the Mineralogical Record

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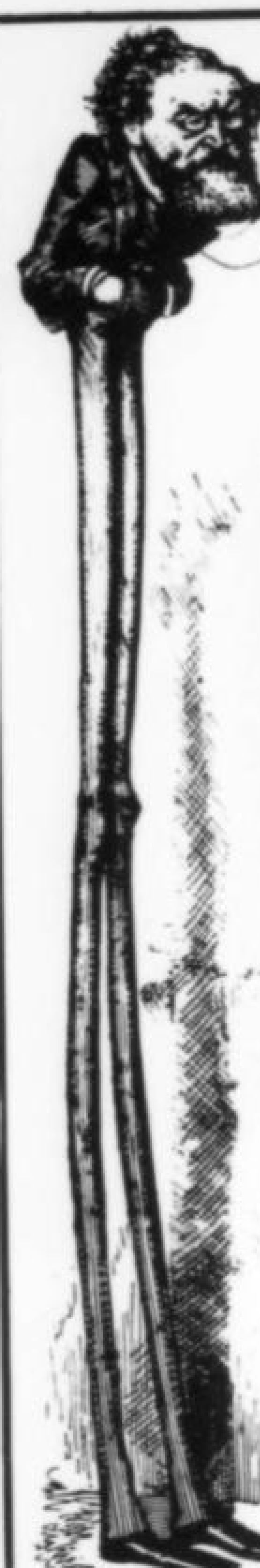
COVER: MALACHITE pseudomorph after azurite from Tsumeb, Namibia. The group is 3 inches tall, and is no. 8877 from the famous Carl Bosch collection (see vol. 9, no. 3, p. 181 for more on this collection; Bosch died in 1940). Wayne and Dona Leicht specimen; photo by Harold and Erica Van Pelt.



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Some Classic Mineral Localities of Southeastern Ontario

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Much of southeastern Ontario is underlain by a complex assemblage of Precambrian rocks containing hundreds of mineral occurrences, some of which have attracted the attention of geologists, mineralogists and mineral collectors for more than a century.

INTRODUCTION

It would be impossible to attempt to describe all known occurrences in southeastern Ontario in one paper, but to illustrate their diverse mineralogy and geological features, and to indicate the reason why southeastern Ontario has long been one of the most popular mineral collecting regions of North America, nine of the more interesting and accessible occurrences are described here. They have been selected from a much larger number visited on an excursion conducted by the four authors for participants at the 24th International Geological Congress, which was held in Canada in 1972. In historical perspective a few of the described localities were known before Confederation (1867) and were included on an excursion for the 12th International Geological Congress, held in 1913. The descriptions are necessarily brief, but do cover the main features as well as providing exact geographical locations and selected references. For more complete accounts and a detailed bibliography the reader is referred to the Excursion Guidebook (Hogarth *et al.*, 1972) and for detailed routing to Sabina (1968, 1971). A well-illustrated summary is also given by Hewitt (1969). Except where otherwise noted, all illustrated specimens are from the National Mineral Collection of Canada housed at the Geological Survey of Canada (GSC numbers) and the National Museum of Natural Sciences (NMNS numbers).

[1] Now retired.

GEOLOGY

The area lies within the Grenville Province of the Precambrian Shield and is underlain by a wide variety of metavolcanic, metasedimentary and igneous rocks. Of particular note are many large bands of crystalline limestone (marble), abundant granitic and syenitic pegmatites and, in the western part, a northeast-trending belt of nepheline rocks 120 miles (193 km) long. The area was complexly folded during the Grenville orogeny about 1000 million years ago, which itself was probably overprinted on still older orogenic belts. Subsequent erosion has reduced the once mountainous terrain to a peneplain in which relief seldom exceeds 600 feet. The area is overlapped on the south and east by relatively undeformed Paleozoic rocks, except for an arch of Precambrian rocks that reaches through the Thousand Islands to the Adirondack Mountains of northern New York State. The bedrock is glacially scoured, and is covered in places by unconsolidated glacial and post-glacial deposits including boulder clay and erratics, marine clay, sand, gravel, peat, marl and the soil on which the mixed forest cover depends. The area, heavily wooded and containing numerous lakes, is a popular tourist region and is well serviced by roads and tourist-oriented facilities. The highway geology map recently issued by the Province of Ontario (Freeman, 1978) is recommended as a useful guide to the general geology and access roads.

Host Rocks

The described localities (Fig. 1) occur within three well-defined

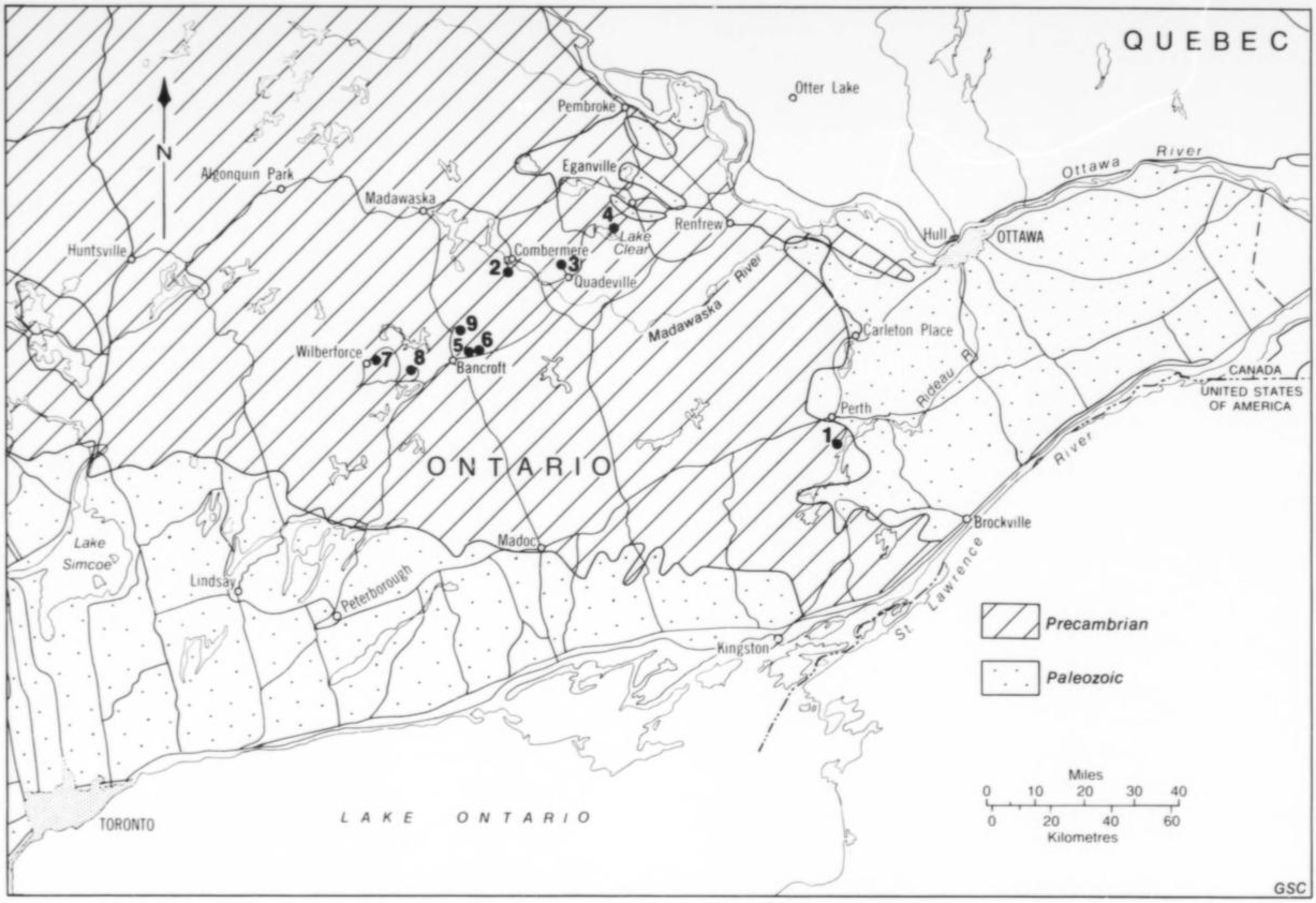


Figure 1. **Generalized geology of southeastern Ontario and locations of classic mineral localities described in this paper: 1 – Perthite occurrence, 2 – Craigmont corundum mine, 3 – Quadeville beryl-lyndochite pegmatite, 4 – Lake Clear apatite vein-dikes, 5 – Princess sodalite mine, 6 – Egan Chute corundum occurrence, 7 – Fission mine, 8 – Silver Crater mine, 9 – MacDonald feldspar mine.**

geological environments, namely: granite pegmatites, nepheline- and corundum-bearing gneisses, and calcite vein-dikes. A full description of these is given in the guidebook and the following is therefore intended only as an introduction.

Granite pegmatites are widespread throughout the region and range up to a mile in length and several hundred feet in width. Most are simple, unzoned dikes, but others are crudely zoned; a few are complex. Most show sharp contacts with their host rocks. The crystallization in some cases has been remarkable, with feldspar crystals up to 15 feet (4.6 m) and allanite crystals to 3 feet (1 m), in length. Numerous pegmatite dikes were quarried for feldspar, quartz and mica in the first half of the century (Hewitt, 1967). One deposit of unzoned pegmatite granite dikes in the Bancroft area is currently being mined for uranium (Madawaska Mines Ltd., at the former Faraday mine).

Nepheline- and corundum-bearing gneisses flank a zone of granitic rocks in the western part of the area, where they occur in a 120-mile (193 km) belt of disconnected sinuous bodies up to 3 miles (4.8 km) long. The rocks are generally gneissic and conformable with their enclosing paragneisses and marble, but here and there contain pegmatite-like patches in which nepheline crystals may reach 6 feet (1.8 m). The origin of the rocks is still controversial, with theories ranging from magmatic differentiation by means of a process of limestone syntexis in which limestone desilicates the magma, to varied combinations of igneous, metamorphic and metasomatic processes. The deposits are especially known for their corundum, sodalite and cancrinite. Large bodies of nepheline gneiss are currently being worked at Blue Mountain, near Peterborough, as a raw material for the glass and ceramics industry.

Calcite vein-dikes are calcite-cored bodies which Ellsworth (1932), who coined the term, described as having "to a considerable degree the form and character of veins but also contain[ing] minerals characteristic of pegmatites." A core of coarsely crystalline calcite is common to all, but otherwise the vein-dikes may contain a wide variety of minerals which typically occur as crystals lining the walls and growing inward and which characteristically reflect the composition of the host rocks. The most common such minerals are apatite, fluorite, alkali feldspars, clinopyroxenes, clinoamphiboles, phlogopite, titanite and scapolite. The calcite is either whitish or, as at Turner's Island, salmon-colored. Apatite may be green or reddish. Radioactive minerals such as uraninite, uranothorite and allanite occur in some deposits. When associated with such minerals the fluorite occurs as the dark purple *antozonite* variety, but otherwise it is light colored and transparent. The vein-dikes appear to be late magmatic or metamorphic differentiates with the calcite likely being derived from local marble. The cores commonly exhibit planar flow-line structures resulting from their deformation under regional stresses.

MINERAL LOCALITIES

(a) PEGMATITES

Perthite Occurrence

Lot 4, Concession VI, North Burgess Township, Lanark County.

Perthite was the name given by Thomas Thomson (1843) to a whitish *aventurine* feldspar collected by Dr. James Wilson from an occurrence near Perth, Ontario. Thomson was Regius Professor of Chemistry, and Mineralogist, at the University of Glasgow, and Wilson a medical doctor and ardent mineral collector at Perth. What is believed to be Wilson's original occurrence is a pegmatite dike cropping out beside a paved county road about 6 miles (9.7 km) southwest of Perth and west of Adam Lake. Here the perthite, consisting of narrow lenticular bands of whitish plagioclase in a reddish microcline host, occurs as cleaved crystals up to 12 inches (31 cm) across. Although noteworthy primarily as the type locality for perthite, one of the most prevalently used feldspar names, the occurrence is popular with collectors and lapidarists because of its easy access and attractiveness of the mineral intergrowths both in hand specimen (Fig. 2) and polished form.

The town of Perth, established in 1816, is one of the loveliest original towns of the Ottawa Valley, characterized especially by many magnificent stone residences and commercial buildings that reflect its Scottish ancestry. Mining was carried out locally on a small scale, especially in the late 1800's, for apatite, phlogopite, titaniferous magnetite, graphite and feldspar and, recently, for vermiculite and marble. The area also claims the type localities for peristerite and the now discredited *wilsonite* (altered scapolite) and *raphilite* (a synonym for tremolite).

Selected References: Thomson (1836, 1843).

MacDonald Feldspar Mine

Lots 18, 19, Concession VII, Monteagle Township, Hastings County.

The MacDonald mine is located about 6 miles (9.7 km) northeast of Bancroft and is perhaps Canada's best known pegmatite dike. It was operated from 1919 to 1935, producing about 35,000 tons of

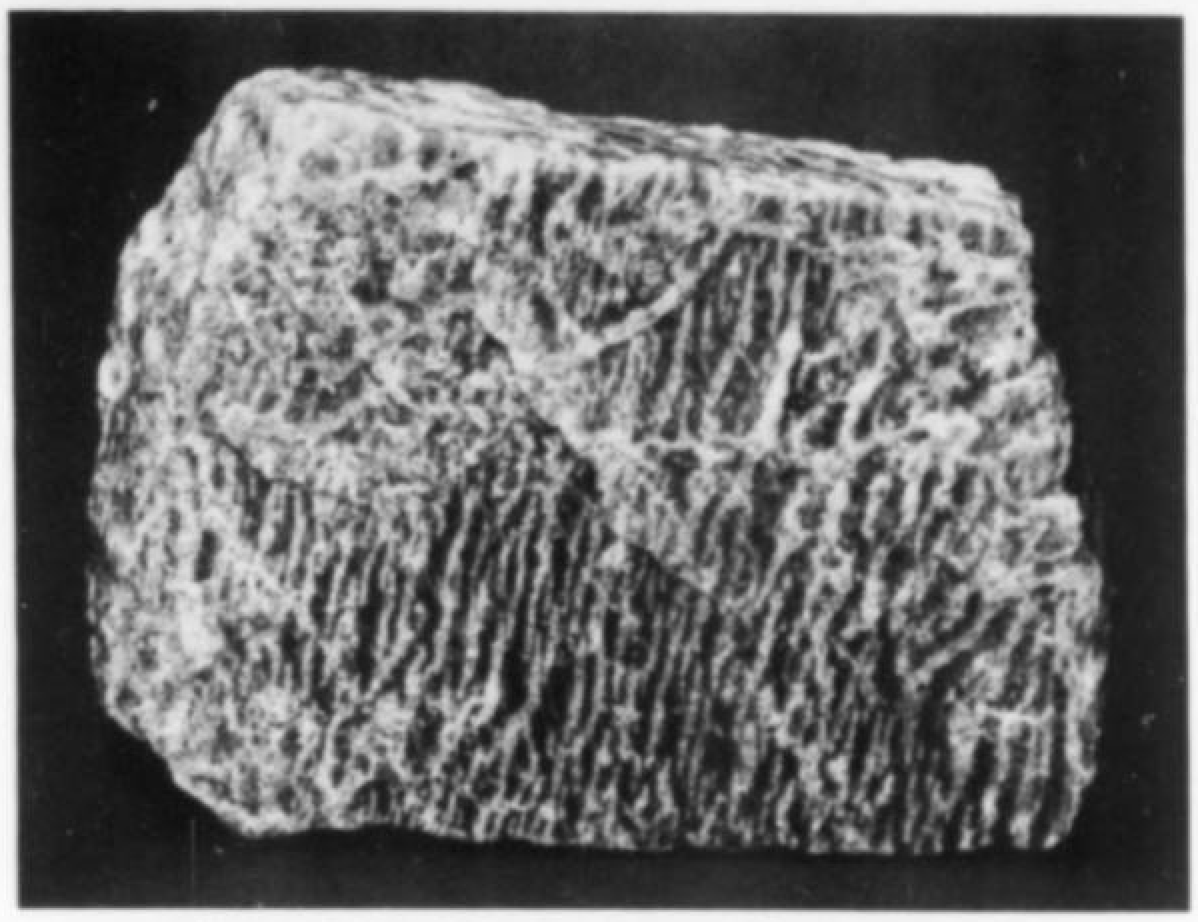
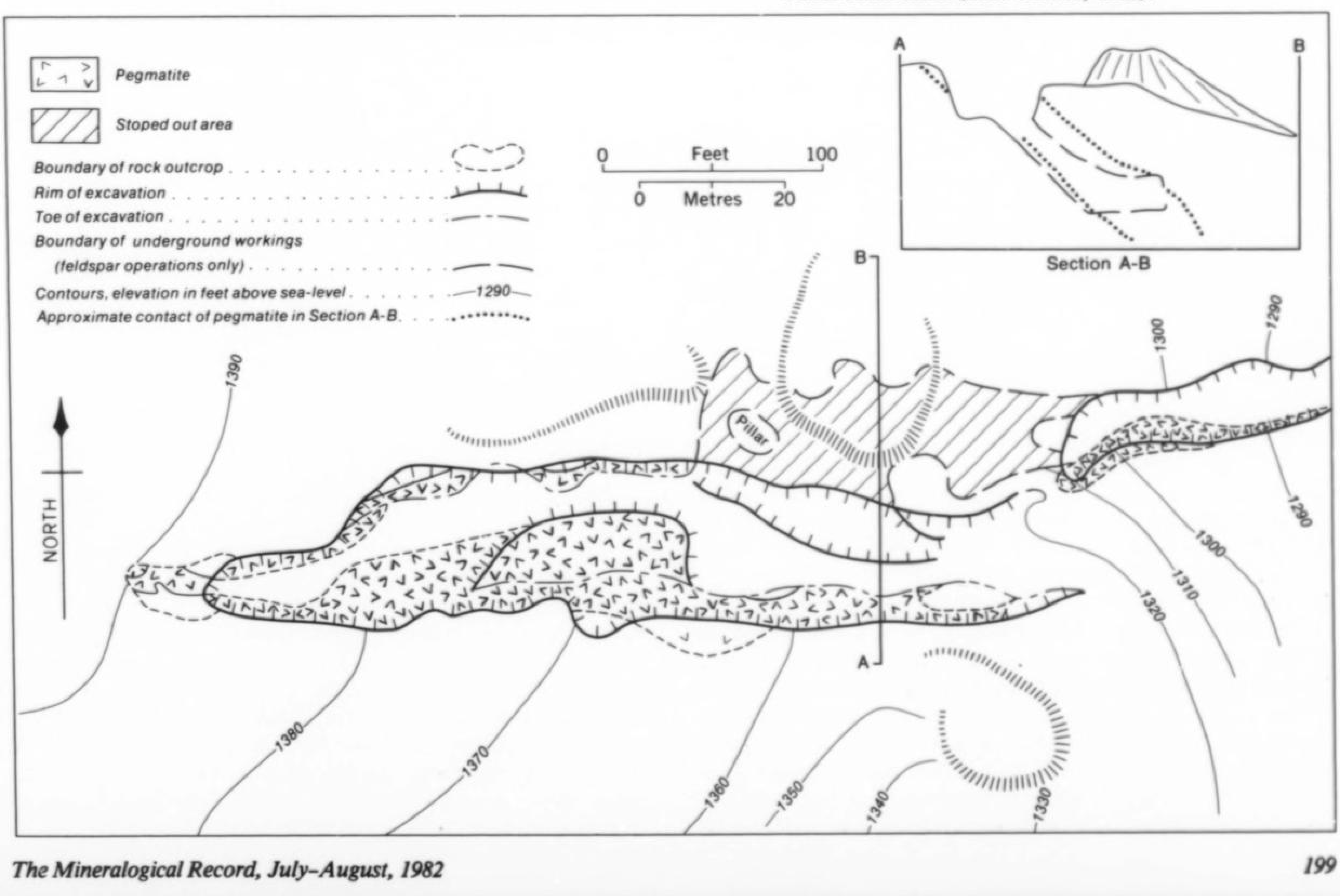


Figure 2. **Perthite, Perth area. Hand specimen exhibiting white lamellae of plagioclase in a microcline host.**

feldspar. In the 1950's it was explored as a possible source of radioactive minerals. The mine is developed on a steeply-dipping zoned pegmatite cutting a complex series of gneisses, amphibolite and silicated marbles. The workings consist of an open cut 150 feet (46 m) long, 70 feet (21 m) wide and 120 (37 m) deep, and a lower connecting chamber reflecting entry and up-dip stoping from below (Fig. 3). To the collector the MacDonald mine is best known for *ellsworthite,* a hydrous variety of uranpyrochlore named by Walker and Parsons (1923) in honor of H. V. Ellsworth, former chemist-mineralogist and rare-element specialist of the Geological Survey of Canada, and for large clusters of crystals of the *cyrtolite* variety of

Figure 3. **Plan and section of main workings, MacDonald mine (after Hewitt, 1955).**



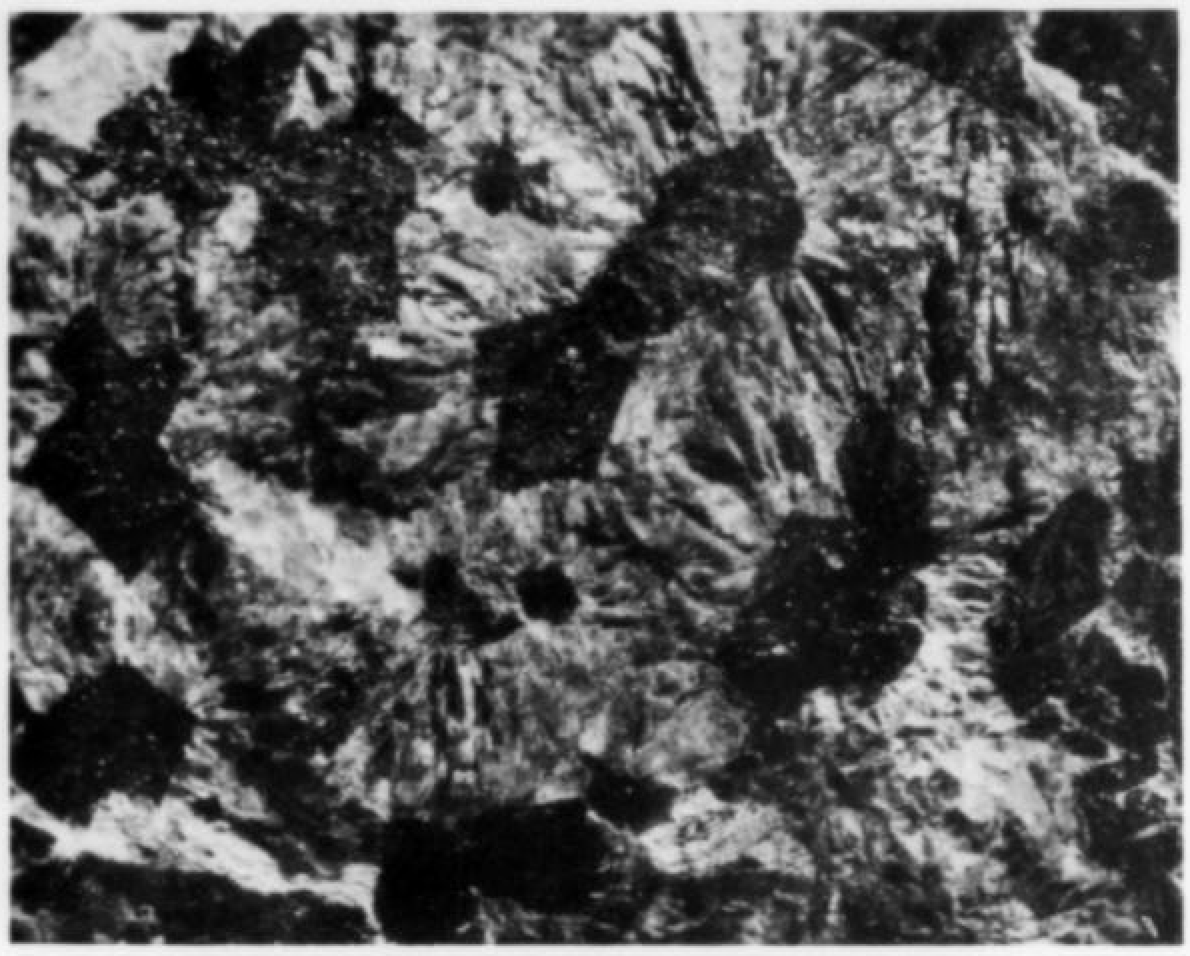


Figure 4. **Radial shattering of feldspar around crystals of uranothorite, MacDonald mine (X5 GSC 61242).**

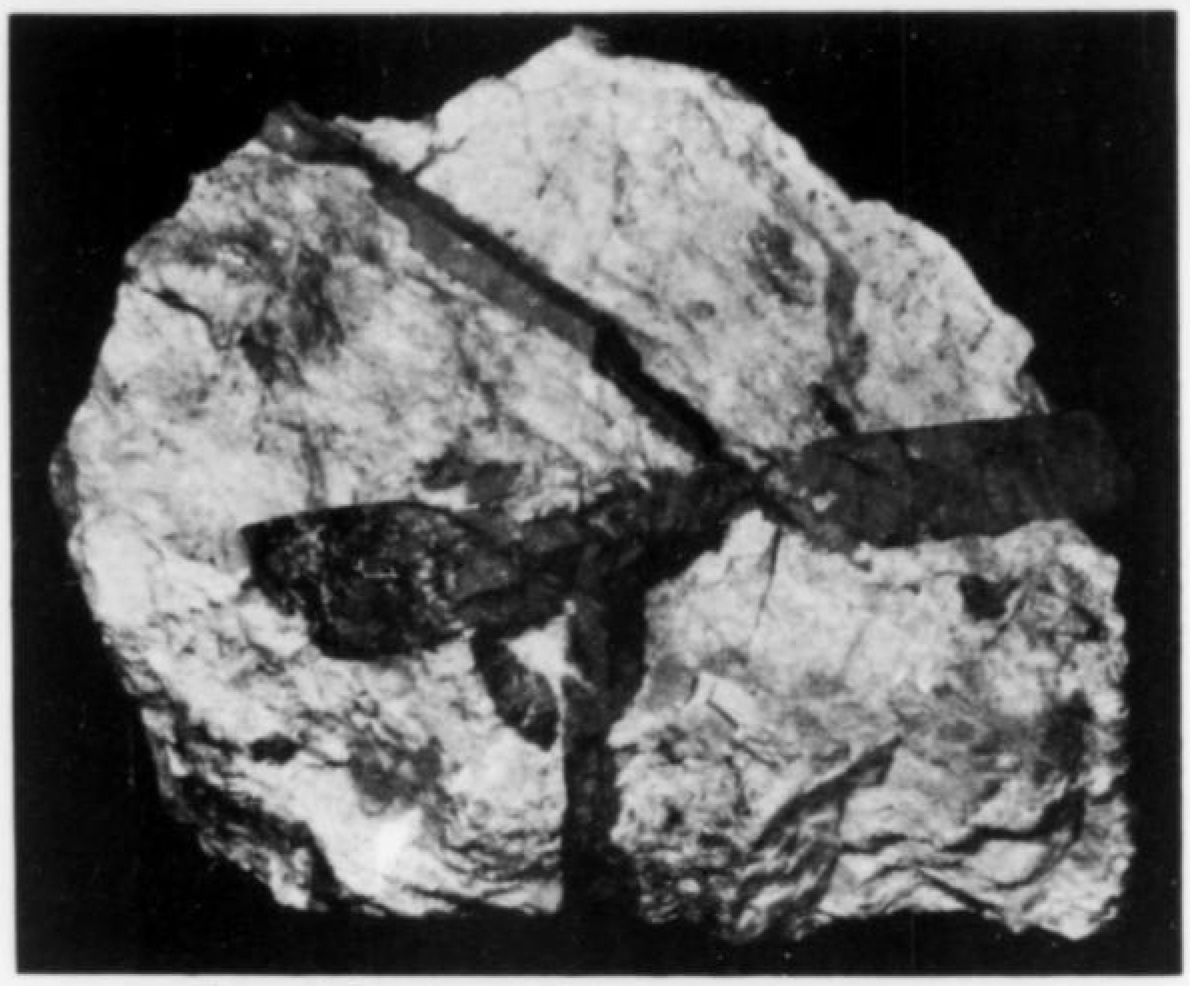


Figure 5. **Beryl crystals in pegmatite, Quadeville beryl-lyndochite quarry. The largest crystal is 10½ inches (27 cm) long (NMNS 42580).**

zircon. However, the mine's importance today is not only in the specimen potential of its dumps but more so in its preservation as a classic example of the pegmatites that were worked throughout Eastern Ontario and Western Quebec for feldspar, and for its splendid in-situ examples of certain features associated with radioactive minerals. These features include the radial shattering of quartz and feldspar around discrete radioactive grains (Fig. 4) and darkening of quartz, ranging from slightly smoky quartz in contact with feldspar crystals to black quartz where intimately associated with radioactive minerals. Sharp contacts with the country rock may be seen, together with the zoning and typical coarse crystallization characteristic of pegmatites. For example, feldspar crystals up to 15 feet (4.6 m) in length are exposed on the quarry walls. Of special petrologic interest are large masses of coarsely crystalline calcite associated with quartz that were encountered within the dike, remnants of which are still to be seen in the lower chamber. This material, which is more akin to a calcite vein-dike than typical pegmatite, carried most of the ellsworthite in the deposit.

Selected References: Ellsworth (1932).

Quadeville Beryl-Lyndochite Occurrence

Lot 23, Concession XV, Lyndoch Township, Renfrew County.

This complex, rare-element pegmatite has produced the finest beryl specimens in Canada and is the type locality for *lyndochite.* It is located about a mile north of Quadeville, which in turn is about 15 miles (24 km) south of Barry's Bay. The pegmatite cuts granite and gneiss and is exposed by an open cut 250 feet (75 m) long, 50 feet (15 m) wide and 6 (1.8 m) to 35 feet (11 m) deep. A central constriction divides the dike into two parts, one of which is coarse grained and well zoned, and the other undifferentiated. The dike was worked on a small commercial scale for beryl in the late 1930's, at which time crystals up to 3 feet (1 m) in length were recorded. A group of smaller crystals is shown in Figure 5. A little aquamarine beryl was also encountered, of which beautiful faceted stones are to be seen in the Mineral Gallery of the Royal Ontario Museum in Toronto. Lyndochite, first recorded by Miller (1898), was studied in detail by Ellsworth (1927), who considered it to be a new mineral related to euxenite, but rich in niobium, thorium and the yttrium subgroup of rare earths, and which he named after the township. It occurs as stout, black prismatic crystals up to 7½ inches (19 cm) long, commonly associated with magnetite in feldspar. It has since been found to be as rich in cerium-earths as yttrium-earths and is now classed as a thorian-neodymian aeschynite (Fleischer, 1966). Columbite-tantalite occurs as flat masses as much as a foot (0.3 m) in diameter, in places showing concentric structures (Fig. 6). Large crystals of black tourmaline and platy masses of the *cleavelandite* variety of albite occur in vuggy zones. Some of the finest *peristerite* in Ontario occurs in this quarry. Tiny zircon crystals occur in swarms within the pegmatite.

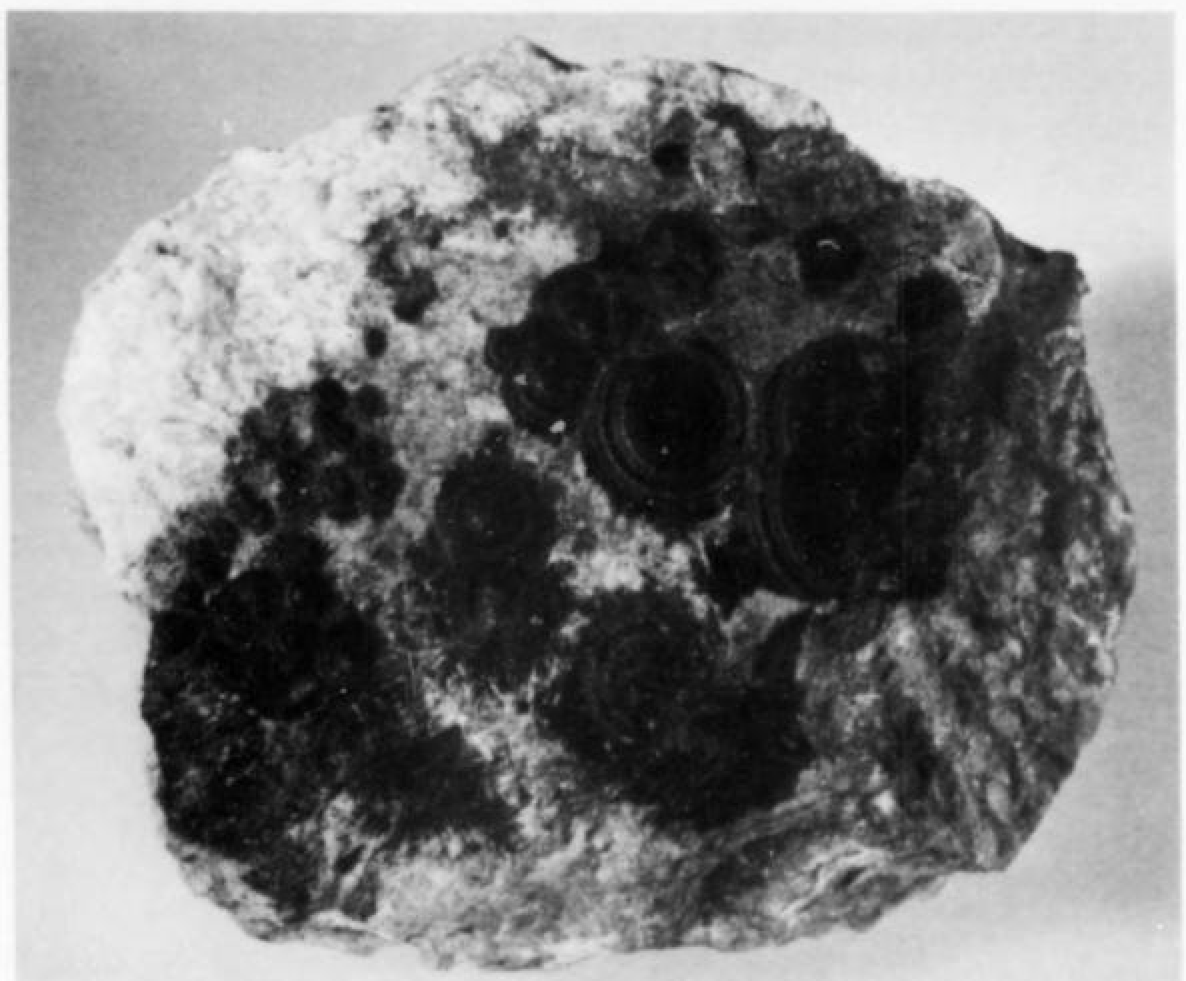


Figure 6. **Concentric columbite, Quadeville beryl-lyndochite quarry. Central mass is 1.5 cm in diameter (GSC 60007).**

Selected References: Ellsworth (1932); Hewitt (1954); Rose (1960).

(b) CALCITE-FLUORITE VEIN-DIKES

Fission (Richardson) Mine

Lot 5, Concession XXI, Cardiff Township, Haliburton County (underground workings)

The Fission mine exposes some of the finest examples to be seen of uranium-bearing vein-dikes. It lies about 2 miles (3.2 m) northeast of Wilberforce and consists of an en-echelon series of vein-dikes that have been explored by stripping and trenching over a length of 700 feet (214 m) and, on the main showing, by an adit

Figure 7. **Flow texture in specimen from calcite-fluorite vein-dike, Fission mine. Aligned, dark mineral is *antozonite,* the deep purple variety of fluorite. Speckled mass at right is an entrapped rock fragment. Black mass at left is magnetite. Specimen is 13½ inches (34 cm) long (GSC 61244).**

Figure 8. **Cuboctahedral betafite crystals, Silver Crater mine. This 2½ inch specimen was collected in situ on the International Geological Congress Excursion, 1972 (NMNS 42584).**

with some drifting and stoping. Individual occurrences actually range progressively from pegmatites with minor calcite to the typical calcite-cored vein-dikes and transitionally from these into their host-rock gneisses. The vein-dikes dominate and are composed essentially of calcite and fluorite, with subordinate alkali feldspars, hornblende, apatite and magnetite, which occur for the most part as well defined crystals usually attached to the walls. The flowage structure is especially evident (Fig. 7). The deposit first came to attention in 1922 with the discovery of uraninite and was subsequently explored for radium and then uranium and fluorite. Several unsuccessful attempts to mine and mill the ore material were made in the 1950's. Uraninite still remains the mineral of greatest interest, occurring as sharp, simple or modified cubes up to several centimeters. One crystal weighing nearly 5 pounds (2.3 kg) was recovered in 1945 (Meen, 1948) and is currently at the Royal Ontario Museum.

Selected References: Ellsworth (1932); Hewitt (1959); Satterly (1943).

Silver Crater Mine

Lot 31, Concession XV, Faraday Township, Hastings County.

This mine, also called the Basin property, is well known to collectors throughout the world for its betafite crystals. It lies about 8 miles (13 km) west of Bancroft and consists of a lenticular mass of coarsely crystalline calcite, 400 feet (122 m) long and 50 (15 m) to 100 feet (31 m) thick, enclosed within easterly dipping hornblende-plagioclase gneiss. Large crystals of hornblende, biotite and albite are developed along the borders, while crystals of apatite, biotite, betafite, zircon and molybdenite are scattered throughout the mass. Hornblende crystals up to 11 feet (3.3 m) long may be seen in place. The mine was originally worked in 1925 for biotite mica and from 1947 to 1949 for scrap mica. In the early 1950's some excellent crystals of betafite, containing 15 to 20 percent uranium, were encountered in the residual soil, which led to the carbonate body being explored for its uranium potential by stripping, trenching and drilling, and subsequently by an adit and several hundred feet of drifting. Betafite (Fig. 8) occurs as individual crystals up to 4 inches (10 cm) across and as intergrowths, mainly showing a cuboctahedral development. Although possibly a carbonatite, the carbonate body is believed to be more closely linked to the vein-dike class of deposits.

Selected Reference: Hewitt (1959).

Lake Clear Apatite Vein-Dikes

Turner's Island: Island D, Lake Clear, Sebastopol Township, Renfrew County.

Smart Mine: Lot 31, Concession X, Sebastopol Township, Renfrew county.

