GEOLOGICAL SETTING OF GOLD MINERALIZATION IN THE VICINITY OF THE NEW BRITANNIA MINE, SNOW LAKE, MANITOBA

A thesis submitted to the
UNIVERSITY OF MANITOBA
in partial fulfillment of the requirements
for the degree of
Master of Science

by

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ABSTRACT

The New Britannia Mine is located in the Flin Flon - Snow Lake greenstone belt portion of the Trans-Hudson Orogen at Snow Lake, Manitoba. Between 1948 and 1958 this lode gold deposit, formerly called the Nor-Acme gold deposit, produced 628 461 ounces of gold from approximately 5.3 M tons grading 0.15 ounces gold/ton. TVX Gold Inc. re-opened the mine in 1995 and is a major gold producer at present.

Gold mineralization at the New Britannia Mine is hosted in poly-deformed, mafic to felsic meta-volcanic rocks, which are of early Proterozoic age. There are a number of other gold mineralized occurrences in the vicinity of the New Britannia Mine, the most prominent being the No.3 Zone, the Birch Zone, Boundary Zone and the Bounter Zone. The gold mineralization in the Snow Lake area is associated with arsenopyrite, and an intense alteration including, carbonatization, biotitization and silicification of the host rocks. This alteration and gold mineralization is structurally controlled in early (D_1/D_2) ductile shear zones, such as the Birch Zone shear, and later brittle-ductile structures, such as the Howe Sound fault and the shear fracture at No.3 Zone. The brittle-ductile structures form imbricate structures that are spatially and structurally associated with the McLeod Road Thrust. In the vicinity of Snow Lake the large-scale outcrop pattern and structures suggest that the exposed meta-volcanic rocks are an oblique section through the hanging wall or side wall ramp structure of a regional scale thrust sheet.

ACKNOWLEDGMENTS

First and foremost I wish to express my appreciation and thanks to my advisor, Dr. Norman Halden for proposing and putting this project together and for his consistent encouragement, enthusiasm, guidance and the many impromptu discussions. I also greatly appreciate and thank John Danko for proposing and putting this project together and for all his support and help during the summer field seasons at Snow Lake. Special thanks go to TVX Gold Inc. and High River Gold Mines Ltd. for providing the funding for this project.

Thanks are also due to all the New Britannia Mine staff, including Ernie Guiboche, Bill Lewis, Janet Wishart, Peter Snajdr and Tom Flemming for their support, help and many comments; to the Manitoba Energy and Mines staff Dave Schledewitz, Alan Bailes and George Gale for their field observations, many discussions, comments and in particular for being great chefs; to Pamela Fulton for the geological discussions and for being a constant friend throughout the project; to Wendy-Joe Mosbry and Angela Dowd for their capable field assistance during the 1997 field season, and last but certainly not least, the many friends and staff from the Department of Geological Sciences, University of Manitoba who gave their time, advice and friendship.

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CHAPTER 1
INTRODUCTION

1.1 PREAMBLE

The New Britannia Mine at Snow Lake, Manitoba, is situated in the Flin Flon - Snow Lake greenstone belt which is of early Proterozoic age (Fig. 1). Gold mineralization at the New Britannia Mine is hosted in a fault bounded slice of poly-deformed, mafic to felsic meta-volcanic rocks called the McLeod Road-Birch Lake allochthon (Bailes and Schledewitz 1998). There are a number of smaller gold mineralized occurrences in the vicinity of the New Britannia Mine, the most prominent being the No.3 Zone, the Birch Zone, Boundary Zone and the Bounter Zone (Fig. 2). The gold mineralization in the Snow Lake area is associated with arsenopyrite, and an intense carbonatization and silicification of the host rocks. The gold mineralization and alteration is structurally controlled and related to shear and fault zones that cross cut the earlier pervasive foliation fabric. In recent years, there have been a number of regional scale geological studies in the Snow Lake area (Kraus and Williams 1993, 1994a & b, 1995 & 1998; Menard and Gordon 1994 & 1997; Kraus and Menard 1997; Bailes and Schledewitz 1998; and Schledewitz 1997 & 1998). This work focuses on the structure and gold mineralization at a local scale, however the results do have significant regional scale implications for gold exploration. This thesis presents the results of a study on the structural and geological setting of the gold mineralization in the vicinity of the New Britannia Mine.

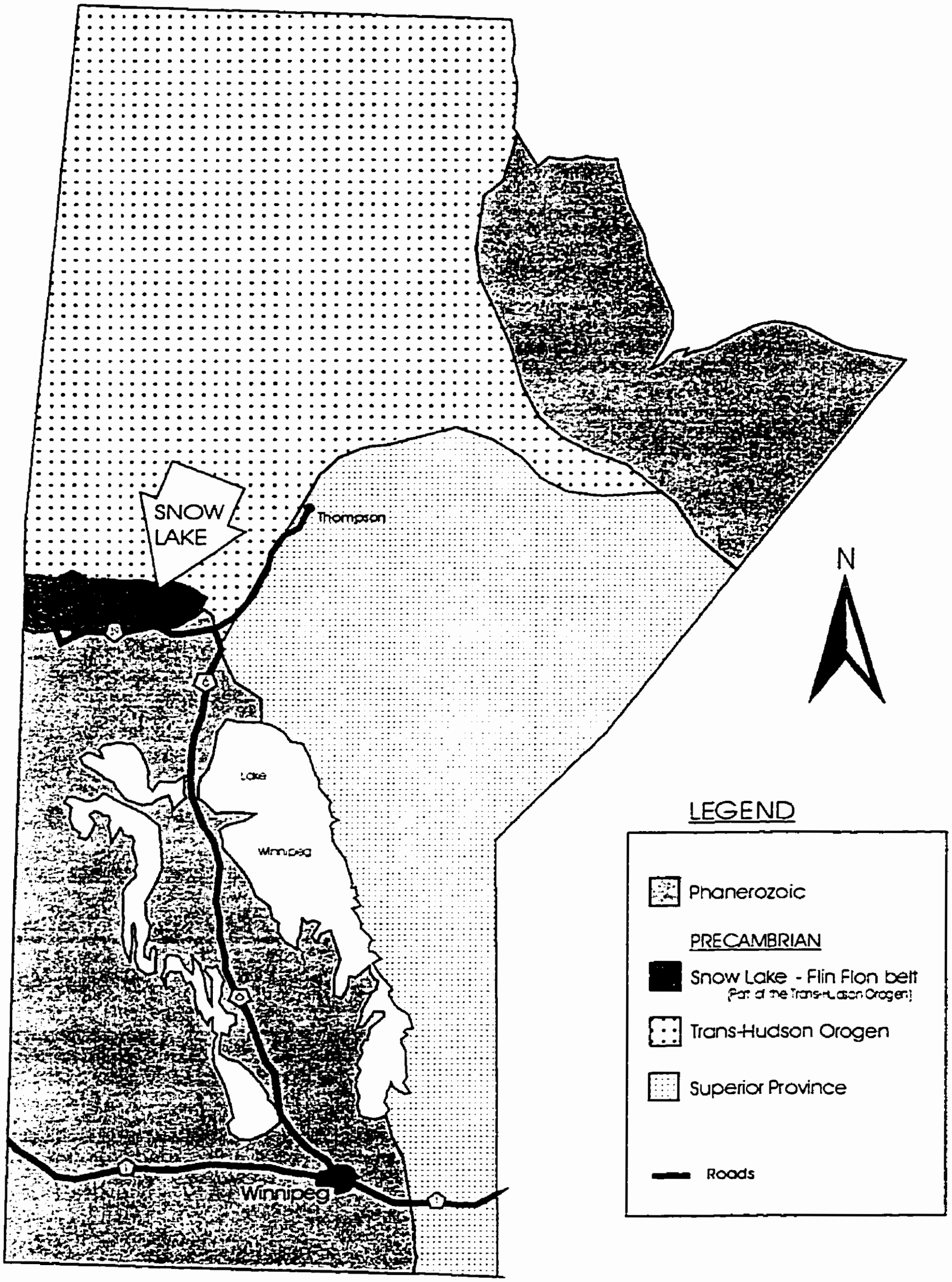

Figure 1: Map of Manitoba showing the location of Snow Lake. Snow Lake is located in the eastern end of the Flin Flon-Snow Lake greenstone belt. This greenstone belt forms part of the Trans-Hudson Orogen.

