the
Mineralogical
Record

Volume Thirteen, Number Three
May-June 1982 $4


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the Mineralogical Record

(USPS 887-700)

Volume Thirteen, Number Three
May-June 1982

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John S. White
Smithsonian Institution

editor
Wendell E. Wilson

associate editors
written content:
Paul E. Desautels
Smithsonian Institution
Pete J. Dunn
Smithsonian Institution
Peter G. Embrey
British Museum
(Natural History)
Richard C. Erd
U.S. Geological Survey
Richard V. Gaines
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photomicrography
Julius Weber
Mamaroneck, New York

circulation manager
Mary Lynn White

designed by
Wendell E. Wilson
Mineralogical Record

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

published
bimonthly by the
Mineralogical Record Inc.,
6349 N. Orange Tree Dr.,
Tucson, Arizona 85740
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Italy:
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COVER: ADAMITE from the Ojuela mine, Mapimi, Durango, Mexico; collected in 1981. The group is 1¼ x ⅞ inches; John Whitmore collection; photo by Harold and Erica Van Pelt, Los Angeles.

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GUEST EDITORIAL

Locality-oriented mineral societies

Mineral collectors are numerous. They have been sorted, for the most part, on the basis of where they reside. Although this residence-determined sorting does provide ease of meeting regularly and generate additional social contact, it serves few other purposes well. The diversity of a local club in having members of all inclinations (crystal-collectors, micromounters, lapidaries, metal-smiths, field collectors, etc.) can be a frustration in that there are only a few with similar interests, which generates clustering on the basis of speciality.

Specialization in mineral collection-building is an activity that comes naturally to many collectors, especially to those who had more diversified interests as their hobby developed. Such specialization is not for everyone but, for those whose dispositions and abilities are well-suited to the challenge, it can be a most rewarding endeavor. For most such collectors, specialization takes the form of either certain mineral or locality specialization. The latter is the subject of this discussion.

What I propose is that serious consideration be given to the formation of mineral societies whose common focus is the collecting of specimens and the search for understanding of a particular mineral deposit, or a closely related group of deposits. Here and there in a collector community are individuals with a strong interest in one deposit (or a series of related deposits) who are pretty much operating on their own. The sum of the knowledge of several such people would be greater than the parts, so to speak, but it is not gathered together in any way. Strong possibilities that come to mind include: a Laurion Society, a Långban Society, a Hagendorf Society, a Cornwall Society, a California Pegmatite Society, to name but a few (with sincere and deep apologies to those whose favorite locality was not mentioned). In a few cases, such societies already exist: The Franklin-Ogdensburg Mineralogical Society being a case in point.

The excitement that is generated by such specialization is contagious! An annual or biannual gathering can be quite an intense experience! Collections are generated which have indisputable value to the science of mineralogy. Visits to museums become much more meaningful because one focuses on certain specimens instead of being overwhelmed by everything. There is a special feeling of making a worthwhile contribution as one develops a certain expertise that is held by few others, and then goes on to share that expertise enthusiastically.

These societies could begin in several different ways. Some might form in an informal structure wherein a mineralogist concentrating on a particular mineral deposit may choose to interact intensely with a small group of people who are self-designated collectors of that locality. This interaction benefits both the collector and the mineralogist, but such groups must be small to be effective.

It seems to me that there are needs for somewhat larger structured groups of collectors who might study deposits of interest to them. The interest-level exists within the collector-community at this time; collectors may gather and become contributors. The opportunity to contribute and benefit the science is a real one. There is much that might be done by locality-intensive societies in the way of specimen preservation, compilations of lists of species, the hosting of symposia, re-mapping of old workings, new field studies, specimen donation programs and more.

The development of specialized societies is both easy and difficult. The easy part is locating the enthusiasts. The difficult part is to identify the critical person(s) who have the energy level and dedication necessary to coordinate communications, arrange an annual gathering (likely at a major mineral show), and see to it that projects are completed. Most of the work will be done by a few, a usual, and those who choose to start-up a society should accept this fact before commencing. My experience has revealed one strong handicap, and that is the fact that few mineral collectors are skilled correspondents. Successful species collectors usually tend to their correspondence, but few other collectors have such inclinations. The formation and continuation of specialized societies requires the discipline of written communications; there is no other way. It should be a requirement for membership.

The rewards are many, the satisfactions are significant. The development of locality-focused mineral societies could assist the hobby, the science, and future collectors, and could also be a lot of fun for everyone involved.

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

notes from the EDITOR

CRYSTAL MODELS AVAILABLE

A set of transparent acrylic plastic crystal models is being manufactured and marketed by Saul Krotki and Kathleen Nowell of Krotki Iron Mines (P.O. Box 42793, Los Angeles, CA 90042). The models, called *Plastihedrons,* are duplicates of the old F. Kranz set and are Dana-correlated. The first set of models (other sets are planned) average about 2 inches each and come 48 to the set, for $1000.

ARIZONA ISSUES

As of this writing, we have a box or two of Bisbee issues left . . . not many, considering that we had 2000 *extra* copies printed. Anyone wanting an extra copy should write soon to the circulation manager ($2.40 plus 50¢ postage per copy to subscribers and dealers; $4.00 per copy to everyone else).

Early next year the fourth and final issue of the Arizona series will be published, completing our planned four-issue treatment of the state. And, yes, there are plenty of famous localities still to be covered in Arizona-IV!

Minrecordite

a new mineral from Tsumeb

by **Carlo G. Garavelli** and **Filippo Vurro**
Instituto di Mineralogia e Petrografia
University of Bari, Piazza Umberto
70121 Bari, Italy

and **Gian Carlo Fioravanti**
Gruppo Mineralogico Romano
2 Via Monterone
00186 Rome, Italy

ABSTRACT

Minrecordite is the Ca and Zn member of the dolomite series, $CaZn(CO_3)_2$, with an ordered arrangement of cations and belonging to space group $R\bar{3}$. It was found on a unique dioptase specimen from Tsumeb, Namibia, which came from the second oxidation zone, presumably at the 30–32 level. The mineral forms minute, twisted, pearly, lustrous rhombohedrons up to about 0.5 mm. They grew following a first generation of large dioptase crystals, and before a second generation characterized by more minute and morphologically complex individuals.

Two distinct variants of minrecordite have been identified. **Type A** represents nearly pure $CaZn(CO_3)_2$, with only a minor substitution of Mg, Fe, and Mn for Zn. It has $a = 4.8183(4)$, $c = 16.0295(10)$Å. Measured specific gravity is 3.45(2); calculated density is 3.445 g/cm³. The indices of refraction are $\omega = 1.750(2)$, $\epsilon = 1.550(2)$. **Type B** is a magnesian variety. Its unit-cell parameters are larger; specific gravity and indices of refraction are lower. Its deposition is apparently earlier than that of pure minrecordite.

On several dioptase druses from Tsumeb a mineral occurs, quite similar in appearance to minrecordite, and occupying the same position in the paragenetic sequence. This mineral can be easily confused visually with minrecordite itself, but analyses show it to be merely a zincian variety of dolomite.

The mineral and its name were approved by the I.M.A. Commission in February 1981. It is named from *Min*eralogical *Record,* a worthy magazine in promoting both a better knowledge of Tsumeb minerals and a more beneficial interaction between professional and amateur mineralogists. The holotype specimen of minrecordite is in the Museum of the Institute of Mineralogy, Bari (Italy) University.

INTRODUCTION

In 1967 one of us (G. Fioravanti) obtained in exchange, from a Johannesburg collector, several specimens of crystallized dioptase from Tsumeb. One specimen, about 5 x 5 x 6 cm, exhibited, scattered on dioptase, a number of microcrystals of a white mineral. These were provisionally labeled "willemite," perhaps on the basis of its high Zn content as revealed by some qualitative chemical tests.

Some years later, a more accurate re-examination of this specimen showed that the white mineral forms very small, strongly twisted rhombohedral crystals, quite dissimilar in their morphology from any known willemite crystals. Moreover, the occurrence of younger willemite on dioptase seemed in disagreement with the paragenetic sequences of Tsumeb secondary minerals, as described by Keller (1977). For these reasons, the specimen was submitted to the attention of the Institute of Mineralogy of Bari University, in order to establish the true identity of the minute white crystals.

As a result of this detailed study, we became convinced that we were dealing with a new mineral species, of ideal composition $CaZn(CO_3)_2$, corresponding to a new member of the dolomite series. For this new mineral we have proposed the name *minrecordite.* This name is in honor of the magazine the *Mineralogical Record,* which is especially worthy as an active promoter of a better knowledge of Tsumeb minerals. Moreover, this mineral has been found as a result of collaboration between professional mineralogists and a collector. Thus the name seems particularly appropriate owing to the worldwide success of the *Mineralogical Record* in bridging the gap between professional and amateur mineralogists.

The new mineral and its name were approved by the I.M.A. Commission on New Minerals and Mineral Names in February 1981.

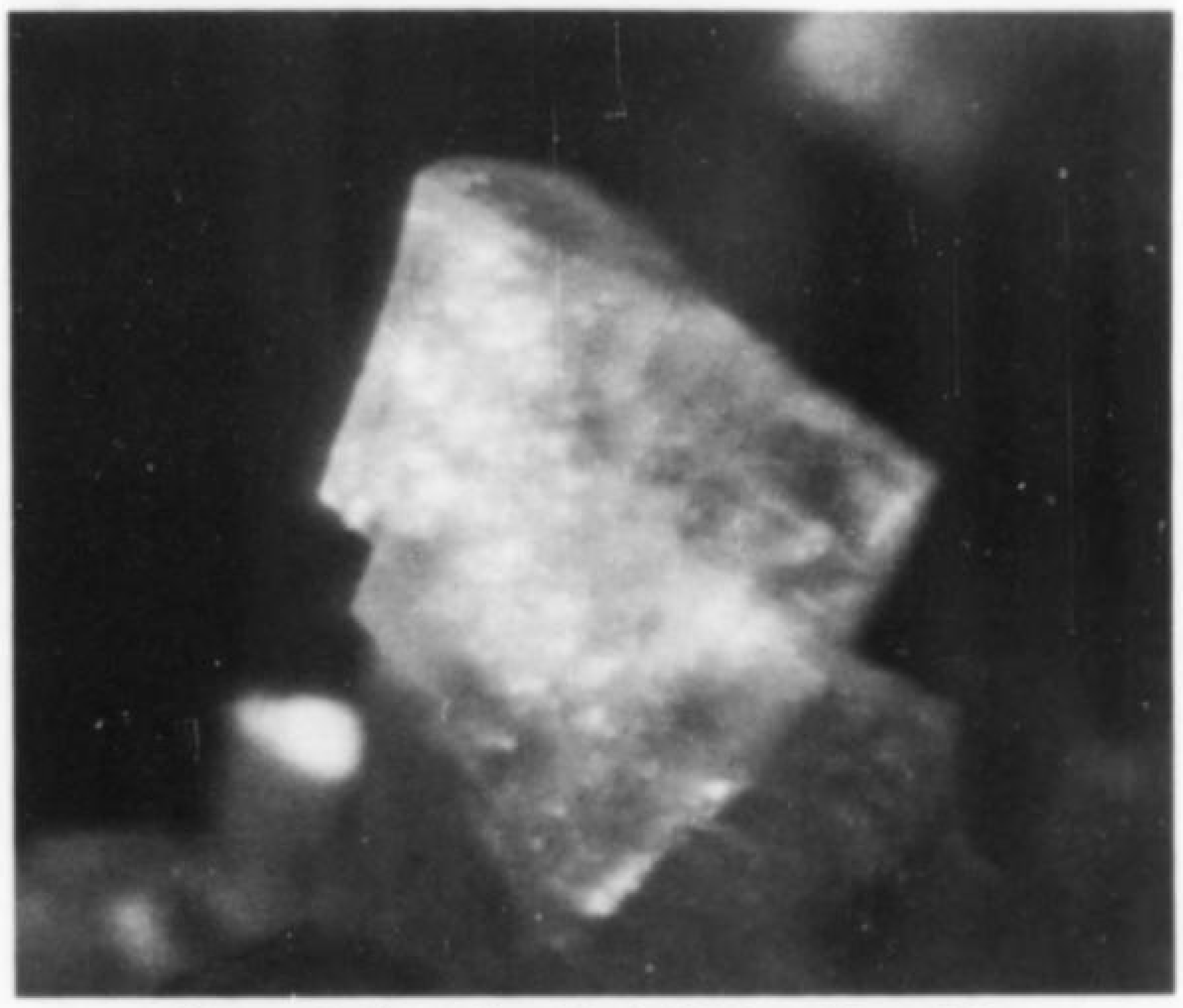

Figure 1. **A moderately twisted, milky white mosaic rhombohedron of minrecordite measuring 0.075 mm on edge. Fioravanti specimen.**

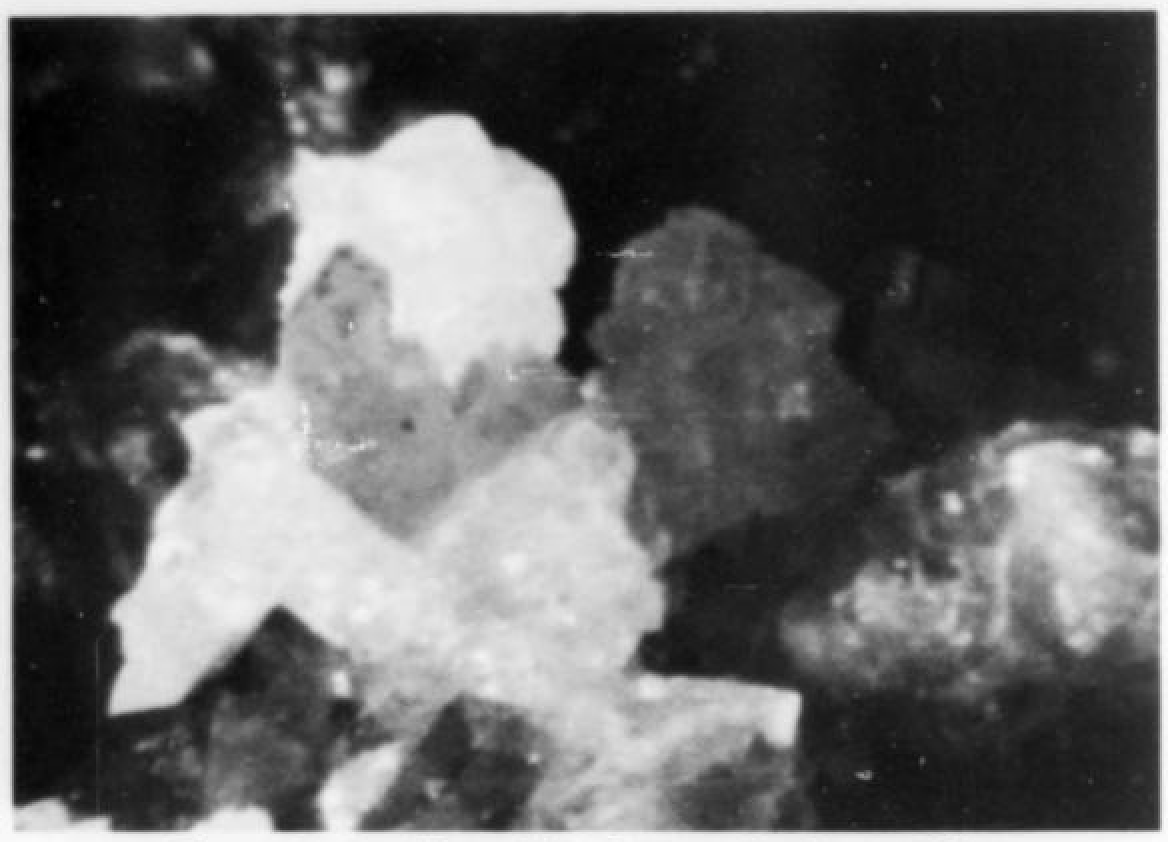

Figure 2. **A milky white cluster of minrecordite about 0.7 mm across at the base. A dioptase (II) crystal is perched on the cluster, and a darker cluster of magnesian minrecordite is present behind and to the right. Fioravanti specimen.**

The original minrecordite-bearing single specimen was subsequently divided into several fragments (only three of which still exist) for mineralogical studies. A piece (designated as the holotype) is now deposited in the mineral collection of the Institute of Mineralogy of Bari University, numbered HO-4/81. Cotypes are in the private collections of G. Fioravanti (Rome) and C. L. Garavelli (Bari).

DESCRIPTION and PARAGENESIS

The matrix of the minrecordite-bearing specimen is reddish, massive and partly earthy or ocherous. It has the well-known appearance of dioptase specimens from the second Tsumeb oxidation zone, at the 30–32 levels; the only distinctive feature is the complete lack of country rock (gray dolostone) usually present in the matrix of dioptase druses from Tsumeb. The reddish matrix is rich in small masses and veins of milky white crystals, mostly anhedral and only occasionally (on the inside of small vugs) in the form of well-shaped minute rhombs. These crystals are a zincian variety of dolomite, admixed with spathic calcite. As a rule, they include or are partly coated with very fine-grained, light green duftite and much smaller amounts of malachite needles. A thin layer of this material can also be observed between the matrix and the large dioptase crystals.

The malachite crystals range from about 10 to 15 mm in length. They are lustrous, semitransparent, dark emerald-green, and are partly strewn with minute minrecordite crystals.

Minrecordite occurs as two variants which are visually distinguishable from each other:

Type A (generally referred to here simply as minrecordite or "pure" minrecordite, with the understanding that "pure" is used as a relative term): Rhombohedral microcrystals up to about 0.5 mm, which are very markedly saddle-shaped, milky white in color and with a typical very strong pearly luster.

Type B (generally referred to here as "magnesian" minrecordite): More regular and less twisted rhombohedral microcrystals. As a rule, they are almost completely transparent, glassy and colorless; typically they nest at the bases of small hemispherical aggregates, which are composed principally of pure minrecordite (but see addendum).

Magnesian minrecordite crystals are smaller (0.2 mm as the maximum rhomb edge) and by far scarcer than pure minrecordite. They typically include a very fine-grained, reddish ocherous pigment; occasionally they are intimately admixed with cerussite and calcite.

Table 1. **Indexed powder patterns for minrecordite (Diffractometer, Cu K_α filtered radiation, step-scanning at 0.01° 2ϑ steps and $2\cdot10^4$ fixed counts).**

			Minrecordite			Magnesian Minrecordite		
h	k	l	$d_{calc.}$ (Å)	$d_{obs.}$ (Å)	I	$d_{calc.}$ (Å)	$d_{obs.}$ (Å)	I
1	0	1	4.038	4.039	10			
0	1	2	3.7012	3.7008	20	3.7171	3.7180	20
1	0	4	2.8903	2.8896	100	2.9059	2.9056	100
0	0	6	2.6716	2.6723	3			
0	1	5	2.5422	2.5418	3	2.5569	2.5569	< 1
1	1	0	2.4091	2.4095	25	2.4177	2.4176	20
1	1	3	2.1962	2.1965	20	2.2054	2.2060	25
0	2	1	2.0689	2.0685	3			
2	0	2	2.0191	2.0192	15	2.0267	2.0266	2
0	2	4	1.8506	1.8506	10	1.8586	1.8578	10
0	1	8	1.8062	1.8064	33	1.8179	1.8180	35
1	1	6	1.7891	1.7889	40	1.7983	1.7990	35
2	1	1	1.5696	1.5696	5	1.5752	1.5757	3
1	2	2	1.5475	1.5475	8	1.5532	1.5533	10
2	1	4	1.4676	1.4675	10	1.4735	1.4735	12
2	0	8	1.4452	1.4452	3	1.4530	1.4528	2
1	1	9	1.4322	1.4322	3			
1	2	5	1.4152	1.4152	2	1.4212	1.4211	1
0	3	0	1.3909	1.3909	5	1.3959	1.3957	5
0	0	12	1.33579	1.33575	3			

As will be shown below, these two minrecordite variants differ slightly in chemical composition, unit-cell parameters and physical properties.

The youngest mineral in this assemblage is represented by a second generation of dioptase, which occurs as very small (always less than 1 mm) individuals of rather complex morphology. They correspond to "dioptase II," according to Keller (1977), while the much larger crystals of this mineral, grown before minrecordite, are equivalent to Keller's "dioptase I." In our specimen, the minute dioptase II individuals are emerald-green and completely transparent when perched on magnesian minrecordite. The much larger number of dioptase II crystals, grown on pure minrecordite, are, as a rule, slightly opalescent, with a distinctive, lighter, bright bluish green color. Therefore the paragenetic sequence is as follows:

1. Calcite + zincian dolomite + duftite (also in small veins within the matrix).

2. Dioptase I, in large euhedral emerald-green crystals.

3. Magnesian minrecordite, rarely associated with cerussite and calcite.

4. Minrecordite.

5. Dioptase II, either bluish green or emerald-green in color, as emphasized above.

In many other dioptase specimens from Tsumeb, a mineral was observed very similar in appearance to the above-mentioned minrecordite, both in the pearly luster of the crystals and in their evident saddle-shape. This mineral was shown, however, to be merely zincian dolomite or, in some cases, nearly pure dolomite; in the latter case the crystals are not markedly twisted. Because of the close external similarity of this zincian dolomite to minrecordite, some information about it will be given in a further section.

PHYSICAL and OPTICAL PROPERTIES

The minute minrecordite crystals exhibit, as their only form, the $\{10\bar{1}4\}$ rhombohedron, with markedly twisted and saddle-shaped faces. Minrecordite is distinguished also by its strong, sometimes dazzling, pearly luster and by the mosaic structure of the crystals. The $\{10\bar{1}4\}$ cleavage is prominent.

Mohs hardness is 3.5. Specific gravity, measured by immersion in Clerici's solution, is 3.45(2) for pure minrecordite and 3.32(2) for magnesian minrecordite. Calculated density values derived from unit cell parameters and chemical composition (see below) are 3.445 g/cm³ and 3.306 g/cm³ respectively.

Optically, minrecordite is uniaxial negative and strongly birefringent. The indices of refraction (Na light) are:

Minrecordite: $\omega = 1.750$ $\epsilon = 1.550$
Magnesian minrecordite: $\omega = 1.734$ $\epsilon = 1.542$

These values are approximate to ± 0.002 for minrecordite and ± 0.003 for magnesian minrecordite. Independent of the experimental precision, a larger dispersion of the results was noted for the magnesian variety. This may be related to slight compositional differences between individual crystals of this type.

No fluorescence was observed under longwave or shortwave ultraviolet light.

These results suggest that we are dealing with a trigonal carbonate containing a substantial amount of cations smaller than Ca, and with either an ordered, less symmetrical, dolomite-like or a disordered, calcite-like structural arrangement of the cations.

X-RAY CRYSTALLOGRAPHY

X-ray single-crystal study would have been desirable in order to determine the amount of distortion of coordination polyhedra around the cations. However, this study was impossible due to the inferior quality of the mosaic crystals.

A high-resolution powder diffraction pattern was recorded separately for minrecordite and for its magnesian variety. The step-scanning technique (0.01° 2ϑ intervals) was adopted, operating with high resolution slits on two samples of about 3 mg each. The examined minerals were spread on the surface of a pure, powdered and compressed NaF support, allowing the NaF surface to remain exposed between sample grains. With this preparation technique, the NaF may also be used as a standard. The examined materials came from a number of different crystal clusters yielding the powder pattern of pure minrecordite, but from only two clusters having the pattern of the magnesian variety.

Observed and calculated $d_{(hkl)}$ values are given in Table 1. Both patterns are satisfactorily indexed in terms of a trigonal unit-cell, space group $R\bar{3}$. Some reflections are present, the indices of which violate the requirements of the $R\bar{3}\,c$ space group to which calcite belongs; this indicates that the mineral has an ordered, dolomite-like cation arrangement.

Least-squares calculation on the powder diffraction data resulted in the following unit-cell parameters:

Minrecordite
a = 4.8183(4) Å
c = 16.0295(10) Å
c/a = 3.3268
V = 322.28 Å³
a_{rh} = 6.0240 Å
α_{rh} = 47° 09'

Magnesian Minrecordite
a = 4.8355(4) Å
c = 16.1433(12) Å
c/a = 3.3385
V = 326.89 Å³
a_{rh} = 6.0622 Å
α_{rh} = 47° 01'

These values are consistent with the chemical composition of the analyzed minrecordites (see below). They follow the linear variation rules given by Goldsmith and Graf (1958) for unit cell parameters of trigonal carbonates, as a function of their chemical composition.

CHEMISTRY

Minrecordite is very slowly soluble in cold dilute HCl. The solubility and accompanying effervescence increase with acid concentration and, more markedly, with temperature. The mineral is easily soluble in 2N HCl at 80° C.

The chemical determination of cations was performed by atomic absorption spectrometry (A.A.S.). Taking into account the physical and optical properties of the mineral, as well as the results of the X-ray diffractometer study, and because only very small quantities were available, no direct determination of CO_2 was attempted and all the values were calculated as carbonates.

For pure minrecordite, four separate microanalyses were performed, on four different crystal clusters. The results are given in Table 2. Though the single analyses differ slightly from each other, the atomic ratio between Ca and the sum of the other metals is always very close to unity. On the basis of 6 oxygens, the averaged values yield the formula:

$Ca_{0.979}(Zn_{0.917}Mg_{0.067}Fe_{0.034}Mn_{0.003})(CO_3)_2$

or, ideally, **$CaZn(CO_3)$**.

For magnesian minrecordite, two microanalyses were performed (Table 3), but only one of these on a well-purified sample. The results of these analyses yield the formula:

$Ca(Zn_{0.699}Mg_{0.134}Ca_{0.090}Fe_{0.068}Mn_{0.009})(CO_3)_2$.

Thus, magnesian minrecordite is a compositional variety less rich in Zn, and more calcian and magnesian in comparison with pure minrecordite. Its composition easily explains the lower indices of refraction and specific gravity values, and the larger unit-cell parameters, with respect to pure minrecordite.

The second analysis of magnesian minrecordite was performed on crystals not susceptible to hand-purification and greatly contaminated by admixed cerussite and calcite, both recognized (as the sole impurities) optically and by means of X-ray examination. Therefore the results, also given in Table 3, show a substantial amount of Pb, and excess Ca when compared with the content re-

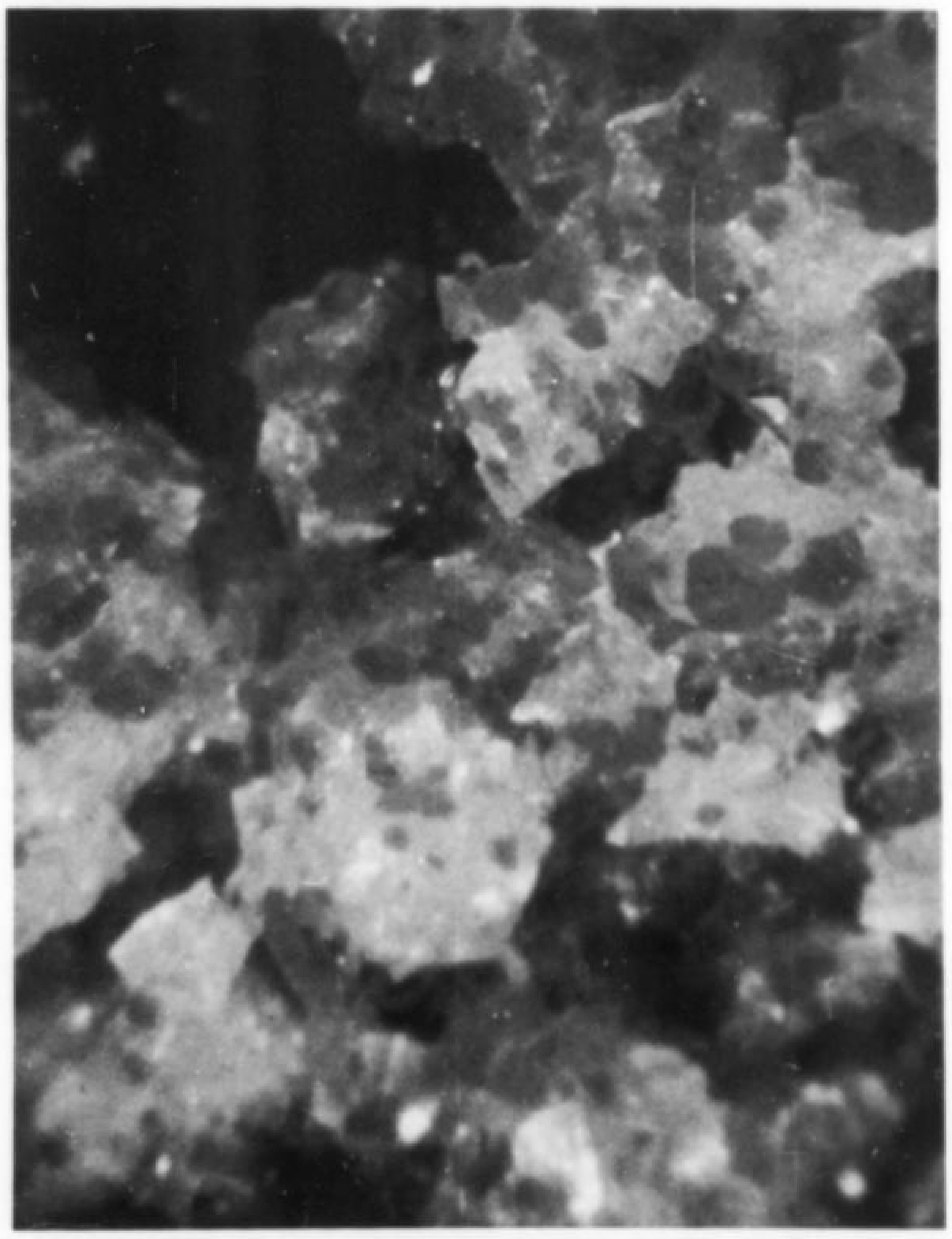

Figure 3. **Very small, green dioptase (II) crystals to 0.25 mm strewn across white minrecordite crystal clusters. Fioravanti specimen.**

Table 2. **Chemical analyses of minrecordite**

		Sample I	Sample II	Sample III	Sample IV	Average
Weight Percent	$CaCO_3$	44.69	44.34	45.01	41.85	43.97
	$ZnCO_3$	51.22	50.30	50.86	53.85	51.56
	$MgCO_3$	1.99	4.33	2.08	1.66	2.52
	$FeCO_3$	1.69	1.14	2.19	2.12	1.78
	$MnCO_3$	0.15	0.14	0.18	0.18	0.16
	Sum	99.74	100.25	100.32	99.66	99.99
Molar Ratios Basis: 6 oxygens	$CaCO_3$	0.9984	0.9973	0.9988	0.9426	0.9793
	$ZnCO_3$	0.9133	0.8850	0.9009	0.9682	0.9167
	$MgCO_3$	0.0528	0.1133	0.0548	0.0444	0.0666
	$FeCO_3$	0.0326	0.0217	0.0420	0.0413	0.0343
	$MnCO_3$	0.0029	0.0027	0.0035	0.0035	0.0031
		1.0016	1.0227	1.0012	1.0574	1.0207

quired by a dolomite-like formula.

In spite of this, it seems possible to obtain some chemical information by calculating a formula after the subtraction of all the $PbCO_3$ and assuming the atomic ratio between Ca and the sum of the remaining cations is equal to 1. The formula calculated on this basis is:

$Ca(Zn_{0.611}Mg_{0.251}Fe_{0.217}Mn_{0.011})(CO_3)_2$.

Obviously, no definite information is available about the ratio between Ca and the sum of the other metals. It is evident, however, than Zn is dominant among the small cations, though accompanied by higher amounts of other cations (especially Mg) when compared with the formula obtained for magnesian minrecordite in pure crystals.

Among the minor elements, Sr, Pb, Cu, and Co were sought in all the analyzed materials. In pure minrecordite, they were not found (each less than 10 ppm) with the exception of Cu in analysis IV (1300 ppm), probably due to a dioptase impurity. In magnesian minrecordite, Sr (85 ppm) and traces of Co (about 20–25 ppm) were detected. Larger amounts of Sr (160 ppm) are present in the contaminated sample, probably linked with the cerussite or calcite impurities.

ASSOCIATED ZINCIAN DOLOMITES

As pointed out above, a zincian variety of dolomite has been identified in the small veins of carbonates, occurring within the matrix, or interposed between the matrix and dioptase I crystals. In these occurrences, zincian dolomite is always admixed with calcite and duftite, as revealed by optical and X-ray evidence. No other minerals are present, excepting some malachite needles.

Chemical analyses of these materials were performed by means of A.A.S. They gave the results quoted in Table 4, sample I (small veins within the matrix) and II (between matrix and dioptase I). Owing to the ascertained presence of admixed calcite, the composition of these zincian dolomites cannot be definitely established. On the assumption of an atomic ratio 1:1 between Ca and the sum of smaller cations, the following formulas are calculated on the basis of 6 oxygens:

$Ca(Mg_{0.764}Zn_{0.234}Mn_{0.001}Fe_{0.001})(CO_3)_2$

$Ca(Mg_{0.726}Zn_{0.243}Fe_{0.028}Mn_{0.003})(CO_3)_2$

for samples I and II respectively.

As mentioned above, and as shown in Table 4, zincian dolomite and calcite are admixed in these occurrences with duftite and malachite. Duftite percentages were calculated on the basis of determined Pb contents: the minor amounts of Cu still remaining were calculated as malachite. No direct determination of As was carried out, but the presence of this element was qualitatively ascertained.

A third analysis of zincian dolomite was obtained from pearly white, twisted, rhombohedral crystals occurring on another dioptase specimen from Tsumeb, and quite similar to minrecordite in appearance.

Table 3. **Chemical analyses of magnesian minrecordite**

		Sample I	Sample II	
			II-a	II-b
Weight Percent	$PbCO_3$	///	41.95	///
	$CaCO_3$	50.65	41.25	46.81
	$ZnCO_3$	40.67	11.50	35.84
	$MgCO_3$	5.24	3.18	9.91
	$FeCO_3$	3.67	2.20	6.85
	$MnCO_3$	0.46	0.19	0.59
	Sum	100.69	100.27	100.00
Molar Ratios Basis: 6 oxygens	$CaCO_3$	1.0904	///	1.0000
	$ZnCO_3$	0.6988	///	0.6112
	$MgCO_3$	0.1339	///	0.2513
	$FeCO_3$	0.0683	///	0.1265
	$MnCO_3$	0.0086	///	0.0110
		0.9096		1.0000

Note – II-a column: weight percent obtained for a cerussite and calcite admixed minrecordite.
II-b column: recalculated weight percent after subtraction of all the $PbCO_3$ and 26.23 percent $CaCO_3$ (excess of $CaCO_3$ with respect to a carbonate with 1:1 ratio between Ca and the sum of other cations).

Unlike samples I and II, this material was very pure, and thus a fully reliable formula may be calculated directly from the analytical results. On the basis of 6 oxygens, we have:

$Ca_{1.001}(Mg_{0.894}Zn_{0.056}Fe_{0.045}Mn_{0.004})(CO_3)_2$

which corresponds to a far less zincian dolomite.

Traces of Co were detected in all these three zincian dolomites. Sr is also present; it has a higher concentration (185 ppm) in the less zincian dolomite.

DISCUSSION

The natural occurrence of a new mineral phase which is structurally a member of the dolomite series, and is a presumably very

Table 4. **Chemical analyses of zincian dolomite**

		Sample I		Sample II		Sample III
		I-a	I-b	II-a	II-b	
Weight Percent	$CaCO_3$	53.52	51.58	52.21	51.23	53.33
	$ZnCO_3$	11.88	15.11	12.73	15.62	3.72
	$MgCO_3$	26.11	33.21	25.54	31.33	40.12
	$FeCO_3$	0.03	0.04	1.34	1.64	2.80
	$MnCO_3$	0.05	0.06	0.15	0.18	0.23
	Duftite	7.58	/	7.64	/	/
	Malachite	0.33	/	0.21	/	/
	Sum	99.50	100.00	99.82	100.00	100.00
Molar Ratios Basis: 6 oxygens	$CaCO_3$		1.0000		1.0000	1.0012
	$ZnCO_3$		0.2339		0.2434	0.0557
	$MgCO_3$		0.7643		0.7259	0.8939
	$FeCO_3$		0.0007		0.0276	0.0454
	$MnCO_3$		0.0011		0.0031	0.0038
			1.0000		1.0000	0.9988

Note – Columns I-b and II-b: recalculated weight percent after subtraction of duftite and malachite, and of 12.98 and 10.44 percent $CaCO_3$ respectively (no excess $CaCO_3$ in Sample III). See text.

rare Tsumeb secondary mineral, seems to be conclusively established. This conclusion is fully supported by the very good agreement between chemical, optical and physical data. As far as chemical composition, indices of refraction and specific gravity are concerned, and using the well-known Gladstone-Dale relationship, compatibility indices of -0.018, -0.015 and -0.011 can be found for minrecordite (averaged values) and magnesian minrecordite (analyses I and II) respectively. Such values are listed as "superior" by Mandarino (1979). It is significant that the best agreement is observed for sample II of magnesian minrecordite: it gives full justification for the assumptions made in order to calculate its formula.

The possible existence of a pure compound $CaZn(CO_3)_2$ with a dolomite-like, ordered structure (and more generally the stability of transition metal "dolomites") was recently discussed by Rosenberg and Foit (1979). According to these authors, small cation size cannot be the only critical factor controlling the stability of these structures, which chiefly depends upon the distortion of $R^{+2}O_6$ octahedra, R^{+2} being a cation of a transition metal. Octahedral distortion apparently raises the free energy of formation of these dolomite-like structures, until they become metastable phases, when the sum of free energies for two binary disordered solid solutions is reached.

Many works on this subject (e.g. Goldsmith and Northrop, 1965) suggest the following series in order of decreasing stability:

$Mg \gg Mn > Zn > Fe > Co > Ni \gg Cu$

According to Rosenberg and Foit (1979), the stability limit for a dolomite-like structure occurs in the vicinity of Zn in the above series. These authors state that: "Zn-dolomite is probably not a stable phase, although very extensive solid solution toward $CaZn(CO_3)_2$ is predicted." Actually, accepting the hypotheses assumed by Rosenberg and Foit, it is possible to calculate, for $Ca(Zn,Mg)(CO_3)_2$ a stability limit, which lies at a maximum Zn content (in atoms) between 85 and 90 percent of the small cations. We find, for pure minrecordite from Tsumeb, a value of 91.7 percent (or a little more, including Fe), which seems to agree with the provisions, taking into account the approximations involved in Rosenberg and Foit's calculation.

Moreover, it is likely that minrecordite is not grown under ideal conditions of chemical equilibrium. Analytical data seem to indicate that minrecordite chemical composition varies from one point of growth to the next. It is possible that surface equilibria between solutions and growing crystals may have played an important role in the formation of this mineral (and of the associated zincian dolomite). This was pointed out by Tsusue (1967) for rhodochrosite and magnesian kutnohorite, and by other authors (e.g. Sims and Barton, 1961) for different hydrothermal minerals.

The paragenetic position of minrecordite falls within the sequence outlined by Keller (1977): dolomite → duftite → plancheite → dioptase I → calcite → dioptase II. Apart from the absence of plancheite, the main difference between the above-mentioned sequence and that observed on the minrecordite-bearing specimen is the presence of minrecordite instead of calcite in the position stated by Keller. However, the inspection of many dioptase druses from Tsumeb leads us to consider the occurrence of a dolomitic phase (as the intermediate between dioptase I and II) as not uncommon. These dolomitic phases are most commonly represented by nearly pure dolomite or, less commonly, by zincian dolomite. The deposition of minrecordite is probably due not only to an adequate concentration of Zn in the circulating solutions, but also to a quite uncommon scarcity of Mg in the latter, and perhaps (Keller, 1977) to a slightly higher environmental pH. The deposition of crystals of composition not too different from the ideal $CaZn(CO_3)_2$ must, in any case, be considered a rather uncommon event.

A careful examination of the many dioptase druses from Tsumeb might result in the discovery of other minrecordite specimens. Their identification must be achieved by accurate chemical, optical or X-ray studies because of the close similarity, in outward appearance, to some dolomite (or, particularly, zincian dolomite) crystals.

With regard to the presence of zincian dolomite among the secondary minerals from Tsumeb, this compositional variety was previously described (or merely mentioned) for the locality by Hurlbut (1957); Strunz, Söhnge and Geier (1958); Geier and Weber (1958); Geier (1974); and Pinch and Wilson (1977). In these studies, the name "Zn-dolomite" (or "zinkdolomit") was used to mean a compositional variety, as stated, for example, by Geier (1974). On the other hand, Rosenberg and Foit (1979) used "Zn-dolomite" as a name for the compound $CaZn(CO_3)_2$. Taking into account this ambiguity, and because of the introduction of the name minrecordite, it seems better to drop "zinkdolomit" and "Zn-dolomite," in favor of *zincian dolomite,* when the purpose is to designate a compositional variety.

All the zincian dolomites previously described for Tsumeb lie below this compositional limit: their maximum Zn value is quoted as 21.65 percent $ZnCO_3$ (private communication of Geier in Strunz, 1970). Assuming that no other substitutents for Mg, in significant amounts, are contained in it, this would correspond to an atomic ratio Zn:Mg not far from 1:2.

A zincian dolomite described by Jasienska and Zabinski (1972) seems to be much richer in Zn. This was found as a major mineral component of an oxidized zinc ore from the Waryński mine, near Bytom (Upper Silesia, Poland). These authors state that, in this solid solution, the Zn:Mg atomic ratio "is approximately equal to or even exceeds 1." The results of microprobe analyses were: Ca = 16–18 percent, Zn = 10–14 percent, Mg = 3–4 percent, Fe < 1 percent. If the semiquantitative evidence from these values is confirmed, then also these mixed crystals from Silesia might be classed within the minrecordite range.

ACKNOWLEDGMENTS

The authors sincerely thank Richard C. Erd for reviewing the manuscript and offering many helpful suggestions. Our thanks also to Giorgio Sala for assistance in the photographic work.

ADDENDUM

During 1980 and the first half of 1981, we examined vast numbers of dioptase druses from Tsumeb in the hope of encountering another minrecordite specimen.

After the above manuscript was written, we were fortunate enough to find, among a great many dolomite and some zincian dolomite-bearing dioptase druses, a small (18 x 26 mm) specimen with a number of minrecordite crystals.

These crystals have the very same external appearance as described here for pure minrecordite crystals. A quantitative estimation of the major elements indicated, however, an atomic ratio Ca : Zn : Mg = 1.00 : 0.65 : 0.25. Fe and Mn were not determined; the analysis sums to 97.6, calculating the metals as carbonates. In spite of its outward appearance, this mineral is therefore a magnesian minrecordite.

In this new magnesian minrecordite specimen, some clear rhombs are present, quite similar to the first-found magnesian minrecordite, and apparently formed after dioptase but before minrecordite. These rhombs proved to be merely zincian dolomite with an atomic ratio Ca : Zn : Mg = 1.00 : 0.19 : 0.78 (Fe and Mn were not sought).

