collecting, the finely disseminated black pyrite and other sulfide minerals coated everything, and everybody. Sunburn was a constant companion (number 45 sun block helped).

Collecting crews rotated in and out of the project on a monthly basis. The crews consisted of three to four people borrowed from the Sweet Home mine, in Colorado. Modern mining codes require MSHA-trained staff, therefore each miner had to have a current MSHA (Mine Safety and Health Administration) certificate in order to gain access to the site. Additional on-site training was provided by Newmont safety staff prior to any collecting activity.

Between March and September a total of 6 trips, lasting one to two weeks each, took place. The excitement level reached a peak in mid-summer when, on each of two collecting trips, over a thousand specimens were collected.

During the first trips, Newmont engineers and Collector's Edge staff devised a means to save the orpiment zones while not impeding mine production. The plan began with logging and mapping orpiment zones during the drilling stage of the blasting schedule. While drilling each blast hole, care was taken to log the areas where orpiment was seen in the drill cuttings. Then, all holes, except those showing orpiment, were shot. After the blast rock was removed, a long orpiment-bearing column was left standing in the middle of the pit floor. This structure often measured about 25 feet wide by 100 to 200 feet long by 20 feet high. The entire structure was removed down to the pit bottom during collecting activities, and then the drilling cycle would begin again to drop the floor another 20 feet.

Collecting orpiment required a variety of tools. Newmont provided Collector's Edge with a large excavator and front-end loader to expedite the removal of thousands of tons of rock separating pocket zones. Once inside pocket zones, everything slowed down and collecting consisted of breaking open pockets with air chisels and hand tools. Several excellent orpiment specimens were extracted with the diamond chain saw.

The Mega pit is large enough that, at any one time, it was possible for three or four areas to be mined at once. Since orpiment collecting occurred in only a single area, the mine planners allowed collecting while shifting gold mining activity to elsewhere in the pit. The flexibility of this schedule promoted collecting without negatively impacting gold production schedules.

Once or twice a day, all mining and collecting activities would cease as the entire Mega pit was evacuated for blasting. Each blast broke up over 350,000 tons of rock and consumed 61 tons of

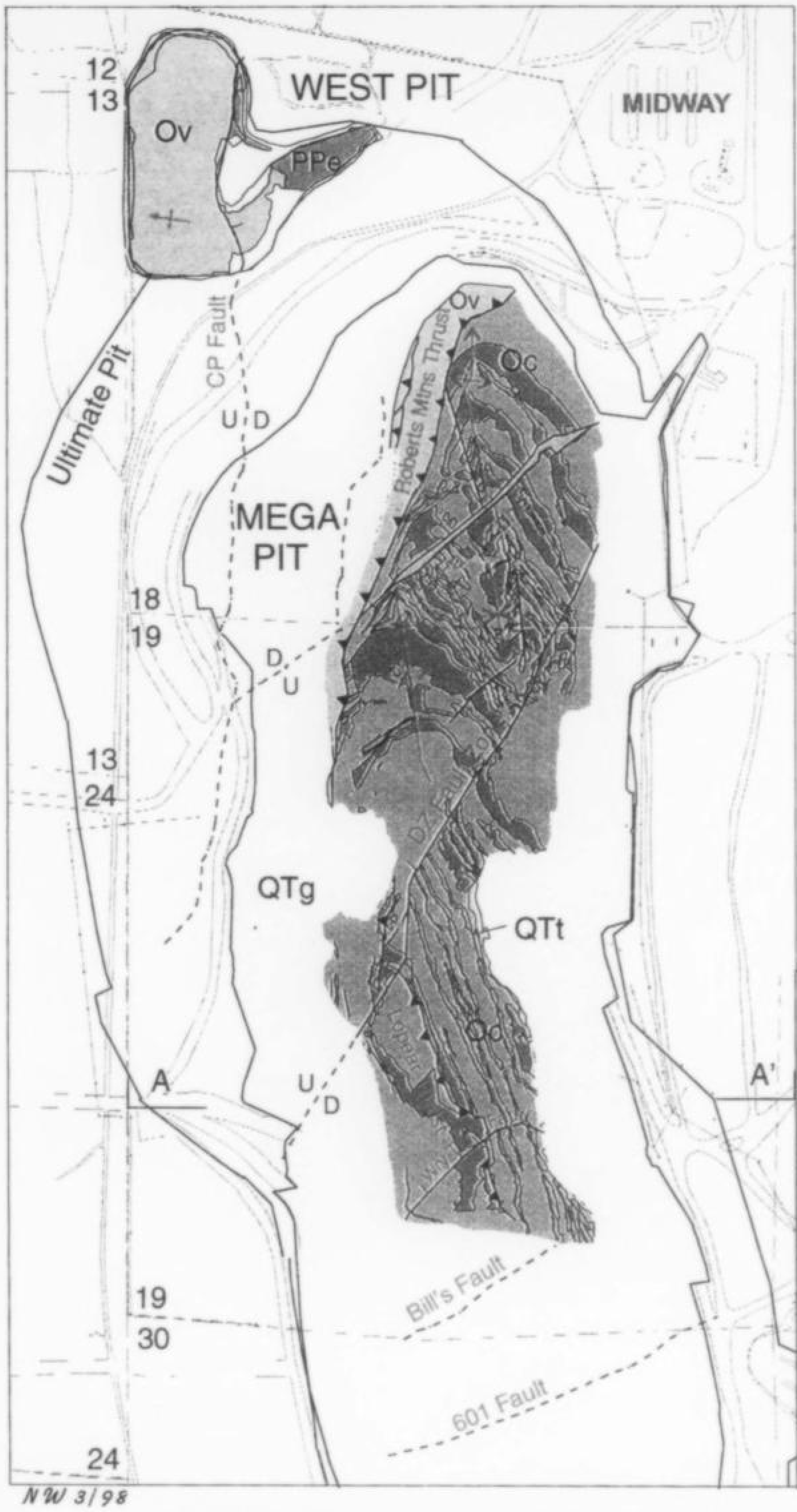
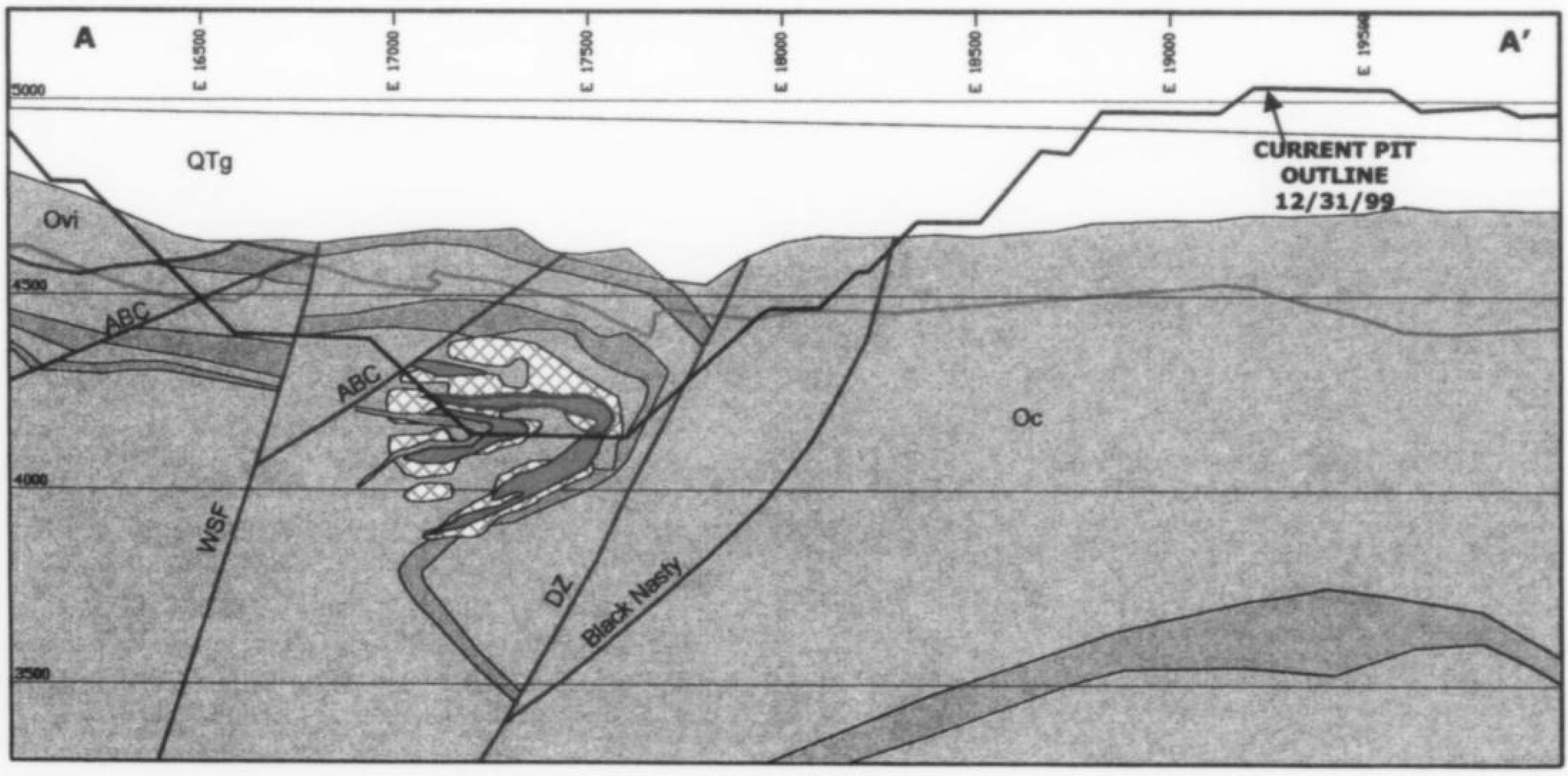


Figure 3. **Geology of the Mega pit and West pit, Twin Creeks mine.**

Qtg = Quarternary/Tertiary gravel. QTt = Quaternary/Tertiary tuff. PPe = Permian-Pennsylvanian Etchart Formation. Ov = Ordovcian Valmy Formation. Oc = Ordovician Comus Formation: igneous (blue-violet) and sediments (red-violet). Fold axes shown in red. Green outline (below) = orpiment collection site. Cross-hatched = >0.08 oz/st Gold.

Figure 4. **Geological cross-section through the Mega pit, Twin Creeks mine (looking north).**



explosives. After the blast, work resumed as dozens of large trucks carried the blast rock out of the pit. Much of this material, about 85%, went to the waste rock piles while the balance, about 40,000 tons, went to the processing plant for gold recovery. Each truck can haul between 180 and 240 tons of rock (that is, up to half a million pounds!).

After blasting, work resumed in the specimen collecting zones to complete a 10-hour work day Then it was a 1-hour trip back to Winnemucca for a shower, dinner and sleep. Six or seven hours later, the cycle started over again. Time was of the essence; since Newmont staff went to extremes to work around the collecting effort, there was much pressure to finish collecting the orpiment zones, so that gold mining activities could resume. By October, 1999, 4000 individual specimens had been collected.

Ideal conditions in any collecting scenario require large open spaces unencumbered by pocket bridging. Large pockets also increase the odds of recovering plates with minimal margin contact damage. Cut 62 contained a few large orpiment pockets that realized the collector's dream of pulling out large, clean, outstanding specimens. Unfortunately, most of the largest orpiment plates contained minor damage.

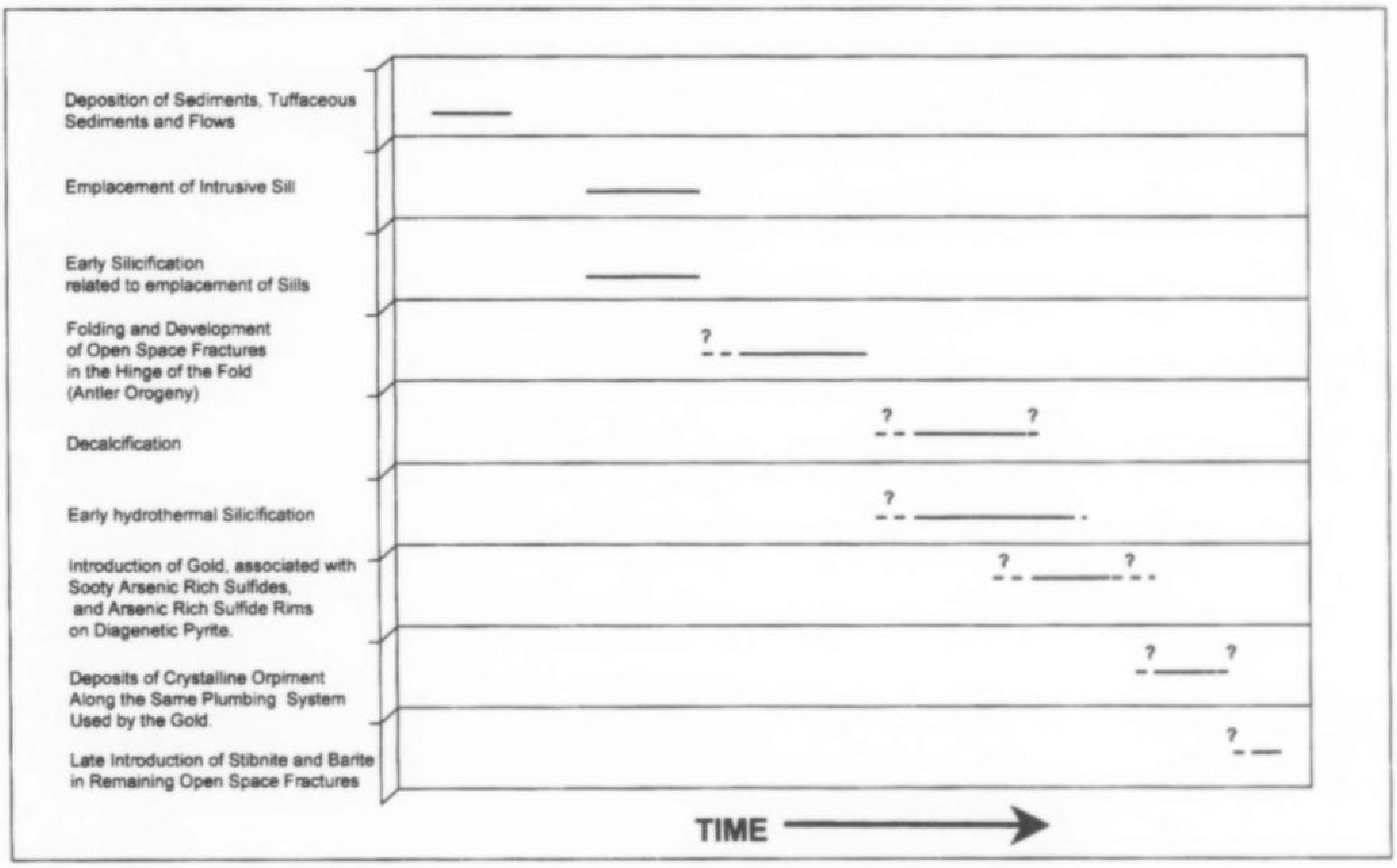


Figure 5. **Geologic and paragenetic history of the Mega pit area.**

Perhaps the most critical factor to clean specimen recovery in the Mega pit was the orientation of the pocket zone to the nearest blast hole. While Newmont engineers made extraordinary efforts to blast around the pocket zones, some shots telegraphed into neighboring open spaces anyway. Since the largest open spaces are most susceptible to such collateral damage, they suffered the most. Quite often, large pockets (those measuring up to 4 feet long) were partially collapsed due to blast damage. It was rare to pull a completely undamaged, uncontacted orpiment specimen from anywhere in the Mega pit.

As the pit was deepened, more and more crystallized orpiment was discovered. Beginning with the 4220 Bench (at the top of the fold structure), the pit was deepened down through the 4120 Bench. The 100 feet of orpiment-rich ground was removed in 20 foot intervals. At about the 4120 Bench, the bottom of the fold structure pinched out and the orpiment specimen collecting ended. The entire zone was removed over a 6-month period. The orpiment zone measured approximately 100 feet deep by 25 feet wide by 300 feet long, blocking out a volume of 28,000 cubic yards of rock.

Orpiment pockets were usually small, averaging 10 to 14 inches in diameter and 1 to 3 inches wide. Occasionally, a pocket measured up to 4 feet deep with an opening up to 6 inches wide. Good pocket zones contained pockets clustered tightly together, one atop the other. Some isolated minor pockets occurred up to 100 feet away from the major pocket zones and did not contain significant quantities of orpiment specimens. Collecting activity was boringly slow to impossibly frantic depending on where and when good zones were discovered.

Most pockets produced less than 10 specimens, and many produced only one good specimen. Because most pockets measured less than 14 inches, many of the orpiment specimens contain contact damage from stalactitic growths bridging the open space (a phenomenon dubbed "pocket bridging" by the collecting crew). Damage also occurred when specimen plates were pulled apart during the collecting process, as interlocking crystals broke away from around the pocket margin.

GEOLOGY

The Twin Creeks mine is situated in a valley southeast of the Dry Hills in northern Humboldt County, Nevada. The area is underlain by Paleozoic sedimentary rocks containing gold-mineralized rock characteristic of Carlin-type deposits. The mine is located at the intersection of the Getchell Trend and the northern end of the Valmy Trend, along which lie many other Carlin-type gold deposits (Fig. 1).

The host rock for the orpiment is Ordovician in age, and consists of a thick sequence of carbonates and siltstones, intrusive sills, basalt flows and tuffs. The Comus Formation, making up much of these Ordovician rocks, contains most of the sulfide gold reserves

Figure 6. **View of the west wall of the Mega pit, showing the dark-colored Z-shaped fold structures. Orpiment occurs within the overturned nose of the anticline in the pit floor. (Note the collecting operation under way at the pit bottom.)**

and is an important mining target in the Mega pit. Emplaced by the Robert's Mountain Thrust, an Ordovician sequence known as the Valmy Formation overlays the Comus Formation.

Lying unconformably over the Valmy Formation is the Permian-Pennsylvanian Etchart Formation. This unit is the primary source of gold in the Vista pit. To date, no crystallized orpiment has been discovered in this pit and none is expected, as this formation contains oxide ore and few if any sulfides. The Etchart sequence, over 3000 feet thick, consists of limestone, siltstone and sandstone.

Pushed over the Etchart Formation by the Golconda Thrust is the Mississippian-Permian Havallah Formation. It consists of intensely sheared mudstones, siltstones and sandstones. These rocks do not contain gold, and no orpiment has been discovered in them.

Cretaceous granodiorite dikes and sills can be found throughout the Paleozoic rock sequences at the Twin Creeks mine. They are pre–ore-stage systems and do not contain gold mineralization. Tertiary volcanic deposits and Quaternary/Tertiary alluvium overlay the Paleozoic rocks and fill the valley floor.

Both gold and orpiment mineralization are contained in a very complex, northwest-trending fold called the Conelea anticline, developed during the Antler Orogeny. This system lies within the Ordovician sequence and plunges to the northwest. The mineralization postdates the anticline and is contained within the over-

Figure 7. **Collecting orpiment in the floor of the Mega pit; the orpiment zone here is about 25 feet wide and dips near-vertically.**

Figure 8. **An afternoon blast at the Mega pit. Twice each day the pit is cleared for blasting.**

Figure 9. **Graham Sutton working on an orpiment pocket in the Mega pit. Although the orpiment zone is 25 feet wide, individual pockets are generally less than 6 inches wide and 12 inches long. Great care is required to avoid bruising the soft crystals.**

turned nose of the fold (see Fig. 4). The fold is broken up by a series of northeast-trending faults. In its northern portion, classic "Z"-shaped chevron fold structures can be seen in the walls of the Mega pit (Fig. 6). Within the anticline, the best crystallized orpiment is found near the upper hinge area, where the most stress, and therefore the largest openings, occurred. These open areas were conduits for mineralized solutions which created replacement orebodies in and around the hinge zones. These orebodies contain some of the highest gold values found in the Mega pit.

The age of mineralization has been determined by Simon *et al.* (1999) to be 41.9 million years, based on argon isotopic ratio analysis.

The rock throughout the orpiment zone is heavily decalcified, argillized and silicified. Hand samples in orpiment pocket zones show chert-like inclusions indicative of heavy silicification. Besides arsenic and silica, the matrix contains large proportions of aluminum, at 35,600 ppm, and iron, at 33,500 ppm. Zinc, calcium and magnesium constitute a total of 1.5% of the matrix material.

Decalcification, silicification and folding created ideal conditions for orpiment deposition. Intense folding prepared the ground, allowing for later decalcification and silicification. The two latter events enlarged and then strengthened the open spaces. The voids were later filled with orpiment crystals. Latent solutions, perhaps meteoric in origin, remobilized small amounts of silica from the surrounding bedrock and deposited it as light-colored dustings on some of the orpiment. Analysis of the coatings shows the quartz content over 41% while carbonate is only 0.1%. Other important constituents of the coatings include aluminum at 64,500 ppm and iron at 38,200 ppm. One other item of interest is the presence of carbon: 0.96%. The silica-rich rock surrounding the crystal pockets includes sulfide mineralization containing the highest gold values in the Mega pit.

Low-grade orpiment is abundant throughout the northern portion of the Mega pit. Mapping orpiment mineralization is helpful to mine geologists because orpiment occurrences correlate well with areas of high gold values, and serve as a valuable exploration tool. It was not until late 1998, however, that quantities of well-crystallized orpiment were observed. The first good orpiment outcrop came on the 4220 Bench of Cut 62 in the northern portion of the Mega pit. This discovery coincides with the deepening of the pit over the Conelea anticline. As the open spaces inside the nose of the anticline were exposed, beautifully crystallized orpiment specimens were uncovered.

Figure 11. **Orpiment, 4.3 cm, from the Mega pit. Newmont Mining Corporation specimen; Jeff Scovil photo.**

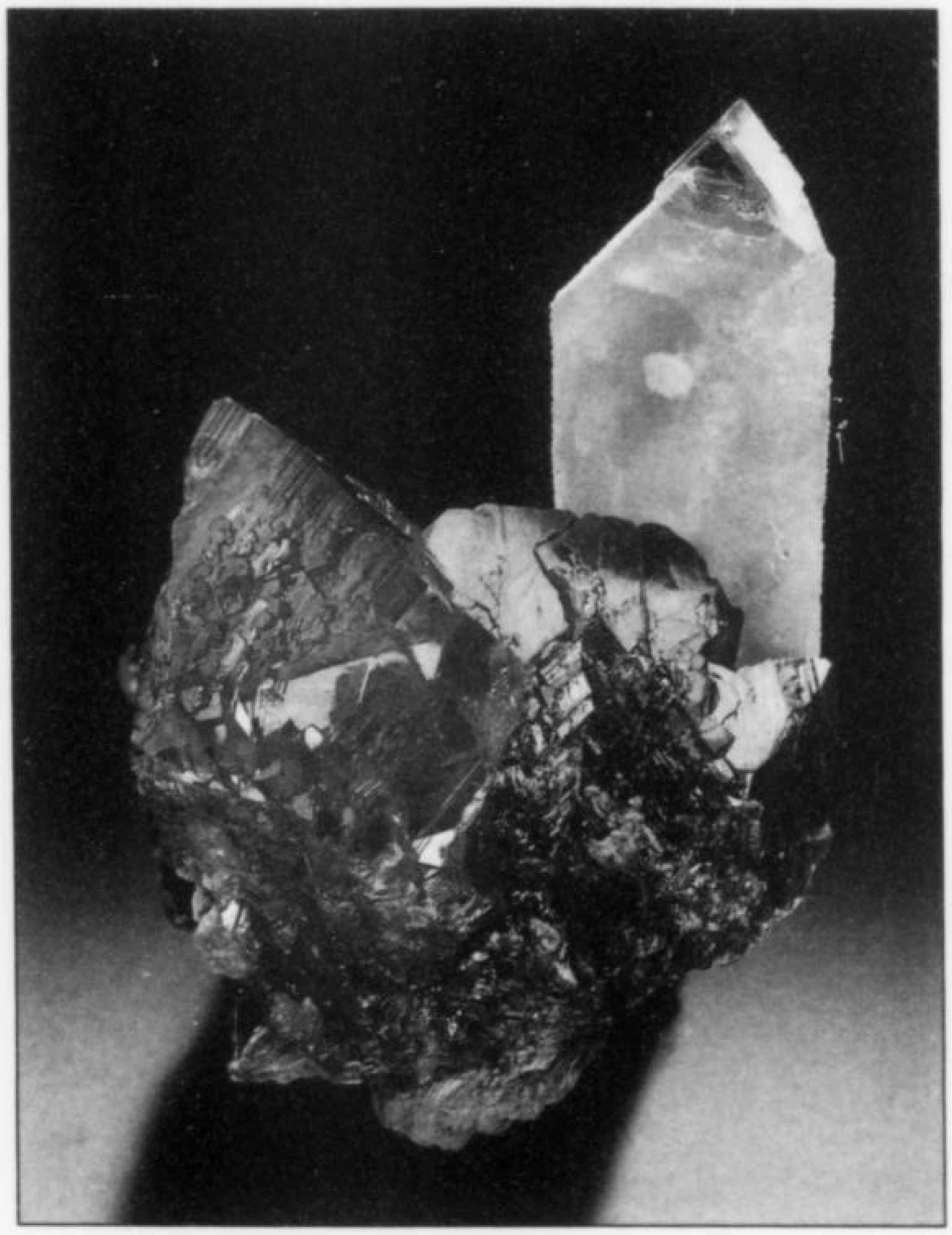


Figure 12. **Orpiment with barite, 3.4 cm, from the Mega pit. Newmont Mining Corporation specimen; Jeff Scovil photo.**

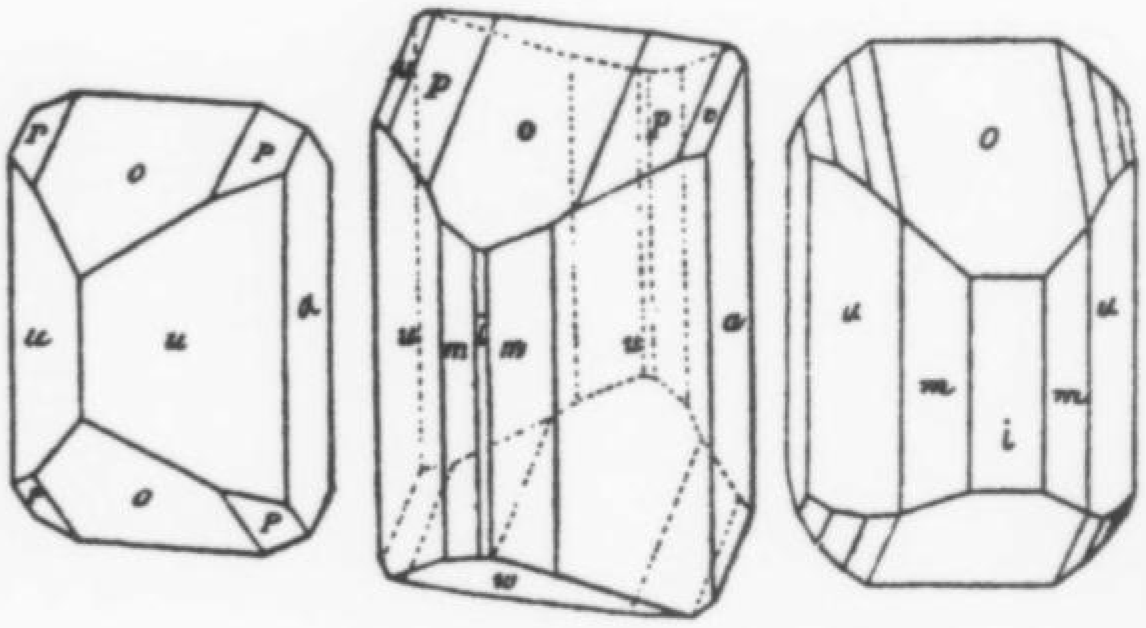


Figure 10. **Orpiment crystal drawings showing habits typical of Twin Creeks mine specimens (based on crystals from Tajov, Czech Republic; Goldschmidt, 1913).** ***o*****{101},** ***p*****{111},** ***i*****{100},** ***m*****{110}, a{010} (rare or absent),** ***u*****{120}.**

ORPIMENT

Orpiment (As_2S_3), originally named *auripigmentum* (Latin for "golden paint") in 1747, is a common mineral in low-temperature hydrothermal veins and hot spring deposits. Good crystals, however, are rather rare; until the Nevada discovery came to light, the highest quality crystals known were those from the Quiruvilca mine, Peru, and Shimen, Hunan, China. Twin Creeks orpiment is at least their equal.

Morphologically the crystals resemble those from other prominent localities, consisting primarily of {101} and {111} on the terminations and {110}, {120} and (rarely) {100} comprising the other faces in the [001] zone. Faces are usually striated, probably through oscillation of {101} and {111} across the terminal faces and {110} and {120} parallel to [001]. The {010} form, parallel to the very easy cleavage, is very rare or absent. Crystals have a rather stubby, chisel-shaped aspect, measuring not much more along the *c* direction than the *a*, perhaps to a maximum ratio of 2:1.

The Twin Creeks crystals are fairly consistent in size throughout

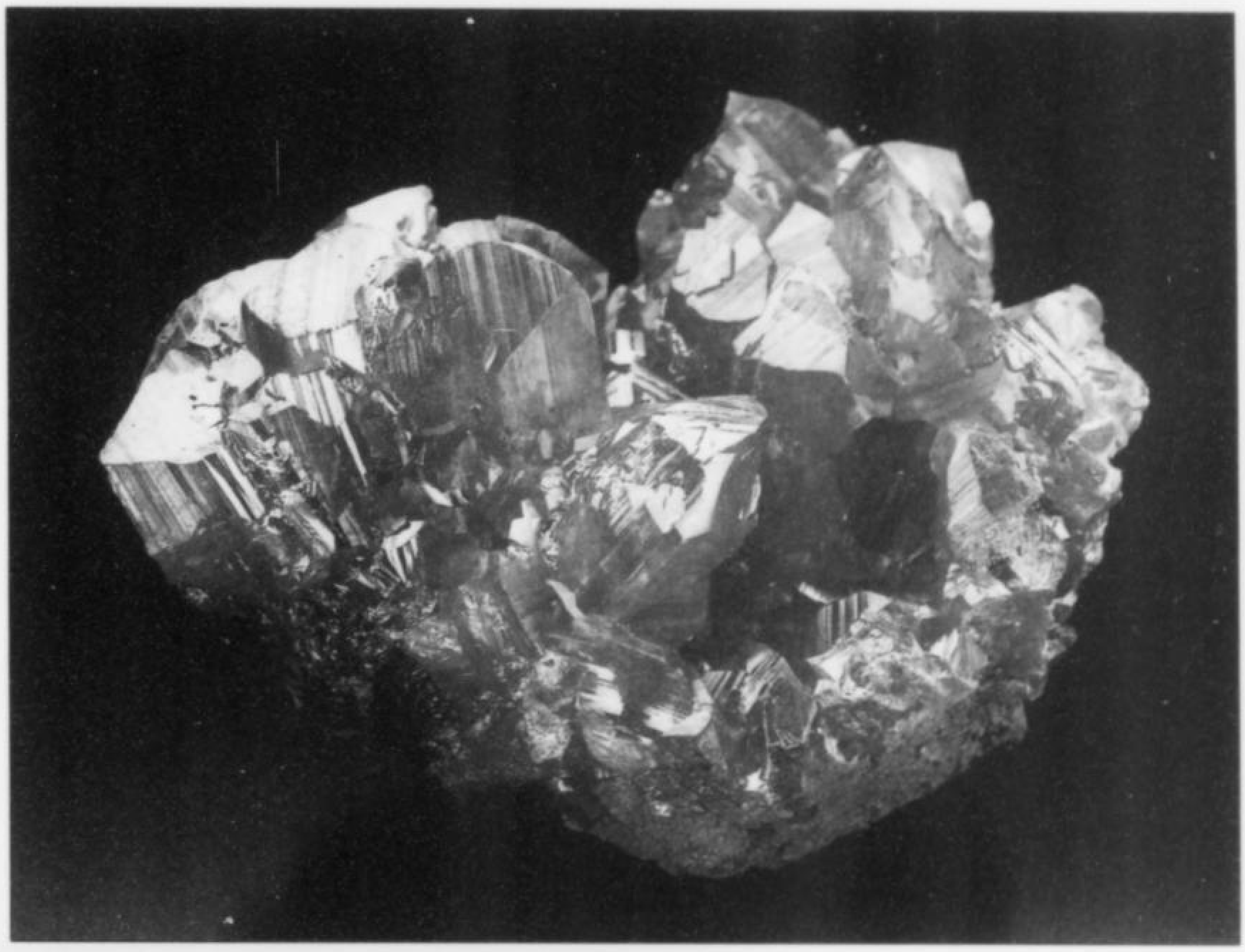


Figure 13. **Orpiment, 7 cm, from the Mega pit. Newmont Mining Corporation specimen; Jeff Scovil photo.**

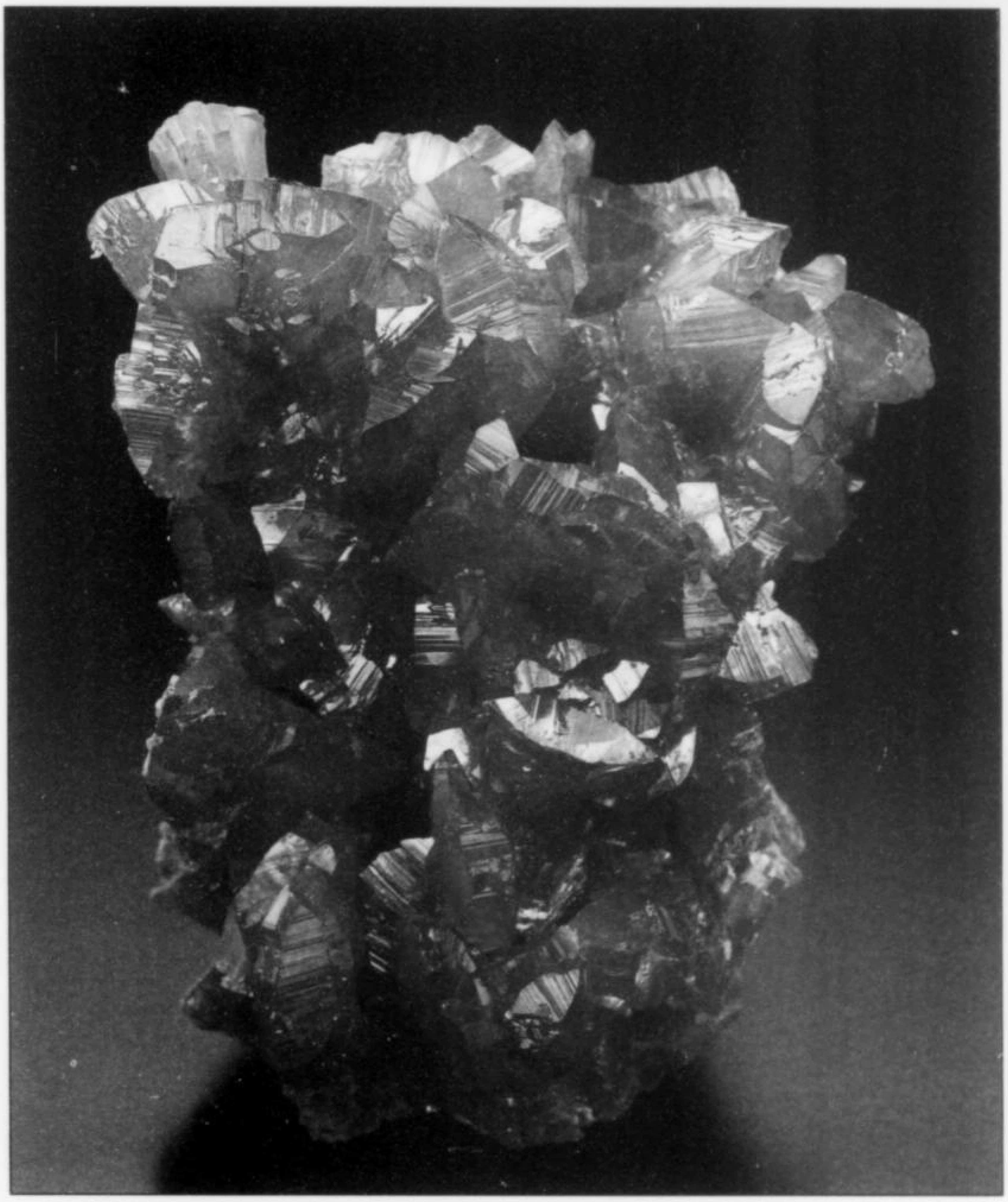
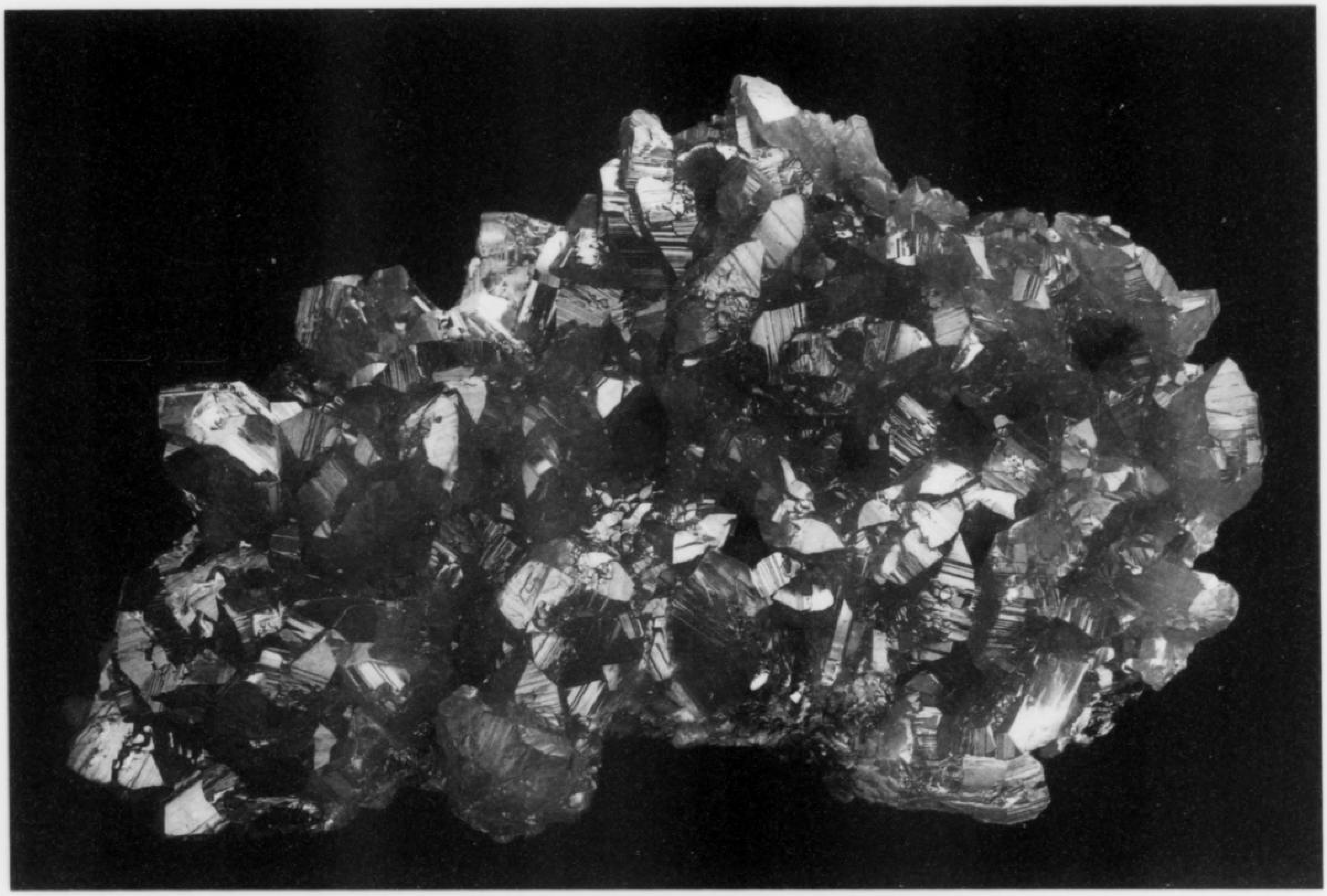


Figure 14. **Orpiment, 7.1 cm, from the Mega pit. Newmont Mining Corporation specimen; Jeff Scovil photo.**



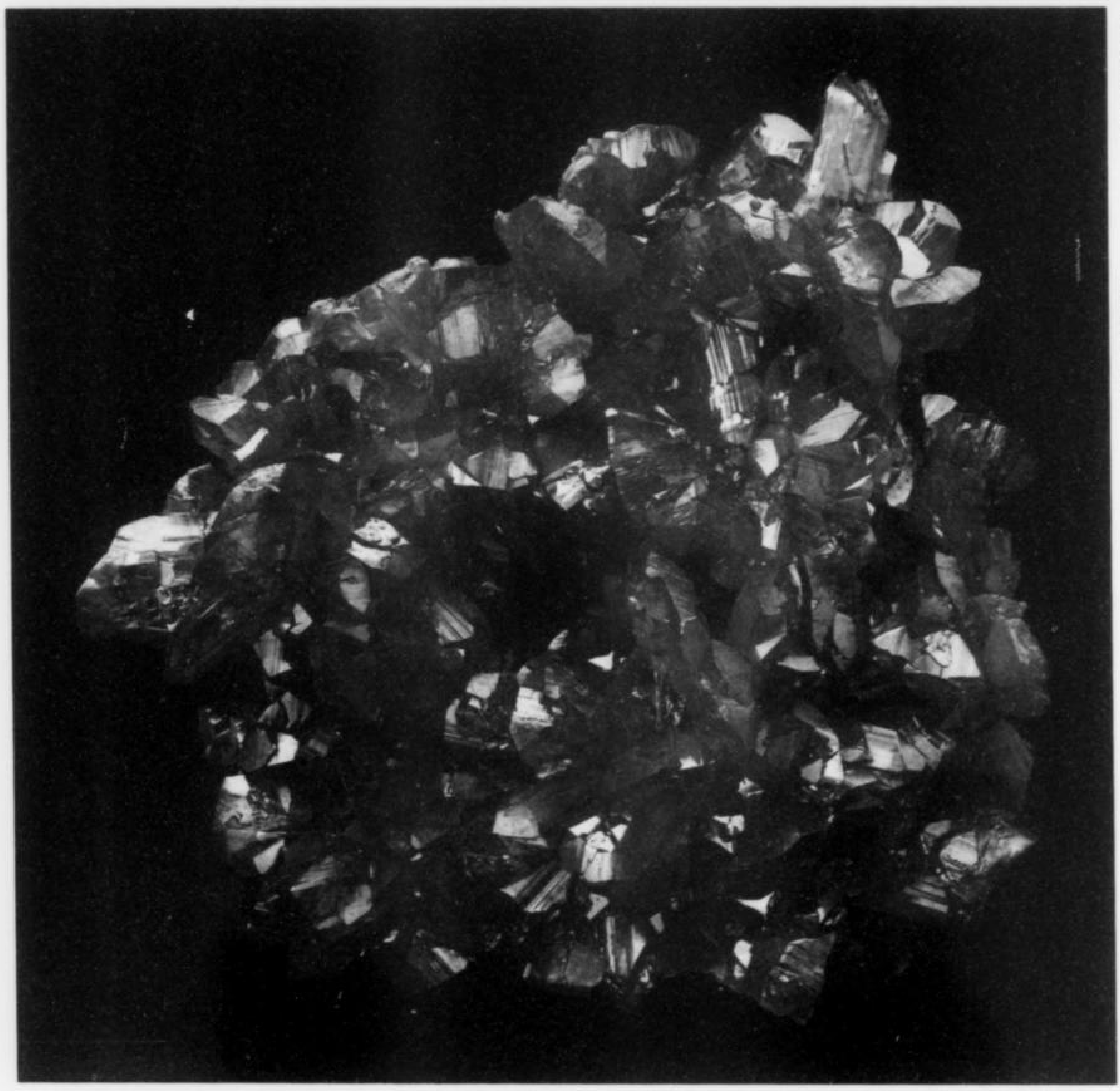


Figure 15. **Orpiment, 13 cm, from the Mega pit. Newmont Mining Corporation specimen; Jeff Scovil photo.**