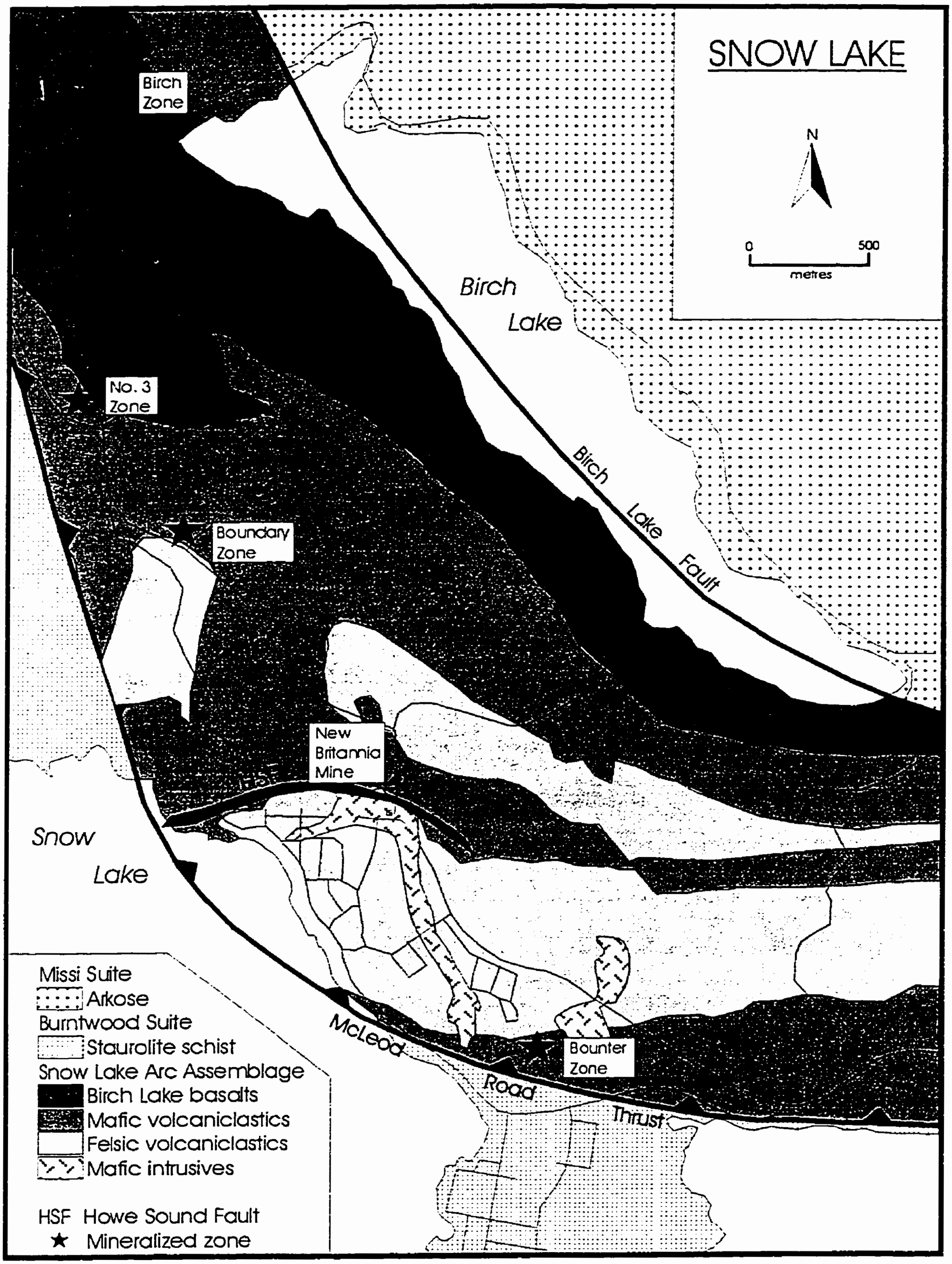

Figure 2: A simplified geological map of the Snow Lake area. This map shows the location of the New Britannia Mine and the other principal gold mineralized zones in the vicinity of Snow Lake.

1.2 OBJECTIVES

The primary objective of this study is to interpret the structural geology of the McLeod Road-Birch Lake allochthon and its control on the gold mineralization in the vicinity of the New Britannia Mine. This main objective is broken down into a number of sub-objectives. These are to: -

1) document the structural properties of the volcanic rocks in the vicinity of the New Britannia Mine,
2) define the structural constraints, geometry and timing relationship between the gold mineralized zones,
3) characterize the basic texture and mineralogy of the gold occurrences with reference to each type of structural setting,
4) develop a structural model to aid further exploration for gold.

These studies will be of use in the mine development and in regional exploration as there are a number of other gold occurrences and there is a tendency for them to "appear" as small and isolated occurrences. If we can gain an understanding of the plumbing system and its structural controls then discrete zones and structures may be linked and new zones discovered.

1.3 GEOGRAPHICAL LOCATION AND ACCESS

The New Britannia Mine is located in the town of Snow Lake, which is situated in western Manitoba, approximately 679 km NNW of Winnipeg in the Flin Flon - Snow Lake greenstone belt (Fig. 1). Access to Snow Lake from Winnipeg is provided by provincial trunk highways (PTH), the route being north along PTH 6, west along PTH 39 and then north along PTH 392 to Snow Lake (Fig. 1). The New Britannia Mine is situated at the north end of the town (Fig. 2). The other gold mineralized occurrences included in this thesis are all in the vicinity of the New Britannia Mine and access is by gravel/dirt mine roads. Some zones may require a short walk from a road (Fig. 2).

1.4 TOPOGRAPHY, EXPOSURE AND VEGETATION

The topography is generally of low relief, (maximum relief ~ 30m), with glacial eroded bedrock forming the low, drift covered hills. Lakes, swamps and muskeg occupy the lower lying areas. These lakes, swamps and muskeg cover a considerable portion of the study area and restrict access to the outcrop.

Bedrock exposure on the higher ground is poor due to lichen and moss. A number of known gold mineralized zones have shallow trenches dug across them and the more important zones, such as the Boundary Zone, have larger areas of overburden removed to expose the bedrock and mineralization.

The vegetation is typical of the Canadian Precambrian Shield at this latitude, i.e. boreal forest. The higher ground is generally moderately to thickly forested, mostly with spruce and lesser amounts of pine and poplar. The poplar tends to grow adjacent to ridges where the glacial till is thicker. The muskeg areas generally consist of sphagnum moss, low shrubs and stunted spruce trees. For the duration of the field seasons for this study the muskeg areas were generally "dry" in that one can walk across them.

