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Volume Thirteen, Number Two
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Articles

Amethyst from the Thunder Bay region, Ontario 67
by D. G. Elliott

An introduction to the mineralogy of Ontario's Grenville Province 71
by G. Robinson and S. Chamberlain

The fluorite mines of Madoc, Ontario 87
by F. Melanson and G. Robinson

A re-examination of the Madoc sulfosalts 93
by J. L. Jambor, J. H. G. LaFlamme and D. A. Walker

Bytownite – a legacy of early Ottawa, a Montreal medical doctor and a Royal Engineer 101
by H. R. Steacy and E. R. Rose

Departments

Microminerals by V. Anderson 107
Letters 127

COVER: AMETHYSTINE QUARTZ group 4 x 5 cm, collected in 1978 by Donald Elliott at the Diamond Willow mine near Thunder Bay, Ontario. Photo by Harold and Erica Van Pelt, Los Angeles.

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Amethyst
from the Thunder Bay Region, Ontario

by **Donald G. Elliott**
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Amethyst from the Thunder Bay region of Ontario has been collected, sold to tourists, and exported to Europe since the 1880's. The most recent amethyst boom began with the opening of the Thunder Bay amethyst mine in 1967, and in 1975 amethyst was declared by the legislature to be Ontario's official mineral.

INTRODUCTION

Amethyst has long been found in the Thunder Bay region in association with several silver, lead and zinc deposits. Those original metal mines have since been overshadowed by the present tourist and building stone industries which have grown up around the production of amethyst. The mineral finds use as collector specimens and jewelry because of its color, form and clarity, and as a decorative building stone because of its hardness and lack of cleavage. Today a large number of mines and rock shops in the area cater to tourists and also export thousands of tons of amethyst to the United States, England, Europe, Australia and Japan.

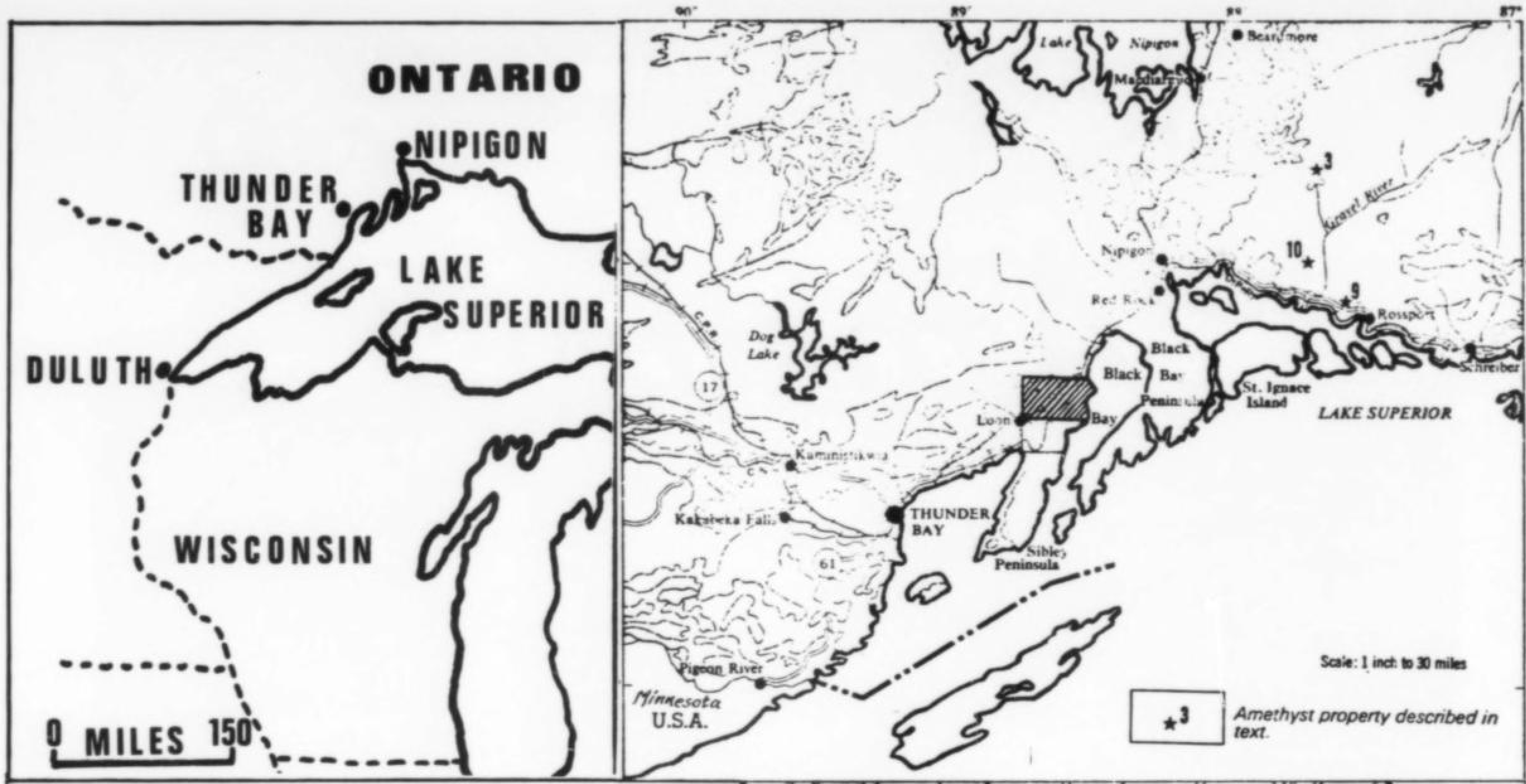
ACCESS

The majority of the amethyst mining activity is confined to a 40 x 196 km area, approximately 56 km northeast of the city of Thunder Bay (Vos, 1976). This area may be reached via Highway 11-17 going northeast out of Thunder Bay. From Highway 11-17, logging roads and mining roads provide access to the heavily forested areas. The map shown in Figure 1 locates some of the more important currently producing amethyst properties. Probably the best known occurrence is the Thunder Bay amethyst mine, at Elbow Lake, which has been in operation since 1967. Other important occurrences nearby include the Diamond Willow mine, operated by Gunnard Noyes and also by the author, the Ontario Gem mine, the Dorion amethyst mine, several properties worked by Nick Dzuba, and numerous smaller claims that are privately owned. Collecting is usually permitted at most of these localities on a fee basis, and very good specimens have been found at all the occurrences.

GEOLOGY

The oldest rocks in the area are early Precambrian amphibolite and migmatitic metasediments, which are intruded and underlain by the Algoman granitic rocks, which range in composition from quartz monzonite to trondhjemite. The Animikie and Sibley groups of sedimentary rocks overlay the granitic rocks, with the Osler group overlying the Sibley. The Osler group consists of amygdaloidal basalt flows interbedded with conglomerate, sandstone and shale approximately 0.9 to 1.2 billion years old. The amethyst deposits appear to be genetically related to this last Precambrian event of volcanism and faulting. The faulting runs in different directions at different localities, from east-west at the Thunder Bay mine, to north-south at the Diamond Willow mine. Lead and zinc-bearing quartz/carbonate veins occur in breccia zones along the contact between the Sibley group rocks and the granitic rocks. The amethyst deposits occur in or near the granitic rocks, and at the contact with the Sibley group. An early generation of veins of massive white quartz has been cut by later veins of amethystine quartz.

The amethyst and associated minerals were subsequently deposited in the openings along the fault planes due to leaching of the neighboring rock units. Franklin (1970) concludes that the sources of the metallic minerals were the Rove shales and the Sibley sedimentary rocks. Dennen and Puckett (1972) suggest that the conditions for the deposition of amethyst must be such that the solution is iron-rich, aluminum-poor, oxidizing, moderate in temperature and low in pressure. Holden (1925) concludes from heating and fluid inclusion experiments that the temperature of



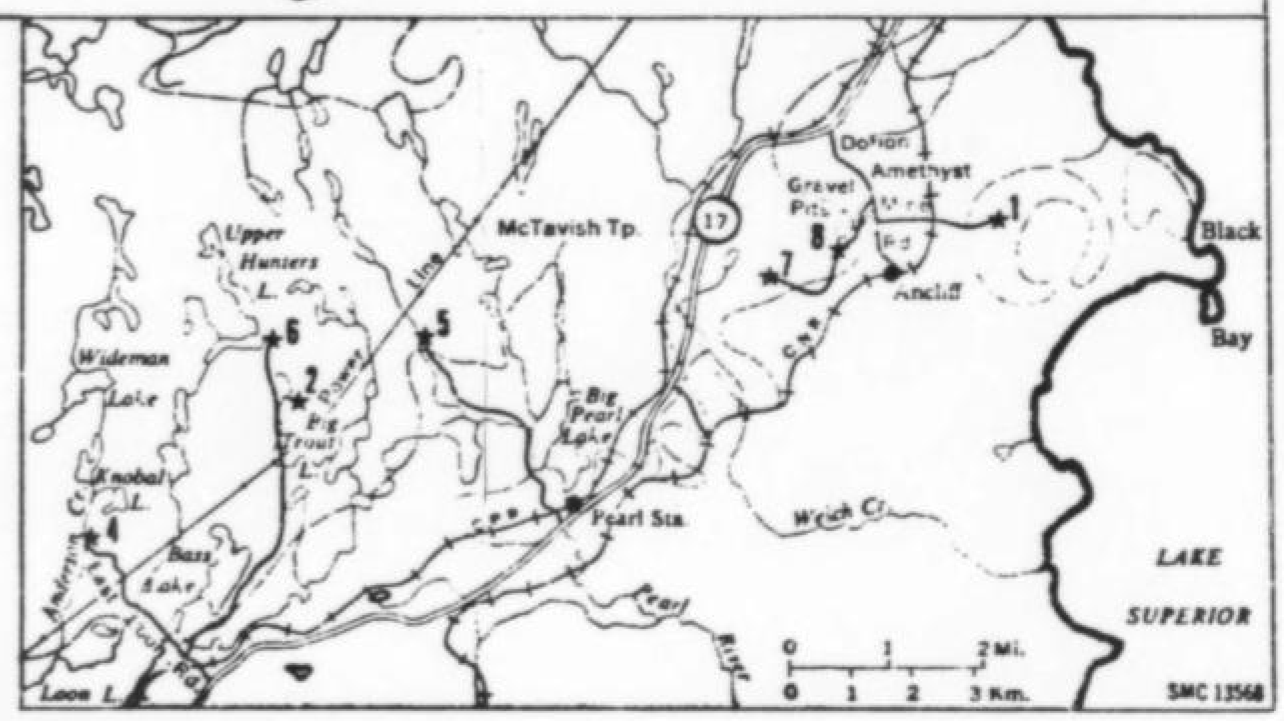
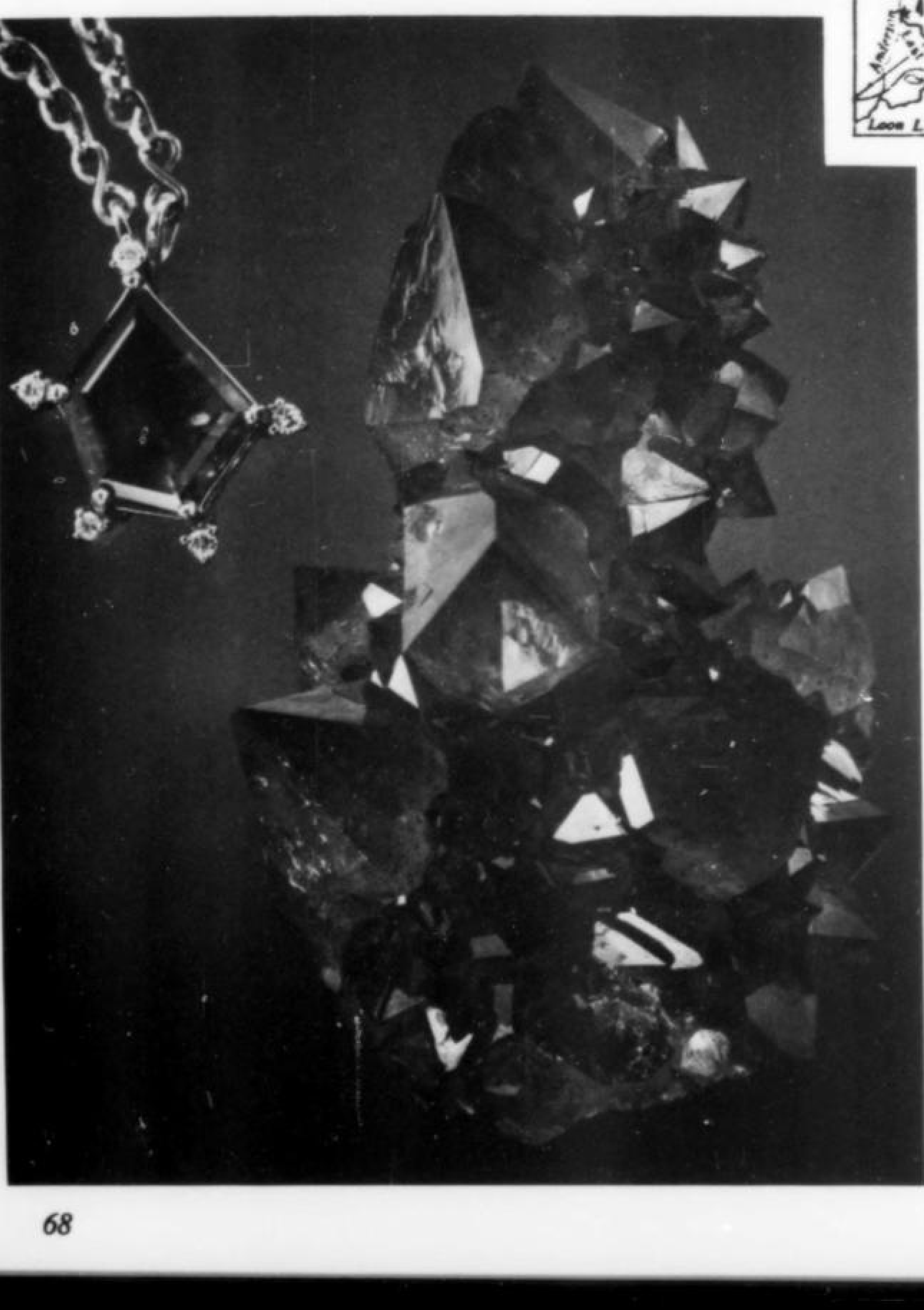


Figure 1. **Amethyst deposits in the Thunder Bay, Ontario, area. (1) Nick Dzuba claim (large amethyst cave), (2) Nick Dzuba claim, (3) Galarneau claim, (4) Johnson claim, (5) Diamond Willow mine (Noyes claim), (6) Thunder Bay Amethyst Mining Company, Ltd., (7) Williamson claim, (8) Nick Dzuba claim, (9) Halonen claim, and (10) Thorsteinson claims. (After Vos, 1976; some of these deposits may be under new claims by other people.)**



deposition for most amethyst is between 90° and 250°C, at relatively low pressure.

AMETHYST

Quartz in the Thunder Bay area occurs in all shades from white or colorless through palest reddish violet to dark purple. Crystals are commonly color-zoned parallel to the terminal rhombohedrons, in alternating layers of lighter and darker violet. Inclusions of iron oxide are very common. Heating causes the amethyst to turn colorless or pale brownish white, as opposed to Brazilian amethyst which turns bright yellow to yellow-orange upon heating. Analyses by Kustra (1969) indicate that white quartz from Thunder Bay contains 150 ppm iron, whereas amethyst from the same occurrence contains 500 ppm iron. This is in keeping with recent studies (e.g. Hassan, 1972) which indicate that iron (its structural position and valence state) accounts for the amethyst color.

Crystals commonly exhibit only the terminal rhombohedrons, typically with one set dominant. Small hexagonal prism faces can often be seen as well, but are always poorly developed.

The amethyst occurs in veins which range from 7 mm to 1.2 m in width, containing vugs up to 3 m in size. A very large vug, 1.8 x 3 x

Figure 2. **Amethyst from the Diamond Willow mine, collected by the author in 1978. The faceted stone is 7.71 carets. Specimen from the collection of Wayne and Dona Leicht; photo by Harold and Erica Van Pelt.**

Figure 3. An amethyst specimen 40 cm across, with red hematite inclusions, from the Diamond Willow mine. Photo by the author.

Figure 4. An amethyst specimen 60 cm across, with minor inclusions of hematite, from the Diamond Willow mine. Photo by the author.

Figure 5. An amethyst pocket 2 meters tall, *in situ* at the Diamond Willow mine. Photo by the author.

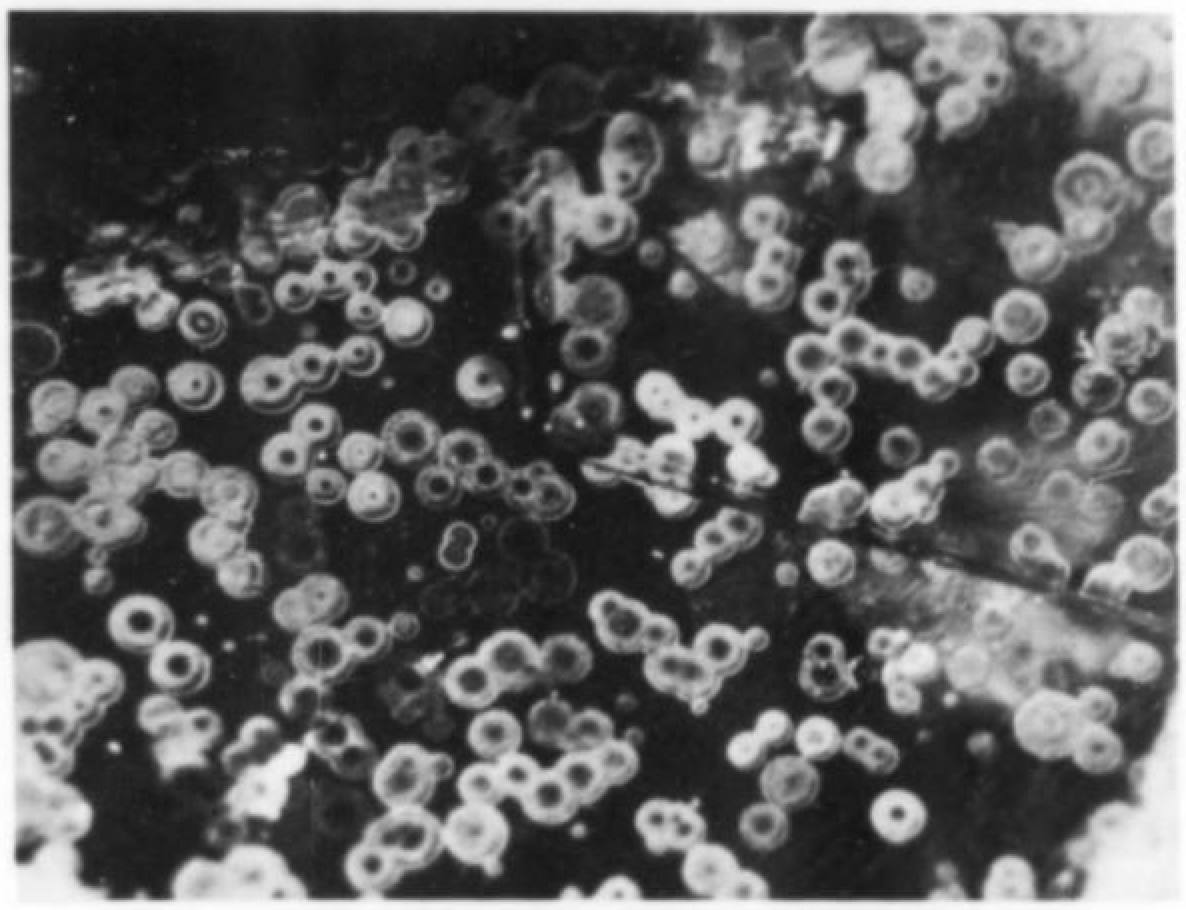


Figure 6. Red hematite (?) inclusions in amethyst from the Diamond Willow mine. The spherules are about 0.1 mm each. Photo by the author.

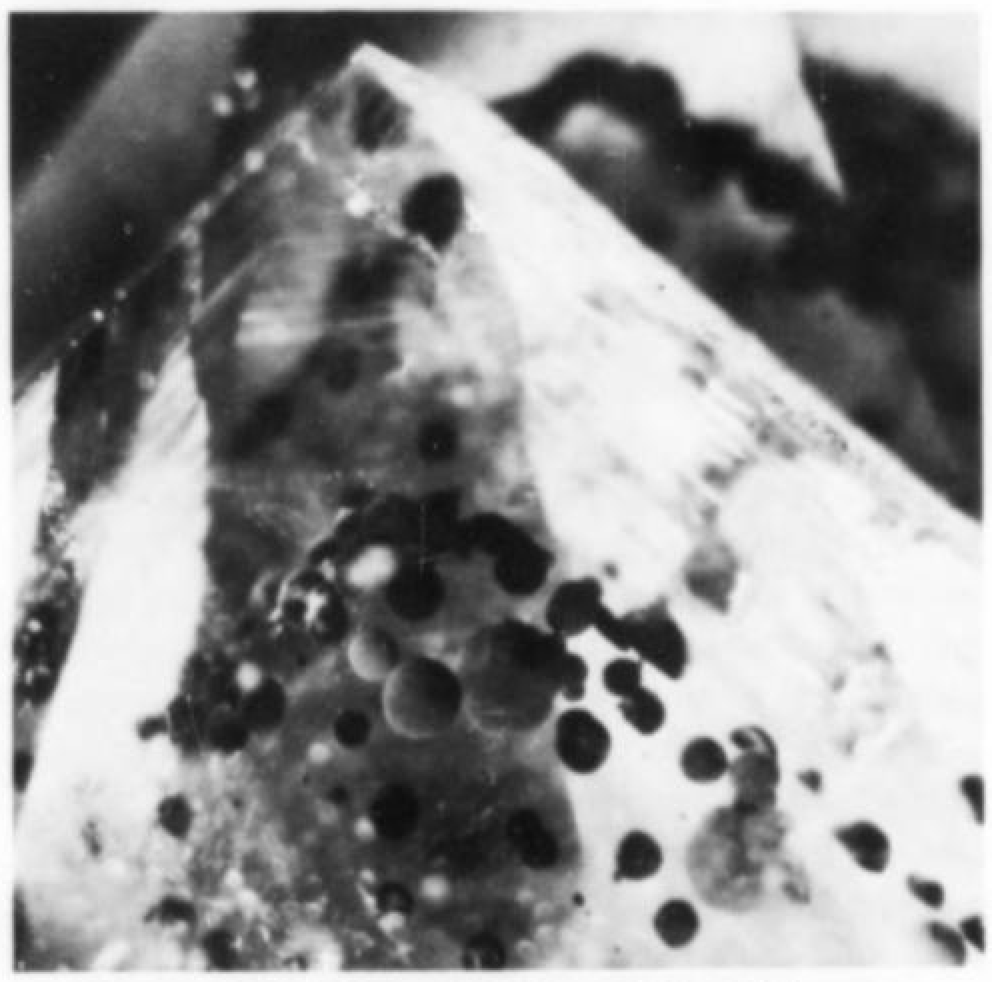


Figure 7. Red hematite (?) and blackish green chlorite (?) inclusions in amethyst from the Diamond Willow mine. The spherules are about 0.1 mm each. Photo by the author.

Figure 8. **Clearing underbrush and drilling blast holes at the Diamond Willow mine. Photo by the author.**

5 m, was encountered at the Thunder Bay mine in 1969, and produced a 38-cm crystal. One of the properties operated by Nick Dzuba consists of an excavation in a single vug, the largest ever in the area, measuring at least 2.4 by 3 by 15 m. The region's largest crystal (61 cm) was found at this property. Although very little amethyst from the region is of gem grade, Robinson (1969) reports that many of the large crystals from the Dzuba mine have deeply colored cores with areas of faceting-quality amethyst. Large slabs of crystals are not uncommon in the mines of the region. Slabs in the 150 to 250-kg range have been removed intact on a semi-regular basis, but the largest is probably a 1588 kg slab removed from the Thunder Bay mine in 1967 for exhibit at Expo 67 in Montreal.

OTHER MINERALS

Inclusions of red iron oxide (presumably hematite) within the amethyst and white quartz are very typical of the region. The inclusions occur in zones parallel to the terminal rhombohedrons, typically in preferential deposition on the faces of one side of each crystal in the pocket. Where sufficiently thick the iron oxide zones are opaque, and some excellent examples of ferruginous quartz are found in some of the amethyst veins. Pale citrine and smoky quartz occur locally (Robinson, personal communication, 1980).

Other species which formed concurrently with the amethyst include pyrite, goethite, sphalerite, galena, chalcopyrite, chlorite (?) and rutile (?). Minerals forming later than the amethyst include pyrite, hematite, goethite, marcasite, barite, fluorite and calcite in uniformly unexciting specimens. Of notable exception, however, is a specimen of pyrite-coated fluorite crystals on amethyst in the collection of the Royal Ontario Museum in Toronto.

AVAILABLE LITERATURE

Amethyst Deposits of Ontario by M. A. Vos (Geological Guidebook No. 5, price $2.00) may be obtained from the Public Service Center, Map Unit, Ministry of Natural Resources, Whitney Block, Queen's Park, Toronto, Ontario M7A 1W3 Canada. This is probably the most complete account of the amethyst localities in the Thunder Bay district, and is indispensable for those planning to visit the area. Also available is a free color brochure, *Purple Gemstone of the North: Amethyst,* and a free booklet, *Rocks and Minerals Information 1979.*

ACKNOWLEDGMENT

My thanks to George Robinson and Wendell Wilson for critiquing and revising the original manuscript of this article.

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An Introduction to the Mineralogy of Ontario's

Grenville Province

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The Grenville province of Ontario has been a source of fine mineral specimens for many years. The emphasis in this article is on the classic occurrences and some of the more prolific newer localities.

INTRODUCTION

The term "Grenville" was probably first used by W. E. Logan (founder of the Geological Survey of Canada, and for whom the mineral weloganite was named) in 1863, to describe a metasedimentary sequence of marble, quartzite, and paragneiss near the village of Grenville, Quebec. As shown in Figure 1, the Grenville province is actually a subdivision of the vast Canadian Shield, and is composed largely of metamorphic and igneous rocks that range from 0.9 to 1.2 billion years old (Krough and Hurley, 1965; and Silver and Lumbers, 1965). Although the province extends over 1700 km from northern Quebec into New York State, this article is concerned only with that portion which lies within Ontario.

It should be noted from the outset that this article serves only as an introduction to and not as a complete account of Grenville mineralogy. It would be virtually impossible to describe every species found or locality known in the Grenville in an article of this nature, and numerous omissions have necessarily been made.

GENERAL GEOLOGY

The bulk of Ontario's Grenville province is composed of granitic gneisses, biotite and hornblende paragneisses, marbles and metavolcanic rocks which are locally intruded by anorthosite-mangerite plutons, gabbros, pegmatites, diabase dikes, diorites, granites and syenitic rocks (Stockwell *et al.*, 1970). Metamorphic "pyroxenites" (nearly all the rocks in the Grenville referred to as "pyroxenites" are probably highly metamorphosed siliceous dolomites, and not true pyroxenites) and nephelinized gneisses are also present. Such intrusions and their accompanying metasomatic and hydrothermal processes, along with complex folding and faulting, make Grenville stratigraphy extremely complicated. To make matters worse, geologic interpretation is further hindered by the presence of copious glacial overburden. Those readers desiring a detailed description of Grenville geology may refer to an excellent summary presented by R. F. Emslie in *The Geology of the Canadian Shield*, Chapter 4, (Stockwell *et al.*, 1970).

Figure 1. **Canada's Grenville province (after Van Diver, 1976).**

Such a wide range of geologic environments is bound to host an equally wide variety of mineral assemblages of both scientific and economic value. Although interesting specimens can be found in nearly all the rock types, for convenience the localities to be discussed will be grouped into four general categories: **(1)** those occurring in marble contacts and calcite vein-dikes, **(2)** those occurring in fracture zones, where mineralizing solutions have filled in open spaces in the rock, **(3)** pegmatites, and **(4)** the nepheline-corundum belt.

MINERALOGY

The Marble Contacts

Contact metamorphic zones between the Grenville marble and adjacent rocks (notably syenites, gneisses, pegmatites, and calc-silicate rocks) in addition to the famous calcite "vein-dikes" of uncertain origin (Ellsworth, 1932; and Moyd, 1972) have furnished a wealth of mineral specimens which can be viewed in many major museums and private collections.

Although the origin of the vein-dikes may depart somewhat from the processes of contact metamorphism exclusively, both environments host such similar mineral assemblages that it would be redundant to discuss them separately here. In both these environments coarse-grained igneous or metamorphic rocks are in contact with coarsely crystalline calcite (commonly with fluorite), resulting in skarn-like mineral assemblages. Large, well-formed crystals of microcline, plagioclase, clinopyroxenes, amphiboles, micas, apatite, scapolite and accessory minerals (titanite, zircon, magnetite, ilmenite, quartz, pyrite, idocrase, epidote, uraninite, allanite and others) typically protrude into or become completely enclosed by calcite. In some cases the calcite has naturally weathered away, freeing the crystals, which may be found loose in dirt-filled pockets. Similarly, good specimens may often be obtained at home by leaching away the enclosing calcite with dilute hydrochloric acid.

The majority of the mineral occurrences in the Grenville fall under this category, and the following lists present some of the more important species that have been found:

Alkali Feldspars

Undoubtedly the most common alkali feldspar found throughout the vein-dike systems in the Bancroft and Tory Hill areas is microcline. Nearly all show perthitic intergrowth, and in at least one instance (at Davis Hill, near Bancroft) crystals of antiperthite are known to occur. (The name perthite itself is for the type locality near Perth, Lanark County, Ontario.) Huge crystals of microcline up to half a meter long have been found in the vicinity of Tory Hill and at the Gibson Road occurrence nearby. At both these localities the crystals are intimately associated with equally large crystals of biotite, amphibole (usually near richterite in composition), apatite, pyroxene (usually diopside-salite or augite), and more rarely titanite. Smaller but finer crystals abound at the locally famous Highway 62 roadcut just north of Bancroft, and in numerous other collecting sites in the immediate area (Fig. 2).

Allanite

Large, well-formed crystals of allanite occur in a small vein-dike near Long Lake in Olden Township, Frontenac County. Tabular pseudo-orthorhombic euhedra up to 10 cm on an edge have been found (Fig. 3). Particularly fine, large groups of crystals may be seen in the collections of the Royal Ontario Museum and Harvard University.

Similar crystals of allanite have also been found associated with titanite on the Cardiff mine property near Wilberforce.

Amphibole group

Perhaps one of the most common yet diverse groups to be found in the calcite vein-dikes is the amphibole group. Although most of the amphiboles found in the Grenville have commonly been termed "hornblende" if black, or "actinolite" if green, it should be realized that it is virtually impossible to identify such a chemically complex species accurately by simple inspection (Robinson, 1981). More likely than not, any given sample will not be at an end member composition, but rather within a particular field, the boundaries of which are determined by the extent of solid solution permissible in the crystal structure (Leake, 1978). Microprobe analyses done by

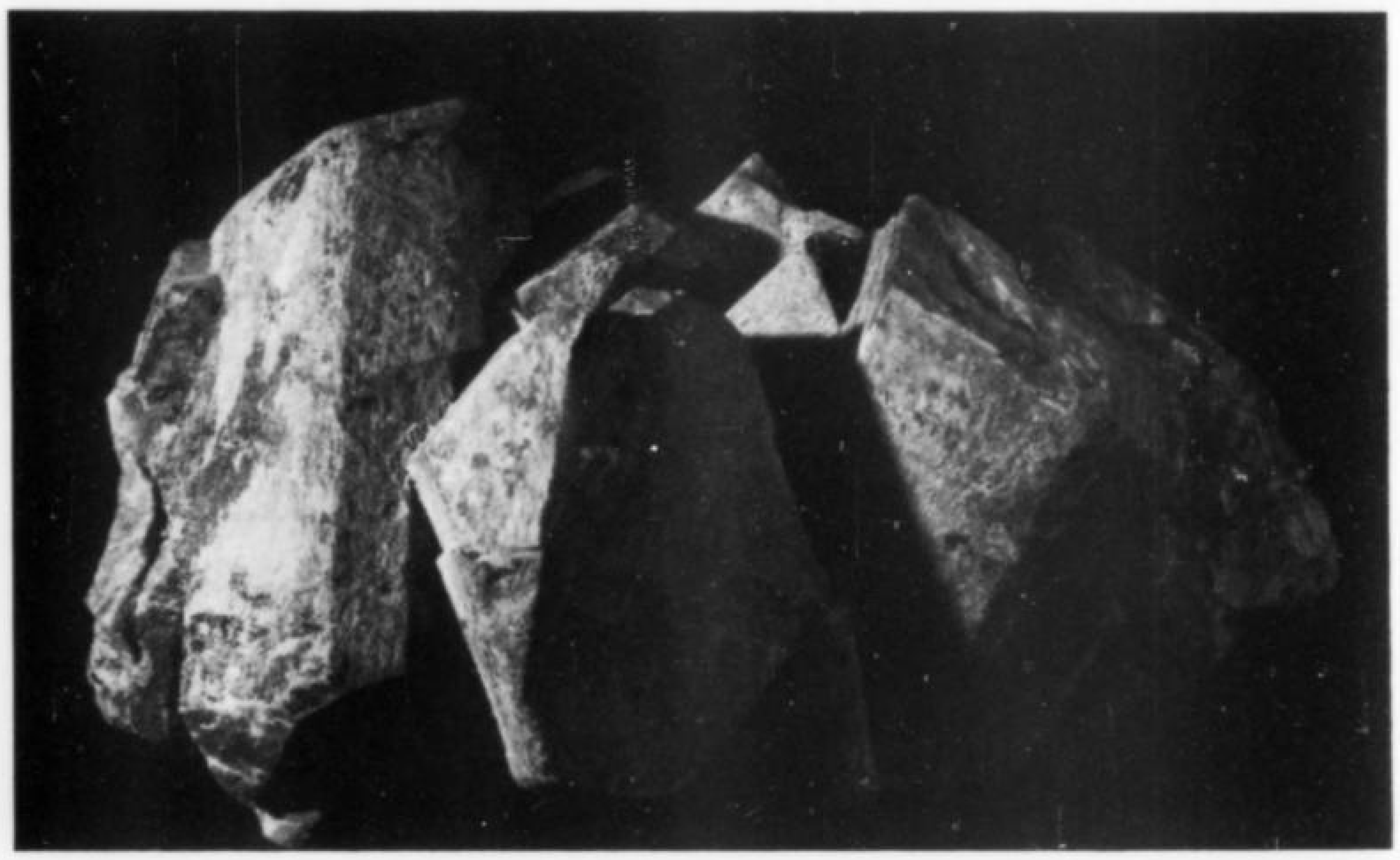


Figure 2. **Microcline, a 4 x 6 x 9-cm group of flesh-colored crystals from the Taylor farm, Hybla, Ontario. National Museums of Canada specimen.**

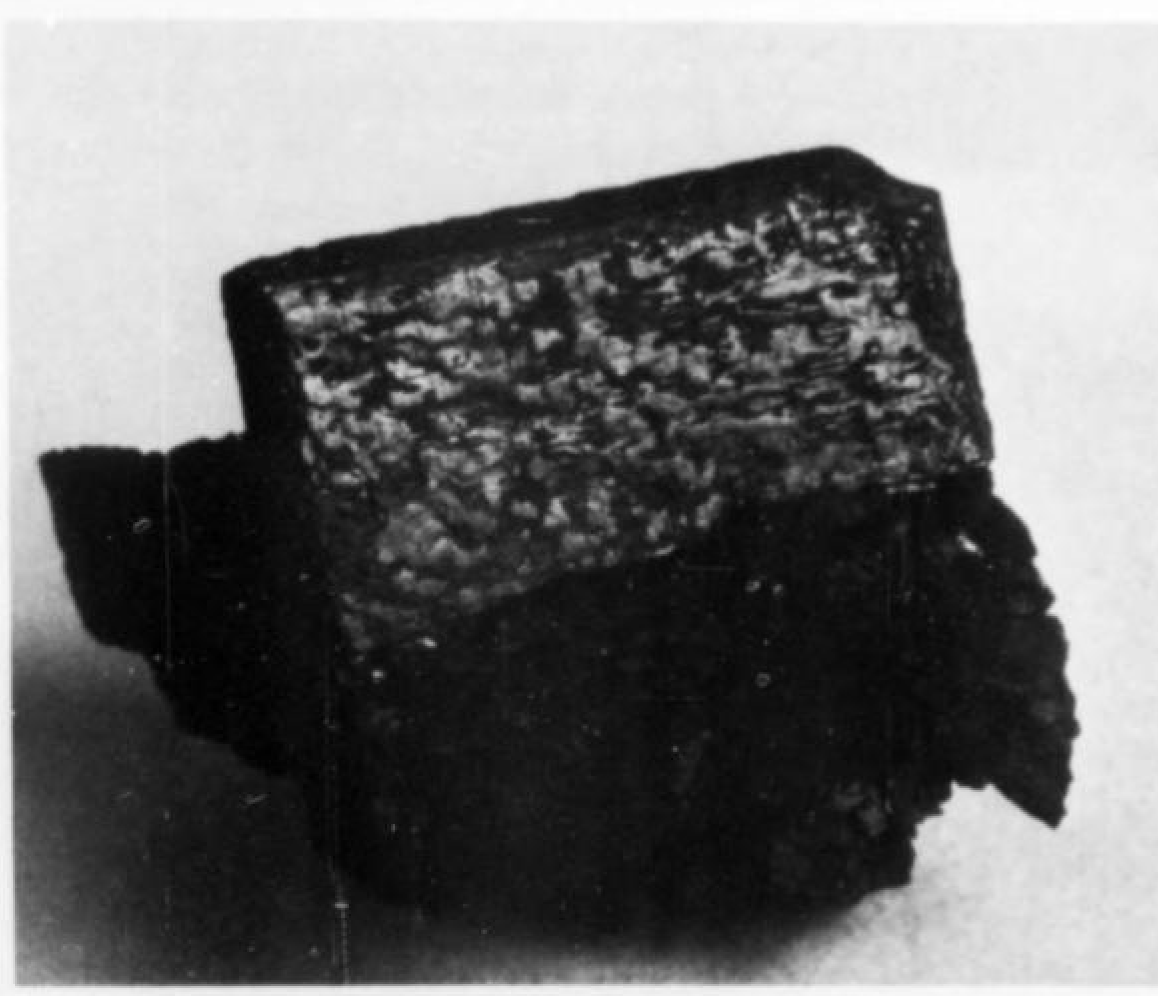


Figure 3. **Allanite, a sharp, slightly curved black crystal (1.6 x 2 cm) from Olden Township, Frontenac County, Ontario. George and Susan Robinson specimen.**

Table 1. **Energy Dispersive Microprobe Analyses for Selected Minerals**

	1	2	3	4	5	6	7	8	9
SiO_2	35.98	54.21	55.53	–	36.43	42.80	37.26	52.04	53.72
TiO_2	0.64	0.29	–	–	0.53	0.97	0.14	–	0.27
Al_2O_3	5.76	3.05	1.42	64.99	27.13	14.44	20.71	1.10	3.32
Fe_2O_3	22.34	–	0.72	–	–	–	16.85	–	–
FeO	–	5.28	1.67	17.07	5.60	4.01	–	15.75	4.71
MgO	0.22	20.21	23.00	17.29	10.90	17.36	–	8.20	21.13
CaO	33.35	8.72	10.90	–	2.19	12.92	23.08	21.35	9.30
MnO	–	0.30	0.18	–	–	0.09	0.13	0.55	0.51
Na_2O	–	4.73	3.09	–	1.87	2.56	–	1.75	4.90
K_2O	–	1.46	1.11	–	–	1.08	–	–	1.61
Total	98.29	98.25	97.62	99.35	84.65	96.23	98.17	100.74	99.47

Note: Total Fe is reported as either FeO or Fe_2O_3, unless otherwise noted below.