Figure 16. **Orpiment, 10.2 cm, from the Mega pit. Azurite Corporation specimen; Jeff Scovil photo.**

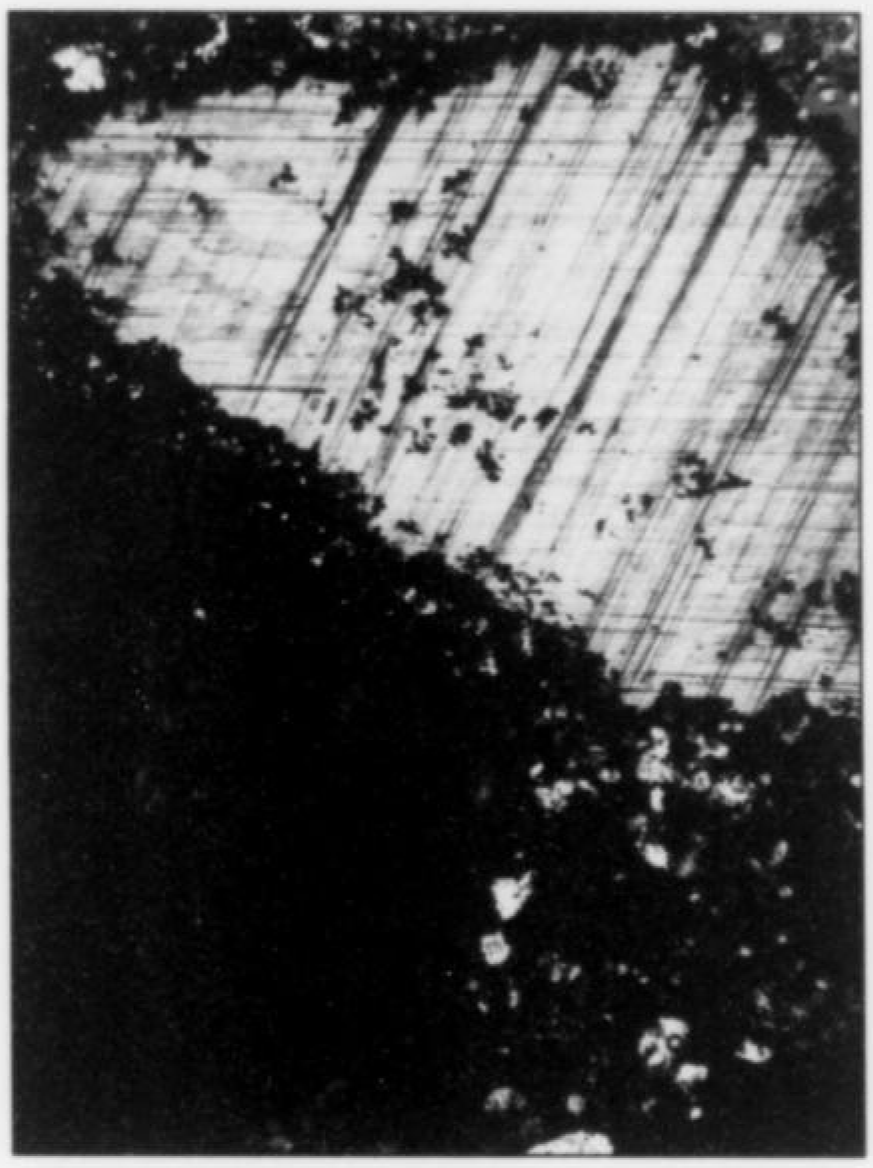


Figure 17. **Photomicrograph showing orpiment crystals in thin section; the pale crystal is essentially pure orpiment whereas the murky crystal is discolored by trace amounts (≈ 500 ppm) of iron. Field of view: 1.5 mm.**

Figure 18. **Orpiment, 9.5 cm, from the Mega pit. Newmont Mining Corporation specimen; Jeff Scovil photo.**

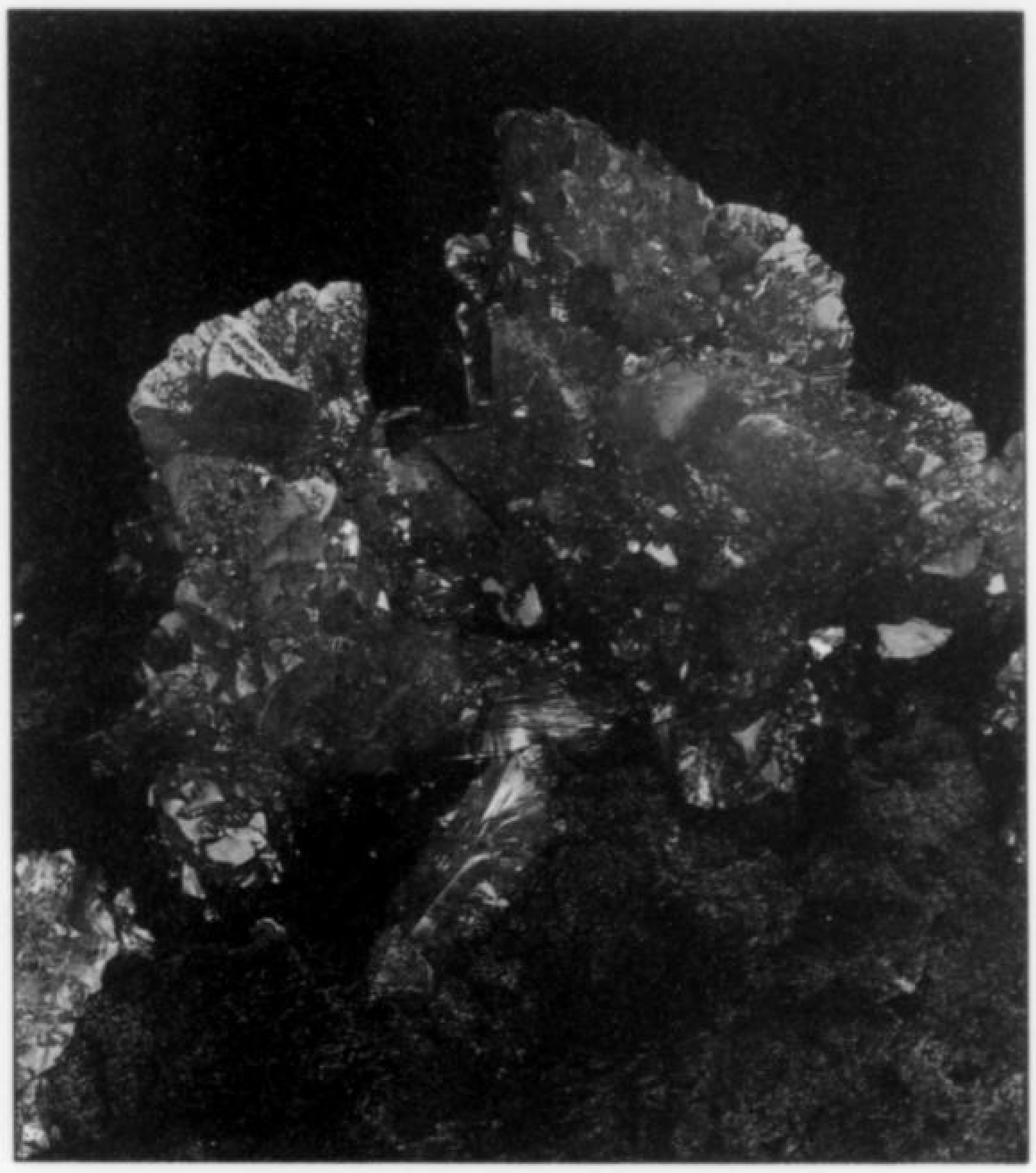


Figure 19. **Orpiment, 12 cm, from the Mega pit. Carnegie Museum of Natural History specimen; Jeff Scovil photo.**

the deposit, ranging from 5 mm to 2 cm along the *c* axis and 2.5 mm to 1 cm across. A few crystals reach 4 cm, but their quality is generally poor.

Crystal clusters and matrix specimens are generally less than 15 cm across; most consist of plates of interlocking crystals covering a dark-colored matrix, but a few specimens were recovered in which isolated crystals and small clusters perch aesthetically on a larger matrix.

The color of the crystals varies from reddish orange to orange, yellow-orange and honey-yellow, with many subtle shades in between.

The general quality of the specimens collected varies dramatically. Although most specimens have a bright luster, others are dull (the result of coatings or etchings).

The only significant associated species is barite, occurring rarely as elongated, thin blades to 7 cm on orpiment; these crystals vary from opaque gray to golden yellow in color. Microcrystalline arsenian pyrite, realgar and stibnite have been found in or near the ore zones. The pyrite is commonly seen as a dusty, sooty-looking dark layer on rock. Of course there is also finely disseminated gold, accompanied by arsenic enrichment in the zone between the TC and DZ faults wherein the orpiment occurrence is located.

Although orpiment specimens from other localities have graced the world's mineral collections for decades without suffering

Table 1. **Electron microprobe analyses of two orpiment crystals (P1 andP2) from the Mega pit (atomic %). Analyses courtesy of Karen Wenrich; Comeco electron microprobe; beam current 17 nanoamps. Standards used: orpiment for As, pyrite for Fe, stibnite for Sb.**

	S	*As*	*Sb*	*Fe*	*Co*	*Ni*	*Cu*	*Zn*	*Ag*	*Au*	*Bi*	*Total***
P1-5-1	62.18	37.59	0.22	0	0	0	0	0	0.01	0	0	100.00
P1-5-2	62.52	37.29	0.18	*0.01	0	0	0	0	0	0	0	100.00
P1-5-4	61.82	38.03	0.11	0	0.01	0.01	0.01	0.01	0	0	0.01	100.00
P1-5-5	66.06	0.68	0	33.23	0	0.01	0.01	0	0.01	0	0.01	100.00
P1-5-6	66.79	0.05	0	33.11	0	0	0.02	0	0.03	0	0	100.00
P1-5-9	61.01	38.35	0.59	0.03	0.01	0	0	0	0	0	0	100.00
P1-5-10	61.64	37.76	0.55	0.03	0.01	0	0.01	0.01	0	0	0	100.00
P1-5-11	66.44	0.06	0.01	33.47	0	0	0	0	0.02	0	0	100.00
P1-5-12	61.80	37.31	0.38	0.42	0	0	0.01	0.01	0.05	0.01	0	100.00
P1-5-13	62.04	36.95	0.65	0.32	0.01	0	0	0	0.03	0	0	100.00
P2-2-1	62.14	37.65	0.18	*0.01	0	0	0	0	0	0.01	0	100.00
P2-2-3	61.23	38.18	0.49	0.05	0.02	0.01	0	0	0	0	0.01	100.00
P2-2-4	61.63	37.82	0.46	0.05	0	0	0	0.01	0.01	0	0	100.00
P2-4-5	61.68	37.61	0.66	0.02	0	0	0.02	0	0.01	0	0	100.00
P2-4-6	62.63	36.71	0.63	0	0.01	0.01	0	0.01	0	0	0	100.00
P2-1-7	62.02	37.15	0.82	0	0.01	0.01	0	0	0	0	0	100.00
P2-1-8	63.03	35.85	1.08	0.03	0	0	0	0	0	0	0	100.00
P2-1-9	62.44	36.98	0.52	0	0	0	0	0.04	0	0.02	0	100.00

*Below detection limit (<0.02)

**Sums adjusted to 100%—Weight % totals ran between 98 to 101%

noticeable change, some collectors have expressed concern about the long-term stability of Nevada specimens. Will exposure to direct sunlight, for example, cause any degree of alteration over time? Twin Creeks orpiment has not been known for long enough to answer that question definitively, but, as with *any* mineral species, it is always advisable to protect them from long-term exposure to direct sunlight.

Perhaps the fact that realgar alters, under exposure to light, to a powdery yellow orpiment-like mineral named pararealgar has inspired worries about the stability of orpiment, which in fact is not known to undergo any such transition.

It might be speculated that impurities or inclusions of other species might affect stability. Electron microprobe analyses of orpiment specimens have determined them to be essentially pure As_2S_3, with no realgar and with traces of Sb and Fe too small to have any conceivable effect on stability. The purest and least pure points analyzed were (respectively) $(As_{1.84}Sb_{0.005})_{1.89}S_3$ and $(As_{1.8}Sb_{0.04})_{1.92}S_3$ (points P1-5-4 and P2-1-7) (see Table 1).

The difference between the crystals of clean, bright color and those having a darker, murky appearance was found to be the presence of microscopic pyrite inclusions. Orpiment surrounding such inclusions carries a higher iron content which may also cause a darkening of the color. Brightly colored orpiment lacks such inclusions and has an extremely low iron content.

Because realgar is unstable it was specifically sought for as inclusions, but none was found, either during the microprobe analyses or the study of eight polished thin sections.

Considering the above studies, it is our conclusion that Twin Creeks orpiment is as stable as pure orpiment from any other locality.

SPECIMEN CLEANING

At the Collector's Edge cleaning lab in Golden, Colorado, cleaning experiments started in May to determine the best approach for specimen preparation. After dozens of tests, it became apparent that heavy coatings would not come off without damaging the specimen luster. Specimens with any degree of etching could not be improved.

An unattractive gray-brown material was sometimes found coating and/or included in specimens, rendering them unaesthetic. Specimens whose quality was unimprovable were returned to the Mega pit for ore processing. Of the entire specimen production (over 4000 pieces), about one third had to be returned. During the entire collecting effort, hundreds of pockets were uncovered that contained heavily coated, or off-color specimens. These pockets were dug out, but the specimens ultimately had to be sent to the crusher. If not for such coatings, many tens of thousands of specimens could have been saved.

Specimens with only slight coatings could usually be cleaned to display an excellent to perfect luster. A sodium citrate bath worked best to remove such coatings. The specimens were then neutralized in a solution of sodium bicarbonate and water. Almost any acid or strong base reacts with orpiment and should be avoided. Hundreds of specimens were recovered with glassy luster, and needed no sodium citrate cleaning at all. Many specimens have a resinous luster, the product of complex crystal overgrowths, and also require little cleaning. Unetched crystals are translucent to semi-transparent.

FUTURE POTENTIAL

The orpiment in Cut 62 is exhausted. At the depth of the 4120 Bench, much of the fold structure containing the orpiment mineralization is completely mined out. The current pit model places the 4120 level at the lowest developed part of the mine, so there will be no additional mining of the structure at depth in this area.

There are several places within the Mega pit walls where drilling intercepts show additional orpiment zones occurring along the strike of the fold axis. Unfortunately, the pit wall will not advance to uncover them because they lie in areas of uneconomical gold concentrations. Should the price of gold skyrocket, the potential exists for revising the mine plan and widening the Mega pit.

To the northwest, work is underway on Cut 20 (near Cut 62). During mining activity in this area, signs of orpiment have been seen. This is the most likely target for future specimen orpiment production. However, no crystallized orpiment has been encoun-

(continued on p. 331)

THE PURPLE PASSION MINE

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The Purple Passion mine is among Arizona's most unusual wulfenite occurrences, producing attractive crystals of tabular and acicular habit on purple fluorite.

INTRODUCTION

The Purple Passion mine (originally known as the Diamond Joe mine) is located approximately 8 miles northeast of Wickenburg, Arizona (about 60 miles west and a little north of Phoenix). In addition to the usual tabular habit, the Purple Passion mine produces several unusual crystal habits of wulfenite and also hosts some uncommon associations, including wulfenite on smoky quartz, amethyst and fluorite. Other associations include calcite, galena, anglesite, cerussite, sulfur, chlorargyrite, smithsonite and willemite. The calcite, fluorite, wulfenite and willemite are strongly fluorescent.

Through the years, the surrounding property has occasionally yielded small quantities of minerals and, in the mid-1990's, a fair amount of good quality wulfenite specimens. The mine consists of two unpatented claims on government land (controlled by the Bureau of Land Management) in the White Picacho mining district, in Yavapai County, Arizona. The mountains around Wickenburg have been extensively mined for gold, silver, lead and molybdenum, so it is common to see tailings piles and adits in the general area on the way to the mine. In addition to many small prospect sites, the King Solomon, Octave and Monte Cristo mines are located to the north; to the southeast are the Great Southern and the Monarch mines. This is the wulfenite location referred to in *Mineralogy of Arizona* by Anthony *et al.* (1995) as being an "unusual deposit" near the Great Southern mine.

LOCATION and CLIMATE

The Purple Passion mine is situated in the Wickenburg Mountains, Yavapai County, located on the USGS Arizona *Morgan Butte* 7.5-minute topographical map at T8N, R3W, Sec. 30, SE 1/4. The mine is in the Sonoran Desert, about 3,200 feet above sea level. At this elevation, the desert climate is somewhat milder than in the lower desert, but during the summer months, daytime temperatures routinely climb above 110°F, making it almost unbearable for the casual mineral collector. Winter temperatures get down to freezing some nights. The average rainfall is about 6 inches yearly.

On the way to the mine we have seen typical desert wildlife including rabbits, range cattle, three deer, a coyote, many birds, a gopher snake, several rattlesnakes, a javelina, scorpions, tarantulas, honey bees, lizards and a gila monster. Two diamondback rattlesnakes currently live about 40 to 50 feet down one of the old vertical shafts.

HISTORY and WORKINGS

Late in the fall of 1995, we got together with four other mineral collectors (John "Mac" McClelland, Gaylord "Jay" Hayes, Gary Spraggins and Scott McCloed) to actively work the Diamond Joe mine, a site that Jay knew about. On the surface we saw a vein of material which consisted of small wulfenite crystals in calcite with an occasional thin vein of fluorite or galena. Along the base of the hill, about 100 feet south of a small pile of purple waste, we found

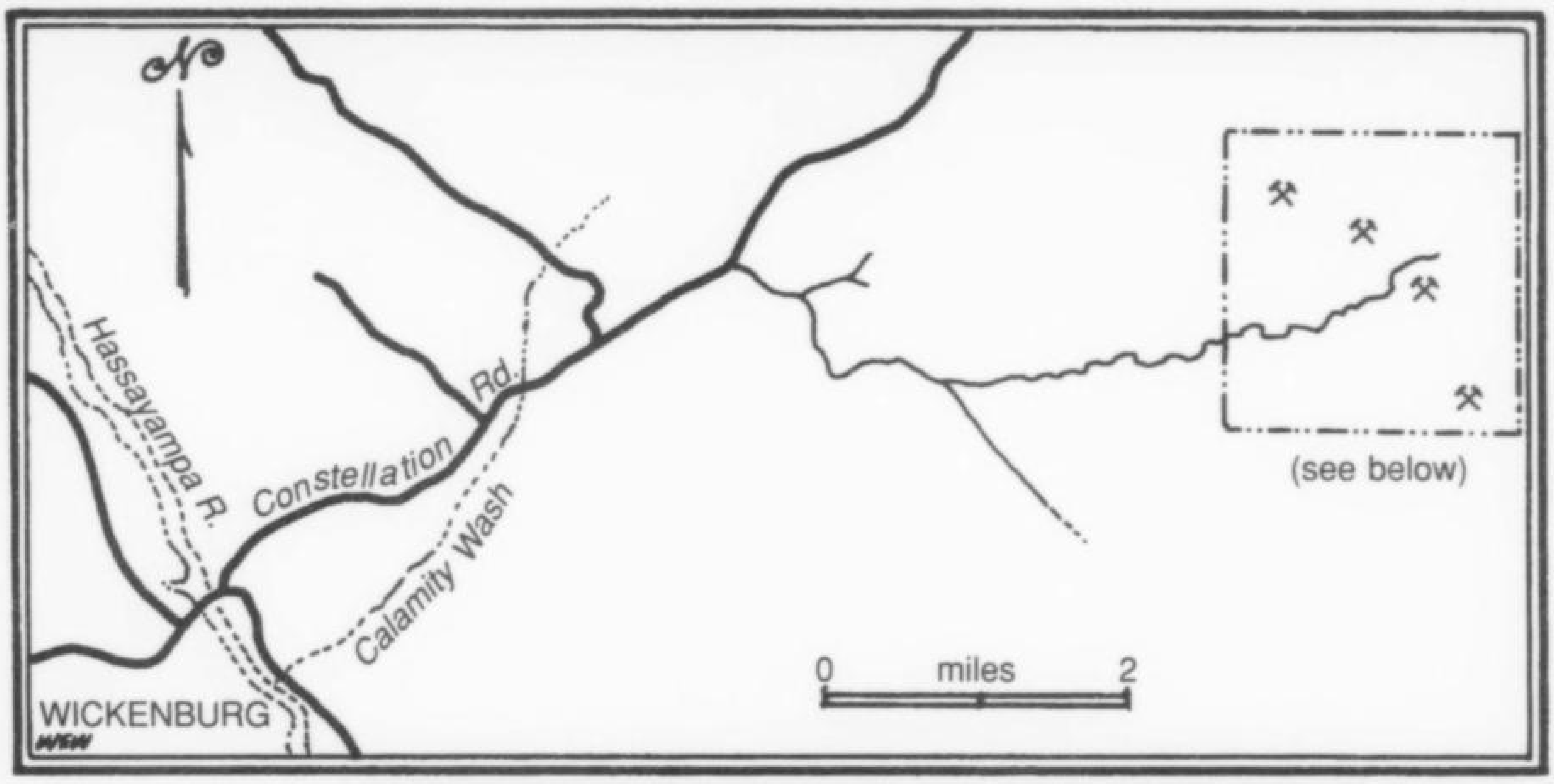


Figure 1. **Location maps.**

an inclined shaft, a vertical shaft, a windmill-powered water pump, two water tanks, an old forge and some small concrete bases for a winch system. The vertical shaft is about 15 to 20 feet in diameter and goes straight down approximately 45 to 50 feet. There does not appear to be any significant mineralization in the vertical shaft. The inclined shaft follows the vein down at about a 55° angle toward the vertical shaft. It is about 6 feet square and is collapsed after the first 15 feet. The vein exposed in this inclined shaft is mostly calcite containing small layers of green fluorite with traces of galena and wulfenite. Across the wash and up a hill, about 500 feet to the southwest, is another vertical shaft and some major concrete foundations; this shaft is collapsed about 20 feet down. Only a small amount of tailings are present at any of these locations and we originally believed the whole site must have been either a millsite for trucked-in material, or just prospect holes with no major workings, but this was not the case. Conversations with other mineral collectors turned up rumors that an extensive series of tunnels once existed at the site, but that the tunnels were now caved in.

We eventually located Bill Hunt, a micromount collector with some first-hand knowledge of the site. Bill came up to the mine in the middle of May (1996), and shared with us what he remembered about the site. The mineralized vein lays on a fault surface in a hill which extends above the wash. Around 1975, Bill Hunt (and some of his friends) worked the surface of this deposit and looked down into some of the old tunnels. Working from ground level up, Bill's group excavated a section of the exposed purple fluorite vein containing wulfenite. The waste pile of purple fluorite at the north end of our shaft turns out to have been left by Bill Hunt's group. Art Roe (1980) indicated six localities where acicular wulfenite

Figure 2. **Purple Passion mine area.**

(needles) can be found, and stated that Bill Hunt (and others) found acicular wulfenite at the Great Southern mine in Yavapai County. That reference is actually to the Diamond Joe (Purple Passion) mine, but Bill thought our mine site was part of the Great Southern mine and he had labeled his specimens accordingly. Later, Bill's group found references which indicated the site is associated with a group of claims under the names of Kelly and/or Hogan; the Great Southern mine actually lies in a parallel vein about 1,500 feet to the east. The small amount of material that can be found in collections up until this time may be labeled with several alternative names such as the Kelly, the Hogan, or the Great Southern. Despite these labeling discrepancies, material that has the appearance of what is currently being mined is almost certain to have come from the Purple Passion mine, and should be labeled (or relabeled) accordingly.

A stroke of luck and several days researching the file data at the Arizona Department of Mines and Mineral Resources (ADMMR) solved the mystery of the mine's name. The Purple Passion mine is located at the site of what was known as the Diamond Joe mine. Due to an incorrect "guess" during a mapping survey, the ADMMR records had placed the Diamond Joe mine at one of its prospect claims some distance to the east, and it was consequently recorded as being in the southwest quarter of section 29 instead of its true location in the southeast quarter of section 30.

The Diamond Joe vein was discovered in 1890 by A. B. Lovell and it was worked sporadically from 1901 to 1926. No assay records can be found for the early time period when the inclined shaft and vertical shaft number 1 were started. In 1926–27 a millsite was erected and a medium-sized operation was started by

Figure 3. **Rebuiding the collar at the head of the vertical shaft, Purple Passion mine.**

the Diamond Joe Mining Company Inc., owned in full by George R. Kyok of Wickenburg. The inclined shaft reached a developed length of 325 feet along the vein, for a depth of 225 feet. Vertical shaft number 1 intersected the inclined shaft at a depth of 83 feet and continued down to 180 feet. At that time, 60 tons of ore per week were being processed, averaging 12–15% lead, 13.5 ounces of silver/ton and about .025 ounces of gold/ton (no records have been found for molybdenum). Unfortunately, at only 15 gallons per minute, the mine did not produce enough water for processing the ore full-time when the production was increased to 100 tons/day. In an effort to keep the mill running, a 500-foot vertical shaft (number 2) was sunk in 1927-28. The first 225 feet were used as the main entrance to the lowest working level of the mine and the bottom 275 feet were used as a water reservoir. Roughly 135,000 tons of ore were removed and a total of 2,250 feet of tunnels, shafts, and stopes were driven, with levels at 45, 83, 180 and 225 feet. The reason there are no large tailings piles is that the vein was approximately tunnel-width, so there was very little waste rock; the waste piles are mostly the barren material from the vertical shafts. All the ore was milled on site and processed prior to shipping. Late in 1928 the mine was closed due to insufficient water (Gohring, 1934). According to the ADMMR records, the mine was briefly reopened in 1945, but only shipped a small amount of ore before reclosing again.

GEOLOGY

According to Stimac *et al.* (1987):

> the area is composed of a metamorphic-plutonic basement unconformably overlain by Tertiary volcanic and sedimentary rocks. The oldest rocks, assigned to the Proterozoic (1.8–1 billion years) Yavapai Supergroup, consist of amphibolite, schist and gneiss, intruded by granite, leucogranite and pegmatite. . . . Proterozoic rocks are intruded by Late Cretaceous granodiorite, granite, pegmatite and aplite. Basement rocks are cut by numerous felsic and mafic dikes and sills related to Tertiary volcanism. . . . Volcanism was accompanied and followed by low-angle to moderate-angle normal faulting produced by northeast-southwest-oriented regional crustal extension. Major north to northwest-trending moderate-angle faults, which dip 30 to 50 degrees to the southwest, cut and tilt Tertiary rocks and crystalline basement rocks, producing domino-style repetition of sections. . . . Precious-metal and base-metal prospects occur in both the Tertiary volcanic and sedimentary rocks and the crystalline basement. Many of the prospects are localized along low-angle to moderate-angle faults characterized by intense brecciation and quartz, calcite and iron oxide veining. Such mineralization is middle Tertiary in age.

The Purple Passion claim is located (according to Pratt, 1938) on the southern slope of an exposed batholith. The uplift of the batholith has produced numerous fissures as channels for ore deposition. The main fissure strikes N 27° W, dipping 55° southwest. It is a true fissure vein, widened by displacement of the wall rock, and can be traced on the surface for a distance of about 3000 feet. The vein is cross-faulted several times, but little displacement of the vein can be seen. The country rock is granitoid, containing quartz, plagioclase feldspar, orthoclase, hornblende and biotite. Quartz predominates over orthoclase, and this makes the country rock a quartz diorite, shading to granodiorite. The mineralized vein has a banded structure, but in general one finds lead and silver minerals disseminated across the vein. Coarse-grained calcite predominates along the footwall, often intermingled with veins of quartz and purple or green fluorite. Two distinct periods of mineralization are recognizable with the second period having a higher percentage of iron and silver. As the hanging wall is approached, an iron-stained, leached, calcareous material becomes prevalent, with a thin vein of galena between the two portions of the vein. The highly intruded condition of the hanging wall has resulted in extensive kaolinization which has widened the mineralized vein to a total thickness of 10 feet in some places (Pratt, 1938).

In arid districts such as this, the oxidized zone can be quite deep. Furthermore, the Purple Passion mine lies at an elevation considerably above the nearest major present-day watercourses. However, since 1947, surface water has flooded the old tunnels to about the 45-foot level. The old mining reports show that down to the 225-foot level the lead and silver minerals are mostly in their oxidized forms (the lead forms anglesite and cerussite with a small percentage of galena; the silver is almost all in chlorargyrite, with small amounts of silver sulfide or native silver present (Pratt, 1938).

MINERALS

Anglesite $PbSO_4$

Anglesite is typically found as a massive silvery-black submetallic massive material in small seams and pockets throughout the vein. In some cases the anglesite has a core of galena, in other cases it serves as a core for further oxidation products such as cerussite and wulfenite.

Aragonite $CaCO_3$

Aragonite is found as druses and spheres coating other minerals in some pockets.

Barite $BaSO_4$

According to Sedgwick (1923), in lead and silver veins of this kind, barium and zinc are usually associated with the ore. In this respect, the mineralogy of the Purple Passion mine is somewhat atypical because only small amounts of barite and zinc are found. The barite occurs as translucent to white blades associated with purple fluorite and sometimes with calcite. The blades range in size from microscopic to as large as 0.75 inch. The striking contrast of snow-white barite blades and yellow wulfenite on purple fluorite produces some excellent specimens. Some of the micromount specimens have barite blades covered with gemmy purple fluorite crystals.

Calcite $CaCO_3$

A fairly translucent, white to yellow calcite serves as a major matrix mineral in the mine. Near the footwall, coarse-grained calcite dominates the vein in thicknesses up to 7 feet. Typically, these large calcite crystals surround pockets containing quartz (clear, milky, smoky, and amethyst) or wulfenite crystals. In the pockets, the smaller calcite crystals are usually transparent and are intermixed with all of the other minerals. The calcite fluoresces bright red to hot-pink under ultraviolet light, and the caliche fluoresces a peach color.

Cerussite $PbCO_3$

Cerussite is found as brilliant, transparent, colorless to honey-yellow or sherry-colored crystals usually 0.25 inch or less (although we have seen a 1 inch crystal that was collected here some years ago).

Chlorargyrite AgCl

As deep as 225 feet, chlorargyrite appears to account for the majority of the silver in the deposit. It occurs as a greenish or brownish to copper-colored crust. Sometimes the chlorargyrite completely fills pockets in the fluorite matrix.

Figure 4. Dark smoky-colored cerussite crystals, 0.1 inch, from the Purple Passion mine; Bill Gardner photo.

Figure 5. Acicular wulfenite spray, 0.1 inch, with purple fluorite, from the Purple Passion mine; Bill Gardner photo.

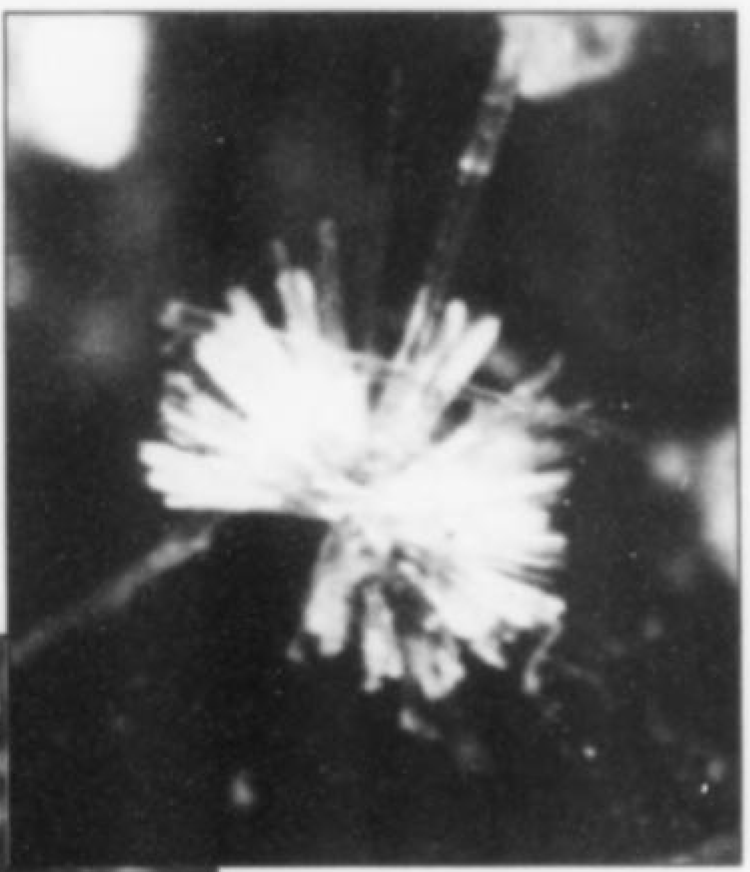
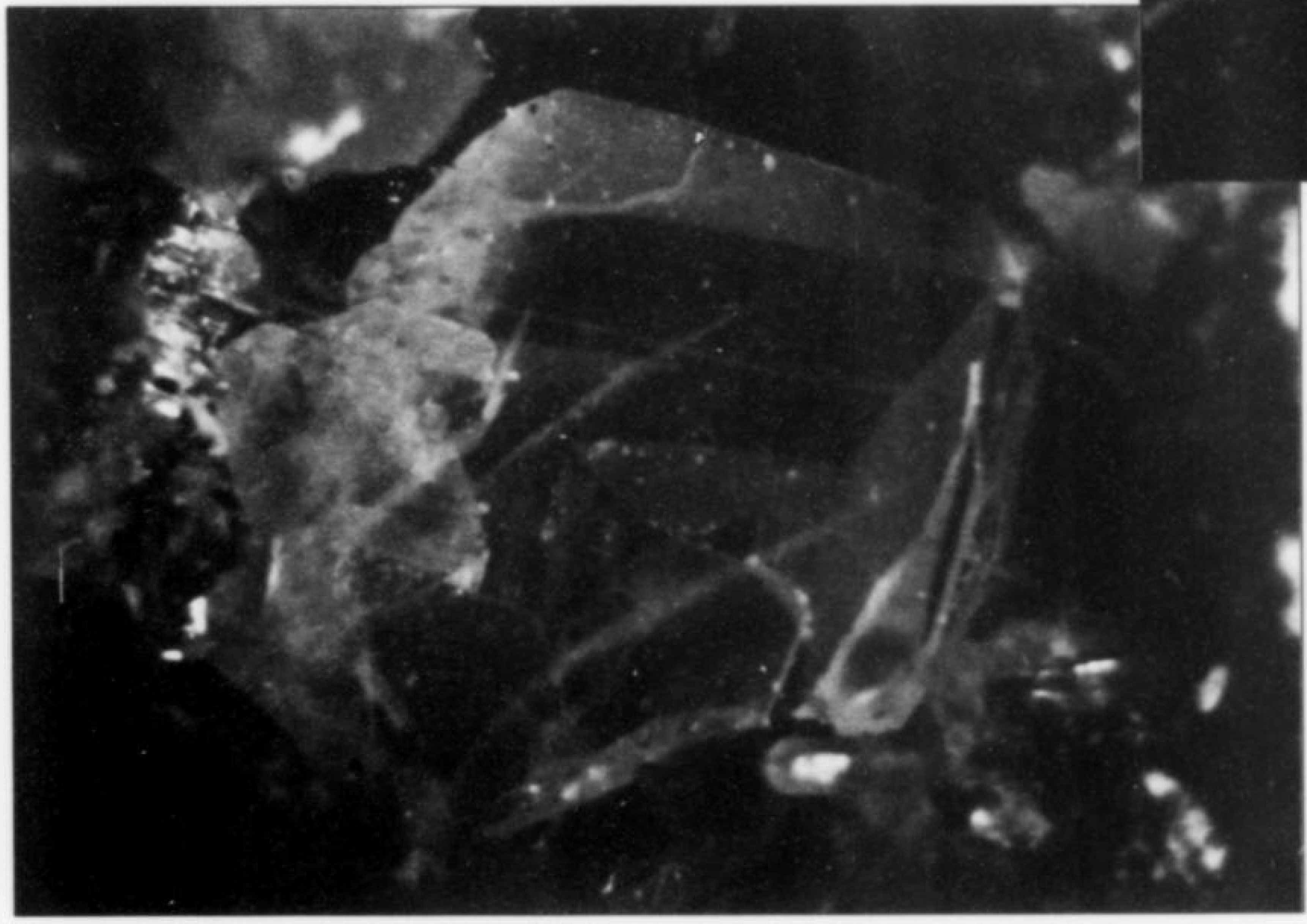


Figure 6. Willemite crystal spray, 0.04 inch (1 mm), from the Purple Passion mine; Bill Gardner photo.

Figure 7. Wulfenite crystals to 0.1 inch, from the Purple Passion mine; Bill Gardner photo.



Fluorite CaF_2

Fluorite occurs both as a purple and green granular matrix, and as seams and well defined crystals in pockets. The purple matrix is often botryoidal in shape and banded, with deep purple and lilac-colored layers. In some parts of the vein, the fluorite tends to be a translucent, vivid apple-green color, and occasionally traces of yellow or cranberry color are present in the purple fluorite. Only a few pieces have been found with intergrown fluorite crystals up to 0.25 inch, but on the microscopic level (at 15x) the crystals are well defined cubes, octahedrons, and dodecahedrons. The green fluorite usually fluoresces a brilliant blue color under longwave ultraviolet light.

Galena PbS

Minor amounts of galena are found across the vein as thin stringers and small pockets, and also as a thin layer between the upper and lower portions of the vein. The galena is usually very fine grained (slightly blue in color) and the assays indicate it contains about 10% silver sulfide. To date, we have only seen one specimen with a small, well-defined galena cube.

Gold Au

The assays indicate 0.02 to 0.03 ounces of gold/ton evenly distributed throughout the vein. Extremely small particles of free gold can be seen in some of the material.

Quartz SiO_2

Quartz occurs as small seams and also as well-formed crystals in pockets. Small, clear quartz crystals are common, and pockets of amethyst, as well as lustrous smoky quartz, are found occasionally. Tiny scepters, reverse scepters and phantom crystals are fairly common. The largest quartz crystals found so far are about 0.5 inch long; wulfenite crystals have been found on all of the varieties of quartz. Before being split open, the largest smoky quartz pocket measured 10 x 7 x 2 inches and contained crystals up to 0.25 inch long.

Silver Ag

Native silver is found as small wires, ribbons and globules. The old reports indicate that silver sulfide was beginning to appear at the 225 foot level (Pratt, 1938).

Smithsonite $ZnCO_3$

In this deposit, only small amounts of zinc are encountered (Sedgwick 1923), as smithsonite and willemite. The smithsonite is found as white to greenish or aquamarine-colored microscopic botryoidal shapes.

Sulfur S

Microscopic sulfur crystals have been found, usually in association with smoky quartz.

Uranium mineral

Several specimens of wulfenite and purple fluorite have been found to be slightly radioactive (up to 50,000 counts per minute), and the radioactive element was identified by gamma spectroscopy as uranium 238 and its daughter products. The specific uranium minerals have not yet been positively identified although samples have been sent to be tested.

Willemite Zn_2SiO_4

Willemite occurs as microscopic sprays of transparent, colorless to white or pinkish crystals, often on a smoky quartz crystal matrix. It shows a strong pale yellow to pale green fluorescence under ultraviolet light, and an afterglow after the light source is removed.