1.5 HISTORY OF THE NEW BRITANNIA MINE PROPERTY

The Snow Lake area has a long history of gold exploration. The following summary of the history is information taken from Gold Deposits of Manitoba (1996).

The New Britannia Mine (former, in part, Nor-Acme Mine) property is covered by two claims, the Chums and Toots, both staked in 1925 by C.R. Parres. In 1938 Nor-Acme Gold Mines Ltd. was formed to develop the property. Nor-Acme optioned the property to Howe Sound Exploration Company Ltd. who further developed the property through drilling. Production started at the Nor-Acme Mine on June 1, 1949 and continued until July 1958, during which 628 461 ounces of gold were produced. After closure of the mine the property was optioned a number of times, during which further gold reserves were found through exploration drilling. The Nor-Acme Mine was optioned by High River Gold Mines Ltd. in 1987 who did further exploration work. Later, High River Gold Mines Ltd. amalgamated with the former owner Nor Acme Gold Mines Ltd. Inco Gold, a subsidiary of Inco Ltd. optioned the property from High River Gold Mines Ltd. in 1988. Inco Gold combined with Consolidated TVX to form TVX Gold Ltd. The Nor-Acme Mine property became a 50-50 joint venture between High River Gold Mines Ltd. and TVX Gold Ltd. who also secured two adjoining properties from W. Bruce Dunlop Ltd. in 1993. These properties hosted two satellite ore deposits to the northwest of the main mine. In 1994 TVX Gold Ltd. and High River Gold Mines Ltd. commissioned a new feasibility study of the Nor-Acme Mine that confirmed the viability for production at lower capital costs. A new mine and mill, the New Britannia Mine, was built and officially opened on November 14, 1995. It continues to produce gold at present.

1.6 PREVIOUS STUDIES IN THE SNOW LAKE AREA

There have been a number of geological studies done in the Snow Lake area, both regionally and more specifically at the New Britannia Mine site. The more local studies concentrated on the gold mineralization at the New Britannia Mine and in the immediate vicinity. Earlier work on the gold mineralization includes Wright (1931), Ebbutt (1944), Harrison (1948 & 1949) and Hogg (1957). More recently Ziehlke (1983), Galley *et al.* (1986 & 1988), Long (1997), Gale (1997) and Schledewitz (1997 & 1998) have studied the gold mineralization at Snow Lake. Work by Galley *et al.* (1988) is the most complete study of the gold mineralization and this work concluded that the gold mineralization is controlled by a series of sinistral oblique slip reverse faults within Amisk Group meta-volcanic rocks in the hanging wall of the McLeod Road Thrust fault.

On a regional scale, previous studies have focused on the structure, metamorphism, mineralization and tectonic setting of the volcanic and sedimentary rocks. Harrison (1951) and Galley *et al.* (1989) have done regional scale studies on the mineralization in the Flin Flon-Snow Lake belt. Harrison (1951) and Russell (1957) completed regional scale mapping and an interpretation of the Snow Lake area. More recently Zaleski and Gordon (1990), Kraus and Williams (1993, 1994a & b, 1995 & 1998) and Schledewitz (1997 & 1998) have addressed some of the structural aspects of the rocks in the Snow Lake area. Kraus and Williams have, using the meta-turbidites, interpreted the relative timing of deformational events and commented on their affect on the surrounding rocks such as the structure and fabric produced.

The tectonic setting and association of the Snow Lake rocks has been the subject of many authors. Bell *et al.* (1975) found evidence for the greenstone belt being of Proterozoic age rather than Archean as previously assumed, Bailes (1980a) concluded that the boundary between the Kisseynew and Flin Flon belts is gradual and is a metamorphic boundary rather than a structural one. Stern *et al.* (1995) studied the geochemical nature of the basaltic rocks from the Amisk collage and interpreted their tectonic setting as ocean-floor and ocean-island basalts. Connors (1996) studied the boundary between the turbidites of the Kisseynew belt and volcano-plutonic rocks of the Flin Flon belt and concluded that the boundary is a structural boundary. This structural boundary is in the form of an early thrust fault that places 1.86-1.84 Ga Kisseynew belt turbidites over previously deformed 1.91-1.88 Ga arc and ocean-floor assemblages of the Flin Flon belt. Lucus *et al.* (1996) interpreted and discussed the tectonic evolution of the Flin Flon belt with David *et al.* (1996) focusing on the tectonic evolution of the Snow Lake portion of the Paleoproterozoic Flin Flon and Kisseynew belts. Recently Bailes and Schledewitz (1998) described the meta-volcanic rocks between the McLeod Road and Birch Lake faults and suggested that these rocks are a structural repetition of the upper part of the Snow Lake arc assemblage.

Froese and Gasparrini (1975), Froese and Moore (1980) and Zaleski and Gordon (1990) addressed the metamorphism in the Snow Lake area by defining and refining the isograds, metamorphic reactions and timing of metamorphism using the pelitic rocks in the area. Kraus and Williams (1994b & 1995) have also addressed the timing of the metamorphism in the Snow Lake area. Menard and Gordon (1994 & 1997), and Kraus and Menard (1997) researched the pressure and temperature paths of the pelitic rocks in the Snow Lake area.

There has also been considerable research done on the several volcanic massive sulphide (VMS) deposits and their host rocks in the Snow Lake area, such as Bailes and Galley (1996), Zaleski (1989) and Trembath (1986). These VMS deposits are located below the McLeod Road Thrust fault and occur at different levels within the Amisk rock sequence, indicating more than one mineralizing event. The mafic volcanic rocks associated with the VMS deposits typically show arc tholeiite chemistry, enrichment in the light ion lithophile elements and depletion in the high field strength elements suggesting that the magmas are subduction related.

1.7 METHODS OF PRESENT STUDY

The research for this study was largely field based. In order to interpret the structural geology and its control on the gold mineralization in the McLeod Road-Birch Lake allochthon it was necessary to obtain the basic but fundamental lithological and structural geological information from the study area through geological mapping. An area to the north of the New Britannia Mine, which contained most of the mineralized occurrences and rock types, was selected and mapped at 1:2400 (Map-A). In addition to this, detailed mapping of some of the mineralized zones, such as the Boundary Zone (Map-B), and underground mapping at the New Britannia Mine was carried out to obtain further details. During the entire mapping process, particular attention was paid to the nature and relative timing of the structures. Rock samples from the different lithological units and mineralized zones were collected for geochemical analysis and petrographic work in order to compare and contrast the volcanic suites, the alteration, the mineralization and microstructures. Other sources of information were earlier geological maps and studies of the area, aerial photographs, geophysical data and drill core. The structural and geological information gained from the mapping and other sources was then applied to earlier, large-scale geological maps of the Snow Lake area. This resulted in a new interpretation of the structural geology of the McLeod Road-Birch Lake allochthon and its control on the gold mineralization in the vicinity of the New Britannia Mine.

CHAPTER 2
REGIONAL GEOLOGICAL SETTING

2.1 TECTONO-STRATIGRAPHIC ASSEMBLAGES

Snow Lake is located in a granite-greenstone belt of early Proterozoic (Aphebian) age known as the Flin Flon-Snow Lake greenstone belt (Fig. 3). This greenstone belt lies in the southeastern part of the Reindeer Zone within the Trans-Hudson Orogenic terrane. The approximate dimensions of the greenstone belt are 250km east west by 50km north south. To the north of the greenstone belt is the Kisseynew meta-sedimentary gneiss terrane and to the south the belt is overlain unconformably by the sedimentary rocks of the Palaeozoic (Figs. 2 & 3).