This specimen was kindly submitted to our attention by Natale Borghi, a skilled and esteemed mineral collector and dealer in Rome. It was obtained about six years ago from Sid Pieters of Windhoek, Namibia.

The new chemical data, though approximate, strengthen the conclusion that compositional differences may exist among minrecordite crystals grown at different locations within the Tsumeb oxidation zone, or even at the same point but at different times. Therefore, the chemistry of growing minrecordite appears very sensitive to the composition of the circulating solutions.

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TSUMEB!

new minerals and their associations

by **Paul Keller**
Institut für Mineralogie und Kristallchemie
Universität Stuttgart
Pfaffenwaldring 55
D-7000 Stuttgart 80, West Germany

and **Wolfgang Bartelke**
Wallstrasse 26
D-5600 Mainz
West Germany

There have been 15 new mineral species described from Tsumeb and 17 minerals new to the locality since the Tsumeb issue of The Mineralogical Record was published in 1977. Some of these new minerals occur in typical assemblages, knowledge of which is helpful in the search for and identification of these rare minerals. The occurrence of some other new minerals is unique and seems to be a caprice of nature, like the Tsumeb deposit itself.

INTRODUCTION

Namibia's Tsumeb mine, the world's greatest mineral locality, has again and again been the topic of interesting mineralogical publications (Weber, 1977), and there have also been some excellent review articles (Strunz, Söhnge, and Geier, 1958; Geier, 1974; and Bartelke, 1976). The most comprehensive and famous work ever published was the Tsumeb issue of the *Mineralogical Record* in 1977; 172 approved minerals were described, among them 25 minerals for which Tsumeb is the type locality (Pinch and Wilson, 1977).

Five years have now passed; what has been happening at Tsumeb? Tsumeb is still producing! There is ore production, the economic task of a mine. But what is of interest to all friends of mineralogy, is that there have been new mineral discoveries as well.

In the last five years, 29 minerals new for Tsumeb have been reported; these expand the long list of Tsumeb minerals to a total number of 201 species. Since 1977, no less than 14 new species were approved for which Tsumeb is the type locality; that raises the type total to 39 species. But Tsumeb is not exhausted! Investigations on several other proposed new species are under way.

In the first chapter of this report, a short description of each mineral is given. Several spectacular new finds of previously known Tsumeb species are briefly mentioned in the second chapter, together with some remarks about doubtful minerals. And lastly, different assemblages and sequences of the new minerals and their possible conditions of formation are described. In addition to the scientific value, this report will be a help to mineral collectors in their search for and identification of these minute and rare species.

DESCRIPTIVE LIST

In the following descriptive list only those characteristics that are particularly useful for visual identification, such as color, crystal forms and habit, are given. Details about the optical properties, space group and unit cell dimensions, X-ray powder patterns, etc., may be found in the references or in standard reference works. As an aid to identification, the associated minerals are given in order of their frequency of occurrences. For sequences not described in the last chapter there will be some remarks in this section.

Where available, information is given about location of specimens in the mine. New minerals for which Tsumeb is the type locality are indicated with an asterisk (*).

Anhydrite

$CaSO_4$, orthorhombic, has been found as water-clear to white crystals up to 3 mm in size, tabular on {100} and striated parallel to [001] (Fig. 7). There are also white crusts and grains showing perfect cleavages on {010} or {100}.

Anhydrite occurs on a deeply oxidized lead ore commonly covered by massive blue chalcanthite. The most important associates are chalcanthite, leightonite, lammerite, unidentified silicates, and a TK-like mineral (Keller, 1981).

Anhydrite was found in the North-East stope, 35 level, in January and February of 1980 (Innes, personal communication).

Arsendescloizite*

$PbZn(OH)(AsO_4)$, orthorhombic, forms rose-like aggregates 1.5 mm tall (Fig. 8) consisting of crystals tabular on {001}. Other forms are {011}, {101} and {111} (Fig. 9). The mineral is pale yellow with a brilliant subadamantine luster. No cleavage is ob-

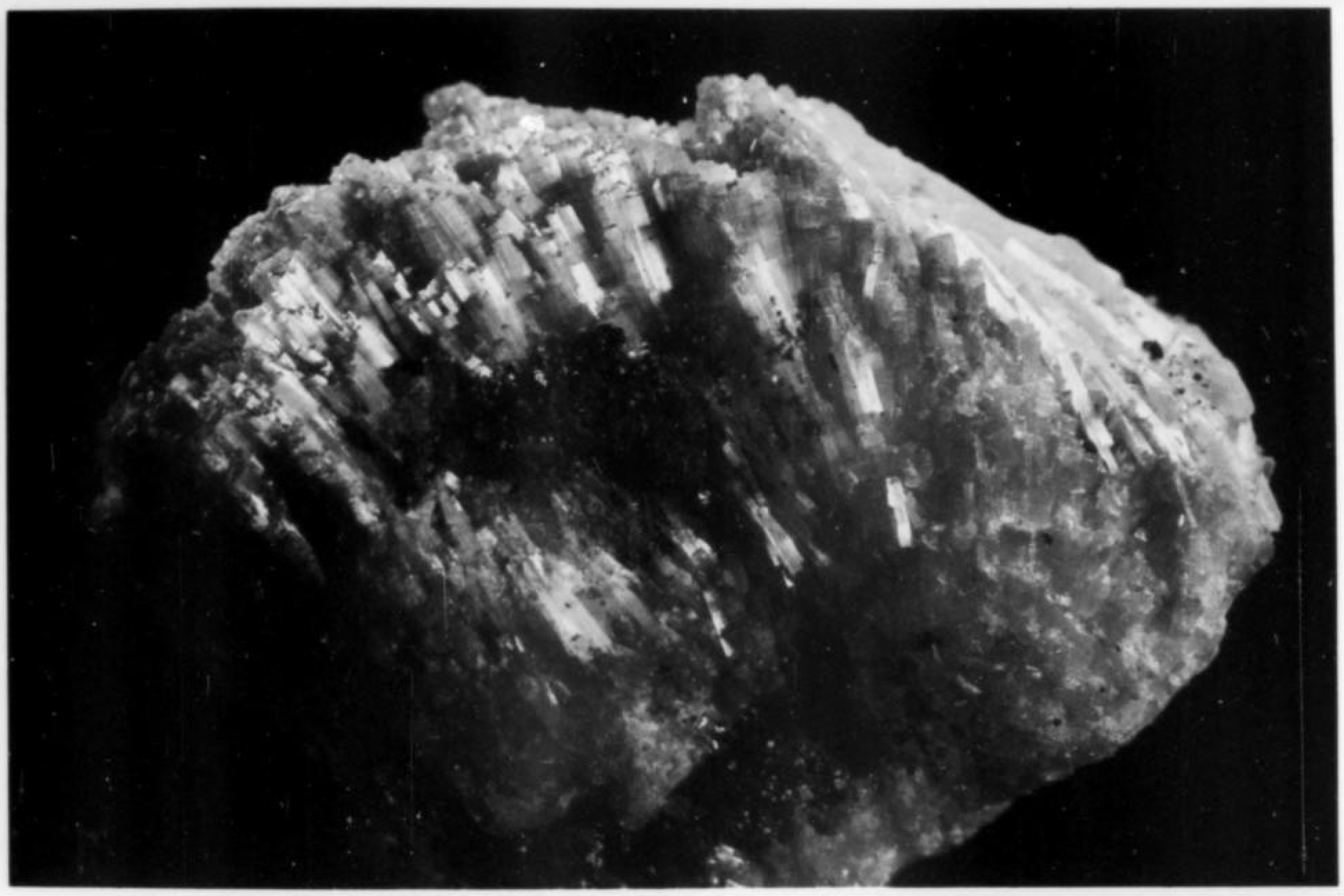


Figure 1. **Fleischerite. Width of picture: 40 mm. Collection of W. Bartelke; photo by O. Medenbach.**

served. Arsendescloizite is associated with a water-clear willemite, euhedral chalcocite crystals, quartz, corroded mimetite, and goethite. The sequence is chalcocite, quartz, mimetite, arsendescloizite, goethite, and willemite. Arsendescloizite may be mistaken for descloizite or pale yellow tsumcorite or adamite, sparsely found in former years. Several specimens of arsendescloizite are known (Keller and Dunn, 1982a).

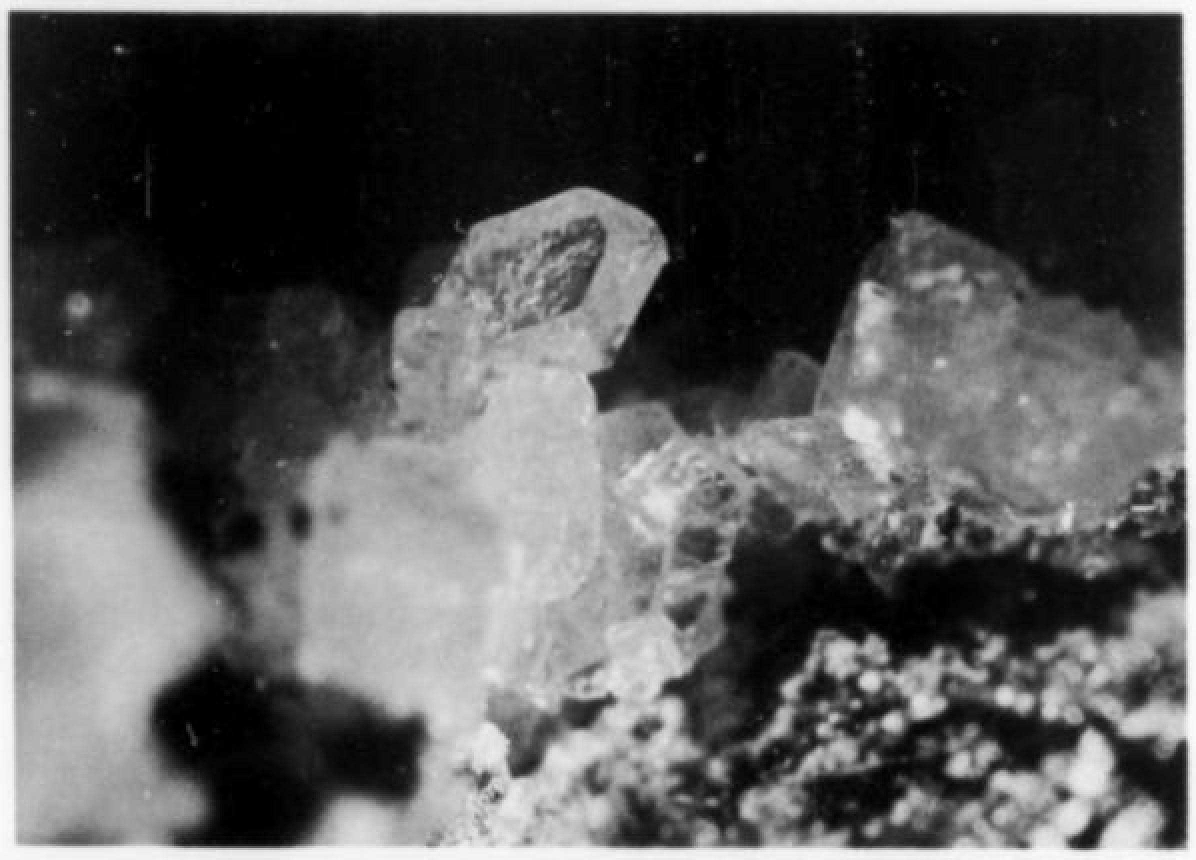


Figure 2. **Helmutwinklerite Crystals to nearly 5 mm.**

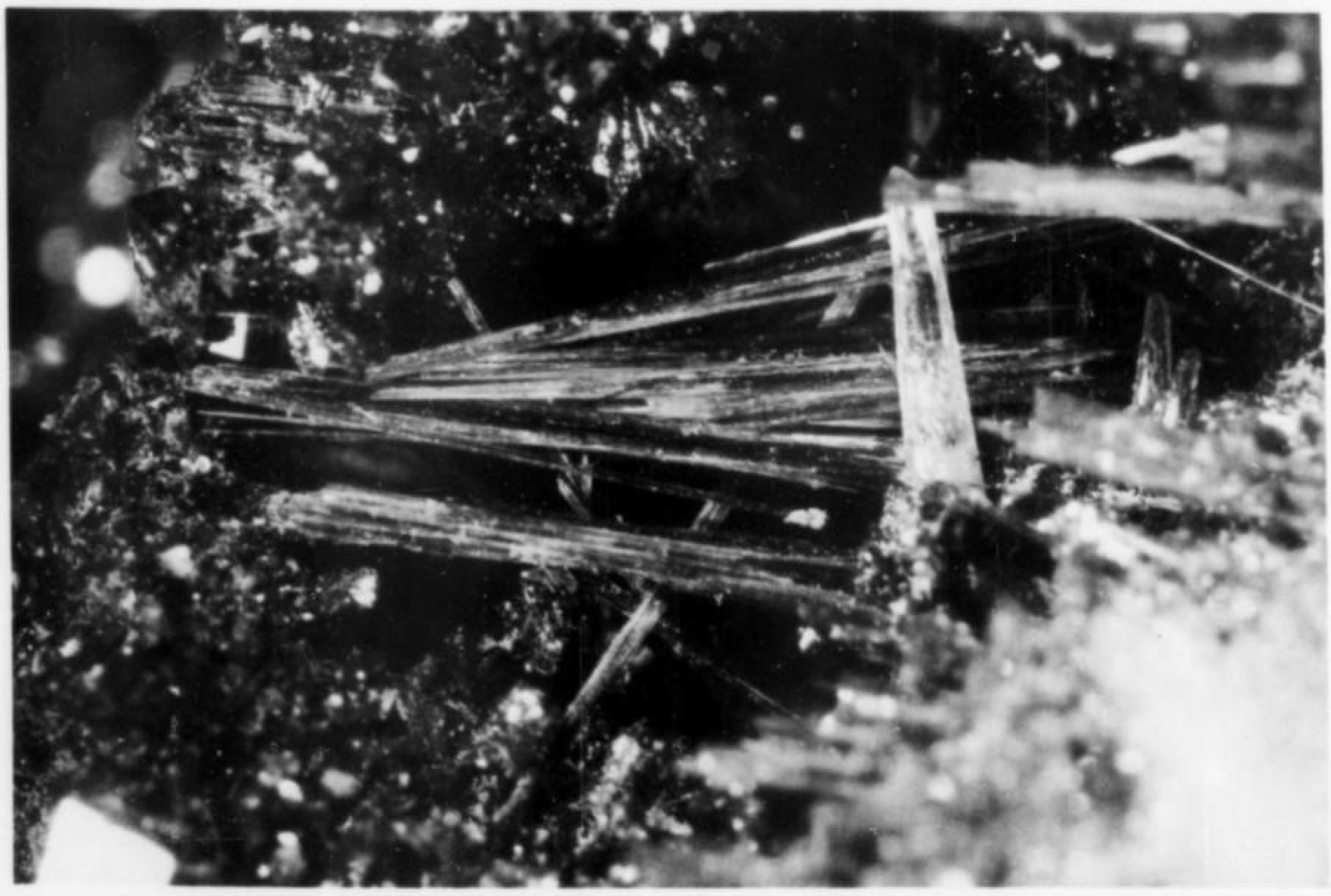


Figure 3. **Gebhardite. Width of crystals is 3 mm. Photo by O. Medenbach.**

Figure 4. **Warikahnite, yellow, with koritnigite and helmutwinklerite. Size of crystal: 2 mm. Collection of P. Keller; photo by J. Weber.**

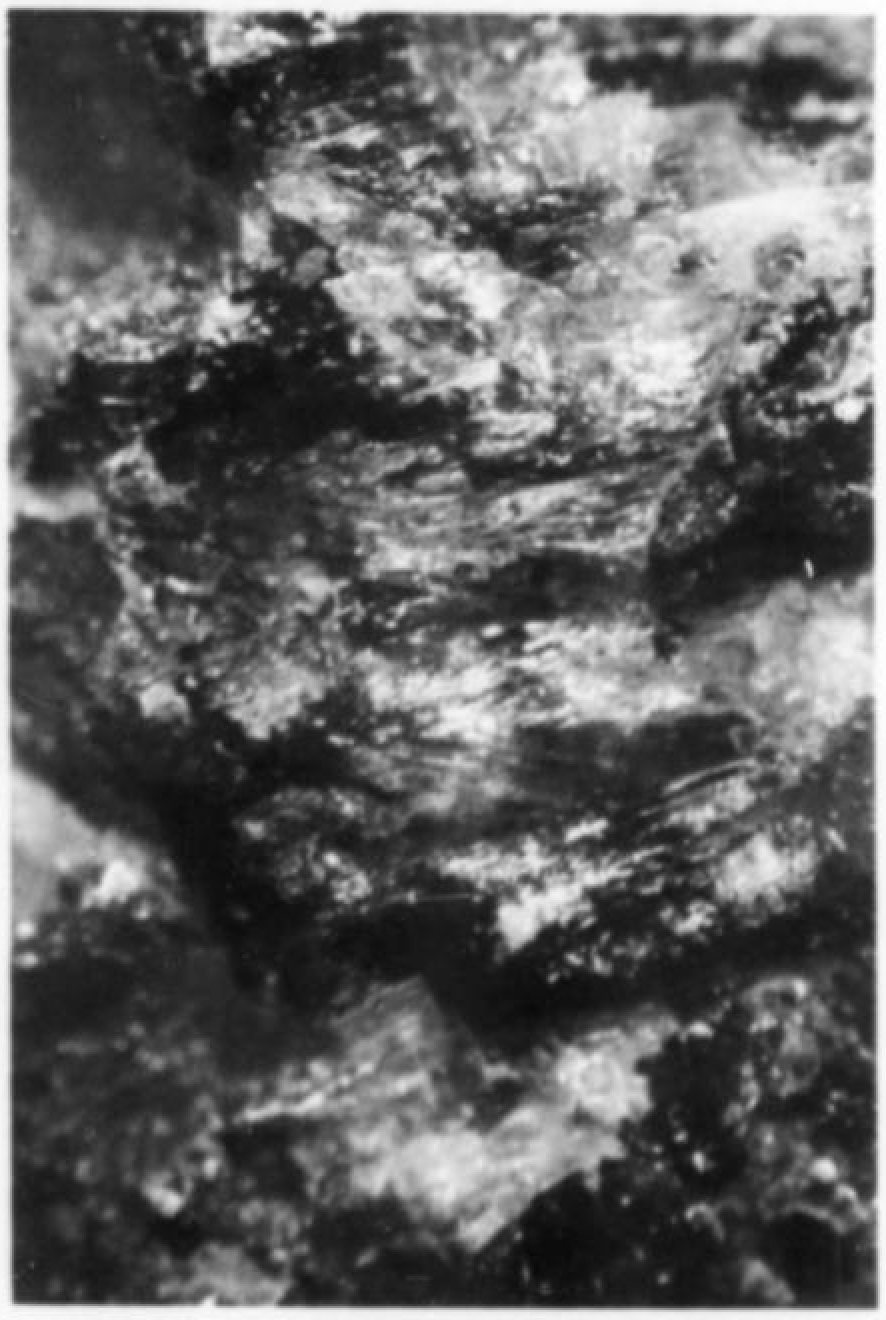


Figure 5. **O'Danielite with prosperite and cuprian adamite. Width of picture: 3 mm. Collection of P. Keller; photo by P. Keller.**

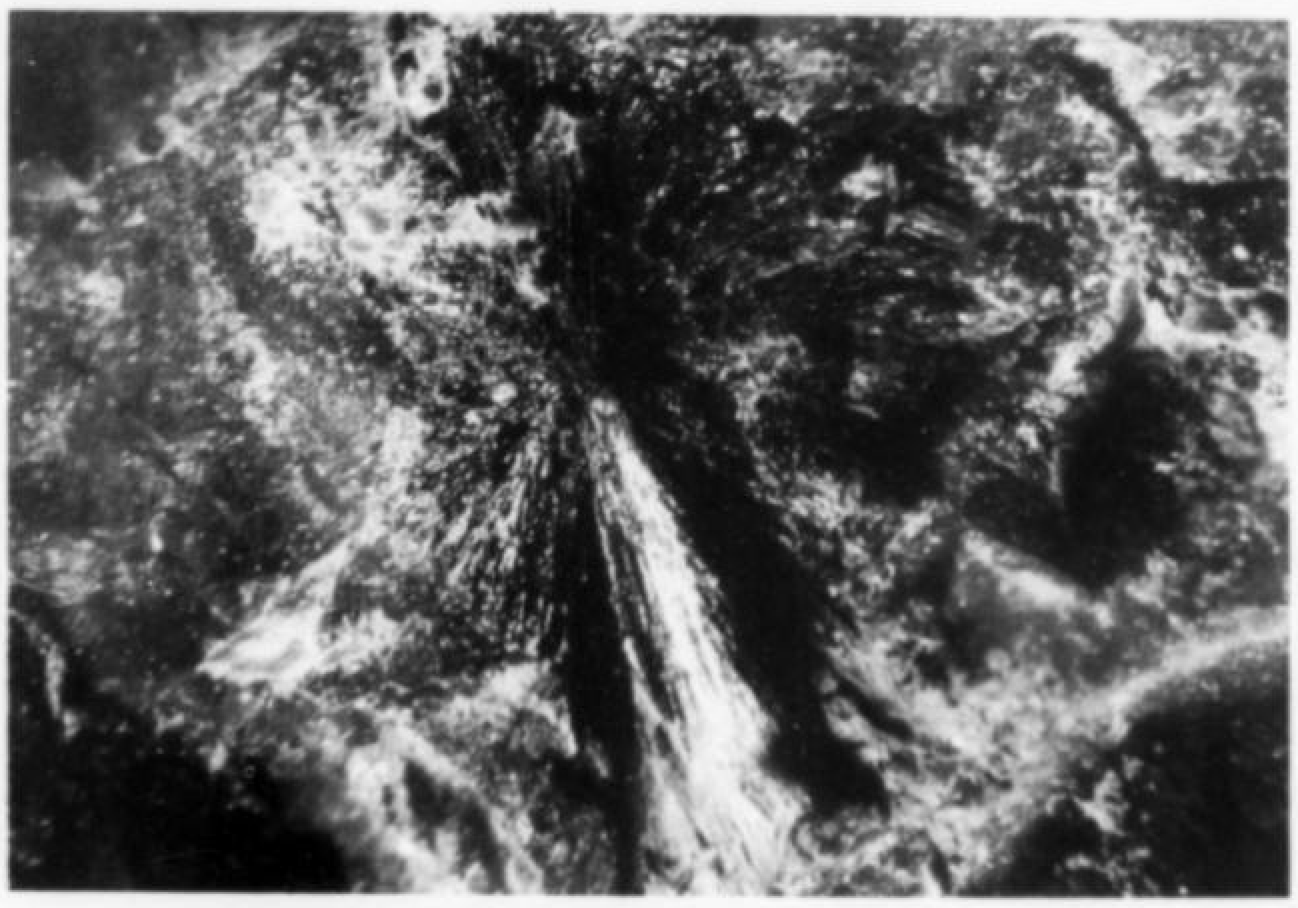


Figure 6. **Johillerite on cuprian adamite. Width of picture: 4 mm. Collection of W. Bartelke; photo by J. Weber.**

Bartelkeite*

$PbFeGe_3O_8$, monoclinic, occurs as euhedral crystals up to 0.2 x 0.3 x 1.0 mm, elongated parallel to [101] or tabular on $\{10\bar{1}\}$. The tabular crystals commonly show characteristic notches (Fig. 10). The mineral is colorless to pale greenish in color with a subadamantine luster. Cleavage {101} is distinct.

Bartelkeite has been found in small cavities in an oxidized germanium and copper ore, consisting mainly of germanite, renierite, tennantite and galena. Only two finds are known (Keller, Hess, and Dunn, 1981c).

Beta-Roselite

$CaCo(H_2O)_2(AsO_4)_2$, triclinic, as rose to reddish brown aggregates in association with calcite (personal communication, K. Schmetzer).

Fraipontite

$(Zn_{2.35}Al_{0.65})(OH)(Si_{1.35}Al_{0.65})O_5$, monoclinic, forms pearly to dull white coatings and glossy scales covering deeply oxidized ore; found on the gebhardite specimen (Medenbach, pers. comm.). Fraipontite has also been found in association with willemite and cerussite on other specimens. The mineral may be more abundant, but it is commonly inconspicuous and therefore overlooked. The glossy scales are easily confused with kegelite.

Gaitite*

$Ca_2(Zn,Mg)(H_2O)_2(AsO_4)_2$, triclinic, developed mostly as a polycrystalline coating. Only a few crystals have been found, with the faces {010}, {001} and $\{0\bar{1}1\}$. Gaitite is white to colorless with a vitreous luster. Cleavage is good on {010}, {001} and $\{0\bar{1}1\}$ (Sturman and Dunn, 1980; Keller, Hess, and Riffel, 1981).

Gaitite was found in vugs in partially altered copper ore, associated with conichalcite (sometimes are brilliant grass-green crystals), cuprian adamite, pale green cuprian austinite, chalcocite, prosperite (as brilliant colorless crystals), quartz, cuprite and yellow

Figure 7. **Anhydrite on a TK-like mineral. The width of picture is 4 mm. Collection of W. R. Kahn; photo by P. Keller.**

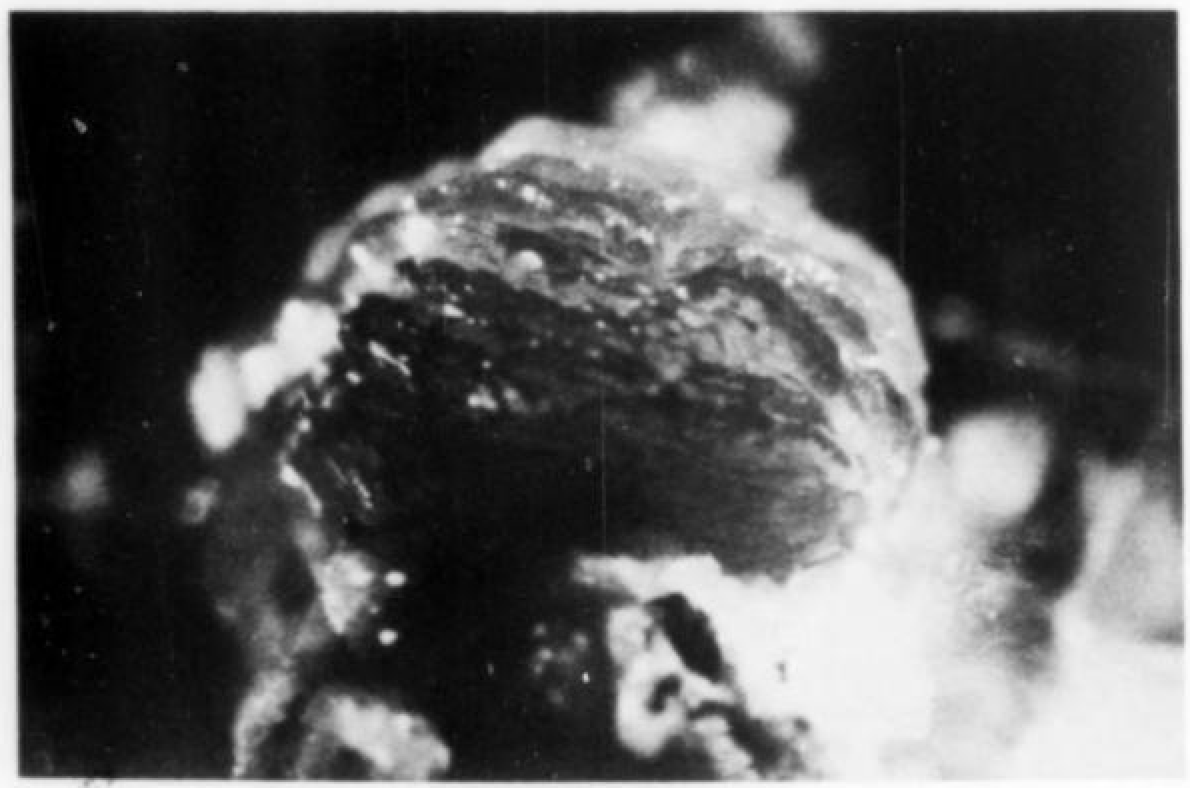


Figure 8. **Arsendescloizite. The width of picture is 4 mm. Collection of P. Keller; photo by J. Weber.**

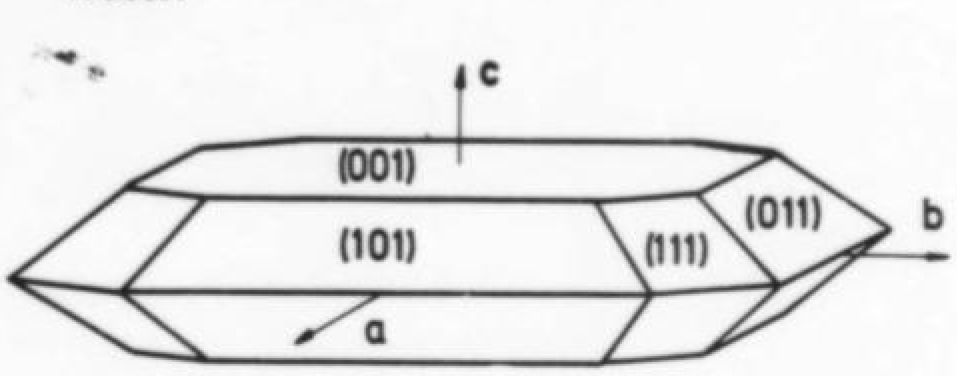


Figure 9. **Arsendescloizite. Idealized drawing.**

euhedral crystals of barite. The most likely sequence seems to be: chalcocite, cuprite, conichalcite + austinite, adamite, prosperite, gaitite, austinite, and barite.

Gebhardite*

$Pb_8Cl_6As_4O_{11}$, monoclinic, occurs as transparent brown crystal groups up to 3 mm in length, consisting of lathlike parallel to subparallel crystals (Fig. 3). Cleavage is perfect on {001} and good on {010}. Associated minerals are reinerite, hematite, smithsonite, willemite, fraipontite, mimetite and quartz (Medenbach, pers. comm.).

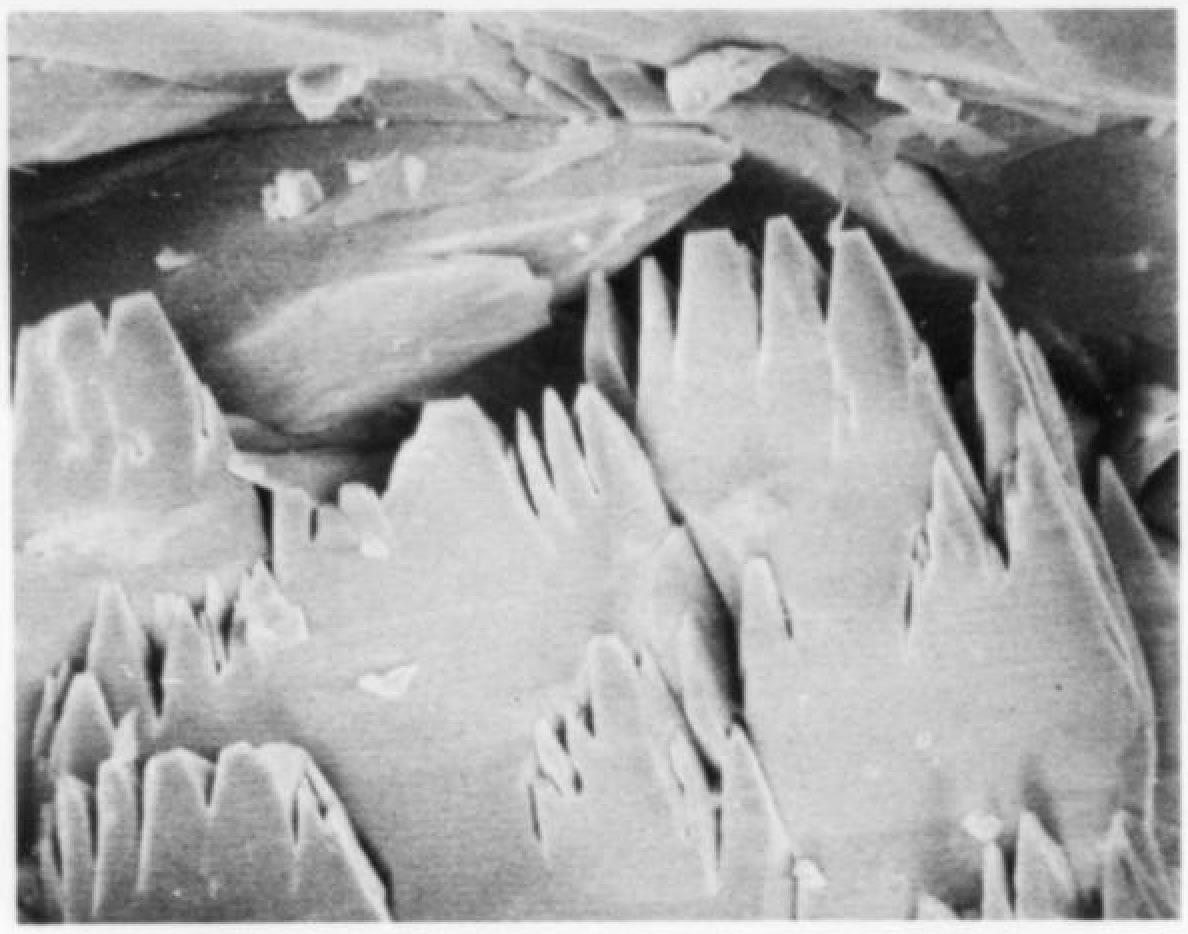


Figure 10. **Bartelkeite, crystals with notches. The width of picture is 0.2 mm. Collection of W. Bartelke; SEM photo by K. Schmetzer.**

Helmutwinklerite*

$Pb(Zn,Cu)_2(H_2O)_2(AsO_4)_2$, triclinic, forms translucent to transparent, light blue to sea-green crystals which reach nearly 5 mm in length (Fig. 2). The euhedral crystals are tabular on (100) with the faces {001}, {010}, $\{1\bar{1}0\}$ and $\{11\bar{1}\}$. The luster is vitreous (Süsse and Schnorrer, 1980).

Specimens with helmutwinklerite were found in the E9 pillar, 31 level. It is associated with white koritnigite and willemite, pale yellow warikahnite, cuprian adamite and quartz. Helmutwinklerite is the earliest of these minerals.

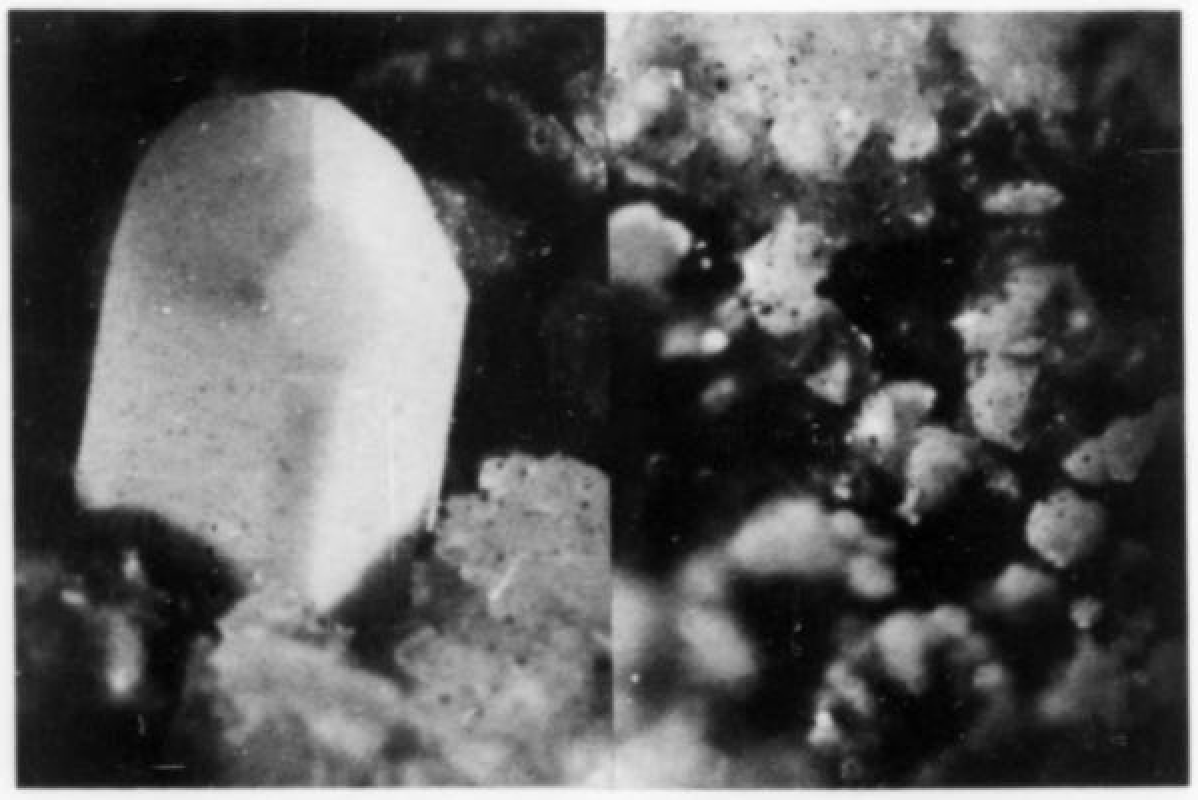


Figure 11. (left) **Hydrocerussite pseudomorphs after cerussite. Width of picture: 3 mm. Collection of P. Keller; photo by P. Keller.** ***(Right)*** **Hydrocerussite as pearly scales. Width of picture: 2.5 mm. Collection of W. R. Kahn; photo by P. Keller.**

Hydrocerussite

$Pb_3(OH)_2(CO_3)_2$, hexagonal, has been found in different habits. *First:* it forms glossy scales or tabular crystals up to 0.3 mm, in association with azurite, randomly altered to tenorite, malachite, mimetite and calcite. *Second:* as inclusions in or coatings on cerussite together with mimetite and phosgenite or with arsentsumebite, azurite and malachite. *Third:* as pseudomorphs after euhedral crystals of cerussite up to 2 mm (Fig. 11), where it is found with mimetite and duftite.

Hydrocerussite is an indicator for extremely basic condition of formation. It is stable only in solutions with a pH of about 10 to 13.

Unfortunately, the locations in the mine where the specimens were found are not known (Keller, 1977).

Jamesite*

$Pb_2Zn_2Fe_5O_4(AsO_4)_5$, triclinic, occurs as reddish brown, translucent to transparent crystals and radiating masses. The euhedral crystals are acicular or bladed on {010} and elongated parallel [100] with a maximum size of 0.05 x 0.2 x 0.5 mm. The streak is pale brown and the luster subadamantine (Fig. 12).

Figure 12. **Jamesite. Width of picture: 0.2 mm. SEM photo by P. J. Dunn.**

Jamesite occurs in a variant of sequence I/1 (Keller, 1977), that is: duftite I, tsumcorite, goethite, jamesite, duftite II, and dolomite, in that order. The masses of jamesite may be confused with goethite and the euhedral crystals with ludlockite or altered carminite. But the associations of those minerals are very different (Keller, Hess, and Dunn, 1981b).

Johillerite*

$Na(Mg,Zn)_3Cu(AsO_4)_3$, monoclinic, a remarkable violet-blue in color and cannot be overlooked. It forms radiating masses consisting of blades and fibers up to 0.2 x 0.5 x 2.0 mm, elongated along the *c*-axis (Fig. 6). The luster is vitreous and the streak white. A perfect cleavage on {010} and good cleavages on {100} and {001} have been observed.

Only one specimen has been found as yet; the johillerite is associated with earlier conichalcite and cuprian adamite (Keller, Hess, and Dunn, 1981d).

Koritnigite*

$Zn(H_2O)(HOAsO_3)$, triclinic, usually water-clear to white, though one specimen is known with a pale rose color. The cleavage on {010} is very perfect and cleavage traces parallel to [001] and [100] are distinctly visible on {010}. The luster is subvitreous, pearly on the {010} cleavage. It is easily flexible and the hardness (Mohs) = 2. Koritnigite is very similar to gypsum and both minerals have probably been mistaken for each other (Keller, Hess, Süsse, Schnorrer, and Dunn, 1979).

Koritnigite is a fairly abundant mineral, but euhedral crystals are extremely rare (Fig. 13). Possible forms are dull {001}, small {010}, striated {110} and {$\bar{1}$10}, and some very small {hk0} and {hkl} faces. Koritnigite is associated with many other new minerals. Approximately in order of occurrence, the association is: green conichalcite, cuprian adamite, pale sea-green helmutwinklerite, pale yellow tsumcorite, yellow warikahnite, water-clear prosperite, pale violet o'danielite, water-clear adamite, koettigite, white claudetite, schultenite, stranskiite and lavendulan.

Specimens with koritnigite have been found in the E9 pillar, 31 level. In addition to the similarity with gypsum, koritnigite may also be mistaken for schultenite or claudetite. Unfortunately all of these minerals occur in the same association.

Figure 13. **Koritnignite. Size of crystals: 2.5 mm. Collection of P. Keller; photo by J. Weber.**

Kasolite

$Pb_2(UO_2)_2(SiO_4)_2 \cdot 2H_2O$, monoclinic, identified by X-ray and chemical analysis; the first uranium mineral found at Tsumeb.

It occurs as prismatic crystals up to 2 mm, commonly coated by goethite and associated with arsendescloizite, mimetite and willemite (Medenbach, pers. comm.).