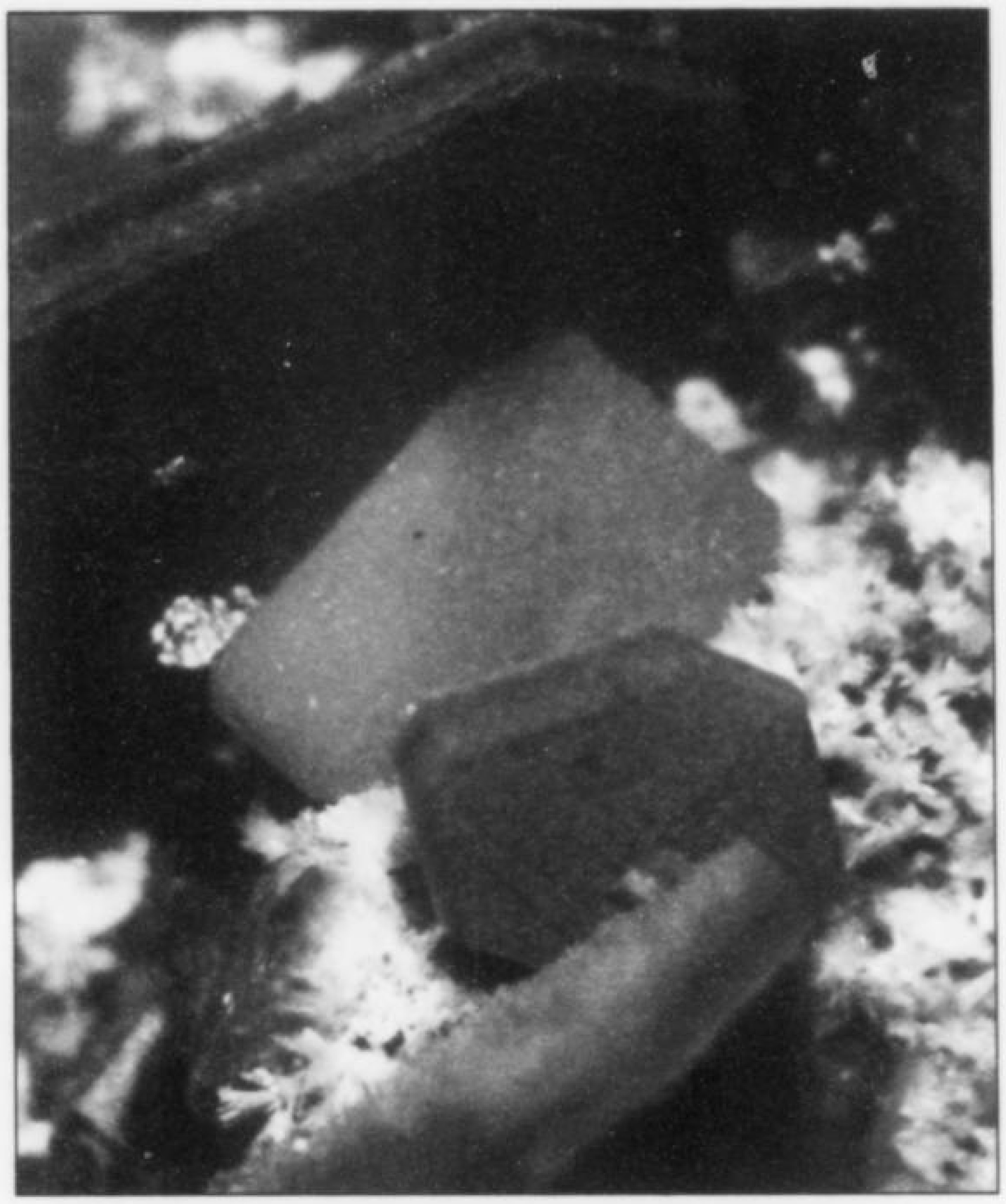


Figure 8. **Tabular wulfenite crystals to 0.2 inch with willemite on fluorite, from the Purple Passion mine; Bill Gardner photo.**

Figure 9. **Acicular wulfenite crystals to 0.1 inch, from the Purple Passion mine; Bill Gardner photo.**

Wulfenite $PbMoO_4$

Wulfenite is distributed throughout the vein and also in fissures in the bordering country rock. The wulfenite crystals exhibit an array of colors ranging from dull opaque caramel and butterscotch

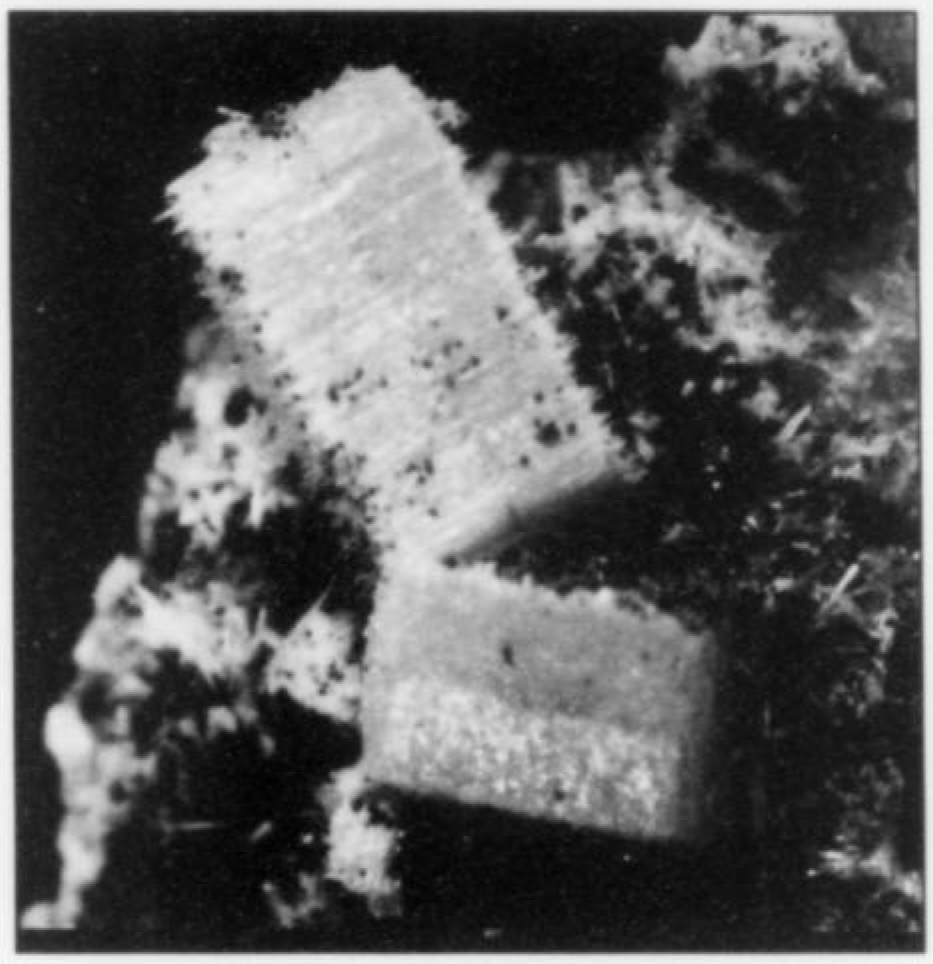


Figure 10. **Fuzzy tabular wulfenite crystals to 0.1 inch; Bill Hunt photo.**

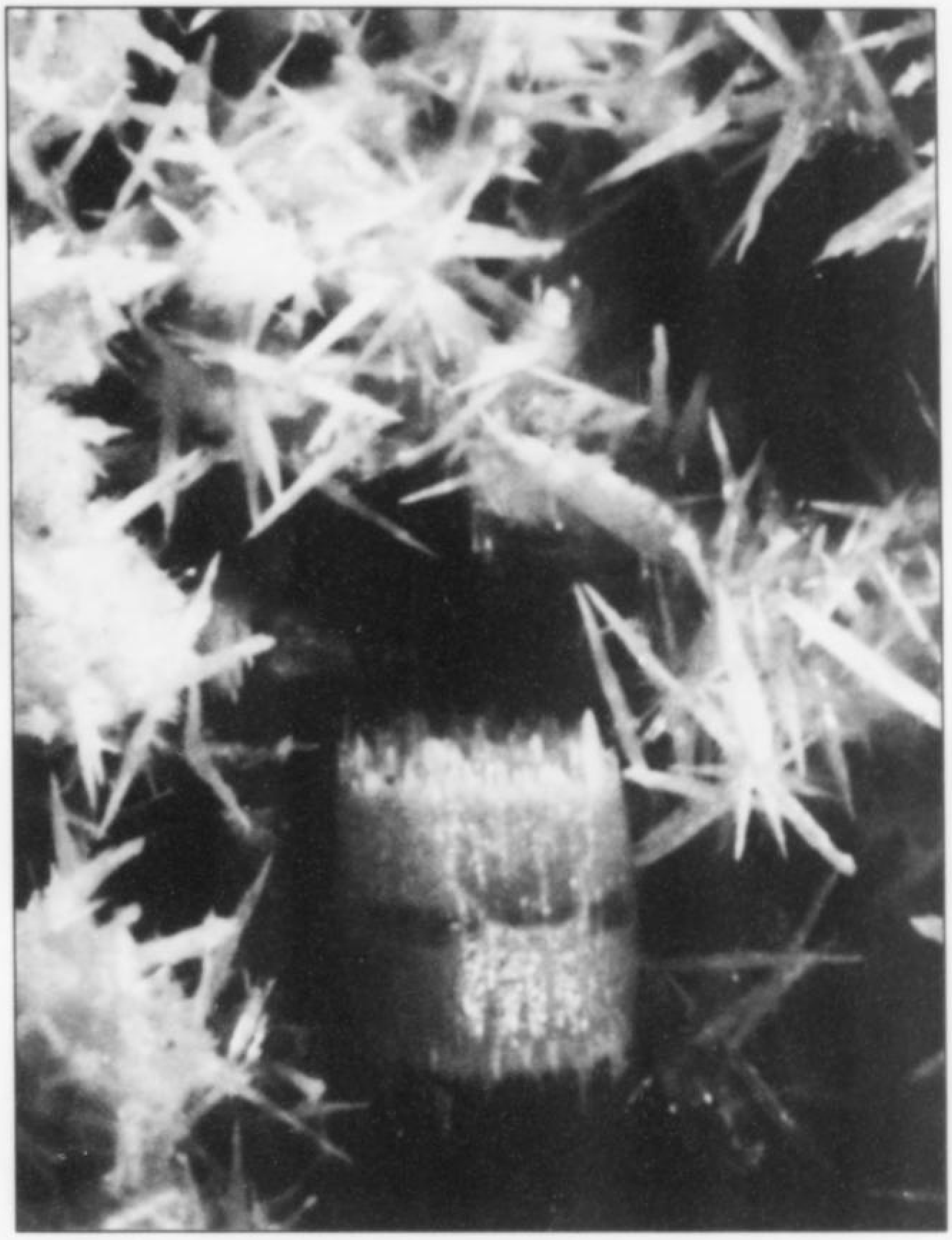


Figure 11. **Acicular wulfenite crystals to 0.1 inch; Bill Hunt photo.**

Figure 12. **Acicular wulfenite cluster, 0.1 inch; Bill Hunt photo.**

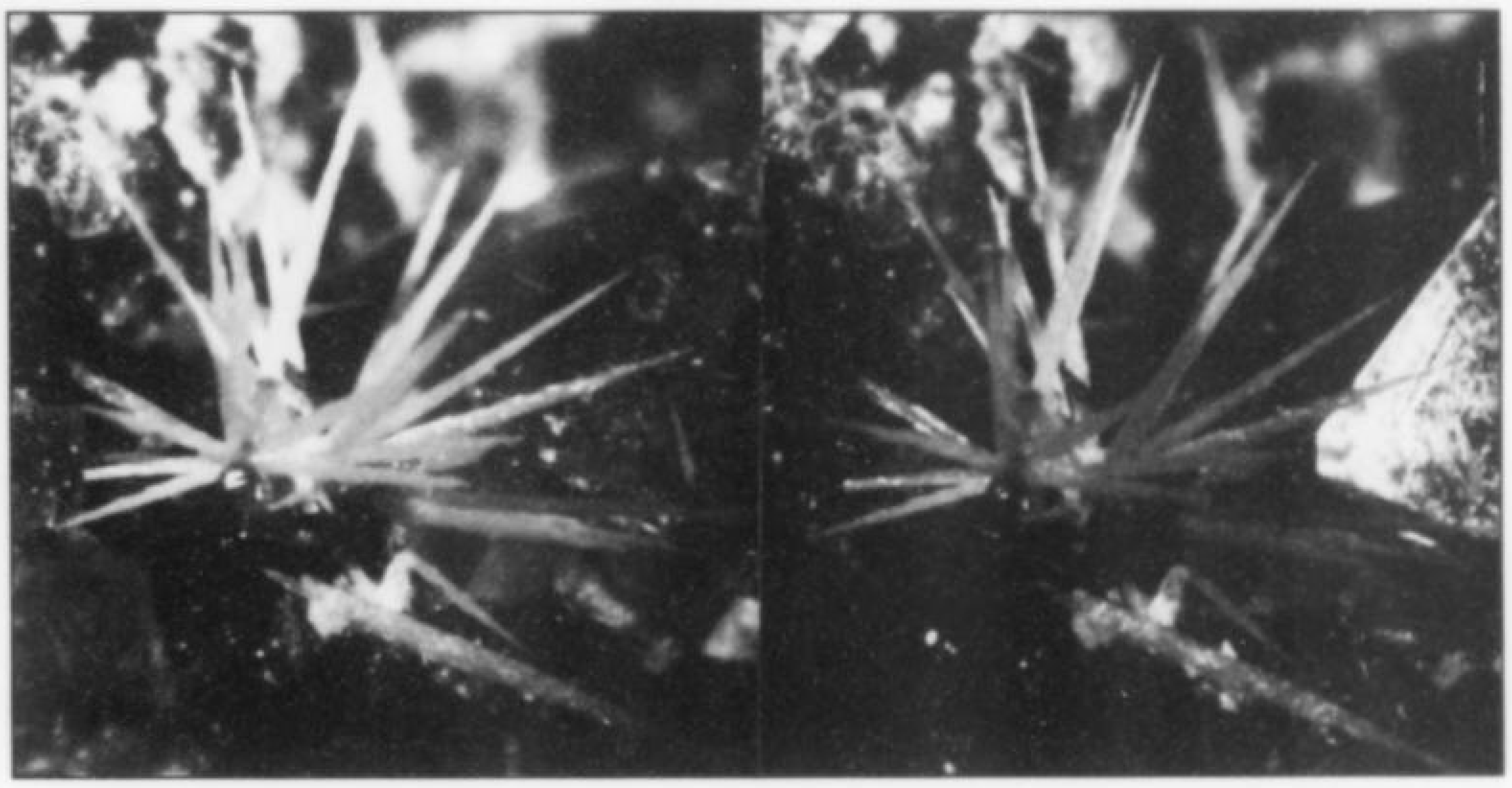


Figure 13. **Acicular wulfenite spray (0.1 inch) with fluorite; stereopair by Bill Hunt.**

through yellow and orange to lustrous, transparent orange-yellow. Some of the color changes appear to be caused by the weathering action of near-surface waters. Where groundwater has altered the smooth tabular crystals, the crystal surface has turned an opaque yellow or butterscotch but the inside of the crystal remains transparent. The crystal habits are: tabular, bipyramidal, pyramidal, acicular and acicular-tabular. Wulfenite specimens can be found as unattached clusters of intertwined blades (usually quite battered) weighing from a few grams up to 3 kg. Unattached, opaque, tabular blades up to 2 inches on a side and 0.12 inch thick have been found. Thin attached blades up to 1 inch on an edge, have been collected on quartz as well as on calcite and granular purple fluorite matrix. Occasionally, in pockets that were protected from the ground water, lustrous, transparent blades, up to 0.5 inch on an edge have been found. A few crystals show concentric square zoning, alternating between transparent colorless and yellow. Some of the wulfenite fluoresces a dull orange color under ultraviolet light.

The most interesting and complex habit of wulfenite found at the mine is the acicular-tabular type; we have coined the term "fuzzy tabs" to describe them. They have the appearance of two scrub

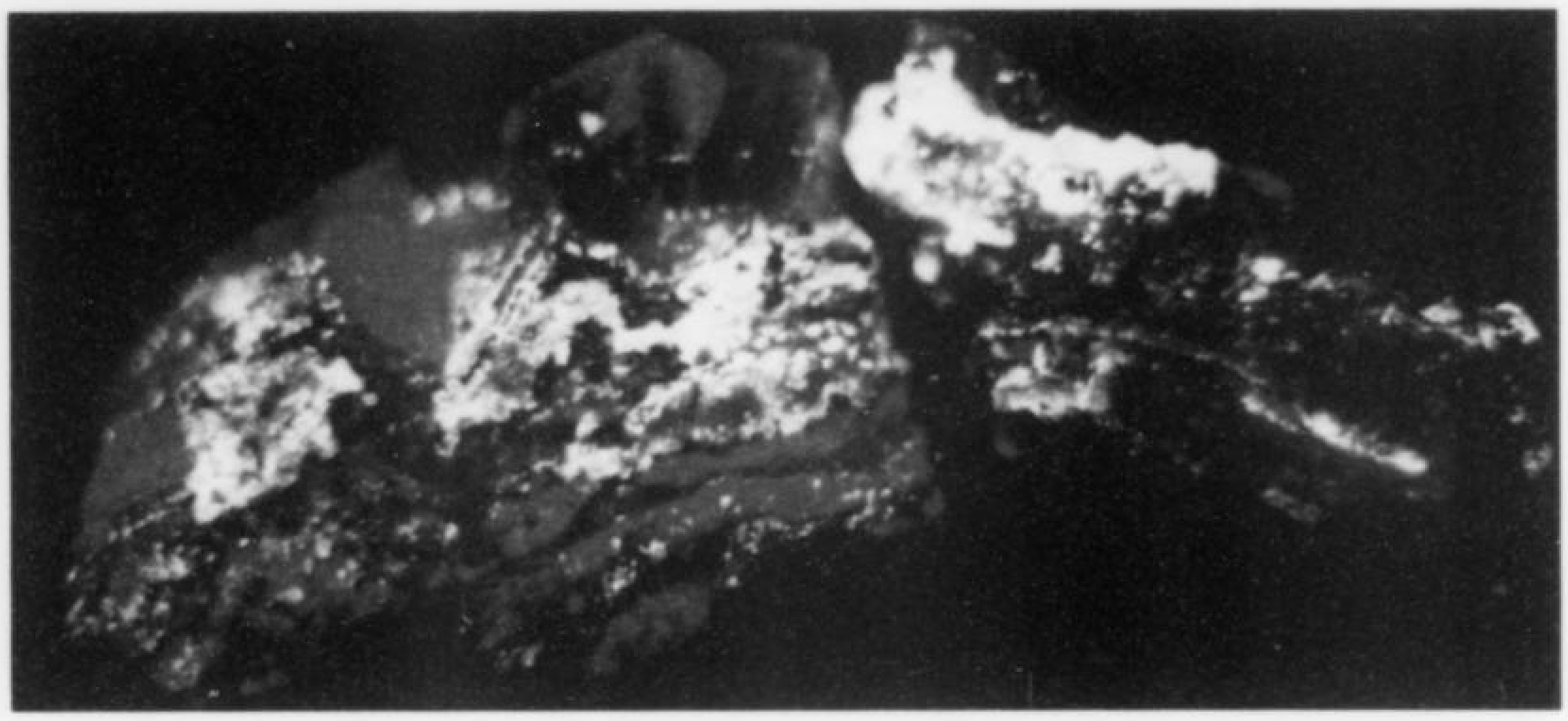


***Figure 14.* Fluoresecent minerals from the Purple Passion mine: red = calcite, blue = fluorite, green = willemite. The two specimens shown measure 5 and 4 inches.**

brushes placed back to back. The fuzzy tabs appear to have a normal tabular crystal in the center which sprouted a secondary growth of needles perpendicular to the broad side of the wulfenite tablet and in crystallographic continuity. The needles usually grew an equal distance out of both sides and the original crystal shows as a dark band down the center of the "fuzzy tab." In pockets containing "fuzzy tabs," the mineralizing solution often deposited small needles lining the rest of the pocket.

Nearly 50% of the wulfenite specimens found at the mine have acicular crystals which are very elongated bipyramids (only a small percentage of the wulfenite formed the more normal short bipyramids). These needle-shaped crystals tend to be a drab, opaque tan to a translucent, honey-yellow color. The largest wulfenite pyramid was about 0.63 inch long and 0.06 inch in cross section (unfortunately, it broke while trimming the specimen). The wulfenite needles sometimes bundle together like a stack of logs to form multiple crystals which do not appear to have a tabular crystal in the center. These bundles of needles look different from the "fuzzy tabs," because they do not have a center stripe and the proportions are not the same.

CONCLUSION

To date at least 14 minerals have been found, many of them well crystallized and abundant. Some of the minerals display multiple crystal habits, and a substantial number of mineral associations may be found on a single specimen. Considering the fluorescence and also the vivid color combinations, an extensive range of attractive specimen material is available. The majority of the specimens currently being produced are micromount or thumbnail size up to small cabinet pieces, with an occasional larger specimen. The current shaft is about 40 feet below grade and the mine is producing larger and gemmier crystals with depth. We expect that the Purple Passion mine will eventually connect to the Diamond Joe tunnel system.

ACKNOWLEDGMENTS

Darrel Dodd put us in contact with many interested parties including Bill Hunt and Steve Decker. Bill Hunt performed chemical tests to identify minerals and also provided a wealth of information about the site. Steve Decker wrote a short article about the mine and placed it on the Internet. Niles Neismith guided us through the maze of data at the Arizona Department of Mines and Mineral Resources. The photographs were taken by Bill Gardner, Bill Hunt and Gary Spraggins. Richard A. Bideaux and Wendell E. Wilson reviewed the manuscript.

For more information please contact Bill Gardner at (602) 547-2234 or wggardner@aol.com.

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(continued from p. 322)

tered here to date. This cut will be the western-most extension of the pit.

FINAL WORD

Orpiment mining activities at the Twin Creeks mine preserved many fine mineral specimens and created no slowdowns in ore production. Constant communication between mine staff and collecting crews ensured that high levels of safety were maintained and the best possible collecting procedures were followed.

The level of cooperation between Newmont and the Collector's Edge is, perhaps, unprecedented in modern mineral collecting and proves that mineral collecting and commodity mining can be symbiotic in nature rather than detrimental to mining company profits. Newmont's commitment to preserving mineral specimens is an exciting event in the mineral world. Too often, great discoveries are carried off to a crusher and lost forever. Specimen preservation efforts such as the orpiment project may help encourage other mining companies to re-evaluate their mineral collecting policies and become more proactive in saving mineral specimens. Mineral specimens are one of earth's treasures and saving them in today's environment-conscious world cannot help but improve mining's image. The positive benefits to public relations are immeasurable.

Since June 1999, several Nevada newspapers have covered Newmont's efforts to preserve mineral specimens. The response to these articles has been very favorable. And, as if to underscore the effort, Barrick Resources' specimen preservation effort to save the golden barites from their Meikle mine in Nevada has received similar attention in Nevada newspapers and mining and mineral journals.

ACKNOWLEDGMENTS

The author wishes to thank the geology staff at the Twin Creeks mine; Ron Thoreson, Pat Donovan and Leroy Schutz provided invaluable support in promoting this project and supplying information for this article. Trent Tempel, General Manager of the Twin Creeks mine, was instrumental in clearing the way for the collecting effort to begin. Lyle Avey and Randy Ford, the engineering staff, and the entire crew at the Twin Creeks mine could not have been more helpful in making the collecting effort as efficient and successful as it could be. Doug Hock and Louis Schack, Newmont Public Relations managers, spent long hours promoting the project both inside and outside the Newmont organization.

And finally, thank you to all of the people in the Newmont organization for believing in the project and helping to make it happen.

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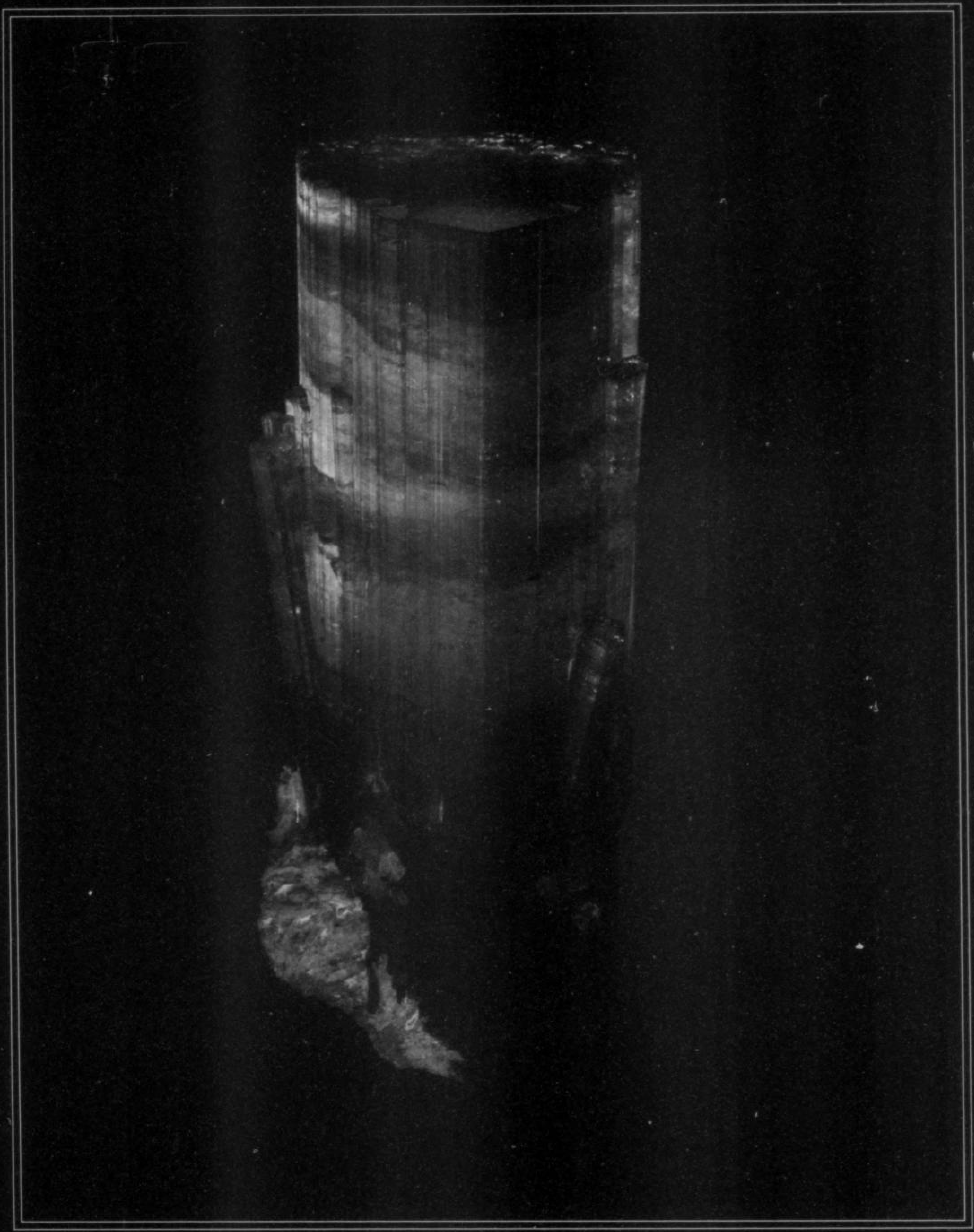

Elbaite; Blue Cap Pocket, Tourmaline Queen mine, Pala, California, 13.2 cm.

Wayne A. Thompson

FINE MINERALS

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photo by Jeff Scovil

CHROMIAN DAWSONITE AND CHROMIAN ALUMOHYDROCALCITE FROM ORESTIMBA CREEK, STANISLAUS COUNTY, CALIFORNIA

Gail E. Dunning
773 Durshire Way
Sunnyvale, California 94087

The chromian varieties of dawsonite and alumohydrocalcite occur as late syngenetic or epigenetic minerals in the Diablo Range of the Franciscan Complex, California. This is the third occurrence for the two varieties in mutual association.

INTRODUCTION

The chromian varieties of dawsonite, $Na(Al_{1-x}Cr_x)CO_3(OH)_2$, and alumohydrocalcite, $Ca(Al_{2-x}Cr_x)(CO_3)_2(OH)_4 \cdot 3H_2O$, have been identified from a new locality in the Franciscan Complex, California. These uncommon carbonate minerals generally occur in geologically diverse sedimentary formations under low-temperature hydrothermal environments where carbonate-rich fluids and alkaline or calc-alkaline rocks and aluminum-bearing silicates or hydroxides exist. When these carbonates are found associated with ultrabasic rocks containing chromium minerals such as magnesiochromite, appreciable amounts of trivalent chromium can substitute for aluminum in their structures during formation. This substitution colors these minerals a beautiful light to dark pink, depending on the amount of chromium present.

LOCATION

The new California chromian dawsonite-alumohydrocalcite locality is in the NE¼ of the NE¼, Sec. 36, T8S, R5E, Mount Diablo Meridian, Stanislaus County. This area is the Gill-Mustang Addition to Henry Coe State Park, and is shown on the *Mississippi Creek Quadrangle* of the U.S. Geological Survey. The specific area is a metagraywacke outcrop on the east side of the south fork of Orestimba Creek near its headwaters, and is within the Diablo Range of the Franciscan Complex (Jurassic). This complex is composed of metagraywackes, shales, greenstones, arkosic sandstones, serpentinite intrusions and other rocks typical of this diverse formation. The sediments are highly fractured and folded, often showing local intrusion by serpentinite masses. Local metamorphism has altered portions of the serpentinite to small silica-carbonate and eclogite bodies. The geological features of this formation have been investigated by Bailey *et al.* (1964) and Crittenden (1951).

Chromian alumohydrocalcite previously has been identified along the Diablo Range east of Mount Hamilton, Santa Clara County by Dunning *et al.* (1975). At this locality the chromian alumohydrocalcite occurs as 1-mm spheres and masses with dolomite on the contact between a nickeliferous serpentinite body and a dark, partially silicified shale. The Mount Hamilton locality is about 23 km north of Orestimba Creek and has produced, in addition to chromian alumohydrocalcite, the finest examples of melanophlogite crystals ever found (Cooper and Dunning, 1972). Dawsonite has been previously reported from California at the Oriental mine in the Alleghany district, Sierra County (Ferguson and Gannett, 1932; Coveney and Kelly, 1971).

Some of the other world localities for alumohydrocalcite and dawsonite have been recorded by Alabaster (1989), Goldbery and Loughnan (1977), Ryback (1988), Smith and Milton (1966), Brobst and Tucker (1974), Chu *et al.* (1987), Aikawa *et al.* (1972), Sabina (1982), Stevenson and Stevenson (1965), Bačo and Pacindová (1993), Smith and Young (1975) and Loughnan and See (1967).

DISCOVERY AND INDENTIFICATION

During the late 1980's, Dennis Sorg (retired) of the U.S. Geological Survey, Menlo Park, California, discovered a metagraywacke outcrop containing a tan silica-carbonate vein on the south fork of Orestimba Creek, western Stanislaus County. This vein, which has margins composed of a dark green nickeliferous serpentinite, was found to contain a white to pale pink radiating mineral along thin fracture surfaces cutting across the vein direction. Representative hand specimens from the outcrop were brought back to the Survey by Sorg and given to Richard C. Erd for identification. From a megascopic examination, the mineral appeared to be the chromian variety of alumohydrocalcite, since it resembled the chromian alumohydrocalcite found just east of Mt. Hamilton, California (Dunning *et al.*, 1975). Erd then performed optical tests on the pink crystals which showed a close comparison to the data for alumohydrocalcite. The results of his optical tests are compared with that of dawsonite and alumohydrocalcite in Table 1.

However, a subsequent X-ray powder-diffraction pattern and energy dispersive analysis (EDS) test by Erd identified these crystals as dawsonite, a mineral with a physical appearance similar to alumohydrocalcite. Qualitative EDS by Erd proved sodium, aluminum and chromium as major elements with a lesser amount of nickel and silicon. The unit cell parameters calculated from the powder diffraction data show a close comparison to those of chromian dawsonite. Table 2 compares the unit cell parameters obtained by Erd to the chromian varieties of dawsonite and alumohydrocalcite. A micro closed tube heating test resulted in a yellowish green residue, which did not fuse, with little or no evidence of water or other volatiles. Carbonate was confirmed by microchemical tests. No further tests were performed on these crystals until 1997 when all the specimens and data collected were given to the author for the purpose of completing the description of the locality.

A complete megascopic examination was made of these specimens to identify all of the mineral phases present. After breaking the specimens into smaller sizes, several thin veins of a dark pink radiating mineral were exposed within a porous quartz-dolomite vein rich in nickeliferous serpentinite. EDS tests of the flat, radiating crystal groups by the author using a light-element detector showed major peaks for Na, Al, Cr, O and C with minor Ca or no Ca. The sodium and calcium peaks varied from crystal to crystal, with no specific area either sodium-free or calcium-free. Several of the spheroids recovered from thin seams gave major Ca, Al, Cr, C and O with minor Na. A subsequent X-ray powder-diffraction pattern by A. C. Roberts of the Geological Survey of Canada proved this dark pink material to be a mixture of alumohydrocalcite and dawsonite, which would account for the variable Ca and Na peaks. Based on the Al/Cr peak integral ratio range (1.95:1 to 4.78:1), both minerals were identified as the chromian varieties, where Cr<Al. Megascopically, these carbonate minerals are very difficult to distinguish from each other except by X-ray powder-diffraction and EDS, since they both possess a radiating habit. When chromian dawsonite is observed as isolated radiating crystal groups, it can be distinguished from the more massive chromian alumohydrocalcite. However, when both are intimately associated together, there is no apparent macroscopic difference between the two minerals. There was no evidence that one mineral preceded the other during formation, although chromian dawsonite is the predominant mineral along the fractures.

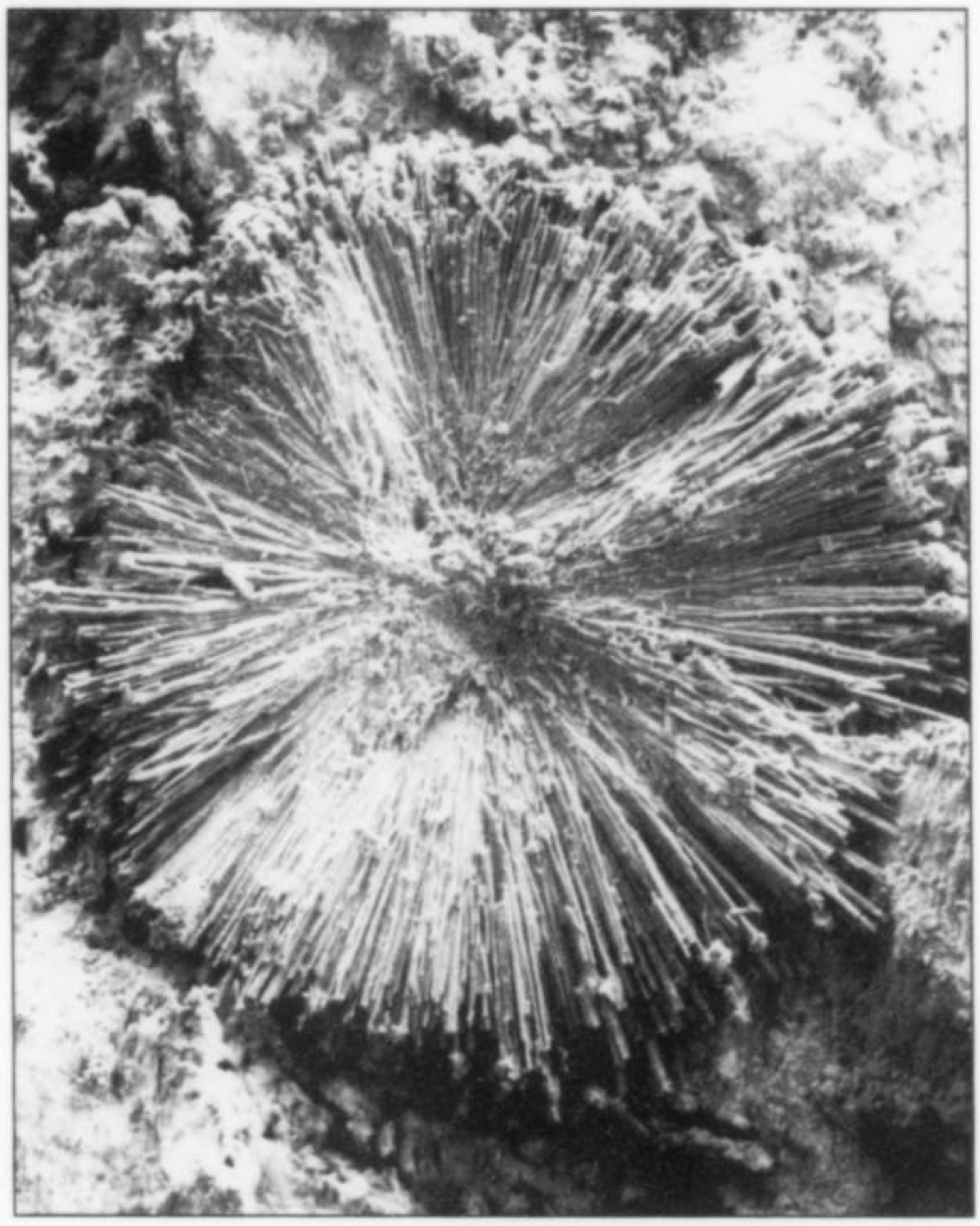

***Figure 1.* SEM photo of chromian dawsonite radiating spherulite, 0.08 mm in diameter. G. Dunning SEM photo and specimen.**

DESCRIPTIONS

Chromian Dawsonite $Na(Al_{1-x}Cr_x)CO_3(OH)_2$ *where x varies from 0.12 to 0.29 (in this study)*

Chromian dawsonite occurs as isolated spherulites in cavities and as flattened spherulitic masses up to 4 mm in diameter along thin cross seams in a tan, hydrothermally altered (silicified) serpentinite containing dolomite, barite, pyrite and magnesiochromite. The dawsonite varies from nearly white to very light pink (lowest chromium) to a dark reddish violet (highest chromium), which reflects the variable chromium content. EDS spot analyses along the long axis of the flat crystal bundles show that the chromium generally increases from the center of the flattened spherulitic masses to the terminations of the crystals. Many of the flat spherulites have a pale green nickel silicate (possibly nimite or pecoraite) coating the radiating crystal surfaces.

EDS analysis of several flat, radiating crystal groups showed major Na, Al, Cr, O and C with minor Ca. The predominance of Na in the octahedral position confirms that it is the chromian variety of dawsonite. Using the accepted formula for dawsonite as a model, the analytical formulas for the two colored varieties of chromian

Table 1. **Comparison of optical data for dawsonite, alumohydrocalcite, and chromian dawsonite.**

Optical Data	*Dawsonite McGill University campus, Montreal (Frueh and Golightly, 1967)*	*Alumohydrocalcite Izumi group, Osaka Prefecture, Japan (Aikawa et al. 1972)*	*Chromian Dawsonite Orestimba Creek, Stanislaus Co., California (This study)*
α	1.462–1.466	1.502	1.474
β	1.537–1.542	1.562	1.564
γ	1.589–1.596	1.585	1.607
2V	≈76°	≈64°	66°

Table 2. **Unit cell data comparison for chromian alumohydrocalcite, chromian dawsonite and dawsonite.**

Unit cell parameters	*Chromian Dawsonite Sana area, Japan (Inaba and Minakawa, 1990)*	*Dawsonite McGill University campus, Montreal (Frueh and Golightly, 1967)*	*Chromian Alumohydrocalcite Akenobe mine, Japan (Roberts and Bonardi, 1983)*	*Chromian Dawsonite Orestimba Creek, Stanislaus Co., California (This study)*
a (Å)	6.768	6.71	6.45	6.69
b (Å)	10.430	10.411	14.31	10.47
c (Å)	5.588	5.58	5.66	5.59

Table 3. **Chemical analysis for chromian dawsonite from Sana area, Mie Prefecture, Japan and Orestimba Creek, Stanislaus County, California.**

Constituent	*Sana area, Mie Pref., Japan (Inaba and Minakawa, 1990)*	*Orestimba Creek, Stanislaus Co., California (light pink)*	*Orestimba Creek, Stanislaus Co., California (dark pink)*
Na_2O	21.72	19.0	19.6
CaO	n/r	2.7	2.1
Al_2O_3	26.65	31.2	25.1
Cr_2O_3	16.13	12.4	18.2
$CO_2 + H_2O$ (by difference)	35.50	34.7	35.0
Total	100.0	100.0	100.0

n/r = not reported

dawsonite are: $Na(Al_{0.88}Cr_{0.12})CO_3(OH)_2$ and $Na(Al_{0.71}Cr_{0.29})$-$CO_3(OH)_2$. Table 3 compares the analysis of light and dark pink chromian dawsonite from Orestimba Creek with that of the Sana area, Mie Prefecture, Japan, which gives a formula of $Na(Al_{0.75}Cr_{0.25})$-$CO_3(OH)_2$. The small Ca values observed in the analysis may be in part admixed chromian alumohydrocalcite or a partial substitution of Ca for Na in the octahedral site. Without a detailed crystal structure analysis, this substitution is problematic.

Frueh and Golightly (1967) report on the crystal structure of dawsonite. It consists of an assemblage of distorted $NaO_4(OH)_2$ octahedra, $AlO_2(OH)_4$ octahedra and CO_3 groups, with some hydrogen bonding. Additional structure work on dawsonite has been reported by Chu *et al.* (1987).

Chromian Alumohydrocalcite $Ca(Al_{2-x}Cr_x)(CO_3)_2(OH)_4 \cdot 3H_2O$
where x = 0.47 (ave) (in this study)

Chromian alumohydrocalcite appears to be much rarer and occurs as subcrystalline masses to small, radiating spheroids composed of minute crystals intimately associated with chromian dawsonite (?). These minerals are found as cavity fillings in a leached vein composed of quartz with minor dolomite, nickeliferous serpentinite and altered grains of magnesiochromite.

These magnesiochromite grains are less than 2 mm in diameter, jet black and occur along the veins and cavities containing the chromian dawsonite and chromian alumohydrocalcite. In some cavities, the magnesiochromite occurs as a soft, sooty black powder, indicating its instability within the chemical environment which formed the carbonates. These grains are considered to have provided the chromium necessary for the formation of the chromian varieties of alumohydrocalcite and dawsonite.

EDS analysis of individual radiating groups of chromian alumohydrocalcite consistently showed low levels of sodium, less than 3% Na_2O. Using the ideal formula for alumohydrocalcite, the average analysis of several small spheroids gives: $Ca(Al_{1.53}Cr_{0.47})$-$(CO_3)_2(OH)_4 \cdot 3H_2O$. Table 4 compares the chemistry of chromian alumohydrocalcite for Mt. Hamilton, the Akenobe mine, Japan, and Orestimba Creek. No attempt has been made to incorporate the small amount of Na into the chromian alumohydrocalcite formula because it has yet to be proven that sodium actually has substituted for calcium in the octahedral site position. This case was also made for the small amount of Ca detected in the chromian dawsonite analysis.

The crystal structure of alumohydrocalcite has not been solved. Roberts and Bonardi (1983) report X-ray crystallographic and microprobe data for a chromian alumohydrocalcite from the Akenobe mine, Hyogo Prefecture, Japan. It was found to be triclinic $P1$ or $P\bar{1}$. Their microprobe results agree closely with the chromian alumohydrocalcite from Mount Hamilton, California, reported by Dunning *et al.* (1975), both of which contain no sodium.

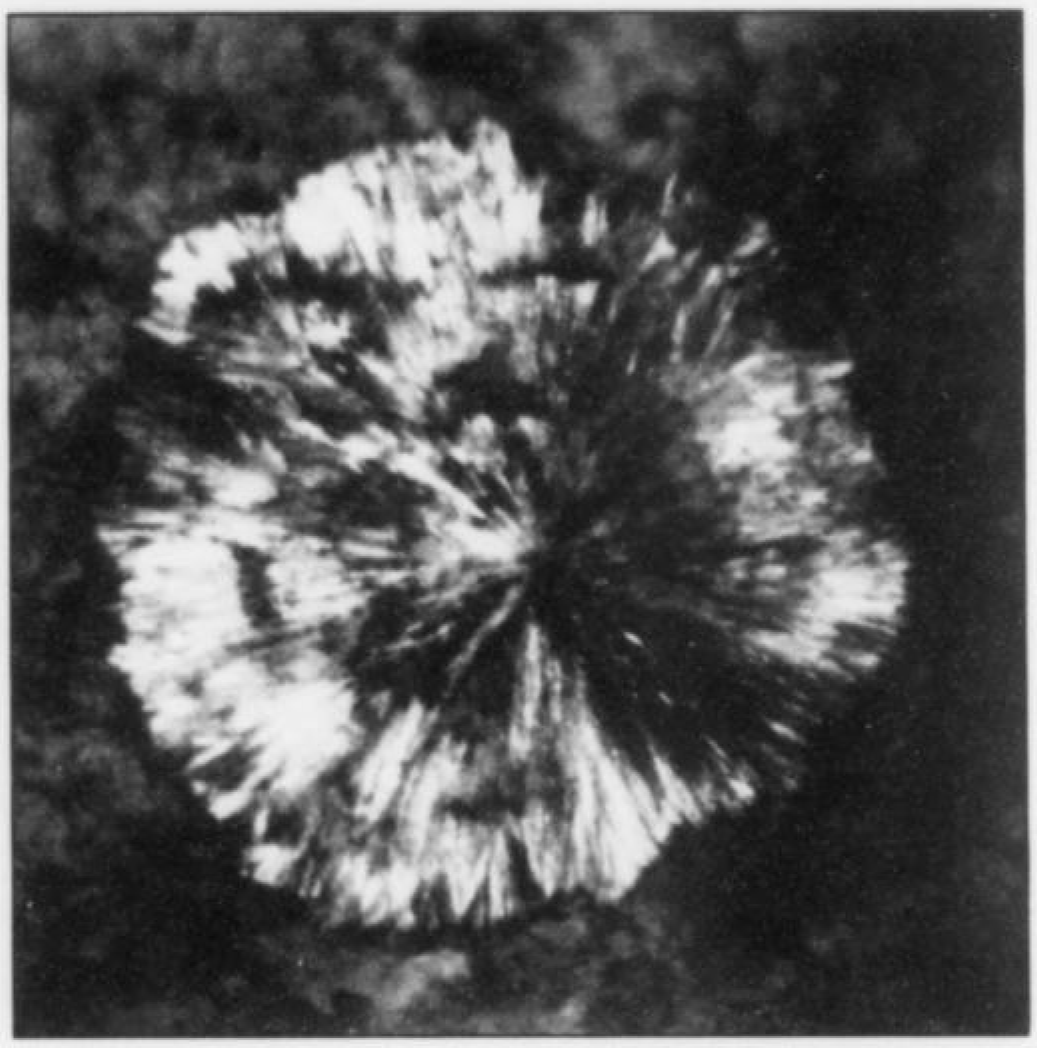

Figure 2. **Single spherulite of pale pink chromian dawsonite, 2.4 mm in diameter, with green nickel silicate coating. G. Dunning specimen; T. Hadley photo.**

Figure 3. **Group of pale pink chromian dawsonite spherulites with green nickel silicate coating. Field of view 13 mm. G. Dunning specimen; T. Hadley photo.**

Table 4. **Comparison of chronmian alumohydrocalcite chemical data for Mt. Hamilton, California, Akenobe mine, Japan and Orestimba Creek, California.**

Constituent	*Mt. Hamilton, Santa Clara Co., California (Dunning et al., 1975)*	*Akenobe mine, Hyogo Pref., Japan (Roberts and Bonardi, 1983)*	*Orestimba Creek, Stanislaus Co., California (This study)*
Na_2O	n/d	n/r	2.3
CaO	16.5	14.8	14.1
Al_2O_3	22.0	19.3	20.5
Cr_2O_3	8.3	11.2	10.6
CO_2	26.4	n/r	n/r
H_2O	26.6	50.7(1)	52.5(1)
Total	100.0	100.0	100.0

n/d = not detected; n/r = not recorded; (1) CO_2 + H_2O by difference

PARAGENESIS

An examination of the altered rocks containing the chromian varieties of dawsonite and alumohydrocalcite at Orestimba Creek clearly shows that these minerals filled fractures and cavities that developed after the replacement of the serpentinite by silica-carbonate-rich fluids and partial leaching of dolomite and calcite by relatively low-pH fluids (3–5?). This would suggest that these carbonates were of late syngenetic or epigenetic origin and post-dated the earlier-formed dolomite and calcite.

