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Ministry of
Northern Development
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**Ontario Geological Survey
Open File Report 5891**

**Amethyst in the
Thunder Bay Area**

1994



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and Mines

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ONTARIO GEOLOGICAL SURVEY

Open File Report 5891

Amethyst in the Thunder Bay Area

By

M.I. Garland

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TABLE OF CONTENTS

ABSTRACT	xix
1.0 INTRODUCTION	1
1.1 Purpose of Study	1
1.2 History of Amethyst	1
1.3 History of Thunder Bay Amethyst and Silver Mining	3
2.0 REGIONAL GEOLOGY	6
2.1 Regional Geology and Tectonic Setting	6
2.2 Metallogeny Related to Regional Geology	14
3.0 AMETHYST MINERALOGY	19
3.1 Amethyst/Quartz	19
3.2 Colour of Amethyst	25
3.2.1 General Causes of Colour	25
3.2.2 The Concept of Colour Centres	27
3.2.3 History of Research into Amethyst Colour	34
3.2.4 Colour of Amethyst	36
3.3 Commercial Production of Amethyst	37
3.3.1 Global Perspective of Amethyst Production	37
3.3.2 Canadian Amethyst	42
3.3.3 Gemstone Marketing and Enhancement	43
3.3.4 Enhancement Techniques for Amethyst	49
4.0 AMETHYST IN THE THUNDER BAY AREA	52
4.1 Deposit Characteristics	52
4.2 Property Descriptions	77
Barrett Claims (2)	79
Big Pearl Lake Occurrence (4)	83
Blue Points Amethyst Mine (6)	85
Blue Star Resources Quarry (7)	89
Breezy Lake Property (8)	93
Diamond Willow Amethyst Mine (12)	95
Dorion Amethyst Mine (13)	102
Dzuba Ancliff (14), Pipeline (15), and Thunder Bay (16) Occurrences	105
The Enterprise Mine (18)	110
Little Bear Amethyst Quarry (21)	113
Gem Mountain Mine (22)	117
M. Grieve and Family Mine (23)	119
Jean Township Occurrence (25)	125
Little Bear Amethyst Mine (27)	128
G. McLeod Quarry (30)	130
Mount Baldy Occurrence (32)	132
Ontario Gem Company Amethyst Mine (33)	134
Pearl Lake Amethyst Mine (34)	142
D. Bak Occurrences (38A and B)	149
Tartan Lake Area (43)	153
Thunder Bay Amethyst Mine Panorama (45)	159
Walkinshaw Creek Area (47A and B)	168
5.0 CONCLUSIONS AND RECOMMENDATIONS	171

6.0 BIBLIOGRAPHY	176
APPENDIX I	182
APPENDIX II	185
CONVERSION TABLE	197

LIST OF FIGURES

Figure 2-1: Location map for the project area.	7
Figure 2-2: Geology of the Lake Superior Region.	8
Figure 3-1: Stability relations within the SiO ₂ field.	20
Figure 3-2a: Common forms in quartz.	24
Figure 3-2b: Dauphine twin.	24
Figure 3-2c: Brazil twin.	24
Figure 3-3: The electromagnetic spectrum.	26
Figure 3-4a: Frenkel and Schottky defects.	29
Figure 3-4b: Irradiation of hole and electron precursors.	29
Figure 3-5: Schematic diagram illustrating energy levels within a molecular structure.	30
Figure 3-6: Schematic representation of the structure of quartz and the formation of a smoky quartz colour centre.	33
Figure 3-7: General geologic map of the major amethyst occurrences of eastern North America.	39
Figure 4-1: Geology of the Barrett occurrence.	82
Figure 4-2: Plan view of the Blue Points amethyst mine.	88
Figure 4-3: Quarry face, Blue Star Resources Ltd.	92
Figure 4-4: Plan view of the Diamond Willow amethyst mine.	101
Figure 4-5: The Little Bear amethyst quarry and the Little Bear amethyst mine.	116
Figure 4-6: Ontario Gem Company Ltd. mine.	141
Figure 4-7: The north pit, Pearl Lake mine.	148
Figure 4-8: The main vein, Tartan Lake area, plan view.	158
Figure 4-9: Plan view of the Thunder Bay amethyst mine pit.	165

LIST OF PHOTOGRAPHS

Photo 4-1:	Large, well-developed amethyst crystals in an exposed vug, Thunder Bay Amethyst Mine Panorama.	53
Photo 4-2:	Very large vug formed at the intersection between a NNW trending fault and a N-S fault, Pearl Lake Amethyst Mine.	54
Photo 4-3a:	Thunder Bay Amethyst Mine Panorama, facing northwest.	56
Photo 4-3b:	Pearl Lake Amethyst Mine, south end, facing west.	57
Photo 4-3c:	The Diamond Willow Amethyst Mine, facing west.	58
Photo 4-4a:	Angular fragments of Sibley Group mudstone, Diamond Willow Mine.	59
Photo 4-4b:	Breccia consisting of granitic fragments, Pearl Lake Amethyst Mine.	60
Photo 4-5:	Exposed vug in breccia zone, showing dark purple amethyst crystals lining the vug, Blue Star Resources amethyst quarry.	62
Photo 4-6a:	Zoned amethyst vein, Pearl Lake Amethyst Mine.	66
Photo 4-6b:	Sample from Ontario Gem Amethyst Mine showing roses of orange barite crystals growing on top of purple amethyst druse.	67
Photo 4-7a:	Amethyst sample exhibiting several generations of quartz and amethyst deposition.	68
Photo 4-7b:	Sample from the Thunder Bay Amethyst Mine Panorama showing several generations of amethyst crystallization.	69
Photo 4-8a:	Large, well-zoned amethyst crystals from the Grieve's amethyst quarry.	70
Photo 4-8b:	Lighter coloured amethyst crystallizing on the rhombohedra of earlier-formed, darker amethyst crystals, Grieve's amethyst quarry.	71
Photo 4-9:	Well-formed, dark purple, amethyst druse, Ontario Gem Amethyst Mine.	73
Photo 4-10:	A vein of large amethyst crystals which has formed between the host granite wall-rock on the left and the breccia zone, now mined out, Thunder Bay A Amethyst Mine Panorama.	74

Photo 4-11a:	Sample from T. Twomey amethyst occurrence showing beautifully-formed amethyst crystals of a very pale violet colour with a touch of darker purple inside each rhombohedron, giving each crystal a "shadow" effect.	75
Photo 4-11b:	Sample from G. McLeod's quarry, displaying amethyst so dark it appears black.	76
Photo 4-12:	Large amethyst crystals covered by a layer of brick-red hematite inclusions in silica.	78
Photo 4-13:	J. Barrett quarry, east end, facing south-east.	81
Photo 4-14a:	View facing east of the Blue Points Amethyst Mine, taken from the Diamond Willow Mine.	63
Photo 4-14b:	Quartz vein in Sibley mudstone at the Blue Points Amethyst Mine.	64
Photo 4-15:	Blue Star Resources quarry, facing south-west.	91
Photo 4-16a:	Diamond Willow Amethyst Mine, west end, facing west.	96
Photo 4-16b:	Gunnar Noyes quarry, the original pit on the Diamond Willow and Blue Points properties.	97
Photo 4-16c:	Shop and picking tables, Diamond Willow Mine.	100
Photo 4-17:	Dorion Amethyst Mine shop and picking tables as they were before the mine closed.	104
Photo 4-18:	Dzuba Ancliff occurrence, showing the breccia and silicified Sibley mudstone.	107
Photo 4-19:	Shop at the Little Bear Amethyst Quarry.	114
Photo 4-20a:	Breccia zone exposed along the side of a granite ridge at the Grieve's amethyst mine.	121
Photo 4-20b:	Large amethyst crystals, M. Grieve's amethyst quarry.	122
Photo 4-20c:	Silica flooding in granite, Grieve's amethyst quarry.	124
Photo 4-21a:	Tile, 1 ft x 1 ft x 2 in, made from breccia taken from the Ontario Gem Mine, displaying the variety of lithology types and fragment sizes.	137
Photo 4-21b:	Stromatolites lying unconformably on Archean granite, Ontario Gem Mine.	138

Photo 4-21c: Large amethyst vug, Ontario Gem Mine.	139
Photo 4-22a: Rock shop and amethyst display area, Pearl Lake Amethyst Mine.	144
Photo 4-22b: Large cobbles near the bottom of the conglomerate unit, Pearl Lake Amethyst Mine.	145
Photo 4-23: Massive druse of light purple amethyst, D. Bak occurrence.	151
Photo 4-24a: Stripped area exposing quartz veining, breccia and amethyst in vugs, Tartan Lake occurrence.	155
Photo 4-24b: Green amethyst crystallizing on darker, purple amethyst, Tartan Lake occurrence.	156
Photo 4-25a: Aerial view of the Thunder Bay Amethyst Mine.	162
Photo 4-25b: Thunder Bay Amethyst Mine Panorama.	163
Photo 4-25c: Exposure of new amethyst-filled vugs, eastern part of the quarry, Thunder Bay Amethyst Mine Panorama.	164
Photo 4-26: Amethyst vein in granite, Walkinshaw Creek occurrence.	170

TABLES

Table 1: Amethyst Occurrences

189

MAPS

Map A.	Geology and Amethyst Occurrences of the north part of McTavish Township	back pocket
Map B.	Geology and Amethyst Occurrence of MacGregor Township and Tartan Lake area	back pocket
Map C.	Thunder Bay Area - West	back pocket
Map D.	Thunder Bay Area - East	back pocket
Map E.	RosSPORT Area	back pocket

ABSTRACT

This project was instigated to compile the already known geology of the amethyst occurrences in the Thunder Bay area and to stimulate marketing of Thunder Bay amethyst.

Amethyst has a history of being an important mineral in ancient times. The word, amethyst, comes from the Greek, meaning "not-drunken". Powers attributed to the mineral encompass everything from meditation to curing illnesses, increasing intelligence and protection from harm. The mineral is worn as a gemstone by royalty and religious orders.

Early exploration for copper and silver in the north shore of Lake Superior region marked the first documented exploitation of the amethyst deposits. As early as the mid-1860's, amethyst was being mined from this area and sold in Toronto. Amethyst mining eventually grew into a small industry and Ontario amethyst became a featured commodity. In 1975, the Government of Ontario named the mineral the Provincial Mineral Emblem.

Amethyst is a form of quartz. The purple colour requires several phenomena to occur during the crystallization of quartz. Amethyst requires a silica saturated system and there must be ferric iron in the silica solution available to the quartz as it crystallizes. The iron in substitution for silicon provides the electron instability required for formation of a colour centre. Energy to make the colour centre comes from radioactivity in the surrounding rocks after the quartz has crystallized. Further hydrothermal activity will bleach already existing amethyst to a green or yellow colour. Amethyst must be able to crystallize in uncompleted space. This requires open veins systems, fractures, or vugs, indicative of structurally high levels of crystallization activity.

The geology of the Thunder Bay area has all the ingredients for amethyst to occur. The fracturing associated with the mid-continental rift has provided a comprehensive fracture system for fluid migration. The thick piles of Proterozoic sediments and volcanics are a potential source for hydrothermal fluids and for iron and possibly for the silica. The unconformity between the Archean and Proterozoic and the Archean granitoid rocks have enough radioactive minerals to provide the necessary energy for the development of colour centres in the quartz.

The gemstone industry is unusual in that some of the stiffest competition comes from enhanced or falsified gems. In order to participate in this industry, it is important to understand the enhancement treatments now widely used and the legalities involved.

1.0 INTRODUCTION

1.1 Purpose of Study

Amethyst has been a small industry in the Thunder Bay area for the latter half of this century. Through the years the staff of the Resident Geologist's office in Thunder Bay have collected information on the occurrences as they become known and developed. This project was developed to consolidate the collection of geological information on file. This includes all the information in the files in the Thunder Bay Resident Geologist's files, guidebooks, and reports. New information to update the files was obtained from geological mapping. The second part of the project focused on developing a marketing strategy for those people currently in the amethyst industry and through a public relations program attempted to increase the awareness of Thunder Bay amethyst on a provincial level.

1.2 History of Amethyst

The name amethyst comes directly from the Greek word "amethystos", meaning not-drunken. Greek legend relates the story that the god Dionysus, angered at an insult, vowed to set tigers on the first person he encountered. This person happened to be Amethyst, a young girl on her way to the shrine of the goddess Diana. Attacked by the tigers, the girl cried to Diana,

and the goddess turned her into rock crystal to protect her. Ashamed at his display of anger, Dionysus poured an offering of wine to the rock-crystal-maiden, turning the crystal a purplish colour. This legend fostered the belief that amethyst would prevent drunkenness, thus the Greeks drank their wine from amethyst cups.

Other powers were attributed to amethyst as well. The stone was believed to control evil thoughts and to promote love. It was believed to increase intelligence and shrewdness in business. Amethyst had the power to protect soldiers from harm and to assist hunters. The wearer of amethyst would be protected from contagious diseases.

Amethyst is mentioned in the book of Exodus in the Bible. It was one of the 12 gems used as decoration on the breastplate of a particular high-priest. The ring of 12 stones was based on the zodiac, and those stones are known today as the 12 birthstones. Amethyst is the birthstone for Pisces, or the month of March. Saint Valentine wore an amethyst ring, and to this day amethyst is a part of Vatican jewellery.

The first mineralogists worked for royalty, verifying that the crown jewels were actually gems and not fakes. By the 16th century, physical properties of minerals were the criteria used to differentiate true gemstones from a look-a-like mineral. The

first actual study on the subject was Georgius Agricola's "De Natura Fossilum". It was in this publication that Agricola mentions that amethyst is similar in habit to quartz (Hassan 1972). It was not until the beginning of the 19th century that amethyst was explicitly identified as a variety of alpha-quartz.

By the 17th century, some of the myths surrounding gemstones began to lose credibility. The work of physicist Robert Boyle on the properties of gemstones discounted the usefulness of gemstones for medicinal purposes. Scientific techniques to separate gem minerals on the basis of physical principles such as density, static electricity, and hardness became popular in the 18th century. By the 19th century, optical properties of minerals were documented, providing a non-destructive method for identification. The 19th century also heralded the advent of gem manufacture. Mineralogists experimented with crystals grown in laboratory conditions and gemstones enhanced by artificial means.

1.3 History of Thunder Bay Amethyst and Silver Mining

Early reports from explorers and missionaries posted along the north shore of Lake Superior mention use of amethyst and copper by native people. Dwindling ore reserves from Bruce Mines, the first copper mine in Ontario, increased exploration efforts for

more copper which led to the discovery of silver veins in the Thunder Bay area. From 1840 to 1850, the Thunder Bay area was systematically surveyed by parties from several mining companies, notably the Montreal Mining Company. In 1845, Colonel Prince found silver on Spar Island, now known as the Prince Location (McWilliam undated; Tanton 1931). In 1868, the rich veins of the Silver Islet mine were discovered, and in 1883, silver was discovered in the area west of Thunder Bay. The business of supplying the Rabbit Mountain, Beaver, Silver Mountain, and other silver mines in the region just west of Thunder Bay required a road system and railway into the area. Small towns once prospered at these sites, and the prosperity of the towns Port Arthur and Fort William grew.

The mines tended to be small, lasting 1 or 2 decades. Amethyst was an associated mineral in most of the mines, and attracted the interest of a few prospectors. In the early 1860's, the McEachern brothers prospected for amethyst in the Thunder and Black Bay areas. In 1862, they actually mined 2 tons of amethyst crystals which they barged to Toronto, to sell in that city. About the same time, a shipment of amethyst from the Thunder Bay area was sold in Montreal. The success of the mineral as a valued item for sale even in an unprocessed state and the ease of mining encouraged other prospectors and developers to try searching for and producing amethyst.

The Amethyst Harbour area was mined in the late 1880's, with samples marketed in Niagara Falls and noted tourist spots in the U.S. The discovery and export of high-quality, inexpensive amethyst from Brazil dampened interest in amethyst from the Thunder Bay area. It was not until the mid 1900's that amethyst was once again produced from local occurrences.

The occurrence which became known as the Thunder Bay Amethyst Mine Panorama was originally discovered in 1935 by enthusiastic fishermen. When the fire tower was built in the 1950's, near Elbow Lake in McTavish Township, the large amethyst veins were uncovered by the roadbuilders. In the early 1960's, the area was staked, and trenches exposed the veins in what is now the open pit for the mine.

The discovery and development of the Thunder Bay mine led to increased interest in that area of McTavish Township. Prospectors attracted to the potential of the purple mineral discovered more showings east of the Thunder Bay mine and by the late 1960's a fledgling amethyst industry had been born again in the Thunder Bay area. The industry became successful to the extent that in 1975 the Ontario government named amethyst as the mineral emblem for the Province of Ontario.

2.0 REGIONAL GEOLOGY

Amethyst in the Thunder Bay area is associated with a series of vein systems which host silver, lead, and zinc mineralization along with barite, calcite, fluorite and quartz. The vein systems occur within Archean rocks of the Quetico and Wawa subprovince (Superior Province) and Proterozoic rocks of the Animikie and Sibley Groups and the Keweenawan Supergroup (Southern Province). Regional geology and structure of the Southern Province has been described by Card et al. (1972); Sims et al. (1981); and Wallace (1981). Detailed geology and mineral occurrences for specific regions within the Proterozoic of Lake Superior have been described by: Tanton (1931); Franklin (1970, 1978); Franklin and Mitchell (1977); Franklin et al. (1980); Franklin et al. (1986); McIlwaine (1971, 1972). A good summary of the regional geology is presented in the Geology of Ontario, volume 1, by Sutcliffe (1991).

2.1 Regional Geology and Tectonic Setting

The area of interest for this project extends from just east of Lake Nipigon to west of Kakabeka Falls, and from Lake Superior to a line extending from the edge of the Gunflint Formation to Hurkett. Both Archean and Proterozoic rocks underlie this area (Figure 2-1).

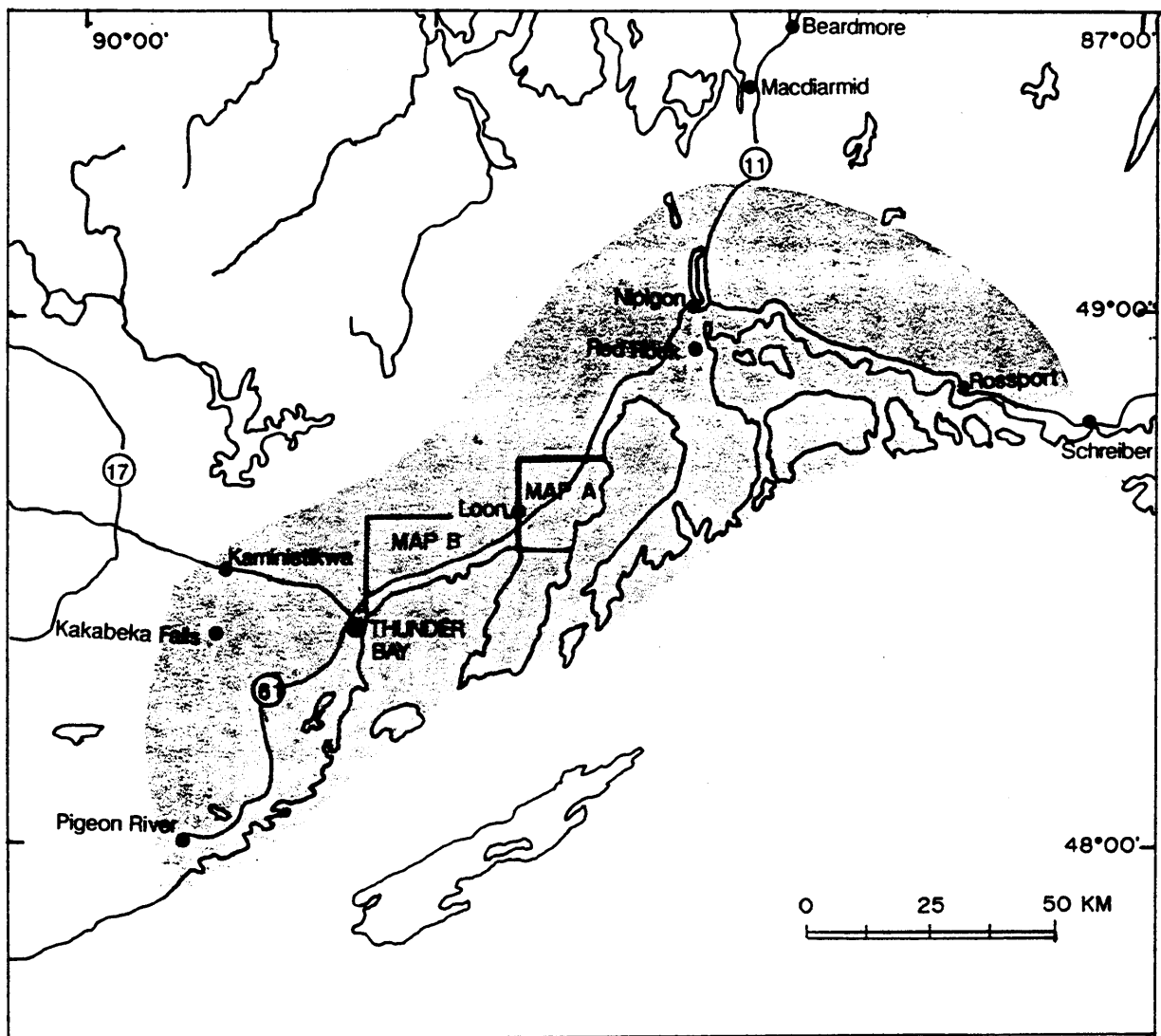


Figure 2-1: Location map for the project area (shaded). Map A and B are in the back pocket.

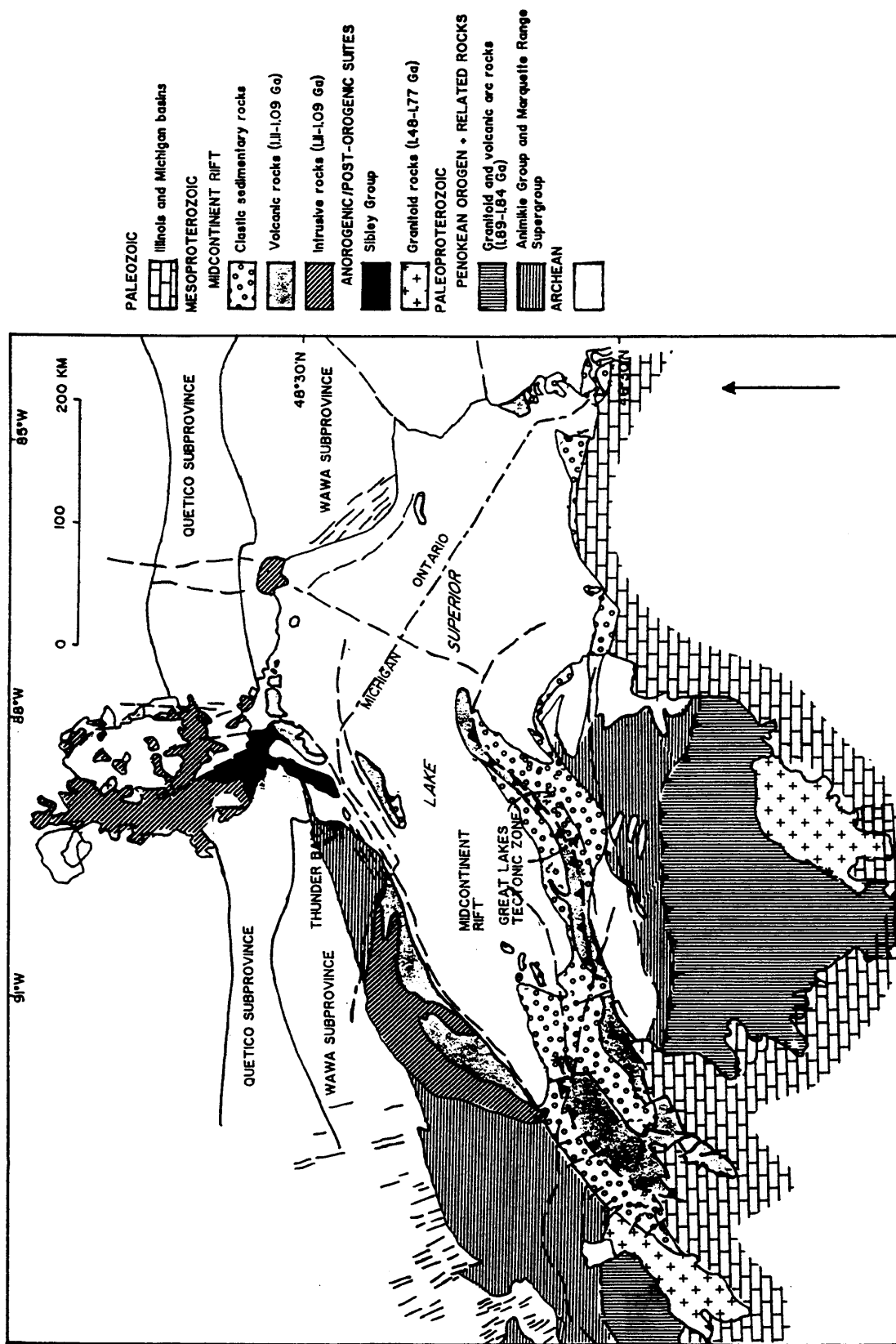


Figure 2-2: Geology of the Lake Superior region. Modified from Hoffman (1989), Franklin et al. (1982), and Sutcliffe (1987).

The Archean rocks fall into 2 categories: rocks belong to either the Wawa or Quetico Subprovinces of the Superior Province (Figure 2-2). Rocks of the Wawa Subprovince are part of the Shebandowan greenstone belt. These consist of an arcuate assemblage of basalt flows, felsic tuffs, metasediments, and granitic and syenitic intrusions (Williams et al. 1991). The Quetico Subprovince consists of a series of highly metamorphosed metasedimentary rocks which mantle a central core of granitic and migmatitic rocks (Scott 1987). The Quetico subprovince structurally overlies the Wawa Subprovince to the south (Williams (1991). In the area defined for this project, the Archean rocks form a band of volcanic, metasedimentary, and granitic rocks which separates the Proterozoic rocks into 2 areas.

The Proterozoic rocks in the Lake Superior region belong to the Southern Province (Card et al. 1972) (Figure 2-2). These rocks lie unconformably on rocks of the Archean Wawa and Quetico subprovinces. At least 3 distinct events in the Paleoproterozoic and Mesoproterozoic have been identified (Sutcliffe 1991), starting with deposition of the Animikie Group sediments from 2200 to 1900 Ma ago, prior to and during the Penokean Orogeny at 1860 Ma (Sims 1981). The next event, during the Mesoproterozoic at 1540 Ma, resulted in anorogenic granitic and anorthositic intrusions (Van Schmus et al. 1975; Sutcliffe 1991), followed by deposition of the Sibley Group sediments (Sims et al. 1981). The last, and main tectonic event, was the Mesoproterozoic mid-

continental rifting at 1110 to 1090 Ma (Sutcliffe 1991). Associated volcanism and sedimentation formed the Keweenaw Supergroup (Wallace 1981; Cannon 1989).

Animikie Group sediments were deposited in an east-trending basin on the Archean platform, forming a southward thickening wedge which now occupies parts of Ontario, Minnesota, Wisconsin and Michigan. The midcontinent rift separates the Animikie Basin into a southern and northern segments resulting in different formational names being attached to rocks of similar time-stratigraphic units. The southern segment rocks are part of the Marquette Range Supergroup (Cannon and Gair 1970). The Animikie Group and Mille Lacs Group belong to the northern segment (Morey 1973).

South of the Great Lakes Tectonic Zone, which separates Archean gneissic from greenstone-granitoid terranes, Animikie Group rocks were deformed during the Penokean Orogeny (Sims et al. 1980). On the north side, rocks of the Animikie Group are relatively undeformed, forming a homoclinal sequence with a persistent southward dip of from 2 to 5° south (Card et al. 1972). The Duluth Complex, a gabbro intrusive, further subdivides the Animikie Group, and different formational names have been applied to the western and eastern parts. The western part, occurring in Minnesota, contains the Mesabi and Cayuga iron ranges. The

eastern part, situated in Ontario, contains the Gunflint Formation and overlying Rove Formation.

The Gunflint Formation consists of a lower unit up to 15 m thick of a gravelly basal conglomerate, sometimes referred to as the Kakabeka conglomerate (Sims et al. 1981), taconite, algal stromatolites, chert-carbonate, and argillite sediments (Scott 1987). The Rove Formation consists of a lower part of black, pyritic shale. This grades upward into interbedded shale and arkosic greywacke deposited by turbidity currents (Geul 1973). In the project area, rocks of the Gunflint and Rove Formations occur extensively to the west of the city of Thunder Bay and as a thin strip along the shore of Lake Superior. The Rove Formation is exposed along the western side of the Sibley Peninsula, at the base of cliffs formed by the Sibley Group sediments.

The Mesoproterozoic Sibley Group, dated at 1339 Ma (Franklin et al. 1982), is a red bed sedimentary sequence (Franklin et al. 1980) exposed on the Sibley Peninsula and south of Lake Nipigon. The sediments are preserved in a fault-bounded, north-trending basin, deepening to the east and south to a maximum thickness of 420 m (Ojakangas and Morey 1982).

The Sibley Group is divided into 3 formations. The lowest unit is the Pass Lake Formation, lying unconformably on the Animikie Group sediments (Franklin et al. 1980). An excellent example can

be seen near the railway tracks at Pass Lake. To the north of the Sibley Peninsula, the Pass Lake Formation unconformably lies on Archean rocks of the Quetico Subprovince (McIlwaine 1971). The Pass Lake Formation consists of quartz arenite with lenses of conglomerate which formed as immature fans along the base of the unit (Franklin and Mitchell 1977). The arenite contains approximately 15% matrix, composed of dolomite, calcite, and minor barite (Franklin and Mitchell 1977).

The Rossport Formation unconformably overlies the Pass Lake Formation. The Rossport Formation is approximately 152 m thick, including an upper and lower member of dolomite, and a thin central chert carbonate and stromatolitic dolomite member (Franklin and Mitchell 1977). Hematite, which forms 2% of the rock, is the cause of the striking red colour of the dolomite.

The Kama Hill Formation, the uppermost member of the Sibley Group, is transitional from the Rossport Formation. It consists of red shale and mudstone, is thin (10 m), but extensive laterally (Franklin and Mitchell 1977). The Formation is characterized by fine silt-sized particles, a red to purple colour, distinct sedimentary structures and features indicative of deposition in shallow water to partially evaporitic environment.

Rocks of the Keweenawan Supergroup were deposited in and marginal

to the midcontinental rift system from 1000 to 1300 Ma (Wallace 1981). This rift, initiated as an arcuate system of axial faults, occupies a belt over 2000 km long in central North America (Chase and Gilmer 1973). Originally hypothesized as a series of en echelon linear segments (King and Zietz 1971), seismic reflection studies have shown that the rift is a system of linked half-grabens of alternating structural polarity (Cannon et al. 1989). The rift acted to focus cycles of magmatic activity and the graben structures controlled deposition of thick sequences of sediments. The original normal faults were later reactivated as high-angle reverse faults, resulting in late uplift of the central graben. Alkalic intrusions were emplaced along major fracture zones associated with the rifting (Wallace 1981). Rift development, based on the seismic profiles (Cannon et al. 1989), are summarized into three stages. The earliest stage of rift development is characterized by wide-spread volcanism, basin development due to crustal downwarping, and subordinate normal faulting. The second stage of rift development, characterized by crustal extension and thinning, resulted in the development of a fault-bounded central graben. Deposition of volcanic and sedimentary rocks were controlled by the developing graben structure. The late stages of rifting were dominated by thermal collapse, termination of volcanism, and the beginning of major sedimentation. Crustal compression resulted in steepening of the sides of the basin and reactivation of the boundary faults as reverse faults.

2.2 Metallogeny Related to Regional Geology

An interesting array of metallic minerals are associated with the Proterozoic rocks in the Lake Superior area. These include: hydrothermal copper breccia pipes (Thomson 1954, Blecha 1965, Grunsky 1991) and red-bed copper mineralization; silver-sulpharsenide hydrothermal veins (Franklin and Mitchell 1977, Franklin et al. 1986); magmatic copper-nickel-platinum group sulphide mineralization associated with mafic intrusions (Geul 1973); uranium veins associated with the unconformity between the Sibley Group and Archean rocks (Scott 1987); niobium-uranium mineralization associated with the Prairie Lake carbonatite; and iron from the Mesabi and Gunflint iron ranges. Past producers of copper and silver in the Thunder Bay area were instrumental in turning Thunder Bay into a thriving community from the original isolated fur-trade outpost. There are currently no producing metal mines in the Proterozoic rocks, but amethyst is produced from veins near Thunder Bay, and there is potential for platinum group elements in the alkalic and gabbroic complexes. Building stone and other industrial minerals are commodities of interest in both the Archean and Proterozoic rocks.