Historically, the Flin Flon-Snow Lake belt has been divided into two stratigraphic groups, the Amisk Group volcanic rocks and Missi Group continental sedimentary rocks. More recently the rocks of the Flin Flon-Snow Lake belt have been divided geographically into segments or assemblages based on their interpreted evolution and accretion history (Fig. 3; Lucas *et al.* 1996). Major faults, intervening ocean-floor, turbidite or older basement rocks separate these assemblages. The supracrustal rocks of the Snow Lake volcanic arc assemblage are interpreted to have had an independent evolution distinct from that of the Amisk collage (Fig. 3; David *et al.* 1996 & Lucas *et al.* 1996). These rocks are interpreted to be part of a south-verging, allochthonous zone that was thrust over the previously amalgamated and intruded rocks of the “Amisk collage” along the Morton Lake fault zone (Kraus and Williams 1994a, Connors and Ansdell 1996 & Syme *et al.* 1995).

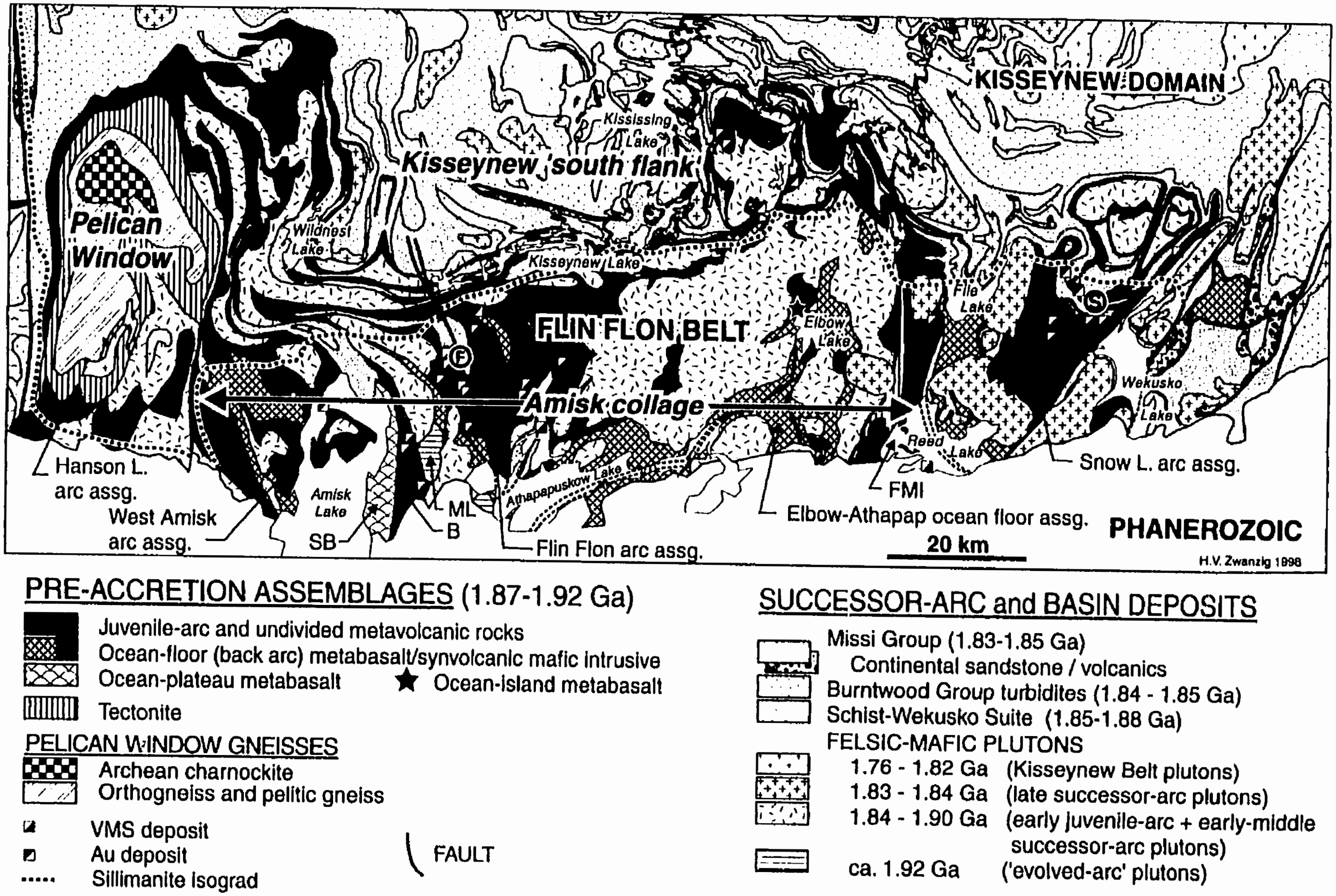

Figure 3: Map of the Flin Flon-Snow Lake greenstone belt showing the major tectonostratigraphic assemblages and post-accretion (successor-arc) plutons, volcano-sedimentary basins and faults (Bailes and Syme, 1989; Syme and Bailes, 1993; Syme *et al.*, 1995 Reilly *et al.*, 1994; Lucas et. al., 1996; Zwanzig, 1996, in press). B: Birch Lake arc assemblage; F: town of Flin Flon; FMI: Fourmile Island arc assemblage; ML: Mystic Lake 'evolved-arc' assemblage; S: town of Snow Lake; SB: Sandy Bay ocean-plateau assemblage.

The Snow Lake assemblage is composed of a lithologically and structurally diverse package of highly deformed and metamorphosed volcanic, sedimentary and intrusive rocks that can be grouped into five major lithotectonic components (Fig. 4; David *et al.* 1996): -

1) ~1.89 Ga metamorphosed basalt, basaltic andesite, dacite, rhyolite and related sub-volcanic intrusions;

2) turbidites of the Burntwood suite;

3) fluvial-alluvial sediments of the Missi suite;

4) successor arc volcanic rocks; and

5) calc-alkaline plutons.

David *et al.* (1996) interpreted and summarised the assembly of the Proterozoic crust in the Snow Lake portion of the Trans-Hudson Orogen into four main stages over a time span of approximately 60-70 million years: -

1st) ~1.89 Ga bimodal mafic and felsic juvenile oceanic arc volcanism and plutonism that display features consistent with minor recycling of older crustal material, including Archean rocks,

2nd) 1.86-1.84 Ga episode of submarine fan turbidite sedimentation that incorporated detritus shed from an intra-oceanic tectonic collage (Amisk collage) assembled during 1.88-1.87 Ga accretion,

3rd) isoclinal folding (F_1) and bedding parallel faults (thrusts) that formed during pre-1.84 Ga southwest convergence of the Kisseynew and Flin Flon-Snow Lake Belts,

4th) further southwest thrusting, three episodes of folding (F_2, F_3 and F_4) and an associated 1.82-1.81 Ga event of high-grade metamorphism.