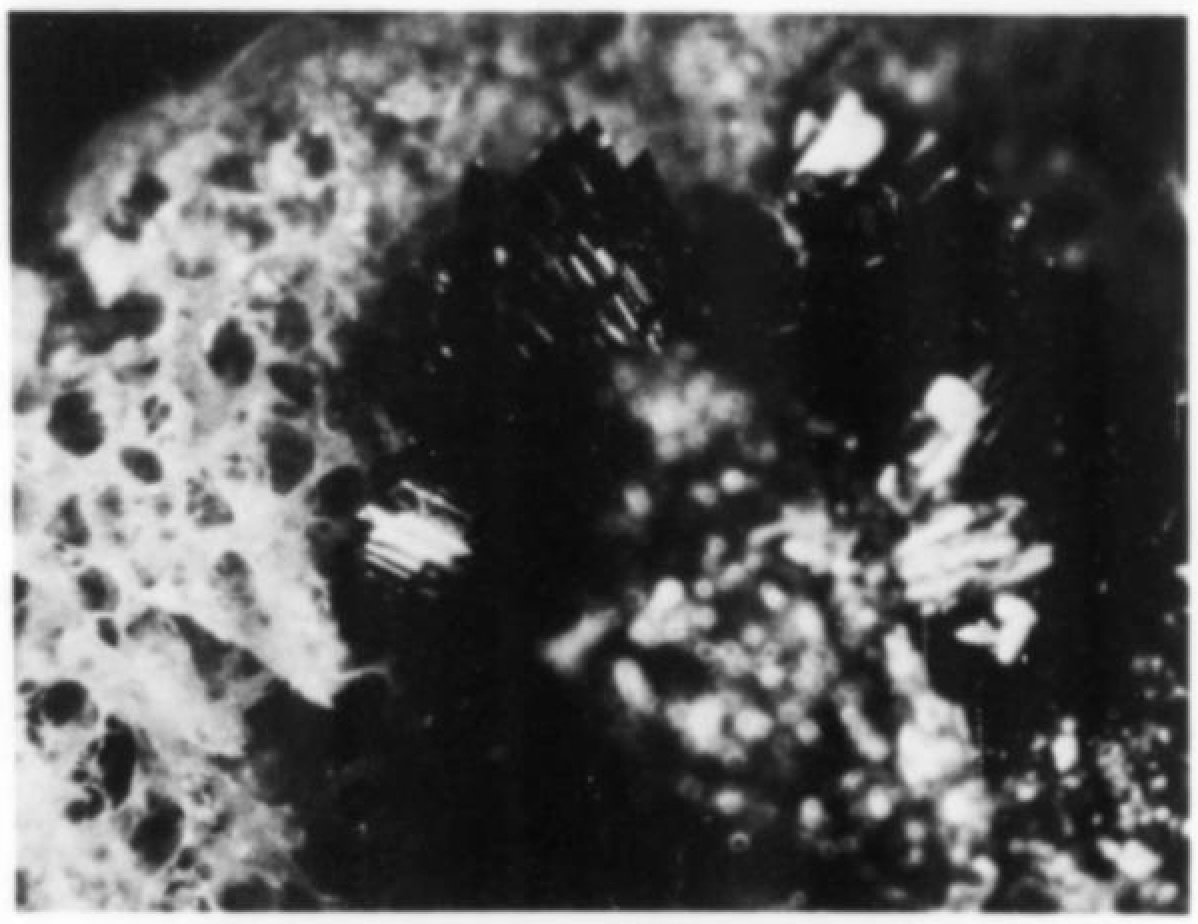


Figure 14. **Lammerite. Width of picture: 4 mm. Collection of P. Keller; photo by P. Keller.**

Lammerite

$Cu_3(AsO_4)_2$, monoclinic, a recently described new mineral from Laurani, Bolivia (Keller, Paar, and Dunn, 1981). A few months later it was also found at Tsumeb, as groups of very nice crystals up to 0.4 x 0.7 x 1.0 mm (Fig. 14), better than the type material. The crystals show the faces {100}, striated {120} and termination with {011}. They are elongated parallel to [001]. Lammerite is dark green and transparent. The luster is brilliant subadamantine and the streak very pale green. Cleavage is probably distinct on {010}, {100} and {001} (Fig. 14).

Lammerite was found in the North-East stope, 35 level, in Jan-

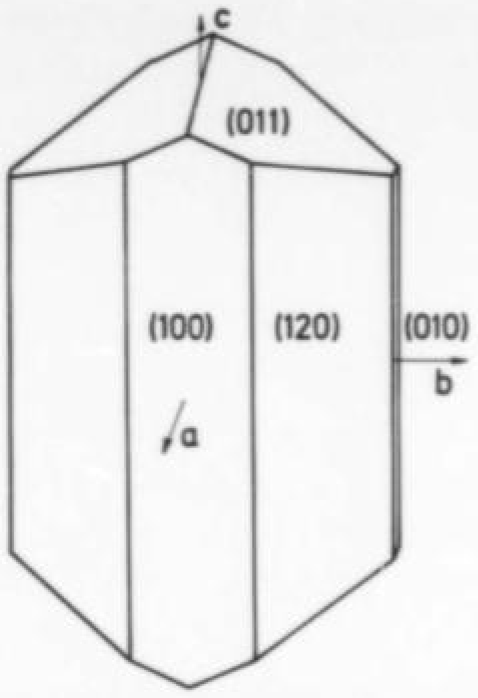


Figure 15. **Lammerite. Idealized drawing.**

uary or February of 1980. The mineral is often covered by blue masses of chalcanthite and further associated with anhydrite, leightonite, a TK-like mineral, and unidentified silicates.

Lammerite may be confused with olivenite or cuprian adamite due to its crystal form and color, or with brochantite due to its color and assemblages (Keller, 1981).

Figure 16. **Larsenite, white dull, with willemite. Width of picture: 8 mm. Collection of P. Keller; photo by P. Keller.**

Larsenite

$PbZn(SiO_4)$, orthorhombic, has been found in the assemblages of queitite and alamosite. It forms radiating masses of very fine, dull white fibers up to 2 mm in length (Fig. 16).

Legrandite

$Zn_2(H_2O)(OH)(AsO_4)$, monoclinic, found by one of the authors (W.B.) on the 31 level in March of 1978. It occurs as brilliant orange-yellow radiating masses. Single crystals reach a maximum size of nearly 10 mm. Legrandite is only associated with smithsonite.

Perhaps this mineral is much more common at Tsumeb, but might sometimes be mistaken for mimetite.

Leightonite

$K_2Ca_2Cu(SO_4)_4 \cdot 2H_2O$, pseudo-orthorhombic, occurs as white to very pale greenish blue crystals elongated parallel to [001], up to 1.0 mm in length. The dominant crystal form is {110} with very small {010} faces and terminated by {111} and {131}. The crystals are dull and often edged. No cleavage is obvious.

Specimens with leightonite have been found in the North-East stope, 35 level. It is associated with chalcanthite, anhydrite, and lammerite and may be overlooked as anhydrite (Keller, 1981). But, in contrast to leightonite, anhydrite shows perfect cleavages.

Maghemite

Fe_2O_3, cubic, was described as small cubic crystals with the main face {100} in combination with small {110} and {111} faces. The associations are willemite and duftite (Schnorrer-Köhler, 1980).

Minrecordite*

$CaZn(CO_3)_2$, trigonal, as minute, milky white rhombohedrons, some crystals curved or twisted. Associations include dioptase, zincian dolomite, calcite, dufite, malachite and cerussite. A magnesian variety, usually characterized by less distorted crystals, has also been observed (Garavelli, Vurro and Fioravanti, 1982).

O'Danielite*

$Na(Zn,Mg)_3H_2(AsO_4)_3$, monoclinic, occurs as pale violet, transparent grains with a vitreous luster. The grains are sometimes tabular on {100} and elongated parallel to [001]. The maximum size is 0.5 x 1.0 x 3.0 mm (Fig. 5). Cleavage is perfect on {010} and {100}, and observed on {001}. O'Danielite is isostructural with johillerite.

Only one specimen is known; o'danielite is associated with a pink, manganiferous koritnigite, brilliant water-clear needles of prosperite, green conichalcite and cuprian adamite. The sequence is: conichalcite, cuprian adamite, o'danielite, prosperite, and koritnigite (Keller, Hess, Dunn and Newbury, 1981).

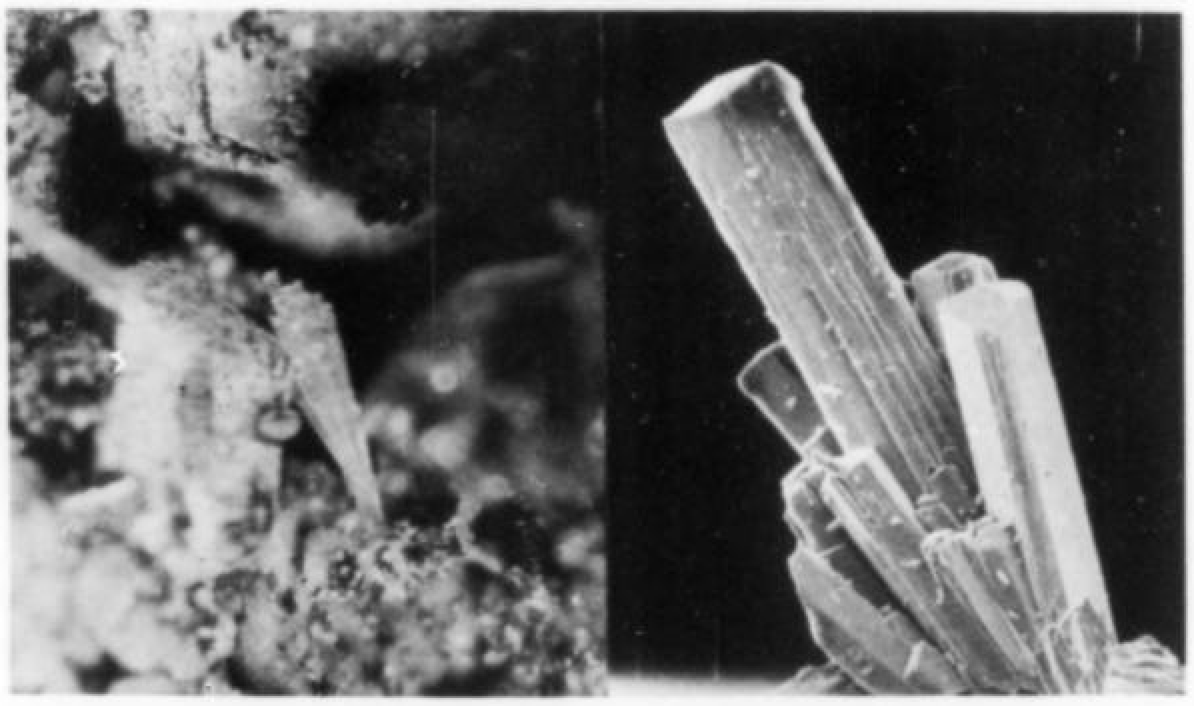


Figure 17. (left) **Otjisumeite with chalcocite. Width of picture: 3 mm. Collection of W. R. Kahn; photo by P. Keller.** ***(Right)*** **Width of picture: 0.5.mm. SEM photo by P. J. Dunn.**

Otjisumeite*

$PbGe_4O_9$, triclinic, formerly known as mineral TI (Keller, 1977), now approved as a new species. Otjisumeite is colorless, transparent to white with a subadamantine luster. It forms euhedral, pseudohexagonal crystals and fibers elongated along the *c*-axis up to 1 mm, commonly intergrown as sprays (Fig. 17).

The mineral is intergrown with siderite as the older and schaurteite as the younger mineral. Only two specimens are known as yet. But Otjisumeite may be easily misidentified as willemite needles (Keller, Hess, and Dunn, 1981a).

Paradamite

$Zn_2(OH)(AsO_4)$, triclinic, has been found as brilliant, water-clear, tabular crystals or as cleaved grains up to 3 mm tall. There is only one specimen known, where the sequence is: chalcocite, wulfenite, paradamite, cobaltian smithsonite crystals (very

Figure 18. **Paradamite with cobaltian smithsonite. Width of picture: 6 mm. Collection of P. Keller; photo by P. Keller.**

remarkable deep red color), unusual sand-colored, tabular adamite crystals up to 5 mm in tall, and very small needles of köettigite (Fig. 18).

Philipsbornite

$PbAl_3H(OH)_6(AsO_4)_2$, hexagonal, as very tiny, transparent crystals in association with quartz, azurite, tsumcorite, bayldonite, malachite and hematite (personal communication, K. Schmetzer).

Phlogopite

$KMg_3(F,OH)_2(AlSi_3O_{10})$, monoclinic, occurs as a low temperature secondary mineral in association with wulfenite (Medenbach, pers. comm.).

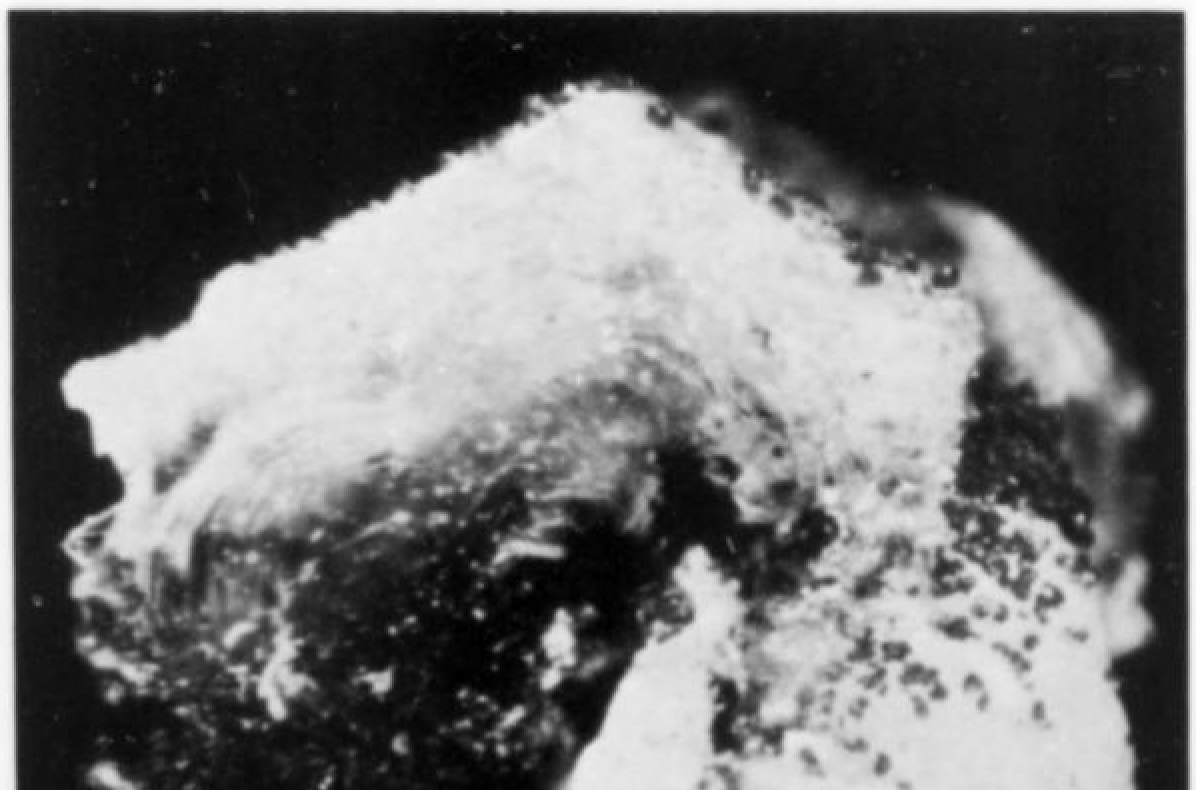


Figure 19. **Plumbotsumite with alamosite and melanotekite. Width of picture: 1.5 mm. Collection of W. Bartelke; photo by J. Weber.**

Plumbotsumite*

$Pb_5(OH)_{10}(Si_4O_8)$, monoclinic, has been found as colorless cleaved grains and as crystals tabular on {001} with undeterminable {h0l} or {0kl} faces up to 0.5 x 1.0 x 1.0 mm (Fig. 19). Cleavage on {001} is perfect. The luster is vitreous to subadamantine, pearly on the cleavage.

There is only one specimen known as yet. It is a large, exceptional piece of alamosite about 4 cm tall. Plumbotsumite was found in small vugs, mainly on the termination of the alamosite crystals, covered by tiny melanotekite spots.

It may be that plumbotsumite is more abundant, but often overlooked beside the rare and exceptional alamosite (Keller and Dunn, 1981b).

Prosperite*

$Ca_2Zn_4(H_2O)(AsO_4)_4$, monoclinic, forms white to colorless acicular crystals up to 10 mm in length and 1 mm in diameter, and also radiating aggregates. The crystals are elongated parallel to [001] with the important forms {100}, $\{\bar{1}01\}$, {110}, $\{\bar{1}11\}$ and {421}. Luster is brilliant vitreous to silky. No cleavage is observed.

On the few specimens known, prosperite is associated with conichalcite, cuprian adamite, austinite, koritnigite, gaitite, o'danielite, chalcocite and cuprite (Gait, Sturman, and Dunn, 1979).

Figure 20. **Queitite with melanotekite. Width of picture: 8 mm. Collection of P. Keller; photo by J. Weber.**

Queitite*

$Pb_4Zn_2(SO_4)(SiO_4)(Si_2O_7)$, monoclinic, colorless to pale yellow. It forms euhedral sword-like crystals, tabular on {001} and elongated on the *b*-axis, up to 0.5 x 3 x 10 mm. The crystal forms are dominant {001} with $\{10\bar{1}\}$ and terminated by {110} and {112} (Figs. 20 and 21). Cleavages on {010} and {001} are observed in traces. The luster is subadamantine.

Queitite has been found on a matrix of lead-copper ore associated with willemite, quartz, melanotekite, alamosite, larsenite, leadhillite, mimetite and wulfenite.

There has been only one find of few specimens. Queitite may be misidentified as pale yellow adamite, rarely found in former years (Keller, Dunn, and Hess, 1979).

Stibiconite

$SbSb_2O_6(OH)$, cubic, was described by Schnorrer-Köhler (1980) together with stibnite from an old specimen labeled "Otavi Mine

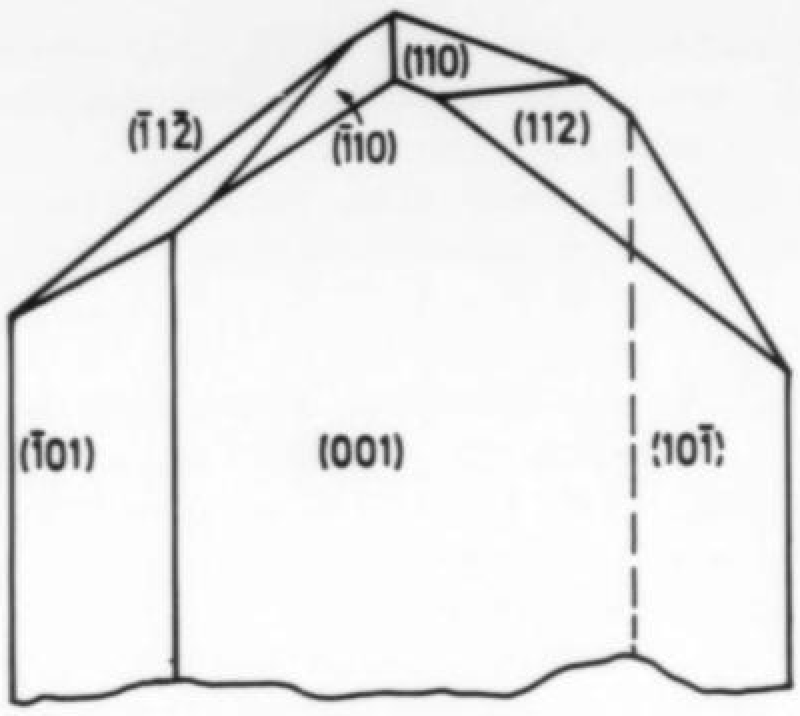


Figure 21. **Queitite. Idealized drawing.**

(Obere Teufe)," 1920. He presumed it to be a specimen from Tsumeb.

Stibnite

Sb_2S_3, orthorhombic, determined on a recently found specimen from Tsumeb. There is a tiny spray of acicular crystals associated with chalcocite on a matrix of tennantite ore.

Stolzite

$PbWO_4$, tetragonal, found as spectacular yellow crystals up to 2.5 cm in size (Foord and Conklin, 1982).

Warikahnite*

$Zn_3(H_2O)_2(AsO_4)_2$, triclinic, forms pale yellow to colorless, transparent crystals with a brilliant vitreous luster. Specimens are mostly radiating or subparallel intergrown aggregates of acicular or bladed crystals, elongated on [100] and about 5 mm in length. Euhedral crystals are very rare. Observed forms are {001}, {010}, {100} and some {0kl} and {hkl} faces (Fig. 4). Cleavage is perfect on {001} and distinct to good on {010} and {100}.

Warikahnite has been found in the E9 pillar, 31 level. It occurs in small vugs and on a matrix of tennantite ore. The association is: pale to emerald-green cuprian adamite, white koritnigite, blue stranskiite, pale sea-green crystals of helmutwinklerite, white corroded crystals of claudetite, ludlockite, tsumcorite and lavendulan. The colorless warikahnite is very unpretentious and may be overlooked (Keller, Hess, and Dunn, 1979).

Figure 22. **Ojuelaite. Width of picture: 4 mm. Collection of P. Keller; photo by P. Keller.**

Ojuelaite (zinc analog of authurite)

$(Zn, Cu)Fe_2(H_2O)_4(OH)_2(AsO_4)_2$, monoclinic, approved as a new species from another locality (Cesbron, Romero and Williams, 1981).

This new mineral occurs in Tsumeb as pale yellow-green, dishevelled fibers or sprays of acicular crystals elongated parallel to [001] (Fig. 22) and up to 1.5 mm in length. Possible forms are {110} and {112}. The luster is silky to vitreous for the acicular crystals. Cleavage is observed on {010}.

Ojuelaite is associated with earlier smithsonite and goethite and occurs on a matrix of tennantite.

INTERESTING NOTES

In the last five years, some known Tsumeb minerals have been found in spectacular quality and size or unusual habit. For example:

Fleischerite and **kegelite** from the 35 level, found in 1978.

Colorless, silky needles of fleischerite, up to 15 mm in length, were found grown on and through large yellow crystals of anglesite, which were partly covered by greenish black nodules of melanotekite and very perfect rosettes of pearly kegelite scales with maximum size of 2 mm.

Exceptional is a fleischerite specimen of 1.5 x 3.0 x 3.5 cm in size, consisting of subparallel intergrown pinkish needles up to 0.5 x 1 x 15 mm (Fig. 1); it may be the best ever reported.

Schultenite, mimetite and **chalcanthite** from the North-East stope, 35 level, found in 1980.

In January and February of 1980 a series of cavities in a partially oxidized lens of massive galena-tennantite ore yielded a suite of remarkably fine minerals. The most exceptional is the largest schultenite crystal ever reported, 17.5 cm tall. The maximum size of white and dull mimetite is 7.5 cm (Innes, pers. comm.). But the crystals are not as spectacular as the clear and sometimes doubly terminated mimetite found in 1971. Remarkable, too, are bright blue masses of chalcanthite up to several cm, containing several new Tsumeb minerals including lammerite and anhydrite.

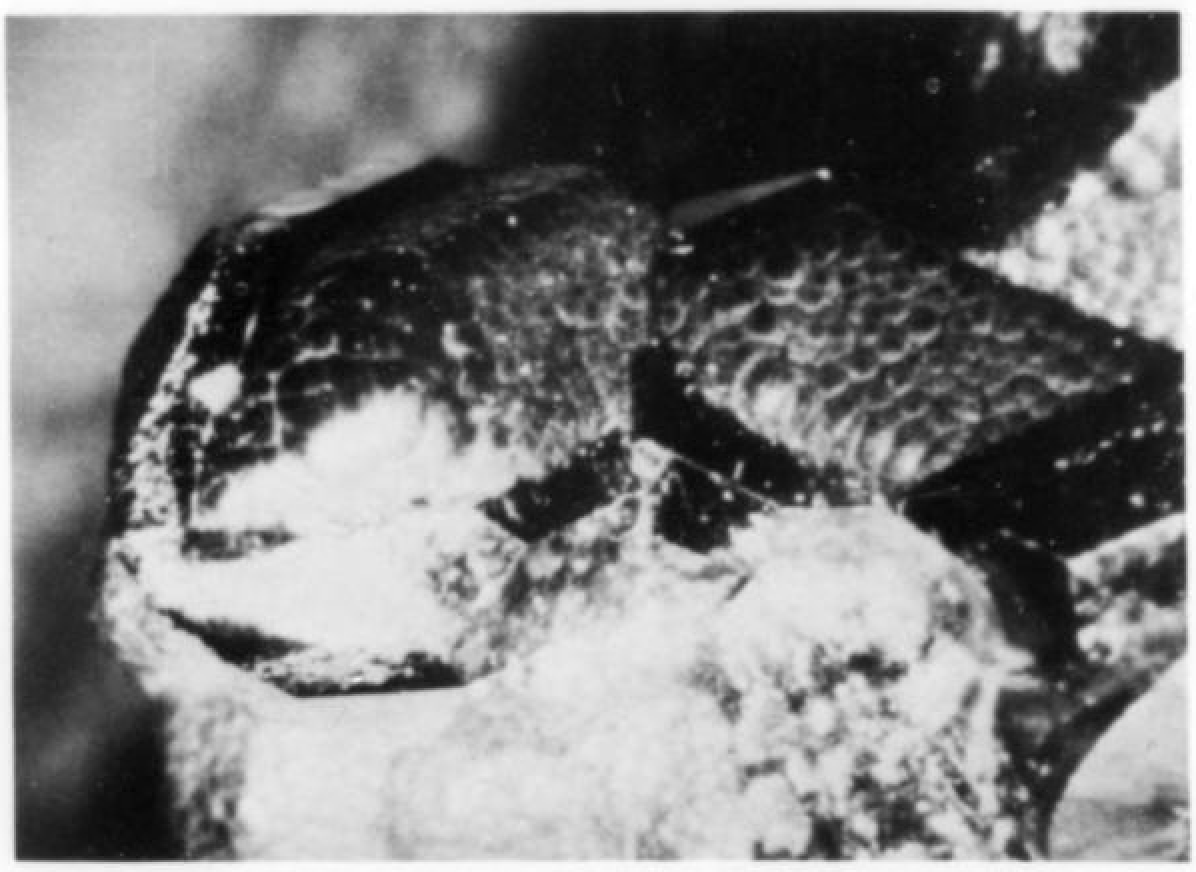


Figure 23. **Mimetite and hematite intergrowth. Width of picture: 8 mm. Collection of P. Keller; photo by P. Keller.**

Mimetite-hematite intergrowth.

Brilliant black crystals of mimetite up to 1 cm tall have been found in an unusual intergrowth with reniform masses of hematite (Fig. 23). A core of mimetite is covered by hematite which is partly or completely overgrown by a second generation of mimetite. Nevertheless, mimetite occurs as euhedral crystals with dominant prismatic and pyramidal faces. Associated minerals are smithsonite and quartz. Some very nice specimens are known.

Doubtful minerals

The algodonite described from Tsumeb may be an artificial (smelter?) product. Not a trace of matrix has been found and the crystals are covered by drop-shaped native lead!

The bindheimite of the Smithsonian collection was not found at Tsumeb. The original label gives another location in Namibia.

ASSEMBLAGES and SEQUENCES

The new minerals found at Tsumeb have been mostly zinc arsenates, followed by lead-zinc arsenates and silicates, and a few lead germanates, and finally a few with other chemical elements such as calcium, iron, magnesium and sodium.

The occurrence of new minerals consisting of common chemical elements is an indication of formation conditions different from those previously known. A mineral like hydrocerussite is an indicator of strong basic formation solutions with a pH of about 10 to 13, while minerals like koritnigite or o'danielite are stable in solutions with a pH of about 1 to 5. Both values may extend the former field of stability of Tsumeb minerals (Keller, 1977).

In most of the newly found minerals copper occurs only in traces and, surprisingly, there were only two new minerals of which copper is an essential part. Since copper ions were available, it may be that under the newly discovered conditions of formation well known copper minerals like conichalcite and cuprian adamite were also stable, or that only a few new copper minerals were able to crystallize.

Most of the new minerals reported from Tsumeb have been found in a few very typical assemblages as an indication of fairly wide-spread conditions of formation. The existence of some other new minerals is unique, as a fortuitous result of very special conditions; those probably occur in small, often isolated vugs in the orebody and country rock.

The most interesting and most abundant assemblage of new minerals has been found in the E9 pillar, 31 level. This assemblage dovetails into the sequence II/4 reported in Keller (1977) and extends it to an important family of Tsumeb minerals. The most abundant minerals are conichalcite as the earliest and a younger, often typically emerald-green cuprian adamite. All other minerals in this assemblage are rare. Known as of 1977 were keyite, a mineral that crystallized at about the same time as the cuprian adamite, and schultenite as the next youngest mineral in a sequence.

The new minerals koritnigite, warikahnite, helmutwinklerite, prosperite, gaitite, o'danielite and johillerite were described as members of the same assemblage, associated with other minerals such as claudetite, stranskiite, austinite, leiteite and ludlockite in special sequences. Koritnigite and, of lesser importance, warikahnite and prosperite are the more abundant of these rare minerals and connect together the different sequences in this assemblage (Table 1).

The conditions of formation of these minerals have to be acidic with pH less than 5 and a medium oxidation potential. Because of the stability of As^{+3} ion in claudetite and the pH values, synthetic compounds isostructural with koritnigite, o'danielite and johillerite are stable in this assemblage (Zettler, Riffel, Hess, and Keller, 1979).

The next interesting assemblage, especially for new species, is the secondary lead silicate group. In association with alamosite there is larsenite and the two new species queitite and plumbotsumite. The investigation into another proposed new lead silicate will be furnished in the near future (mineral T1). The whole assemblage is, in order of frequency: queitite, willemite, melanotekite, quartz, larsenite, leadhillite, mineral T1, mimetite and wulfenite. Only a few specimens of this assemblage have been found in one unknown place in the Tsumeb mine. But some minerals dovetail well in the sequence R/1 (Keller, 1977).

Although alamosite and queitite occur on the same specimen, they build up different sequences. Queitite occupies nearly the same place as alamosite in this sequence; according to the circumstances queitite is older than melanotekite, mineral T1 and larsenite. But the sequence of queitite is younger than that of alamosite and some

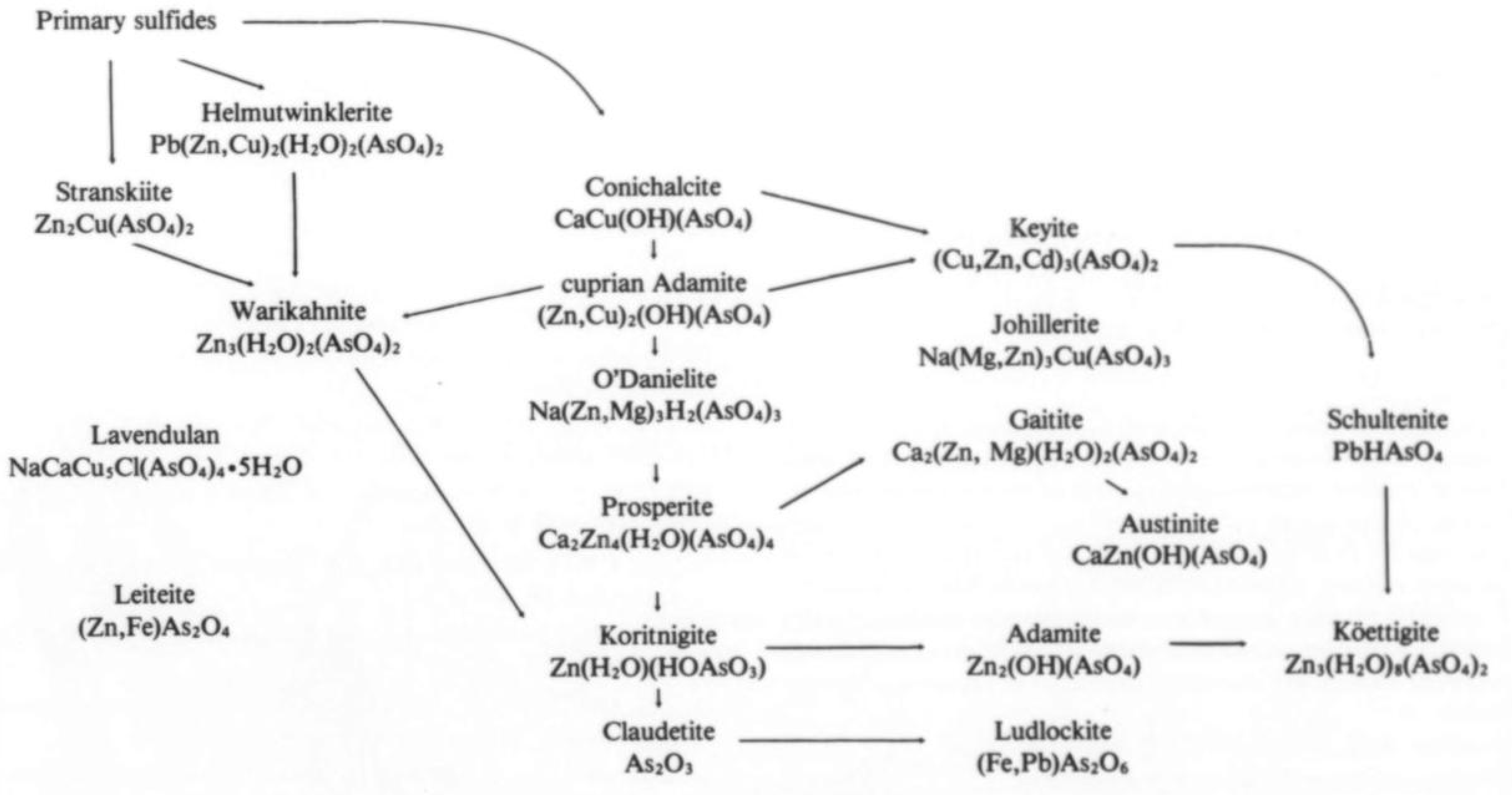
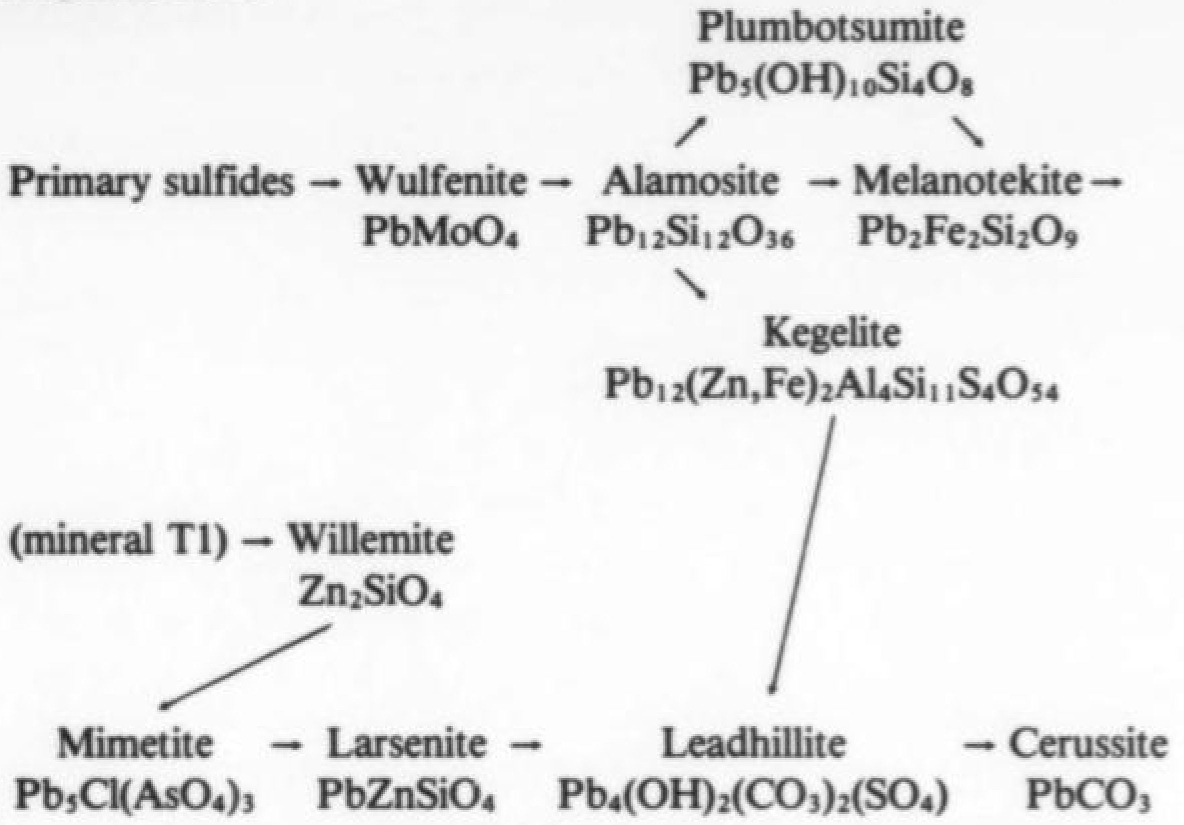


***Table 1.* The sequence II/4. The arrows indicate the direction of the passage of time and do not indicate reactions between minerals.**

indications for a removal of alamosite by the younger lead silicates have been observed (Sequence R/4).

Sequence R/1:



Sequence R/4:

Primary sulfides → Quartz → Willemite → Queitite →
SiO_2 Zn_2SiO_4 $Pb_4Zn_2(SO_4)(SiO_4)(Si_2O_7)$

Melanotekite → (mineral T1) → Willemite → Larsenite
$Pb_2Fe_2Si_2O_9$ Zn_2SiO_4 $PbZnSiO_4$

No definitive data yet exist about the conditions of formation of these lead silicates.

The two new secondary lead-germanium minerals otjisumeite and bartelkeite have been found in very fine cavities in germanite-renierite-briartite-bearing tennantite ore. Cavities of this kind are commonly more or less filled with quartz, chalcocite, calcite, siderite and gypsum. Rarely, they contain fine white needles of schaurteite.

Up to now, only two specimens of otjisumeite and bartelkeite are known. Therefore, the exact relations between these minerals are still unknown. Previous sequences are:

Sequence R/5:

Primary sulfides → Chalcocite → Siderite → Otjisumeite → Schaurteite
Cu_2S $FeCO_3$ $PbGe_4O_9$ $Ca_3Ge(OH)_6(SO_4)_2 \cdot 3H_2O$

Sequence R/6:

Primary sulfides → Chalcocite → Bartelkeite
Cu_2S $PbFeGe_3O_8$

A very interesting assemblage of copper minerals was found in January and February of 1980 in the North-East stope, 35 level. Deeply oxidized ore, mainly consisting of galena and tennantite, formed porous masses with vugs of several centimeters in diameter. The vugs are more or less filled with bright blue chalcanthite as the youngest mineral, covering some other minerals new for Tsumeb.

In order of their occurrence, the assemblage consists of chalcanthite, anhydrite, lammerite, leightonite, a TK-like mineral, unidentified silicates, and secondary gypsum. The sequence of crystallization is:

Sequence R/7:

Primary sulfides → Chalcocite → Lammerite → unidentified silicates →
Cu_2S $Cu_3(AsO_4)_2$

TK-like mineral → Anhydrite → Leightonite →
$CaSO_4$ $K_2Ca_2Cu(SO_4)_4 \cdot 2H_2O$

Chalcanthite → Gypsum
$CuSO_4 \cdot 5H_2O$ $CaSO_4 \cdot 2H_2O$

The conditions of crystallization of anhydrite have been investigated in detail relative to the formation of salt deposits (Braitsch, 1962). In the pure system $CaSO_4$-H_2O, anhydrite is temperature-stable up to 40° C. In the presence of other ions, the gypsum-anhydrite transformation temperature is lowered. But in the presence of higher activation energy for nucleation, gypsum will crystallize as a metastable phase at temperatures up to 50° C and more. Added to this is the information about the formation of chalcanthite and about lammerite synthesized in acidic solutions. This indicates that the minerals of this assemblage may crystallize from acidic solutions at relatively high temperatures (Keller, 1981).

In addition to scientific applications, the assemblages and sequences data are also very useful to the mineral collector in the search for and identification of rare and minute new minerals, those easily overlooked or misidentified as common or uninteresting species; these include gypsum/koritnigite and lammerite/brochantite.

ACKNOWLEDGMENTS

We are very grateful to W. R. Kahn, Bayersoien, Germany; C. S. Queit, Tsumeb; B. H. Geier, Grootfontein; J. Innes, Tsumeb; and R. Schedler, Tsumeb, Namibia, for donation or loan of minerals for scientific research. Thanks also are due to O. Medenbach, Bochum, Germany, and J. Innes, Tsumeb, for important unpublished information. We are also grateful to all the photographers who donated their superb pictures. This publication was suggested by editor W. E. Wilson, and we are thankful to him for the refinement of the manuscript.

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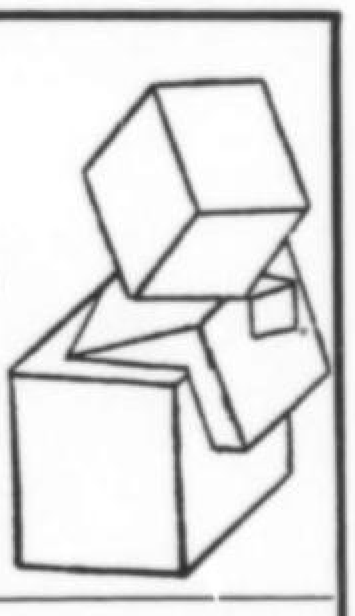

Stolzite from Tsumeb

by **Eugene E. Foord**
Stop 905
U.S. Geological Survey
Denver Federal Center
Denver, Colorado 80225

and **Nancy M. Conklin**
Stop 954
U.S. Geological Survey
Denver Federal Center
Denver, Colorado 80225

The Tsumeb mine can now add the world's finest stolzite crystal to its list of distinctions. The crystal was originally sold as anglesite.

INTRODUCTION

Tsumeb, Namibia (Southwest Africa), is world-famous for fine mineral specimens (Wilson, 1977). As part of a study of primary and secondary tungsten minerals from Nevada, we found that we needed a reference specimen of stolzite. Richard A. Kosnar provided a specimen for study which was purchased by him from Charles L. Key in 1973; Key had labeled it anglesite, $PbSO_4$, from Tsumeb. Key purchased the specimen from a miner in Tsumeb, and suspects that it is probably from the 28 level of the mine where many specimens of dioptase, cerussite and other species were mined at that time (Key, 1980, personal communication). The specimen is 3.2 x 5.1 x 6.4 cm, and consists of a matrix of metallic tennantite with clear prismatic, terminated quartz crystals that are typically 1.3 cm long on one surface of the specimen. A single, doubly terminated, transparent, light yellow crystal of stolzite, 1.3 x 1.3 x 2.5 cm (1 inch) rests on the quartz crystal and tennantite matrix (Fig.