Native copper nodules in the Keweenawan basalts were easily retrieved and used by early populations of native peoples. Recognized by Jesuits and early traders as valuable, interest in copper resulted in exploration for the metal. Construction of

the Bruce Mines copper smelter on Lake Huron provided access to a refinery within shipping distance on the Great Lakes. Production of copper from the Upper Peninsula of Michigan, Mamainse Point area, and Michipicoten Island in the late 1800's fuelled exploration interest in the north Lake Superior area. The 1845 expedition under Colonel Prince to the Thunder Bay area led to the discovery of silver on Spar Island, near Thunder Bay.

Production of silver from the Prince Mine on Spar Island and copper from the east side of Lake Superior resulted in increased interest in the mineral potential of the Superior area. In 1868 the Ontario government passed a series of regulations to licence prospectors, fix claim boundaries, and relinquished the right to retain silver and gold for the Crown. The Montreal Mining Company decided to survey its vast land holdings in the Superior area. The survey team documented the Thunder Bay and Shuniah silver mines discovered by Peter McKellar and the Prince Mine. They proceeded to discover a silver vein on Jarvis Island and on Silver Islet. The Silver Islet vein went on to become the richest silver mine in history.

The silver veins in the Thunder Bay area are divided into three groups, each of which has a distinct geological setting: 1) the Mainland veins; 2) the Island veins; and 3) the Coldwell veins (Franklin 1970, Franklin et al. 1986). The Mainland and Island group veins are spatially associated with the Rove shale of the

Animikie Group (Franklin et al. 1986).

The veins in the Mainland group occur within a fault zone that forms part of the boundary separating Archean and Proterozoic rocks. The veins strike parallel to the main trend of the fault zone, an east-northeast direction. Most of the veins are in the lower part of the Rove Formation and upper Gunflint Formation, but a few have been documented to extend downward into the Archean and upward into the Logan diabase (Franklin et al. 1986). The richest veins are located in the Rove shale. The Mainland group veins are mineralogically simple, containing copper, zinc, lead, and silver with calcite, quartz, fluorite and barite. Alteration adjacent to the veins consists of silicification of the shale and hydration of the diabase (Franklin et al. 1986).

The Island group veins occur in a northeast-trending belt parallel to the shore of Lake Superior. The veins are hosted in both the upper Rove Formation and gabbroic dykes. The dykes also trend in the northeast direction but the veins strike north, perpendicular to the dykes. Veins in the Rove Formation tend to have lower silver values than those in the gabbroic dykes (Franklin et al. 1986). The metal assemblage has been coined "5-element" (Oja 1967), consisting of silver, cobalt, nickel, arsenic, and bismuth, in sulpharsenide minerals. The silver-deficient veins in this group are composed of calcite with barite, sphalerite, and chalcopyrite. The silver-rich veins

have a complex sulphosalt-sulphide native silver assemblage with quartz, barite and fluorite (Franklin et al. 1986).

The silver veins near Port Coldwell, called the Coldwell group, are hosted by Archean metasedimentary rocks (Franklin et al. 1986). There has been no silver production from these veins.

Magmatic copper-nickel-platinum group mineralization is associated with the marginal zones or anorthositic phases of gabbroic intrusions (Geul 1973). Deposits in the Crystal Lake Gabbro and the Pine River-Mount Mollie Gabbro have been explored for nickel and more recently for platinum group mineralization (Geul 1970, Postle et al. 1986). The Crystal Lake Gabbro is a Keweenawan layered intrusion, intrusive into the Animikie Group sediments. The Pine River-Mount Mollie Intrusion is a composite, northeast-trending dyke with sulphide mineralization along the margins (Geul 1970). A copper and platinum group element deposit occurs on the eastern margin of the Port Coldwell alkalic complex, hosted in pegmatitic gabbro (Dahl et al. 1986).

Uraniferous veins associated with fault and fracture systems occur proximal to the Archean-Proterozoic unconformity and are similar in type to the uranium deposits in the Athabaska basin in northern Saskatchewan (Scott 1987). Areas where the Sibley Group

sediments lie directly on the Archean are good prospects for uraniferous veins.

The Prairie Lake carbonatite is one of a series of alkalic complexes intruded along zones of major faulting. The complex, located between Terrace Bay and Marathon, contains deposits of uranium, niobium, phosphate and wollastonite (Scott 1987). The complex has been extensively explored for uranium, niobium, phosphates, and wollastonite.

Iron ore has been produced from the Mesabi Iron Range in the Marquette Range Supergroup in Minnesota. Magnetite taconite iron formation occurs in the Gunflint Formation of the Animikie Group, but there has been no commercial production from the Gunflint taconite on the Canadian side of the border.

3.0 AMETHYST MINERALOGY

3.1 Amethyst/Quartz

Amethyst is a variety of quartz. Quartz is one of the most abundant minerals, occurring in a variety of forms. The common silica polymorphs are listed as follows: alpha- and beta-quartz, alpha- and beta-tridymite, alpha- and beta-cristobalite, coesite and stishovite (associated with meteorites), keatite (a high-pressure, synthetic phase), silica glass, and cryptocrystalline silica (chalcedony). Quartz, tridymite, and cristobalite are the three crystalline forms, and have distinct crystal structures and well-defined stability fields (Figure 3-1). Transformations from one form to another tend to be slow, enabling the higher temperature forms, cristobalite and tridymite, to exist metastably below their inversion temperatures. Quartz, tridymite, and cristobalite have high- and low-temperature modifications, designated alpha- and beta- respectively. At atmospheric pressure and in a dry system, quartz is the stable form up to 867°C, tridymite is stable from 867°C to 1470°C, and cristobalite from 1470°C to the melting temperature at 1713°C (Berry and Mason 1959).

Amethyst is a variety of alpha-quartz, the low-temperature polymorph of quartz. The composition of quartz is very close to 100% SiO₂. Impurities result from small amounts of other

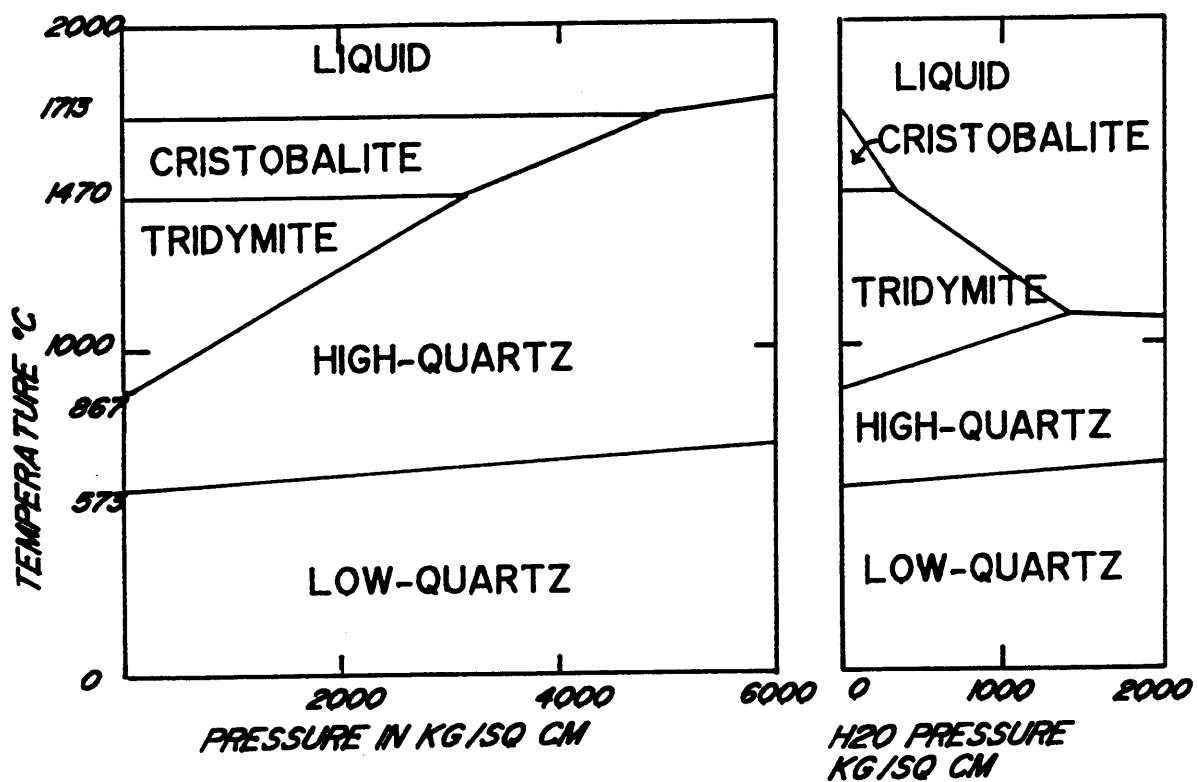


Figure 3-1: Stability relations within the SiO_2 field; dry system on the left and system under water vapour pressure on the right. Adapted from Berry and Mason (1959).

minerals as inclusions, liquid infillings in cavities within the quartz, or atomic substitution of the silicon $+4$ ion by aluminum $+3$. Aluminum substitution is usually accompanied by alkali ions lithium $+1$ or sodium $+1$ for charge balance. Unlike beta-quartz which belongs to the hexagonal system, alpha-quartz has trigonal symmetry. The 6-fold symmetry of the hexagonal system is reduced to 3-fold in the trigonal system and is manifest by the development of 2 sets of rhombohedra creating the 6 triangular faces terminating in an approximation of a point (Figure 3-2a). Each rhombohedron has its own capacity for growth and uneven development of crystal faces is common.

Both alpha- and beta-quartz exhibit enantiomorphism, meaning the mineral can form two crystals which are mirror images of each other, labelled right- and left-handed. This phenomenon is caused by improper crystallographic reflection across a plane and inversion through a point. The structure of alpha-quartz is similar to that of beta-quartz, but the SiO_4 tetrahedra are less regular and are rotated from their ideal positions. The tetrahedra are composed of a central silicon atom bonded to 4 oxygen atoms in tetrahedral coordination. Each tetrahedron shares a corner with an adjoining tetrahedron, forming a spiral around the vertical axis. This spiral arrangement can form as either a right- or left-handed screw thread giving quartz the enantiomorphic character (Figure 3-2a). It is this characteristic that causes quartz to be optically active; the

plane of polarization of light passing along the optic axis is rotated either clockwise or counterclockwise depending on whether the quartz is right- or left-handed.

Twinning in quartz is common and renders the crystal useless for optical or electrical purposes. The most common twin laws observed in quartz are the Brazil law, the Dauphine law, and the Japanese law.

Brazil twinning combines a right- and left-handed crystal in a complex penetration twin with $\{1120\}$ as the twin plane. Not observable in plane light, this twinning is detectable in polarized light due to the opposite rotation of the plane of polarization by each twin. The twinned crystal, seen in polarized light, will have alternating bands of light and dark in basal sections (Figure 3-2c).

Dauphine twinning combines 2 right- or 2 left-handed crystals with c as the twin axis. The horizontal striations on the prism faces, caused by incipient development of rhombohedral faces, are interrupted at an irregular line which marks the boundary between the twins. One set of rhombohedral faces (positive) on one twin coincides with the opposite set of rhombohedral faces (negative) on the other, resulting in an irregular line on the rhombohedral faces. This type of twinning reverses the direction of the a crystallographic axes rendering the crystal useless for electric

purposes. Recognizable in plane light by the irregular line on prism and rhombohedral faces, this type of twinning is not observed in polarized light since the crystals are twinned with identical optical properties (Figure 3-2b).

The Japanese twin law is named from the type location for these twins in Japan. This twinning combines 2 crystals in a contact twin with {1122} as the twin plane. The c crystallographic axes intersect at $84^{\circ}33'$ and one pair of prism faces is common to both crystals.

It has been noted by Sir David Brewster in 1821 that amethyst was almost exclusively twinned according to the Brazil law (Fron del 1962). Amethyst tends to crystallize in a simple habit with only the prism and 2 rhombohedra developed. These faces are designated m, r, and z respectively (Figure 3-2a). The dominate rhombohedron is r, colour is usually concentrated in the r growth sectors, and Brazil twinning occurs within the r sectors (Figure 3-2c).

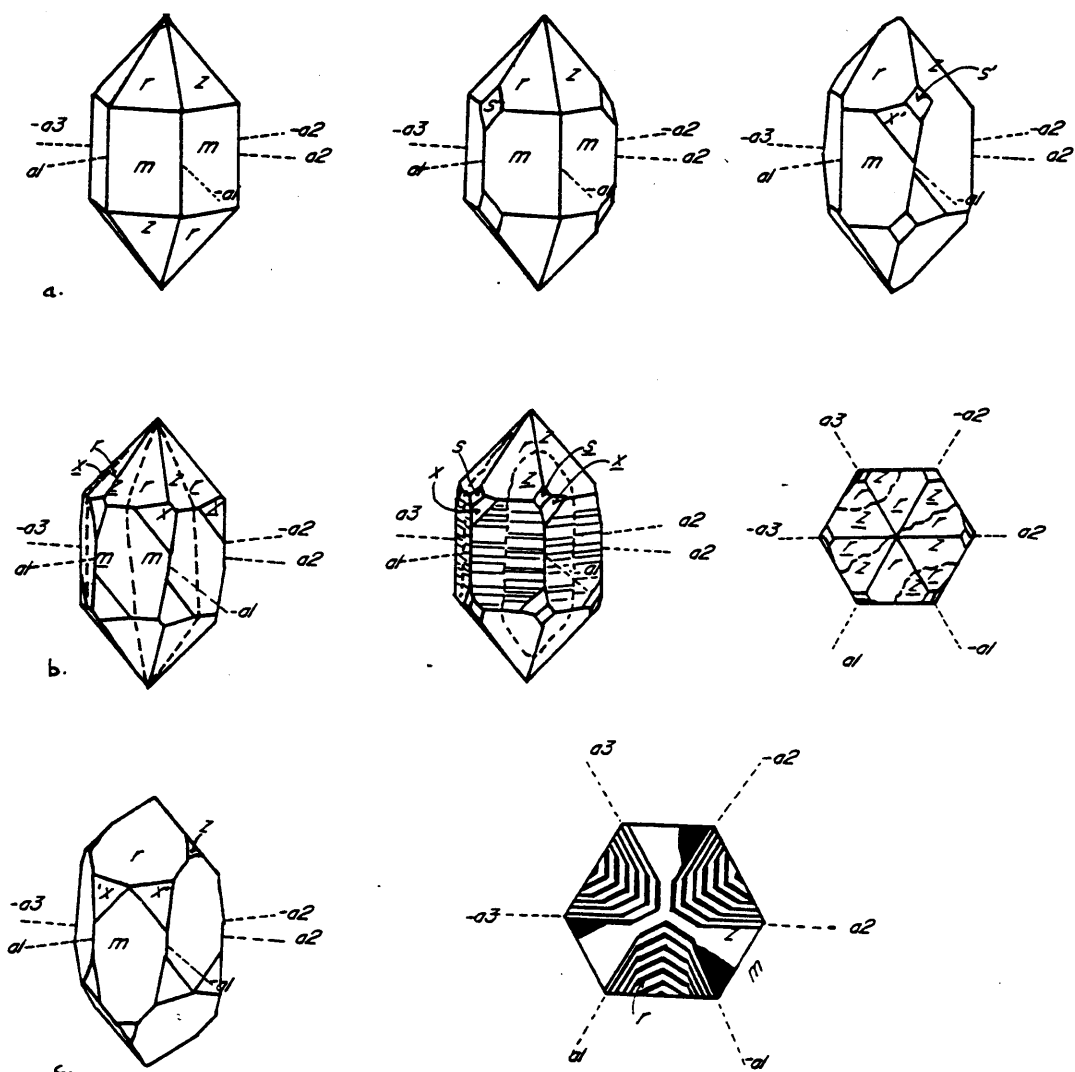


Figure 3-2: a) Common forms in quartz, showing the prism (m) and 2 rhombohedra (r and z), then with left trigonal pyramids (s), and with 2 rhombohedra, right trigonal pyramid, and right trigonal trapezohedron (x). b) Dauphine twin, twin axis c, interpenetration of 2 right-handed crystals on the left, and 2 left-handed crystals on the right. Plan view of the left-handed Dauphine twin. c) Brazil twin, twin plane {1120}, interpenetration of a right- and a left-handed crystal. Plan view of Brazil twinning in polarized light.

Modified from Berry and Mason (1959) and Schlossen and Lang (1965).

3.2 Colour of Amethyst

3.2.1 General Causes of Colour

Colour is not only a characteristic of an object, it is also a characteristic of light rays and a description of a class of sensations. Light and colour are the stimulants of vision, one of the most important human senses, and attempts to describe and explain these phenomena have occupied philosophers and scientists throughout history. The science of colour begins with Sir Isaac Newton's observations on spectral colours in 1672. Newton demonstrated with prisms that white light could be broken into a spectrum of different colours and recombined into white light, proving that white light is a combination of all colours.

Light is a form of energy and forms a small part of the electromagnetic spectrum. Visible light is contained in the part of the spectrum with wavelengths of 400 to 700 nanometres; longer wavelengths grade into infrared and shorter wavelengths grade into ultraviolet (Figure 3-3). Energy is not destroyed, instead it is converted into other forms of energy. Thus when light is absorbed by matter, part of its energy may appear as heat or vibrations of the constituent atoms, part of its energy may be converted into electronic excitations (fluorescence), or part of its energy may appear as electricity, potential chemical energy, or mechanical motion.

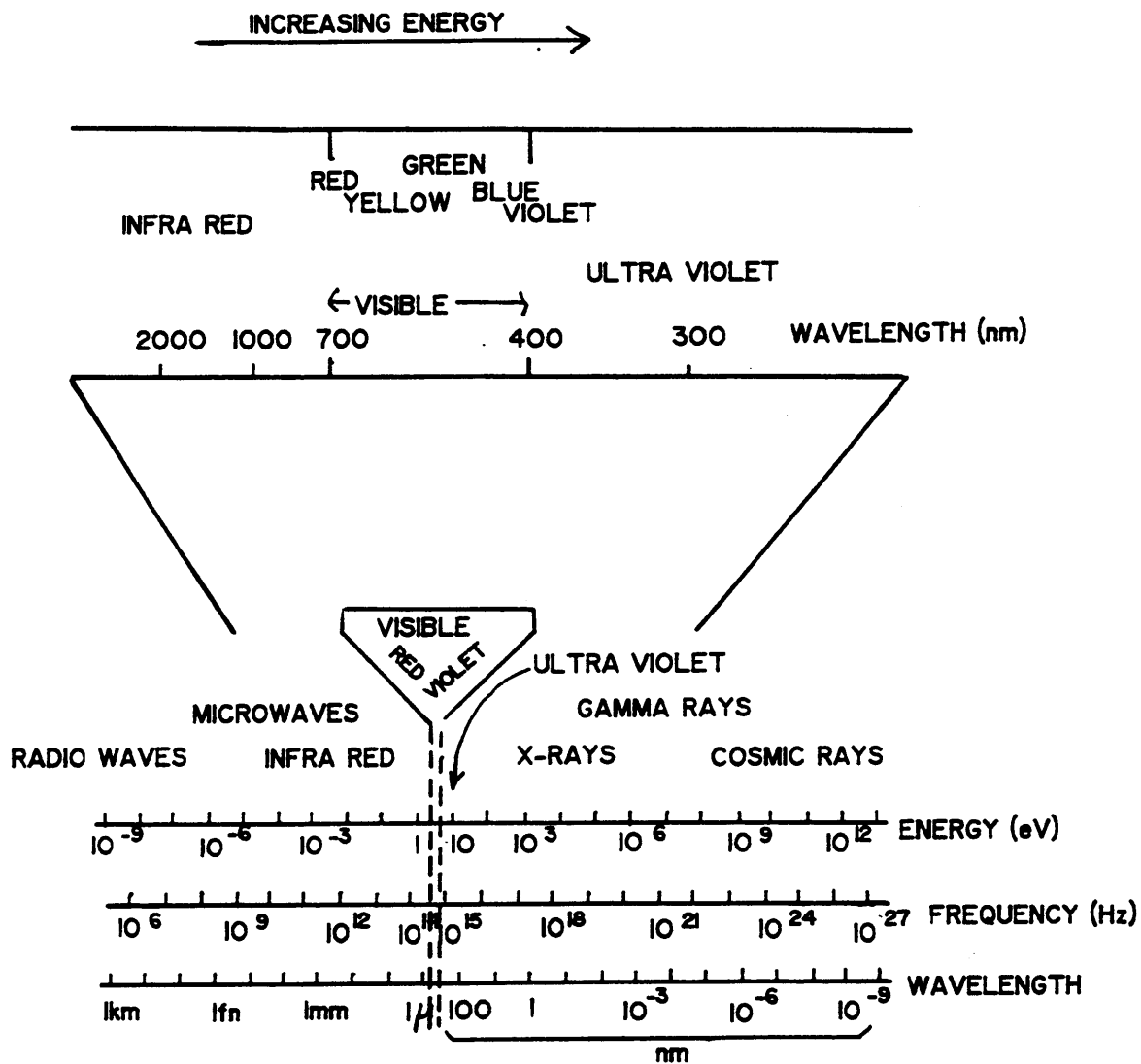


Figure 3-3: The electromagnetic spectrum. Modified from Nassau (1983, 1984).

An object appears to have a colour when light interacts with it. Some light is reflected directly from the surface in either a specular or mirrorlike reflection from a very smooth surface or a more diffuse reflection from a surface with some roughness. Some light is absorbed and may be scattered inside the material and some may be internally reflected and some may be transmitted. Whatever wavelength of light that is returned to the viewer's eye will determine the colour perceived by that viewer. Light absorbed by a material is manifest by increased heat, increased atomic or molecular vibrations and rotations, or transitions in energy bands within the molecular structure. Nassau (1983) has separated the selective absorption and emission of light by materials into 15 different effects resulting in colour. All involve the excitation of electrons.

3.2.2 The Concept of Colour Centres

Any crystal growing either naturally or synthetically contains a small number of defects in the crystal structure. There are two well-known defect arrangements in crystals, called the Frenkel defect and Schottky defect. The Frenkel defect consists of an ion displaced from its normal place in the crystal into an interstitial site. This displacement of an ion results in a vacancy and an interstitial ion. A Schottky defect consists of a pair of vacancies with no interstitial ion, because a pair of oppositely charged ions move to the surface leaving two spaces.

In either case there will be local areas within the crystal with positive or negative charges, but the crystal as a whole will remain electrically neutral (Figure 3-4a).

Apart from forming naturally in crystals as they grow, Frenkel or Schottky defects can be produced by energetic radiation. The more usual result is the formation of a displaced electron from an ion. When this electron is prevented from returning to its original position on the ion by entrapment in a relatively stable charge configuration, such as a Frenkel or Schottky defect, an F centre, either a hole or electron centre, is created (Figure 3-4b). It is the F centre which produces light absorption and imparts a colour to the crystal. Considered from the energy band view, excitation of an electron results in that electron changing energy levels, from the valence band to the conduction band. From the conduction band the electron is attracted to the halide vacancy (Frenkel or Schottky defect resulting from a halide ion) and is trapped in that vacancy by the surrounding cations (Figure 3-5) (Nassau 1983).

The transitions between the additional energy levels available between the vacancy and the conduction band produce light absorptions resulting in the particular colour of the colour centre. Heating reverses the formation process with the electron going from the colour centre back to the conduction band and then

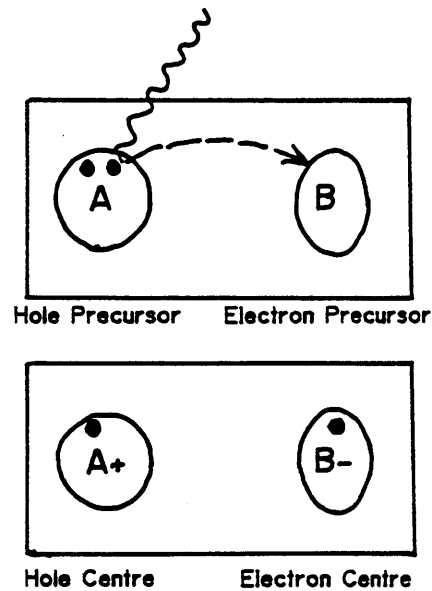
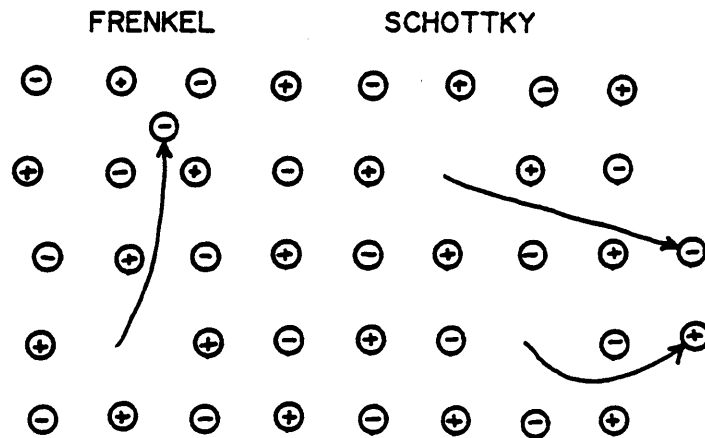


Figure 3-4: a. Frenkel and Schottky defects in an ionic crystal (schematic).
 b. Irradiation of hole and electron precursors to form hole and electron centres. Modified from Nassau (1983).

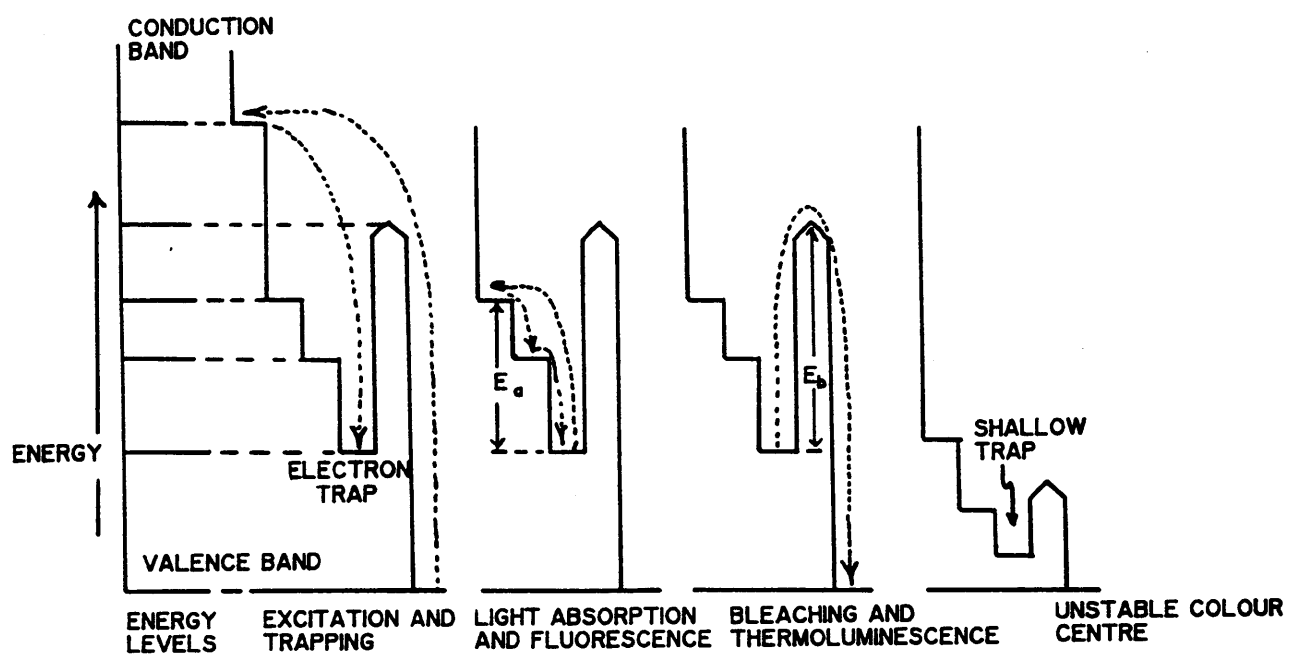


Figure 3-5: Schematic diagram illustrating energy levels within a molecular structure and formation of a colour centre, light absorption by a molecule, bleaching and an unstable colourcentre. Modified from Nassau (1983).

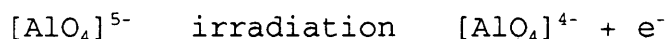
to the valence band. This is why colour due to the formation of colour centres can be bleached by heat.

The exact temperature required to cause bleaching is determined by the energy difference (E_p) between the halide vacancy trap and the conduction band (Nassau 1983).

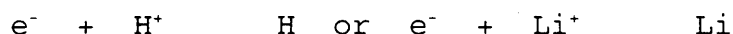
When the electron is present in a position where an electron is not normally found, the F centre is an electron colour centre. When the electron is missing from its normal position, a hole colour centre is created (Figure 3-4b). The properties of trapped hole and trapped electron colour centres are mainly related to the nearest neighbouring ions (Cohen and Makar 1982). In covalent silicates the hole centres are related to oxygen anions in tetrahedral coordination. Each tetrahedron can have none or all of its oxygen anions bound to neighbouring tetrahedra. In quartz, the tetrahedra must have at least one oxygen anion bound. The tetrahedra with unbound oxygen ions must have interstitial cations present for charge balance. The unbound oxygens are usually adjoining a trace cation substitutional for Si^{4+} , such as a 3^+ ion (Al^{3+} or Fe^{3+}) (Cohen and Makar 1982).

When an Al^{3+} replaces one of the Si^{4+} ions in quartz, there must be a proton H^+ in an interstitial site for charge neutrality. This is usually accomplished by the addition of an alkali such as

Li⁺ or Na⁺. The positive ion is usually located at some distance from the Al³⁺. If irradiation ejects an electron from one of the unbound oxygen anions adjacent to the Al³⁺ ion, this electron can be trapped by the cation, maintaining the oxygen minus one electron (Figure 3-6). This equation is usually written as the Al³⁺ cluster as follows:



with



The [AlO₄]⁴⁻ group absorbs light, producing the colour centre in quartz which results in the smoky colour (Nassau 1983).

If the substitutional cation is Fe³⁺ instead of Al³⁺ in the quartz, the colour of the quartz is pale yellow due to changes in the ligand field of the atomic structure. When the [FeO₄]⁵⁻ group is irradiated, the resulting [FeO₄]⁴⁻ colour centre absorbs light to produce the purple colour of amethyst (Nassau 1983). Heating bleaches the amethyst back to the original yellow colour by reversing the equations above. When Fe²⁺ is incorporated into the structure with 2 positive cations for charge balance, irradiation now ejects 2 electrons. The first electron converts Fe²⁺ to Fe³⁺ and the second forms the [FeO₄]⁴⁻ colour centre. Bleaching as a result of heating restores both electrons and the Fe²⁺ imparts a green colour to the quartz (Nassau 1983).

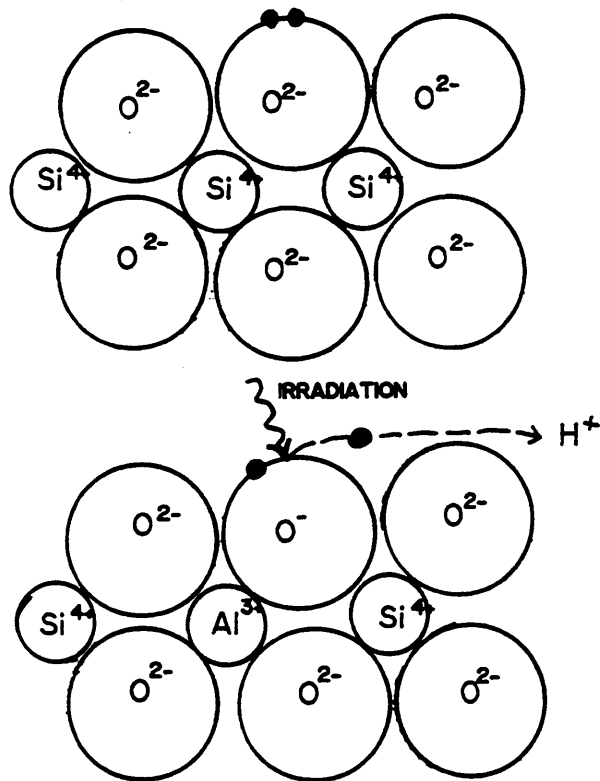


Figure 3-6: Schematic representation of the structure of quartz and the formation of a smoky quartz colour centre by irradiation. Amethyst colour centre requires an Fe^{3+} instead of the Al^{3+} ion. Modified from Nassau (1984).