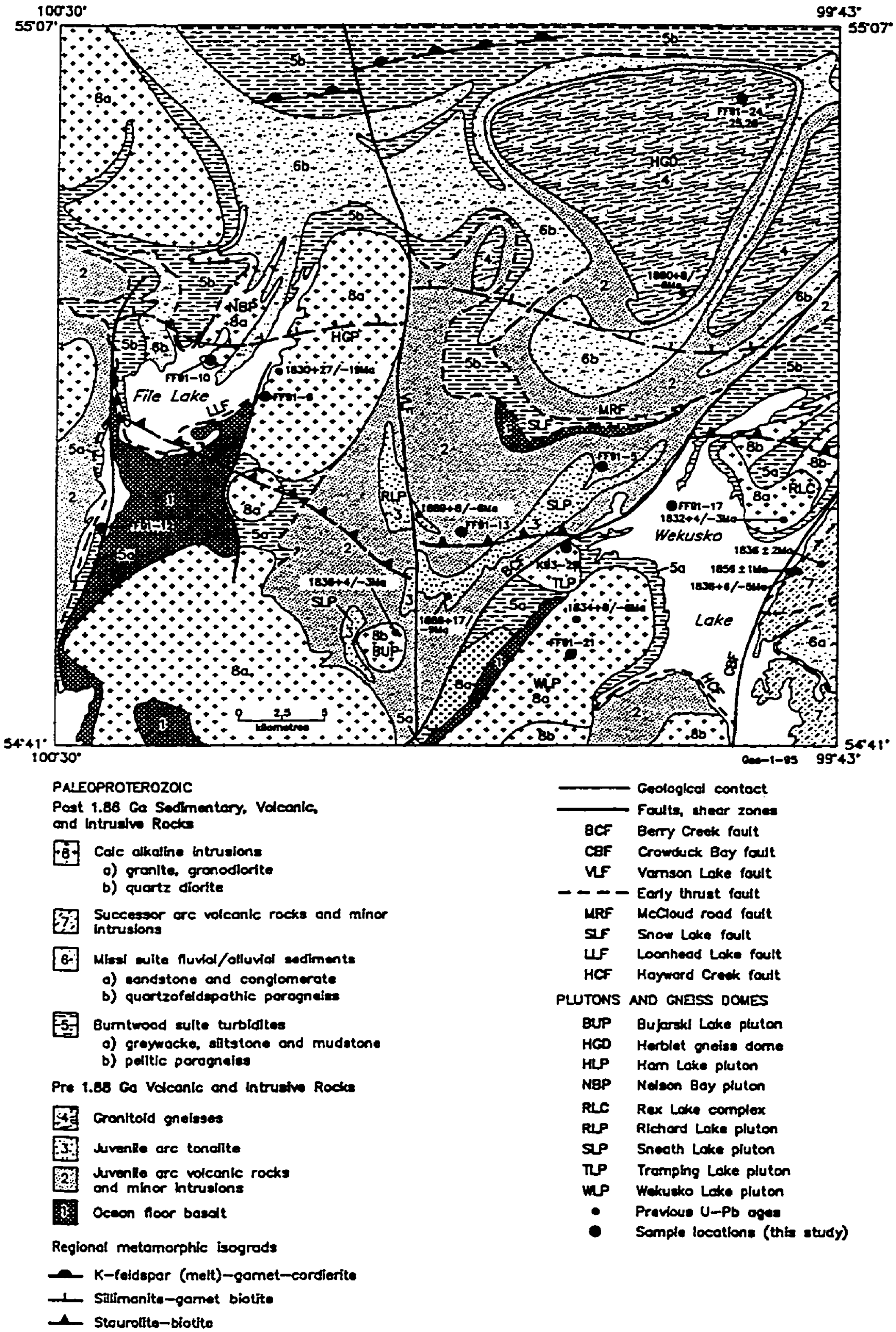

Figure 4: Map of the Snow Lake area showing the major tectonostratigraphic assemblages, plutons and isograds. (after David *et al.* 1996)

It is worth noting that the slice of volcanic rocks that is sandwiched between the McLeod Road Thrust and the Birch Lake fault, and which hosts most of the gold mineralization in the vicinity of Snow Lake have not been dated. However, Bailes and Schledewitz (1998) interpret those rocks of the McLeod Road-Birch Lake allochthon to be correlative to the rocks of the upper part of the Snow Lake arc assemblage, which lies below the Snow Lake fault. This implies that the McLeod Road-Birch Lake allochthon to be a structural repetition of the upper part of the Snow Lake arc assemblage and thus to be of the same age, i.e. 1.89 Ga. (Bailes and Schledewitz 1998).

CHAPTER 3

LITHOLOGICAL ROCK SUITES AND TYPES IN THE SNOW LAKE AREA

3.1 INTRODUCTION TO THE LOCAL GEOLOGY AND MAPS

All the rocks in the Snow Lake area have been metamorphosed and the prefix "meta-" has been omitted from all the rock names. At Snow Lake there are three major tectonostratigraphic rock suites representing very different geological settings. These are the McLeod Road-Birch Lake allochthon (Snow Lake Arc Assemblage) consisting of felsic to mafic volcanic rocks, the Burntwood suite pelites consisting of greywacke turbiditic sequences and the Missi sediments consisting of arkosic sandstones and conglomerates (Fig. 5). The contacts between these major rock suites in the Snow Lake area are the regional scale McLeod Road Thrust fault and Birch Lake fault (Fig. 5). The Burntwood pelites are located to the south and west of the McLeod Road Thrust fault; the Snow Lake arc assemblage volcanic rocks between the McLeod Road Thrust and Birch Lake faults; and the Missi sediments are located to the north and east of the Birch Lake fault (Fig. 5).

The primary rocks of interest are the volcanic rocks between the McLeod Road Thrust fault and the Birch Lake fault, which form the McLeod Road-Birch Lake allochthon (Fig. 5). The area covered by Map-A includes the volcanic rocks of the McLeod Road-Birch lake allochthon, a minor amount of the Burntwood suite pelites and is on the NW-limb of the Threehouse syncline (Fig. 5). The mapped area covers the principal gold mineralized zones in the local vicinity of Snow Lake except for the New Britannia Mine, the Bounter Zone and a few minor zones. The area was mapped using an established cut grid, which has 100ft spacing between the gridlines. The grid has two