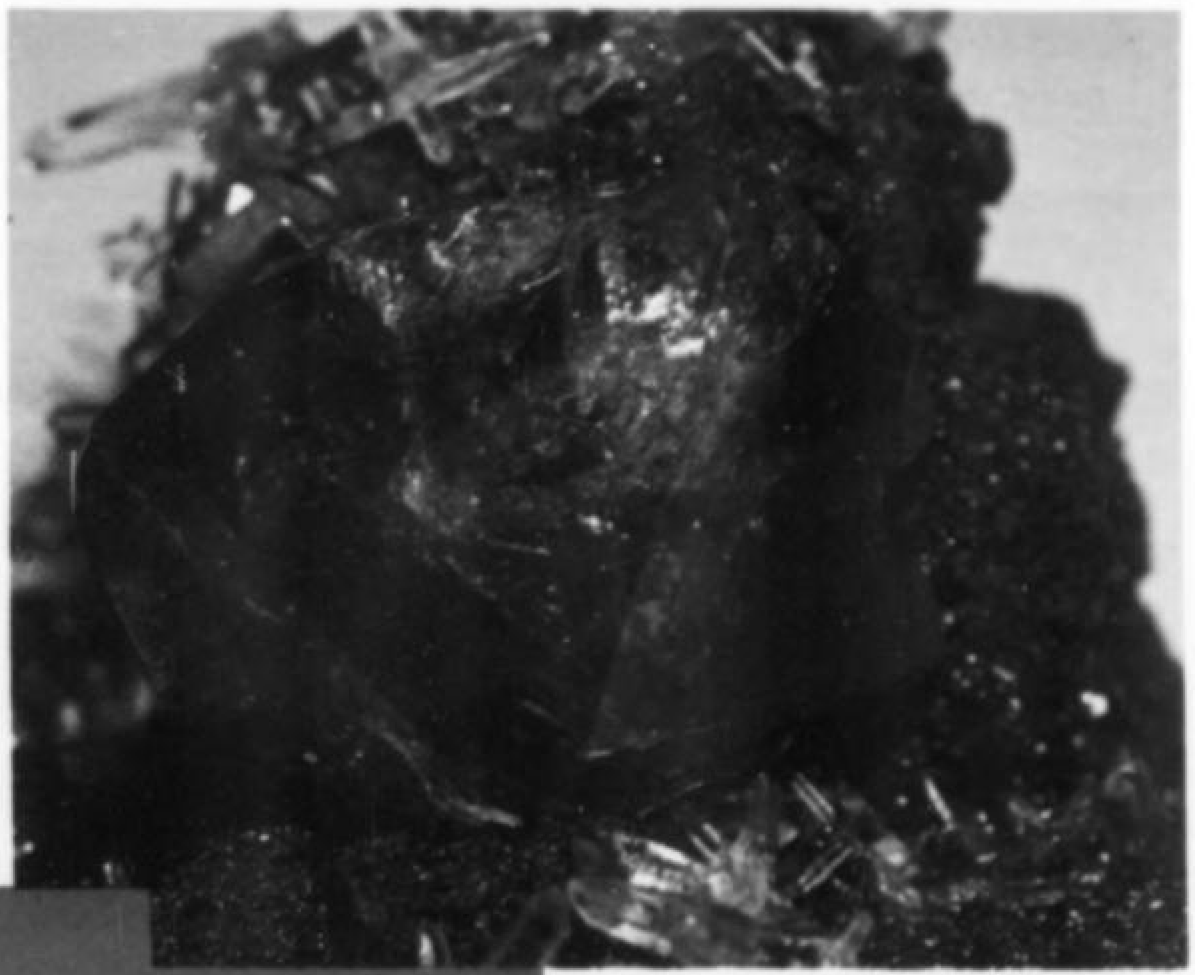

Figure 1. Close-up view of the stolzite crystal showing perfection of crystal form and internal quality. Photo by R. A. Kosnar.

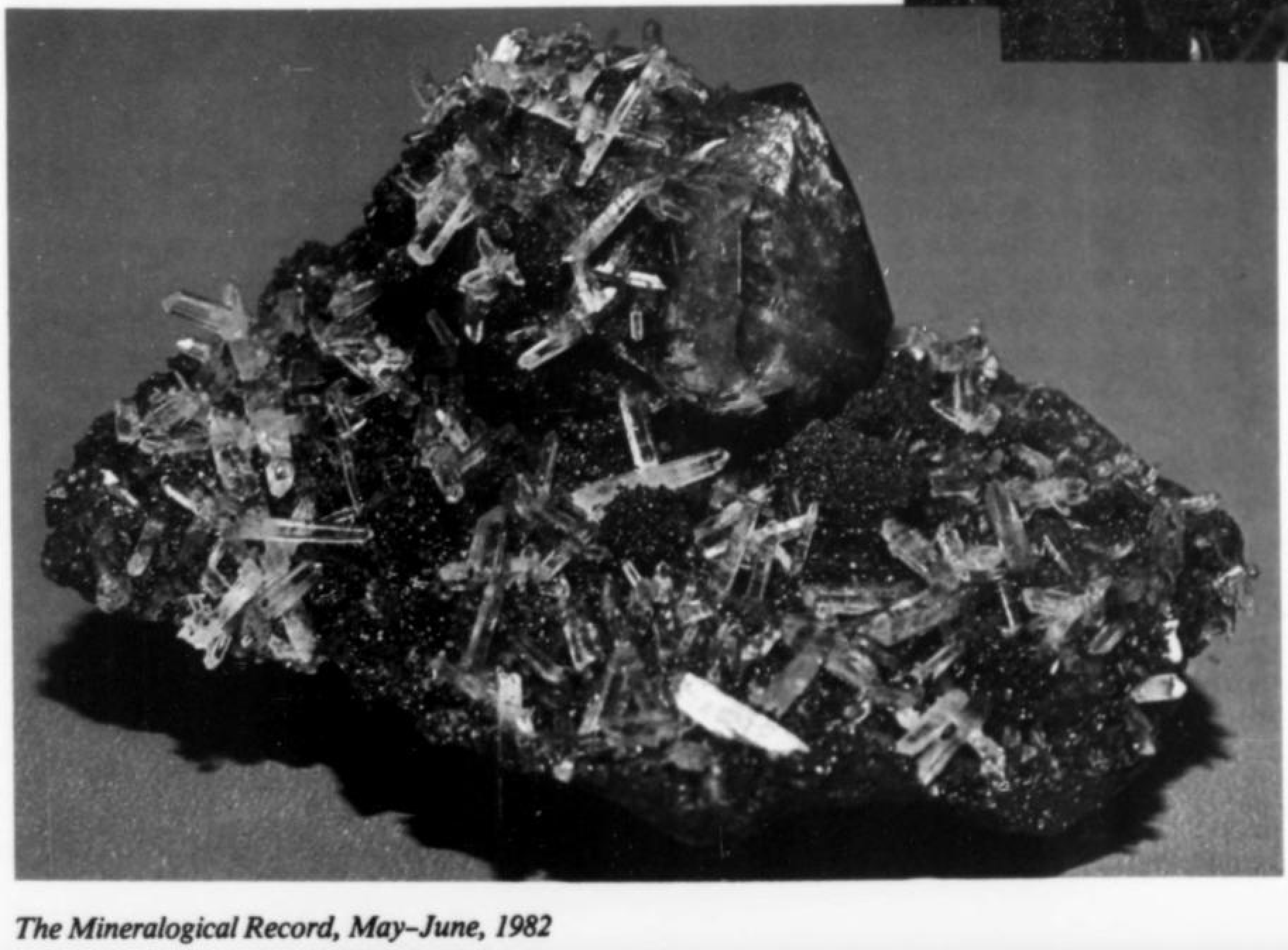

Figure 2. Matrix specimen of stolzite, quartz and tennantite. Stolzite crystal is doubly terminated. Photo by R. A. Kosnar.

1). The stolzite crystal is a doubly terminated tetragonal dipyramid, flattened on *c*, resting on *a* and shows development of the dominant forms {001}, {111}, {101}, and {122}, with subordinate development of {212}. Three additional, much smaller, crystals of stolzite originally were present on the specimen. Two have been removed for mineralogical studies. The stolzite crystals are fluorescent under both shortwave and longwave ultraviolet radiation. The shortwave fluorescence color is medium-strong lemon-yellow, and the longwave fluorescence color is bright red to red-orange. Fluorescent stolzite has been reported from only a few world localities.

MINERALOGY

Two small crystals (each less than 2 mm in maximum dimension) were removed from the specimen for identification and characterization. One crystal was powdered and examined using a standard petrographic microscope. The information thus obtained ruled out anglesite immediately. The remaining powder (about 10 milligrams) was consumed in a spectrographic analysis using a Vreeland[1] visual reading spectrograph that showed major lead and tungsten and only traces of molybdenum. The second crystal was powdered and examined using X-ray diffraction techniques. The X-ray pattern is an excellent match for stolzite. The distinction between wulfenite and stolzite is made on the basis of the presence or absence of one crucial reflection. At this point, the identity of the mineral as stolzite was confirmed.

Semiquantitative emission spectrographic analysis of the stolzite (3.1 milligrams) (powdered X-rayed fraction) by N. M. Conklin showed the following percentages of elements: Fe, 0.07; Ca, 0.01; As, 1; Cu, 1.5; Zn, 0.2; Mn, 0.005; Ag, 0.002; Ba, 0.005; and Mo, 0.2 (Pb and W are major constituents). All other elements were not detected or were less than the respective limits of detection. The Ag, As, Cu, Zn and most of the Fe are probably present as impurities (tennantite). The stolzite thus has the following substitution: $(Pb, Ca, Fe, Ba, Mn)(W, Mo)O_4$.

The identity of the associated tennantite was confirmed by X-ray diffraction and by semiquantitative emission spectrographic analysis. The analysis by Conklin showed the following percentages of elements: Fe, 3; Ti, 0.007; Mn, 0.015; Ag, 0.015; As, major; Ba, 0.0015; Cd, 0.3; Co, 0.003; Cu, major; Ni, 0.0015; Pb, 0.03; Sb, 0.3; W, 0.015; Zn, 10; Ga, 0.007; and Ge, 0.07. Approximately 0.7 percent Si was present as contaminant quartz. Possible other contaminants are stolzite and sphalerite. Several X-ray patterns showed no additional lines, however. The tennantite thus may be characterized as being close to end-member composition in terms of As-Sb ratio (only 0.3 percent Sb), and as a Zn-rich variety (10 percent).

DISCUSSION and CONCLUSION

The discovery of stolzite at Tsumeb is a first for that locality, and the size of the large single crystal makes it currently the world's largest known crystal for the species. The stolzite has a nearly end-member composition with only traces of Mo present and lesser amounts of Fe, Ba, Ca and Mn. The crystal morphology of other suspected stolzite crystals from Tsumeb should be examined carefully to distinguish them from anglesite, which is orthorhombic. Other stolzite crystals from Tsumeb undoubtedly exist.

REFERENCE

WILSON, W. W. (1977) Tsumeb! (editor) *The Mineralogical Record,* **8**, no. 3, 129 pp.

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[1] Use of trade names is for descriptive purposes only and does not constitute endorsement by the U.S. Geological Survey.

pyromorphite, wulfenite and other minerals from the Bwlch-Glas mine central wales

by **Richard S. W. Braithwaite**
Chemistry Department
University of Manchester Institute of Science and Technology
Manchester, M60 1QD, England

INTRODUCTION

In 1968 Peter Thomson and the author found tiny crystals of wulfenite on thin, microcrystalline coatings of pyromorphite on shale and quartz. These were found on an old dump derived from an open adit level at 850 ft. O.D.* of the abandoned Bwlch-Glas mine, Ceulanymaesmawr, Cardiganshire (now part of the new county of Dyfed), Wales. The find was of interest as wulfenite is a very rare mineral in Britain. Exploration of the underground workings accessible from the adit led to the discovery of a gossan zone rich in microcrystalline pyromorphite, with small amounts of cerussite and traces of wulfenite. Further exploration of this zone revealed a small chimney-like breccia-filled pipe rich in beautiful, bright green, well crystallized pyromorphite, which was subsequently worked upwards for about 12 feet until it narrowed out. Some of these specimens reached mineral dealers, and have been labeled as coming from "near Plynlimon," a well-known mountain in the area.

The lead-zinc mining district of central Wales has been worked from pre-Roman times to recently (Jones, 1922; North, 1962; Lewis, 1967; Bick, 1976). The area is mountainous, Mt. Plynlimon rising to 2468 ft. O.D. The lodes, which mostly trend east-northeast, are emplaced in Ordovician and Silurian mudstones, shales and grits, which were folded during the Caledonian orogeny into a number of periclinal structures, of which the "Plynlimon dome," in which the Bwlch-Glas mine is situated, is the most important. The primary mineralization consists of galena, sphalerite and minor scattered chalcopyrite in a quartz gangue, with carbonates and occasionally barite. Pyrite and marcasite are also common, other primary minerals very rare. Supergene alteration has affected some areas but not others, and is not normally intensive.

The Bwlch-Glas mine, on the east-northeast trending Hafan lode system, was little worked in earlier centuries, the bulk of its production of lead taking place in the early 1900's (Bick, 1976). The mine was worked from two adits, Upper adit at about 850 ft. O.D. at SN 710 875,** and Deep adit at about 680 ft. O.D. at SN 710 878, in which an interesting feature is an underground headframe for access to lower levels (Bick, 1976). Jones (1922) noted the presence of a gossany lode of cavernous, quartzose breccia in the upper level, which almost certainly corresponds with the pyromorphite-rich zone, though the presence of pyromorphite was not recorded.

MINERALS

The primary minerals occur in a quartz gangue and are not usually well crystallized; this is typical of minerals in the area. Two sulfides not previously reported are **greenockite,** CdS, found very rarely here as thin, bright yellow films on sphalerite, and **cinnabar,** HgS. Minute traces of cinnabar were found as brick-red powdery spots in quartz-"limonite" gossan carrying pyromorphite, on one specimen from the upper adit. This is the first record of cinnabar (or any mercury mineral) from Wales. Mercury minerals are most rare in Britain, the first (cinnabar) having been identified as recently as 1963 (Braithwaite, Greenland and Ryback, 1963).

Pyromorphite $Pb_5(PO_4)_3Cl$

Pyromorphite from the breccia pipe forms bright grass-green crystals, mostly quite small (about 1 to 2 mm long), but occasionally reaching 5 or 6 mm; the larger are commonly a more olive-green color. These crystals richly carpet or are scattered on milky white or iron-stained quartz pyramids coating angular breccia fragments, and are sometimes spotted with small patches of a brownish black, oily, bituminous material. Some specimens are completely coated with pyromorphite crystals on all sides. The specimens can be most attractive, not from crystal size as much as color, texture and shape.

The infrared absorption spectrum of this pyromorphite shows the PO_4^{3-} ν_3 absorption maxima in the normal positions, near 970 and 1030 cm^{-1}, and shows no absorptions due to arsenate.

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*O.D. = Ordnance Datum, height above Mean Sea Level at Newlyn, Cornwall.

**National Grid Reference, the coordinates defining a point on all Ordnance Survey maps.

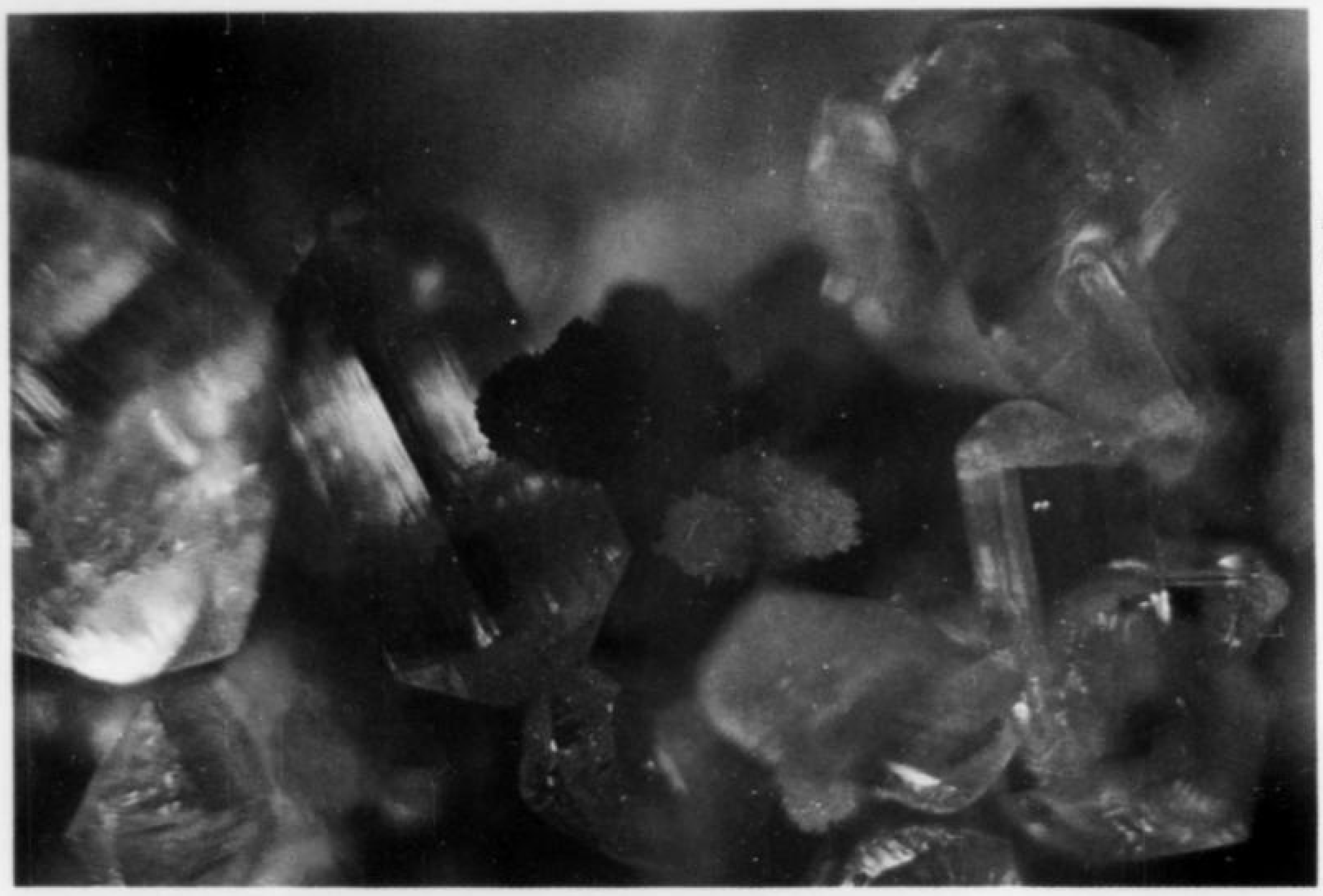

Figure 1. **Cerussite crystals, with pyromorphite, Bwlch-Glas mine. R.S.W.B. specimen (77-81) and photomicrograph (field 4.3 X 3 mm). Collected by R.S.W.B. and J. I. Wilson, 1977.**

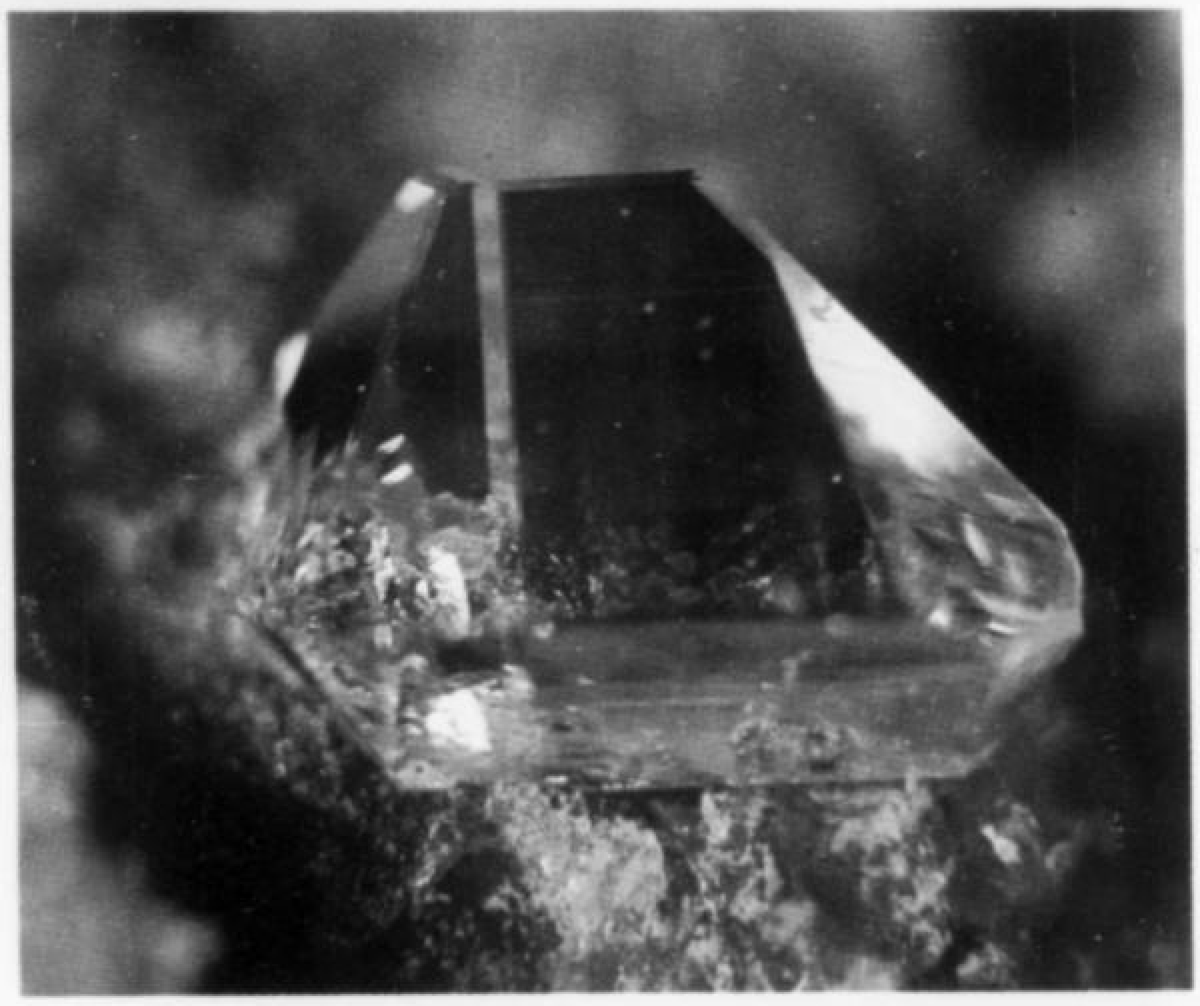

Figure 2. **Cerussite, transparent crystal, Bwlch-Glas mine, R.S.W.B. specimen (77-119) and photomicrograph (field 4.3 X 3 mm). Collected by J. I. Wilson, 1977.**

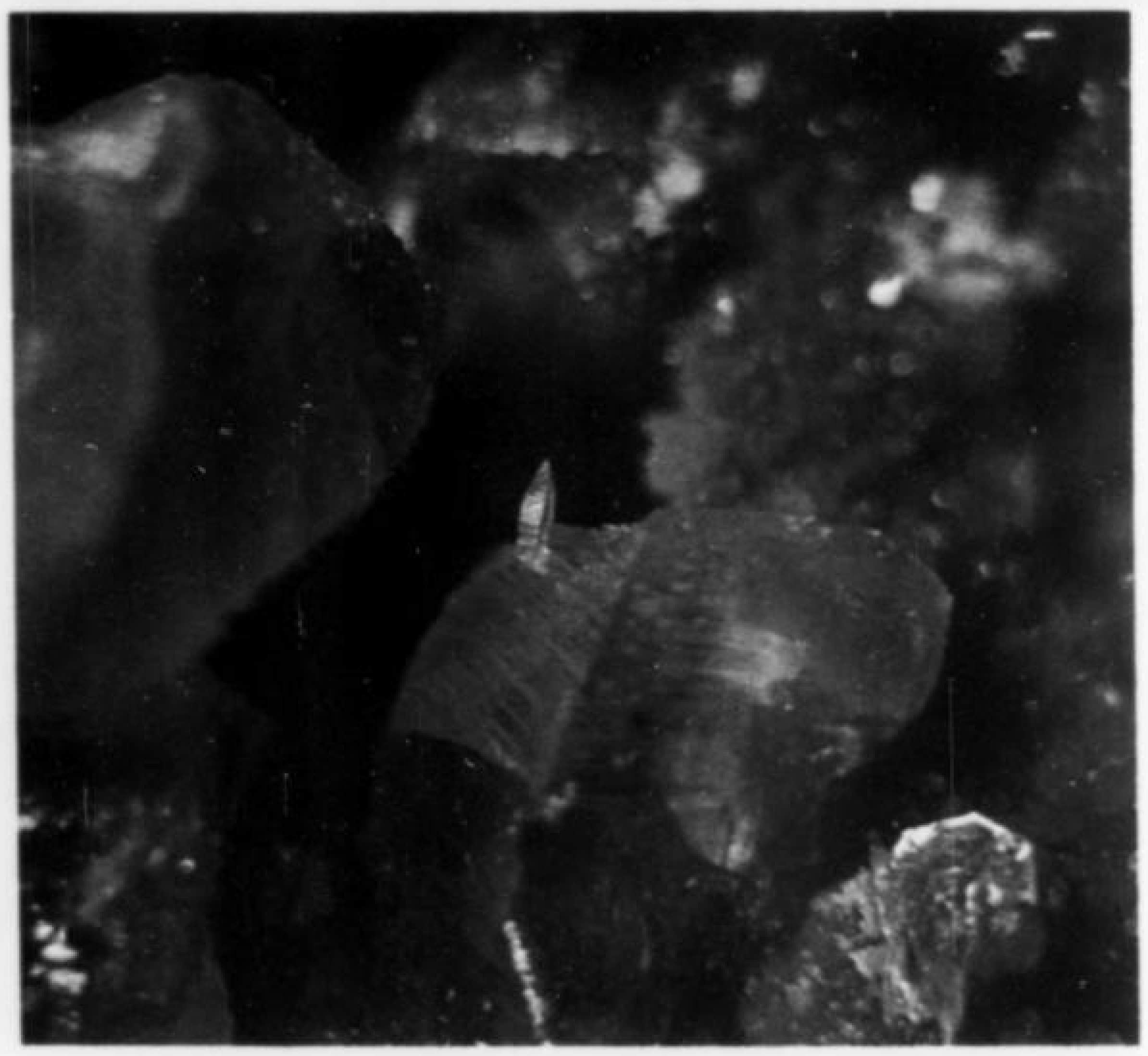

Figure 3. **Wulfenite on corroded cerussite, Bwlch-Glas mine. R.S.W.B. specimen (77-80) and photomicrograph (field 4.3 X 3 mm). Collected by R.S.W.B. and J. I. Wilson, 1977.**

Pyromorphites from other parts of the gossan zone are not particularly distinguished, apart from their bright green color, mostly forming microcrystalline crusts. Small amounts of orange pyromorphite were found in one cavity, and are discussed below with cerussite and wulfenite.

Pyromorphite from this mine is found both earlier and later in generation than early-generation cerussite and wulfenite. Druses of acicular, late-generation pyromorphite have been noticed decorating earlier, larger crystals.

Cerussite $PbCO_3$

Cerussite is found here in three modes:

(1) crystals of platy habit, lining fracture surfaces,

(2) recent, stalactitic but well-crystallized rippled "flowstone" crusts on adit walls, giving attractive but very friable specimens,

(3) clear, separate crystals associated with the fine-grained pyromorphite and with wulfenite from one small cavity.

Crystals of the third mode can be of great beauty, though small. They are sharp, transparent crystals, mostly about 2 mm long and of an unusual habit reminiscent of anglesite. In part of this cavity, cerussites encrusted with late-generation pyromorphite have been partly to completely dissolved away, leaving a shell of pyromorphite, typically orange in color, which has continued to grow on the inside of the shell, accompanied by small, clear, scattered, reddish-orange wulfenite crystals of steep bipyramidal habit. These latter are also found on the corroded cerussite crystals. The lead content of this wulfenite is probably derived from dissolved cerussite, a local pH shift having taken place to more acidic conditions under which wulfenite and pyromorphite are stable and can grow at the expense of cerussite.

No cerussite was found with the well-crystallized pyromorphite in the breccia pipe.

Anglesite $PbSO_4$

Rare at this locality. Small amounts of microscopic crystals of long prismatic habit have been found in cavities within oxidizing galena.

Wulfenite $PbMoO_4$

Wulfenite from this mine is invariably found in close association with pyromorphite and with cerussite, but has not been found in the breccia pipe. Two generations of wulfenite occur, the earlier contemporaneous with early pyromorphite and before early cerussite, and a later generation parasitic on corroded cerussite and

Figure 4. **Bwlch-Glas mine, from the northeast. The Upper adit portal is out of sight just above the large upper dumps. (1979 photo by J. I. Wilson.)**

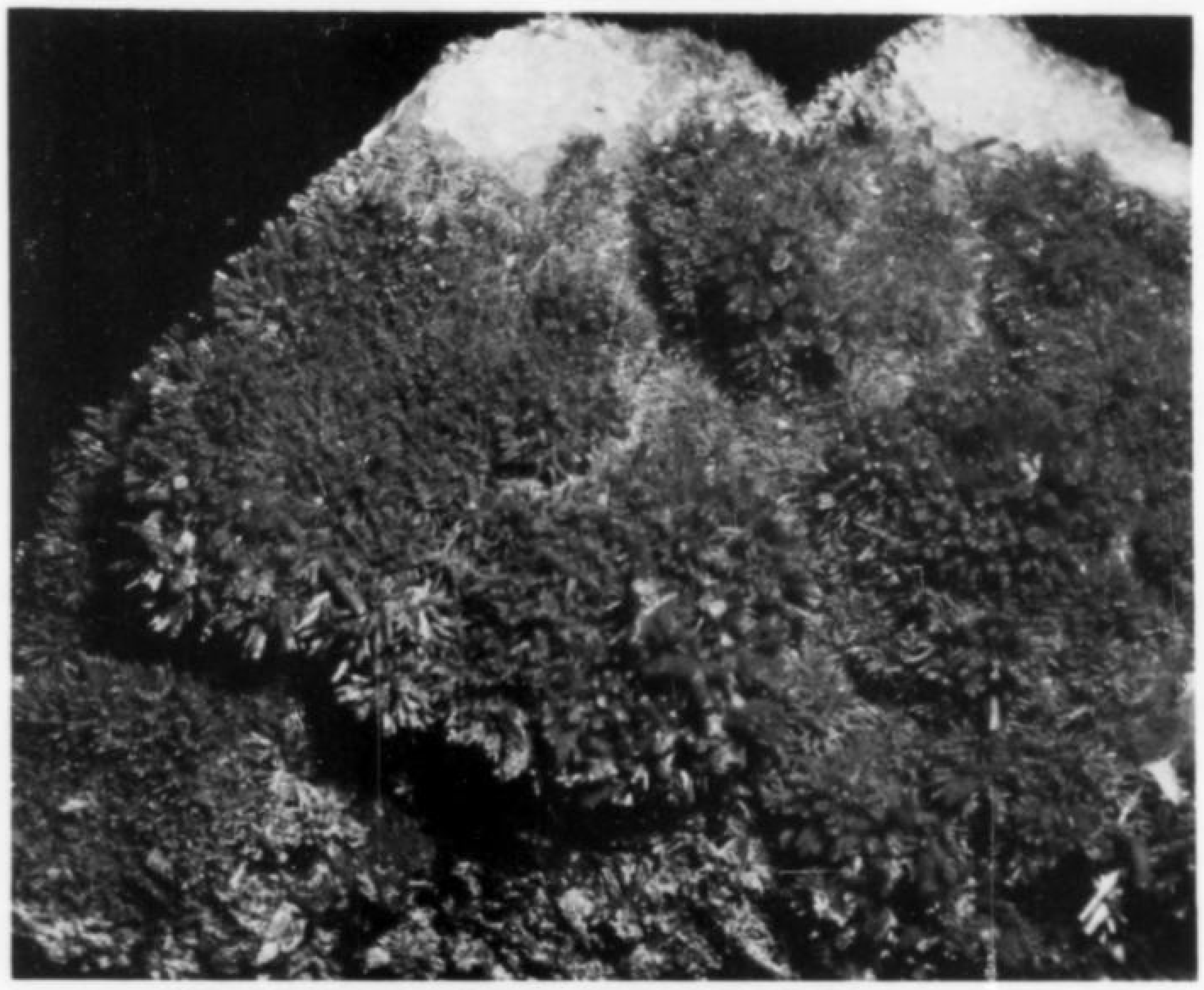

Figure 5. **Pyromorphite on quartz, Bwlch-Glas mine. R.S.W.B. specimen (76-10) (7 cm across) and photograph. Collected 1976.**

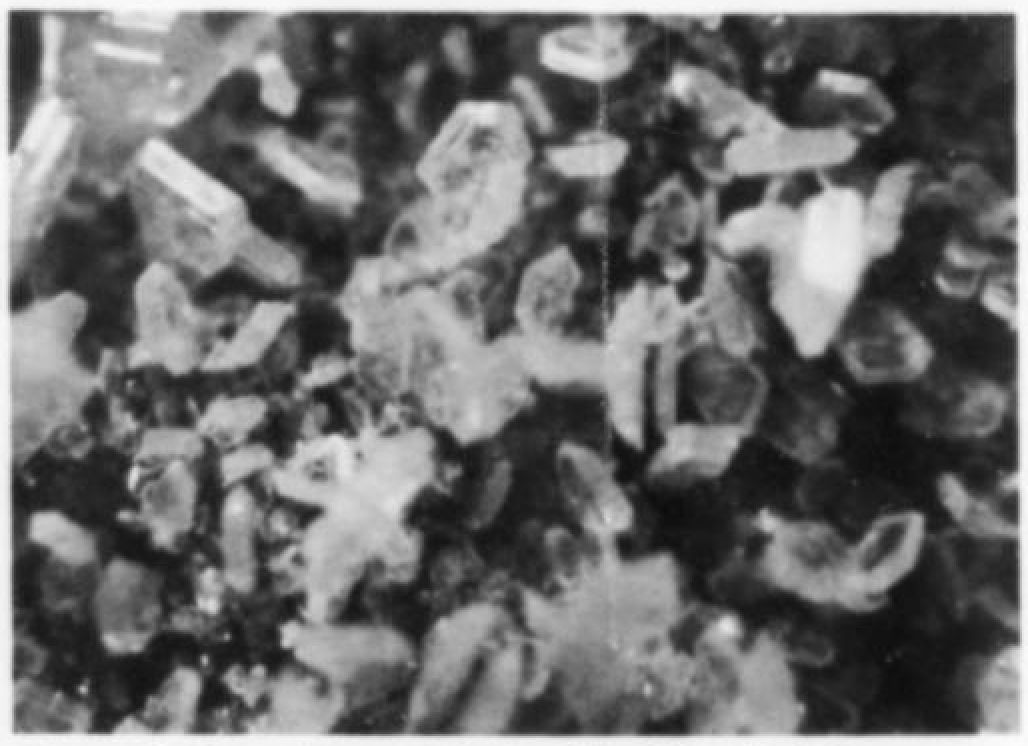

Figure 6. **Cerussite crystals in stalactitic rippled crust, Bwlch-Glas mine. R.S.W.B. specimen (77-74) and photomicrograph (field 4.3 X 3 mm).**

associated with orange pyromorphite. The early generation crystals are usually yellowish-orange in color and of bipyramidal habit, but a few have been found having short prismatic habit terminated with basal planes. The later generation crystals are more reddish orange and have an acute bipyramidal habit.

Hemimorphite $Zn_4Si_2O_7(OH)_2 \cdot H_2O$

Small amounts of hemimorphite as tiny, colorless, radiating crystals have been found on the dumps of the deep adit level.

ACKNOWLEDGMENTS

The author wishes to thank Peter Thomson and J. I. Wilson for their valuable contributions to the field work.

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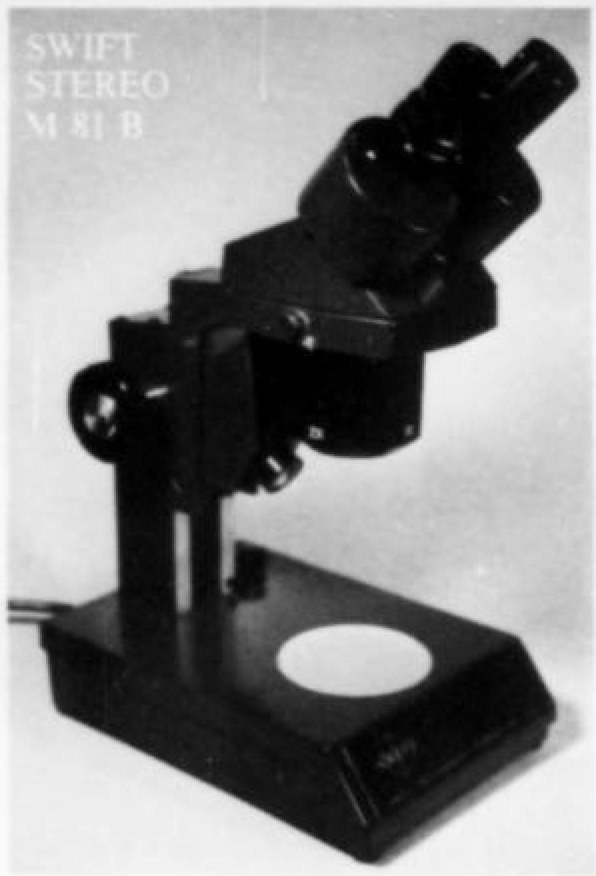

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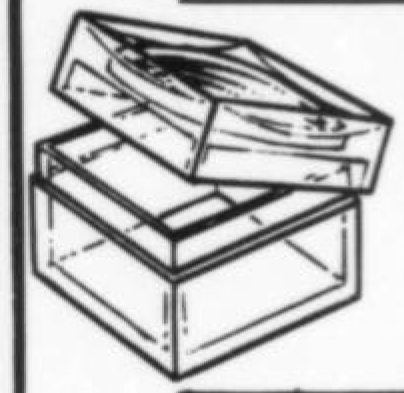

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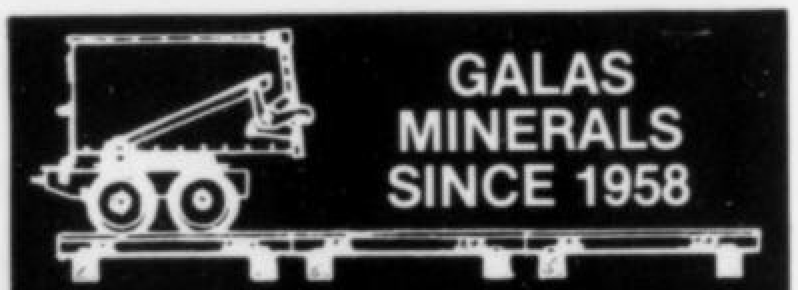

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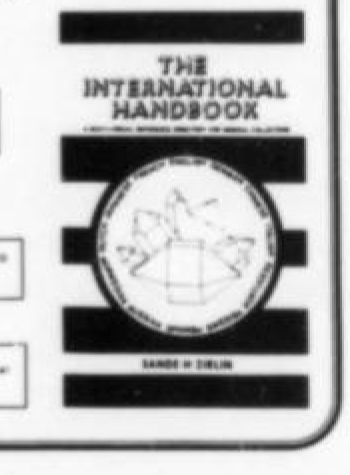

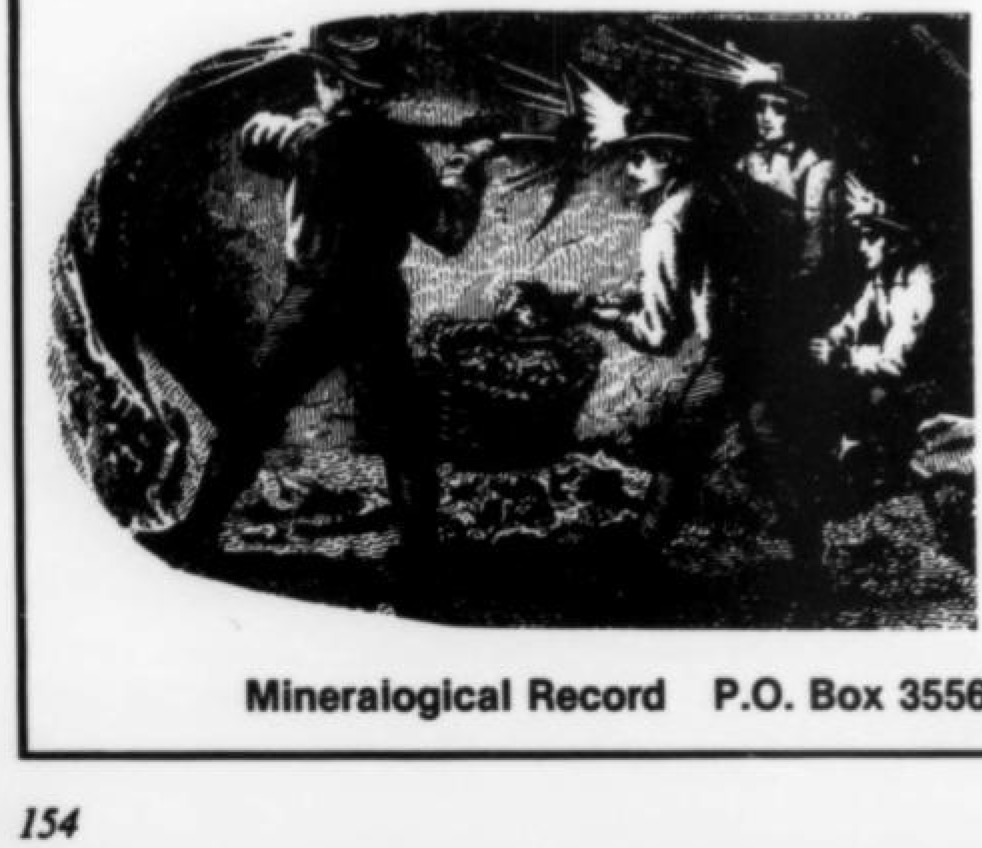

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Arsendescloizite

a new mineral from Tsumeb

by **Paul Keller**
Institut für Mineralogie und Kristallchemie
Universität Stuttgart
Pfaffenwaldring 55
D-7000 Stuttgart, West Germany

and **Pete J. Dunn**
Department of Mineral Sciences
Smithsonian Institution
Washington, DC 20560

ABSTRACT

Arsendescloizite, $PbZn(OH)(AsO_4)$, was found as yellow tabular crystals intergrown in rose-like aggregates in tennantite ore from Tsumeb, Namibia, associated with willemite, chalcocite, mimetite, quartz and goethite.

Microprobe analysis gave **PbO** 52.3, **ZnO** 18.5, **FeO** 0.3, **As_2O_5** 26.5, **H_2O**(TGA) 2.9, sum 100.5 percent. Cell contents for As = 1 are: $Pb_{1.06}(Zn_{1.03}Fe_{0.02})_{\Sigma 1.05}H_{1.46}As_1O_{5.34}$ ideally $PbZn(OH)(AsO_4)$ for which $D_{calc.} = 6.57$ g/cm³. Slightly soluble in hot HNO_3.

X-ray single crystal study showed it to be orthorhombic, $P2_12_12_1$, *a* 6.075(2), *b* 9.358(2), *c* 7.634(2) Å, Z = 4. The strongest lines in the X-ray powder diffraction pattern are: 3.23(10)(102), 2.88(10)(031,210), 2.60(8)(131), 1.559(8)(313,251,060), 4.23(6)(111), 2.09(6)(231), 1.656(6)(331,143,233)Å.

Crystals are tabular on {001}. Observed forms are {001}, {011}, {101} and {111}. Color pale yellow, transparent. Luster subadamantine, brilliant. Streak white. Hardness (Mohs) about 4. Biaxial negative, 2V about 30(5)°, dispersion $r > v$, with α 1.990(5), β 2.030(5), γ 2.035(5). Optical orientation: $X = b$, $Y = a$, and $Z = c$.