3.2.3 History of research into Amethyst Colour

The popularity of amethyst as a gem throughout history and the unusual purple colour so different from other gemstones inspired a long history of interest in the mineral. Inorganic pigments, carbon particles, radium radiations, or trace amounts of iron or manganese were attributed to cause the colour of smoky quartz and amethyst. Work by Holden (1925) on the transmission versus the wavelength of light energy through a specimen of amethyst revealed that the maximum absorption was complementary to that of violet light. He also found that amethyst contains relatively large amounts of iron compared to white quartz and that the percentage of iron decreases as specimens become paler.

The combination of trace amounts of iron coupled with radiation energy to cause reduction of the iron was first hypothesized by Vedeneeva in 1940. Frondel in 1945 realized that the rhombohedral zonation of colour in amethyst was related to Brazil twinning in quartz. Early in the 1950's, the first quantitative spectroscopic study of amethyst produced a spectrum of the absorption bands and the effect of heat on the spectrum (Bappu 1952, 1953). Rose and Lietz (1954) produced a spectrum of "greened" amethyst from Brazil, and showed that the absorption bands were similar to those of heat-treated amethyst.

The method of exactly how the iron caused the purple colour in amethyst was still undetermined. Research by Raman and Jayaraman (1954) and Cohen and Sumner (1958) tackled the problem of the substitutional process and resulting symmetry changes within the quartz lattice. Cohen and Sumner (1958) recognized that Al^{3+} substitution for Si^{4+} in the quartz structure causes an increase in the lattice constants. The interstitial cations required to maintain charge neutrality fill the long channel spaces parallel to the c axis and cause expansion along the a axes. This phenomenon explained the biaxiality observed in amethyst when quartz is uniaxial. It also provided a mechanism to produce an electron transfer due to radiation. O'Brien (1955) explained the colour of amethyst was produced by a missing electron on an oxygen ion bonded to an aluminum ion in a tetrahedral site. The energy required to remove the electron was provided by radioactivity and the resulting "trapped-hole" or colour centre caused the purple colour. Cohen and Hassan (1970, 1974) furthered this hypothesis by attributing the colour to the Fe^{4+} ion, produced by ionizing radiation (Hassan and Cohen 1974).

The intricate relationship of colour distribution within amethyst to Brazil twinning and the channels present in the alpha-quartz structure began to be realized by work done by Cohen and colleagues in the 1980's (Adekeye and Cohen 1986; Cohen 1984, 1985, 1989). There is still interest in working with the colouring agents in amethyst for purposes of colour enhancement,

production of citrine and green amethyst, and improving the colour of amethyst gemstones.

3.2.4 Colour of Amethyst

As mentioned in section 3-1, the structure of alpha-quartz has 3 channels, parallel to the c axis, parallel to the a axes, and perpendicular to the rhombohedral faces. All the channels meet at one point on the basal plane. Schlossen and Lang (1965) showed that the iron content in alpha-quartz is highest in the basal plane, parallel to the twinning laminations. During hydrothermal growth of quartz in the presence of iron, Fe^{3+} is incorporated interstitially into the open channels in the alpha-quartz structure. From there substitution of the iron for aluminum occurs. Interstitial iron is found only in conjunction with the major rhombohedral faces (Adekeye and Cohen 1986). Cohen (1989) showed that there was a difference in the concentrations of iron and aluminum ions between the major and minor rhombohedral faces.

Substitutional iron forms the $[\text{FeO}_4]^{4-}$ colour centre required for the amethyst colour, interstitial Fe^{3+} in the channels perpendicular to the major rhombohedral faces produces Brazil twinning to relieve the strain of iron in the quartz lattice. Experiments with citrine quartz not related to Brazil twinning remained inert upon radiation. Citrine Brazil-twinning quartz

becomes amethyst when irradiated. Therefore it is common to see the major rhombohedral faces coloured amethyst and the minor faces either clear or citrine.

The colour of amethyst bleaches to yellow or green when heated. Heating provides energy for the trapped electron to jump to the conduction band and then return to the valence band (Nassau 1983). The bleaching effect starts at temperatures of 350°C (Cohen and Hassan 1974; McLean 1984). There has been speculation that amethyst fades in ultraviolet light present in sunlight, but there has been no conclusive data to show that sunlight can impart enough energy to reverse the ionizing effect on amethyst.

3.3 Commercial Production of Amethyst

3.3.1 Global Perspective of Amethyst Production

Amethyst has been used from early history, is referenced in the bible, but there is little information as to the sources of this early amethyst. As early as the 4th Century B.C., Theophrastus mentioned in his work "On Stones" that amethyst could be found inside certain rocks, but did not explain where these rocks were located. Hassan (1972) mentions that export of amethyst from Brazil began in 1727. Brazilian amethyst did not flood the North American market until early 1900's. Before the onslaught of

South American amethyst, the mineral was considered precious as opposed to semi-precious. For example, an amethyst necklace owned by Queen Charlotte of England was valued at L2000 in the early 19th century is now worth L100 due to the availability of amethyst (Bauer 1904; Vos 1976).

Speculation on what is considered to be valuable amethyst varies with the fashion of the time and personal preference. Bauer (1904) refers to the term "occidental" amethyst for the quartz variety to differentiate it from the "oriental" amethyst which is actually violet-coloured corundum. According to Bauer, perfectly clear amethyst was considered precious and that the best amethyst came from Oberstein, near the Rhine River. Durand (1983) considers that the best amethyst from generations ago came from Siberia, and was a deep red-purple colour rather than the clear violet associated with gem quality amethyst. At one time there were 75 amethyst mines in the Ural Mountains, producing amethyst from quartz veins in weathered granite (Bauer 1904). Amethyst localities, other than Canada, which have been or still are of importance are: various places in the United States, Mexico, Zambia, Zimbabwe, Malagasy Republic, Sri Lanka, parts of Australia, Uruguay and Brazil.

The best known and documented amethyst occurrences in the U.S. occur along the eastern margin of the U.S., along the Appalachian orogenic belt (Figure 3-7). Most of the amethyst occurrences are

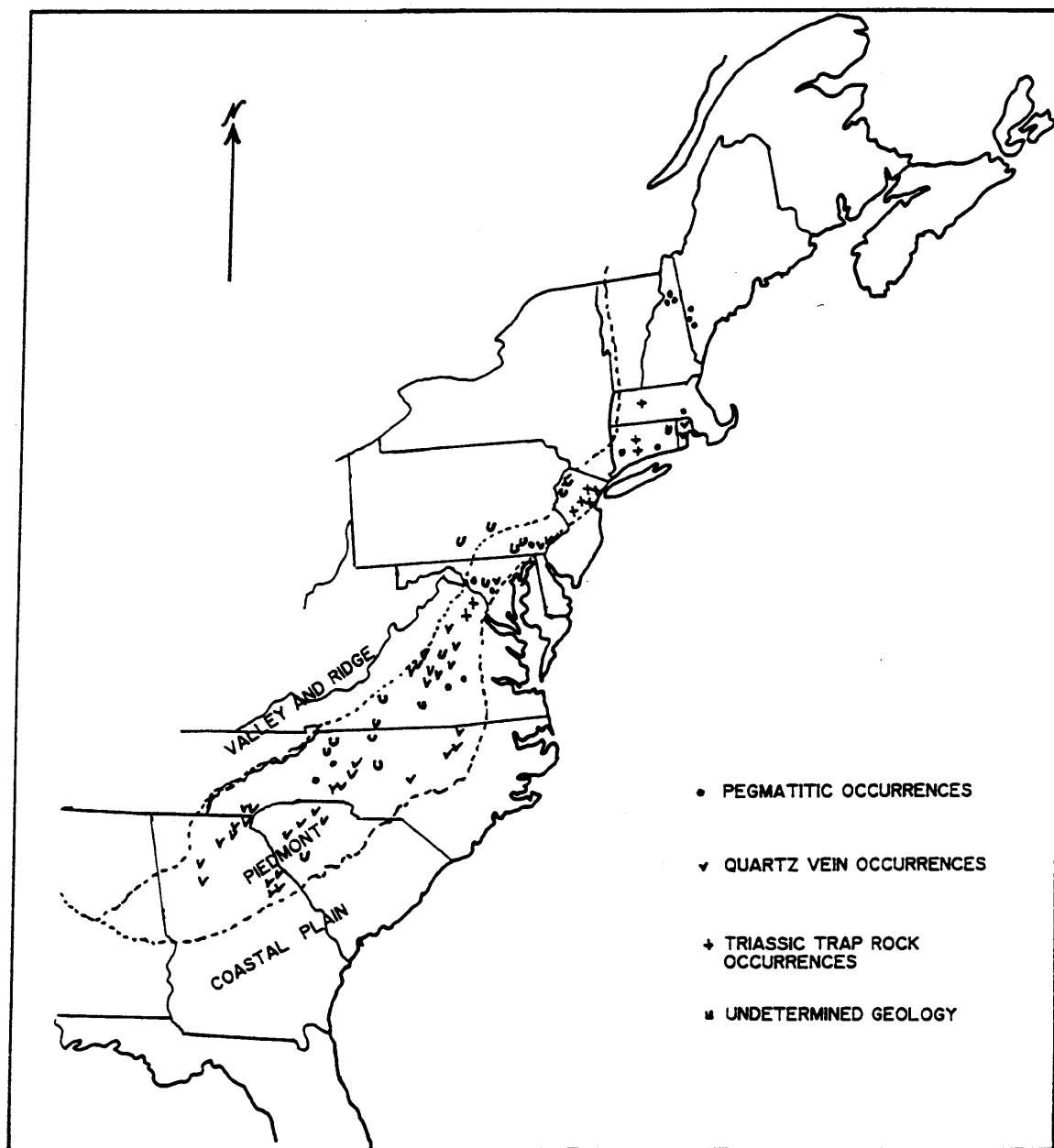


Figure 3-7: General geologic map of the major amethyst occurrences of eastern North America. Modified from White and Cook (1990).

restricted to the crystalline units of the Piedmont and Blue Ridge physiographic provinces, extending from the Northern Piedmont in Georgia, through the Northern, Inner, and Southern Piedmont in the Carolinas, Virginia, Maryland, and Pennsylvania, to the high-grade metamorphic terrain of New England and Maine (White and Cook 1990). Host rocks for the amethyst are either pegmatites, quartz veins, or what is termed Triassic trap rock.

In the southeastern United States, amethyst occurrences are separated into those located in rocks of the Northern Piedmont and those located in rocks of the Inner and Southern Piedmont. Amethyst deposits within the Northern Piedmont are in the form of pockets within quartz veins or lenses or small pegmatites. Most deposits produce 100 kg of amethyst, some of it gem quality (White and Cook 1990). Amethyst deposits within the Inner and Southern Piedmont are typically associated with major granitic intrusions. Amethyst is found within the intrusion or in veins and pegmatites adjacent to the intrusion. Amethyst occurs in clay-filled pockets or vugs, connected by narrow quartz stringers (Hudson 1980). Individual occurrences have produced over 1000 kg of amethyst (Lucas 1975; White and Cook 1990). Usually not known for gem quality amethyst, this area has produced spectacular deep purple amethyst sceptres growing on white quartz.

Amethyst occurrences of the east-central United States, located in the Piedmont region, tend to be small, interconnected vugs

associated with a granitic intrusion. Amethyst deposits of the northeastern states are found in pegmatites hosted by granitic intrusions of late Paleozoic age (White and Cook 1990). Rhythmic zonation of amethyst and quartz is characteristic of amethyst from this area (Jones 1991).

Amethyst is also found in basaltic sills of Triassic age in a region extending from Virginia to Nova Scotia, Canada. Pockets and vugs within the basalt are lined with amethyst druze.

Brazil is the largest producer of not only gem amethyst, but all varieties of gem quality quartz. In 1986, the 3 main amethyst areas produced over 35 tonnes of gem quality amethyst and over 150 tonnes of mineral specimen material (Sutherland 1991).

Maraba has been the area with the largest production since 1988. Amethyst occurs in large veins in a fractured quartzite of Proterozoic age. The best gem amethyst is associated with reddish, iron-stained quartzites. Pau d'Auro is 250 km south of Maraba and is known for producing the finest gem material. The amethyst is found in alluvial gravels. Crystals up to 20 kg and rarely 40 kg have been found in the alluvium, believed to be from the Maraba fields. The third area, Irai and Santa Maria, is actually an extensive zone stretching to Uruguay. Amethyst was discovered in 1860 when an immigrant to Brazil noted a fence made of amethyst nodules. Amethyst crystals line cavities and tubes

within particular horizons in young flood basalts (130 Ma) believed to be related to Atlantic rifting (Sutherland 1991).

Amethyst occurs associated with hydrothermal silver veins in Guanajuato, Mexico. Dark purple amethyst is found along the Zambezi escarpment in Zambia. Flood basalts of similar age to those in Brazil contain amethyst occurrences in Zimbabwe and Pretoria, South Africa. Dark violet to red amethyst occurs in pegmatites in the Malagasy Republic and in the gem gravels of Sri Lanka. Amethyst is also found in the Stanthorpe granite belt, Broken Hill, and Mount Isa, Australia.

It is interesting to note that amethyst occurrences, when considered in a global perspective, tend to be found in areas of rifting (flood basalts) and orogenic activity (orogenic granitic intrusives with abundant pegmatites).

3.3.2 Canadian Amethyst

Amethyst has been reported from numerous locations throughout Canada (Boyd and Wight 1983; Vos 1976). There are only two areas that have produced any quantity of high-grade specimen and gem material, and these are the Thunder Bay area and Nova Scotia. The Thunder Bay area amethyst, being the focus of this project, is discussed in detail in the next chapter.

There are two localities where amethyst has been found in Nova Scotia: the beaches between Cape Blomidon and Cape Spite in the Minas Basin, and near Berwick. Apparently in 1605, ten amethyst crystals picked up from the beaches, were sent to King Henry IV of France and consequently made into royal gems (Boyd and Wight 1983). The amethyst found on the beaches is alluvial and the source was never located. Deep purple, gem quality amethyst on massive magnetite has been found near Berwick. The host rock is an amygdaloidal basalt and the occurrences are similar to the amethyst deposits in Tertiary basalts found in the eastern United States.

Only a few fine specimens were produced from the Nova Scotia occurrences. The major source for fine amethyst for mineral specimens and gem material is the Thunder Bay area of Ontario.

3.3.3 Gemstone Marketing and Enhancement

The field of gemstones is divided into diamonds and coloured stones. Whereas the diamond trade is carefully controlled by a cartel, the world of coloured gemstones is much more chaotic, being influenced by smugglers, illegal gems, and a distinct lack of pricing guidelines. Gemstones pass through the hands of middlemen, usually international traders who operate bases in major cities and travel to the mine sites to purchase gem material. The value and legalities involved in the sale of

gemstones depend on the true identity of the stone. Since the gem has already changed hands several times, testing of its characteristics becomes very important. Nearly all coloured gems change in appearance according to lighting conditions, making it very difficult to determine enhancement by artificial means by eye alone. Gemological trade centres do exist and have set standards for gem testing, identifying gems, as well as offering courses in gemology.

Gemstone enhancement is considered to be any process other than cutting and polishing that improves the appearance of colour, clarity, or durability of a gemstone. The common techniques for enhancing gemstones are: heat treatment; irradiation; and treatments other than heating or irradiation. The other category includes chemical treatments and impregnations, surface modifications, composite gemstones, and synthetic overgrowths. Chemical treatments and impregnations, most surface modifications, composites, and synthetic overgrowths work by actually physically adding a substance to the gem and can be detected by their very presence; heat and irradiation treatments work by adding energy to the crystal lattice of the gem and inducing a change in the electronic structure. Unless there have been side effects from the treatment, this type of enhancement may be difficult to detect.

Heat treatment of gemstones is a process so old that the earliest treatments are surmised, not recorded. By 3000 BC, the use of shaped gemstones from powdered and glazed quartz was at a sophisticated level. Red agate and carnelian, heated to oxidize to a red colour, were found in Tutankhamen's tomb (Nassau 1984; Sutherland 1991). The temperatures used for heat treatments vary from low to very high, depending on the material and the desired change. The main minerals routinely subjected to heat treatments are: corundum, topaz, beryl, tourmaline, quartz, and zircon. The heat treatment of corundum is one of the most commercially significant operations; almost all of the blue sapphires and rubies that are in the jewellery market today have been subjected to high-temperature treatments (Hurlbut and Kammerling 1991).

The process of irradiation involves the exposure of a gemstone to one of a variety of radiations. These include the high energy rays of the electromagnetic spectrum, as well as various energetic particles such as alpha, beta or neutron radiation. Most colour alterations require energy inputs of 10 000 eV or more. For most gemstones the nature of the irradiation source is immaterial as long as there is enough energy supplied to produce changes in the electronic configuration of the colour centres. Many naturally occurring gemstones have been coloured by natural irradiation over geological time periods, but irradiation by artificial means is responsible for a number of gemstone colours that would otherwise not exist. Beryl,

corundum, diamond, pearl, quartz, spodumene, topaz, tourmaline, and zircon are the minerals most commonly enhanced with irradiation.

Irradiation-induced colour changes work in the same manner whether natural or artificial. A colour centre is involved, caused by an electron vacant from its normal position in an electron-pair and trapped somewhere else. The energy to do this is supplied by irradiation. The vacancy created by the removed electron is a hole-colour centre and the extra electron is an electron-colour centre. The now unpaired electron, is capable of absorbing energy from a white-light beam, removing part of the spectrum and producing colour. Light or heat energy can return the electron and reverse the reaction. The amount of light or heat energy required depends on how much energy is needed to break out of the electron trap. Very unstable colour centres will fade in sunlight or even in dark situations. For strong traps, the colour will be stable even on heating to high temperatures.

Irradiation and heat treatments can be used together: the irradiation to produce the desired colour and subsequent heat treating to remove undesirable hues. For example, topaz, irradiated to produce a blue colour, is then heat treated to remove the unwanted secondary yellow-brown colour.

Treatments other than heating and irradiation cover a wide variety of enhancing techniques and will only be summarized here. Nassau (1984, 1985), Hurlbut and Kammerling (1991), and Sinkankas (1963) cover the subject in much more detail. Chemical treatments and impregnations penetrate the surface of the gemstone and can completely alter the material. These include bleaches, colourless oil, wax, plastic impregnations, coloured impregnations, and dyeing. Surface coatings affect the surface of the gemstone and include surface paints, varnishes, interference filters, foil backs, surface decoration and inscribing. Composite stones include doublets, triplets, gel- and insect-containing stones, and synthetic overgrowths of either the same or a different mineral.

The major problem in the gemstone industry deals with the determination of the source of a gem, whether natural or man-made. There are official guidelines in the United States and Europe which apply specifically to the jewellery and gemstone industry. There are regulations pertaining to the disclosure of any treatments applied to a gemstone, but the problems lie with undisclosed, treated or upgraded gemstones competing with natural gemstones. Gemstone testing for the presence of treatments or enhancements becomes a very important part of the gemstone business.

The major limitation on gemstone testing is the inability to perform destructive tests on gems. Cleaning is essential and many imperfections which may be indicative of a natural gem are visible on a visual inspection. Surface coatings, external junctions, cement layers, characteristic fractures, and crack infillings are also usually visible with magnification. Instruments such as a refractometer, a polariscope, and a dichroscope permit the determination of refractive indices, optical character, presence of double refraction and anomalous strain, and pleochroism. A spectroscope will yield an identification of the material plus any dyes or coatings. Certain oils used for impregnations will fluoresce in ultraviolet light and waxes reveal themselves when probed with a hot needle. Gemstone treatments which closely resemble natural processes, such as irradiation or heating, can be next to impossible to detect.

The Federal Trade Commission (FTC) of the United States and the International Confederation of Jewellery, Silverware, Diamonds, Pearls, and Precious Stones (CJIBO) have a set of guidelines for disclosure of enhanced gems (Nassau 1984). In very general terms, the guidelines state that any gem which has been artificially coloured or tinted by coating, irradiating, or heating must be disclosed as such, unless the heat treatment is non-detectable by a qualified gemological laboratory or the results are stable under normal conditions. In practice,

treatments disclosed in the US trade are those which are not considered stable, such as irradiated beryl to produce the Maxixe blue colour, impregnated beryl or emerald, impregnated emerald or ruby, surface asterism or colour in sapphire (Nassau 1984). In both the FTC and CJIBO guidelines irradiation or heat treatment of quartz to produce amethyst, citrine, or prasiolite do not need to be disclosed.

3.3.4 Enhancement Techniques for Amethyst

In the quartz minerals, heating is used to improve the colour of dark amethyst by bleaching out some of the purple colour and remove the smoky component. Heating amethyst to a high enough temperature causes the mineral to turn a yellow colour by reversing the electronic configuration caused by irradiation. Practically all commercial citrine is heat-treated amethyst. Because of the rhombohedral zonation of the colour centres, heat-treating certain amethysts will produce citrine in the major rhombohedral zones and amethyst in the minor zones (Koivula 1980). The resulting yellow- and purple-zoned crystal has the trade name "ametrine". Amethyst with the Fe^{2+} ion will revert to a green colour when heated and is marketed under the name "prasiolite". The heating is time- and temperature-dependent. The process can take weeks at 180°C or minutes at 400°C (Nassau 1984). Commercial citrine is made by heating amethyst, starting

at 150°C. The stones are checked every 25°C interval and the ones reaching what is considered optimal colour are removed. By 450°C, most of the stones have reached marketable citrine colour.

Irradiation of quartz containing either Fe^{2+} or Fe^{3+} will produce the purple colour of amethyst since the same colour centre is produced from either cation.

The development of synthetic quartz was initiated during the second world war for radio frequency oscillators. Quartz for this application must be untwinned. Once the manufacture of synthetic quartz was firmly established, the production of coloured quartz followed by irradiating iron-bearing synthetic quartz. Since synthetic quartz grown from seed crystals is usually either untwinned, or twinned with dophinean or flame-like twins (Balitsky 1980), the Brazil twinning common to natural amethyst is one method to determine the mineral's authenticity as natural. It will not determine irradiated natural quartz from natural amethyst, since both will exhibit Brazil twinning.

Brazil twinning results in alternating lamellae usually under the faces of the major rhombohedron. When viewed in cross polars, the twinning shows up as narrow bands of colour and dark under the major rhombohedra and broad bands of colour under the minor rhombohedra. Using a gemological polariscope and aligning the gem so that the optic axis is parallel to the line of sight, it

is possible to undestructively observe twinning in a gemstone. The only times a natural stone will not exhibit Brazil twinning is if it has been either cut from the coloured area completely under the minor rhombohedron, or is one of the very rare untwinned natural stones (Crowningshield, Hurlbut, and Fryer 1986). Colour zoning has been noted in synthetic amethyst, usually parallel to the seed crystal and consisting of broad bands of dark and lighter purple. Zonation within natural amethyst is related to the Brazil twinning. Since one twin may preferentially colour darker than the other, there will be bands of purple alternating with bands of light or colourless quartz and will be in more than one direction.

4.0 AMETHYST IN THE THUNDER BAY AREA

For terms of this project, the Thunder Bay area encompasses the silver-vein region to the west of the town of Thunder Bay and the region east of Thunder Bay to include the occurrences around Nagunagisic Lake, north of Rossport. The area of established amethyst production just east of Thunder Bay includes the geographical townships MacGregor and McTavish and was the focus of interest. Maps A and B, in the back pocket, outline the geology and depict the amethyst occurrences in these 2 townships.

4.1 Deposit Characteristics

The formation of amethyst requires precipitation of quartz at low temperatures in near-surface conditions, from hydrothermal solutions containing iron. At the crystallization location there must be a source of ionizing radiation, necessary for the production of the colour centres in alpha-quartz.

Crystallization must take place in a system of open fissures or cavities to promote the crystalline habit and rhombohedral growth essential for amethyst.

Amethyst veins in the Thunder Bay area occur in parallel to subparallel vein systems. The main fault zones strike 045°, parallel to major Keweenawan faults. Smaller, en echelon systems



Photo 4-1: Large, well-developed amethyst crystals in an exposed vug, Thunder Bay Amethyst Mine Panorama.



Photo 4-2: Very large vug formed at the intersection between a NNW trending fault and a NS fault, Pearl Lake Amethyst Mine.

strike 090°. The best amethyst crystals occur in vugs (photo 4-1) and the best developed vug systems occur at the intersection between the two fault systems (photo 4-2). Well developed vugs are filled with a dense red clay which is actually a fault gouge consisting of finely ground quartz, feldspar, chlorite, and biotite (Patterson 1985). The near surface deposition, indicated by the preservation of large, open cavities, means that the occurrences are located at or near the subhorizontal unconformity between the Archean and Proterozoic rocks. Radioactivity, required for colouration, is provided by radioactive minerals both within the Archean granite bodies and concentrated along the unconformity.

The veins cut all known formations, including Archean rocks and Proterozoic Animikie Group and Sibley Group rocks. There is usually a fault breccia associated with the veins. Wall rocks of the breccia zone can be both Archean, one wall Archean and one Proterozoic, or both Proterozoic (photos 4-3a,b,c). In most occurrences, evidence of a well-developed breccia zone indicates the presence of substantial amounts of amethyst. The breccia consists of angular clasts, in a variety of sizes, of any of the above-mentioned lithologies, vein material, and rebrecciated fragments (photo 4-4a,b). The occurrence fragments representative of lithologies stratigraphically higher than the existing wall rocks of the existing breccia indicates collapsing of former host material, now weathered away, into the fault zone. Deformation

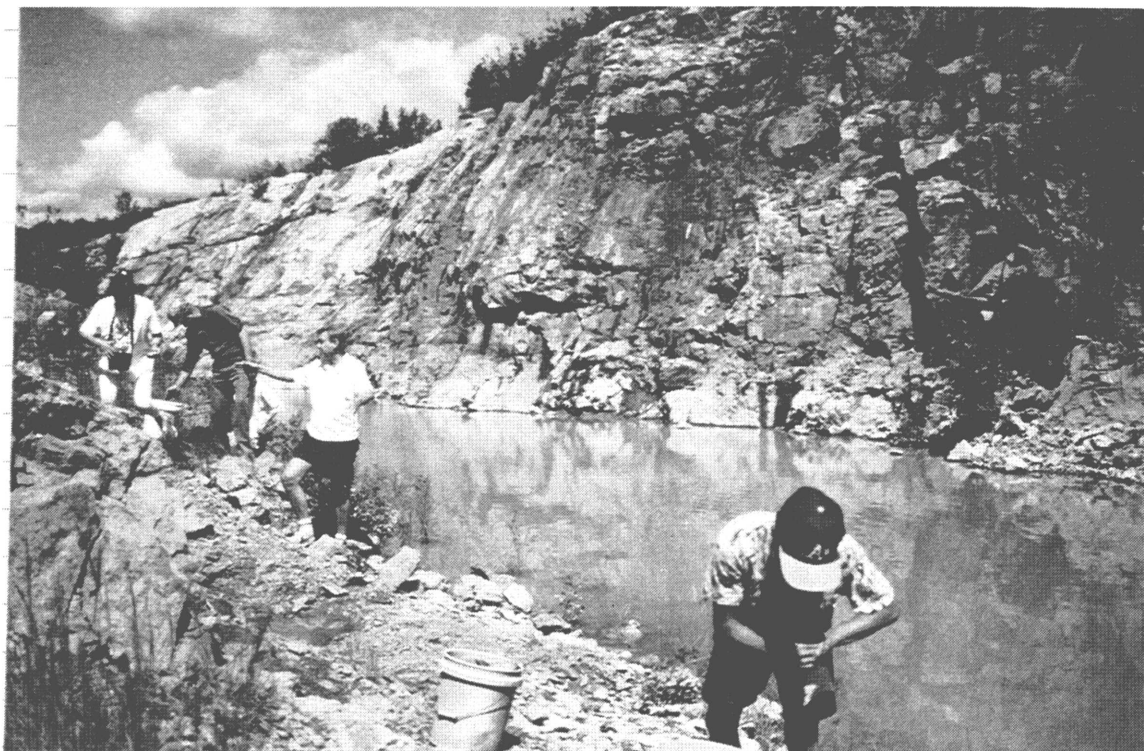


Photo 4-3a: Thunder Bay Amethyst Mine Panorama, facing northwest. The breccia zone in this part of the mine is now under water. The host rocks are Archean granite on both the north and south sides. Proterozoic rock fragments are present in the breccia, due to collapse of pieces of the now eroded Proterozoic rocks.



Photo 4-3b: Pearl Lake Amethyst Mine, south end, facing west. The breccia zone is the worked area, separating Archean granite on the north side from Sibley conglomerate on the south side.



Photo 4-3c: The Diamond Willow Amethyst Mine, facing west.
The breccia zone, now under the trench, separates
Proterozoic mudstone on the south side from
Proterozoic conglomerate on the north side.

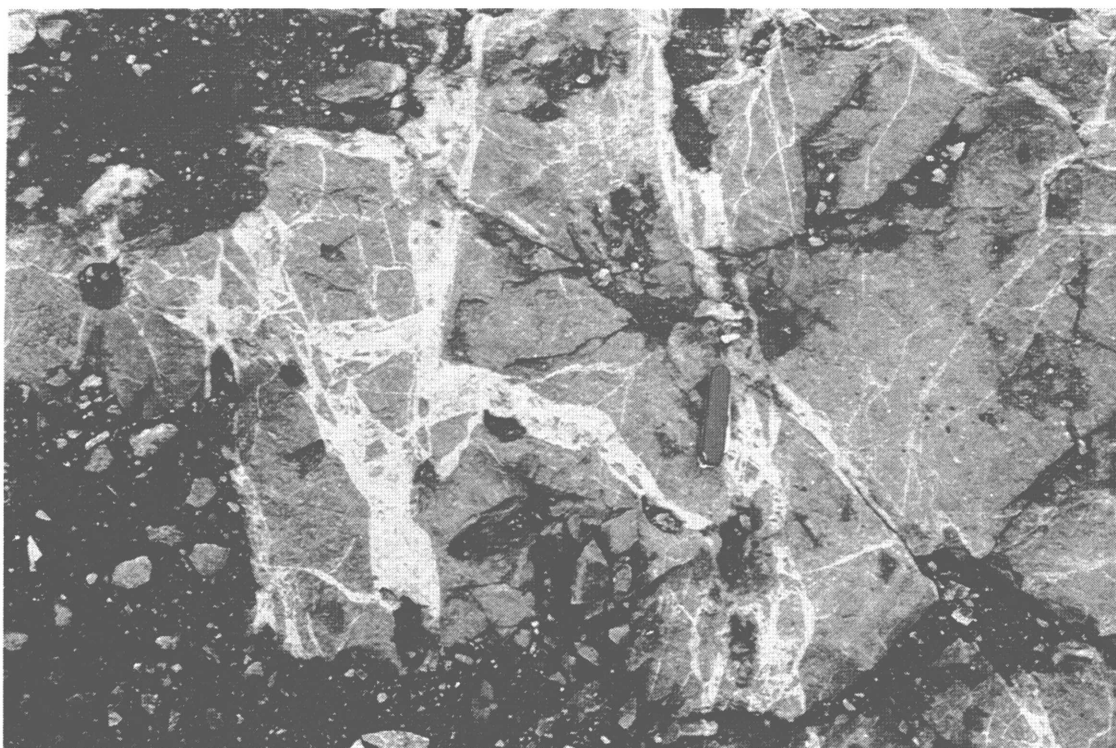


Photo 4-4a: Angular fragments of Sibley Group mudstone,
Diamond Willow Mine.