The metagraywacke outcrop was fractured during emplacement of a serpentinite body at depth and then was subjected to hydrothermal alteration at depth which replaced most of the serpentinite with silica-carbonate, mostly quartz and dolomite. Original serpentinite textures remain along the margins of the fracture zone and are rich in nickel silicates.

The tan silica-carbonate was cross-fractured after which low-temperature carbonate-rich fluids containing sodium, calcium, aluminum and chromium migrated along these fractures, depositing both chromian dawsonite and chromian alumohydrocalcite, although not necessarily in that order. The source of the calcium was most likely dolomite or calcite and the sodium from the more acidic margin rocks to the serpentinite body. Albite and other sodium-rich minerals are common in this formation and can be observed where these rocks are exposed. Following the formation of chromium-rich carbonates, residual fluids rich in nickel and silica deposited thin coatings and foliated masses of nickel silicates, which accounts for much of the chromian dawsonite showing a very thin layer of green serpentinite covering the crystal faces.

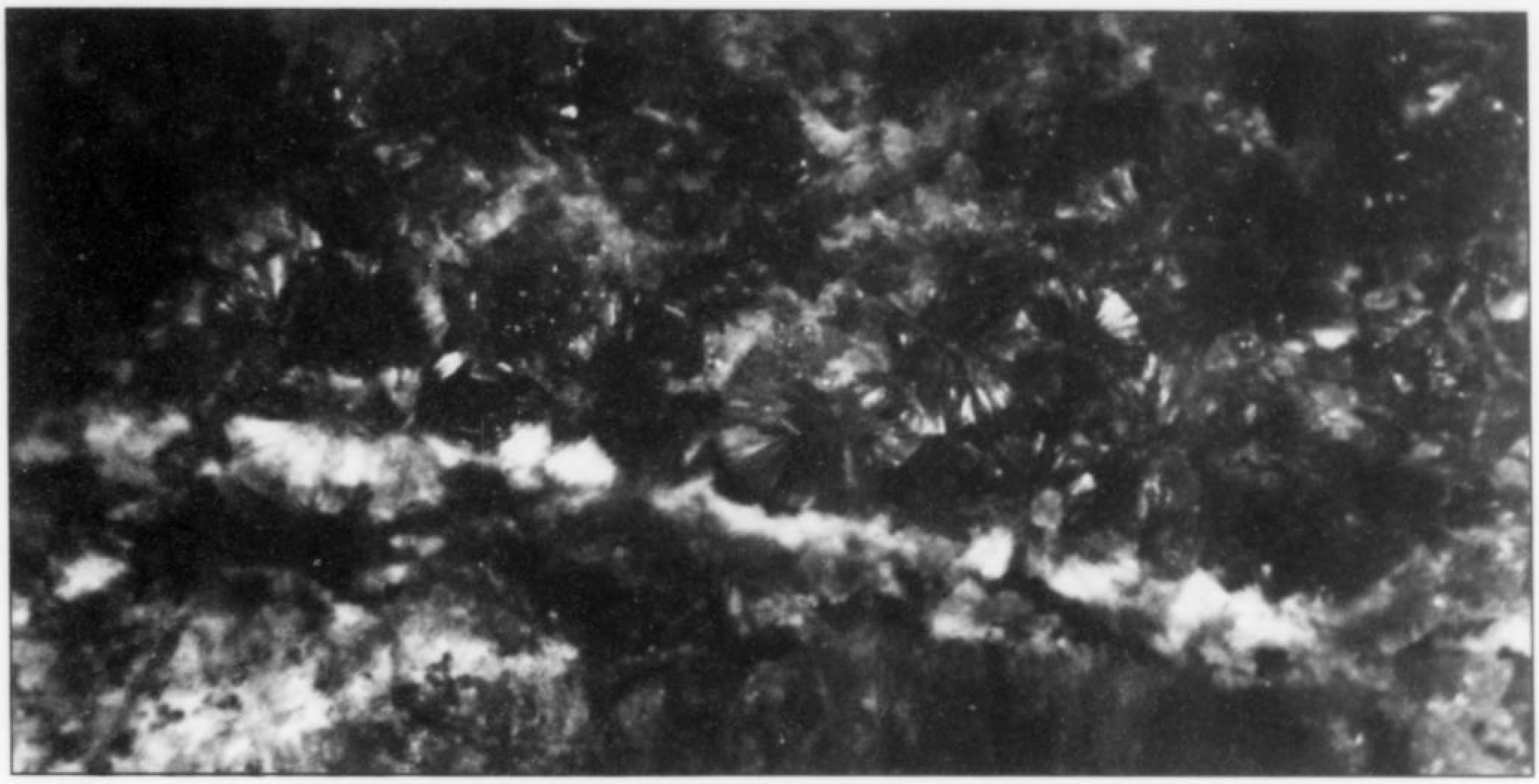

Figure 4. **Dark pink vein composed of chromian alumohydrocalcite and chromian dawsonite in leached silica-carbonate rock. Field of view 10 mm. G. Dunning specimen; T. Hadley photo.**

DISCUSSION

The intimate association of these two carbonate minerals would suggest that their Eh-pH stability conditions overlap. The fluid pH which would precipitate these minerals is a function of the $(CO_3)/(OH)$ ratio (A. Christy, personal communication, 1997). Since both minerals have the same ratio, the fluid conditions were most likely very close. The low level of Na in the chromian alumohydrocalcite analysis may be the result of an intimate mixture of chromian dawsonite or a partial replacement of sodium for calcium in the alumohydrocalcite calcium octahedral site. Likewise, the low level of calcium detected in the chromian dawsonite may be either a fine, intimate mixture of both carbonates or a partial substitution of calcium for sodium in the sodium octahedral site.

When the formation conditions of chromian varieties of dawsonite and alumohydrocalcite from Orestimba Creek are compared to those of the Mt. Hamilton chromian alumohydrocalcite, certain similarities are seen. Both localities show weathered chromite which is black and sooty. The chromian alumohydrocalcite at Mt. Hamilton continues to form at normal ambient temperature in contact with surface water percolating in the friable serpentinite, possibly containing organic acids derived from the heavy organic matter in the area.

The intimate association of dawsonite and alumohydrocalcite together is rare, although both occur separately in many worldwide sedimentary formations. Though there are more than twelve recorded occurrences of dawsonite and alumohydrocalcite in the world (Aikawa *et al.*, 1972; Roberts and Bonardi, 1983), few occurrences of their intimate association are known. Aikawa *et al.* (1972) report both minerals in the lower part of the Izumi group (Upper Cretaceous marine sediments) in southern Osaka, Japan. The association of both minerals at this locality was found not to be synchronous and therefore their paragenesis is in agreement with other occurrences reported in the literature. Goldbery and Loughnan (1977) report the occurrence of dawsonite, alumohydrocalcite, nordstrandite and gorceixite in Permian marine strata of the Sydney Basin, Australia. Here, the assemblages were apparently of late syngenetic or epigenetic development and resulted from two interrelated processes. The first process was a precipitation from solutions rich in sodium, aluminate and carbonate ions while the second was a reaction of these solutions with earlier-formed minerals leading to the development of complete and partial pseudomorphs. Neither of these aforementioned occurrences contains the chromian varieties.

Two other world localities hosting both chromian varieties include the crush zone (black schist) in the Median tectonic line of the Sana area, Mie Prefecture, Japan (Inaba and Minakawa, 1990) and in serpentinite at Tatarazawa, Fujioka, Gunma Prefecture, Japan (Hori *et al.*, 1986). Other single localities for chromian alumohydrocalcite include Poland (Hoehne, 1953), Pakistan (Parr, 1977), Russia (Nefodov, 1953) and Japan (Roberts and Banardi, 1983).

The reported chemical analyses in the literature of dawsonite and alumohydrocalcite show no signigicant interchange of sodium for calcium. However, it would seem possible for some substitution of the alkali atoms in the octahedra of the structures, assuming that the structure of alumohydrocalcite has the same type of octahedra as that of dawsonite. Microprobe analysis of selected X-ray-proven crystal groups of both dawsonite and alumohydrocalcite from Orestimba Creek would prove whether alkali substitution actually occurred or there is a very fine mixture of the two minerals. There is at present no evidence which would suggest that either mineral has been substituted in the alkali octahedral position by sodium or calcium. A detailed structural analysis of alumohydrocalcite would be required to confirm the possibility of sodium substitution in the octahedral structure sites.

ACKNOWLEDGMENTS

I sincerely thank Richard C. Erd for the opportunity to finish the description of this interesting dawsonite-alumohydrocalcite occurrence. I also thank Andrew C. Roberts for providing the X-ray powder-diffraction verification of alumohydrocalcite and dawsonite and Ted Hadley for providing the color photography.

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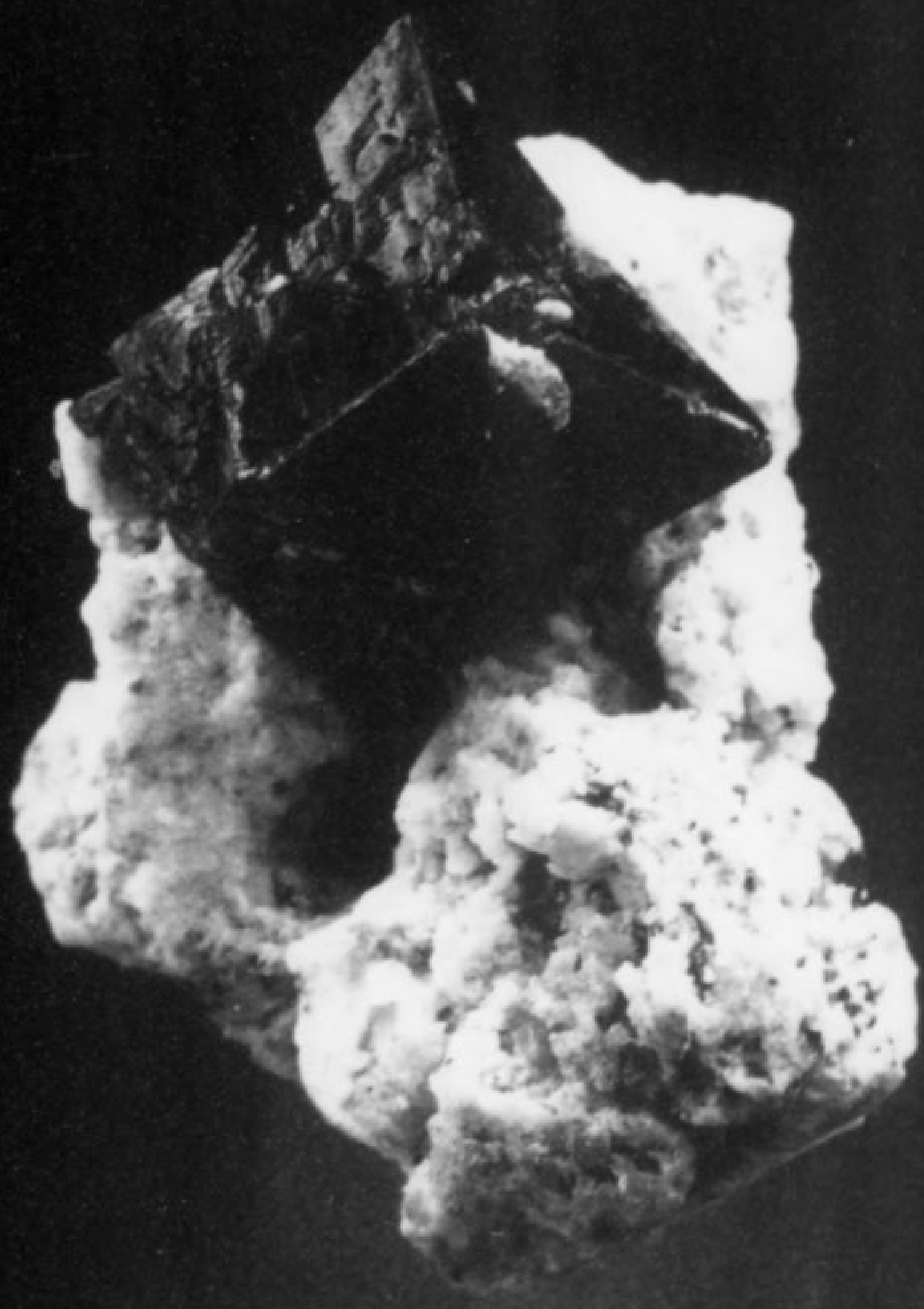
Stuart & Donna Wilensky



Cumengite, 2.4 cm, Amelia mine, Boleo, Mexico
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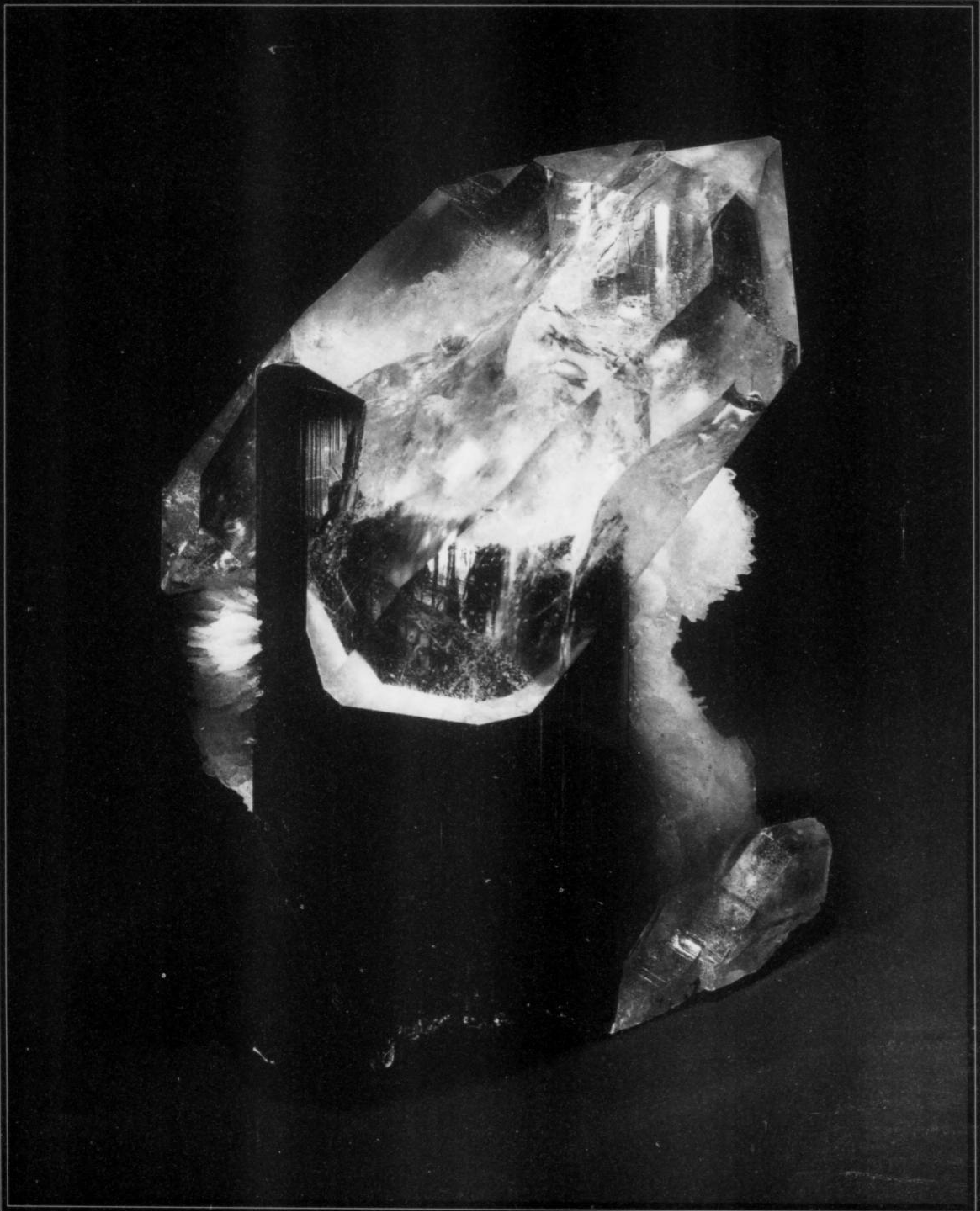

QUARTZ on Schorl with Albite, 4 inches, Shigar, Pakistan. Acquired (by C. & S. Smale) in Peshawar, June 7, 1989, from Bari.

BROOKITE

FROM HALE CREEK, TRINITY COUNTY, CALIFORNIA

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Fine, doubly terminated, deep reddish brown crystals of brookite have been discovered in a chert vein cutting across Hale Creek, Trinity County, California. The crystal habit and forms closely resemble brookite from near Tremadoc, Carnarvon, Wales, and Ellenville, New York.

INTRODUCTION

Brookite, the orthorhombic trimorph of TiO_2, occurs in fine, doubly terminated, deep reddish brown crystals in chert cutting Hale Creek, Trinity County, California. Among the three crystallographic variations of TiO_2, anatase and brookite are the rarest in California. Pemberton (1983) records only one locality for brookite (Kern County) and two for anatase (Lake and San Bernardino Counties), although other unrecorded localities probably exist. Palache *et al*. (1941) record brookite with anatase from El Dorado County, California, which may be the locality near Georgetown.

DISCOVERY

During one of our trips to the Hale Creek mine area in the early 1970's, several small, waterworn chert specimens containing small, bruised, dark-red, elongated crystals were found among the rocks of Hale Creek. To locate the source, we walked up Hale Creek to an area about 300 meters from its junction with the Mad River, where we found a narrow, massive chert zone cutting across the creek. The vein contained visible crystals similar to those discovered in the creek. Also, considerable calcite was seen filling many of the cavities in the chert.

Specimens were cleaned and carefully etched in 50% nitric acid to remove the calcite. This procedure revealed a host of beautiful, doubly terminated dark reddish brown crystals perched on the cavernous surfaces of the chert. Energy dispersive X-ray analysis and crystal morphology proved these crystals to be brookite. Occasionally, doubly terminated, water-clear quartz crystals occur attached to the brookite, in addition to covering the void surfaces within the chert.

DESCRIPTION

The brookite crystals attain a maximum length of 3 mm, and occur either free-standing on the quartz or lying flat. Because the crystals are of such fine quality and sharpness, we wanted to take this opportunity to identify as many of the crystal forms as possible. Using the crystal drawings and forms of brookite illustrated by Palache *et al*. (1941), the following forms were sight-

***Figure 1.* View up Hale Creek at the brookite locality. Gail Dunning photo.**

identified: The axial pinacoids $a\{100\}$, $b\{010\}$ and $c\{001\}$ are all present, with $b\{010\}$ being the most dominant, $c\{001\}$ next, and $a\{100\}$ only rarely visible as a very narrow face. The prism faces $y\{012\}$, $M\{120\}$. $l\{140\}$, $t\{201\}$ and $x\{011\}$ all occur, with $M\{120\}$ being the most dominant. Only rarely are the faces, $e\{111\}$ and $\varepsilon\{324\}$, present. Penetration intergrowths occur on some of the crystal groups, but they are not common. The crystal forms and habit show many of the same characteristics as brookite from Tremadoc, Carnarvon, Wales, and the Ellenville lead mine, Ulster County, New York.

ORIGIN OF BROOKITE

The brookite formed from Ti-containing fluids which penetrated along open channelways in the chert. Silica-rich fluids formed minute quartz crystals both on the chert and to a lesser extent, on the brookite crystals. Following this silica influx, calcite filled much of the remaining voids in the chert host rock.

The area geology and mineralogy of the Hale Creek mine have been summarized by Dunning and Cooper (1987). The rocks exposed at the Hale Creek mine are typical of the Franciscan-Knoxville group of late Jurassic age and consist of sandstones, shales, cherts, greenstones and graywackes. Quartz is common in this diverse assemblage of rocks. Fracturing, related to the greenstone intrusion, provided ideal channelways for ascending hydrothermal fluids rich in both silica and calcium carbonate.

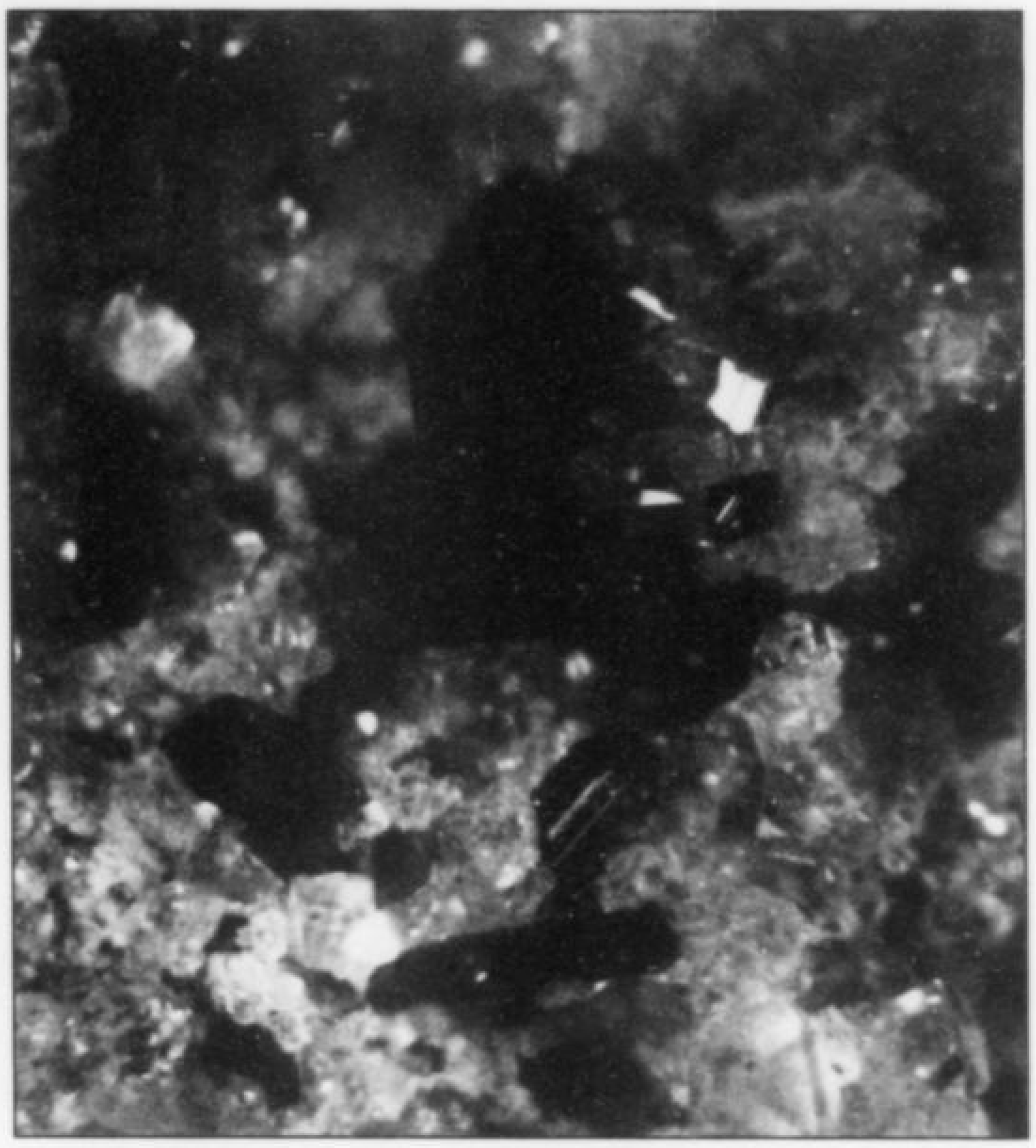

***Figure 2.* Brookite crystal group on quartz; view 5.2 mm. Gail Dunning specimen; Ted Hadley photo.**

LOCALITY STATUS

The area was visited again in 1992 to relocate the chert zone. While walking up the creek, several similar chert specimens were recovered from the creek bed. Most did not show any evidence of brookite. The trail of chert was traced for about 20 meters, at which point it ended. It was quite evident that the course of the creek had changed dramatically. The chert zone was no longer visible in the creek bed and no sign of it was found after digging along the creek banks. Heavy rain in the area during the years had caused

Figure 3. **Brookite crystal, 1 mm, on quartz. Gail Dunning specimen; Ted Hadley photo.**

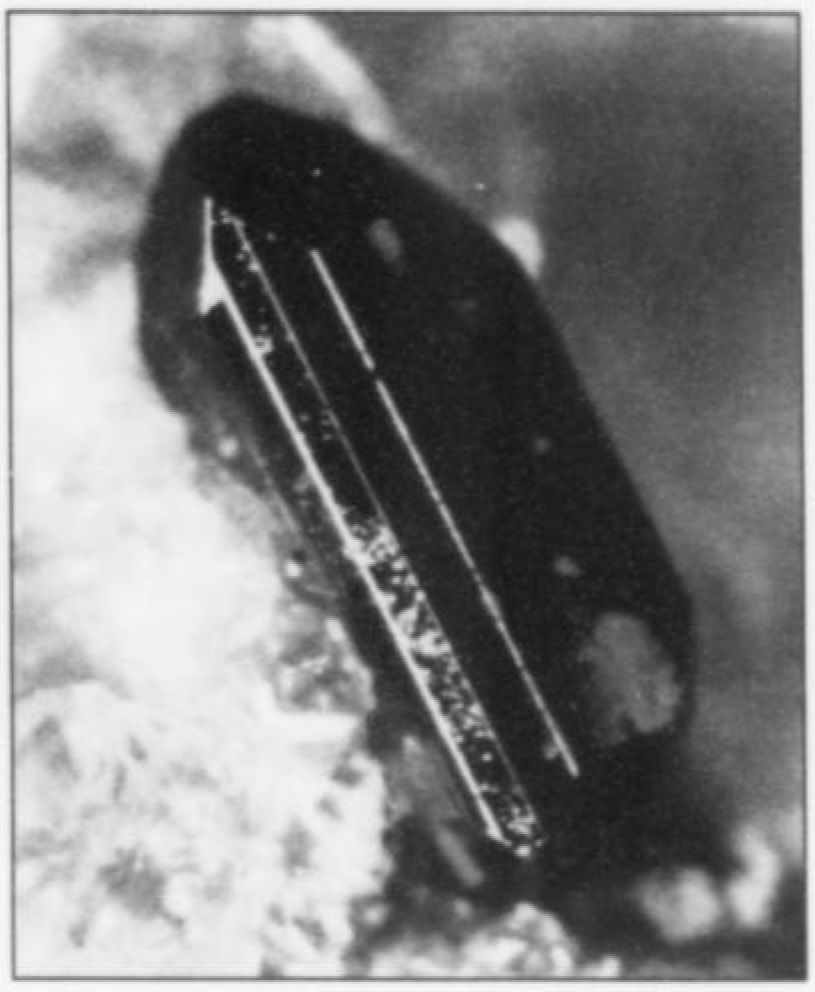

Figure 4. **Brookite crystal, 5 mm, on quartz. Gail Dunning specimen; Ted Hadley photo.**

Figure 5. **Brookite crystal, 1.5 mm, on quartz. Gail Dunning specimen; Ted Hadley photo.**

Figure 6. **Brookite crystal, 1.2 mm, on quartz. Gail Dunning specimen; William Wise photo.**

considerable shifting of the original creek. It would appear that the creek had moved several meters to the east, leaving the original chert vein covered by at least a meter of overburden. After further searching, no additional chert samples were found in the area.

ACKNOWLEDGMENTS

We sincerely thank William Wise and Ted Hadley for the color photography of the brookite crystals, and the late Dr. Adolf Pabst for optical measurements of the crystals.

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BROOKITE AND ANATASE

FROM NEAR GEORGETOWN
EL DORADO COUNTY
CALIFORNIA

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Brookite, in fine, pale golden brown, tabular crystals with typical hourglass-shaped inclusions, occurs in association with deep blue, euhedral, bipyramidal anatase crystals and several accessory minerals in soil about 6 km from Georgetown, El Dorado County, California.

INTRODUCTION

A well-known locality northeast of Georgetown, El Dorado County, California, where fine quartz crystals exceeding 40 cm in size were mined from the 1930's to the 1980's, has yielded fine crystals of brookite, anatase, ilmenite and clinochlore. This is the first recorded locality in California where these two TiO_2 polymorphs occur together. In fact, both brookite and anatase have only rarely been identified in the state. Palache *et al.* (1941) mention brookite "with anatase upon quartz, near Placerville, El Dorado County, California." They may be referring to this locality as Placerville is the only town of any size nearby. Pemberton (1983) lists both minerals occurring as tiny vesicle fillings in lava and in pegmatites. Rutile, the third TiO_2 polymorph, is not found at Georgetown, but is known from many other California localities, sometimes in large and spectacular crystals.

The Georgetown locality is on National Forest land; access is open and collecting is allowed, though there are many private homes in the immediate area. Finding the exact locality is difficult even for those familiar with the region.

All of the minerals reported here are found in lateritic soils derived from the weathering of shales with intruded quartz veins within Paleozoic undifferentiated rocks in a broad area approximately 6 km northeast of Georgetown, at an elevation of 900 meters. The general geology of the area is recorded by Oliver *et al.* (1985).

COLLECTING AND CLEANING

Collecting at this locality involves several steps. First, the soil is collected in buckets, after removing the larger rocks. Second, the soil is sieved through a 7-mm wire mesh to remove all of the quartz cobbles and organic material. Third, the soil which passed through the first sieve is passed through a 5-mm sieve. Fourth, the material collected by the second sieve is rinsed and dried and examined carefully for loose crystals. It is important that all of the sieving be done with large amounts of water to reduce the crystal breakage. Also, be forewarned that the soil is so rich in finely divided iron oxides that it will permanently stain all clothing, tools and work areas a dark rust-orange. Finally, all recovered crystals must be cleaned in an ultrasonic cleaner.

MINERALS

Anatase TiO_2

Georgetown anatase commonly forms euhedral, doubly terminated crystals with the forms *p*{011} prominent, *q*{111} very tiny,

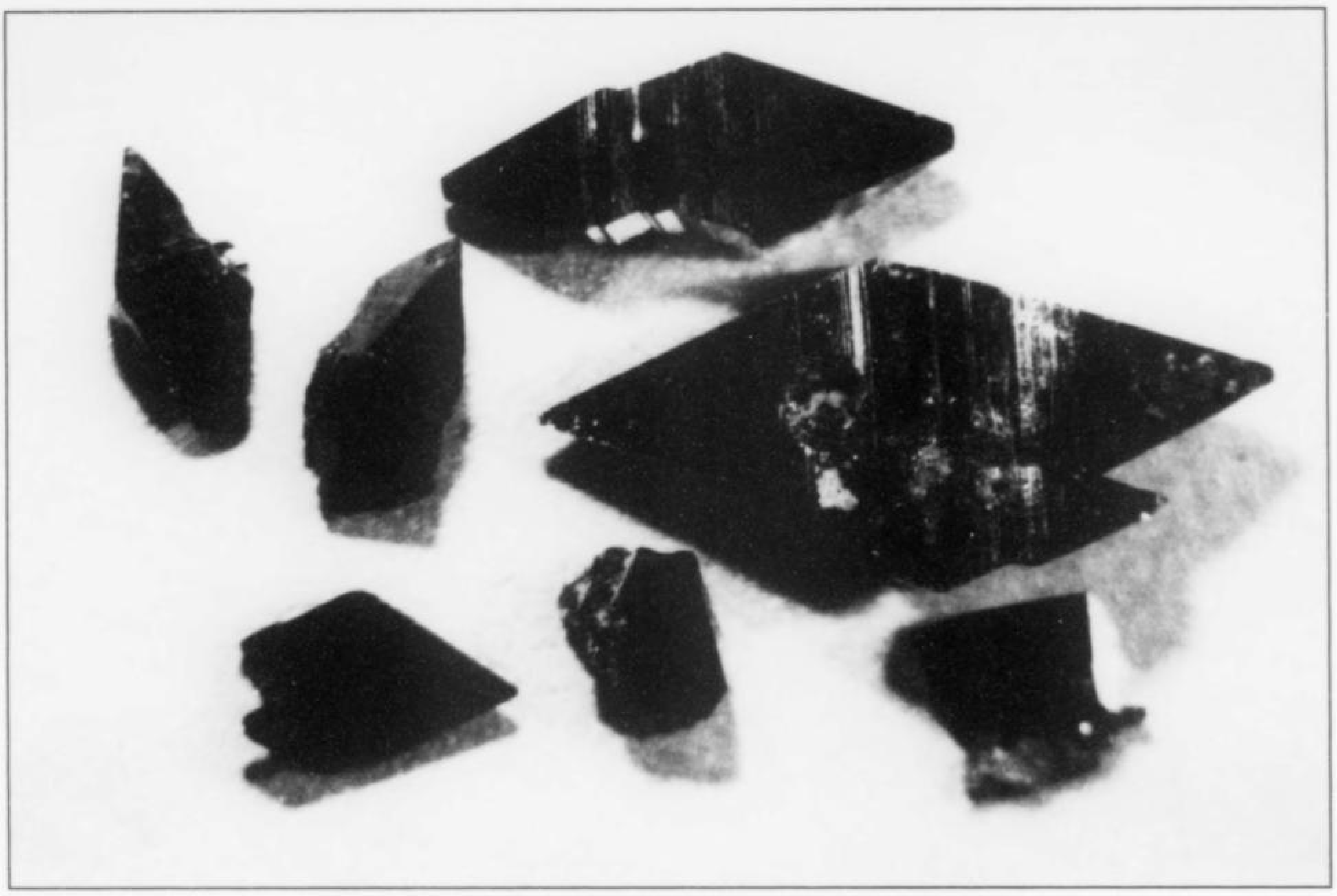


Figure 1. **An assortment of loose anatase crystals up to 6.9 mm.**

Figure 2. **Tabular anatase crystal, 2.3 mm.**

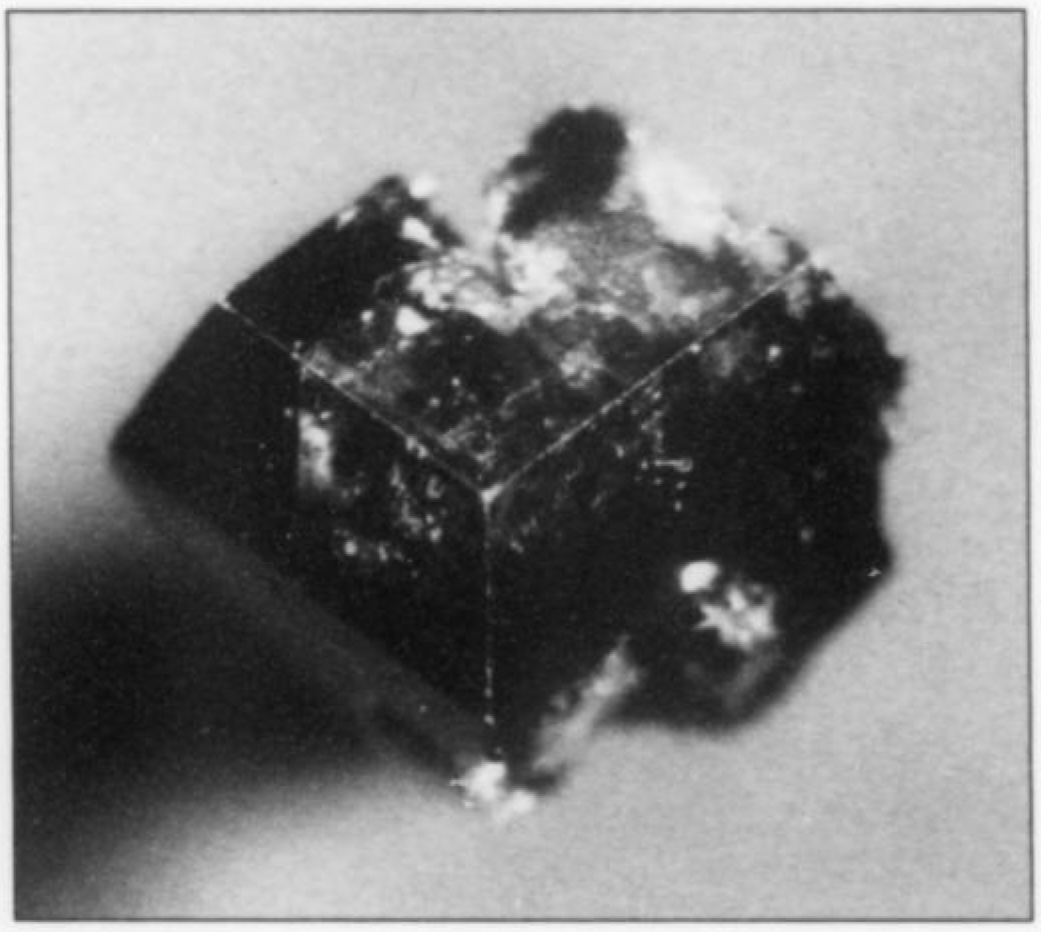


Figure 3. **Sceptered anatase crystal, 4.1 mm.**

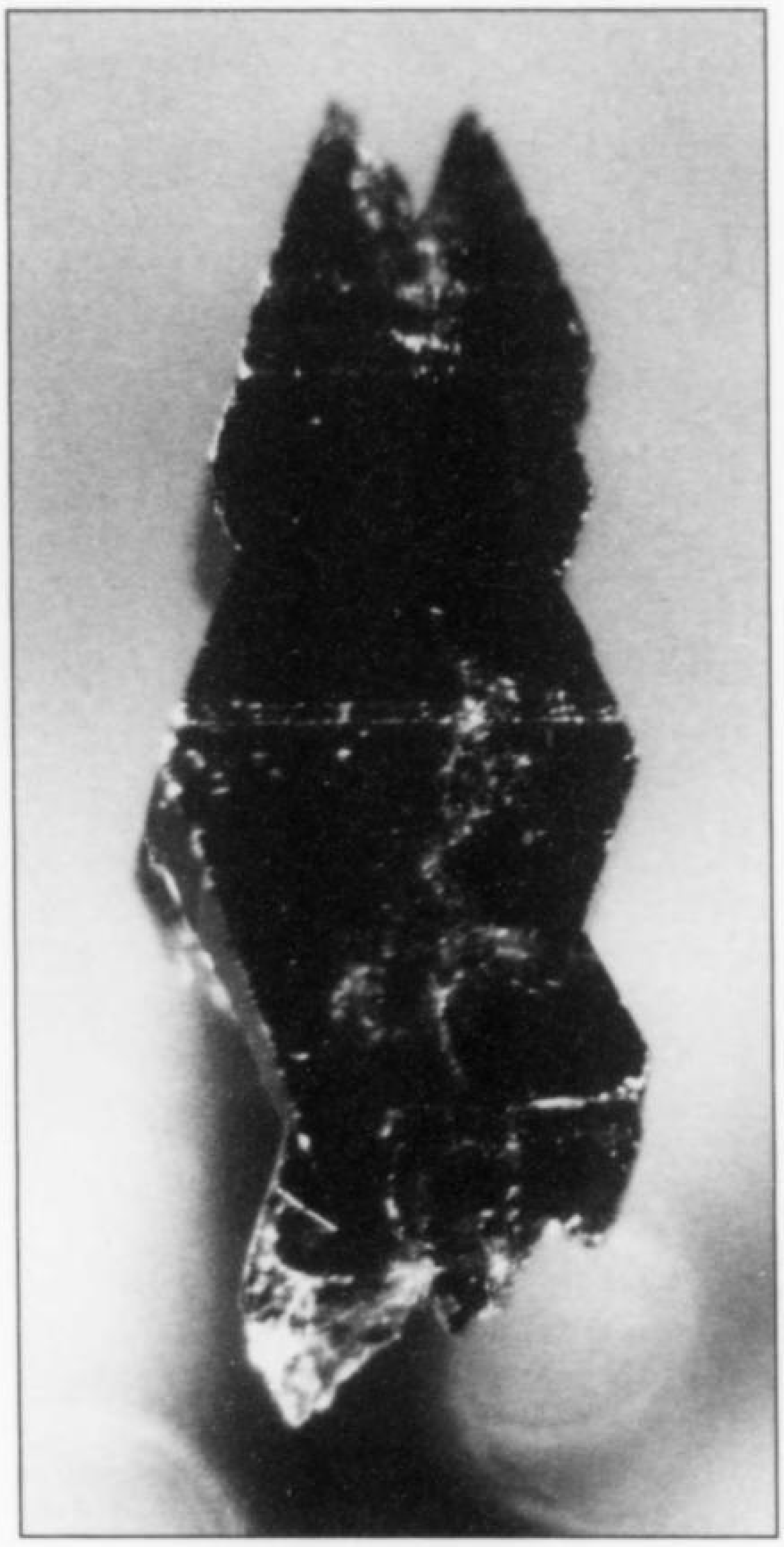
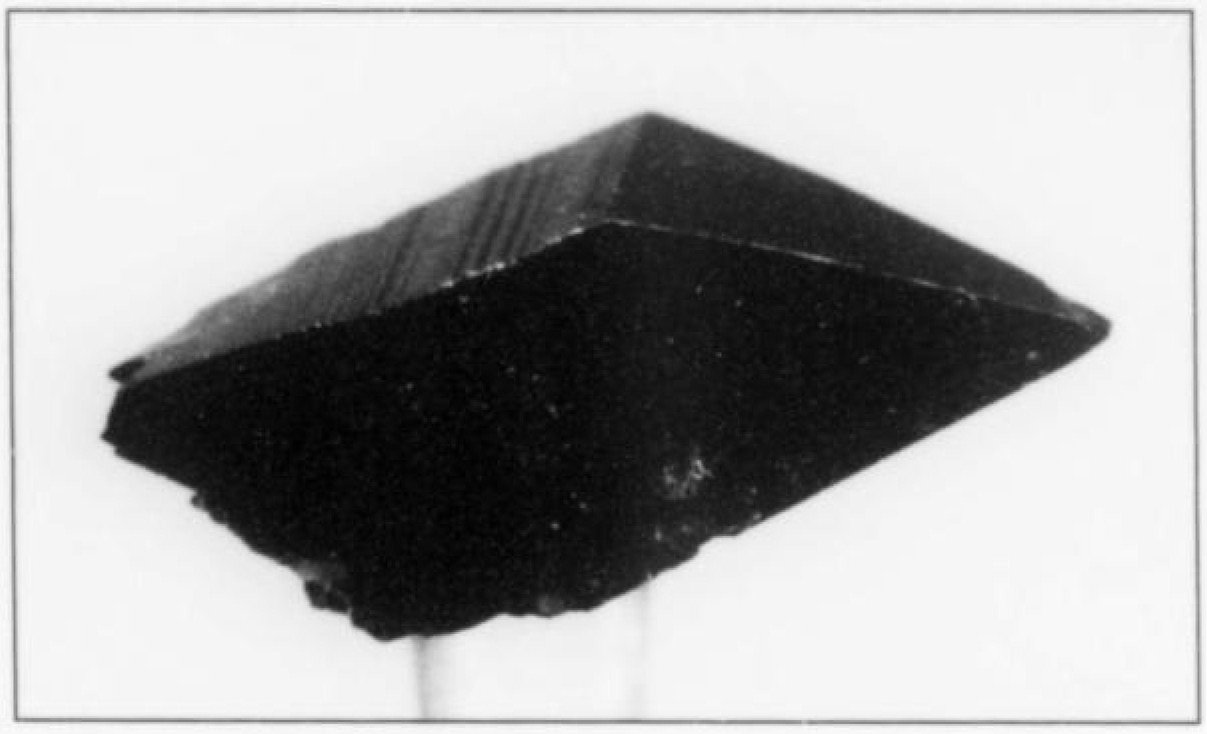


Figure 4. **Anatase crystal, 6.4 mm.**



a{010} as striations, and occasionally form *c*{001}. The crystals are a translucent deep blue color, ranging to black in some of the larger specimens. The maximum size is over 1 cm, but the majority of the crystals are only about 3 mm long. Most of the anatase crystals are very smooth and lustrous, but a few once had clinochlore inclusions which have been weathered out of the anatase, leaving a deeply pitted surface with channels throughout individual crystals. Anatase crystals attached to quartz are present, though uncommon, and are quite unattractive.