The name is for the chemical and crystallographic relations to descloizite, which is the vanadium analog of this mineral.

OCCURRENCE

Arsendescloizite was brought to our attention by Wolfgang Bartelke, who submitted for identification a pale yellow mineral looking like adamite or tsumcorite. Surprisingly, the powder diffraction pattern was nearly identical with that of descloizite. However, there was no trace of vanadium, so we became convinced that we were dealing with a new species, probably the arsenic analog of descloizite.

Arsendescloizite was found as a secondary mineral on a matrix of copper ore consisting mainly of tennantite, $(Cu,Fe)_{12}As_4S_{13}$, and chalcocite, Cu_2S. The new mineral is associated with willemite, Zn_2SiO_4, in water-clear prismatic crystals, with euhedral chalcocite crystals, corroded mimetite $[Pb_5Cl(AsO_4)_3]$, quartz, and goethite [∞-FeOOH], in order of abundance. The observed sequence of deposition, from the oldest to the youngest, is:

chalcocite → quartz → mimetite → arsendescloizite → goethite → willemite

Unfortunately, we have no information about which part of the mine our specimens came from.

PHYSICAL and OPTICAL PROPERTIES

Arsendescloizite crystals are tabular on {001}, up to 0.1 x 0.4 x 0.5 mm in size and intergrown as rose-like aggregates (Fig. 1). Observed forms are {001}, {011}, {101}, and {111} (Fig. 2). The new mineral is pale yellow with a brilliant subadamantine luster. The streak is white and the hardness (Mohs) is about 4. No cleavage was observed.

Arsendescloizite is optically biaxial negative, 2V about 30(5)°, dispersion $r > v$. The indices of refraction are α 1.990(5), β 2.030(5), and γ 2.035(5), with the optical orientation $X = b$, $Y = a$, and $Z = c$. Calculation of the Gladstone-Dale relationship using the constants of Mandarino (1976) and the calculated density yields a value

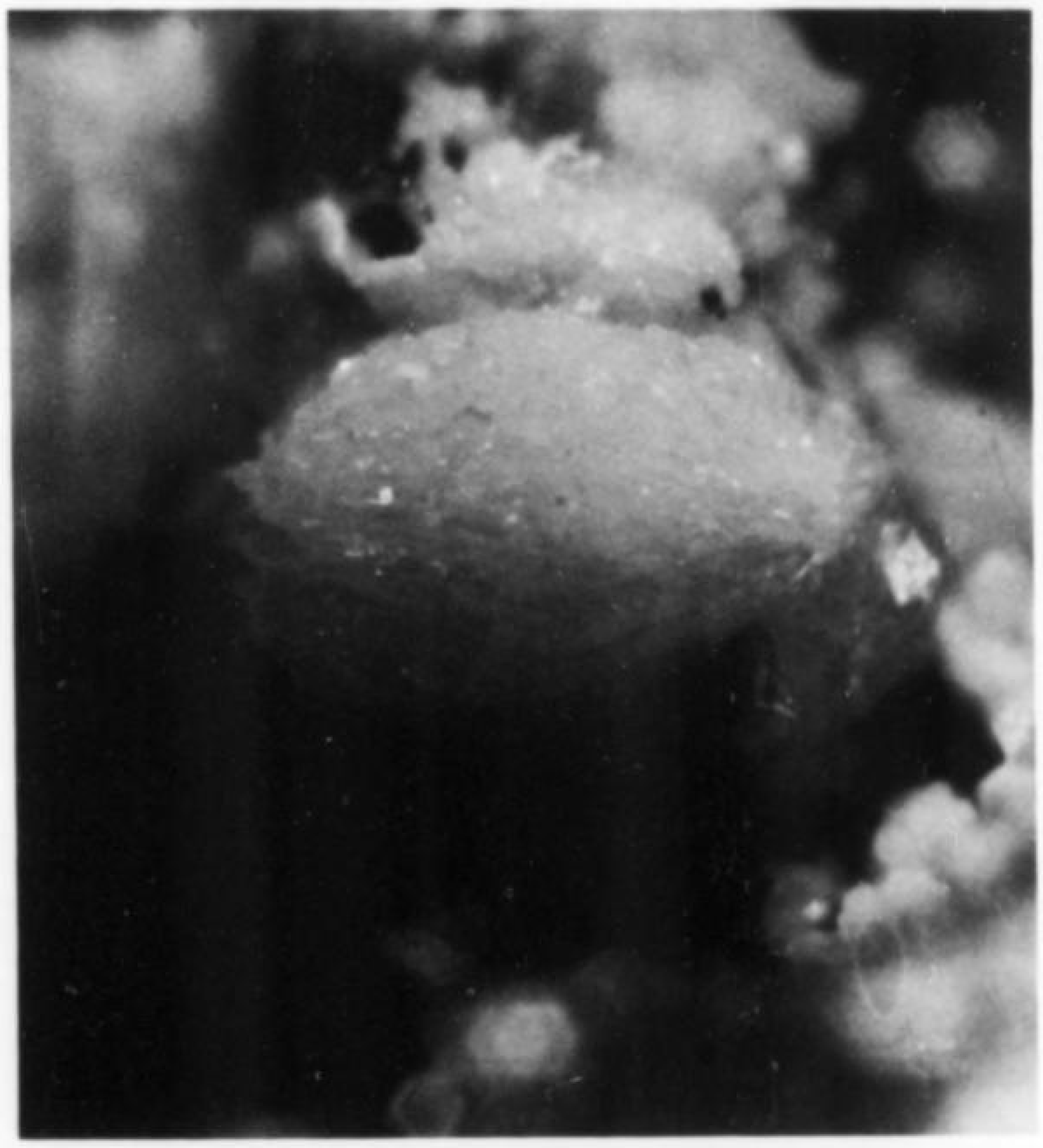

Figure 1. **Arsendescloizite: tabular crystals intergrown in rose-like aggregates. Size: 3 mm wide. Collection of W. Bartelke; photo by J. Weber.**

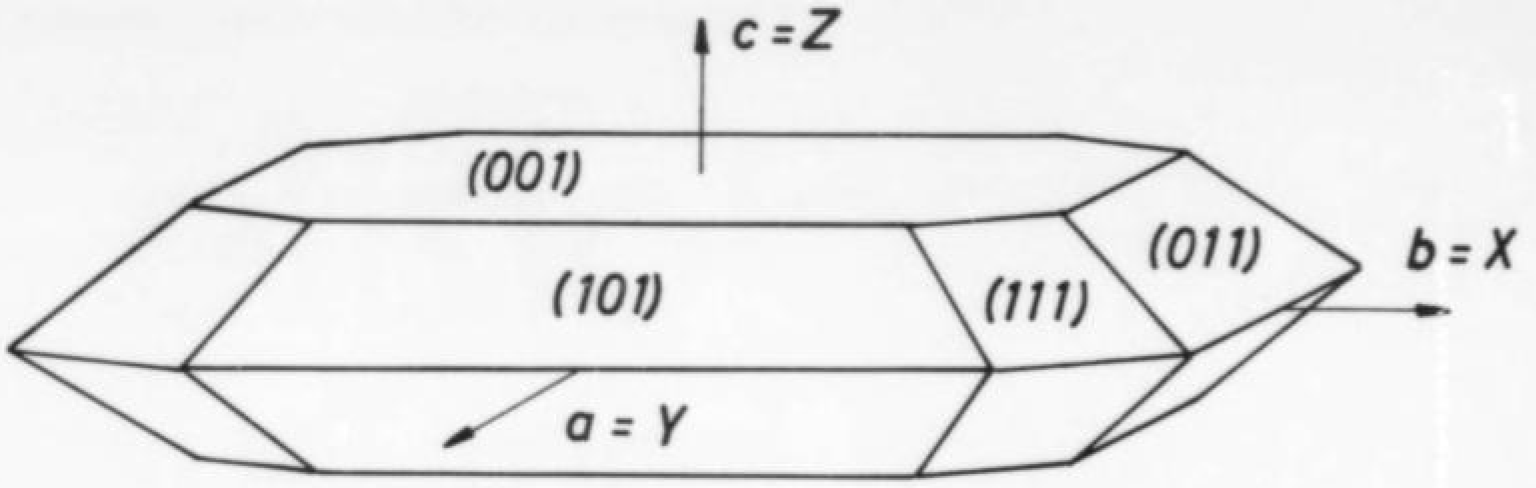

Figure 2. **Arsendescloizite: idealized drawing with faces and optical orientation.**

of $K_C = 0.152$, in good agreement with the value calculated for physical properties, $K_P = 0.155$.

X-RAY DIFFRACTION STUDY

A small fragment of a euhedral crystal was examined by Weissenberg and precession techniques and finally measured with an automatic four-circle diffractometer.

Arsendescloizite is orthorhombic; systematic absences show the space group to be $P2_12_12_1$. The unit cell parameters are a = 6.075(2), b = 9.358(2), and c = 7.634(2) Å. For Z = 4 and the ideal formula, the calculated density is $D_{calc.} = 6.57$ g/cm³. A powder diffraction pattern (Table 1) was obtained using a 114.6-mm-diameter Debye-Scherrer camera and Fe$K\alpha$ X-radiation without standards. The calculated d values and the indices are derived from four-circle diffractometer data. The intensities I/I_o were estimated visually.

Table 1. **Indexed powder pattern for arsendescloizite, $PbZn(OH)(As^{7}/_{8}{}_{4})$, Fe-$K\alpha$ radiation, camera diameter 114.6 mm. Intensity I/I_o is estimated.**

$d_{obs.}$ (Å)	I/I_o	$d_{calc.}$ (Å)	hkl
5.09	4	5.088	110
4.67	5	4.680	020
4.23	6	4.238	111
3.98	1	3.990	021
3.54	2	3.535	012
3.33	2	3.336	121
3.23	10	3.231	102
3.04	3	3.037	200
2.88	10	2.889, 2.887	210, 031
2.70	4	2.703	211
2.66	5	2.659	122
2.60	8	2.608	131
2.55	1	2.549	220
2.46	2	2.456	013
2.42	2	2.417, 2.415	221, 032
2.30	4	2.303	212
2.24	5	2.237, 2.236	041, 023
2.10	1	2.099, 2.098	141, 123
2.09	6	2.092	231
1.970	1	1.972	033
1.911	2	1.909	400
1.877	5	1.876	133
1.850	2	1.854	240
1.788	5	1.789, 1.789, 1.787	150, 302, 114
1.764	3	1.767	024
1.720	4	1.723	043
1.678	1	1.681	052
1.668	1	1.671, 1.667	322, 242
1.656	6	1.658, 1.657, 1.654	331, 143, 233
1.618	4	1.620, 1.616	152, 204
1.559	8	1.562, 1.560, 1.560	313, 060, 251

CHEMICAL ANALYSIS

Arsendescloizite was chemically analyzed using an ARL-SEMQ electron microprobe with an operating voltage of 15 kV and a beam current of 0.15 μA. The results were corrected for background, backscatter, fluorescence and absorption using the MAGIC-4 computer program. The standards used were: synthetic olivenite for As, synthetic ZnO for Zn, synthetic PbO for Pb, and analyzed hornblende for Fe. The new mineral was checked for the presence of elements with atomic number greater than 9 by electron microprobe wavelength-dispersive scan but none were found except those reported in Table 2.

Table 2. **Electron microprobe analysis of arsendescloizite, $PbZn(OH)(AsO_4)$, H_2O by TGA, in weight percent.**

	Analytical	No. of atoms		Theoretical	No. of atoms	
FeO	0.3	Fe	0.02	–		
ZnO	18.5	Zn	1.03	18.99	Zn	1.00
PbO	52.3	Pb	1.06	52.09	Pb	1.00
As_2O_5	26.5	As	1.00	26.82	As	1.00
H_2O	2.9	H	1.46	2.10	H	1.00
		O	5.34		O	5.00
Total	100.5			100.00		

The water content was determined with a thermobalance using a 6.8 mg sample of arsendescloizite. There is a 2.9 weight percent water loss at a mean temperature of 530° C. The heating rate was 10° C/minute.

Arsendescloizite is slightly soluble in hot HNO_3.

The empirical formula was calculated on the basis of As = 1 because the water determination may not be of high accuracy, in view of the very small sample weight. The result is:

$$Pb_{1.06}(Zn_{1.03}Fe_{0.02})_{\Sigma 1.05}H_{1.46}As_1I_{5.34}$$

and idealized: **$PbZn(OH)(AsO_4)$**.

DISCUSSION

According to chemical composition alone, the new mineral could be the zinc analog of duftite, the lead analog of austinite, or the arsenic analog of descloizite. However, since the powder diffraction pattern of the new mineral is most similar to that of descloizite, it is named arsendescloizite. Also, there have been reported arsenic-containing descloizites from several localities (Palache, Berman and Frondel, 1951) with a maximum content of As_2O_5 7.13 weight percent (Bannister, 1933). Such arsenic-containing varieties of descloizite were named "araeoxene" by Von Kobell in 1850 (Strunz, 1970). Arsendescloizite is the pure end member of a possible solid solution series with descloizite. Surprisingly, the analyzed arsendescloizite contains no vanadium, copper or calcium.

NAME and TYPE SPECIMENS

The name is for the chemical and crystallographic relationship to descloizite, which is the vanadium analog of this mineral.

The Commission on New Minerals and Mineral Names, I.M.A., has approved the new mineral and its name prior to publication. Type material will be deposited in the Institut für Mineralogie und Kristallchemie, Universität Stuttgart, D-7000 Stuttgart 80, Federal Republic of Germany, and in The Smithsonian Institution, Washington, D.C. 20560.

ACKNOWLEDGMENTS

We thank Wolfgang Bartelke, Mainz, for the generous loan of specimens, H. Hess, Stuttgart, for the diffractometer measurement, J. Weber, Mamaroneck, for the photomicrograph.

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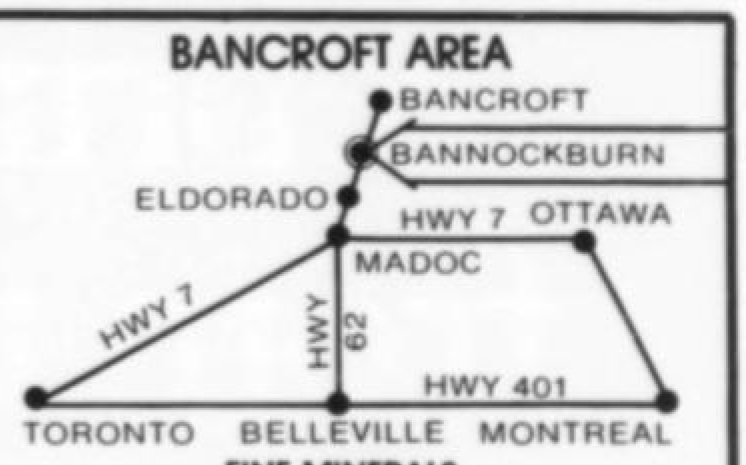

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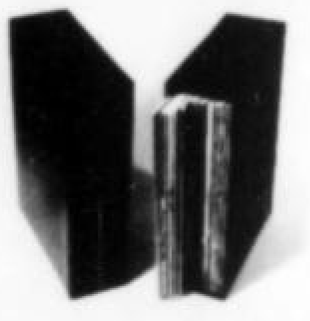

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Sperrylite
from the type locality

by **Robert I. Gait**
Department of Mineralogy and Geology
Royal Ontario Museum
100 Queen's Park
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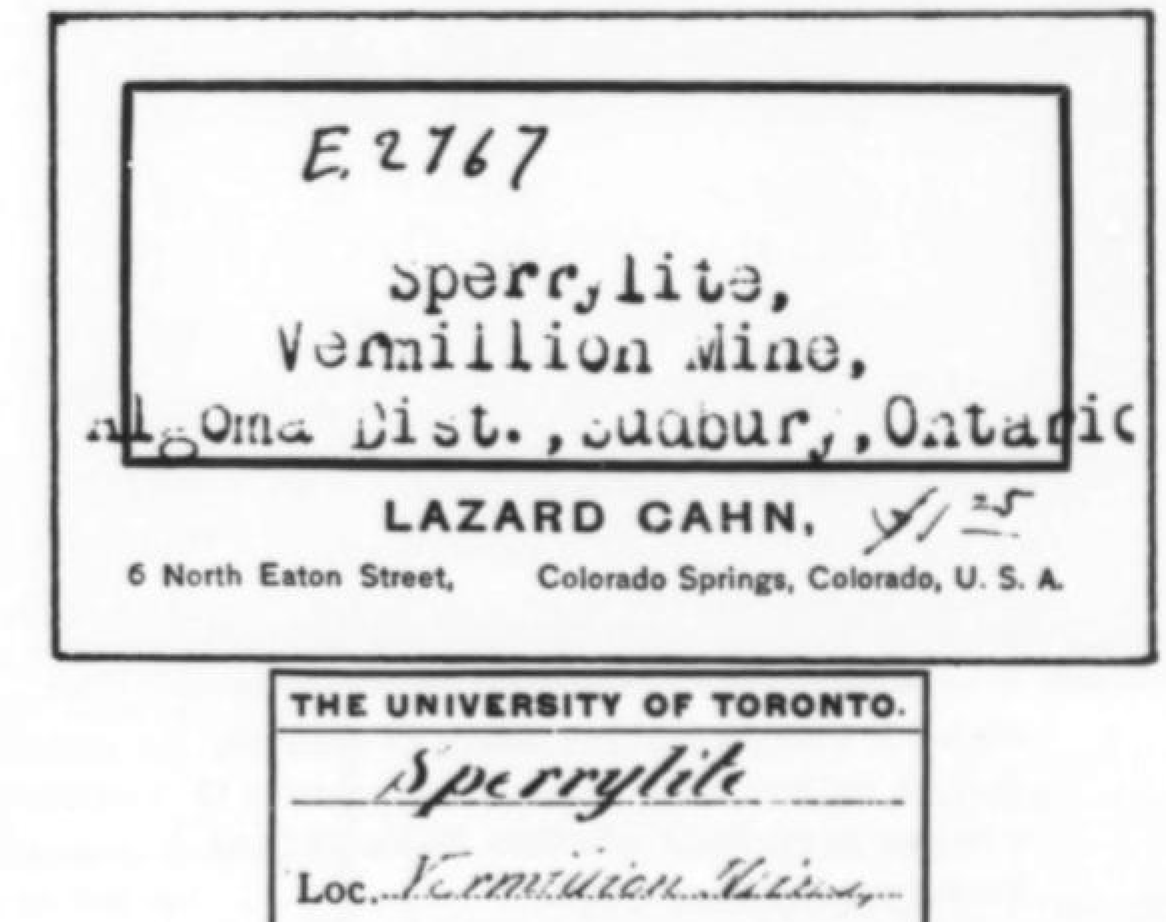
Sperrylite ($PtAs_2$) was first described in 1889 by Horace H. Wells, who, at that time, was at the Sheffield Laboratory, Yale University. He worked on material sent to him in October of 1888 by Mr. Francis L. Sperry, a chemist with the Canadian Copper Company of Sudbury, who had obtained that material from the Vermilion mine, located in Lot 6, Conc. IV, Denison Township, Sudbury District, Ontario. In his paper Wells quotes Sperry's description of the occurrence as follows:

> "The mineral was found at the Vermillion (sic) mine in the district of Algoma, Province of Ontario, Canada, a place 22 miles west of Sudbury and 24 miles north of Georgian Bay, on the line of the Algoma Branch of the Canadian Pacific Railway. The mine was discovered in 1887, and a 3-stamp mill was put up for the purpose of stamping gold quartz. Associated with this gold ore are considerable quantities of pyrite, chalcopyrite and pyrrhotite and, at the contact of ore and rock and occupying small pockets of decomposed masses of the ore, there is a quantity of loose material composed of gravel containing particles of copper and iron pyrites. It was in the milling of this loose material that several ounces of the arsenide of platinum were gathered on the carpet connected with the stamp mill. Through the kindness of Mr. Charlton, the genial president of the Vermillion (sic) Mining Co., all of the mineral that was available was generously placed at my disposal."

After a considerable amount of chemical work, Wells was able to show that the mineral was indeed an arsenide of platinum with the ideal composition $PtAs_2$ and thus was a new mineral. He pointed out also that this was the first platinum mineral to be found that was not an alloy with another metal of the platinum group. Crystals and crystal fragments were sent to S. L. Penfield at the Mineralogical Laboratory, Sheffield Scientific School, Yale University, for a crystallographic examination. Penfield (1889) identified the cube, octahedron, dodecahedron and pyritohedron {012}, on the crystals and noted that the mineral belonged to the pyrite group on the basis of its crystal symmetry and chemical composition. Wells named the mineral in honor of Francis L. Sperry.

In 1903 Nicol and Goldschmidt published a paper entitled "Ueber Sperrylith" where they described many more forms of sperrylite crystals from the Vermilion mine. They measured 9 crystals and identified a total of 17 forms, 13 of which had not been previously noted. Apart from the cube, octahedron, dodecahedron and pyritohedron {012}, they found 4 different trapezohedrons, a trisoctahedron, 4 other pyritohedrons and 4 diploids (2 of the diploids were listed as uncertain).

A few years ago, through the courtesy of INCO Limited, the present owners of this property, Royal Ontario Museum staff members were fortunate enough to make several visits to the old dumps of the Vermilion mine, and to collect not only some good sperrylite specimens but also some of the other minerals associated with the "gold ore." Unfortunately the area is no longer available to collectors since the dumps have been removed. Some of the other minerals that have been identified are: michenerite and froodite (Cabri *et al.*, 1973), arsenohauchecornite (Gait and Harris, 1980), millerite,



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ONE GRAMME
SPERRYLITE.
(Pt. As. 2.)
Collected at Vermillion Mine,
Near Sudbury, Canada,
By F. L. Sperry
M8779

Figure 1. **Original labels from some of the sperrylite specimens in the Royal Ontario Museum. Top to bottom – 1912, 1913, and 1914.**

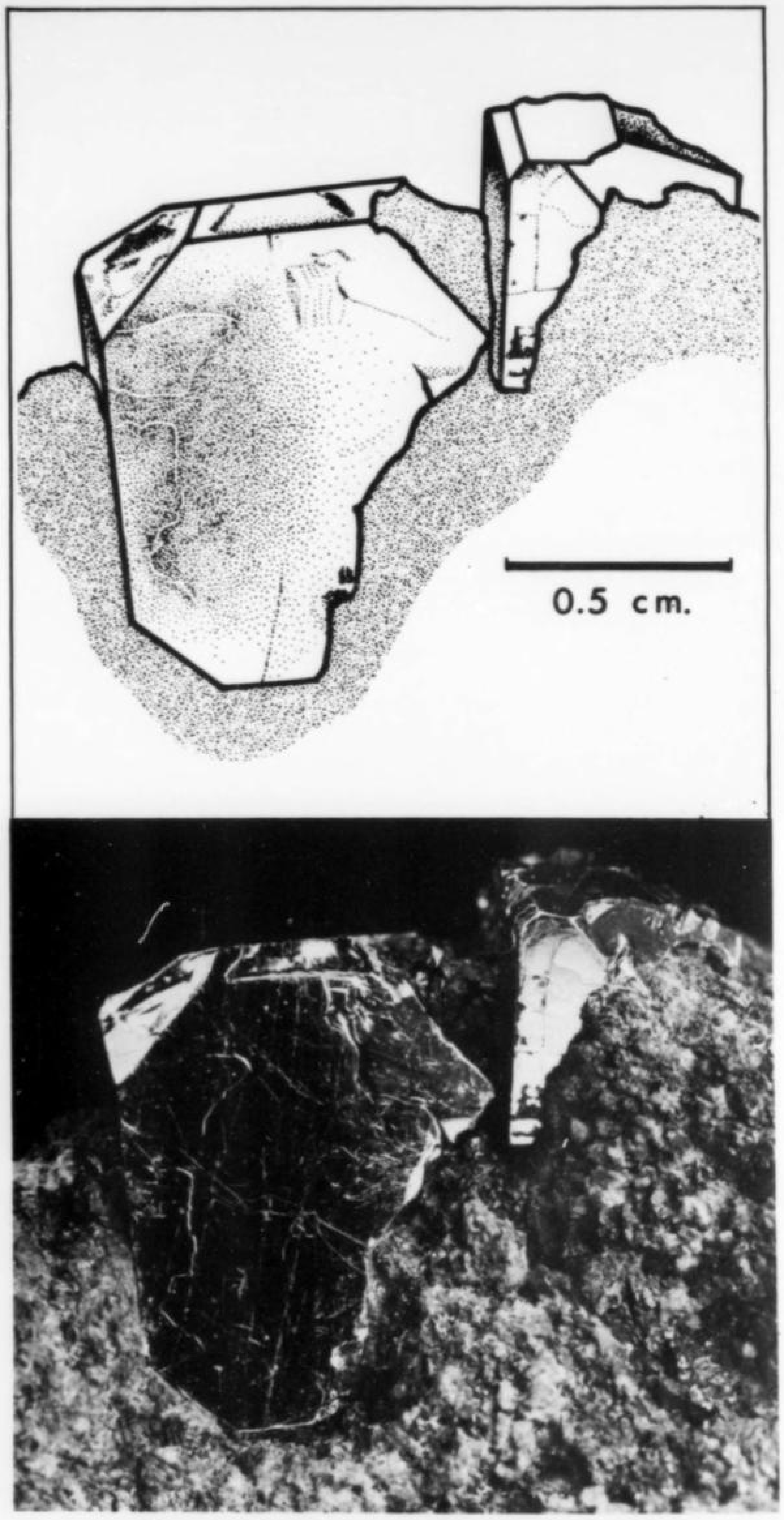

Figure 2. **Photograph and sketch of sperrylite, R.O.M. #M31065. The large crystal measures 12 x 10 mm on the front cube face. Photo: R.O.M. Department of Photography.**

galena, gersdorffite, polydymite, nickeline, molybdenite (both 2H and 3H polytypes), cassiterite (colorless and transparent, Wells, 1889), annabergite, chalcanthite, gypsum, gold and bismuth (Cabri, personal communication).

There are about 25 specimens of sperrylite from this locality registered in the collection of the Royal Ontario Museum. The earliest were acquired prior to 1909; in 1912 a small vial of very fine grained concentrates was purchased from Lazard Cahn ($1.25); in 1913 two similar vials were acquired from the Ferrier collection; and in 1914 several sealed glass vials were acquired, each containing one gram of sperrylite concentrate and tagged with a label autographed by F. L. Sperry. Figure 1 reproduces the original labels of these three specimens. As far as can be ascertained these specimens with Sperry's autograph are the closest to type material that is available.

Various other specimens were added to the R.O.M. collection between 1914 and 1929, but all consisted of concentrates; no matrix specimens were acquired until 1969. In fact, no specimens of sperrylite at all were acquired during the 40 years from 1929 to 1969. In 1969, amateur mineralogists who had "re-discovered" the old Vermilion dumps brought a few matrix specimens to our attention. Between 1969 and 1973 some important pieces were added to the R.O.M. collection. These range in size from sharp micro-crystals, up to 1 mm on matrix, to the large crystal on matrix described below.

Figure 2 is a photograph and sketch of the sperrylite crystals on R.O.M. #M31065, a superb matrix specimen whose overall measurements are 11 by 9 by 6 cm, purchased in 1971. The two main crystals, both undamaged, are side-by-side in weathered, friable chalcopyrite; the largest crystal measures 12 by 10 mm on the main cube face and is about 11 mm deep. The part of the crystal not shown in the photograph consists of a complex skeletal growth composed mainly of octahedral surfaces intergrown with chalcopyrite. This is believed to be the largest sperrylite crystal known from an Ontario locality. The forms present are the cube, octahedron and pyritohedron. The smaller crystal, on the right in Figure 2, measures 8 by 6 by 5 mm and shows similar forms.

A recent electron microprobe analysis of sperrylite from the Vermilion mine is given in Table 1 with the kind permission of L. J. Cabri of CANMET, Ottawa.

Table 1. **Electron microprobe analysis of sperrylite from the Vermilion mine.***

Element	Weight percent	Atomic Proportions
Pt	56.8	1.000
Rh	n.d.	–
As	42.8	1.962 }1.965
Sb	0.08	0.003

*Cabri and Laflamme (1976).

ACKNOWLEDGEMENTS

Special thanks are due to mineral collectors, especially R. C. Butler of Lively, Ontario, whose efforts made it possible for many museums to acquire some important matrix specimens of sperrylite from the Vermilion mine.

The author would also like to thank the R.O.M. Department of Photography for the photograph and J. A. Mandarino for his comments on the manuscript.

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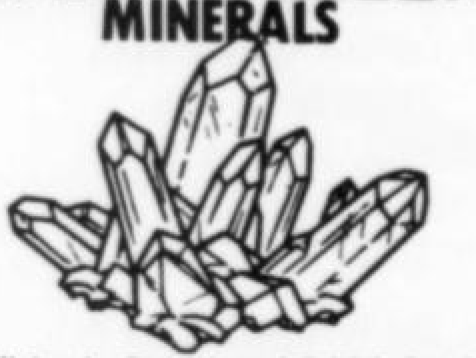

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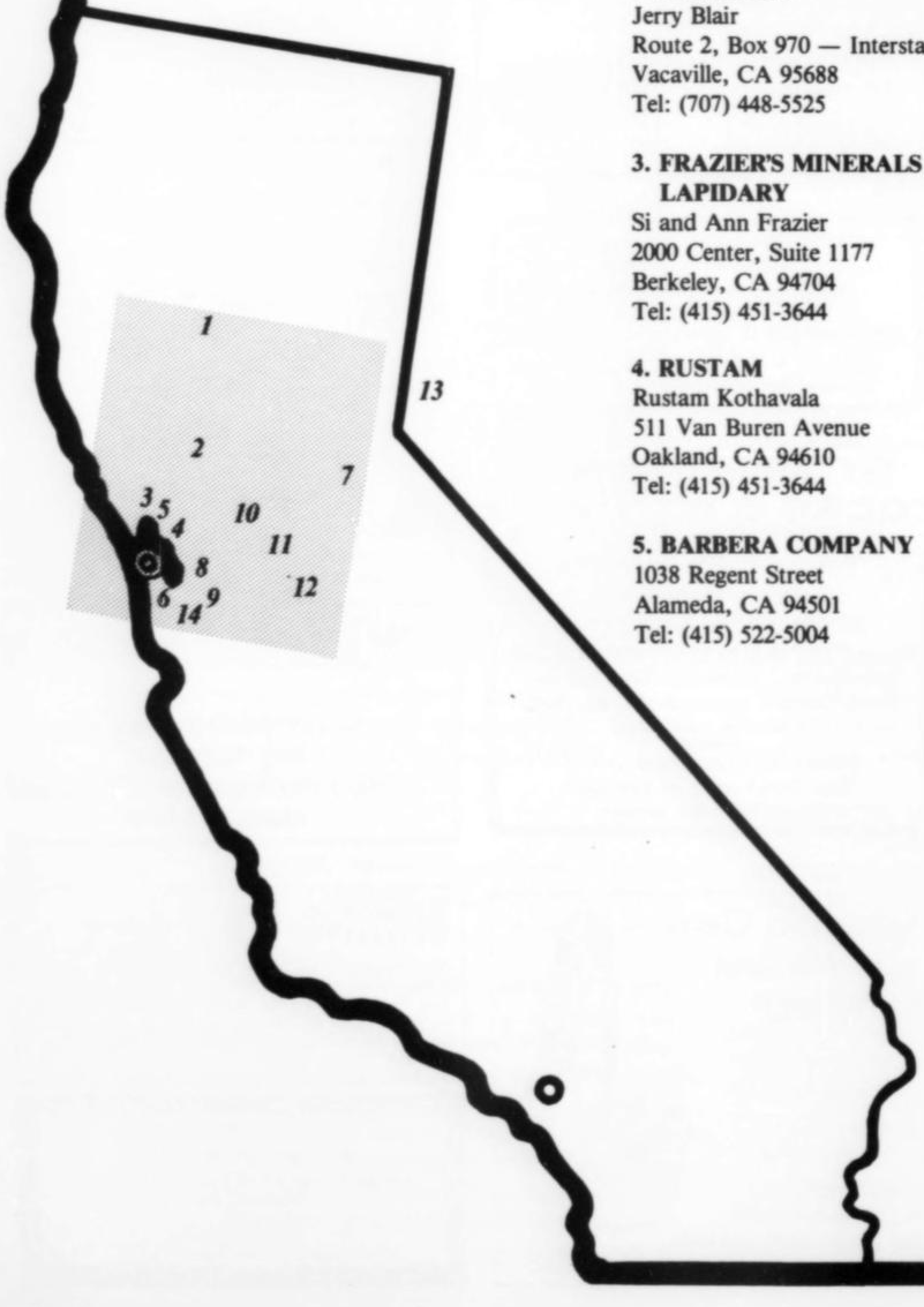

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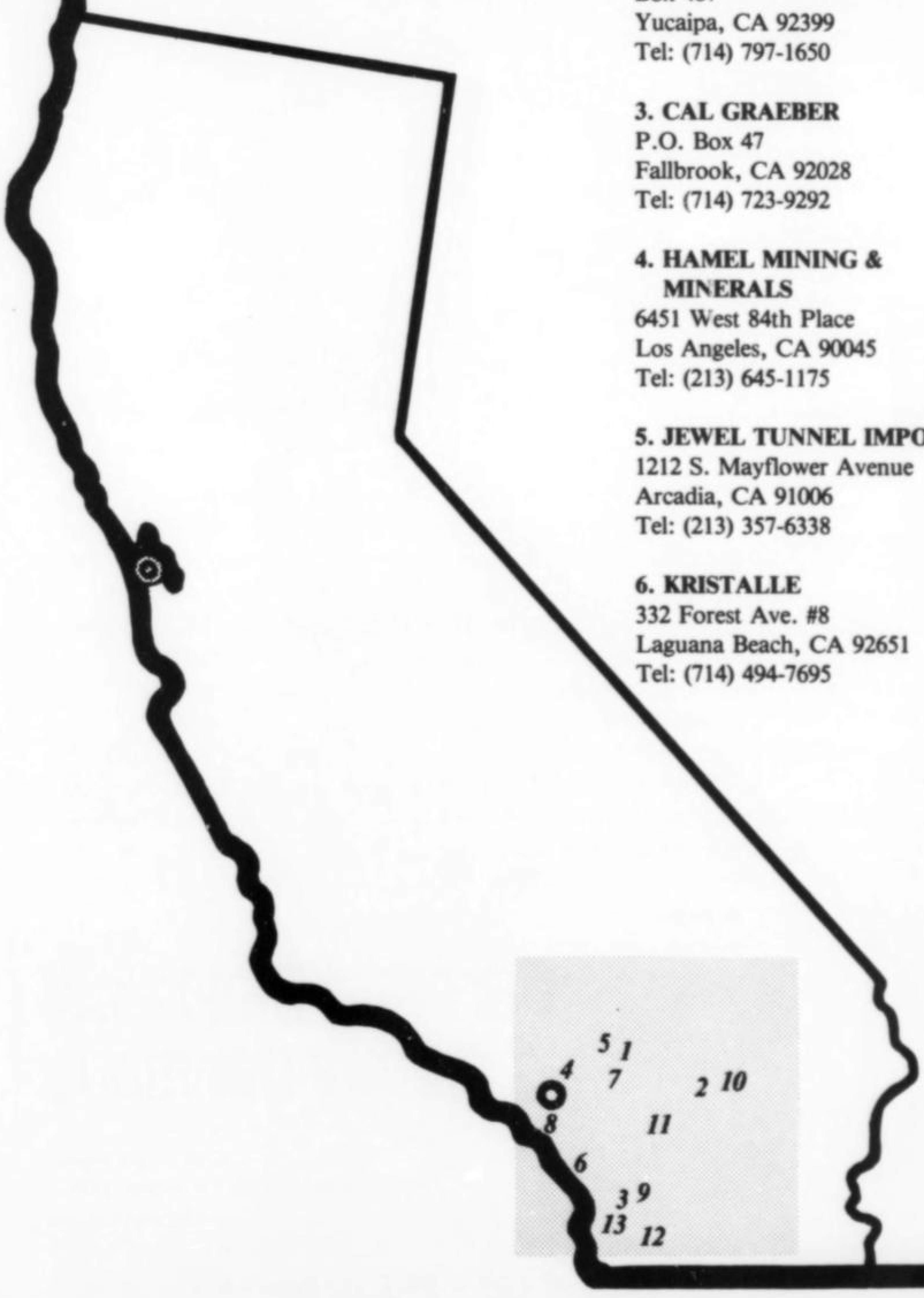

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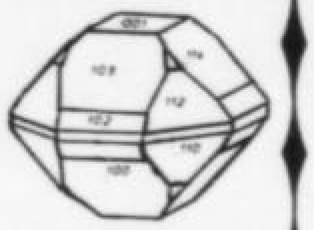

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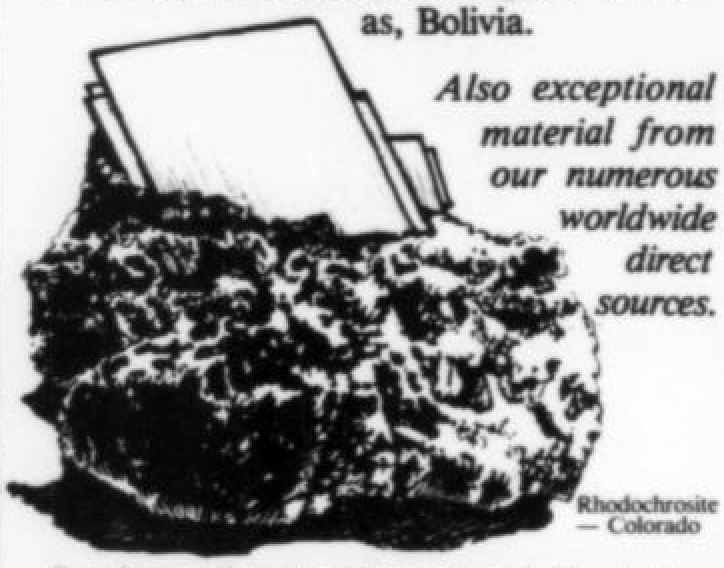

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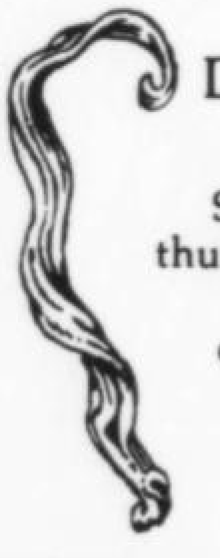

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Wroewolfeite
in Britain

by **Richard S. W. Braithwaite**
Chemistry Department
University of Manchester Institute of Science and Technology
Manchester, M60 1QD, England

Described as a single specimen from Loudville, Massachusetts, in 1975, the rare copper sulfate wroewolfeite has also been found in Scotland and at five other British localities.

INTRODUCTION

Wroewolfeite, [$Cu_4SO_4(OH)_6 \cdot 2H_2O$], a monoclinic (Pc or P2/c) polymorph or close relative of langite and posnjakite, was first described using electron probe microanalyzer data in 1975 (Dunn and Rouse) from a single specimen from Loudville, Massachusetts. Dunn and Rouse note, "A recent communication from Dr. M. H. Hey indicates the existence of samples of wroewolfeite from the Ladywell mine, Shelve, Shropshire, England, and the Nantycagal mine, Ceulanymaesmawr, Cardiganshire, Wales. These samples are in the collections of the British Museum (N.H.)." Subsequently, Livingstone, Macpherson and Jackson (1976) have reported its occurrence at West Blackcraig mine, Kirkcudbrightshire, Scotland.

Among a suite of supergene copper and lead minerals collected by the author and T. B. Greenland in 1962 from the dumps of Pool Vein New Engine shaft, Ladywell mine, Shelve, Shropshire, were some small, blue-green, tabular to lath-like crystals which defied identification; specimens were sent to the British Museum (Natural History) for examination. The late R. J. Davis showed that some of these crystals were langite, but that some were an unknown mineral, now known as wroewolfeite. Microchemical tests showed the presence of copper(II) and sulfate ions, but insufficient pure material was available for quantitative analysis, and more was requested. Further samples were found, but still not sufficient for analysis, partly because of the difficulty in separating them from closely associated minerals. Small amounts of the same mineral were subsequently identified on specimens from Drws-y-Coed mine, Llandwrog, Caernarvonshire, Wales, collected by George Ryback in 1969, and on a specimen from Tynebottom mine, Alston, Cumberland, England, sent to the British Museum for identification at about the same time. Much better material, including small well-formed crystals with occasional blades exceeding 1 mm in length, were collected by the author and colleagues, from the dumps of the Nantycagal (Eaglebrook) mine, Ceulanymaesmawr, Cardiganshire, Wales, in 1965 and subsequently; specimens were forwarded to the British Museum for analysis, but unfortunately still in insufficient quantity for analysis.

In order to obtain enough material for analysis, and to throw light on its conditions of formation, a number of attempts were made to synthesize wroewolfeite. These all failed, yielding brochantite, langite, posnjakite, devilline (in the presence of limestone) or mixtures of these.

WROEWOLFEITE LOCALITIES

Ladywell mine, Shelve, Shropshire

This mine exploited a number of intersecting veins in Mytton flags (Lower Ordovician) from shafts and from the Wood level, a crosscut drainage and exploration adit about 1½ miles long (Dines, 1958). Apart from early outcrop workings, from which cerussite was recorded (Murchison, 1839), serious mining was not started until the 1870's, and ended in 1882 (Brook and Allbutt, 1973).

The ore (galena, sphalerite and chalcopyrite, with some pyrite, in a gangue of calcite and quartz) has suffered oxidation in some parts of the upper levels. The supergene minerals were particularly noticeable on one part of the dumps of the Pool Vein New Engine shaft (SO 3275 9920*), now unfortunately bulldozed away. From here we have identified, apart from the primary minerals, goethite ("limonite"), buff powdery jarosite, green pyromorphite coatings (uncommon), white acicular cerussite, anglesite (rare), malachite, beautiful linarite, brochantite and langite crystals, devilline (rare) and wroewolfeite.

The wroewolfeite usually forms greenish blue, bladed to tabular crystals to 0.5 mm in length, and is found in close association with greenish blue langite crystals of about the same size, bright green brochantite crystals, and blue blades of linarite to 1 mm or more in length, on calcite and shale. The wroewolfeite and langite are very difficult to distinguish from each other by eye, except when the langite displays its tendency to pseudohexagonal twinning. In general, wroewolfeite is more common on calcite matrix than on shale, whereas langite is more common on shale, suggesting some pH control of the polymorphism.

Drws-y-Coed mine, Llandwrog, Caernarvonshire (now part of Gwynedd), Wales (SH 545 535)

Drws-y-Coed is a copper mine about 4 miles west of Snowdon, worked from early 19th century to 1918 (North, 1962; Archer,

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*National Grid Reference, the coordinates defining a point on all British Ordnance Survey maps.