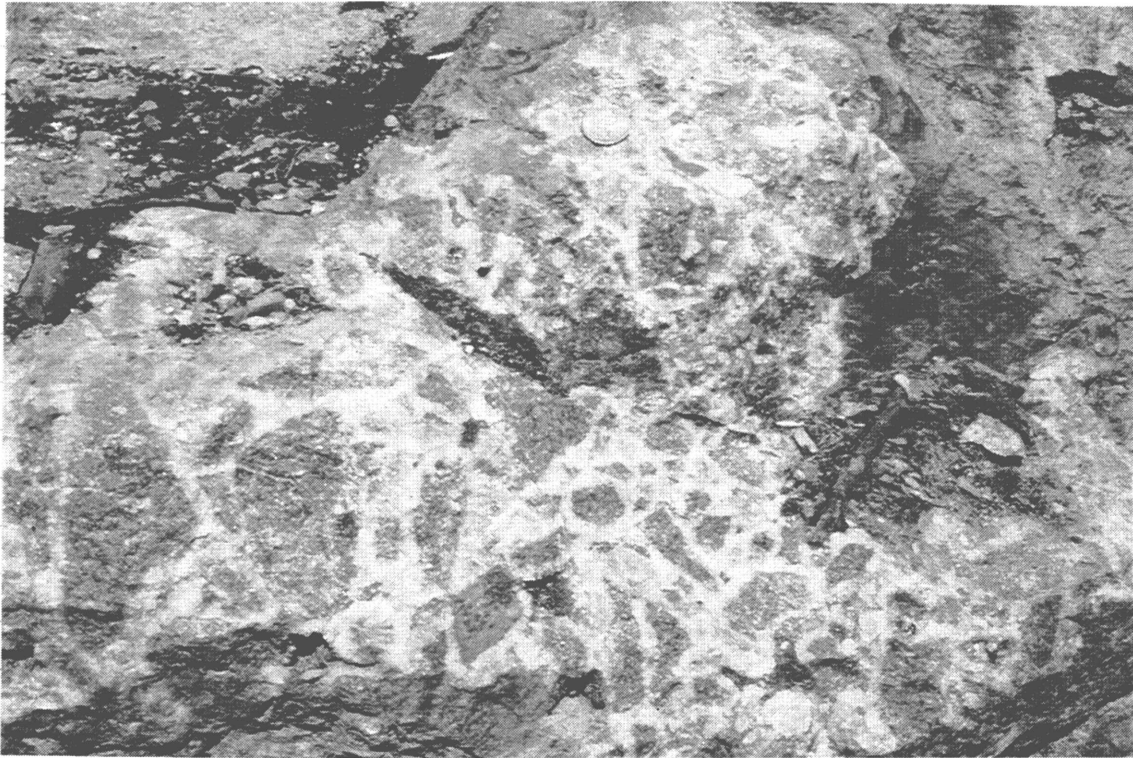


Photo 4-4b: Breccia consisting of granitic fragments, Pearl Lake Amethyst Mine.

continued within the fault zones, rebrecciating fragments and recementing these fragments into a new breccia zone. At least two periods of deformation are evident.

The breccia varies from clast-supported, with less than 20% white quartz matrix, to matrix-supported, with 60% white quartz matrix. There is no evidence of ductile deformation. Vugs occur between the clasts, in areas devoid of the quartz matrix and are lined with amethyst druse (photo 4-5).

The major strike direction of the breccia fault zones is north-northeast, the second common direction is east. Dips are steep to vertical, but the zones are irregular with depth and dips can be variable. The zones can be traced for at up to 1 km along strike and have been extrapolated to extend for several kilometres. Widths vary from less than 10 cm to 5 m and any of these widths are possible along the strike extension of a zone. There is definitely normal offset along the fault zones, shown very well by the large age differences between host rocks in many of the occurrences. Lack of distinctive vertical indicators render it impossible to determine lateral offset.

The mineralogy of the amethyst vein systems varies regionally. West of Thunder Bay, amethyst is spatially associated with silver-calcite veins, and occurs as a minor constituent within a system containing calcite, barite, galena, sphalerite, fluorite,



Photo 4-5: Exposed vug in breccia zone, showing dark purple amethyst crystals lining the vug, Blue Star Resources amethyst quarry.



Photo 4-14a: View facing east of the Blue Points Amethyst Mine, taken from the Diamond Willow Mine. The breccia zone extends for almost 1 km, exposed in pits and in outcrop along the strike length. Gunnar Noyes original quarry is visible at the right side of the picture.



Photo 4-14b: Quartz vein in Sibley mudstone at the Blue Points Amethyst Mine. Greenish weathering extends for approximately 10 cm either side of the vein.

and silver minerals. In vein systems occurring east of Thunder Bay, quartz becomes the dominant mineral, with a few exceptions, accompanied by minor amounts of calcite, barite, galena, sphalerite, and chalcopyrite.

Several episodes of hydrothermal deposition have resulted in a mineralogical zonation within the veins. In veins where carbonate is the predominant mineral, calcite is the first phase, then quartz with amethyst if present, then barite and fluorite if present (photos 4-6a,b). Sulphides occur within the calcite and quartz phases. Within the quartz-dominated veins, there are usually several generations of quartz, then calcite, barite, and fluorite, if present (photos 4-7a,b). Sulphides occur as discontinuous lenses within the quartz and at the base of the amethyst layer. Early formed quartz is white, sugary-looking, and coats the host rocks and fragments in the breccia. Successive generations of quartz consist of amethyst, green quartz which is most likely bleached amethyst, more amethyst, hematite in quartz, and occasionally a layer of milky white chalcedony (photos 4-8a,b). Barite, if present, forms beautiful, orange rosettes on the amethyst or large orange blades in the centre of quartz pods. At several occurrences, amethyst has crystallized on top of barite blades, making a very unique wormy-looking crystal pattern.



Photo 4-6a: Zoned amethyst vein, Pearl Lake Amethyst Mine. The hammer is lying on granite, the chisel part of the head is lying across the amethyst, just touching the massive pinky-orange barite core of the vein.

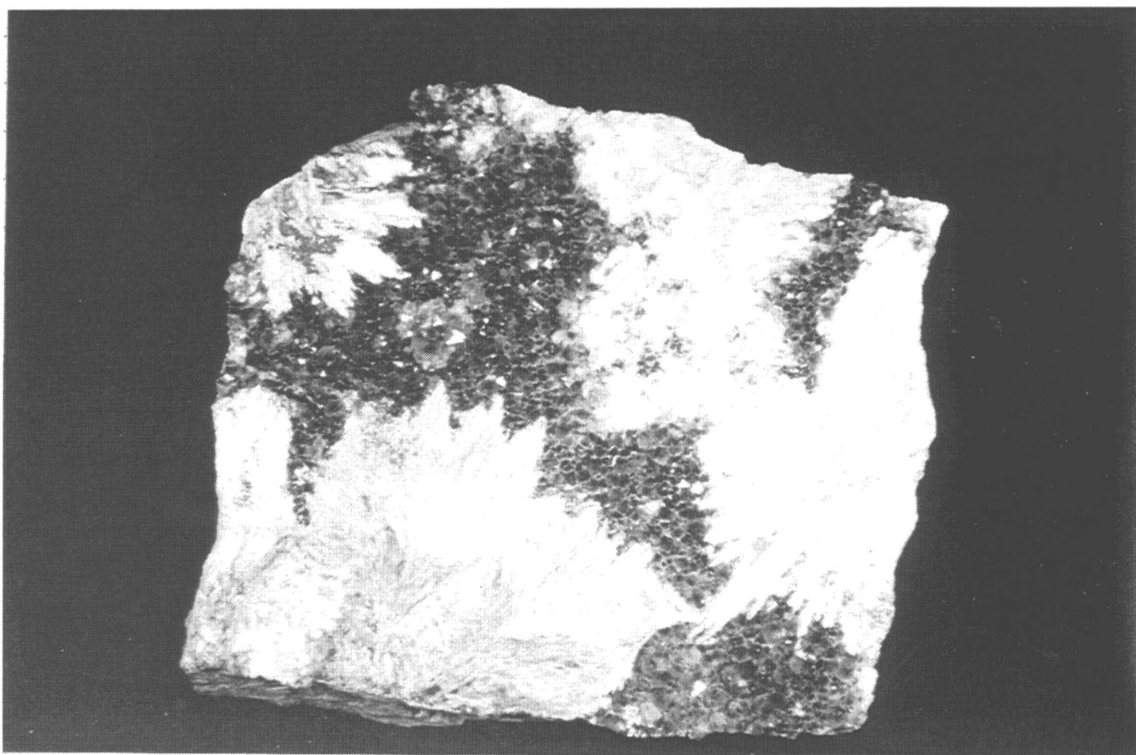


Photo 4-6b: Sample from Ontario Gem Amethyst Mine showing roses of orange barite crystals growing on top of purple amethyst druse. The sample is approximately 18" square.



Photo 4-7a: Amethyst sample exhibiting several generations of quartz and amethyst deposition. The final layer is a coating of brick-red haematite.

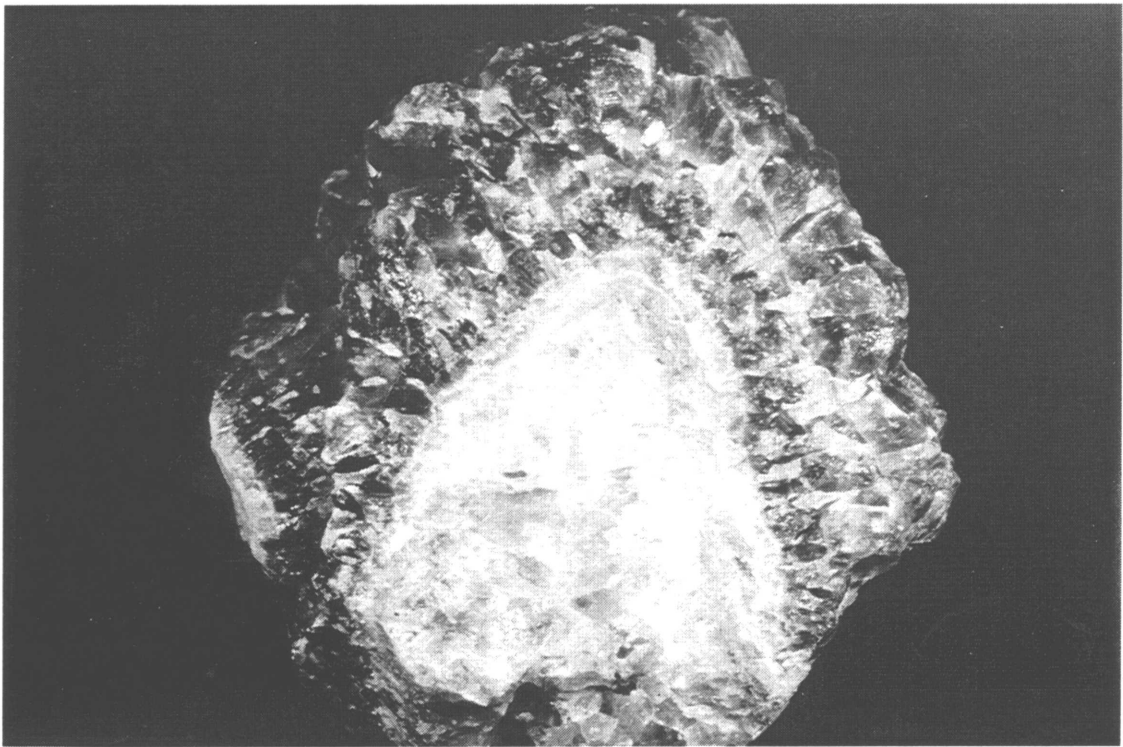


Photo 4-7b: Sample from the Thunder Bay Amethyst Mine Panorama showing several generations of amethyst crystallization.



Photo 4-8a: Large, well-zoned amethyst crystals from the Grieve's amethyst quarry. The thin, solid white lines in the zonation pattern are layers of chalcedony.



Photo 4-8b: Lighter coloured amethyst crystallizing on the
 rhombohedra of earlier-formed, darker amethyst
 crystals, Grieve's amethyst quarry.

In all the vein systems, amethyst occurs as one of the later generations of mineral deposition. It occurs as crystals with the rhombohedral faces well-developed, forming druse along vein walls and the inside of vugs (photo 4-9). If veins of relatively massive, purple amethyst are present, they occur at the margins of the breccia zone, between the breccia and the wall rock (photo 4-10). A complete range of colours is common from pale violet to royal purple to almost black (photos 4-11a,b). Occurrences tend to have one predominate colour type, but it is not unusual to have several colours in one occurrence. The intensity of the purple colour seems to depend on amount of irradiation, which varies according to distribution of radioactivity within the host rocks. McArthur (1988) suggests that the salinity changes of the precipitating solution would change the concentration of Fe^{3+} substituting into the quartz lattice. The increase in iron would cause a more intense purple colour. Irradiation studies have shown that very little substituted Fe^{3+} is required to cause quite a dark purple colour (Nassau 1984).

Colour varies within individual crystals. Fine, sharply-defined colour bands are the result of preferential colouration of one set of Brazil twins. Wider zones of colour, still parallel to crystal faces are due to solution fluctuations during crystal growth. Several pulses of hydrothermal solution may be the cause of zones of bleached, green amethyst alternating with white quartz and purple amethyst within the same crystals. Fluid

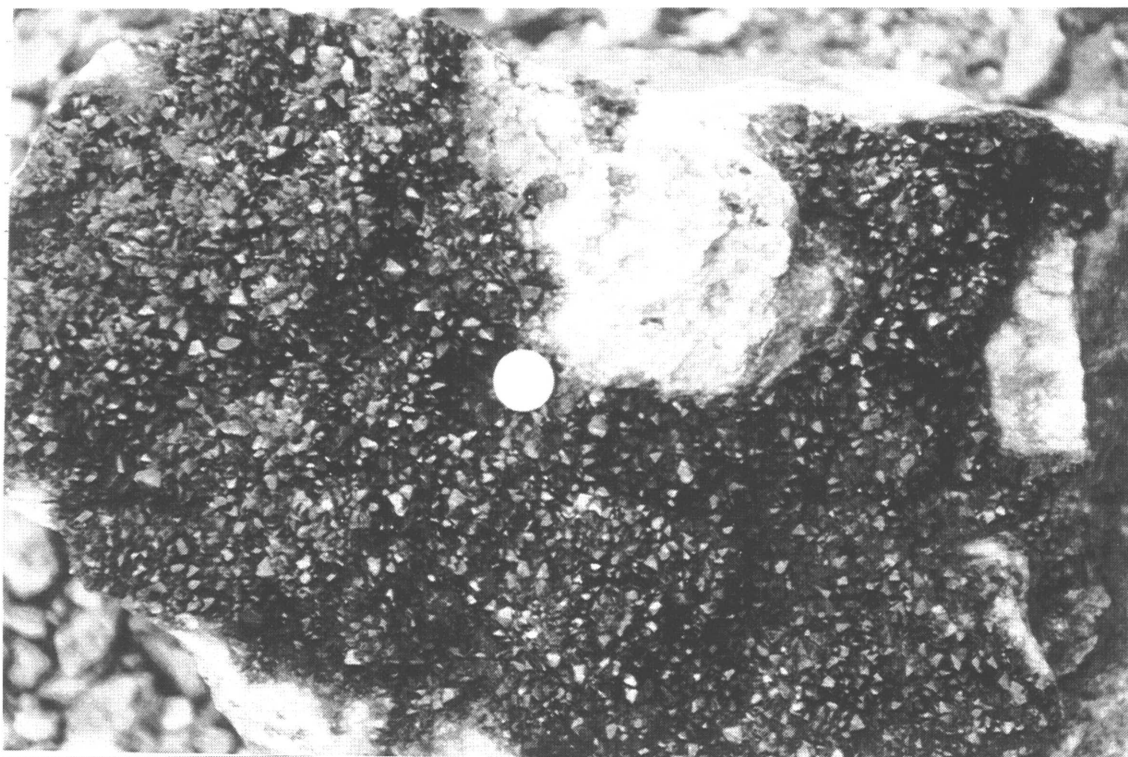


Photo 4-9: Well-formed, dark purple, amethyst druse, Ontario Gem Amethyst Mine.



Photo 4-10: A vein of large amethyst crystals which has formed between the host granite wall-rock on the left and the breccia zone, now mined out, Thunder Bay Amethyst Mine Panorama. (Photo by M. Gerow).



Photo 4-11a: Sample from T. Twomey amethyst occurrence showing beautifully-formed amethyst crystals of a very pale violet colour with a touch of darker purple inside each rhombohedron giving each crystal a "shadow" effect.

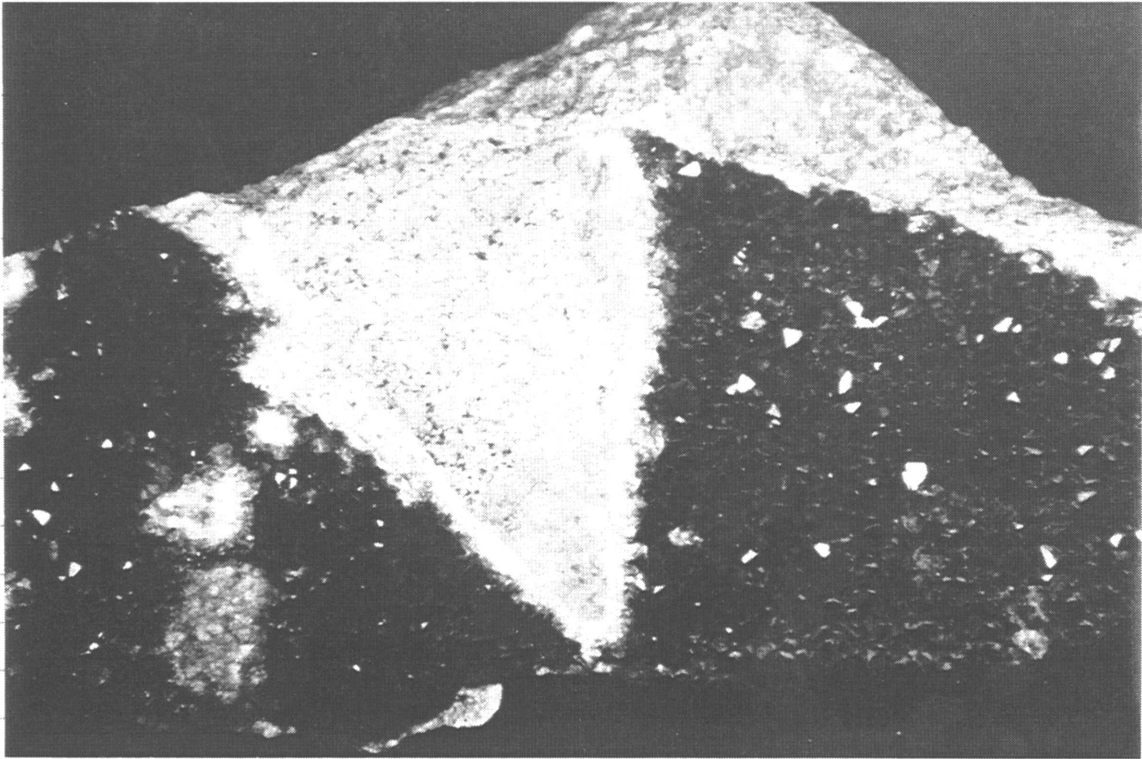


Photo 4-11b: Sample from G. McLeod's quarry displaying amethyst so dark it appears black.

inclusion data on amethyst samples indicate two stages of precipitation temperatures, one at 135°C to 146°C and another set at 60°C to 90°C (McArthur 1988). Amethyst crystallizing at 135°C would be hot enough to bleach the underlying amethyst layer. Inclusions within the amethyst are common. Bright red to brown hematite both coats and occurs as spots within crystals (photo 4-12). Milky white chalcedony can also coat crystals.

4.2 Property Descriptions

The major producing mines, quarries, and occurrences are discussed in detail in the property descriptions. There are many amethyst occurrences in the region, some associated with silver or lead-zinc mines and many with minor amethyst. All the occurrences, from major producers to small showing are included on Table 1, included in the back pocket. All the occurrences in Table 1 are located on the accompanying location maps, Maps C, D, and E, in the back pocket. The number for each occurrence in the table is keyed to the map. This is the number in brackets after each of the property name in the following section.



Photo 4-12: Large amethyst crystals (bases 5-8 cm) covered by a layer of brick-red hematite inclusions in silica.

BARRETT CLAIMS (2)

LOCATION: The property consists of 2 leased claims on the northeast side of Sword Lake, McTavish Township, C. IV, Lot 5. The claim numbers as of 1992 are: 1165072 and 766854.

ACCESS: Highway 11/17 east to Road 5 North in the town of Pearl, Ontario. Turn left just after the railway tracks and left onto quarry road 1.8 km from turn-off. The quarry is at the end of the road.

OWNERSHIP:

J. Barrett estate

GEOLOGY: The occurrence is located within Archean pink, coarse-grained granite and monzonite. Red mudstone of the Sibley Group is exposed near the top of a cliff along the south side of the quarry. Mr. Barrett worked the north side of this ridge. The amethyst is associated with a breccia zone trending 090° and dipping very close to vertical. The fragments composing the breccia are a dark green and pink gneiss, coarse-grained, pink granite, and brown Proterozoic mudstone. The matrix is white quartz. The zone is from 1 to 5 m wide, and

extends for the length of visible outcrop,
approximately 100 m.

Amethyst occurs as a druse covering the exposed quarry face. The points are even in size, approximately 1 cm in diameter, and are dark purple to smoky black. There are some vugs, also filled with dark purple amethyst (Figure 4-1).

MINING INFORMATION:

The quarry consists of a trench 40 m long by 3 m wide, along the side of a north-facing cliff. The trench is now partially water-filled (photo 4-13). Many of the large blocks and pieces of rock lying around the quarry area contain substantial amounts of purple amethyst and smoky quartz. There is no data as to the tonnage of amethyst removed.



Photo 4-13: J. Barrett quarry, east end, facing south-east. The quarry wall consists of Archean granite laced with quartz veins. Proterozoic mudstone is just visible to the left of the person. The breccia zone is exposed along the ledge at the base of the cliff. (Photo by M. Gerow).

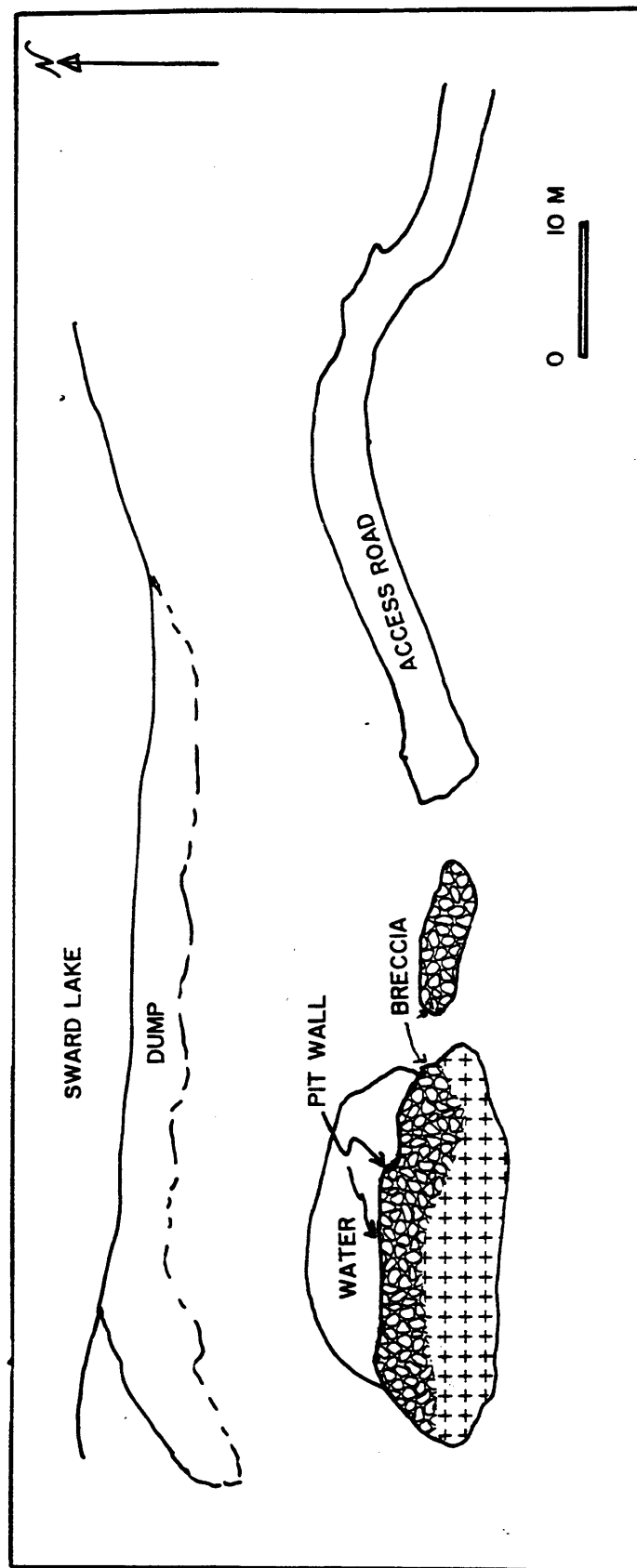


Figure 4-1: Geology of the Barrett occurrence.

BIG PEARL LAKE OCCURRENCE (4)

LOCATION: Big Pearl Lake Occurrence consists of 3 claims on the southwest corner of Big Pearl Lake, McTavish Township, northwest part of southwest 1/4 of Lot 5, C III. Claim is TB 830425, leased as of 1992, the other claims are TB 1165209 and 1174088.

ACCESS: Highway 11/17 east to Pearl, Ontario, then Road 5 North to the first left after the railway tracks. Follow this gravel road for 0.7 m. Just after the power lines there is a logging road on the left side which leads to the showing.

OWNERSHIP:

T. Twomey

GEOLOGY: The area is included in McIlwaine's (1971) mapping of McTavish Township. Tanton (1931) also mentions an amethyst and sulphide occurrence near Pike Lake, which is now Big Pearl Lake. Several old trenches are on the property. The host rocks for the occurrence consist of dark pink, Archean granite with xenoliths of greenish metasediments exhibiting good boudinage structures. Coarse-grained feldspar and white quartz pegmatites within the granite are not amethyst-bearing. The

amethyst veins occur in the vicinity of the power line, within the pink granite. The veins strike at from 030° to 043° and at 075°. Amethyst occurs with vuggy white quartz, usually in thin veins. At one location a 1 m wide granite breccia zone was noted. Sphalerite, galena, pyrite, and barite are present with the quartz.

MINING INFORMATION:

The Detroit Algoma Mine, a lead-zinc producer, discovered in 1871, is 1 km north of the property. Tanton (1931) describes several trenches in the vicinity of Big Pearl Lake, some up to 450 feet in length. The veins are described as being well-mineralized with galena and pyrite, and low gold values were reported (Tanton 1931). There are 3 producing amethyst mines within 2 km of this property.

BLUE POINTS AMETHYST MINE (6)

LOCATION: Blue Points amethyst mine is the eastern half of the old, original Diamond Willow mine. It is located in McTavish Township, C III, Lot 4, near the northeast end of Big Pearl Lake.

ACCESS: Highway 11/17 east to Pearl, Ontario, then Road 5 North to the first left past the railway tracks. Follow this road for about 6 km. Blue Points is the second mine, just past the Diamond Willow turn-off.

OWNERSHIP:

Francis Grann

GEOLOGY: The main fault, manifest by a very well-developed breccia zone, trends approximately 090° and extends for almost a kilometre (photo 4-14a). The fault separates Sibley Group conglomerates of the Pass Lake Formation on the north side, from Sibley Group mudstone of the Rossport Formation on the south side. The breccia zone varies from 1 to 5 m wide, characterized by a quartz-rich core and fragments of wall-rock material. Fragment density increases away from the core, but is always matrix supported. Massive calcite is visible in one of the pits, along the north wall, between the

conglomerate and the breccia. Quartz veins are predominant in the mudstones and have a green, chloritic alteration for 10 cm on either side of the vein (photo 4-14b). This veins trends at 090° and at 000o, dips are almost vertical. Amethyst occurs as a druse of fine, dark purple crystal points, from 0.5 to 1 cm in diameter, between the breccia zone and the mudstone. Dark purple amethyst occurs in large, clay filled vugs within the breccia zone. Some of the vugs approach 1 m in diameter.

MINING INFORMATION:

The original Diamond Willow mine was staked by Gunnar Noyes. The mining leases were split pending inheritance and the original mine is now the Diamond Willow and Blue Points amethyst mines, owned by a son and daughter respectively. Blue Points is operating 2 and 3/4 of the 4 pits situated along the breccia zone. The centre pit is the original and the largest, almost 60 m long and 4 m deep. A fence divides the pit between the 2 mines. Blue Points has 2 other pits to the east of the original pit. The 2 pits have a total length of 90 m and a maximum depth of 3 m (Figure 4-2).

The mine functions as a pick-your-own tourist operation

and there is a small shop on the mine site where mineral specimens are available for purchase. Amethyst and breccia is also available in bulk orders and is sold by the ton. Tonnage figures for 1991 are estimated to be 25 tons total amethystine rock removed and sold. The figures for 1992 will be similar. Major products are amethyst samples and specimens and amethystine breccia.

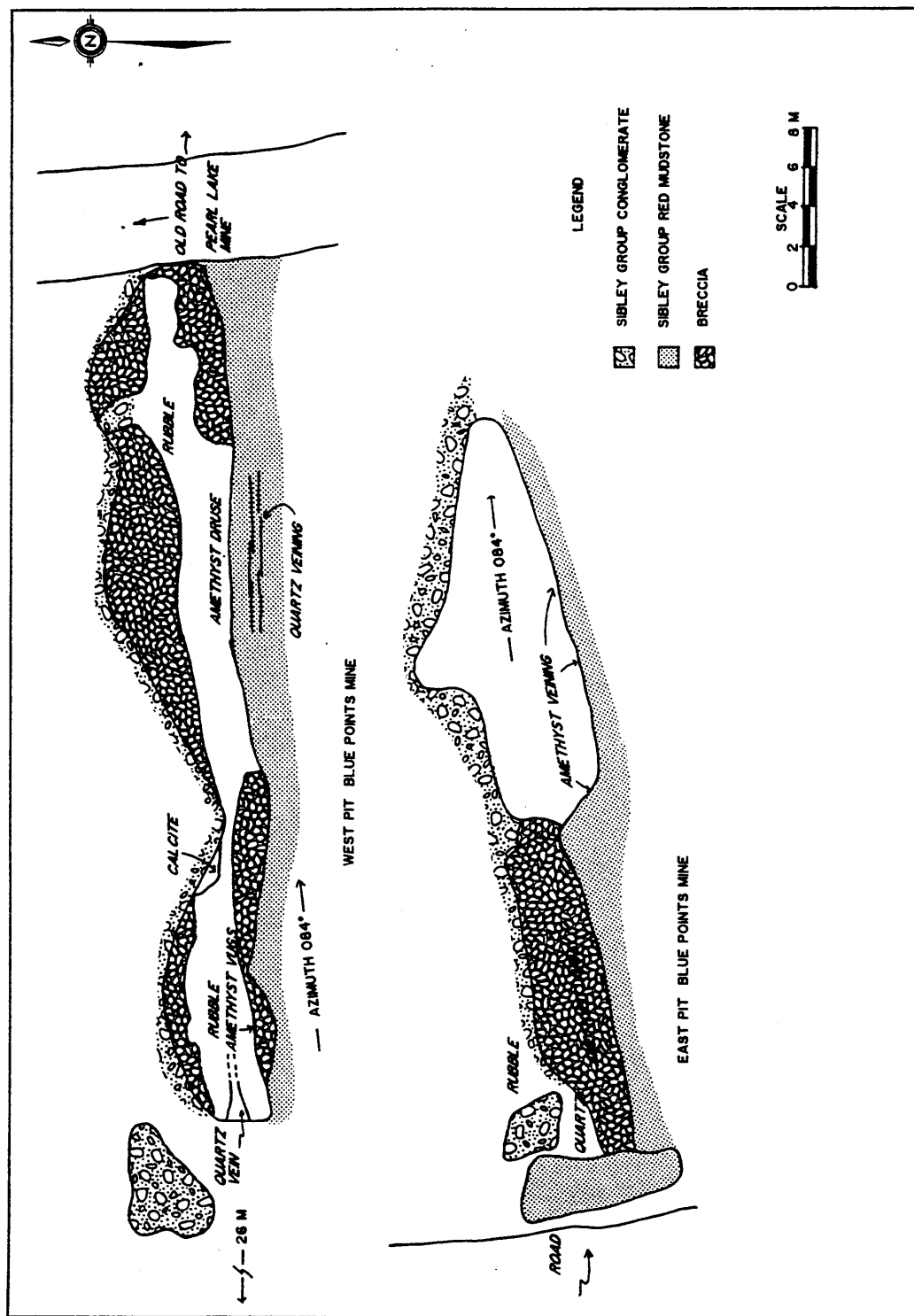


Figure 4-2: Plan view of the Blue Points amethyst mine.

BLUE STAR RESOURCES QUARRY (7)

LOCATION: The property consists of 8 claims, located in North of MacGregor Area, near Walkinshaw creek. The quarry is on claim 1166702.

ACCESS: Highway 11/17 east to the Armstrong highway (527). North for 9 km to the Magone Lake road, a logging road leading east into the North of MacGregor area. East along this road for 10 km. At the top of a hill, there is a road leading south, marked R 10. Turn right onto this road and the quarry is 200 m south, on the left.