Analysis 1: Andradite – Marmoraton Mines, Marmora, Ontario.
Analysis 2: Richterite – Tory Hill, Ontario.
Analysis 3: Silicic Edenite – Wilberforce, Ontario. Fe^{+2}/Fe^{+3} determined wet chemically by method of Shapiro and Brannock (1962); also contains 1.10 percent F (determined electrochemically) and 1.75 percent H_2O (by ignition loss), with $O \equiv F = 0.46$, giving total 100.01 percent.
Analysis 4: Spinel – Bathurst Township, Ontario.
Analysis 5: Dravite – Tait farm, Lamable, Ontario.
Analysis 6: Pargasite – Wolfe Lake, Bedford Township, Ontario.
Analysis 7: Epidote – near Steenburg Lake, Ontario.
Analysis 8: Ferro-augite – near Steenburg Lake, Ontario.
Analysis 9: Edenite – Wilberforce, Ontario.

contains 1.10 percent F (determined electrochemically) and 1.75 percent H_2O (by ignition loss), with $O \equiv F = 0.46$, giving total

the author on a number of so called "hornblendes" and "actinolites" from the Bancroft area have shown many of these to range in composition from silicic edenite to tremolite.

Notable occurrences abound in the vicinity of Tory Hill and Wilberforce. Crystals from these localities are shown in Figures 4 and 5. The commonest forms at these occurrences are {110}, {010}, {100}, and {011}, with frequent shortening along **c** [001]; {130} faces are less frequently observed. Microprobe analyses of crystals from some of these localities are given in Table 1.

Fluorine is frequently present in many of the Grenville amphiboles, and fluor-richterite has been identified from the Earle farm near Wilberforce (Mandarino, personal communication, 1978). The doubly terminated crystals, which are typically prismatic and somewhat flattened along [100], occur profusely scattered through calcite with phlogopite (Fig. 6). Many of the crystals are twinned on (100). It is interesting to note that similar crystals found only 100 meters north of the fluor-richterite locality are edenite. A specimen is shown in Figure 7.

Very fine crystals of tremolite-actinolite occur at the Keller farm near Hardwood Lake, at Norland, Irondale, Miner's Bay, and at the Tait farm near Lamable (Fig. 8 and 9). Chromian tremolite has been noted at Dark Lake, near Wilberforce, and near Kaladar, but the occurrences are small, and very few good specimens have been found.

Lustrous black crystals of pargasite have been found with diopside, phlogopite and apatite at the McLaren (?) mine near Wolfe Lake, Bedford Township. An analysis is given in Table 1.

Anhydrite

Large purple-gray cleavages of anhydrite occur with gypsum at the Madawaska mines near Bancroft. Similar material is reported to have been found at the McLaren mine west of Otty Lake, near Perth, and at Craigmont (Moyd, 1979).

Apatite

As shown by Dunn (1977), the majority of the classic Canadian apatite specimens are probably fluorapatite. To list all the occurrences from which fine crystals have been recovered would be impossible. However, the prolific localities certainly include Turner's Island in Lake Clear, and the nearby Meany and Smart mines, all near Eganville, Renfrew County. Sabina (1965) reports a 320-kg crystal from Turner's Island. At the Liscombe mine near Wilberforce, gem-quality crystals have recently been mined and marketed under the trade name "trilliumite." The Silver Crater mine near Bancroft, the Smith-Lacey mine near Sydenham, the Taggart mine near Crow Lake, the Gibson Road occurrence near Tory Hill and the Richardson property near Wilberforce have all produced significant numbers of excellent specimens. Dark blue crystals resembling those from Lake Baikal in the Soviet Union have also been found near Canoe Lake, Bedford Township (Fig. 10). For a more complete account of the apatite occurrences in the Grenville, the reader is referred to Spence (1920).

Chalky white crystals of chlorapatite rivaling those from Snarum, Norway, have been reported from Bob's Lake, Oso Township (Hounslow and Chao, 1970).

Axinite

Crystals of this mineral have been found at the Pinchin (Bonter) quarry near Malone. Although the crystals are well-formed and of fair size, they are not common at the locality.

Betafite

Perhaps some of the finest specimens of betafite known have been found at the Silver Crater mine near Bancroft, where cuboctahedral crystals in excess of 5 cm occur in calcite with apatite, biotite, amphibole and zircon (Fig. 11). (Although there is some evidence to suggest that this deposit may in fact be a small carbonatite body, it has been listed here along with the marble contacts because of its overall geologic and mineralogic similarities to this group.)

Chondrodite

Chondrodite and other members of the humite group frequently occur as small grains at many localities in the Grenville marble. In

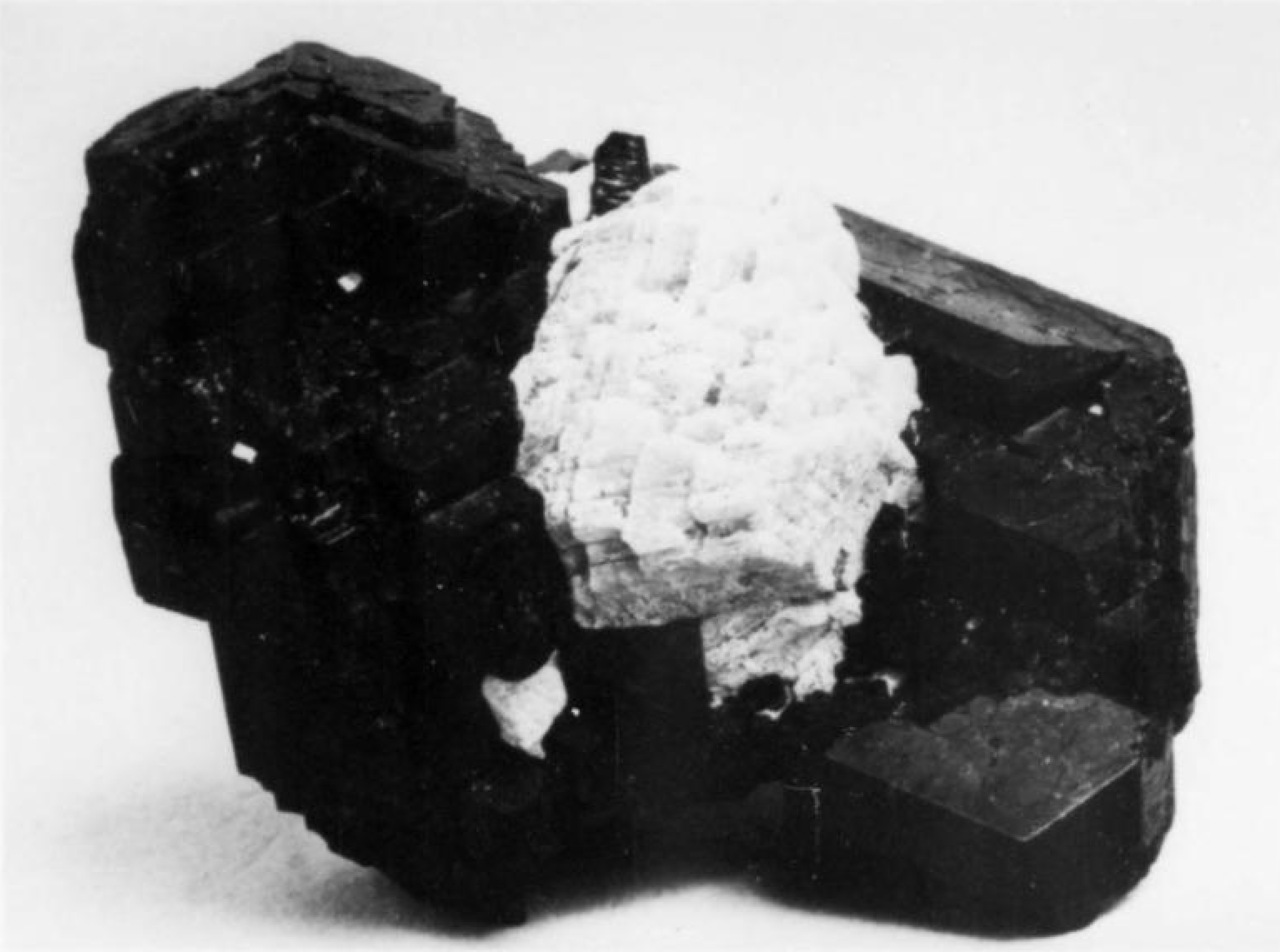


Figure 4. **Richterite, a lustrous, black 5 x 8-cm crystal with calcite from Tory Hill, Ontario. George and Susan Robinson specimen.**

Figure 5. **Silicic edenite, a 5 x 7-cm group of dark green crystals from Wilberforce, Ontario. George and Susan Robinson specimen.**

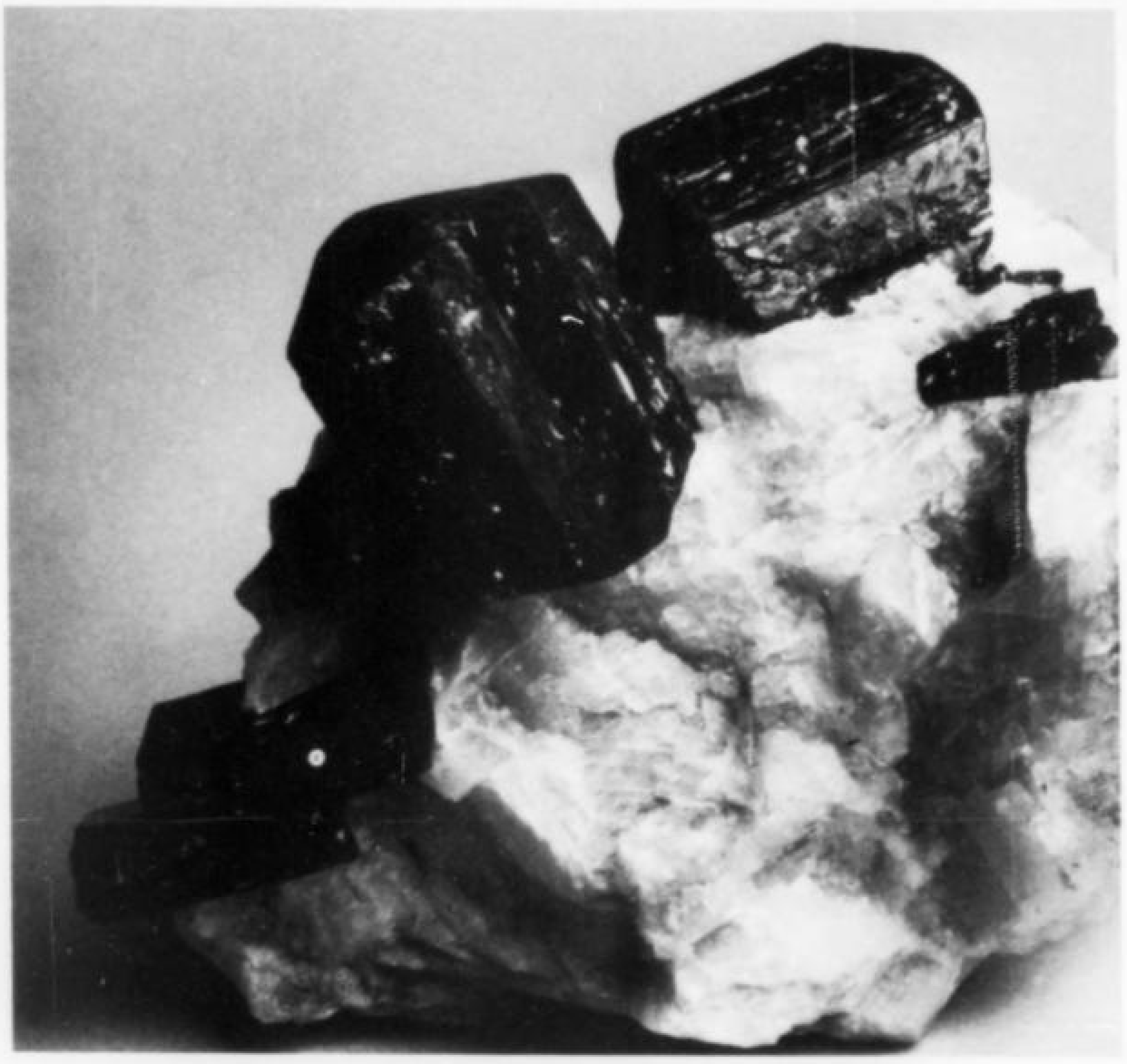


Figure 6. **Fluor-richterite, dark gray-brown crystals in calcite (8 x 11 cm) from the Earle property, Wilberforce, Ontario. George and Susan Robinson specimen.**

some places, such as in the railroad cuts near Harcourt, at Chaffey's Locks, and in various roadcuts in the Godfrey-Westport area, chondrodite may locally constitute more than 25 percent of the rock. Yellow-orange crystals up to 2 cm have been found associated with small pink spinel octahedrons in the marble at the Cameron quarry near Carleton Place. Clinohumite occurs at the skarn zone on the York River east of Bancroft (Sabina, 1977).

Datolite

Large crystals of datolite were reported to have occurred at the Smith-Lacey mine near Sydenham (Pirsson, L. V., *American Journal of Science,* XLV, 100–102). Small crystals also occur at the Taggart mine near Bob's Lake, and at the Madawaska mine near Bancroft.

Epidote

Good crystals of epidote occur at the Pinchin (Bonter) marble quarry near the village of Malone, at the Marmoraton iron mines near Marmora, and in the vicinity of Steenburg Lake, south of Coe Hill (Fig. 12). A microprobe analysis of a crystal from Steenburg Lake is given in Table 1.

Fluoborite

Sabina (1977) reports the occurrence of fluoborite in various roadcuts near Kinmount, Minden and Wilberforce, and at the Cardiff mine southeast of Wilberforce. At each occurrence fluoborite is typically present as small crystals and grains (somewhat resembling apatite) in marble, typically associated with humite group minerals.

Garnet Group

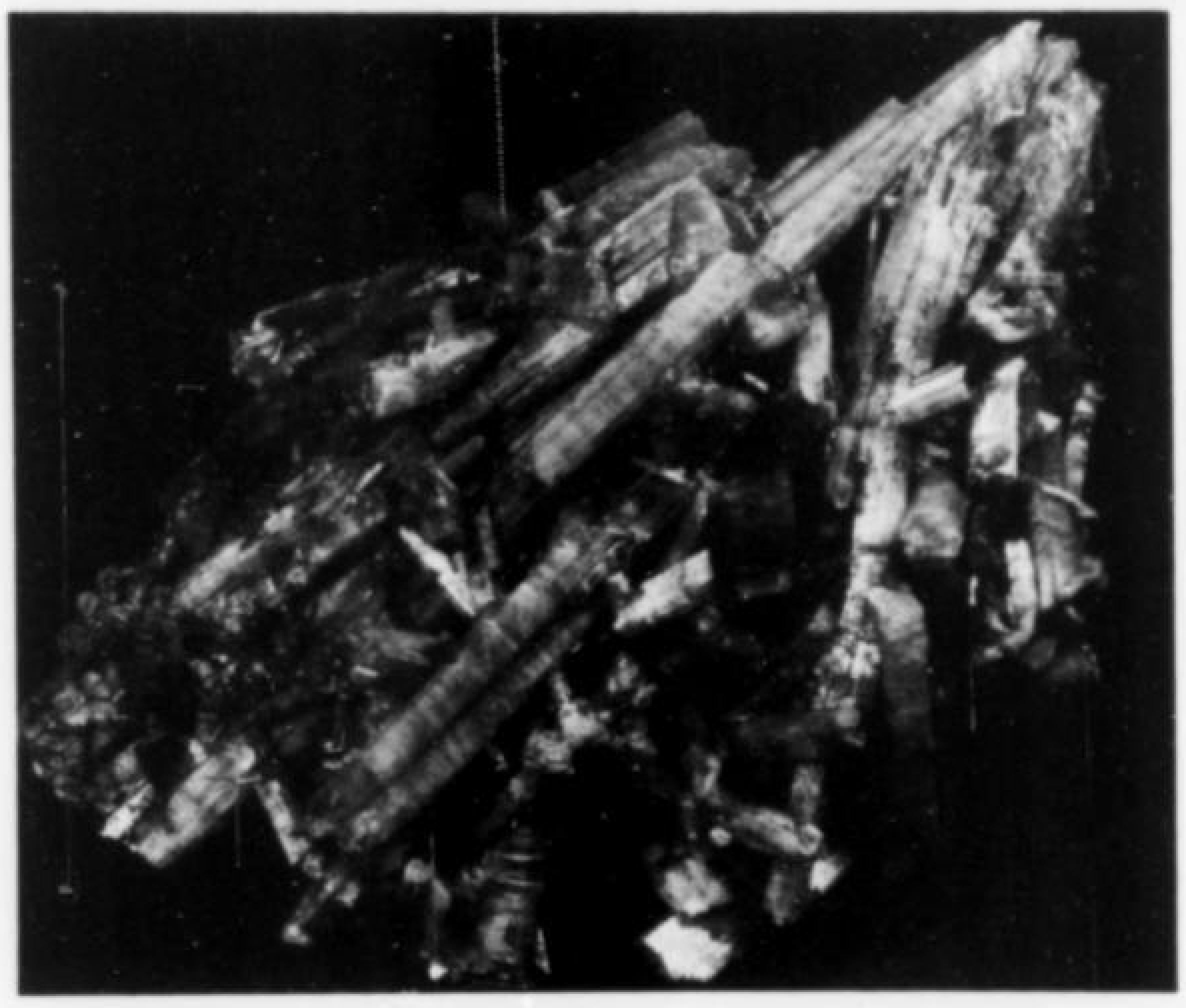
Perhaps the most important garnet found in the skarns and marble contacts of the Grenville is grossular-andradite. The large magnetite skarn at the Marmoraton iron mines near Marmora has produced literally tons of specimens. Microprobe analyses by the author (see Table 1) have shown that the majority of the large, dark brown dodecahedrons from this mine are approximately 70 percent andradite, 30 percent grossular. The lighter colored, red-brown trapezohedral crystals, however, average 60 percent grossular and 40 percent andradite.

Small cinnamon-colored crystals of grossular ("hessonite") have also been found near Bancroft. The locality is known locally as "the skarn (tactite) zone," and is situated on the east bank of the York River, just north of where it crosses Highway 500, about 15 km east of Bancroft. Crystals up to 5 cm occur in calcite with diopside, vesuvianite, spinel, olivine and brugnatellite (Sabina, 1977). Similar crystals of slightly darker color have recently been discovered in a roadcut west of Coe Hill.

Figure 7. **Edenite, a 4 x 6-cm, black, doubly terminated crystal from the Earle property, Wilberforce, Ontario. George and Susan Robinson specimen.**

Figure 8. **Tremolite, 2 x 4-cm green crystals on matrix from the Keller farm near Hardwood Lake, Ontario. National Museums of Canada specimen No. 75/82/1.**

Figure 9. **Tremolite, a 7 x 9 x 14-cm cluster of prismatic, white crystals from Irondale, Snowdon Township, Ontario. National Museums of Canada specimen No. 75/98/14.**



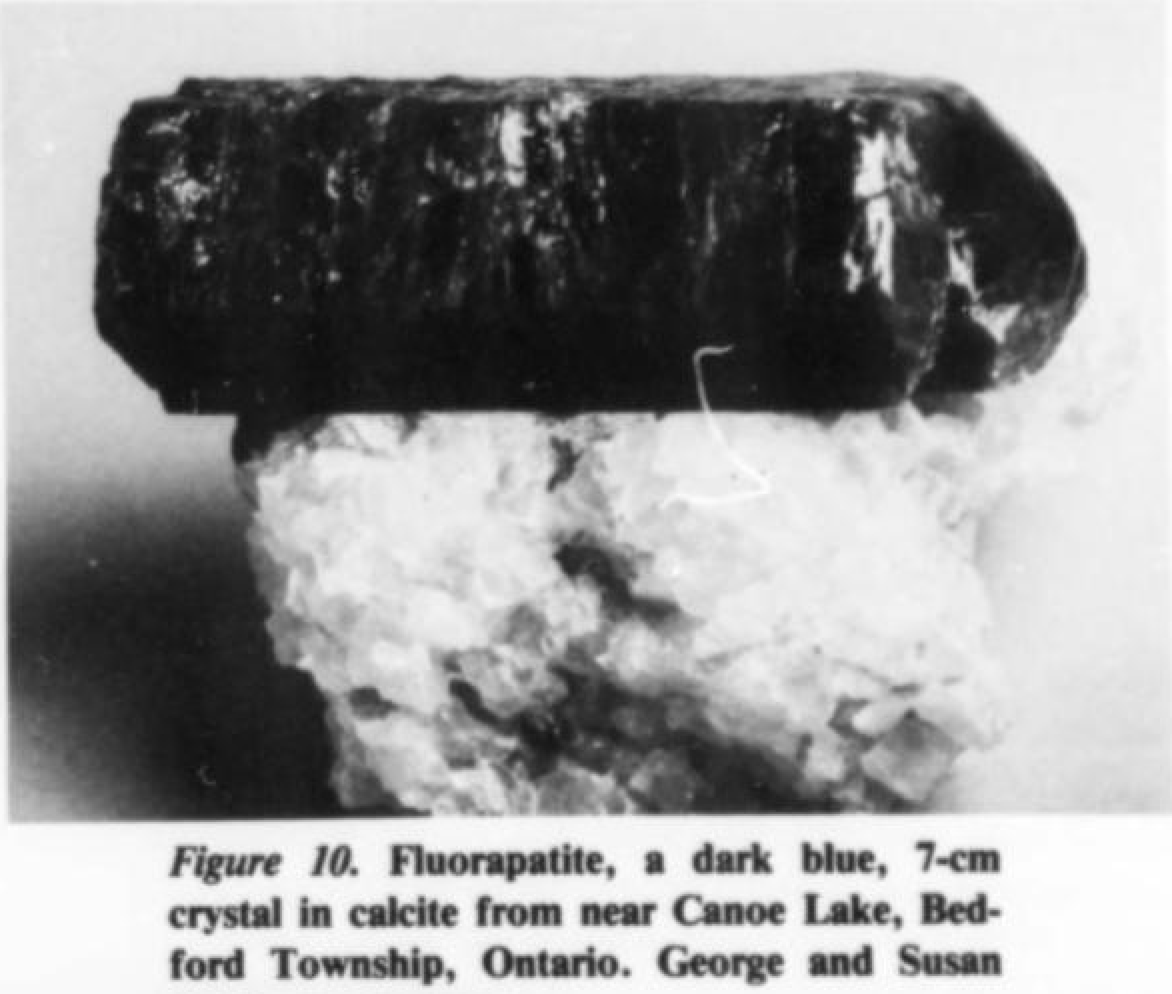


Figure 10. **Fluorapatite, a dark blue, 7-cm crystal in calcite from near Canoe Lake, Bedford Township, Ontario. George and Susan Robinson specimen.**

Figure 11. **A 2.5-cm cuboctahedron of dark brown betafite with a double terminated, 3-cm crystal of tan-colored zircon from the Silver Crater mine, Bancroft, Ontario. National Museums of Canada specimen No. 74/2/8.**

Graphite

Graphite is a widespread accessory mineral in the Grenville marble, and occasionally reaches concentrations of economic importance. It has been mined at various occurrences near Bancroft, Wilberforce and Calabogie. Although most graphite tends to be unphotogenic, there is one particular specimen in the collection of the Royal Ontario Museum that is quite spectacular and deserves mention here. This piece comes from the Virginia mine, Monmouth Township, Haliburton County (Satterly, 1977), and is shown in Figure 13. The unusual habit as free-standing, crystallized rosettes attractively scattered on a matrix of white crystallized calcite makes this a truly outstanding specimen – perhaps one of the world's finest for the species.

Ilmenite

Fine crystals of ilmenite weighing more than 30 kg have been found associated with magnetite, biotite, microcline and apatite in a small calcite vein-dike on the Madawaska mines property near Bancroft. The crystals are generally simple, the common forms being positive and negative rhombohedrons, with large basal pinacoids (Fig. 14), and are somewhat reminiscent of the large crystals from Kragero, Norway. Some of the crystals are replaced by anatase, which exists as microscopic, unusually tabular crystals shortened on [001] and showing only one set of tetragonal prisms terminated by large basal pinacoids (Breen, pers. comm., 1977).

Magnetite

Large, sharp, octahedral crystals of magnetite have been found in at least two localities near Bancroft. Both occurrences have pro-

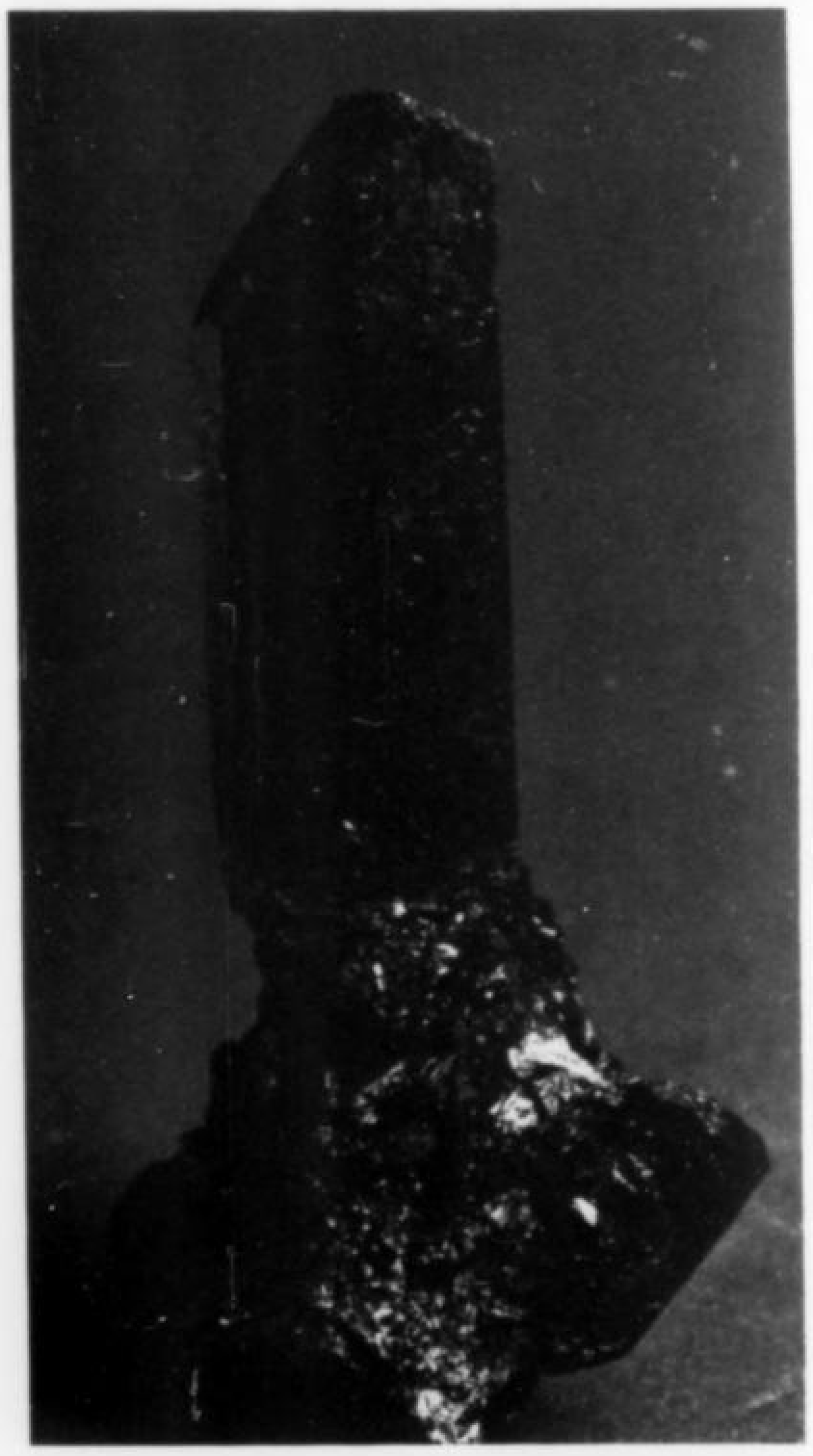


Figure 12. **Epidote, a 4-cm dark green crystal on matrix from Steenburg Lake, Ontario. George and Susan Robinson specimen.**

Figure 13. **Graphite rosettes to 1 cm with pyrite on a 9 x 10-cm matrix from the Virginia mine, Monmouth Township, Haliburton County. Royal Ontario Museum specimen (M9883) and photo.**

Figure 14. **Ilmenite, a 4 x 6-cm group of sharp, black crystals from the Faraday (Madawaska) mine property, Bancroft, Ontario. National Museums of Canada specimen No. 34221.**

duced crystals in excess of 10 cm on an edge. The first of these localities is the Princess sodalite mine where, in the 1960's, quarrying exposed a small calcite vein-dike in contact with nepheline syenite. Numerous specimens of magnetite, apatite, lepidomelane and nepheline were recovered. The second occurrence is at the ilmenite locality on the Madawaska mines property, where hundreds of fine crystals have been removed (Fig. 15).

Mica group

Perhaps one of the most overlooked minerals consistently collectible in good crystals throughout the Grenville is the mica group. The vast majority of the mica crystals found in the marble contacts and vein-dikes are biotite-phlogopite. Euhedral, pseudohexagonal crystals ranging in diameter from under a centimeter to over a meter have been found at innumerable occurrences. The huge crystals from the Silver Crater mine, Davis Hill occurrence and Smith-Lacey mine are classic. As with the apatite localities, to list all noteworthy collecting sites is virtually impossible; the reader is referred to Spence (1929) for a more complete listing. Figure 16 illustrates a typical specimen.

Molybdenite

Molybdenite is not an uncommon accessory in the marble contacts of the Grenville. Large flakes and crude crystals up to 10 cm are known to occur at several localities, usually in contact zones with pegmatites and/or "pyroxenites." Among some of the better collecting sites are the Zenith mine south of Renfrew, the Spain mine near Griffith, the Enterprise mine near Enterprise and the Jamieson mine in Lyndoch Township.

Nepheline

Probably some of the largest crystals of nepheline found anywhere occur on Davis Hill, east of Bancroft.