Figure 1. **A view from the north, showing the dumps of the Nantycagal mine where wroewolfeite has been found. (Photo by J. I. Wilson, 1979.)**

Figure 2. **The type locality for wroewolfeite, seen from the southwest. Part of the dumps of Pool Vein New Engine shaft, Ladywell mine, in 1962. Ruins of the engine house are visible in background. R.S.W.B. photograph.**

1959). Four east-west-trending lodes in Upper Cambrian and Lower Ordovician sediments were worked containing chalcopyrite, galena, sphalerite, pyrite, pyrrhotite in a gangue of quartz (some enclosing green chlorite) and calcite (Dewey and Eastwood, 1925; Archer, 1959). Arsenopyrite has also been found, associated with the chalcopyrite (G. Ryback, personal communication, 1969). A little supergene alteration has taken place, giving malachite (Dewey and Eastwood, 1925) and dump-growths of a mineral related to "woodwardite" but with a low Cu:Al ratio (Nickel, 1976). A few small specimens bearing what was later to be known as wroewolfeite were found by George Ryback in 1969 and studied using infrared spectroscopy. The wroewolfeite forms greenish blue blades from about 0.1 to 1 mm in length, on calcite, and associated with amorphous blue-green crusts of ill-defined basic copper sulfate composition.

Tynebottom mine, Alston, Cumberland (now part of Cumbria), England (NY 738 419)

On the west bank of the River Tyne near Garrigill village, this mine worked a series of flats associated with the Browngill vein, in the Tynebottom limestone (Carboniferous) until it was closed in 1873 (Dunham, 1948). The primary minerals are galena, sphalerite and minor chalcopyrite, with pyrite and marcasite, in a gangue of quartz, chalcedony, fluorite, calcite and ankerite. Supergene minerals include gypsum, aragonite, erythrite, hydrozincite, malachite, chrysocolla, linarite and brochantite. Wroewolfeite has been identified using X-ray diffraction, by the staff of the British Museum on a specimen from this mine.

Nantycagal (Eaglebrook) mine, Ceulanymaesmawr, Cardiganshire (now part of Dyfed), Wales (SN 734 892)

The Nantycagal mine, in the Plynlimon dome (see paper on pyromorphite from the Bwlch-Glas mine elsewhere in this issue), exploited an approximately east-west-trending gossany lode, with a steep dip to the north, traversing an anticline in Van mudstones and underlying grits (Upper Ordovician) (Jones, 1922). The lode was worked prior to 1708, abandoned in 1722, and worked again from about 1854 until finally closed in 1874 (Bick, 1976), having produced a total of about 600 metric tons of lead ore and about 70 tons of copper ore (Jones, 1922). The dumps of several long-blocked shafts straddle the mountain road to Talybont, and are part of a reforestation area planted with conifers since our investigations. There is no access to the underground workings.

The main primary minerals are galena, chalcopyrite and sphalerite in a gangue of quartz and dolomite cementing gray mudstone vein-breccia. Supergene oxidation has produced an interesting suite of secondary minerals, with much cerussite, mostly acicular; occasional small sharp anglesite crystals; microscopic hexagonal tablets of leadhillite; a little colorless radiating hemimorphite; a little native copper with microscopic octahedrons of cuprite; green velvety malachite; brochantite in bright green, platy microcrystals associated with beautiful blue blades of linarite to 2 mm in length, commonly in radiating bunches; langite in greenish blue, tabular, single crystals and pseudohexagonal twins; devilline as green blades to about 2 mm, typically coating fracture surfaces in massive dolomite; and serpierite in pale blue, microscopic, radiating blades. Pale blue micro-botryoidal coatings give a similar infrared spectrum to that of "woodwardite," which has also been identified by X-ray diffraction by W. Birch, of the National Museum of Victoria, Australia. Wroewolfeite forms clear, sharp, greenish blue blades with rectangular, chisel-shaped terminations, the longer blades generally having less well-defined terminations. It is a late-generation supergene mineral closely associated with, and post-dating, linarite and brochantite. Amorphous, pale blue-green, basic copper sulfate crusts are later than wroewolfeite.

Wheal Friendship (= Devon Friendship mine), Mary Tavy, Devonshire (near SX 505 793)

Excellent specimens of wroewolfeite, with blades up to approximately 1 mm in length, have been found at this locality, and appeared in a mineral dealer's catalogue (R. W. Barstow) in January, 1980.

The mine is a very old one, in the metamorphic aureole on the western edge of the Dartmoor granite mass. A wide range of minerals has been found here, including galena, sphalerite, chalcopy-

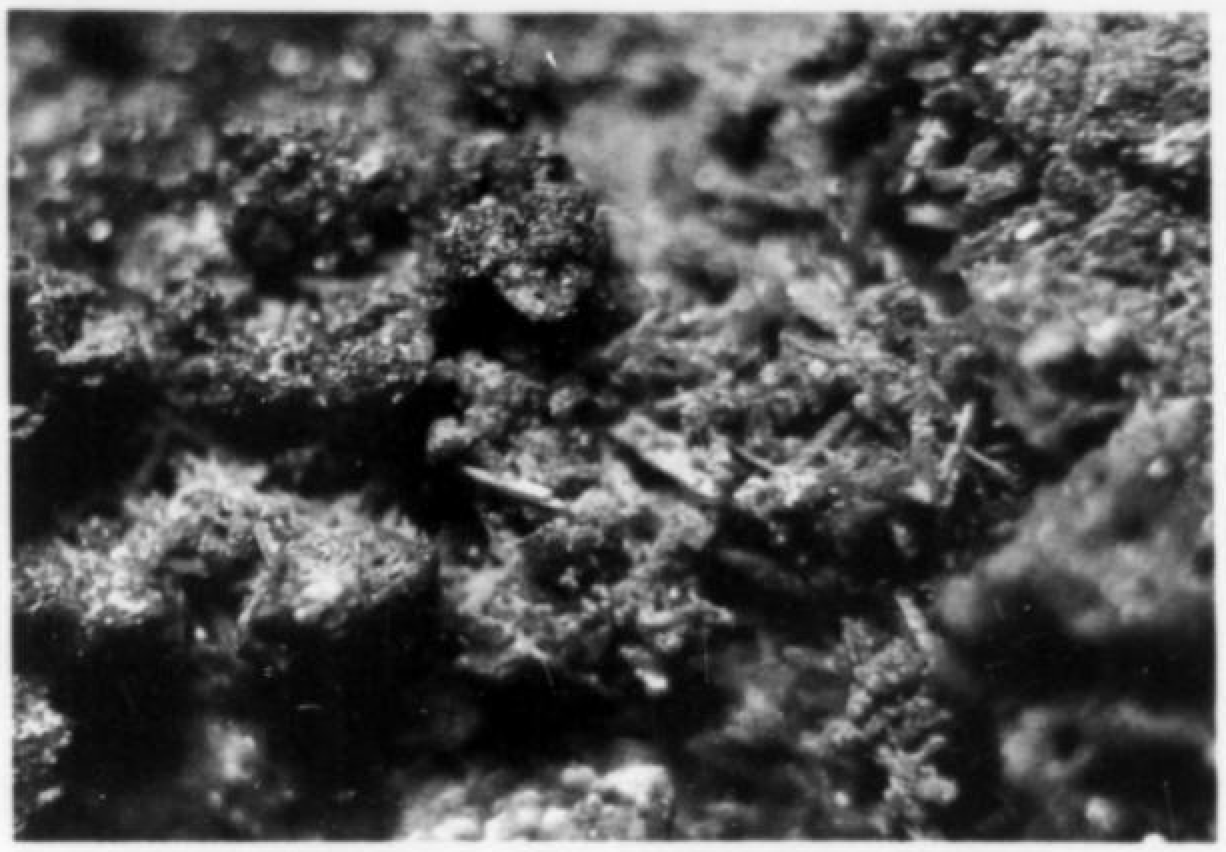


Figure 3. **Wroewolfeite, elongated crystals with brochantite and langite, from the Ladywell mine. R.S.W.B. specimen (62-426) and photomicrograph; field 4.3 X 3 mm. Collected 1962.**

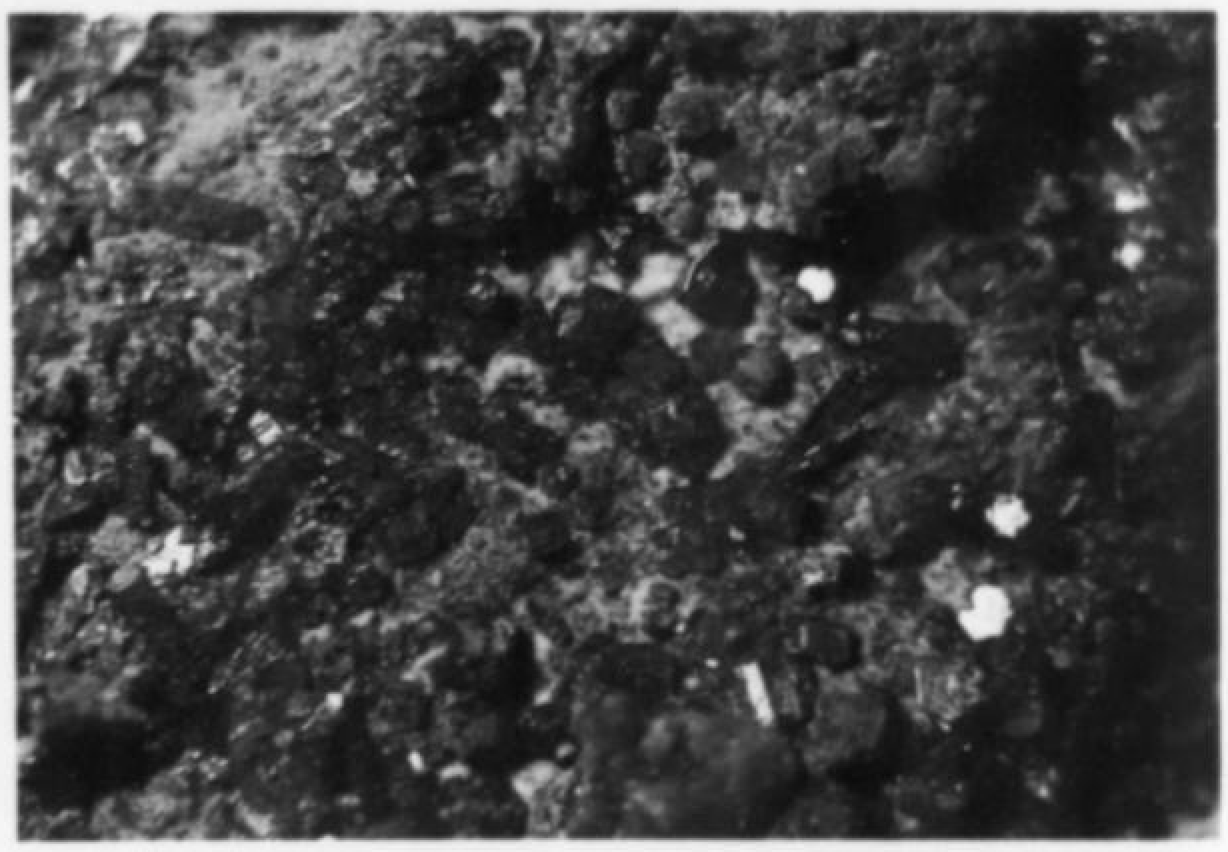


Figure 4. **Langite, pseudohexagonal twinned crystals, with linarite from the Ladywell mine. R.S.W.B. specimen (62-430) and photomicrograph; field 4.3 X 3 mm. Collected 1962.**

Figure 5. **Wroewolfeite, crystal cluster with brochantite, from the Nantycagal mine. R.S.W.B. specimen (68-418) and photomicrograph; field 4.3 X 3 mm. Collected 1968.**

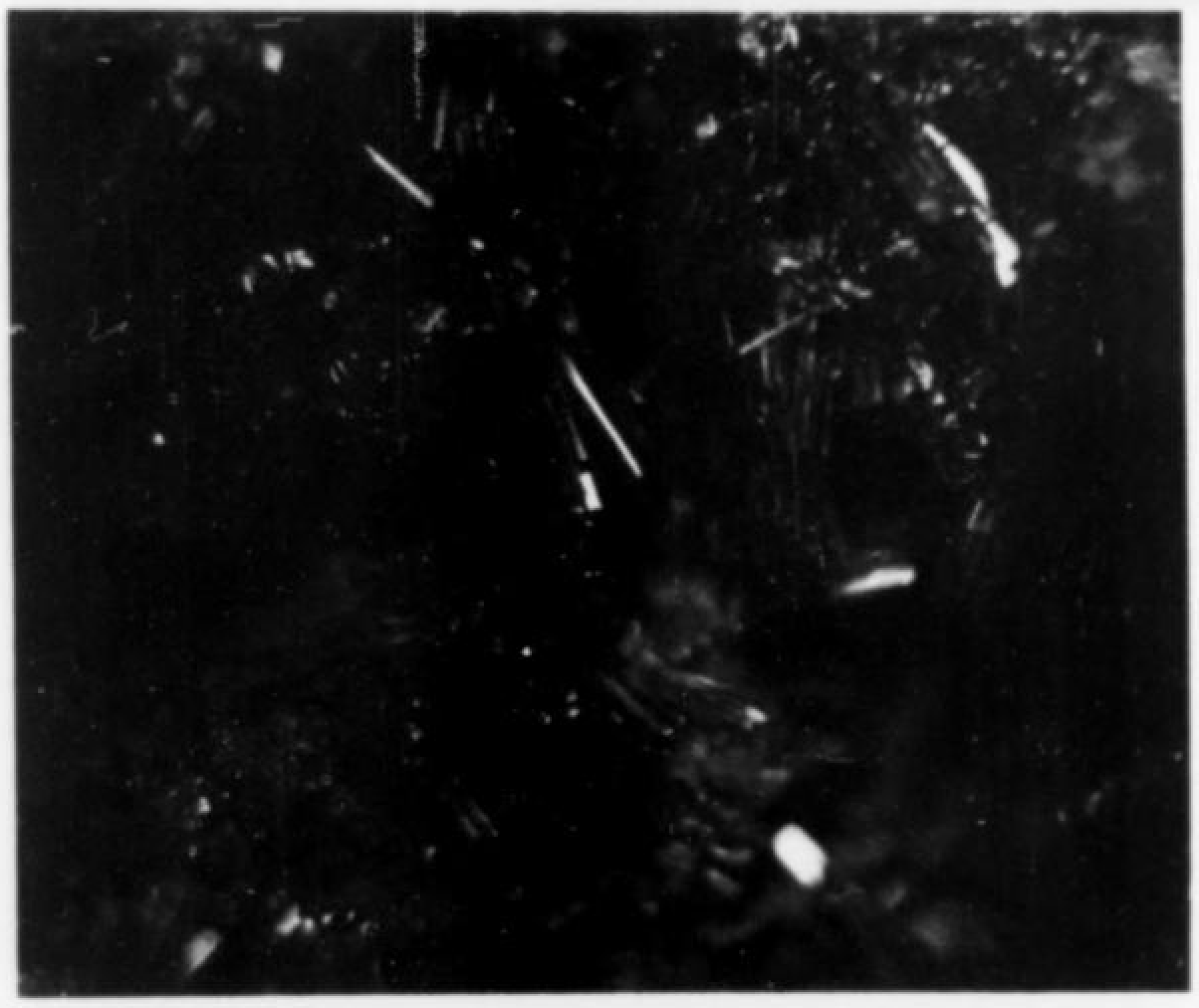


Figure 6. **Linarite crystal sprays from the Nantycagal mine. R.S.W.B. specimen (68-102) and photomicrograph; field 4.3 X 3 mm. Collected 1968.**

rite, pyrite, arsenopyrite, cassiterite, wolframite, molybdenite, cobaltite, bismuth, scheelite (including yellow bipyramidal crystals to 4 cm), axinite, erythrite, quartz, chlorite, calcite, dolomite, siderite and fluorite.

INFRARED SPECTRA

The infrared spectra of the basic copper sulfates are characteristic, and offer a rapid means of identification, using samples of less than 1 mg. The infrared spectra of a number of samples of brochantite, langite, posnjakite, wroewolfeite, ktenasite, devilline, serpierite, spangolite, "woodwardite," and "enysite" were measured in

Table 1. **Wavenumbers and probable assignments of infrared absorption maxima of some basic copper sulfate minerals.**

Absorption maxima, cm^{-1} (1)	(2)	(3)	(4)	(5)	Assignments	
	(405)	385 mw		373 m		Metal - oxygen vibrations
420 s	(420)	420 mw				
447 m		440 mw	460 m	462 m	SO_4^{2-} ν_2 bend	
483 m		485 m	470 m	495 m		
(500)	500 m	515 m				
550 w	(565) vw					
598 s	595 s	600 s	610 s	605 s	SO_4^{2-} ν_4 bend	
	(605)					
650 w		628 m		640 s		
		670 w				
763 m	775 w	720 w				
828 ms	870 w	850 m	830 w, br	835 m, br		
880 m	935 w	873 m				
965 m, sh	960 w, sh	950 w	980 w, sh	985 m, sh	SO_4^{2-} ν_1 stretch	
(1040)	1050 s	(1040) w		1055 ms	SO_4^{2-} ν_3 stretch	
1080 vs	1110 s	1088 vs	1100 vs	(1100) vs		
1105 vs	1140 s	1145 vs	(1120)	1120 vs		
		(1580)				
1670 m, br	1645 m, br	1630 m, br	1620 m, br	1655 m, br	H-O-H bend	
(3250)	3180 m	(3200)	3200 - 3400	(3160) m	O-H stretch	
3370 s, br	(3300)	3380 s, br	s, vbr	3360 s, br		
(3480)	3380 ms, br	(3540)	(3540)	(3540) m		
3580 m, sh			(3580)	3600 m, sh		

w = weak, m = medium, s = strong, v = very, br = broad, sh = sharp
Values in brackets are of shoulders.

(1) *Langite,* Fowey Consols mine, Cornwall. Off BM 95218.
(2) *Posnjakite,* Fowey Consols mine, Cornwall. Off BM 80046.
(3) *Wroewolfeite,* Nantycagal mine, Wales. Off RSWB 68-418.
(4) *Ktenasite,* Glomsrudkollen, Buskerud, Norway. Off RSWB 75-266.
(5) *Serpierite,* Laurium, Greece. Off BM 63887.

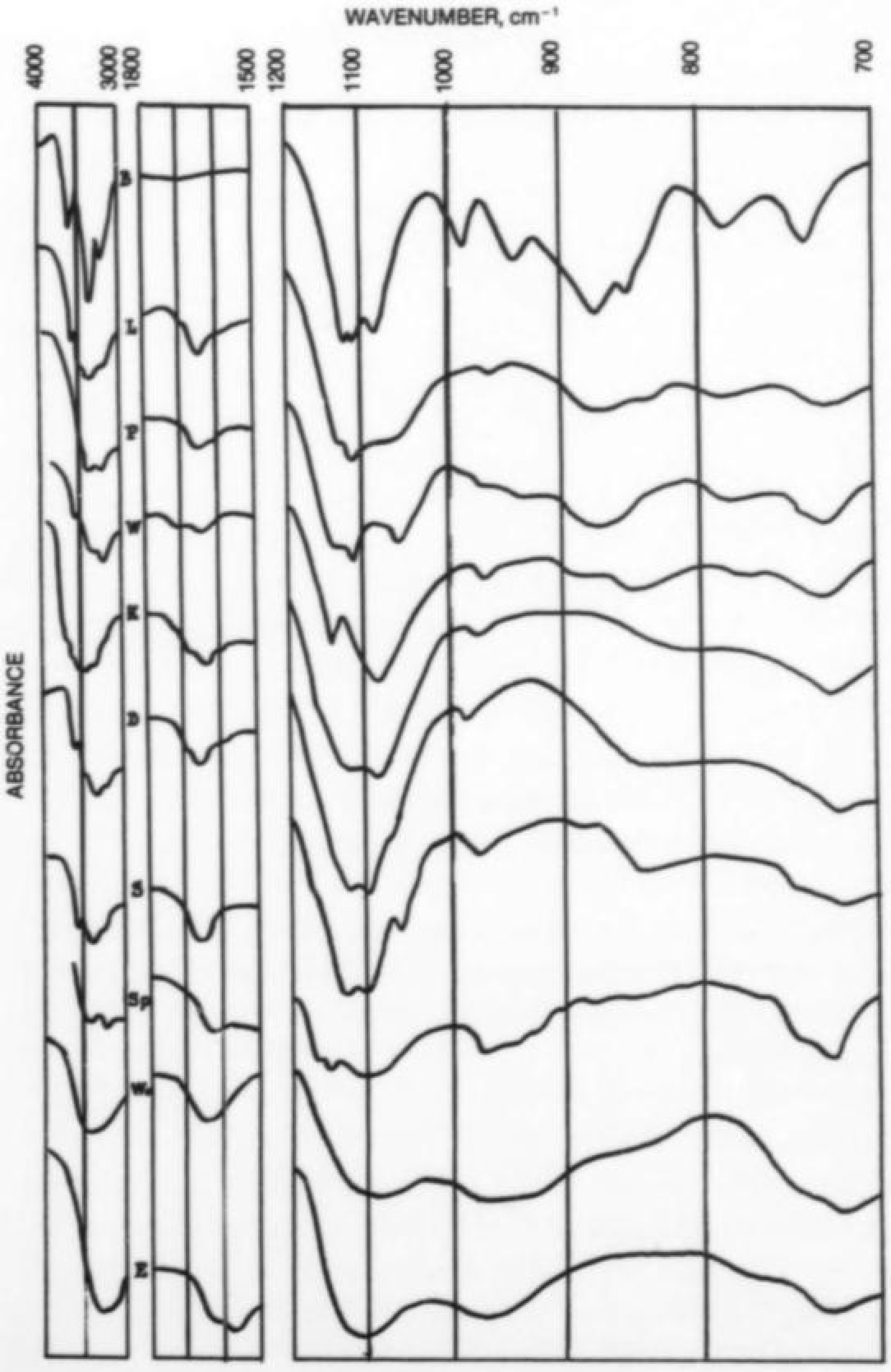


Figure 7. **Infrared spectra of some basic copper sulfate minerals.**

From top to bottom:
(B) *Brochantite,* Scar Vein, Leadhills, Lanarkshire, Scotland. G. Ryback spectrum. Off GR 55-237.
(L) *Langite,* Fowey Consols mine, Cornwall. Off BM 95218.
(P) *Posnjakite,* Fowey Consols mine, Cornwall. Off BM 80046.
(W) *Wroewolfeite,* Ladywell mine, Shropshire. Off RSWB 62-391.
(K) *Ktenasite,* Glomsrudkollen, Buskerud, Norway. Off RSWB 75-266.
(D) *Devilline,* Nantycagal mine, Wales. Off RSWB 68-114.
(S) *Serpierite,* Laurium, Greece. Off BM 63887.
(Sp) *Spangolite,* Kamariza, Laurium, Greece. Off RSWB 67-277.
(Wo) *"Woodwardite,"* South Caradon mine, Cornwall. Off RSWB 73-462.
(E) *"Enysite,"* St. Agnes, Cornwall. Off Manchester Museum specimen N 2448.

(continued on page 174)

Micromounting in the eastern alps of Austria

by **Karl Kotal**
Wipplingerstrasse 18
A-1010 Vienna, Austria

Figure 1. **"Welcome to the Rauris Valley."**

Many localities in the Salzburg area of Austria have been described in mineral magazines over the years. The area is heavily mineralized and provides excellent opportunities for the micromount collector. I have noticed among my American trading partners an increased interest in Alpine minerals. Perhaps this description will stimulate some collectors to visit Europe and do some digging in the Alpine cleft deposits.

Coming from Salzburg, Mozart's home town, the Bundesstrasse 158 leads through the towns of Boschofshofen, Lend and Taxenbach to the Rauris Valley. This trip takes about an hour. Coming from the western part of Austria the route is from Zell am See via the Grossglocknerstrasse, and eastward to Taxenbach. From there, on a good mountain road, it is only 15 minutes to Rauris, the main town in the valley.

The tourist in Rauris will find every possible comfort, either in the excellent Salzburg-style hotels or in the simpler tourist rooms of the lower price range. Despite the close proximity of the famous Grossglockner *Hochalpenstrasse* (high alpine road) the area is still somewhat removed from the rapid pace of other tourist and vacation centers.

South of Rauris, only 15 minutes driving time, is the first highlight for micromounters, the *Plattenbruechen* (quarries that produce stone plates) of the Kaiserer and Lohninger Companies. In prehistoric times a gigantic avalanche brought thousands of tons of rock into the valley. The fallen rock consists largely of mica shists, and the good cleavage of this material makes it suitable for commercial use in construction. Fortunately for micromounters, the rocks include gneiss boulders cut by numerous quartz and pegma-

Figure 2. **Sonnblick Mountain.**

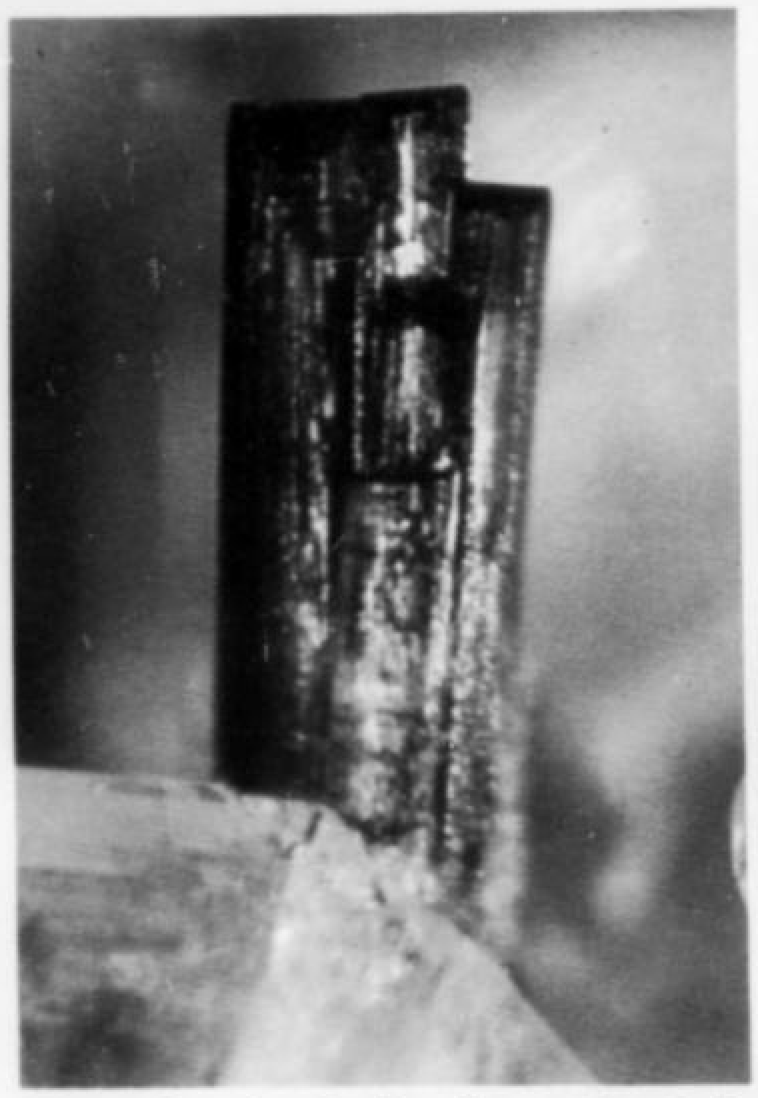


Figure 4. Anatase from the Grieswies locality. (1.5-mm crystal.)

Figure 3. Aeschynite from the Lohninger quarry. (3-mm crystal.)

Figure 5. Titanite from the Schafkar locality. (4.5-mm crystal.)

Figure 6. Monazite from Erfurterweg. (3-mm crystal.)

Figure 7. A platy brookite crystal with anatase from the Lohninger quarry. (2.5-mm brookite crystal.)

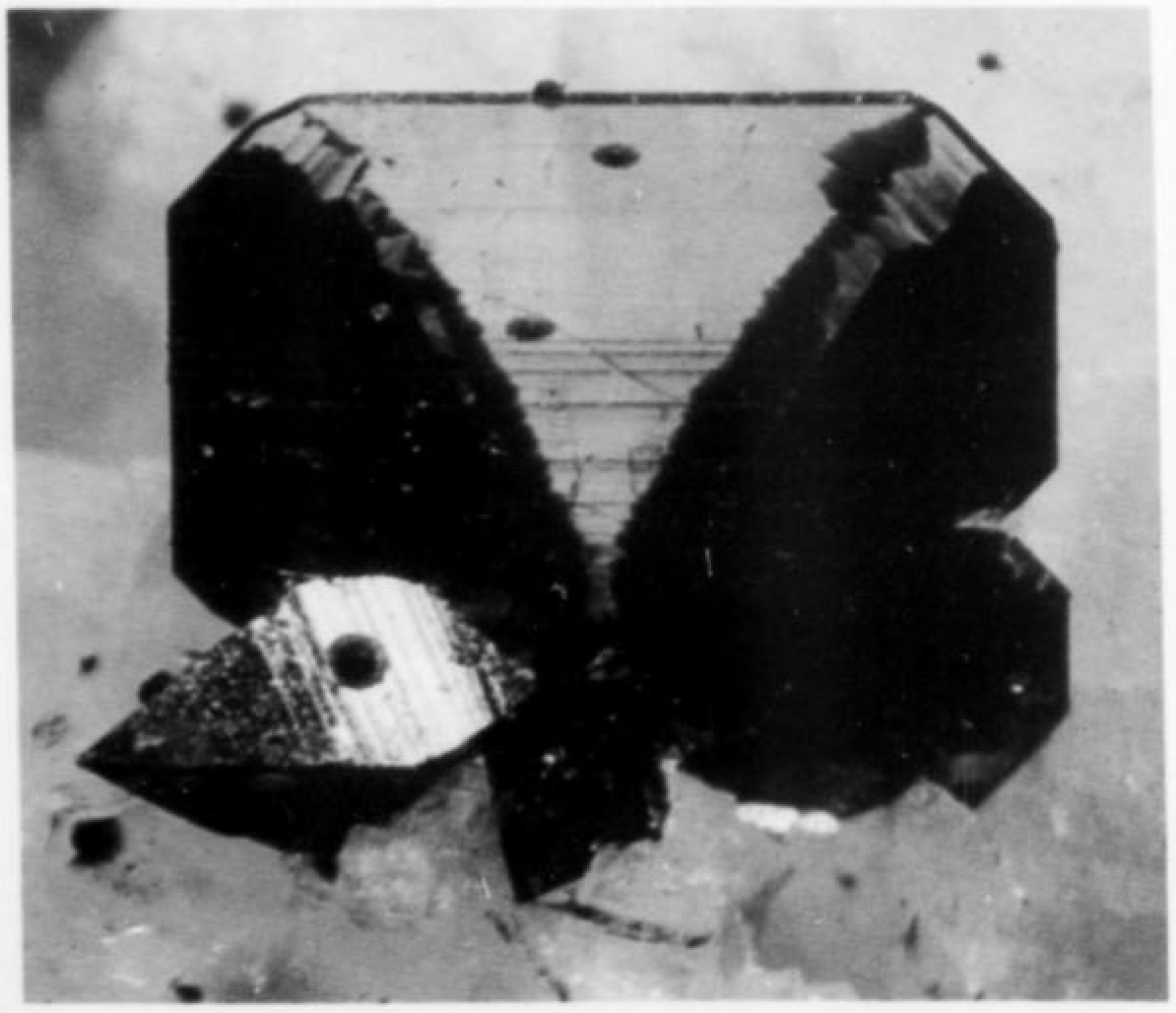
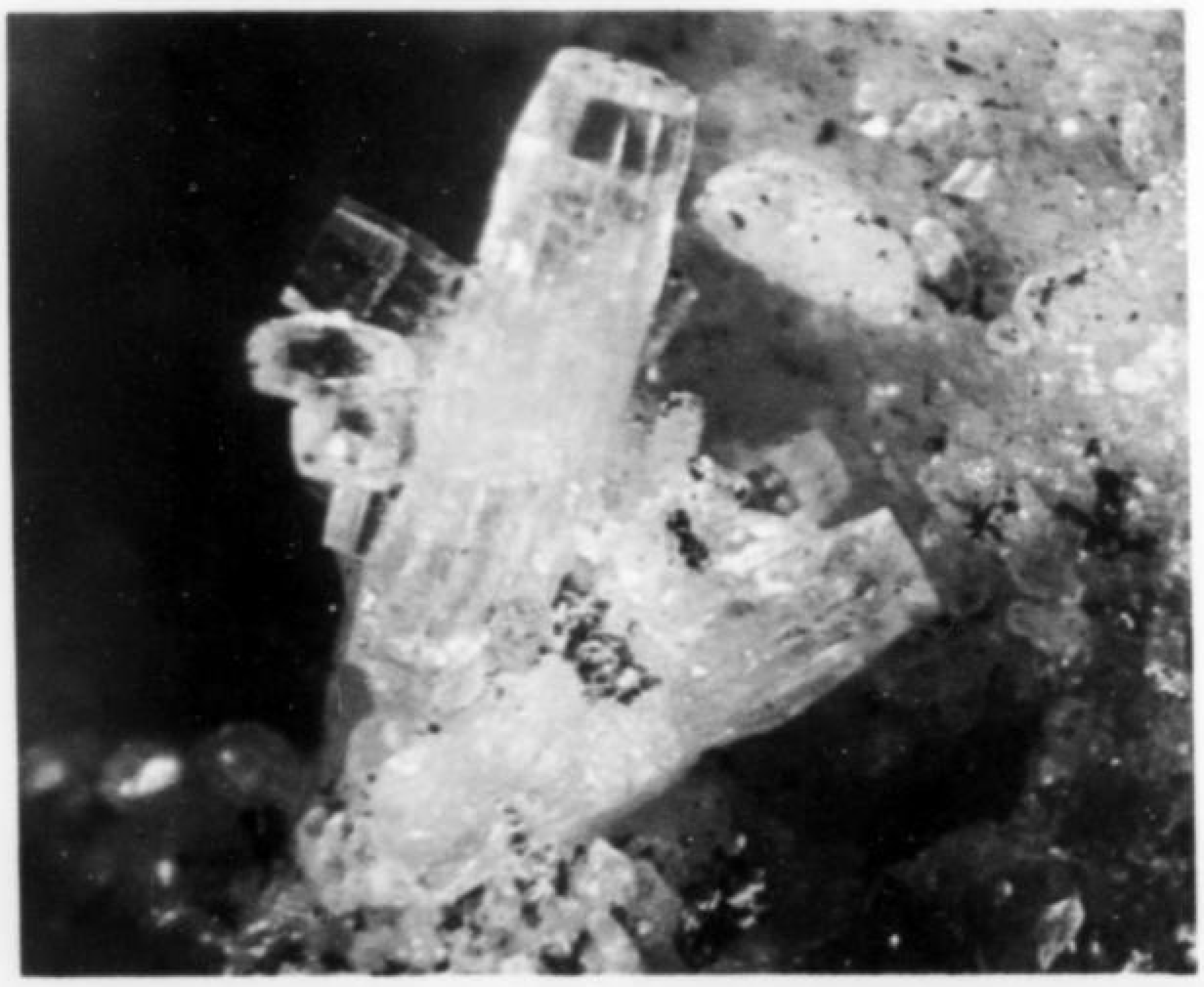


Figure 8. Synchysite from the Kaiserer quarry. (2.5-mm crystal.)



tite veins and small Alpine clefts, yielding several very rare minerals. This material is not used commercially and is piled up in large dumps, along with other waste material. Chances of making good discoveries are excellent due to the very good exposure of potential material. Large boulders should also be checked because a constant turnover occurs during quarrying operations.

During the many visits my wife and I paid this locality over a span of many years, we found a wealth of rare and attractive micromaterial. The rare minerals include xenotime, monazite, aeschynite and bertrandite. Unfortunately I haven't been as lucky as another well known collector who found fine crystals of gadolinite last year. A few months ago fine phenakite crystals were also found here, associated with synchysite, on albite.

As is the case with all localities, frequent visits are advantageous. And even if sometimes one's luck has not been the greatest, the fantastic views are a reward in themselves. Collecting is generally tolerated, but please ask for permission first. Do not disturb the good relations between collectors and the owners by destroying already finished and stacked plates. Only in this way can the locality remain open and continue to be a paradise for micromounters. Readers should consult the excellent article in *Lapis* magazine by Theodor Fischer of Zell am See. Mr. Fischer is the most knowledgeable specialist on the locality.

Beyond the quarries the valley narrows and a winding sandy road leads through a mountain forest to the end of the valley at Kolm Saigurn. One can also travel there by bus. (In summer bus service is from Taxenbach to Rauris to Kolm Saigurn.) Some experience in mountain driving is helpful; the steeper sections can cause some trouble. Nonetheless it is still worth the effort; the scenery at road's end in Kolm Saigurn is breathtaking. Fair weekends will bring more than 100 cars into the large parking lot. Beginning here, at 1620 meters above sea level, is the starting point for mountain excursions of varying difficulty. Here also is an exceptionally mineral-rich area, where even the beginner or wanderer, with a little patience or luck, can bring home some nice mineral specimens.

A few minutes by car before Kolm Saigurn is the Grieswiesalm bus stop. One crosses a wooden bridge over a lovely glacier-fed stream to find after a little while a rolling, radiant mountain meadow. The landscape rises to greater steepness where the productive area, called Grieswies, begins. The area is deeply eroded and every year avalanches bring new and interesting material down. A rock-snow mixture is dropped in avalanches and should be carefully inspected where the snow has melted. The material is a schist with a large number of little clefts. From a distance worked out quartz clefts in the mountain face itself can be seen, but only experienced mountaineers and local mineral collectors should attempt to search for clefts *in situ*. The less steep areas sometimes also yield opened clefts and the debris can bring some surprises.

I once found, on a little chunk of schist, all three titanium oxides: anatase, brookite and rutile (probably some paramorphism involved). A fist-size piece proved to contain, after cleaning, more than 100 crystals of anatase, some of light blue color.

The quartz here is associated with albite, adularia, knee-shaped rutile twins, monazite, actinolite, titanite and pyrite. Up until a few years ago, local collectors cared little for microminerals and searched only for large quartz crystals. A spectacular find of a cleft containing hundreds of kilograms of quartz crystals was made in this area. When in Salzburg be sure to visit the Hans der Natur and see the fantastic collection of Alpine minerals; here is exhibited the great quartz cleft, which has been reassembled again as it was found.

A little further south, past the locality of Grieswies, is another good area, the Schafkar. To get there follow the marked Erfurterweg from the Naturfreundehaus in Kolm Saigurn. This path is fairly narrow, partially very steep and will lead to the location in about 2 hours. A little coordination and mountaineering experience are necessary for this trip. As is the case in all higher altitudes, adequate and weatherproof clothing as well as rugged shoes are an absolute must. The last steep section is at an altitude of about 2000 meters and right after this the scenery levels and widens. Huge boulders and talus piles, always dotted by mountain meadows, are characteristic of the area. One sees strong evidence of collecting activities in the entire Schafkar which have not always been carried out with the gentlest methods. In recent years even prohibited blasting has been done here in search of quartz veins. The grass and topsoil layers have been dug up (which are not extensive to begin with) and every true nature lover watches the development with second thoughts. But the large number of outcrops makes micromount collecting easy. There are numerous Alpine clefts to be found here, some as large as the collector himself. The discarded material from these should always be carefully inspected. At the end of the day one discovers how heavy a backpack filled with promising material can become.

The assemblage found here is similar to that at Grieswies. In addition, xenotime, scheelite and bertrandite have been found, and also small crystals of quartz with rutile inclusions (commonly the variety *sagenite*) and olive-green twins of titanite on pericline.

Another locality lies beneath the north slopes of Sonnblick Mountain. A hanging glacier here creates immense danger (stay away!). A comfortable mountain path leads from Kolm Saigurn to Neubau cabin at 2100 meters, which can be used as a base, if one is satisfied with a plain meal and simple bed. Surrounding the cabin is an old mining region. Here gold has been mined over the centuries, with more or less success. The whole area produces interesting micromounts. Once, not too far from the path to the summit of the Sonnblick, I found scheelite, monazite and anatase. A friend of mine found a cleft in an avalanche boulder which yielded two crystals of the very rare euclase, 8 and 10 mm long.

A tip for readers in good shape and with an eye for the beauties of nature (even though it has nothing to do with minerals): the summit of Sonnblick Mountain can be reached in 3 hours from Neubau cabin. Here is located the highest meteorological station in the Eastern Alps. In summer the neighboring Zittelhaus cabin serves food and provides overnight lodging. If you see once, as I have, a sunset from the summit, you will understand my enthusiasm for this trip. Essential for success are a careful study of the map, proper equipment and, of course, fair weather.

Minerals can be found in the entire region of the Rauris Valley and its side valleys. Many more pages would be required to name and describe all the known localities. I have intentionally mentioned only those which are in relatively easy reach and where good finds are likely. A few days in this beautiful Alpine valley will surely make you, too, a Rauris fan.

In conclusion I would like to express my gratitude to two friends in the USA: Al Falster of Waussau, Wisconsin, for the translation and Julius Weber of Mamaroneck, New York, for the photography. I am grateful to my friend Karl Schebesta of Vienna, Austria, for continually sharing his great mineralogical knowledge with me. I would also like to express my thanks to Alex Kipfer in Zurich, Switzerland, whose great book *Der Micromounter* inspired my interest in micromounts.

RECOMMENDED READING

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(continued from page 170)

"Nujol" mulls, in the 670-4000 cm^{-1} range, using a Perkin-Elmer 137 spectrophotometer with sodium chloride optics, calibrated against polystyrene; portions of the spectra of typical samples are produced in Figure 7. The spectra of langite, posnjakite, wroewolfeite, ktenasite, and serpierite were measured in similar conditions over the 400-4000 cm^{-1} range, using a Perkin-Elmer 621 or a Perkin-Elmer 397 spectrophotometer to give greater resolution and precision in wavenumber, and to cover a wider range to include the ν_2 and ν_4 regions of sulfate absorption. The absorption maxima are given in Table 1.

All the minerals studied show O-H stretching absorptions near 3000-3600 cm^{-1}, some of which have characteristic patterns. The hydrated species show the H-O-H "scissor" bending mode near 1600 cm^{-1}, of limited diagnostic value apart from indicating the presence of water. The broad absorption centered near 1100 cm^{-1} is due to the ν_3 unsymmetrical stretching vibration of the sulfate anion. Distortion of the anion results in a multiplicity of absorption maxima in this band, due to removal of spectroscopic degeneracy. The characteristic patterns so produced are of major diagnostic value in this group of minerals. The "forbidden" symmetrical stretching absorption ν_1 of the sulfate ion appears in the 960-1020 cm^{-1} region when the anion is distorted from its normal T_d (tetrahedral) symmetry. The ν_4 bending vibration of the sulfate ion is found in the 590-700 cm^{-1} region, and its ν_2 symmetrical bend ("forbidden") near 420-500 cm^{-1}. Metal-oxygen, including metal-water vibrations are found between about 300 and 900 cm^{-1}.