Lake Clear, approximately 5 miles (8 km) west of Eganville, is a scenic cottage-bordered lake 4 miles (6.4 km) long and 2 miles (3.2 km) wide situated on one of the down-dropped Precambrian blocks associated with Ordovician rift-faulting of the region. From 1878 to 1885 a number of calcite vein-dikes near the eastern end of the lake and on small islands nearby were explored and worked for apatite, of which less than 2000 tons were shipped. The vein-dikes occur within banded gneisses, amphibolites and pyroxenites. The most accessible and easily identified localities are the Smart mine, ½ mile (0.8 km) northeast of the lake, and those on Turner's Island, a small island in the east end of the lake and about ¼ mile (0.4 km) offshore. These relatively small and obscure vein-dikes have yielded some of the largest and finest crystals of zircon and titanite in the world, including zircon crystals up to a foot (0.3 m) in diameter and twinned titanite crystals up to 80 pounds (36 kg) in weight. The Smart mine is noted especially for its twinned zircons, up to 4

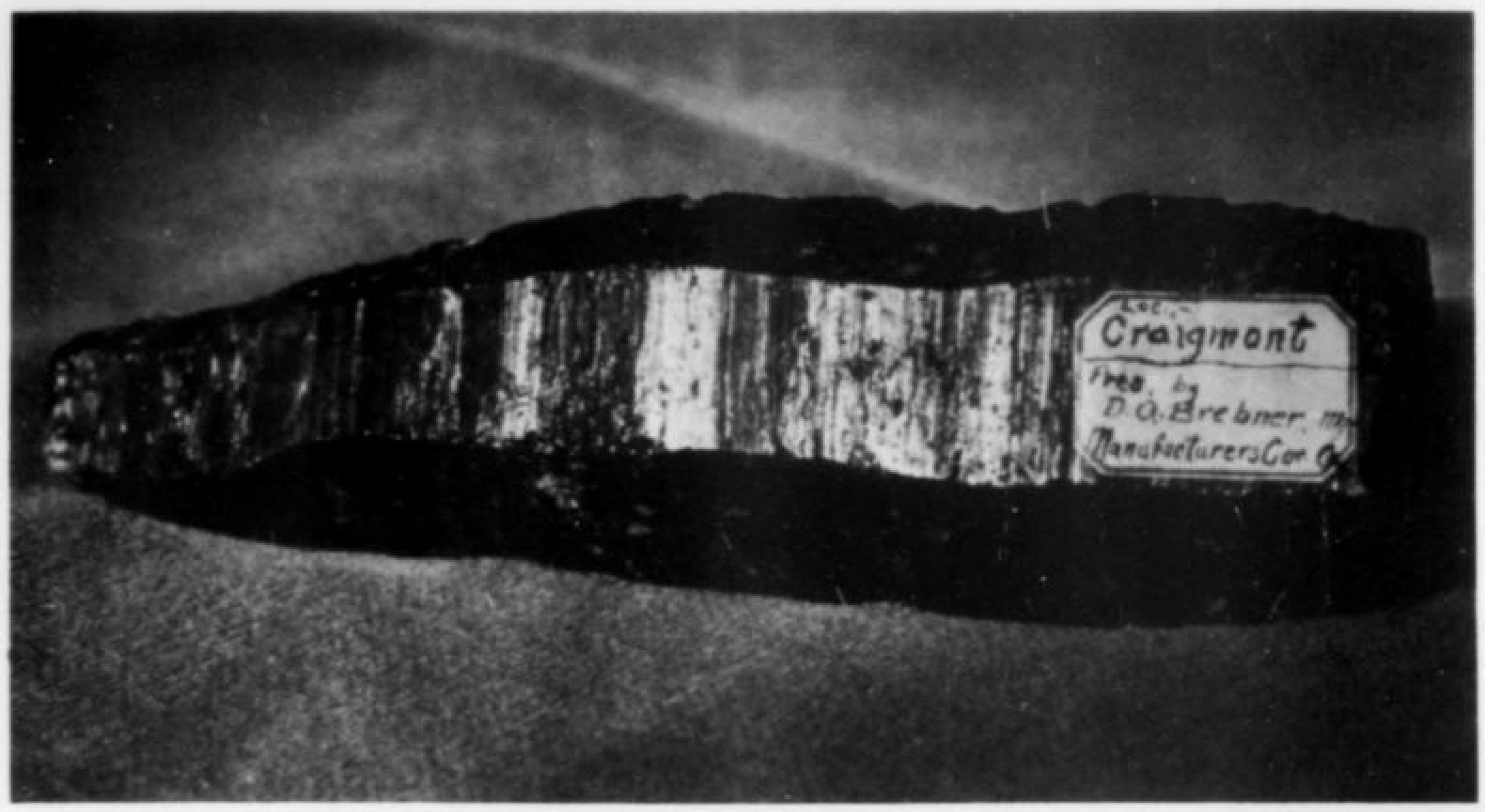
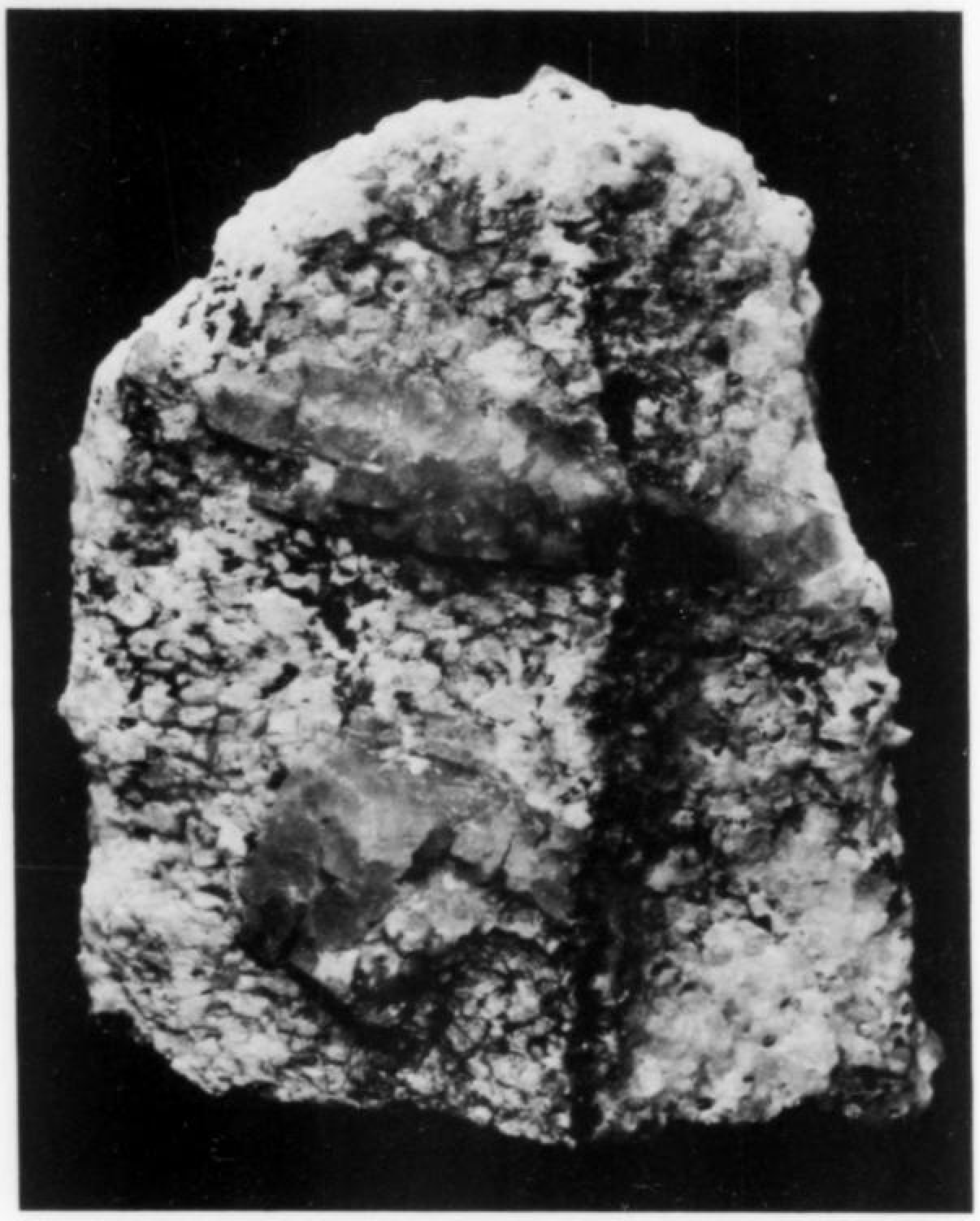


Figure 9. **Exceptional 5½ inch (14 cm) crystal of corundum, Craigmont mine (GSC 61241).**

Figure 10. **Corundum crystals in relief on weathered surface of nepheline syenite gneiss, Egan Chute, York River. The larger crystal is 1¼ inches (3.5 cm) long (GSC 14983).**



inches (10 cm) long. The value of such specimens was fortunately appreciated at the time and a great many were sold or otherwise distributed, to find their way into collections throughout the world; such specimens included the superb twinned zircons at the British Museum, the 1-foot (25 cm) long zircon crystal at the Academy of Natural Sciences at Philadelphia, and the 63 pound (28.6 kg), 7 x 26 inches (17 x 65 cm) titanite crystal that was purchased in 1881 by the Museum at Harvard University. Apatite in excellent crystals to a foot (0.3 m) in length are abundant, particularly in the vein-dikes on Turner's Island, where scapolite is also a significant constituent. The calcite here is salmon-colored. Old specimens may be variously labeled as Lake Clear, Turner's Island, Smart Mine, Meany Mine (near the Smart), Sebastopol Township, "near Eganville," or Renfrew, Canada. The correct localities for the Lake Clear area titanites, zircons and apatite are noted above. For a more detailed description the reader is referred to the accompanying article by J. Grice.

Selected References: Spence (1920); Satterly (1945).

(c) CORUNDUM- AND NEPHELINE-BEARING GNEISSES

Craigmont Corundum Mine

Lots 3 and 4, Concession XVIII and XIX, Raglan Township, Renfrew County.

(Klondike workings: Lot 2, Concession XIX)

Craig Mountain, about 6 miles (9.7 km) south of Combermere, is a dominant local topographic feature, rising 500 feet (152 m) above the surrounding countryside. The south face reflects the dip of a series of hybrid syenitic gneisses many of which contain corundum, the largest concentrations being found in a pegmatitic facies. First mistaken in 1876 by "local experts" for apatite and ignored for many years, the corundum was eventually recognized, and from 1900 to 1913 Craigmont was the world's largest producer of grain corundum. The ore was quarried from open pits developed on the south slope and was milled on site. The western pits were called the Klondike workings. At the peak of its operation the mine employed 400 people and had created a town with a population of 2000, of which very little evidence remains. The corundum occurs as irregular grains and as stocky crystals (Fig. 9) weighing up to 60 pounds and generally of a brownish color. Most crystals exhibit the typical basal parting with a bronze schiller, and a large proportion is surficially altered to muscovite. Other than some brown star corundum, no gem varieties were encountered. Some 25 other minerals have also been collected, many in fine crystals, including titanite, allanite, magnetite, zoned muscovite, tourmaline, garnet and natrolite. The mine workings cover an enormous area and are a popular collecting site. In contrast to the general blocky nature of the Craigmont corundum, excellent elongate crystals of brown corundum up to 8 inches (20 cm) long occur about 8 miles (13 km) to the northeast in an albite-nepheline-scapolite host in a prospect on the Gutz farm. Fine matrix specimens of these are becoming widely distributed.

Selected References: Adams and Barlow (1910); Barlow (1915); Moyd (1950).

Princess Sodalite Mine

Lot 25, Concession XIV, Dungannon Township, Hastings County.

Opened up in 1906 to produce ornamental stone for a residence in Hyde Park, London, and operating intermittently since then, the Princess Sodalite mine is one of the most popular of many accessible mineral localities within the alkaline gneisses of the Bancroft area. The mine, immediately north of a paved road and about 2½ miles (4 km) east of Bancroft, consists of an old open cut 200 feet (61 m) long and 20 feet (6 m) wide, with some more recent stripping and shallow quarrying. The hill consists of nepheline-rich gneisses with some locally developed pegmatitic patches; a glacially polished exposure of the pegmatite with large nepheline euhedra is one of the interesting petrographic features to be seen at the quarry. Sodalite occurs as veins and nearly pure masses up to 4 feet (1.2 m) in dimension replacing both the gneisses and pegmatites. Most sodalite is accompanied by reddish, radial natrolite. Magnetite and lepidomelane are common associates. The dense deep-blue mylonitized sodalite is particularly attractive. Several small vein-dikes with calcite cores and lined with crystals of nepheline and sometimes magnetite cut the gneisses; these are similar to, though much less spectacular than, the ones on Davis Hill. The mine is currently (1980) in active operation. Some of the beautiful sodalite has been used as an inlay in the floor of the Royal Ontario Museum in Toronto.

Selected References: Adams and Barlow (1910); Hewitt and James (1956).

Egan Chute Corundum Occurrence

Lot 12, Concession XII, Dungannon Township, Hastings County.

Egan Chute is a waterfall on the York River about 8 miles (13 km) east of Bancroft. The Chute, which funnels water in a furious, spectacular fashion, and the adjacent shore-line outcroppings expose the base of the York River series of alkaline gneisses, a slender band about 6 miles (9.7 km) long that dips gently to the east and which is underlain and overlain by crystalline limestone. Corundum-bearing zones are developed locally within the band, the most accessible being one on the west bank of the river, just upstream from the Chute. Here, a corundum-bearing zone 5 feet (1.5 m) thick, with an overall content of 14 percent corundum, has been exposed by some trenching and by many years of active mineral collecting. The corundum occurs as bluish gray crystals up to 2 inches (5 cm) long (Fig. 10), normally with a patina of muscovite. Associated minerals are perthite, biotite and greasy-appearing scapolite that may easily be mistaken for nepheline in hand specimen. A second corundum-bearing zone is exposed about 2 miles (3.2 km) north by a trench 80 feet (24 m) long. Egan Chute is of particular interest to petrologists because a complete gradation may be seen from nepheline-rich gneisses to calcareous metasediments, providing evidence here, at least, for a metamorphic-metasomatic origin for the gneisses. Probably the most famous corundum specimen to have been collected in the York River area is the crystal described by Ellsworth (1924), possessing a 1-inch (2.5 cm) sapphire-blue core of near-gem quality. The provenance of the crystal is not precisely identified and it continues to cause speculation on the sapphire potential of the area.

Selected References: Adams and Barlow (1910); Hewitt and James (1956).

CONCLUSION

The geology and mineralogy of the described localities and rustic beauty of their environment would provide any visiting collector with a satisfying and memorable field experience as well as a first-hand acquaintance with some of the classic mineral occurrences of the world. It is hoped that this brief account will attract attention to this splendid part of Ontario's natural heritage.

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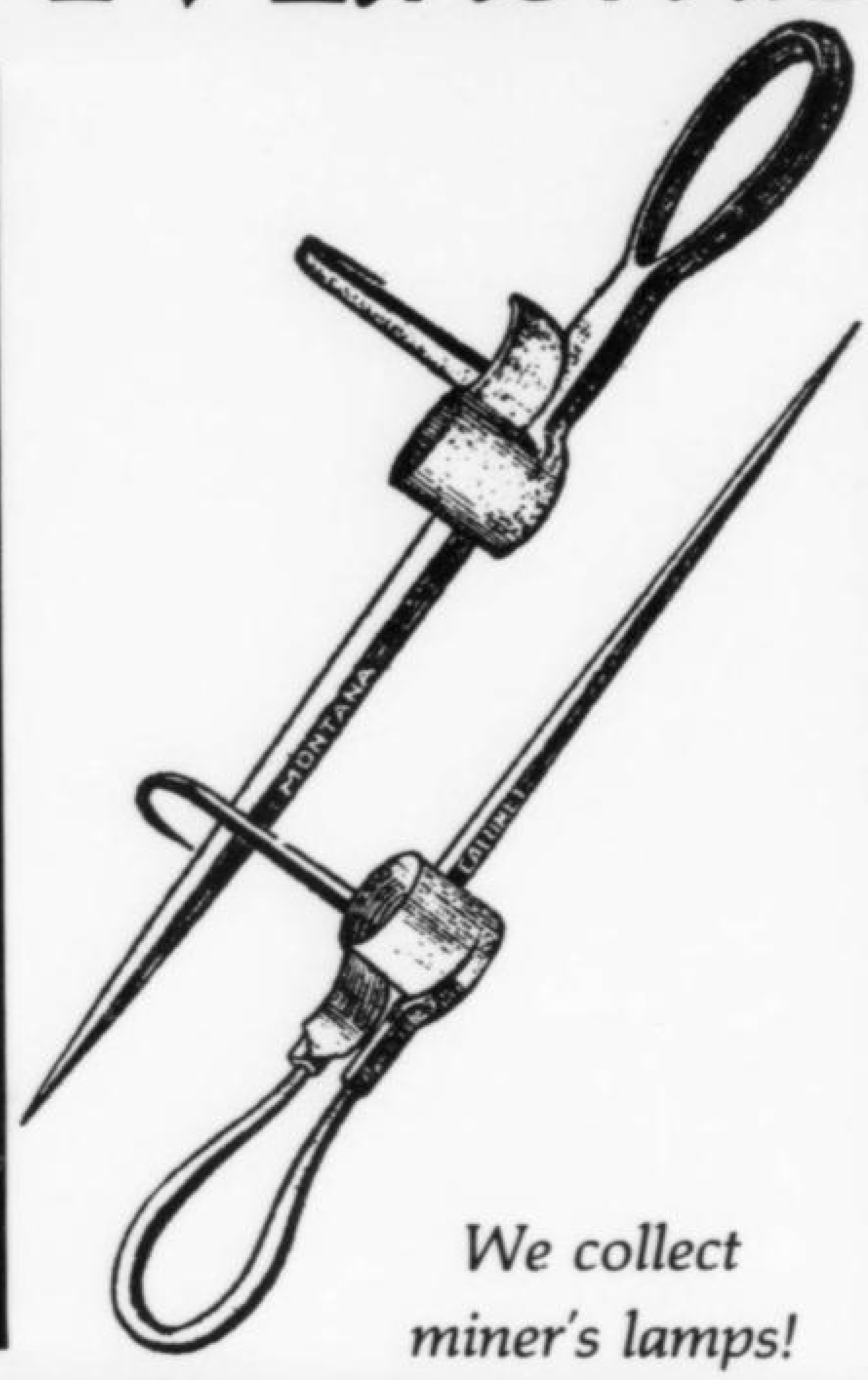

Diamond
Collecting in Northern Colorado

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The discovery of numerous diamond-bearing kimberlite diatremes in the northern Front Range of Colorado and Wyoming has been of considerable scientific interest and more recently of potential economic interest.

INTRODUCTION

Diatreme is a general term for a volcanic vent or pipe vent that has been forced through enclosing rocks by the explosive energy of gas-charged material (American Geological Institute, 1962). Although the material found in diatremes (pipes) can be any type of brecciated rock, kimberlite is the main rock type filling the diatremes of the northern Front Range of Colorado and Wyoming. Kimberlite is a type of peridotite, an ultramafic igneous rock principally composed of olivine, pyroxene, melilite and biotite. It is the only commercial diamond-bearing rock found in the upper parts of the earth's crust (Orlov, 1973).

For a number of years the kimberlite bodies in northern Colorado were overlooked or misidentified. The Sloan I diatreme (Fig. 1*A*, *B*) was mined for several decades for serpentine which was used as a decorative building stone (Chronic *et al.*, 1965; Hausel *et al.*, 1979). At the time of the quarry's operation, and for a number of years after being shut down in 1960, the contained kimberlite went unidentified. During 1958 and 1959, some of the diatremes, because of their sedimentary xenoliths, were described as lower Paleozoic outliers in a Precambrian terrane (Chronic and Ferris, 1961, 1963). It was not until 1964 that M. E. McCallum established that the Sloan I was a kimberlitic diatreme (Hausel *et al.*, 1979). Since then he has shown other similar features in the area to be of the same nature.

After the initial identification of the Sloan I diatreme as a kimberlite pipe, more than 90 separate kimberlite bodies were identified in the Colorado-Wyoming border area and in the Iron Mountain district of Wyoming (Hausel *et al.*, 1979; Fig. 1*A*). Since the initial diamond find in a peridotite nodule from one of the Schaffer diatremes (Fig. 1*A*) in June 1975, a number of these pipes have yielded diamonds (McCallum and Mabarak, 1976). The largest recorded diamond from the Colorado-Wyoming area is a distorted octahedron recovered from the Sloan II diatreme. It measures 1.3 by 1.75 by 2.8 mm and has a weight of nearly 6/100's of a carat (11.8 mg; McCallum and Mabarak, 1976); McCallum *et al.*, 1979). It was at this pipe, the Sloan II, that a search for diamonds was undertaken by the author.

GENERAL GEOLOGY

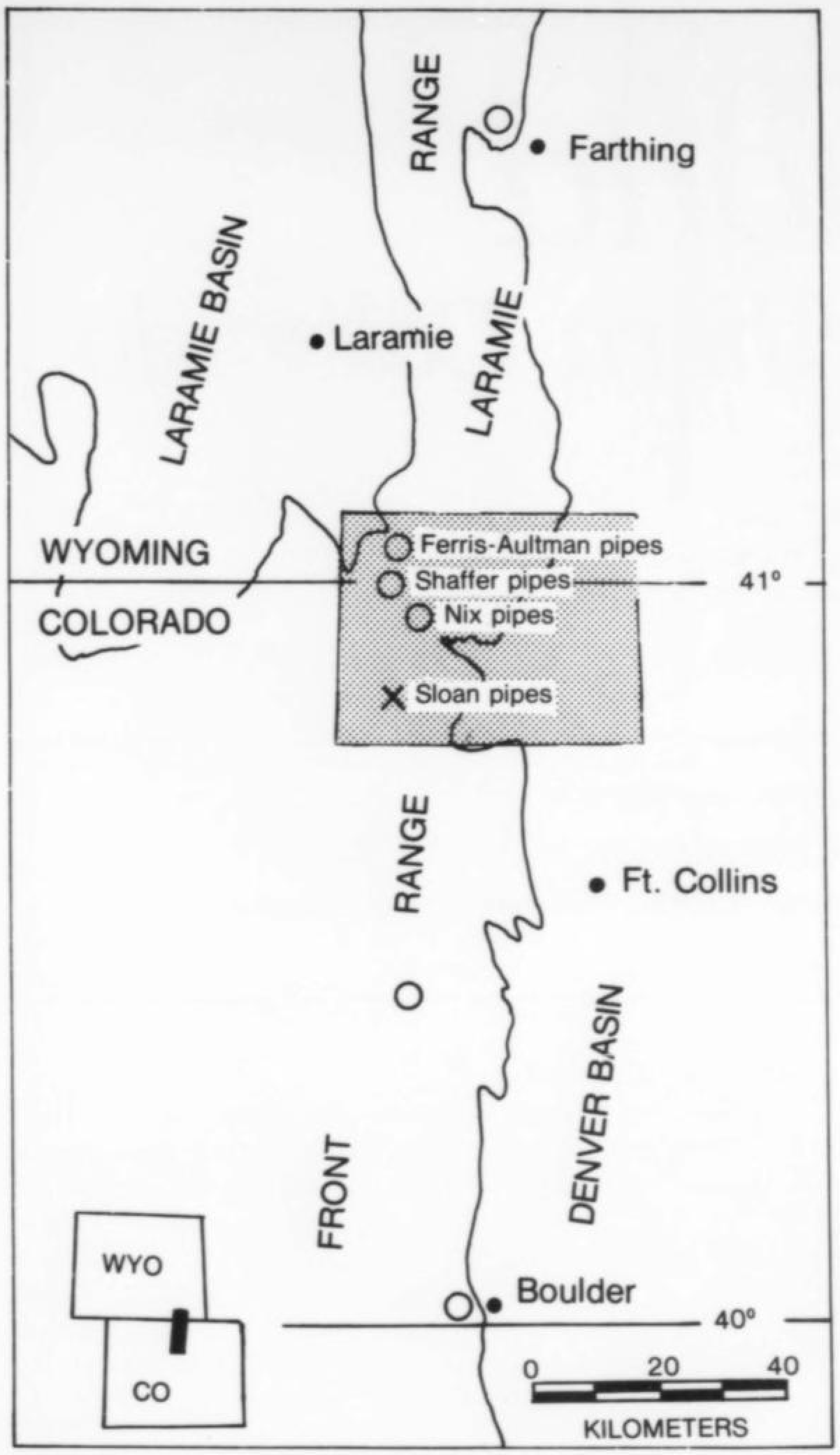
The State Line diatremes, pictured in the shaded square of Figure 1*A*, intrude Precambrian granitic rocks which include portions of the Log Cabin (in which the Sloan II is found) and the Sherman batholiths. The Sherman granite is emplaced in a sequence of metamorphic rocks and in turn is cut by the Virginia Dale ring-dike complex (Fig. 1*B;* approximately 1.61 km north of the Sloan diatremes). Eggler (1967) divided the complex into four zones: an outer arcuate dike of biotite-hornblende granite; a composite zone of diorite, andesite, and metamorphic rock; and two inner regions of biotite-quartz monzonite.

Eggler (1967) found that the Log Cabin batholith differs from the Sherman batholith by its finer grain size, primary muscovite, and abundant small bodies and dikes of pegmatite and aplite within and, especially, immediately outside the batholith. Radiogenic Rb-Sr ages for granites of the Sherman and Log Cabin batholiths are, respectively: 1.41 $\pm$ 0.003 and 1.42 $\pm$ 0.003 billion years (Peterman *et al.*, 1968).

Two prominent structural features in the area are the Copper King and the Prairie Divide faults. The Copper King fault, trending east-west, is offset by the northwest-trending Prairie Divide fault. Both faults are believed to have been developed during the Precambrian and were later reactivated during Laramide and (or) a later time (Mabarak, 1975). These faults are of major importance because they probably controlled the emplacement of the Sloan kimberlite diatremes. The Sloan I pipe is at the intersection of the two faults and Sloan II is a short distance to the northwest of their intersection along the Prairie Divide fault (Fig. 1*B*).

EMPLACEMENT AND NATURE OF THE SLOAN II DIATREMES

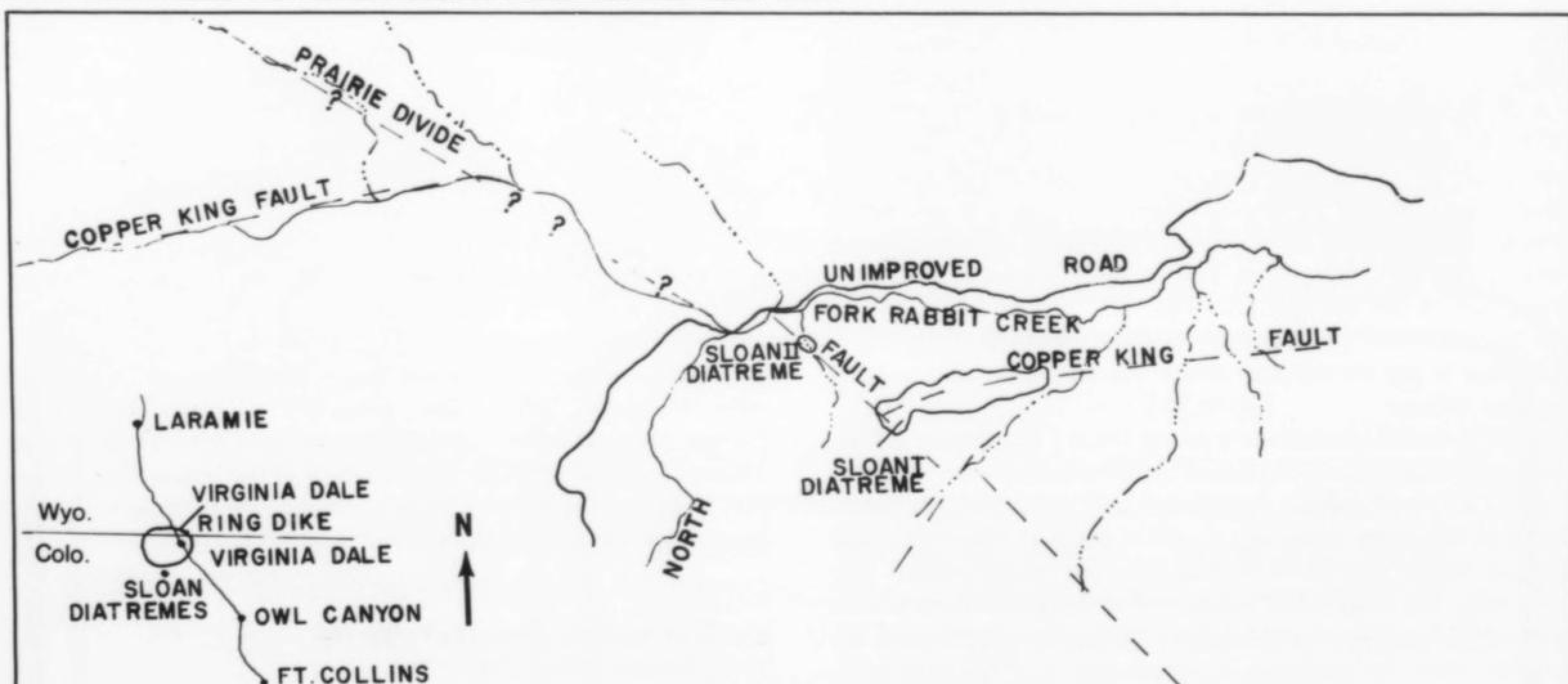
The State Line diatremes were probably emplaced by highly gas-charged kimberlite ascending along fracture or fault systems and breaking explosively to the surface; the conduit was then enlarged and infilled by fluidized kimberlite to form a diatreme structure (Dawson, 1962, 1972). The highly brecciated nature of kimberlite is



due to its explosive passage to the surface and to fluidization processes which involve gas passing through and mixing with loose rock types penetrated by the pipe, thus causing them to flow like a liquid. However, unlike other pipes in the area, the Sloan II diatreme does not contain fragments of Paleozoic rocks, suggesting that the pipe-forming action of the Sloan II did not penetrate the Paleozoic rocks. M. E. McCallum (oral communication, 1976) suggested that this kimberlite body is a blind pipe that may be related to the Sloan I pipe at depth. Fossils from Paleozoic sedimentary xenoliths, and other geological relationships suggest that the emplacement of the State Line diatremes occurred in Late Silurian and Early Devonian time (Chronic *et al.*, 1969). Fission-track dating of kimberlitic zircons from the Shaffer 3 pipe (Fig. 1*A*) in Wyoming give an average age of 377 ± 9 million years (Naeser and McCallum, 1977). Both age determinations indicate a Devonian age of emplacement for these pipes. The Sloan II diatreme may have been emplaced during the same period.

The areal extent of the Sloan II diatreme is largely unknown due to the heavy soil and vegetation cover; however, a trench dug along the trace of the Prairie Divide fault exposed over 75 linear ft. (22.9 m) of kimberlite (Fig. 2). The trenching also revealed bedded alluvial deposits resulting from an intermittent tributary which appears to have flowed north along a portion of the fault zone into the North Fork of Rabbit Creek. This intermittent tributary reworked the surface of the diatreme and formed a small alluvial fan. It is in the channel lag deposits that the author believes the odds of finding diamonds are greatest. These deposits appear to be primarily composed of the heaviest mineral fractions from the weathered kimberlite material and surrounding country rock.

***Figure 1. A*, Generalized map showing the location of the Colorado-Wyoming diatremes (⊙). The State Line diatremes are within the shaded rectangle. *X*, Location of the Sloan pipes. *B*, Location map showing the Sloan diatremes relative to the Copper King and the Prairie Divide faults.**



COLLECTING FROM THE SLOAN II DIATREME

In the spring and fall of 1979, the author and several others made two field trips to the Sloan II diatreme. Collecting at this site is fairly easy. The trenched diatreme is within 91 m of the North Fork Rabbit Creek improved road (Fig. 1*B*) and readily exposes weathered kimberlite which can be sampled in volume for later examination. Silt and clay-size particles can be removed by washing. After drying, approximately 70 to 80 percent of the remaining weathered and altered material can be dissolved in hydrochloric acid (0.1 N). The undissolved fraction is then searched for diamonds. Heavy liquids (for example, bromoform, Sp.Gr. 2.85) are useful to isolate the heavy-mineral fraction to be searched for diamonds.

Concentrations of diamond in what is considered to be a rich kimberlite diatreme (for example, the Premier in South Africa) are approximately 0.2 gm/tn (1 carat/tn) or one part diamond per 4.5 million parts of waste rock (McCallum and Mabarak, 1976); concentrations in the Sloan II kimberlite are believed to be much lower. Ratios of diamond to waste rock for the Sloan II diatreme do exist, but are not available for publication.

MINERALS

Minerals recovered from the heavy-mineral concentrates include chrome diopside, spinel, magnesian ilmenite, pyrope garnet and diamond; most of these are highly rounded, fractured, and grooved. Also found was a nodule (approximately 2 cm in diameter) tentatively identified as a graphite-diamond eclogite. Eclogites are igneous or metamorphic rocks consisting of jadeite-diopside (omphacite) and garnet (almandine-pyrope).

Angular fragments of chrome diopside found range in color from light to dark emerald-green and have a maximum size of more than 3 cm in diameter. The octahedral spinel crystals are black and are up to 2 mm across. Rounded to angular ilmenite grains recovered are a dark metallic gray and have a maximum size of 2.5 cm in diameter. Pyrope garnets are purple, orange, and various shades of red in color. The largest pyrope crystal collected is approximately 1 cm in diameter and possesses a kelyphitic reaction rim composed of amphibole, muscovite and calcite.

Figure 2. **View to the northwest along the trench cutting the present surface of the Sloan II diatreme.**

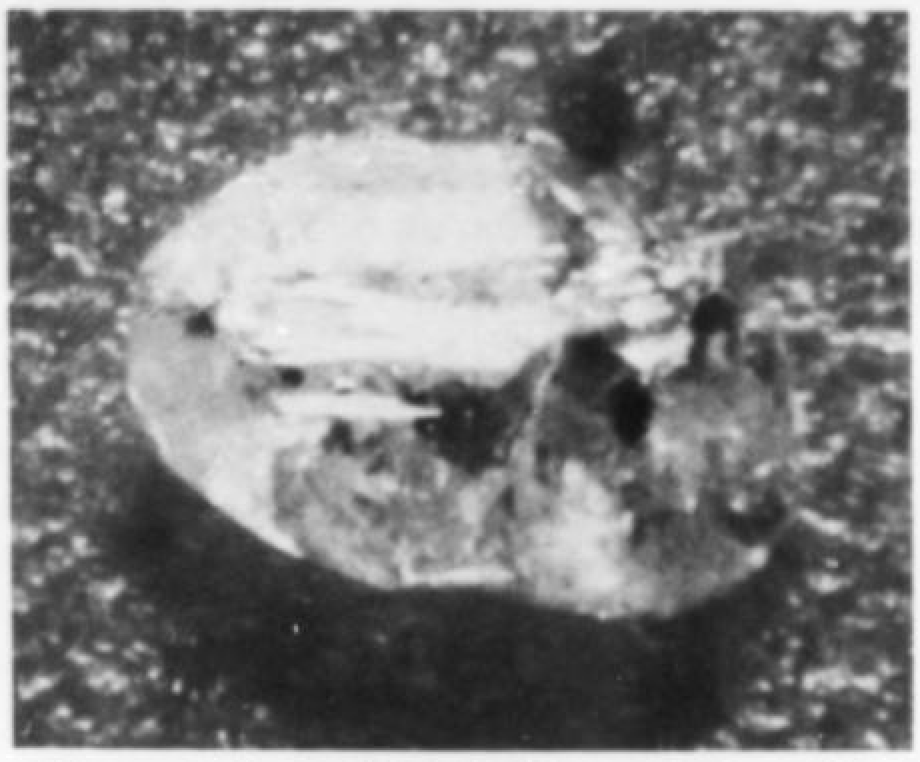


Figure 3. **A modified double octahedron diamond measuring approximately 0.5 by 0.3 mm.**

Three octahedral diamonds less than 1 mm in size were recovered from the weathered kimberlite. Two of the stones are white, the third is light yellow. One of the white diamonds, not pictured, is a double octahedron crystal (joined on (111)) of gem quality with carbon (?) inclusions. The other white diamond (Fig. 3) is a modified double octahedron crystal. The light yellow stone is also of gem quality, but only half of the crystal form is developed.

Diamonds on the eclogite nodule are white octahedrons with stepped development on their {111} faces (Fig. 4). One of the larger diamonds present has a graphite mass protruding from its surface. The largest diamond exposed on the nodule is 1.5 by 1 mm and the smallest is approximately 0.4 mm in diameter. Gray graphite platelets are also present on the nodule. Based on microscopic examination this nodule has been tentatively identified as a graphite-diamond eclogite.

CONCLUSIONS

Considering the ratio of diamonds to waste rock in the African diatremes, this may be an unusually rich find. The other minerals

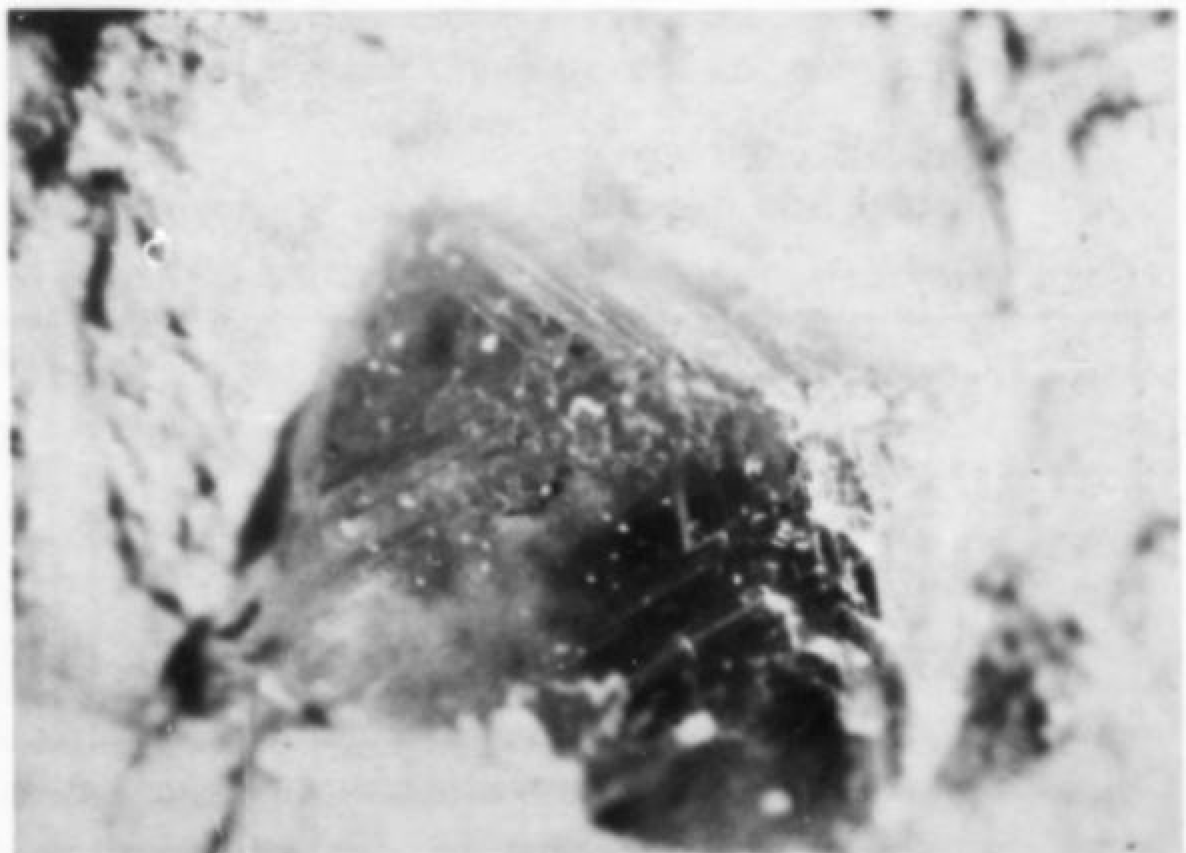


Figure 4. **One of the larger diamonds (1.5 by 1 mm) in an eclogite nodule.**

recovered are very common in kimberlites, but somewhat rare in peridotites as a whole.

As with many of the diamond-bearing pipes of the Colorado-Wyoming area, the Sloan diatremes are currently under claim; it is essential to gain permission from the owners before considering a collecting trip.

ACKNOWLEDGMENTS

The author thanks the following personnel of the U.S. Geological Survey: Richard Tripp for the loan of his diamond and spinel crystals from the weathered Sloan II kimberlite (photographs of his minerals were used in this article); Louise Hedricks for photographing the samples; and Eugene Foord for his tentative identification of the nodule, mineralogy of the kelyphitic rim, and his aid in photographing the samples.

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the Lake Clear – Kuehl Lake area, renfrew county, ontario

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This famous collecting area has been known for a century due to its large crystals of zircon, apatite, titanite and scapolite. Excellent specimens can be seen in most major collections throughout the world.