Plagioclase

Crystals of plagioclase (predominantly albite-oligoclase) have been found in hundreds of localities throughout Hastings, Dungannon and Haliburton Counties, particularly in the Tory Hill, Wilberforce and Bancroft areas. Crystals of peristerite displaying the characteristic play of colors have been found at several occurrences near Tory Hill. Perhaps one of the most interesting, rela-

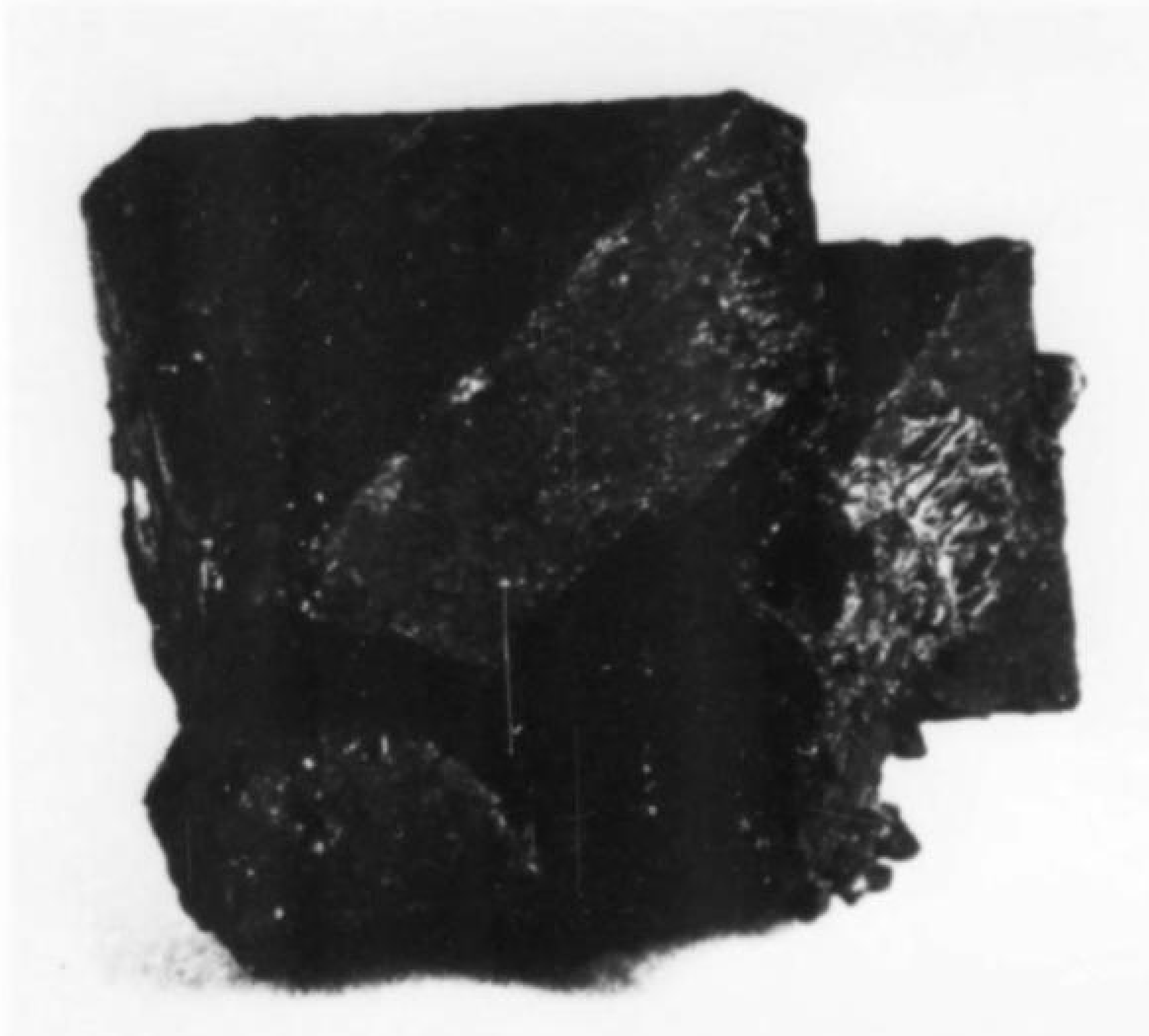


Figure 15. **Magnetite, a 6 x 7-cm group of sharp, black octahedrons from the Faraday (Madawaska) mine property, Bancroft, Ontario. George and Susan Robinson specimen.**

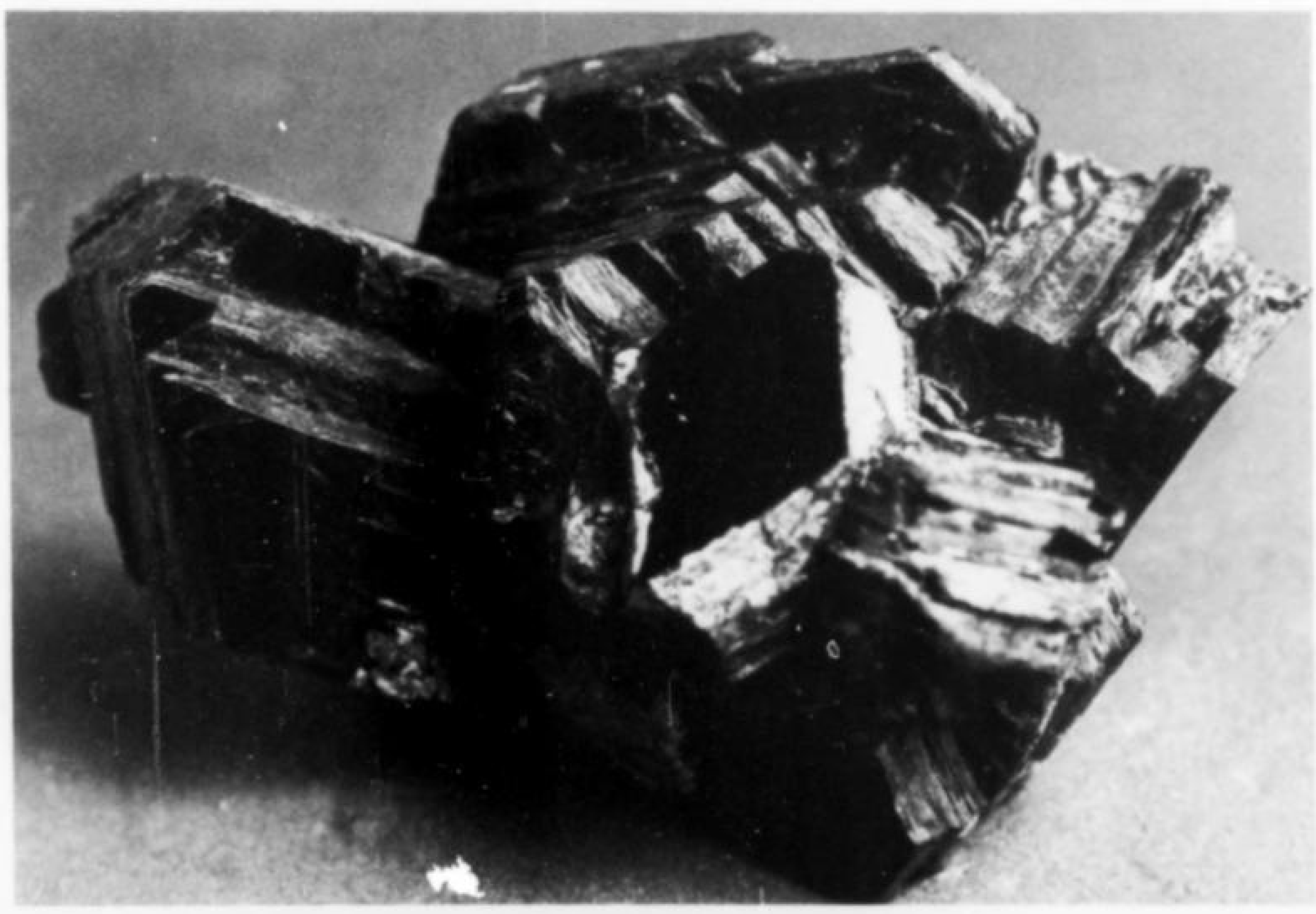


Figure 16. **Biotite, a 5 x 7-cm group of black crystals from Tory Hill, Ontario. George and Susan Robinson specimen.**

Figure 17. **Plagioclase pseudomorph after scapolite, an 8 x 10-cm group of pinkish brown crystals from near Griffith, Ontario. George and Susan Robinson specimen.**

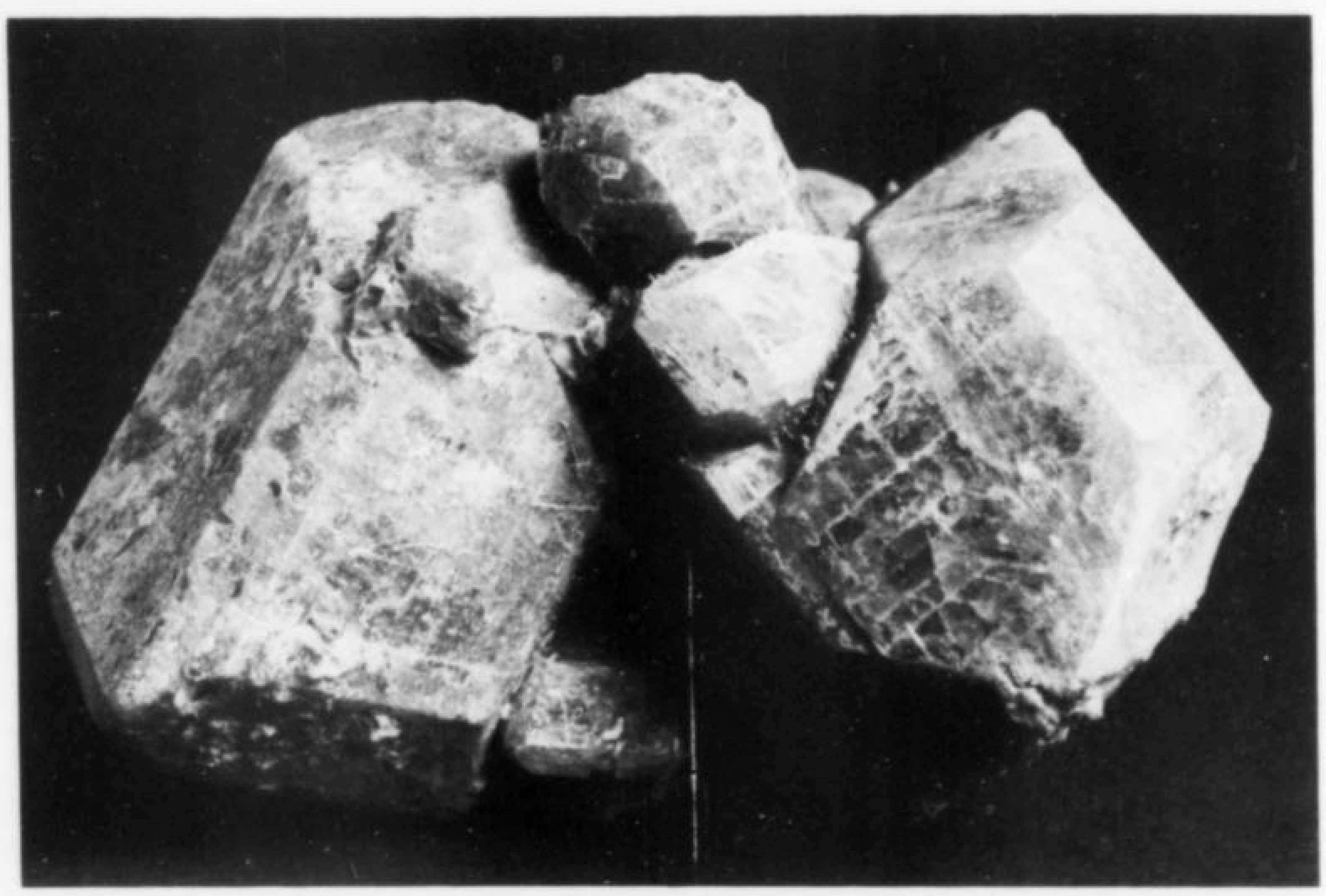


Figure 18. **Diopside, a 6 x 7-cm group of doubly terminated, pale green to white crystals from Dog Lake, Storrington Township, Ontario. George and Susan Robinson specimen.**

tively recent discoveries is the plagioclase pseudomorphs after scapolite which were found in a roadcut on Highway 41 near Griffith (Fig. 17). Here crystals of scapolite have been completely replaced by a mixture of plagioclase with minor hematite and epidote. The pseudomorphs occur with crystals of microcline, pyroxene, titanite, ilmenite and (rarely) byssolite in a small calcite vein-dike cutting gneiss.

Pyrite

Crystals of pyrite associated with pyrrhotite, calcite and cacoxenite have been found at the Billings pyrite mine near Brockville (old specimen labels may give the locality as Elizabethtown). One octahedron measuring approximately 8 cm on the edge is preserved in the collection of the National Museum of Canada.

Pyroxene group

Like the amphiboles, clinopyroxenes occur abundantly in the Grenville. Also, like the amphiboles, chemical variation is the determining factor in proper nomenclature. All too often anything that is green becomes labeled "diopside," and anything black, "augite." Although this method may work some of the time, it precludes a positive identification. Because of widespread occurrence, only the more important localities can be considered here.

Perhaps two of the best localities for diopside in Ontario are the occurrences at Birds Creek near Bancroft, and at Dog Lake, Storrington Township, Frontenac County (Fig. 18). The crystals from both these localities are remarkably similar, but the ones from Birds Creek are typically greener. At both localities the diopside occurs as sharp, doubly terminated crystals with phlogopite thickly disseminated through the marble. Some of the Dog Lake crystals show partial replacement by tremolite and are often encrusted with a thin white coating of talc (?). Parsons (1922) lists the commonest forms for these crystals as {001}, {111}, {111}, {221}, {110}, {100}, {010} and {021}.

Large, well-formed crystals of dark green to black clinopyroxene occur at the following localities: on Turner's Island in Lake Clear and at the Meany and Smart mines in the Eganville area; at the Highway 62 roadcut and at a roadcut near Diamond Lake, both north of Bancroft; on the Cardiff mine property near Wilberforce; and at numerous sites in the vicinity of Tory Hill.

Small pinacoidal crystals of ferro-augite have been found with the epidote crystals from Steenburg Lake. A microprobe analysis of one of the crystals is given in Table 1.

Scapolite

Scapolite is found throughout the Grenville province. At many localities crystals exceeding 10 cm in length are the rule rather than the exception. Most crystals are dense white but, on occasion, some with gem-quality areas are encountered (Sabina, 1965). The following list gives some of the more important localities: Bob's Lake mine, Bedford Township, Frontenac County; Bathurst and North Burgess Townships, Lanark County; throughout Monmouth Township, Haliburton County (Fig. 19); on Turner's Island, Sebastopol Township; the Craigmont mine, Raglan Township, and at various other occurrences in Renfrew County; at a roadcut near Diamond Lake, north of Bancroft; and as mauve-colored crystals in a roadcut near Gooderham.

Figure 19. **Scapolite, an 11 x 11-cm group of tan-colored crystals from Highland Grove, Haliburton County, Ontario. National Museums of Canada specimen No. 38987.**

Figure 21. **Thorite, a 3-cm brick-red crystal from the Kemp prospect, Cardiff Township, Ontario. George and Susan Robinson specimen.**

Figure 22. **Titanite, a lustrous, chocolate-brown 4 x 5 x 9-cm twinned crystal from the Miller mine, near Tory Hill, Ontario. National Museums of Canada specimen No. 72/34/6.**

Scheelite

Crude crystals of scheelite have been found with pyrrhotite and brown tourmaline at a small roadcut in the village of Sharbot Lake. Some of the crystals approached 10 cm in their longest dimension. The locality now appears to be exhausted.

Spinel

Probably one of the best localities for spinel in Canada is in Bathurst Township, Lanark County, where sharp black octahedrons up to 5 cm have been found (Fig. 20). Microprobe analyses

Figure 20. **Spinel, a 2 x 3-cm group of black octahedrons showing pale yellow corundum overgrowths from Bathurst Township, Ontario. George and Susan Robinson specimen.**

Figure 23. **Uvite-dravite, a lustrous black 5 x 7-cm group of crystals with quartz from the Tait farm, near Lamable, Ontario. George and Susan Robinson specimen.**

by the author (see Table 1) have shown these crystals to be an iron-magnesium spinel (*pleonaste*). Perhaps one of their most interesting features is the frequent presence of corundum overgrowths, and complete pseudomorphs of corundum after spinel have been found. It is not known whether there exists an epitaxial relationship between the two phases but it may be suspected, considering the structures involved.

Stillwellite

Small, reddish brown crystals of stillwellite have been found associated with bastnaesite, monazite, thorite, uranothorite, thorianite and other minerals at the Desmont Mining Corporation property near Wilberforce (Sabina, 1977).

Sulfosalts

An interesting suite of extremely rare sulfosalt minerals has been found at the Ed Taylor farm near Madoc. The following species have been described: baumhauerite, boulangerite, geocronite, guettardite, jamesonite, launayite, madocite, playfairite, robinsonite, semseyite, sorbyite, sterryite, twinnite, veenite and zinkenite.

Szaibelyite

Sabina (1977) describes an occurrence of several rare borate minerals exposed in a roadcut in Grenville marble on the South Baptiste Lake Road, northwest of Bancroft. Szaibelyite, sinhalite, and warwickite occur in small (1–5 mm) masses with spinel, apatite, mica, chondrodite, and other minerals in the marble. Though unspectacular in size and beauty, the rarity of these species makes their discovery in the Grenville noteworthy.

Thorite

Reddish brown crystals of thorite over 7 cm on an edge have been found at the Kemp uranium mine near Cheddar, Cardiff Township. The crystals are associated with pyroxene and calcite, and are typically flattened on the basal pinacoids (see Fig. 21).

Titanite

Perhaps some of the world's largest and finest crystals of titanite have been found in the Grenville rocks of Ontario. Lustrous, dark brown crystals, commonly twinned, are known from dozens of localities but the following ones are probably among the more significant: on Turner's Island in Lake Clear, and at the Meany and Smart mines in Sebastopol Township; at the Gibson Road occurrence near Tory Hill (see Fig. 22); at the Diamond Lake roadcut northwest of Bancroft; near the village of Miners Bay; and on the Cardiff mine property near Wilberforce. Some of the crystals from the Cardiff mine property have been replaced by anatase, resulting in light brown "leucoxene" pseudomorphs after titanite.

Tourmaline group

Tourmaline is a common constituent in the Grenville marble, but usually as small, anhedral grains. One notable exception, however, is an occurrence on the Tait farm near the village of Lamable, where large groups of uvite-dravite have been found. The lustrous black crystals which occur here are highly similar in both habit and genesis to those from the classic locality at Pierrepont, New York (Dunn and Appleman, 1977). The Tait farm tourmalines are associated with quartz, pyrite, uralite and tremolite-actinolite (see Fig. 23). Microprobe analyses by the author (see Table 1) have shown that both uvite and dravite are present, with compositional ranges from $Drav_{0.6}Uv_{0.4}$ to $Uv_{0.6}Drav_{0.4}$. Similar crystals were found years ago in a series of small pits near Enterprise, Lennox and Addington County, but their exact location is in question. Microprobe studies have shown these crystals to be dravite (Grice, pers. comm., 1981). A typical crystal is shown in Figure 24.

Uraninite

The calcite-fluorite vein-dikes near the village of Wilberforce have produced some of the finest and largest uraninite crystals known. Local concentrations were high enough in several instances to be of economic interest, and a number of mines and prospect

Figure 24. **Tourmaline, a lustrous, 3-cm, black crystal from Enterprise, Ontario. Queen's University specimen and photo.**

trenches were developed on the veins. The Montgomery (Nu-Age), Tripp, and Richardson (Fission) properties, together with the Cardiff uranium mines, have probably provided the best crystals. At each of these locations the crystals occur in a fine-grained matrix of banded calcite and fluorite (var. "*antozonite*"), associated with apatite, phlogopite, titanite, microcline, plagioclase, pyroxene and amphibole. The commonest form is the simple cube, commonly modified by the octahedron. Penetration twins were occasionally encountered, particularly at the Cardiff mine. Figure 25 shows a typical specimen. Similar crystals have also been found near Bronson, southeast of Bancroft.

Figure 25. **Uraninite, a 1.5-cm group of gray cubes in calcite from the Cardiff uranium mine, near Wilberforce, Ontario. George and Susan Robinson specimen.**

Vesuvianite

Probably the best locality for vesuvianite in Ontario is the Pin-

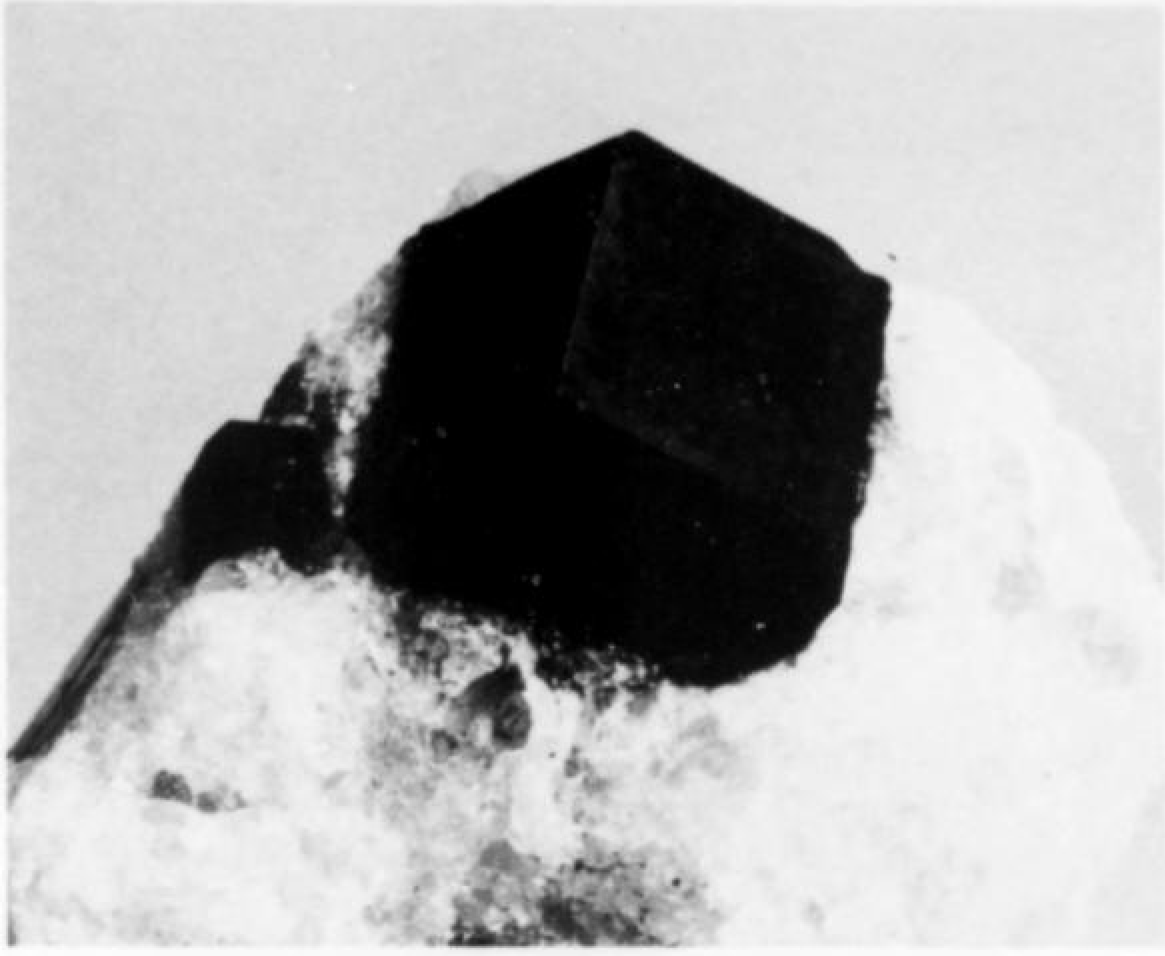


Figure 26. **Vesuvianite, a dark green, doubly terminated crystal in calcite (6 x 6 cm) from the Pinchin marble quarry, near Malone, Ontario. George and Susan Robinson specimen.**

Figure 27. **Zircon, a 2.5-cm red-brown crystal from Tory Hill, Ontario. George and Susan Robinson specimen.**

chin (Bonter) marble quarry near the village of Malone, where dark green and brown crystals over 10 cm long have been found in granular calcite with pyrite. Figure 26 illustrates a typical crystal, showing the common forms {100}, {110}, {101} and {001}. Epidote and axinite are also found, but not in immediate association with the vesuvianite.

Small, dark brown, tabular crystals of vesuvianite have also been found in the marble at the York River skarn zone, east of Bancroft (Sabina, 1977).

Zircon

Outstanding crystals of zircon have been found at a number of localities throughout the Grenville province. The crystals are generally of two types: elongate pink-brown individuals encountered in the apatite-mica deposits; and the shorter, darker brown *cyrtolites* associated with the uranium-bearing vein-dikes. Crystals of the first type have been found as exceptional pieces at all the following localities: on Turner's Island in Lake Clear, and at Kuehl Lake, Brudenell Township (as well-formed, terminated crystals in excess of 20 cm at both localities); at the Smart mine, Sebastopol Township, as red geniculate twins with apatite, augite, microcline and titanite; at the Silver Crater mine near Bancroft, as sharp tan-colored crystals associated with betafite; at the Silver Queen mine and McLaren mine (near Otty Lake), south of Perth, Lanark County; at the Smith-Lacey mine near Sydenham, and at a small mica prospect east of Verona, Frontenac County; and in a series of roadcuts near the village of Tory Hill (Fig. 27).

Crystals of the second type are shown in Figures 28 and 29. Probably some of the best localities for *cyrtolite* of this type are in the vicinity of Wilberforce. Good crystals have been found at the Richardson (Fission mine) property, the Cardiff mine property and in the roadcuts between Dark Lake and Mumford Station; and in Westmeath Township, in Renfrew County.

Figure 28. **Cyrtolite variety of zircon, a chocolate-brown, 2.3-cm crystal in calcite from the Cardiff mine property, Wilberforce, Ontario. George and Susan Robinson specimen.**

Fracture-filling Deposits

Wherever there exist open channels in a rock, mineralizing solutions may enter and deposit crystals in the voids. Regional and local faulting created such a situation in many places throughout the Grenville, resulting in numerous brecciated rocks and vein systems containing well-crystallized minerals. Due to the nature of vein-filling systems (the actual vein filling is younger than the enclosing rock), some of the minerals to be discussed may themselves post-date the Grenville. Therefore the localities included here have been selected so those that are clearly post Grenville (e.g. the Madoc fluorite veins, the numerous calcite-galena veins such as at Draper Lake and Galetta, etc.) have been omitted. Some of the most important occurrences are summarized below.

Arsenopyrite

Arsenopyrite is a common constituent in many of the gold-bearing hydrothermal veins in the area around Madoc, Ontario. Probably the best crystals occurred at the Ackerman, Deloro, and Gawley mines near Deloro, where shiny pseudo-orthorhombic crystals and mimetic twins over 3 cm long were found with quartz, ankerite and native gold.

Figure 29. **Cyrtolite zircon, a 2.5 x 2.5 x 2-cm group of dark brown crystals from the Cardiff mine property, Wilberforce, Ontario. National Museums of Canada specimen No. 40567.**

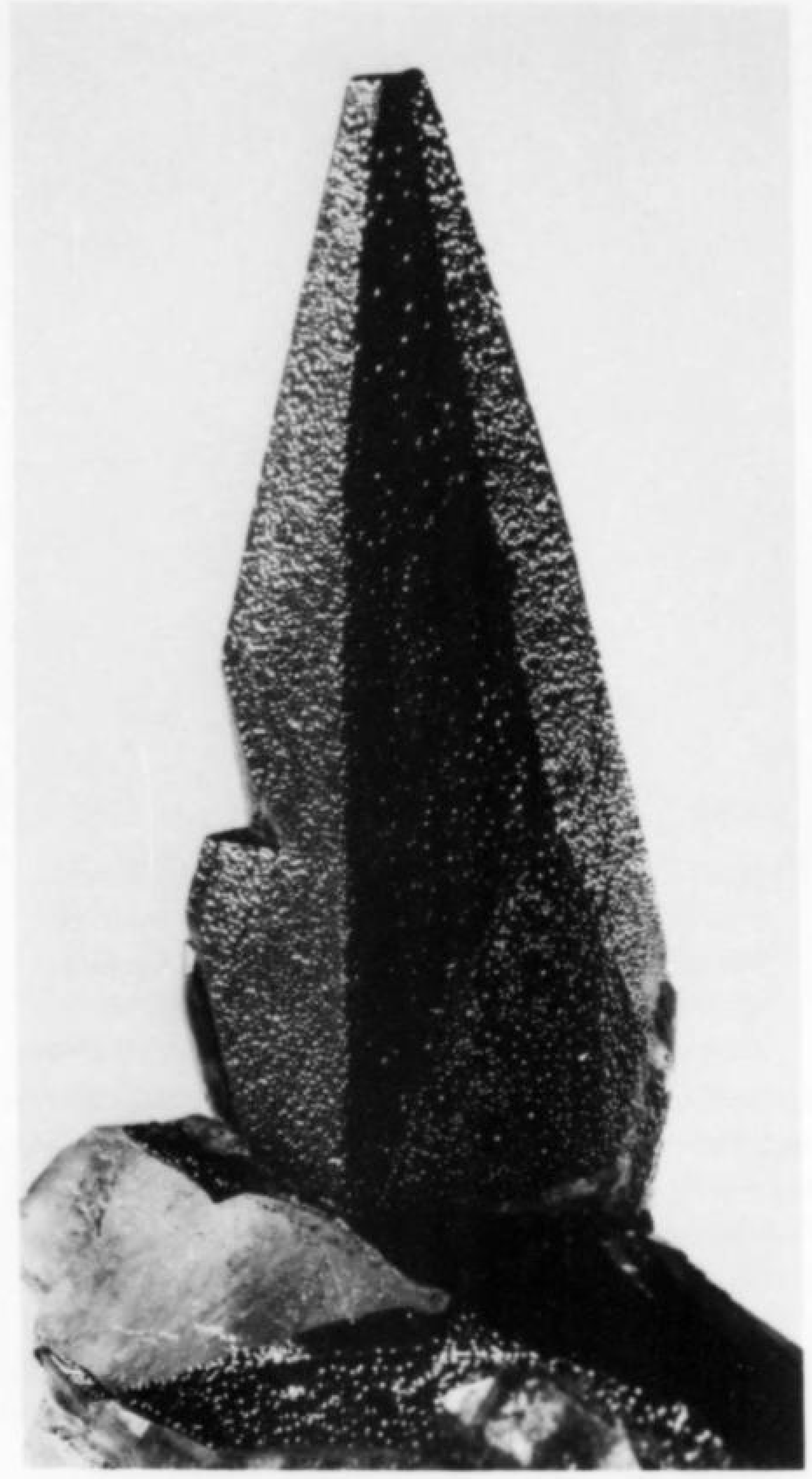


Figure 30. **Hematite-coated calcite crystal from the Madawaska mine, Hastings County. Royal Ontario Museum specimen (M32449) and photo.**

Calcite

Probably one of the most common yet diverse minerals encountered in any fracture-filling type of mineral deposit is calcite. The number of known occurrences in the Grenville where good crystals have been found is so great that only a few of the most famous can be discussed here.

Perhaps one of the most interesting localities for calcite in recent years has been the Faraday (Madawaska) mine, near Bancroft, where exceptionally large crystals of iceland spar, often with spiralling inclusions of pyrite, were encountered. These crystals (usually large rhombohedrons modified by scalenohedron faces) were typically etched and coated with iron oxides so that most of the specimens were cleaved to expose their water-clear interiors. A second, somewhat different habit found consisted of groups of long scalenohedrons with flat-topped basal terminations which, when coated with a thin black layer of botryoidal goethite, provide very esthetically pleasing specimens (Fig. 30). Some of the finest of these are in the collections of Cranbrook Institute (Detroit), and the Royal Ontario Museum.

In the early 1970's a series of huge calcite pockets was encountered at the Long Lake (Lynx) mine near the village of Parham. The dominant forms are the simple rhombohedron modified by the scalenohedron and large basal pinacoids. The crystals are nearly always twinned and coated with microscopic crystals of marcasite (Fig. 31). Of particular interest on some specimens is the association of a globular (presumably Precambrian) hydrocarbon which appears blood-red in transmitted light.

Although better known for its quartz crystals, the Lyndhurst (Steele) quartz mine at Black Rapids also produced many fine specimens of calcite. Many of the crystals are quite complex, exhibiting phantoms, secondary overgrowths, color zoning and twinning (often all on a single specimen!), not to mention the universal presence of pyrite and hematite inclusions (Fig. 32).

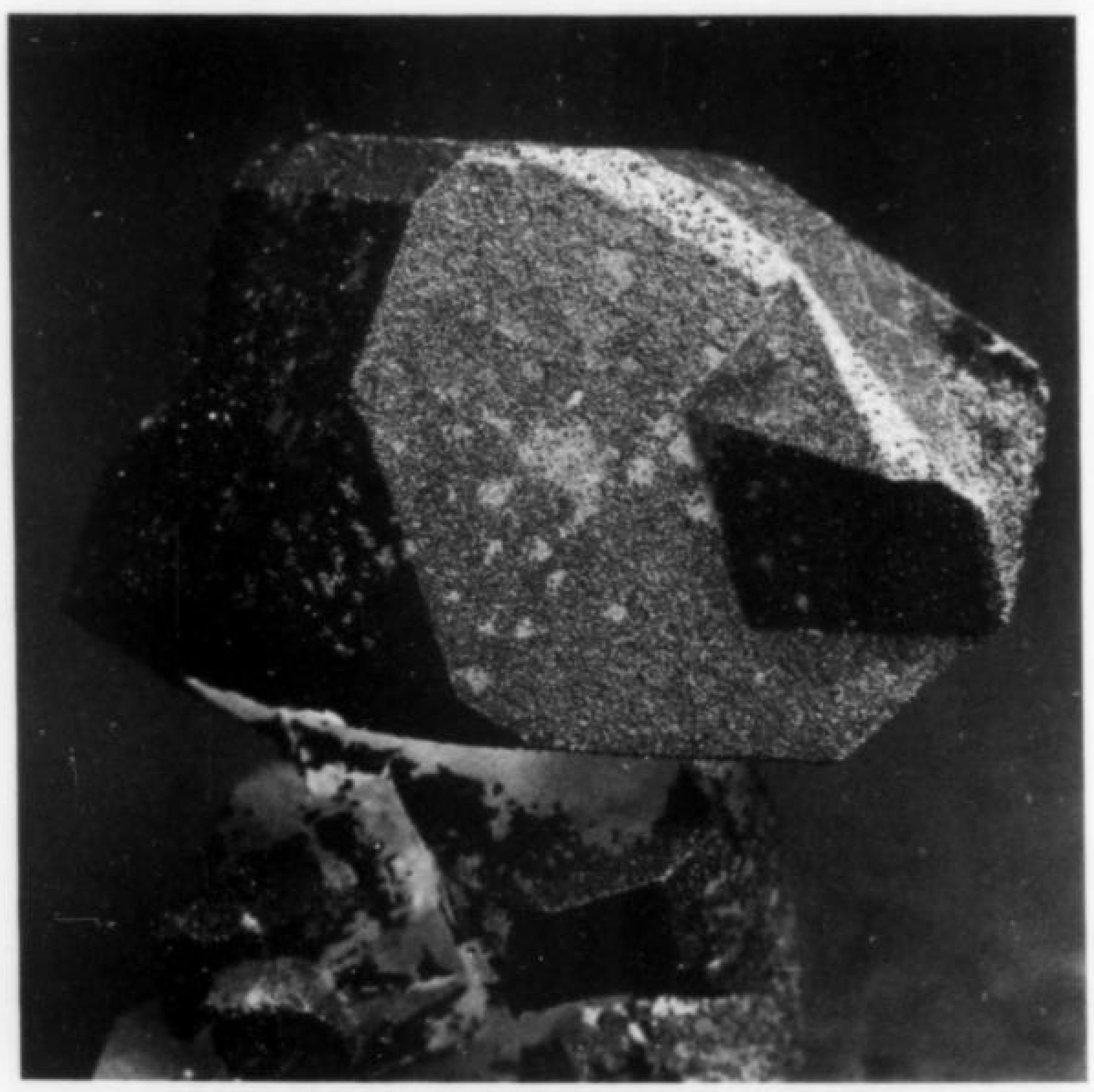


Figure 31. **Calcite, a 4 x 4.5-cm twinned crystal of Iceland spar coated with marcasite from the Long Lake (Lynx) mine, near Parham, Ontario. George and Susan Robinson specimen.**

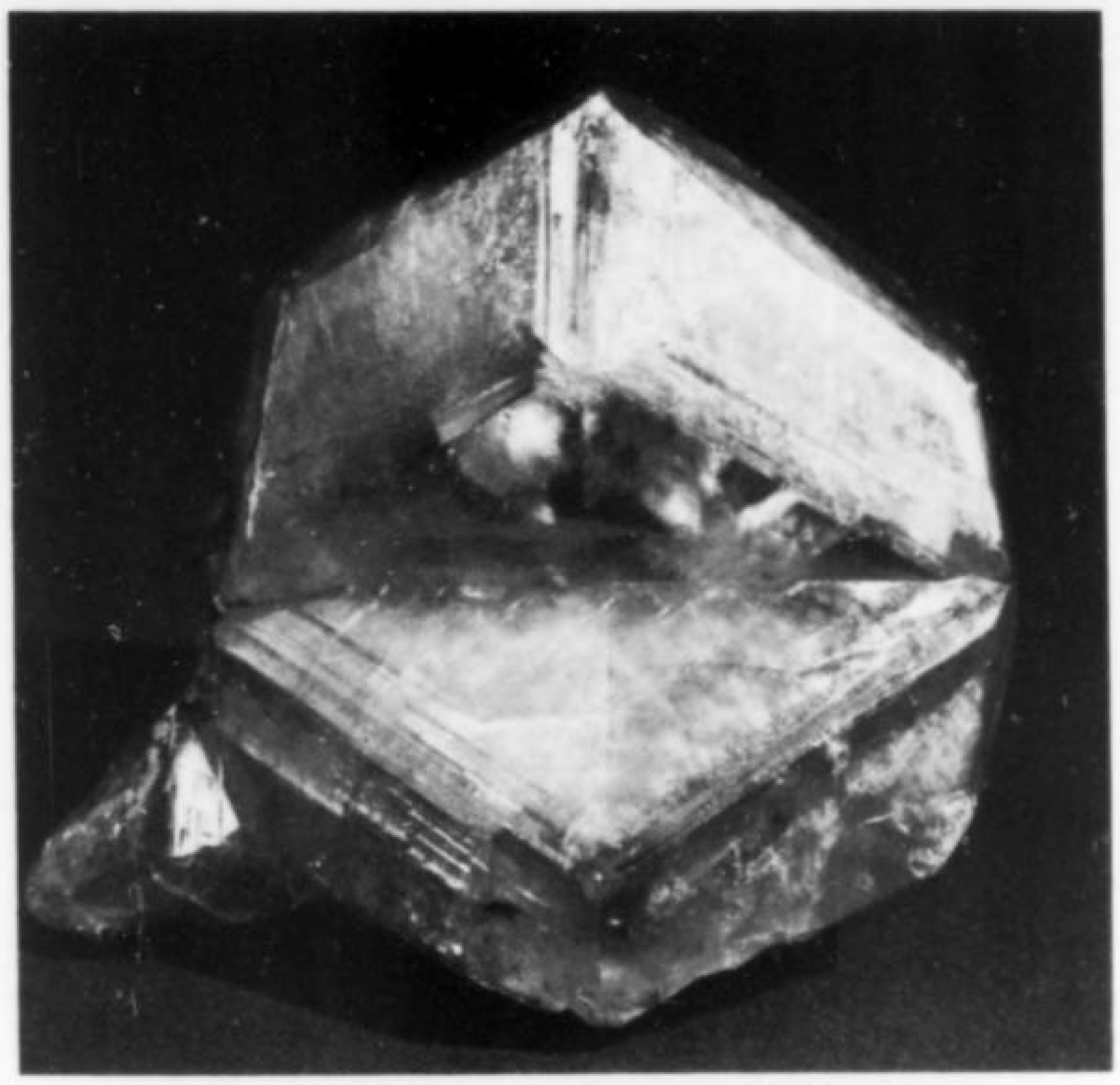


Figure 32. **Calcite, an exceptionally lustrous, twinned beige crystal (6 x 6.5 cm) from the Lyndhurst (Steele) quartz mine near Black Rapids, Ontario. National Museums of Canada specimen No. 35311.**

Other localities worthy of mention are the Marmoraton iron mines at Marmora, where crystals of varied habits were found associated with quartz, hematite, chalcopyrite and chlorite; a large cave of calcite crystals near the village of Godfrey, from which hundreds of large, twinned scalenohedrons and hematite-stained phantom crystals were removed; at the Conley and Henderson talc mines near Madoc, where fine twinned scalenohedrons were found (Fig. 33); and at numerous roadcut occurrences in the Arnprior, Bancroft and Miners Bay areas.