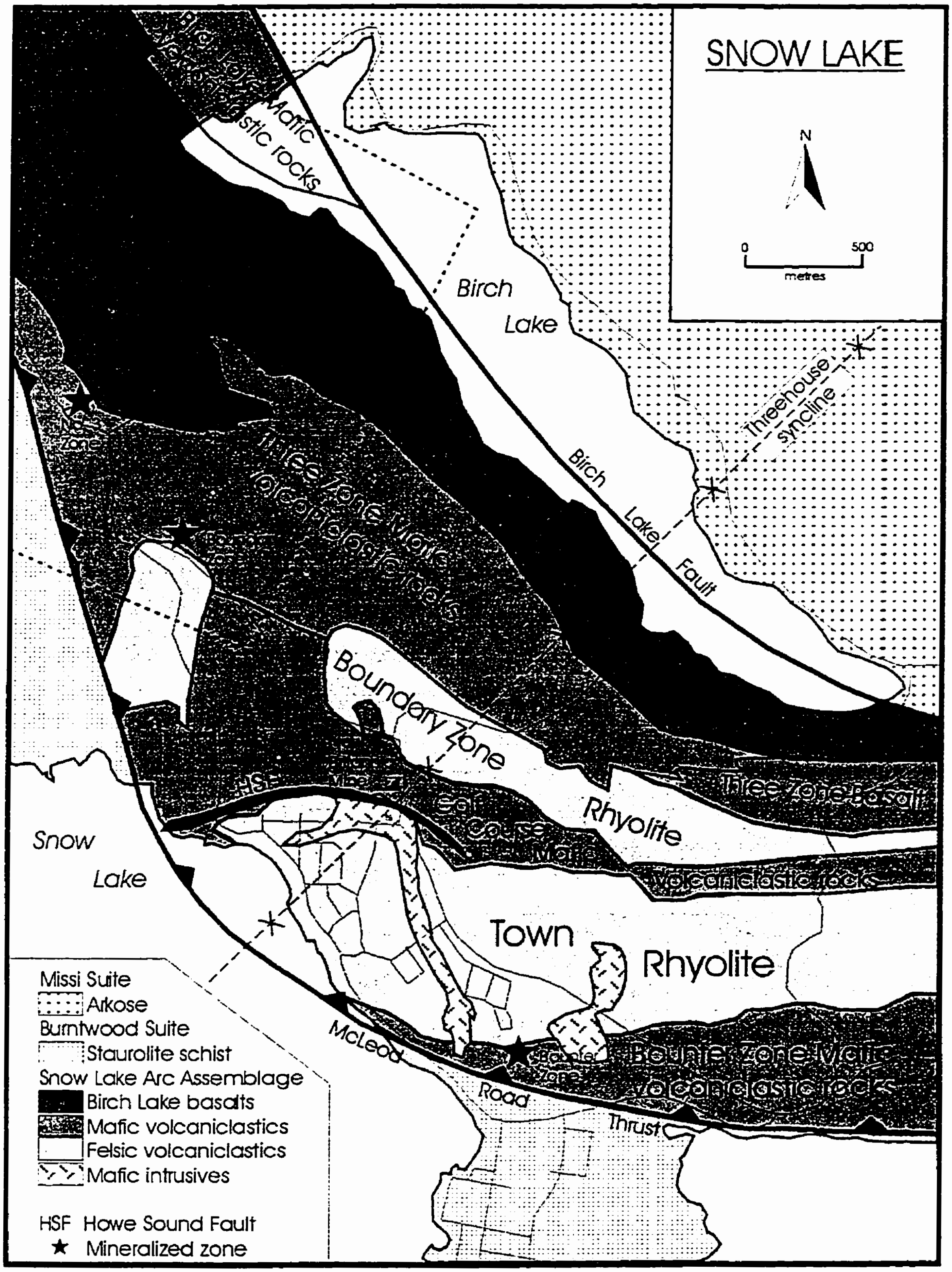

Figure 5: A simplified geological map of the Snow Lake area. This map shows the main lithological rock units and regional scale structures in the vicinity of the New Britannia Mine. The area covered by Map-A is also shown.

numbering systems. North of the 3800N base line 1 prefixes the northing grid reference numbers such that they increases by 10000. The easting grid reference number is changed north of the 3800 base line as well by prefixing it with 1 and the westing numbers are changed into easting grid reference numbers decreasing from 10000E, for example, the gridline 0400W becomes 9600E north of the 3800 base line.

3.2 MCLEOD ROAD-BIRCH LAKE ALLOCHTHON (SNOW LAKE ARC ASSEMBLAGE)

The 1.89 Ga volcanic rocks of the McLeod Road-Birch Lake allochthon, which hosts most of the gold mineralized occurrences, are sandwiched between two sub-parallel faults, the McLeod Road Thrust fault and the Birch Lake fault (Fig. 5). In the vicinity of Snow Lake the volcanic rocks of the McLeod Road-Birch Lake allochthon have been openly folded about the NE trending Threehouse syncline (Fig. 5). These volcanic rocks can be divided up into a number of distinct lithostratigraphic units. For consistency, the names of these lithostratigraphic units mentioned in this study are those used by Bailes and Schledewitz (1998), except for the Birch Lake mafic volcaniclastic unit which is named here. The lithostratigraphic units are elongate in outcrop and are crosscut by the McLeod Road Thrust. On the E-limb of the Threehouse Syncline they have an E-W strike and a northerly dip (Fig. 5). On the NW-limb of the Threehouse Syncline the lithostratigraphic units have a NW-SE strike and dip to the NE (Fig. 5). The lithostratigraphic rock units form a volcanic rock sequence that consistently faces to the north and northeast (section 4.1). The stratigraphic sequence of these lithstratigraphic rock units is from bottom to top, the Bounter Zone mafic volcaniclastic rocks, the Town Rhyolite, Golf Course mafic volcaniclastic rocks, the Boundary Zone Rhyolite, the Three

Zone mafic volcaniclastic rocks and the Birch Lake basaltic rocks (Fig. 5). These lithostratigraphic rock units forming the volcanic sequence of the McLeod Road-Birch Lake allochthon can be broadly grouped into three distinct rock types, these being mafic volcaniclastic rocks, felsic volcanic rocks and mafic flows. These rock units vary in thickness from 100 to 500m thick and are intercalated with one another through the McLeod Road-Birch Lake volcanic sequence (Fig. 5).

The mafic volcaniclastic rock units are predominantly composed mafic breccias with minor mafic wacke beds. The mafic breccias are typically heterolithic and both matrix and clast supported can be found. The mafic fragments often contain amygdules and are almost always porphyritic, containing amphibole pseudomorphs after pyroxene phenocrysts and feldspar phenocrysts. There is a considerable variation in the size and abundance of these phenocrysts and amygdales. Some mafic breccia beds contain minor amounts of felsic and intermediate clasts. This is particularly evident in the mafic breccia beds that immediately overlie the felsic units. The mafic wacke beds vary in thickness up to ten's of metres and are typically composed of fine grained mafic to intermediate material forming finely laminated layers. Bailes and Schledewitz (1998) have interpreted the mafic volcaniclastic rocks as sub-aqueous debris flows and sediment gravity deposits because of their turbidite bed forms and their intercalation with pillowed mafic flows.

The felsic volcanic rock units are composed of rhyolite flows and felsic breccias. The rhyolite flows are charcterized by massive lobes with intervening microbreccia and vary from sparsely quartz-phyric to porphyritic (Bailes and Schledewitz 1998). The felsic breccias consist of heterolithologic to monolithic breccias with both matrix and clast supported breccias being found. The clast size varies widely up to ten's of centimetres.

Bailes and Schledewitz (1998) interpreted these felsic rocks to have been deposited sub-aqueously.

There are three mafic flow units recognised in the vicinity of Snow Lake. These are the Bounter Zone, Three Zone and Birch Lake basalts. The Birch Lake basalts are discussed in detail in section 3.2.3. The Bounter Zone basalts occur within the Bounter Zone mafic volcaniclastic and outcrop to the east of Snow Lake unit where they are up to 30m thick and are discontinuous along strike (Bailes and Schledewitz 1998). These flows were deposited sub-aqueously and display both pillowed and amoeboid pillowed facies (Bailes and Schledewitz 1998). The Three Zone basalts outcrop to the west along strike from the Three Zone mafic volcaniclastic unit where they form a 300m thick unit (Fig. 5). Bailes and Schledewitz (1998) documented this unit as being dominantly massive with up to 50% pyroxene (2-10mm) phenocrysts but locally having pillow selvages and complete pillows.

The area covered by Map-A only includes the rocks in the upper part of the McLeod Road-Birch Lake volcanic sequence on the NW limb of the Threehouse syncline. The rock units found within the mapped area of Map-A are discussed in more detail below.