LOCATION

The Lake Clear – Kuehl Lake area is located approximately 120 km west of Ottawa (Fig. 1). Localities are variously given as Lake Clear, Sebastopol, Brudenell, Renfrew, Eganville or more specifically as Kuehl Lake, Meany mine, Smart mine or Turner's Island. The descriptions of these localities given here may help to improve locality information in some collections.

HISTORY

In the 1850's the Madawaska Valley began opening up to settlers who were primarily interested in the timber trade. Several years later (in the early 1880's) a number of pits were developed to the east of Lake Clear and on Turner's Island in Lake Clear to recover apatite; the phosphate was used primarily for fertilizer but it also found an application in the production of baking powder and a cream of tartar substitute. These mines varied in size from a few meters up to 7 m in depth by 5 m wide and 40 m long (Meany mine). This industry employed only a few men on contract from the neighborhood, generally farmers whenever they were unemployed, who drilled, blasted and hand-cobbed out the apatite for overland haulage to Smith's Falls, Ontario. One problem in this system, as noted by W. J. Morris to the Royal Commission in 1890, was: "In loading the cars we have had to break every crystal with the hammer for fear they would be stolen as specimens." At the Standard Fertiliser and Chemical Company, Smith's Falls, the apatite was finely ground and acid-treated to concentrate the desired phosphate. For the Lake Clear area the mining operation lasted a decade, ending with the discovery of larger deposits in the southern United States. The total production for the area probably did not exceed 2000 metric tons (Satterly, 1944).

Fortunately, during this period of activity there were individuals who recognized the importance of these specimens and collected them for sale throughout the world. Charles Willimott (formerly of the Geological Survey of Canada) reported in 1883 that Mr. Townsend had collected from the Smart mine "two crystals of zircon, doubly terminated with the termination of a third crystal projecting from one of the lateral planes. They were of a brilliant hyacinth red color, and were valued by the owner at $25 each." It is interesting to note that the equivalent buying power of $25 in 1883 would be approximately $900 today (1979).

The Kuehl Lake occurrence was reported about the same time as the apatite deposits east of Lake Clear (Willimott, 1883; Kunz, 1887) but due to the scarcity of apatite no interest was shown until 1930 when Professor A. L. Parsons, of the Royal Ontario Museum, Toronto, collected a number of "giant zircons" (Parsons, 1931). No further interest was shown in the deposit until 1943 when Universal Light Metals Company of Hamilton, Ontario, tried unsuccessfully to recover zircon for zirconium.

RECENT WORK

During the summer of 1977 the authors organized a field party in the Lake Clear – Kuehl Lake area to collect specimens and research material primarily from the following localities (Fig. 1) in Renfrew County: **1.** Park property, Concession XII, Lot 32, Sebastopol Township; **2.** Meany mine, Concession XI, Lot 31, Sebastopol Township; **3.** Smart mine, Concession X, Lot 31, Sebastopol Township; **4.** Turner's Island mine, Lake Clear, Sebastopol Township; and **5.** Kuehl Lake, Concession V, Lot 1, Brudenell Township. All sites were readily accessible by road and short traverses through open bush. In general, pits have been overgrown by scrub vegetation and partly filled by unconsolidated sediments and organic debris. In one instance several generations of porcupines had amassed dung to a depth of 2 m. Sites chosen for major collecting were stripped by hand or with a high-pressure water jet (Fig. 2), then drilled for blasting or wedging. Each of the localities described is on private property and collecting is prohibited without proper authorization.

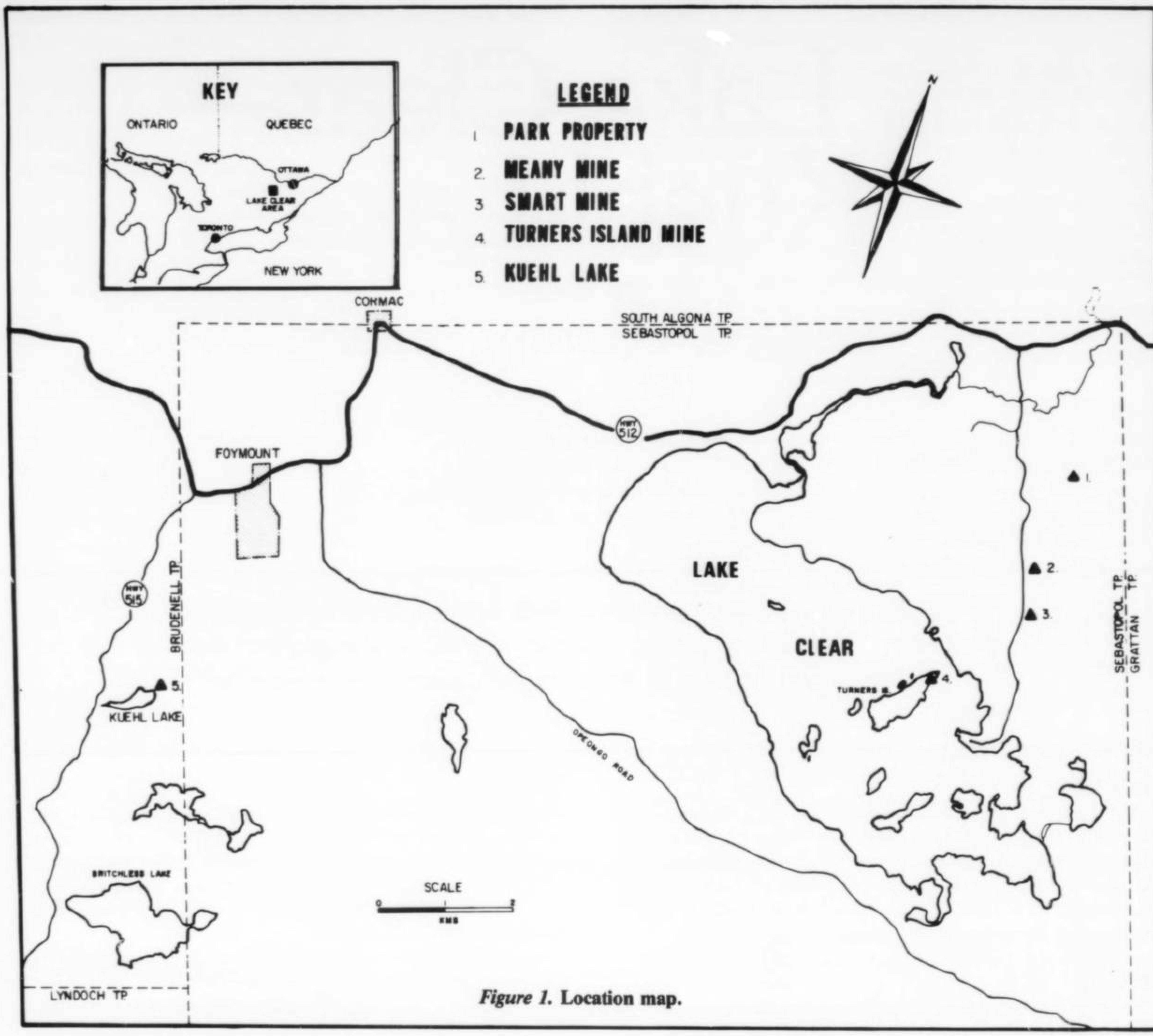

Figure 1. **Location map.**

The crystals of fluorapatite are well-formed, elongated hexagonal prisms which are always terminated by a hexagonal dipyramid, in some cases combined with a pinacoid. The color of the fluorapatite from this area, while not definitive, is at least distinctive. It is a dense red-brown, in contrast to apatites from other Canadian localities which have various shades of green or blue and generally have a somewhat higher degree of translucency. Crystals are imbedded in coarse salmon-colored calcite and are randomly distributed throughout the calcite dike. Fluorapatite is found on the dike contact but very rarely in the country rock. The crystals are sometimes immense. The largest recorded crystal from Turner's Island is a prism weighing 300 kg (Penrose, 1890). In addition to those from Turner's Island, excellent crystals have been found in veins on a small island west of Turner's Island and on the Smart and Park properties. No crystals were seen at the Meany mine, where the fluorapatite occurs in massive form. Fluorapatite is uncommon at Kuehl Lake.

Scapolite was found only at the Turner's Island locality. It usually occurs on country rock projecting into the calcite dike but doubly terminated crystals (Fig. 3) completely enclosed by calcite are also found. EDS analysis reveals that these specimens fall closer to the meionite end of the marialite-meionite solid solution series. Although the term *mizzonite* has been applied to scapolites of intermediate composition the series name scapolite is used in order to avoid awkward or somewhat dubious terminology.

The scapolite crystals are white to gray and have a stubby, prismatic habit. Small crystals of approximately 1 cm across are somewhat translucent but larger crystals of up to 40 cm have a woody appearance due to minor alteration along cleavage planes. The observed forms, measured for an axial ratio of a:c = 1:0.622, are tetragonal prisms a{100}, m{110}, h{310} and tetragonal dipyramid r{101}.

For collectors, **zircon** has always been one of the most desirable minerals from the Lake Clear – Kuehl Lake area. This world famous locality is the source of the "giant Brudenell," and geniculate twins which are displayed in many museums and figured in numerous texts. The zircon is closely associated with and most often found in syenite. Crystals were observed in associated calcite dikes but it is probable that the syenite intrusion was the source of the zircon. The zircon is a dark wine-red color with some specimens having a slight brownish tint. Crystal fragments are translucent and sometimes gemmy: unfortunately, crystals tend to be very fractured and the authors are not aware of any faceted stones larger than 0.8 carat (collection of G. Waite) from this area.

Figure 2. **Clearing an outcrop on Turner's Island.**

Figure 3. **Cream-colored scapolite crystal with dark colored epidote coating portions of the faces. Crystal forms are: prisms a{100} and m{110} (forward) and tetragonal dipyramid r{101}. The crystal is 6 cm long (NMNS #37629) and was found on Turner's Island.**

At Kuehl Lake, Brudenell Township, the zircons are very large. Broken crystals up to 30 cm long by 5 cm across (Parsons, 1931) have been reported and the authors observed one partial crystal of 15 cm. As is often true in nature, large is not always beautiful, yet one cannot help but be impressed by these "giants." The form of the crystals is a simple prism with one or more pyramids which tend to be rounded in large crystals. No twins were observed. EDS analysis did not indicate the presence of any major elements (i.e. greater than 0.5 weight percent) except zirconium and silicon. The zircons are usually in a pink syenite which consists of fine grained microcline and albite with varying amounts of biotite and titanite. Parsons (1931) observed that for every large crystal (4 cm or greater) recovered approximately 3 tons of rock had to be removed and this was painfully verified during the field work. The matrix is both hard and tough, necessitating the use of explosives and heavy sledging. Needless to say, any specimens from this locality have been collected only through perseverance combined with a certain amount of luck.

There do not seem to have been any recent discoveries of excellent zircon crystals from east of Lake Clear or Turner's Island, but there is little doubt that this was the locality for the fine geniculate twins such as those shown in Figure 4. Penrose (1890) reported a crystal of zircon from Turner's Island that was almost 30 cm in diameter. A few small crystals (up to 1 cm) were found at the syenite-calcite dike contact at the Smart mine. One such crystal is sketched in Figure 5 and, although it is not a spectacular display specimen, it is an excellent crystal for morphological study. For the axial ratio a:c = 1:0.90 the forms represented are tetragonal prism a{100}, tetragonal dipyramids p{101}, v{201} and u{301}, ditetragonal dipyramid x{211} and the twin plane (112). The classic crystal drawing of Hidden (1881) is given in Figure 6 for comparison. The Philadelphia Academy of Natural Sciences has one of the finest Lake Clear zircons, measuring 11 x 11 x 25 cm.

Figure 4. **Deep wine-red zircon from the Smart property. Geniculate twin with the forms: prism a{100} and tetragonal dipyramid p{101}. The vertical portion of the crystal measures 3 cm (NMNS #40579).**

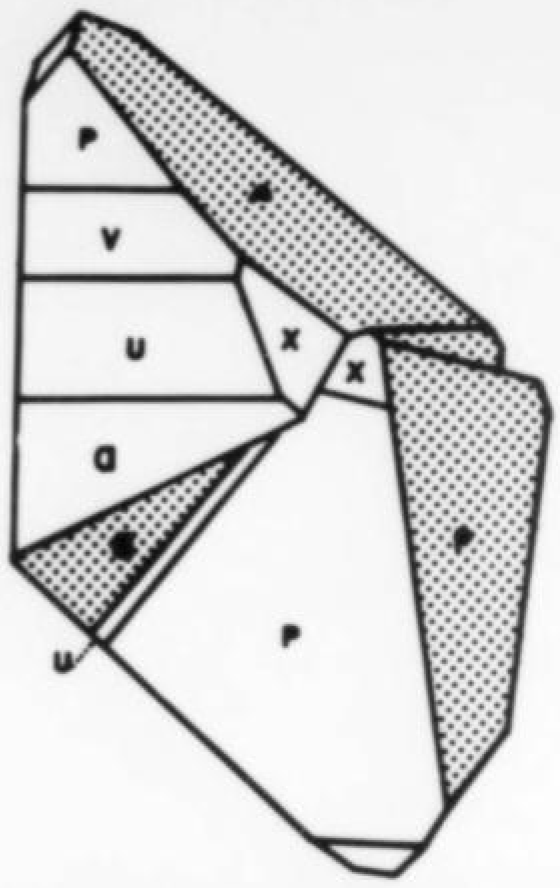

Figure 5. **Sketch of a geniculate twinned zircon crystal from the Smart property. Crystal forms are: tetragonal prism a{100}, tetragonal dipyramids p{101}, v{201} and u{301}, ditetragonal dipyramid x{211} and the twin plane (112). The actual overall crystal measures 1.5 cm (NMNS #37632).**

Titanite from Lake Clear is world-renowned for its size and perfection. The titanite normally occurs as euhedral, wedge-shaped crystals with the common forms pinacoid c{001} and prisms m{110} and u{111}. Crystals are a very dark brown color and are highly lustrous. Titanite is a common accessory mineral in the syenite of the Lake Clear – Kuehl Lake area, and this syenite was likely the source of the titanium-rich fluids. The best specimens come from the calcite dikes where they can easily be removed. Excellent specimens are particularly common on the Smart property but the very large crystals of titanite were probably recovered from the main dike on Turner's Island (Penrose, 1890). The largest known is in the Mineralogical Museum of Harvard University and measures 65 x 17 x 17 cm. It weighs 28.6 kg.

GEOLOGICAL SETTING

The Lake Clear – Kuehl Lake area lies within the Precambrian Grenville Province which is exposed in a broad (400 km) belt extending northeastly from Lake Huron to the Labrador Coast (2000 km). Within the area being discussed the oldest rocks consist predominantly of metamorphosed sedimentary rocks (Themistocleous, 1978). These rocks were intruded by a number of plutonic rocks and all but the youngest of these were deformed in the Grenville orogeny about 950 million years ago.

At some stage in the complex geological history of the Grenville Province calcite dikes were emplaced. These dikes are of special interest to collectors as they are the major source of fine mineral specimens. The minerals of the calcite dikes are generally related to the composition of the enclosing rocks (Hogarth *et al.*, 1972). Large crystals of microcline-perthite, apatite, augite, hornblende and titanite are commonly found attached to the country wallrock at the calcite dike contact. Apatite and titanite form excellent crystals completely enclosed in calcite but there is no apparent systematic zoning within dikes. In some veins weathering has leached the calcite leaving freed crystals in the bottom of the trench.

MINERALOGY

The mineralogy associated with the calcite dikes is relatively simple. The main constituent minerals are microcline, hornblende, augite, biotite, fluorapatite, zircon, titanite and scapolite. For some minerals the major chemical constituents were determined using an energy dispersive spectrometer (EDS). Although the method employed did not give a very precise analysis it was adequate to characterize the species within a group. Where Miller indices have been determined a contact goniometer was used due to the large crystal size. Readers comparing Miller indices given in this paper with those described elsewhere should be aware that for some minerals the axial ratios have been revised in recent literature.

Calcite is the major component of the calcite-apatite dikes. It occurs as coarse-grained cleavable masses but never as well-formed crystals. Its color ranges from dull gray-white, through pale pink to salmon-orange. It has afforded an excellent medium in which other minerals have grown large, well-formed crystals. Within these large crystals (notably fluorapatite, scapolite and augite) spherical inclusions of calcite up to several millimeters in size are present, indicating a co-crystallization of the calcite and its associated minerals; the large crystals entrapping beads of a calcium carbonate-rich fluid during growth.

Feldspar crystals are common in the Lake Clear – Kuehl Lake area. Optical and X-ray examination reveals that they are a microperthitic intergrowth of microcline and albite with microcline the predominant phase; these will be referred to as microcline-perthite.

Microcline-perthite crystals occur on the calcite dike/country wall contact as euhedral crystals with free faces terminating toward the calcite core. Very fine, light orange colored crystals line the walls of several veins of the Park property and at the Smart mine there are extraordinary crystals up to 30 cm. The forms observed, described in terms of orthoclase with axial ratios a:b:c = 0.66:1:0.56, are pinacoids b{010}, c{001}, x{$\bar{1}$01} and y{$\bar{2}$01} and prisms m{110}, z{130}, n{021} and o{$\bar{1}$11}.

Biotite is also a common mineral in this area, and sheets up to 50 cm across can be seen. Some of the biotite is brown in color as opposed to the more common black. Table 1 gives the chemical analysis of a lighter colored brown mica from the Smart mine in addition to an analysis of the black mica from Kuehl Lake. The phlogopite range of chemical composition is defined by the atomic ratio Mg:Fe, which must be equal to or greater than 2:1. Although both micas are biotite, the Smart mine biotite with Mg:Fe = 2:1.13 is close to phlogopite in composition. The black biotite from Kuehl Lake has a higher iron content with Mg:Fe = 2:1.58.

Pyroxene is a common mineral at calcite dike contacts. EDS analysis indicates that the pyroxene is a sodium-bearing augite (less than 1 weight percent Na). Crystals are generally short prisms and dark green to black in color with a rather dull luster probably due to surface alteration to amphibole. Individual crystals, while

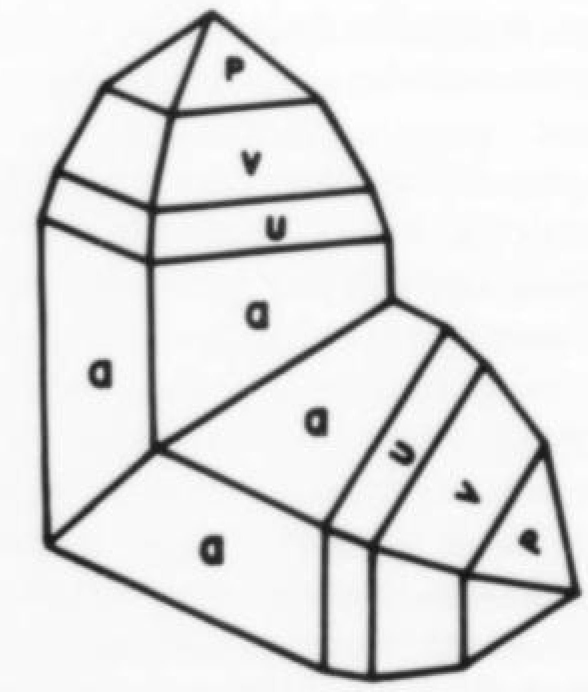

Figure 6. **Crystal drawing by Hidden (1881) of a twinned zircon from Renfrew County. Forms are designated in the same manner as Figure 5.**

Table 1. **Chemical analyses of biotites from the Lake Clear – Kuehl Lake Area, Ontario.**

	Smart Mine NMNS #38644	Kuehl Lake NMNS #38648
SiO_2	39.9	36.6
TiO_2	2.24	2.50
Al_2O_3	12.2	13.6
Fe_2O_3	3.0	3.33
FeO	13.6	16.0
MnO	.23	.31
MgO	16.1	13.5
CaO	.27	.16
Na_2O	.30	.17
K_2O	9.20	9.18
F	2.70	1.76
H_2O	1.05	1.30
	100.79	98.51
O ≡ F	−1.14	−.45
Total	99.65	98.06

seldom exceeding 15 cm in length, can form large groups weighing up to 50 kg. This is particularly true at the Smart mine where augite is associated with large microcline-perthite crystals.

Hornblende is not as common as augite in the calcite dikes of the area but it is found as dull to lustrous, black stubby prisms. Considering the enormous crystal size of the other species found in these veins, the hornblende crystals are relatively small, less than 10 cm in length. Some very fine hornblende crystals were found in a small vein near the Kuehl Lake zircon occurrence. EDS analysis indicates that these are a magnesio hornblende (terminology compiled by Leake, 1978).

There are many notable occurrences of **apatite** throughout the southern portions of Ontario and Québec but perhaps the best known locality – a Dana locality – is Turner's Island on Lake Clear. Here the main calcite-apatite dike is 1 to 5 m in width and during the early 1880's was mined to a depth of 4 m over a distance of 50 m. Dunn (1977) determined the apatite group mineral species to be fluorapatite.

ACKNOWLEDGEMENTS

The authors are indebted to the following individuals for allowing collecting on their property: A. Edgecomb, H. Lenser and F. Miller. Information concerning specimens from the discussion area was kindly provided by: C. A. Francis, Harvard University; R. I. Gait, Royal Ontario Museum; and R. G. Middleton, The Academy of Natural Sciences of Philadelphia. We would like to thank R. C. Rucklidge, University of Toronto for the EDS analysis of the specimens. Generous assistance in the preparation of this manuscript was given by a number of National Museums of Canada staff: R. Williams critically reviewed the paper and made a number of helpful suggestions; R. Dinn typed the manuscript; J. G. Runnells took the photographs; J. Van Velthuizen drafted figures; and J. Sparks and R. Waller helped collect specimens. The authors enjoyed the company and enthusiastic field support of G. Farr, Wilberforce. The efforts of J. A. Mandarino, Royal Ontario Museum, for helping to organize this issue are appreciated.

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Quartz Crystals
from the granite creek—lolo pass area montana

by **Marlen O. Tweten**
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INTRODUCTION

The Granite Creek-Lolo Pass area along the Montana-Idaho border has produced many smoky quartz crystals during the last two decades. The area has been a popular collecting site for people from all parts of the United States. Granite Ridge, particularly on the Granite Creek side (Fig. 1), has been the most popular collecting area, due largely to the extensive road network. Mud Creek, a small stream originating on the northern end of the ridge, has also been noted for its crystals.

The collecting area is about 40 miles southwest of Missoula, Montana. U.S. Highway 12 passes along the eastern slopes of Granite Ridge. Primary access into Granite Creek drainage is a graded forest route leaving Highway 12 a short distance below and above Lolo Hot Springs. Numerous logging roads branch off from the Granite Creek road and ascend the adjacent ridges.

Land ownership is both public and private. The U.S. Forest Service owns and manages the largest acreage with Champion International and Burlington Northern Railroad controlling the remaining land. Prior to 1972, the Anaconda Company owned what is now Champion International land. When Anaconda sold their lands they retained the mineral ownership.

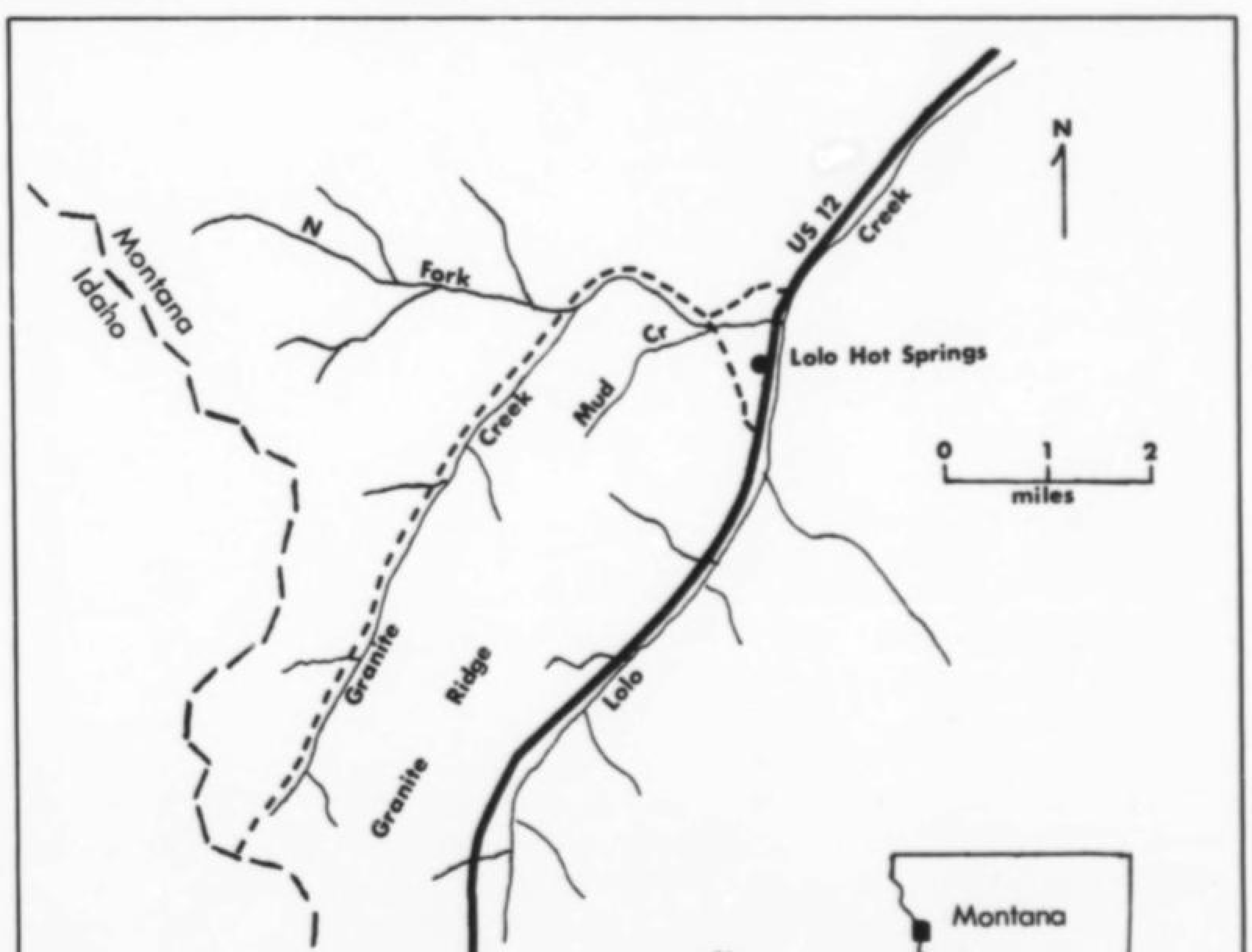

Figure 1. **Map of the Granite Creek-Lolo Pass quartz crystal collecting area.**

Figure 2. **A brown and white quartz crystal displaying an unusual growth. Crystal length is 6.5 cm. Photo by Gardner Miller.**

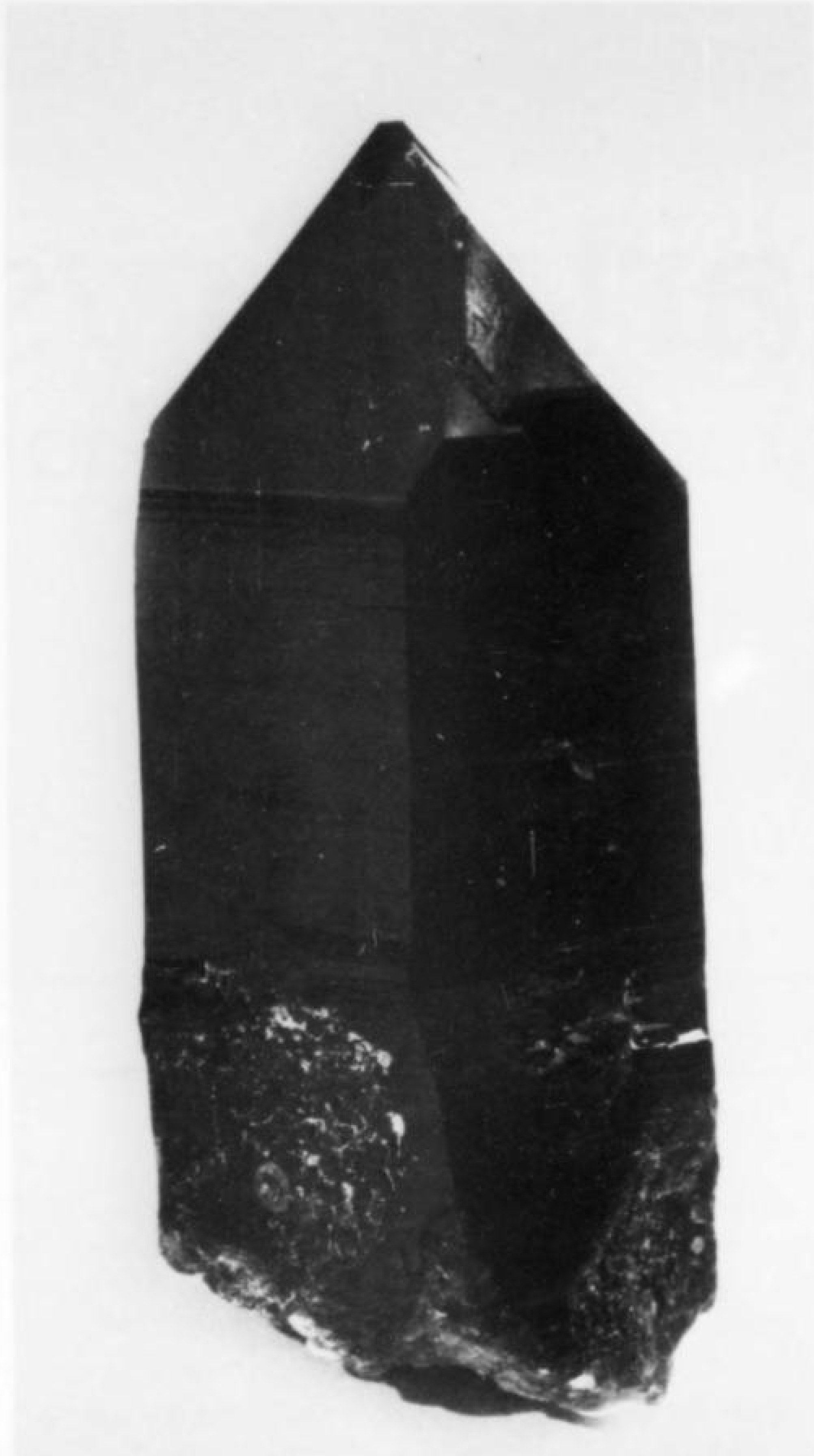

Figure 3. **An exceptionally lustrous black 10-cm quartz crystal. Photo by Gardner Miller.**

GEOLOGY

The collecting area borders the Idaho Batholith, a major intrusion covering 16,000 square miles in western Montana and eastern Idaho. The batholith in the Granite Creek area is composed primarily of granodiorite and quartz monzonite (Nold, 1968). Rocks of the Lolo Hot Springs Batholith, a smaller intrusive body immediately adjacent to the Idaho Batholith, underlie the Lolo Pass-Granite Creek region in this section of Montana and adjacent areas in Idaho. Argillites, quartzites, and limestones of the Belt series mark the northern margin of the Lolo Hot Springs Batholith near a point where Granite Creek enters Lolo Creek.

Nold examined the formation and composition of the shallow Lolo Hot Springs Batholith. His analysis revealed a medium to coarse grained granite and quartz monzonite with the quartz composition averaging 15 to 25 percent. Other principal minerals are potassium feldspar and plagioclase.

The high silica content is responsible for the distinctive topography around Lolo Hot Springs. Granite monoliths of varying sizes characterize Granite Ridge and the surrounding canyons. Nold noted that these outcrops contain miarolitic cavities, some with small quartz crystals. Except for the granite outcrops, the area is covered by a dense growth of coniferous forest. Presumably, the higher silica of the monoliths enabled them to better withstand erosion.

QUARTZ CRYSTALS

The prismatic habit is typical of quartz crystals from this area. The a:c axial ratios can be highly variable in some specimens (Fig. 2). Variations in this habit manifest themselves in the trigonal trapezohedral and rhombohedral zones. A few crystals also have equant habits although this is uncommon.

Crystal colors range from black to shades of brown and white. Some crystals may be an intense black (Fig. 3) while others may have brown tips with a brownish-white prism (Fig. 4). Some of the smaller crystals under 4 cm may be transparent. One of the most beautiful crystals found in this area is the transparent variety with a deep orange-brown color; these are rare. The bulk of the crystals have inclusions which render them opaque. Deep shades of brown and black normally mask the inclusions.

Crystals may reach 20 cm or more in length. There are rumors that crystals exceeding a meter in length were uncovered and used as road fill in construction of the Mud Creek road. Most crystals are under 8 cm.

Crystal luster, color and perfection of form are related to size. Those in the smaller sizes (1–6 cm) have better-formed terminations and more lustrous prism faces. These desirable characteristics are rarer in the larger crystals.

Double and multiple terminations on single crystals are frequently found. Some crystals are flattened parallel to the *c* axis and are doubly terminated.

Single crystals make up the bulk of the specimens. Matrix examples are generally confined to the smaller crystals (under 2 cm).

Erosion, in addition to freeing the crystals from the miarolitic cavities, has also removed the feldspar matrix. Larger crystal groups usually have massive quartz as a matrix.

COLLECTING TECHNIQUES

Even though the quartz crystals were formed in miarolitic cavities, virtually all collecting is done in the soils and underlying decomposed granite. Weathering has freed crystals from the confining granite. Evidence of cavities in the granite outcroppings is rare. One cavity located in a large monolith near the top of Granite Ridge measured about 25 cm in diameter and contained crystals up to 10 cm in length. The cavity was situated deep within a narrow cleft about 4 meters from the monolith face, making extraction of the crystals impossible.

Success in locating crystals in this area is dependent on newly constructed logging roads. Road construction removes the heavy cover of trees and brush and exposes the subsoils. Crystals may be encountered in both the roadbed or the bank.

One or more crystals protruding from the road bank may indicate a pocket. Digging behind and around the exposed crystal may produce more crystals. All too often, however, the exposed crystal will be the only one found at that site. Sometimes crystals may be scattered over a wide area in the road, indicating the bulldozer passed through the pocket. The entire pocket may be in or on the road or a portion may still be in the bank. A careful search of the bank usually can turn up the original position of the pocket, if any crystal evidence still remains.

Changes in road building techniques are making it more difficult to locate crystal pockets. To reduce the erosion potential, the banks are beveled to a lower slope. Exposed crystals in the original position may be scattered a short distance from the pocket, and greater care must therefore be exercised in the search.

Determining the exact original position of exposed crystals can be very important in locating a pocket. Crystal pockets vary widely in character; some have crystals densely packed together in an area only 10 cm in diameter, while others are isolated in the soil, perhaps as much as a meter apart.

A few pockets have produced only thumbnail crystals, many of which are transparent. Most of the pockets have crystals of varying sizes. A small minority of the pockets will yield crystals of exceptional perfection and luster. As with many specimen-producing areas, only a few of the crystals are of top quality. Each pocket has its own unique combination of crystals.

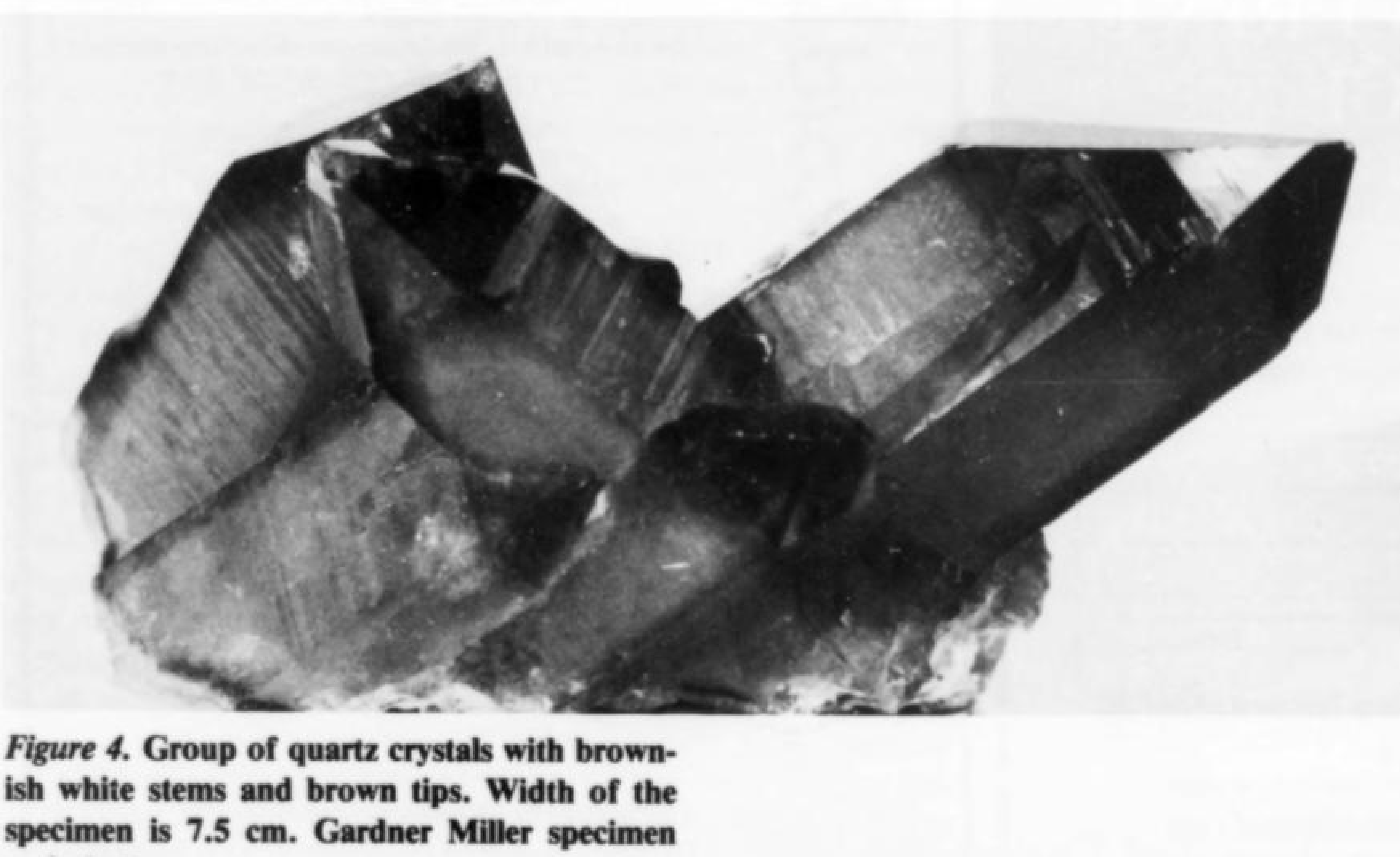

Figure 4. **Group of quartz crystals with brownish white stems and brown tips. Width of the specimen is 7.5 cm. Gardner Miller specimen and photo.**

Crystal size and quality does not seem to vary with elevation on Granite Ridge. Good as well as poor quality crystals have been found on all parts of the ridge. Crystal pocket location and size are also not related to position of the ridge. For some unknown reason, the ridge west of Granite Creek and the drainages immediately east of Lolo Creek above the hot springs have never produced significant quantities of crystals, in spite of similar granitic composition.

Surface indications of crystal pockets are rare. The crystal pictured in Figure 2 came from a pocket partially exposed near the top of Granite Ridge. Crystal fragments scattered down slope from the pocket led to its discovery. No man-made disturbance exposed the crystals. This particular pocket, measuring about a meter in diameter and 2 meters deep contained over 450 kg of crystals. Most sections of Granite Ridge are too heavily covered with vegetation to allow the natural exposure of crystal pockets such as this one.