OWNERSHIP:

Blue Star Resources Ltd. The main contact person is Howard Pillsmaker.

GEOLOGY: The host rock for the whole North of MacGregor area consists of phases of the Penassen Lakes granite or large rafts of grey metasediments caught within the granite. In this case, the granite is a very dark pink, coarse-grained syenitic to monzonitic phase with very coarse pegmatitic patches. Outcrops exposed by stripping near the quarry area reveal the dark pink monzonite in contact with dark grey, schistose metasedimentary rock. A breccia zone, 1 to 1.5 m wide

is situated between the host monzonite and a massive amethyst vein. Fragments in the breccia consist of angular, pink monzonite and darker, slightly banded, gneissic rock. The fragment size is fairly uniform, about 15 to 25 cm. The amethyst vein appears to be about 0.5 m wide and is massive, dark purple amethyst. In growing out from the sides of the vein, the amethyst points have grown together, forming a jagged line down the centre of the vein, delineating the two sides. The vein is zoned, with a thin layer of white quartz, 1 cm wide, lining the wall rock, then a layer of green quartz, 4 cm wide, and then the dark purple amethyst. The zoning is mirrored on both sides of the vein. The best amethyst points occur in vugs within the breccia. Vugs attain almost 0.5 m in size and can have points of 2 cm diameter or larger. Colour of the amethyst in the vugs varies from pale violet to almost black. Sulphides, notably chalcopyrite, galena, and pyrite, occur scattered through the breccia (Figure 4-3).

MINING INFORMATION:

Blue Star Resources began production in 1991, using an aggregate permit to extract amethyst (photo 4-15). The amethyst was hand-cobbed into select, fist-sized pieces, decorated with pewter figurines, and sold as gift items. Tonnage of amethyst removed appears to be several tons.



Photo 4-15: Blue Star Resources quarry, facing southwest. Workers are hand-cobbing amethyst pieces from vugs within the breccia zone, exposed along the working face of the quarry.

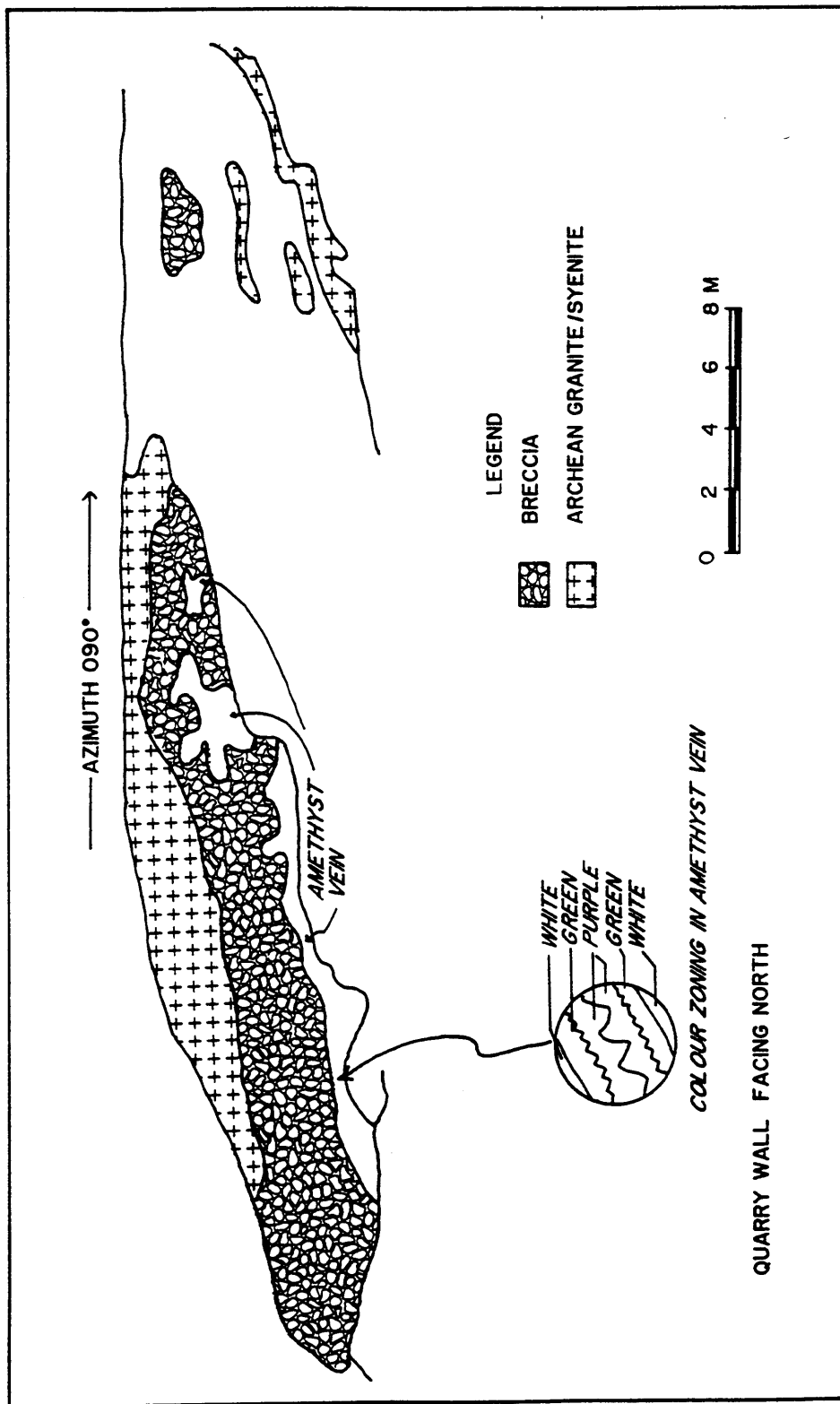


Figure 4-3: Quarry face, Blue Star Resources Limited.

BREEZY LAKE PROPERTY (8)

LOCATION: The Breezy Mountain property consists of 2 claims, in C IV, Lot 4, McTavish Township, just west of Breezy Lake.

ACCESS: Highway 11/17 east to Pearl, Ontario, then Road 5 North. Just before the Diamond Willow mine road, there is a gravel trail leading north into the bush. This road is gated, and permission must be obtained from Clark Noyes. About 2 km up this road an overgrown trail leads northeast to the amethyst occurrence.

OWNERSHIP:

Claim 835253 is owned by Tim Twomey. Claim 845723 is owned by Tim Twomey and Phil Durocher.

GEOLOGY: McIlwaine (1971) mapped the area including the Breezy Mountain occurrence. The amethyst and breccia zone are situated at the base of a prominent Archean granite cliff. The zone and the cliff strike at 050°. The granite is pink, medium-grained, massive, and highly altered to kaolin next to the breccia zone. The breccia zone is 5 m wide. Fragments are large, 1 to 1.5 m to pebble-sized, and very angular. Rock types showing up as fragments are the pink granite, the altered granite, Sibley Group mudstone, dark grey

metasediments. Quartz, in anastomosing veinlets, cuts the breccia and the fragments, indicating several stages of fracturing and deposition. Angular vugs, which can be up to 1 m wide are lined with red, hematite-coated amethyst.

MINING INFORMATION:

The Detroit Algoma lead-zinc mine is located 1 km south of the property. Serious interest in base metals waned by World War I. A brief flurry of activity centred around a regional uranium survey and now the active interest is for amethyst.

DIAMOND WILLOW AMETHYST MINE

LOCATION: The Diamond Willow mine is located in McTavish Township, C III, Lot 4, northwest of Big Pearl Lake. The present Diamond Willow is the west extension of the original Diamond Willow mine.

ACCESS: Highway 11/17 east to Road 5 North at Pearl, Ontario. Follow Road 5 North, take the first left after the railway tracks, and follow this road to the mine road, about 6 km.

OWNERSHIP:

Doug Noyes

GEOLOGY: The Diamond Willow mine is at the western end of a kilometre long breccia/fault zone, separating Sibley Group mudstones on the south from Sibley Group conglomerates on the north side (photo 4-16a). The trend of the fault zone is 090°. Both the mudstone and the conglomerate are well-layered, giving them a blocky appearance (photo 4-15b).

The Diamond Willow operates 1 and 1/4 of the 4 quarries situated along the breccia zone. The breccia here is similar to the breccia at the Blue Points mine,



Photo 4-16a: Diamond Willow Amethyst Mine, west end facing west. The trench follows the breccia zone, separating Sibley Group mudstone on the south from Sibley Group conglomerate on the north side.



Photo 4-16b: Gunnar Noyes quarry, the original pit on the Diamond Willow and Blue Points properties. This view of the Sibley Group mudstone on the south wall shows the blocky appearance of the mudstone and the network of quartz veining.

consisting of a quartz-rich core with fragment density increasing towards the wall rocks. Fragments are angular and representative of the wall rocks. Amethyst forms beautiful pale to medium purple crystals within cavities in the breccia. Vugs can attain sizes of over 1 m and are lined with large, dark purple crystal points. The vugs also tend to be filled with a dense, red clay, which must be removed in order to mine the amethyst. Medium to dark purple amethyst forms an extensive druse covering along the south wall, crystallizing between the mudstone and the breccia. The crystal points in this druse tend to be small, but are very well-formed, yielding excellent mineral specimens. Galena occurs as seams of crystals 1 cm in size, within the quartz at the west end of the exposed breccia zone.

MINING INFORMATION:

The Diamond Willow pit is 70 m long and up to 10 m wide and 2.5 m deep. The original Diamond Willow pit, now shared with the Blue Points mine, is 60 m long, close to 10 m wide and 4 m deep (Figure 4-4). The 2 mines, Diamond Willow and Blue Points, were once just the Diamond Willow mine owned by Gunnar Noyes. Inheritance of the mining leases resulted in a division of the property. Mining is accomplished with controlled

blasting and hand-picking crystals out of red clay. Fine samples are sold as specimens and as raw material for jewellery. The breccia is sold for small-scale construction and landscape stone.



Photo 4-16c: Shop and picking tables, Diamond Willow Mine.

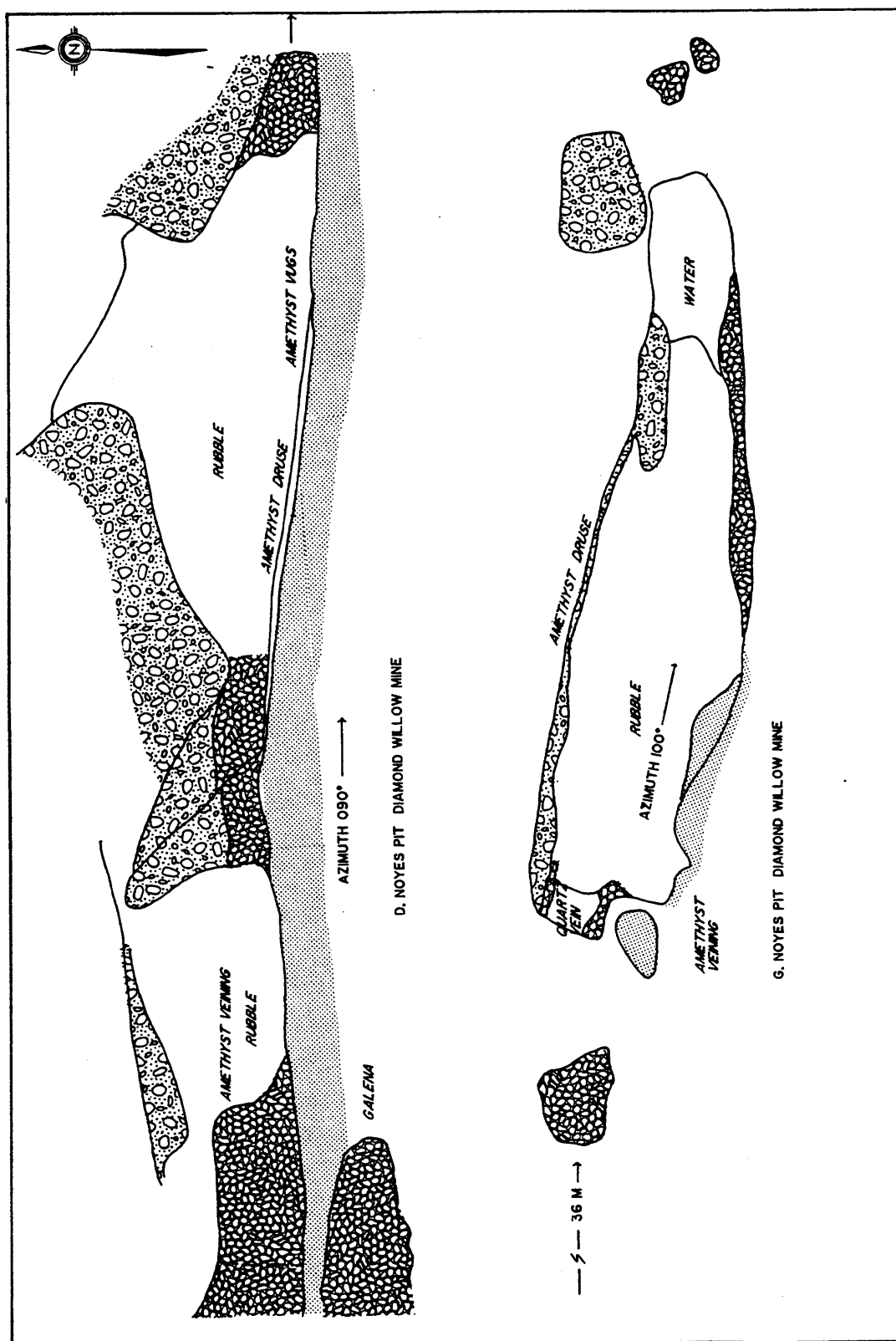


Figure 4-4: Plan view of the Diamond Willow amethyst mine.

DORION AMETHYST MINE (13)

LOCATION: The property is located in C I, east 1/2 and south 1/2 of Lot 3, McTavish Township., on mining leases TB 129262, TB 129263, and TB 129265.

ACCESS: Highway 11/17 east, past Pearl, Ontario, to the Dorion Mine Road. This road is marked with a finger board on the highway. Turn south on this road, then west on the pipeline road. It is approximately 4 km to the mine.

OWNERSHIP:

E. Williamson

GEOLOGY: The area was mapped by McIlwaine (1972). Amethyst occurs within a large calcite vein, 5 m wide, trending 080°. The vein is hosted in both Archean monzonite and Sibley Group sandstone and mudstone. The present erosional surface appears to be within metres of the unconformity between Archean and Proterozoic rocks. A carbonate-quartz breccia zone consisting of Sibley Group fragments and weathered calcite matrix, lies just north of the vein, trending 090°. Portions of the vein are impregnated with chalcopyrite and galena, and are radioactive. Amethyst occurs as dark to pale purple crystals lining large vugs within the calcite vein.

One large vug runs water, indicating that there is substantial permeability within the vein, which may be due to a system of vugs.

MINING INFORMATION:

The property was drilled in 1967 for copper. The breccia zone was intersected in the drill holes (Vos 1976). E. Williamson obtained the mining rights when they came open and developed the claims for amethyst. At one time there was a store on site with samples and jewellery for sale. The property is no longer active (photo 4-17).



Photo 4-17: Dorion Amethyst Mine shop and picking tables as they were before the mine closed. (Photo M. Gerow).

DZUBA ANCLIFF (14), PIPELINE (15), AND THUNDER BAY (16)

OCCURRENCES

LOCATION: The Ancliff occurrence consists of 2 leased claims, TB 352386 and TB 132986, in mining locations 7 and 5, McTavish Township.

The Pipeline showing is virtually on the pipeline right-of-way, in the southeast corner of mining location 13, McTavish Township, on leased claim TB 404862.

The Thunder Bay occurrence is at the south end of a small lake, C IV, southeast 1/4 Lot 4, McTavish Township. It is approximately 1 km south of the Thunder Bay Amethyst Mine Panorama.

ACCESS: The Ancliff occurrence: Highway 11/17 east to the Dorion Mine Road. Head south for 1.6 km, just before the second gravel pit turn east onto a bush road. Follow this road for 1 km to the railway track. Follow the path for 600 m to the west end of the occurrence.

The Pipeline occurrence: Highway 11/17 east to the Dorion Mine Road. Take this road south to the pipeline road and turn west onto the pipeline road. The

showings are just past Number 26 on the pipeline.

The Thunder Bay occurrence: Highway 11/17 east to the East Loon Road. Turn left on the East Loon Road and follow this road for 6.2 km. A bush road leads east 210 m to the occurrence.

OWNERSHIP:

Dzuba family

GEOLOGY: The Ancliff occurrence: The main part of the occurrence is in a wide carbonate-quartz breccia zone which has been traced along strike for 600 m at an azimuth of approximately 090°. The breccia separates Archean monzonite to the north from Sibley Group mudstone to the south. The monzonite is dark pink and massive, the mudstone is red, fine-grained, thinly-bedded, with small grey reduction spots. Silicification of the mudstone is evident close to the breccia zone (photo 4-18). The breccia zone varies from 1.5 to 4.5 m wide and consists of angular clasts of monzonite and mudstone in a matrix of quartz, calcite and some barite. Sulphides, chalcopryrite, galena, and sphalerite, occur in disseminations and veinlets towards the northeastern end of the breccia. Concentrations are rich enough to have sparked interest



Photo 4-18: Dzuba Ancliff occurrence, showing the breccia and silicified Sibley mudstone.

as there are old workings on the site, particularly an adit. Amethyst occurs in the quartz-carbonate matrix and as spectacular points lining some very large vugs in the vein. The colour of the amethyst is quite variable, from almost pink to very dark purple.

The Pipeline occurrence: The host rock for this occurrence is the pink Archean monzonite. A breccia/fault zone, trending 110°, consists monzonite fragments in a quartz matrix. Vugs occur within the breccia and are lined with amethyst. Colour of the amethyst is again quite variable from very pale to dark purple.

The Thunder Bay occurrence: Amethyst occurs within a breccia zone trending 040°, in Archean monzonite. The zone varies from 1 to 5 m in width. The fragments in the breccia are monzonite, floating in a fairly massive quartz matrix. Vuggy sections within the breccia contain minor drusy amethyst of a light to medium purple colour.

MINING INFORMATION:

The Ancliff occurrence: The property has a history dating back to the late 1940's. That part of McTavish Township was prospected for base metal mineralization

and the large carbonate veins carrying some sulphides were considered good targets. Old workings consist of several trenches and the adit. Amethyst, noted by the early workers, did not become the prime mineral of interest until the 1960's. Mr. Dzuba acquired the mineral rights in 1967 and proceeded to work the claim for the amethyst and continued production for approximately 15 years.

The Pipeline occurrence: There are 2 trenches on the occurrence. Production from this occurrence is unknown.

The Thunder Bay occurrence: There are 2 trenches on this occurrence and at one time there was extensive stripping done to expose the zone.

THE ENTERPRISE MINE (18)

LOCATION: The Enterprise Mine is located in north 1/2 of Lot C, C V, McTavish Township. The 2 shafts are on the north side of the railway and are visible from the tracks.

ACCESS: Highway 11/17 east. The bush road to the mine is approximately 3 km east of Road 5 North in the town of Pearl and is marked with a yellow pipeline indicator. Turn south onto this road, keeping to the left and follow it to the end. The mine shafts are a short walk towards the railway from the end of the road. Another amethyst occurrence is located 400 m along the pipeline from the intersection of the pipeline and the railway. This second occurrence, owned by W. Forsgren, is sometimes referred to as the Enterprise, but it is actually separate from the Enterprise mine.

OWNERSHIP:

The mining rights for the ground on which the Enterprise mine is located are currently held by K. Kukkee.

GEOLOGY: The property is very close to the unconformity between the Archean monzonite and Proterozoic Sibley Group mudstone of the Rossport Formation. The unconformity

is exposed in outcrop along the railway track, just below the fenced-in shaft. Quartz-carbonate veining and a breccia zone are associated with a fault zone trending 070°. The vein averages 1 m in width with numerous splays. Galena, chalcopyrite, barite and amethyst occur in discontinuous concentrations throughout the vein system. Gold and silver values from assay results are reported by Tanton (1931). Radioactivity associated with the galena and the unconformity can be used as a prospecting tool to locate continuations of the vein system in overburden. Preliminary scintillometer surveys done over extrapolated extensions of the unconformity revealed a change in count rate in going from the Archean to the Proterozoic and a peak at the unconformity, as long as the overburden was not too deep.

MINING INFORMATION:

The vein was discovered by Peter McKellar in 1865. Between 1870 and 1876 two shafts were sunk. The Number 1 shaft went to a depth of 180 ft and accessed 2 levels and a stope. The Number 2 shaft was 60 ft deep. Total production from the mine was a single shipment to Wales in 1875 and then mining ceased in 1876. Numerous people have expressed interest in the property since that time, but there was no further production.

The W. Forsgren property has a pit and 2 trenches exposing a quartz-rich breccia zone trending 070°. The pit is small, 1 m by 1 m, and the trenches are 6 m by 1 m and 3 m by 1 m, each 1 m deep. The breccia contains galena, pyrite, sphalerite, barite, and amethyst. W. Forsgren has collected amethyst from this occurrence for several years but there is no record of commercial production.

LITTLE BEAR AMETHYST QUARRY (21)

LOCATION: The quarry is situated north of the northeast arm of Kabamichigama Lake, 45 km north-northwest of Rossport, Ontario.

ACCESS: Highway 11/17 east to the Domtar Woodlands road, 16 km east of Nipigon, Ontario. Turn north on this road and be wary of logging trucks. At km 18, turn right on a sideroad. The little shop and sign for the quarry is approximately 18 km along this road (photo 4-19).

OWNERSHIP:

T. Galarneau

GEOLOGY: The host rock is an Archean biotite granite with pegmatitic sections and lots of quartz veining. Amethyst occurs in open spaces within quartz veins, forming sheets of druse. Crystal points are about 2 cm wide, but tend to be rusty. The quartz is white at the edge of the vein, becoming darker purple towards the centre.

MINING INFORMATION:

The trench which constitutes the quarry is 100 m long and 1 to 1.5 m wide. It is parallel to the quartz



Photo 4-19: Shop at the Little Bear Amethyst Quarry.

veining, trending 140° . Mr. Galarneau extracts amethyst using an aggregate permit and sells it from the mine site. The site is open to tourists. According to Vos (1976), the name comes from a black bear cub who decided to make the quarry its home. Mr. Galarneau sold a leased claim to Richard Patterson, who operates the Little Bear Amethyst Mine on that claim. The Little Bear Mine is approximately 100 m north of Mr. Galarneau's quarry (Figure 4-5). The similarity in names causes confusion.

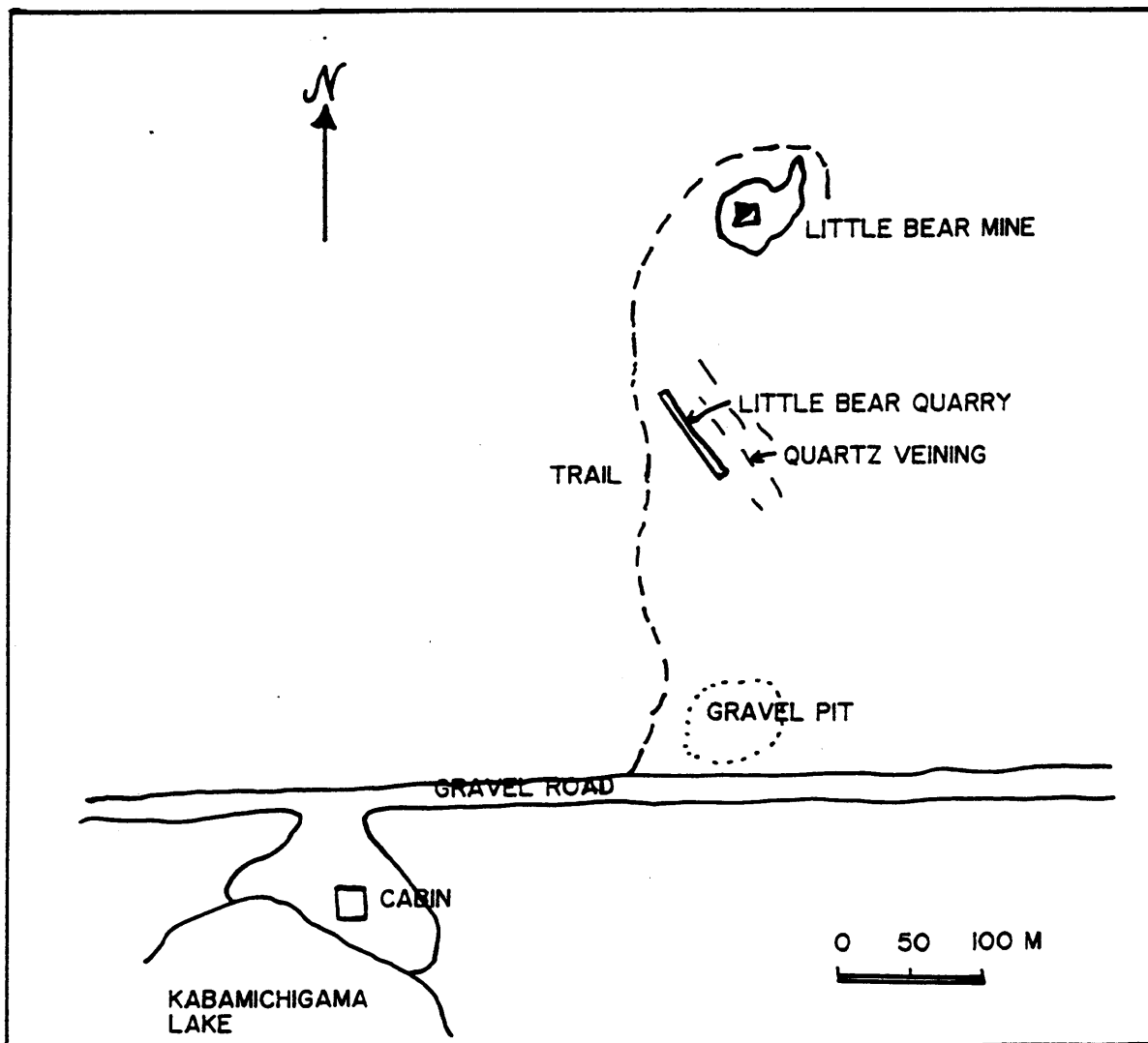


Figure 4-5: The Little Bear Amethyst Quarry and the Little Bear Amethyst Mine.

GEM MOUNTAIN MINE (22)

LOCATION: The Gem Mountain mine is located on mining lease 974958 in the North of MacGregor area. The lease is about 1 km north of the township line, lot 8 in MacGregor Township.

ACCESS: Highway 11/17 east to the Armstrong highway (527). North to the Magone Lake road at km 9. The Magone Lake road is gated at km 9 and the gate is closed on weekends and at night. East for 10 km to road 10, then southeast as far as the road goes, then walk east to the claim. The logging road is a 4-wheel drive only road, and changes as Great Lakes Pulp and Paper continues to log. The alternate access is from MacKenzie Station road which heads north from highway 11/17 at MacKenzie Station. Park at the gate and take ATV's to the mine road, about 7 km. The mine road is a track going north up a steep hill.

OWNERSHIP:

Richard and Onni Harty

GEOLOGY: The host rock for the occurrence is the dark pink, feldspar-rich, massive to porphyritic Penassen Lakes granite. The granite in this part of the North of

MacGregor area forms very high ridges and hills. Quartz veins with small vugs and spaces are common, striking 080°. Boulders of a very coarse breccia lie at the base of a northeast-trending cliff which forms the south side of a prominent ridge. The breccia zone also occurs on the north side of this ridge. Fragments in the breccia are composed of the granite, metasediments, and Sibley Group rocks. Amethyst occurs in vugs as crystals of pink, purple, and red, hematite-coated points.

MINING INFORMATION:

Commercial production from this mine has been sporadic. The Hartys have had this ground for several generations and have prospected the area extensively. Exploration and work on the access roads continues to improve this area which has a high potential for amethyst.

M. GRIEVE AND FAMILY MINE (23)

LOCATION: The Grieve property is located in the North of MacGregor area on mining lease 656461, approximately 2 km north of the township line at Lot 8 in MacGregor Township.

ACCESS: Highway 11/17 east to the McKenzie Station road. North on this road for 2.45 km then turn right just past the railway tracks. Turn left at 5 km onto a dirt track and proceed to the gate. This is private property and permission is required to access the gate. The mine is approximately 6 km north and ATV's are required.

Alternate access is via the Magone Lake road, 9 km north off the Armstrong highway (527). Follow the Magone Lake road for approximately 10 km. Just after the road turns north, there is a bush road heading east. Take this road to the end (4-wheel drive required) then follow the trail to the claim group.

OWNERSHIP:

Michael and Sandra Grieve and sons

GEOLOGY: The bedrock and host to the amethyst is a dark pink granite. This is the same granite body which extends

throughout most of the north part of MacGregor Township and into the Tartan Lake area and is known as the Penassen Lakes granite. It is characteristically medium-grained, pink, and texturally uniform. The mine workings are on the sides of a large ridge; the same ridge of granite which hosts the Gem Mountain mine. The main breccia zone trends at 240° . This zone is characterized by breccia fragments, usually 2 to 30 cm in size, which are cemented together by several generations of quartz. On the southwest side of the ridge, the breccia fragments consist of small, angular pieces of Gunflint shale and jasper in addition to granite (photo 4-20a). This means that the unconformity was very close to the present exposed surface. It also means that the Gunflint Formation once extended farther north than is presently exposed. Amethyst occurrences to the southwest and on strike, such as the Gem Mountain mine are probably lower in the sequence relative to the unconformity and may indicate possible depths to the amethyst veins.

The amethyst veins trend at 090° and consist of massive amethyst as well as druse lining vugs (photo 4-20b). When massive, the veins consist of banded amethyst of varying degrees of purple and white quartz. Zonation within massive veins trends from pale to dark towards



Photo 4-20a: Breccia zone exposed along the side of a granite ridge at the Grieve's amethyst mine. Workings along this zone have exposed the large vug in the foreground.



Photo 4-20b: Large amethyst crystals, M. Grieve amethyst quarry.

the centre. Thin bands of chalcedony seem to indicate separate fluid impulses since chalcedony is usually the first and last to crystallize. Vugs and open spaces within the veins are lined with amethyst points up to 6 cm in diameter. Dark, almost black amethyst occurs in places where black, radioactive minerals are visible in the granite. Near the veins, the granite has been altered to a light cream colour due to kaolinization of the feldspar. Quartz veining is very prominent to the point of silica flooding; in some outcrops anastomosing quartz veins completely mask the rock (photo 4-20c).

MINING INFORMATION:

Amethyst in this area has been known for a long time by fishermen and hikers who used the trail to access the interior area. The showing was first staked in 1967 and for the next 16 years various prospectors staked and worked the occurrence. Dzuba and Barrett both held the mining rights at one time. The present owners staked the property in 1982. There are several pits on the east side of the ridge and 1 on the west side. The largest pits on the east side are 3 to 4 m deep. There are large stockpiles of amethyst and breccia obscuring most of the outcrop around the pits. Amethyst samples are removed and sold at an outlet in Kakabeka Falls.

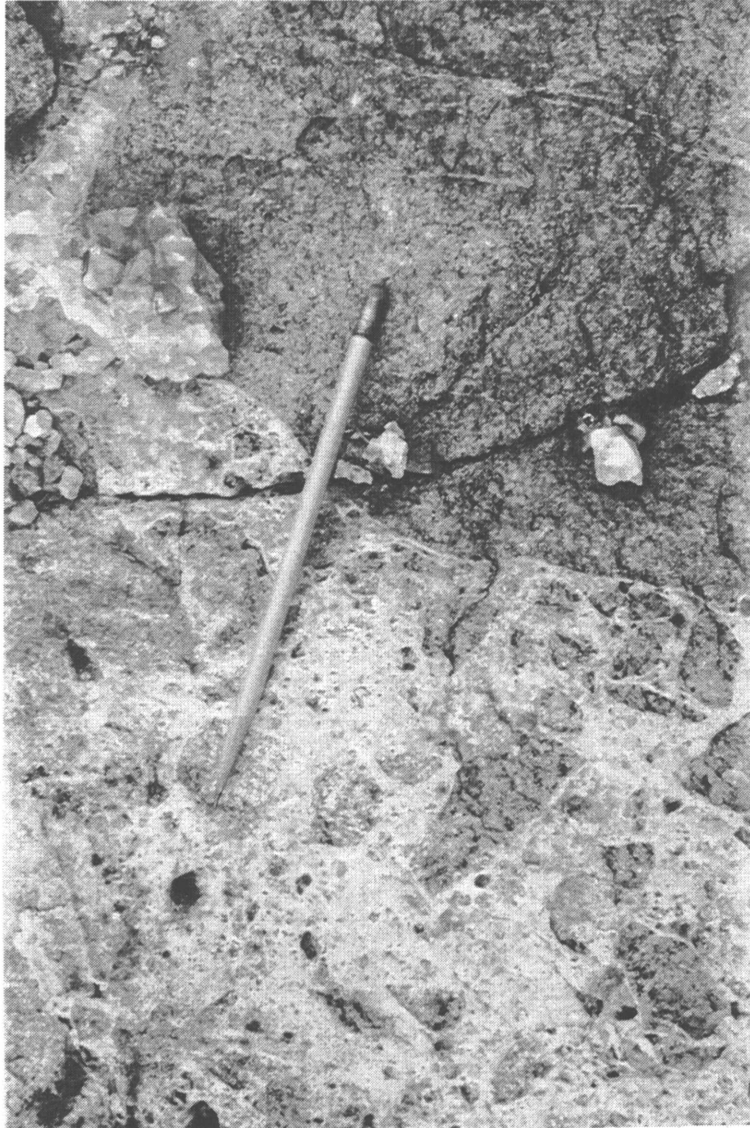


Photo 4-20c: Silica flooding in granite, Grieve's amethyst quarry.