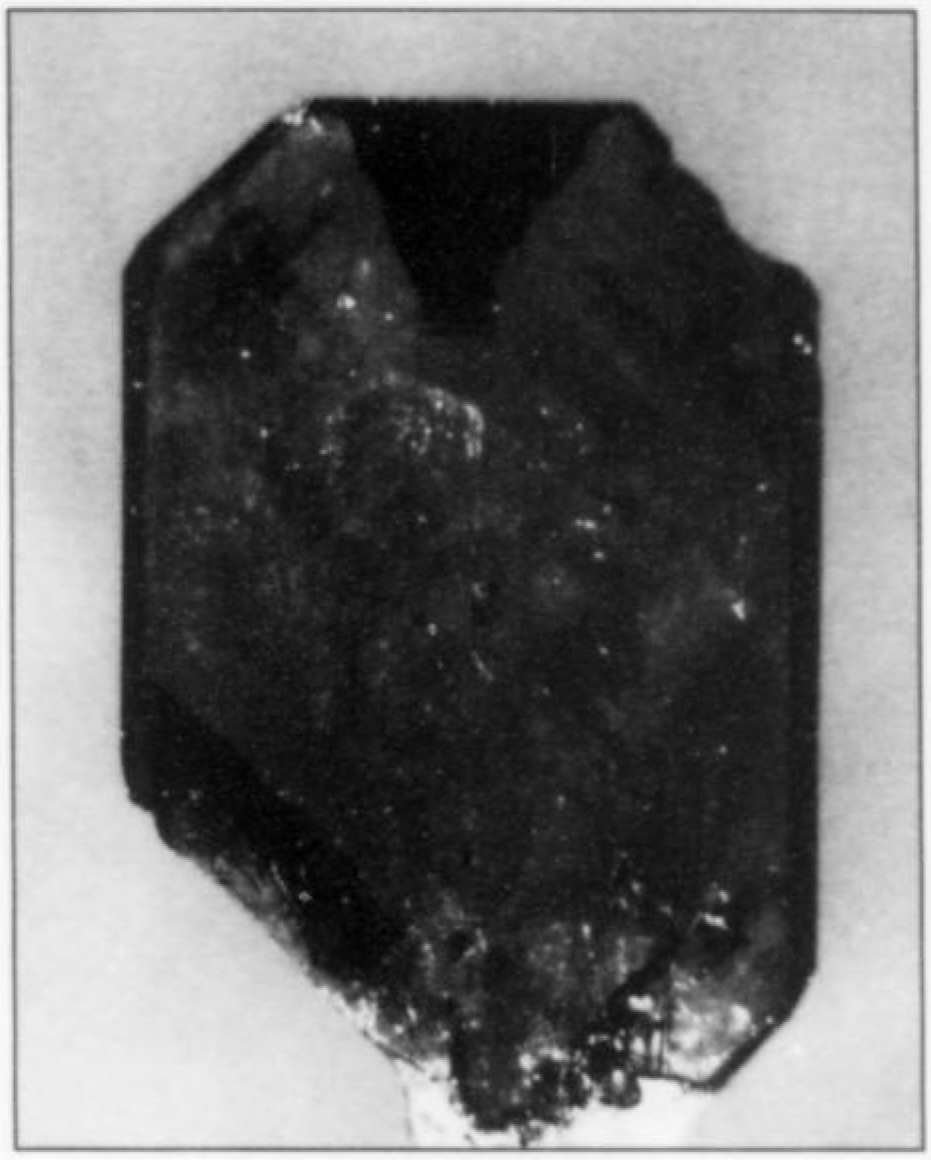


Figure 5. **Brookite crystal, 4.5 mm.**

Figure 6. **Brookite crystal, 4.7 mm.**

Brookite TiO_2

Georgetown brookite crystals always show a broken point of attachment, presumably from quartz. All of the crystals are tabular on *b*{010} and elongated along *c*{001}. Other forms present include *a*{100}, *y*{012}, *M*{120}, *l*{140}, *t*{201}, *d*{403} and *e*{111}. The crystals are a transparent, pale golden brown with an hourglass-shaped deep brown inclusion pattern common to this species. Like the anatase, most crystals are smooth and lustrous, striated on *b*{010} parallel to *a*{100}; rare crystals contain weathered clinochlore inclusions. Crystals up to 2 cm are known, but 8–10 mm crystals are the most common.

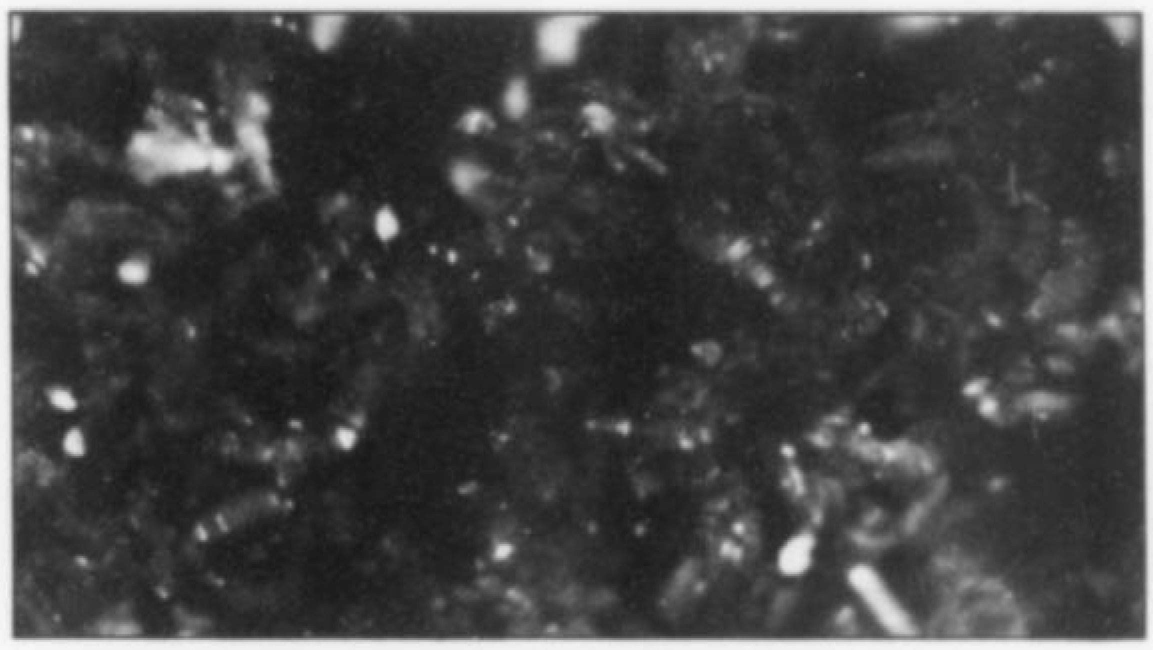


Figure 8. **Weathered clinochlore in quartz; view 6.4 mm. across.**

Figure 7. **Unweathered clinochlore in quartz; view 4.3 mm. across.**

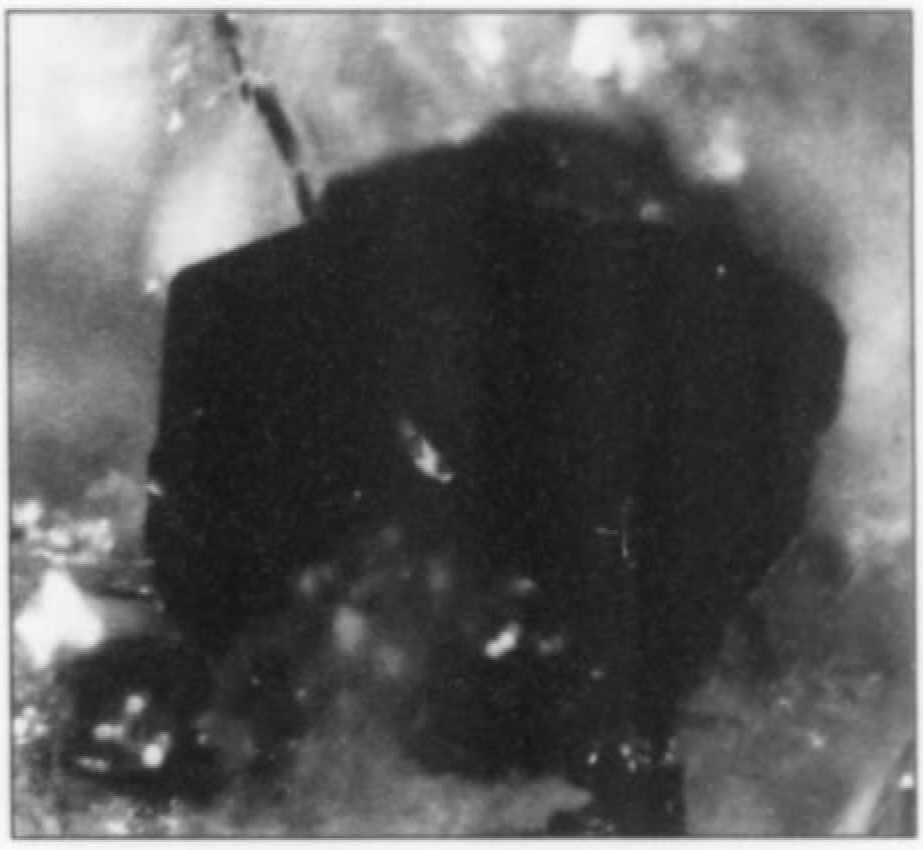


Figure 9. **Ilmenite crystal group, 1.4 mm, in quartz.**

Clinochlore $(Mg,Fe)_5Al(Si_3Al)O_{10}(OH)_8$

Clinochlore at Georgetown occurs as pale green stacked plates of crystals resembling inchworms. All of the material is small, about 0.75 mm in diameter and up to 1 cm long. Only the clinochlore which is completely sealed within quartz crystals is actually intact. Any clinochlore exposed to weathering, e.g., at the surface of a quartz crystal, is completely altered to dark rust-orange, fine-grained, massive iron oxides.

Ilmenite $FeTiO_3$

Ilmenite occurs in two forms: loose broken plates in the soil associated with the anatase and brookite, and as fine, small, totally euhedral inclusions within small transparent quartz crystals. Some specimens of ilmenite are apparently damaged though fully enclosed in quartz, which would seem to indicate a geological fracturing episode sometime late in the formation of the deposit. The identity has been confirmed by EDS analysis.

Quartz SiO_2

Quartz is the mineral which brought the locality to the attention of early mineral collectors. Very large crystals have been mined from the soils in the surrounding areas, and cobbles of milky white quartz up to 10 cm are abundant. Fine transparent crystals are common but are small, usually under 1 cm. Transparent shards of broken crystals are often found which contain attractive ilmenite and clinochlore inclusions. Crystals in excess of 3 cm are rare on the surface, though one example 9 cm long showing 4 levels of phantoms was found in 1991. The phantoms are composed of clinochlore or a similar mineral, based on visual identification. Finally, some small (1–2 cm) quartz crystals show spectacular voids where a previous mineral was coated by the quartz and then leached away, producing a phantom outline. These voids are up to 3 mm across and hexagonal-tabular in aspect. Their form would rule out all minerals known to occur at the locality, with the possible exception of clinochlore.

Table 1. **Paragenetic position of minerals near Georgetown.**

Mineral	*Early*						*Late*
Quartz	——		——		——		———
Clinochlore		——		——		——	——
Ilmenite							——
Anatase							——
Brookite							——

PARAGENESIS

The paragenetic relationships of the minerals were deduced from a megascopic examination of the loose samples within the soils. It should be noted that very few of the mineral specimens found have shown any relational associations because nearly all crystals are found loose in the soils. Only a few specimens are known in which an anatase crystal was found perched upon quartz from this locality. From the appearance of the brookite and anatase, one can see that at the time of formation, they were probably attached to quartz crystals, as points of attachment are common. A four-member quartz phantom containing clinochlore is indicative of multiple episodes of quartz and clinochlore deposition. There was an apparent episode of faulting or fracturing late in the last quartz deposition episode which is shown by the fact that occasional ilmenite plates are broken or chipped though completely enclosed by quartz. Also, because both anatase and brookite are largely unassociated with quartz, it would indicate that they formed late in the mineralization sequence and subsequently broke off during the massive weathering or excavation. No anatase or brookite has been observed fully enclosed within any of the quartz crystals at this locality.

ACKNOWLEDGMENTS

I would like to thank Gail Dunning for his assistance in writing this article and for his EDS analysis of the ilmenite. I would also like to thank J. Fen Cooper for his review of the geology and comments regarding the paragenesis. All illustrations show the author's specimens and photos.

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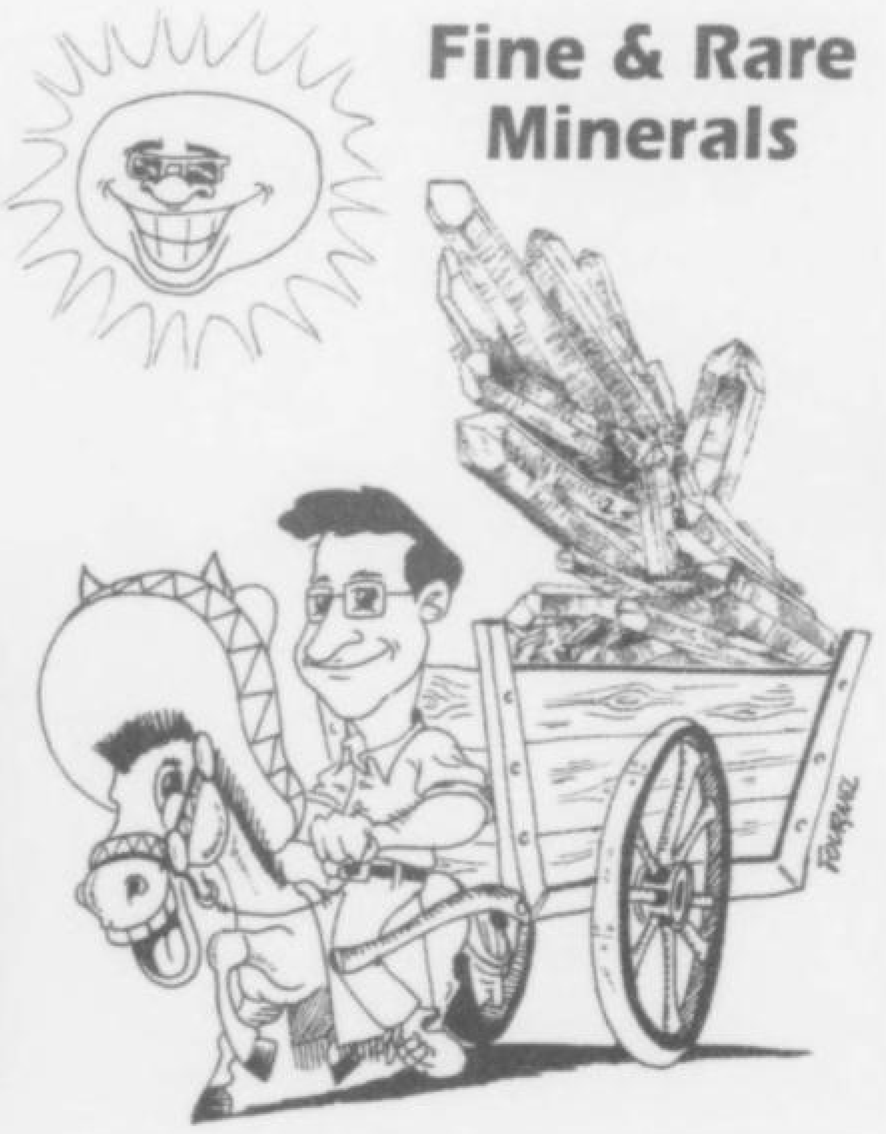

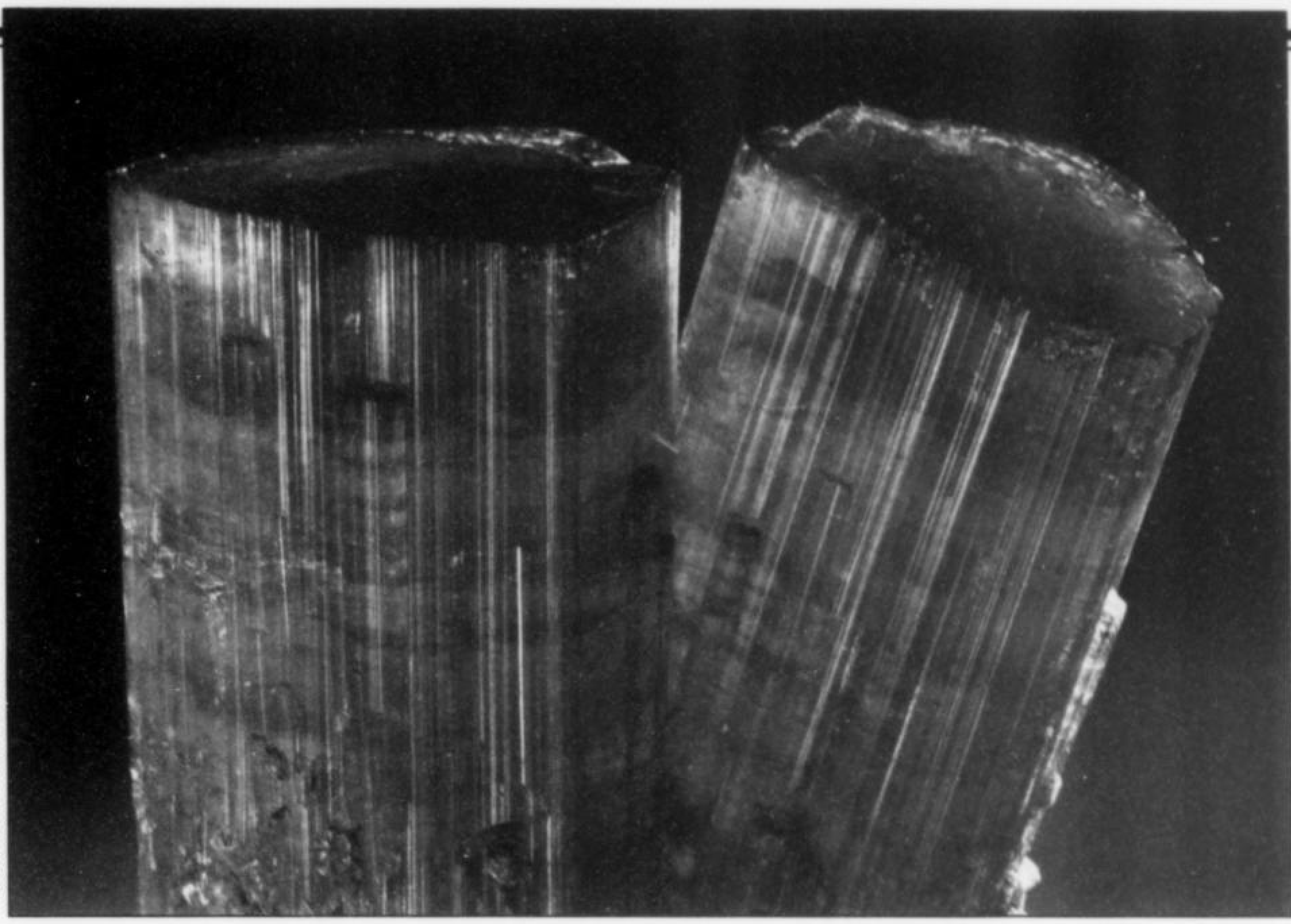

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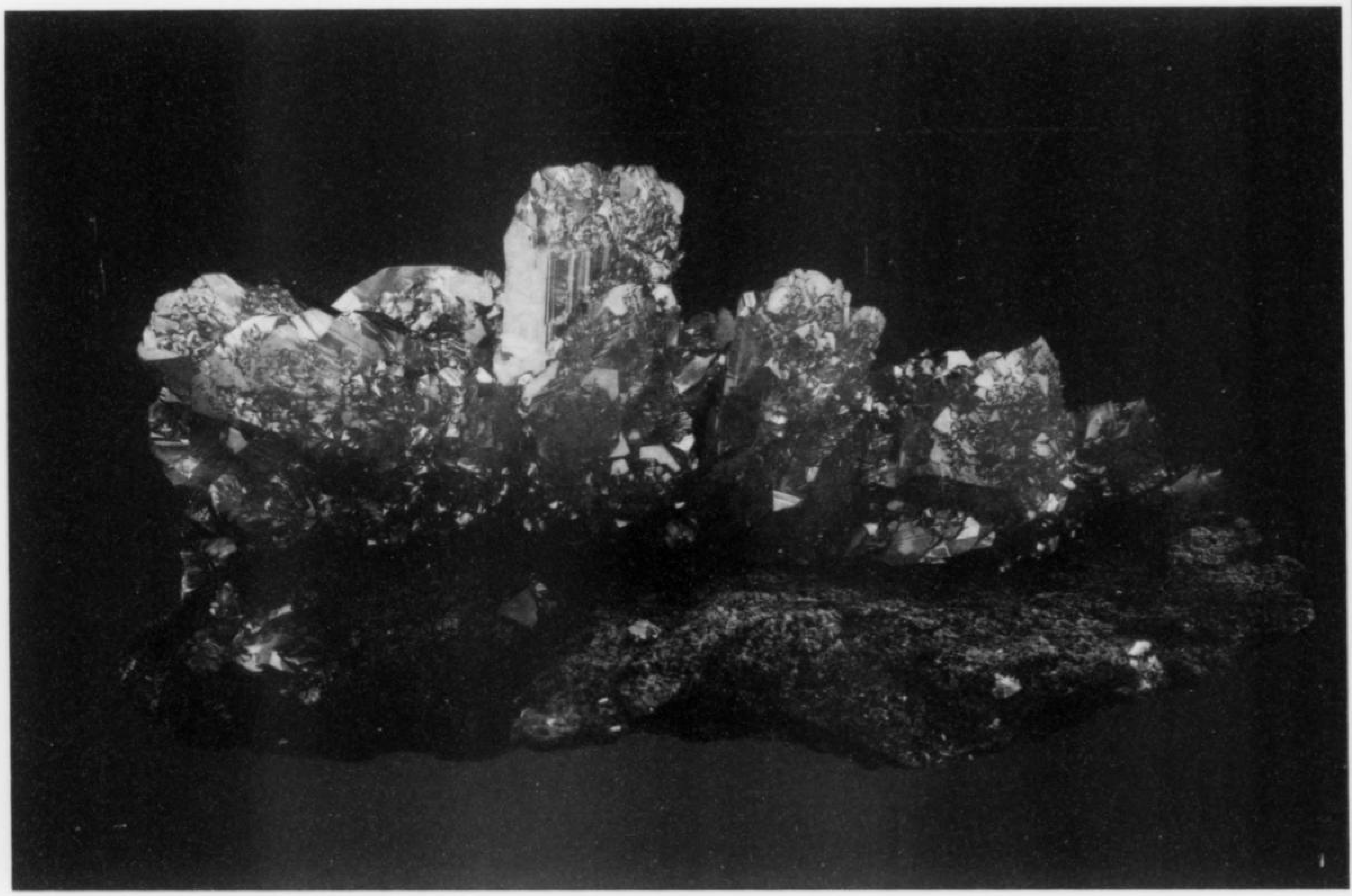

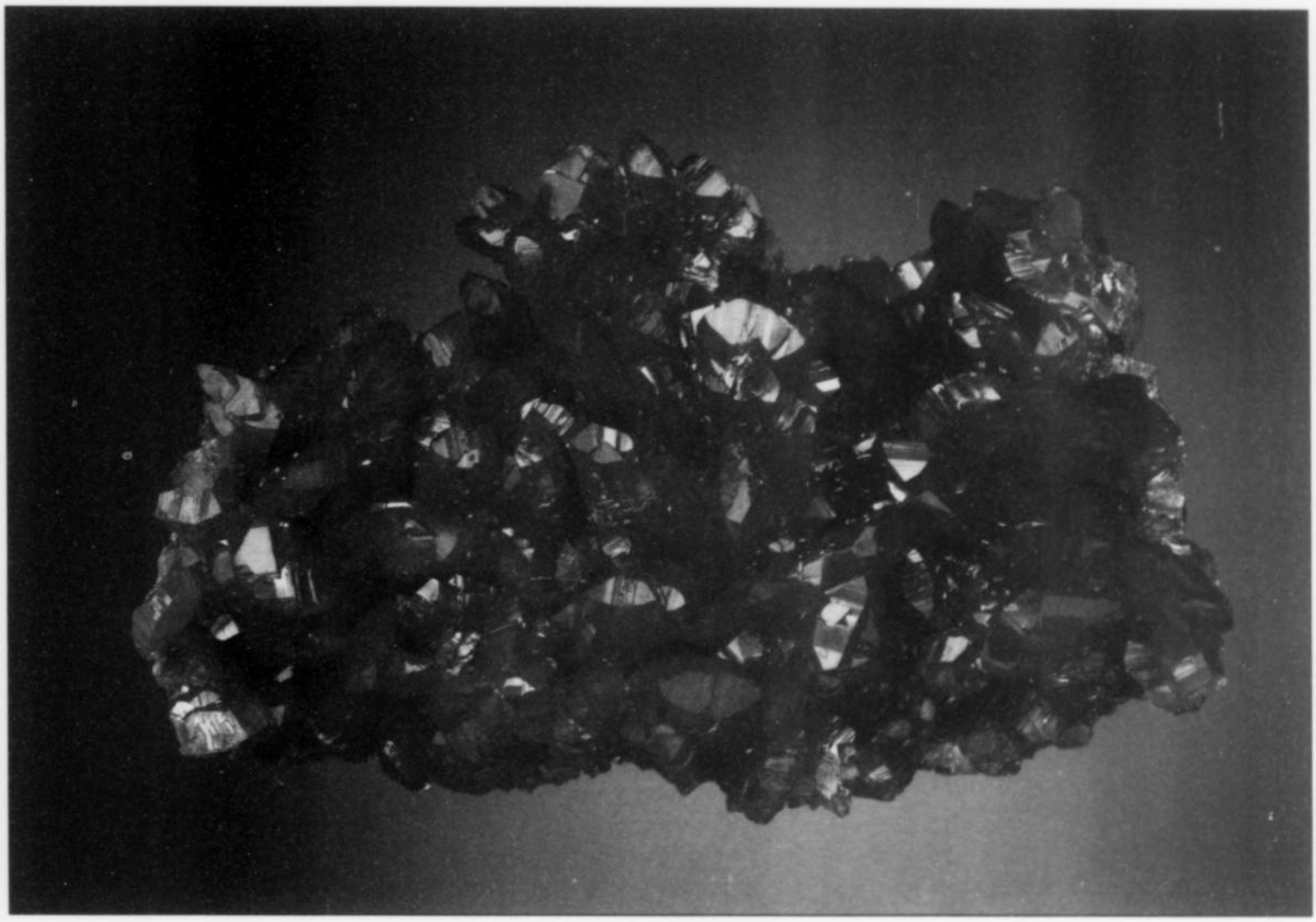

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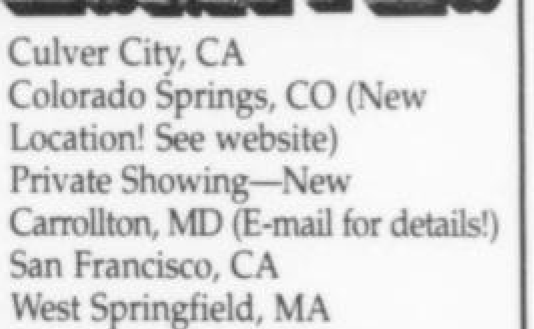

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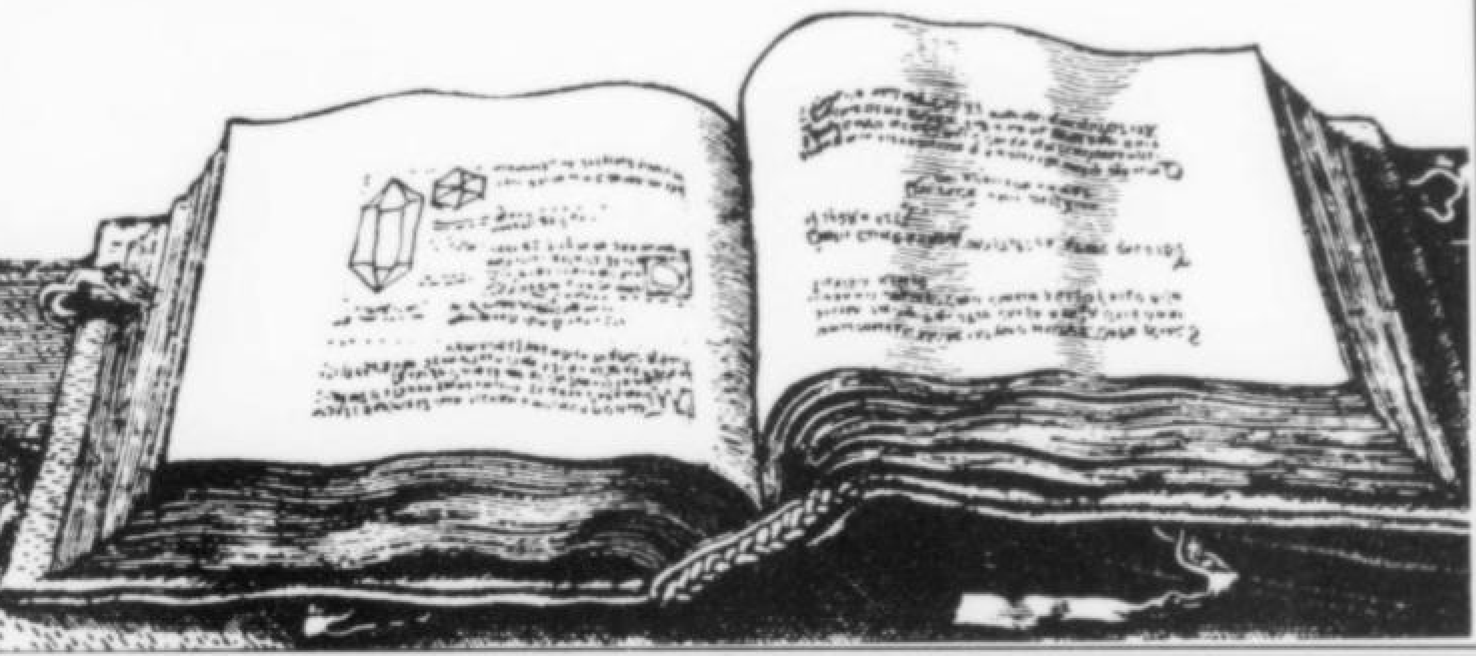
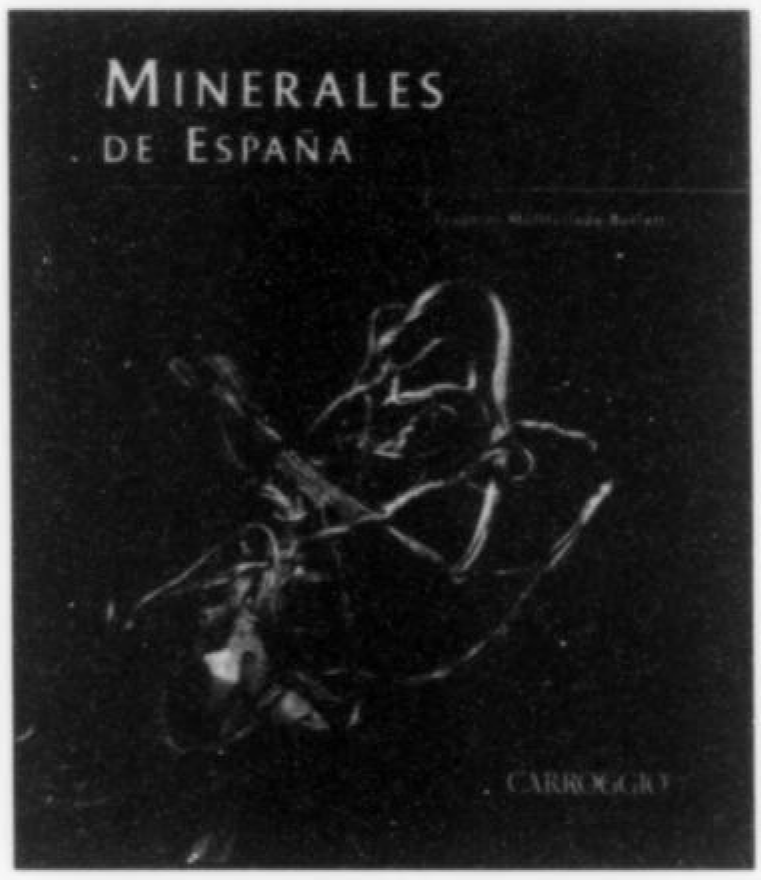




Minerales de España

[Minerals of Spain] by Joaquim Mollfulleda Borrell. Published (1999) by Carroggio S. A. de Ediciones-Barcelona, Softcover, 24.7 x 29.5 cm, 319 pages, ISBN: 847254799-4.

This beautifully produced book is, as far as I know, the first work to compile the minerals of Spain since the scholarly *Los Minerales de España* (1910) by Salvador Calderón. It is printed in large format (about 10 x 11.5 inches) on thick, high-quality matte-finish paper, with a sewn binding. The most striking feature of the book is the more than 500 color photographs, most of which show specimens from Spanish localities taken from some of the most important public and private collections in Spain, especially that of the author. The photographic quality and reproduction are generally very good (with some exceptions), and the specimen quality runs the full gamut from top-level museum quality to broken massive chunks and study specimens.

The book begins with a brief prologue and introduction, followed by an enormously abbreviated three-page review of the "history of mineralogy in Spain" which is so sparse that it might just as well have been eliminated (Calderón is not even mentioned).

The rest of the book is divided (unnecessarily) into two main sections. The first section contains the 471 mineral photos accompanied by brief text on each species, arranged chemically. This text gives only basic data obtainable from any systematic mineralogy book (hardness, color, etc.) without reference to any specific occurrences. The photo captions, it must be said, do cite specific localities for each specimen pictured (along with photographer and owner), but unfortunately never indicate specimen *size*.

The second main section goes through the entire species list again, this time citing only locality lists. There is value here, as the locality lists are updated from Calderón to include many new occurrences not known in 1910. But it should have been combined with the species descriptions, as is usually done in topographical mineralogies.

A useful six-page review of Spanish mineral museums is also included, as well as a one-page general bibliography. Regrettably there is no alphabetical species index, which would have been particularly useful with the species texts split between two non-alphabetical sections.

This is an enjoyable coffee-table book for the collector, and is certainly worth having. However, for the serious student it has two important failings. Firstly, it makes no connection whatever between physical characteristics (habits, colors, crystal sizes) and specific localities. This, it seems to me, should be one of the principal duties of any topographical mineralogy. Secondly, it is entirely unreferenced and therefore lacks scholarly value; there is no way to confirm the data by rechecking the source literature, and no way to know which data are original contributions based on the author's own observations. Calderón remains unchallenged on those points. Nevertheless, such a huge body of specimen photographs conveys much data by itself, and is more than sufficient to recommend this book.

Wendell E. Wilson

Bibliografía Fundamental de la Antigua Mineralogía y Mineria Españolas

[Fundamental Bibliography of Antiquarian Works on the Mines and Minerals of Spain] by Miguel Calvo Rebollar. Published (1999) by the Asociación de Libreros de Viejo, Madrid, Spain, in an edition of 2000 numbered copies commemorating the 11th Madrid Antiquarian Book Fair, October 1–17, 1999. Softcover, 16.5 x 23.2 cm, 259 pages.

Here is an excellent bibliographical review of antiquarian literature dealing with the mines and minerals of Spain. Mineral book collectors take note: you *must* obtain a copy of this reference work if you wish to have a competent understanding of the literature of Spain.

A brief preface, prologue and introduction are followed by a discussion of the prescientific literature (Spanish editions of Pliny, Dioscorides, Strabo, Theophrastus, Saint Isidor of Seville, Marbode, Albertus Magnus, and, of course, the *Lapidario* of Alfonso X). Then comes an overview chapter on works of the 16th to 18th centuries, beginning with the various *Probierbuchlein*, Biringuccio's *Pirotechnia*, Agricola's *De re metallica* and Perez de Vargas's *De re metallica* (1569). Soon, however, we begin to learn of early works less familiar to the non-Spanish bibliophile: Joan de Arphe de Villafañe's *Quilatador de la plata, oro y piedras* (1572) ["Assayer of silver, gold and stones"], published in Valladolid.

Many works pertaining to early Spanish America are discussed, especially Barba's *Arte de los Metales*, but also books by Fernández de Oviedo, José de Acosta, Hernandez, Antonio de Ulloa, Molina, Gamboa, Fernández del Castillo, José Cavallero, Bernard Muñoz, Martin Saenz and numerous others, concluding with Del Rio's *Elementos de Orictognosia* (1795).

The next chapter, just two pages, deals briefly with "anti-scientific" mineralogy, those works describing the magical or metaphysical powers and properties of minerals. Here we have Gaspar de Morales, *Libro de las virtudes y propiedades maravillosas de las piedras preciosas* (Zaragoza, 1605), based on the medieval lapidaries. Also Jerónimo Cortés' book on "natural magic" utilizing stones: *Fisonoméia y varios secretos de naturaleza* (Valencia, 1594) and several others.

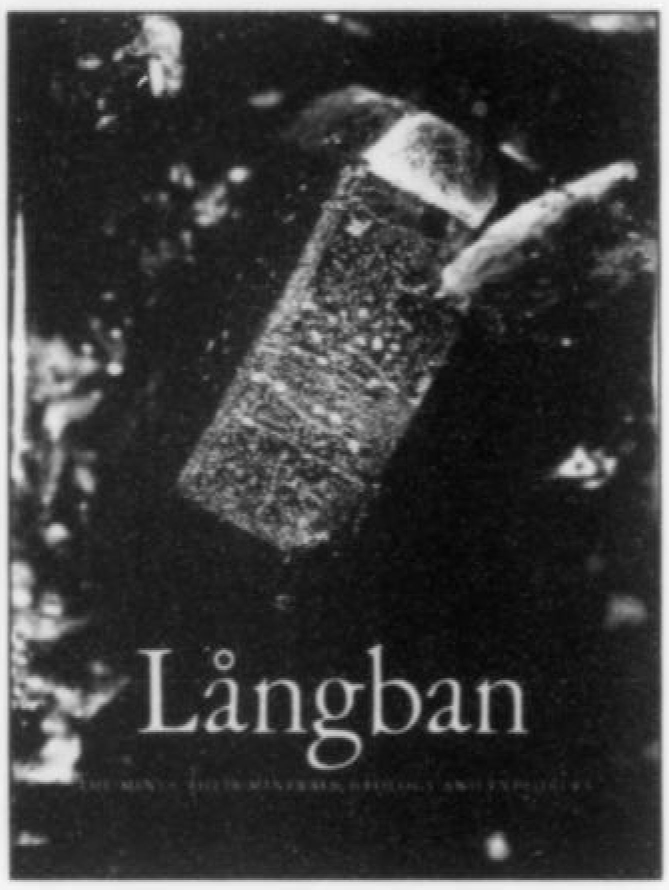
The fourth chapter after the introduction deals generally with "anecdotal mineralogies," that is, travel documentaries and other peripheral works which mention minerals and mines. For example, there is Bernardino Gomez Miedes' *Commentariorum de sale* (Valencia, 1579), dealing with rock salt and giving various interesting details on the Spanish salt mines.

Thereafter follow overview chapters on natural histories and encyclopedias, the 19th-century rebirth of mining in Spain, early geologies of Spain, and the various mineralogies of Spain culminating with Calderón's *Los Minerales de España* (Madrid, 1910).

Finally, the major part of the book (pages 51–243) is a chronological catalog of over 150 of the most important works, each discussed in detail. It begins with Bartholome Yngles's *Tratado de los metales y piedras preciosas: y de sus virtudes* (1495), and ends with Maximino San Miguel de la Cámara's *Estudio de las rocas eruptivas de España* (1936). In between is a wealth of bibliographical data unavailable in any other compilation. Yes, the book is in Spanish, but even without a facility in that language the bibliophile can glean a tremendous amount of data and perspective from this work. There is even an author index.

Unfortunately, this book was not published with the intention of selling it to the general public. Sponsored by booksellers belonging to LIBRIS (a Spanish association of antiquarian booksellers) and also in part by the Madrid School of Mining Engineering, it was intended as a promotional give-away, a gift to university libraries, to visiting professors, to important booksellers' customers and so on. However, the author believes that most of the member booksellers *would* sell a single copy to someone interested. The organization may be contacted at: LIBRIS, P.O. Box 156.336, 28080 Madrid, Spain; internet address: www.libris.es. The price can only be guessed at, but would probably be in the $20 to $40 range.