Figure 33. **Calcite, a fine group of clear, twinned crystals (major crystal 1.5 x 4.5 cm) from Canada Talc Company mine, Madoc, Ontario. National Museums of Canada specimen No. 35553.**

Dolomite

Sharp white rhombohedrons of dolomite were found on some of the calcite crystals from the Long Lake (Lynx) zinc mine near Parham. Due to included hydrozincite, some of the crystals fluoresce blue upon exposure to ultraviolet radiation.

Fluorite

A very fine, though not well-known, locality for fluorite is the Faraday (Madawaska) mine near Bancroft. Here, fluorite occurred as small (generally less than a centimeter) emerald-green octahedrons, somewhat resembling small clusters of dioptase. Most specimens were found in the early 1960's in a small fracture zone, but unfortunately relatively few pieces were recovered and those quickly found their way into private collections.

Kainosite

This mineral occurred sparingly as small, tan to pink crystals lining cavities in calcite at a now-lost locality in North Burgess Township, Lanark County. Some excellent specimens from this locality are present in the mineralogical collection of Harvard University. Kainosite has also been reported from the Bicroft, Madawaska and Greyhawk mines, all near Bancroft.

Quartz

Like calcite, quartz is a common accessory in vein deposits throughout the Grenville, although good crystals are relatively uncommon. Probably the best locality is the Lyndhurst (Steele) quartz mine near Black Rapids. Here, finger-sized crystals of clear and

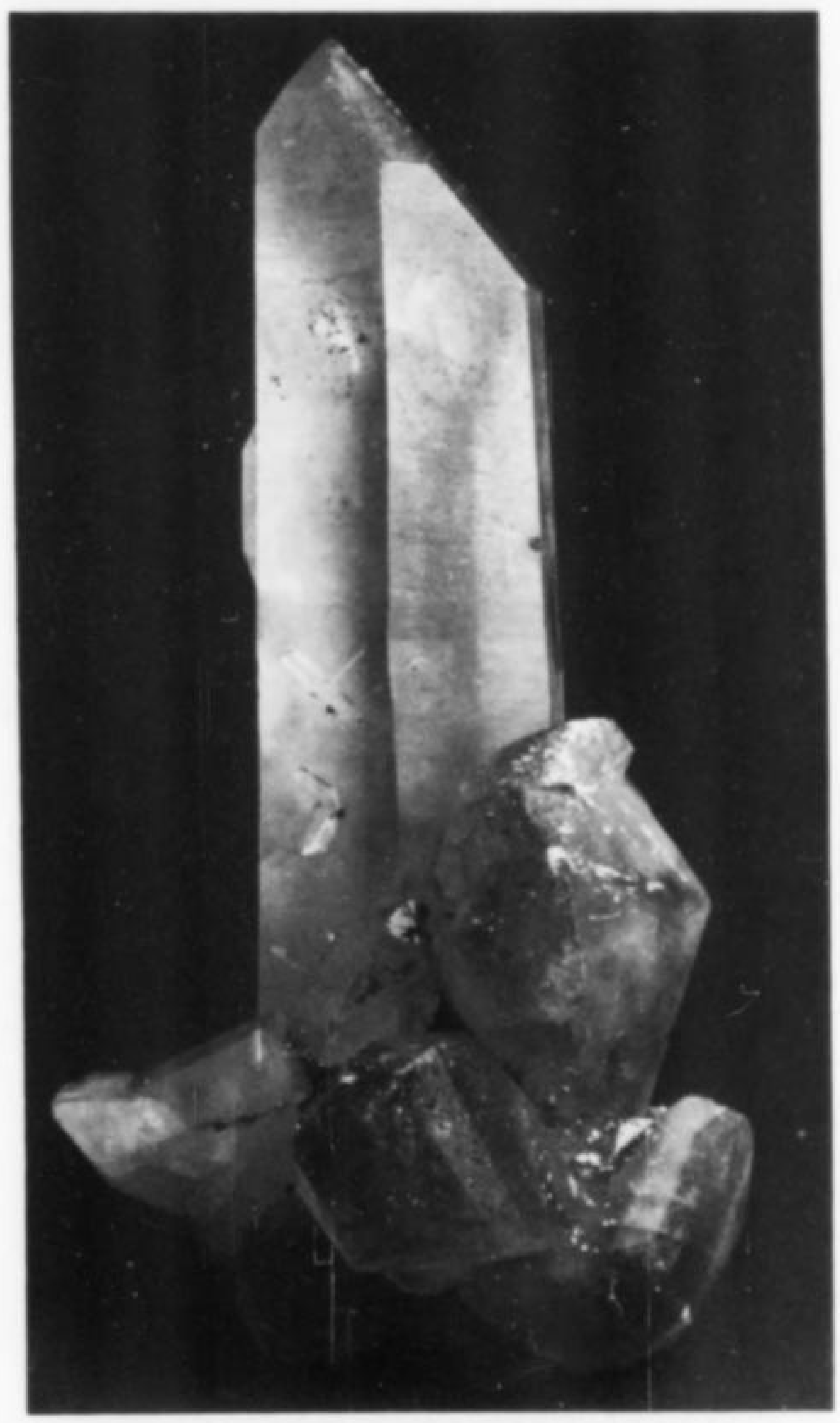


Figure 34. **Quartz, a 12-cm crystal of clear quartz with 3-cm beige-colored calcite crystals from the Lyndhurst (Steele) quartz mine near Black Rapids, Ontario. George and Susan Robinson specimen.**

milky quartz are extremely abundant, and crystals up to half a meter in length have been reported. Crystal groups a meter across associated with calcite, pyrite, hematite and chlorite have been found on the dumps. A typical specimen is shown in Figure 34. Similar specimens were also found at Marble Rock, Leeds County.

In addition to its calcite, the Long Lake (Lynx) mine near Parham has also produced a number of good quartz specimens. The crystals from here are typically shortened along [001] with extremely small prism faces, mimicking hexagonal dipyramids. Their colors range from clear to milky, and smoky to amethystine. Associated minerals include calcite, hydrozincite and pyrite.

Good specimens of quartz have also been collected from roadcuts near the village of Miners Bay and Verona, and at other localities too numerous to mention.

Uranophane

The uranophane crystals from the Faraday (Madawaska) mine at Bancroft, are probably among the finest known. Canary-yellow sprays of acicular crystals over a centimeter in length against a dark brown-to-black matrix afford striking specimens (Fig. 35). Uranophane-beta has also been found, but in small quantities.

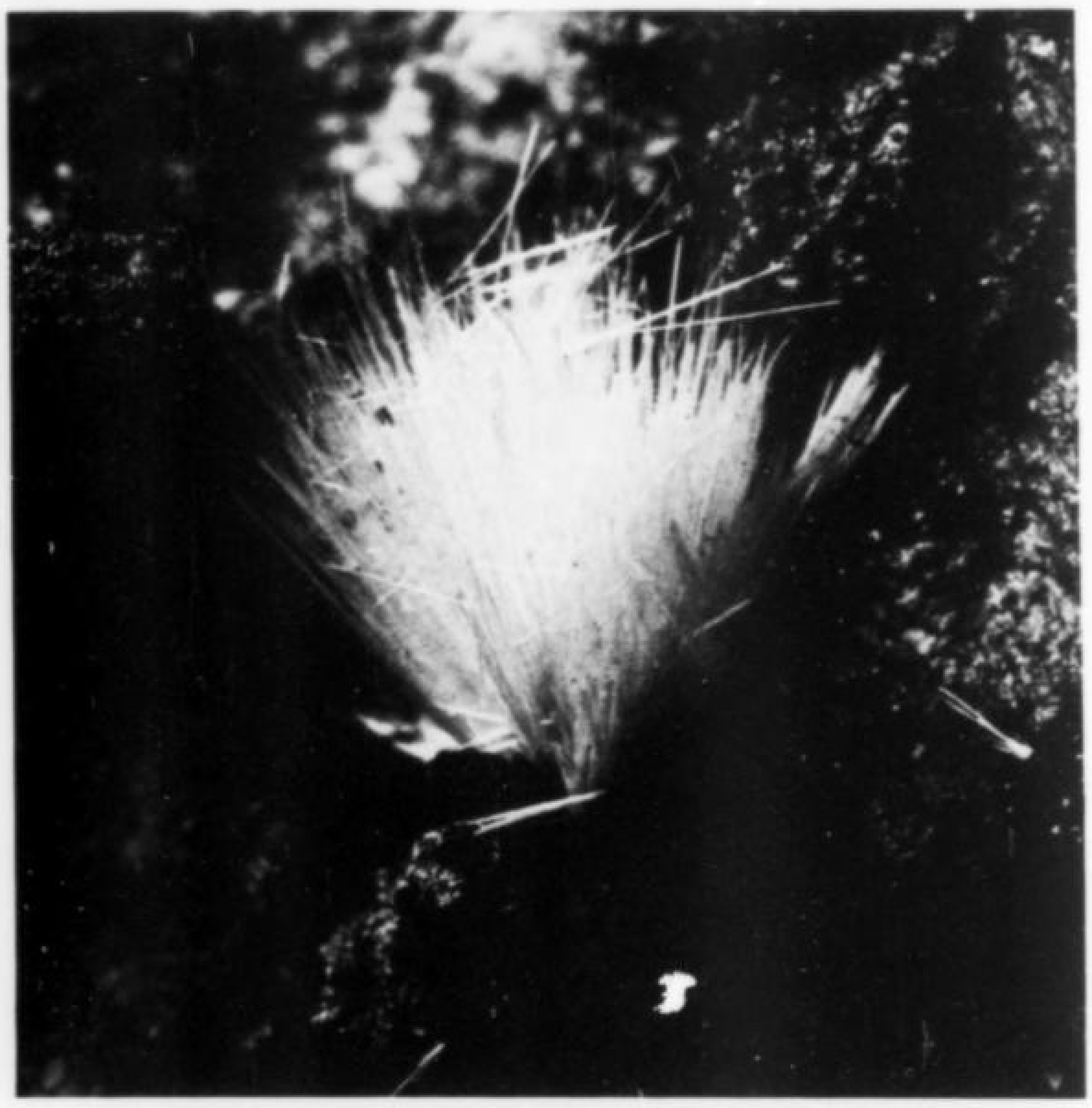


Figure 35. **Uranophane, a 10 x 12-mm spray of canary-yellow crystals from the Faraday (Madawaska) mine, Bancroft, Ontario. George and Susan Robinson specimen.**

Pegmatites

Because of their large crystal texture and relative abundance of otherwise uncommon elements, pegmatites often provide a variety of interesting mineral specimens. Most pegmatites in the Grenville lack the well-developed cleavelandite zones and miarolitic cavities that are sometimes encountered in other pegmatites. Their major minerals are microcline (usually perthitic), quartz, plagioclase (often peristerite) and biotite, with muscovite generally being less common. A notable exception is the Purdy mine near Mattawa, where huge crystals of clear muscovite over a meter across were removed (Moyd, pers. comm., 1979). As with most pegmatites, the accessory minerals are usually of the greatest interest to the collector. The list below summarizes some of the better-known occurrences.

Allanite

Large, platy crystals of allanite have been found with a number of other rare-earth-containing minerals in several pegmatites in the Grenville. Allanite occurs at the MacDonald mine near Hybla with cyrtolite, uranothorite and uranpyrochlore; at the Faraday (Madawaska) mine at Bancroft, with uraninite and uranothorite; at the J. G. Gole quarry near Madawaska, with fergusonite, euxenite, and cyrtolite; and at the beryl mines in Quadeville, with euxenite, cyrtolite, columbite and monazite.

Beryl

Large crystals of blue-green beryl occur at the Canadian Beryllium Mines and Alloys Limited properties near Quadeville. Crystals up to 20 cm have been found in association with columbite, euxenite, fergusonite, cyrtolite, monazite, peristerite, amazonite, allanite, quartz and tourmaline.

Euxenite

As mentioned above, crystals of euxenite occur at the beryl mines in Quadeville. The crystals are very sharp and many attain a length of several centimeters. Older labels may refer to these euxenites as "lyndochite," named for Lyndoch Township. Euxenite also has been found in very fine crystals at the J. G. Gole quarry (Fig. 36).

Figure 36. **Euxenite, a 1.5 x 4-cm doubly terminated black crystal from the J. G. Gole quarry, near Madawaska, Ontario. George and Susan Robinson specimen.**

Fergusonite

Fergusonite has been identified from a number of pegmatites in Ontario. However, the best locality is probably the J. G. Gole quarry near Madawaska. Terminated, tapered prisms over 5 cm long occur in pods of biotite with euxenite, cyrtolite, uraninite and microcline (Fig. 37).

A few crystals of fergusonite have also been found at the Card quarry, west of Verona. The specimens are similar to those from the Gole quarry, but somewhat less abundant. Small pieces of thucholite are rarely associated.

Gadolinite

Ellsworth (1932) reports the occurrence of large gadolinite

Figure 37. **Fergusonite, a 2-cm, black, terminated crystal from the J. G. Gole quarry, near Madawaska, Ontario. Jerry VanVelthuizen specimen.**

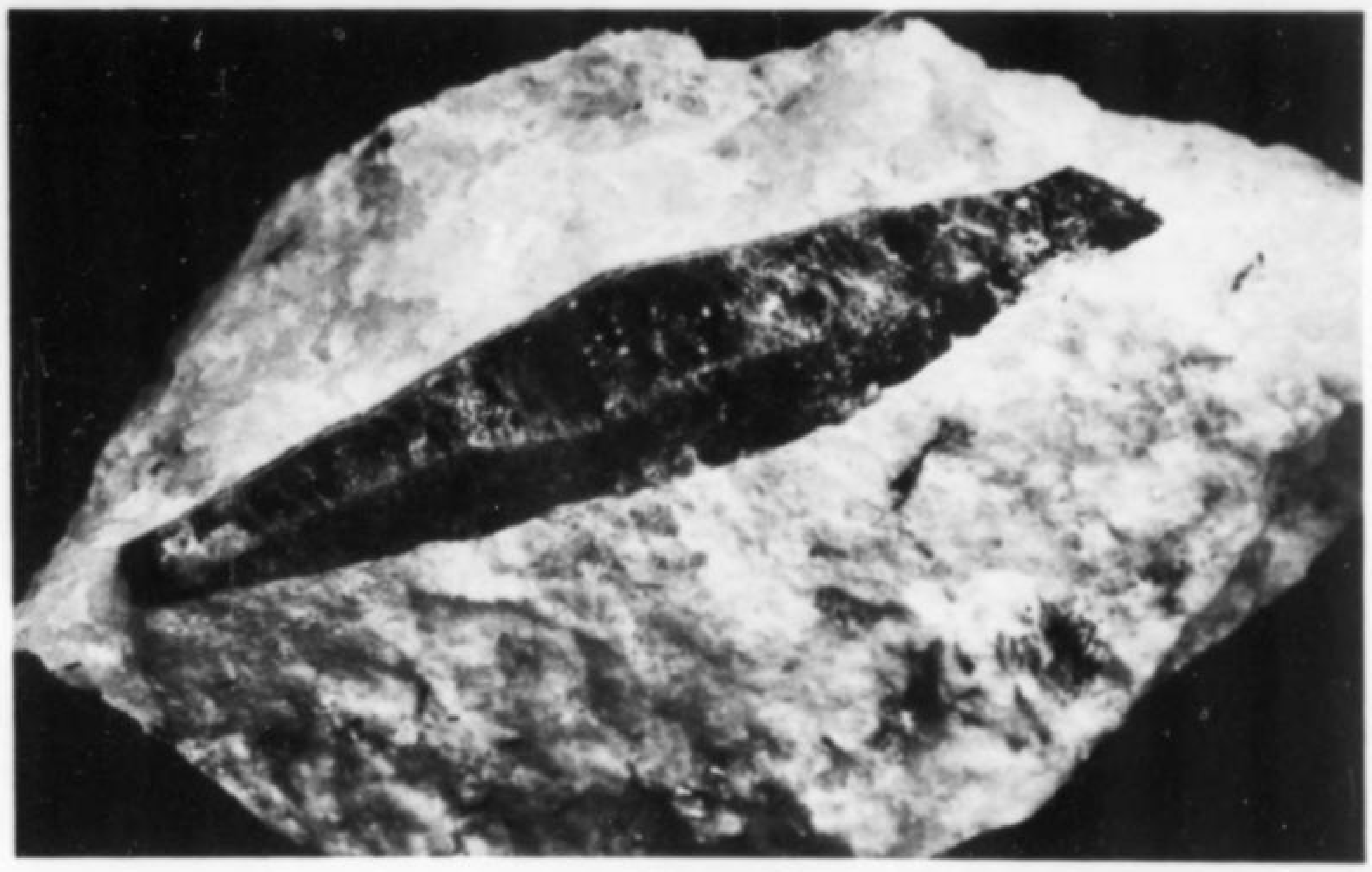


Figure 38. **Corundum, a doubly terminated brown crystal in syenite (4 x 6 cm) from the Gutz farm, near Rosenthal, Ontario. George and Susan Robinson specimen.**

crystals "weighing a quarter of a pound" from a pegmatite dike on lot 11, concession IX, Loughborough Township.

Tourmaline group

Large crystals of schorl have been found at the Canadian Beryllium Mines and Alloys Ltd. properties in Quadeville. Logan (1863) reports large crystals from Tar Island (near Thousand Islands) in the St. Lawrence River, and on lot 18, concession IV, Bathurst Township.

Uranpyrochlore

The mineral formerly called *ellsworthite* and now identified as uranpyrochlore (Hogarth, 1977) occurs in a complex pegmatite at the MacDonald mine near Hybla. Resinous brown masses are found with cyrtolite, allanite, titanite, uranothorite and quartz in a portion of the dike rich in orange calcite.

Zircon

Very fine crystals of cyrtolite (a variety of zircon containing uranium, thorium, and sometimes small quantities of rare earth elements) have been found in a number of Grenville pegmatites. At each occurrence the crystals are of chocolate-brown color and typically barrel-shaped due to the development of multiple {hhl} forms. Excellent specimens have been found at the J. G. Gole quarry near Madawaska, the MacDonald mine near Hybla, the Canadian Beryllium Mines and Alloys Ltd. properties at Quadeville, and with thorite at the Saranac mine near Tory Hill.

The Nepheline-Corundum Belt

The main (northern) nepheline-corundum belt extends over 120 km from Sebastopol Township in Renfrew County, westward to Glamorgan Township in Haliburton County. In addition, two smaller belts lie to the south in Methuen Township, Peterborough County, and in Oso Township, Frontenac County. The "syenites" which constitute the bulk of these belts actually comprise a variety of rock types with overall syenitic compositions, and are not necessarily in *sensu stricto* plutonic igneous rocks. Many of the so-called syenites in the Grenville (including those discussed here) show metamorphic textures and mineral assemblages, and should probably be termed metasyenites and gneisses.

The following list presents some of the more interesting species to be encountered in the nepheline-corundum belt, but see Moyd (1949) and Hewitt (1960) for a more complete account.

Cancrinite

Yellow masses of cancrinite are a common constituent in the nepheline syenites around the Bancroft area, particularly at Blue Mountain, Methuen Township, and at the Davis quarry and Cancrinite Hill, east of Bancroft. Some of the best cancrinite in Canada, however, occurs in the nepheline syenites in the Franch River area, and pink cancrinite has been reported from near Gooderham (Armstrong, 1960).

Corundum

Probably one of the best crystallized species to be found in the syenites is corundum. The large barrel-shaped, bronze-colored crystals from the Craigmont area are world famous and, in the early 1900's, numerous mines were in operation. It would be difficult to say which mine produced the best crystals, as good specimens were removed from nearly all the workings.

The Burgess mine, Logan Cuts, Craigmont mine, and Jewellville pits all produced euhedral crystals. Somewhat more elongated crystals occur on the Gutz farm near Rosenthal (see Fig. 38), and blue corundum has been found along the York River, east of Bancroft. A few pieces from the latter occurrence are asteriated and of acceptable color to afford gemstones. A few black star sapphires were also recovered from the Lily Robertson pits near Bancroft.

For a comprehensive coverage of the corundum occurrences, the reader is referred to Barlow (1915).

Natrolite

Clear to white prismatic crystals of natrolite are occasionally found with prehnite in cavities in the Blue Mountain and Indusmin nepheline quarries in Methuen Township, Peterborough County. Massive natrolite containing fibrous aggregates of dawsonite occurs at the Princess sodalite quarry, east of Bancroft. Tiny but well-formed crystals of nordstrandite are occasionally found with boehmite in small vugs in the natrolite (Sabina, 1977).

Sodalite

The blue sodalite from Bancroft, Ontario, is world famous among mineral collectors and lapidaries alike. Although no well-formed crystals are met with, the solid, blue, cleavable masses found here provide very colorful specimens. The best locality has been and remains, the Princess sodalite quarry, approximately 4 km east of Bancroft. Sodalite (var. *hackmanite*) also occurs at the Davis quarry near the York River further east, and fluoresces a bright apricot-orange color in ultraviolet light.

Zircon

Sharp pinkish brown crystals of cyrtolite have been found at a number of the nepheline syenite deposits in the Gooderham and Bancroft areas. Among the best known are the MacKay property near Gooderham, and the Golding-Keene and Davis quarries along the York River east of Bancroft. At the Davis quarry, large masses (up to several kilograms) of crystals in parallel growth were found associated with pyrrhotite in the syenite.

DISCUSSION

As previously stated, any attempt to completely cover the mineralogy of the Grenville in an article of this nature is a near impossibility. In discussing the various mineral occurrences, it has been necessary to limit both the species descriptions and specific information regarding their localities. Rather than attempt to provide detailed directions and collecting information regarding each locality, a recommended reading list is offered below for those seeking further information.

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*Most of these publications are available from the Geological Survey of Canada, 601 Booth St., Ottawa, Ontario.

**Available from the Ontario Government Bookstore, 880 Bay Street, Toronto, Ontario.

ACKNOWLEDGEMENTS

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the Fluorite Mines of Madoc Ontario

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Many fine crystals of fluorite have come from the Madoc mines. Excellent specimens may be seen in the collections of the Royal Ontario Museum, the National Museum of Canada, the Geological Survey of Canada, the Cranbrook Institute in Detroit, and most major museums worldwide.

INTRODUCTION

The Madoc fluorite mines are situated on a relatively small system of fluorite-barite-calcite veins that roughly parallel the Moira fault to the south and west of Moira lake, near the village of Madoc, Hastings County, Ontario. Figure 1 shows the locations of these mines, which may be divided into two groups: the Lee-Miller group, approximately 6.5 km west of Madoc, and the Moira Lake group, immediately to the north and south of Moira Lake. Both groups of mines contained mineable concentrations of fluorite, but the Moira Lake group was the more important both economically and as a source of specimens.

It is unfortunate that more specimens were not preserved. The mines were worked for optical-grade fluorite which was hand-cobbed and sorted, thus lessening the chances of larger crystals ever reaching the hands of collectors. Documentation for many of the specimens that were saved is rather sketchy, and to assign a specific mine to any given piece is, at best, only an educated guess; many of the mines produced rather similar looking material. Furthermore, some of the mines changed names, or mined the same vein on different properties, further complicating the recording of accurate locality information. Fortunately, specimens found in recent years have been more carefully documented.

Although all the mines are now closed, reasonably good specimens have been collected periodically from some of the dumps and nearby roadcuts. At present, most of the best sites are on privately owned land, and collecting is usually discouraged.

HISTORY

Although fluorite was known to exist in the Madoc area since 1875, it was not until 1905, when Stephen Wellington put down the first pit on the Bailey property, that the first mining operation commenced. Production from these early open cuts was limited until World War I, when demand pushed up the price of fluorite. At the end of the First World War, production dropped off substantially, and major mining did not resume until World War II, when increased demand once again caused the price to rise. This time operations continued for about 25 years, until the Kilpatrick mine closed in 1959, followed by the Rogers mine in 1961.

The mines of the Lee-Miller group probably never produced any worthwhile specimens due to the non-vuggy nature of the deposits. Many of the old open cuts have been bulldozed in by the local farmers to prevent their cattle from falling into the holes. Thus, the mines of the Lee-Miller group may be dismissed as having little of interest to offer the collector. Similarly, about half the mines of the Moira Lake group were not great producers of specimens, and will not be discussed. The remaining mines were, however, good specimen producers, and a brief discussion of these properties follows.

The Bailey Mine

Fluorite was first discovered on the Bailey property in the mid-1890's by Nicholas Fleming, while excavating the cellar for a house (Wilson, 1929). It was not until 1905, however, that Stephen Wellington undertook the first mining operation, which was followed by the Hungerford Syndicate, and the Millwood Fluorspar

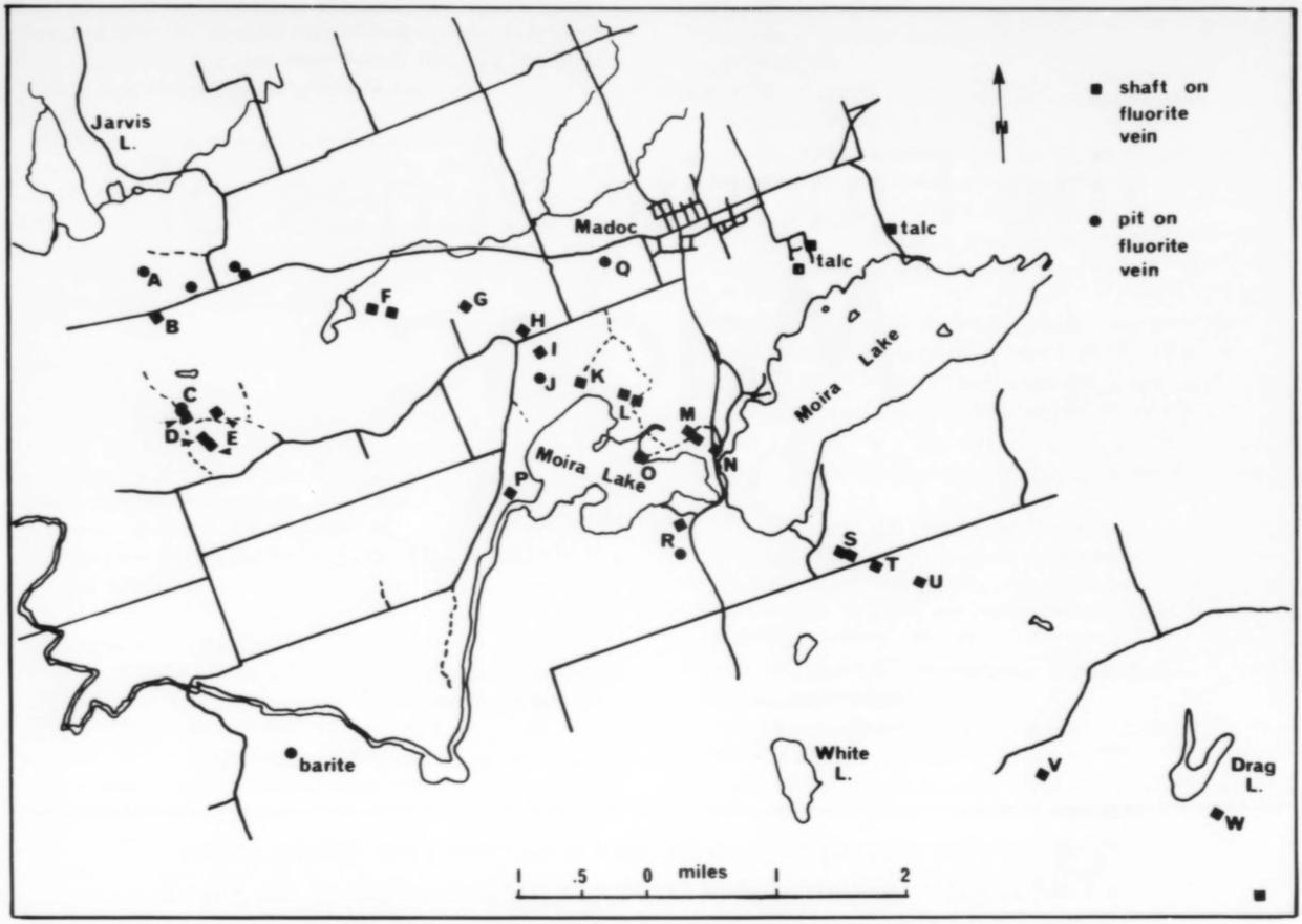

Figure 1. **A map of the Madoc area, showing the locations of the major fluorite occurrences (after Guillet, 1964). A – William Reynolds, B – Miller, C – Herrington, D – Wallbridge, E – Lee Senior, F – Lee Junior, G – McIlroy, H – Bailey, I – Keene, J – North Reynolds, K – Kilpatrick, L – Rogers, M – Perry, N – Perry Lake, O – Coe, P – South Reynolds, Q – Hill, R – Blakely, S – Noyes, T – Johnston, U – Howard, V – Jones, W – Palmateer.**

Mines Limited, who recovered 25,000 tons of ore from both surface and underground workings (Guillet, 1964). The Bailey mine produced large specimens of green fluorite crystals, commonly encrusted by white barite. Early specimens of this type are in the collections of the British Museum of Natural History, and the National Museum of Canada. Most of the fluorite crystals show a combination of the simple cube and octahedron, with the octahedron typically dominant. Wilson (1929) reports numerous large caverns in the underground workings, and notes one in particular: "In the drift southwest of the shaft (35 feet) beneath the Bailey farmhouse, a large, open cavern was met in which stalactites and stalagmites of barite and fluorspar are said to have been present." A specimen of this stalactitic barite is shown in Figure 2.

The Bailey mine is now completely off limits to collectors. The shaft has been filled, and the dumps covered and made into a lawn by the present owner.

The Keene Mine

The Keene mine was first opened by Rinaldo McConnell in 1917 (Wilson, 1929). The property was further developed at different times by Canadian Fluorite Limited, H. C. Miller, and Millwood Fluorspar Mines Limited, yielding a total production of approximately 5,000 tons (Guillet, 1964).

According to Wilson (1929), "the principal vein contains a considerable proportion of brilliant transparent crystals of fluorspar up to 4 or 5 inches in diameter." These optical-grade crystals reportedly occurred in a gray, fibrous celestine. As with the crystals from most of the other mines in the area, the predominant form is the simple cube, sometimes modified by the octahedron or tetrahexahedron (Elevatorski, 1973). Very fine crystals of pale blue, colorless, red (due to included hematite), light green, and honey-yellow fluorite have been found. In the early 1940's, some deep green crystals associated with white, crested spheres of barite and pyrite crystals were found (Fig. 3). One exceptional specimen of this type is in the collection of the Royal Ontario Museum, and another is owned by Don Demaray, of London, Ontario.

Throughout its history, the Keene mine has been variously listed as the "Kane," "Bradley," and "Keene," the latter being correct. It is interesting to note that both the Keene and Bailey mines drifted into the North Reynolds property, which lay between them. Thus, some specimens labeled as coming from the Keene or Bailey, may in fact have come from the North Reynolds property.

The Keene shaft is now flooded to the ground level. There are a few small dumps, but the present owners do not permit collecting on the property.

The Kilpatrick (Detomac) Mine

The Kilpatrick (Detomac) mine is located approximately 0.6 km to the southeast of the Keene mine, and appears to be a continua-

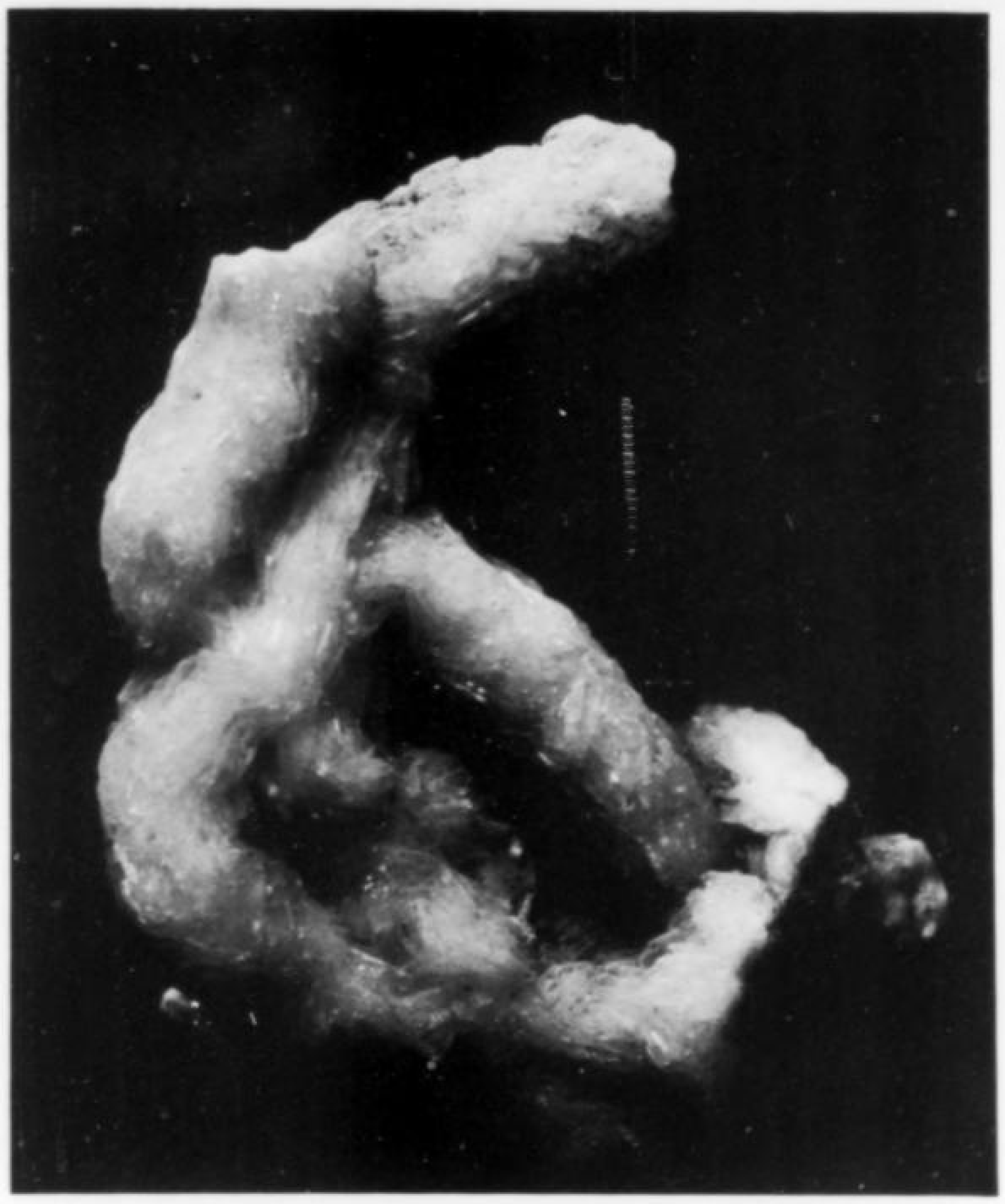

Figure 2. **Stalactitic white barite from the Bailey mine. The specimen is about 13 cm tall. Frank Melanson specimen; photo by Steven Chamberlain.**

Figure 3. **A 3 cm white, crested barite sphere on pale green fluorite and pyrite from the Keene mine. Frank Melanson specimen; photo by Steven Chamberlain.**

tion of the Keene vein (Guillet, 1964). Detomac Mines Limited first opened the mine in 1944, but it was later operated by Huntingdon Fluorspar Mines Limited until 1959, when excessive water forced abandonment. The total production of ore was estimated at 11,566 tons (Guillet, 1964).