FUTURE COLLECTING

Undoubtedly, more crystals remain on Granite Ridge than have been found so far. The potential for collecting even a part of these crystals is low. Since collecting is dependent on road construction and the road system is essentially established, the collector cannot expect new areas to be opened to collecting. The few small tracts of unharvested timber will not be cut in the near future. Stream discharge and wildlife habitat considerations require a certain amount of land to remain undisturbed.

Awareness of the relationship between timber harvest methods and stream flow has increased dramatically in the last 10 years. The granitic soils in this area are highly erosive when disturbed by logging and road construction. In the 1960's it seemed that a road was built to every tree. Now, to assist in protecting soils, wildlife habitat, and water quality, smaller areas are logged and fewer roads were built. Clear-cutting, once the primary harvest method, is being supplemented by selective cutting. These changes in timber management mean less ground is exposed.

The collector can always dig on the undisturbed section of Granite Ridge. About the only reward for this effort is exercise. Without some surface indication of crystals, it is highly unlikely that pockets can be located.

Collectors should follow one rule when searching for crystals in this area. Always fill in your excavations. Past digging in the road banks has resulted in the plugging of some drainage ditches. During the spring runoff water is diverted around the filled areas and across the road, resulting in erosion. Forest Service and Champion International personnel are understandably upset by the actions of a few careless collectors.

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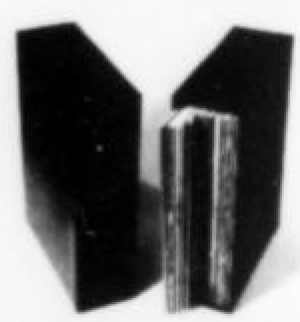

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Endlichite & Descloizite
from the Chalk Mountain mine, Churchill County, Nevada

by **Martin Jensen**
P.O. Box 545
Crystal Bay, Nevada 89402

INTRODUCTION

About five years ago, fine crystal specimens of delicate vanadinite (variety endlichite) perched on brilliant orange descloizite were discovered at the old Chalk Mountain mine located in central Nevada, about 45 miles east of Fallon in Churchill County (see Fig. 1). Situated midway between the famous Fairview and Wonder districts, Chalk Mountain is a conspicuous whitish hill in what is known locally as Dixie Valley. It is roughly 3 miles long, 2 miles wide, and rises to an altitude of 5,440 feet or about 1,000 feet above the valley floor. It is separated from the west front of the Clan Alpine Mountains by a narrow valley approximately 1 mile wide.

A paved highway, U.S. Highway 50, passes within about 4 miles of the mine. The road from the highway to the mine is a fair dirt road passable at all times of the year. The climate is typically hot and arid during the summer months, while colder temperatures and light snows are seen through the winter. Timber is scarce, with the only vegetation consisting of the usual desert sagebrush.

HISTORY

Since the early Comstock days, it had been known that ore occurred at Chalk Mountain but, until 1921, there was only sporadic production, occasionally in carload lots running about 60 percent lead and 60 ounces of silver to the ton. Until about 1920, the operators believed that the mountain contained considerable ore, but that it was of too low grade to be shipped and that the veins were not persistent.

Beginning with the operations of the Chalk Mountain Lead-Silver Mines Company in 1921, more extensive deposits were found which stimulated activity and increased production. Initially, ore was mined from a 110-foot vertical shaft having two levels. By May of 1923, the company had shipped, mostly from development work, 120 tons of $80 ore, comprising about 80 percent of the ore mined. And, in 1925, a 5-foot orebody had been developed for 375 feet on the 110-foot level.

Soon thereafter, a new vertical shaft was sunk 600 feet to the south of the old shaft. The ore body was greatly enlarged, and production increased to 12 tons of $100 ore daily from the now 10-foot-wide ore zone on the 160 level. In July 1926, a large, rich orebody was opened on the 335 level. It alone produced $175,000 worth of ore, some of which ran 70 percent lead. The ore was found to continue down to the 510 level, where the main vein was 6 feet thick and still quite rich. By February 1927, the company had shipped 51 cars of ore, valued at $127,000, or an average net value of $60 to the ton. About $500,000 of $25 mill ore had been blocked out in the mine, and about 3,000 tons of $20 ore accumulated on the dump.

In 1928, a treatment plant was erected at the mine to recover not only the lead-silver values, but vanadium as well. The idea came from a civil engineer in Fallon, who proposed to recover vanadium from the lead vanadates that occur there, in association with other lead ores. But because more attention was paid to the attempted recovery of vanadium than to the lead-silver values, the plant was a failure.

Since that time, the mill has been removed and very little work has been done, mostly by lessees. The majority of the workings are still accessible and the main shaft is in relatively good condition down to the 510 level.

There has never been any problem with obtaining entry to the

Figure 1. **Outline map showing the location of the Chalk Mountain and Quartz Mountain mining districts, Nevada (Schrader, 1947).**

mine, and it appears entirely open to collectors. Nevertheless, a title search should probably be done to determine whether the mine is still privately owned.

GEOLOGY

The geology of the Chalk Mountain mine has been dealt with by several people including Bryan (1972) (thesis on Chalk Mountain) and Schrader (1947) (U.S.G.S. open file report). The summary below is drawn from these sources.

The region consists mainly of a whitish dolomitic limestone which has been folded into an anticlinal fault block along its longitudinal axis and intruded by granodiorite. Both the limestone and granodiorite were later intruded by dikes of diorite. These diorite dikes are closely related to the ore deposition. Figure 2 is from Schrader (1947) and shows a general plan view and cross section of the area.

The limestone is medium to thick bedded and contains the ore deposits. It has been faulted, sheeted and locally intensely folded. Pronounced faults occur along the east front of the mountain, and with them is associated the principle zone of mineralization.

No fossils indicative of the age have yet been found in the limestone of Chalk Mountain, but because of Jurassic fossils found in limestone in the foothills to the south and because of the more highly metamorphosed character and shattered condition of the limestone at Chalk Mountain, it is thought to be of Triassic or Permian age and probably belongs to the Koipato group that occurs 12 miles to the north.

The granodiorite prophyry, with which the ore deposits are thought to be genetically connected, is a medium-grained gray porphyritic rock composed chiefly of alkali feldspars, quartz, biotite and hornblende.

The limestone and granodiorite porphyry are both intruded by dikes of a greenish, iron-gray diorite and a whitish aplite, which are presumably complementary to each other and differentiated from the granodiorite magma. In places, ore deposits are associated with these dikes.

Covering the consolidated rocks on the lower slopes of the mountain is a thin mantle of alluvium, which increases in thickness to at least 150 feet in the surrounding valley.

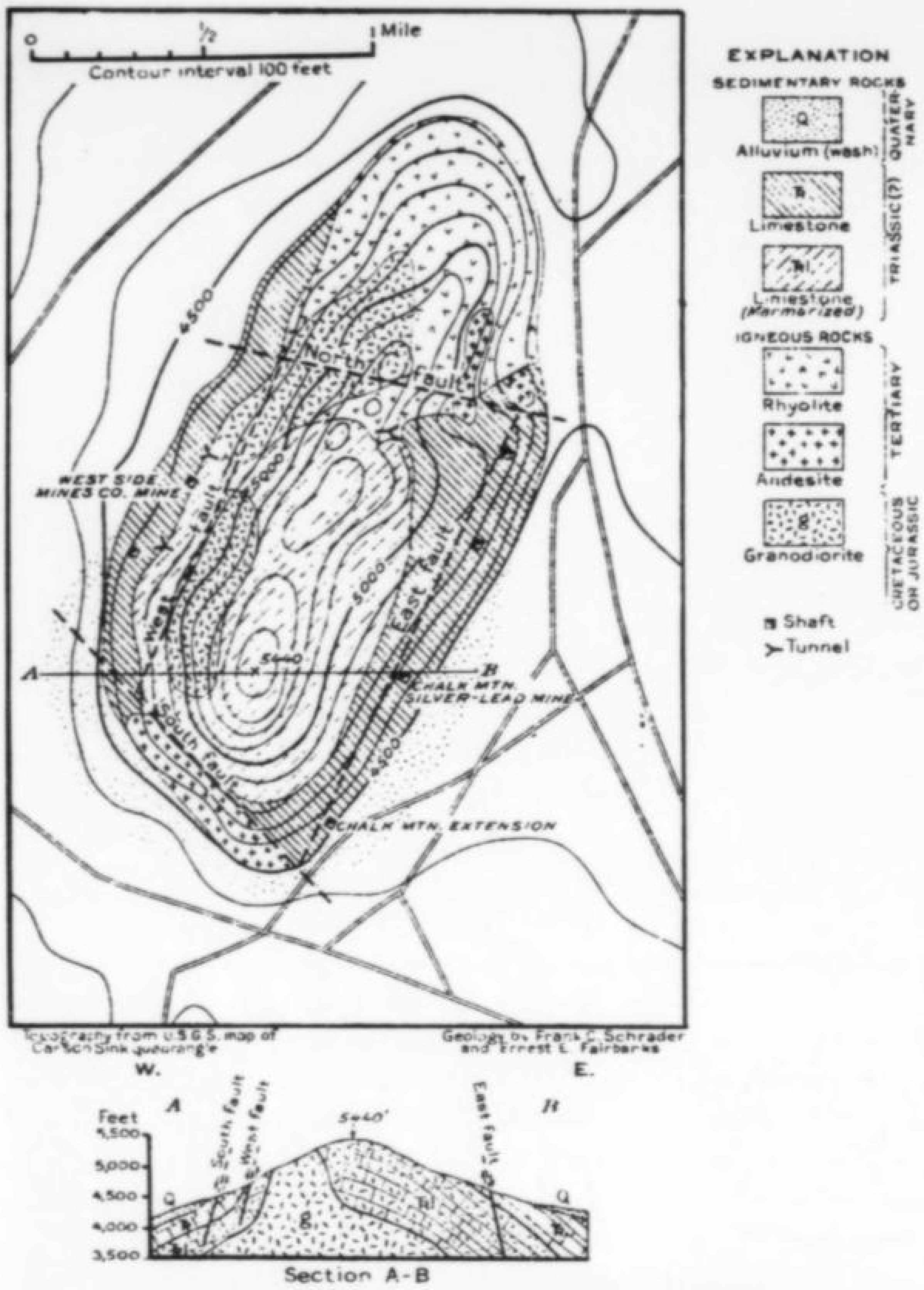

Figure 2. **Sketch map and section of Chalk Mountain, Churchill County, Nevada (Schrader, 1947).**

Figure 3. **Endlichite crystals to about ⅓ inch and brown in color from the Chalk Mountain mine. Photo by the author.**

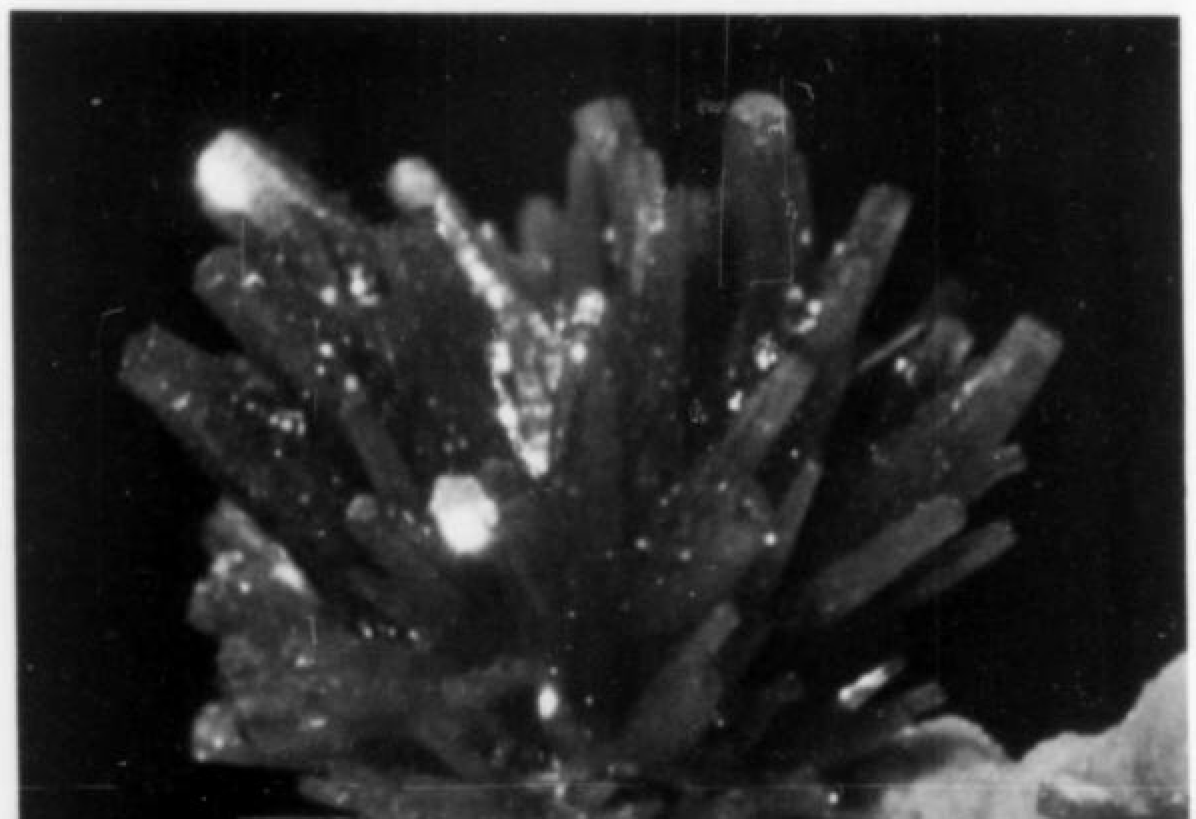

Figure 4. **Brown endlichite crystals on orange descloizite. The crystal spray is about ¼ inch across, from the Chalk Mountain mine. Photo by the author.**

ORE DEPOSITS

The deposits are mostly oxidized, and the orebodies, though a few are tabular, are mostly irregular masses of porous, iron-stained material. They occur as veins and replacement deposits along fractures or bedding planes in the limestone. The principle ore minerals are argentiferous galena, cerussite, wulfenite and vanadinite (variety endlichite). The gangue consists of altered limestone, calcite, quartz, dolomite and porous limonite. Iron is present in sufficient quantity to make the ore desirable for smelting.

The ores were deposited as sulfides, mainly argentiferous galena and pyrite, by hydrothermal solutions that ascended from the granodiorite porphyry magma and circulated through the openings in the limestone. They were deposited soon after consolidation of the granodiorite, probably at depths of about 1,000 feet below the surface, largely in the places that they now occupy. Since their deposition, they have been partly enriched through the processes of leaching and concentration by descending surface waters. Most of the veins, especially those of steep dip, probably continue in depth to, or below the water table, which is at a depth of from 300 to 500 feet in the mines. Below the water table, however, the deposits are probably leaner than above, having received less, if any, enrichment from descending surface waters.

MINERALOGY

Vanadinite ($Pb_5(VO_4, AsO_4)_3Cl$) (var. endlichite)

Endlichite is a variety of vanadinite, in which arsenic substitutes for vanadium in approximately a 1:1 ratio. The crystals are very similar to vanadinite, usually occurring as hexagonal barrel-shaped prisms terminated by the basal pinacoid {0001}, but are more of a golden-brown color than bright orange or red like the Arizona vanadinites. The maximum single crystal size observed is about ⅕ inch in length and ¹⁄₁₆ inch in width. The best specimens are quite translucent and euhedral while the poorer ones are opaque and exhibit more exaggerated barrel-shaped forms.

The crystals occur implanted upon orange descloizite as palm-tree-like groups, commonly beginning with a single crystal at the base and then diverging into numerous radiating crystals at the top.

The endlichite seems to be restricted to certain fairly large openings in stopes on the 510 level. These vugs are located where at least two prominent joint sets in the dolomite intersect one another. The pocket from which the specimens were obtained was roughly 3 by 4 by 5 feet, and when first opened was filled with large horizontal-lying slabs of altered dolomite coated with descloizite and endlichite. (In doing work for his thesis, Byran recovered many of these larger pieces, which are now in his collection.)

Descloizite ($(Zn,Cu)Pb(VO_4)(OH)$)

Descloizite is the zinc-rich member of the descloizite-mottramite group in which zinc and copper substitute for each other in varying amounts. At Chalk Mountain, descloizite is present as microcrystals only, and has been identified by X-ray diffraction. It ranges from almost fluorescent orange to light lemon-yellow in color, and provides a sharply contrasting background for the endlichite crystals. In the vugs, it forms mammillary and botryoidal coatings on the altered dolomite. It is also found in interstices within the hard boxwork limonite which is present in some of the stopes.

Wulfenite ($PbMoO_4$)

Wulfenite at Chalk Mountain is most abundant within the limonite and in the small pods and veinlets consisting of altered galena and cerussite. The crystals exhibit the common tabular forms with some showing the prismatic and pyramidal forms as well. The largest crystal found measured approximately ½ inch across, and was of a bright red-orange color similar to wulfenite from the Red Cloud mine, Arizona.

Cerussite ($PbCO_3$)

This mineral occurs as gray spongy masses surrounding relict galena and no distinct crystals have been seen. It is confined to the ore veinlets and is not present within the limonite zones.

Galena (PbS)

Primary galena in massive form is abundant in the stopes on the 510 level. It forms small vertically dipping veinlets up to 2 inches wide and is commonly completely surrounded by oxidation minerals, principally cerussite and wulfenite. Upon exposure to air it tarnishes readily from a shiny steel gray color to a dull black.

Quartz (SiO_2)

Quartz is fairly common and occurs both as crystalline and cryptocrystalline varieties. It is not associated with endlichite, but rather forms small (up to ¹⁄₁₀ inch) doubly terminated, perfectly clear, euhedral crystals in the limonite. In most instances, yellow descloizite crystals are sprinkled on the faces and make identification difficult.

Calcite ($CaCO_3$)

Small, hexagonal plates of clear to white calcite occur in vugs and cracks in limonite. The limonite is reddish-brown and provides an attractive matrix for the calcite crystals.

CONCLUSION

Chalk Mountain is one of the more interesting localities in Nevada. Replacement deposits in limestone are typically good areas to collect crystallized specimens of many exotic minerals, and Chalk Mountain is no exception.

Wulfenite crystals, descloizite on quartz crystals, and calcite crystals can still be found on the 335 level. The endlichite crystals and orange descloizite specimens from the 510 level are still available from the large vug, however they are not as fine as those shown in the photos.

From the exploration of the 510 level, several vugs were found which had been cleaned out by previous collectors. Thus, the possibility of finding new pockets still exists.

The main shaft is still accessible down to the 510 level by a series of 33 ladders. The majority of the stopes and orebodies are also accessible. Unfortunately, most of the timbers in them are rotten. There is no water present in any of the workings except in a small pool in a drift beneath the 510 level. The air is adequate.

The Chalk Mountain area should continue to be a seldom visited, quite rewarding collecting locality in Nevada.

ACKNOWLEDGMENTS

The author is grateful to Ron Gibbs and Joel Cort for sharing their enthusiasm for mineral collecting and interest in mineralogy and to Becky Weimer for helpful discussions of geologic information.

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Some Rare Minerals of the Bancroft area

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INTRODUCTION

Bancroft, the focal point of Ontario's most prolific and popular mineral collecting area, is located in the scenic Hastings Highlands of Eastern Ontario, about 235 km (146 miles) northeast of Toronto. Originally a lumbering town, it became the commercial center for intermittent mining activity that began at about the turn of the century. More recently it has become a growing tourist and recreational area and the site of the annual Bancroft Gemboree featuring mineral displays and sales, and field excursions to nearby collecting localities.

GEOLOGY

The geological location of the Bancroft area is at the southern end of the Grenville Province of the Canadian Shield, a region characterized by metamorphic and igneous rocks that date back more than one billion years. A glance at the geological map of the Bancroft area reveals a complex assemblage of rock types including marble, quartzite, amphibolite, granite, diorite, gabbro, schists, gneisses, syenites and pegmatitic rocks. The sequence of events that produced these rocks began about 1300 million years ago with mountain-building activity that intensely metamorphosed the existing sedimentary and volcanic rocks, altering them to marble, quartzite, paragneiss and amphibolite. Subsequent deformation, intrusion and concomitant metamorphism during a span of about 250 million years produced diorite, gabbro, ultrabasic rocks, schist, and granitic, syenitic, and gneissic rocks and pegmatites. There followed a long period of erosion which reduced the moutainous terrain to a rolling peneplain whose topography was later modified by the repeated advance and retreat of continental glaciers in Pleistocene time.

The varied rock types are the hosts for numerous mineral deposits including corundum, nepheline, sodalite, apatite, mica, fluorite and feldspar, and ores of uranium, iron, gold, lead, graphite and molybdenum.

MINERALS

To mineral collectors, the Bancroft area is known throughout the world as one that provides numerous classic mineral collecting localities. Not so well known are the uncommon to rare mineral species that occur in the area. For the more advanced species collector, these occurrences may provide added interest for collecting in the Bancroft region.

Selected localities in which rare minerals occur are described in the text; the locality numbers correspond to those shown on the map (Fig. 1).

Crystal Lake Road. **Locality 1.**
FLUOBORITE

Fluoborite ($Mg_3(BO_3)(F,OH)_3$) occurs at several localities in the Bancroft area, but most abundantly at the Crystal Lake Road occurrence where it forms hexagonal prisms measuring up to 2 cm long and 8 mm in diameter; it also occurs as small, finely crystalline masses. The crystals lack terminal faces and are characterized by rounded edges giving them a log-like appearance. They occur individually or in parallel and, less commonly, divergent or stellate groups. Fluoborite is colorless and transparent with a vitreous luster, or white to cream-white, translucent to almost opaque with a silky, pearly or chalky (in weathered specimens) luster; crystals are generally transversely zoned with colorless bands alternating with white. They resemble apatite. The fracture is uneven. Fluoborite fluoresces strongly white or yellowish white when exposed to shortwave ultraviolet light. Inclusions of graphite, pyrrhotite and norbergite were noted in the crystals.

Fluoborite occurs in dolomitic crystalline limestone in which it is associated with anhedral grains of orange norbergite and minor disseminations of colorless to light green clinoamphibole, gray to green serpentine, violet and amber fluorite, amber mica, rutile, graphite and pyrrhotite. In some specimens, fluoborite comprises an estimated 10 percent of the rock.

The fluoborite-bearing crystalline limestone is in contact with red granite pegmatite and is exposed by a roadcut on the south side of the Crystal Lake Road at a point 10.8 km (6.7 miles) east of its junction with Highway 121. This junction is 7.1 km (4.4 miles) south of the village of Kinmount which is 81 km (50.3 miles) southwest of Bancroft.

Fluoborite occurs less abundantly at the Cardiff Uranium mine (see Locality 3). Minor occurrences were noted at two roadcuts: one on Highway 35 at a point 12.4 km (7.7 miles) south of its junction with Highway 131 in Minden, and another on Highway 648 at a point 0.3 km (0.2 mile) south of its junction with the Dark Lake Road in Wilberforce. At these roadcuts fluoborite occurs sparingly as colorless, pink or white granular patches in dolomitic, chondrodite-bearing, crystalline limestone. Other minerals disseminated in the limestone include amber mica, green serpentine, light green clinoamphibole, colorless fluorite, light blue apatite, pyrite and graphite.

Collecting fluoborite, which is essentially the same color as the host rock, is facilitated at any of these localities by the use of an ultraviolet lamp.

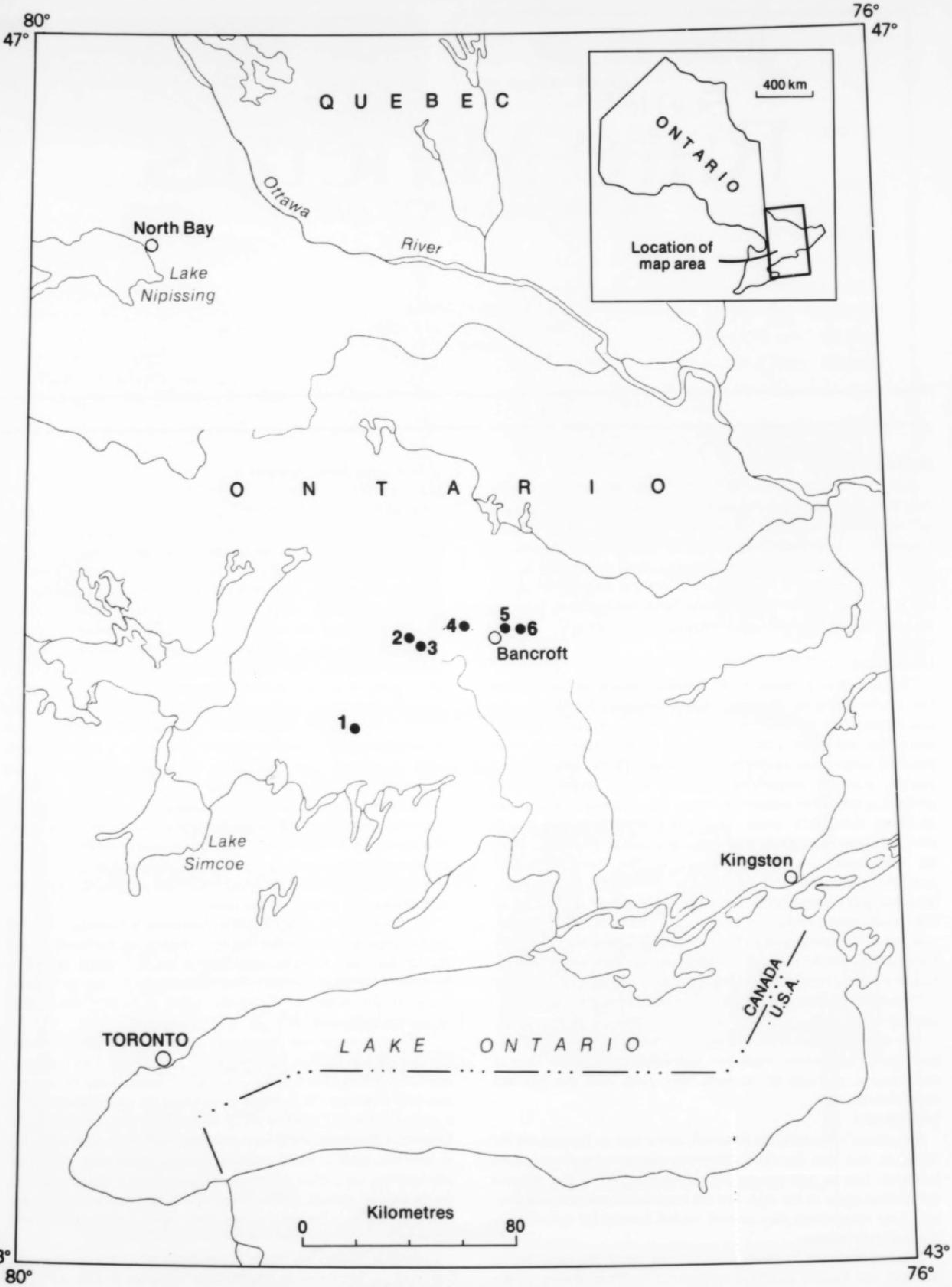

Figure 1. **Location map.**

Figure 2. **Fluoborite crystals in crystalline limestone, Crystal Lake Road occurrence. Crystal in the center is 15 mm long (GSC 203442-A).**

Desmont Mine. **Locality 2.**
STILLWELLITE, HYDROXYL-BASTNAESITE, PERRIERITE

These minerals occur in a deposit of radioactive mineralization; stillwellite and hydroxyl-bastnaesite, both of which are relatively new species, occur in calcite, and perrierite in crystalline limestone.

Stillwellite ($(Ce,La,Ca)BSiO_5$) occurs as maroon-red hexagonal tabular crystals measuring up to 4 by 5 mm, and as gray, pink, brownish red to brown lenticular and irregular masses (measuring up to 1 cm long) in white to salmon-pink cleavable calcite. The massive variety is smooth-textured to porcelain-like and is commonly mottled in these shades. It is generally opaque with a waxy to resinous luster but some of the brown variety is almost transparent and resembles titanite. The fracture is sub-conchoidal. Stillwellite commonly forms partial crusts around smoky quartz and green clinopyroxene. Yellow to orange monazite, light yellow ancylite and brown and dark green hydroxyl-bastnaesite are intimately associated with stillwellite.

Hydroxyl-bastnaesite ($(Ce,La)(CO_3)(OH,F)$) occurs as intergrowths with stillwellite or as small, finely granular masses in calcite. It is brown, pinkish brown or dark green, opaque with a waxy, resinous or greasy luster and uneven fracture.

A number of minerals are associated with stillwellite and hydroxyl-bastnaesite including euhedral crystals of bright green clinopyroxene and micro crystals of pyrite exhibiting a variety of forms. Other minerals include gray to green prismatic scapolite, black tourmaline, serpentine, light green apatite (crystals), plagioclase and K-feldspar (crystals), colorless to light green clinoamphibole, titanite, smoky quartz (crystals), marcasite, molybdenite (2H), magnetite, goethite, sulfur (black, associated with pyrite), and the radioactive minerals thorite, thorianite and uranothorite. They occur in coarsely crystalline white to salmon-pink calcite which forms veins and lenses in marble.

Perrierite ($(Ca,Ce,Th)_4(Mg,Fe)_2(Ti,Fe^{+3})_3Si_4O_{22}$) is disseminated sparingly in crystalline limestone. It occurs as reddish brown to almost black, opaque, striated plates and small irregular masses with jagged edges and measuring up to 2 mm in diameter. Its luster is resinous to greasy. It resembles titanite but may be distinguished from it by its luster, platy habit and striations. Other minerals disseminated in the limestone are: chondrodite, amber mica, titanite, clinoamphibole, tourmaline, clinopyroxene, pyrite, pyrrhotite, sphalerite, graphite and molybdenite (2H).

The Desmont deposit was explored for radioactive minerals in 1955 by Desmont Mining Corporation, Ltd. It is exposed by a series of open cuts extending over a distance of 1052 meters (3450 feet). The stillwellite and associated hydroxyl-bastnaesite occur in the East and Main showings in the southern part of the property and perrierite occurs in an open cut toward the northern end. The property is located 1.9 km (1.2 miles) northwest of Wilberforce which is about 42 km (26 miles) west of Bancroft.

Cardiff Uranium Mine. **Locality 3.**
FLUOBORITE, SEPIOLITE

These minerals occur in norbergite-rich dolomitic crystalline limestone. ***Fluoborite*** is colorless to light pink and forms hexagonal prisms measuring about 2 mm in diameter and irregular masses generally less than 1 cm across. Although it is not abundant at this locality, it can be found in nearly all specimens containing norbergite, particularly those in which the norbergite forms bands in the limestone. ***Sepiolite*** ($Mg_4Si_6O_{15}(OH)_2 \cdot 6H_2O$) occurs as white to light amber, silky, matted fibers forming patchy encrustations on the crystalline limestone.

A number of other minerals occur as disseminated grains in the norbergite-bearing crystalline limestone; they include amber mica, light blue apatite, colorless to gray clinoamphibole, green serpentine, white and light blue talc, peach-colored tourmaline, colorless and white fluorite, brownish pink titanite, light green clinopyroxene, graphite, pyrite and pyrrhotite.

The fluoborite and sepiolite specimens were collected from the mine dump adjacent to the shaft in the South zone of the property which was formerly (1947–1955) explored for fluorite and uranium. The exploration was done by Cardiff Uranium Mines, Ltd. and by its predecessor, Cardiff Fluorite Mines, Ltd. The property is now

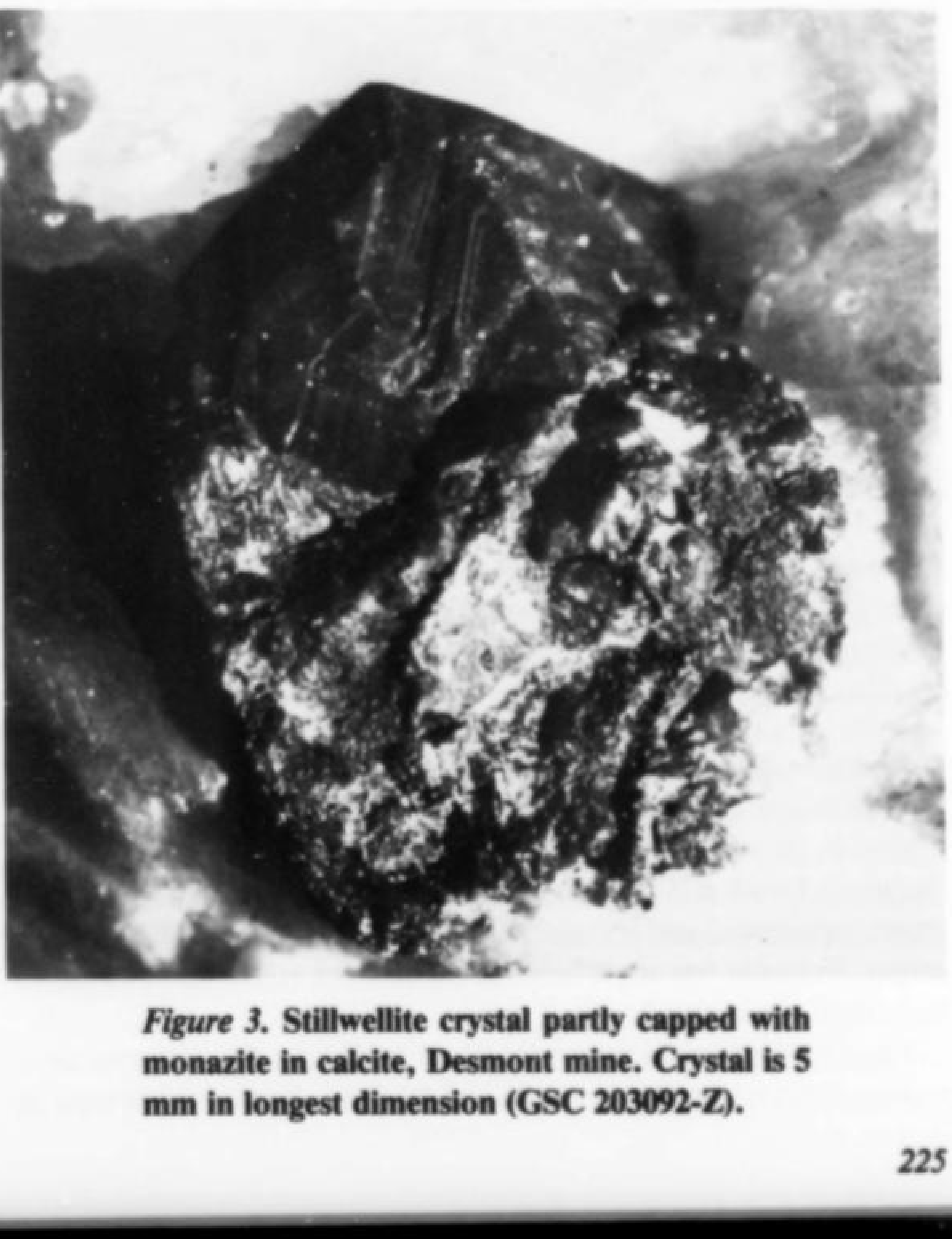

Figure 3. **Stillwellite crystal partly capped with monazite in calcite, Desmont mine. Crystal is 5 mm in longest dimension (GSC 203092-Z).**

held by Esso Minerals Canada, from whom permission is required for entry. It is located 5 km (3.1 miles) south of Wilberforce.

***South Baptiste Lake Road.* Locality 4.**

WARWICKITE, SINHALITE, SZAIBELYITE, TOCHILINITE

The borate minerals and tochilinite occur in chondrodite-rich bands in dolomitic crystalline limestone on the South Baptiste Lake road. ***Warwickite*** ($(Mg,Ti,Fe^{+3},Al)_2(BO_3)O$) which was originally described from a Warwick, New York, locality was, prior to its characterization, referred to by collectors as hypersthene which it resembled. The name *encelladite* was given to a mineral with similar characteristics from the same locality; this mineral was later found to be altered warwickite (Hunt, 1851).

At the Bancroft locality, warwickite occurs as prisms measuring up to 2 mm by 5 mm, as anhedral grains, and as small microcrystalline masses. The crystals are characterized by rounded edges and the absence of terminal faces. Warwickite is black, subtranslucent to opaque with adamantine or submetallic to dull and, less commonly, pearly luster. The surface may be tinged with coppery red or gray and the streak is reddish brown. Dull gray to tan-colored anatase forms transverse irregular lines on the prism faces giving them a ribbed effect. Warwickite alters to gray or brownish gray anatase.

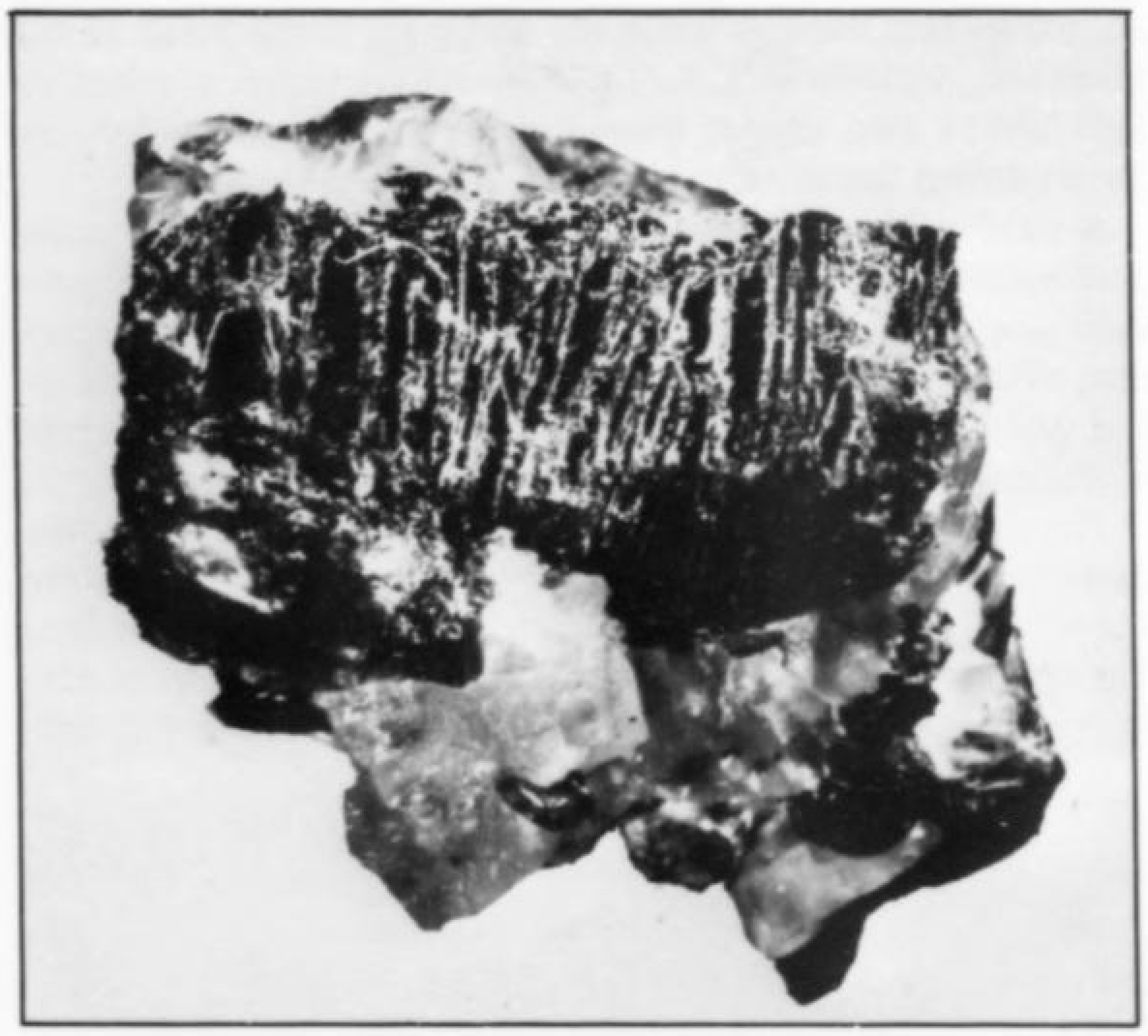

***Figure 4.* Warwickite crystal with crystalline limestone at edges. White irregular bands are due to anatase. Crystal is 5 mm long (GSC 203441-R).**

Along with chondrodite, the following minerals are disseminated in the warwickite-bearing crystalline limestone: amber mica, dark green spinel, light green to brown clinoamphibole, amber to orange and dark brown tourmaline, green serpentine, light blue apatite, light green and yellow fluorite, light yellow scapolite, sinhalite, szaibelyite, ilmenite, marcasite, pyrrhotite, pyrite, graphite, goethite and tochilinite.