Wendell E. Wilson



Långban, the Mines, their Minerals, Geology and Explorers

by Dan Holtstam and Jörgen Langhof (editors). Published (1999) by Raster Förlag, Stockholm, and the Swedish Museum of Natural History. Hardcover, 22 x 29 cm, 217 pages, ISBN 91-87214-881, $75 + $7 shipping from the North American distributor: Excalibur Mineral Company, 1000 N. Division St., Peekskill, NY 10566.

Långban, a picturesque lake and village in Värmland, Sweden, is the site of one of the world's great mineralogical occurrences: a two-billion-year-old iron and manganese deposit that has yielded a unique trove of rare species. Mineralogists worldwide have long been fascinated by the extraordinary assemblage of nearly 270 minerals, many of them unique to the deposit, and 67 found there first. For species diversity and geochemical interest Långban is the equal of Franklin, New Jersey, and Tsumeb, Namibia; and it continues to yield new discoveries.

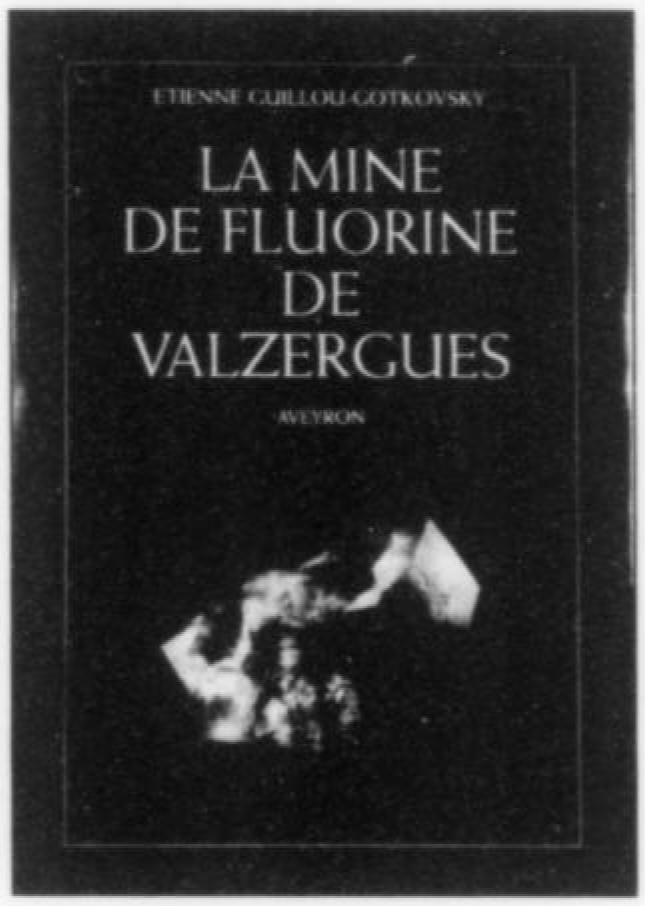
This new book is a welcome and long-overdue addition to the literature of the world's greatest mineral deposits. It is beautifully published on oversize pages of high-quality paper, with a sewn, hardcover binding. More than 200 illustrations are included, 130 of which show mineral specimens in color. The extensive bibliography covers 567 references.

A foreword by Paul B. Moore is followed by a brief introduction, then chapters on geology, ore genesis, mining history, mineralogists and collectors who have focused on Långban, nearly 100 pages devoted to the minerals, and lastly a note about collecting at Långban. All are beautifully illustrated.

The individual mineral descriptions carefully document the physical characteristics of each species in each of its known assemblages and locations at Långban, listing the associated species in each assemblage. Discovery dates, correlations with Flink's list of unknowns, provisional names, dealer sources which in some cases provided original type material, excellent crystal drawings, historical notes, composition, and meticulous literature references are all included. The only aspect which could conceivably be called lacking is analytical tables, but the detailed referencing points the way for readers needing such data.

This is quite simply a gorgeous book, thoroughly professional in its publishing, design, illustrations and scientific content. It is difficult to imagine how it could have been better done. Considering the quality level and the invaluable compilation of diverse mineralogical data, the price is very reasonable. It merits the highest recommendation.

Wendell E. Wilson



La Mine de Fluorine de Valzergues, Aveyron

[The Valzergues Fluorite Mine, Aveyron, France] by Etienne Guillou-Gotkovsky. Published (1999) by the author, 46 Petite Rue Verte, F-78610 Le Perray-en-Yvelines, France. Hardcover, 21 x 29.7 cm, 228 pages, ISBN 2-9514462-0-9, Price: 290 Francs plus 80 Francs postage for "economy airmail." (In French)

The Valzergues fluorite mine is famous among European collectors for its fabulous specimens of bright yellow, gemmy fluorite in large cubic crystals and clusters. Although the mine was worked for 50 years, there has not until now been a thorough documentation of the occurrence. The author has scoured France for rare documents, old photos, research materials and the best specimens in order to create this excellent book, which was clearly a labor of love.

The book is divided into four main sections (1) Geography and Geology, (2) Veins and Mine Workings, (3) History and Production, and (4) Mineralization. Each section is abundantly illustrated in color; locality photos, geologic maps and cross-sections, mine plans, claim maps, underground photography, and especially color mineral photography all add interest to the text. The photos of crystal-lined cavities in place are rare to see. The work concludes with a three-page list of references.

Well published in large format on high-quality paper, this book is a fine contribution to the literature of important localities. It will surely establish Valzergues as one of France's premier fluorite occurrences along with such other famous French occurrences as Fontsante, Beix and Chamonix.

Wendell E. Wilson

La Minéralogie du Dauphiné

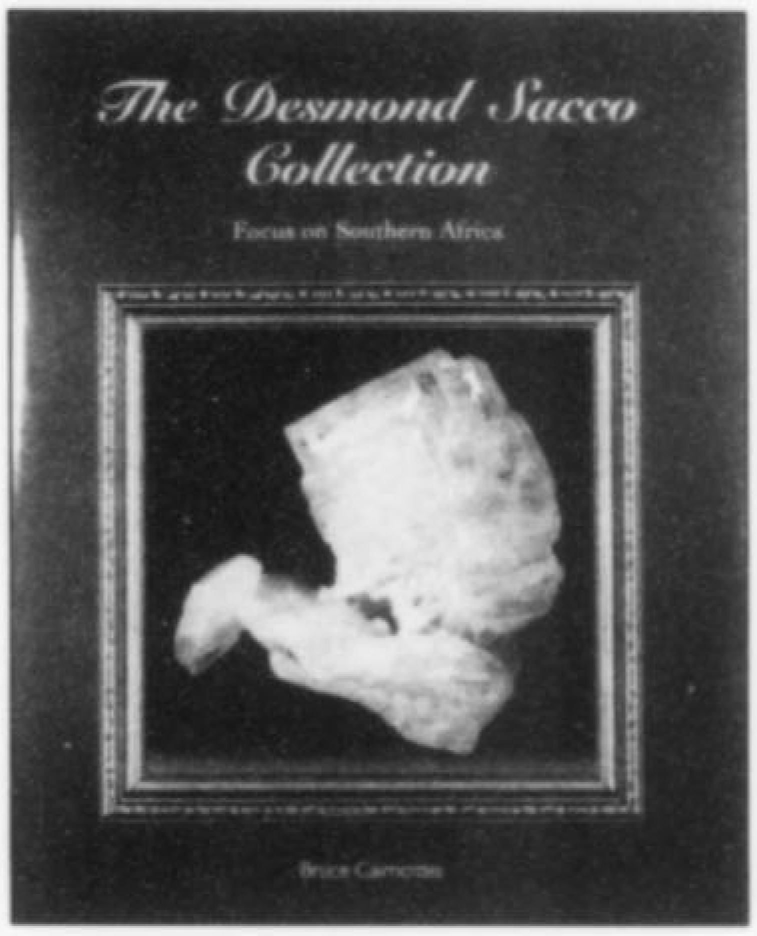
[The Mineralogy of Dauphiné (France)] by Jean-Etienne Guettard, a reprint of the famous 1782 edition. Published (1999) by Les Editions du Piat, 1 bis, rue du Piat, F-43120 Monistrol sur Loire, France, in three versions: (1) the "quality version," 450 Francs, (2) the "luxury version," 900 Francs, and (3) the "prestige version" (sold out). The "luxury version" (50 numbered copies) is characterized by 100% cotton paper. All are hardcover, 255 pages of text plus 20 plates, in large format (21 x 30 cm). (Add 140 Francs for postage.)

Jean-Etienne Guettard (1715–1786) was among the most diligent naturalists of 18th-century Paris. The son of a family of physicians and apothecaries, he studied medicine, chemistry, botany, geology and mineralogy, and accumulated a fine collection of minerals which was ultimately confiscated during the French Revolution and turned over to the School of Mines in Paris. In 1779 he published what is surely among his most famous works, *La Minéralogie du Dauphiné*, which province at the time included parts of present-day Isère, Drôme, Rhône, Vaucluse and Haute-Alpes provinces as well. Guettard gathered information not only on mineralogy but also general geology, paleontology and geography, and on the rocks, fossils and minerals found in certain mines. With its fine engravings of specimens, it is a true classic of French antiquarian mineralogical literature. Guettard himself has been honored by the naming of the mineral *guettardite* in 1967.

The publishers of the French mineral magazine *Le Règne Minéral* have produced this superb facsimile reprint of the folio-size 1782 edition. New front matter prefacing the original text includes a note from the editor (Louis-Dominique Bayle), and biographical notes (in French *and* English!) on Guettard compiled by Laurent Gautron. Following this is a section summarizing the geological history of Dauphiné (again in duplicate text, French and English) by Wolfgang Fisher.

Some knowledge of French is required to understand and utilize the reprinted 18th-century text, but the engraved plates are interesting, and the English-language front matter is gratefully appreciated. A work such as this reprint, costing far less than an original, makes an interesting addition to any library emphasizing topographical mineralogy.

Wendell E. Wilson



The Desmond Sacco Collection; Focus on Southern Africa

by Bruce Cairncross. Published (2000) by Desmond Sacco; available through the author at Dept. of Geology, Rand Afrikaans University, P.O. Box 524, Auckland Park, 2006 Gauteng, Republic of South Africa. Visa/MC fax orders: 011-27-11-489-2309. Hardcover, 25 x 30 cm, 408 pages, edition limited to 1,000 copies; price: US $160 plus US $25 surface postage (airmail rates on request); ISBN 0-620-24340-6.

Desmond Sacco was born and raised in Johannesburg, South Africa, the son of a successful Italian mining engineer who had been responsible in part for the discovery and development of the Kalahari Manganese Field. Having a strong interest in his father's profession, he studied geology and geography at the University of Witwatersrand and was awarded a B.S. degree in 1966; during those years as a student he also began seriously collecting minerals. His work as a field geologist at places such as the Beeshoek mine (Cape Province), mines in Zimbabwe, and various other southern African properties fueled his interest, built his knowledge base, and afforded him plenty of opportunities for field collecting.

Although he still retains a number of superb self-collected specimens in his collection of 3000 pieces, he found that it was also necessary to buy other specimens and other entire collections in order to fill his own with the best minerals southern Africa had to offer. That was his specialty, and he has avoided the temptation to broaden into worldwide collecting.

Perhaps the high point in his field collecting was the discovery of wonderful rhodochrosite specimens at the N'Chwaning I mine in 1978. The property was being mined by his company, Associated Ore and Metal Ltd., so he was called in as soon as the pockets began to be encountered. He spent two weeks there personally collecting hundreds of flats of exquisite specimens, the best of which he has retained for his collection.

Today he is Chairman of Associated Ore and Metal Ltd., and also of Associated Manganese Mines of South Africa. The small apartment where he and his wife once lived in Johannesburg has now been exchanged for a palatial estate in Hyde Park, custom designed to include a special mineral room.

The Sacco Collection is one that most of us will never have the chance to see in person—not because of any lack of hospitality on Desmond's part, but simply because South Africa is so far beyond our normal travel range. Consequently, it is a tremendous good fortune to now have this truly superb book to examine which documents his best specimens in over 600 striking color photographs. The photos are printed on high-quality, semi-gloss paper utilizing a five-color ink process. The excellent photographs are all the work of author Bruce Cairncross, a geologist and mineral collector himself, who is a professor at Rand Afrikaans University and the author of numerous books and articles on southern African geology and mineralogy.

What distinguishes this book above a simple assemblage of color plates is, first of all, the geographic specialization and, secondly, the grouping of the illustrations according to 30 featured localities which are each discussed competently in the text by Cairncross. Each locality section even has its own Selected Bibliography. Thus the book serves as a very educational and massively well-illustrated review of a selection of important southern African mineral occurrences.

The book is deceptively long because the paper is not especially thick; at 408 pages it still bulks to only about 1 inch, excluding covers. But the high weight (2.5 kg or 5½ pounds) lets you know right away that this is a highly concentrated work. Just paging through it to see the illustrations seems to go on and on. Not that we are likely to mind! The "Wow!" factor is very high, and I lost count of the number of specimens that really shook me up. There is *so much* here that few of us have ever seen. Two examples that immediately come to mind: (1) An 8.8-cm slab of blocky, rather gemmy, highly lustrous rhombohedral crystals of bright red color that immediately brings to mind Alma rhodochrosite . . . except that this is a cuprite-included Tsumeb calcite. And (2) a sugilite specimen, a species for which even microcrystals are considered a coup, but this one has gemmy, blocky, lustrous, deep royal purple crystals up to *1.1 cm!* I never suspected such crystals existed.

The localities covered are as follows: ***In Namibia***, the Otavi Mountain Land, Abenab, Berg Aukas, Brandberg, Gamsberg, Karibib-Usakos, Klein Spitzkoppe, Kombat, Krantzberg, Okorusu, Omaue, Onganja, Otjosondu, Rehoboth, Rosh Pinah, Rössing, Tschudi, Tsumeb and Uis. ***In South Africa***, the Chrome mine (Bushveld Complex), the Consolidated Murchison mine, the Kalahari Manganese Field, the Postmasburg Manganese Field, Messina, Okiep, Pafuri, Palabora and the Sheba mine. ***In Mozambique***, Alto Ligonha. ***In the Congo***, Shaba (Katanga) province. And ***in Zimbabwe***, the Miami district.

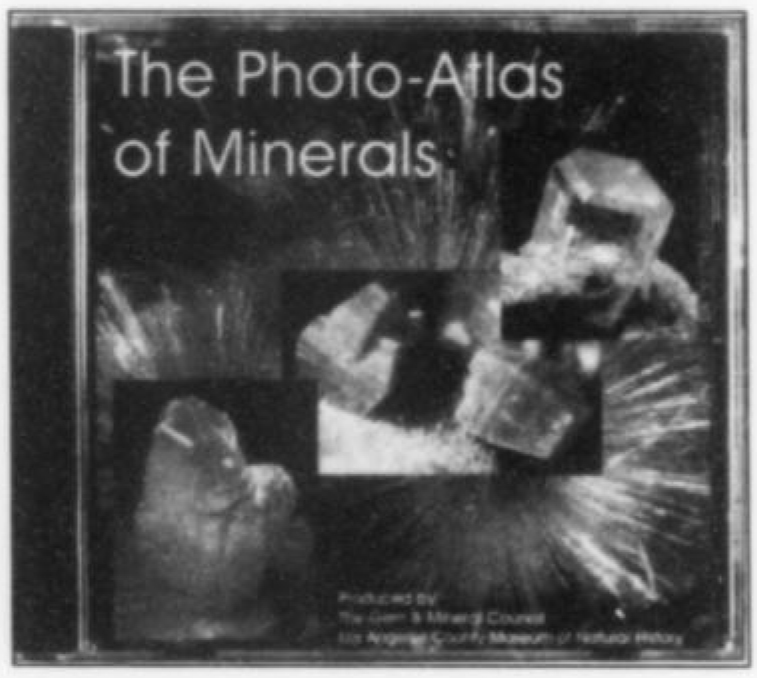
Over half of the color photos are devoted to Tsumeb minerals, making this book an important reference on Tsumeb. Particularly outstanding are a 7-cm triangular leadhillite plate; a superb 5-cm cuproadamite (among many); translucent, pale blue anglesite crystals to over 6 cm; gemmy orange barite crystals; clusters of *green* rhombohedral calcite crystals (colored by dioptase micro-inclusions); red cerussite crystals (colored by cuprite); a 4.9-cm chalcocite crystal cluster; many wonderful mimetites; gemmy scorodite; green, yellow, blue and pink smithsonites to die for; stunning clusters of big, bright yellow wulfenite crystals; and, of course, rafts of fine dioptase, cerussite, azurite, etc. etc.

The specimens from the Kalahari Manganese Field, especially the extensive suites of gorgeous rhodochrosite, yellow ettringite, lustrous hematite and red-pink inesite, also include many jaw-droppers.

It is difficult to find any faults in this book. The brief texts on each locality represent only thumbnail sketches (we might have wanted more), but they are well written and point the way to more comprehensive references. The paper might have been a bit thicker, but it is fairly high quality, and the book already makes quite a dent in your chest as bedtime reading. Another couple of pounds weight from thicker paper might cross the pain threshold. A few of the specimen photos exhibit a color-separation defect called "vignetting," thin black outlines around every bright white highlight. But as a publisher I am sensitive to such things; most photos showing this problem will probably go unnoticed by readers.

This is a wonderful book to have, which will provide much pleasure and interest value to any serious collector, not to mention pangs of envy. It would also make an excellent gift to some lucky recipient. With only 1000 copies printed, I recommend that interested readers act fast to reserve one for themselves. I would also like to thank Desmond Sacco and Bruce Cairncross for producing this book; it is a wonderful service to all of us who cannot travel in person to South Africa, and it is obvious that a tremendous amount of good work went into it.

Wendell E. Wilson



The Photo-Atlas of Minerals

Published on CD (2000) by the Gem and Mineral Council, Los Angeles County Museum of natural History, 900 Exposition Blvd., Los Angeles, CA 90007. Price: $49.95 plus $5 shipping and handling; California orders add 8.25% sales tax. (website: www.nhm.org /~pam) Fax orders: 213-749-4107. Tel: 213-763-3326.

The Photo-Atlas of Minerals is a mineralogical reference for computer users that's been long-awaited and anticipated by this reviewer. Finally, a full-boat mineralogical CD that really exploits the potential offered by personal computer technology in presenting and accessing mineralogical information. The *Photo-Atlas* has been awhile in the making.

During the '98 Tucson show I previewed a beta version that was being demonstrated and sold prior to full implementation of all the features incorporated in the production version that is the subject of this review. I knew after just a quick preview that this CD was going to set new standards for computerized mineralogical references. That's not really all that surprising considering that the CD's credits include Dr. Wendell Wilson, editor of the *Mineralogical Record*, and Lou Perloff, a well-known collector and photographer of microminerals as responsible for the primary photography, with design implementation by Dr. George Gerhold, professor of chemistry at West Washington University, and Dr. Anthony Kampf, curator of mineral sciences at the Los Angeles County Museum of Natural History. The mineral property data was compiled by Lanny Ream, editor of the *Mineral News* newsletter and other publications for collectors and rockhounds.

The *Photo-Atlas* system requirements include a 486-33 or better running Windows 3.1, 95, 98 or NT. I only use real computers, but those of you eccentrics with upscale Macs may be able to run this CD using a PC emulation mode. You will also need a CD-ROM drive, 24-bit graphics and a sound card. They don't call this the ***Photo****-Atlas of Minerals* for nothing, and you just won't be able to really appreciate it without SVGA graphics with a "true color" (24-bit) palette. That requires at least 2 MB of video memory at 640 x 480 video resolution. Up to 4 MB of video memory has become standard fare in new systems these days as typical users employ PCs following the trend to larger monitors, higher video resolutions and enhanced multi-media capabilities.

In the course of reviewing this CD I used it on several different systems, all 133 MHZ and faster Pentiums or Pentium compatibles. For the most part it was evaluated and tested on a 233 MHZ K6 with a 24X CD, 4MB of video memory and a 16-bit Soundblaster compatible sound card.

The *Photo-Atlas* provides descriptive data for all known and recognized minerals, nearly 4000 of them, and more than 6500 accompanying specimen images (including Wendell Wilson's entire personal photo file of images taken from 1970–1998). Not all species are illustrated; in fact the majority are not. Well under half of the known minerals form photogenic crystals, and those species that are typically collected are only several hundred in number. The CD illustrates about 800 species, many represented with multiple images of specimens from various localities, displaying different colors, forms and associations for that species. For instance, vanadinite is illustrated with dozens of different specimen images.

The *Photo-Atlas* also details the origin of mineral names, mineral synonyms and varieties. It provides information on crystal forms, symmetry and twinning, and on mineral localities with index maps, as well as Strunz mineral classification by Dr. Hugo Strunz and Alexander Hoelzel, a hyperlinked glossary of mineral terms, and is cross-indexed for searching. You can copy and print the images and data. The *Photo-Atlas* even incorporates a minerals identification game.

Perhaps the ultimate in bells and whistles on the *Photo-Atlas* CD is the mineral name pronunciator. Assuming your system has a .wav compatible sound card (such as the Soundblaster 16) installed, you can click on a species name, and the *Photo-Atlas* (Forrest Cureton) *says it* for you. Hey, I like it!

The first release edition (1.0) of the *Photo-Atlas* CD sold out. The next revision (1.1) incorporated a number of improvements. The most significant 1.1 enhancements were a much more detailed hierarchical implementation of the Strunz mineral classification system and full implementation of the "Combine Indexes" feature, making it a more powerful database searching tool. No new minerals or images were added to 1.1.

Revision 1.2, incorporating a number of further improvements, is now available. The 1.2 enhancements include: the addition of nearly 150 newly approved minerals; audio pronunciators now available for all minerals; additional data on synonyms/varieties, fracture/tenacity, twinning, and unit cell data for non-illustrated minerals; and indexes for color and streak have been added, along with color and streak data missing for some minerals in earlier versions. Where a mineral property can have a range of values, all possible values are now indexed. The Strunz number for each mineral is now hyperlinked to the hierarchical Strunz "family tree." Several buttons have been added to speed navigation.

I like the *Photo-Atlas* CD so much I bought the company! Hey, just kidding . . . the Los Angeles County Museum of Natural History wasn't for sale. The *Photo-Atlas of Minerals* stands heads and shoulders above any other efforts in this vein to date. If you're interested in a great mineralogical reference on CD, the decision to acquire one of these is a no-brainer. [Ed. note: Version 1.3 just recently became available.]

Bob Keller

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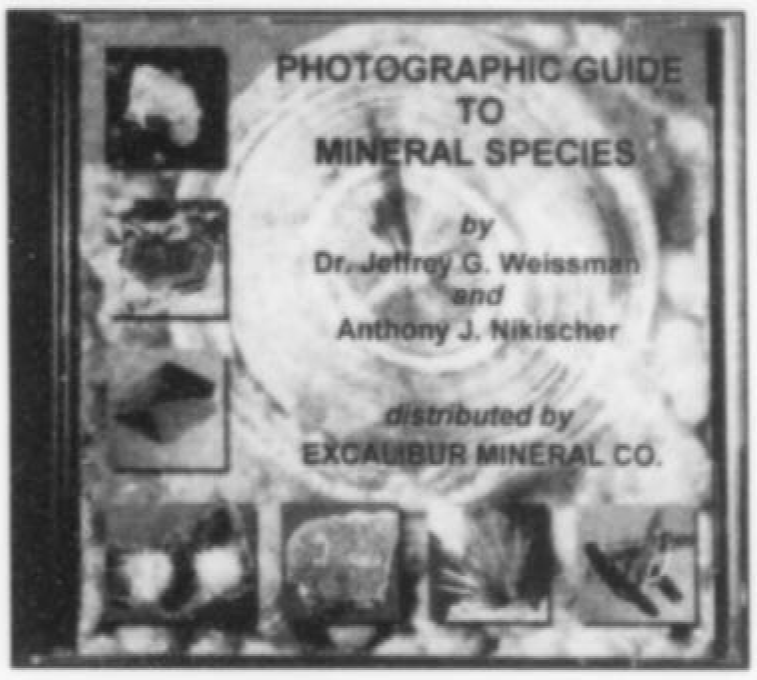

Photographic Guide to Mineral Species

by Jeffrey G. Weissman and Anthony J. Nikischer. Published on CD (1999) by Excalibur Mineral Company, 1000 N. Division Street, Peekskill, NY 10566. [For Windows and Macintosh operating systems; 16 MB memory and 133 Mhz processor recommended; Netscape Communicator included.] Price: $73.95 postpaid.

This photoimage CD is designed primarily with species collectors in mind. Of the 3800 or so valid species, only about 700 have much photogenic appeal; consequently the bulk of the known species are rarely, if ever, illustrated in books and magazines. This paucity of photo documentation is unhelpful to those collectors and curators who deal routinely with rare species and who could use some visual guidance (or at least clues) to the provisional sight-identification of unaesthetic rarities. The *Photographic Guide to Minerals* CD remedies this situation with over 5400 images of more than 3100 different mineral species, focusing on those that are least known.

The quality of the photos is sufficient to the task. And, although many images show what for more common species would amount to poor specimens, in the world of mineralogical rarities they are fascinating to see at all. In fact, even for a non-species-collector, it is very interesting to scroll through photo after photo of species never seen before. It opens up a new world; and, in a fair number of cases, the specimens are much more aesthetic than one might expect for a rarity. The vast majority of the specimens depicted are from the extensive stock of coauthor Nikischer's *Excalibur Mineral Company*. Identifications have been meticulously confirmed.

The CD is easy to use. Species may be called up from an alphabetical list of known species, or from a country list or series of maps that quickly zero in on a geographic area. Many have only a single image of the species, but some include four or five. Cross-links according to mineral groups and pseudomorphism also operate smoothly.

This CD is a unique reference which will give enjoyment and information to anyone who appreciates minerals which are "interesting" as well as aesthetic.

Wendell E. Wilson

Gold: Nuggets of Russia

by Lyudmila S. Sher. Published (1999) as volume 1 of Mineralogical Almanac by Ocean Pictures Ltd., Moscow. Softcover, 22 x 27 cm, 132 pages; Price: $45. Order from Terry Huizing, 5341 Thrasher Drive, Cincinnati, OH 45247. (Make checks payable to Mineralogical Almanac.)

The journal *Mineralogical Almanac* is the successor to the English-language Russian mineral collector's magazine *World of Stones*. Apparently economies of scale have suggested to the publishers that it might work better to produce only one or two issues a year, each one considerably larger (132 pages) than a single issue of *World of Stones* (64 pages) used to be. This format also presents the opportunity to focus on a single topic in more depth, as do some oversize special issues of the *Mineralogical Record*, and *Lapis* magazine's *ExtraLapis* issues.

Their first issue, 132 pages with nearly 200 color photos, is entirely devoted to Russian gold. Chapters cover the history of gold discoveries and mining in Russia, bedrock gold, placer gold, the mineralogy of native gold, nuggets, and crystalline gold. Gold occurrences in the Ural Mountains, Sakha-Yakutia, Kolyma, Transbaikalia, Altai, and the Chuckhi Peninsula are discussed and an amazing array of fine specimens are pictured.

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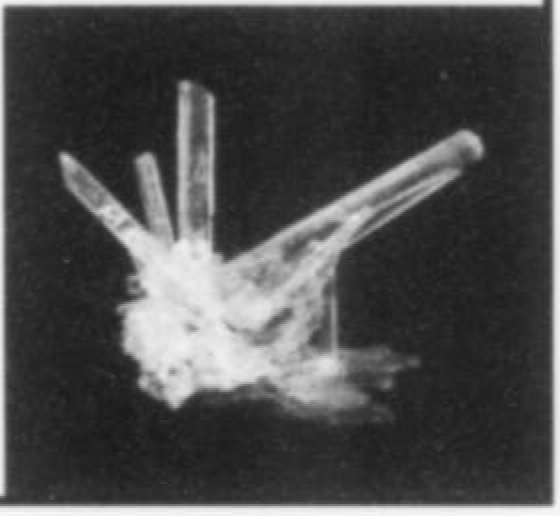

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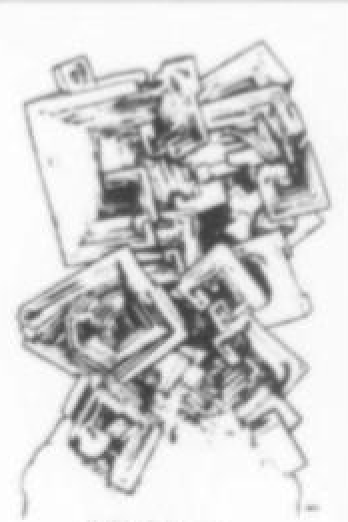

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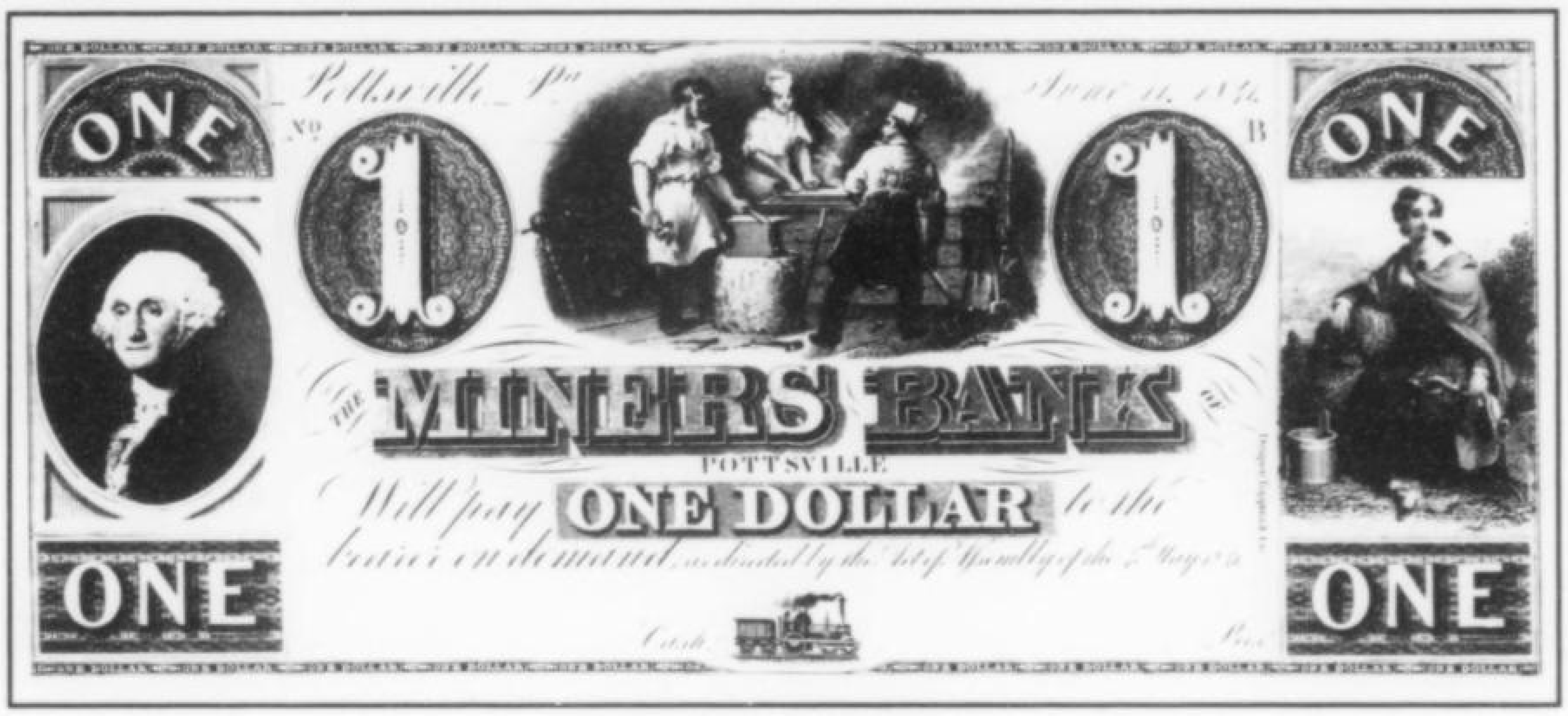

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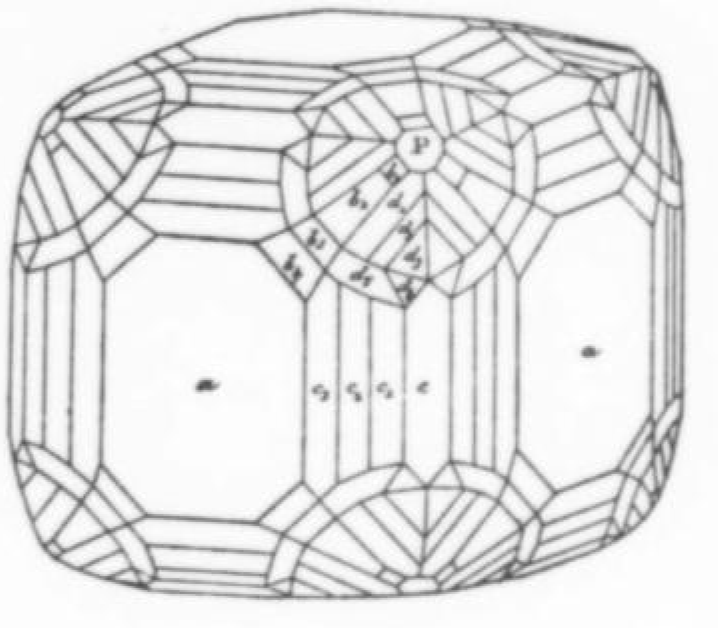

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Andyrobertsite and Calcio-andyrobertsite — Monoclinic

$KCdCu_5(AsO_4)_4[As(OH)_2O_2]\cdot 2H_2O$ and
$KCaCu_5(AsO_4)_4[As(OH)_2O_2]\cdot 2H_2O$

NOTE: This is a departure from the usual abstracts in that it treats two closely related species.

Locality: The Tsumeb mine, Tsumeb, Namibia.

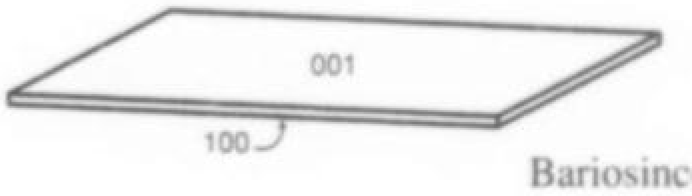
Occurrence: Associated minerals are: zincian olivenite, cuprian adamite and tennantite. A single specimen is known.

General appearance: An aggregate (1.4 cm high x 1 cm wide) of overlapping plates which radiate from a common center; the individual plates are up to 0.1 x 5 x 10 mm.

Physical, chemical and crystallographic properties: *Luster:* vitreous. *Diaphaneity:* not given, but appears to be transparent to translucent from the photograph. *Color:* electric blue. *Streak:* pale blue. *Luminescence:* nonfluorescent. *Hardness:* 3. *Tenacity:* brittle. *Cleavage:* {100} good. *Fracture:* conchoidal. *Density:* was not measured, 4.01 g/cm³ (calc.) given for a 50:50 mixture of the end members. ***Crystallography:*** Monoclinic, $P2_1/m$, *a* 9.810, *b* 10.034, *c* 9.975 Å, β 101.84°, *V* 961.0 Å³, Z 2, *a*:*b*:*c* = 0.9777:1:0.9941. The foregoing data are for andyrobertsite; no data are given for calcio-andyrobertsite. Morphology: platy on {100} with {210}, {001}, {10$\bar{2}$}, {011}. Twinning: none observed. ***X-ray powder diffraction data:*** 9.64 (100) (100), 4.46 (40) (120), 3.145 (50) (130, 122), 3.048 (40) ($\bar{2}$22), 2.698 (40) (320); for andyrobertsite. ***Optical data:*** Andyrobertsite (values in brackets are for calcio-andyrobertsite): Biaxial (−), α 1.720 (1.713), β 1.749 (1.743), γ 1.757 (1.749), 2V(meas.) 50° (50), 2V(calc.) 55° (48); dispersion $r < v$, moderate, asymmetric; nonpleochroic; orientation $X \wedge a = 12°$ (in obtuse angle β), Y = *b*, Z = *c*. ***Chemical analytical data:*** Electron microprobe data: Andyrobertsite: K_2O 4.00, CaO 1.36, MnO 0.64, CdO 6.48, ZnO 0.19, CuO 31.72, As_2O_5 47.58, H_2O (4.44), Total (96.41) wt.%. H_2O was calculated from the crystal structure analysis to give 2(OH) and $2H_2O$. Empirical formula: $K_{1.03}(Cd_{0.61}Mn_{0.11}Ca_{0.29})_{\Sigma 1.01}(Cu_{4.85}Zn_{0.03})_{\Sigma 4.88}(AsO_4)_{4.00}[As(OH)_{1.99}O_2]$-$(H_2O)_{2.00}$. Calcio-andyrobertsite: K_2O 4.05, CaO 3.52, MnO 0.86, CdO 1.26, ZnO 0.04, CuO 32.86, As_2O_5 49.56, H_2O (4.61), Total (96.75) wt.%. H_2O was calculated from the crystal structure analysis to give 2(OH) and $2H_2O$. Empirical formula: $K_{1.01}(Ca_{0.74}Cd_{0.12}Mn_{0.14})_{\Sigma 1.00}(Cu_{4.85}Zn_{0.01})_{\Sigma 4.86}(AsO_4)_{4.06}[As(OH)_{2.00}O_{1.76}]$-$(H_2O)_{2.00}$. ***Relationship to other species:*** Andyrobertsite is the cadmium-dominant analogue of calcio-andyrobertsite and calcio-andyrobertsite is the calcium-dominant analogue of andyrobertsite.

Name: For Andrew (Andy) C. Roberts (1950–), Geological Survey of Canada, in recognition of his contributions to mineralogy and his extensive interactions with the collecting community. Calcio-andyrobertsite is for the relationship to andyrobertsite. ***Comments:*** IMA No. 97-022 and 97-023, respectively. Note that the IMA approved name for the calcium-dominant analogue is calcio-andyrobertsite (i.e., with a hyphen). It is unfortunate that unit cell data and X-ray powder diffraction data could not be measured for calcio-andyrobertsite. The authors state that andyrobertsite is the eleventh mineral containing essential cadmium. Since they submitted their paper another species containing essential cadmium has been published: barquillite (see abstract in *Mineralogical Record* **30**, 399).

COOPER, M. A., HAWTHORNE, F. C., PINCH, W. W., and GRICE, J. D. (1999) Andyroberstite and calcioandyrobertsite (sic): two new minerals from the Tsumeb Mine, Tsumeb, Namibia. *Mineralogical Record* **30**, 181–186.



Bariosincosite

Bariosincosite — Tetragonal

$Ba(V^{4+}OPO_4)_2\cdot 4H_2O$

Locality: The Spring Creek mine (Lat. 31°41′ S, Long. 137°07′ E), about 10 km south of Wilmington and on the eastern flank of Mt. Remarkable, at the southern end of the Flinders Ranges, South Australia, Australia.

Occurrence: Within the copper-mineralized contact zone of a quartzite unit and a slate unit. Associated minerals are: cuprite, quartz, goethite, copper, fluorapatite, whitlockite, barite, and springcreekite.

General appearance: Radiating to divergent groups of platy crystals up to 250 μm square and 5 μm thick.

Physical, chemical and crystallographic properties: *Luster:* vitreous. *Diaphaneity:* transparent. *Color:* pale green with a slightly bluish tinge. *Streak:* very pale green. *Luminescence:* not mentioned. *Hardness:* estimated as 3. *Tenacity:* not mentioned. *Cleavage:* {001} distinct. *Fracture:* splintery. *Density:* could not be measured, 3.33 g/cm³ (calc.). ***Crystallography:*** Tetragonal, *P4/n* or *P4/nmm*, *a* 9.031, *c* 12.755 Å, *V* 1040 Å³, Z 4, *c:a* = 1.4124. Morphology: {001} and {100}; tabular on {001}. Twinning: possibly on {110}. ***X-ray powder diffraction data:*** 5.748 (70) (111), 4.522 (30) (112, 200), 3.100 (100) (203, 221), 2.847 (40) (222, 114), 2.786 (80) (311), 2.368 (30) (313, 115), 2.017 (100) (420, 332, 116). ***Optical data:*** Uniaxial (−), ω 1.721, ε 1.715, pleochroism weak, O = pale greenish, E = colorless, absorption O > E. ***Chemical analytical data:*** Means of an unstated number of sets of electron microprobe data: BaO 23.20, SrO 4.19, CaO 0.36, Al_2O_3 0.50, Fe_2O_3 0.20, VO_2 31.55, P_2O_5 28.15, H_2O (13.93), Total (102.08) wt.%. Water was calculated to give $4H_2O$. Empirical formula: $(Ba_{0.77}Sr_{0.21}Ca_{0.03})_{\Sigma 1.01}$-$[(V^{4+}_{1.94}Al_{0.05}Fe^{3+}_{0.01})_{\Sigma 2.00}O_{1.93}(PO_4)_{2.03}]\cdot 3.95H_2O$. ***Relationship to other species:*** It is the barium-dominant analogue of sincosite whose formula probably should be changed from $CaV^{4+}_2(PO_4)_2$-$(OH)_4\cdot 3H_2O$ to $Ca(V^{4+}OPO_4)_2\cdot 4H_2O$.

Name: For the relationship to sincosite. ***Comments:*** IMA No. 1998-047. The drawing given here conforms to the crystals shown in the photograph in the paper.

PRING, A., KOLITSCH, U., BIRCH, W. D., BEYER, B. D., ELLIOTT, P., AYYAPPAN, P., and RAMANAN, A. (1999) Bariosincosite, a new hydrated barium vanadium phosphate, from the Spring Creek Mine, South Australia. *Mineralogical Magazine* **63**, 735–741.

Bederite

Orthorhombic

$\square Ca_2Mn^{2+}_2Fe^{3+}_2Mn^{2+}_2(PO_4)_6\cdot 2H_2O$

Locality: The El Peñón pegmatite, approximately at (Lat. 24°50′ S, Long. 66°20′ W) and 3920 m above sea level in the El Quemado pegmatite field, Nevados de Palermo, Salta Province, Argentina.

Occurrence: In a rare-element pegmatite of the beryl type, beryl-columbite-phosphate subtype. Associated minerals are: quartz, potassium feldspar, muscovite, beryl, columbite possible heterosite, and powdery coatings of Mn- and Fe-oxides.

General appearance: Massive ellipsoidal nodules up to about 5 cm in diameter.

Physical, chemical and crystallographic properties: *Luster:* vitreous. *Diaphaneity:* not stated but probably translucent to opaque. *Color:* very dark brown to black. *Streak:* dark olive-green. *Luminescence:* nonfluorescent. *Hardness:* 5. *Tenacity:* brittle. *Cleavage:* {100} good. *Fracture:* irregular. *Density:* 3.48 g/cm³ (meas.), 3.49 g/cm³ (calc.). ***Crystallography:*** Orthorhombic, *Pcab*, *a* 12.559, *b* 12.834, *c* 11.714 Å, *V* 1887.8 Å³, Z 4, *a:b:c* = 0.9786:1:0.9127. Morphology: no forms were observed. Twinning: none mentioned. ***X-ray powder diffraction data:*** 5.853 (30) (002), 3.006 (67) (141), 2.9274 (78) (004), 2.8142 (35) (042), 2.7682 (100) (114, 402), 2.1100 (33) (153, 160). ***Optical data:*** Biaxial (-), α 1.729, β 1.738, γ 1.741, 2V(meas.) 54°, 2V(calc.) 60°; dispersion r < v, strong; pleochroism X = Y = olive green, Z = brown, absorption X = Y > Z; orientation, X = *a*, Y = *c*, Z = *b*. ***Chemical analytical data:*** Means of nine sets of electron microprobe data: Na_2O 0.63, MgO 3.45, CaO 10.91, MnO 20.59, FeO 2.25, ZnO 0.40, SrO 0.43, Al_2O_3 0.82, Fe_2O_3 12.00, P_2O_5 41.76, H_2O 3.52, Total 96.76 wt.%. H_2O was determined by the Penfield method. Empirical formula: $(\square_{0.76}Na_{0.21}Ca_{0.03})_{\Sigma 1.00}(Ca_{1.99}Sr_{0.04})_{\Sigma 2.00}(Mn^{2+}_{0.98}Mg_{0.65}Fe^{2+}_{0.32}Zn_{0.05})_{\Sigma 2.00}$-$(Fe^{3+}_{1.54}Mg_{0.23}Al_{0.16})_{\Sigma 1.95}Mn^{2+}_{1.99}(PO_4)_{6.03}(H_2O)_{2.00}$. ***Relationship to other species:*** Isostructural with wicksite and grischunite.