During its operation, the Kilpatrick mine produced some good specimens of pale green fluorite octahedrons and cubes on quartz. Some of the specimens recovered show a multiple intergrowth of cubes in a stair-step fashion.

Although these are extensive mine dumps, now mostly overgrown, the present owners do not permit collecting.

The Rogers Mine

First discovered in 1909, the Rogers mine was probably the most prolific specimen-producing mine in the Madoc area. It was operated by numerous individuals as both surface and underground workings, yielding approximately 45,000 tons of ore.

Fluorite crystals from the Rogers mine are commonly quite large (up to 25 cm across) and of clear, optical grade. Large caverns lined with such crystals were reportedly encountered in the underground workings (W. J. Symon, personal communication, 1975). The crystals are typically pale green and of cubic habit. The large, transparent green cube in the collection of the Royal Ontario Museum may very likely have come from the Rogers mine, although the possibility exists that it may be from the Perry mine (Wilson, 1929) or perhaps the Keene mine (J. Satterly, pers. comm., 1980).

In 1976 a few specimens of smaller crystals on barite were collected by the authors in two small prospect pits nearby (Figs. 4 and 5). However, collecting was limited due to the extremely shallow water table, and the easily available material was soon exhausted.

Of equal interest to collectors is the occurrence of boulangerite rings at the Rogers mine. Although these are strictly microscopic, their peculiar forms make them a popular collector's item. In 1977 a portion of the dumps which contained the boulangerite rings was removed for road fill. There is still good collecting potential on the property, but it too is privately owned and presently off limits to collectors.

The Perry and Perry Lake Mines

These two mines are situated on one vein, but mined from four unconnected shafts. The first mining operations were undertaken in 1910 by G. H. Gillespie and Stephen Wellington at the Perry Lake property. The Perry mine itself did not commence operations until five years later, under Stephen Wellington and William Cross. Reliance Fluorspar Mining Syndicate Ltd. assumed control of the Perry mine in the early 1940's, and of the Perry Lake property in the 1950's. In 1960, Huntingdon Fluorspar Mines Ltd. worked the Perry Lake property. The total production of ore from both properties was about 12,000 tons (Guillet, 1964).

These mines (particularly the Perry Lake) produced excellent, light green, transparent crystals of fluorite. Some fine small crystals showing the combination of cube and octahedron were found associated with barite on the dumps in the early 1970's. In 1977 the headframe became too dangerous and was torn down. The shaft was capped, and the dumps bulldozed into a swamp, so that collecting here is no longer possible.

The Noyes Mine

The Noyes mine was first discovered by Donald Henderson in 1916. The property was sold a year later to Messrs. Wellington and Munro, who worked it for about a year before selling to Canadian Industrial Minerals Ltd. Mining continued for an additional two years until 1920. After lying dormant for two decades, mining activity was once again briefly resumed by R. T. Gilman between 1941 and 1943. The total production of fluorite was estimated at 25,000 tons (Guillet, 1964).

During its sporadic operation, the Noyes mine produced many fine crystals of honey-yellow fluorite in cubes up to 3 cm across, some encrusted with a thin layer of pyrite. The red fluorite reported from the Noyes mine was, like that from the Keene mine, most probably clear fluorite colored red by included hematite. A few

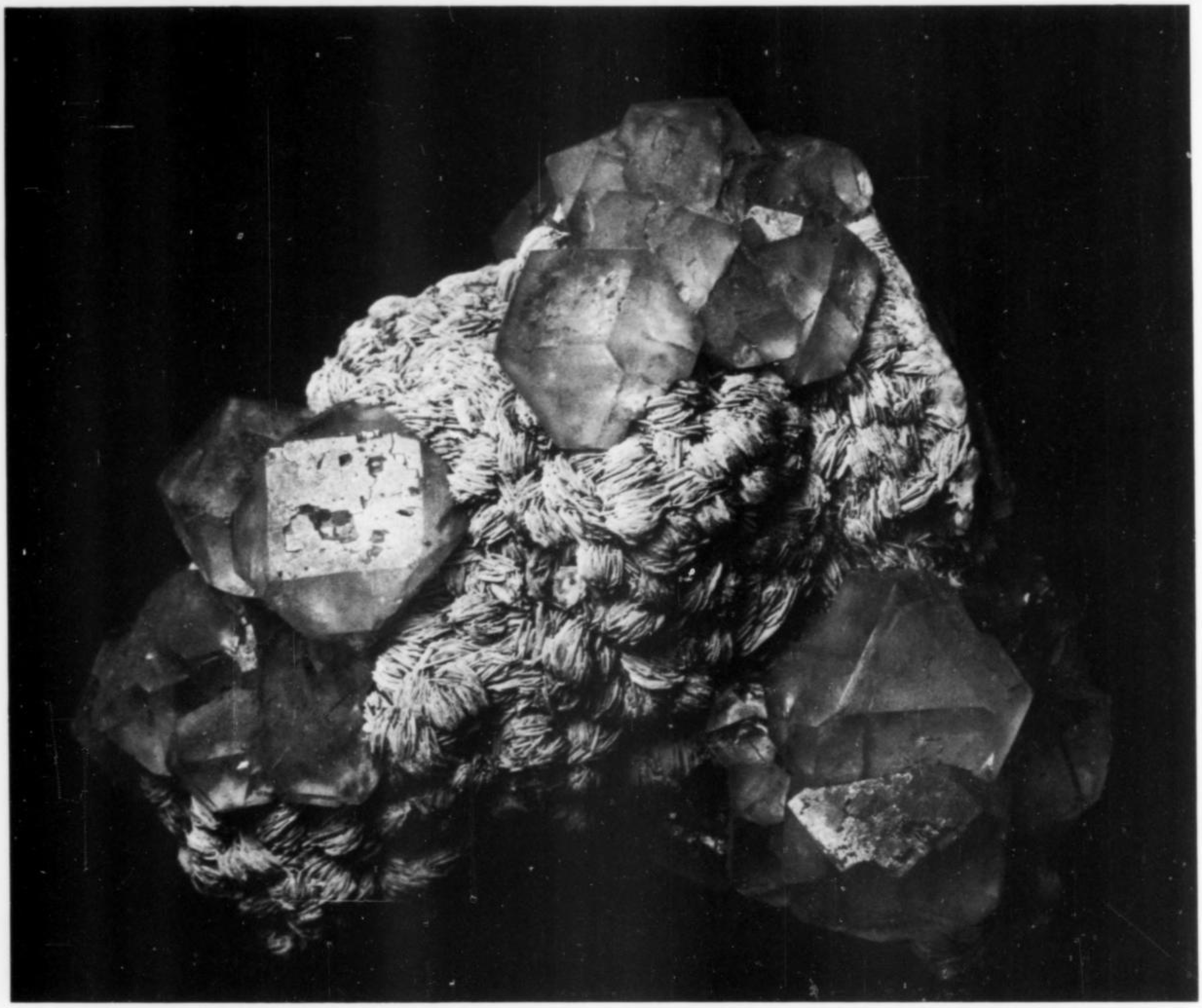

Figure 4. **Pale green crystals of fluorite on beige colored barite from the Rogers mine property (10 x 10 cm). Frank Melanson specimen; photo by Steven Chamberlain.**

clear, pale blue crystals of celestine were also found (Wilson, 1929).

Although the surface and underground workings are now inaccessible, recent collecting from the dumps has produced some interesting specimens of both yellow and dark blue fluorite.

The Coe Mine

Although the Coe property was prospected and worked intermittently by various individuals prior to 1960, it was not until that year that the first serious work was undertaken by Huntingdon Fluorspar Mines Ltd. A 12-meter shaft was sunk on the westernmost vein, and some good yellow fluorite cubes up to 2 cm were found. Economically, though, the overall production was discouraging, and mining was abandoned in 1961.

Today the shaft is capped, the surface pits have been bulldozed level, and grass grows over the Coe workings. No evidence of any mining activity remains, and digging is forbidden.

The Highway 7 Roadcut

In recent years much fluorite marketed as Madoc fluorite actually came from a roadcut on Highway 7, approximately 2 km east of the Deloro turnoff. Here a small fluorite vein cutting granite was exposed during highway construction in the late 1960's, and subsequently excavated by rockhounds to a depth of nearly 5 meters. Most specimens recovered are badly stained by iron oxide, and were usually cleaned in hydrochloric acid. The crystals from this locality are typically flattened, green cuboctahedrons, some with blue cores. Sometimes a thin layer of iron oxide separates the blue and green regions giving the illusion of a pink phantom crystal. Some of the darker green crystals were cut into gems. An exceptionally nice 112.5-carat stone of rich, peridot-green color is in the collection of the National Museum of Canada.

GEOLOGY

Madoc fluorite deposits typically consist of rhythmically banded barite-fluorite-calcite veins cutting both the Ordovician Black River limestone and the underlying Precambrian marbles and granites. Although the deposits are definitely post-Ordovician, their specific age has not yet been determined. The veins are typically situated on northwest-trending fault zones, "occupying lenticular fault cavities that resulted from the horizontal displacement of undulating fault walls" (Lalonde, 1974). Some of the cavities attained enormous proportions (3 x 20 meters) and were lined with crystallized fluorite, barite and calcite (P. Keller, pers. comm., 1979; W. J. Symon, pers. comm., 1975). Chemical weathering of the upper portions of some of the veins preferentially removed the less resistant constituents, resulting in a granular fluorite known locally as "gravel spar."

Much of the ore from the mines in the Lee-Miller group was of this type.

Most of the veins show characteristics typical of low temperature-low pressure hydrothermal deposits, and two theories have been proposed to account for their emplacement: 1) hydrothermal mineralization from deep-seated ascending solutions and 2) meteoric concentration through leaching of the surrounding limestones and redeposition in the fault cavities by descending solutions. There is some evidence to support each theory, and neither has as yet been conclusively proven. A fuller discussion of the problem is presented by Wilson (1929) and later authors. The lack of deep drilling records and present inaccessibility to the mines precludes further speculation here.

MINERALOGY

The mineralogy of the Madoc fluorite mines is rather simple, as may be expected, with fluorite, barite, calcite and celestine comprising the bulk of the collectible species. Fluorite and barite are undoubtedly the two most noteworthy species from the collector's viewpoint and, in addition to the boulangerite rings from the Rogers mine, are probably the most sought-after minerals from these mines.

Only those species of immediate interest to collectors will be described here; most of the others occur as rather poor quality, uninteresting specimens. Table 1 summarizes the occurrence of these additional species.

Barite

Next to fluorite, barite is the most abundant mineral in the Madoc fluorite mines. It occurs in a variety of colors, including beige, pale blue, red and yellow, but white is by far the most common. It is most commonly massive, interbanded with fluorite and calcite, but stalactitic, columnar, nodular, fibrous and ocherous varieties have also been found. Probably the most commonly encountered habit of crystallization is cauliflower-like domes of small tabular crystals, although Wilson (1929) reports single crystals over 2 cm in diameter. The most frequently observed forms are {100}, {001}, {110}, {011} and a series of macrodomes.

Boulangerite

Boulangerite occurs with calcite, sphalerite and fluorite at the Rogers mine. Acicular crystals to 2 cm have been found. The most interesting forms, however, are the rings, cylinders and coils. Although these peculiar structures are microscopic (their maximum diameters are less than 0.25 mm), they are of special interest to micromounters, and have been the subject of much attention (Caesar, 1966; Bideaux, 1970; Mielke, 1977). It is suspected they formed by nucleation around oil droplets in relatively cool, dilute, alkali solutions (Mielke, 1977).

Calcite

Calcite is found in all the mines as a major constituent of the vein material. Milky white to translucent crystals are occasionally found. Most of these seldom exceed 10 cm, and are generally not of high quality. The common forms are the simple rhombohedron and scalenohedron. Twinning is relatively common, and some pieces exhibit a weak red fluorescence in ultraviolet light.

Celestine

Celestine occurs both as radiating, fibrous aggregates up to a meter in diameter, and as pale blue transparent crystals. The fibrous variety was found chiefly at the Keene mine, and forms the matrix for many of the bright, optical grade fluorite cubes for which the mine was famous. Wilson (1929) reports tabular, clear blue crystals of celestine up to 2.5 cm in diameter from the 250-foot level of the Noyes mine. Forms observed include {001}, {102}, {011} and {110}.

Figure 5. **A 5 x 7-cm group of sea-green fluorite crystals from the Rogers mine property. George and Susan Robinson specimen; photo by Steven Chamberlain.**

Table 1. **Some additional accessory minerals of the Madoc fluorite mines.**

Species	Occurrence	Reference
Bindheimite	Rogers mine	Mielke (1977)
Chalcocite	Bailey mine	Wilson (1929)
Chalcopyrite	Stewart property	Guillet (1964)
Galena	Rogers mine	Mielke (1977)
Hematite	Kilpatrick mine	Guillet (1964)
	Rogers mine	Mielke (1977)
Hemimorphite	Rogers mine	Mielke (1977)
Hydrocarbons	Rogers mine	Mielke (1977)
"*elaterite*"	Noyes mine	Wilson (1929)
Malachite	Stewart property	Guillet (1964)
Marcasite	Bailey mine	Guillet (1964)
	Rogers mine	Mielke (1977)
Microcline	Rogers mine	Mielke (1977)
Phlogopite	Rogers mine	Mielke (1977)
Pyrite	Perry Lake mine	Guillet (1977)
	Noyes mine, Hill mine	Wilson (1929)
Quartz	Keene mine, Bailey mine	Wilson (1929)
Semseyite	Rogers mine	Mielke (1977)
Sphalerite	Rogers mine	Mielke (1977)
	Blakely mine	Guillet (1964)
Tetrahedrite	Bailey mine	Wilson (1929)
Tourmaline	Kilpatrick mine	Guillet (1964)

Fluorite

Fluorite occurs interbanded with calcite and/or barite at all the mines. Large crystals and crystal groups have been found. The predominant forms are the cube and octahedron, suggesting a relatively low temperature of formation (Yermakov, 1965). However, Walker (1919) observed the following additional forms on crystals from the Keene mine: {110}, {310}, {441} and {322}. The most common colors are green and colorless to gray, but yellow, blue and pink specimens have been found.

It is impossible to select any one mine as having produced the best specimens; excellent crystals have been found in a number of the workings. Probably most of the best specimens have come from the Keene, Bailey, Perry and Rogers mines, all of which produced lustrous, optical-grade crystals.

DISCUSSION

Although paragenetic sequences may be determined for specific zones within a given vein, multiple zonation and the rhythmical nature of the fluorite-barite-calcite deposition makes it extremely difficult to determine the depositional sequence of the deposits as a whole. Studies of the Rogers mine indicate overall changes from low $f\,O_2$ and $f\,F_2$ to high $f\,O_2$ and $f\,F_2$, and from low total S to high total S (Mielke, 1977). Most of these deposits were probably emplaced at relatively low temperatures by solutions of near neutral pH, but the origin of these solutions still remains a mystery.

The major specimen-producing mines are not presently working and, if the past trend continues, will likely be bulldozed over. Property owners are not anxious to let anyone collect at these sites because the liability for any injuries could be significant. Thus, short of a major mining revival in the Madoc area, any hope of more specimen production in the future is rather dim.

ACKNOWLEDGEMENTS

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A Re-examination of the Madoc Sulfosalts

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INTRODUCTION

The Lengenbach quarry of Switzerland is a world-renowned source of rare sulfosalt minerals, several of which have remained unique to that locality for the more than three-quarters of a century since their discovery. As chronicled recently by Graeser (1977), most of the Lengenbach sulfosalts are characterized by a generalized formula of the type $Me_x(As,Sb,Bi)_yS_z$, where *Me* represents various metals, predominantly Pb, Tl, Cu and Ag. Also distinctive is the overwhelmingly arsenic-rich nature of the Lengenbach sulfosalts, with antimony rare and bismuth negligible; thus, many of the minerals from the Swiss deposit have compositions that represent arsenic end-members of possible As-Sb-Bi solid-solution series.

Known considerably less well than the famous Lengenbach quarry is a sulfosalt occurrence at Madoc, Ontario (Fig. 1). The occurrence is notable in that, not only is it the type locality for several lead-antimony sulfosalts, but some of these were originally described and named as antimony analogues of Lengenbach minerals.

Although not well known for its sulfosalts, Madoc is famous as a former source of fluorite specimens that came from more than 30 now-dormant mines in the area. Fluorite mining peaked during 1916–1920, and 1940–1951. In the early 1920's, field parties led by M. E. Wilson of the Geological Survey of Canada mapped the mine workings and regional geology. Field notes from this period show that on July 5, 1924, one of Wilson's assistants examined a cluster of small prospect pits in marble and collected a few sphalerite-rich grab samples from one of them. Evidently some work on the material was done, as the host marble had been dissolved and the liberated sulfides and silicates were stored in a glass vial in the National Mineral Collection in Ottawa. The accompanying penciled label is in the handwriting of the late H. V. Ellsworth and identifies the material as "Morley Wilson's mineral from lot 12, conc. XIV, Huntingdon Twp. It is probably jamesonite with pyrite, arsenopyrite and possibly galena. See analysis." That the sulfosalt assemblage is considerably more complex than indicated on the label was recognized in the early 1960's (Jambor, 1962). Subsequently, the original prospect pits were rediscovered with the aid of the 1924 field notes.

GENERAL GEOLOGY

The rocks in the Madoc area are Precambrian metasediments and metavolcanics cut by Precambrian intrusions consisting principally of granite. All these rocks are partly overlain by Ordovician limestone. The fluorite deposits are almost vertical veins with associated barite and calcite that cut both the Ordovician limestones and Precambrian rocks. Individual deposits are described by Wilson (1921, 1929) and Guillet (1964). A detailed geological map of the area is given by Hewitt (1968).

The Madoc sulfosalts occur in steeply dipping white to dark gray, banded, micaceous calcite-dolomite marbles near their contact with medium-grained, pink Precambrian granite. The sulfosalt site is in the northwestern corner of lot 13 rather than lot 12, and consists of a shallow pit about 10 m long and 1 m wide. Reference by Segeler (1977) to the former Rogers fluorite mine as being the sulfosalt site may have been prompted by the reports of Caesar (1966) and Bideaux (1970) in which boulangerite from the Rogers mine was included. Boulangerite and sphalerite occur sparingly as disseminated specks throughout the fluorite-bearing part of the Madoc area.

SULFOSALTS

Of the seventeen lead-bearing sulfantimonides identified in the Madoc assemblage (Table 1), Madoc is the type locality for more than half. The bulk of the sulfur-bearing assemblage consists of dark brown sphalerite and abundant boulangerite and jamesonite, all of which are commonly accompanied by fine-grained euhedral arsenopyrite and pyrite. The other sulfosalts occur in only small amounts and are difficult to identify because their physical properties are similar and intergrowths are common. However, the minerals have distinctive X-ray powder patterns and can be reliably identified by this method, even with a 57 mm-diameter camera; an exception is that the distinction between twinnite and guettardite is most easily made on larger films.

The physical properties and X-ray data for the sulfosalts unique to Madoc are given by Jambor (1967a, b) and will not be repeated here. Even though analyses have been obtained for most of the sulfosalts, a continuing concern with these minerals is the conversion of the analytical results into an appropriate formula. The main problem, which is by no means restricted only to Madoc sulfosalts, is that the analytical results can be translated into several possible formulas in which the weight percentages of the elements do not differ by great amounts. Although the correspondence between measured versus calculated densities is invaluable in discriminating various formula possibilities, in some instances measured densities cannot be obtained because of the small amount of material available. This deficiency applies to most of the Madoc suite.

Figure 1. **Location map for Madoc.**

MICROPROBE ANALYSES

In the early 1960's, when the initial work on the new sulfosalts was done, electron microprobe techniques and instrumentation generally had not reached an advanced stage of development in North America, and results were not as precise as are obtainable now. Difficulties in determining compositions of Pb-Sb-As-S minerals still remain, mainly because of a lack of suitable microprobe standards, but some improvement on the older analyses is possible. Therefore, many of the Madoc sulfosalts have been reanalyzed to obtain the results reported here.

Small batches of the loose sulfosalt material from the 1924 collection were spread on white paper, carefully examined under a binocular microscope, and about 25 fragments eventually were selected for scanning electron microscopy. The grains were photographed, checked for identification by powder X-ray diffraction, and prepared as polished sections for microscopic examination and microprobe analyses. The latter were obtained with a Materials Analysis Company 400 instrument operated at 25 kV and a specimen current of 0.030 microamperes. Dadsonite and launayite were analyzed at 20 kV. The X-ray lines and standards used in the study were: PbMα (synthetic galena; CuKα (chalcostibite, synthetic tetrahedrite); FeKα (argentopyrite, synthetic tetrahedrite, jamesonite); AgLα, BiMα (synthetic matildite and silver); AsLα (enargite, synthetic $CoAs_2$); SbLα and SKα (chalcostibite, meneghinite, jamesonite, boulangerite, zinkenite–$6PbS{\cdot}7Sb_2S_3$); ClKα (halite). The microprobe data were processed with a computer program modified from EMPADR VII. The limits of detection for Ag, Fe, Cu, and Cl are approximately 0.05, 0.03, 0.03 and 0.04 weight percent.

Table 1. **Sulfides and sulfosalts from Madoc.**

Simple sulfides	
sphalerite	$(Zn,Fe)S$
pyrite	FeS_2
galena	PbS
chalcopyrite	$CuFeS_2$
Sulfosalts	
arsenopyrite	$FeAsS$
*"baumhauerite"	$Pb_3(Sb,As)_4S_9$
boulangerite	$Pb_5(Sb,As)_4S_{11}$
bournonite	$PbCu(Sb,As)S_3$
dadsonite	$Pb_{23}Sb_{25}ClS_{60}$
geocronite	$Pb_{27}(Sb,As)_{14}S_{48}$
*guettardite	$Pb(Sb,As)_2S_4$
jamesonite	$Pb_4FeSb_6S_{14}$
*launayite	$Pb_{22}(Sb,As)_{26}S_{61}$
*madocite	$Pb_{17}(Sb,As)_{16}S_{41}$
*playfairite	$Pb_{16}(Sb,As)_{18}S_{43}$ (?)
robinsonite	$Pb_4Sb_6S_{13}$
semseyite	$Pb_9Sb_8S_{21}$
*sorbyite	$Pb_{17}(Sb,As)_{22}S_{50}$ (?)
*sterryite	$Pb_{10}Ag_2(Sb,As)_{12}S_{29}$
tetrahedrite	$Cu_{12}(Sb,As)_4S_{13}$
*twinnite	$Pb(Sb,As)_2S_4$
*veenite	$Pb_2(Sb,As)_2S_5$
zinkenite	$Pb_6(Sb,As)_{14}S_{27}$

*Sulfosalts for which Madoc is the type locality. "Baumhauerite," launayite, playfairite, sorbyite, and sterryite have not yet been found elsewhere.

Two of the polished sections containing analyzed grains have been deposited in the Royal Ontario Museum, Toronto, and the remainder are in the National Mineral Collection, Ottawa. Reference numbers in the succeeding text are prefixed by M and NMC to indicate the respective depositories.

Veenite, approximately $2PbS{\cdot}(Sb,As)_2S_3$, is the antimony analogue of dufrenoysite. The Madoc mineral contains appreciable arsenic (Table 2) and the pure Sb member is not known naturally nor in synthetic systems. However, arsenic-bearing veenite has been obtained by hydrothermal synthesis in the $PbS-Sb_2S_3-As_2S_3$ system (Bortnikov *et al.,* 1978), and dufrenoysite with up to 45 mole percent Sb_2S_3 has been obtained by dry synthesis (Walia and Chang, 1973).

Veenite was the most abundant of the new sulfosalts in the 1924 collection, and this position has been maintained in newly collected material. Most veenite is massive and megascopically resembles tetrahedrite, but the latter is rare at Madoc. Bladed grains of veenite have been observed, but stubby crystals (Fig. 2) are more typical.

Madocite has not been found as single crystals, but elongate, multi-crystal grains are known (Fig. 3). A new analysis (Table 2) corresponds to $Pb_{18}(Sb,As)_{15}S_{41}$, equivalent to $17PbS{\cdot}7(Sb,As)_{2.02}S_{3.10}$, whereas the formula was originally proposed to be $17PbS{\cdot}8(Sb,As)_2S_3$. Walia and Chang (1973) reported the synthesis of madocite between the composition range $3PbS{\cdot}(Sb,As)_2S_3$ and $5PbS{\cdot}2(Sb,As)_2S_3$; this range is equivalent to $17PbS{\cdot}x(Sb,As)_2S_3$ where x is 5.7 to 6.8. From calculations of densities for the various possible formulas, the original formula seems to fit best and is retained.

Table 2. **Microprobe analyses of veenite, madocite.**

weight percent	Veenite ROM M 35895	Madocite ROM M 35896
Pb	51.2	54.5
Cu	0.08	n.d.
Fe	n.d.	n.d.
Ag	0.09	n.d.
Sb	19.1	23.1
As	7.9	2.2
S	21.2	19.3
Cl	n.d.	n.d.
	99.47	99.1
atomic proportions		
Pb	1.90	17.95
Cu	0.01 }1.92	
Ag	0.01	
Sb	1.21 }2.02	12.97 }14.95
As	0.81	1.98
S	5.06	41.10
Ideal Formula	$2PbS \cdot (Sb,As)_2S_3$	$17PbS \cdot 8(Sb,As)_2S_3$

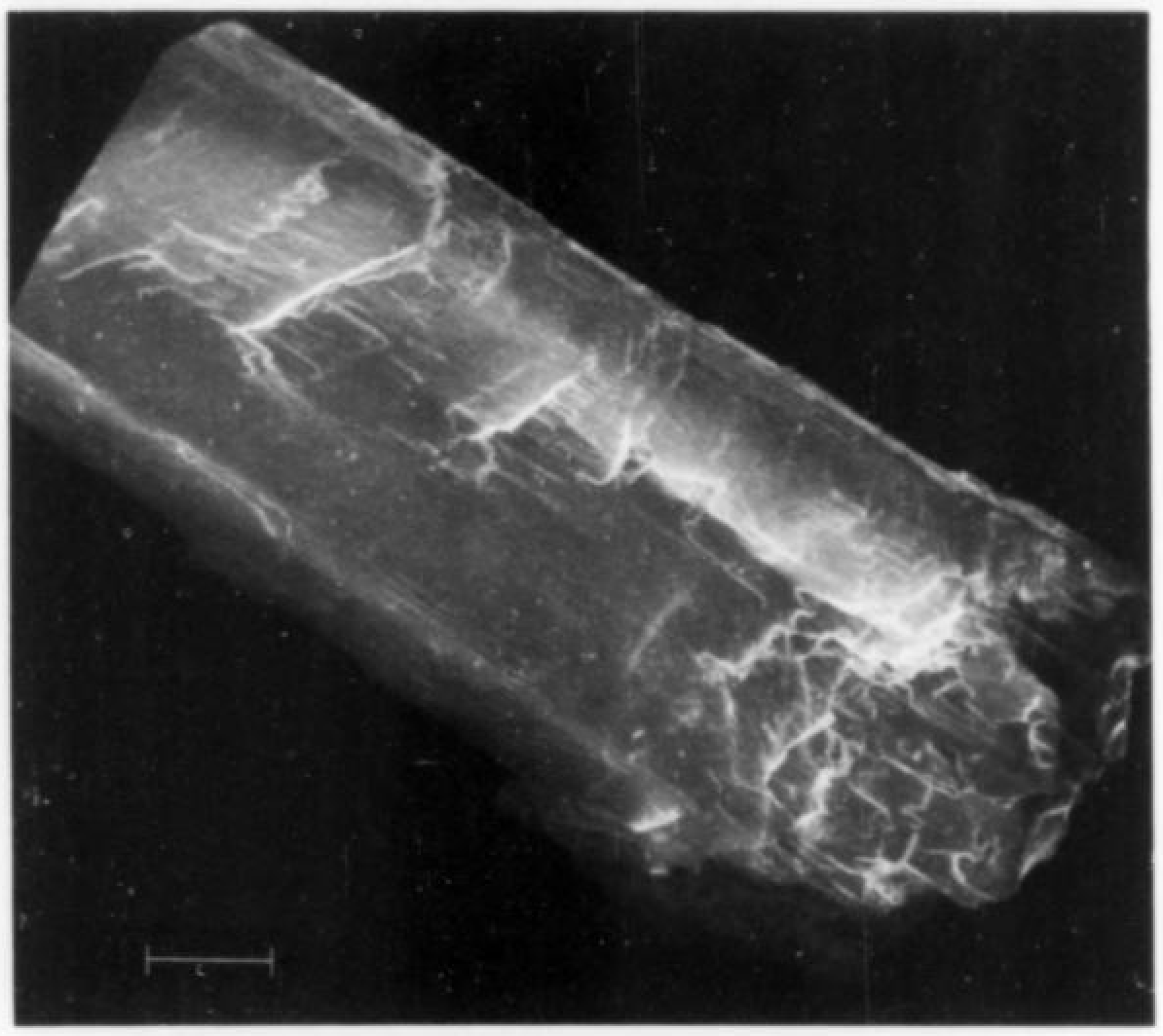

Figure 2. **Typical stubby crystal form of veenite. Bar represents 100 μm. Figures 2-9 inclusive are SEM photographs.**

Launayite is relatively rare and no new grains were found in the present study. Consequently, a cotype specimen in polished section was re-analyzed (Table 3). A small amount of copper was detected in the new analysis, but its non-essential character is evident in that launayite has been synthesized in the pure $PbS-Sb_2S_3$ system (Nekrasov and Bortnikov, 1977). The new analysis fits well with the formula originally proposed, $22PbS \cdot 13(Sb,As)_2S_3$.

Playfairite occurs as a minor constituent in the launayite polished section, and was also found as a minor component associated with madocite and with jamesonite (M 35896 and M 35893, respectively). New microprobe analyses of these playfairite grains give results that differ appreciably from the original, from which the formula $16PbS \cdot 9(Sb,As)_2S_3$ was proposed (Table 4). However, the new results are somewhat closer to the weight percentages required for the theoretical formula. If the small amount of chlorine in playfairite is ignored, the analyses are also close to $8PbS \cdot 5(Sb,As)_2S_3$ and

Figure 3. **Multi-crystal madocite with euhedral arsenopyrite aggregate. Bar represents 100 μm.**

$5PbS \cdot 3(Sb,As)_2S_3$, but neither of these has a calculated density close to that expected from the PbS/Sb_2 ratios.

An alternative to retaining the original formula of playfairite is to isolate its low chlorine content as a single formula atom. This procedure has been followed by Moëlo (1978, 1979) to derive a new formula for dadsonite, in which Cl is added as $PbSbClS_2$. However, the microprobe analyses for Cl in playfairite require additional investigation because the quantitative results obtained for Cl in dadsonite (Table 8) are not satisfactory.

Sterryite occurs as loose grains in the 1924 material and characteristically consists of bundles of acicular crystals that terminate as tufts or brush-like masses (Figs. 4, 5 and 6). The original analyses

Table 3. **Microprobe analyses of launayite, NMC 61062.**

	Previous*	Grain A	Grain B
Pb	48.5	45.0	44.9
Cu	n.d.	1.3	1.4
Fe	n.d.	n.d.	n.d.
Ag	n.d.	n.d.	n.d.
Sb	29.5	30.9	31.8
As	1.5	1.8	1.7
S	21.25	20.9	20.8
Cl	–	n.d.	n.d.
	101.75	99.9	100.6
		atomic proportions	
Pb		20.27 }22.14	20.18 }22.23
Cu		1.87	2.05
Sb		23.72 }25.96	24.27 }26.41
As		2.24	2.14
S		60.90	60.35
Ideal formula		$22PbS \cdot 13(Sb,As)_2S_3$	

*Average of 2 analyses in Jambor (1967b).

Table 4. **Microprobe analyses of playfairite.**

	Previous*	NMC 61062	ROM M 35893	ROM M 35896
Pb	51.0	46.2	46.6	47.2
Cu	–	0.24	0.08	n.d.
Fe	–	n.d.	n.d.	n.d.
Ag	–	n.d.	0.21	n.d.
Sb	28.0	29.6	28.9	28.2
As	2.4	2.8	2.5	2.8
S	18.8	20.5	20.6	20.3
Cl	–	0.28	0.15	0.18
	100.2	99.62	98.89	98.68
		atomic proportions		
Pb		7.94	15.14	15.46
Cu		– }8.01	0.07 }15.35	–
Ag		0.07	0.14	–
Sb		8.65 }9.97	15.95 }18.17	15.74 }18.25
As		1.32	2.22	2.51
S		22.74 }23.02	43.21 }43.48	42.94 }43.28
Cl		0.28	0.27	0.34

*Average of 3 analyses of Jambor (1967b).