These minerals are therefore readily identified by infrared spectroscopy, but the possible occurrence of metal-oxygen absorptions in the ν_2 and ν_4 regions of sulfate absorption makes definite assignments difficult in that region, so that counting of the numbers of sulfate absorptions required for the determination of anion symmetry is unreliable.

Some wroewolfeite samples, even though composed of clear, distinct crystals, give infrared spectra consistent with mixtures with langite, indicating alteration to the latter mineral.

ACKNOWLEDGMENTS

The author thanks T. B. Greenland and other colleagues for their valuable contributions to the field work, and the staff and trustees of the British Museum (Natural History) for X-ray diffraction work and for donating samples for infrared spectroscopy.

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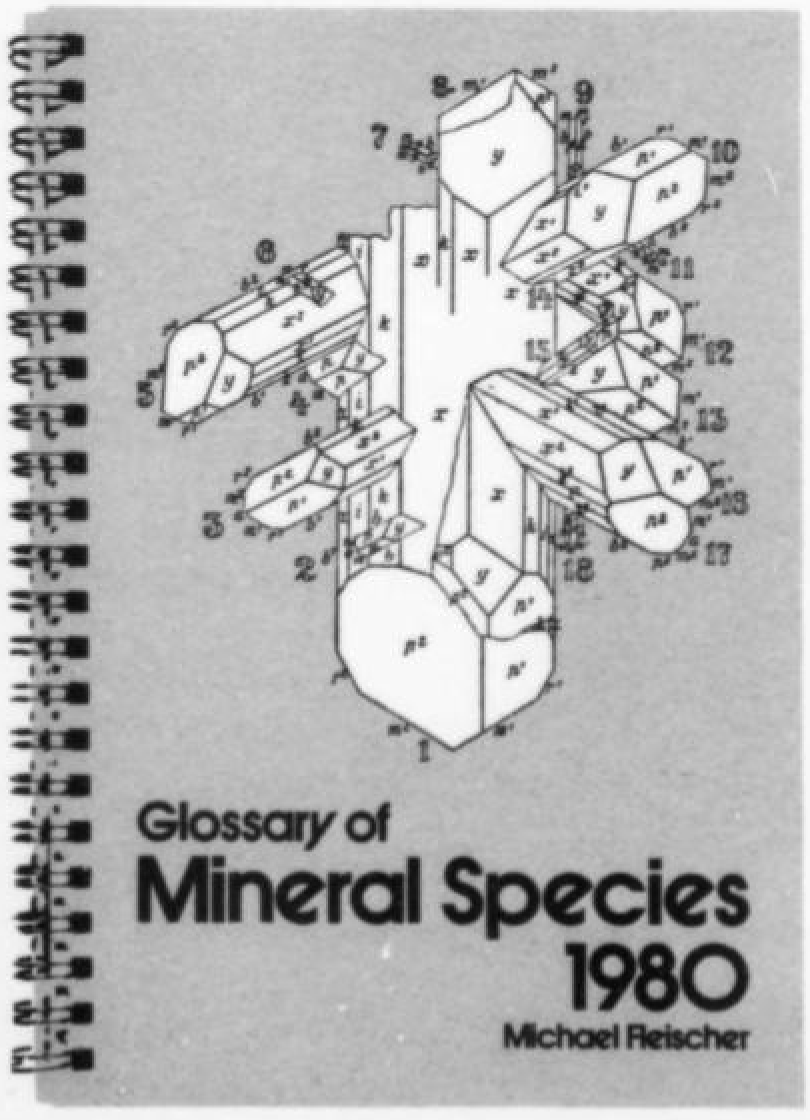

The Record Bookshelf

TITLES RECEIVED

The International Handbook, **by Sande H. Zirlin. Published (1981) by Garnet Books Unlimited, P.O. Box 217, Fort Johnson, New York 12070; 175 pages, 7 x 11 inches, softcover, $7.50 (U.S., Canada, Mexico), $9.00 (all other countries).**

Subtitled "A multi-lingual reference directory for mineral collectors," and "A reference directory of selected mineral names and related terminologies in 12 languages." Geared to the hobbyist collector, this book lists 550 mineral names and 175 related terms, each given in 12 different languages: English, German, French, Spanish, Chinese, Norwegian, Italian, Russian, Dutch, Portuguese, Japanese and Swedish. Also included are 88 geographical names and a bibliography.

A Geology of Ireland, **edited by C. H. Holland. Published (1981) by John Wiley & Sons, Inc., 605 Third Avenue, New York, NY 10158; 335 pages, 7½ x 9¾ inches, hardcover, $49.95 plus $1.09 postage.**

Includes a chapter on economic geology, and one on the history of Irish geology. Indexed.

Minerals of the Washington, D.C. Area, **by Lawrence R. Bernstein. Published (1980) by the Maryland Geological Survey, The Johns Hopkins University, Baltimore, Maryland 21218; 148 pages plus three maps in map pocket, 6 x 9 inches, softcover, 67 figures, $4.00.**

Designed primarily as a guide for mineral collectors, this book describes over 250 localities for over 200 minerals, all within about 40 miles of Washington. It begins with a historical treatment of mining and prospecting in the area going back to the 17th century. Few collectors realize that gold has been commercially produced from more than a dozen mines within 20 miles of the city, that the area was once a major copper producing district, and that Maryland was once the world's leading source of chromium. This is the first publication to describe in detail the mineral occurrences of the District of Columbia and adjoining counties in Maryland and Virginia.

Applied Geophysics (Geology of Petroleum Vol. 1), Introduction to Geophysical Prospecting, **by Gerhard Dohr. Published (1981) by John Wiley & Sons, Inc., 605 Third Avenue, New York, NY 10158; 231 pages, 6 x 9 inches, 166 Figures, 2nd completely revised edition, softcover, $21.95 plus 86¢ postage.**

Rocks and Minerals of Virginia, **a collection of 20 common specimens in removable trays, with an accompanying text about their occurrences and uses. Assembled by Mark P. Phillips (1980). Available from the Virginia Department of Conservation, Division of Mineral Resources, Box 3667, Charlottesville, VA 22903; $6.00 postpaid.**

Gem, Mineral and Gold Collector's Guide to Mineral Laws and Regulations, **by Lanny R. Ream. Published (1981) by the author, P.O. Box 1154, Coeur d'Alene, Idaho 83814; 67 pages, 5½ x 8½ inches, softcover, $00.00.**

Rock and Mineral Analysis **(Second Edition) by Wesley M. Johnson and John A. Maxwell. Published (1981) by John Wiley & Sons, Inc., 605 Third Avenue, New York, NY 10158; 489 pages, 6 x 9 inches, hardcover, $52.50 plus $1.09 postage.**

This second edition emphasizes instrumental analysis, in contrast to the first edition, which emphasized classical "wet" methods. Chapters cover sample selection and preparation; specific techniques for 12 constituents; atomic absorption analysis for 30 major, minor and trace constituents; X-ray fluorescence spectroscopic analysis for 40 major, minor and trace constituents; optical emission spectroscopy; neutron activation analysis; fire assaying; electron microprobe analysis; and a compilation and discussion of data on 80 international standard reference materials.

Historical Sketches of Copper and Lead Mining in Montgomery County, Pennsylvania, **by F. Harold Evans. Published (1980) by the Friends of Mineralogy, Pennsylvania Chapter, Inc.; available from Bryon Brookmyer, Box 19, Blue Ball, PA 17506; 36 pages, 8½ x 11 inches, softcover, $4.50 postpaid.**

Standard Mineralogical Catalogue, **by E. G. Brazeau and L. S. Brazeau. Published (1981) by the authors, Mineralogical Studies, 1145 Foxfire, Kernersville, NC 27284; 110 pages, 5½ x 8¼ inches, softcover, $5.50 postpaid.**

The only attempt (now in its fifth edition) to systematically determine the market prices of mineral specimens.

Minerals of Laurel Hill, Secaucus, New Jersey, **by Nicholas W. Facciolla. Published (1981?) by Don Bosco, Paterson, NJ; 48 pages, 33 black and white photographs, 6 x 9 inches, softcover, $3.50 plus $1.00 postage.**

The Nature of the Stratigraphical Record, **by Derek V. Ager. Published (1981) (Second Edition) by John Wiley & Sons, Inc., 605 Third Avenue, New York, NY 10158; 122 pages, 5½ x 8½ inches, softcover, $17.95.**

This book is more of a commentary, discussion or theorization (sometimes controversial) rather than a textbook or treatise.

Nonparametric Geostatistics, **by Stephen Henley. Published (1981) by John Wiley & Sons, Inc., 605 Third Avenue, New York, NY 10158; 145 pages, 6 x 9 inches, hardcover, $00.00.**

A statistical approach to handling and modeling geological data where hardly any assumptions can be made about the properties of the parent population.

Practical Coal Mine Management, **by Scott G. Britton. Published (1981) by John Wiley & Sons, Inc., 605 Third Avenue, New York, NY 10158; 233 pages, 6 x 9 inches, hardcover, $29.95.**

MINE LAMP REFERENCES RECENTLY PUBLISHED

Miners' Open-flame Lamps; Oil Lamps, Grease Lamps and Candle Lamps, **by Karsten Porezag. Published (1982) (Second Edition) by Verlag Gluckauf, Postfach 10 39 45, D-4300 Essen 1, West Germany; 124 pages, 7½ x 9½ inches, hardcover, 44 DM. In German (actual title: *Des Bergmanns offenes Geleucht; Unschlittlampen, Ollampen, Kerzenlampen*).**

This new edition contains minor text revisions to incorporate new data, and 27 new photographs. The best reference for European mine lamps in general.

Frog Lamps, A Survey of Examples from 1529 to 1979, **by Wendell E. Wilson. Published (1981) by the Rushlight Club, P.O. Box 3053, Talcottville, CT 06066; 112 pages, 6 x 8½ inches, softcover, $9.75 plus $1 postage.**

Includes chapters on history, construction methods and features, and a design classification based on country of origin. Illustrated and discussed are 72 different frog lamps from various regions including the United States, East and West Germany, Austria, Czechoslovakia, Hungary, Poland, Russia and England. Also illustrated are 13 other types of oil-burning miners' lamps and related styles for comparison, including the miner's betty lamp, miner's giesser lamp, French miner's lamp, and the rare German miner's blende lamps.

Many frog lamps were brought to the U.S. by immigrant miners, or were imported to the U.S. and Mexico for sale. Consequently they are a collectible and attractive variety important to any collection of mine lamps.

The (Nearly) Complete Bottom-Guide for Carbide Cap Lamps, **by Wendell E. Wilson. Published 1981; available from the author, 4631 Paseo Tubutama, Tucson, AZ 85715; 20 pages, 8½ x 11 inches, softcover, $3.00 plus 75¢ postage.**

Includes: illustrations (two views) of 78 bottoms or carbide chambers for nearly all known American brands, as an aid in identifying spare bottoms, mismatches and bottoms needed. Also contains a section on cleaning techniques, reproductions of old advertisements, a graph showing the relative rarity of the various brands, and an index.

Miners' Candlesticks from 20 Collections; **a statistical survey showing the relative rarity of 82 named or patented miners' candlesticks, by Wendell E. Wilson; 1 page, available at no charge from the author, 4631 Paseo Tubutama, Tucson, AZ 85715.**

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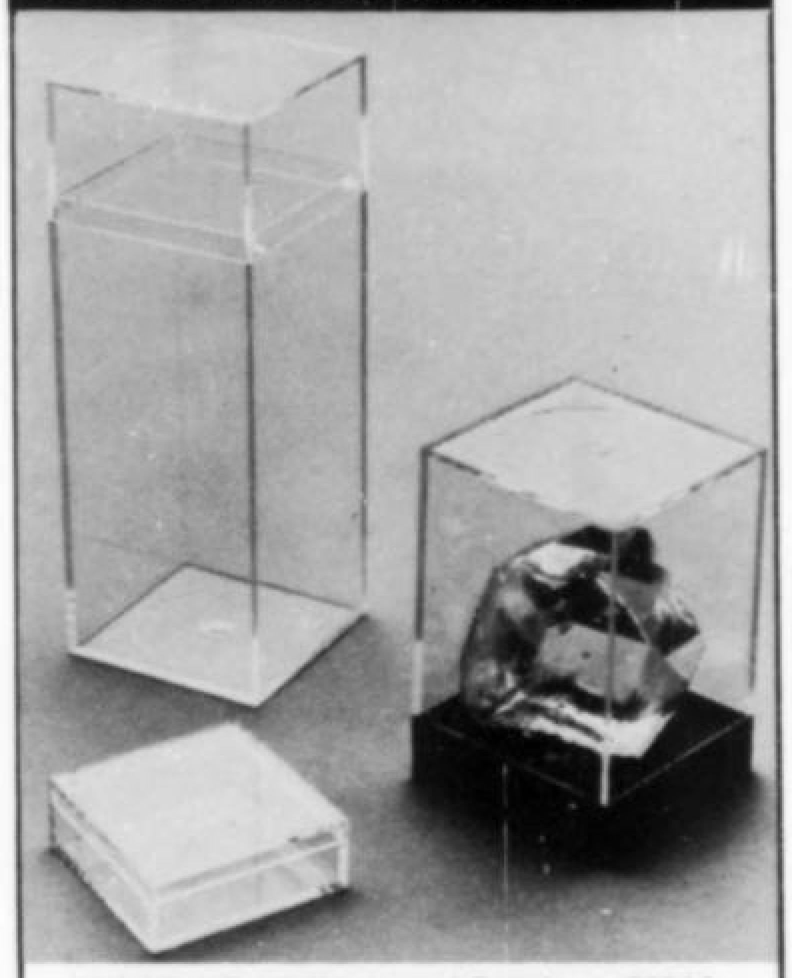

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Letters

FAN MAIL

Dear sir,

The *Record* here is tremendously popular and highly regarded, although the mineral collectors in Melbourne are not all that numerous. But we all look forward to the journal's arrival, and there are plenty of comments between us when each new number comes out. The zeolite articles delighted us because the Dana locality in Flinders is one to which we have access; all of us own very fine material from that locality, so that we tend to be zeolite-happy.

I personally greatly enjoy the continuing series on famous mineral localities very much indeed. But in all cases there seems to be something for everyone in each new issue of the *Record*. This, I feel, is the great virtue of the *Record*, and quite an achievement over the years.

Ruth Coulsell
Victoria, Australia

MONGOLIAN MINERALS FOUND

Dear sir,

I thought your readers might be interested to learn that in 1980 a team of Czechoslovakian and Russian geologists and engineers discovered crystals of cassiterite, topaz and quartz at Bain Mod, about 9 miles northwest of Tsenhermandal, Hentiy district, Outer Mongolia.

The Soviets believed the area to contain a very rich tin deposit, which is why they sent Czechoslovakian engineers to investigate. These men have studied the cassiterite deposits of Cornwall, and are currently employed in the mines near Horni Slavkov, Czechoslovakia (where nice 2-inch crystals of cassiterite have been found).

The Bain Mod minerals are probably from a pegmatite. The cassiterite is not as brilliant as crystals from Bolivia, but they are well-formed and quite large (up to ¾ inch), and some are twinned. I have seen a quartz crystal from this locality, about 2¾ inches long, clear and lustrous, with some small cassiterite crystals to ¼ inch imbedded in one side. The topaz crystals are perhaps the most interesting; they are transparent with some grayish areas, and beautifully terminated. The largest topaz crystals are about 1½ x 2 inches.

Soviet authorities are keeping the exact location secret.

J. Stobbe
Den Helder, Netherlands

WHO?

Dear sir,

I enjoy your publication so very much. [But] when did Nature get to be Father? (Mineral fakes article, page 214, last line).

Mary Ann Burtner
Flippin, AR

Theologians seem to feel that this change took place about the time that Pete Dunn began writing papers. Ed.

FAKES ARTICLE COMMENTS

Dear sir,

I feel that the guest editorial ("Mineral Fraud" by Dunn and Bentley) and the article on mineral fakes (by Dunn, Bentley and Wilson) in the July-August issue need a bit of rebuttal, or at least an explanation of someone else's point of view.

I believe and agree that repaired pieces should be so labeled, as well as fakes if they are known. But oiling, heat treatment and irradiation should not be considered forms of fakery. Oiling generally serves to return a crystal to its original luster and clarity for the purposes of display, and I see nothing wrong in this. And it is not permanent . . . these oils dissipate over a short period of time, leaving the piece as it was before the treatment. As to heat and radiation, these are known as natural phenomena as well as laboratory treatments, and it seems immaterial how they were generated; many specimens have been altered by nature through heat and radiation.

There is some commercial fraud and always will be, but to imply that oiling, heat-treatment and irradiation are forms of fraud is, to me, the height of narrow-mindedness. There are no Ten Commandments on this subject, and dealers have only reacted to what people want and are willing to buy. Otherwise, dealers would still be offering the same class of material that was available 25 years ago. Like the ad says, "You've come a long way baby," and I like the direction we've come.

Cal Graeber
Fallbrook, California

Authors' response

The issues raised by Mr. Graeber (above) do not result from any misunderstandings, but rather from a clearly articulated viewpoint with which we strongly disagree.

Mr. Graeber asserts that "oiling generally serves to return a crystal to its original luster and clarity for the purpose of display and I see nothing wrong with this." We do see something wrong with this practice and we addressed the matter quite specifically under the headings *falsified clarity, falsified luster,* and *falsified color* in our paper. We most certainly would have no objection to the exhibition or sale of such oiled crystals with labels which indicate that the specimen had been oiled but, in the absence of such labeling, the crystal or specimen is being presented to the viewer or buyer as natural, when in fact some characteristic has been falsified. Regarding Mr. Graeber's argument that such treatments return a crystal to its original luster and clarity: this cannot be proven unless one viewed the original luster and clarity. The assertion that such oilings dissipate over a short period of time is unsubstantiated; they may evaporate or sublime from the surface, but oils within internal cracks must linger some long length of time.

Concerning the matter of heat and radiation alterations, we disagree with Mr. Graeber's assertion that it does not matter how they were generated because the same effects might take place naturally. Our point is that if such effects were generated naturally, they are natural. If they were generated by man, they are unnatural.

We thank Mr. Graeber for focusing some issues quite clearly. He indicates that "dealers have only reacted to what people want and are willing to buy." Although we had not addressed the matter of dealer's motivations, we presume that Mr. Graeber is correct and, if so, then all is well. Those who want oiled or irradiated specimens will have them provided and those who want natural specimens will have them provided as well. The mineral marketplace will respond to demand, as it always has. We only ask that people be told exactly what they are getting.

Pete J. Dunn
Ronald E. Bentley
Wendell E. Wilson

Dear sir,

Many thanks to you and your co-authors for the really interesting report on "Mineral Fakes" (vol. 12, p. 197), and the large number of instructive photos. The article should be an eye-opener for serious mineral collectors, dealers and museum curators. Unfortunately, the uninformed tourist (who does not subscribe to the *Record*) will probably continue to waste a lot of money on fakes.

I noticed that, of the 52 fakes pictured, seven are from localities in the Austrian Alps (Tauern Valleys, Pinzgau, Salzburg and Zillertal, Tyrol) . . . these are a fairly representative sampling of the more sought-after species from the Alps. Of the four Swiss examples, at least hematite and pink flourite are found and faked in the Austrian Alps as well. Considering these, almost a fifth of your illustrated fakes are associated with the Austrian Alps. Even today there is a proverb saying that more specimens are "produced" ("home-made"!) in the Pinzgau region during the winter months (when collecting is impossible) than are found during the summer months. An excerpt from your article regarding the Alpine minerals (translated into German) might make a worthwhile warning to be distributed in the Alpine tourist centers.

I can add a few fakes to your list, from my own experience in the Tauern region:

Emerald from Habachtal. Cut glass glued onto original brown mica schist matrix. Faulty interfacial angles were obvious.

Emerald from Habachtal. Short pieces of bright green plastic have been "salted" into the creek coming from near the mouth of the Habachtal emerald mine, for the purpose of stimulating the tourists during the tourist season.

Anatase on quartz from Rauristal. The small anatase crystals have been glued on quartz, and are very difficult to distinguish from natural specimens.

The list could be extended. But my main purpose in writing is to thank you for your comprehensive report on fakes, and to confirm that the high proportion of Alpine fakes you included is not a sampling error, but is unfortunately representative of the problem here.

Karl Götzendorfer
Leonding, Austria

Dear sir,

I was very pleased to see the article on fakes in your July-August issue. I find the subject extremely interesting; and it is necessary and important that Europeans as well become informed on the problem. During the Münchner Mineralientage (Munich Show) of last year the jury awarded a prize to a stuck-together specimen, without having noticed the glued area. This issue is one of the best you have ever produced.

Christian Weise
Editor and Publisher, *Lapis* magazine
Munich, West Germany

Dear sir,

Your article on fakes is incredible, tops all. The subject is a parallel to stamp fakes. Valuables will always have that problem.

D. Bloch
San Francisco

Dear Readers,

Would you believe that the above are all of the substantive responses we had to the fakes article? Considering the potentially controversial nature of the subject, we expected more. One deterrent, apparently, was that most dealers who disagreed with us on some point were unwilling to write, because they thought they'd appear to be supporting fakes (which would be bad for their image).

I did glean a few grumbles and comments privately. The main complaint among dealers seemed to be that the length of the article was disproportionate to the seriousness of the problem, and tended to poison the enthusiasm of buyers for a while. That may or may not be true, but we had a certain amount of data to present and that's how much space it required.

Comments from collectors have been uniformly positive, sometimes downright grateful. We want to thank everyone who wrote in; the letters column is an important and interesting forum for readers to express their own opinions. We'd publish more if we received more . . . so get writing! This is **your magazine** *. . . don't be shy about utilizing it to the fullest.* *Ed.*

EXCHANGES

I have for exchange, turquoise crystals on turquoise, with some wavellite crystals in association; the specimens are micromounts but very beautiful, and come from Australia.

H. Bunker
61 Noble Parade
Dalmeny, N.S.W. 2546 Australia

ERRATA

Regarding the article on the Boltsburn mine by R. J. King (vol. 13, no. 1), the mineral name *fluorite* was misspelled ("flourite") in Figure captions 8, 9, 10, 11, 16, 17 and 21. We are deeply mortified by this error, and wish to apologize to author King and readers. The spellings were correct on the original manuscript but the subsequent typesetting errors were overlooked by us at the proofing stage.

Ed.

What's New in Minerals?

TUCSON SHOW 1982

"WELCOME GEM AND
MINERAL SHOW
TWO WEEKS OF BEDLAM
BUT WE LOVE IT"

. . . So said a billboard at one of the show motels, near the Tucson Community Center, expressing the feeling of everyone in town for this year's Tucson Show! Dealers began opening their motel doors for business on Tuesday, a week and a half before the opening of the main show. And, judging from conversations with many of them later, business was good.

Several recent discoveries dominated conversation before and during the show. The most prolific find came from the Bunker Hill mine in Idaho (see *M.R.,* November-December 1981, p. 339 for Norm Radford and Jack Crowley's article on that locality). As a last gasp of activity, this mine on the verge of closing yielded a walk-in pocket, lined with superb crystals of what may well be the world's finest pyromorphite. The best specimens have crystals of a yellow-green to apple-green color ranging from ½ inch to more than 1 inch, some exquisitely well-formed. We have received an article on Idaho pyromorphite (including this discovery) for a future issue, so I won't belabor the descriptions. But the photos shown here can speak for themselves.

Most remarkable about the pyromorphite discovery is the enormous number of specimens removed . . . several *hundred* flats. Of course the exceptionally fine pieces comprise only a small fraction, but the sheer bulk of specimens removed (by miners!) is impressive. So is the care and skill with which these delicate specimens were collected and packed. Two major lots resulted, of which the first was marketed to the public by Harvey Gordon during the show, from his room at the Newton Travellodge. The second lot, still in the hands of the mining company at showtime, was scheduled to be released soon after the show. Cabinet pieces are truly spectacular; Harvey's best piece carried a $35,000 price tag, though fine competition-quality thumbnails and miniatures could be found for less than $1000. In any case, collectors who missed the show or missed Harvey will have a second shot when the other batch of pyromorphite reaches the market (and I have it on good authority that there are some habits in the second batch which were not represented in the first batch). A different dealer will most likely be handling these.

The other big newsmaker at the show was the incredible find of purple adamite hinted at in this column earlier (January-February 1982, p. 39). A large case containing dozens of specimens from the pocket drew continuous crowds at the show. This pocket yielded only a few flats of choice specimens, and they sold for high prices, generally more than $1000 for good miniatures and well over $10,000 for the best cabinet piece. There were only enough specimens to satisfy a few of the better funded collectors . . . many more could have been sold at similar prices.

Quite a few other recent discoveries were stirring up interest. Chris Wright (*Wright's Rock Shop*) purchased before the show an entire pocket of autunite, nearly 50 flats, found at a new locality in Washington given only as Pend Orielle County. The crystals are generally less than half an inch, but form attractive crusts which are yellow in color and fluoresce an *intense* yellowish green in sunlight.

Several dealers carried ferroaxinite from a new discovery in California. In the fall of 1981, specimens were first discovered in a huge, excavated spillway of the New Melones Reservoir near Jamestown in Calaveras County. Since then, several parties have collected material, some of which may exceed in quality even those famous axinites from le Bourg d'Oisans, France. Many crystals are gemmy and well over an inch in size. (We have just received an article on this discovery as well, so I will leave the complete description until then.) Collecting at this locality must be difficult; the vast majority of specimens are damaged.

At the Desert Inn, Carlos Barbosa had specimens of very fine autunite (in far smaller quantity than the Washington discovery) from a new mine near the village of Malacacheta, in Malacacheta County, Minas Gerais, Brazil. The deposit was opened in a futile search for aquamarine, but several dozen nice specimens of autunite crystals up to 1 inch were uncovered instead. Carlos also had what must be the world's biggest wodginite crystal (a twin!), about 6 inches in size, heavy and blocky, and a lustrous black.

Entering Bart Cannon's motel room tends to make a collector feel uninformed all of a sudden. He and other Washington collectors have a way of finding new localities and new occurrences totally unknown and rather surprising to collectors from outside the state. Imagine an entire room filled with dozens of occurrences not seen in any other dealer's booth or room . . . it's disorienting. For example, Bart had quite a number of very fine garnet specimens, gemmy, root beer-colored crystals from ⅓ inch to 2 inches, in tight groups and parallel growths on matrix. The crystals are composed primarily of a glassy-faced dodecahedron modified by frosty cube faces (will someone ever find fully cubic garnet?). Several hundred pieces were collected from a 25-foot tubular pocket near Vesper Peak, Snohomish County, Washington. Bart also had gersdorffite crystals from 1 to 3 inches and parisite crystals from the Snowbird mine, Montana, and some new axinite crystals to more than 1 inch, on garnet, from Washington (Bart's address: 1041 NE 100th Street, Seattle, Washington 98125).

Rich Whiteman (*Red Metal Mineral Company,* 1439 Garden Street, Hancock, Michigan 49930) is well known to all collectors fond of Michigan copper country minerals. This year his room was filled with copper as usual, including about 60 specimens of cubic copper showing rather small crystals in parallel growth, from the Ojibway mine, Keweenaw County, Michigan.

Mark Rogers at the main show put out a fine selection again, including some blocky, twinned huebnerite crystals to ½ inch from Mundo Nuevo, Ancash Province, Peru. Rock Currier and Gary Nagin also obtained some of these, the largest crystal of which is reputed to be over 1 inch in size.

Before the show, Tony Jones (of *California Rock and Mineral,* 1812 Evergreen Drive, Duarte, CA 91010) sent me a couple of the big zircon specimens from Alta, Norway, to photograph for this report. (See Bob Sullivan's column, *M.R.*, vol. 13, no. 1, p. 51.) At the time, Tony had about 50 relatively good specimens; the crystals are dark red, partially gemmy, and very fractured inside. Some

Figure 1. **A group of pyromorphite crystals 2⅛ inches across, from the Bunker Hill mine, Idaho. Harvey Gordon specimen.**

Figure 2. **A group of pyromorphite crystals 1⅜ inches across, from the Bunker Hill mine. Harvey Gordon specimen.**

Figure 3. **Adamite from the Ojuela mine, Mapimi, Durango, Mexico. The crystal spray is 2⅛ inches across. Artrox and associates specimen.**

come attached to a white nephaline matrix, and others come with black biotite.

As usual, Mike Sprunger had a roomful of fine Utah topaz crystals; and he also had some excellent garnets, black and lustrous, and up to more than an inch in size.

This is certainly not a complete listing of what was

Figure 4. **Adamite group 3⅜ inches across, from the Ojuela mine. Artrox and associates specimen.**

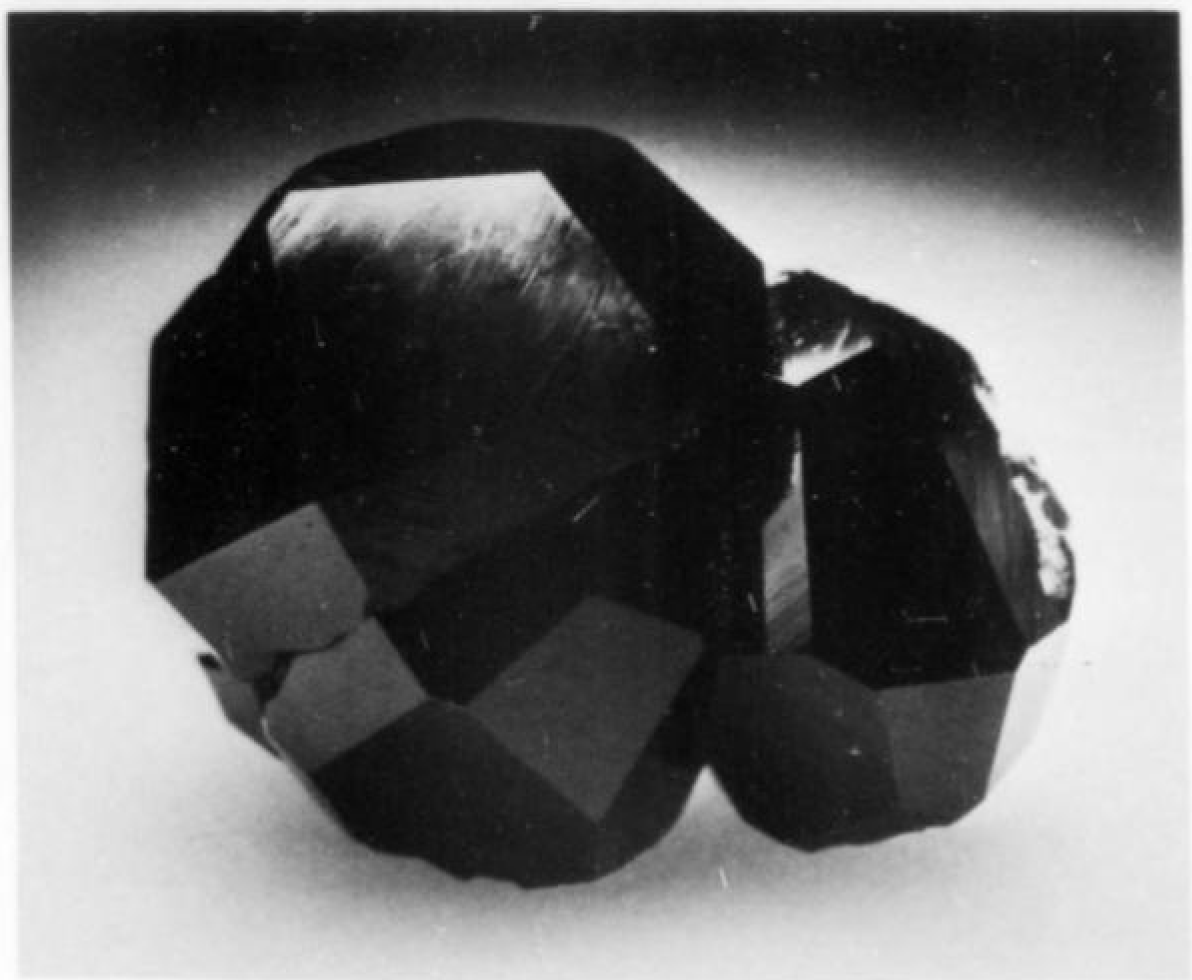
Figure 5. **Adamite from the Ojuela mine; the crystal group is $^{11}/_{16}$ inch across. Artrox and associates specimen.**

Figure 6. **Autunite crystals, the largest measuring ½ inch diagonally, from Pend Orielle County, Washington. Wright's Rock Shop specimen.**

Figure 7. **Autunite from Malacacheta, Minas Gerais, Brazil; the largest crystals are nearly ½ inch on an edge. Carlos Barbosa specimen.**

Figure 8. **Dark red-brown zircon crystals from near Alta, Norway. The crystal on the left, on white nepheline matrix, is 1⅝ inches across; the other is 2 inches in maximum dimension. Tony Jones specimens.**

Figure 9. **Black garnet from Topaz Mountain, Utah; the group is 2 inches across. Mike Sprunger specimen.**



impressive this year . . . Gary Hansen showed me an unbelievable gemmy-yellow anglesite from Morocco; Sharon Cisneros (*Mineralogical Research Co.*) had a fresh batch of extremely rare Russian minerals; and there were a few specimens of superb cerussite in blocky, waterclear twins just surfacing from the Kombat mine near Tsumeb . . . and more, and more.

SATURDAY NIGHT

The evening started off in style, with Paul Desautels introducing Rustam Kothavala to speak on the sapphire deposits of northern India. This was an adventure tale of a kind never before seen at a Saturday night program. Beautiful slides documented Rusty's trek into the Himalayas (on a crutch) in search of a near-legendary deposit long off-limits to outsiders and insiders alike. He reached it, but you'll have to await his promised article for the details.

Following the lecture, the Friends of Mineralogy presented their award to Richard Graeme for the year's best *Record* article: his monograph on Bisbee, which comprised the entire September-October 1981 issue (plus 16 extra pages). His was the first monograph ever published by the *Record;* according to award-presenter Bob Jones, the choice was nearly a toss-up between Dick's Bisbee article and Rock Currier's *Jewel Tunnel Imports* advertisements, but Dick won in the end. (His prize: a lifetime subscription to the *Record* of course.)

The annual slide competition was unfortunately not held this year due to an insufficient number of entrants. This was no doubt traceable to your humble editor's failure to publish an advance notice of the competition. But rest assured that the competition will be held next year, with one major change: as an entry fee, each slide must be accompanied by a 5 x 7-inch glossy color print which will not be returned. A loose-leaf book composed of all the entry prints will be auctioned off Saturday night, and the resulting funds will go toward the prize money.

The McDole trophy this year went to Jim Bleess for his thumbnails, and he swigged straight from the bottle of Ed's old black rum to become an Old Bounder and a Peer with Ed. The touching ceremony is guaranteed to bring tears to your eyes, especially if it is *you* who is forced to drink that rum before claiming your trophy. Ed Huskinson's fine miniature of hematite from near Quartzsite, Arizona (collected by Dick Jones), won the Lidstrom Trophy for best single specimen in competition.

Then the annual auction to benefit the *Mineralogical Record* got underway, and the rest is history. Auctioneers Gary Hansen, A. L. McGuinness, Dick Hull and John Patrick rotated their way through the nearly 200 lots donated by the many friends of the *Record*. The other volunteers who together made this year's auction possible are (in no particular order): Walt Risch, Paul Desautels, Ron Bentley, Pat Carlon, Carolyn Wilson, Wendy White, Kendahl White, Leslie White, Jonathan Weiss, Don Olson, Bob Jones, Dick Thomssen, Tony Kampf, Gale Palmer, Bill Basbagill, Marie Huizing and Terry Huizing. It always amazes me how many volunteers and how much work it takes to put on this event; they deserve the thanks of every *Record* reader.

We have some interesting changes lined up for the program next year, which promise to make the evening even more entertaining . . . and you're invited.

W.E.W.

ANNUAL LIST OF DONORS TO THE *MINERALOGICAL RECORD*

Presented here is a listing of everyone, according to our records, who donated to the auction this year or made cash donations to the *Mineralogical Record* during the last 12 months or so (except a few who wished to remain anonymous). If you made a donation and are not listed here, or if you did not get a letter of acknowledgment (usable for tax purposes), please write to me and I will rectify the matter.

I know all the readers of the *Mineralogical Record* will join with me in saying thanks to these generous people who help to keep our magazine going year after year.

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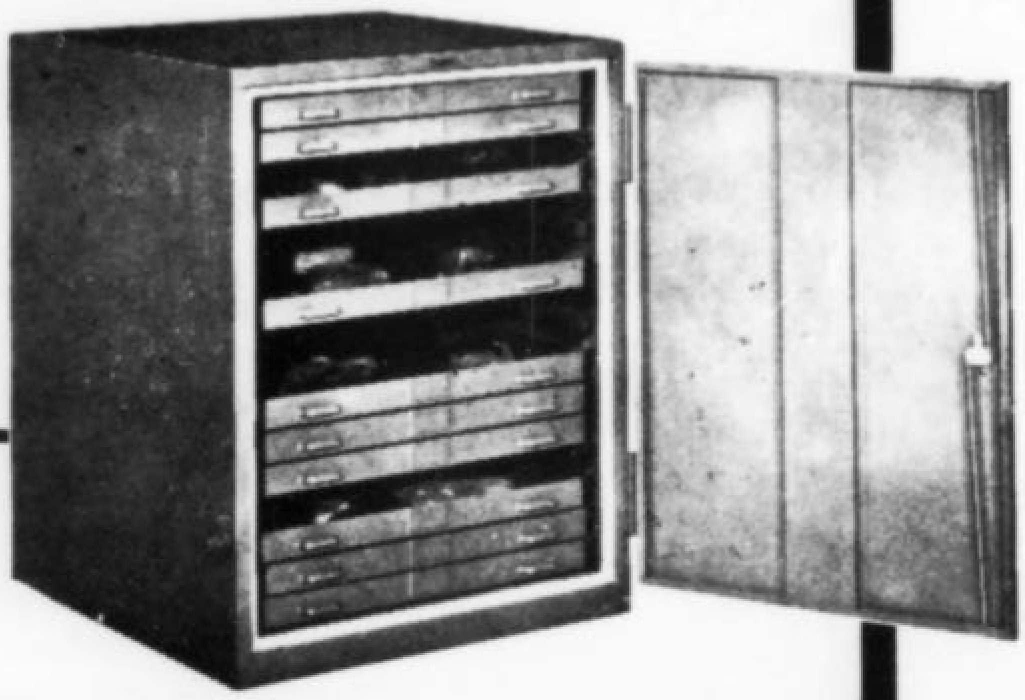

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Crystallized Gypsum from the playa lake clays of Lake Gilles

by **Brian M. England**
28 Byng Street, Tenambit
East Maitland, New South Wales 2323
Australia

Lake Gilles is well known in Australia as a source of exceptionally fine crystallized gypsum, which is disseminated through clays in the lake bed as well-formed single crystals, groups and twin crystals of unusual clarity and habit. The large variety of crystal morphologies present and the perfection of crystal forms make this locality unique.

LOCATION and ACCESS

The gypsum deposit lies adjacent to a small island in the northeast corner of Lake Gilles (Fig. 1), which is situated just beyond the western boundary of Corunna Station, 30 kilometers northwest of Iron Knob, South Australia. The lake is over 40 km long but only a few km wide at its northern extremity where the gypsum deposit is located. Access to the edge of the lake is provided by a good dry-weather road via Corunna Homestead (Lancaster, 1979). However vehicles cannot be driven onto the lake bed itself and the deposit can only be reached on foot, a distance of approximately 1½ km from the lake shore.

The locality has been erroneously called "Lake Gillies" by some authors.

FORMATION of the GYPSUM DEPOSIT

The concentration and crystallization of gypsum in salt lake deposits has been discussed previously by the author (England, 1978) as being the result of groundwater and water table movements during successive wet-dry periods. Very little additional information on the formation of gypsum deposits has been published.

One of the most interesting phenomena associated with the Lake Gilles gypsum deposit is the abundance and variety of reasonably large, perfectly formed crystals. The finest of these crystals are disseminated through a 30-40 cm layer of dense clay, which forms the bed of the lake (Fig. 2). Beneath the clay is a zone of saturated soft mud of unknown depth, which also contains gypsum. Calcium sulfate released by the weathering of surrounding rock formations during the gradual denudation of the landscape has migrated to the lake bed and slowly built up in concentration in its sub-surface water.

The following process is suggested as the probable mechanism of gypsum growth at Lake Gilles:

As evaporation proceeds in the surface layers of the lake bed, water containing $CaSO_4$ from the saturated mud zone is very slowly drawn by capillary action through the clay layer toward the surface. On evaporation the dissolved $CaSO_4$ is precipitated out as gypsum and once nucleation of crystals within the clay has occurred this migrating mineralized water provides a continually replenished source of material for crystal growth. The crystals slowly enlarge by forcing the clay aside and areas of crystallization are usually revealed by bulges in the lake bed. Growth of crystals by the diffusion of components through a suitable medium is well-known in nature and also as a technique used to produce crystals of various minerals under laboratory conditions. There is little reason to doubt that this is the process by which the Lake Gilles crystals have formed and it would certainly explain the abundance of relatively large perfect crystals.

By its very nature, the dense clay in which the crystals occur would insulate them against sudden changes in the growth environment, allowing the relatively slow growth of large perfect crystals within stable surroundings, more or less unaffected by long wet or dry periods. Although Lake Gilles is only one of several such playa lakes on Eyre Peninsula, no other lake contains muds of the consistency of the Lake Gilles clays and that in itself is probably the reason for this unique occurrence.

ASSOCIATED MINERALS

The only other evaporite mineral occurring at Lake Gilles is halite, which is occasionally found as crystallized crusts floating on the surface of small pools, or encrusting twigs, mud, or rarely the gypsum itself. Normally the halite only appears during hot dry spells after rain, since it is the most soluble of the lake salts and hence the last to crystallize out of solution. It is not found associated with the gypsum in the clay bed.

Figure 1. **Looking north from the island adjacent to the gypsum deposit on Lake Gilles. The area of the lake bed containing the crystals is shown by mounds of disturbed mud.**

Figure 2. **Collecting gypsum crystals from the Lake Gilles clays. Note the water level corresponding to the lower limit of the clay bed.**

EFFECT of HALITE on GYPSUM CRYSTALLIZATION

Previous investigators (e.g. Francis, 1968) have found that solubility of the gypsum crystals increases in the presence of NaCl, so that a sudden increase in NaCl levels results in the rapid dissolution of previously-formed gypsum crystals. Decay of the crystals appears initially as hollows or irregular indentations in the crystal faces and usually begins at damage points or areas of contact between crystals. Gypsum crystals enclosed in the clay bed appear largely unaffected by this phenomenon, whereas those below that level show considerable decay after periods of heavy rain.

It has been shown that excess NaCl in the growth environment will prevent the crystallization of gypsum. However halite concentration in the clay bed at Lake Gilles is very low and never reaches sufficient proportion to affect crystal growth.