3.2.1 BOUNDARY ZONE RHYOLITE UNIT

The Boundary Zone rhyolite is the upper most felsic volcanic rock unit that outcrops in the McLeod Road-Birch Lake allochthon volcanic sequence. In Map-A this felsic unit outcrops at the Boundary Zone and extends southwards where it terminates against the McLeod Road Thrust. This felsic rock outcrop at the Boundary Zone is part of a larger felsic block that is interpreted to be structurally dislocated from the rest of a felsic rock unit, which is to the southeast (Fig. 5).

At the Boundary Zone (Map-A) this volcanic rock unit is composed of fine-grained massive rocks to large fragments of felsic composition. On unweathered surfaces the rocks are light to dark grey in colour and weather to light tan colour, often with rusty patches. These rocks are interpreted to be tuffs, crystal tuffs, lapilli tuffs, breccias and flows. The coarser volcaniclastic rocks have fragments that are up to tens of centimetres in length and are sub-rounded to sub-angular (Fig. 6). This rounding is interpreted to be primary and has been enhanced by later deformation and alteration. The fine-grained tuffs are massive, aphyric with no discernible primary features. The crystal tuffs form a quartz porphyritic rock in which the quartz crystals are up to 2 mm in size with an aphanitic groundmass. The lapilli tuffs or breccias can only be distinguished from the tuffs on weathered surfaces where the fragments can be identified. Primary structural features such as bedding between the different sized fragments can be seen at the Boundary Zone (Fig. 7). Flow features have been observed in this unit, to the south of the Boundary Zone (not on Map-A). These flow features are interpreted to be lobes or small flows. The coarser fragmental rocks / breccias have a much stronger foliation than the finer grained tuffs.

The only exposed contact between this felsic rock unit and the overlying mafic volcaniclastic rocks is at the Boundary Zone where the contact is a fault which has a complex history of multiple movements with a fine grained mafic rock intruded in places along the contact.

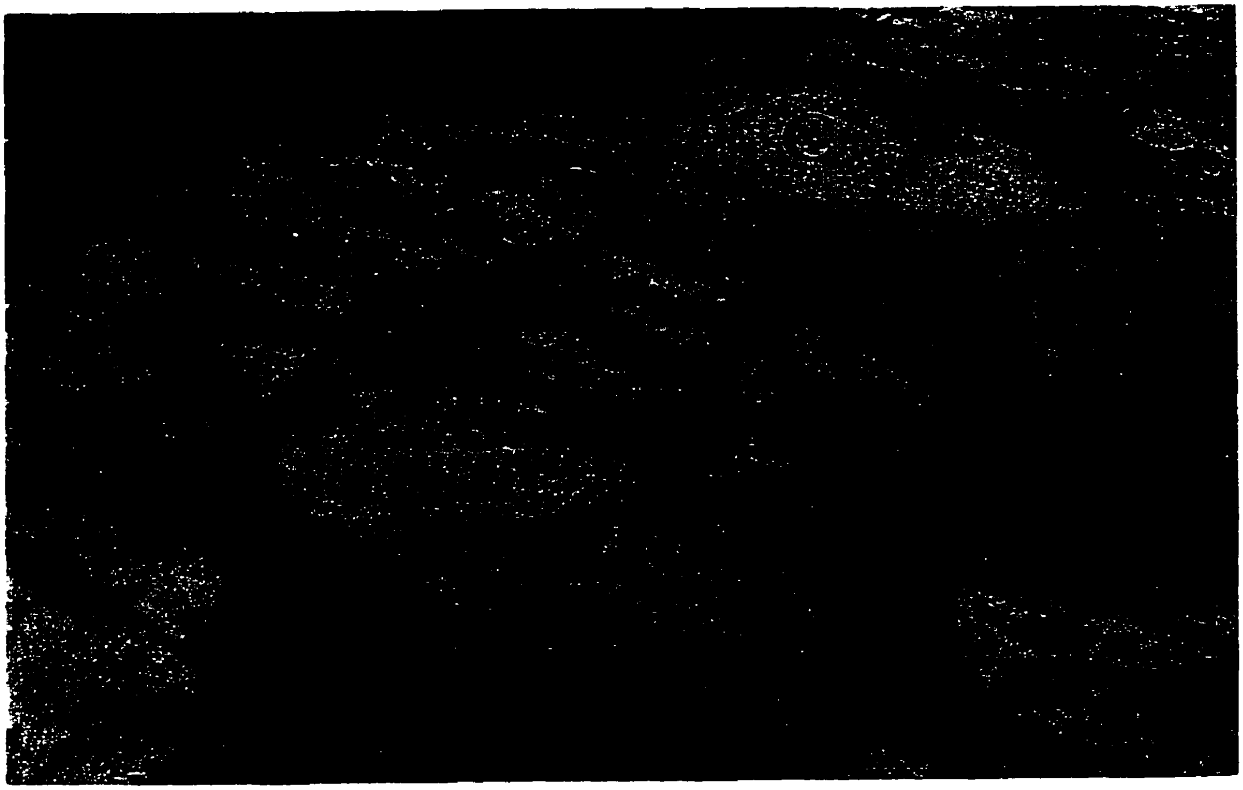

Figure 6: Felsic clasts in the felsic rock unit exposed at the Boundary Zone. The clasts (C) are angular to well rounded. The fabric (F) seen in the rocks is the pervasive S_1/S_2 foliation.

Figure 7: Primary bedding features (B) in the felsic rocks at the Boundary Zone. The clasts have been rotated into the pervasive S_1/S_2 foliation (F).

3.2.2 THREE ZONE MAFIC VOLCANICLASTIC UNIT

The Three Zone mafic volcaniclastic rock unit covers much of the southeastern corner of Map-A. This rock unit is cut off to the west by the McLeod Road Thrust fault and extends eastwards from the No.3 Zone. This mafic volcaniclastic rock unit is composed mainly of coarse mafic breccias interbedded with minor, finely laminated mafic wacke beds. The mafic volcaniclastic rocks in this unit are best exposed at the No.3 Zone portal and at the Boundary Zone. At both these locations well bedded to massive mafic breccias are found. Most of these breccias are heterolithic, however, monolithic breccias do outcrop at the No.3 Zone portal (Figs. 8 & 9). Both clast supported and matrix-supported breccias are exposed. The fragments in the breccias are variable in size, up to 40 cm, but most are in the 5-20 cm range. These fragments are tabular to irregular in shape with angular edges. The angular fragments and minimal sorting indicate these rocks were deposited proximal to their source. The fragments in the mafic volcaniclastic rocks are characterized by the presence of medium to very large (2-10mm) phenocrysts of hornblende pseudomorphs after pyroxene and 1-3 mm feldspar phenocrysts. The amphibolized pyroxene phenocrysts are stubby, euhedral, dark green to black in colour, and are very variable in their concentration. The interstitial material of these mafic breccias is variable, but is generally of similar composition to the fragments and contains the amphibolized pyroxene phenocrysts and feldspar phenocrysts that are found in the fragments (Figs. 8 & 9).

Within this mafic volcaniclastic rock unit at the outcrop directly above the No.3 Zone portal there are pillow like structures. The pillows are comprised of large pseudo pyroxene phenocrysts, up to 2 cm, and orbicular feldspar, up to 6 cm, in a fine-grained groundmass.