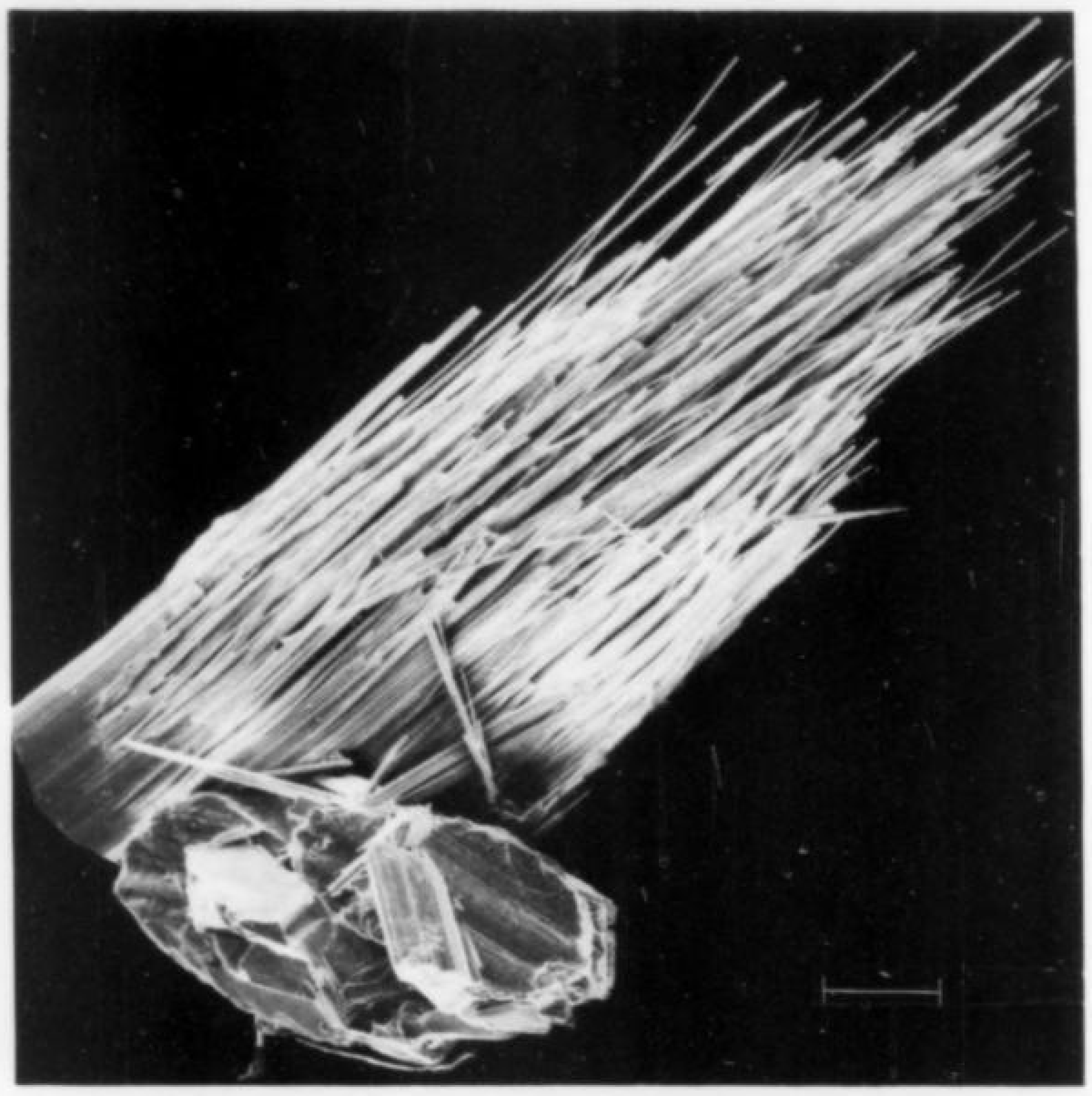

Figure 5. **Typically fibrous sterryite, with arsenopyrite at base. Bar represents 100 μm.**

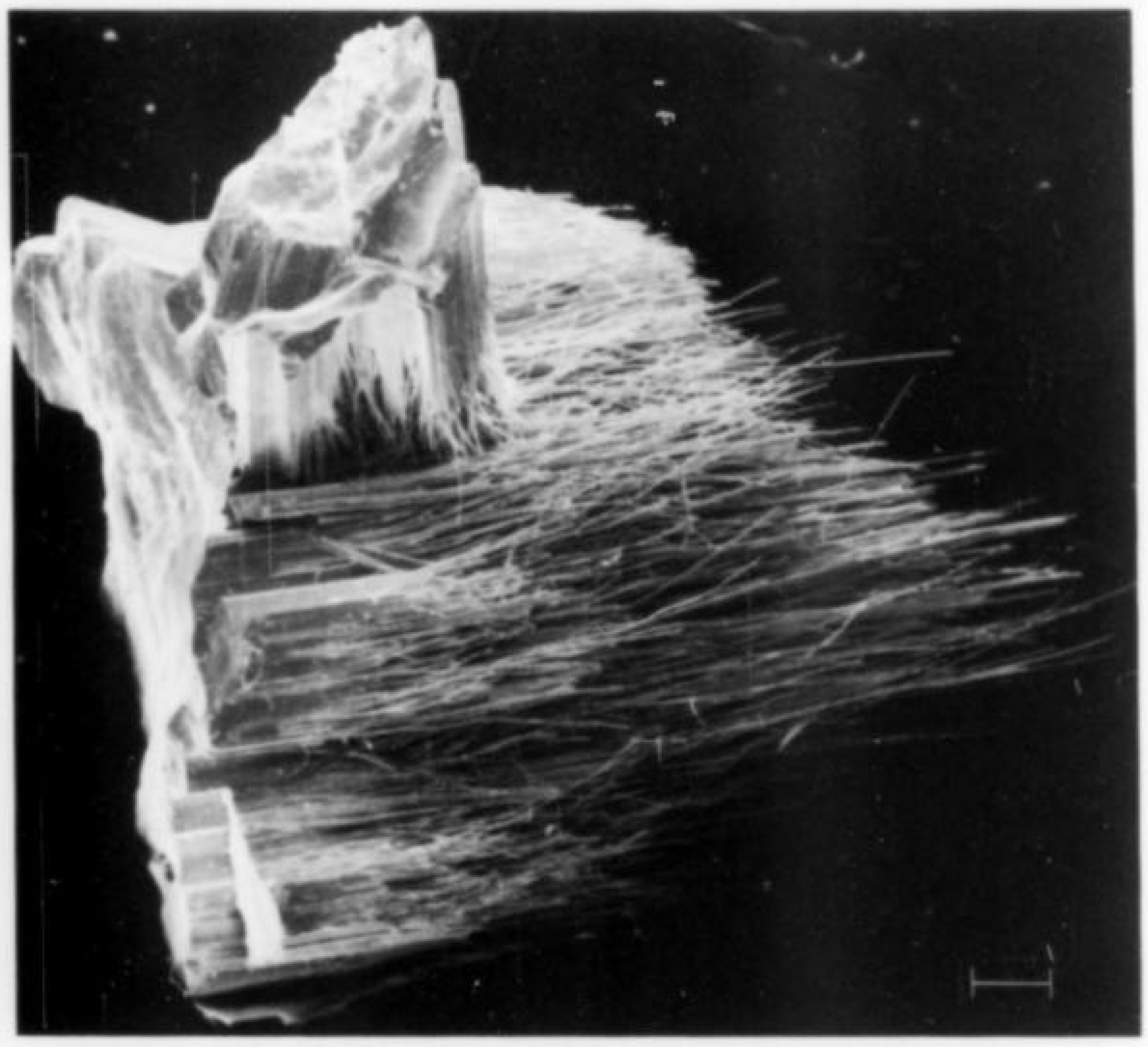

Figure 4. **Characteristic fibrous bundles and tuft-like termination of sterryite. Bar represents 100 μm (M 35894).**

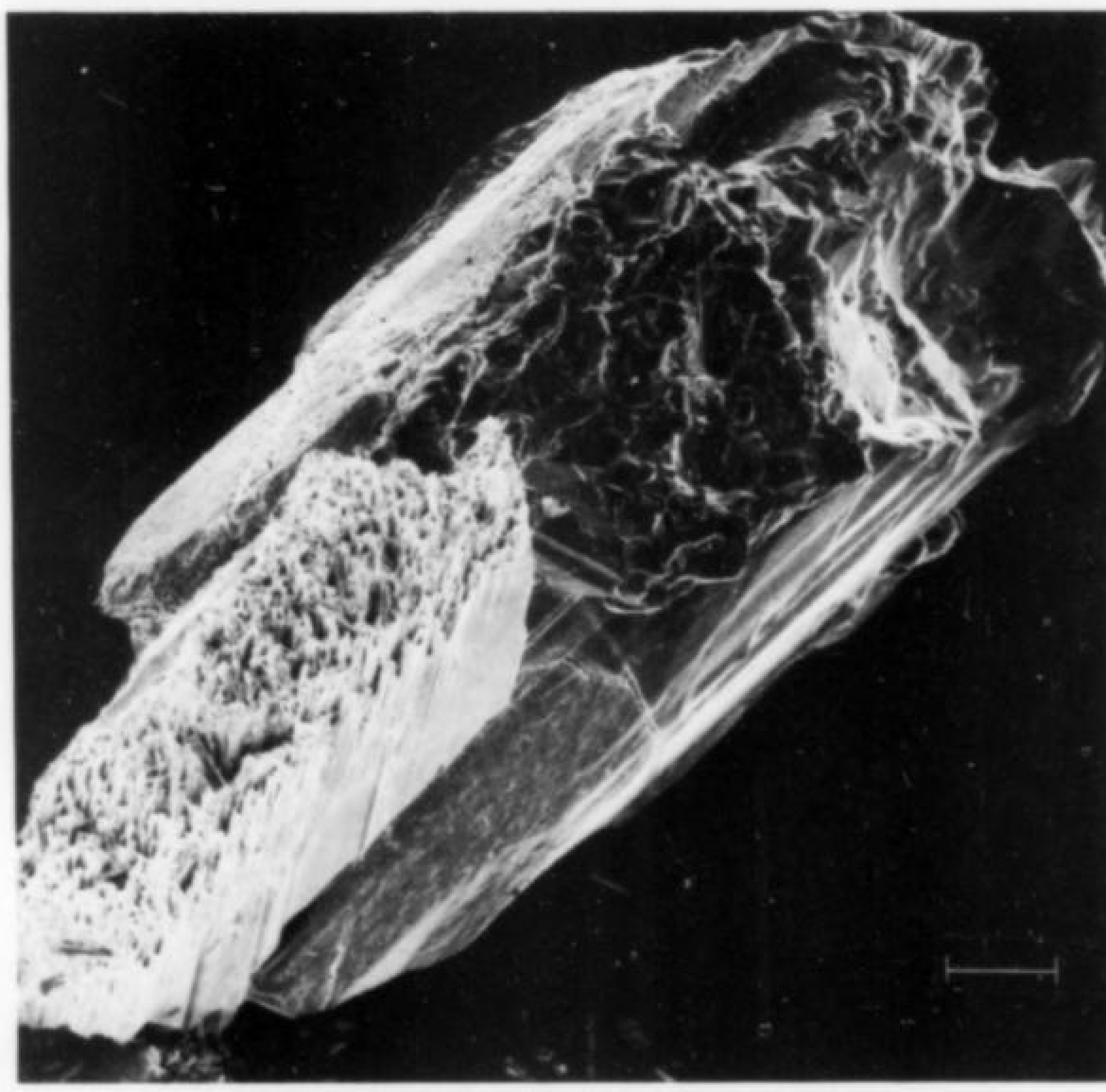

Figure 6. **Stubby, broken crystal of guettardite with brush-like clump of sterryite at base. Bar represents 100 μm (M 35890).**

of sterryite were among the poorest obtained for the Madoc sulfosalts, partly because the fibrous material was unstable under the electron beam. Optical spectrographic analysis did not confirm the apparently low Ag and Cu that had been detected by microprobe.

New microprobe analyses of the grains shown in Figures 4 and 7 give compositions somewhat different from those obtained previously, especially with respect to Ag content (Table 5). Therefore, a thorough search was made for more material and 12 additional grains were mounted in a single polished section for analyses. The average and range of these results are shown in Table 5. For the 14 new analyses, the composition of sterryite averages $(Pb_{1.68}Cu_{0.10}Ag_{0.24})_{\Sigma 2.02}(Sb_{1.42}As_{0.62})_{\Sigma 2.04}S_{4.94}$, very close to $2PbS \cdot (Sb,As)_2S_3$. The latter formula corresponds to that of veenite, as was described above, and other compounds approximating $2PbS \cdot Sb_2S_3$ have been synthesized by Sugaki *et al.* (1973) and Wang (1973, 1977). None of these corresponds to sterryite, and in fact sterryite is the only one of the new Madoc sulfosalts that has not yet been synthesized.

The persistent presence of small amounts of silver in sterryite indicates the probability that the element is an essential component, and that the mineral does not belong in the pure Pb-Sb-As-S system. Assuming Ag is essential, the new formula can be written as $Pb_{10.08}(Ag,Cu)_{2.04}(Sb,As)_{12.24}S_{29.64}$, theoretically $Pb_{10}Ag_2(Sb,As)_{12}S_{29}$. The theoretical Ag-Sb end-member formula yields D_{calc} 6.263 g/cm^3 for 8 formula weights in the true cell, and the average analytical formula yields D_{calc} 6.088 g/cm^3. This new formula with Ag as a separate entity is preferred and represents a major revision from the original proposal of $12PbS \cdot 5(Sb,As)_2S_3$ for sterryite.

Table 5. **Microprobe analyses of sterryite.**

wt per- cent	Original analyses (Jambor, 1967b)		M 35891 (Fig. 7)	M 35894 (Fig. 4)	NMC 61066 Av.	Range, 12 grains
Pb	44.5	47	45.7	46.5	45.43	44.6 -45.9
Cu	tr	n.d.	0.76	0.76	0.86	0.75- 0.97
Fe	—	—	n.d.	n.d.	n.d.	n.d.
Ag	«0.5	n.d.	3.7	3.1	3.39	3.1 - 3.8
Sb	21	23	21.6	22.3	22.63	20.5 -26.6
As	5.5	6	6.4	5.5	6.18	2.9 - 8.3
S	21.5	20.5	20.7	20.6	20.76	20.3 -21.1
Cl	—	—	n.d.	n.d.	n.d.	n.d.
	92.5	94.5	98.86	98.76	99.25	

Figure 7. **Platy sterryite (st) on massive guettardite. Bar represents 100 μm (M 35891).**

Twinnite, $PbS{\cdot}(Sb,As)_2S_3$, is the antimony analogue of sartorite. The latter occurs as the arsenic end-member at Lengenbach. The type locality for twinnite is Madoc, but the mineral also has been reported to occur at Jas Roux, France (Picot and Johann, 1977).

Twinnite is rare at Madoc and no new grains were found in the present study. Results from the re-analysis of a cotype specimen are given in Table 6.

Guettardite physically resembles twinnite. That the two minerals are structurally related is evident from the similarity of their powder and single-crystal X-ray patterns (Jambor, 1967b). Both minerals have lattice translations of 7.9Å and 8.4Å, a feature characteristic of the rathite-group sulfosalts of Lengenbach (Ozawa and Nowacki, 1974).

The original analyses of guettardite gave results close to $6PbS{\cdot}5(Sb,As)_2S_3$, but on theoretical grounds it was suggested that the formula might be $9PbS{\cdot}8(Sb,As)_2S_3$. The new analyses (Table 6) indicate that guettardite may be dimorphous with twinnite. However, it is felt that small departures from stoichiometry more likely account for the structural differences. The adoption of a particular structure is apparently not dependent on Sb-As content: twinnite has the highest Sb/As ratio (Table 6) but is the more closely related to sartorite ($PbS{\cdot}As_2S_3$). Guettardite has somewhat

Table 6. **Microprobe analyses of twinnite and guettardite.**

	Twinnite	**Guettardite**			
wt percent	NMC 12175	M 35890 (Fig. 6)	M 35891 (Fig. 7)	NMC 61066 (grain 3)	NMC 12173 (grain 6)
Pb	39.3	39.0	39.1	38.8	39.6
Cu	n.d.	0.05	n.d.	n.d.	n.d.
Sb	28.1	25.9	25.2	24.1	24.2
As	8.9	10.6	11.3	12.2	11.8
S	23.7	24.0	24.2	24.1	23.9
	100.0	99.55	99.8	99.2	99.5
	atomic proportions				
Pb	1.04	1.02	1.02	1.01	1.03
Sb	1.26 }1.91	1.15 }1.92	1.11 }1.92	1.07 }1.95	1.08 }1.95
As	0.65	0.77	0.81	0.88	0.86
S	4.04	4.05	4.06	4.05	4.03
Sb/As	1.94	1.49	1.37	1.22	1.26

Fe, Ag, Cl not detected; Cl not determined for twinnite.

variable Sb/As (Table 6) and was synthesized by Walia and Chang (1973) at the composition $PbS{\cdot}(Sb_{0.59}As_{0.50})_2S_3$.

Although the synthesis of guettardite by Jambor (1968) and Walia and Chang (1973) was achieved by heating dry charges, twinnite was not obtained under these conditions. Interestingly, both twinnite and guettardite were obtained by Bortnikov *et al.* (1978) using hydrothermal methods.

Sorbyite was found as crystal fragments in both the original and present studies (Figs. 8 and 9). The grains are usually multiple rather than single crystals, but one well-formed needle has been found (Fig. 9). In order to re-examine the apparently enormous cell obtained in the original single-crystal study, the needle was broken into fragments and two of these, one with the needle axis horizontal and the other with the axis vertical, were mounted in polished section. Microscopic and microprobe checks indicate that the fragments were homogeneous and without visible twinning. The unmounted remainder of the needle is being used for an X-ray study that is still in progress.

The formula $17PbS{\cdot}11(Sb,As)_2S_3$ was originally assigned to sorbyite because it provided a plausible match between the analytical results and calculated density. The new analysis (Table 7) is close to $19PbS{\cdot}10(Sb,As)_2S_3$, which in terms of the original formula is $17PbS{\cdot}9\text{–}10(Sb,As)_2S_3$. However, possible revision of the sorbyite formula will be delayed until the single-crystal restudy has been completed.

Dadsonite was originally designated as mineral Q (Coleman, 1953) and QM (Jambor, 1967b) because of its incompletely known

Table 7. **Microprobe analysis of sorbyite, M 35892.***

	wt percent		atomic ratios
Pb	46.6		
Cu	1.2		
Fe	n.d.	Pb	17.34
Ag	0.17	Cu	1.46 }18.95
Sb	26.3	Ag	0.15
As	3.5	Sb	16.64 }20.26
S	20.7	As	3.62
Cl	n.d.	S	49.78
	98.47		

*Fig. 8.

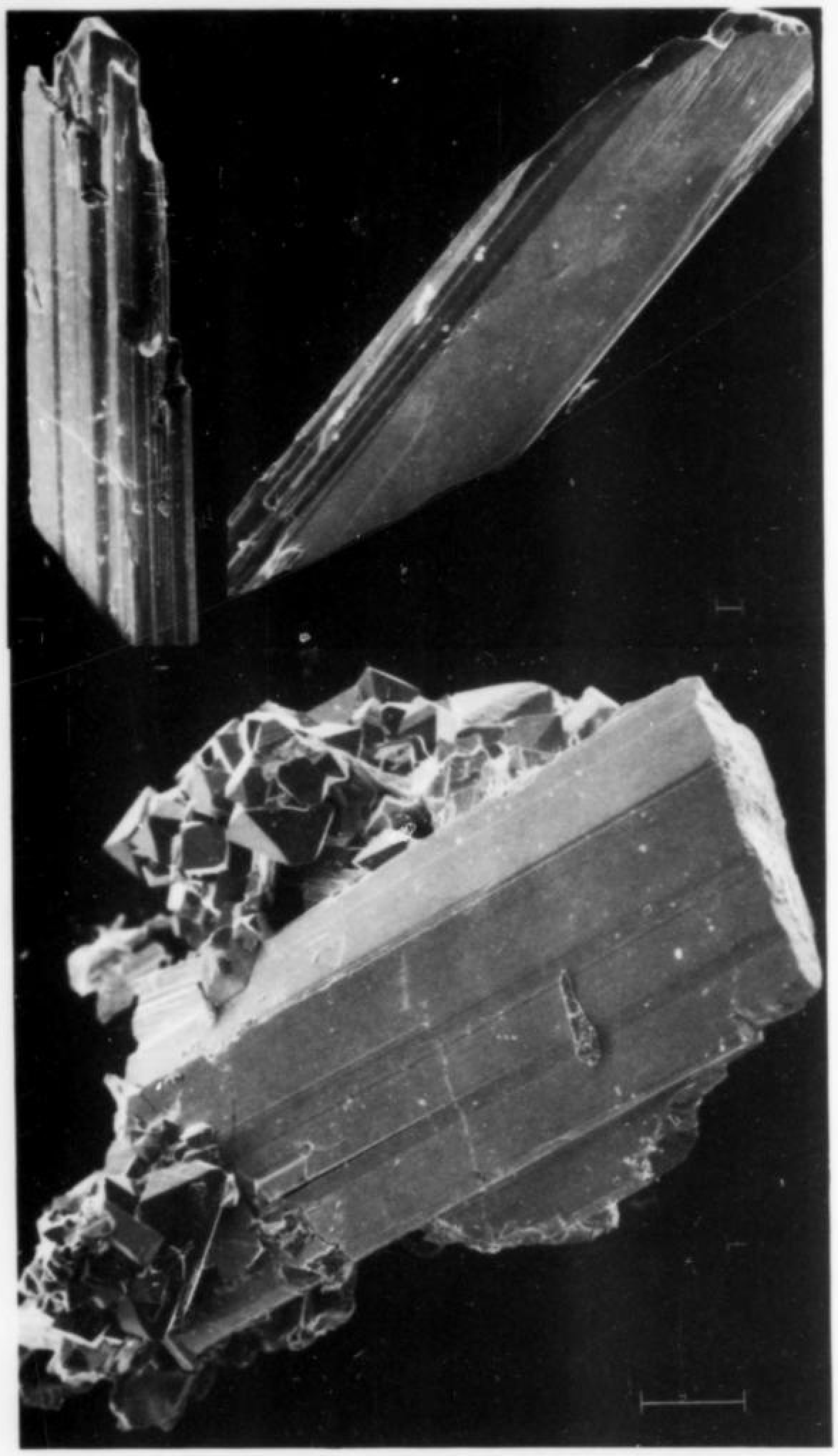

Figure 8. **Upright, multiple crystals of sorbyite (top). Bar represents 10 μm.** ***Bottom:*** **sorbyite with euhedral arsenopyrite. Bar represents 100 μm (M 35892).**

chemistry, and was named when the discovery of additional material from Wolfsberg, Germany, permitted a more complete description of the mineral (Jambor, 1969). New analyses of the Wolfsberg and Madoc dadsonite, and of newly discovered material from St-Pons, France, (Moëlo, 1979) are given in Table 8. Moëlo (1978, 1979) was the first to note the consistent presence of chlorine in dadsonite, and he has concluded that the mineral is a chlorsulfantimonide with the formula $Pb_{23}Sb_{25}ClS_{60}$. The Cl values in Table 8 are lower than the 0.4 weight percent obtained by Moëlo for St-Pons and Wolfsberg material, but results for the other elements agree well. Chlorine values obtained for playfairite (Table 4), which is the only other Cl-bearing sulfosalt at Madoc, may have to be revised upwards.

"Baumhauerite" is rare at Madoc, but the mineral is of special interest in that the original microprobe analyses yielded Sb:As mole ratios of about 1:1. Thus, because of the analytical uncertainty, it has not been known whether the Madoc mineral is antimony-rich baumhauerite, or whether it is in fact the antimony analogue of baumhauerite. New microprobe analyses of two grains mounted in a single polished section showed that the grains have slightly differ-

Table 8. **Microprobe analyses of dadsonite.**

	Wolfsberg, Germany NMC 12130	St-Pons, France NMC 61064	Madoc, Ontario NMC 61066
Pb	48.8	49.0	48.9
Cu	n.d.	n.d.	n.d.
Fe	n.d.	n.d.	0.04
Ag	–	–	n.d.
Sb	30.4	30.4	29.1
As	n.d.	n.d.	1.0
S	19.5	19.6	19.9
Cl	0.23	0.20	0.19
	98.93	99.2	99.13

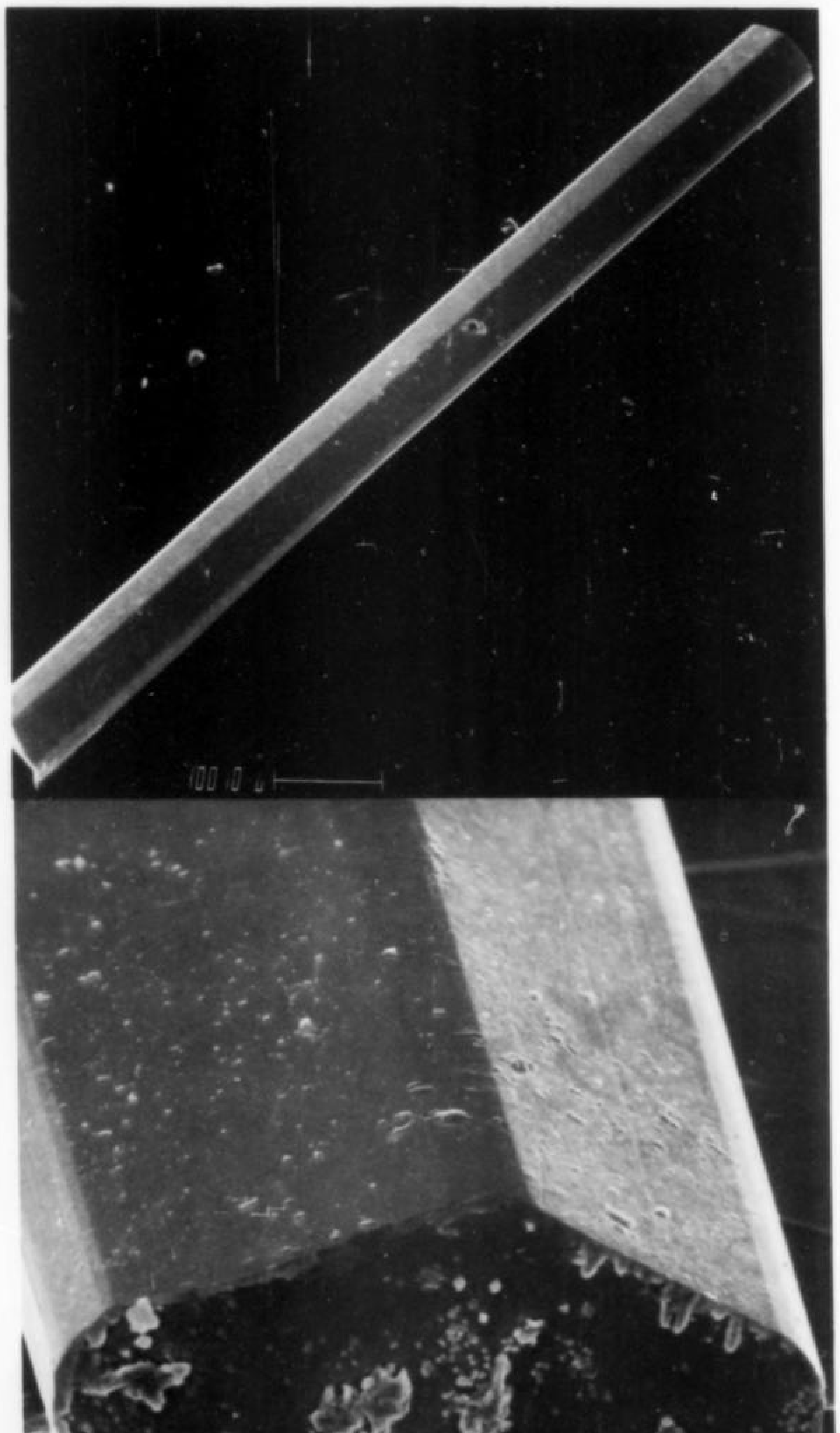

Figure 9. **Needle of sorbyite and end view of same crystal. Top bar represents 100 μm and bottom bar represents 10 μm (NMC 61065).**

ent Sb:As mole ratios, but with Sb predominant in both (Sb:As = 1.03 and 1.12). Thus the Madoc mineral falls in the unnamed Sb-rich part of the solid-solution series, the arsenic end member of which occurs only at Lengenbach (Graeser, 1977).

Table 9. **Relative ages of the Madoc sulfosalts and sulfides.**

			Approximate Sb/As
LATE	semseyite		
	bournonite, chalcopyrite		
	tetrahedrite		
	playfairite, launayite	↑	7, 11
		geocronite	
	boulangerite		8
	madocite	↑	6.5
		zinkenite, dadsonite	
	jamesonite	↑	
		sterryite, sorbyite	2.3, 4.6
	twinnite		1.5
	veenite		1.5
	guettardite		1.4
	"baumhauerite"		1.1
	sphalerite, (chalcopyrite?)		
EARLY	pyrite, arsenopyrite, galena		

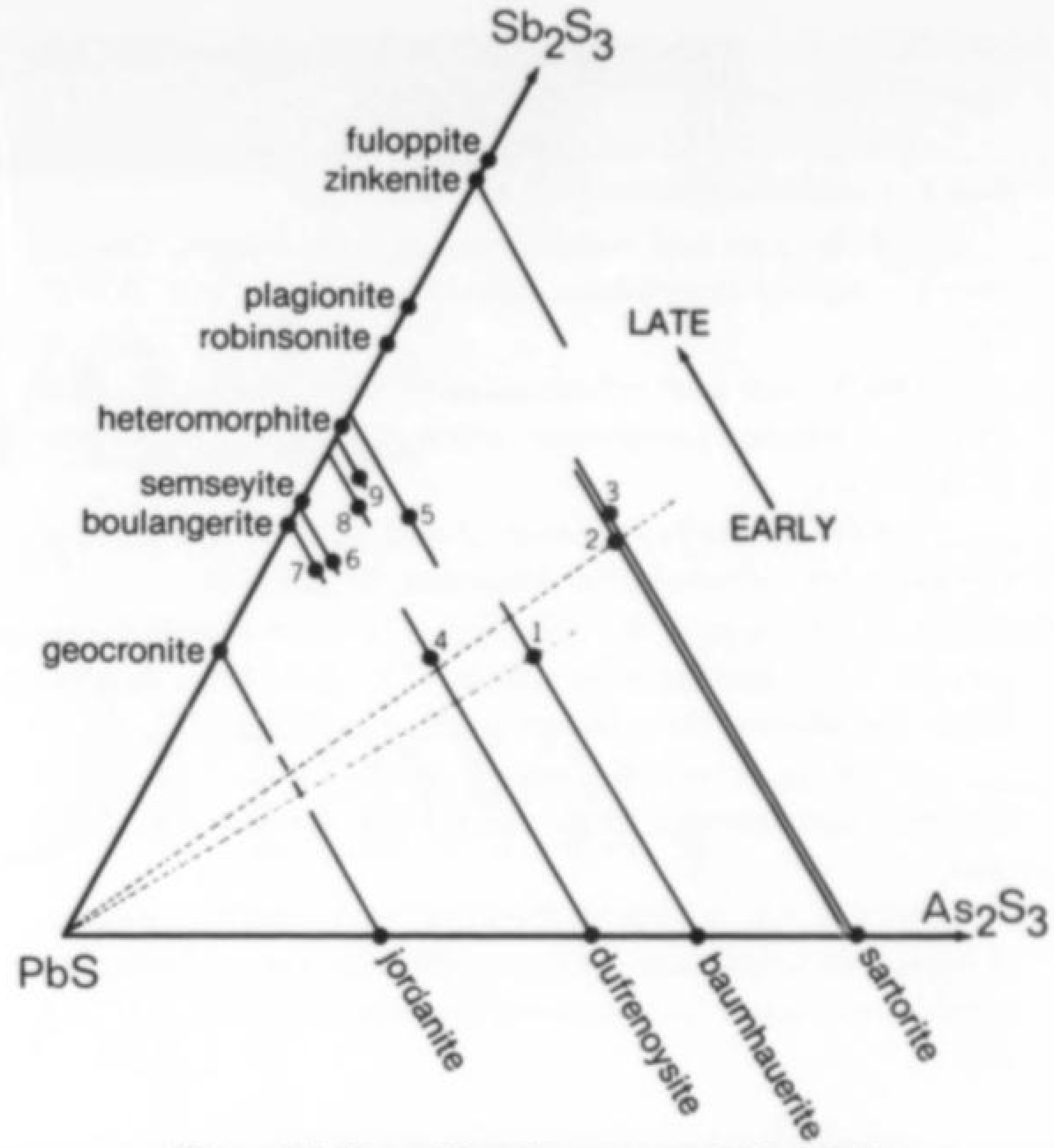

Figure 10. **Depositional sequence of the Madoc sulfosalts: (1) "baumhauerite," (2) guettardite, (3) twinnite, (4) veenite, (5) sorbyite, (6) madocite, (7) arsenian boulangerite, (8) playfairite, (9) launayite. Dashed lines from PbS to first two minerals show how the sequence was progressively depleted in arsenic. Similar projection to the other minerals shows that the early-formed sulfosalts fall on the right (As_2S_3-rich) and later sulfosalts gradually approach the $PbS-Sb_2S_3$ join.**

PARAGENESIS

Deposition of the Lengenbach sulfosalts was characterized by the initial formation of minerals relatively low in arsenic, and the subsequent formation of sulfosalts progressively enriched in arsenic (Graeser, 1977). In contrast, the depositional sequence of the Madoc sulfosalts seems to have been controlled largely by Sb-As variations: the early-formed sulfosalts are As-rich and the later ones are Sb-rich. The general sequence is shown in Table 9, wherein oldest minerals are at the bottom, youngest at the top, and vertical arrows show that the youngest possible age of a mineral has not been delimited. For example, sterryite and sorbyite replaced veenite, but the relationship of sterryite and sorbyite to later minerals, higher in the sequence, is not known. The tabulation shows that an early assemblage of pyrite, arsenopyrite, galena and sphalerite was followed by the lead sulfantimonides and then by copper-rich sulfosalts.

Figure 10 shows the chemical changes that occurred during the progressive formation of the Madoc sulfantimonides. Mineral compositions are plotted in the lead-rich segment of the triangular diagram for $PbS-Sb_2S_3-As_2S_3$ and the sulfosalts are numbered sequentially from oldest to youngest. By projecting from the PbS corner toward the $Sb_2S_3-As_2S_3$ join, as indicated by the two dashed-line examples in Figure 10, it can be seen that the sulfosalts were deposited along a well-defined trend of arsenic depletion. Subsequently, minerals with compositions near or along the $PbS-Sb_2S_3$ join seem to have followed a trend of Sb enrichment relative to Pb.

Two mineralization events of different types and different ages may have been involved in the genesis of the Madoc deposit. In the first stage, galena-pyrite-sphalerite are thought to have been deposited in the Precambrian limestone. This carbonate-hosted mineralization subsequently was metamorphosed, and the upright marbles were invaded by granitic rocks. Intrusion of the granite pluton adjacent to the sulfosalt site is thought to have initiated hydrothermal activity in which solutions charged with arsenic, antimony and sulfur reacted with the older galena-bearing sulfide suite to form the sulfosalts.

CONCLUSIONS

New microprobe analyses of the Madoc sulfosalts have confirmed some of the original results and have substantially modified others. The most significant changes are revisions to the formulas for sterryite and guettardite. Sterryite has been found to be consistently silver-bearing and has the probable formula $Pb_{10}Ag_2(Sb,As)_{12}S_{29}$, whereas the formula originally proposed was $Pb_{12}(Sb,As)_{10}S_{27}$. Guettardite, previously assigned the composition $Pb_9(Sb,As)_{16}S_{33}$, has been found to approximate $Pb_8(Sb,As)_{16}S_{32}$. The analyses indicate that playfairite, as well as Madoc dadsonite, contains small amounts of chlorine.

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Bytownite– a Legacy of Early Ottawa, a Montreal Medical Doctor and a Royal Engineer

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INTRODUCTION

Mineral nomenclature, fortunately, is on a much firmer footing now than it was a century or more ago, in Bytown days. Today, new minerals and new mineral names are recognized by the professional community only after they have received strict review and the approval of the International Mineralogical Association's Commission on New Minerals and New Mineral Names, or for some countries by national commissions, such as the Soviet Union's Commission of New Minerals (KNM) and Mineralogical Terminology. The fact that this control, established in the 1960's, was not always so elaborate is one of the reasons for the synonymy, varietal names, misidentifications and other errors that have caused the literature to become cluttered with some 22,000 names for about 2,600 distinct species. Much of the superfluity was generated during the 1800's and many of the early names, applied hurriedly to incompletely examined minerals, have since been discarded for one reason or another, largely as the result of the use of X-ray diffraction techniques. However, of the many earlier names that have survived, including those of most of the common minerals, some have undergone a rough and precarious voyage. Bytownite, a plagioclase feldspar found by Dr. A. F. Holmes in a boulder near Bytown (now Ottawa) and named by Dr. T. Thomson in Glasgow in 1835, is one such mineral.

HISTORICAL SETTING

The bytownite story began in 1826 with the construction of a navigable waterway between the present site of Ottawa on the Ottawa River and Kingston on Lake Ontario. The waterway was routed along a series of lakes and rivers, and necessitated the construction of several locks and canals, the largest canal being that which now bisects the City of Ottawa. At the time, Canada and the United States were in a period of uneasy truce following the War of 1812, and the 125-mile waterway (now known as the Rideau Canal) was intended to provide the Canadian government with a safe military passage between Upper and Lower Canada, as it circumvented the narrow reaches of the St. Lawrence River that were exposed to the American artillery at Ogdensburg, New York. The man chosen to direct the construction of the canal was Colonel John By (Fig. 1) a veteran of the Peninsular Wars and one who had accumulated nine years' experience on military works in Canada, including fortifications at Quebec City. Although beset by many obstacles, particularly by the long severe winters, rough terrain and disease, including "malaria," Colonel By and his Royal Engineers along with local contractors and tradesmen completed the waterway in six years, a remarkable achievement in view of the primitive construction methods then in use. Colonel By subsequently returned to England, where he died in 1836 in Sussex at the age of 56 (Moon, 1979). The waterway was never used for military purposes, but it did carry some commercial traffic between Canada and the United States; it currently serves both nations more companionably as a popular tourist route.