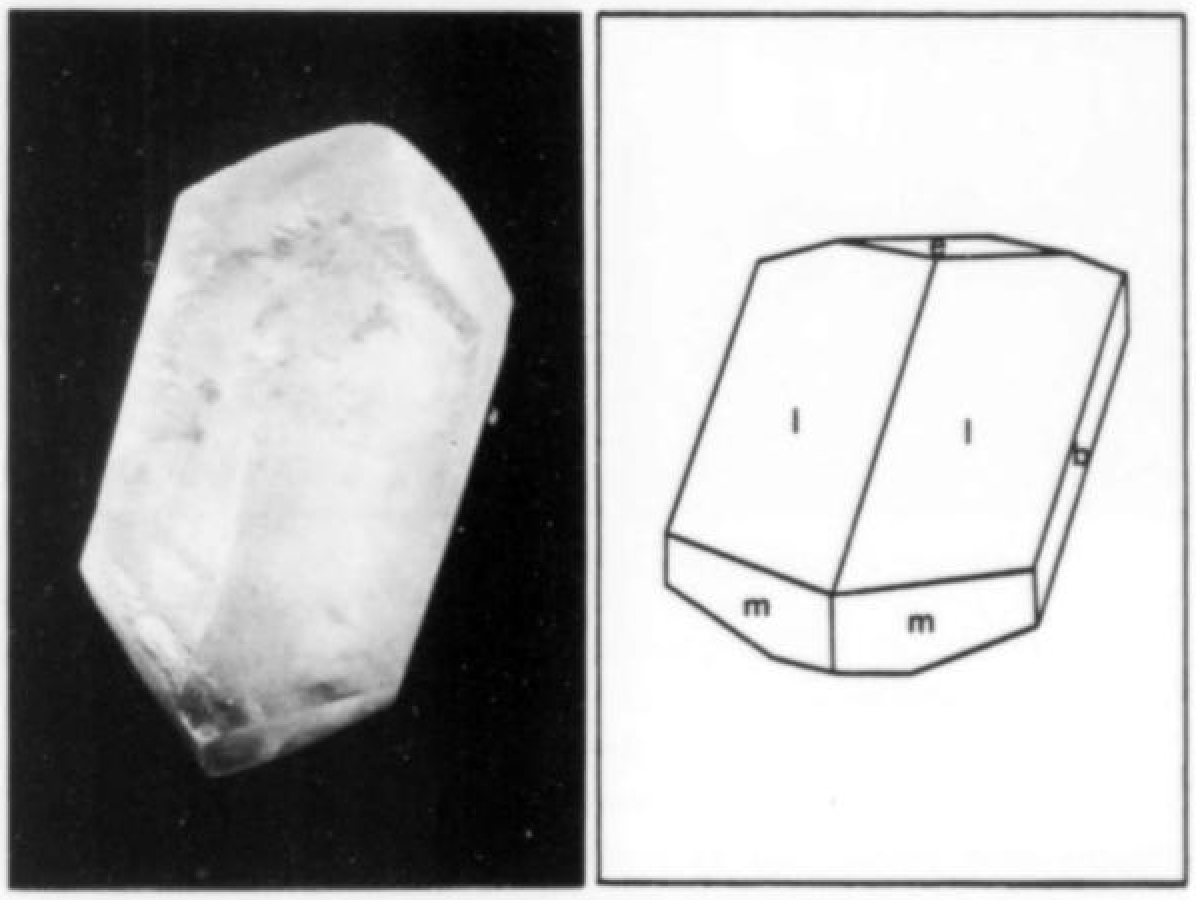

Figure 3. **Single gypsum crystal, showing the tabular nature.**

MORPHOLOGY of the GYPSUM CRYSTALS

Single Crystals

Single crystals from Lake Gilles are characterized by relatively small hemi-prism m{110} and *m*$\{\bar{1}\bar{1}0\}$ and clinopinacoid b{010} faces terminated by prominent hemi-pyramids l{111} and *l*$\{\bar{1}\bar{1}1\}$, giving the crystals a tabular appearance (Fig. 3). Hemi-orthodome e$\{\bar{1}03\}$ faces are also present on most crystals but these are usually small, rough and convex in nature and hence seldom noticed. The hemi-pyramid faces, although well formed, are always rough in appearance while the prism and clinopinacoid faces are smooth and lustrous. This consistent difference in appearance between these forms aids in the identification of crystal faces, particularly on twinned crystals.

Curved or convex crystal faces, such as shown by the small hemi-orthodome, have been shown to be due to the presence of NaCl as an impurity (Deicha, 1946).

Twinned Crystals

It is the unusual variety of twinned crystals which has made Lake Gilles well-known among collectors worldwide.

(a) Morphological Types resulting from Contact Twinning on a(100)

Twinning on a(100) has resulted in at least eight apparently quite different crystal morphologies, some of which resemble complex penetration twins.

No acceptable explanation can be given at present for this great variety of crystal shapes based on the one simple twin law. Relative $CaSO_4$-NaCl concentrations may play some part, as may the particular confining pressures in the clay surrounding the growing crystal as produced by adjacent crystals.

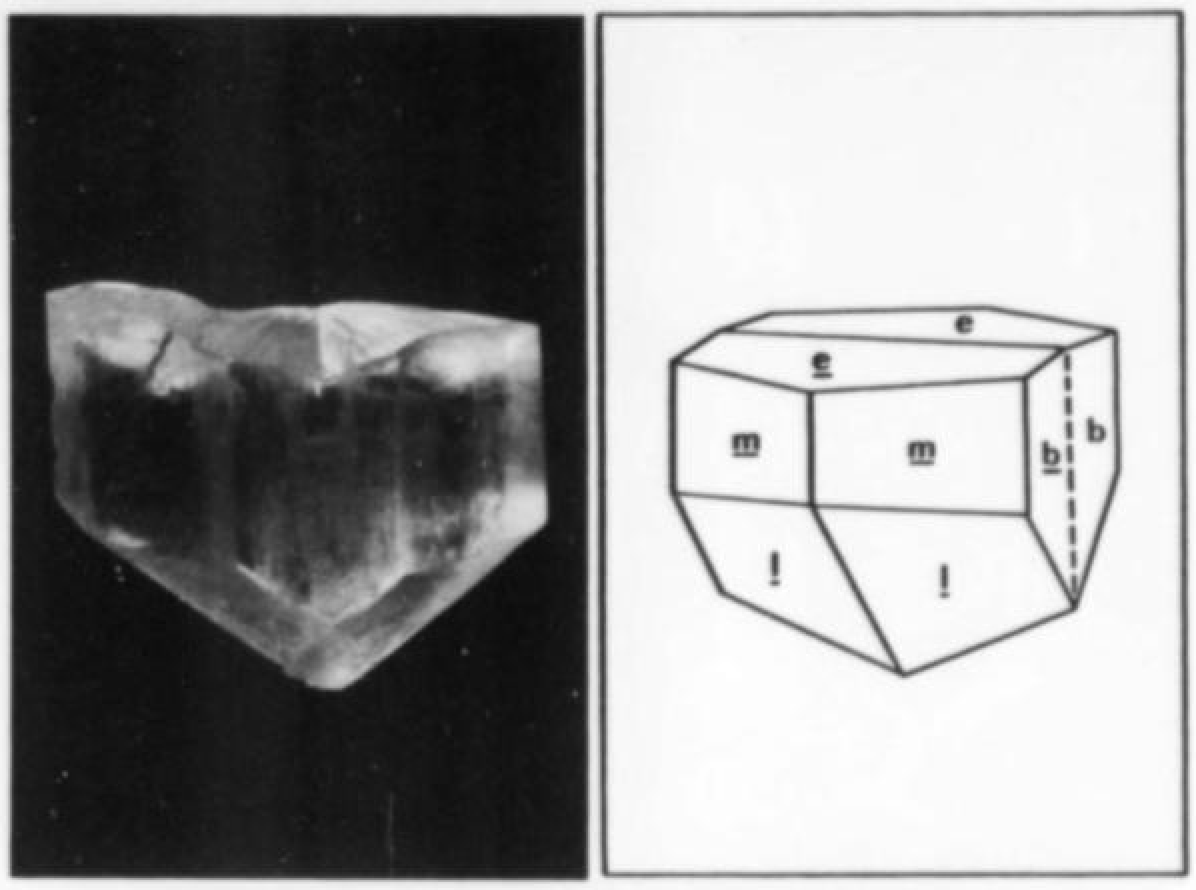

Figure 4. **Swallowtail twin in which the hemi-orthodome faces (e) predominate on the positive termination, giving a very shallow re-entrant angle.**

(i) Simple Swallowtail Twins Terminated by Hemi-pyramid and Hemi-orthodome Faces

In this type (Fig. 4) the prism and clinopinacoid faces of the two individuals result in a pseudo-hexagonal crystal, terminated at one end by an apparent basal plane formed by the junction of the two opposing hemi-orthodome faces e$\{\bar{1}03\}$ and *e*$\{10\bar{3}\}$ and at the other by a pseudo-pyramid formed by the hemi-pyramid faces l{111} and *l*$\{\bar{1}\bar{1}1\}$. This combination gives the crystals a false hemimorphic appearance.

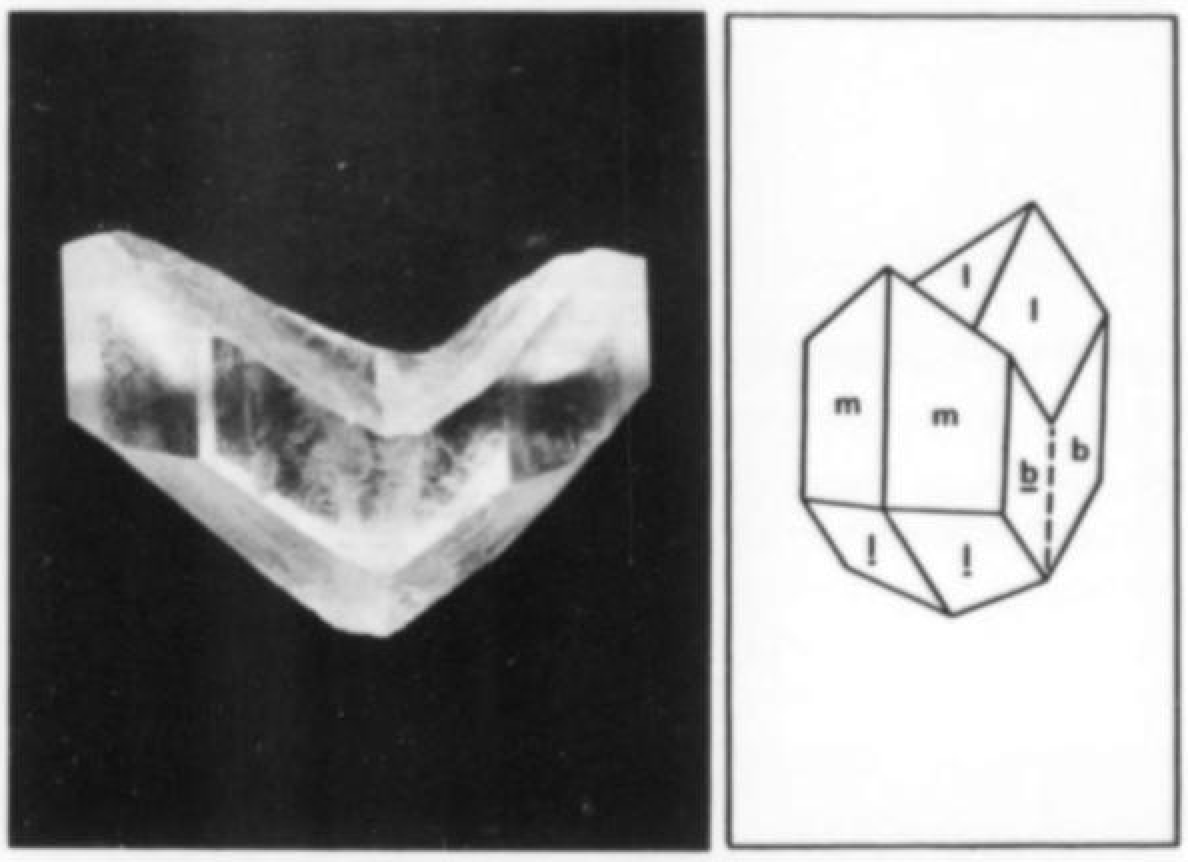

Figure 5. **Swallowtail twin in which the hemi-pyramid (l) faces predominate on the positive termination, giving a relatively deep re-entrant angle.**

(ii) Simple Swallowtail Twins Terminated by Hemi-pyramid Faces only

This is the more usual swallowtail twin type (Fig. 5). Here a prominant re-entrant angle is formed by the junction of opposing hemi-pyramid l{111} faces of the two individuals. The other termination is a pseudo-pyramid, again formed by the junction of the hemi-pyramids of the two individuals.

(iii) Pseudo-Hexagonal Crystals (Extended Swallowtail Twins)

These are merely an elongated variety of types (i) and (ii) described above, formed by the preferred growth of the prism and clinopinacoid faces in the direction of the common *c*-axis (Fig. 6). Length-to-width ratios of up to 4:1 have been recorded for these crystals at Lake Gilles.

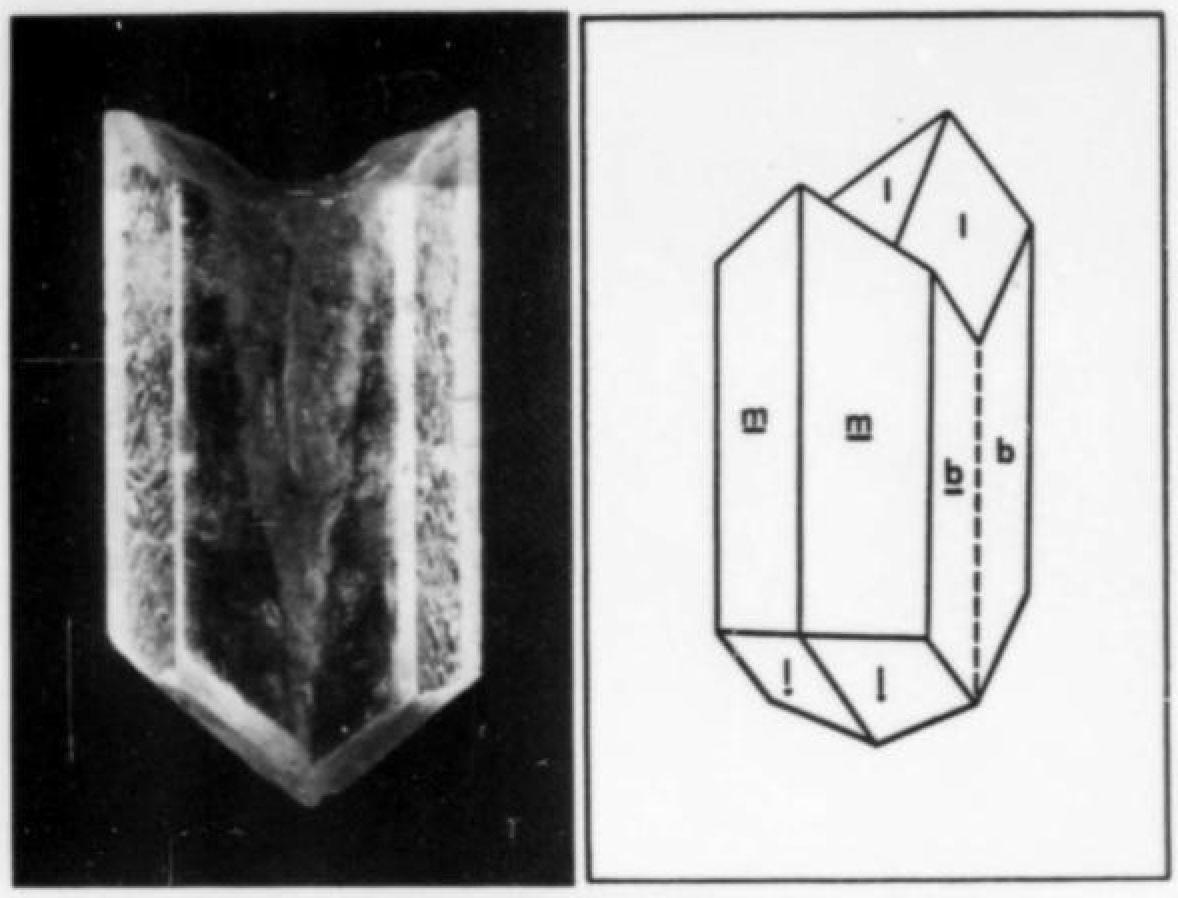

Figure 6. **Pseudohexagonal crystal, or an extended swallowtail twin.**

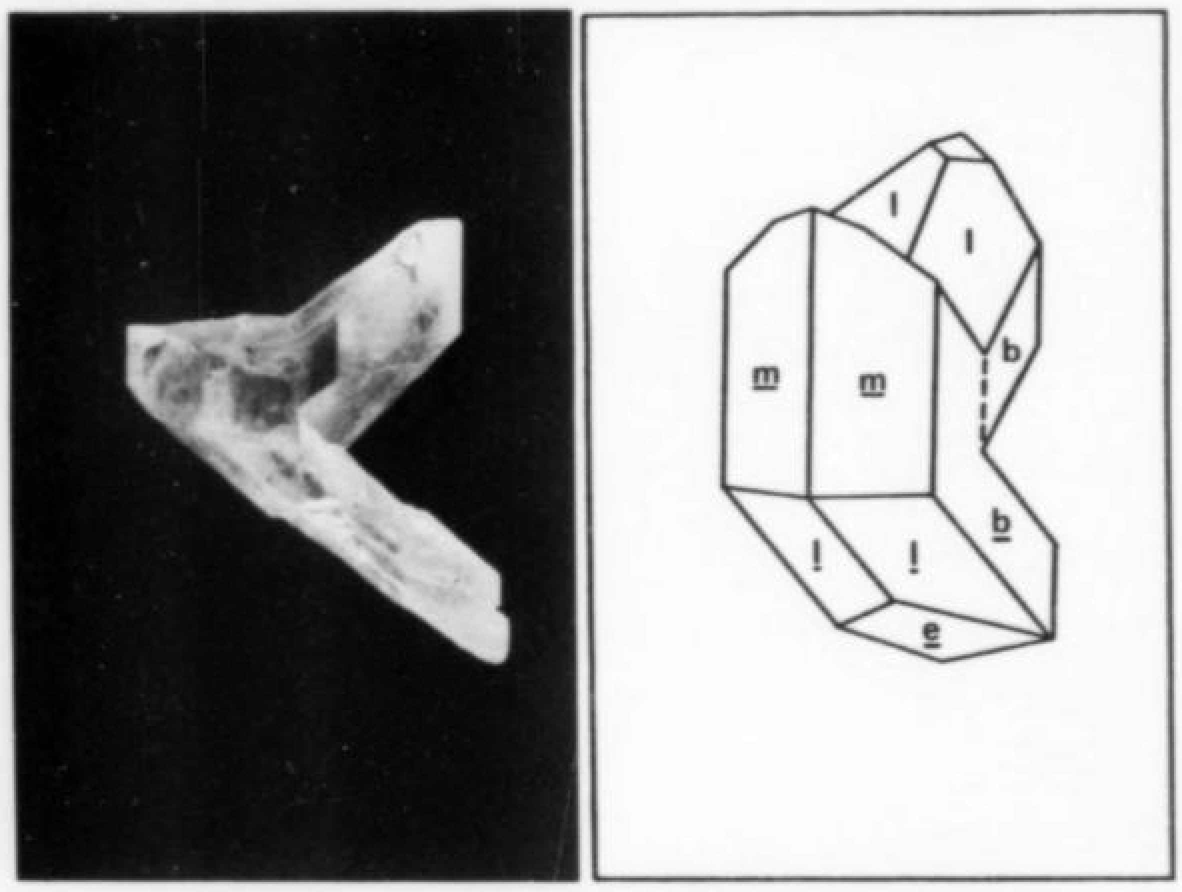

Figure 7. **Arrowhead twin. Either hemi-pyramid or hemi-orthodome faces can predominate on the positive termination.**

(iv) Arrowhead Twins

The arrowhead twin type can be regarded as an extension of the swallowtail type, in which one of the component crystals forming the twin has grown past the other at the negative termination to form a fully faced single crystal as part of the termination (Fig. 7).

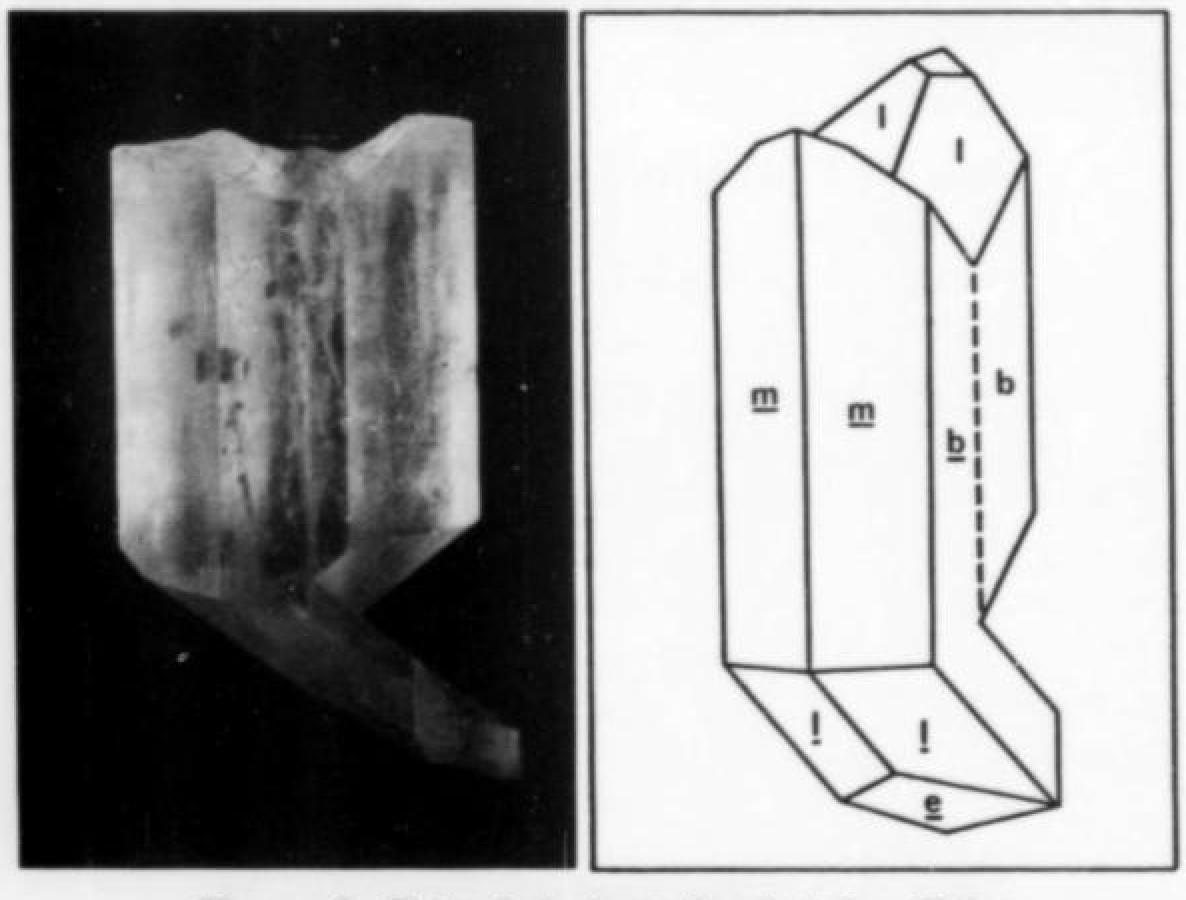

Figure 8. **Extended Arrowhead twin. Either hemi-pyramid or hemi-orthodome faces can predominate on the positive termination.**

(v) Extended Arrowhead Twins

These crystals are an elongated variety of type (iv) above, again formed by the preferred growth of prism and clinopinacoid faces in the direction of the common *c*-axis (Fig. 8).

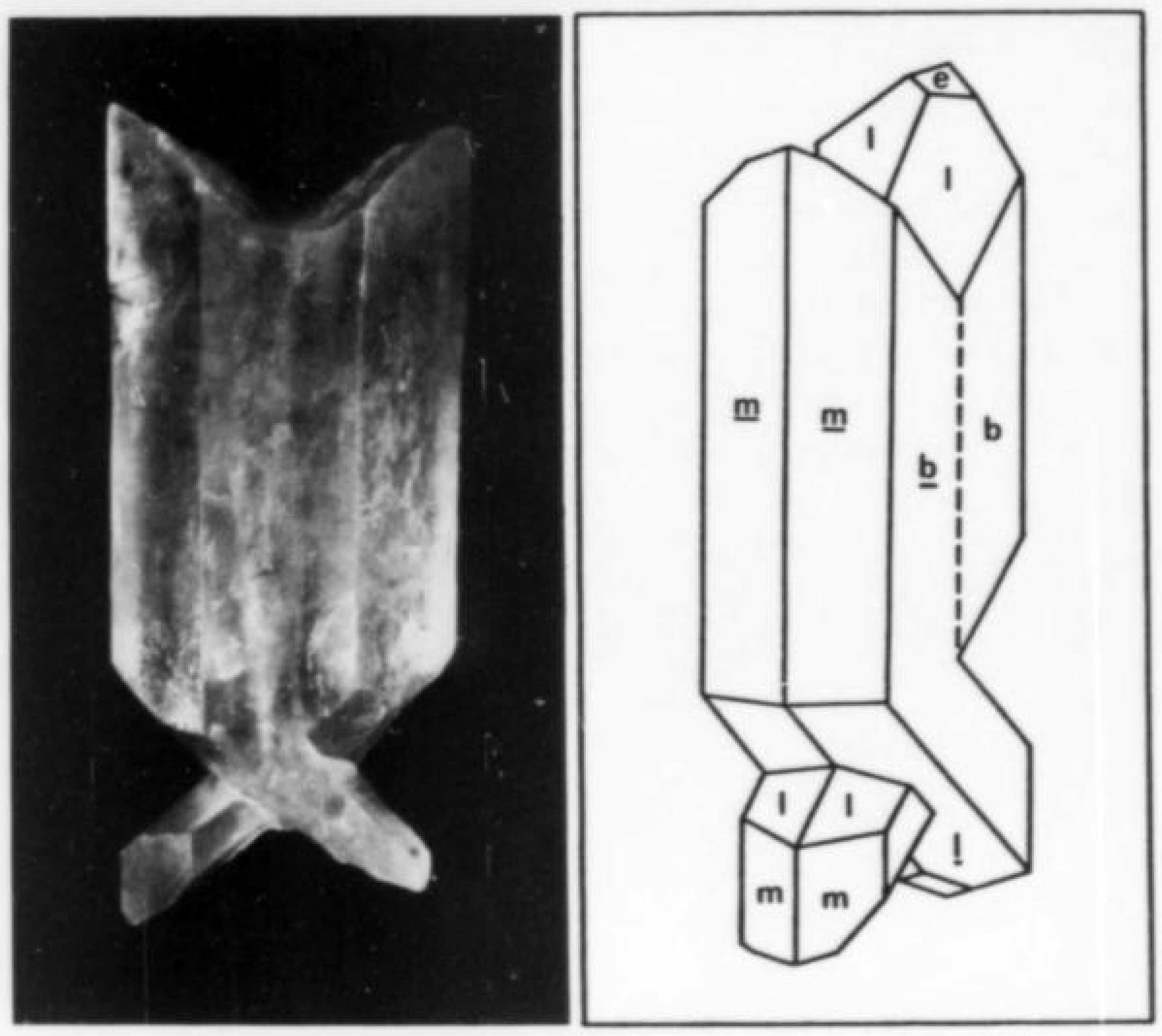

Figure 9. **Corkscrew twin.**

(vi) Corkscrew Twins

An unusual twin perhaps unique to Lake Gilles formed as an extension of the arrowhead type in which both of the component crystals have grown past each other at the negative termination, each forming a separate fully-faced single crystal as part of the termination (Fig. 9).

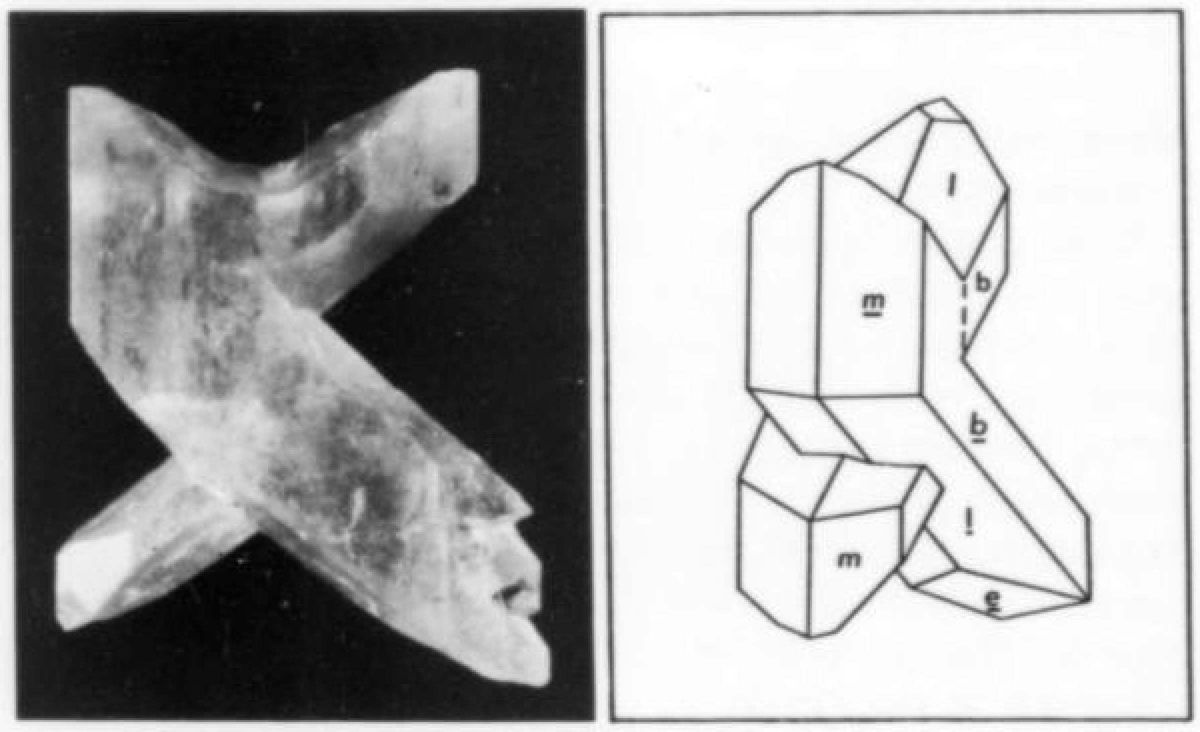

Figure 10. **Z-twin.**

(vii) Z-Twins

This type is an extension of the corkscrew type in which the overlapping single crystal terminations have continued to grow preferentially in the direction of the common *c*-axis to form another pseudo-hexagonal crystal, and leaving two prominent V-shaped re-entrant angles in the resultant crystal. This is another variety characteristic of Lake Gilles (Fig. 10).

(viii) Hourglass Twins

These are very similar in morphology to the Z-twins described above, but with preferential growth of the prism and clinopinacoid faces in the direction of the common *c*-axis (Fig. 11).

Note: In any of the above types either the hemi-pyramid or the hemi-orthodome faces can predominate on the positive termination, giving either a very pronounced or a very shallow re-entrant angle.

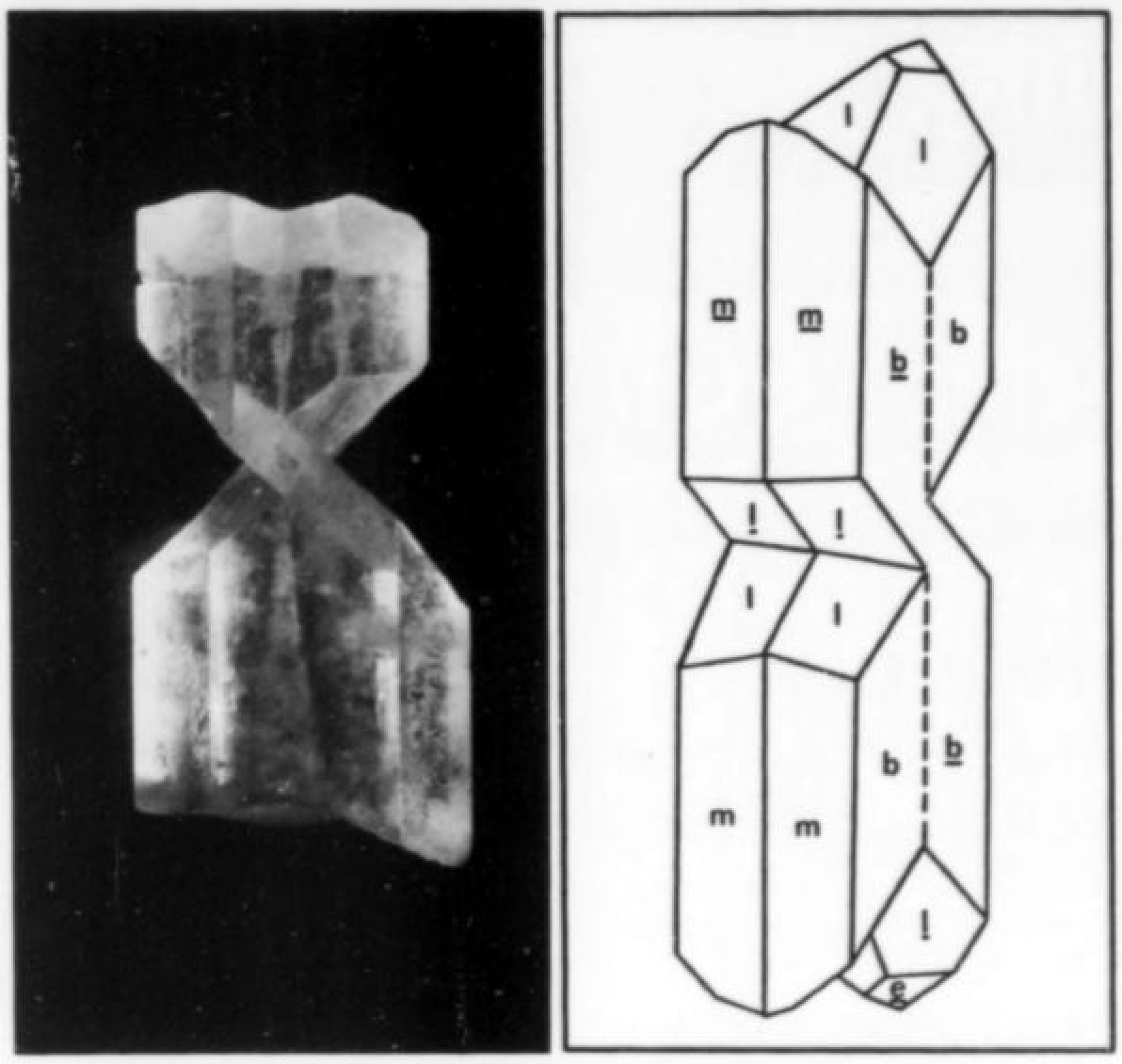

Figure 11. **Hourglass twin.**

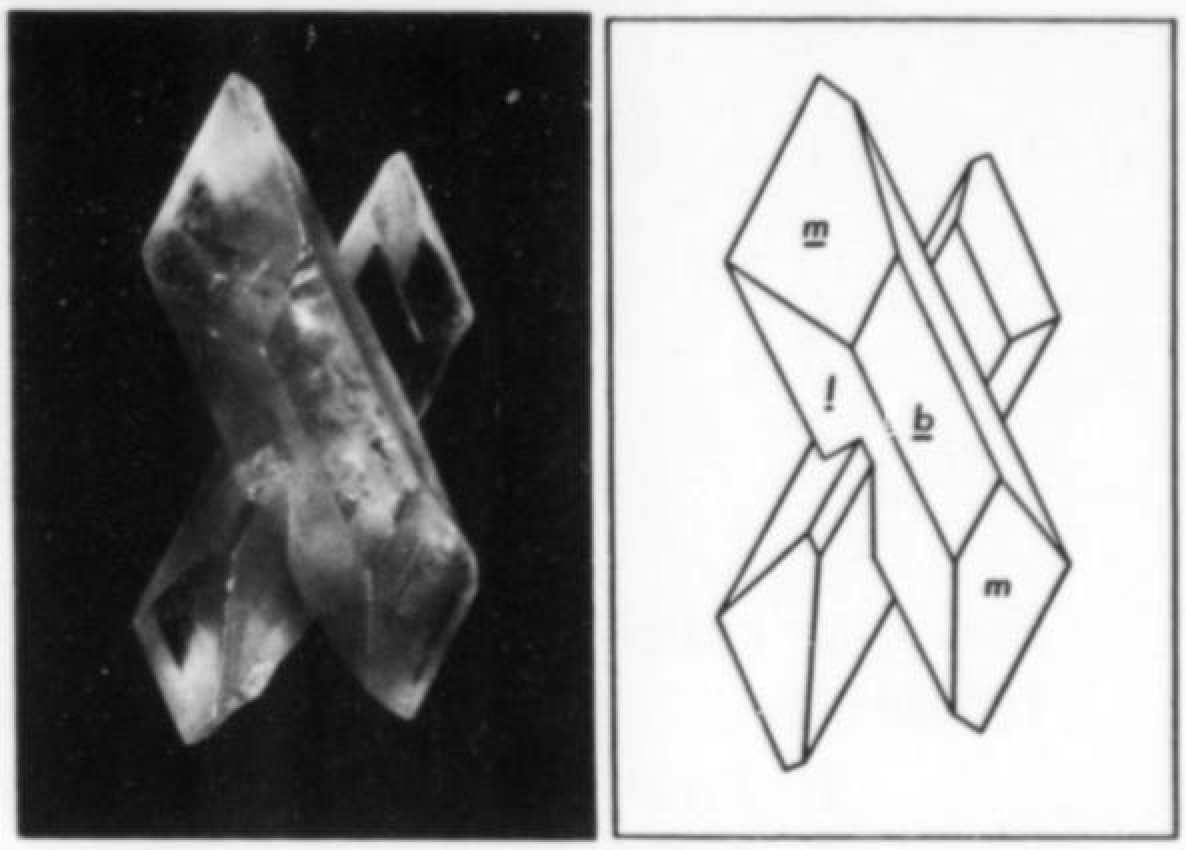

Figure 12. **Penetration twinning on b(010) according to the Montmartre law.**

(b) Penetration Twinning on b(010)

These crystals are twinned according to the rare Montmartre Law (Blount and Shulman, 1977). Only a few examples have been found in the Lake Gilles clays (Fig. 12) and these have always been found in association with single crystals.

NOTES

1. Crystal form notation is that used by Ford in Dana's *Textbook of Mineralogy* (1932).
2. Photographs of the crystals are oriented to show characteristic shapes to the best advantage, while the crystal drawings are presented in the correct crystallographic orientation, except for the Montmartre twin in Figure 12.

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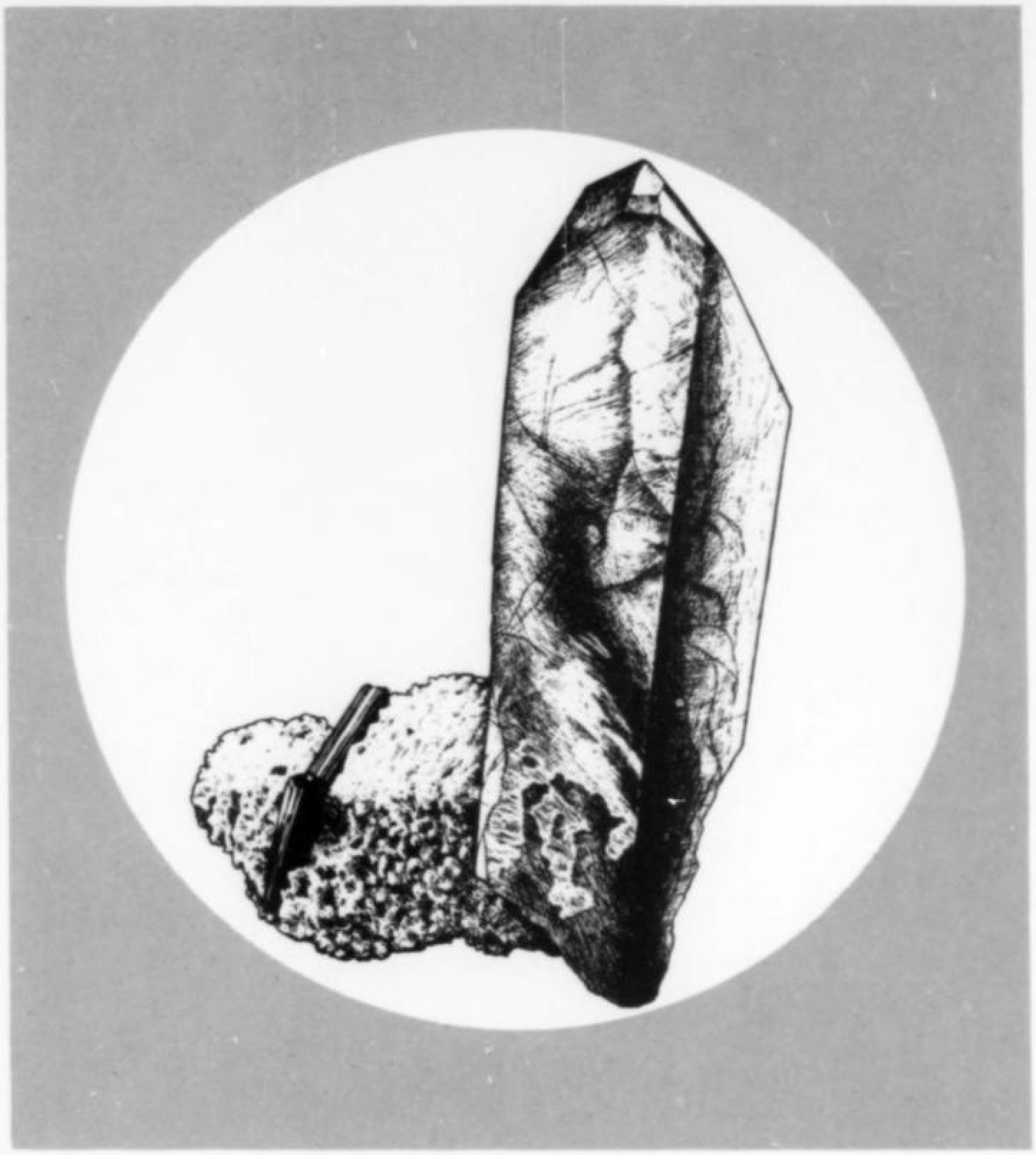

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