JEAN TOWNSHIP OCCURRENCE (25)

LOCATION: The Jean Township amethyst occurrence is on the south side of Tower Lake. The township is unsurveyed and there are very few access roads.

ACCESS: The easiest access is by ATV on a bush road leading north from highway 588. The bush road is approximately 2 km past the Strange/Jean Township line, at Whitefish Lake. The alternate route is to take highway 590 to the Boreal Road. Follow this road for almost 25 km, keeping left on all the main forks. At 25 km there is a rough logging road on the left heading south to Chota Lake. The road may go farther now, but it is possible to walk to Tower Lake from Chota Lake, about 2 hours.

OWNERSHIP:

There are 3 claims staked in the area of the showing. One is registered to Raymond Hietapakka, one to Glen Duffy, and one jointly to Raymond Hietapakka and Aki Siltamaki.

GEOLOGY: Tanton refers to several silver-bearing veins in the area north of Whitefish Lake, but lack of surveyed reference points makes it very difficult to pinpoint which vein is where. The heavy forest growth in the

township makes it difficult to find the old workings. The amethyst showings are hosted in an Archean gneissic granite. The first showing on claim 1165879 consists of white quartz veins striking 030° to 000° and dipping steeply east. Only a pod of breccia was exposed, with fragments of granite and chloritized metasediments in a white quartz matrix. The north end of this vein is exposed in a cliff face, but blasting by previous owners has left piles of debris obscuring the outcrop. There are vugs within the vein, filled with clay, and lined with dark purple amethyst points. Some of the crystals are quite large, up to 20 cm wide at the base. Massive amethyst in the veins is beautifully banded violet, dark purple, and white. Individual crystals are not as well-formed as the amethyst in vugs, but intact crystals are very large, 10 by 20 cm. Dark purple fluorite was noted with the amethyst.

The amethyst on claim 1164445 occurs in an irregular vein system which strikes 060°. The main feature of this occurrence is a large vug, at least 2 m high but still partially filled with red clay, and lined with large crystals of brilliant red, hematite-coated quartz crystals. The quartz druse lines both sides of the huge vug, with crystal points 5 to 8 cm in diameter. The colour of the quartz is pale violet to white, but

this is compensated by brilliant red colour and size of the crystals. The only indication of continuation of the vein system within the granite is a shear zone and kaolinization of the feldspars along the shear. At very irregular intervals, open spaces within the vein are lined with more brilliant, red-coated quartz crystals.

MINING INFORMATION:

Mining locations were special permits for use of Crown land, issued prior to the mining act and encompassing both mineral and surface rights. The location for the Jean Township amethyst and the silver veins mentioned in Tanton (1931) is covered by mining location T 190 on older versions of the Jean Township M plan. Tanton (1931) mentions a quartz vein 600 feet southwest of a diabase-capped hill (Tower Hill) and another vein 2 1/2 miles south with amethyst and fluorite, which would be approximately the correct location. In 1973, 2 claims were staked over both occurrences and stripping and trenching was done. The claims were restaked in 1978 and again in 1983 by the same person. The present owners staked in 1990 and 1992.

LITTLE BEAR AMETHYST MINE (27)

LOCATION: The property is located north of the northeast arm of Kabamichigama Lake on leased claim TB 277890. The Little Bear Mine is 100 m north of the workings of Little Bear Quarry. The 2 occurrences are frequently confused as being one and the same.

ACCESS: Highway 11/17 east to the Little Bear Quarry Road, also known as the Domtar Woodlands road, 16 km east of the town of Nipigon, Ontario. At approximately 26 km on this road turn east onto a branch road for 18 km. The building belonging to Little Bear Quarry is on the left and the trail to the quarry and the mine is across the road and through the gravel pit.

OWNERSHIP:

Richard Patterson

GEOLOGY: The area has been mapped by the Ontario Geological Survey (Carter 1970). The host rock is a biotite granite with pegmatitic sections. A quartz breccia zone, 1 m wide, strikes 150° and dips steeply west. Fragments in the breccia tend to be less than 10 cm in size and are very angular pieces of granite. A white quartz vein, almost 1 m wide, occurs with the breccia

zone and there is lots of smaller quartz veins through the granite. Amethyst druse coats the sides of veins. The crystals are small and tend to be flattened. The quartz is rusty due to the presence of sulphides.

MINING INFORMATION:

The workings at the Little Bear Mine consist of a trench 30 m by 5 m by 2 m deep and a pit 2 to 3 m deep, now water filled (Figure 4-5). The claim was purchased by R. Patterson from Ted Galarneau in 1980. Ted Galarneau found the occurrences by noting the amethyst float in the gravel pit near the road. There was no production from the mine in 1992.

G. McLEOD QUARRY (30)

LOCATION: G. McLeod's claim is situated in the northeast corner of C II, Lot 12, MacGregor Township, at the northeast end of the Penassen Lakes.

ACCESS: Highway 11/17 east to the Armstrong highway (527). North for 9 km to the Magone Lake road. East on the Magone Lake road turning right at the fork at 4 km. Follow this fork for approximately 1 km. A trail, on the right, leads south to the working area, about 2 km.

OWNERSHIP:

G. McLeod

GEOLOGY: The country rock in the area is pink, massive, coarse-grained granite, part of the Penassen Lakes intrusion. The granite in this locale is porphyritic in texture. Pieces cut and polished are attractive, indicating a potential for building stone. The amethyst showing is at the edge of a cliff, just north of the Penassen Lakes. The cliff strikes at 010°. There are lots of quartz veins, all striking 080° and dipping vertically. The veins are 25 to 30 cm apart and are quite narrow, 1 to 1.5 cm wide. The veins are lined with white, smoky,

and purple-black quartz (see photo 4-11b). Colour distribution within the quartz seems to depend on proximity to radioactive minerals within the granite. The quartz crystals are less than 1 cm wide, but are very well-formed and clear of any coatings. The granite near the veins is quite red in colour and very densely porphyritic.

MINING INFORMATION:

G. McLeod extracts amethyst from his claim with an aggregate permit. The amethyst is usually left on the host granite and made into bookends or pen holders.

MOUNT BALDY OCCURRENCE (32)

LOCATION: The Mount Baldy occurrence is located in mining location 24 Z, at the south west corner of MacGregor Township.

ACCESS: Highway 11/17 east to the Armstrong highway (527). North to the Mount Baldy road, then east for 500 m. Follow the trail southwest for 150 m to the cleared site.

OWNERSHIP:

Basil Smith and Tim Twomey

GEOLOGY: The area was mapped by John Scott (1986) of the Ministry of Northern Development and Mines, Thunder Bay, Ontario. The occurrence consists of a quartz breccia, 5 m wide, occupying a fault zone trending 060°. The fault separates Archean mafic volcanic to the north from iron-rich chert of the Proterozoic Gunflint Formation to the south. The Proterozoic rocks form a small outlier from the main band of Gunflint Formation farther south. The majority of the fragments in the breccia are volcanic, cemented with white quartz. There is lots of quartz veining parallel to the breccia zone. The breccia zone contains many small

vugs, lined with light purple amethyst. The points, all around 1 to 1.5 cm wide, are very well formed, and have no deleterious coating. There is a shadow of dark purple just at the crystal tips. Along the strike of the fault zone, 200 m to the southwest, is an amethyst, copper, lead, zinc occurrence.

MINING INFORMATION:

Amethyst has been noted in the area from the heyday of the silver mines. Most of the lead-zinc occurrences are associated with amethyst and deserve to be prospected, especially along strike of any major structures. The area has been extensively stripped and mapped by the present owners.

ONTARIO GEM COMPANY AMETHYST MINE (33)

LOCATION: The Ontario Gem amethyst mine is located in McTavish Township, C IV, Lots 10 and 12. There are 10 leased claims which constitute the entire property.

ACCESS: Highway 11/17 east to the Dorion Mine Road, just past Pearl, Ontario. Follow this road south for 4 km, cross the railway tracks and proceed straight, not to the left after the tracks. The parking lot and mine store are about 1 km from the tracks.

OWNERSHIP:

Peter Marino owns the mine--some of the mining leases are jointly owned with his brother.

GEOLOGY: The regional geology was mapped by McIlwaine (1971). The main topographic feature is a high ridge of Archean monzonite which runs at 038°. The cliff along the north face of this ridge is a result of a fault/breccia zone separating the Archean monzonite from Sibley Group mudstone on the northwest side of the fault. The ridge is at least 1 km long and the breccia zone is exposed in 3 places. Drilling or stripping would confirm the continuity of the breccia zone. The breccia zone pinches and swells, reaching a maximum width of 10 m in

the main pit. Fragments in the breccia vary dramatically in size, from almost a metre to pebble-sized. Monzonite, mudstone, and older breccia are all represented as fragment lithologies (photo 4-21a). Amethyst occurs in vugs within the breccia and as drusy veins between the monzonite and breccia. Large bladed, orange barite crystals are splashed across the amethyst druse, forming spectacular exposures of the 2 minerals (see photo 4-6b).

There are 3 pits situated along the 1 km fault zone. The main pit, the largest excavation, is the first one reached via the bush road from the mine office (Figure 4-6). In this pit, the cliff wall is exposed for 70 m and consists of pink monzonite, some narrow exposures of the breccia zone, and amethyst druse with the orange barite roses. Rock has been blasted to expose the amethyst vein and now forms a rubble pile 5 m high which obscures much of the breccia and Proterozoic rocks. Small outcrops of mudstone and breccia are visible on the pit floor amidst the rubble and along the edge of the cliff. Breccia matrix in this pit consists of quartz, barite and coarse calcite. Seams of galena are associated with the calcite.

The middle pit is a smaller excavation 500 m southwest along strike from the main pit. Part of the cliff face has been blasted, leaving large blocks of breccia lying at the foot of the cliff. Vugs in the breccia are lined with smoky and light to dark purple amethyst.

The farthest south pit is another 300 m southwest along strike from the middle pit. The breccia zone has dwindled to quartz breccia shears within massive, pink monzonite which shows evidence of bleaching due to the veins. Another set of quartz veins with galena, trending 070°, cut across the quartz breccia. In this location the Sibley Group mudstones lie unconformably on top of the Archean. In depressions within the monzonite, malachite-stained, cherty stromatolite layers have survived erosion (photo 4-21b). In one area, the 3 rock types, the monzonite, stromatolites and mudstone are exposed together. Pieces of the stromatolite have been broken and incorporated into the basal part of the mudstone. Vugs occur along the breccia and vary from cm sized to cavern-sized. One vug is 3 m deep and 2 m wide and at one time was completely lined with large, dark purple amethyst crystals (photo 4-21c). Amethyst also occurs between layers within the stromatolites forming very interesting samples.

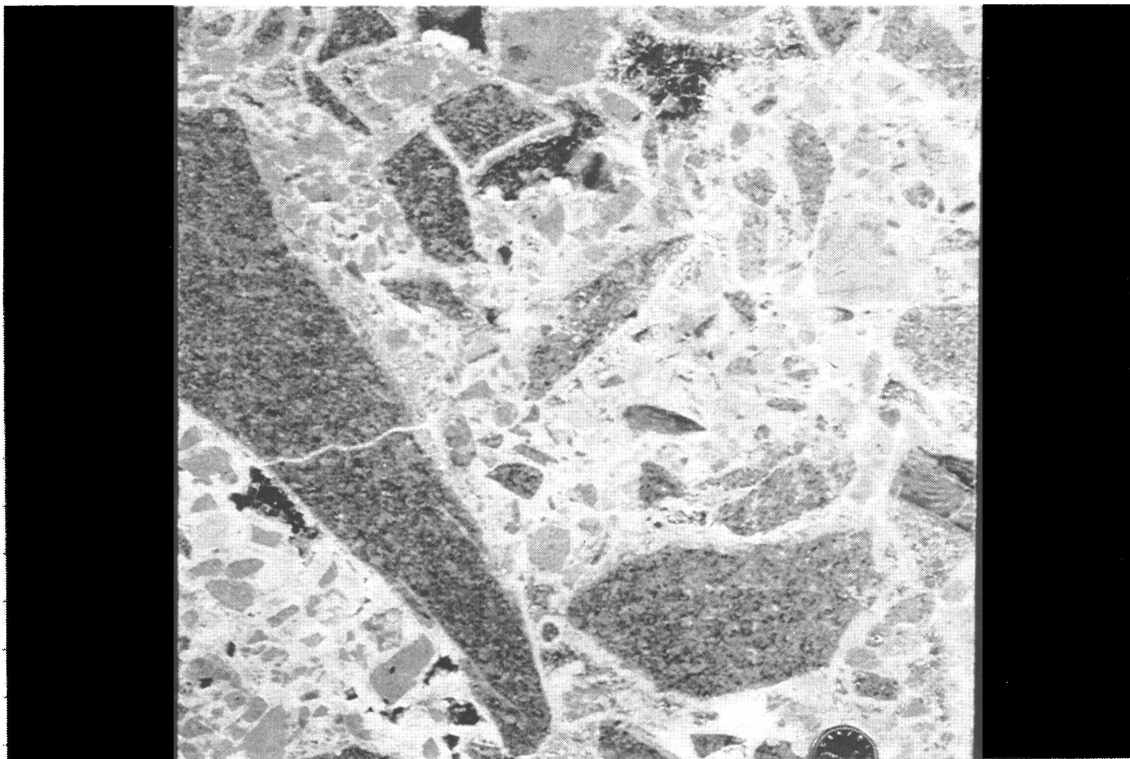


Photo 4-21a: Tile, 1 ft x 1 ft x 2 in, made from breccia taken from the Ontario Gem Mine, displaying the variety of lithology types and fragment sizes.



Photo 4-21b: Stromatolites lying unconformably on Archean granite, Ontario Gem Mine. The wavy edge of the stromatolites is at the toe of the boot.



Photo 4-21c: Large amethyst vug, Ontario Gem Mine.

MINING INFORMATION:

The original leased claim was developed by Rickaby Mines Ltd. and sold successively to different people until the present owner bought the claim in 1982. The mine is open to the public and amethyst from the mine is made into jewellery, giftware, or faceted into cut stones. All products are sold in the store on site.

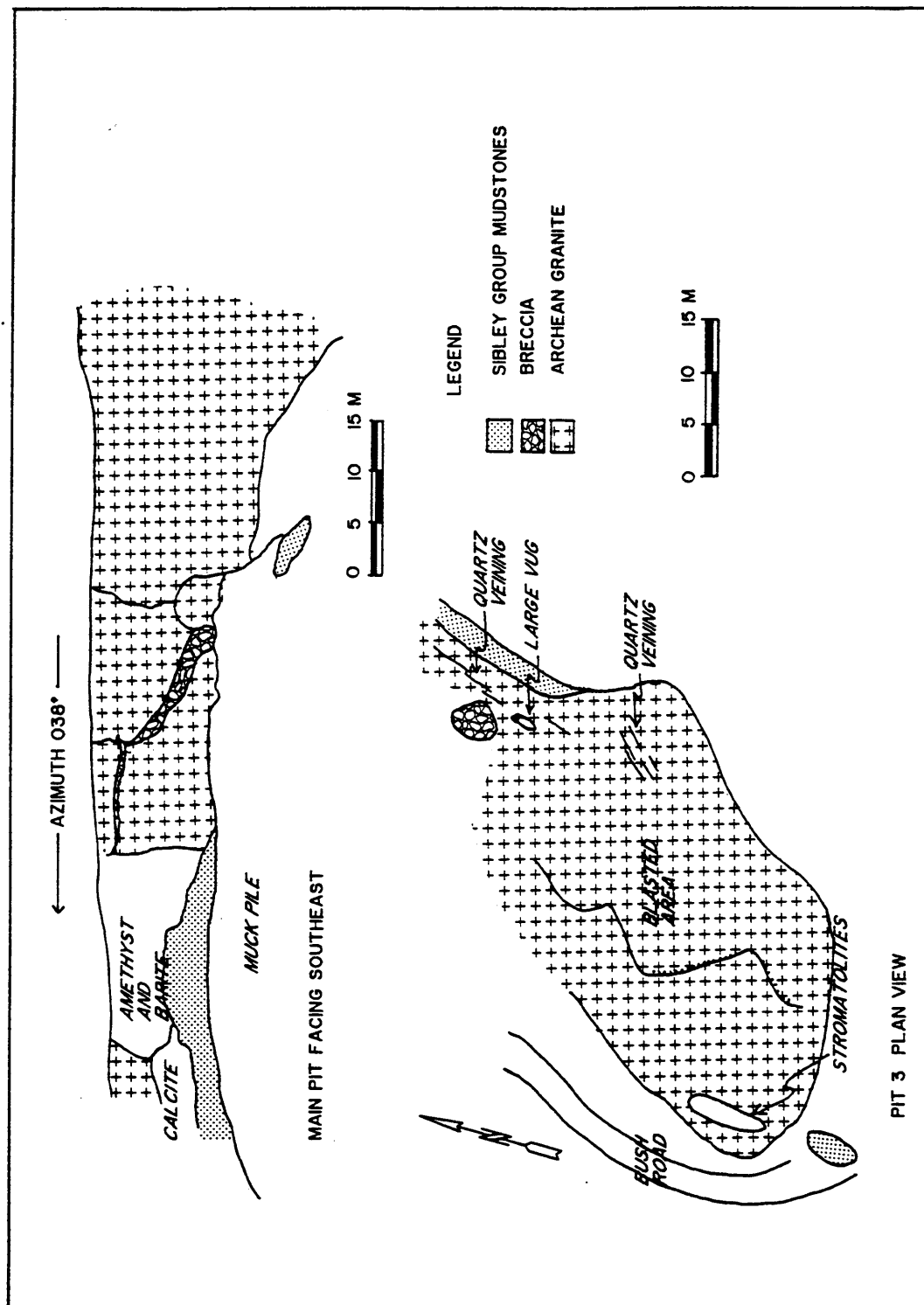


Figure 4-6: Ontario Gem Company Ltd. mine.

PEARL LAKE AMETHYST MINE (34)

LOCATION: The Pearl lake amethyst mine is located in McTavish Township, C III, southern half of Lot 3, north of Big Pearl Lake. There are 9 leased mining claims registered to Pearl Lake amethyst mine. The original 4 leased claims are TB 645197-200.

ACCESS: Highway 11/17 to Road 5 North in Pearl, Ontario. Turn left just past the railway tracks and follow this road to the signs for the Diamond Willow and Blue Points mines (3.8 km). The gate for the Pearl Lake mine is just past the Blue Points mine road. The mine shop is 2 km from the gate (photo 4-22a).

OWNERSHIP:

Phil Durocher and Eleanor Castagne

GEOLOGY: The area was mapped by McIlwaine (1971) for the Ontario Geological Survey. The unconformity between the Archean and Proterozoic is exposed in various places on the property. A main fault zone, trending 035°, characterized by a breccia zone 5 to 10 m wide, separates Archean granite to the northwest from Sibley Group conglomerate to the southeast (see photo 4-3b). A secondary fracture system, trending at 070° to 090°,

has been dilated by the first fault creating spaces and vugs perfect for amethyst deposition (see photo 4-2).

The Archean monzonite is dark pink, coarse-grained, potassium-rich rock with pegmatitic sections. Areas next to amethyst veins have bleached to a white colour due to kaolinization of the feldspar. Metasedimentary xenoliths occur as biotite-chlorite schists within the monzonite. The conglomerate consists of well-rounded cobbles averaging 10 cm, occasionally up to 50 cm in diameter, cemented by a sandy matrix. Granite cobbles predominate, Gunflint taconite and sandstone occur rarely as cobbles near the bottom of the unit and all the cobbles are matrix supported (photo 4-22b).

There are 5 areas along the main fault zone which have been worked for amethyst. The northern working consists of a pit blasted into the side of a monzonite knoll (Figure 4-7). The breccia zone in this pit strikes 070° and is 2 m wide. The fragments are angular pieces of mudstone, monzonite, and gneissic rock in a white quartz matrix. Pink barite occurs next to the wall rocks and coarse amethyst veins occur between the barite and the breccia. The host rock on both sides is Archean monzonite and bleaching of the



Photo 4-22a: Rock shop and amethyst display area, Pearl Lake Amethyst Mine.



Photo 4-22b: Large cobbles near the bottom of the conglomerate unit, Pearl Lake Amethyst Mine. (Photo by G. Patterson).

monzonite is quite evident along the walls. Dark purple amethyst lines vugs within the breccia and as massive vein material along the sides of the breccia.

The main fault zone which trends at 035° can be followed to the southwest from the northern pit by tracing a breccia zone exposed along the side of a linear wetland. Sibley Group conglomerate outcrops to the southeast of the breccia. Archean monzonite on the northwest side is visible where the wetland narrows to the width of the breccia zone, about 10 m. Amethyst occurs within the breccia in vugs and as veins. There are small pits along the breccia zone where amethyst has been mined. Since amethyst mineralization is fairly continuous in the breccia, it can be mined wherever breccia is exposed.

The southern working area, where the wetland narrows and monzonite and conglomerate are both exposed, a large, water-filled pit has been blasted into the breccia. In the monzonite hill northwest of this pit, a large, open fracture, 1 m wide, 5 m deep, and surface extension of 5 m, was lined with large, dark purple amethyst crystals. This enormous vug has supplied the mine with many exceptional samples and the bottom of the vug is still clay-filled (see photo 4-2).

MINING INFORMATION:

The original showing, found by tracing amethyst float to the vein system, was staked by Alf Castagne and he developed the Pearl Lake amethyst mine. His stepson is now running the mine.

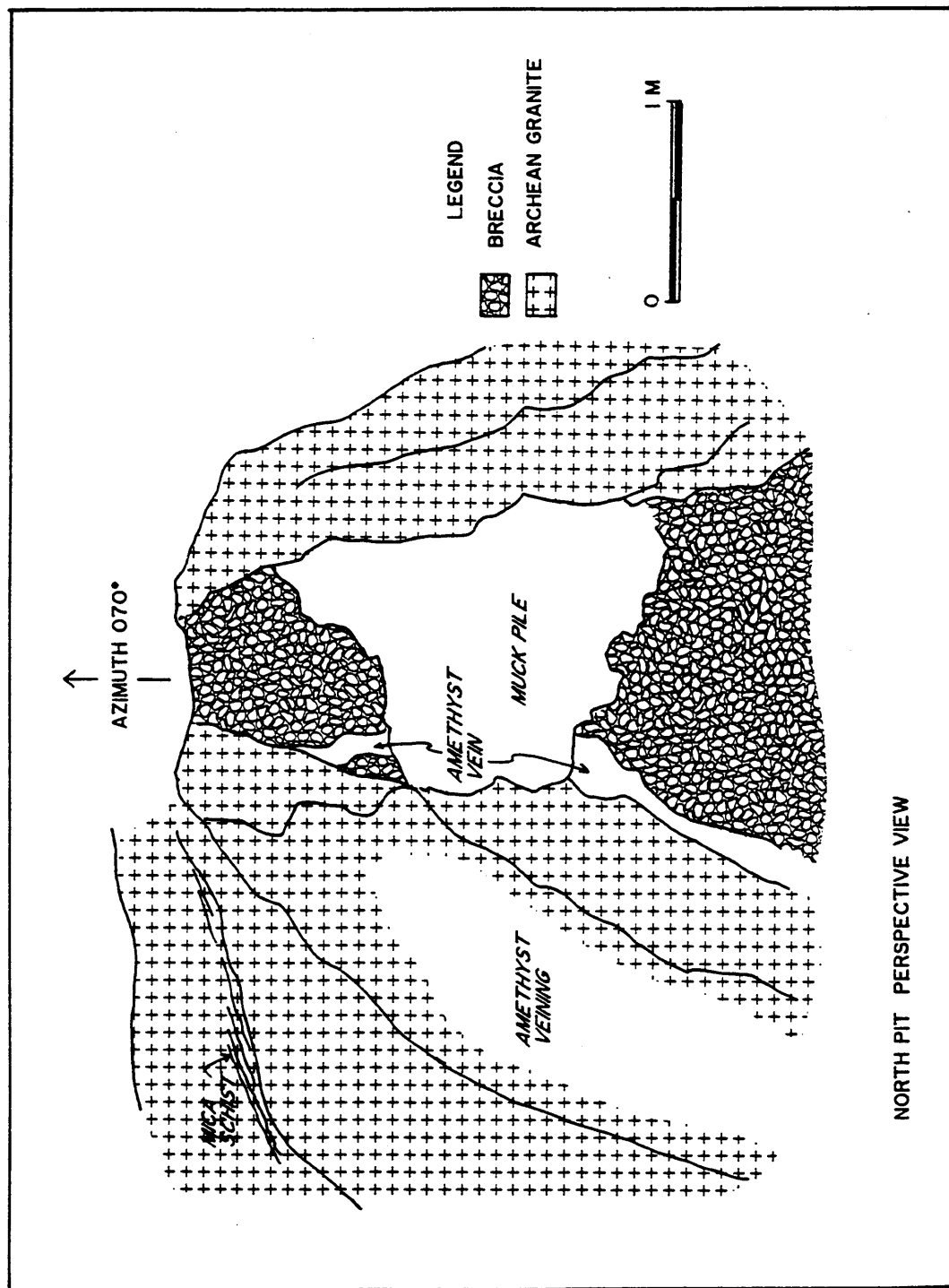


Figure 4-7: The north pit, Pearl Lake mine.

D. BAK OCCURRENCES (38A AND B)

LOCATION: The first occurrence is located on the west side of C IV, lot 5, McTavish Township, on the west side near the south end of Sword Lake (claim 1011028). The second occurrence is located in C V, lot 5, McTavish Township, just east of Big Trout Lake and north of Pike Lake (claim 1011024).

ACCESS: Highway 11/17 to Pearl, Ontario. Take Road 5 North, turning left just after the railway tracks. At approximately 1 km after the turn, there is a gravel road to the left heading up a steep hill. Take this road which heads east around the south end of Sword Lake into the Big Trout Lake area. The first trenched area is on the right just at the south end of Sword Lake. The second area is reached by following the road to the end and walking along a trail to the area of interest.

OWNERSHIP:

D. Bak

GEOLOGY: The area was originally mapped by McIlwaine (1971) and the occurrence in C V, Lot 5 of McTavish is noted in Tanton's report (1931). The occurrence at the south

end of Sward Lake is in almost horizontal Sibley Group red and yellow mudstone. Amethyst occurs in fractures associated with quartz and barite veins, which trend at 100°. The quartz veining has altered the red mudstone to light beige colour for almost 10 cm on either side of the veins. Pale purple crystals, 1 cm or less in size, form a massive druse on the side of the veins (photo 4-23). Very little breccia was noted at this location. A 100 m northeast along the road a trench, 100 m long by 1 m deep, exposes mudstone with quartz veins and amethyst. The veins trend at 080°. Blebs of galena and malachite are associated with the quartz and barite.

The second occurrence is situated along a cliff edge reached by a trail where the logging road ends. The cliff is made of Archean metasediments and pegmatite. Talus along the cliff edge contains blocks of Sibley Group mudstone and pieces of breccia material. The breccia consists of fragments of pink, granitic rock and Proterozoic sediments in white quartz. Vugs in the breccia are lined with crystals of clear quartz and light coloured amethyst. Some of the breccia blocks contain quartz and barite vein material with nodules of sphalerite. The granite outcrop on top of the ridge is

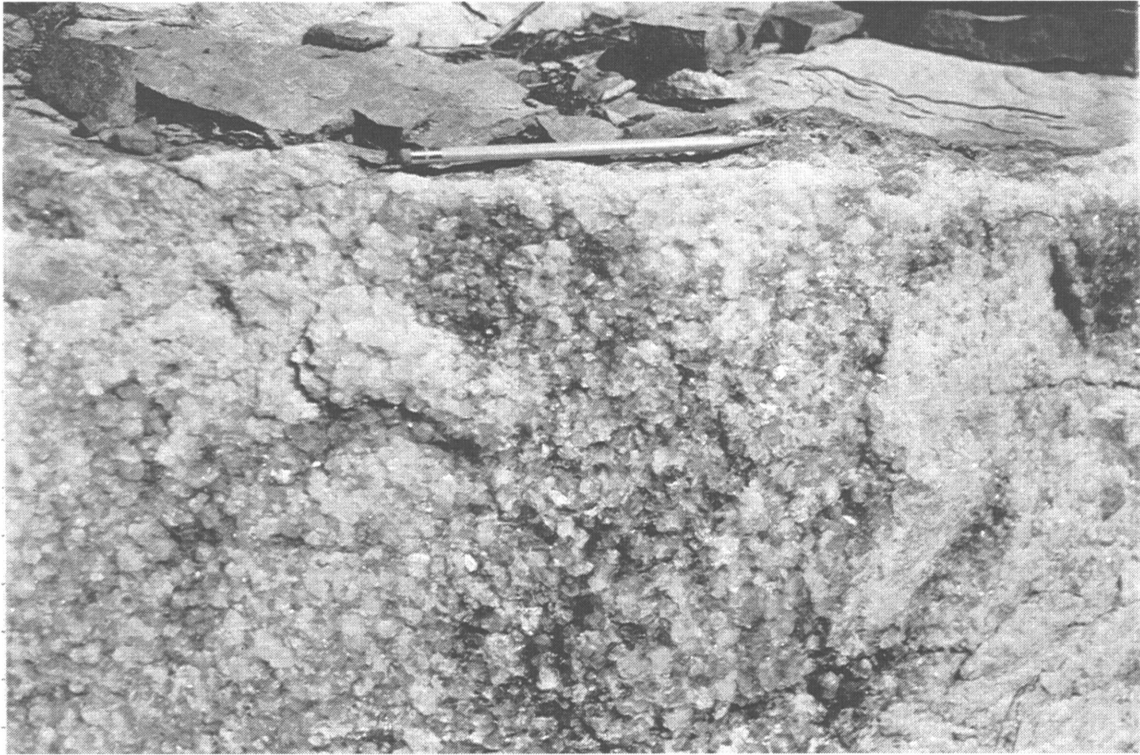


Photo 4-23: Massive druse of light purple amethyst, D. Bak occurrence.

cut by quartz veins and vugs trending 090°. The vugs are lined with dark purple amethyst.

MINING INFORMATION:

D. Bak has 12 claims in good standing as of 1992.

Amethyst is extracted from the first location using an aggregate permit. An aggregate permit for the second location has just been issued.

TARTAN LAKE AREA (43)

LOCATION: The Hietapakka-Siltamaki Tartan Lake occurrence is situated in the southwest corner of Tartan Lake map area, plan G-2706. The 3 claims are just west of Lake Nineteen and border the Great Lakes Lumber Company's logging road.

ACCESS: Highway 11/17 east to the Armstrong highway (527). North for 9 km then right on the Magone Lake road. Follow this logging road past the R 10 turn-off at 10 km. The road swings north after the R 10 turn and the claim group is approximately 2.5 km from R 10. The main vein and stripped area is visible on the east side of the road.

OWNERSHIP:

Raymond Hietapakka and Aki Siltamaki

GEOLOGY: The area has not been systematically mapped. J. Scott (1990), with the Ministry of Northern Development and Mines, Thunder Bay, mapped MacGregor Township to the south of the area. Bedrock to the south in MacGregor Township consists of Archean granite and metasediments. The granite is pink to red, coarse-grained and massive to porphyritic in texture. It is known as the Penassen

Lakes granite and has potential for building stone. Fractures in this granite seem to be amethyst-bearing and the potential for amethyst in this unmapped territory is just being realized.