When Colonel By arrived in 1826, the Ottawa River terminus was but a small settlement called Richmond Landing, which served mainly as a transfer point for water traffic from Montreal to points inland, such as Richmond, Merrickville, Smiths Falls, Lanark and Perth. The settlement, at the foot of the Chaudière Falls, was formerly a portage site used by Algonquin Indians, *courier-de-bois* and *voyageurs* in their travel along the Ottawa. Expanded by the military and construction camps on the nearby limestone flats and

Figure 1. **John By (1779–1836), Lieutenant-Colonel, Royal Engineers, designer and builder of the Rideau Canal (1826–1832). Portrait painted in 1830.**

Figure 2. **Andrew Fernando Holmes, M.D., LL.D. (1797–1850). Physician, chemist, botanist, mineralogist and educator. One of the founders and first Dean of the Medical Faculty, McGill University, Montreal. Portrait painted in 1819 by John Watson (later Sir John Watson Gordon).**

plateau during the period of canal construction, Richmond Landing came to be known as Colonel By's Town, or simply Bytown.[1] Buoyed subsequently by a growing lumber industry and its increasing importance as a center of commerce and industry, Bytown expanded and flourished. In 1855 the former Bytown became the city of Ottawa and in 1858 it was chosen by Queen Victoria to be the capital of Canada.[2]

The medical doctor of our story, Dr. Andrew Fernando Holmes (Fig. 2), was a physician, chemist, botanist, mineralogist and first dean of medicine at McGill University, Montreal. On a visit to Bytown in the 1830's, possibly to see the new canal or to visit his colleague, Dr. James Wilson of Perth, Holmes collected samples from a boulder that attracted his attention. Believing the find might represent a new mineral, he forwarded the samples to Dr. Thomas Thomson (Fig. 3), Regius Professor of Chemistry, and mineralogist, at the University of Glasgow, Glasgow, Scotland. The only record of the location of Holmes' samples is "from a boulder near Bytown." Although never located, the boulder was probably one of the large glacial erratics that are so abundant in the area, near the Ottawa River and the Richmond Road.[3]

EARLY ANALYSES

Thomson (1836) analyzed two portions of Holmes' mineral and, on the basis of his analyses, considered that it represented a new species which he appropriately named bytownite. On the basis of a later analysis by Tennant on another Holmes sample from Bytown, Thomson (1838) concluded the sample was amphodelite (anorthite). The results are shown in Table 1, columns 1 and 2. Attention is drawn particularly to the lime (CaO) contents, viz: 8.800 and 9.32 (mean: 9.06) and 16.25, respectively. Fifteen years later, T. Sterry Hunt, mineralogist and chemist with the Geological Survey of Canada, then situated in Montreal, published (1851) a slightly different description and analysis of a sample he had received from Holmes and "pronounced by Thomson to be the mineral described by himself under the name of bytownite." Hunt noted that it was "massive, granular, strongly coherent and with the exception of occasional disseminated grains of black hornblende, is homogeneous." Hunt's analysis is shown in column 3, Table 1. It shows a content of 14.24 percent CaO and 2.82 percent Na_2O.

[1] So designated by the Governor, Lord Dalhousie, in 1827.

[2] An interesting account of the beginnings of Bytown, its conversion to Ottawa and its choice as the national capital is given by Eggleston (1961).

[3] A large anorthositic erratic derived from the Gatineau hills, and now located between the Richmond Road and the old trail to the foot of the Deschênes rapids in the Ottawa River, is a prime suspect. It carries labradorite, pyroxene, hornblende and possibly bytownite.

Figure 3. **Thomas Thomson, M.D., F.R.S. (1773–1852). Professor of Chemistry, and Mineralogist, University of Glasgow.**

labradorite and anorthite in 1823 and oligoclase in 1836; andesine, another member of the series, was described in 1840. However, their relationship with one another was not understood. Then Tschermak (1864) presented the revolutionary theory that all feldspars were really only mixtures of three molecules, orthoclase ($KAlSi_3O_8$), albite ($NaAlSi_3O_8$) and anorthite ($CaAl_2Si_2O_8$) and that the plagioclases were isomorphous mixtures of albite (Ab) and anorthite (An). Although Tschermak's latter suggestion was strongly opposed at the time, because of the substitution of univalent sodium (Na^+) for bivalent calcium (Ca^{++}), it is now widely accepted. The plagioclases are known today to consist of linked SiO_4 and AlO_4 tetrahedra in which sodium and calcium ions occupy the interstices and the resulting electrical charge is balanced by substitution of other ions including K^+, Ba^{+2} and Be^{+2}.

Tschermak arranged the plagioclases in a series ranging from albite ($NaAlSi_3O_8$) through a progressively calcium-rich series of oligoclase, andesine, labradorite and bytownite to anorthite ($CaAl_2Si_2O_8$), assigning a specific range of composition to each. With the inclusion of bytownite in the series, Tschermak evidently accepted the *name* given by Thomson, but the *analysis* given by Hunt, as Hunt's rather than Thomson's analysis fell within the designated range of composition. Tschermak's classification was later modified slightly by Calkins (1917), which is the series now in use: the four intermediate members have equally wide compositional ranges and the two end members one half that. In this series albite occupies the range from pure albite to a composition of 90 percent albite and 10 percent anorthite, $Ab_{90}An_{10}$; any plagioclase with a composition within this range would be termed albite. Oligoclase occupies that portion ranging from $Ab_{90}An_{10}$ to $Ab_{70}An_{30}$; andesine from $Ab_{70}An_{30}$ to $Ab_{50}An_{50}$; labradorite from $Ab_{50}An_{50}$ to $Ab_{30}An_{70}$; bytownite from $Ab_{30}An_{70}$ to $Ab_{10}An_{90}$ and finally, anorthite from $Ab_{10}An_{90}$ to pure anorthite.

Hunt noted the discrepancy between his analysis and that of Thomson in the proportion of lime, soda and potash, and regarded the mineral as anorthite (thiosaurite). He also indicated that samples of similar material that had been found and widely distributed as bytownite from a locality in the vicinity of Perth, Ontario, were mixtures.

The distribution of the Perth area specimens may be ascribed to Dr. A. Krantz, a mineral collector and dealer of this era in Bonn, Germany. One of the Krantz specimens is in the British Museum (Natural History), London, England, where it is catalogued as follows: "BM 26491. Krantz 29. Bytownite – with hypersthene in compact dark-green granular rock. Bytown (now Ottawa), Ontario, Canada. Bought of A. Krantz 1851." Another, quite similar specimen was recently found at Gregory Bottley & Company, a long time mineral dealer in London, by Dr. Peter Tarassoff, of Montreal, who kindly allowed us to examine the contained feldspar; this proved to be labradorite. The analysis is given in Table 1, column 8. The specimen was labeled: "Bytownit (Thomson), Kiesels: Thon u. Kalkerde, Eisen u. Natron, von Bytown Ob. Canada. A. Krantz in Bonn." Many years later Zirkel (1871) examined thin sections of evidently the same material obtained from the "store of Dr. Krantz in Bonn" and found it to consist of feldspar, which he regarded as anorthite, hornblende, mica, quartz and magnetite. He argued that because this material labeled "bytownite" was actually a mixture of minerals, the name bytownite should be dropped. However, because the source of Krantz specimens is unknown, Zirkel's argument may be based not on his examination of type material but on material represented to him as bytownite.

BYTOWNITE and the PLAGIOCLASE SERIES

Thomson's bytownite was but one of five plagioclases identified at that time. Barth (1969) notes that albite was known in 1815,

MORE RECENT STUDIES

Many years later Walker and Parsons (1927) attempted to unravel the possible confusion and conflicting analyses for bytownite by the examination and analysis (column 4, Table 1) of a Thomson specimen labeled as "449 Bytownite – silicate of alumina, lime, iron, magnesia and soda, T. – Bytown, Upper Canada," obtained from Dr. James A. Kershaw, Director of the National Museum, Melbourne, Australia. The authors found the material to be crushed and granulated anorthosite, consisting mainly of plagioclase of labradorite ($Ab_{45}An_{55}$) composition, and concluded that the sample analyzed by Hunt (1851) was a different type of feldspar than the type bytownite of Thomson.

We have investigated this problem further by electron probe analyses on the actual specimens analyzed by Thomson and by Hunt and others. Dr. Bill Birch, Curator of Minerals, National Museum of Victoria, Melbourne, Australia, kindly provided fragments of feldspar from the Thomson type specimen that the Museum earlier provided to Walker and Parsons, now registered as No. 3800 in the Victoria Museum Collection. According to Birch, John Calvert, an English mineralogist, purchased Thomson's collection, culled it (of probably the esthetic portion) and then between 1861 and 1866 sold the remainder to the Victorian Mines Department from where it eventually reached the National Museum of Victoria. Our analysis, indicating labradorite and confirming Walker and Parsons results, is given in column 7, Table 1. Through the kindness of Louise Stevenson, Curator of Geology, Redpath Museum, McGill University, Montreal, where the Holmes' collection is maintained, fragments of Holmes' type specimens, presumably similar to those provided to Hunt, were made available for analyses. These were taken from specimens labeled in Holmes' own hand as "bytownite and hornblende, Ottawa, from old No. 285" and "bytownite, to compare with number 3, 1837." The two specimens represent quite similar rocks and in both cases the feldspar – the essential constituent – proved to be bytownite; the results are presented in columns 5 and 6, Table 1. They correspond very closely with Hunt's analysis of 1851 of "type material from Holmes," confirming in both cases that the samples are indeed "bytownite" in both the modern and original usages. Both Hunt's and our analyses show much higher lime (CaO) and lower soda (Na_2O) than did Thomson's original analyses but the lime contents are close to that of Tennant (Thomson, 1838). If Thomson's and Tennant's analyses were correct they may have analyzed slightly different samples than Hunt, or mixtures. On the other hand, the sample of "bytownite" acquired by the Australian museum from Thomson's collection, and the samples distributed by Krantz – who may in turn have received them from Thomson – are proven to be labradorite, more calcium-rich than either of the Hunt or Thomson analyses. From this it appears that the original samples were sufficiently inhomogenous or intermixed as to provide both the bytownite and labradorite that were distributed by Holmes and Thomson as bytownite.

CONCLUSION

The bytownite story is thus seen to have a fairly complicated plot, with many facets and at least five main characters: By, Holmes, Thomson, Hunt and Tschermak. Without By there would not, of course, have been a Bytown, nor a bytownite; and without Holmes the mineral would not have reached Thomson. Thomson named the mineral; Tschermak adopted the name in his plagioclase series; and Hunt's analysis was the accepted one. It is also fortuitous that Hunt obtained a higher lime analysis than did Thomson for, had he not, the name bytownite may not have been retained by Tschermak (cf. Zirkel, 1871). This and other noted discrepancies, coupled with the verification of labradorite in some of the samples, is strongly suggestive of either sample inhomogeneity or sample differences rather than analytical errors. However, as no correspondence between Holmes and Thomson has been uncovered, the location of the original boulder and true nature of samples shipped to Thomson may never be known. Out of the confusion, the fact now stands clear that the samples sent by Holmes to Thomson did indeed contain bytownite!

***Table 1.* Comparative analyses of "bytownite"**

	1	2	3	4	5	6	7	8
Locality and Description	From Boulder Near Bytown Upper Canada	Amphodelite From Bytown Upper Canada	Bytownite Type Material From Holmes	Bytownite From Thomson Via Australia	Bytownite Ottawa, 285 From McGill	Bytownite No. 3, 1837 From McGill	Bytownite From Thomson Via Australia	Bytownite Bytown, Canada Per A. Krantz
Reference	Thomson, T. (1836)	Thomson, T. (1838)	Hunt, T. S. (1851)	Walker and Parsons (1927)	This Paper	This Paper	This Paper	This Paper
Collector	Holmes, A. F.	Holmes, A. F.	Holmes, A. F.	Holmes, A. F.	Holmes, A. F.	Holmes, A. F.	Holmes, A. F.	Unknown
Analyst	Thomson, T.	Tennant, J.	Hunt, T. S.	Rickaby, H. C.	Bonardi, M.	Bonardi, M.	Bonardi, M.	Bonardi, M.
Mineral	Bytownite	Amphodelite [1] (Anorthite?)	Anorthite [2] (Amphodelite) (Thiosaurite)	Andesine-Labradorite (limits of 4 anal.)	Bytownite	Bytownite	Labradorite	Labradorite
Silica (SiO_2) Kieselerde	47.735 47.400 47.567	45.80	47.40 47.30	53.47 - 54.80	49.41	49.08	53.78	56.31
Alumina (Al_2O_3) Thonerde	29.695 29.60 29.647	26.15	30.45	27.49 - 28.59	32.23	32.40	28.08	28.35
Lime (CaO) Kalk	8.800 9.32 9.060	16.25	14.24	10.21 - 10.80	15.05	15.09	10.81	10.24
Iron oxides (FeO,Fe_2O_3) Eisenoxydul	3.750 3.4 3.575	4.70 (5.22)	0.80	0.70 - 1.27	0.07	0.06	0.28	0.12
Magnesia (MgO) Magnesia	trace 0.4 0.400	2.95	0.87	0.39 - 0.52	n.d.[3]	n.d.	n.d.	n.d.
Soda (Na_2O)	7.600 7.6 7.6		2.82	4.76 - 4.90	2.90	3.12	4.87	5.66
Potash (K_2O)			0.38	0.84 - 1.32	0.13	0.07	0.36	0.30
Moisture (H_2O) Wasser	2.000 1.96 1.98	2.00	2.00 1.80	– - 0.79	n.d.	n.d.	n.d.	n.d.
Totals	99.58 99.68 99.64	97.85	98.96	100.17 - 100.72	99.79	99.82	98.18	100.98
Sp. Gr.	2.80		2.73	2.681 - 2.709	n.d.	n.d.	n.d.	n.d.

[1] Thomson (1838) considered the material supplied to him by Holmes from Bytown, Upper Canada, to be identical to amphodelite from Lojo, Finland.
[2] Hunt (1851) considered the material supplied to him by Holmes from Bytown, Upper Canada, to be identical to thiosaurite (anorthite) from Iceland, regarded by Rammelsberg as anorthite, and scarcely to be distinguished from the amphodelite of Uton, Sweden.
[3] Not determined.

The name bytownite, thus faithfully preserved in geology and mineralogy, is a tribute to the perceptiveness of one of Canada's earliest amateur mineralogists. It recalls and honors as well the pioneering beginnings of Bytown (now Ottawa), the Nation's capital.

This story also fully supports the argument that, to avoid similar confusion, all type and described material should be documented and deposited without delay in a curated and accessible collection.

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The authors gratefully acknowledge the assistance of several persons and organizations. Louise Stevenson and Peter Tarassoff, Montreal, and Bill Birch, Melbourne, provided samples and Maurizio Bonardi, Geological Survey of Canada, performed the electron probe analyses. Portraits of By, Holmes and Thomson were supplied respectively by the National Archives, Ottawa, McGill University, Montreal, and G. P. Durant, Hunterian Museum, The University of Glasgow. The paper was read by the foregoing persons and by R. J. Traill, who offered many helpful suggestions. To all of these we offer our sincere appreciation.

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Microminerals

by Violet Anderson

Micromounting in Ontario

The time is ambiguous. The place is Ontario.

Collecting microminerals in Ontario is not like picking raspberries off a raspberry bush. With the Precambrian Shield comprising more than two-thirds of the province, rocks come first to mind, and then the massive ores, and finally mineral crystals large enough to thoroughly defeat the micromounter. Fortunately, that is not the whole story. If microminerals do not fall into your hand like ripe raspberries, neither are they so difficult to find as whooping cranes.

A geologic map of Ontario may look largely pink: granitic rocks, very old, 1000 to 2500 million years old. Through this large area will be jagged patches of a different color on the map: Ontario's oldest rocks, older in some cases than 2700 million years. The precious mineral elements of Ontario followed hard on the heels of the oldest rocks, not all of them on the same day, but easily within several million years of one another. You cannot underestimate the great depth of time which has gone into the making of that tiny silver crystal which lies under the lens of your microscope.

The past is past. What is it we see?

I plan to arrange the microminerals of Ontario into five main locality areas: those found in the Precambrian Shield north of Lake Superior; those found in the Shield around Cobalt and Sudbury; those in the Bancroft area, still within the Shield; those on the edge of the Shield around Madoc and Marmora; and those found outside the Shield, in the limestone quarries spaced at intervals through southern Ontario from Niagara Falls to the Bruce Peninsula. I am not going to make any attempt to be exhaustive.

No amateur mineralogists are likely to go further west than Kakabeka Falls (near Thunder Bay) nor further north than Cobalt and Gowganda. What is likely to be found in the places I shall mention will vary from year to year. Your best bet is to go on a field trip having a leader who is familiar with the localities and who knows what to expect. Some mines have recently cleared out their dumps in order to extract any straying assets of their prized deposits. Others are posted, forbidding all would-be collectors. So it is that old collecting areas temporarily fade out, but who knows what others will come into being, what unexpected pegmatites will be opened up, what new dumps will appear? Or what you may find in rock crevices on a roadside?

There are old silver mines around Kakabeka Falls and Thunder Bay, abandoned, previously visited by collectors, but still a source of microminerals. Right across the north shore of Lake Superior one is likely to find quartz crystals, most often in skins of sharp points, clear or smoky or amethyst in color, sometimes with inclusions of hematite or goethite. Not to be dismissed lightly. In the old Thunder Bay silver mines the quartz crystals may be coated with acanthite or argentite, and closely associated with pyrite or chalcopyrite crystals. Crystals of acanthite also occur, as well as those of marcasite, galena, and a very attractive pale green or purple fluorite. It is exciting to find an acanthite crystal; they are a fine black, gleaming, and they retain the cubic shape of the argentite from which they have inverted. Sphalerite here is less common, and not well formed.

I bypass the Thunder Bay amethyst mines; someone else is tackling them in this issue of the *Record*. But I should like to mention the Diamond Willow mine at Pearl, where malachite sprays have been found on amethyst.

If you scan the map from Thunder Bay to Sault Ste. Marie, certain key points may be noted: Nipigon, Rossport, Marathon, Wawa and Mamainse Point. From any one of these points you may fan out into the nearby countryside, assisted by those who know the area, to locate what may be found.

The Leitch mine near Lake Nipigon (somewhat off our beaten path) may give you a chance at gold. Gold is where you find it, but you cannot always carry it away.

There used to be an old roadcut on Highway 17 about 7 miles west of Rossport where the skins of micro quartz points, and the rather shallow groups of purple fluorite, were unusually fine. One could find doubly terminated smoky quartz crystals attached to purple fluorite, purple fluorite phantoms in clusters, honey-colored fluorite crystals, some of which had purple edges, and finally, pink barite. A splendid collecting spot. If this roadcut has disappeared into the hinterland, one might still search the hinterland – or look for a similar cut nearby.

Marathon is near the point from which one can head north to Manitouwadge, where deposits of zinc, copper, lead and silver are found. At Norando's Geco mine, the ore is mainly pyrite, sphalerite, pyrrhotite and chalcopyrite, with some galena. In 1970, aside from our trip down to the 1450-foot level in the mine, to slosh around on muddy railroad ties in dim light, we worked on the dumps. The only additional thing discovered was cordierite, and that not in crystals. However, a mile east of Marathon, on Highway 17, we faced a cliff running along the road for about a quarter mile. We searched for crystals barely a millimeter in size. This was parisite, its formula $(Ce,La)_2Ca(CO_3)F_2$. Crystals are of a fine, slightly orange-red, hexagonal, layered and occasionally capped (Fig. 1).

Out of Wawa one can locate the Algoma Steel open pit mines: the George W. MacLeod mine, the Lucy mine, and others. Their ores are made up largely of siderite. Here and there bands of siderite alternating with bands of chert make up a most attractive rock. Some of the pyrite crystals from the MacLeod mine show interesting curved faces which I am told are made up of a stepped series of diploid faces (Fig. 2). Silvery arsenopyrite crystals come from both the mines mentioned. The sixlings from the Lucy mine can at times resemble a maple leaf (Fig. 3).

One further area of the Lake Superior north shore needs mentioning. That is Mamainse Point where two mines, Coppercorp and Tribag, have yielded copper. The main ore was chalcocite. Crystals of chalcocite, *adularia* (a variety of microcline), tiny green acicular crystals (almost hidden in vugs) which are probably malachite, and pale gemmy epidote, were picked up in the vicinity of Coppercorp, along with the most sparkling drusy quartz I have ever seen, forming into odd shapes like florets and steeples. The prize crystals from there, however, are bornite. Bornite is a copper iron sulfide. Its crystals are rarely found. They are cubic, the faces sometimes

Figure 1. **Reddish parisite crystal, 2.2 mm high, from a roadcut on Highway 17, 1 mile south of Marathon, Thunder Bay district. Lawrence La Chapelle specimen.**

Figure 2. **A blackish pyrite crystal, 1.3 mm wide, from the George W. MacLeod mine, 2 miles north of Wawa, Algoma district. Royal Ontario Museum specimen.**

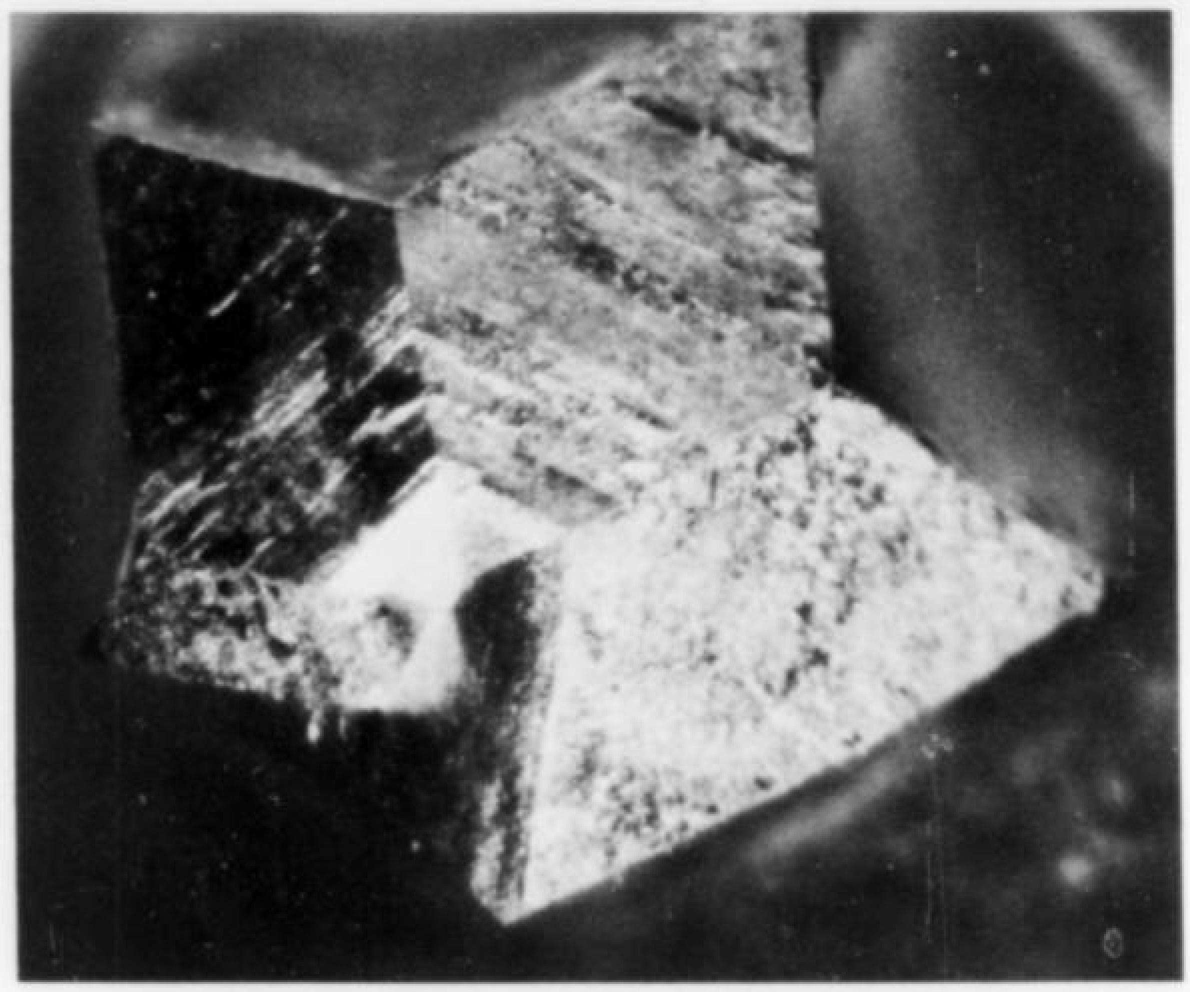

Figure 3. **A silvery arsenopyrite sixling, 2.2 mm wide, from the Lucy mine, 2 miles north of Wawa, Algoma district. Royal Ontario Museum specimen.**

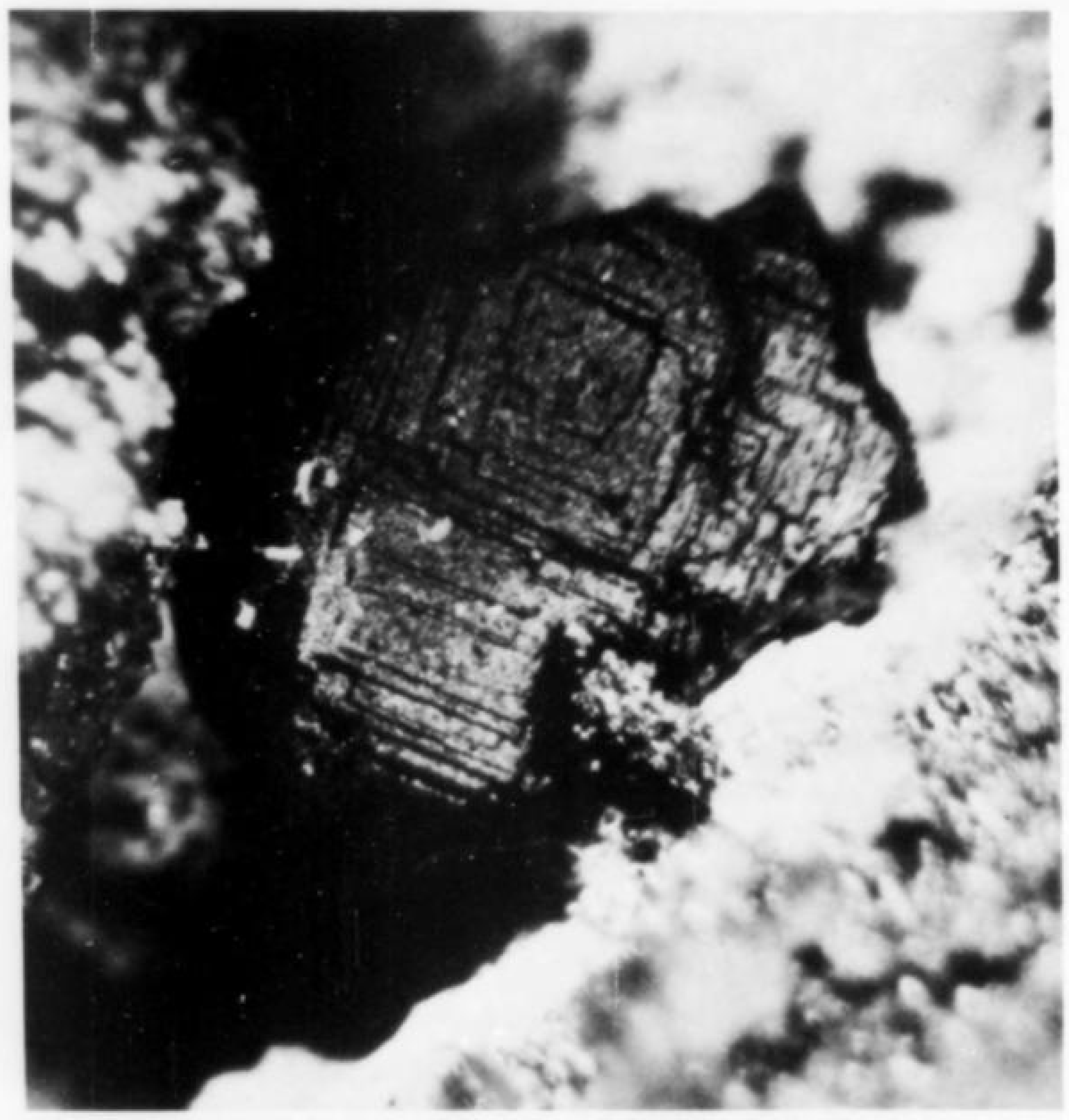

Figure 4. **A black bornite crystal, 1.7 mm wide, from the Coppercorp mine, Mamainse Point, Algoma district. Cynthia Peat specimen.**

rounded a little and tarnished into a rich variety of colors. A photographer cannot catch the colors without blurring the shape, so you must think the glory of color into the crystal (Fig. 4).

This listing of the minerals of one Ontario area has been half-travelog, since up-to-date information is not too easily come by. Suffice it to say, I'd take a chance on the north shore of Lake Superior anytime.

Heading east now, omitting any uranium deposits at Elliot Lake (since I never did get any closer to uranium minerals in the Lake Superior area than to hold an ugly piece of pitchblende), we touch down at the Vermilion mine near Sudbury. At the moment the dumps have been removed in an attempt to garner any stray slivers of platinum. That's bad news for collectors. While we hope for bet-

Figure 5. **A lustrous, silvery sperrylite crystal, 1 mm on an edge of the cube, from the Vermilion mine, Sudbury district. Royal Ontario Museum specimen.**

Figure 6. **A blackish cubanite twin, 3.3 mm high, from the Strathcona mine, Sudbury district. Royal Ontario Museum specimen.**

ter days in the future, there are still the sperrylite crystals of yesterday to keep in mind. Figure 5 shows a little cube with an octahedral corner. Through the microscope, when the light reflects at a certain angle, this tiny object can be too dazzling for the eyes. Sperrylite is a platinum arsenide, and very rare indeed.

From the Strathcona mine, also in the Sudbury area, comes this interesting specimen of cubanite (Fig. 6). It looks twinned, and very different from the elongated striated crystals which come out of Brazil.

Further north, in the Cobalt area, either at Gowganda or near Cobalt Lake, there should be splendid microminerals for collectors. I talked to a mine-assayer at Cobalt who reported that, for collectors, recent trips to Gowganda have been disappointing. In such cases I must direct you to the mineral dealers. Often it is they who save the day for us. (Where else right now could you find the beautiful secondary uranium minerals from Zaire?) Perhaps they will have some of the native wire silver (Fig. 7) from the Keeley mine (south of Cobalt), its tangles of silver in such swirling designs that any mineral photographer can become quite unmineralogical. In the same category are the silver dendrites. Above all, collectors should have red proustite crystals (Fig. 8). Proustite is a trigonal mineral and as such may have steep rhombohedral terminations, looking very different from the crystal in Figure 8. But whatever forms it assumes, it has an inner fire that should leave no mineralogist cold. The other silver sulfosalts (polybasite, stephanite, and pyrargyrite) occur in good crystals, the first two black, the last one very dark red. Xanthoconite, a dimorph of proustite, has very minute orange-yellow monoclinic crystals, pretty when associated with scarlet proustite.

On compounds of both nickel and cobalt, colorful arsenates may form, green annabergite on the nickel, pink erythrite on the cobalt. At their weakest they are mere powdery blooms; at their best, they

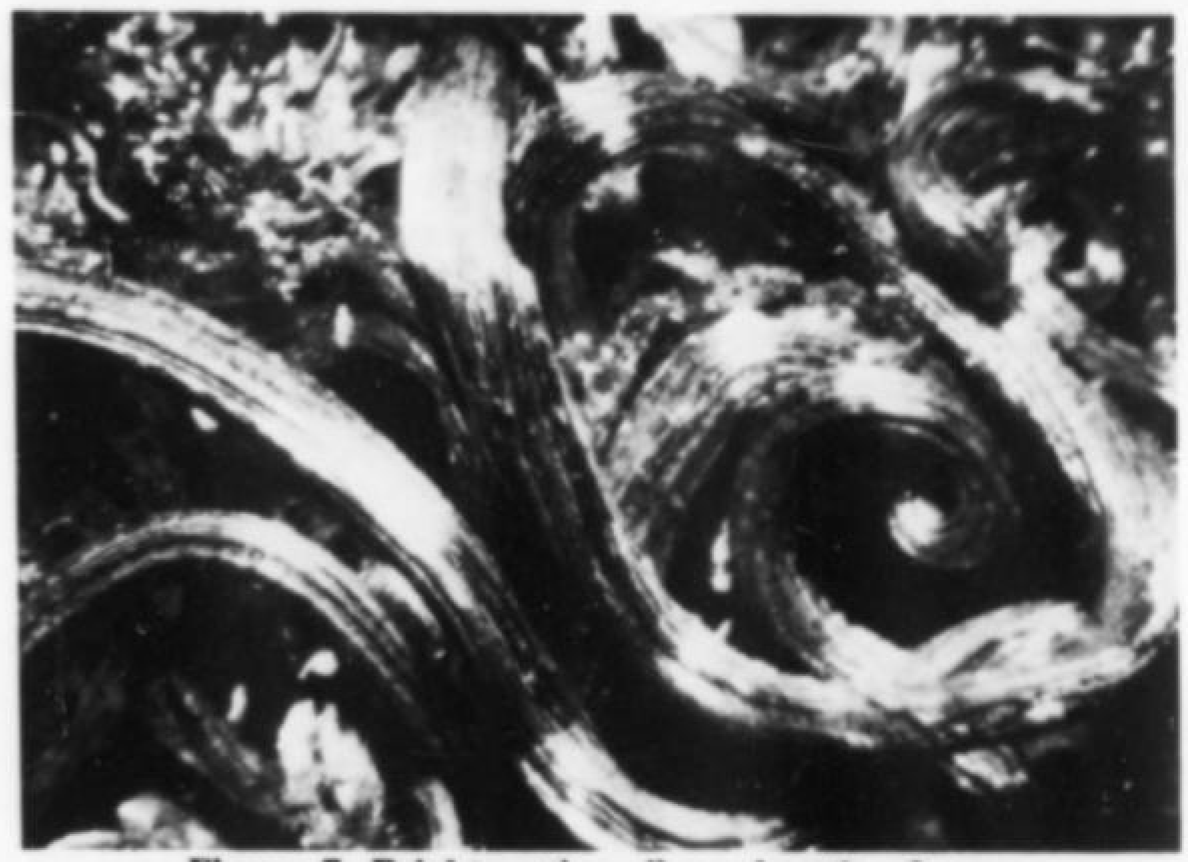

Figure 7. **Bright native silver; length of area photographed, 7 mm. From the Keeley mine, South Lorrain township. Royal Ontario Museum specimen.**

Figure 8. **Ruby-red proustite, 1.3 mm high, from the Keeley mine, South Lorrain township. Royal Ontario Museum specimen.**

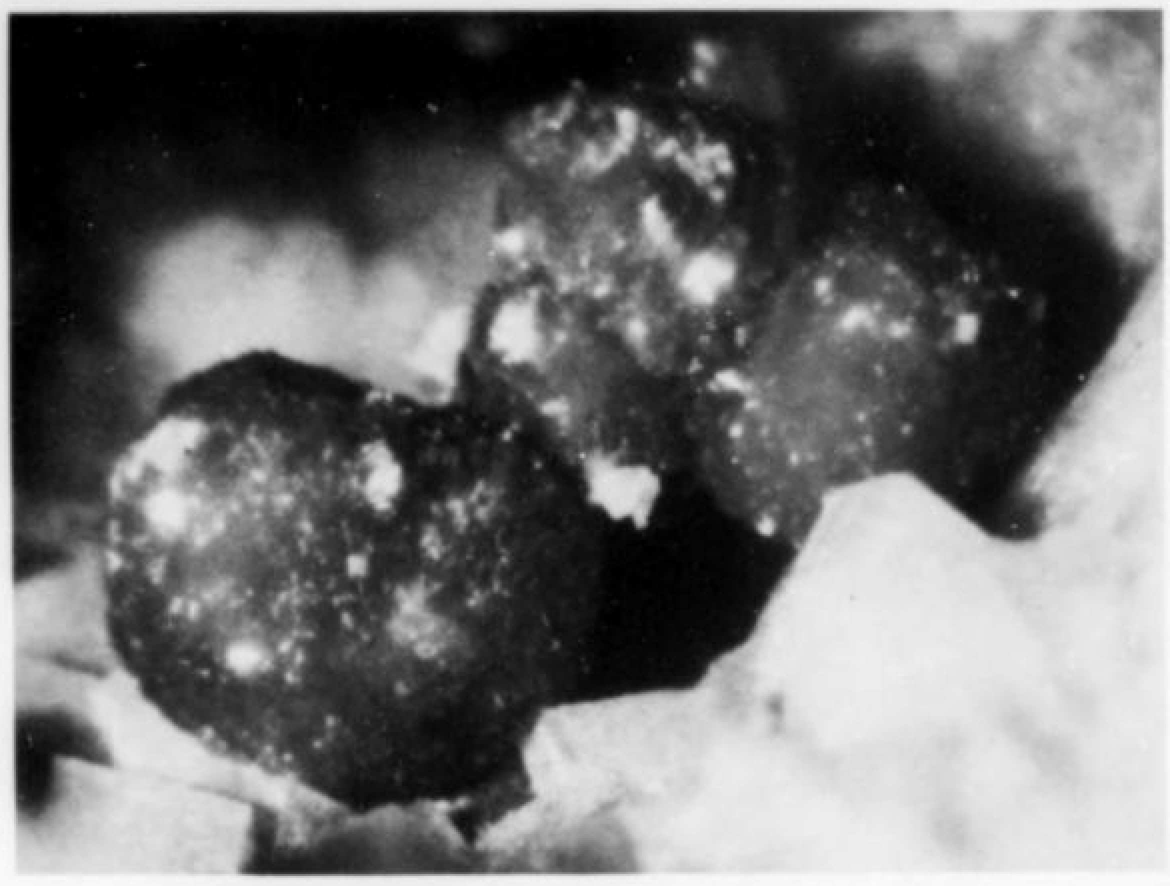

Figure 9. **Apple-green annabergite, about 3 mm wide, from the Cobalt area, Coleman township. Royal Ontario Museum specimen.**

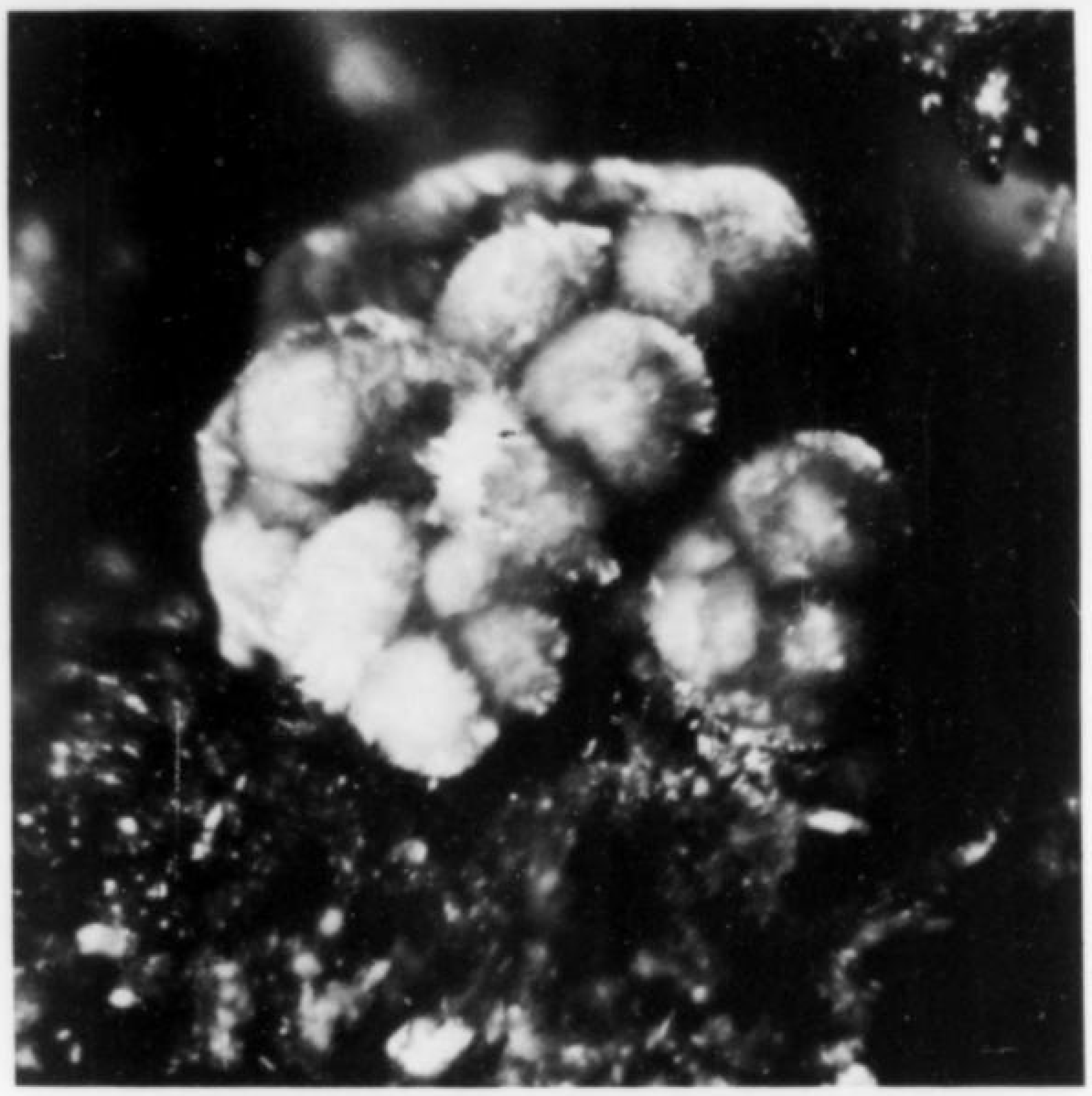

Figure 10. **A magenta-pink erythrite clump 1 mm wide, from the Cobalt area, Coleman township. Violet Anderson specimen.**

are found respectively in Laurium, Greece, or in Morocco. Here (Figs. 9 and 10), they are seen as little clumps, blossoming bright pink or a sharp green.