Sinhalite ($MgAlBO_4$) was originally described as a result of an investigation of several light yellow to brown gemstones labeled as olivine in the collections of the British Museum and the Geological Survey in London (Claringbull and Hey, 1952). Some of these gemstones originated in Ceylon (Sri Lanka), others were of unknown origin. Sinhalite has since been reported from a few other localities including one in the Bancroft area.

The Bancroft sinhalite is colorless to light yellow, transparent with a vitreous luster and conchoidal fracture. It occurs sparingly as irregular masses averaging about 2 mm in diameter in the crystalline limestone, and as a microcrystalline crust around dark green anhedral spinel with which it is generally most closely associated. It is difficult to detect in the crystalline limestone, but its conchoidal fracture, lack of cleavage and superior luster and transparency distinguish it from the calcite in which it is embedded.

Szaibelyite ($MgBO_2(OH)$) occurs in small concentrations at or near the exposed surfaces of chondrodite-rich bands in warwickite-bearing crystalline limestone. It occurs as buff-colored to rusty, scaly, craggy or woody aggregates occupying pockets in the limestone or, less commonly, as nodules embedded in the rock. It has a silky luster except on exposed surfaces where it has an earthy appearance. The nodules and szaibelyite-filled pockets are irregularly shaped and measure 2 to 5 mm long.

Tochilinite ($6Fe_{0.9}S \cdot 5(Mg,Fe^{+2})(OH)_2$) was originally described in 1971 from serpentinite in a copper-nickel deposit in the Voronezh region, U.S.S.R. and since then several other occurrences have been reported, including the Cross and Maxwell quarries near Wakefield, Quebec, where it occurs conspicuously in serpentine marble (Sabina, 1978). It also occurs at the York River tactite zone (Locality 6).

At the South Baptiste Lake Road occurrence, it is both inconspicuous and uncommon in the dolomitic crystalline limestone that bears warwickite, sinhalite, etc. It occurs as microscopic black plates or scales and smear-like patches along dolomite cleavage planes. It has a bronze tinge with a greasy luster, characteristics that distinguish it from graphite which, at this locality, occurs as brilliant metallic flakes. The aggregates are about a millimeter in diameter.

The dolomitic crystalline limestone containing warwickite, szaibelyite, sinhalite and tochilinite is exposed by a roadcut on the north side of the South Baptiste Lake Road at a point 12 km (7.5 miles) west of its junction with Highway 62 which is 6.7 km (4.2 miles) north of Bancroft.

***Princess Sodalite Mine.* Locality 5.**

NORDSTRANDITE, BOEHMITE, DAWSONITE

The Princess Sodalite mine is, for many collectors, the focal point of their mineral expedition to the Bancroft area. Sodalite from this locality has been used as an ornamental stone for many years and was first brought to the attention of the world at the 1893 world's Columbian Exposition in Chicago; a rough specimen was displayed in the Ontario Provincial exhibit and polished specimens were exhibited in the Court occupied by the Geological Survey of Canada.

The deposit was first reported in 1894 by Frank D. Adams, who discovered the Bancroft nepheline syenite deposits while investigating the geology of the Haliburton-Hastings area for the Geologi-

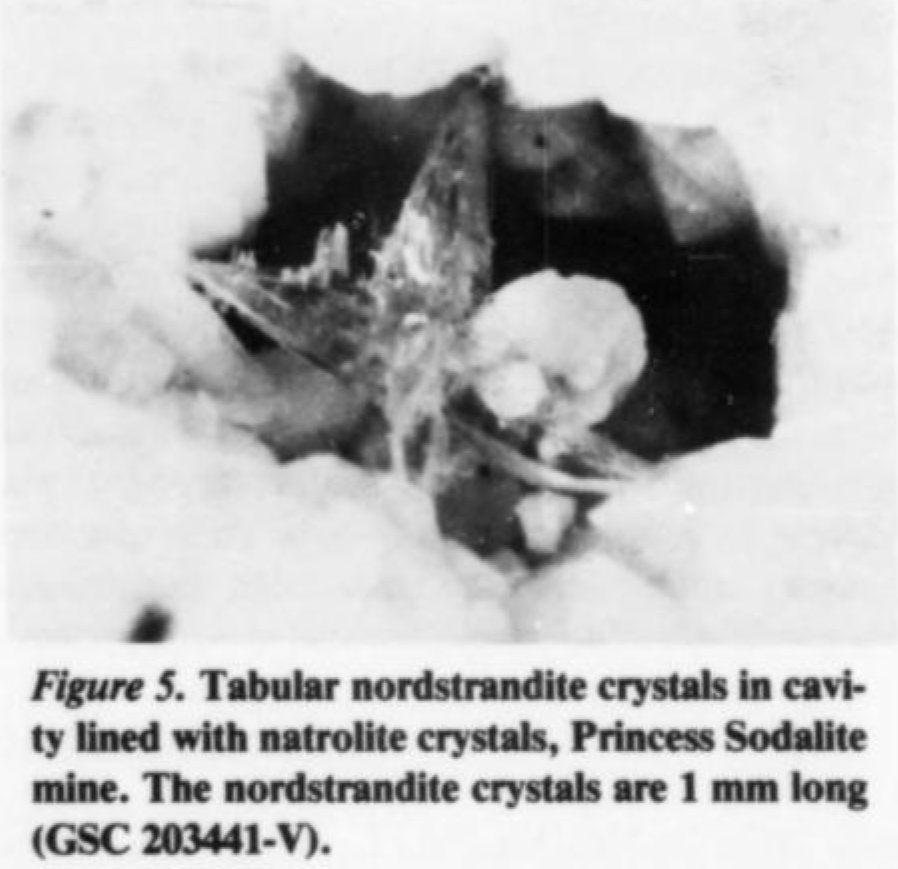

***Figure 5.* Tabular nordstrandite crystals in cavity lined with natrolite crystals, Princess Sodalite mine. The nordstrandite crystals are 1 mm long (GSC 203441-V).**

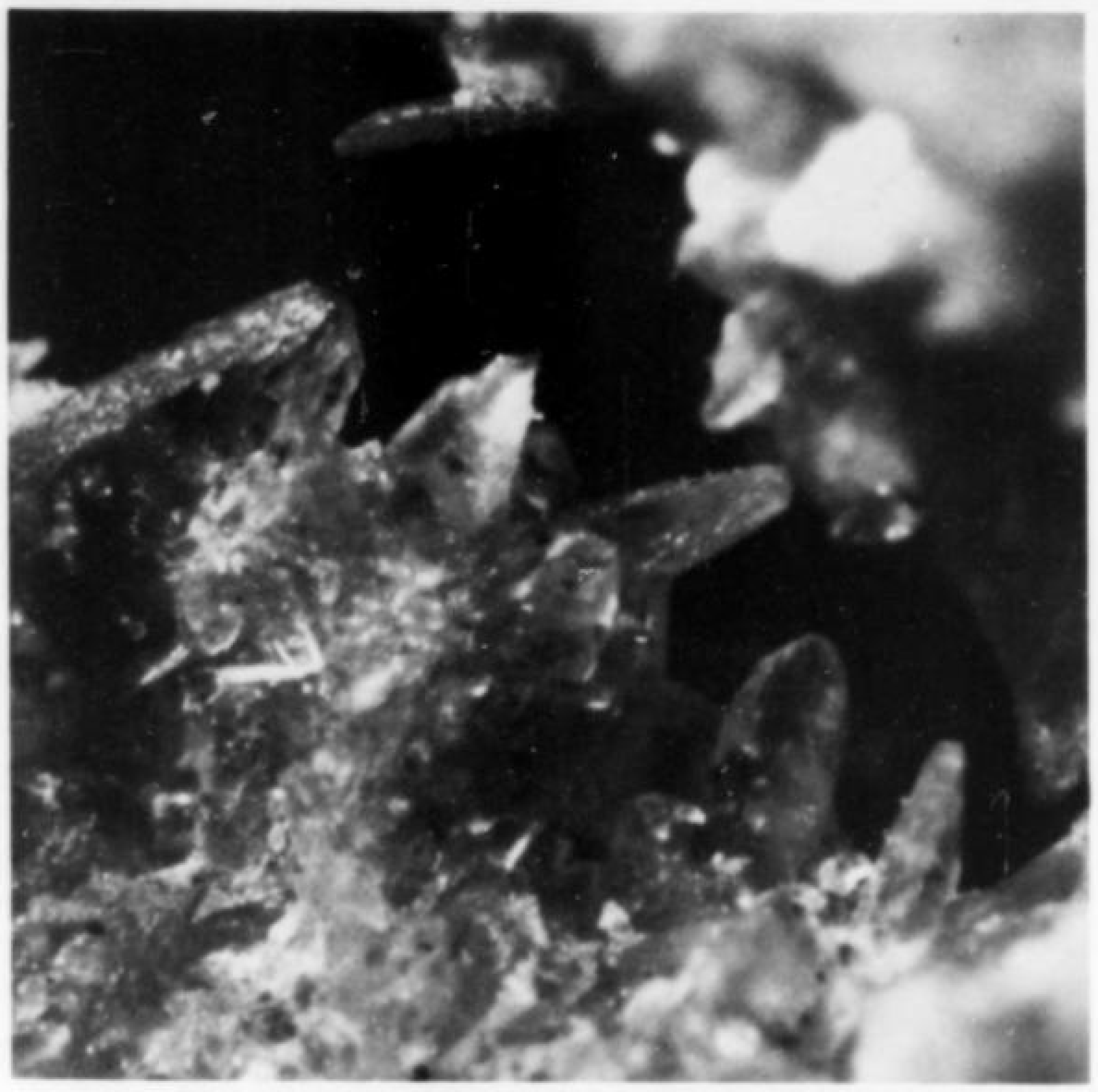

Figure 6. **Nordstrandite crystals protruding from walls of cavity in natrolite, Princess Sodalite mine. The crystals average 0.5 mm long (GSC 202093-G).**

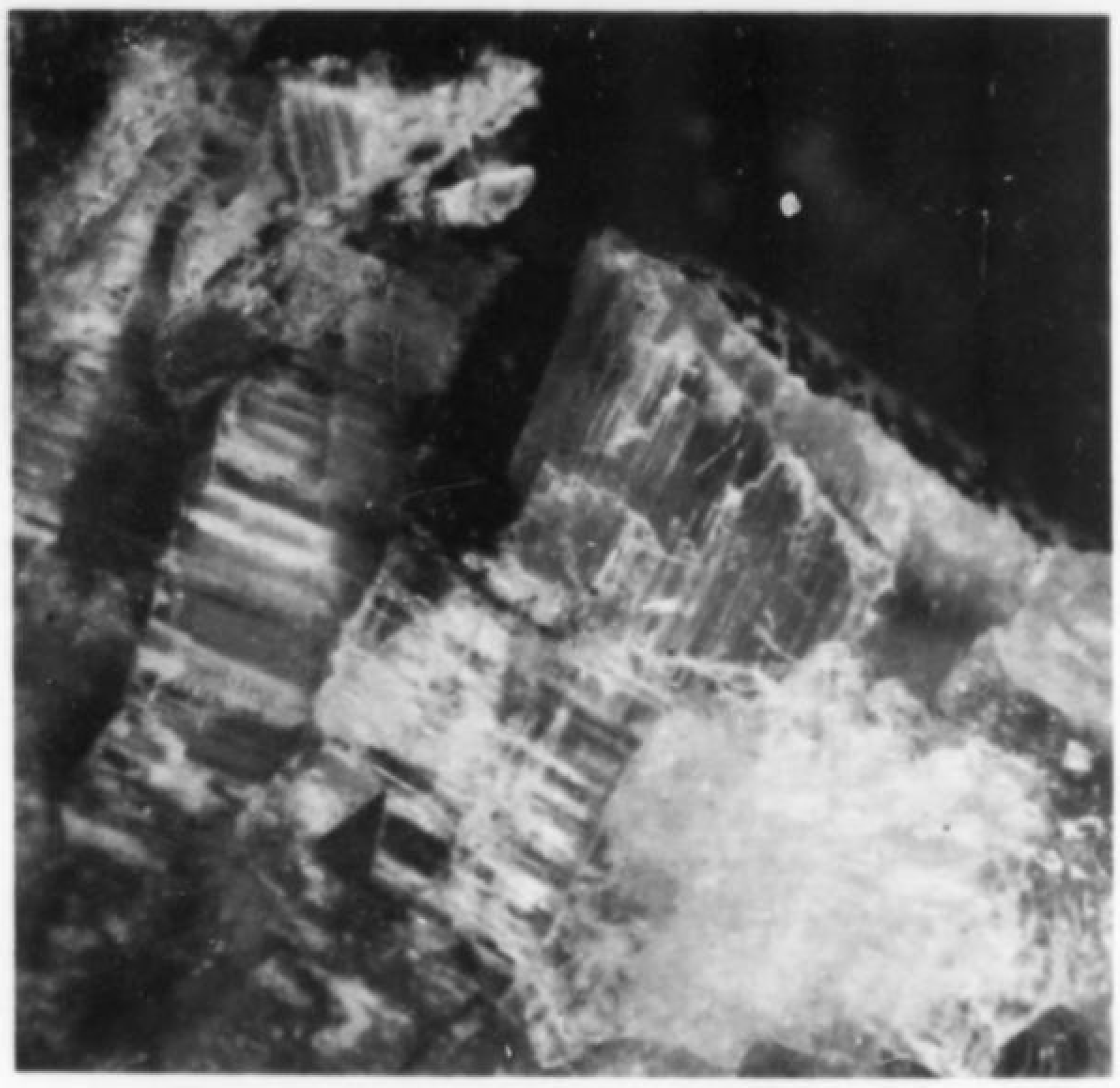

Figure 7. **Massive striated dawsonite in natrolite, Princess Sodalite mine. (X25, GSC 203093-Q).**

cal Survey of Canada between 1892 and 1895. He noted that masses of pure sodalite measuring 25 by 25 by 10 cm occurred on the John Bowers property, which later became known as the Princess mine. The first commercial operation on the deposit was performed in 1906 by Princess Quarries Limited, which extracted 5.7 cubic meters of sodalite for use as a decorative stone (Gibson, 1907). The original workings consisted of two open cuts, one measuring 31 m long and 8 m wide (Corkill, 1906). Since the initial operation, the deposit was worked intermittently and is currently operated by Paul Rasmussen. The mine is located on Highway 500 at a point 4 km (2.5 miles) east of Bancroft.

The sodalite is closely associated with natrolite, which is the host for the minerals nordstrandite, boehmite and dawsonite. ***Nordstrandite*** ($Al(OH)_3$) occurs as colorless transparent and slightly yellowish translucent crystals or aggregates of crystals. The luster is vitreous or pearly in the colorless crystals and oily in the yellowish. The crystals are blade-like to tabular prismatic with pointed or oblique terminations and average 1 mm long. They occur individually or as radiating, stellate or randomly oriented clusters in mariolitic cavities (about 5 mm long) in massive natrolite. Nests of crystals and striated masses (about 3 mm in diameter) are commonly embedded in natrolite. Associated with nordstrandite in the cavities are boehmite and, more commonly, natrolite, the latter occurring as colorless acicular crystals or pearly white tabular or squat prismatic crystals and columnar aggregates. Nordstrandite is widespread in small amounts in chalk-white to light pink weathered-looking natrolite which forms irregular patches in pink to brick-red natrolite.

Boehmite ($AlO(OH)$) occurs with crystals of nordstrandite and natrolite in cavities in massive natrolite. It occurs as fluffy, flaky or granular aggregates partly filling cavities, as a powdery coating on natrolite crystals, and as wispy fibers on massive natrolite. It is white with a pearly to silky luster. Boehmite is a relatively rare mineral at this locality.

Dawsonite ($NaAl(CO_3)(OH)_2$) was originally described in 1874 (Harrington) from a feldspathic dike cutting Trenton limestone on the McGill College property in Montreal. It was named in honor of Sir J. William Dawson, then Principal of the College, who discovered the mineral. Other occurrences in the Montreal area were later reported but its occurrence in the Princess mine is the only one reported from an Ontario locality.

Dawsonite at this locality occurs sparingly in mottled pink to brick-red massive natrolite. It occurs as white silky fibers (about 1 mm long) forming tufts, radiating, parallel and felted masses resulting in a feathery appearance. It also forms cross-fiber veinlets and colorless striated masses in natrolite. The dawsonite aggregates average 1 to 2 mm in diameter but may be as large as 1 cm. Unlike nordstrandite and boehmite, which occur in zones of natrolite that have an altered appearance, dawsonite occurs in pink to reddish natrolite which has a vitreous luster and fibrous texture and does not have the weathered appearance.

Natrolite in which these minerals occur is associated abundantly with sodalite, in which it forms streaks, veinlets and masses. Magnetite, biotite, zircon and pyrite are accessory minerals in natrolite. This deposit occurs in nepheline-rich syenite and pegmatite, the sodalite-natrolite masses replacing nepheline along fractures in the rock. It is exposed by a 62-meter long open cut at the side of a ridge.

***York River Tactite Zone.* Locality 6.**

BRUGNATELLITE, MONTICELLITE, TOCHILINITE, LUDWIGITE

A variety of minerals occurs in a dolomitic marble skarn zone which is exposed along a cliff on the east bank of the York River. The minerals include: orange to brown hessonite garnet, green clinopyroxene, dark green spinel, yellow-green to brown vesuvianite, pink zircon, blue to gray calcite, yellow, green and gray serpentine, yellow to orange clinohumite, colorless to yellow and pink olivine, wollastonite, colorless cancrinite, light green and colorless clinoamphibole, white scapolite, amber mica, aragonite, brucite, hydromagnesite, chlorite, plagioclase, hydrotalcite, pyrrhotite, graphite and magnetite. Brugnatellite, monticellite, tochilinite, ludwigite and perovskite are new additions to this list.

Brugnatellite ($Mg_6Fe^{+3}(CO_3)(OH)_{13}\cdot 4H_2O$) occurs as white silky or waxy, scaly to compact foliated nodules in calcite. The nodules are 1 to 3 mm in diameter and are partial or complete replacements

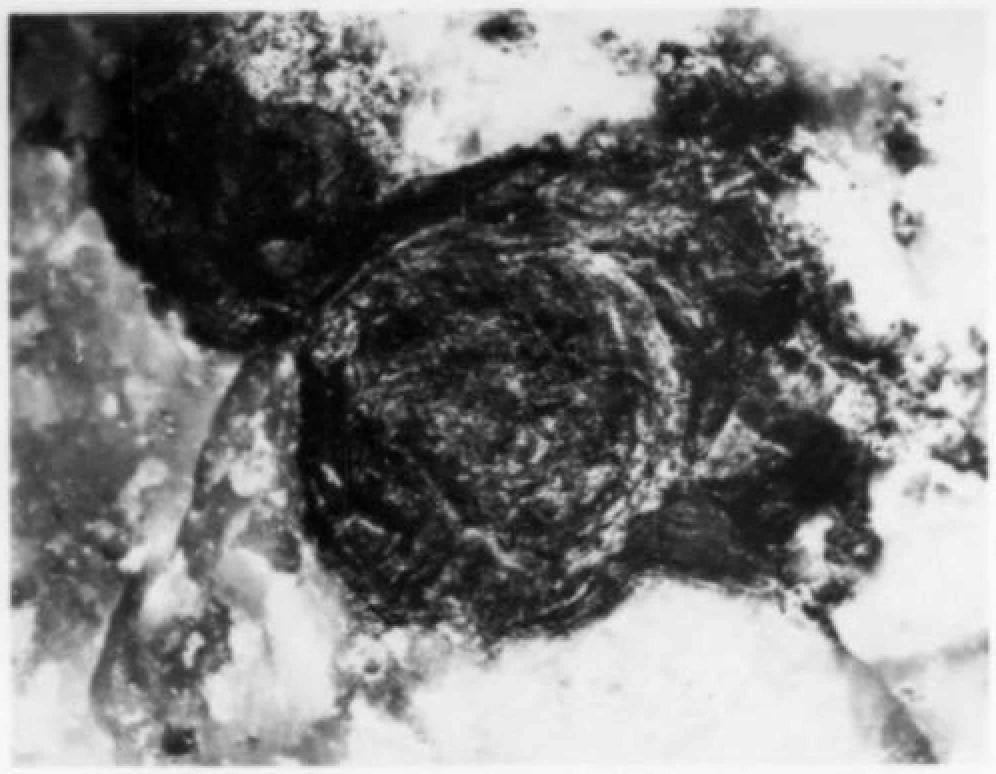

Figure 8. **Foliated brucite nodules replaced by tochilinite, York River tactite zone. The larger nodule measures 7 mm in diameter. (GSC 201836-K).**

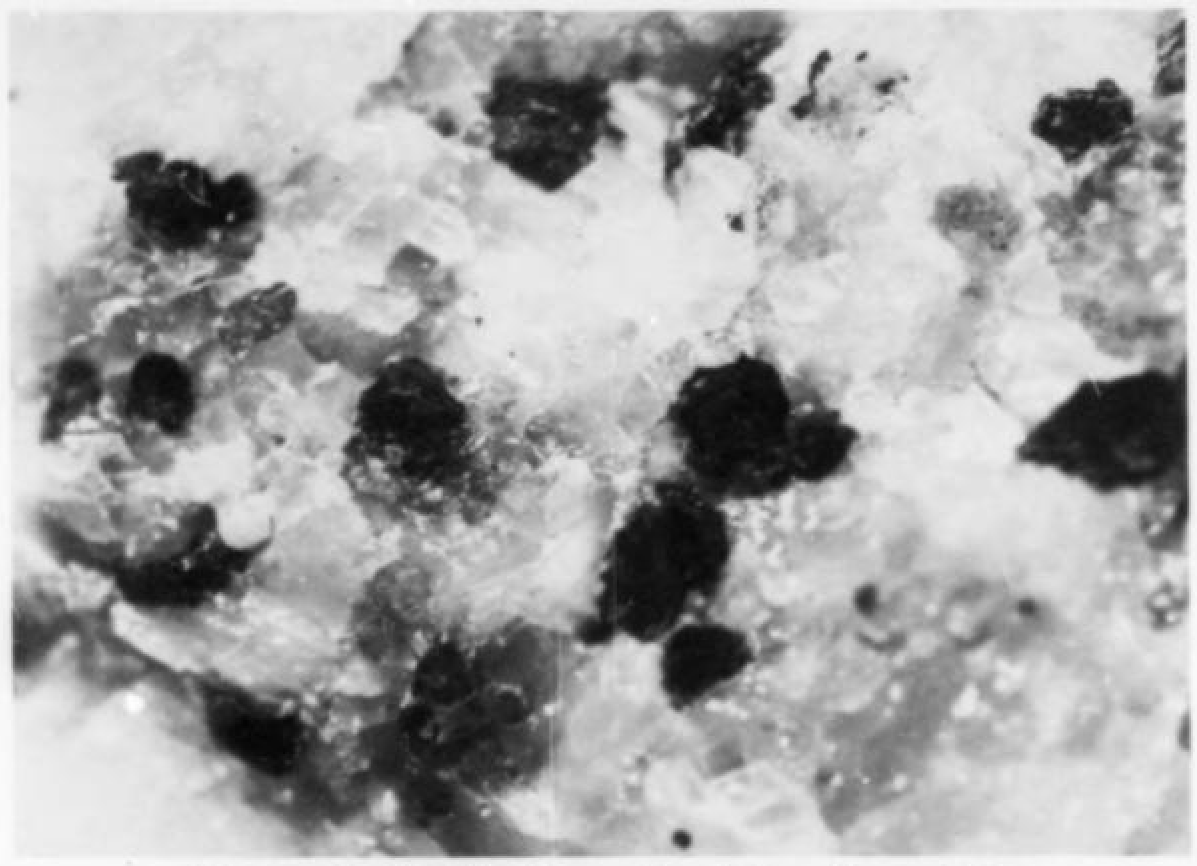

Figure 9. **Tochilinite-replaced brucite nodules (averaging 1 mm in diameter) in calcite. York River tactite zone (GSC 201836-J).**

of brucite. Brugnatellite is associated with serpentine, brucite, aragonite and hydromagnesite.

Monticellite ($CaMgSiO_4$) occurs as colorless and yellowish to greenish gray, transparent, anhedral grains in sugary white calcite. The grains average 1 mm in diameter. They are associated with clinopyroxene, serpentine, mica and blue calcite.

Tochilinite occurs as a partial replacement of serpentine and brucite nodules in sugary white calcite. These nodules measure 1 to 2 mm in diameter and form bands in the calcite, the nodules having a gray to charcoal-gray color due to the presence of tochilinite. As the degree of replacement increases, the color darkens to black and the nodules assume a greasy luster. Tochilinite also occurs as greasy black streaks, irregular patches and veinlets in calcite and as coatings on serpentine. Associated minerals include olivine, perovskite, clinohumite, spinel, hydromagnesite, apatite, mica, graphite and pyrrhotite; they occur as disseminated grains in the calcite.

Ludwigite ($Mg_2Fe^{+3}BO_5$) occurs sparingly as dull to submetallic black, longitudinally striated prisms measuring up to 2 mm long. It is associated with brucite, clinohumite, spinel and magnetite in white cleavable calcite. The brucite nodules are dark gray to black due to partial replacement by magnetite.

The York River tactite zone is located 320 m (0.2 mile) north of Highway 500 at a point 11.1 km (6.9 miles) east of Bancroft.

ACKNOWLEDGEMENTS

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Hodgkinsonite from Franklin and Sterling Hill New Jersey: a Review

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INTRODUCTION

Hodgkinsonite, a zinc manganese hydroxyl silicate, was originally described by Palache and Schaller (1913) who obtained the mineral from J. J. McGovern of Franklin, New Jersey. They named it hodgkinsonite in honor of H. H. Hodgkinson who found the mineral and who was the assistant underground superintendent of the Franklin mine. According to Hodgkinson, the mineral was found in the "northern part of the orebody, in that part of the Parker mine formerly known as the Hamburg mine and quite near the hanging wall of the west leg of the orebody, between the 850 and 900-foot levels." It has subsequently been found in other parts of the Franklin mine and also, as noted by Cook (1973), in the Sterling Hill mine. The number of specimens is sufficiently large to permit the presence of hodgkinsonite in most major and many smaller mineral collections. Although the mineral occurs at Sterling Hill, the reddish microcrystals on seams in ore do not compare with the beautiful pink seams, veins and euhedral crystals found in the Franklin mine.

PHYSICAL and OPTICAL PROPERTIES

Hodgkinsonite is characteristically reddish pink, pink, or violet-pink. Some samples appear black due to the inclusion of finely divided franklinite or euhedral franklinite within hodgkinsonite. Transparent hodgkinsonite which overlies franklinite might appear black due to the underlying black franklinite. Although rare, some samples may have a dull, blackish tarnish, presumably due to secondary formation of manganese oxides, which are unevenly distributed on such specimens. Hodgkinsonite with a light orange color is known from Franklin; the color is due to finely divided zincite, visible only with magnification. Orange material is also known from Sterling Hill, but the cause of the coloration is unknown.

The density, determined with a Berman balance by Graeber and Rosenzweig (1963) is 4.06–4.08 g/cm^3, in excellent agreement with the calculated value of 4.07 g/cm^3. Optical data were given by Palache (1935) and Roberts and Quodling (1962) and are in excellent agreement with each other and with values predicted from the Gladstone-Dale relationship (Mandarino, 1976, 1979). Hodgkinsonite is fluorescent in longwave ultraviolet light. This fluorescence, of a dull, weak, pinkish red color, was first noted by Bernard Kozykowski in 1971 and has been subsequently confirmed by the authors on chemically analyzed specimens. The fluorescence is quite weak and thus easily masked if there are brightly fluorescent phases (like willemite) in contact. Fluorescence of Sterling Hill hodgkinsonite is extremely difficult to detect due to the common association with strongly fluorescing willemite, and to the small crystal size.

Hodgkinsonite could be confused with rhodonite and leucophoenicite or humites at Franklin or Sterling Hill. The three cleavages of rhodonite usually serve to distinguish it from hodgkinsonite, which has one perfect cleavage. The absence of prominent cleavage in leucophoenicite is likewise useful in identification. For samples without crystals large enough for cleavage observations, the previously mentioned fluorescence is useful inasmuch as rhodonite and leucophoenicite do not fluoresce. Hodgkinsonite is more readily soluble in acids than is leucophoenicite; a 1.0 mm^3 chip will dissolve in 1:1 HCl within 20 minutes, while leucophoenicite takes much longer to dissolve.

CHEMISTRY

The samples studied were analyzed with an ARL-SEMQ electron microprobe using an operating voltage of 15 kV and a sample current of 0.015 μA. The standards were: synthetic ZnO (Zn), manganite (Mn), and hornblende (Fe, Mg, Ca, Si). The data were corrected using standard Bence-Albee factors. The analyses are presented in Table 1, together with the three previously published analyses. An examination of the data confirms the accuracy of the older analyses and, in addition, indicates that hodgkinsonite is a mineral with very limited solid solution among the octahedral cations. This is uncommon for a mineral from the Franklin/Sterling

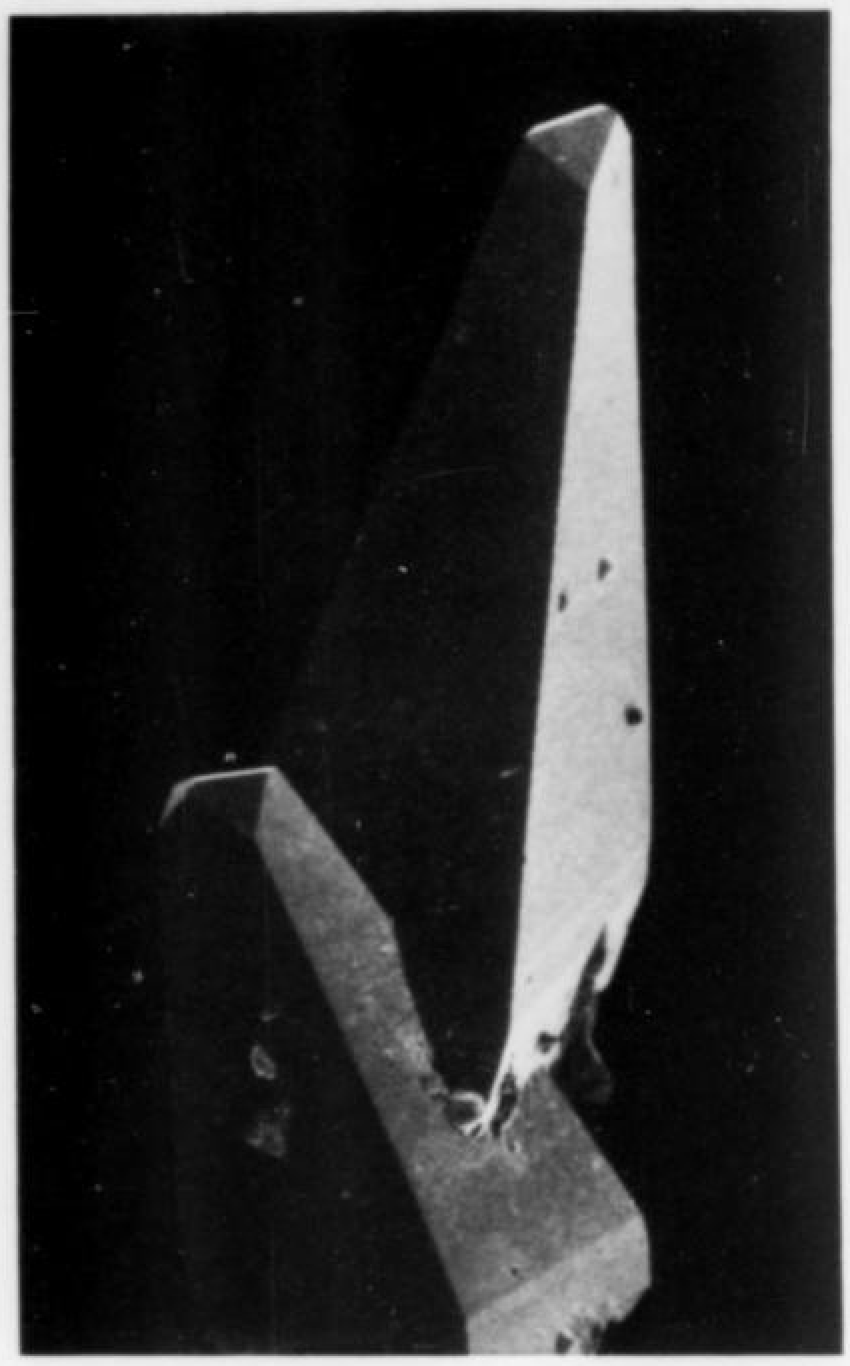

Figure 1. **Prismatic crystals of hodgkinsonite from Franklin, New Jersey. (SEM photo at 52x.)**

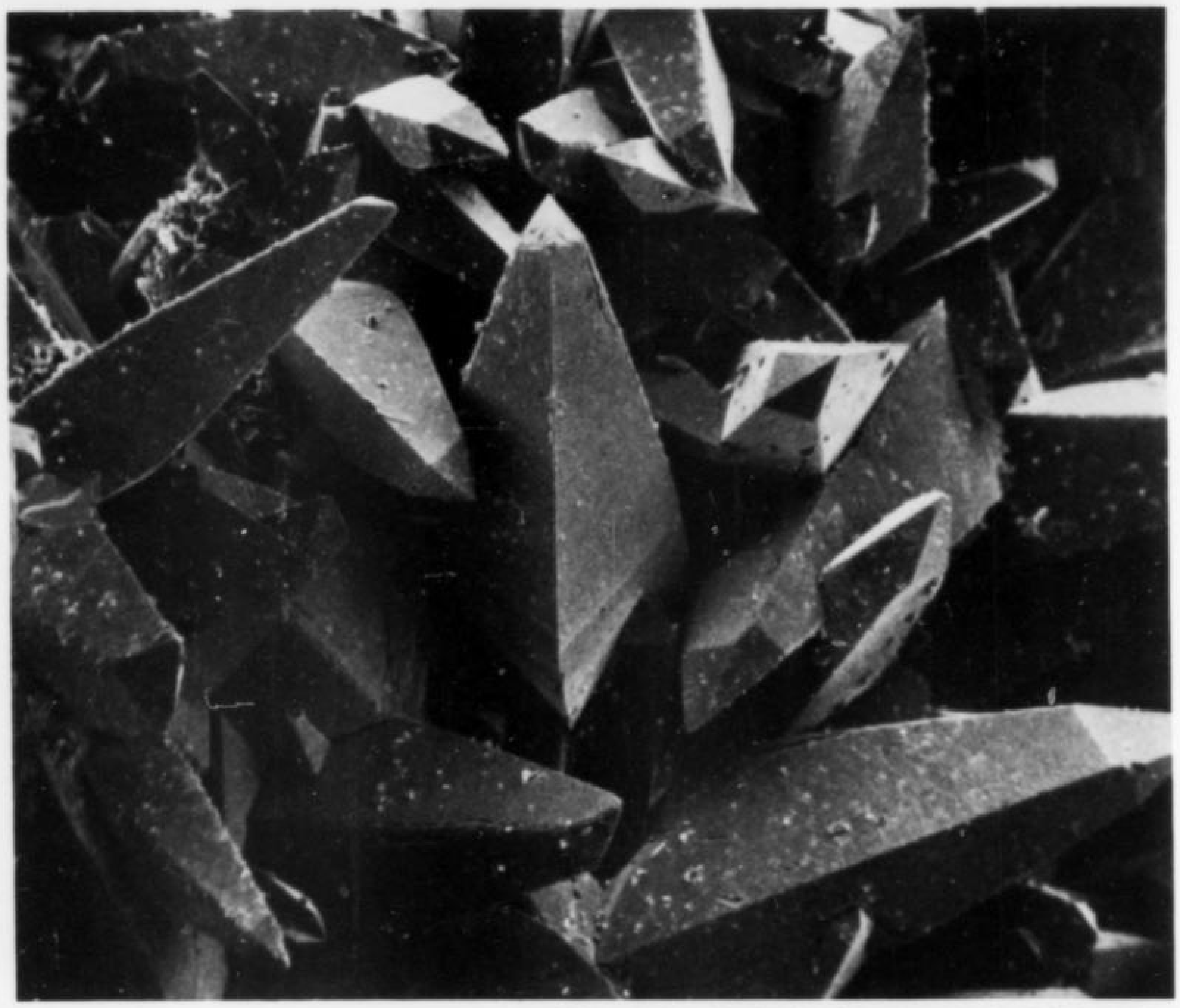

Figure 2. **Typical cluster of hodgkinsonite crystals from Franklin, New Jersey. (SEM photo at 123x.)**

Hill orebodies where solid solution is relatively common in many of the minerals. Hodgkinsonite is chemically homogeneous in all samples analyzed. There was no observable correlation between the detectable elements and the slight violet-pink color of some samples, but *very* light pink, opaque hodgkinsonite did have up to 1.4 weight percent CaO. The data are in excellent agreement with the formula for hodgkinsonite, $Zn_2Mn(SiO_4)(OH)_2$.

X-RAY CRYSTALLOGRAPHY

The unit cell and space group of hodgkinsonite were determined by Rentzeperis (1958) and he subsequently solved the crystal structure with $R = 0.067$ (Rentzeperis, 1963). Additional work by Solov'eva and Belov (1963a) confirmed the findings of Rentzeperis, but they later published another interpretation of the structure (Solov'eva and Belov, 1963b). In an earlier paper, Roberts and Quodling (1962) had suggested an interchanging of the *a* and *c* axes, but this interpretation was rejected by Rentzeperis (1963) who provided the unit cell parameters $a = 8.171$, $b = 5.316$, $c = 11.761$ Å, $\beta = 95°15'$, $P2_1/a$, Z = 4. The X-ray powder diffraction data of Roberts and Quodling (1962) (JCPDS #15-280) are reasonably accurate except for a reflection at ≈11.8 Å observed on every hodgkinsonite specimen we examined. Although not widely disseminated, the powder data provided by Graeber and Rosenzweig (1963) are excellent and include a reflection at 11.82 Å. Because these data have not been published in the mineralogic literature, they are included here in Table 2.