At the Tartan Lake occurrence, quartz veining in massive granite strikes at 040° (photo 4-24a). Amethyst veins and a breccia zone occupy an area 7 m wide (Figure 4-8). The veins contain massive purple and green amethyst which has grown from nucleation points on breccia fragments and vein walls. The crystals have grown in together, filling all available space, forming massive amethyst. At least 4 pulses of quartz crystallization are quite evident, starting with white, sugary quartz coating all fragments and vein walls. The next layer of amethyst has been bleached green by the final, purple layer of amethyst. The last amethyst to crystallize is a fine druse of tiny, black crystals which have cemented together older amethyst crystals, broken from a collapsed vug. Some of this black amethyst has bleached the underlying amethyst to clear, yellow citrine.

The breccia is not well-developed, consisting of large blocks of granite pulled away from the wall and rotated



Photo 4-24a: Stripped area exposing quartz veining, breccia and amethyst in vugs, Tartan Lake occurrence.

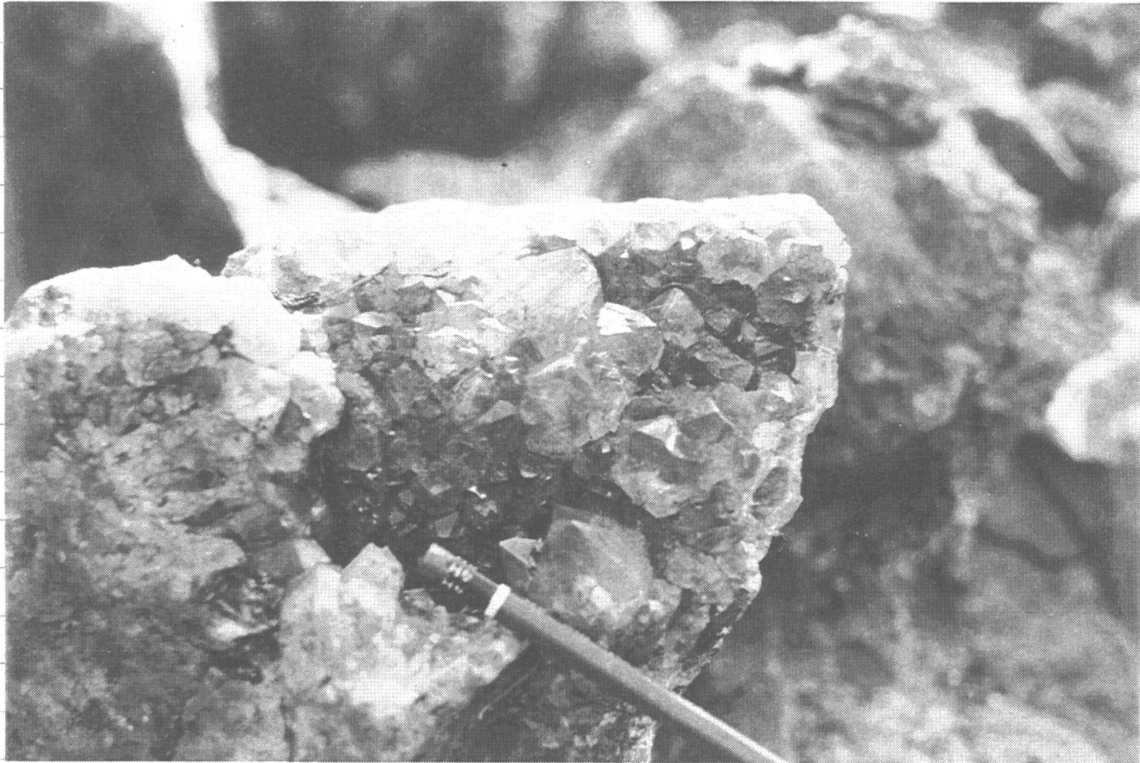


Photo 4-24b: Green amethyst crystallizing on darker, purple amethyst, Tartan Lake occurrence.

into the vein. The granite has been altered and bleached next to the vein.

The zone has been stripped for approximately 50 m along the strike of the vein system and continues to the road. Extension in the northeast direction has not yet been determined.

MINING INFORMATION:

The claims were staked in 1991 by Hietapakka and Siltamaki as a result of prospecting. Float found along the Magone Lake road led them to the vein. They have been removing and selling samples using an aggregate permit.

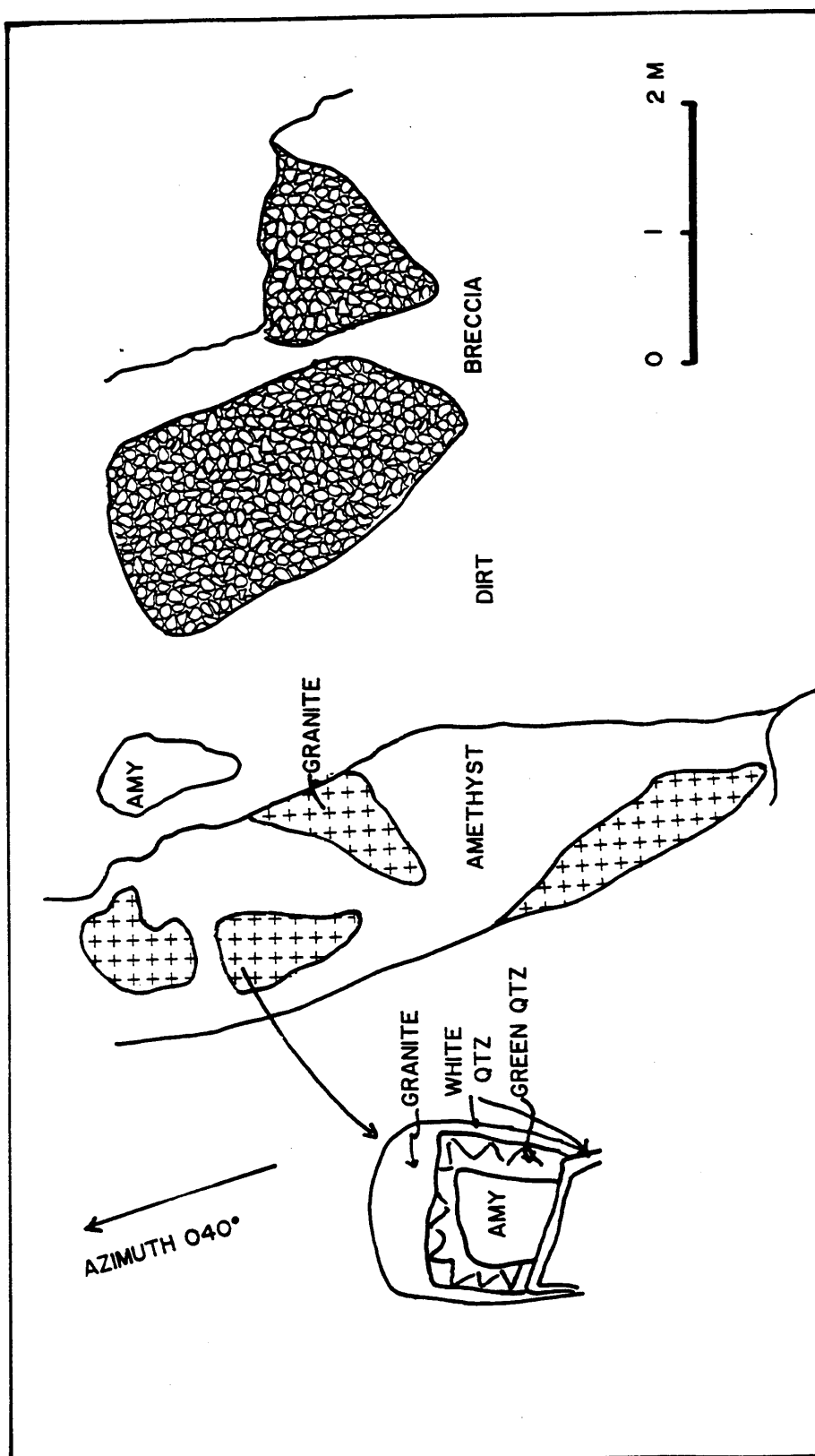


Figure 4-8: The main vein, Tartan Lake area, plan view.

THUNDER BAY AMETHYST MINE PANORAMA (45)

LOCATION: The mine is located just to the east of Elbow Lake, C IV Lots 6 and 7, and C V, lots 6 and 7, McTavish Township.

ACCESS: Highway 11/17 to the East Loon Road which is about 5 km east of the Pass Lake highway. Follow the East Loon road north, staying to the right at the first Y intersection. The mine is about 10 km from the highway (photo 4-25a).

OWNERSHIP:

Precious Purple Gemstones Ltd., president Steve Lukinuk

GEOLOGY: The area was mapped by McIlwaine (1971) and detailed geology of the pit has been mapped by a consultant (Jennings 1985). The owner has also made available samples for fluid inclusion studies (McArthur 1988). The bedrock in the vicinity of the mine is a pink, coarse-grained monzonite (see photo 4-3a). The main fault zone strikes and dips at $110^{\circ}/65^{\circ}\text{S}$ and is contained entirely within the monzonite. The fault is occupied by a breccia zone consisting of fragments of Proterozoic mudstone and monzonite. The fragments tend to be all of similar size, about 15 to 20 cm cemented

by white quartz. Angular spaces in the breccia are lined with medium-purple amethyst points, all very well-formed and free of deleterious coatings. A second fracture system, trending at 010°, has caused dilation where the 2 zones intersect resulting in very large vugs and open spaces (see photo 4-1). Amethyst points up to 15 cm in diameter have been recovered from these vugs. Amethyst veins up to 40 cm wide occur parallel to the main fault direction between the breccia zone and the wall rocks (see photo 4-10). The first sequence of quartz crystallization resulted in white, granular quartz coating every fragment and wall rock. Subsequent layers of quartz vary from colourless quartz to white chalcedony to pale- and medium-purple amethyst (see photo 4-7b). Crystals in veins grow out from the nucleation points, such as the vein walls or fragments in the breccia, meshing together in the centre area of the vein. Some of the crystals are 25 cm from top to bottom. Good gem-quality amethyst requires colour saturation throughout the crystal and good clarity, without inclusions, coatings, microfractures or other defects. Dark-purple amethyst from the large veins and vugs frequently contains parts of the crystal which are gem-quality.

B. Jennings (1985) mapped the pit area in detail. She delineated 2 sets of amethyst veins, at 100°/90° and 016° to 345°/80°. Jennings subdivided the amethyst into colour and clarity groups and noted the paragenesis of quartz sequences in different parts of the pit. In general, the sequence of quartz crystallization consists of an initial layer of white chalcedony followed by colourless quartz and amethyst. This sequence can be repeated 3 times, each sequence initiated with a thin band of white chalcedony. Sometimes only 1 or 2 sequences are observed. Any zoning in the veins is symmetrical from both sides.

The main pit is 25 m wide by 200 m long, 4 to 5 m deep at the west end 1 to 2 m deep at the east end (Figure 4-9). A bench dividing the west part of the pit from the east also serves as an access road into the pit. The breccia zone continues to the west into Elbow Lake and amethyst veins, parallel to the main fault system, have been found 200 m to the north. Stripping to the east of the pit has exposed the fault zone with amethyst for another 200 m (photos 4-25b,c). Diamond drilling east of the pit has outlined amethyst to a depth of 53 m (Grant 1978).



Photo 4-25a: Aerial view of the Thunder Bay Amethyst Mine Panorama. Elbow Lake is at the top of the picture, the older part of the quarry (west end) is flooded and the rock shop is to the left of the quarry. Staff and storage facilities are at the centre of the picture. The east end of the pit (foreground) is currently being mined. (Note: photo reversed during processing)



Photo 4-25b: Thunder Bay Amethyst Mine Panorama. Drilling and blasting at the eastern part of the quarry. The rock shop and pickup area is in the background.



Photo 4-25c: Exposure of new amethyst-filled vugs, eastern part of the quarry, Thunder Bay Amethyst Mine, Panorama.

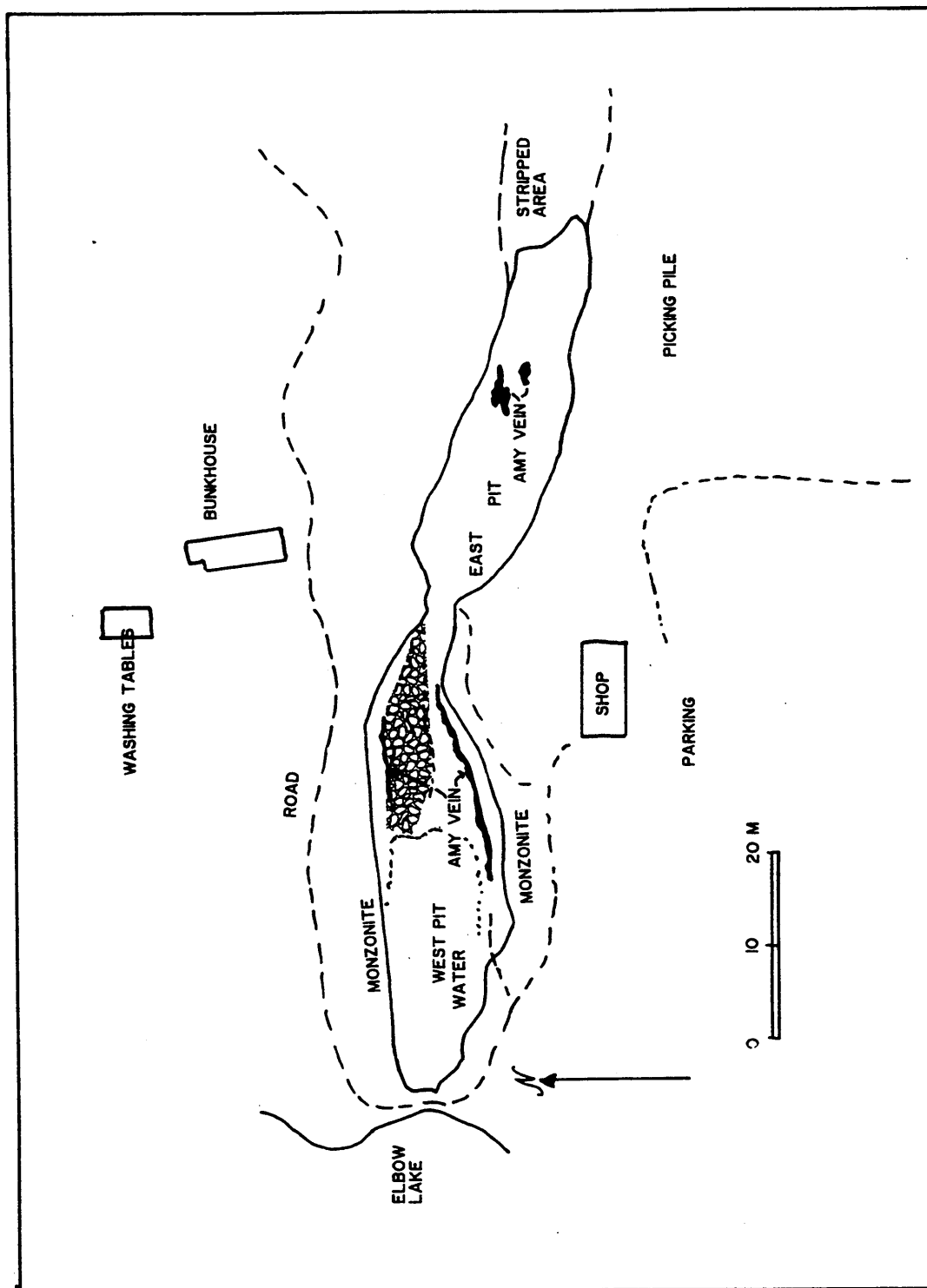


Figure 4-9: Plan view of the Thunder Bay amethyst mine pit.

MINING INFORMATION:

Amethyst in the area near Elbow Lake was originally discovered by fishermen in 1935. The first recorded claims in that area were staked in 1948 and again in 1955, both subsequently cancelled. In 1955, the Department of Lands and Forests built a road through the area to provide access for a fire tower near Elbow Lake. Stripping for the road revealed the large amethyst veins now being mined. The Thunder Bay Lapidary Club had the area staked in 1956 and 1957. A dispute resulted in the claims being acquired by A. Hartviksen and partners in 1959. Continued work on the claims led Mr. Hartviksen to acquire more ground contiguous to the existing claims. In 1965 the Thunder Bay Amethyst Company Limited was incorporated to acquire the 2 original patented claims. The mine officially opened in 1967 and had available 50 000 tons of amethyst (Resident Geologist's Files, Thunder Bay Office). In 1970 the company went public. The mine continued to stockpile amethyst and sold amethyst rock by the box-car-load (Grant 1978). Accumulated visitor numbers to 1977 was 25,708 (Grant 1978).

In 1980, Precious Purple Gemstones Limited purchased the Thunder Bay Mine, changing the name to Thunder Bay Amethyst Mine Panorama. Visitor numbers now are around

25 000 to 30 000 per year. In the 1984 Directory of operating mines, the Thunder Bay amethyst mine listed reserves at 257 000 tons.

Precious Purple Gemstones Limited have been responsible for marketing the gem-quality amethyst available in the deposit. In 1984, the company received funding from the National Research of Canada, Industrial Research Assistance Program to investigate the possibility of amethyst from the Thunder Bay mine for faceted gemstones (Resident Geologist's Files, Thunder Bay). In 1991, Precious Purple Gemstones sold 500 carats of gemstone amethyst. The company sells only its own faceted stones and its own amethyst beads in jewellery.

WALKINSHAW CREEK AREA (47 A AND B)

LOCATION: The Walkinshaw claim group consists of 8 claims in the North of MacGregor area approximately 2 km east of Walkinshaw Creek. The first area where amethyst extraction took place is right in the creek, which is a tributary to Walkinshaw Creek. The second area is at a cliff edge, .5 km east of the first area.

ACCESS: Highway 11/17 east to the Armstrong highway (527). North to the Magone Lake road, 9 km, then east to the Great Lakes Pulp and Paper Gate. The first showing is in the creek right at the gate. The second showing is south down the side road about 500 m east of the creek. About 200 m along this road, the trail to the cliff face leads east.

OWNERSHIP:

Raymond Hietapakka and Aki Siltamaki

GEOLOGY: The creek showing: The host rock is a pink, Archean granite which bleaches almost white and contains large xenoliths of grey metasediments. The granite is a phase of the Penassen Lakes granite. The quartz veins are associated with shearing in both the granite and the metasediments. The veins strike 105°/60°N. The first

crystallization consists of a layer of fine, granular white quartz, 1 cm wide. Smoky to purple quartz points have crystallized on top of the white layer. The quartz points form a druse covering the entire wall of the vein. The points are small, well-formed and have a very high shine. Amethyst is extracted from here with an aggregate permit.

The cliff showing: Anastomosing quartz veins, striking generally 040° to 060°, are hosted in massive, pink granite. Small vugs where the veins widen out are lined with a medium- to dark-purple amethyst (photo 4-26). Football-sized talus from the cliff has piled up on the hill approaching the base of the cliff. Amethyst in the talus was extracted for building stone using an aggregate permit.

MINING INFORMATION:

This area has never been mapped. The township to the south was mapped by J. Scott, Ministry of Northern Development and Mines, Thunder Bay, in 1984 and 1985 (Scott, 1990). Reconnaissance mapping in the vicinity of the claim group noted several areas of amethyst druse on east-west fault systems as well as areas of intensive quartz veining. The entire Penassen Lakes granite has potential for amethyst, particularly where fracturing and quartz veining is evident in outcrop.



Photo 4-26: Amethyst vein in granite, Walkinshaw Creek occurrence.

5.0 CONCLUSIONS AND RECOMMENDATIONS

Early exploration in the Thunder Bay area centred around interest in copper and silver. Secondary industries, supported by the many small silver mines in the vicinity of Thunder Bay, were the nuclei for numerous small towns. Roads and railways were built to connect these towns and the area began to open up.

Amethyst was known to occur in the area since it was usually present in the silver veins. By the 1860's, amethyst was mined for itself and sold in Toronto. Amethyst discovered at Amethyst Harbour was sold in noted tourist locations throughout the United States. Interest in amethyst waned with the onslaught of inexpensive, high-quality amethyst from South America in the early 1900's. The discovery of large amounts of amethyst in McTavish Township, coupled with the early success experienced by the Thunder Bay amethyst mine, encouraged prospectors to once again look for amethyst. By the 1970's, several amethyst occurrences were brought into production and are still actively producing.

Amethyst in the area around Thunder Bay and the north shore of Lake Superior is associated with a series of faults, trending northeast, which are related to the mid-continental rift. The faults have provided channels for a series of vein systems hosting silver, lead, zinc, barite, and amethyst mineralization.

A second set of fractures cuts the main fault direction at an angle. These fractures exhibit dilational features providing open spaces for crystallization of vein minerals.

The veins cross cut all lithologies found in the region. The main lithologies related to the amethyst veins are Archean granites, monzonites, some volcanics and metasediments of the Quetico Subprovince, mudstones, shales, conglomerates, and sandstones of the Proterozoic Animikie and Sibley Group. The subhorizontal unconformity between the Archean and Proterozoic rocks is exposed in various places throughout the region.

For quartz to crystallize as amethyst, 4 conditions must be met:

1. there must be an abundance of silica, to the point where silica-flooding is apparent in the rock,
2. there must be a source of iron in the silica solution, available to the quartz as it crystallizes in order to form the $\{\text{FeO}_4\}_5$ cluster,
3. there must be radioactive energy in the vicinity of crystallization in order to energize the iron-oxygen cluster and make the $\{\text{FeO}_4\}^{4-}$ colour centre,
4. there must be open spaces or fractures for the quartz to crystallize in trigonal point form, allowing the rhombohedrons to grow and Brazil twinning to happen.

The Thunder Bay region provides an environment where all these conditions are met. The basin development associated with the

mid-continental rift resulted in a large sedimentary section, providing a source of fluids, silica, and iron. The fracture system associated with rifting and post-basinal development has provided major conduits for fluid migration and precipitation of minerals from hydrothermal systems. Radioactive minerals, concentrated along the unconformity between the Archean and Proterozoic, as well as present in Archean granitoid intrusions, provide the radioactive energy required for development of colour centres in the quartz.

The north shore area represents the edge of the onlapping Proterozoic sediments; thickness of the sediment pile increases to the south. The unconformity in the Thunder Bay region represents stratigraphic heights very close to the paleosurface and therefore crystallization within the fractures occurred at almost near-surface conditions. This allowed for the relatively cool precipitation temperatures for amethyst formation (McArthur and Kissin 1988) and the preservation of open spaces to encourage crystal development.

Development in the Thunder Bay region has centred around areas of known potential in McTavish and MacGregor townships. In these 2 areas amethyst mineralization occurs associated with northeast trending fault zones characterized by breccia zones and east-west or north-south fracture zones. Amethyst occurrences within the Proterozoic rocks are very close to the unconformity with the

Archean rocks. If the unconformity is not present, occurrences within the Archean are very close to the upper levels of the Archean rocks, close to where the unconformity would have been. As prospecting interest for amethyst increases and lumbering opens up access routes for some of the more inaccessible regions, other areas with good amethyst potential are starting to be developed.

Amethyst occurrences have been found along the Magone Lake road in the North of MacGregor and Tartan Lake areas. The potential is high in these areas for good amethyst deposits. Logging in this area continues to open up access to the interior, which coupled with the high potential for good amethyst occurrences, has increased interest in amethyst exploration.

The McTavish Township amethyst area presently supports 6 producers. The central region of the township has high potential for amethyst, but is also intensely staked. The region to the south of highway 11/17 and north of the present producers has not been prospected extensively and initial work has yielded some interesting results.

The unmapped region between McTavish and MacGregor townships lies right on strike between amethyst deposits in the North of MacGregor area and in McTavish Township. The major fracture systems continue through this area and it is proximal to the

unconformity. Topographical relief indicates a number of north-south lineaments, providing the necessary fracture systems for amethyst deposition. This is an area of untested potential, worthy of prospecting.

The region west of Thunder Bay, noted primarily for silver deposits, also has some good amethyst occurrences. The Archean rocks north of the faulted unconformity provide an area of untested potential and logging continues to open new access routes into this region.

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APPENDIX I

EXTRACTION METHODS FOR AMETHYST

Quarry Methods

Amethyst is usually a quarriable commodity, readily lending itself to the usual methods of open pit extraction. Techniques such as drilling and controlled blasting are used to loosen blocks of stone from the pit wall. The vein is exposed and vugs are opened up. Good crystals in vugs and on vein walls are removed with chisels and prybars. The samples are wrapped in newspaper and transported in buckets or barrels to the shop or storage site.

Loose debris is sorted into roughly graded piles according to use. Landscape and fireplace stone, which is breccia with or without crystals of amethyst, are separated from pieces to be used for mineral specimens. The mineral specimens are sorted according to colour, formation of the points, size of the crystals, clarity, and shine. Any bruising or damage sustained by the sample decreases the value. Pieces exhibiting exceptional, dark purple colour, no inclusions, fractures, or bands are separated for possible faceting. Small or poorly shaped pieces are used for tumbled material. Massive, banded material is used for clocks, book ends, and lapidary material.

The disadvantage with using blasting to break up the vein rock is the development of fractures within the amethyst. Even controlled blasting with a small amount of powder causes micro-fracturing within the crystals, resulting in fine pieces breaking when being cut. Methods used by quarriers to avoid fracture development require the use of saws or drilled holes and plugs and feathers. Quarry saws are expensive, but the tried and true method of perpetrating a fracture with plugs and feathers works well.

To break a block with plugs and feathers requires a line of holes, as deep as the height of the desired block, and about 20 cm apart. Feathers, sheaths of steel with a semi-circular cross-section, are fitted into the holes. The plug fits in between the feathers. Successive blows to the line of plugs in the holes with a sledge hammer gradually forces a fracture to run from hole to hole. An experience quarry person can run curved fractures in massive blocks with this method. The rock material stays intact and there is no percussive damage to internal fabric due to blasting.

Legal Methods

Amethyst, being a non-metallic commodity may be removed using an aggregate permit as well as a mining lease. A mining lease requires assessment work on a staked mining claim, a survey,

application for a lease at the Mining Recorder's office, and the lease fee (\$4400-assessment credits). An aggregate permit requires the application at the Ministry of Natural Resources (MNR), a site plan, and royalty payment. The mining lease grants land tenure for 21 years, with the option of acquiring the surface rights (if available). The aggregate permit is subject to the terms of the MNR, is valid for 1 year, is renewable on reapplication, and does not grant any tenure. The aggregate permit allows the holder to remove a specific commodity from a specific site, at relatively low expense. For amethyst, it allowed prospectors to quarry from one site, maintain a cash-flow allowing them to continue exploration on other sites.

This is only a general description of the 2 different legal methods available to the prospector to mine amethyst. For further information contact the Mining Recorder or MNR lands branch in the relevant district.

APPENDIX II

AMETHYST AS A HEALING STONE

It seems to be a human trait to empower inanimate objects. Even in early history, gemstones were indicative of wealth, power, and the lifestyle bought by having wealth and power. The fine line between indicator or perpetrator fades in some cultures. The belief in crystals and gemstones to cause certain traits follows from ancient mysticism and is frequently couched in a lot of ignorance. Scientific, or human, evidence can refute many of the attributed abilities of minerals and gemstones. For example, quartz crystals, particularly clear varieties, are believed to focus energy within the holder. Quartz crystals, clear or otherwise, transmit and reflect a certain amount of light energy, certain wavelengths are absorbed, and the particular colour of that variety of quartz is created. If the holder's internal energies are focused by the quartz crystal, this is a function of the individual's beliefs, not the actual crystal.

Scientific fact aside, there is a growing interest in the mystic ability of certain crystals to do certain things for people. There is also a growing market demand for certain varieties of minerals.

Amethyst has long been believed to impart certain powers to the wearer. The mineral is supposed to prevent intoxication along with a variety of other benefits (see section 1.2). On a more realistic note, using amethyst cups to serve wine meant that the wine could be substantially watered with no visible colour change. Perhaps in this manner, the amethyst induced sobriety. Crystal mystics believe that amethyst will improve meditation, relieve headaches and tension (Raphaell 1985). Amethyst is purported to heal skin disorders and dissolve blood clots and the list goes on. Some of the claims by writers of crystal enlightenment are confusing and blatantly non-factual. References to violet rays from the planet Mercury, the ability of amethyst to send negative forces into the ether, the ability of amethyst to change molecular structure are fictitious stories (Walker 1989).

TABLES

Table 1: Amethyst Occurrences

MAP #	NAME	OWNER	LOCATION	DESCRIPTIVE REMARKS	COMMODITIES	MINING INFORMATION
1	Arctic Mine	Patented	South part of Lot 5, Conc. C of McTavish Twp.	Hosted by sandstone and conglomerate of the Sibley Group. White and amethystine quartz veins are probably present.	Pb, Ag, plus trace Au.	Development of a number of pits, including a 9 metre shaft. Some ore was shipped away.
2	Barratt Claims	J. Barrett	South of NE arm of Sward Lake North part of Lot 5, Conc. IV, McTavish Twp.	Quartz breccia situated in granite. Fragments are 30-50% granite, chlorite schist, and rare Sibley Group. Amethyst is light to dark purple and occurs with smoky quartz. Crystals measure up to 2 cm at base.	gn, sp, and py occur in qtz with minor cpy. amy	Two pits plus one main mining pit, next to Sward Lake.
3	Beaver Mine	Patented	Mining Location 97T, O'Connor Twp.	Amethystine quartz at south end of property. This consists of white and light purple crystals < 1 cm diameter. Vuggy calcite vein in diabase and shale.	Ag, calc, fl, py with minor ba, gn, sp and cpy.	One shaft and one adit.
4	Big Pearl Lake Occurrence	T. Twomey	Southwest section of Lot 5, Conc. III, McTavish Twp.	Quartz veins occupying faults in quartz monzonite host rock. Vuggy amethystine quartz veins contain amethyst and sulphides. These are found in old trenches.	gn and ba, with minor sp and py. amy	Two old trenches found thus far.
5	Black Fox Mine	Patented	Mining Location 146T, O'Connor Twp.	Calcite vein in diabase and shale. Amethystine quartz veins have been reported, however none were seen recently.	Ag, gn, fl, sp and calc.	Two old adits reported 50 m x 5 m x 1 m dump, undisturbed and moss-covered.
6	Blue Points Amethyst Mine	F. Grann	Southwest corner of Lot 4, Conc. III, McTavish Twp.	100 m breccia zone within Sibley Group siltstone and conglomerate. Ubiquitous silicification in zone. Amethyst is in veins and vugs. Hematite staining.	amy with minor ba, cpy and gn.	Trench along the breccia zone open to tourists.

Table 1, con't.

MAP #	NAME	OWNER	LOCATION	DESCRIPTIVE REMARKS	COMMODITIES	MINING INFORMATION
7	Blue Star Resources	Blue Star Resources, Ltd.	North of Lot 9, Conc. III of MacGregor Twp. (Leased claim 1166702)	Brecciated quartz vein within granite occurs in a fault. Granitic fragments are cemented in an amethystine quartz matrix. Large crystals of amethyst line large vugs. Their colour is very dark.	amy with cpy, gn and py.	Cliff face was stripped. Some blasting has been done.
8	Breezy Lake Property	T. Twomey	Southwest corner of Lot 3, Conc. IV, McTavish Twp. (claim 835253)	Quartz veining in a fault between granite and a wedge of Sibley sandstone. Amethystine quartz stringers and large vugs containing amethyst are also in this fault zone.	amy with minor Pb and Zn.	Old trenching plus recent stripping along fault at L1 + 00E, 0 + 80N of the property.
9	Cavers Hill	Mr. Halonen	4.5 km West of Pays Plat on Hwy. 17.	Quartz breccia zone in epidorized granite contains quartz fluorite veinlets and some vugs with amethyst. Drusy amethyst coated by fluorite.	amy, fl, ba, py.	Old road cuts on old Hwy. 17.
10	Dawson Road Mine	Patented	2.6 km from Hwy. 11/17, north on Spruce River Road, and 800 m East from there. (MacGregor Twp.)	Hosted by mafic to intermediate metavolcanics. Amethystine quartz veins and amethyst present. Calcite is also present.	Ag, Pb, Zn, Cu and amy.	Two old pits, 50 m apart, filled in with dump material. Silver was extracted.
11	Detroit-Algonia Mine	A. Wright Estate	South corner of Lot 4, Conc. IV, McTavish Twp.	Two fault breccias cemented with quartz and calcite. Amethyst and barite veins are present. Irregular sulphide mineralization.	gn, sp, cpy, amy, py and ba.	Two shafts and pits with trenches.
12	Diamond Willow Amethyst Mine	D. Noyes	Southwest corner of Lot 4, Conc. III, McTavish Twp.	50 m quartz breccia occupying a fault between Sibley mudstone and basal conglomerate. Deep purple amethyst (sometimes stained by hematite) occurs in veins and vugs.	amy with minor gn, ba and cpy.	Trench along the breccia zone. Open to tourists.