The cobalt arsenic sulfide, cobaltite, is a tin-white mineral, cubic, with modifications, and very neat. Skutterudite, $CoAs_{2-3}$, likewise tin-white, forms a series with the nickel analog, nickel-skutterudite. I have not seen any free-standing crystals of these minerals, although plenty of partially embedded ones.

For some reason these compounds, outside of proustite, are more pleasant to see than to hear about. Perhaps the names have something to do with it. Whatever can one do with xanthoconite, pyrargyrite, polybasite, stephanite and skutterudite?

The next area of importance, and still within the Precambrian Shield, is the Bancroft area. Here crystals come big; they've gone about as far as they can go. The mountain building which occurred over 1000 million years ago in eastern Ontario affected Bancroft with a vengeance. The region was buried to a depth of about 10 miles. What we see today, after these millions of years of erosion, are the metamorphosed rocks, and the huge crystals that grew during that time: large titanites, crystals of ilmenite, nepheline, apatite, and of the pyroxenes and amphiboles. So where are the microminerals?

They're here and there. Highway 62 can present some enticing roadcuts. The old roadcut (which by now can no longer be a roadcut but two large scoops in the nearby environment) is still being praised. Someone said to me: "Any microminerals you can find in the Bancroft area are likely also to be found in that old Highway 62

Figure 11. **Greenish yellow uranophane-beta crystals; length of area photographed, 1.4 mm. From the Madawaska mine, Hastings county. William Ince specimen.**

Figure 12. **A deep green fluorite crystal; the sloping left edge of the crystal is 4 mm long. From the Madawaska mine, Hastings county. Cynthia Peat specimen.**

roadcut 2 miles north of Bancroft." True or false? You could always take a look. People have reported zircons, crystals of green and blue octahedral fluorite, of allanite and orange chabazite from there. Mention has even been made of phillipsite and heulandite.

For micromounters, the area west of the town of Bancroft has probably the best localities. Go to Wilberforce, following Highway 28 from Bancroft, and then Highway 648. At Wilberforce there is a Rock Shop owned by Ken and Lynn Binskin a mile south of the town (P.O. Box 54, Wilberforce, Ontario, K0L 3C0. Phone – (705) 448-2691). Let this be your reference point. Ken says that within a 10 mile radius of Wilberforce he has found about 70 mineral species. Most of these are not microminerals, of course (Ken is just becoming involved with microminerals), but he does list as microminerals: diopside, fluoborite, gypsum, phlogopite, pyrite and warwickite (there must be boron somewhere about).

The uranium mines, Madawaska (the old Faraday mine) and the Bicroft mine (in Cardiff township) should have secondary uranium. Certainly uranophane and uranophane-beta have come out of Madawaska (Fig. 11), although the most beautiful mineral I have seen from there has been the dark green, gemmy, octahedral fluorite (Fig. 12). A close second to this is the very unusual twinned chalcopyrite, and calcite and quartz with inclusions of hematite or goethite. Also titanite and pyrite crystals.

The Bicroft uranium mine has produced kainosite, a silicate carbonate with cerium and yttrium, orthorhombic, long prismatic, yellowish. Rare. And tiny black cubes of uraninite. Both the Cardiff uranium mine and the Bicroft uranium mine are in Cardiff township. Which of these is open for collecting, if any, is for those in the area to tell.

Around Tory Hill and Wilberforce may be found green or red or brown apatite crystals, commonly doubly terminated. The Saranac mine is known for its zircons. And watch for molybdenite, graphite, and titanite. Ask Ken Binskin what to look for and where. And enjoy a purchase or two.

With time, Highway 35 should be explored from Minden through Miners Bay, and Norland to Coboconk. Quartz crystals with inclusions or incrustations of hematite or goethite can be found in several spots along the road; they are quite beautiful. At Norland are rosettes of hematite. But this is edging out of the Bancroft area.

Rumor has it that 20 or 30 old mines are to be opened up around Bancroft simply as tourist attractions for collectors. It seems not impossible to me that minerals could be discovered around every corner in this part of the province. North of Bancroft I can remember only very large crystals. South of Bancroft, heading towards Madoc on Highway 62, things are more to the point. At Coe Hill there are said to be garnets along the roadside. At Malone a marble quarry some years back held epidote and axinite crystals.

And so to Madoc. On the edge of the Precambrian Shield, the Madoc area has suffered far less metamorphism than has the Bancroft area. Still, there have been many mines. It was in Madoc township that the first gold in Ontario was discovered, and at the Ackerman mine on Highway 7 between Madoc and Marmora occasional flakes of gold are found today, along with quite handsome arsenopyrite geniculate twins. There has been mining of copper, lead, fluorspar and, finally, talc in Madoc, but it is the Rogers mine with its boulangerite and fluorite which has appealed most to micromounters, boulangerite with the rings, the tubes, the hairpin turns, the misty knots of wire catching rings as if in spider webs (Fig. 13). One can still get into the Rogers mine, but for a fee.

By and large the Madoc area is strong in fluorite, celestine, barite, tremolite, quartz and calcite; less so in pyrite, chalcopyrite, arsenopyrite, titanite, zircon, magnetite, hematite and goethite. At the talc mine east of the town, sharp micro dravite is found. At the Eldorado mine near Madoc, stilpnomelane crystals in reddish spheres associated with thin shining plates of hematite and with

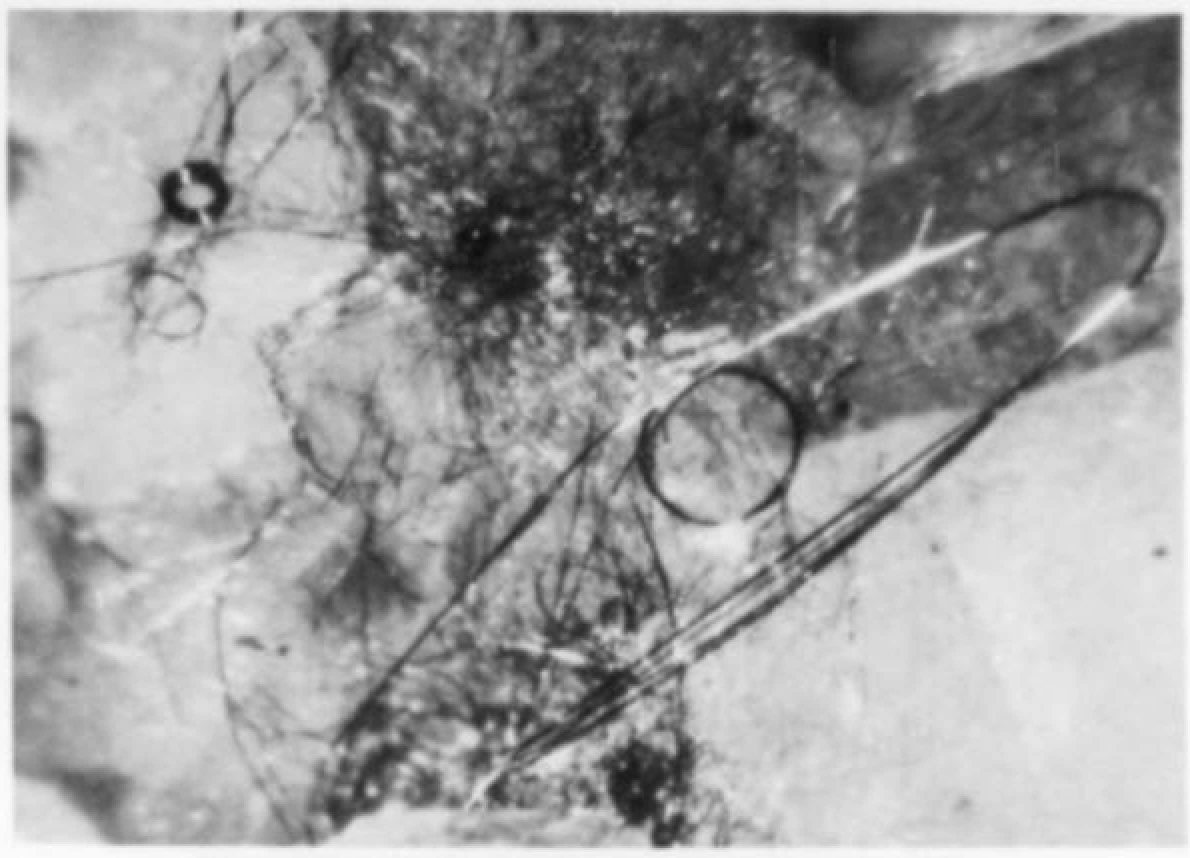

***Figure 13.* Boulangerite crystals; length of area photographed, 3 mm. From the Rogers mine near Madoc, Hastings county. Violet Anderson specimen.**

calcite have been collected. At the Noyes mine, fluorite occurs with hydrocarbon on the cube faces.

Associated with Madoc on all club field trips has been the Marmora iron mine to the south. The orebody here was magnetite, and the mine went under the name of Marmoraton. The microminerals available were splendid andradite garnet in all sizes, pyrite octahedrons, colorless barite crystals, epidote crystals also in various sizes and goethite with quartz. Marmoraton is now under new management, concentrating on producing building material; I'm not sure whether the name has been retained. To the west, in the Deloro gold mine, were (are?) striking sixlings of arsenopyrite resembling six-sided crystals.

Of the limestone quarries in southeastern Ontario, little need be said, since you will know the sulfides likely to be collected. Both the Lincoln quarry at Beamsville and the Steetley quarry in Dundas continue to provide micromounters with fine specimens. At Beamsville, the sphalerite is versatile both in habit and color (Fig. 14).

***Figure 14.* A galena hopper crystal, 0.4 mm across the upper hopper edge, from the Lincoln quarry, Beamsville, Lincoln county. Cynthia Peat specimen.**

Figure 15. **Sulfur-yellow sphalerite crystal, 0.8 mm wide, from the Lincoln quarry, Beamsville, Lincoln county. Violet Anderson specimen.**

Galena may produce an unusual specimen, like the hopper galena shown (Fig. 15). At Dundas, the marcasite and pyrite can perform a great many tricks; I have written about this pyrite before, as did Neal Yedlin. There is plenty of pale blue celestine, and various colors of fluorite – delicate pale purple to deep violet. Either quarry is likely to please the collector.

Well, I have left out a great deal. Ontario, I have discovered, is big, big, big. I'd like to thank everyone whom I phoned, inquiring for the state of affairs in their localities. I cannot name everyone any more than I could put every locality in this column. But I should like to name one person: Joe Mandarino, curator of mineralogy at the Royal Ontario Museum. He made some fine suggestions, and tried to steer me away from pitfalls. He is not responsible for what I have written, although he did say if I described a mineral as a heavenly creature with great wings (or something to that effect) he wouldn't bat an eye.

Violet Anderson
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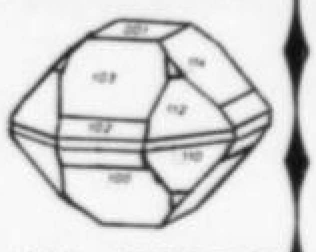

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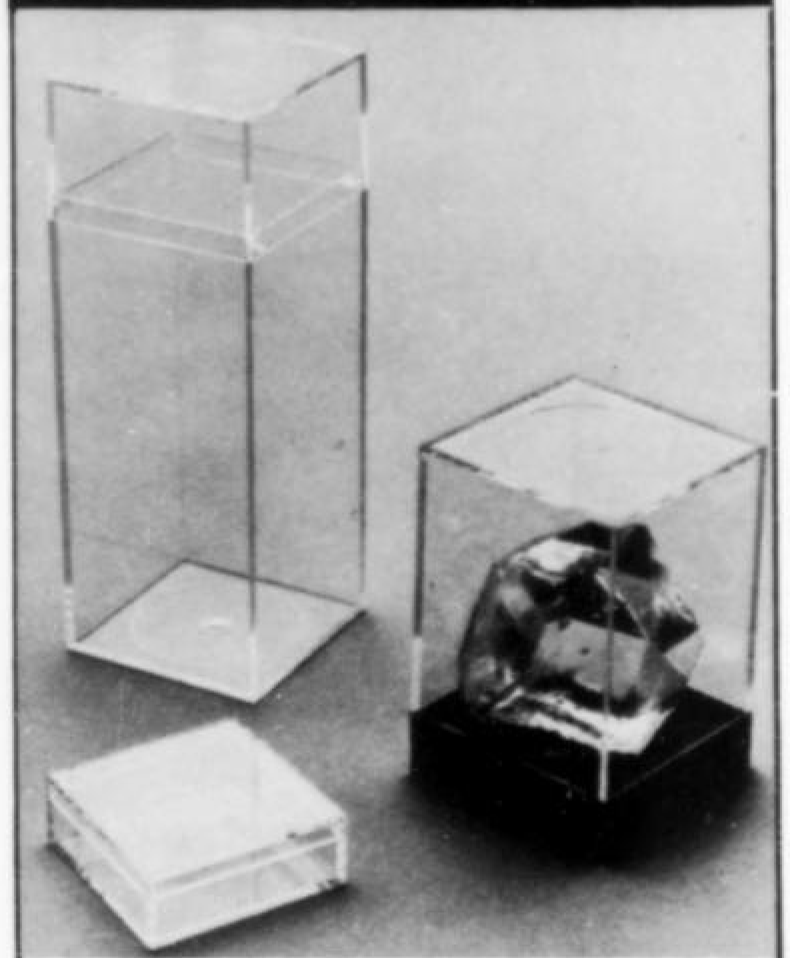

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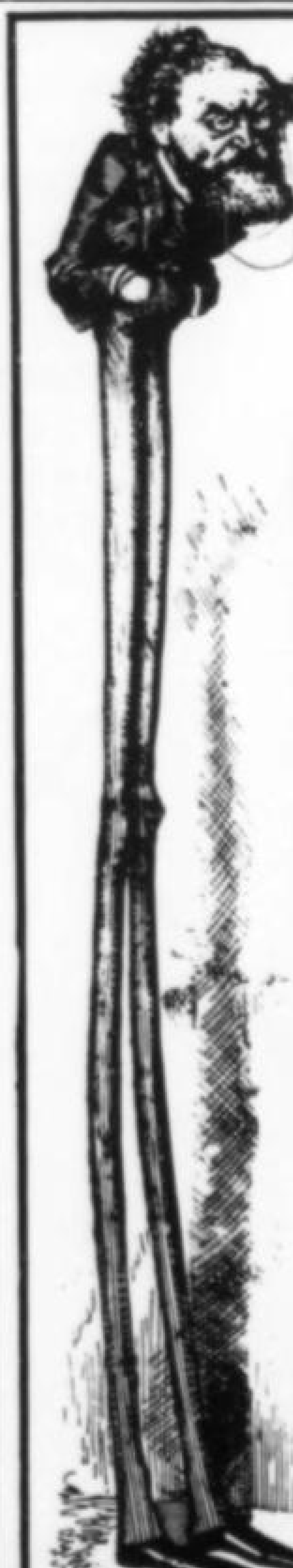

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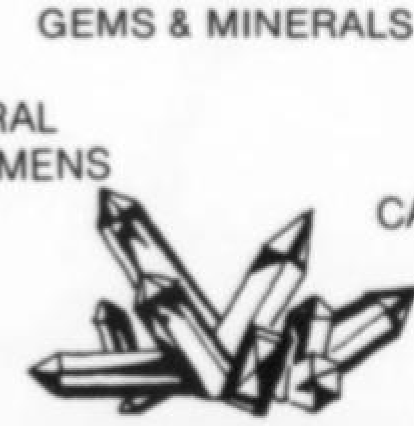

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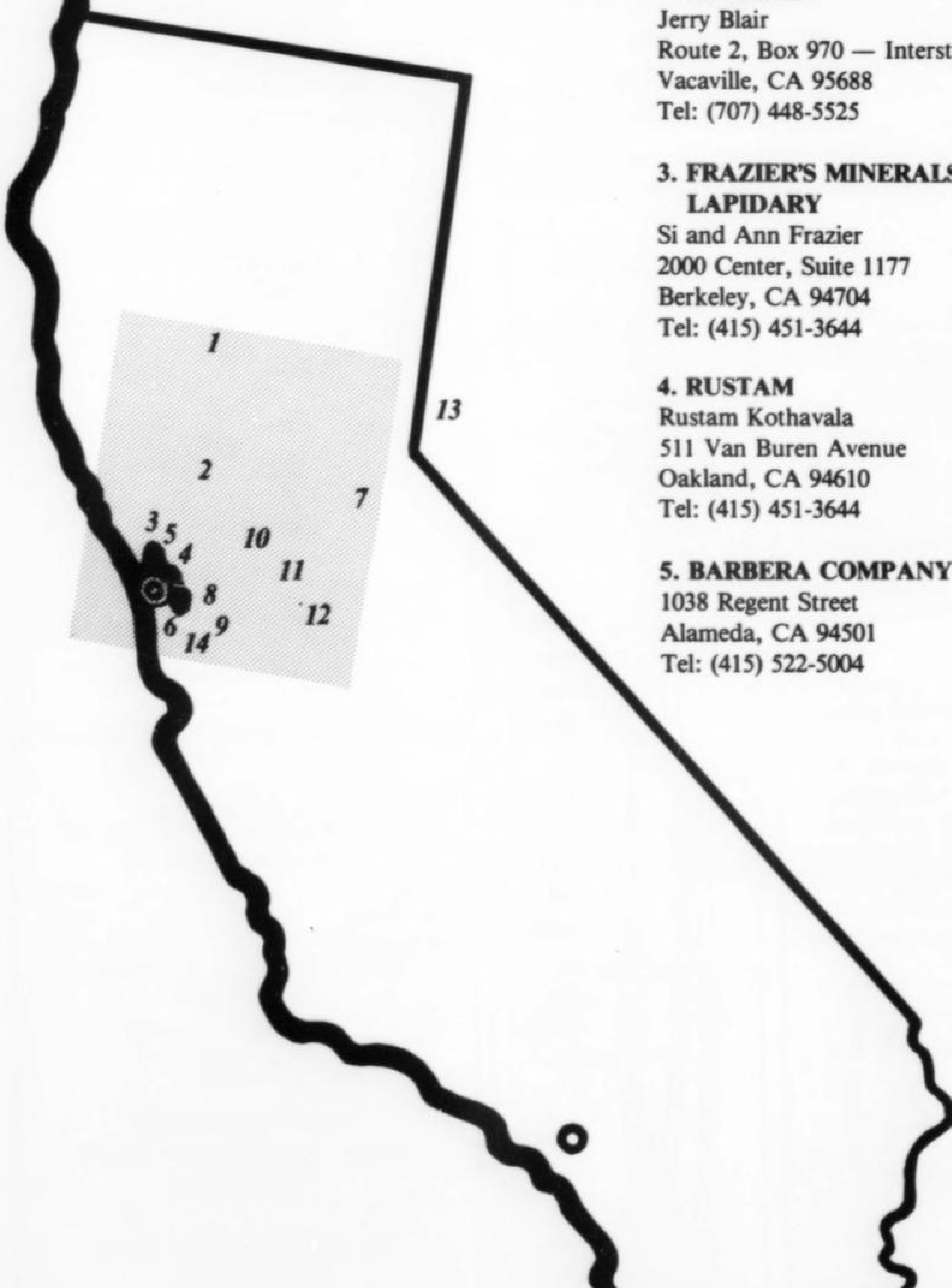

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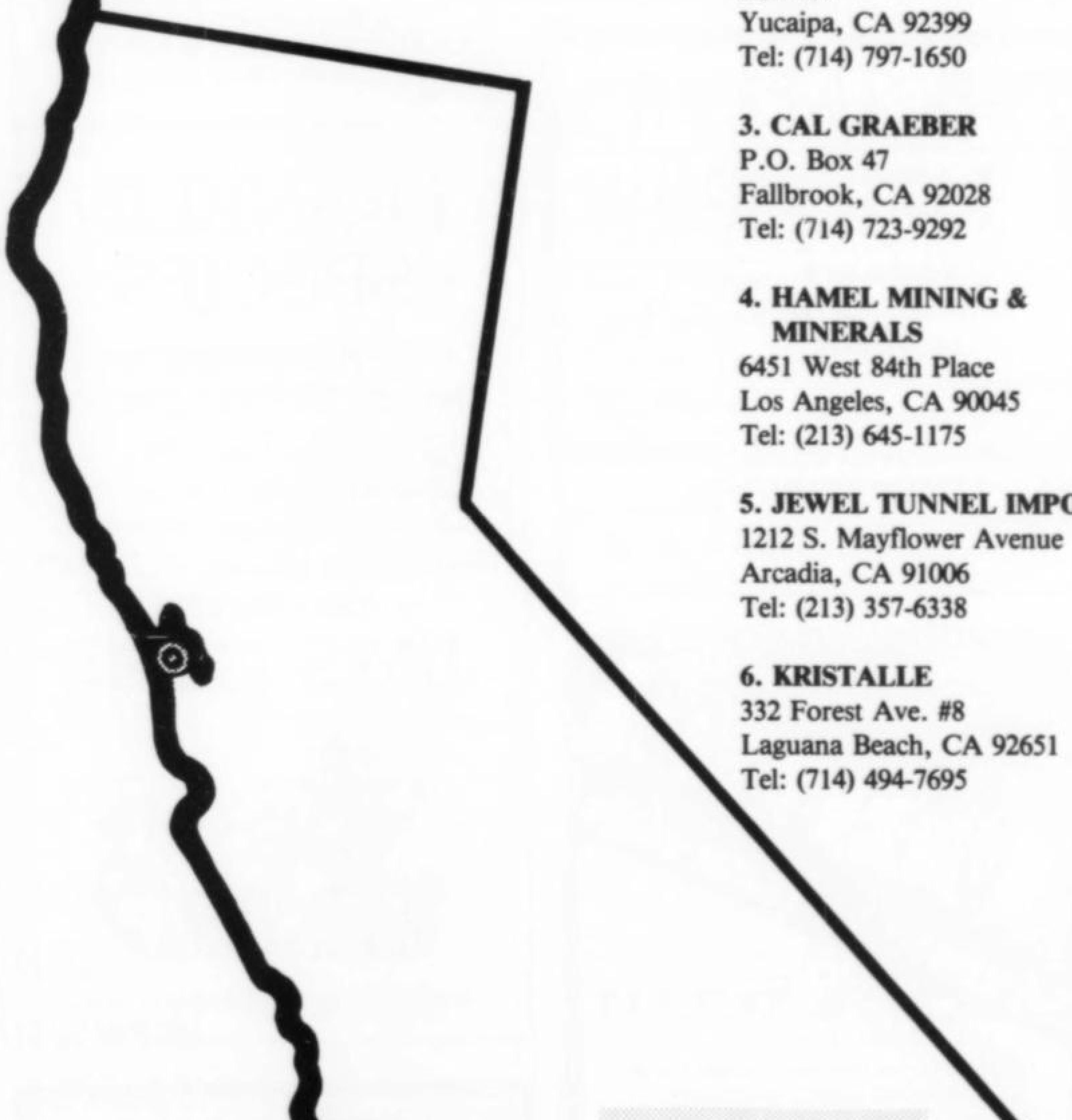

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The *International Directory of Micromounters* is published biennially (in "even" years) by the Baltimore Mineral Society at the time of its annual Micromount Symposium in September. The 11th edition will be published in September of 1982, and in order for it to be as correct and up-to-date as possible the following information is needed.

1. The full name, address and zipcode of each micromounter who wishes to be listed without charge in the 11th edition and who was not (or who does not remember if he/she was) listed in the 10th edition; we will do the checking if you are not sure. If a listing is to be for both husband and wife, please also furnish the wife's first name.

2. The new (and old) address and/or name of each person listed in the 10th edition who has moved and/or changed his or her name since it was published.

3. Identification of each person listed in the 10th edition whose mail is undeliverable at the address shown therein. Furnishing the face of one or more envelopes returned by the post office would be an easy method of doing this.

4. The zipcode of each Canadian micromounter (and the equivalent for each English one) listed without zipcode in the 10th edition – there are lots of them.

5. If you are a member of a group, club or society which has at least five members who are active micromounters, please send – or ask your secretary to send – an up-to-date list of your micromounter members showing not only the name and address of your organization but also indicating which one of them is the best contact person. We began this new club listing with the 10th edition of the Directory but have a long way to go before being even partially complete.

6. The full name and address of each dealer in micromounts, micromount material and/or tools who would like to be listed without charge in the Directory of Dealers which is a part of the Directory of Micromounters. If each such dealer who uses the Directory for business purposes would comply with item 3, above, by contacting the editor named below, it would be most helpful.

The cost of each copy of the 11th edition will be $1.50; by mail in the United States and Canada, $2.50; for all other countries the mail costs are higher and the price will vary accordingly. All information and checks for copies to be mailed should be sent, and made payable to, the editor: Randolph S. Rothschild, 2909 Woodvalley Drive, Baltimore, Maryland 21208, U.S.A.

1982 STANDARD MINERALOGICAL CATALOG

Dear sir,

Enclosed is a complementary copy of the recently published *1982 Standard Mineralogical Catalog;* the new edition is the fifth in the series. Thousands of price changes and hundreds of new listings are incorporated over the previous edition. New this year is a special section, at popular request, for the evaluation of lapidary rough. Also included are additional evaluation criteria, expanded listings, and extraordinary specimen listings. The book has been sold to collectors in the U.S. and 29 foreign countries.

Generally the overall trend for pricing is still up. However the torrid pace of previous years has reduced significantly. Many species, due to abundance of supply or a drop in interest, have actually fallen in price. The greatest gainers have been the specimens of gemstone species, some of which are still displaying spectacular rises. Rare species, as in the past, continue to bear high prices upon initial offering, followed by a significant drop in price with gradual recovery.

Edward Brazeau
Minerlogical Studies

UTAH FLUORITE

Dear sir,

Regarding your report on Utah Fluorite (November-December 1981 issue, page 389), these crystals were first offered to Utah collectors back in April of 1981 by David Lewis of *Diversified Minerals,* who is still the exclusive supplier to collectors and other dealers. When found, the fluorite crystals are covered with quartz and manganese oxide which requires removal with hydrofluoric acid (1 molar concentration). The locality is near Marysvale.

Also, I would like to compliment your magazine on the scholarly article by R. S. W. Braithwaite. His report on turquoise crystals is an excellent example of a well-written, properly referenced article geared for both the layman and the professional. The information on the use of infrared spectra is intriguing, and I might suggest that the use of a *Digilab FTIR* (Fourier Transform Infrared Spectrometer) could provide even more detailed spectra for researchers with access to such a device.

Michael R. Weiler
University of Utah

MUSINGS

Dear sir,

I wonder if anyone has ever considered the idea of a cemetary just for departed mineral folk . . . a collection of ex-collectors, as it were. What more fitting repository for those who spend their lives under the spell of stones? And they could be buried under the particular stone of their choice, as were the late Lazard Cahn (whose headstone is a large granite model of a cahnite crystal), and Job Charnock (whose tombstone is still the "type specimen" of the rock charnockite). The monuments could be shaped to reflect the interests of the now-returned-to-earth . . . what a magnificent and disorderly array of crystal clusters, cabochons, matrix specimens, facted gem shapes, big cabinet sizes and little micromounts would eventually develop at such a site! And these varied headstones would certainly deserve some fitting labels (epitaphs) honoring those who did well or did anyway. It's an interesting thought.

Pete J. Dunn

ELECTRUM (Au,Ag) FROM TSUMEB

Dear sir,

In the course of recataloging our mineral collection, our curatrix came across a specimen of electrum from the Tsumeb mine [Namibia]. We note that in your descriptive list of Tsumeb minerals (in the Tsumeb issue, vol. 8, no. 3. 1977) electrum is not listed, though silver and a single specimen of gold are reported.

Our records do not show our source for the specimen, nor its exact location within the mine. The specimen consists of a piece of chalcocite measuring about 3 cm, with a small cavity partially filled by a lamellar mass of electrum. The color is golden yellow and untarnished.

Director
Geological Survey
Republic of South Africa, Pretoria

ADVERTISERS INDEX

Abel Minerals (303-695-7600) 122
Alpine Exploration 121
Althor Products (203-762-0796) 117
American Mineralogist 117
Barstow, R. W. (0822-832381) 117
Behner, Ugo 128
Behnke, R. (203-235-5467) 117
Bideaux Minerals (602-888-6015) 100
Binders 126
Canadian Mineralogist 114
Carolina Biological Supply Co. (800-334-5551) 123
Carousel Gems and Minerals (215-441-4257) 117
Casa de Piedras (915-593-3777) 112
Chaver, J. 112
Collector's Choice (713-862-5858) 117
Colorado Gem & Mineral Co. (602-966-6626) 116
Crystal Cavern Minerals (915-593-1800) 121
Cureton Mineral Co. (209-462-1311) 92
Dupont, J. 121
Earth Resources (414-739-1313) .... inside back cover
Eckert Minerals & Fossils (303-861-2461) 121
Excalibur Mineral Co. 112
Ferri, Alfredo (435000, Milan) 121
Franklin — Ogdensburg Min. Soc. 126
Frazier, Si & Ann (415-843-7564) 121
Galas Minerals (209-847-4782) 106
Glossary of Mineral Species (602-297-6709) 125
Golden Minerals (303-233-4188) 115
Goudey, H. 120
Gregory, Bottley and Lloyd 106
Hamel Mining and Minerals (213-645-1175) 120
Hansen Minerals (314-569-0842) 114
Hawthorneden (613-473-4325) 120
International Handbook 106
Jewel Tunnel Imports (213-357-6338) 114
Jim's Gems (201-638-0277) 120
Kristalle (714-494-7695) .... inside front cover
Languages D. B. (415-433-8600) 128
Lesnicks 105
Lesnicks-West (602-749-4234) 105
Lidstroms (503-447-7104) 120
Lythe Minerals 125
Machlis, M. 120
Mathiasen Minerals (415-657-0994) 114
McGregor and Watkins (501-767-4461) 112
McGuinness, A. L. (415-345-2068) 121
Metersky's Minerals 120
Miller, Mary & Gardner (406-549-7074) 117
Mineral Classics (303-642-7556) 115
Mineral Collection (215-576-5639) 121
Mineral Collection Sale 128
Mineral Decor 115
Mineral Enterprises 116
Mineral Kingdom (713-868-4121) 124
Mineral Mailbox (206-833-6067) 115
Mineralogical Research Co. (408-263-5422) 106, 128
Mineralogical Studies 115
Minerals Unlimited 121
Mirchandani (240503, Bombay) 115
Mono International 125
Monteregian Minerals 125
Mountain Gems and Minerals (303-420-1657) 115
Nature's Treasures (213-373-3601) 115
Northern California Dealers 118
Obodda, Herbert (201-467-0212) 106
Oceanside Gem Imports (516-678-3473) 115
Pala Properties Int'l. (714-728-9121) .... outside back cover
Peri Lithon Books (714-488-6904) 115
Philosopher's Stone 115
Precious Earth 115
Keith Proctor (303-598-1233) 66
Prospector 116
Reed — Mining Lore 105
Revista Mineralogia Italiana 126
Rich, C. C. 105
Roberts Minerals (209-586-2110) 113
Rochester Symposium 105
Runner, Bruce & Jo (209-634-6470) 116
Salt Minerals 116
S & M Enterprises 115
Schneider's Rocks & Minerals (714-748-3719) 116
Shannon, David (602-962-6485) 116
Sierra Nevada Mineral Co. (702-329-8765) 116
Silverhorn (403-762-3918) 116
Simkev Minerals 116
Southern California Dealers 119
Stonecraft (317-831-7713) 121
Thornhill Minerals 116
Topaz-Mineral Exploration 120
Treasure Tunnel 120
Universal Gems & Minerals (915-772-5816) 120
University Microfilms 126
Upper Canada Minerals (613-238-5497) 120
Weber's Minerals (714-436-4350) 121
Weller, Sam (0736-788217) 116
Western Minerals (602-325-4534) 116
What on Earth (614-436-1458) 116
Wright's Rock Shop (501-767-4800) 113
Yount, Victor (703-347-5599) 121