Name: For Swiss-born Roberto Beder (1888–1930) in recognition of his major contributions to the development of mineralogy in Argentina, especially in morphological crystallography. ***Comments:*** IMA No. 1998-007.

GALLISKI, M. A., COOPER, M. A., HAWTHORNE, F. C., and CERNY, P. (1999) Bederite, a new pegmatite phosphate mineral from Nevados de Palermo, Argentina: description and crystal structure. *American Mineralogist* **84**, 1674–1679.

Cobaltlotharmeyerite

Monoclinic

$Ca(Co,Fe^{3+},Ni)_2(AsO_4)_2(OH,H_2O)_2$

Locality: On dump material from the mining area "Am Roten Berg," approximately 4.8 km southwest of the center of Schneeberg, Saxony, Germany (type locality). It has also been found on dump material at the Rappold mine and the Pucher mine, both near Schneeberg, Saxony, Germany.

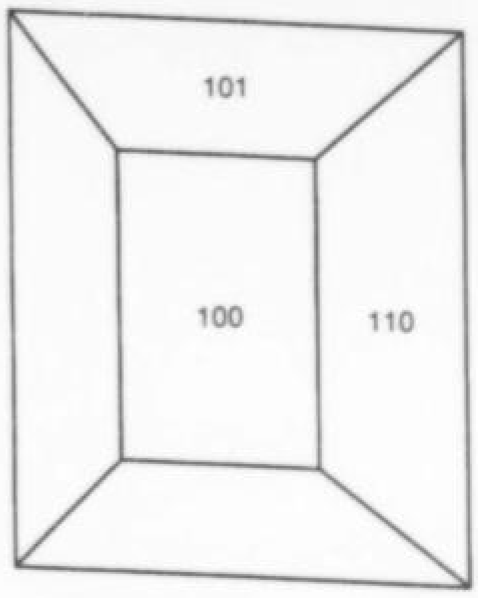
Occurrence: At the type locality, the mineral occurs on quartz and associated minerals are: Ba-bearing alumopharmacosiderite, barium-pharmacosiderite, arseniosiderite, zeunerite, olivenite, rooseveltite, Co-bearing mawbyite, Co-dominant tsumcorite, waylandite and scorodite. At the Rappold mine it is associated with $Pb(Co,Ni)_2(AsO_4)_2\cdot 2H_2O$; at the Pucher mine it is associated with $Ca(Ni,Fe,Co)_2(AsO_4)_2(OH,H_2O)_2$.

General appearance: Aggregates (up to 1 mm) of fan-shaped, lath-like crystals (up to 0.1 mm).

Physical, chemical and crystallographic properties: *Luster:* given as vitreous, but the indices of refraction indicate adamantine. *Diaphaneity:* transparent. *Color:* brown. *Streak:* light brown. *Luminescence:* nonfluorescent. *Hardness:* 4½. *Tenacity:* not given. *Cleavage:* none observed. *Fracture:* not given. *Density:* could not be determined, 4.14 g/cm³ (calc.). ***Crystallography:*** Monoclinic, *C2/m*, *a* 9.024, *b* 6.230, *c* 7.421 Å, β 115.15°, *V* 377.1 Å³, Z 2, *a:b:c* = 1.4485:1:1.1912. Morphology: {$\bar{1}$01}, {102} and, possibly, {111}. Twinning: none mentioned. ***X-ray powder diffraction data:*** 4.955 (66) (110), 3.398 (54) ($\bar{2}$02), 3.188 (85) ($\bar{1}$12), 3.115 (51) (020), 2.972 (82) (201), 2.828 (88) (021), 2.545 (100) ($\bar{2}$21). ***Optical data:*** Biaxial (+), α 1.78 (calc.), β 1.79, γ 1.85, 2V(meas.) 48°; dispersion r > v, distinct; pleochroism strong, X = yellow, Y = brown, Z = pale yellow; X ∧ *c* = 10° (in obtuse angle β), Y = *b*. ***Chemical analytical data:*** Means of sixteen sets of electron microprobe data: CaO 12.18, NiO 5.76, CoO 15.70, CuO < 0.05, PbO < 0.05, Fe_2O_3 11.53, Bi_2O_3 < 0.05, As_2O_5 49.36, SO_3 < 0.05, H_2O (6.39), Total (100.92) wt.%. H_2O was calculated from the ideal composition. Both OH and H_2O are confirmed by IR spectroscopy. Empirical formula: $Ca_{1.01}(Co_{0.98}Fe^{3+}_{0.67}Ni_{0.36})_{\Sigma 2.01}(AsO_4)_{2.00}[(OH)_{0.71}(H_2O)_{1.30}]_{2.01}$. The cotype specimen has a high percentage of Bi_2O_3 (16.92 wt.%). ***Relationship to other species:*** It is a member of the tsumcorite group, specifically the Co-dominant member.

Name: For the chemical relationship to lotharmeyerite. ***Comments:*** IMA No. 1997-027.

KRAUSE, W., EFFENBERGER, H., BERNHARDT, H.-J., and MARTIN, M. (1999) Cobaltlotharmeyerite, $Ca(Co,Fe^{3+},Ni)_2$-$(AsO_4)_2(OH,H_2O)_2$, a new mineral from Schneeberg, Germany. *Neues Jahrbuch für Mineralogie, Monatshefte* **1999**, 505–517.



Coparsite

Coparsite — Orthorhombic

$Cu_4O_2[(As,V)O_4]Cl$

Locality: The fumarole "Yadovitaya" (= "Poisonous") in the North Breach of the great fissure Tolbachik eruption (1975–1976), Kamchatka Peninsula, Russia.

Occurrence: As a fumarole exhalative product. Associated minerals are: euchlorine, tolbachite, kamchatkaite, klyuchevskite, alumoklyuchevskite and ponomarevite.

General appearance: As small inclusions in euchlorine (up to 0.4 x 0.2 x 0.1 mm).

Physical, chemical and crystallographic properties: *Luster:* metallic. *Diaphaneity:* opaque. *Color:* black or dark gray. *Streak:* brown. *Hardness:* could not be measured. *Tenacity:* very brittle. *Cleavage:* {100} perfect. *Fracture:* not given. *Density:* could not be measured, 4.73 g/cm^3 (calc.). ***Crystallography:*** Orthorhombic, *Pbcm*, *a* 5.440, *b* 11.154, *c* 10.333 Å, *V* 627.0 Å^3, Z 4, *a:b:c* = 0.4877:1:0.9264 (see Comments). Morphology: {100}, {110}, {101}. Twinning: none mentioned. ***X-ray powder diffraction data:*** 5.31 (30) (010), 4.69 (40) (110), 3.70 (30) (012), 3.03 (60) (310), 2.62 (100) (312, 004, 213), 2.39 (40) (022, 221). ***Optical data:*** Because of the very small amount of material available, reflectance measurements were not attempted. ***Chemical analytical data:*** Means of two sets of electron microprobe data: CuO 69.03, Fe_2O_3 0.17, As_2O_5 15.50, V_2O_5 7.72, SO_3 0.57, Cl 8.47, sum 101.46, less O = Cl 1.91, Total 99.55 wt.%. Empirical formula: $Cu_{3.89}Fe_{0.01}O_{1.93}[(As_{0.60}V_{0.38}S_{0.03})_{\Sigma 1.01}O_{4.00}]Cl_{1.07}$. ***Relationship to other species:*** None apparent.

Name: For the chemical composition: *cop*(per) and *ars*(enic). ***Comments:*** IMA No. 1996-064. The *a:b:c* ratio given by the authors is 2.050:1:1.899 which clearly is wrong.

VERGASOVA, L. P., STAROVA, G. L., KRIVOVICHEV, S. V., FILATOV, S. K., and ANANIEV, V. V. (1999) Coparsite, $Cu_4O_2[(As,V)O_4]Cl$, a new mineral species from the Tolbachik volcano, Kamchatka Peninsula, Russia. *Canadian Mineralogist* **37**, 911–914. STAROVA, G. L., KRIVOVICHEV, S. V., and FILATOV, S. K. (1998) Crystal chemistry of inorganic compounds based on chains of oxocentered tetrahedra. II. Crystal structure of $Cu_4O_2[(As,V)O_4]Cl$. *Zeitschrift für Kristallographie* **213**, 650–653.

Esperanzaite — Monoclinic

$NaCa_2Al_2(AsO_4)_2F_4(OH)\cdot H_2O$

Locality: The La Esperanza mine, Zaragosa mining district, 3.7 km southeast of the village of Madero, Durango, Mexico. Madero is 60 km northeast of the city of Durango.

Occurrence: On altered rhyolite. Associated minerals are: hematite, cassiterite, quartz, tridymite, cristobalite, opal, calcite, "zeolites," mimetite and unidentified clay minerals.

General appearance: Botryoidal patches up to 0.8 cm across and separated spheres up to 1.5 mm in diameter made up of radiating crystals.

Physical, chemical and crystallographic properties: *Luster:* vitreous. *Diaphaneity:* transparent to translucent. *Color:* blue green (seafoam green). *Streak:* white. *Luminescence:* nonfluorescent. *Hardness:* approximately 4½. *Tenacity:* brittle. *Cleavage:* perfect parallel to [001]; no parting. *Fracture:* not mentioned. *Density:* 3.24 g/cm^3 (meas.), 3.36 g/cm^3 (calc.). ***Crystallography:*** Monoclinic, *P*2$_1$*/m*, *a* 9.687, *b* 10.7379, *c* 5.5523 Å, β 105.32°, *V* 557.0 Å^3, Z 2, *a:b:c* = 0.9021:1:0.5171. Morphology: no forms were mentioned. Twinning: none mentioned. ***X-ray powder diffraction data:*** 5.364 (80) (001, 020), 4.796 (80) (011), 3.801 (80) (021), 3.527 (90) (220), 2.966 (100) (13$\bar{1}$, 31$\bar{1}$, 031), 2.700 (90b) (221, 002, 040). ***Optical data:*** Biaxial (-), α 1.580, β 1.588, γ 1.593, 2V(meas.) 74°, 2V(calc.) 76°; dispersion r < v, medium; X ∧ c = 35° (in acute angle β), Y = *b*, Z ∧ *a* = 50.5° (in obtuse angle β). ***Chemical analytical data:*** Means of six sets of electron microprobe data: Na 2.86, Ca 14.83, Zn 0.70, Al 10.16, As 26.50, F 0.70, H_2O 8.65, O 24.45, Total 102.15 wt.%. These have been recalculated here in terms of "oxide" constituents and the data are: Na_2O 3.86, CaO 20.75, ZnO 0.87, Al_2O_3 19.20, As_2O_5 40.65, H_2O 8.65, F 13.90, sum 107.88, less O = F 5.85, Total 102.03 wt.%. Empirical formula: $Na_{0.68}(Ca_{2.03}Zn_{0.06})_{\Sigma 2.09}Al_{2.06}As_{1.94}O_{7.87}F_{4.01}(OH)_{1.00}\cdot 2.13H_2O$. ***Relationship to other species:*** None apparent.

Name: For the mine. ***Comments:*** IMA No. 1998-025.

FOORD, E. E., HUGHES, J. M., CURETON, F., MAXWELL, C. C., FALSTER, A. U., SOMMER, A. J., and HLAVA, P. F. (1999) Esperanzaite, $NaCa_2Al_2(As^{5+}O_4)_2F_4(OH)\cdot H_2O$, a new mineral species from the La Esperanza mine, Mexico: descriptive mineralogy and atomic arrangement. *Canadian Mineralogist* **37**, 67–72.

Formicaite — Tetragonal

$Ca(HCO_2)_2$

Locality: The Solondo boron deposit, Buryatia and the Novofrolovskoye copper deposit, Urals, Russia.

Occurrence: Associated minerals are: pentahydroborite, frolovite, fedorovskite, calcite, solongoite, turneaureite and johnbaumite.

General appearance: Tabular crystals (up to 30 x 30 x 5 μm) and aggregates of these crystals.

Physical, chemical and crystallographic properties: *Luster:* vitreous. *Diaphaneity:* transparent. *Color:* white to light blue. *Streak:* white. *Luminescence:* not observed. *Hardness:* 1. *Tenacity:* brittle. *Cleavage:* {100} perfect. *Fracture:* stepped. *Density:* 1.9 g/cm^3 (meas.), 1.89 g/cm^3 (calc.). ***Crystallography:*** Tetragonal, *P*4$_1$2$_1$2, *a* 6.77, *c* 9.463 Å, *V* 434 Å^3, Z 4, *c:a* = 1.3978. Morphology: no forms were mentioned. Twinning: none mentioned. ***X-ray powder diffraction data:*** 5.54 (90) (011), 3.40 (100) (200), 3.19 (60) (021), 2.859 (80) (013), 2.196 (70) (031), 2.046 (50) (032), 1.947 (60) (132). ***Optical data:*** Uniaxial (+), ω 1.553, ε 1.573. ***Chemical analytical data:*** Means of twelve sets of electron microprobe and gas chromatography data: Na 0.13, K 0.10, Ca 29.80, Mn 0.23, H 1.90, O (49.19), C 20.28, Total (101.63) wt.%. Oxygen calculated for the ideal composition. Empirical formula: $(Ca_{0.90}Na_{0.01}Mn_{0.01})_{\Sigma 0.92}(H_{2.29}C_{2.05}O_{3.74})$. ***Relationship to other species:*** The mineral is the natural analogue of synthetic calcium formate.

Name: For the composition, a formate. ***Comments:*** IMA No. 1998-030.

CHKANOV, N. V., MALINKO, S. V., LISITSYN, A. E., DUBIN-

CHUK, V. T., KUZ'MINA, O. V., and ZADOV, A. E. (1999) Formicaite $Ca(HCO_2)_2$, a new mineral. *Zapiski Vserossiyskogo mineralogicheskogo obshchestva* **128(2)**, 43–47.

Gilmarite Triclinic

$Cu_3(AsO_4)(OH)_3$

Locality: The old copper mines of Roua (North group, municipality of Guillaumes), the Alpes-Maritimes area, France (about 50 km from Nice).

Occurrence: In veinlets that crosscut pelites and sandstones. Associated minerals are: dolomite, calcite, cuprite, posnjakite, langite, clinotyrolite, connelite, brochantite, malachite, vesignieite, cornubite, olivenite, trippkeite, domeykite and djurleite.

General appearance: Rosettes (up to 0.3 mm in diameter) and isolated crystals (up to 0.1 x 0.04 x 0.02 mm).

Physical, chemical and crystallographic properties: *Luster:* given as vitreous, but the optical properties indicate adamantine. *Diaphaneity:* transparent. *Color:* green-blue. *Streak:* blue-green. *Luminescence:* nonfluorescent. *Hardness:* ~3. *Tenacity:* brittle. *Cleavage:* {010} good. *Fracture:* uneven irregular. *Density:* 4.2 g/cm³ (meas.), 4.27 g/cm³ (calc.). ***Crystallography:*** Triclinic, *P*1, *a* 5.445, *b* 5.873, *c* 5.104 Å, α 114.95°, β 93.05°, γ 91.92°, *V* 147.5 Å³, Z 1, *a:b:c* = 0.9271:1:0.8691. Morphology: {100}, {010}, {001}, {101}, elongated on [101] or [100] and flattened on {010}. Twinning: none. ***X-ray powder diffraction data:*** 4.613 (100) (001), 4.580 (50) $(01\bar{1})$, 3.654 (20) $(10\bar{1})$, 3.390 (60) (101), 2.713 (40) (200), 2.543 (40) $(01\bar{2}, 12\bar{1})$, 2.445 (30) $(1\bar{2}0)$, 2.125 (20) $(12\bar{2})$. ***Optical data:*** Biaxial (−), α 1.760, β 1.80, γ 1.83, 2V(meas.) 77°, 2V(calc.) 80°; dispersion r > v, weak; pleochroism weak, X = Y = light green, Z = green; orientation: on {010} X ∧ *c* = 33°, Y ∧ *a* = 37.1°; on {001} Y ∧ *a* = 34.3°, Z ∧ *b* = 30.1°; on {101} Z′ ∧ *b* = 44° and Y′ ∧ [101] = 36.5°. ***Chemical analytical data:*** Means of five sets of electron microprobe data: CuO 63.0, As_2O_5 29.64, H_2O 7.36, Total 100.00 wt.%. Empirical formula: $Cu_{3.00}(AsO_4)_{0.98}(OH)_{3.10}$. ***Relationship to other species:*** A polymorph of clinoclase.

Name: For Gilbert Mari (1944–), mineralogist, University of Nice-Sophia Antipolis, president of the Association of Naturalists of Nice and the Alpes-Maritimes, in recognition of the work he has done with his wife Danielle and Pierre Rolland on the old copper mines of the area. ***Comments:*** IMA No. 1996-017.

SARP, H. and ČERNÝ, R. (1999) Gilmarite, $Cu_3(AsO_4)(OH)_3$, a new mineral: its description and crystal structure. *European Journal of Mineralogy* **11**, 549–555.

Haigerachite Monoclinic

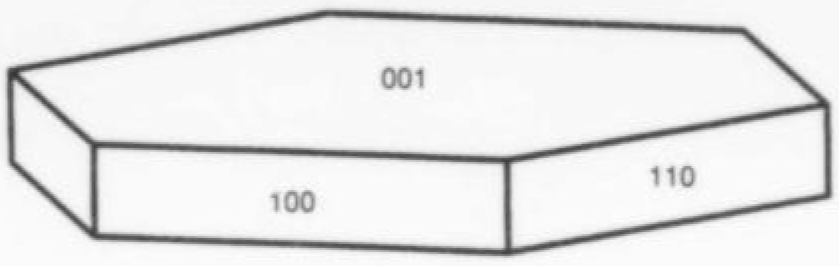
$KFe^{3+}_3(H_2PO_4)_6(HPO_4)_2 \cdot 4H_2O$

Locality: The dump of the Silberbrünnle mine in the Haigerach valley near Gengenbach, Central Black Forest, Germany.

Occurrence: Associated minerals are: pyrite, quartz, gypsum, jarosite, diadochite, and another new phosphate.

General appearance: Spherulitic aggregates (up to 0.2 mm in diameter) composed of scaly crystals (up to 0.05 mm); rarely as well-developed thin, tabular, six-sided crystals.

Physical, chemical and crystallographic properties: *Luster:* vitreous. *Diaphaneity:* translucent to transparent. *Color:* white. *Streak:* white. *Luminescence:* not mentioned. *Hardness:* about 2. *Tenacity:* not mentioned. *Cleavage:* {001} good. *Fracture:* uneven. *Density:* 2.44 g/cm³ (meas.), 2.45 g/cm³ (calc.). ***Crystallography:*** Monoclinic, *C*2/*c*, *a* 16.95, *b* 9.59, *c* 17.57 Å, β 90.85°, *V* 2855.7 Å³, Z 4, *a:b:c* = 1.7675:1:1.8321. Morphology: {001}, {100}, {110}, flattened on {001}. Twinning: none mentioned. ***X-ray powder diffraction data:*** 8.83 (10) (002), 7.60 (4) $(\bar{1}11)$, 3.75 (10) $(\bar{3}13, 222)$, 3.30 (4) $(\bar{3}14)$, 3.23 (5) $(\bar{1}15, 314, 024, 115)$, 3.11 (4) $(\bar{4}21, 421, \bar{1}31, 131)$, 3.02 (9) $(\bar{2}24, 404, \bar{5}12, 224, \bar{4}22)$. ***Optical data:*** Biaxial (−), α 1.557, β 1.598, γ 1.602, 2V(meas.) 32°, 2V(calc.) 34°; X ~ *c*, Y = *b*, Z ~ *a*. ***Chemical analytical data:*** Means of electron microprobe data: Na_2O 0.34, K_2O 3.79, MgO 0.19, CaO 0.66, MnO 0.42, Al_2O_3 0.66, Fe_2O_3 21.66, P_2O_5 53.39, H_2O (18.89), Total (100.00) wt.%. H_2O by difference. Empirical formula: $K_{0.85}Na_{0.12}Ca_{0.12}Fe^{3+}_{2.85}Al_{0.14}Mn_{0.06}Mg_{0.05}P_{7.91}H_{22.05}O_{36.00}$. ***Relationship to other species:*** None apparent, but it is the natural analogue of the synthetic compound.



Haigerachite

Name: For the locality. ***Comments:*** IMA No. 1997-049. The drawing shown here was produced from the data and photograph in the paper.

WALENTA, K. and THEYE, T. (1999) Haigerachit, ein neues Phosphatmineral von der Grube Silberbrünnle bei Gengenbach im mittleren Schwarzwald. *Aufschluss* **50**, 1–7.

Itoigawaite Orthorhombic

$SrAl_2Si_2O_7(OH)_2 \cdot H_2O$

Locality: On the seashore of Oyashirazu, about 15 km WSW of Itoigawa Station, Itoigawa-Ohmi district, Niigata-ken Prefecture, Japan (Itoigawa is at Lat. 37°02′ N, Long. 137°52′ E).

Occurrence: As a veinlet in jadeitite boulders. Associated minerals are: Ti-bearing jadeite, natrolite, Sr-bearing pectolite, rutile, titanite and an undetermined Sr-Ti silicate.

General appearance: Minute tabular crystals (up to about 50 µm across) in a thin veinlet (<0.8 mm wide).

Physical, chemical and crystallographic properties: *Luster:* vitreous. *Diaphaneity:* transparent. *Color:* blue. *Streak:* white. *Luminescence:* nonfluorescent. *Hardness:* VHN_{100} 550 to 680 kg/mm², Mohs 5 to 5½. *Tenacity:* not given. *Cleavage:* good in one direction. *Fracture:* not given. *Density:* could not be measured, 3.34 g/cm³ (calc.). ***Crystallography:*** Orthorhombic, *Cmcm*, *a* 6.031, *b* 8.945, *c* 13.219 Å, *V* 713.1 Å³, Z 4, *a:b:c* = 0.6742:1:1.4778. Morphology: no forms were mentioned. Twinning: none mentioned. ***X-ray powder diffraction data:*** 4.68 (s) (111), 4.26 (vs) (021), 3.31 (vs) (113), 2.75 (vs) (114, 202), 2.68 (vvs) (130), 2.63 (s) (131), 2.50 (s) (220, 203, 132), 2.45 (s) (221) and five other lines of (s) intensity. ***Optical data:*** Biaxial (+), α 1.664, β 1.674, γ 1.688, 2V not measured, 2V(calc.) 81°; dispersion not given; nonpleochroic; orientation not given. ***Chemical analytical data:*** Means of seven sets of electron microprobe data: MgO 0.11, CaO 0.46, FeO 0.10, SrO 27.71, Al_2O_3 27.67, SiO_2 32.98, TiO_2 0.25, H_2O (10.72), Total (100.00) wt.%. H_2O calculated by difference. Empirical formula: $(Sr_{0.96}Ca_{0.03}Mg_{0.01})_{\Sigma 1.00}(Al_{1.94}Ti_{0.01})_{\Sigma 1.95}Si_{1.97}O_{7.00}(OH)_{1.74} \cdot 1.26H_2O$. ***Relationship to other species:*** It is the Sr-dominant analogue of lawsonite, the Al-dominant analogue of hennomartinite and the Sr- and Al-dominant analogue of noélbensonite.

Name: For the locality. ***Comments:*** IMA No. 1998-034.

MIYAJIMA, H., MATSUBARA, S., MIYAWAKI, R., and ITO, K. (1999) Itoigawaite, a new mineral, the Sr analogue of lawsonite, in jadeitite from the Itoigawa-Ohmi district, central Japan. *Mineralogical Magazine* **63**, 909–916.

Khaidarkanite Monoclinic

$Cu_4Al_3(OH)_{14}F_3{\cdot}2H_2O$

Locality: The Khaidarkan antimony-mercury deposit near Khaidarkan, northern slope of the Alai Range, Fergana Valley, Kyrgyzstan.

Occurrence: Associated minerals are: calcite, quartz, barite, fluorite, malachite, cuprian allophane, conichalcite, chrysocolla and Al-F fluorohydroxide.

General appearance: Needle-like crystals (up to 3 x 0.05 x 0.05 mm) as sprays, radial and random aggregates in cavities.

Physical, chemical and crystallographic properties: *Luster:* vitreous. *Diaphaneity:* translucent. *Color:* bright blue. *Streak:* light blue. *Luminescence:* nonfluorescent. *Hardness:* 2½. *Tenacity:* sectile. *Cleavage:* {100} imperfect. *Fracture:* rough. *Density:* 2.84 g/cm³ (meas.), 3.04 g/cm³ (calc.). ***Crystallography:*** Monoclinic, *C*2/*m*, *a* 12.346, *b* 2.907, *c* 10.369 Å, β 97.90°, *V* 368 Å³, Z 1, *a*:*b*:*c* = 4.2470:1:3.5669. Morphology: no forms were mentioned. Twinning: none observed. ***X-ray powder diffraction data:*** 10.29 (8) (001), 5.589 (9) $(20\bar{1})$, 4.232 (10) $(20\bar{2})$, 2.828 (9) (203), 2.362 (10) (310), 1.871 (8) $(114, 51\bar{1})$, 1.817 (8) $(51\bar{2})$. ***Optical data:*** Biaxial (+), α 1.585, β 1.615, γ 1.648, 2V(meas.) 80° to 90°, 2V(calc.) 89°; dispersion not mentioned; pleochroism strong, X = colorless, Y = light blue, Z = bright blue; orientation not given. ***Chemical analytical data:*** Means of two sets of electron microprobe data: Na_2O 1.58, CuO 46.09, Al_2O_3 22.35, SO_3 2.32, SiO_2 0.78, H_2O 22.30, F 8.05, sum 103.47, less O = F 3.39, Total 100.08 wt.%. F was determined by selective ion electrode and H_2O by the Penfield method. Empirical formula: $Na_{0.34}Cu_{3.90}Al_{2.95}(OH)_{13.40}F_{2.85}(SO_4)_{0.19}(SiO_4)_{0.09}{\cdot}1.62H_2O$. ***Relationship to other species:*** None apparent.

Name: For the locality. ***Comments:*** IMA No. 1998-013.

CHUKANOV, N. V., KARPENKO, V. Yu., RASTSVETAEVA, R. K., ZADOV, A. E., and KUZ'MINA, O. V. (1999) Khaidarkanite $Cu_4Al_3(OH)_{14}F_3{\cdot}2H_2O$, a new mineral from the Khaidarkan deposit, Kyrgyzstan. *Zapiski Vserossiyskogo mineralogicheskogo obshchestva* **128(3)**, 58–63.

Khmaralite Monoclinic

$Mg_{5.5}Al_{14}Fe_2Si_5Be_{1.5}O_{40}$

Locality: From "Zircon Point," Khmara Bay, Enderby Land, Antarctica (Lat. 67°20′ S, Long. 49°00′ E).

Occurrence: In a single specimen of pegmatite. Associated minerals are: quartz, microcline, sillimanite, surinamite, musgravite, "garnet," biotite, "apatite," rutile, dumortierite and spinel.

General appearance: A foliated aggregate (nearly 3 cm across) of parallel tablets. Individual tablets are 1 to 7 mm across and 0.5 to 4 mm thick.

Physical, chemical and crystallographic properties: *Luster:* vitreous. *Diaphaneity:* transparent. *Color:* very dark green. *Streak:* green-gray. *Luminescence:* not mentioned. *Hardness:* about 7. *Tenacity:* brittle. *Cleavage:* none observed. *Fracture:* uneven. *Density:* not measured, 3.61 g/cm³ (calc.). ***Crystallography:*** Monoclinic, $P2_1/c$, *a* 18.800, *b* 14.371, *c* 11.254 Å, β 125.53°, *V* 2605.7 Å³, Z 4, *a*:*b*:*c* = 1.3780:1:0.7832. Morphology: Only {010} was observed. Twinning: none mentioned. ***X-ray powder diffraction data:*** 2.8260 (45) (042), 2.4446 (100) $(\bar{4}52)$, 2.4385 (44) $(\bar{8}02)$, 2.3405 (43) (441, 450), 2.0140 (61) (800), 2.0106 (85) $(\bar{4}54)$. ***Optical data:*** Biaxial (−), α 1.725, β 1.740, γ 1.741, 2V(meas.) 34.4°, 2V(calc.) 29°; dispersion r < v, strong; pleochroism X = colorless or very light tan, Y = blue-green, Z = deep blue-green; Y = *b*. ***Chemical analytical data:*** Means of thirteen sets of electron microprobe data (Li, Be and B by ion microprobe): Li_2O 0.01, Na_2O 0.00, K_2O 0.03, BeO 2.51, MgO 15.49, CaO 0.16, MnO 0.01, FeO 9.43, ZnO 0.10, B_2O_3 0.05, Al_2O_3 51.15, Cr_2O_3 0.01, Fe_2O_3 0.70, SiO_2 20.27, Total 99.92 wt.%. Iron was partitioned to give 28 cations. Empirical formula (ignoring Cr, Mn, Zn, K and Li): $Mg_{5.46}Ca_{0.04}Al_{14.26}Fe^{2+}_{1.87}Fe^{3+}_{0.12}Si_{4.80}Be_{1.43}B_{0.02}O_{40.00}$. ***Relationship to other species:*** Chemically similar to sapphirine.

Name: For the locality, which was named in honor of Ivan Fedorovich Khmara (1936–1956), a tractor driver on the Soviet Antarctic Expedition who perished in Antarctica. ***Comments:*** IMA No. 1998-027.

BARBIER, J., GREW, E. S., MOORE, P. B., and SU, S.-C. (1999) Khmaralite, a new beryllium-bearing mineral related to sapphirine: A superstructure resulting from partial ordering of Be, Al, and Si on tetrahedral sites. *American Mineralogist* **84**, 1650–1660.

Khomyakovite Trigonal

$Na_{12}Sr_3Ca_6Fe^{2+}_3Zr_3W(Si_{25}O_{73})(O,OH,H_2O)_3(OH,Cl)_2$

Locality: The Poudrette Quarry, Mont Saint-Hilaire, Rouville County, Quebec, Canada.

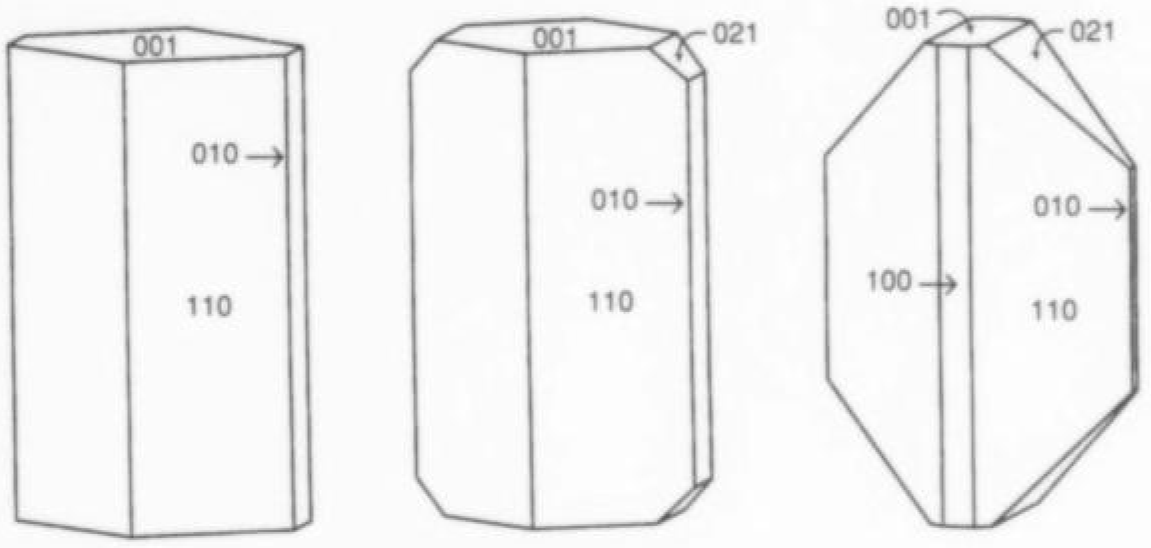
Occurrence: In nepheline syenite. Associated minerals are: analcime, annite, calcite, natrolite, pyrite and titanite.

General appearance: Pseudo-octahedral crystals 0.5 mm in diameter.

Physical, chemical and crystallographic properties: *Luster:* vitreous. *Diaphaneity:* transparent to translucent. *Color:* orange to orange-red. *Streak:* white. *Luminescence:* nonfluorescent. *Hardness:* 5 to 6. *Tenacity:* brittle. *Cleavage:* none. *Fracture:* uneven. *Density:* could not be measured, 3.14 g/cm³ (calc.). ***Crystallography:*** Trigonal, *R*3*m*, *a* 14.2959, *c* 30.084 Å, *V* 5324.6 Å³, Z 3, *c*:*a* = 2.1044. Morphology: no forms were observed. Twinning: none mentioned. ***X-ray powder diffraction data:*** could not be measured, but the data calculated from the crystal structure data are practically identical to those measured for manganokhomyakovite. ***Optical data:*** Uniaxial (−), ω 1.6279, ε 1.6254, pleochroism moderate, O = yellow-orange, E = pale yellow. ***Chemical analytical data:*** Two electron microprobe analyses were carried out. The data for the grain chosen for the crystal structure analysis are: Na_2O 11.35, K_2O 0.52, MgO 0.04, CaO 10.42, MnO 1.63, FeO 4.33, SrO 8.45, Al_2O_3 0.09, La_2O_3 0.21, Ce_2O_3 0.18, SiO_2 43.70, TiO_2 0.11, ZrO_2 10.62, HfO_2 0.18, Nb_2O_5 1.33, Ta_2O_5 0.02, WO_3 3.80, H_2O 0.87, Cl 0.67, sum 98.52, less O = Cl 0.15, Total 98.37 wt.%. H_2O was calculated from the crystal structure results. Empirical formula: $(Na_{12.26}K_{0.38}Ca_{0.33}REE_{0.08})_{\Sigma 13.05}(Sr_{2.78}Na_{0.22})_{\Sigma 3.00}Ca_{6.00}(Fe_{2.05}Mn_{0.78}Mg_{0.03})_{\Sigma 2.86}(Zr_{2.94}Ti_{0.05}Hf_{0.03})_{\Sigma 3.02}(W_{0.56}Nb_{0.34})_{\Sigma 0.90}(Si_{24.78}Al_{0.06})_{\Sigma 24.84}O_{73.00}(O,OH,H_2O)_{3.70}(OH_{1.36}Cl_{0.64})_{\Sigma 2.00}$. ***Relationship to other species:*** A member of the eudialyte group, specifically the iron-dominant analogue of manganokhomyakovite.

Name: For Dr. Alexander Petrovich Khomyakov (1933–), Institute of Mineralogy, Geochemistry and Crystal Chemistry of Rare Elements, Moscow, Russia, for his extensive contributions to the mineralogy and geochemistry of alkaline rocks. ***Comments:*** IMA No. 1998-042.

JOHNSEN, O., GAULT, R. A., GRICE, J. D., and ERCIT, T. S. (1999) Khomyakovite and manganokhomyakovite, two new members of the eudialyte group from Mont Saint-Hilaire, Quebec, Canada. *Canadian Mineralogist* **37**, 893–899.



Korobitsynite

Korobitsynite

Orthorhombic

$Na_3(Ti,Nb)_2[Si_4O_{12}](OH,O)_2·3–4H_2O$

Locality: (1) Mount Alluaiv and (2) Mount Karnasurt, Lovozero alkaline massif, Kola Peninsula, Russia.

Occurrence: In high-alkaline hydrothermalites. Associated minerals are: (1) aegirine, albite, elpidite, epididymite, lorenzenite, quartz, shortite, sidorenkite, natroxalate, leifite, rhodochrosite, tainiolite, pyrrhotite, sphalerite, galena, thermonatrite, trona and nahpoite; (2) aegirine, K-feldspar, elpidite, labuntsovite, natrolite, apophyllite, fluorite, sphalerite, galena and molybdenite.

General appearance: (1) prismatic crystals up to 2 cm and (2) grains up to 1 mm.

Physical, chemical and crystallographic properties: *Luster:* vitreous. *Diaphaneity:* transparent. *Color:* colorless. *Streak:* white. *Luminescence:* not mentioned. *Hardness:* about 5. *Tenacity:* brittle. *Cleavage:* {100} imperfect. *Fracture:* rough. *Density:* 2.68 g/cm^3 (meas.), 2.59 g/cm^3 (calc.). ***Crystallography:*** Orthorhombic, *Pbam*, *a* 7.349, *b* 14.164, *c* 7.130 Å, *V* 742.2 Å^3, Z 2, *a*:*b*:*c* = 0.5189:1:0.5034. Morphology: {110}, {010}, {100}, {001}, {021}. Twinning: none observed. It forms epitaxial overgrowths on elpidite crystals. ***X-ray powder diffraction data:*** 7.09 (72) (001, 020), 6.53 (85) (110), 3.262 (100) (201, 220), 3.180 (52) (022, 211, 041), 2.553 (56) (202, 240), 2.075 (57) (242), 1.735 (50) (262). ***Optical data:*** Biaxial (+), α 1.646, β 1.654, γ 1.763, 2V(meas.) 30°, 2V(calc.) 32°; dispersion not observed; nonpleochroic; orientation, X = *b*, Y = *c*, Z = *a*. ***Chemical analytical data:*** Seven sets of electron microprobe data are given (five from Alluaiv and two from Karnasurt). One set from Alluaiv (with H_2O by TGA) gave: Na_2O 13.87, K_2O 0.03, BaO 0.54, SiO_2 40.91, TiO_2 21.38, ZrO_2 0.04, Nb_2O_5 10.14, H_2O 12.20, Total 99.11 wt.%. Empirical formula: $Na_{2.62}(Ti_{1.56}Nb_{0.45})_{\Sigma 2.01}Si_{3.98}O_{13.03}(OH)_{0.97}·3.48H_2O$. ***Relationship to other species:*** It is the titanium-dominant analogue of nenadkevichite.

Name: For Mikhail F. Korobitsyn (1928-1996), an amateur mineralogist and collector who made significant contributions to the mineralogical study of the Lovozero massif. ***Comments:*** IMA No. 1998-019. The calculated density given in the paper is 2.69 g/cm^3.

PEKOV, I. V., CHUKANOV, N. V., KHOMYAKOV, A. P., RASTSVETAEVA, R. K., KUCHERINENKO, Ya. V., and NEDEL'KO, V. V. (1999) Korobitsynite $Na_{3-x}(Ti,Nb)_2[Si_4O_{12}](OH,O)_2·3\text{-}4H_2O$. *Zapiski Vserossiyskogo mineralogicheskogo obshchestva* **128(3)**, 72–79.

Laforêtite

Tetragonal

$AgInS_2$

Locality: The disused Montgros mine (Pinols claim), near the hamlet La Boriette, about 10 km SW of Langeac, Haute-Loire, France (French Lambert coordinates: x = 683,72; y = 303,20).

Occurrence: In a breccia vein sample from the dumps. Associated minerals are: galena, sphalerite, barite, carbonates and quartz.

General appearance: Tiny anhedral inclusions (less than 30 µm) in galena.

Physical, chemical and crystallographic properties: *Luster:* metallic. *Diaphaneity:* opaque. *Color:* havana brown (synthetic material). *Streak:* chocolate brown (synthetic material). *Hardness:* VHN_{100} 183 kg/mm^2, Mohs about 3. *Tenacity:* not given. *Cleavage:* none observed on synthetic material. *Fracture:* not given. *Density:* could not be measured, 4.92 g/cm^3 (calc.). ***Crystallography:*** Tetragonal, $I\bar{4}2d$, *a* 5.880, *c* 11.21 Å, *V* 387.57 Å^3, Z 4, *c*:*a* = 1.9065. Morphology: no forms were observed. Twinning: polysynthetic lamellar observed in polished section. ***X-ray powder diffraction data:*** Because of preferred orientation, the following data are for synthetic material: 3.351 (100) (112), 2.942 (80) (200), 2.082 (75) (220), 2.030 (75) (204), 1.768 (80) (312), 1.707 (35) (116), 1.189 (40) (424). ***Optical data:*** In reflected light (in oil): brownish gray, strong anisotropism brick red with orange tint to bluish-gray purplish, bireflectance not mentioned, weakly pleochroic with brown to clear brown-gray tints. R_{mean}: (26 %) 480nm, (24.6 %) 540nm, (24.2 %) 580nm, (25.8 %) 660nm. ***Chemical analytical data:*** Means of eight sets of electron microprobe data: Cu 0.04, Ag 37.68, In 40.22, Fe 0.02, Se 0.01, S 22.42, Total 100.39 wt.%. Empirical formula: $Ag_{1.00}In_{1.00}S_{2.00}$. ***Relationship to other species:*** It is a member of the chalcopyrite group; specifically the silver-dominant analogue of roquesite, $CuInS_2$.

Name: For Claude P. Laforêt (1936–) a metallographer at the Bureau de Recherches Géologiques et Minières, who first observed the mineral from the Montgros mine. ***Comments:*** IMA No. 1995-006. Because of the very small size of the grains some data had to be obtained from synthetic material.

MEISSER, N., THELIN, P., CHIAPPERO, P.-J., and MAUREL, C. (1999) Laforêtite, $AgInS_2$, a new mineral of the chalcopyrite group from the Montgros mine, Haute-Loire, France. *European Journal of Mineralogy* **11**, 891–897.

Manganokhomyakovite

Trigonal

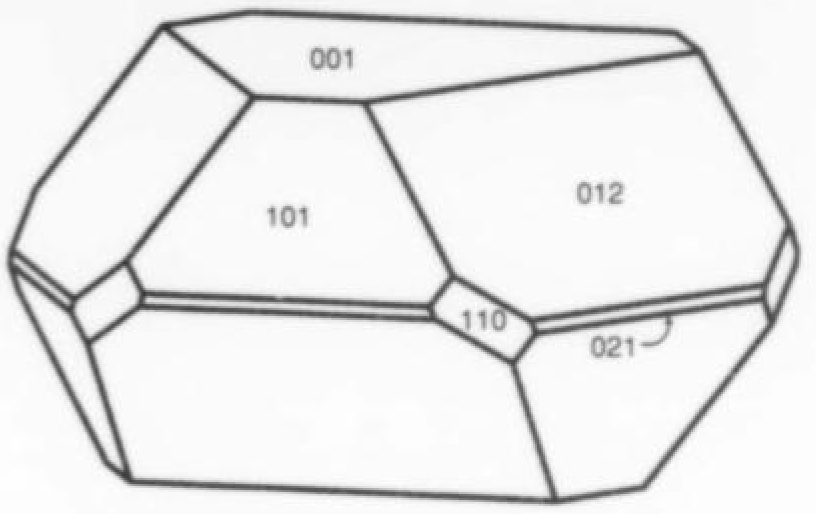
$Na_{12}Sr_3Ca_6Mn^{2+}_3Zr_3W(Si_{25}O_{73})(O,OH,H_2O)_3(OH,Cl)_2$

Locality: The Poudrette quarry, Mont Saint-Hilaire, Rouville County, Quebec, Canada. See Comments.