Table 1, con't.

MAP #	NAME	OWNER	LOCATION	DESCRIPTIVE REMARKS	COMMODITIES	MINING INFORMATION
13	Dorion Amethyst Mine	E. Williamson (Lease)	Southeast corner of Lot 3, Conc. I, McTavish Twp.	Carbonate-quartz breccia in contact between granite and Sibley conglomerate. Dark purple crystals of good size line a 2 m vug. Water flows out of this vug.	amy, cpy, ba with minor gn, sp and U.	Drill holes and a large pit.
14	Dzuba Anciliff Occurrence	N. Dzuba (Lease)	Mining Locations 7 and 5 McTavish Twp. (claims 352386 and 132986)	Quartz-carbonate breccia at contact between quartz monzonite and red Sibley mudstone with fragments of each. Large vugs present with large, dark purple amethyst crystals.	amy, calc with minor gn and py.	Pits and trenches. The western trench includes an adit into a vug system.
15	Dzuba Pipeline Showing	N. Dzuba	Mining Location 13, McTavish Twp. (Leased claim 404862)	Quartz-carbonate breccia near Sibley/Archean unconformity. Vuggy sections contain amethyst of variable colour: pale to dark purple. Average size is 0.5 cm.	amy.	Small trenches, two zones.
16	Dzuba Thunder Bay Occurrence	N. Dzuba	Southwest corner of Lot 4, Conc. VI, McTavish Twp. (Leased claim 287820)	Quartz breccia in altered quartz monzonite. Vuggy sections contain drusy amethyst in minor quantity. Hematite staining is common.	amy, ba with accessory gn, sp and py.	Trenching and stripping for 200 m.
17	East End Silver Mountain	Lakehead Board of Education	Mining Locations R53 and R54, Lybster Twp.	Calcite vein with vuggy quartz, light purple in colour. This vein is within Rowe Shale and within diabase to some extent.	arg and/or native Ag, sp, fl, calc with minor amy and ba.	Several pits, two adits, and five shafts are on the property. The mining took place in the east side of Silver Mountain.
18	Enterprise Amethyst Property	K. Kukke	Lot C, Conc. V, McTavish Twp.	A quartz breccia zone lies on the contact between quartz monzonite and Sibley mudstone.	gn, py, sp, cpy, ba and amy.	Two shafts have been made. Discovered by P. McKellar in 1865.

Table 1, Con't.

MAP #	NAME	OWNER	LOCATION	DESCRIPTIVE REMARKS	COMMODITIES	MINING INFORMATION
19	Furcate Lake Amethyst- Copper	H.A. Swanson & T. Atkinson	Lot 8, Conc. XIII, Dorion Twp.	Quartz vein in quartz monzonite host. It contains amethystine quartz, and pale blue to pale red amethyst up to 4 cm in size. Hematite coating and smokey quartz is also present.	any, cpy, mc and az.	Trench of dimensions 7 m x 2 m, 1.5 m deep.
20	Gagnon Falls Occurrence	G. Noyes	Northeast corner of Lot 4, Conc. V, McTavish Twp.	Two quartz breccias in quartz monzonite. Large vugs in each zone. These contain large, purple amethyst crystals. Drusy amethyst is prevalent also. Smokey quartz. Amethyst often coated with hematite or white quartz.	any with minor py, cpy and gn.	Trench at falls as well as a west pit which has been heavily blasted. Third occurrence at powerlines.
21	Little Bear Amethyst Quarry	T. Galarneau	At northernmost point of Kabamichigama Lake, 50 km Northeast of Nipigon.	Quartz veins in a fault zone. Large vugs in the system are lined with amethyst. Amethystine veins cross-cut white quartz veins. The host rock is biotite granite. Sibley float are in the area.	any.	Quarry has been in production. Drilling has been done around the property.
22	Gem Mountain	R. Harty	North of Lot 8, Conc. III of MacGregor Twp. (Leased claim 974958)	Quartz breccia in granite host. The zone has small vugs which are lined with light to dark purple amethyst of medium size. Amethyst veins cross the zone.	any.	A cliff has been stripped and blasting has been performed on either side of the ridge there.
23	Grieve Property	M. Grieve & S. Grieve	North of MacGregor Twp. (Leased claim 656461)	Quartz breccia within granite follows a fault. Metasedimentary fragments are also in the breccia 5 cm amethyst crystals are white to green to purple.	any with minor mo and py.	One main working area west of creek. It includes several pits. One trench is west of this area.
24	Holzem Occurrence	M. Holzem	Northeast shore of Shaco Lake, 95 km West of Thunder Bay.	Quartz veins in a granite host. These veins consist of white, smokey and amethystine quartz. 2 cm crystals in vugs. Amethyst comprises less than 10% of the veins.	any.	One large vug at a cliff face.

Table 1, con't.

MAP #	NAME	OWNER	LOCATION	DESCRIPTIVE REMARKS	COMMODITIES		MINING INFORMATION
25	Jean Twp. Occurrence	R. Hietapakka & A. Siltamaki & G. Duffy	Southeast of Tower Lake, Jean Twp.	Quartz breccia in granite. Amethyst occurs in vugs and veins. Crystals develop in vugs. They are medium to dark purple and bright red when stained by hematite.	amy, fl.		Six old pits west of creek. Vugs are being explored.
26	Johnson Occurrence	F. Johnson	Lot 6, Conc. VIII (Northeast corner), McTavish Twp.	Quartz breccia zones in granite to monzonite host. Veins are 25% white quartz, 0-5% vugs, 70-75% granite fragments. Amethyst is lavender to smokey and < 1 cm in size.	amy.		A quarry has been developed.
27	Little Bear Amethyst Mine	R. Paterson	At northernmost point of Kabamichigama Lake, 50 km Northeast of Nipigon.	Quartz breccia zone in granite host rock. Amethyst occurs in seams and vugs. It is mostly pale lavender but some crystals are dark purple and 2.5 cm in size.	amy.		Three trenches. One is a grave pit.
28	Lily of the Valley Mine	Mr. Belluz	Lot 19, Conc. II, Paipoonge Twp.	Quartz-carbonate breccia within black Rove Shale. 20 cm vugs are lined with quartz and pale amethyst crystals up to 10 cm across.	gn, arg, sp, py, mar, fl and amy.		Three shafts and a series of trenches. Diamond drilling has been done.
29	Lookout Amethyst	Leased	Across from the Terry Fox Lookout on Hwy. 11/17.	Quartz vein in Gunflint Formation of horizontal attitude. Drusy quartz and pale purple amethyst. Deeper in vug, crystals are larger and darker purple (1 cm).	amy and ba.		Small hole partially filled with asphalt.
30	McLeod Quarry	G. McLeod	Northeast shore of the east Penassen Lake.	Quartz veining in a granite to quartz monzonite host. Amethyst is drusy and well-developed. Well-developed crystals are light purple to black.	amy, red granite.		Stipped area at cliff edge.

Table 1, con't.

MAP #	NAME	OWNER	LOCATION	DESCRIPTIVE REMARKS	COMMODITIES	MINING INFORMATION
31	McTavish Location 3 Property	T. Twomey	Mining Location 3, McTavish Twp.	Quartz veins in a fault contact between granite and red Sibley sandstone. Veinlets are amethystine and have a comb structure.	amy, cc.	Shaft and trench with a muck pile.
32	Mount Baldy Occurrence	B. Smith & T. Twomey	On Mount Baldy Road, 400 m East of Spruce River Road. (MacGregor Twp.)	Amethyst veins occupy a fault between Archean mafic metavolcanics and Gunflint Formation.	amy, Zn, Cu and Pb.	Old pits and one shaft. Recent stripping has been done.
33	Ontario Gem Amethyst Mine	P. Marino	Mining Location 12, McTavish Twp.	Amethyst and barite veins occupy a fault between Archean granite and Sibley Group mudstone. A breccia zone pinches and swells. Stromatolites occur with amethyst at the south end of the property. A deep vug contains very dark and well-developed crystals.	amy, ba, gn, fl, sp, cpy, mc and py.	Three pits along a one kilometre long ridge. The north pit is open to tourists.
34	Pearl Lake Amethyst Mine	P. Durocher	Lot 3, Conc. III, McTavish Twp.	Two fault zones. One is a breccia zone which separates granite from Sibley conglomerate. Fractures splay off this causing vug development. Amethyst crystals are large and can be hematite stained.	amy, cpy and py.	Five working areas along a main fault zone. A deep vug is at the south end. Tourists are allowed in the north end.
35	Prince Location	Patented	32 km Southwest of Thunder Bay, South of Mink Bay, Lake Superior. Spar Island and Prince Point.	Calcite vein through argillite and diabase. Clear and amethystine quartz is present. The vein is in a fault.	sp, Ag and arg, gn, cc, cpy, calc, mc and az.	Two shafts on Spar Island and an adit on Prince Point.
36	Rabbit Mountain	Patented	Mining Locations 39T and 40T, Scoble Twp.	Calcite veins in diabase and shale. Amethyst found in dump.	Ag with minor amy.	Two shaft (including Rabbit Mountain Junior to the west). Three adits are on the property.

Table 1, con't.

MAP #	NAME	OWNER	LOCATION	DESCRIPTIVE REMARKS	COMMODITIES	MINING INFORMATION
37	J. Redden Property (Caribou)	Patented	Northeast part of Mining Location 8, McTavish Twp.	Two breccia zones representing faults between quartz monzonite and Sibley mudstone and sandstone. Diabase is present at one area. Amethyst is poor. It is pale purple with occasional red hematite spots.	gn, cpy, py, sp, calc and ba.	Pits and trenches as well as two shafts and two adits.
38A	Bak Quarry	D. Bak	West side of lot 5, Conc. IV, McTavish Twp.	Quartz veins within Sibley Group sandstone. Drusy amethyst is present. Colour is pale purple.	gn, am, py and ba.	Several trenches along the west side of Sward Lake.
38B	Bak Occurrence	D. Bak	Northeast of Big Trout Lake, McTavish Twp.	Quartz breccia in Archean granite. Amethyst lines vugs and is light to dark purple and up to 2 cm in size.	am, sp and ba.	Veins are exposed. Rubble is about.
39	Silver Fox Mine	Patented	West of Sun Hill, Jean Twp.	Quartz veins in shale of Gunflint chert. Quartz is white and no amethyst.	arg, fl, calc and gn.	Four dump areas, several pits, and three adits are on the property.
40	Silver Valley Occurrence	T. Twomey	Mining Location Rill, Lybster Twp.	Quartz vein within shale. It is very vuggy. Amethyst is of good quality; clear to light purple, up to 5 cm in diameter. Crystals have random orientation.	Ag, fl and am.	Adit into the vein on the side of a hill.
41	Shuniah Mine	Patented	Behind radio tower off Hwy. 11/17, between Balsam Street and Current River.	Calcite vein within red cherty Gunflint Formation. Some amethystine quartz is in the vein. It is not very purple but mostly smokey.	Ag, sp, mar and calc.	Filled in shaft. Many dump piles with abundant calcite.
42	Stenlund Amethyst Occurrence	D. Stenlund	5 km east of Nipigon, 60 m and 170 m North of Hwy. 17 on a logging road.	Quartz-barite veins in muddy, limestone of Sibley Group. Breccias and vugs contain smokey and amethystine quartz. Amethyst is lavender to deep purple and 2 cm in size.	am and ba.	Two stripped areas.

Table 1, con't.

MAP #	NAME	OWNER	LOCATION	DESCRIPTIVE REMARKS	COMMODITIES	MINING INFORMATION
43	Tartan Lake Area	R. Hietapakka & A. Siltamaki	Claims T8 1183115-1183117 North of MacGregor Twp. and south of Fitzpatrick Lake.	Quartz vein in granite including several vugs and a breccia. Amethyst is green to dark purple and crystals are of medium size. Malachite and hematite coating is common.	amy, cpy and mc.	A long trench on the side of a hill.
44	Thorsteinson Property	D. Thorsteinson	20 km North of Pays Plat, Northwest shore of Ngunagisic Lake.	Quartz breccia in granitic rock. Vugs contain very dark amethyst up to 1 cm in size.	amy, cpy and py.	Series of trenching exposing the vein.
45	Thunder Bay Amethyst Mine Panorama	S. Lukinuk	East shore of Elbow Lake, McTavish Twp.	A major fault runs through the property in Archean granite. Smaller fractures cross-cut this fault, creating large vugs and as veins. In veins, it is massive and in vugs, amethyst is dark purple and up to 200 m in size.	amy.	A deep trench running from the lakeshore, 50 m to the east. A picking pile is open to tourists.
46	Thunder Bay Silver Mine	Leased	400 m East of Terry Fox Lookout on Hwy. 11/17.	Quartz-calcite vein in Rove Shale. Many veinlets of quartz are present, however, the quartz is only smokey and not purple. Iron Formation and diabase nearby.	gn, sp, calc, arg and Ag.	Adits and trenches as well as a shaft.
47A	Walkinshaw Creek Area	R. Hietapakka & A. Siltamaki	2 km Northeast of Walkinshaw Creek, north of MacGregor Twp.	Small quartz veins cross-cut a north-south fault. The amethyst is drusy and in veinlets. Crystals are dark purple. The host rock is granite and metasediments.	amy.	Exposed veins only.
47B	Walkinshaw Creek Area	R. Hietapakka & A. Siltamaki	1.5 km Northeast of Walkinshaw Creek, North of MacGregor Twp.	Drusy quartz lining fractures in a cliff of pink granite. Fairly large purple and hematite coated crystals in vugs. Minor breccia present.	amy.	Exposed veins only.

Table 1, con't.

MAP #	NAME	OWNER	LOCATION	DESCRIPTIVE REMARKS	COMMODITIES	MINING INFORMATION
48	72	Patented	Mining Location 72, MacGregor Twp. North of Amethyst Bay.	Quartz veins in diabase and Gunflint Formation. Vugs contain dark purple amethyst crystals which measure 1 cm across. Vein extends into granite.	amy with gn, sp and py.	Old trenches and dump piles and two shafts.
49	82	Patented	Mining Location 82, MacGregor Twp. North of Amethyst Bay.	Quartz veins in diabase and Gunflint Formation. Pale to dark purple amethyst crystals up to 1 cm in size are in a vug.	amy with minor sulphides.	Old trenches and dump piles.

CONVERSION FACTORS FOR MEASUREMENTS IN ONTARIO GEOLOGICAL SURVEY PUBLICATIONS

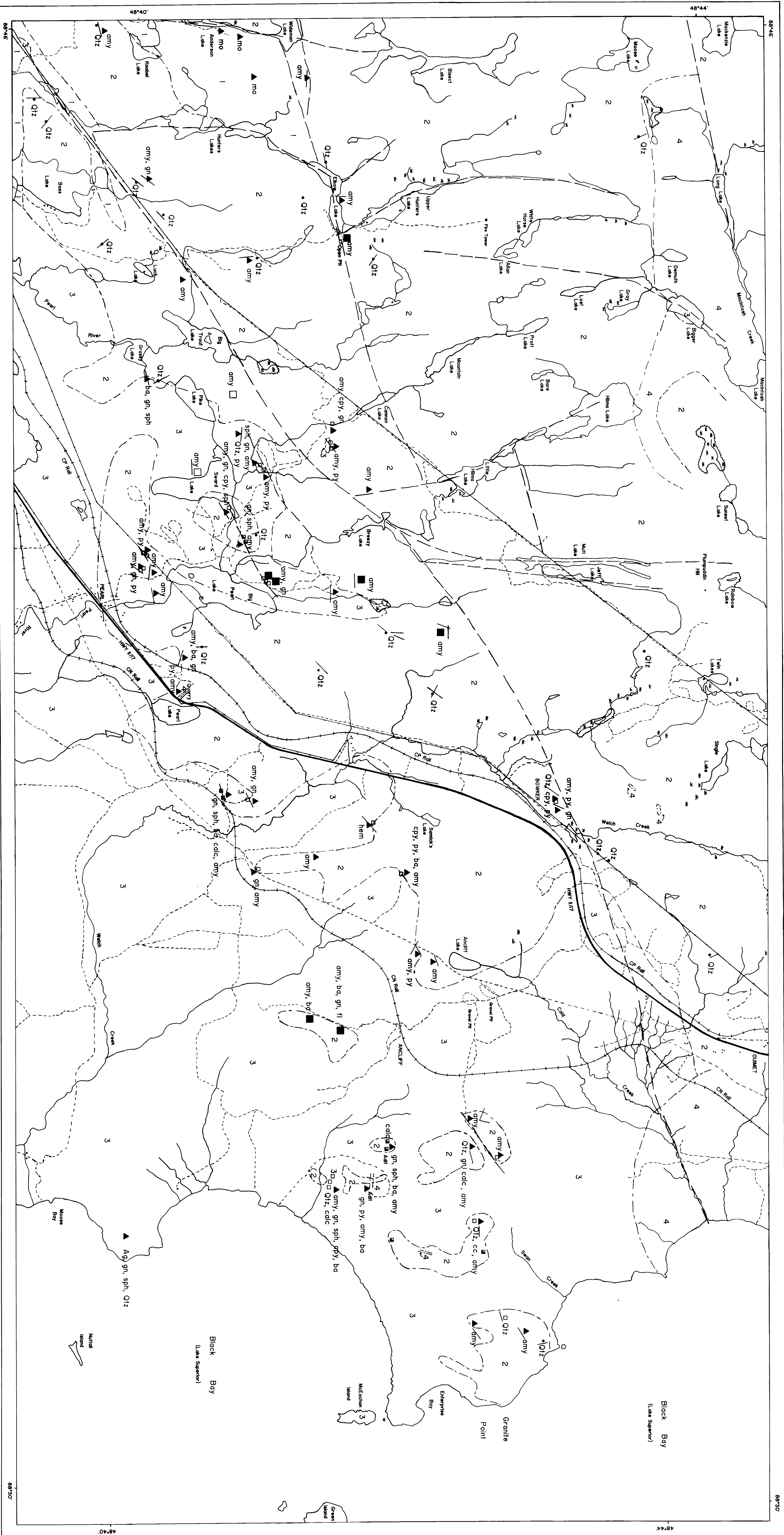
Conversion from SI to Imperial			Conversion from Imperial to SI		
SI Unit	Multiplied by	Gives	Imperial Unit	Multiplied by	Gives
LENGTH					
1 mm	0.039 37	inches	1 inch	25.4	mm
1 cm	0.393 70	inches	1 inch	2.54	cm
1 m	3.280 84	feet	1 foot	0.304 8	m
1 m	0.049 709 7	chains	1 chain	20.116 8	m
1 km	0.621 371	miles (statute)	1 mile (statute)	1.609 344	km
AREA					
1 cm@	0.155 0	square inches	1 square inch	6.451 6	cm@
1 m@	10.763 9	square feet	1 square foot	0.092 903 04	m@
1 km@	0.386 10	square miles	1 square mile	2.589 988	km@
1 ha	2.471 054	acres	1 acre	0.404 685 6	ha
VOLUME					
1 cm#	0.061 02	cubic inches	1 cubic inch	16.387 064	cm#
1 m#	35.314 7	cubic feet	1 cubic foot	0.028 316 85	m#
1 m#	1.308 0	cubic yards	1 cubic yard	0.764 555	m#
CAPACITY					
1 L	1.759 755	pints	1 pint	0.568 261	L
1 L	0.879 877	quarts	1 quart	1.136 522	L
1 L	0.219 969	gallons	1 gallon	4.546 090	L
MASS					
1 g	0.035 273 96	ounces (avdp)	1 ounce (avdp)	28.349 523	g
1 g	0.032 150 75	ounces (troy)	1 ounce (troy)	31.103 476 8	g
1 kg	2.204 62	pounds (avdp)	1 pound (avdp)	0.453 592 37	kg
1 kg	0.001 102 3	tons (short)	1 ton (short)	907.184 74	kg
1 t	1.102 311	tons (short)	1 ton (short)	0.907 184 74	t
1 kg	0.000 984 21	tons (long)	1 ton (long)	1016.046 908 8	kg
1 t	0.984 206 5	tons (long)	1 ton (long)	1.016 046 908 8	t
CONCENTRATION					
1 g/t	0.029 166 6	ounce (troy)/ ton (short)	1 ounce (troy)/ ton (short)	34.285 714 2	g/t
1 g/t	0.583 333 33	pennyweights/ ton (short)	1 pennyweight/ ton (short)	1.714 285 7	g/t

OTHER USEFUL CONVERSION FACTORS

	Multiplied by	
1 ounce (troy) per ton (short)	20.0	pennyweights per ton (short)
1 pennyweight per ton (short)	0.05	ounces (troy) per ton (short)

Note: Conversion factors which are in bold type are exact. The conversion factors have been taken from or have been derived from factors given in the Metric Practice Guide for the Canadian Mining and Metallurgical Industries, published by the Mining Association of Canada in co-operation with the Coal Association of Canada.

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SOURCES
Adapted from :

Geology Adapted from :
McIntosh, W.J., 1971 :
McGowan Township (East and West Parts
of North Half) District of Thunder Bay,
Ontario Dept. of Mines and Northern Affairs,
Preliminary Geological Series Map P.720 & 721

McIntosh, W.H. 1971 :
McTavish Township (East and West Parts
of North Half) District of Thunder Bay,
Ontario Dept. of Mines and Northern Affairs.
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SCALE 1:20000



NORTH PART OF McTAVISH TOWNSHIP

MAP A

LEGEND

- | Mineral Occurrence | | Lithologies |
|--|-----------------------------------|--|
| Producing (Lease) | sph = sphalerite | <div style="border: 1px solid black; padding: 2px;">4</div> Logan Database |
| <div style="border: 1px solid black; padding: 2px;">□</div> Producing (Aggregate Permit) | py = pyrite
cpy = chalcopyrite | <div style="border: 1px solid black; padding: 2px;">3</div> Sibley Group |
| any = amethyst | calc = calcite | |
| Qtz = quartz vein, possibly amethystine | mo = molybdenite | <div style="border: 1px solid black; padding: 2px;">2</div> Felsic Intrusives (Quartz Monzonite) |
| gn = galeña | cc = chalcocite | |
| ba = barite | hem = hematite | |
| Ag = Silver | fl = fluorite | <div style="border: 1px solid black; padding: 2px;">1</div> Migmatite and Metasediments |

- Producing (Lease)

- ☐ Producing (Aggregate Permit)

- amy = amethyst

- Qtz = quartz vein, possibly amethystine

- gn = galena

- ba = baritone

- Ag = Silve

- sph = sphalerite

- py = pyrite

- cpy = chalcopyrite

- calc = calcite

- mo = molybdenite

- mo = molybdenum
cc = chalcocite

- CC = CH
- ₂
- CH=O

- hem = hematite
fl = fluorite

- Contact (assumed)

- Fault or Lineament

- 2 —

- Highway

- Bush Road or Tra

- Pit

2. Prüfung

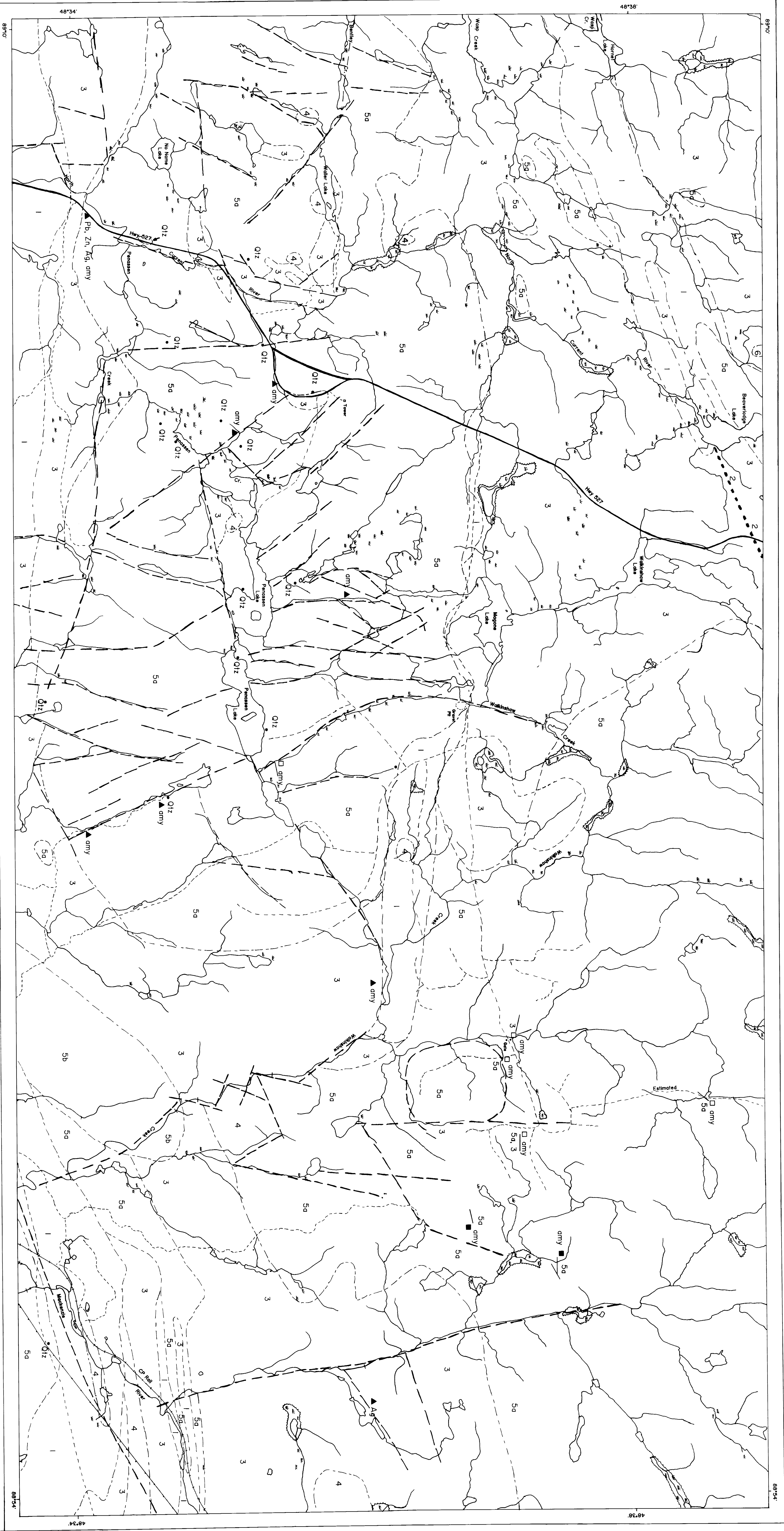
- ## Lithologies

- 4 Logan Diabase

- 10

- 3 Sibley Group

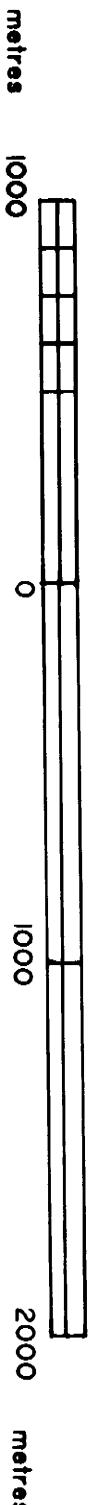
- 5



SOURCES

Geology Adopted from :
Map 2065 Alibon-Laurel Sheet
E.C. Fye and K.S. Farnick (1962-63)
Preliminary Geological Map No. P177
Laurel-Shoshone Sheet by
E.C. Fye and K.S. Farnick (1962)
Map 2232 Nelson-Scribble
Geological Commission, Bureau of
Geology, U.S. Geological Survey
W.H. Williams, and P.A. Wiley (1970-71)
O.S. Preliminary Map 2364 and 2365
by J.F. Scott and J.M. Segin (1984-85)

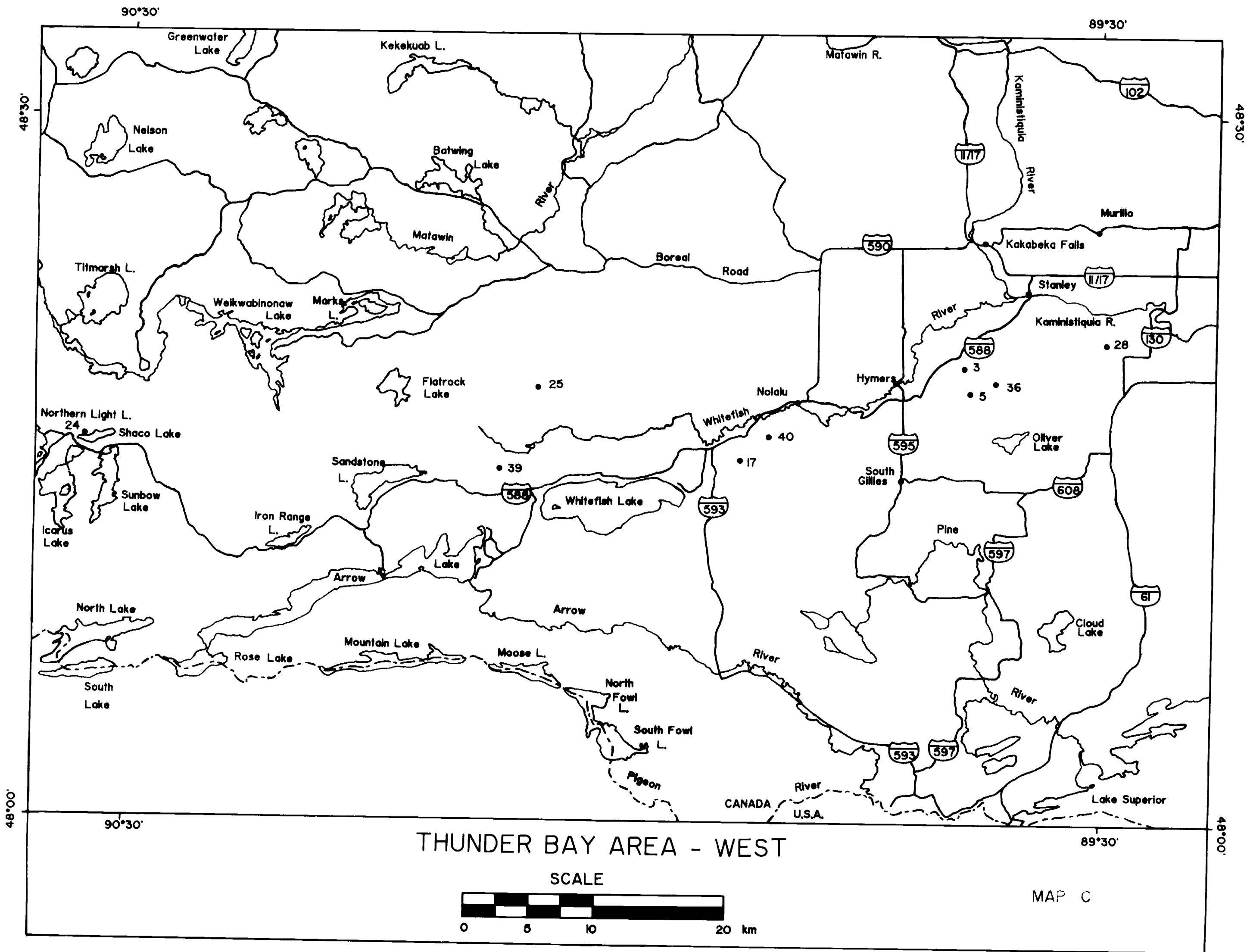
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LEGEND

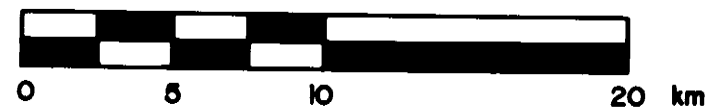
- | | | |
|---|-----------------------------|---|
| ▲ Mineral Occurrence | --- Contact (assumed) | 6 Lithologies |
| ■ Producing (Lease) | --- Fault or Lineament | 5 Logon Diabase |
| □ Producing (Aggregate Permit) | --- Highway | 4 Felsic Intrusives-gr. Granite, b. Syenite |
| amny = amethyst | --- Bush Road or Trail | 3 Mafic to Ultramafic Intrusives |
| Qtz = quartz vein, possibly amethystine | --- Trend of Amethyst Veins | 2 Mafic Intrusives and Migmatite |
| Ag = Silver | | 1 Archean Iron Formation |
| Pb = Lead | | Intermediate to Mafic Metavolcanics |
| Zn = Zinc | | |

PARTS OF MACGREGOR TOWNSHIP AND TARTAN LAKE AREA
MAP B



THUNDER BAY AREA - WEST

SCALE



MAP C