Table 1. **Chemical analyses of hodgkinsonite.**

Locality	SiO_2	FeO	MgO	CaO	MnO	ZnO	H_2O	Total	Sample #
Franklin	19.86		0.04	0.93	20.68	52.93	5.77	100.21	***
Franklin	19.00		1.02	0.60	21.82	51.66	5.98	100.08	****
Franklin	19.14	0.77	0.52	0.60	22.70	50.45	5.40	99.58	****
Franklin	19.7	0.2	0.4	0.1	23.3	49.9	6.4*	100.0	C3191
Franklin	20.2	0.2	0.3	0.2	23.1	50.5	5.5*	100.0	138667
Franklin	20.3	0.2	0.4	0.5	22.7	51.1	4.8*	100.0	R6440-5
Franklin	19.7	0.2	0.5	0.6	22.3	49.9	6.8*	100.0	C6384
Franklin	19.7	0.2	0.4	0.1	23.2	49.9	5.76**	99.3	C6248
Sterling	18.9	0.2	1.0	0.4	21.0	52.8	5.7*	100.0	143054
Franklin	18.9	0.3	0.1	0.3	22.9	51.1	6.4*	100.0	R6440-3
Franklin	19.1	0.2	0.1	0.4	22.9	52.1	5.2*	100.0	R6440-3
	19.6	0.2	0.4	0.3	22.7	50.9	5.76**	99.9	Average/8
Theory	19.28				22.75	52.19	5.78	100.00	Theory †

* H_2O by difference.
** H_2O by the Penfield method.
*** Analysis by Schaller *in* Palache and Schaller (1913); (average of 3).
**** Analyses by Jenkins and Bauer *in* Palache (1935).
† Theoretical composition for $Zn_2Mn(SiO_4)(OH)_2$.
Accuracy of data: ± 3 percent of the amount present.

Table 2. **X-ray powder diffraction data for hodgkinsonite (from Graeber and Rosenzweig, 1963).**

d(obs.)	I (obs.)	*d*(calc.)	*hkl*	*d*(obs.)	I (obs.)	*d*(calc.)	*hkl*
11.82	54	11.71	100	1.755	12	1.755	611
5.88	1	5.86	200	1.729	1	1.729	$61\bar{2}$
4.86	2	4.84	110	1.694	1	1.694	521
4.46	2	4.45	011	1.657	10	1.657	$52\bar{2}$
4.25	1	4.24	$11\bar{1}$	1.615	1	1.614	$50\bar{4}$
4.11	7	4.09	111	1.602	13	1.602	$70\bar{2}$
3.94	35	3.937	210	1.588	1		
3.75	38	3.739	102	1.573	1		
3.64	38	3.636	$21\bar{1}$	1.550	27		
3.41	32	3.398	301	1.527	1		
3.24	45	3.233	012	1.497	2		
3.15	7	3.147	310	1.479	3		
3.07	15	3.059	112	1.470	3		
3.02	35	3.014	$31\bar{1}$	1.443	1		
2.965	81	2.961	$30\bar{2}$	1.429	16		
2.869	100	2.863	311	1.412	20		
2.749	22	2.745	212	1.371	1		
2.699	7	2.694	302	1.363	1		
2.663	24	2.659	020	1.357	2		
2.595	25	2.593	120	1.337	1		
2.567	20	2.565	410	1.306	6		
2.486	23	2.486	$12\bar{1}$	1.288	1		
2.411	28	2.409	$11\bar{3}$	1.267	1		
2.332	35	2.335	$30\bar{3}$	1.245	2		
2.299	15	2.296	221	1.212	1		
2.257	2	2.256	$41\bar{2}$	1.194	1		
2.226	1	2.227	022	1.128	5		
2.166	9	2.167	122	1.097	1		
2.118	28	2.118	$22\bar{2}$	1.090	1		
2.039	7	2.039	$10\bar{4}$	1.065	13		
1.979	3	1.979	$32\bar{2}$	1.051	1		
1.952	9	1.952	502	1.046	2		
1.901	10	1.900	023	1.038	4		
1.852	13	1.852	114	1.029	1		
1.792	1	1.792	413	1.021	1		
1.773	9	1.773	223	1.000	2		

Hodgkinsonite, $a = 11.764$, $b = 5.318$, $c = 8.182$ Å; $\beta = 95°25'$.

MORPHOLOGY

The crystal morphology of hodgkinsonite was initially described by Palache and Schaller (1913) and further modified by Palache (1914). In his classic treatise of the Franklin and Sterling Hill deposits, Palache (1935) added new data on uncommon crystal habits and summarized the older literature. The morphological description of Palache is so complete as to need no amplification here. An interesting study by Hardie *et al.* (1964) compared the theoretical and observed forms and their frequency of occurrence, using the data of Palache.

Most hodgkinsonite crystals are prismatic in habit and euhedral. A typical crystal from the Franklin mine is shown in Figure 1. The majority of hodgkinsonite crystals are elongated on *c* with an elongation ratio of approximately 4:1. Hodgkinsonite crystals vary in size from microscopic to about 20 mm, but most well-formed crystals do not exceed 5 mm in length. Twinning was not observed on the specimens examined, nor were epitaxial relationships, etch figures, or selective encrustation or coloration on different forms. A typical cluster of Franklin hodgkinsonite is shown in Figure 2.

OCCURRENCE

Hodgkinsonite is known from both Franklin and Sterling Hill, but the preponderance of material in systematic collections is from the Franklin deposit, which has produced the most spectacular specimens. Several parageneses were noted by Palache (1935) and need not be redescribed here.

At Franklin, in general, specimens with euhedral crystals are usually formed on rich ore composed of franklinite and willemite and notable for its paucity of calcite. The best known assemblage is that of slightly violet hodgkinsonite associated with a boxwork of white, bladed barite and white barrel-shaped calcite crystals (Fig. 3). In most such specimens, hodgkinsonite follows willemite and barite in the deposition sequence and is, in turn, followed by additional franklinite and in some instances, carbonates. Specimens consisting of massive hodgkinsonite are sometimes associated with willemite, franklinite, barite, zincite, pyrochroite and calcite. Some less common associated minerals include sussexite, chlorite, hetaerolite, serpentine, tephroite, andradite, clinohedrite, cahnite, esperite, pyrobelonite, larsenite and adelite. The last seven associations are relatively uncommon.

One Franklin assemblage is deserving of special mention because it is markedly different in appearance, being fibrous and cherty in habit. These samples, few in number, consist of pink masses with a

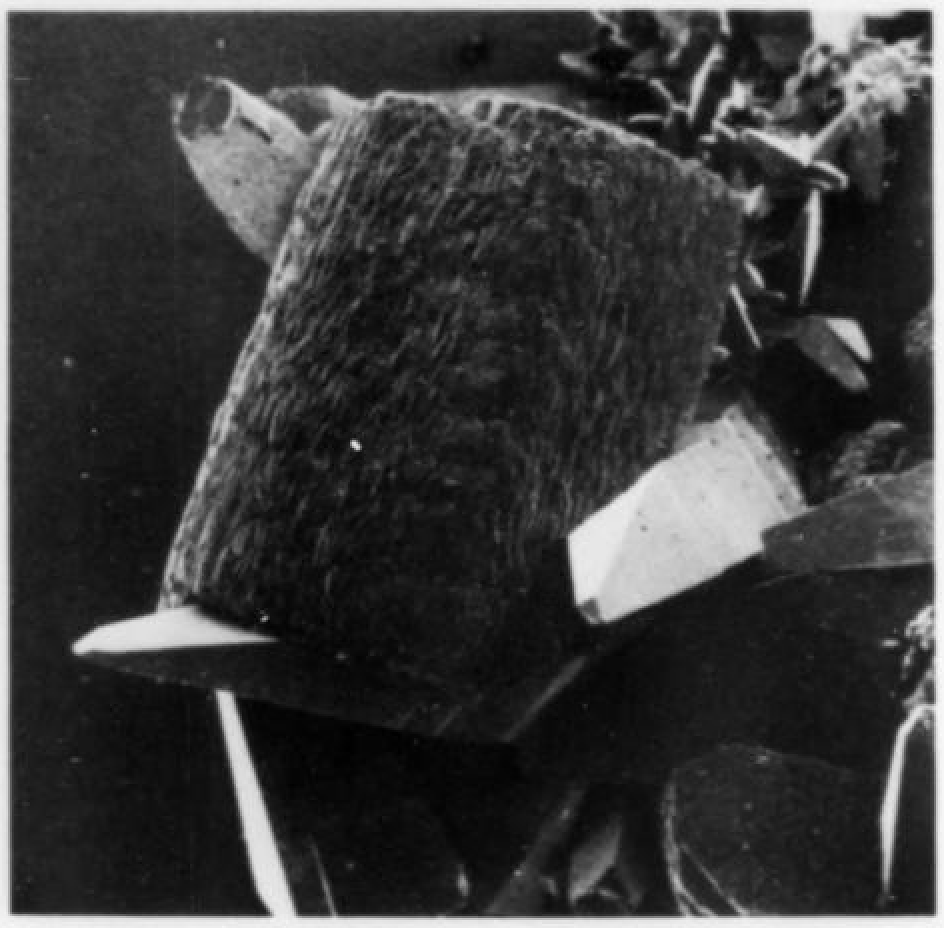

Figure 3. **Hodgkinsonite with barrel-shaped large calcite crystal, from Franklin, New Jersey. (SEM photo at 18x.)**

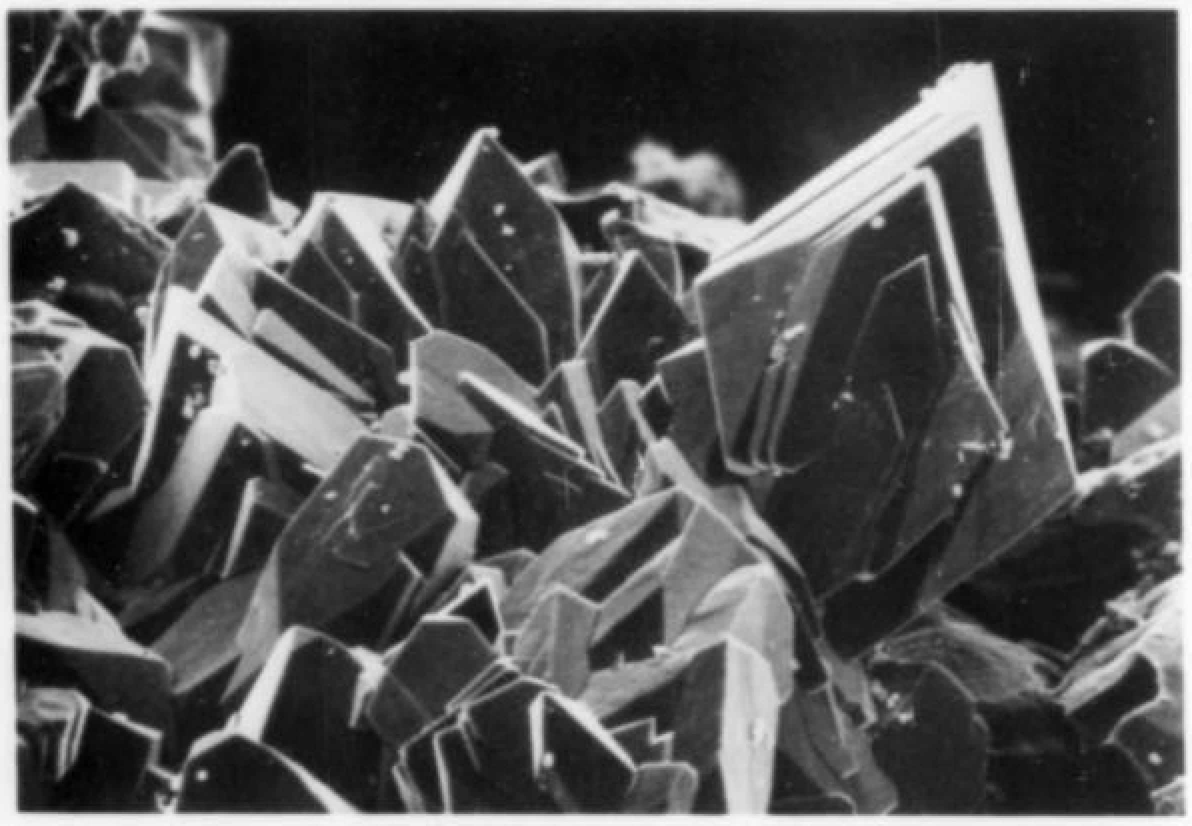

Figure 4. **Hodgkinsonite druse from Sterling Hill, New Jersey. (SEM photo at 285x.)**

peculiar dull luster. The apparent fibrosity is due, in large part, to included sussexite which is intimately associated with the hodgkinsonite, the two minerals intergrown in a sub-parallel arrangement. The assemblage was apparently known to Palache, but was considered by him (1935, p. 127) as a peculiar form of sussexite. He noted that its composition was different from that of type sussexite in having much less magnesium and more manganese than the type sussexite. We have recalculated Bauer's analysis of this material (#4 of Palache (1935), p. 127) and have calculated the Zn and Si, together with part of the Mn and H in stoichiometric quantities, as hodgkinsonite. The remaining proportions are in excellent agreement with sussexite, confirming that what Palache studied is what we are here describing. We note the presence of minor calcite in the assemblage and presume that calcite may account for part of the reported 1.94 weight percent CaO, the remainder easily being accommodated by sussexite or hodgkinsonite. The fluorescence of hodgkinsonite, absent in pure sussexite, allows easy recognition of this most uncommon assemblage.

At Sterling Hill, hodgkinsonite is frequently associated with hetaerolite, chlorophoenicite and zincite, on ores of varying degrees of richness. In addition, hodgkinsonite is also found associated with a number of rare arsenates in assemblages of which few specimens are known, indicating it can exist over widely varying geochemical conditions. Cook (1973) initially noted Sterling Hill hodgkinsonite as a pinkish brown botryoidal coating and as very small reddish brown microcystals. Most Sterling Hill hodgkinsonite occurs as druses of microcrystals in which the recognition of individual forms is nearly impossible. Well-formed crystals, such as are shown in Figure 4, are quite uncommon at Sterling Hill.

Of all the species considered unique to the Franklin area, hodgkinsonite esthetically is the most notable. Its intense color and the clarity and brilliance of its crystals rank it among the more appealing and distinctive of the world's rare minerals.

Hodgkinsonite remains a mineral unique to Franklin and Sterling Hill and is reflective of the Mn-Zn-Si-O mineralogy of the deposits.

ACKNOWLEDGMENTS

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Mercury Amidonitrate crystals from colorado

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Crystalline compounds containing organic ions or molecules are normally confined to chemical laboratories and industrial manufacturing plants. From time to time, however, such compounds are discovered in the natural environment, where they have been produced, directly or indirectly, by the metabolic processes of plants and animals or by industrial activity, particularly mining and smelting. Some recently reported examples are acetamide, CH_3CONH_2, from a coal mine in the Lvov-Volynskiy Basin of the Ukraine (Srebrodolskiy, 1975); abelsonite, $C_{31}H_{32}N_4Ni$, which is a nickel porphyrin from the Utah oil shales (Milton *et al.*, 1978); and copper acetate hydrate, $Cu(CH_3COO)_2 \cdot H_2O$, from Southwest Africa (Dunn, 1981), an occurrence which may be a man-made artifact. We wish to report a possible new addition to this group of naturally occurring substances, which owe their existence, at least in part, to non-geological agencies. This is mercury (II) amidonitrate, $HgNH_2NO_3$, from Pitkin County, Colorado. Since its provenance and mode of formation are still somewhat obscure, it seems inadvisable to define this compound as a new mineral species. However, since additional examples may eventually come to light at other localities, collectors should be informed of its existence and how it may be recognized.

Our specimens of mercury amidonitrate were sent to us in 1977 by a collector, Robert Lewandowski of Toledo, Ohio. Mr. Lewandowski had discovered them occurring loose in the matrix of a specimen from a locality described only as the 600-foot level of an abandoned mine in Pitkin County, Colorado. Preliminary examination established that the crystals were intimately associated with silver and a light blue mineral similar to likasite, $Cu_{12}(NO_3)_4(PO_4)_2(OH)_{14}$. The crystals, which at that point were still not identified, are translucent euhedra, pale yellowish gray in color and up to several millimeters in size. Combinations of the octahedron and dodecahedron were observed with the former being predominant (Fig. 1). The crystals are intergrown in a complex fashion but are not twinned. There is no cleavage, but some specimens exhibit a radial texture on fracture surfaces. The measured and calculated densities are 5.03 and 5.15 g/cm³, respectively. The hardness (Mohs) is 2½ to 3 and the luster is adamantine.

Application of the standard powder X-ray diffraction and electron microanalytical techniques failed to identify the crystals with any known mineral. A wet-chemical analysis proved them to be a nitromercury compound containing 72 weight percent mercury plus nitrogen in two valence states, +5 and −3. Further study by

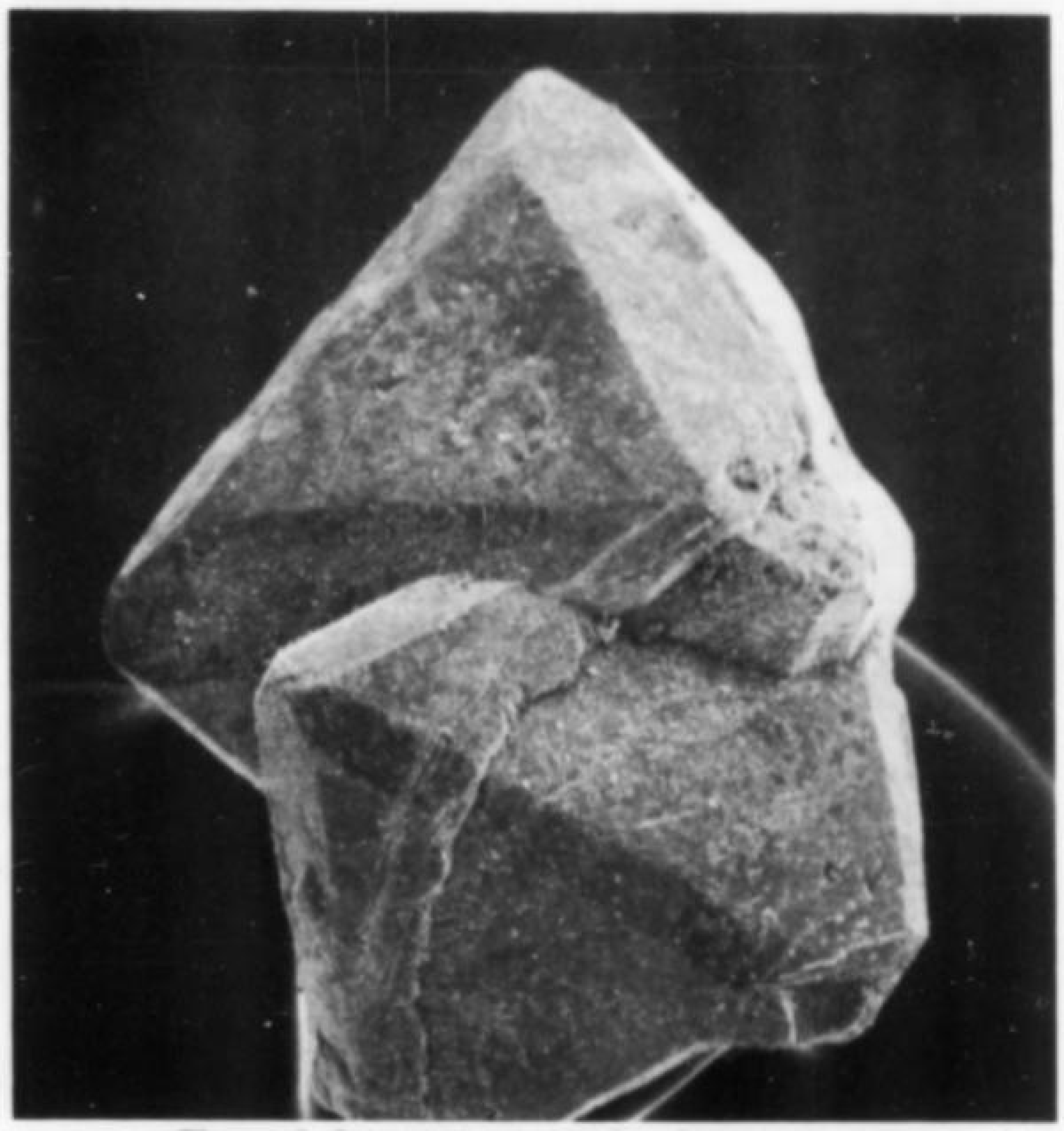

Figure 1. **Intergrown crystals of mercury amidonitrate showing combinations of the octahedron and dodecahedron. (30x.)**

powder and single-crystal diffraction methods finally established the identity of the compound with synthetic $HgNH_2NO_3$ (Hayek and Inama, 1965), which contains N^{+5} and N^{-3} consistent with the chemical analysis of the Colorado material. The symmetry is cubic, space group $P4_132$ or $P4_332$, with a = 10.254 Å. A crystal structure analysis has also been performed, the results of which are reported in Randall *et al.* (1982).

Although its close association with silver and a likasite-like mineral might be considered evidence for a natural origin for mercury amidonitrate, a better case can be made for its formation from the decomposition products of leftover mining explosives. In particular, cellulose nitrate, $[C_6H_7O_5(NO_3)_3]_n$, which is used in dynamite, and mercury fulminate, $Hg(CNO)_2$, which was used in older dynamite caps, are together capable of providing all of the chemical constituents needed to form $HgNH_2NO_3$ (R. W. Thomssen, personal communication). The lack of more exact information about the locality and chemical conditions where mercury amidonitrate occurs precludes further speculation about its genesis. The remaining crystals are preserved in the Smithsonian Institution under catalogue number NMNH 136810.

There are only a few minerals with which $HgNH_2NO_3$ might be confused, once the presence of mercury in significant quantity has been ascertained by a qualitative chemical test. Calomel (Hg_2Cl_2) is easily distinguished by its sectility and lesser hardness, 1½ compared to 2½ to 3 for mercury amidonitrate. Eglestonite ($Hg_6Cl_3O_2H$), terlinguaite (Hg_2ClO), kleinite ($Hg_2N(Cl,SO_4)\cdot nH_2O$), mosesite ($Hg_2N(SO_4,MoO_4,Cl)\cdot H_2O$, and schuetteite ($Hg_3O_2SO_4$) can all be eliminated from consideration by virtue of their much higher densities, 7.7 g/cm³ or greater, compared to 5.1 g/cm³ for mercury amidonitrate. In addition, the crystal habits of terlinguaite (monoclinic prismatic), kleinite (hexagonal prismatic), and schuetteite (hexagonal tabular) are quite different from that shown in Figure 1.

An unequivocal identification can also be made by powder X-ray diffraction. The strongest diffraction lines are 2.953 (100) 222; 7.24 (80) 011; 5.92 (80) 111; 3.412 (60) 122; 2.741 (60) 123; 2.562 (60) 004; and 2.487 (60) 223,014. In the preceding the first number is the d-value in Å, followed by the relative intensity in parentheses and the reflection index. Comprehensive sets of powder diffraction data for both Colorado crystals and synthetic mercury amidonitrate are given by Randall *et al.* (1982).

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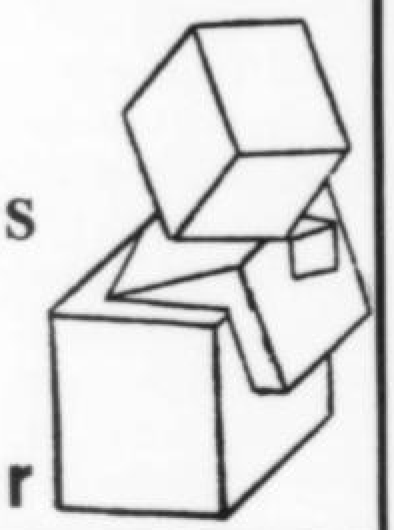

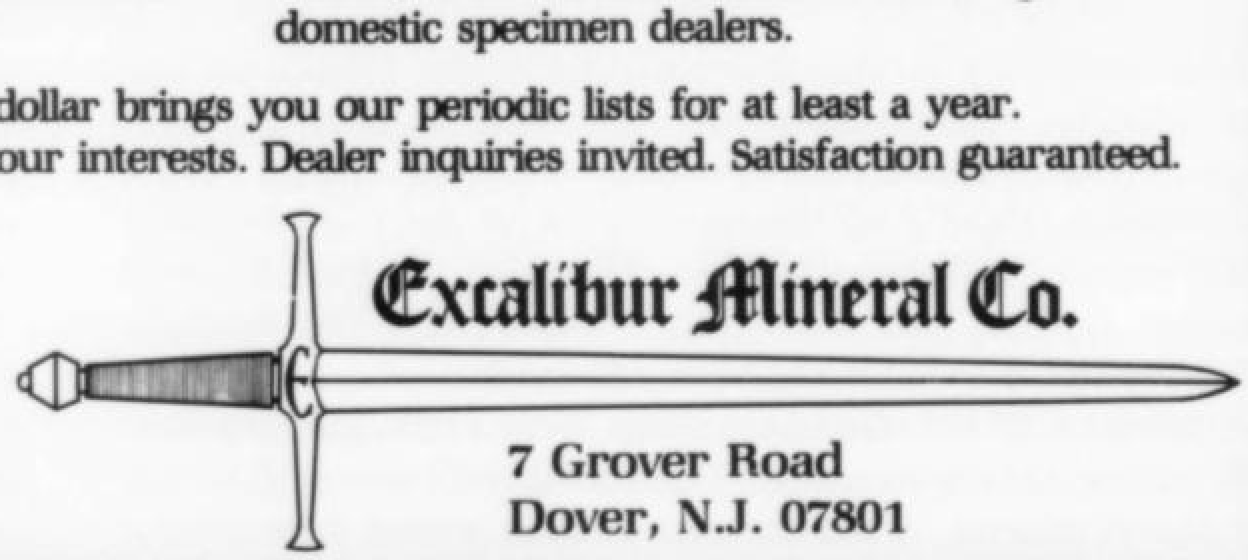

Jeanbandyite

a new member of the stottite group from Llallagua, Bolivia

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INTRODUCTION

In 1977 the extensive mineral collection assembled by Dr. Mark Chance Bandy (Jones, 1973; Bandy, 1978) was donated to the Natural History Museum of Los Angeles County by his widow, Jean. The collection includes many fine specimens from worldwide sources, but it is most noteworthy for its remarkable representation of Bolivian minerals.

Between 1936 and 1944, Dr. Bandy was employed by the Patino Company at Huanuni and Llallagua, Bolivia. During this period, he wrote *Mineralogy of Llallagua* for the Patino Company, published in 1944 and reprinted by the Tucson Gem and Mineral Society in 1976 (now available through the LACMNH). His instincts as a mineralogist and mineral collector led him to preserve many specimens of mineralogical interest. Among these were the beautiful colorless, transparent apatite crystals from Llallagua in which he took special delight. It is on these specimens that the new mineral described herein is found. One such specimen bears the label "whatzit," a term which Bandy coined to designate minerals which he could not identify and which he felt required further study.

In light of its occurrence on Mark Bandy's "favorite" specimens, it seems particularly appropriate to name the new mineral, jeanbandyite, in honor of Mrs. Jean Bandy of Wickenburg, Arizona, a charming and gracious lady who was Mark's wife, companion and confidant for 34 years. She joined him in his worldwide travels and was clearly a source of great comfort to him. After Mark's death in 1963, Jean carefully preserved their collection until her decision to donate it to the Los Angeles County Museum in 1977. (Ed. note: *Bandylite*, a hydrated borate-chloride of copper from Chile, was named for Mark C. Bandy in 1938 by Palache and Foshag.)

The name and description have been approved by the Commission on New Minerals and Mineral Names, I.M.A. Type specimens have been deposited at the Smithsonian Institution (NMNH 149348), Harvard Mineralogical Museum (HMM 119125) and the Los Angeles County Museum of Natural History (LACMNH 18309).

OCCURRENCE

Jeanbandyite has been identified on about three dozen specimens from Llallagua, Bolivia, in the Los Angeles County Museum's "Bandy Collection." On most of these specimens the most prominent mineral is fluorapatite as colorless, tabular to blocky crystals to 5 cm. The matrix is massive stannite, with well-formed crystals to 2 mm lining pockets. Other pocket minerals include pyrite, jamesonite, cassiterite, quartz and crandallite. These specimens were collected from large vugs on and above level 295 of the Contacto vein (Bandy, 1944). Jeanbandyite has been confirmed on similar apatite specimens from Llallagua, Bolivia, in other collections. Most such specimens were probably originally collected by Bandy and others from this same area in the mine.

A few specimens from elsewhere in the mine have also yielded jeanbandyite. On level 250 of the Contacto vein and level 295 of the Contacto-Dolores vein it occurs with fluorapatite, stannite and cassiterite. Twelve meters above level 411 of the Bismark vein it occurs with wolframite, bismuthinite, stannite and pyrite. Twenty meters above level 160 of the Plata vein it occurs with franckeite, stannite and pyrite.

In every case jeanbandyite appears as a late phase in pockets, either growing on or in close proximity to stannite.

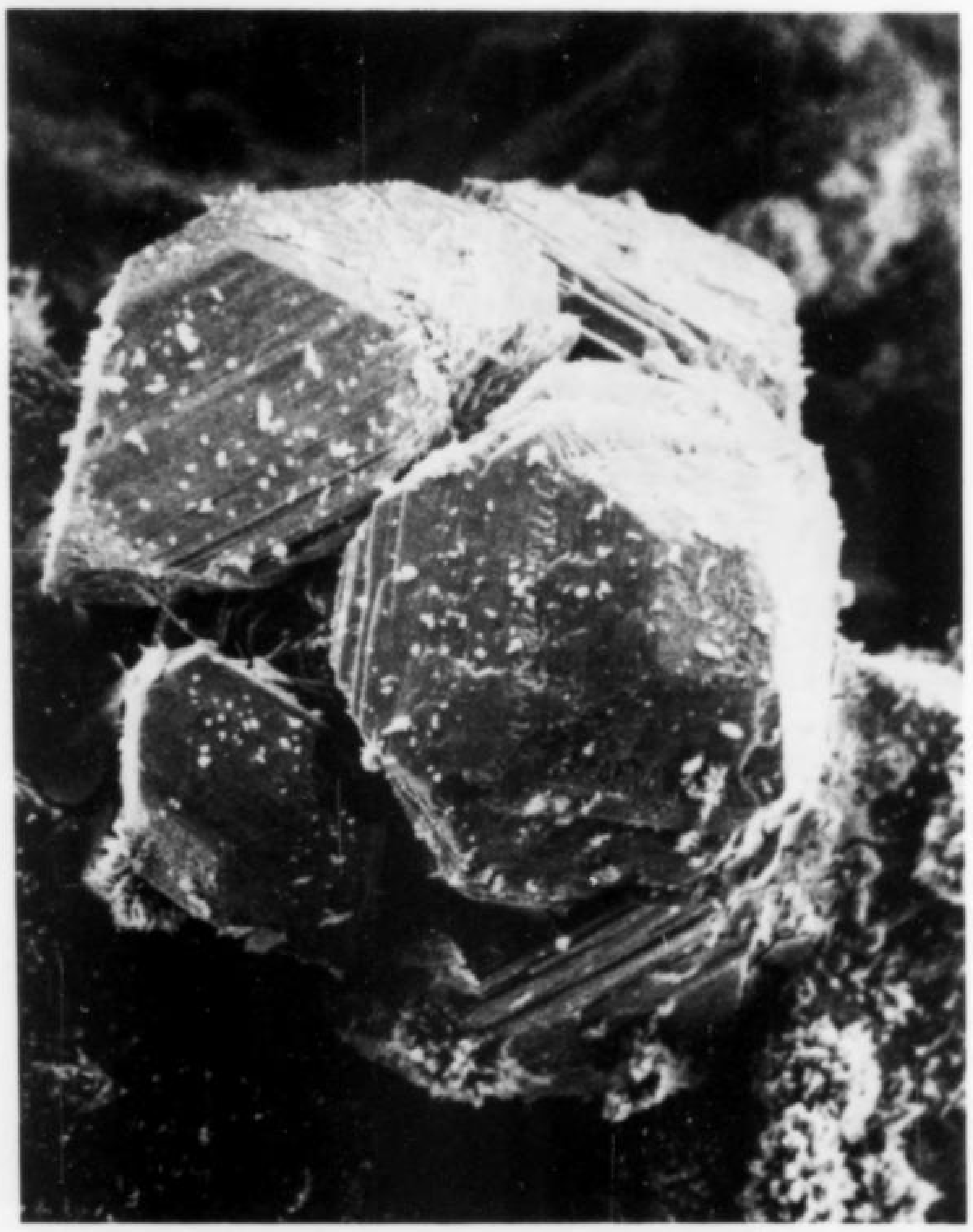
MORPHOLOGY

Jeanbandyite occurs in crudely pseudo-octahedral aggregates generally not exceeding 0.2 mm in maximum dimension. Close examination shows these aggregates to consist of pyramidal tetragonal (pseudo-cuboctahedral) crystals of jeanbandyite in epitactic growth upon the vertices of octahedral crystals of wickmanite with which it is isotypic.

In most cases, jeanbandyite crystals were observed to completely envelope their wickmanite hosts, giving the appearance of crystals twinned about [111] (Fig. 1). The epitactic relationship is clearly indicated, however, by clusters in which the wickmanite is still visible and the individual jeanbandyite crystals are seen perched upon its vertices (Fig. 2).

Figure 1. **Typical pseudo-octahedral aggregate of jeanbandyite crystals (SEM photomicrograph at 350x).**

Figure 2. **Unequally developed jeanbandyite crystals with underlying wickmanite octahedron partially visible (SEM photomicrograph at 350x).**



The optical orientation of the jeanbandyite crystals in the clusters (Fig. 3) indicates that their *c*-axes radiate from the centers of the clusters. Optical examination gave no indication of twinning in the individual crystals.

The only forms observed on jeanbandyite crystals are the pyramid {111}, pinacoid {001} and prism {100}. The pinacoid and especially the prism faces generally appear rough. The pyramid faces are invariably striated parallel to [100], notably consistent with tetragonal rather than cubic symmetry.

PHYSICAL PROPERTIES

Jeanbandyite is brown-orange in color with a pale brown-yellow (buff) streak. Its luster is vitreous to subadamantine. The estimated Mohs' hardness is 3½. Fair cleavage was detected parallel to the pinacoid {001} and prism {100} faces. The mineral is slowly soluble in cold 1:1 HCl.

Individual jeanbandyite fragments were carefully split from their wickmanite hosts for specific gravity determination by sink-float in Clerici solution. This method yielded a specific gravity of 3.81(5).

OPTICAL PROPERTIES

Jeanbandyite is light orange-brown in transmitted light and exhibits no discernible pleochroism. It is optically uniaxial negative, but yields an indistinct optic-axis interference figure. Indices of refraction for all measured crystals from Llallagua fell in the range 1.82–1.85. All exhibited a very low birefringence of approximately 0.004. A representative sample, from level 295 of the Contacto vein, yielded ϵ = 1.833(5) and ω = 1.837(5). No regular variation in index of refraction with chemistry was noted. Within crystals, indices of refraction remained constant or increased slightly toward the crystal peripheries.

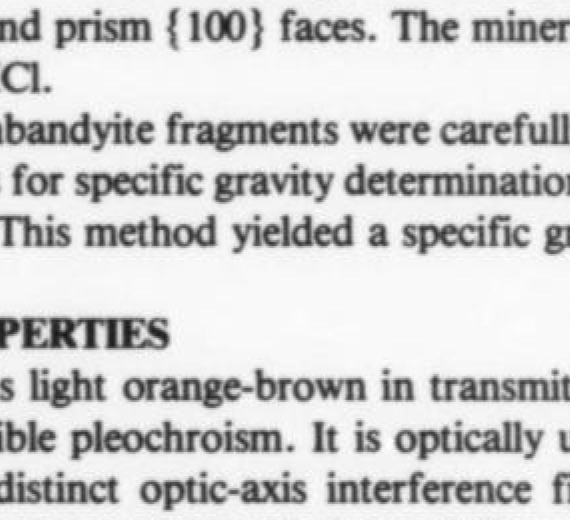


Figure 3. **Diagram showing the optical orientation of jeanbandyite crystals in the clusters.**

The host wickmanite crystals are very pale yellow in transmitted light. They are isotropic and possess an index of refraction of 1.69–1.70.

Mandarino (1979) described the use of the Gladstone-Dale relationship to measure the compatibility of the index of refraction, density (specific gravity) and chemical composition by comparing the specific refractive energy calculated from the mean refractive index and density (K_P) with that calculated from the chemical composition (K_C). The quantity $1 - (K_P/K_C)$ calculated for jeanbandyite (mean refractive index = 1.835) is 0.035 which falls in the range defined by Mandarino as indicating excellent compatibility.

X-RAY CRYSTALLOGRAPHY

The X-ray powder diffraction pattern of jeanbandyite is entirely consistent with cubic symmetry. No splittings of lines typical of pseudocubic tetragonal symmetry were detected. Nevertheless, the evidence for tetragonal symmetry provided by morphology and optics is regarded as conclusive, and jeanbandyite must be considered pseudocubic. The powder diffraction data are listed in Table 1. Least squared refinement yielded $a = c = 7.648(7)$ Å.

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

I_{obs}	d_{obs}	d_{cal}	hkl	I_{obs}	d_{obs}	d_{cal}	hkl
20	4.41	4.42	111	<<5	1.471	1.47	511
100	3.83	3.82	200	5	1.352	1.352	440
70	2.71	2.70	220	<<5	1.292	1.293	531
5	2.422	2.419	310	15	1.275	1.275	600
10	2.308	2.306	311	10	1.210	1.209	620
15	2.205	2.208	222	10	1.154	1.153	622
<<5	2.039	2.044	321	<<5	1.060	1.061	640
20	1.912	1.912	400	15	1.021	1.022	642
5	1.752	1.755	331	<<5	0.9948	0.9957	553
60	1.710	1.710	420	15	0.9276	0.9275	644
35	1.562	1.561	422	15	0.9016	0.9013	660

114.6 mm Gandolfi camera, CuKα radiation, visually estimated intensities.

No significant difference in cell constants was detected on single-crystal precession photographs. Systematic extinctions were consistent with the cubic space groups, *Pn*3 and *Pn*3*m*, and the tetragonal space group, $P4_2/n$. The latter, naturally, was chosen.

In the light of the chemical data given below, unit-cell size and space group, jeanbandyite should be regarded as a tetragonal member of the stottite group.

If care is not exercised in the preparation of the jeanbandyite powder mount, contamination by the wickmanite core is likely, resulting in additional powder lines corresponding to wickmanite. The wickmanite pattern is generally much weaker and yields an approximate *a* cell constant of 7.81 Å.

CHEMISTRY

Jeanbandyite and wickmanite from the Contacto vein were analyzed by electron microprobe. Analyses of eight points over six jeanbandyite crystals and five points over four wickmanite crystals gave the averages and ranges listed in Table 2. Microchemical tests utilizing potassium ferrocyanide and potassium ferricyanide indicate virtually all iron in jeanbandyite to be in the ferric state. It is, therefore, calculated as Fe_2O_3 in the jeanbandyite analyses. Water was calculated by difference.

Chemistry was observed to change abruptly at jeanbandyite-wickmanite interfaces. No regions of intermediate Fe-Mn content were found. Within individual crystals variations of as much as a few percent in Fe_2O_3 and MnO were found, but no consistent spacial trends were noted. Variations in chemistry from crystal to crystal were no greater than variations within crystals. Qualitative analyses by energy dispersive X-ray were conducted on samples from elsewhere in the mine, but no significant differences in chemistry were indicated.

Based upon 6 OH, the empirical formulas of jeanbandyite and wickmanite can be expressed as $(Fe^{+3}_{0.71}Mn^{+2}_{0.21}Mg^{+2}_{0.04})$ $(Sn^{+4}_{0.84}Si^{+4}_{0.03})$ $(OH)_6$ and $(Mn^{+2}_{0.68}Mg^{+2}_{0.24}Fe^{+2}_{0.08})$ $(Sn^{+4}_{0.96}Si^{+4}_{0.04})(OH)_6$, respectively. The formula for jeanbandyite has a positive charge excess of 0.11 suggesting that a small portion of the iron may be ferrous. All iron in wickmanite is considered ferrous for charge balance.