Occurrence: In nepheline syenite. Associated minerals are: aegirine, albite, analcime, annite, cerussite, galena, kupletskite, microcline, molybdenite, natrolite, pyrite, pyrrhotite, sodalite, sphalerite, titanite, wöhlerite and zircon.

General appearance: Pseudo-octahedral crystals 5 mm in diameter.

Physical, chemical and crystallographic properties: *Luster:* vitreous. *Diaphaneity:* transparent to translucent. *Color:* orange to orange-red. *Streak:* white. *Luminescence:* nonfluorescent. *Hard-*



Manganokhomyakovite

ness: 5 to 6. *Tenacity:* brittle. *Cleavage:* none. *Fracture:* uneven. *Density:* 3.13 g/cm³, 3.17 g/cm³ (calc.). ***Crystallography:*** Trigonal, *R*3*m*, *a* 14.282, *c* 30.12 Å, *V* 5320 Å³, Z 3, *c*:*a* = 2.1089. Morphology: {001}, {110}, {021}, {101}, {012}. Twinning: none mentioned. ***X-ray powder diffraction data:*** 11.500 (90) (101), 9.530 (70) (012), 6.450 (50) (104), 6.070 (50) (021), 5.735 (50) (202), 3.406 (50) (131), 3.213 (50) (208), 3.167 (50) (217), 2.980 (100) (315), 2.856 (80) (404). ***Optical data:*** Uniaxial (−), ω 1.629, ε 1.626, pleochroism moderate, O = yellow-orange, E = pale yellow. ***Chemical analytical data:*** Means of four sets of electron microprobe analyses: Na_2O 10.37, K_2O 0.41, CaO 10.20, MnO 4.21, FeO 2.58, SrO 9.17, Al_2O_3 0.02, La_2O_3 0.12, Ce_2O_3 0.20, SiO_2 42.98, TiO_2 0.02, ZrO_2 10.43, HfO_2 0.17, Nb_2O_5 1.58, Ta_2O_5 0.03, WO_3 4.48, H_2O 0.83, Cl 0.84, sum 98.64, less O = Cl 0.19, Total 98.45 wt.%. H_2O was calculated from the crystal structure results. Empirical formula: $(Na_{11.51}K_{0.30}Ca_{0.25}REE_{0.07}Sr_{0.04})_{\Sigma 12.17}Sr_{3.00}Ca_{6.00}(Mn_{2.04}Fe_{1.23})_{\Sigma 3.27}(Zr_{2.91}Hf_{0.03}Ti_{0.01})_{\Sigma 2.95}(W_{0.66}Nb_{0.41})_{\Sigma 1.07}(Si_{24.60}Al_{0.01})_{\Sigma 24.61}O_{73.00}(O,OH,H_2O)_{3.70}(OH_{1.19}Cl_{0.81})_{\Sigma 2.00}$. ***Relationship to other species:*** A member of the eudialyte group, specifically the manganese-dominant analogue of khomyakovite.

Name: For the relationship to khomyakovite.

Comments: IMA No. 1998-043. The part of the Poudrette quarry from which the original material came was then known as the Demix quarry; they are now a single entity. Mr. László Horváth kindly supplied information to reproduce the crystal drawing here.

JOHNSEN, O., GAULT, R. A., GRICE, J. D., and ERCIT, T. S. (1999) Khomyakovite and manganokhomyakovite, two new members of the eudialyte group from Mont Saint-Hilaire, Quebec, Canada. *Canadian Mineralogist* **37**, 893–899.

Nabiasite — Cubic

$BaMn_9[(V,As)O_4]_6(OH)_2$

Locality: Pla de Labasse deposit near the hamlet of Nabias, Central Pyrénées, France.

Occurrence: In veinlets cross-cutting manganese ores. Associated minerals are: rhodochrosite, friedelite, hübnerite, sphalerite, stilpnomelane, albite, barite, hausmannite, tephroite, welinite and an unidentified manganese vanadate. Several other manganese-bearing minerals occur in the deposit.

General appearance: Anhedral grains (up to 100 µm in diameter).

Physical, chemical and crystallographic properties: *Luster:* given as vitreous, but probably is adamantine. *Diaphaneity:* transparent. *Color:* dark red. *Streak:* dark yellow, almost orange. *Luminescence:* nonfluorescent. *Hardness:* VHN_{25} 465 kg/mm². *Tenacity:* not given. *Cleavage:* none observed. *Fracture:* conchoidal. *Density:* greater than 4.04 g/cm³ (sinks in Clerici solution), 4.33 g/cm³ (calc.). ***Crystallography:*** Cubic, $Pa\bar{3}$, *a* 12.832 Å, V 2112.8 Å³, Z 4. Morphology: No forms were observed. Twinning: none mentioned. ***X-ray powder diffraction data:*** 3.01 (vs) (411), 2.859 (s) (420), 2.790 (vs) (241), 2.608 (vs) (422), 2.332 (vs) (521), 2.134 (vs) (600), 1.510 (vs) (660), 1.0020 (vs) (4.12.2). ***Optical data:*** Isotropic, but most grains are slightly anisotropic, n greater than 2.0. ***Chemical analytical data:*** Means of twenty sets of electron microprobe data: SrO 0.07, BaO 11.83, MnO 47.92, V_2O_5 35.91, As_2O_5 6.03, H_2O (1.36), Total (103.12) wt.%. H_2O calculated. Empirical formula: $(Ba_{1.03}Sr_{0.01})_{\Sigma 1.04}Mn_{9.02}(V_{5.27}As_{0.70})_{\Sigma 5.97}O_{23.98}(OH)_{2.02}$. ***Relationship to other species:*** None apparent.

Name: For the locality. ***Comments:*** IMA No. 1997-050.

BRUGGER, J., BONIN, M., SCHENK, K. J., MEISSER, N., BERLEPSCH, P., and RAGO, A. (1999) Description and crystal structure of nabiasite, $BaMn_9[(V,As)O_4]_6(OH)_2$, a new mineral from the Central Pyrénées (France). *European Journal of Mineralogy* **11**, 879–890.

Nickelphosphide — Tetragonal

$(Ni,Fe)_3P$

Locality: In meteorites from several localities; the holotype material is from the Butler meteorite, Bates Co., Missouri, USA. Other meteorites in which it occurs are (with their names italicized): *Canyon Diablo*, Coconino Co., Arizona, USA; *Carlton*, Hamilton Co., Texas; *Edmonton*, Metcalfe Co., Kentucky, USA; *Efremkova*, Pavlodar oblast, Kazakhstan; *Kenton County*, Kenton Co., USA; *Lenarto*, Sáros, Slovakia; *Monahans*, Ward Co., Texas, USA; *Oktibbeha County*, Oktibbeha Co., Mississippi, USA; and *unnamed Ni-rich ataxite*, Aldan River, Yakutia, Russia.

Occurrence: Associated minerals are: kamacite, taenite, troilite and forsterite.

General appearance: Equant grains (up to 30 µm) and elongated inclusions (up to 200 µm).

Physical, chemical and crystallographic properties: *Luster:* metallic. *Diaphaneity:* opaque. *Color:* megascopic color unknown. *Streak:* unknown. *Hardness:* VHN_{25} 874 kg/mm². *Tenacity:* very brittle. *Cleavage:* none observed. *Fracture:* could not be observed. *Density:* could not be determined, 7.61 g/cm³ (calc.). ***Crystallography:*** Tetragonal, $I\bar{4}$, *a* 8.99, *c* 4.396 Å, *V* 355 Å³, Z 8, *c*:*a* = 0.4890. Morphology: no forms were observed. Twinning: none observed. ***X-ray powder diffraction data:*** 2.48 (2) (031), 2.17 (10) (321), 2.13 (5) (330), 2.08 (5) (112), 2.01 (2) (420), 1.995 (7) (411). ***Optical data:*** In reflected light: white with a pink-yellow tint, anisotropism not present in air weak in yellowish pink colors in oil, no bireflectance, nonpleochroic. $R_{max.}$ & $R_{min.}$: (43.9, 42.3 %) 460 nm, (47.5, 45.7 %) 540 nm, (49.1, 47.6 %) 580 nm, (52.5, 51.3 %) 660 nm. ***Chemical analytical data:*** Means of seven sets of electron microprobe data: Fe 35.5, Ni 49.6, Co 0.2, P 15.3, Total 100.6 wt.%. Empirical formula: $(Ni_{1.71}Fe_{1.29}Co_{0.01})_{\Sigma 3.01}P_{1.00}$. Another seven sets of data gives similar results. ***Relationship to other species:*** It is the nickel-dominant analogue of schreibersite, Fe_3P.

Name: For the composition. ***Comments:*** IMA No. 1998-023.

BRITVIN, S. N., KOLOMENSKY, V. D., BOLDYREVA, M. M., BOGDANOVA, A. N., KRETSER, Yu. L., BOLDYREVA, O. N., and RUDASHEVSKY, N. S. (1999) Nickelphosphide $(Ni,Fe)_3P$, the nickel analog of schreibersite. *Zapiski Vserossiyskogo mineralogicheskogo obshchestva* **128(3)**, 64–72.

Oneillite

Trigonal

$Na_{15}Ca_3Mn_3Fe_3Zr_3Nb(Si_{25}O_{73})(O,OH,H_2O)_3(OH)_2$

Locality: Poudrette Quarry, Mont Saint-Hilaire, Rouville County, Quebec, Canada.

Occurrence: At the contact between a vein of fine-grained albite and the host rock, nepheline syenite. Associated minerals are: albite and sodalite, with minor pyrite and aegirine.

General appearance: Anhedral grains (up to 2 mm in diameter).

Physical, chemical and crystallographic properties: *Luster:* vitreous. *Diaphaneity:* transparent to translucent. *Color:* yellowish brown. *Streak:* white. *Luminescence:* nonfluorescent. *Hardness:* 5 to 6. *Tenacity:* brittle. *Cleavage:* none. *Fracture:* uneven. *Density:* 3.20 g/cm³ (meas.), 3.21 g/cm³ (calc.). ***Crystallography:*** Trigonal, *R*3, *a* 14.192, *c* 29.983 Å, *V* 5230 Å³, Z 3, *c:a* = 2.1127. Morphology: no forms were observed. Twinning: merohedral. ***X-ray powder diffraction data:*** 11.348 (44.2) (101), 6.021 (36.1) (021), 4.291 (36.5) (205), 3.389 (42.9) $(\bar{1}41)$, 3.150 (34.9) $(\bar{2}37)$, 2.964 (100.0) $(\bar{3}45)$, 2.844 (89.1) (404). ***Optical data:*** Uniaxial (−), ω 1.6450, ε 1.6406, some grains show 2V up to 15°, nonpleochroic. ***Chemical analytical data:*** Electron microprobe data for the grain selected for the crystal structure analysis: Na_2O 13.60, K_2O 0.28, CaO 2.90, MnO 7.70, FeO 3.00, SrO 0.09, Al_2O_3 0.18, Y_2O_3 0.78, La_2O_3 2.88, Ce_2O_3 5.14, Pr_2O_3 0.48, Nd_2O_3 1.45, Gd_2O_3 0.20, SiO_2 43.46, ZrO_2 11.44, HfO_2 0.16, Nb_2O_5 3.48, Ta_2O_5 0.14, H_2O 0.63, Cl 0.76, sum 98.75, less O = Cl 0.17, Total 98.58 wt.%. Empirical formula: $(Na_{14.34}REE_{1.53}K_{0.20}Sr_{0.03})_{\Sigma 16.10}(Ca_{1.77}Na_{0.67}REE_{0.57})_{\Sigma 3.01}(Mn_{2.76}Y_{0.24})_{\Sigma 3.00}(Fe_{1.43}Mn_{0.95}Zr_{0.26})_{\Sigma 2.64}(Zr_{0.92}Nb_{0.05}Hf_{0.03})_{\Sigma 1.00}(Nb_{0.85}Ta_{0.02})_{\Sigma 0.87}(Si_{24.75}Al_{0.12})_{\Sigma 24.87}O_{73.00}(O,OH,H_2O)_{3.00}[(OH)_{1.27}Cl_{0.73})_{2.00}$. ***Relationship to other species:*** A member of the eudialyte group.

Name: For John Johnston O'Neill (1886–1966), a geologist with the Geological Survey of Canada and later a professor of geology at McGill University, Montreal, Quebec. He was the first to describe the geology of Mont Saint-Hilaire and the first to report eudialyte and other rare, peralkaline minerals at this locality. He was a member of the Stefansson Arctic Expedition of 1913–1918. ***Comments:*** IMA No. 1998-064.

JOHNSEN, O., GRICE, J. D., and GAULT, R. A. (1999) Oneillite: a new Ca-deficient and *REE*-rich member of the eudialyte group from Mont Saint-Hilaire, Quebec, Canada. *Canadian Mineralogist* **37**, 1295–1301.

Palladodymite

Orthorhombic

$(Pd,Rh)_2As$

Locality: In a small unnamed placer deposit in the upper Miass River, South Urals, Russia.

Occurrence: Associated minerals are: ruthenium, isoferroplatinum, cherepanovite, rhodian irarsite, honshiite, sperrylite, tulameenite, and unnamed IrAsTe.

General appearance: Inclusions (up to 30 x 70 µm) in ruthenium.

Physical, chemical and crystallographic properties: *Luster:* metallic. *Diaphaneity:* opaque. *Color:* megascopic color unknown. *Streak:* unknown. *Hardness:* VHN_{20} 566 kg/mm². *Tenacity:* brittle. *Cleavage:* not observed. *Fracture:* not given. *Density:* could not be measured, 11.26 g/cm³ (calc.). ***Crystallography:*** Orthorhombic, *Pnma*, *a* 5.91, *b* 3.90, *c* 7.34 Å, *V* 169 Å³, Z 4, *a:b:c* = 1.5154:1:1.8821. Morphology: no forms were mentioned. Twinning: none observed. ***X-ray powder diffraction data:*** 2.43 (10) (112), 2.24 (5) (211), 2.06 (1) (013), 1.838 (3) (004). ***Optical data:*** In reflected light: brownish gray with a bluish tint, distinct anisotropism from bluish-gray to reddish-brown, bireflectance weak, pleochroism brownish to bluish. $R_{max.}$ & $R_{min.}$: (51.6, 45.8 %) 480nm, (54.0, 46.8 %) 540nm, (56.2, 48.0 %) 580nm, (59.1, 50.2 %) 660nm. ***Chemical analytical data:*** Means of four sets of electron microprobe data: Ni 3.0, Ru 2.4, Rh 27.6, Pd 33.5, Os 1.0, Ir 1.7, Pt 4.4, As 26.5, Total 100.1 wt.%. Empirical formula: $(Pd_{0.90}Rh_{0.77}Ni_{0.15}Ru_{0.07}Pt_{0.06}Ir_{0.03}Os_{0.02})_{\Sigma 2.00}As_{1.01}$. ***Relationship to other species:*** It is isostructural with rhodarsenide and is polymorphous with palladoarsenide and palladobismutharsenide.

Name: From *pallad*ium and the Greek διμοσ (twin) as it is the palladium-dominant analogue of rhodarsenide. ***Comments:*** IMA No. 1997-028.

BRITVIN, S. N., RUDASHEVSKY, N. S., BOGDANOVA, A. N., and SHCHERBACHOV, D. K. (1999) Palladodymite $(Pd,Rh)_2As$, a new mineral from a placer of the Miass River, the Urals. *Zapiski Vserossiyskogo mineralogicheskogo obshchestva* **128(2)**, 39–42.

Parascorodite

Hexagonal or Trigonal

$Fe^{3+}AsO_4{\cdot}2H_2O$

Locality: Weathered ore dumps of the Kuntery mine, Kaňk, near Kutná Hora, Central Bohemia, Czech Republic. Also from the Geschieber vein of the Svornost mine in the Jáchymov (Joachimsthal ore district), Czech Republic.

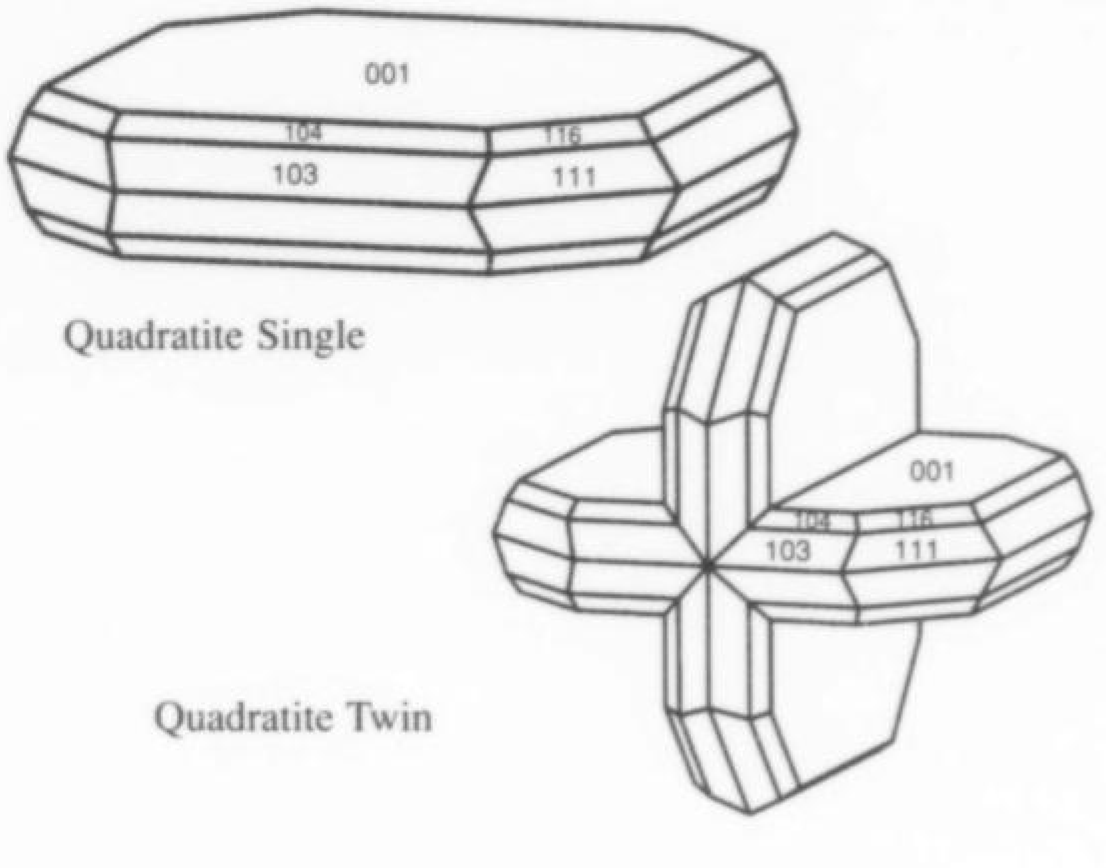
Occurrence: A secondary mineral resulting from the alteration of arsenopyrite. Associated minerals are: scorodite, pitticite, bukovskýite, kaňkite, zýkaite, gypsum, jarosite and amorphous ferric hydroxides. At the Svornost mine, the associated minerals are: scorodite, quartz, pyrite, proustite, kaňkite, "vajdakite" (see Comments) and arsenic.

General appearance: Earthy, cryptocrystalline aggregates of poorly developed hemispherical shape up to 2 cm in diameter consisting of small crystals (between 0.1 to 0.5 µm) and twinned individuals up to 1 µm.

Physical, chemical and crystallographic properties: *Luster:* earthy. *Diaphaneity:* not mentioned but presumably opaque. *Color:* white with a yellowish tint. *Streak:* yellowish-white. *Luminescence:* not mentioned. *Hardness:* soft. *Tenacity:* not mentioned. *Cleavage:* parting is mentioned. *Fracture:* conchoidal. *Density:* 3.213 g/cm³ (meas.), 3.24 g/cm³ (calc.). ***Crystallography:*** Hexagonal or trigonal, space group unknown but the extinction symbol is *P-c-*, *a* 8.9327, *c* 9.9391 Å, *V* 686.83 Å³, Z 6, *c:a* = 1.1127. Morphology: no forms were identified, but prisms are mentioned and hexagonal basal sections were observed. Twinning: present. ***X-ray powder diffraction data:*** 4.973 (61) (002), 4.076 (100) (111), 3.053 (67) (202), 2.806 (68) (211), 2.661 (59) (113), 2.520 (54) (212). See Comments. ***Optical data:*** Because of the fine-grained nature of the material, the usual data could not be obtained. The mean index of refraction is higher than 1.72 and birefringence is very low to almost indiscernible. ***Chemical analytical data:*** Means of two sets of wet chemical analyses gave: Al_2O_3 0.17, Fe_2O_3 34.55, SO_3 1.53, P_2O_5 0.84, As_2O_5 44.45, H_2O^+ 16.81, H_2O^- 1.60, Total 99.95 wt.%. Empirical formula (ignoring H_2O^-): $(Fe^{3+}_{0.98}Al_{0.01})_{\Sigma 0.99}[(AsO_4)_{0.88}(PO_4)_{0.03}(SO_4)_{0.04}]_{\Sigma 0.95}O_{0.08}{\cdot}2.12H_2O$. ***Relationship to other species:*** The hexagonal or trigonal dimorph of scorodite.

Name: For the relationship with scorodite. ***Comments:*** IMA No. 1996-061a. The authors' selection of the strongest lines given in their abstract differs somewhat from that given here. A description of the mineral referred to as "vajdakite" has not been published.

ONDRUŠ, P., SKÁLA, R., VITI, C., VESELOVSKÝ, F., NOVÁK, F., and JANSA, J. (1999) Parascorodite, $Fe^{3+}AsO_4 \cdot 2H_2O$—a new mineral from Kaňk near Kutná Hora, Czech Republic. *American Mineralogist* **84**, 1439–1444.



Quadratite Single

Quadratite Twin

Quadratite Tetragonal

$Ag(Cd,Pb)(As,Sb)S_3$

Locality: The Lengenbach quarry, Binntal, Canton Wallis, Switzerland.

Occurrence: In cavities in dolomite. Associated minerals are: jordanite, galena and pyrite; less commonly with sphalerite, lengenbachite and hatchite.

General appearance: Thin, tabular crystals mostly about 0.1 mm across; rarely over 1 mm.

Physical, chemical and crystallographic properties: *Luster:* metallic. *Diaphaneity:* opaque, but very thin laminae are translucent. *Color:* gray (thin laminae are brown-red). *Streak:* reddish brown. *Hardness:* VHN_{10} 63 kg/mm², Mohs ≤ 3. *Tenacity:* ductile to flexible. *Cleavage:* {001} perfect micaceous, {110} distinct. *Fracture:* not given. *Density:* could not be determined, 5.32 g/cm³ (calc.). ***Crystallography:*** Tetragonal, *I4/amd*, *a* 5.499, *c* 33.91 Å, *V* 1025 Å³, Z 8, *c:a* = 6.1666. Morphology: The following forms were observed: {001}, {103}, {104}, {111} and {116}. Twinning: Penetration along (016). ***X-ray powder diffraction data:*** 3.19 (50) (116), 2.77 (100) (200), 1.960 (80) (2.0.12), 1.679 (70) (2.0.16), 1.664 (40) (2.1.15), 1.598 (70) (2.2.12, 3.0.11), 1.274 (60) (4.0.10). ***Optical data:*** An indistinct nearly uniaxial interference figure of unknown character is seen in transmitted light. In reflected light: grayish-white with a bluish tint, dark red internal reflections along cleavage cracks; because only sections parallel to {001} could be prepared no information could be obtained for anisotropism, bireflectance and pleochroism. R, ^{im}R: (30.5-32.3, 12.5-14.0) 470 nm, (29.6-30.8, 12.2-13.3) 543 nm, (28.7-29.7, 12.0-12.9) 587 nm, (26.3-28.0, 1.3-12.3) 650 nm. ***Chemical analytical data:*** Means of six sets of electron microprobe data: Cu 0.05, Ag 26.30, Cd 21.42, Pb 10.17, Sb 0.27, As 18.06, Tl 0.49, S 23.61, Total 100.37 wt.%. Empirical formula: $(Ag_{1.00})(Cd_{0.78}Pb_{0.20}Tl_{0.01})_{\Sigma 0.99}(As_{0.99}Sb_{0.01})_{\Sigma 1.00}S_{3.01}$. ***Relationship to other species:*** The first example of a silver-cadmium-arsenic sulfide.

Name: For the conspicuous quadratic shape of the crystals which is distinct from other Lengenbach species. ***Comments:*** IMA No. 1994-038. Dr. Graeser kindly supplied SHAPE data to produce the drawings shown here.

GRAESER, S., LUSTENHOUWER, W., and BERLEPSCH, P. (1998) Quadratite $Ag(Cd,Pb)(As,Sb)S_3$—a new sulfide mineral from Lengenbach, Binntal (Switzerland). *Schweizerische mineralogische und petrographische Mitteilungen* **78**, 489–494.

Sidpietersite Triclinic

$Pb_4^{2+}(S^{6+}O_3S^{2-})O_2(OH)_2$

Locality: The Tsumeb mine, Tsumeb, Namibia (Lat. 19° S, Long. 18° E).

Occurrence: On a matrix of fine-grained galena and sphalerite. Other associated minerals are: smithsonite, zincite, greenockite and quartz.

General appearance: Ill-formed, almost warty, nodular masses and crystal groups, earthy masses and, rarely, as free-standing to radiating aggregates of bladed crystals up to 3 mm in maximum dimension; most are much smaller. Individual subhedral to euhedral crystals (up to 0.3 mm long) are elongate along $[01\bar{1}]$ with a length-to-width ratio of 4:1. Some crystals are platy on {001}.

Physical, chemical and crystallographic properties: *Luster:* vitreous to earthy to somewhat pearly. *Diaphaneity:* transparent to opaque. *Color:* beige-cream to off-white to colorless. *Streak:* cream-colored to off-white. *Luminescence:* nonfluorescent. *Hardness:* VHN_{25} 57 to 67 kg/mm², Mohs 1 to 2. *Tenacity:* sectile. *Cleavage:* perpendicular to $[01\bar{1}]$. *Fracture:* uneven. *Density:* could not be measured, 6.88 g/cm³ (calc.). ***Crystallography:*** Triclinic, $P\bar{1}$, *a* 7.447, *b* 6.502, *c* 11.206 Å, α 114.30°, β 89.51°, γ 89.04°, *V* 494.4 Å³, Z 2, *a:b:c* = 1.1453:1:1.7235. Morphology: {001} dominant, {100}, $\{01\bar{1}\}$. Twinning: none observed. ***X-ray powder diffraction data:*** 10.13 (100) (001), 5.93 (50) (010), 4.401 (35) (011), 3.414 (100) (003), 3.198 (80) $(02\bar{2})$, 2.889 (35) $(02\bar{3}, 211)$, 2.805 (35) $(\bar{2}11, 01\bar{4})$, 2.622 (40) $(\bar{2}1\bar{3})$. ***Optical data:*** In reflected light: light gray, bireflectant, perhaps slightly pleochroic. Optical properties were difficult to measure and the reflectance values are considered erroneous due to internal reflections. The general spectral reflectance is low (12 to 14%) and n is about 2. ***Chemical analytical data:*** Means of five sets of electron microprobe data after converting Pb to PbO and partitioning S to S^{6+} and S^{2-} and calculating H_2O to give 2(OH): PbO 89.55, SO_3 7.58, S 3.03, H_2O 1.79, sum 101.96, less O = S 1.51, Total 100.44 wt.%. Empirical formula: $Pb_{4.09}(S^{6+}_{0.97}O_{2.90}S^{2-}_{0.97})O_{2.09}(OH)_{2.03}$. ***Relationship to other species:*** None apparent.

Name: For Mr. Sidney ("Sid") Pieters (1920–) of Windhoek, Namibia, in recognition of his outstanding contributions to Namibian mineralogy. ***Comments:*** IMA No. 1998-036.

ROBERTS, A. C., COOPER, M., HAWTHORNE, F. C., CRIDDLE, A. J., STANLEY, C. J., KEY, C. L., and JAMBOR, J. L. (1999) Sidpietersite, $Pb_4^{2+}(S^{6+}O_3S^{2-})O_2(OH)_2$, a new thiosulfate-bearing mineral species from Tsumeb, Namibia. *Canadian Mineralogist* **37**, 1269–1273. COOPER, M. and HAWTHORNE, F. C. (1999) The structure topology of sidpietersite, $Pb_4^{2+}(S^{6+}O_3S^{2-})O_2(OH)_2$, a novel thiosulfate structure. *Canadian Mineralogist* **37**, 1275–1282

Silvialite Tetragonal

$Ca_4Al_6Si_6O_{24}SO_4$

Locality: McBride Province, northern Queensland, Australia.

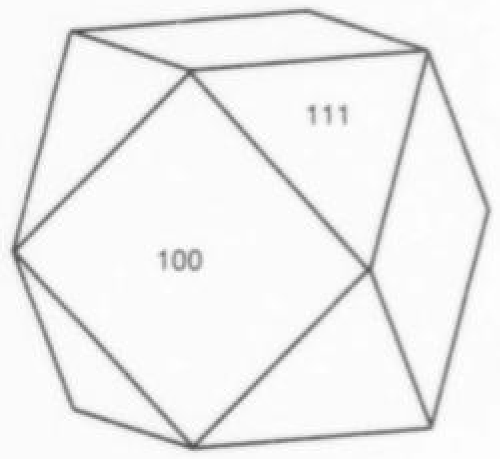
Occurrence: In upper-mantle garnet-granulite xenoliths in olivine nephelinite. Associated minerals are: anorthite and albite (given as plagioclase, An_{70} and An_{45}, respectively), calcite, pargasite, diopside, pyrope, spinel and ilmenite.

General appearance: Subhedral grains elongated [001] (up to 3 mm long).

Physical, chemical and crystallographic properties: *Luster:* subvitreous. *Diaphaneity:* transparent. *Color:* slightly yellow. *Streak:* white. *Luminescence:* non-fluorescent, but shows faint deep-red cathodoluminescence. *Hardness:* about 5½. *Tenacity:* brittle. *Cleavage:* {100} good. *Fracture:* conchoidal. *Density:* 2.75 g/cm³ (meas.), 2.79 g/cm³ (calc.). ***Crystallography:*** Tetragonal, *I4/m*, *a* 12.160, *c* 7.560 Å, *V* 1115.4 Å³, Z 2, *c:a* = 0.6244. Morphology: no forms were observed. Twinning: none mentioned. ***X-ray powder diffraction data:*** 6.03 (5) (020), 3.82 (20) (130), 3.49 (5) (031), 3.45 (100) (112), 3.07 (40) (231), 3.04 (15) (040), 2.74 (5) (141), 2.69 (15) (132). ***Optical data:*** Uniaxial (−), ω 1.585, ε 1.558, ***Chemical analytical data:*** Means of eleven sets of electron microprobe data: Na_2O 3.49, K_2O 0.06, CaO 16.95, SrO 0.08, Al_2O_3 26.25, Fe_2O_3 0.22, SiO_2 45.26, CO_2 1.92, SO_3 4.82, Cl 0.02, sum 99.07, less O = Cl 0.00, Total 99.07 wt.%. Empirical formula: $(Ca_{2.86}Na_{1.07}Fe_{0.03}K_{0.01}Sr_{0.01})_{\Sigma 3.98}Al_{4.87}Si_{7.13}O_{24.03}[(SO_4)_{0.57}(CO_3)_{0.41}Cl_{0.01}]_{\Sigma 0.99}$. ***Relationship to other species:*** A member of the scapolite group; specifically, the sulfate-dominant analogue of meionite.

Name: The name was suggested by Brauns (1914) for the hypothetical SO_4 scapolite endmember. ***Comments:*** IMA No. 1998-010.

TEERTSTRA, D. K., SCHINDLER, M., SHERRIFF, B. L., and HAWTHORNE, F. C. (1999) Silvialite, a new sulfate-dominant member of the scapolite group with an Al-Si composition near the I4/m - $P4_2/n$ phase transition. *Mineralogical Magazine* **63**, 321–329. BRAUNS, R. (1914) Skapolithführende Auswürflinge aus dem Laacher Seegebiet. *Neues Jahrbuch für Mineralogie, Geologie und Paläntologie* **39**, 79–125.



Walfordite

Walfordite

Cubic

$(Fe^{3+},Te^{6+})Te^{4+}_3O_8$

Locality: The Wendy Open Pit, Tambo mine, at the El Indio–Tambo mining property, Coquimbo Province, Chile (approximately Lat. 30° S, Long. 70° W). The property, in the Andes Mountains at about 3,950 m elevation, is approximately 640 km north of Santiago and 160 km east of La Serena.

Occurrence: In hydrothermally altered rhyolitic and dacitic pyroclastic volcanic rocks.

General appearance: Equant crystals 0.2 mm across.

Physical, chemical and crystallographic properties: *Luster:* adamantine. *Diaphaneity:* opaque. *Color:* orange. *Streak:* yellow-orange. *Luminescence:* nonfluorescent. *Hardness:* could not be measured. *Tenacity:* brittle. *Cleavage:* not observed. *Fracture:* not mentioned. *Density:* could not be measured, 5.84 g/cm³ (calc.). ***Crystallography:*** Cubic, $I2_1/a\bar{3}$, *a* 11.011 Å, *V* 1335.0 Å³, Z 8. Morphology: {100} and {111}; mostly cubes, but some modified by octahedral faces. Twinning: None observed. ***X-ray powder diffraction data:*** 4.486 (29) (211), 3.175 (100) (222), 2.943 (23) (321), 2.749 (37) (400), 2.592 (22) (411), 1.944 (44) (440), 1.658 (45) (622). ***Optical data:*** Isotropic, n > 2.00; a value for n of 2.23 was calculated from the Gladstone-Dale relationship. In reflected light, isotropic, pale gray. R, ^{im}R: (16.0, 5.05 %) 470 nm, (15.3, 4.77 %) 546 nm, (15.1, 4.64 %) 590 nm, (15.0, 4.51 %) 650 nm. ***Chemical analytical data:*** Means of three electron microprobe analyses: MgO 0.38, Fe_2O_3 8.30, TiO_2 1.11, TeO_2 81.74, TeO_3 8.67, Total 100.20 wt.%. Empirical formula: $(Fe^{3+}_{0.61}Te^{6+}_{0.29}Ti_{0.08}Mg_{0.06})_{\Sigma 1.04}Te^{4+}_{3.00}O_{8.00}$. ***Relationship to other species:*** Isostructural with winstanleyite, $TiTe^{4+}_3O_8$, and is its (Fe^{3+},Te^{6+})-dominant analogue.

Name: For Mr. Phillip Walford (1945–), who collected the mineral and made material available for the study. ***Comments:*** IMA No. 1996-003.

BACK, M. E., GRICE, J. D., GAULT, R. A., CRIDDLE, A. J., and MANDARINO, J. A. (1999) Walfordite, a new tellurite species from the Wendy Open Pit, El Indio–Tambo mining property, Chile. *Canadian Mineralogist* **38**, 1261–1268.

Zincohögbomite

Hexagonal

$(Zn,Fe)_{2-2x}Ti_xAl_4O_8$

Locality: The emery deposit at Kerketefs Mountain (or Mt. Kerkis), western Samos Island, Greece. Also in the Menderes Massif, Turkey.

Occurrence: In diasporites (diaspore-bearing metabauxites) and emeries (corundum-bearing metabauxites). The type material (Greece) is from an emery and is associated with: corundum (partly altered to diaspore), chloritoid, Ti-rich hematite, ilmenite, gahnite, "tourmaline," rutile, and calcite. The Turkey material is from a diasporite and is associated with: diaspore, chloritoid, muscovite, paragonite, titanian hematite, gahnite, "tourmaline," rutile, "chlorite," and calcite.

General appearance: Star-like aggregates of single crystals (up to 0.3 mm).

Physical, chemical and crystallographic properties: *Luster:* adamantine. *Diaphaneity:* transparent in thin section. *Color:* deep brown to black. *Streak:* brownish. *Luminescence:* non-fluorescent. *Hardness:* VHN_{100} 1200 to 1400 kg/mm², Mohs about 7. *Tenacity:* brittle. *Cleavage:* not observed. *Fracture:* conchoidal. *Density:* could not be determined, 4.36 g/cm³ (calc.). ***Crystallography:*** Hexagonal, probably $P6_3mc$, *a* 5.708, *c* 18.31 Å, *V* 516.7 Å³, Z 4, *c:a* = 3.2078. Morphology: forms {104} and {001} are given, but other forms must be present also (see Comments). Twinning: none observed. ***X-ray powder diffraction data:*** 2.85 (50), 2.60 (80), 2.42 (100), 1.592 (60), 1.550 (50), 1.470 (70), 1.425 (80). ***Optical data:*** Uniaxial (−), ω 1.878, ε 1.832, pleochroism strong with O = dark brown, E = brown. ***Chemical analytical data:*** Means of ten sets of electron microprobe data: MgO 0.48, FeO 13.85, CoO 0.20, NiO 1.01, ZnO 18.87, Al_2O_3 59.90, Cr_2O_3 0.12, TiO_2 5.71, Total 100.14 wt.%. Empirical formula: $(Zn_{0.79}Fe_{0.65}Ni_{0.05}Mg_{0.04}Co_{0.01})_{\Sigma 1.54}Ti_{0.24}(Al_{3.98}Cr_{0.01})_{\Sigma 3.99}O_{8.00}$. ***Relationship to other species:*** It is the zinc-dominant analogue of högbomite and is the -8*H* polytype.

Name: For the relationship to högbomite. ***Comments:*** IMA No. 1994-016. The mineral is stated to occur as epitactic overgrowths on gahnite crystals with [001] of zincohögbomite parallel to [111] of gahnite. The two forms listed in the paper do not result in a complete crystal, so something is wrong.

OCKENGA, E., YALCIN, Ü., MEDENBACH, O., and SCHREYER, W. (1998) Zincohögbomite, a new mineral from eastern Aegean metabauxites. *European Journal of Mineralogy* **10**, 1361–1366.

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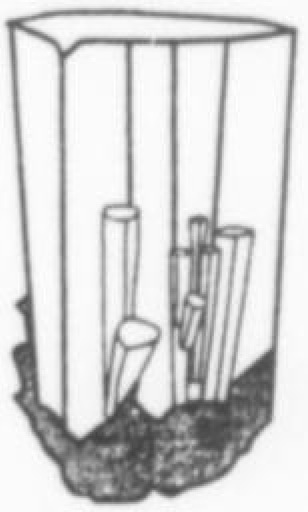

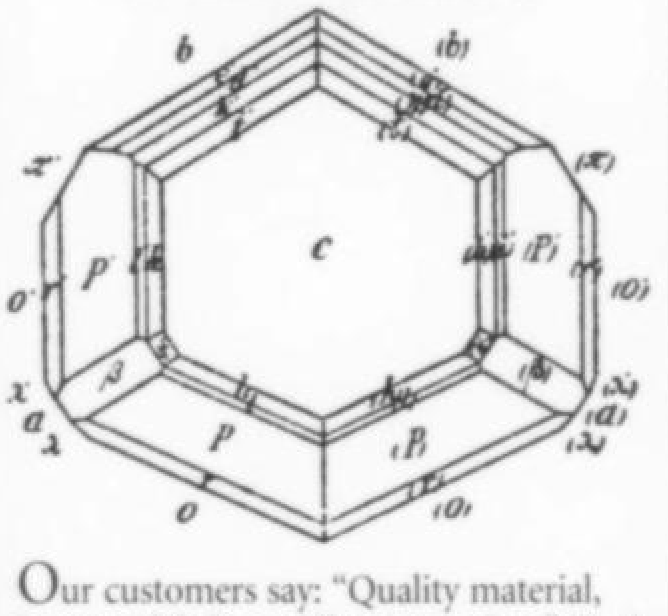
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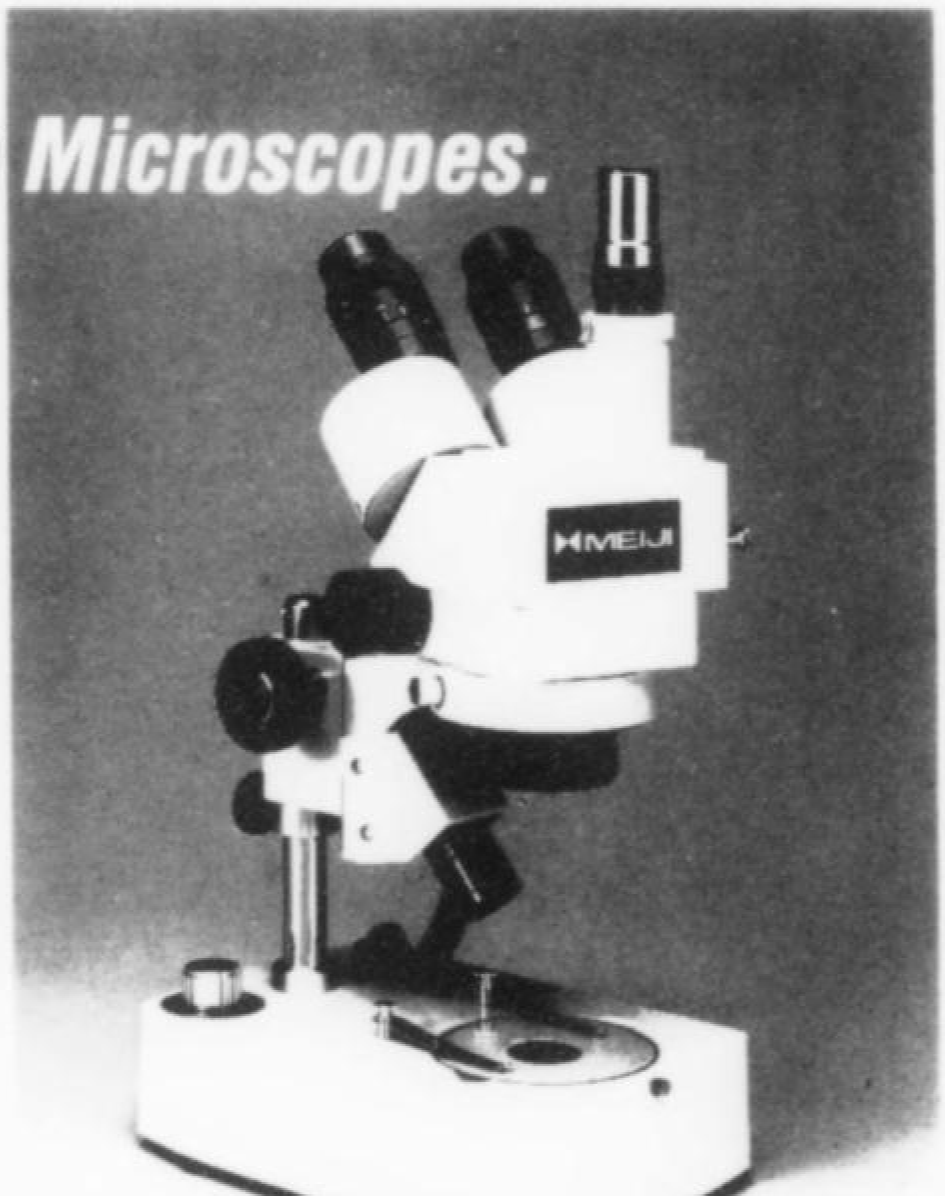
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