The above formula for jeanbandyite requiring cation vacancies is preferred to one in which the charge balance would be maintained by substitution of O^{-2} for OH^- (i.e., $(Fe^{+3}_{0.77}Mn^{+2}_{0.23})$ $(Sn^{+4}_{0.92}Mg^{+2}_{0.04}Si^{+4}_{0.04})(OH_{5.32}O_{0.68})$) because it is much more compatible with the amount of H_2O calculated by difference and because it provides a calculated density of 3.81 gcm^{-3}, in exact agreement with the measured specific gravity. The formula based upon O^{-2} substitution provides a calculated density of 3.98 gcm^{-3}. The ideal formula for jeanbandyite, therefore, takes the somewhat unusual form: $Fe^{+3}_{1-x}Sn^{+4}_{1-y}(OH)_6$ or $(Fe^{+3}_{1-x}\square_x)(Sn^{+4}_{1-y}\square_y)(OH)_6$, where $3x + 4y = 1$ and $\square$ designates a vacancy.

Si was detected in small but significant amounts in all jeanbandyite and wickmanite samples tested. It has been tentatively assigned to the octahedral Sn^{+4} site, as was done by White and Nelen in tetrawickmanite. Si^{+4} in octahedral coordination is recognized as highly unusual and the amounts determined may in fact be due to sub-micron impurities. If the latter is the case, the conclusions drawn here would not be appreciably affected. (The calculated density would be less than one percent smaller.)

RELATED MINERALS

White and Nelen (1973) provided a survey of natural and synthetic members of the stottite group and included data on a mineral from Llallagua which probably corresponds to jeanbandyite. The "tiny brownish orange crude spherules (up to 0.1 mm)" gave powder data identical to that reported here and led them to the assumption that the mineral was cubic. Inexplicably, their "rough" microprobe analysis (converted to oxides), SnO_2 41.3, Fe_2O_3 29.2, MnO 1.8, CaO 14.1, MgO 0.8, differs significantly from that reported here. They did not report optics, but likened the material to unidentified crystals reported by Gordon (1944) from Llallagua.

Gordon described clusters with isotropic octahedral cores, slightly greenish-brown under the petrographic microscope and with an index of refraction of 1.745. Upon each of the octahedral edges, he observed epitactic overgrowths of anisotropic prismatic crystals with about the same index of refraction. The octahedral cores correspond most closely to natanite (see below). However, the overgrowths remain a mystery. They clearly differ from jeanbandyite in both morphology and refractive index.

Marshukova, Pavlovskiy and Sidorenko (1969) described cubic $FeSn(OH)_6$ from tin deposits in Middle Asia (Tian-Shan). This mineral has recently been approved by the Commission on New Minerals and Mineral Names under the name of natanite (Marshukova, Parlovskiy, Sidorenko and Chistjakova, 1980). It yields

Table 2. **Microprobe analyses of jeanbandyite and wickmanite.***

	JEANBANDYITE [1]	WICKMANITE [2]
MgO	0.61 (0.24– 1.27)	3.91 (3.68– 4.26)
SiO_2	0.79 (0.55– 0.94)	0.96 (0.74– 1.12
MnO	5.82 (4.04– 7.54)	19.02 (18.29–20.20)
Fe_2O_3 [3]	22.07 (19.22–24.71)	2.35 (1.78– 3.25)
SnO_2	49.61 (48.30–51.59)	53.50 (52.85–54.35)
H_2O [4]	21.10 (18.14–22.44)	20.26 (19.19–21.15)

[1] Average and range of eight analyses.
[2] Average and range of five analyses.
[3] Calculated as FeO for wickmanite.
[4] By difference.
*in weight percent

powder data nearly identical to jeanbandyite except $a = 7.69$ Å. Its color is greenish-brown, nearly colorless in thin-section, and it is isotropic with $n = 1.755$. The results of microprobe analyses were consistent with all iron being ferrous. The cell constant reported by Strunz and Contag (1960) for synthetic cubic $FeSn(OH)_6$ is 7.79 Å. The smaller cell determined for natanite is probably due to significant substitution of Cu^{+2} and Zn^{+2} for Fe^{+2}.

Natural $FeSn(OH)_6$ has also been reported to occur at Tsumeb, Namibia, by Geier and Ottemann (1970) and at a Malayan tin deposit by Grubb and Hannaford (1966). However, data reported in both works is sketchy and does not state whether the minerals are cubic or tetragonal or whether the iron is ferrous or ferric.

A single micromount specimen from Santa Eulalia, Chihuahua, Mexico, submitted by Richard Thomssen of Carson City, Nevada, exhibits red-brown octahedral crystals to 0.5 mm in association with pyrrhotite, quartz and siderite. Qualitative analysis by energy dispersive X-ray methods showed substantial tin and iron and minor manganese. The powder pattern suggested tetragonal symmetry; however, precession photographs indicated cubic symmetry. Observation of fragments in grain mounts under the polarizing microscope explained this ambiguity. Crystals were seen to consist of a nearly colorless, isotropic octahedron with $n = 1.728$ covered by an approximately 0.01 mm thick brownish-orange, weakly anisotropic coating with $n = 1.845$.

The powder pattern is, therefore, interpreted as a composite of two patterns, one cubic and one pseudocubic. The lower angle pattern is considerably more intense and clearly is produced by the central octahedron. It yields a cell constant $a = 7.79$ Å. The weaker pattern produced by the coating yields $a = 7.64$ Å. The observations above indicate that the crystals from Santa Eulalia are natanite coated by jeanbandyite.

Wickmanite has been reported previously from four localities: Långban, Sweden (Moore and Smith, 1967), Tvedalen, Norway (Åmli and Griffin, 1972), Pitkäranta, Karelia, USSR (Nefedov, Griffin and Kristiansen, 1977), and El Hamman, Central Morocco (Sonnet, 1981). Complete chemical and crystallographic data have been published for all but the El Hamman wickmanite. Llallagua wickmanite contains somewhat more MgO than Pitkäranta wickmanite (3.91 vs. 2.4 percent) and much more than Långban (0.5 percent) or Tvedalen (not detected) wickmanite. Of the four (excluding El Hamman) only Llallagua wickmanite has been found to contain SiO_2 (0.96 percent). The cell constant a of Llallagua wickmanite (7.81 Å) is significantly smaller than those of the other reported wickmanites and also smaller than that predicted by Nefedov, *et al.*, for a wickmanite with its Mn-Mg-Fe content (7.85 Å). This may be due, at least in part, to Si^{+4} substituting for Sn^{+4}.

DISCUSSION

A discrepancy between cell geometry and optics similar to that observed in jeanbandyite has been noted by Sonnet (1981) in the newly described stottite group mineral burtite, $CaSn(OH)_6$. X-ray single crystal study showed no deviation from cubic symmetry, while optics and morphology indicated trigonal symmetry. Sonnet attributed the optics to a simple trigonal distortion of the cubic cell and suggested that the apparent cubic symmetry observed in the X-ray study might be due to twinning. The same explanation does not seem applicable to the cubic-tetragonal inconsistency in jeanbandyite since twinning has not been detected in individual jeanbandyite crystals.

It is tempting to try to correlate the discrepancy between cell geometry and optics (and morphology) in jeanbandyite with the presence of ferric iron since both characteristics set this mineral apart from natanite as well as from the rest of the stottite group. The key to such a correlation may be the inferred presence of cation vacancies.

The vacancies could have resulted from growth under oxidizing conditions from solutions particularly rich in Fe^{+3} and Sn^{+4}. The initiation of growth upon the surfaces of wickmanite or natanite crystals could have induced tetragonal ordering of the vacancies and in so doing stabilized the jeanbandyite structure. Tetragonal ordering of vacancies could produce tetragonal optics and morphology without yielding a significant deviation from cubic cell geometry.

A detailed crystal structure analysis of jeanbandyite will be necessary to prove the existence of cation vacancies and to determine whether ordering is present. Previous structure studies on stottite (tetragonal) by Strunz and Giglio (1961) and on various synthetic cubic stottite group compounds by Strunz and Contag (1960) and Cohen-Addad (1968) utilized only powder data and are consequently in need of modern refinements before they will be useful in helping to decipher the jeanbandyite problem.

ACKNOWLEDGMENTS

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*Available through the Natural History Museum Bookshop, 900 Exposition Boulevard, Los Angeles, California 90007.

Microminerals

by **Bill Henderson**

Mineral Paragenesis at MONT ST. HILAIRE

This column is about my favorite collecting locality, the De-Mix and Poudrette quarries on Mont St. Hilaire. Located a few miles to the southeast of Montreal, in the Province of Quebec, the mountain is one of ten highly alkaline igneous bodies intruded into the flat-lying country rock of the area during Cretaceous time. The rocks to be found in the De-Mix and Poudrette quarries, where most of the collecting is done, are largely nepheline syenite and sodalite syenite.

As is true of similar rocks found in Greenland, Norway and Russia, those of Mont St. Hilaire afford a truly remarkable melange of extremely rare minerals, many of them new to science and large numbers of them in euhedral micro crystals of exquisite beauty. Approximately 160 mineral species have been identified from the two quarries at St. Hilaire, 9 of them new minerals. I have 116 of these species in my collection, while my good friend Marcelle Weber has 132, and the most satisfying thing is that most of these species are self-collected. True, Franklin, New Jersey, and Tsumeb, Namibia, afford more species, but it is impossible to acquire them without resort to the silver pick.

Another fascinating aspect of the minerals at St. Hilaire is the extreme variation within a species. I have, for instance, eight different types (distinct habits and/or associations) of epididymite, while Quintin Wight has described 16 types of rhodochrosite and Marcelle Weber 14 types of donnayite and 12 of apophyllite. On the other hand, the number of look-alikes (white, radiating, acicular crystals, for instance) is truly bewildering. Furthermore, St. Hilaire affords remarkably complex assemblages, all in the same small hand specimen. Where else could one find in a single micromount, all in euhedral crystals, leucosphenite / monteregianite / tetranatrolite / ramsayite / soda amphibole / ancylite / narsarsukite / feldspar or ancylite / epididymite / catapleiite / rhodochrosite / analcime / calcite / aegirine?

Many people who have not collected at St. Hilaire but have obtained specimens from there by exchange feel that it is possible to obtain a large number of the reported species in a single visit to the quarry. This is not the case. As quarrying operations expose one rock type or another, a few species only are available at a given time. Indeed, regular collectors at Mont St. Hilaire recognize this, and can date a specimen by the year when that type of material was available. Expressions such as, "Remember the first year of the green hole" are common. One trip may be a bonanza and the next one, except for the extremely diligent collectors, a bust. Even being at St. Hilaire at the right time is not enough. It takes a trained eye to spot the few square feet of promising matrix among thousands of tons of rubble. A small spot of pink or a patch of mottled green and black is the key to finding one suite of minerals or another.

This phenomenon of different mineral suites in different parageneses is one of the most interesting aspects of collecting at Mont St. Hilaire. In the remainder of this column I will be describing the different parageneses found there, and showing an example or two of interesting micro minerals from each type of occurrence. (Vi Anderson has shown some of these plus other species from St. Hilaire in a previous column in the *Mineralogical Record,* vol. 10, p. 103 (1979).) This treatment is by no means exhaustive; far more knowledgeable people than I will no doubt be writing about the minerals of Mont St. Hilaire in the future.

The Green Hole

In June of 1972 we encountered what I will call, for want of a more scientific name, the green hole. As its name states, it was exposed as a vertical hole or pipe in the quarry floor, the hole being just a bit wider than a man's shoulders. The walls and floor of the hole were covered with a wet, sticky mud, deep green in color, which could be worked like clay. The whole area was made even slimier by the gentle and intermittent rain which was falling. Experience had taught us not to pass up even the least promising material if it appears to be different, so we scooped handfuls of the green muck and loose chunks of rotted wall rock from the hole. In kneeling almost upside down to do so, we soon found that the mud had penetrated clothes and gloves to leave us stained a nearly permanent emerald-green. Every tool and container was likewise stained and, indeed, some are stained to this day. The results, however, made it worthwhile. Subsequent washing, sieving and rewashing of the material removed most of the green clayey material to leave loose, acicular elpidite crystals by the hundreds, heavier and more equant elpidite crystals on matrix, tabular trillings of epididymite striated in three directions, rutile, pyrochlore and pink to brown zircon crystals. The epididymite trillings have been pictured in the *Record* before (Quintin Wight, vol. 10, p. 98), while the columnar, striated elpidite is shown in Figure 1. These larger elpidite crystals are interesting for their color zoning. The bodies of the crystals are the color of old ivory, while the tips of the crystals are snow white. In later years (1978 and 1979) the same or a similar green hole was encountered at a lower level. There the habit of the epididymite trillings was slightly different.

Figure 1. **Elpidite crystals to 3 mm, the color of old ivory but with white tips, associated with small crystals of black rutile.**

The Biotite Hole

We first collected from the biotite hole in late 1975 and in 1976. Unlike the green hole, which was a natural pipe in the country rock, the biotite hole was a depression formed in the quarry floor by mining operations and mineral collectors. It was composed mostly, as its name implies, of large masses of compact biotite, pure black in color. A number of interesting minerals were found in the biotite; species such as mosandrite, rhabdophane and UK 34 (these species have not been straightened out yet) plus galena, lavenite and/or wohlerite, cancrinite, pyrochlore, eudialyte and fluorite. In addition, the new mineral petarasite was found in massive form. More recently it has been found nearby in euhedral crystals as well as massive, the color varying from yellow through orange to brown. It is very much like the yellow to brown, massive eudialyte with which it occurs, except that the petarasite displays three very perfect cleavages which the eudialyte lacks. A specimen of yellow mosandrite (?) in radiating acicular crystals frozen in a biotite matrix is shown in Figure 2.

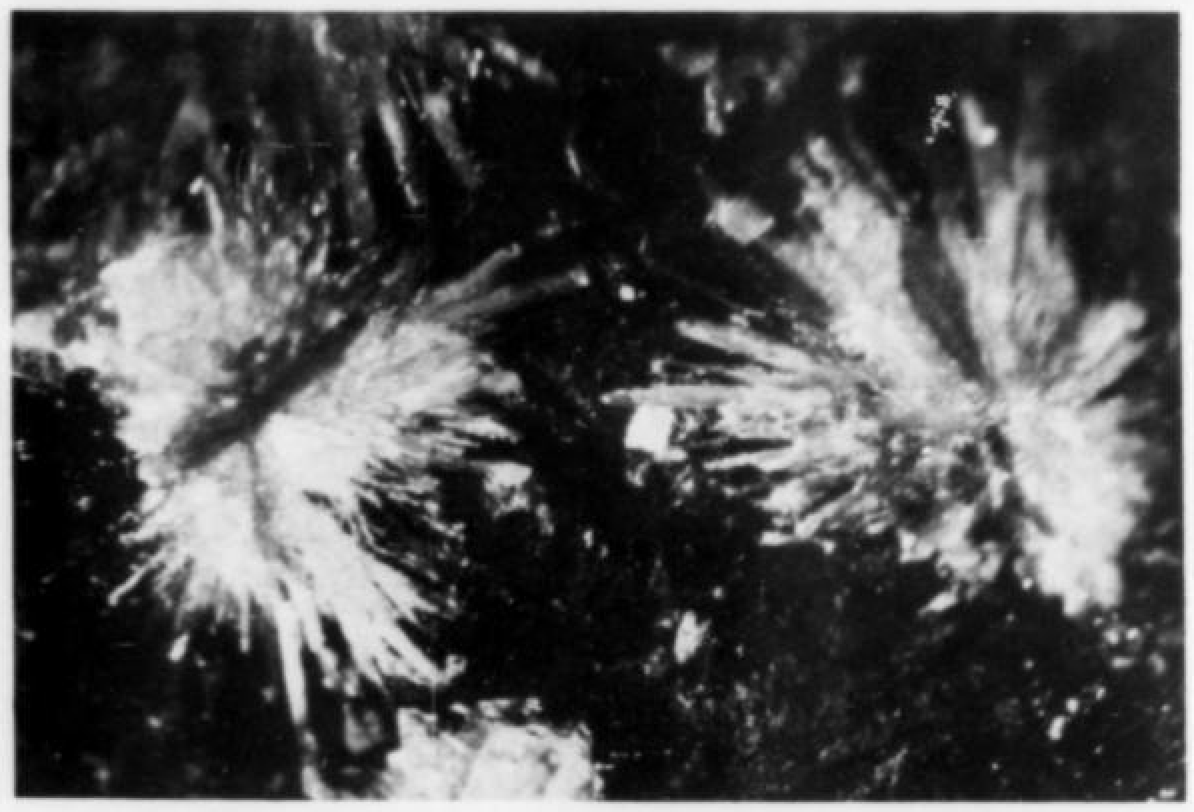

Figure 2. **Sprays of deep yellow mosandrite crystals frozen in a matrix of biotite and dark purple fluorite. The largest spray is 4 mm across.**

Igneous Breccia

An extremely fruitful matrix for collectors at Mont St. Hilaire is a mottled green and grey to black igneous breccia. This turns up rather frequently and is host to a variety of minerals such as labuntsovite, leucosphenite, monteregianite, tetranatrolite, ramsayite and ashcroftine. Of course, not all of these minerals are available at any one time. The minerals listed and others occur as euhedral crystals in vugs and open seams in the breccia. The labuntsovite found in the breccia varies from yellow in the smaller crystals to orange or even reddish orange when larger. Very rarely this titanium silicate is a deep, true red, as is the small, radiating group shown in Figure 3.

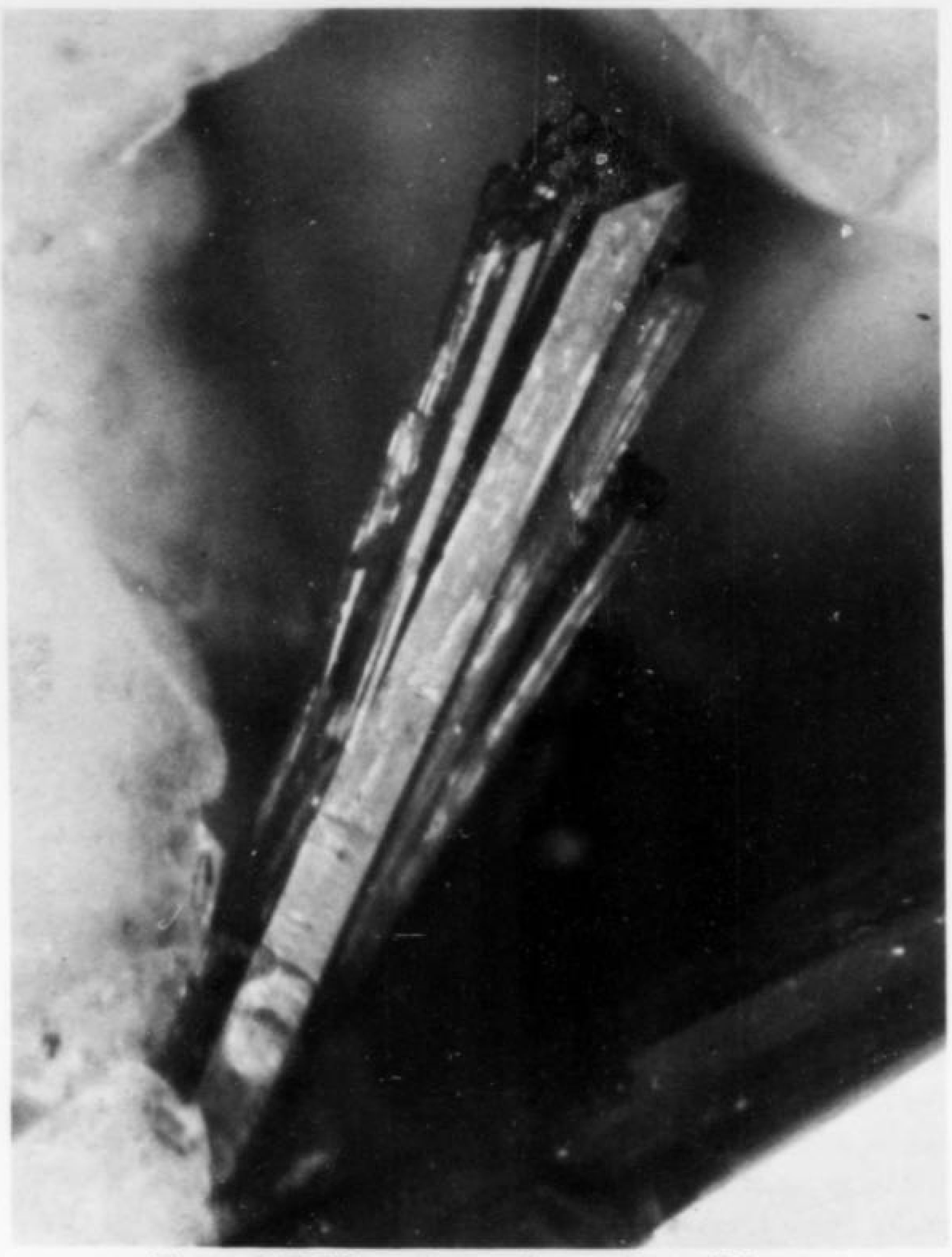

Figure 3. **Brilliant, deep red, translucent labuntsovite crystals to 3mm, in a cavity in albite. Marcelle Weber specimen.**

Leucosphenite, another titanium silicate, contains barium and boron as well, and occurs in the breccia and also in pegmatites. It is found as striated, equant to tabular crystals (Fig. 4). Though usually almost colorless, some crystals are color-zoned gray, pale yellow or pale blue and are transparent. The colorless crystals commonly appear very much like white blocky crystals of feldspar with which they occur, and are very easily overlooked. October of 1973 and July of 1974 were two occasions when fine labuntsovite was to be found, while 1972 and 1974 were good years for leucosphenite.

Figure 5 shows a very interesting epitaxial relationship between two other rare minerals found in the breccia, tetranatrolite and monteregianite. The latter is a new sodium yttrium silicate found only at St. Hilaire. The tetranatrolite, a tetragonal polymorph of natrolite, is shown in Figure 5 as tiny, white crystals growing at right angles to the sides of the much larger, tabular, grey monteregianite laths. Most of the white mineral found at Mont St. Hilaire and called natrolite may well be tetranatrolite, but the two are indistinguishable by eye. The doubling of a few lines in the X-ray pattern of tetranatrolite is diagnostic, and this feature was used to identify the material shown in Figure 5.

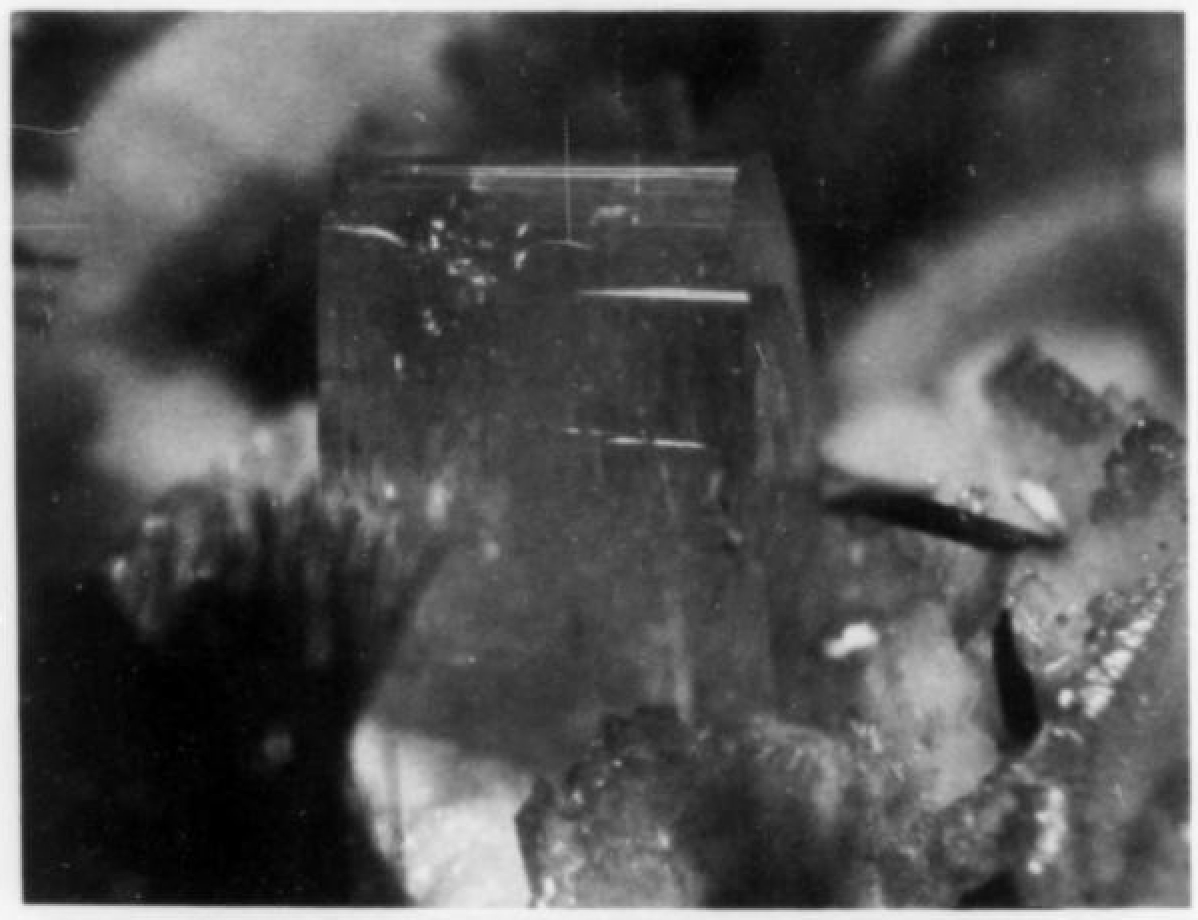

Figure 4. **A colorless, transparent, brilliant leucosphenite crystal 2.5 mm long, the tip of which is a bright blue. Associated with brown needles of ramsayite.**

In years gone by, the breccia has been extremely productive of fine micro minerals. Lately, however, when the breccia has appeared at all, it has been quite dense and much poorer in the vugs and seams where the rare species are found.

Hornfels Breccia

A rusty and altered hornfels breccia of very unpromising ap-

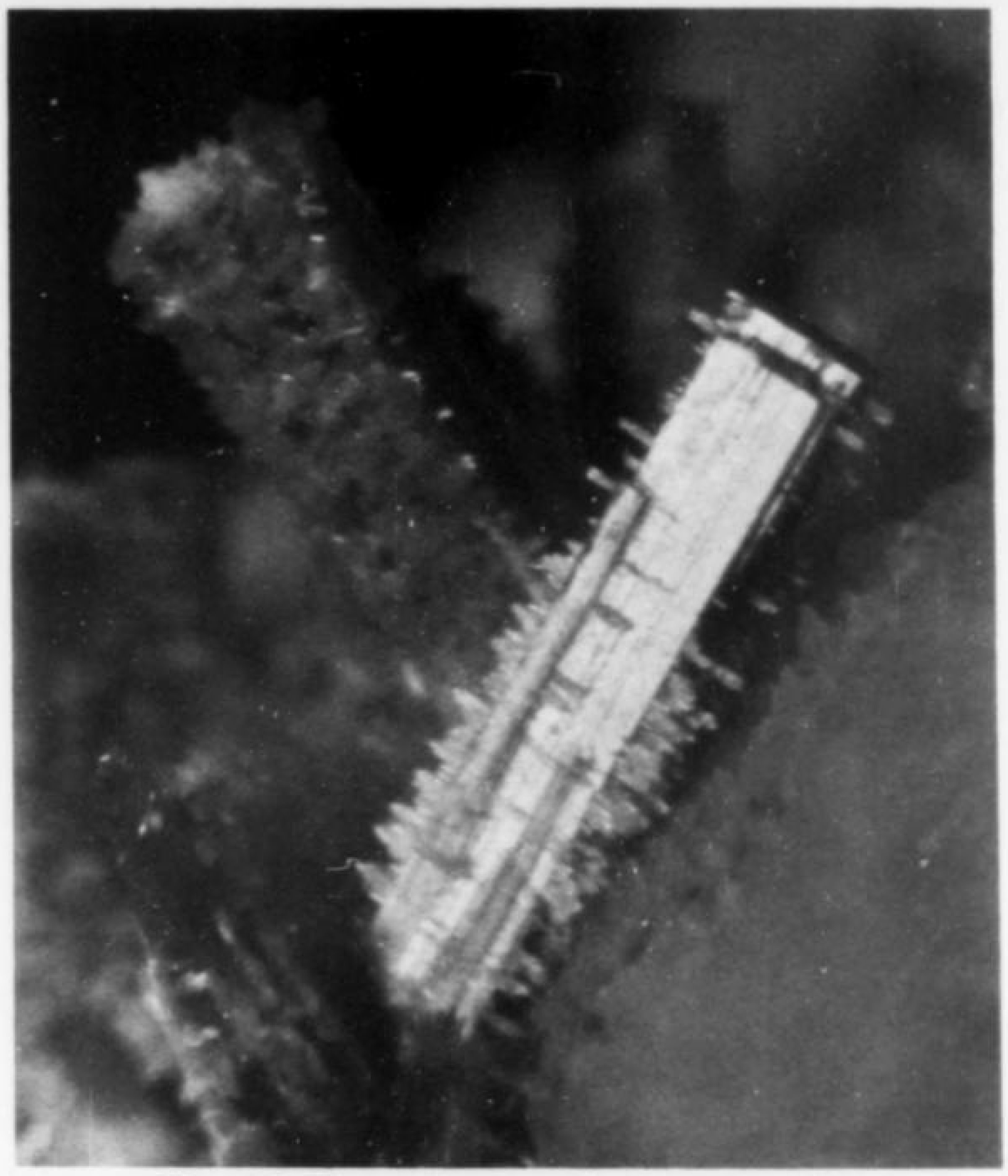

Figure 5. **Tiny, white crystals of tetranatrolite oriented perpendicular to pastel gray laths of monteregianite. The monteregianite crystal is 4 mm long, and the mineral is a new one found only at Mont St. Hilaire.**

pearance was the source in 1975 of some superb narsarsukite as well as smoky quartz, cordylite and brookite. A bright yellow, tabular crystal of narsarsukite, so transparent as to show its internal flaws and incipient cleavage, is shown in Figure 6. The dark, hexagonal, out-of-focus crystal partly obscuring the narsarsukite is a euhedral smoky quartz.

Figure 6. **Transparent, tabular, canary-yellow crystal of narsarsukite 3 mm across, showing internal flaws and incipient cleavage. Associated with a translucent dark smoky quartz crystal.**

Hornfels

It was raining and cold on our collecting trip in October of 1972, always a good sign that the collecting would be fruitful. Early on I sent my wife, Audrey, scouting for a particular green matrix. She returned shortly with a green rock, but not the one I had in mind. I was about to castigate her severely when I noticed a single yellowish crystal embedded in the matrix. It was a narsarsukite, different from the one described above. We both returned to the spot where she found it, and further search showed that a considerable amount of a grey-green hornfels had been broken up in the last blast and thrown a hundred feet or so to lie on the quarry floor in an area the size of a large living room rug. We staked out a modest portion of the site and, within minutes, were surrounded by a dozen or so other collectors. The collecting was excellent, and involved scooping up the rock in the form of small boulders and gravel. The narsarsukite crystals were lying everywhere, either loose or on matrix, and every time the shovel was emptied, narsarsukites were to be seen adhering to the wet blade. Hundreds of crystals were collected, up to 15 mm in size. By the following morning, the place had been excavated to a depth of several feet. Only the largest boulders of barren rock remained, and the resulting hole looked like the vacuumed bed of a gold bearing stream in California.

The narsarsukite crystals occurred as singles showing the base, a dipyramid and two prisms (see Vi Anderson's article) and also as parallel groups (Fig. 7). While the smaller crystals and the centers of the larger ones are yellow, the prism faces and edges of the larger crystals grade to a grey-green in color. The green color, easily seen in Vi's photo, is due to inclusions of tiny crystals in the hornfels in which the narsarsukites grew. It is interesting that the narsarsukite was able to push away the green mineral from its *c*-face as it grew, but could not do as well on its prism zone. Narsarsukite is yet another titanium silicate mineral.

Figure 7. **A 4-mm group of narsarsukite crystals in parallel growth on a hornfels matrix.**

Marble Xenoliths

Marble xenoliths, fragments of limestone country rock which fell into and were metamorphosed by the nepheline syenite magma, are fairly frequently encountered at Mont St. Hilaire. Up to a meter or so across, the xenoliths are composed largely of white to cream-colored calcite plus large amounts of colorless to white, very splintery pectolite. The latter has a nasty habit of working into unprotected fingers and breaking off there. It is also responsible for the remarkable toughness of the xenolith rock. Very fine micro crystal specimens are to be found in fissures and vugs in the xenoliths, species such as apophyllite, datolite, ekanite, vesuvianite, pectolite and thomsonite. In the spring of 1981, many specimens of bright yellow calcite were recovered, together with superb terminated pectolite, yellow vesuvianite and pink ancylite. A transparent crystal of such pectolite is shown in Figure 8.

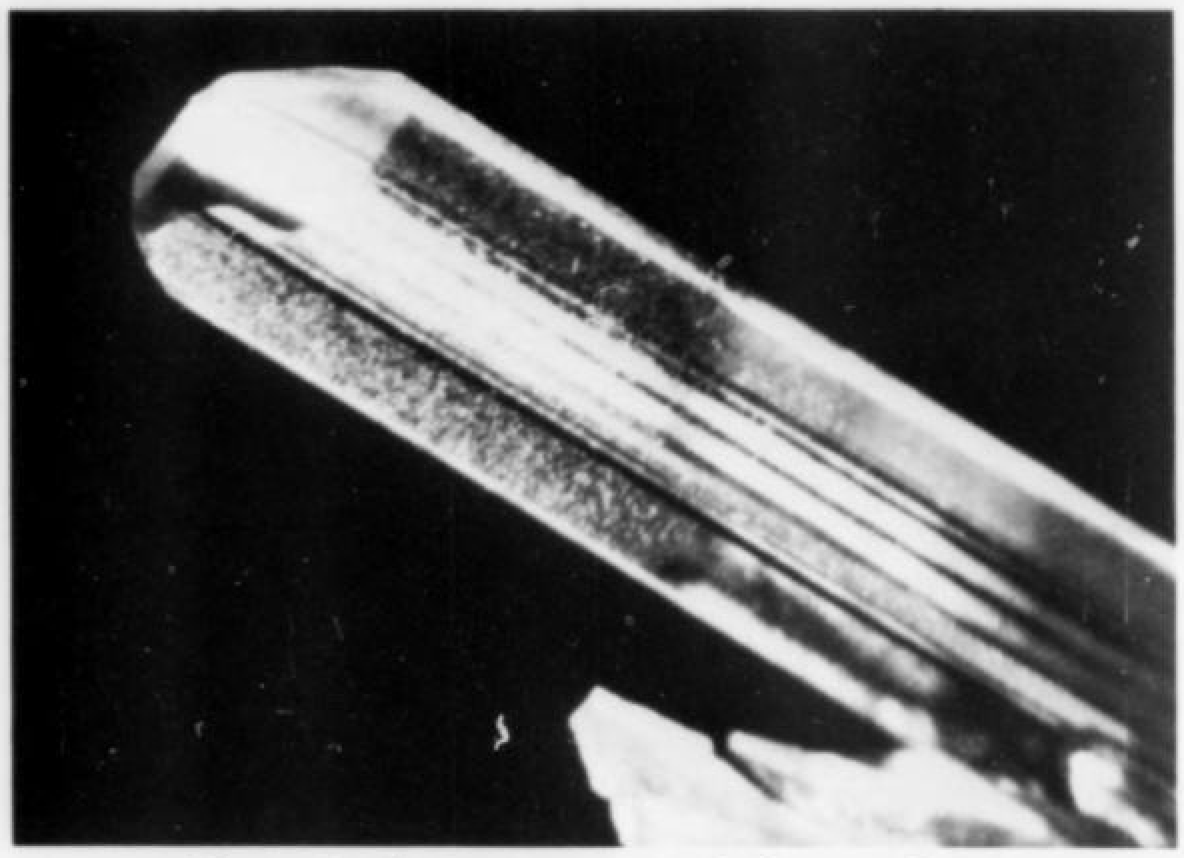

Figure 8. **A transparent, colorless, well terminated crystal of pectolite, 3.5 mm long.**

Silicate Vugs

Silicate vugs at St. Hilaire vary in size from a couple of cm or less across up to a meter or more in dimensions. The larger ones grade into pegmatite cavities, about which I will say more later. They are the host to a wide variety of rare species, at least 60 in number. Unfortunately, they also illustrate *Henderson's Rule,* which states that the difficulty in removing the vug varies as the cube of the desirability of the minerals within it. Those with a mathematical bent will readily see that it is virtually impossible to remove a really desirable vug. It always seems to be exposed in the center of the biggest face of a boulder at least a yard across, and resists the most strenuous efforts with a large sledge. Poorer cavities with broken crystals tend to lie at the edges and corners of pieces of well fractured rock.

Eudialyte is one species found in the silicate vugs. The one shown in Figure 9 is a brilliant orange color, and is associated with white natrolite or tetranatrolite. While eudialyte is at least as common in the pegmatites, there it tends to be pale pink to deep red in color. Also found in the silicate vugs are extremely well formed, lustrous, deep green to almost black dodecahedrons of andradite (Fig. 10). Rarely, the andradite is associated with extremely complex, transparent, canary-yellow crystals of barite and with a peculiar, elongated form of analcime, often mistaken for natrolite.

Carbonate Vugs

A different suite of minerals is found in carbonate vugs. These too vary greatly in size, the largest being the so-called "siderite hole" in the Poudrette quarry. It was large enough for a man to stand in, and was noted for extremely large, simple rhombohedral crystals of siderite up to 40 cm in size growing on albite. Other species found in the siderite hole and smaller carbonate vugs are tabular, grey synchisite crystals of micro size, pink to grey bastnaesite in very tiny crystals, sphalerite, galena, rutile and pink to brown zircon, usually on albite.

A similar suite of minerals turned up in small amounts in the fall of 1979. I won't swear, however, that the occurrence was a true carbonate vug since aegirine was present as well. The material found then contained, besides micro siderite rhombs on and with very attractive snow-white albite plates, immense numbers of deep blue-black, tabular anatase crystals, all three minerals forming after intensely corroded aegirine crystals of larger size. In some cases, the

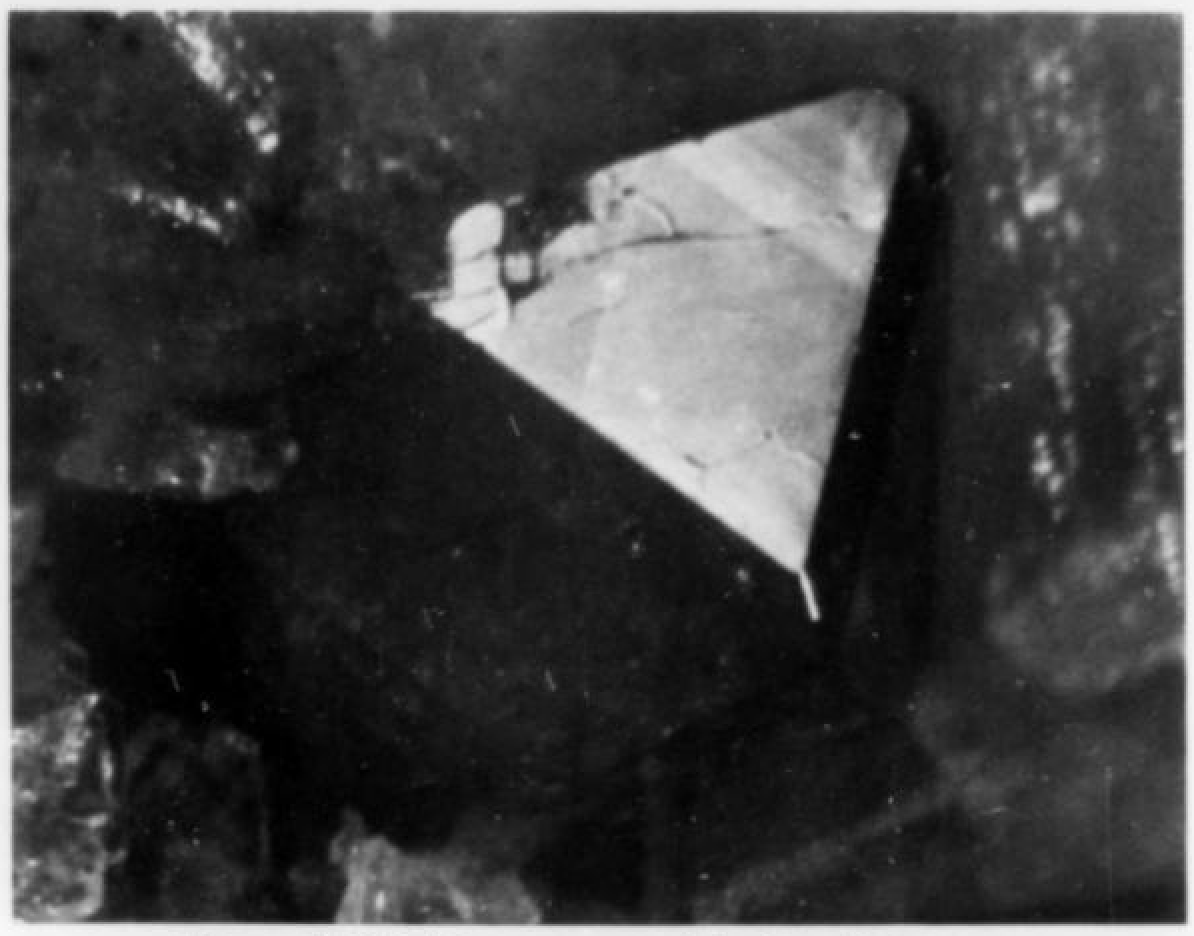

Figure 9. **Bright orange crystal of eudialyte on albite. The crystal is 1.5 mm across.**

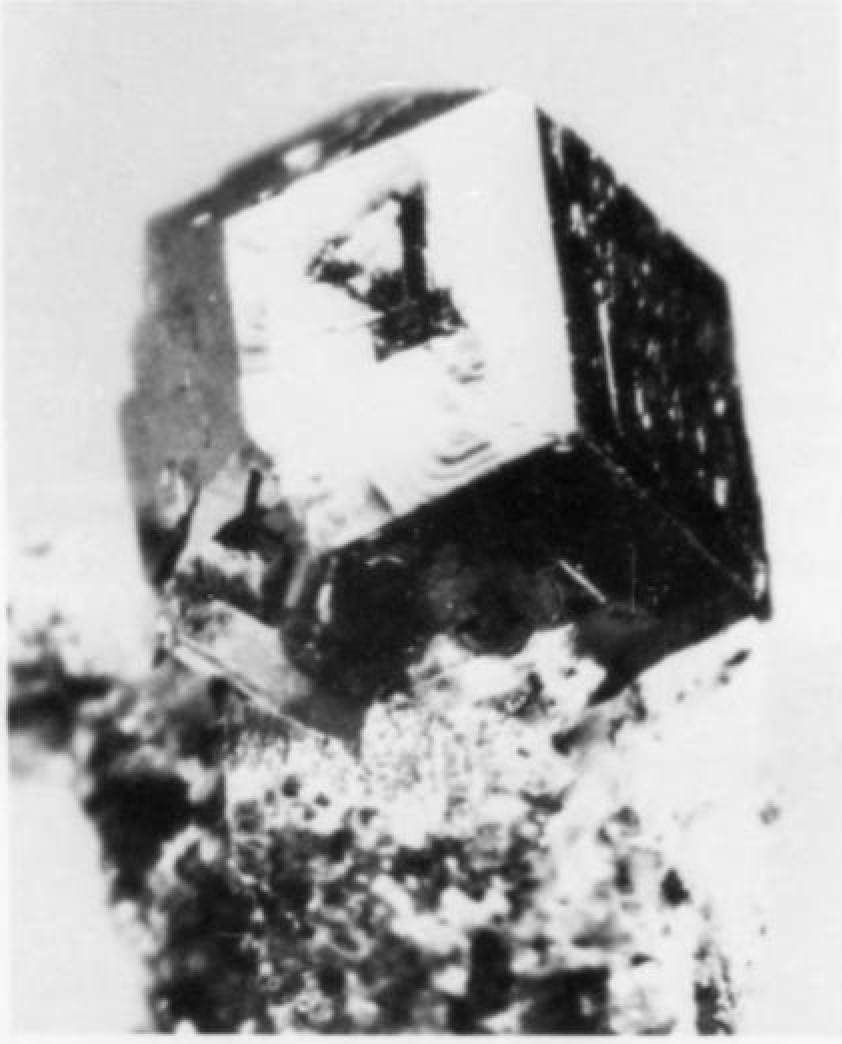

Figure 10. **Deep green dodecahedron of andradite on albite, crystal 3 mm high.**

aegirine was completely corroded away to leave the above minerals in the large, columnar solution cavities. With these minerals were found radiating, white to grey, acicular crystals of an as-yet unnamed mineral, UK50, plus the new mineral donnayite. The latter, a sodium calcium strontium yttrium carbonate, occurred as equant, pseudohexagonal, striated crystals with a warm grey color, the *c*-faces commonly slightly curved. Two such donnayite crystals, striated and dusted with tiny pyrites, are shown in Figure 11. Donnayite is known only from Mont St. Hilaire. It is extremely variable in its color (colorless, white, yellow, grey, brown), but the slightly rounded concave or convex termination is a good clue to its identity.

Pegmatites

By far the most spectacular of the mineral parageneses at Mont St. Hilaire are in the pegmatites. These are not like your run of the mill granitic-type pegmatites composed of quartz, orthoclase, plagioclase and accessory minerals. Rather, they are composed largely of microcline, albite, aegirine and analcime; all, of course, are in large crystals. Besides these, about three dozen other species, many of them quite rare, are to be found. The pegmatites vary from quite small ones merging into the silicate vugs described earlier up to ones many meters long and 2 or 3 meters wide. Fre-

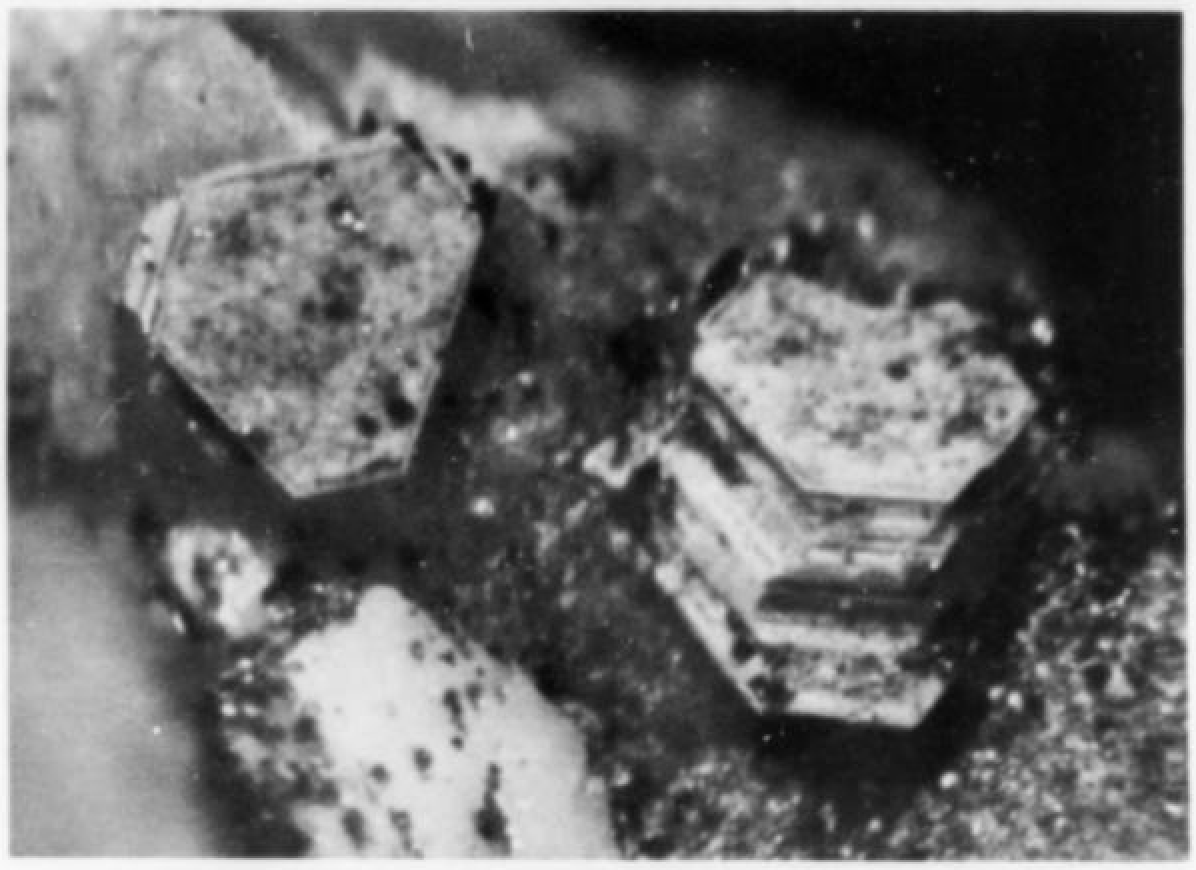

Figure 11. **Pseudohexagonal crystals of donnayite, a new mineral known only from St. Hilaire. The gray crystals are 1 mm in size, the terminal faces are slightly convex, and they are dusted with tiny pyrite crystals.**

quently, the pegmatities are studded with open cavities from a few centimeters in size up to ones large enough to admit an adventurous collector. The walls of such cavities are lined with euhedral crystals. Again, different pegmatites have different suites of minerals, the suite of minerals found varying with the degree of hydrothermal alteration or weathering of the pegmatite. In the following paragraphs, I'll describe a few of the notable pegmatite parageneses.

In June of 1972, the Webers and we were *fossicking* a large bank of nepheline syenite rock broken up by blasting. We found scraps of analcime indicative of a vug or pegmatite, and a little more digging opened up what seemed to have been a collapsed pegmatite cavity perhaps a few tens of centimeters in size. Scratching with small hoes and garden trowels soon exposed in every scoop loose crystals of analcime to the size of golf balls and large, chocolate brown plates of astrophyllite. Loose and also growing on the analcime were tabular, twinned, bright yellow crystals of leucophanite up to 1 cm in size like the one shown in Figure 12. The four corners of the crystal are not damaged, but show re-entrant angles or interrupted growth due to twinning. The crystals, canary-yellow in daylight, fluoresce pink under ultraviolet light. With the leucophanite we also found small numbers of very tiny, colorless, untwinned epididymites. In the haste of collecting, my shirt pockets were stuffed to overflowing . . . I collected some specimens *twice.*

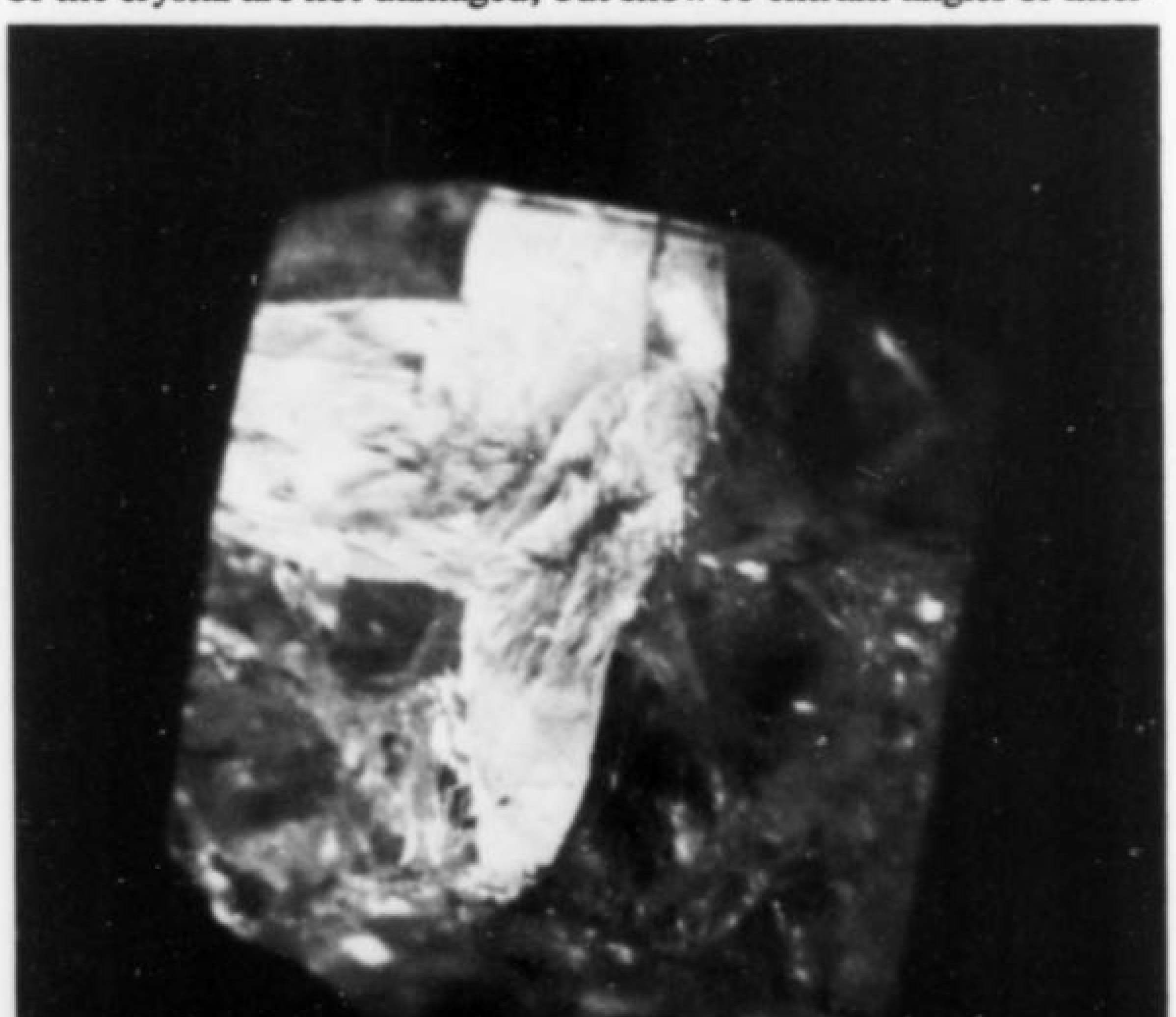

Figure 12. **Twinned, pale yellow, translucent crystal of leucophanite, 4 mm across.**

Returning to astrophyllite, the crystals found in the pocket just described were about 1 to 2 cm in size and frozen in a matrix of analcime and/or natrolite. Astrophyllite commonly occurs at St. Hilaire in columnar or acicular, tan to brown crystals with rather poor faces. The crystal shown in Figure 13, however, combines the good features of both of the above types. It is tabular, shows excellent development of its crystal faces, and is free-growing in a cavity. The dark brown crystal shows a re-entrant angle on its terminal faces, the result of interrupted growth, not damage.

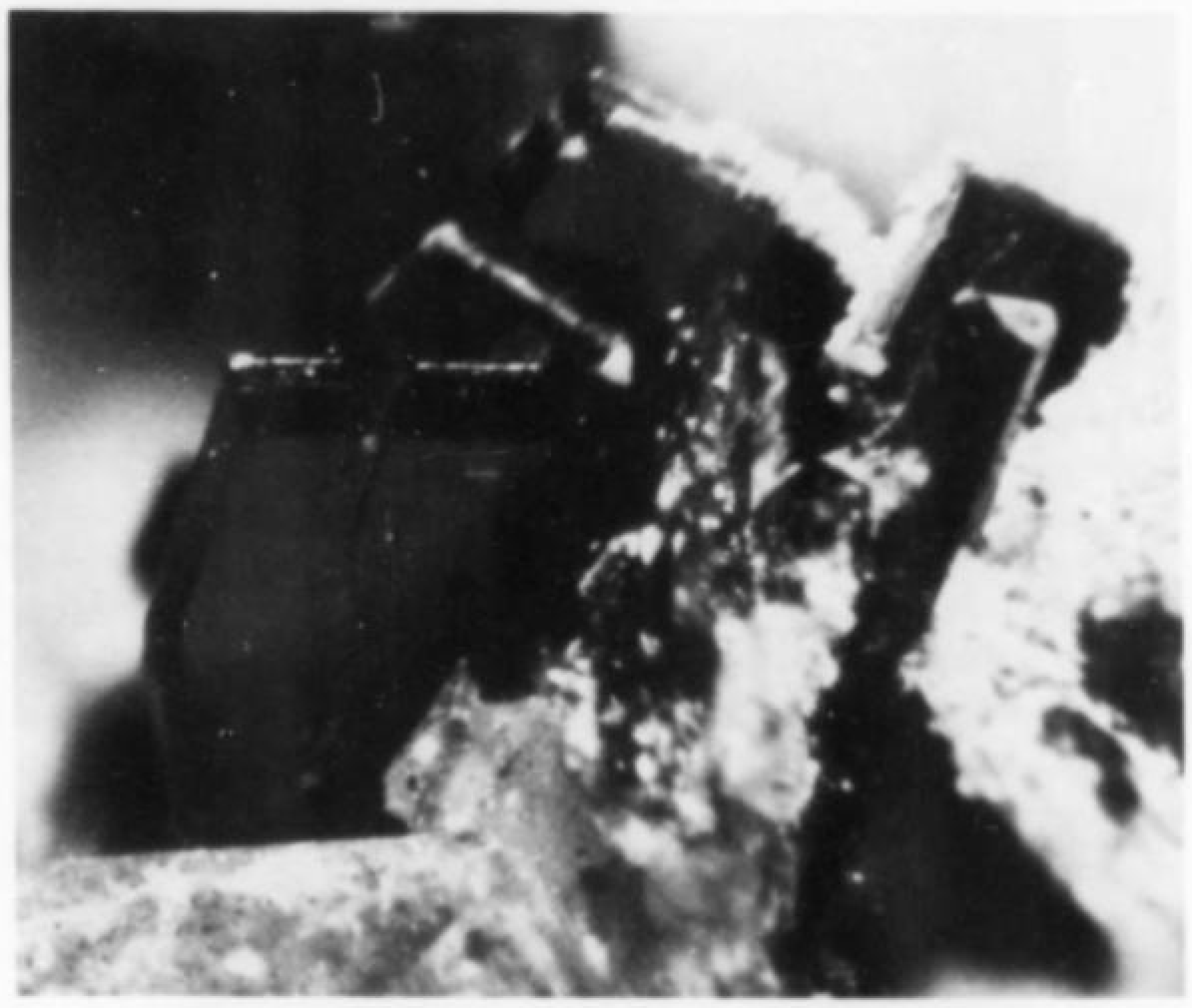

Figure 13. **Dark brown crystal of astrophyllite 1.5 mm high on natrolite and analcime. The terminal faces show interrupted growth.**

The capped nenadkevichite, a sodium calcium niobium silicate shown in Figure 14, was collected from another small pegmatite in May of 1971. The crystals are transparent, light tan in color, and I suppose the caps indicate a second period of growth. They are on albite, and make a pretty combination with the associated pink ancylite and blue-green fluorite. Other associates were tan catapleiite, multi-colored, glassy, platy aggregates of monteregianite, pink rhodochrosite and colorless sprays of astrophyllite needles.

The next specimen illustrated, the mangan-neptunite in Figure 15, came from a small pegmatite discovered in 1973 and known to a select coterie of cognoscenti as "Peter's pink hole." It was named after its discoverer, Peter Tarassoff, after whom the new mineral petarasite was named. While I did not collect there personally, I was given a small vial of sand and gravel from the pegmatite. Sorting the material under the microscope gave, in addition to several crystals of the mangan-neptunite, nice, terminated pink crystals of serandite and pink to lavender groups of radiating raite, all of micro size. The mangan-neptunite shown is honey-yellow in color and so transparent that the matrix can be seen through the crystal. This and other crystals show some color zoning, the light colored areas being surprisingly high in zinc. Although this particular crystal is not twinned, quite a few from this pegmatite are in the form of V-shaped twins. Peter tells me that the only hints of pegmatite at that point in the quarry floor were a few scraps of pink serandite and white microcline. The shattered pocket was only exposed on digging, and was pervaded by a pink mud, after which the hole was named. The primary minerals were coarse and heavily corroded microcline, analcime, serandite and albite. The raite probably was

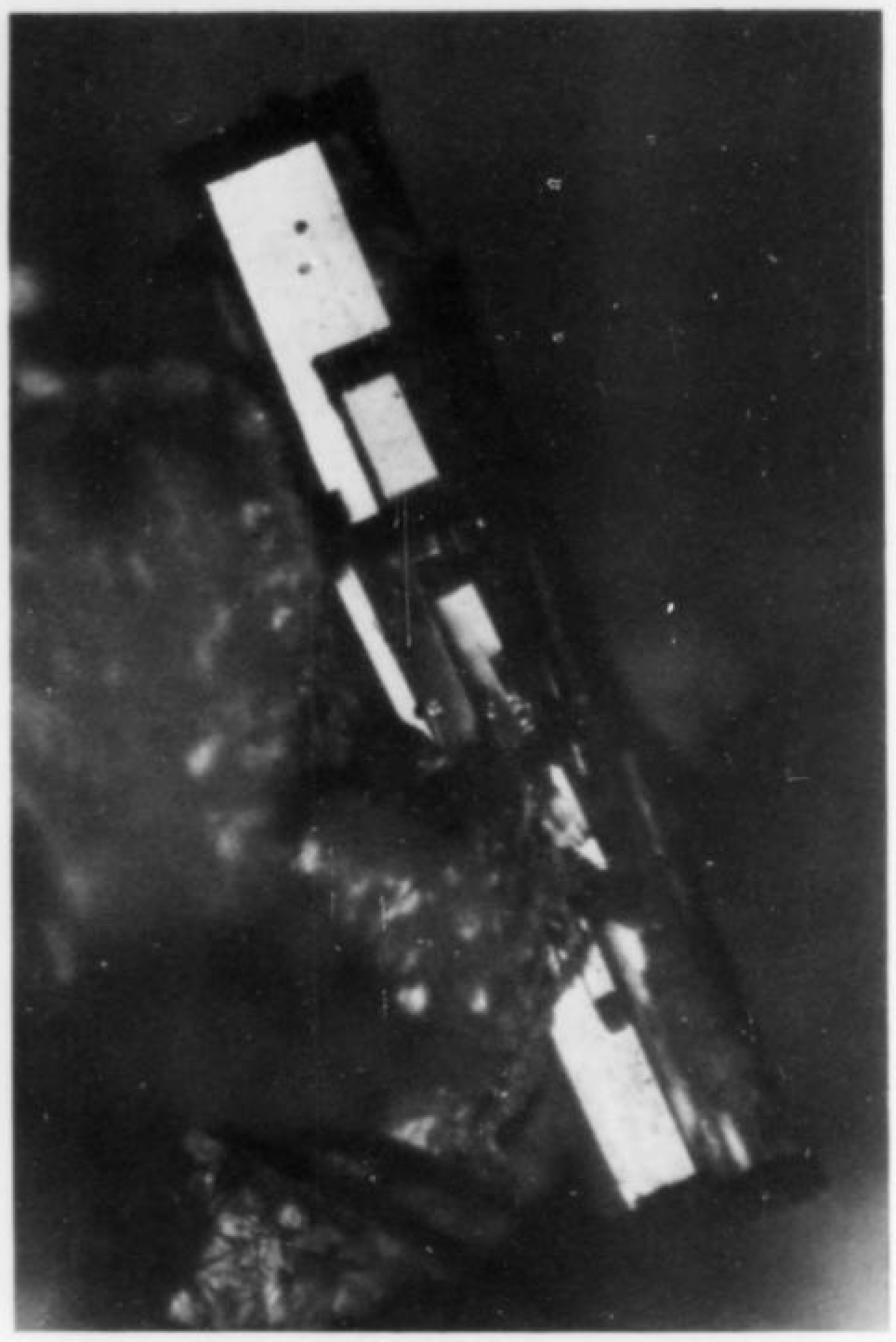

Figure 14. **Capped crystals of transparent, light tan nenadkevichite in parallel growth. The largest crystal is 1.5 mm long.**

Figure 15. **Transparent crystal of mangan-neptunite 0.8 mm high. The matrix and far side of the crystal can be seen through it.**

the source of the pink color, while other secondary minerals present included nenadkevichite, polylithionite, more serandite and mangan-neptunite.

The colorless epididymite shown in Figure 16 is from yet another small pegmatite. These single crystals are quite unlike the pseudo-hexagonal trillings found in the green hole, and are easily mistaken for feldspar crystals. The striations in the prism zone and their half-hearted attempts at twinning are distinguishing features. Besides fluorite and dodecahedrons of analcime (such as the out-of-focus one in the photo), these epididymites are associated with light tan crystals of three very rare minerals, hilairite, gaidonnayite and

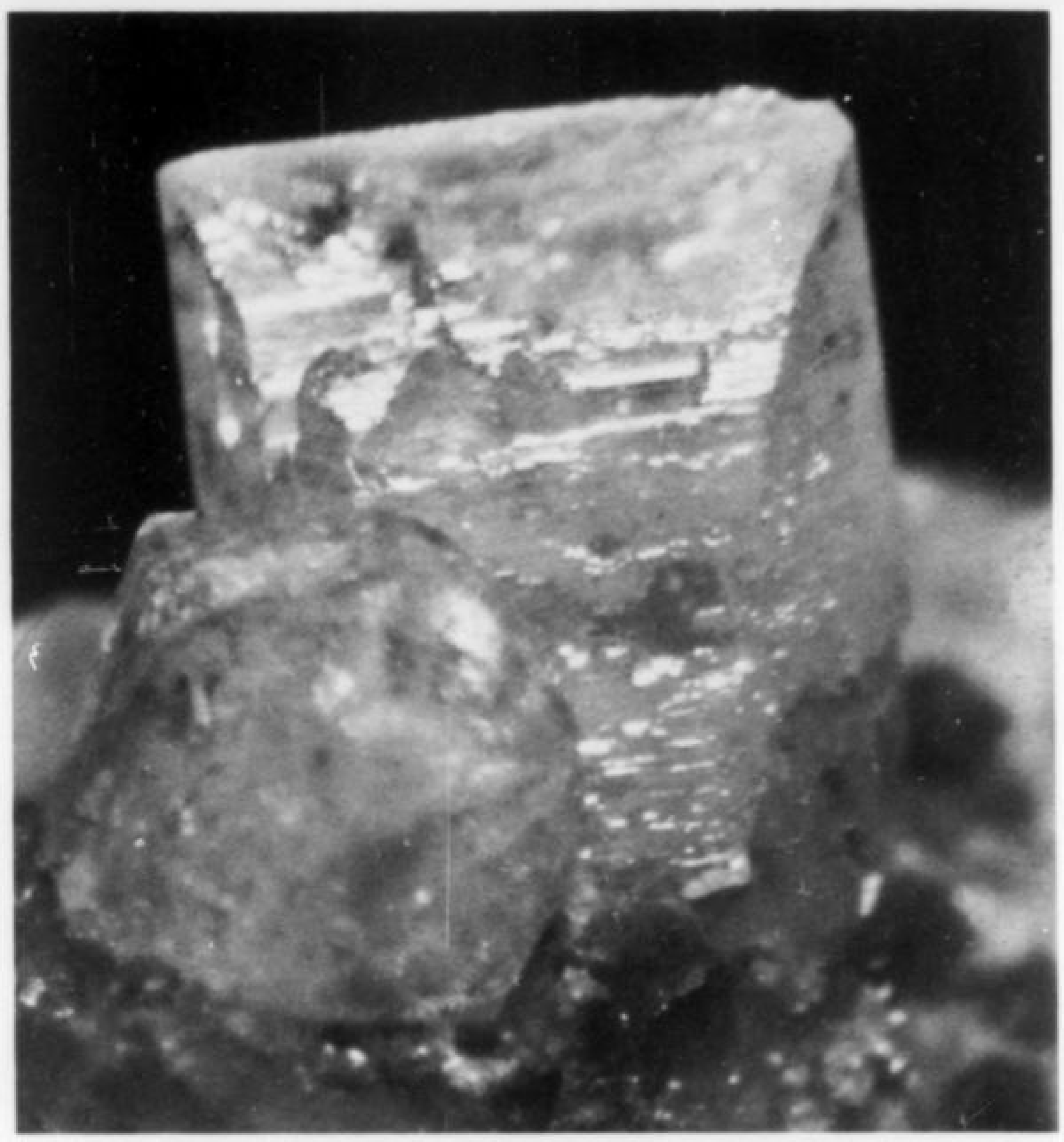

Figure 16. **Colorless 2 mm crystal of epididymite associated with an out-of-focus analcime dodecahedron.**

catapleiite, all three being sodium zirconium silicates. Micromounts perhaps 2 by 2 cm in size from this pegmatite frequently show all of the above named minerals in well developed crystals. The dodecahedron, by the way, is only very rarely found on analcime at other localities, but it is the major face on the crystals found here.

From time to time, a feature called the serandite pipe or the serandite hole has appeared. This is another pegmatite which has been the source of extremely large, bright-pink serandite crystals associated with analcime crystals of great beauty and size and natrolites to many centimeters in length. Earlier serandites were equant to somewhat columnar, and well terminated. In its most recent appearance in the spring of 1981, the serandite was in much longer crystals and poorly terminated. While the hand specimen collectors were fighting over this material, micro collectors were also picking up rhodochrosite in a variety of habits, all of them either in or closely associated with the pipe. The finest of these were almost colorless to bright orange crystals, perfectly transparent, and in scattered groups such as that shown in Figure 17. With the rhodochrosite were large amounts of aegirine on which were skew-

Figure 17. **Transparent orange plates of rhodochrosite on albite; field of view is 10 mm across.**

Figure 18. **Pink plates of catapleiite on dark green aegirine needles; field of view is 3 mm across.**

ered a variety of micro minerals. Figure 18 shows a number of hexagonal plates of catapleiite on slender aegirine needles. Catapleiite at St. Hilaire is usually colorless, white, grey or tan, but many of these crystals are a pale pink. In addition, tiny natrolites were found on the aegirine needles, as in Figure 19. In some cases the natrolites are so large and the aegirines so thin that the whole assemblage will sway with the slightest breath or motion.

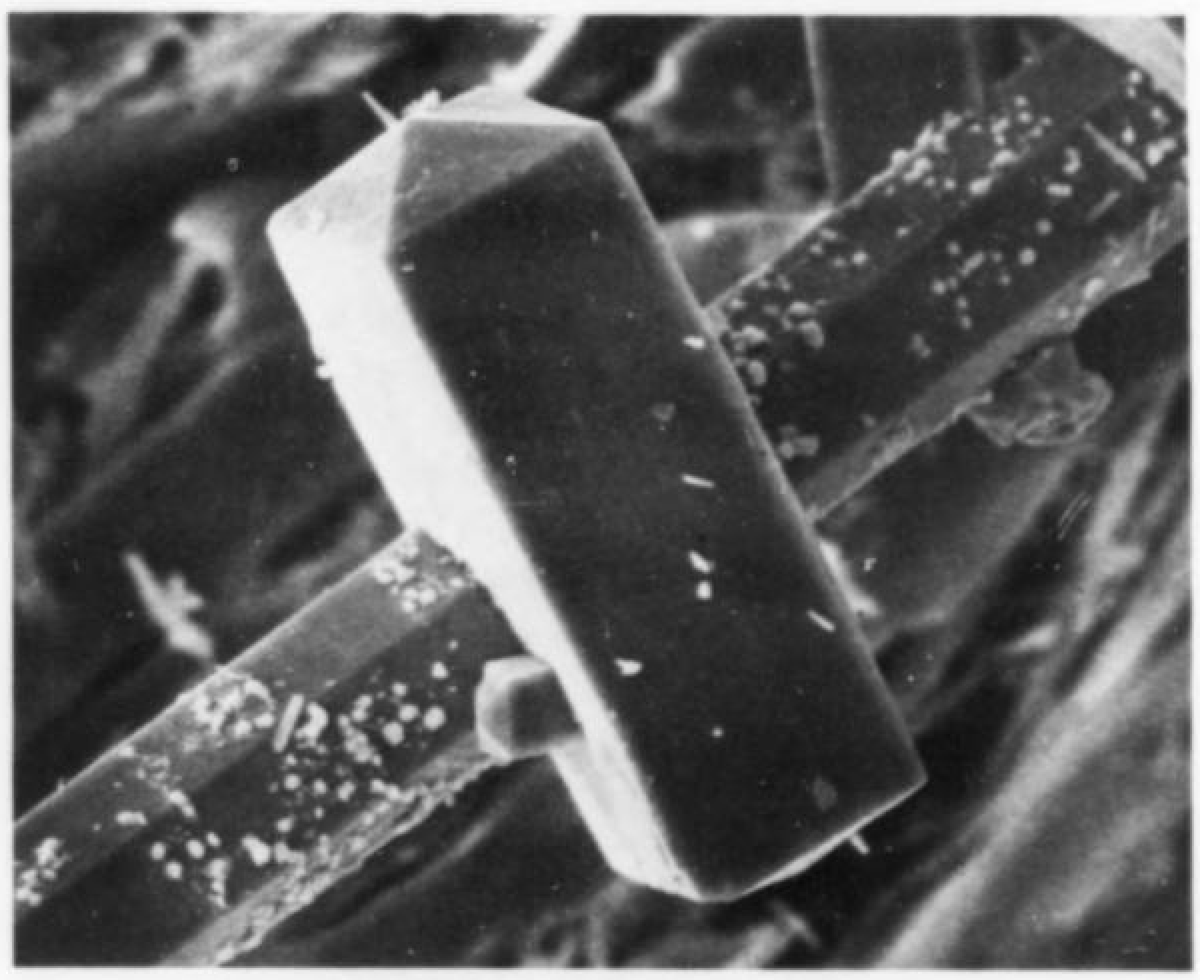

Figure 19. **White, doubly terminated crystal of natrolite or tetranatrolite on dark green aegirine needle; field of view is 4 mm.**

Frequently found in a variety of parageneses at Mont St. Hilaire is the strontium rare-earth carbonate ancylite. Usually it occurs in equant to short columnar crystals and is colorless, pink or grey. Crystals occur as singles or randomly arranged small groups. A quite different habit is shown in Figure 20 where the ancylite appears in radiating clusters of much longer crystals. With their pink color, the groups look very much like asters. They are associated with colorless epididymite crystals, pink rhodochrosite rhombs, very fine, tan catapleiites, and blue-green fluorite, a really pretty combination. Interestingly, this small pegmatite was closely associated with marble xenoliths containing still more ancylite plus deep yellow calcite and yellow vesuvianite crystals.

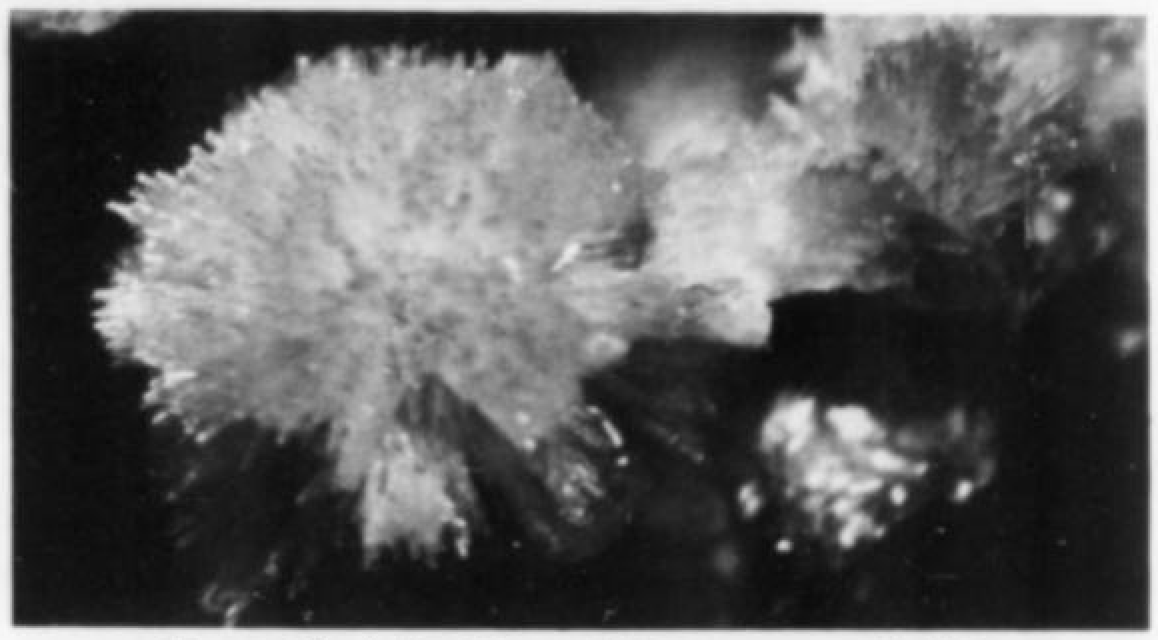

Figure 20. **Aster-like, radiating groups of pink ancylite on albite, associated with epididymite and catapleiite. The largest spray is 3 mm across.**

CONCLUSION

I hope this column will give readers an idea of the apparently endless variety of minerals and parageneses at Mont St. Hilaire. These have made it a fascinating place to collect. Harder to convey are the feelings of intense excitement and anticipation of the faithful as they meet at the quarry gates early in the morning. Those first few moments after the quarry gates have opened and the hundred or so waiting collectors from a dozen or more states and provinces have driven up to the quarry floor are truly memorable. Neither freezing rain, snow, nor broiling heat slow their endeavors, and a tired but happy crew gather in the evening to compare their finds and plot the next day's work. In the "good old days," a few collectors could, with a little effort, pick up a carload of fine micro material in a weekend's time. But these days, within hours, the quarry is picked as bare as though it had seen the passing of the hordes of Attila the Hun; but still the trips were well worthwhile. Sadly, the De-Mix quarry, the source of most of the good material, has shut down for the foreseeable future. The Poudrette quarry has been closed to collectors for a number of years. Perhaps they will reopen someday. In the meantime, there is still a source of St. Hilaire material in the cellars and garages of those who have collected there for the past few years. I am at a loss to name collectors with whom readers can exchange, but could pass on a few letters to people I know. I do know that Marcelle and Charlie Weber (39 Benson Place, Fairfield, Connecticut 06430) have a very large number of Hilaire specimens in their basement, and are willing to trade. Those who resort to the silver pick should write to Elsie and Les Horvath of *Monteregian Minerals.* They advertise in the *Record* and have a superb assortment of choice material from St. Hilaire, including some of the rarest species.

Finally, I want to express my thanks, which I am sure are shared by other collectors and professionals alike, to the owners of the De-Mix quarry, De Mix Ltee., for giving permission to collect, and to Alain Robin and Ecole Polytechnique who made the arrangements for clubs to enter. At considerable cost and aggravation to themselves, they have given many responsible groups the opportunity to save enormous amounts of material of great value to collectors and the scientific world. Without their aid, all of this material would have gone through the crushers. Would that more quarry owners on the American side of the border were so cooperative! My thanks also go to Marcelle Weber and Peter Tarassoff for their help with dates and information needed to flesh out this column.

All but one of the specimens in these photos are from the collection of the author. All photos are by the author except the two SEM pictures, which were taken by Carol Garland.

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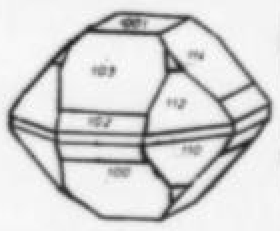

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