Figure 8: Very large pseudo-pyroxene phenocrysts in the mafic volcaniclastic unit. The pseudo-pyroxene phenocrysts (P) are contained in both the light gray fragments (F) and in the interstitial material between the fragments suggesting a similar source. The fine-grained, light coloured material, which constitutes the groundmass in the fragments, is absent from the interstitial material suggesting minimal sorting. (Loc. No.3 Zone portal)

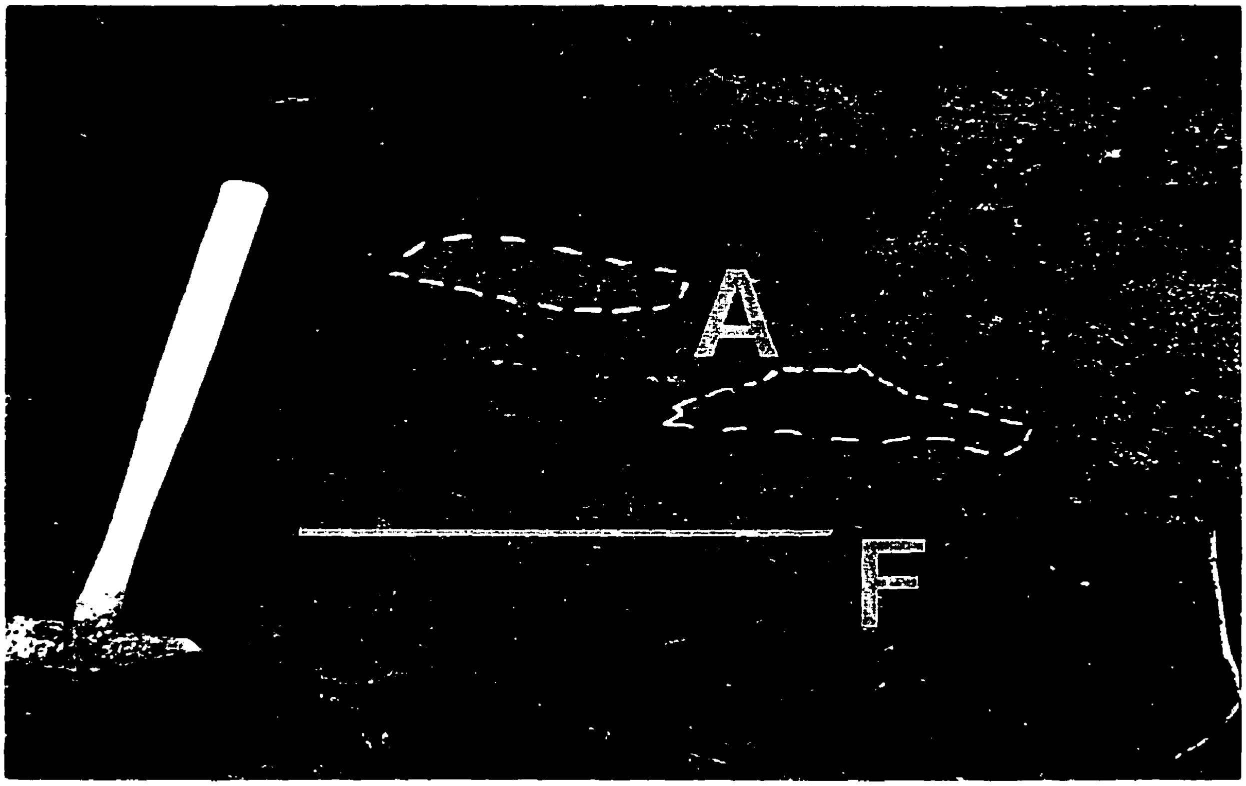

Figure 9: Flattened fragments (A) in a heterolithic mafic breccia. The fabric (F) is the S_1/S_2 foliation fabric. This mafic breccia is in the Three Zone mafic volcaniclastic rock unit (Loc. No.3 Zone portal).

At the top of this mafic volcaniclastic unit, east of the Blood Zone, there is thick, finely laminated mafic wacke bed (Map-A). At its eastern end this mafic wacke bed is approximately 30 m thick and thickens up to about 100m near the Blood Zone where the unit is terminated structurally. The mafic wacke bed is composed of finely laminated, fine-grained material of mafic to intermediate composition. Darker and lighter coloured bands on the mm-cm scale (Fig. 10) define the laminations. In thin section the darker bands are composed of approximately 40% quartz + feldspar, 30% biotite, 30% actinolite and ±2% sulphides. The light coloured bands are composed of approximately 60% quartz + feldspar, 20% biotite, 20% actinolite and accessory disseminated sulphides. Over lying the Three Zone mafic volcaniclastic unit is the Birch Lake basalt (sect. 3.2.3).

The interlaying of the mafic volcaniclastic rocks with pillowed flows and the sedimentary features of the mafic wacke beds suggest a sub-aqueous depositional environment. The mafic volcaniclastic rocks are therefore interpreted to be sub-aqueous debris flows deposited from a proximal source.

The contact between Three Zone mafic volcaniclastic unit and the Birch Lake basaltic unit is best exposed above the No.3 Zone at Loc. 6.00E/15.00N. Here, above the No.3 Zone, the contact is very sharp and linear. East of the Blood Zone, where a thick bed of finely laminated mafic wacke is at the top of the mafic volcaniclastic rock unit, the contact between the Birch Lake basalt rock unit and the Three Zone mafic volcaniclastic rock unit is not exposed.

3.2.3 BIRCH LAKE BASALT UNIT

The Birch Lake basaltic unit is composed of pillowed to massive flows and intrusions of basaltic composition. This unit outcrops along the southwestern shore of

Figure 10: Finely laminated mafic wacke. This outcrop shows the fine mm to cm scale bedding (B) in the mafic wacke. This finely laminated mafic wacke forms a thick bed at the top of the Three Zone mafic volcaniclastic rock unit (Loc. 1350E/2680N).

Birch Lake and forms a 200-500m thick sequence at the top of the volcanic package (Fig. 5).

Pillowed basalts are exposed in several places with the best exposures being located at 0800E/3480N and 1720E/3220N. At these locations the pillow shape, convex upwards, indicate the younging direction to be to the NE (Fig. 11). The pillowed basalts are fine grained, aphyric, green coloured and form pillows that average 30-50 cm in size but larger pillows up to 1m in size are common (Fig. 11). The pillows are slightly to moderately deformed in the outcrop exposures. The pillows have thin selvages with very little hyaloclastite in between them. The pillows often have elongated lens-shaped veins with quartz and/or carbonate filling which are interpreted to be deformed amygdales and/or fractures. The pillowed basalts make up an estimated 10-20% of the Birch Lake basaltic unit, however there are numerous outcrops of fine grained, aphyric, green basaltic rock in which no pillow selvages are observed, these make up an estimated 40-50% of the Birch Lake basaltic unit.

Medium to coarse grained, massive rocks are also contained in the Birch Lake basalt unit. These rocks have an equigranular gabbroic texture and are composed of tabular hornblende, (up to 4 mm in size), plagioclase and quartz. These rocks are irregularly interspersed with the finer grained basaltic rocks and have the same basaltic composition as the pillowed basalts. These rocks are interpreted to be shallow intrusions and massive flows. These medium to coarse grained rocks make up an estimated 50-60% of the Birch Lake basalt rock unit. They are more prevalent to the north west of this basaltic unit where it becomes difficult to distinguish between the coarser grained rocks of this unit and the rocks of the mafic volcaniclastic unit.

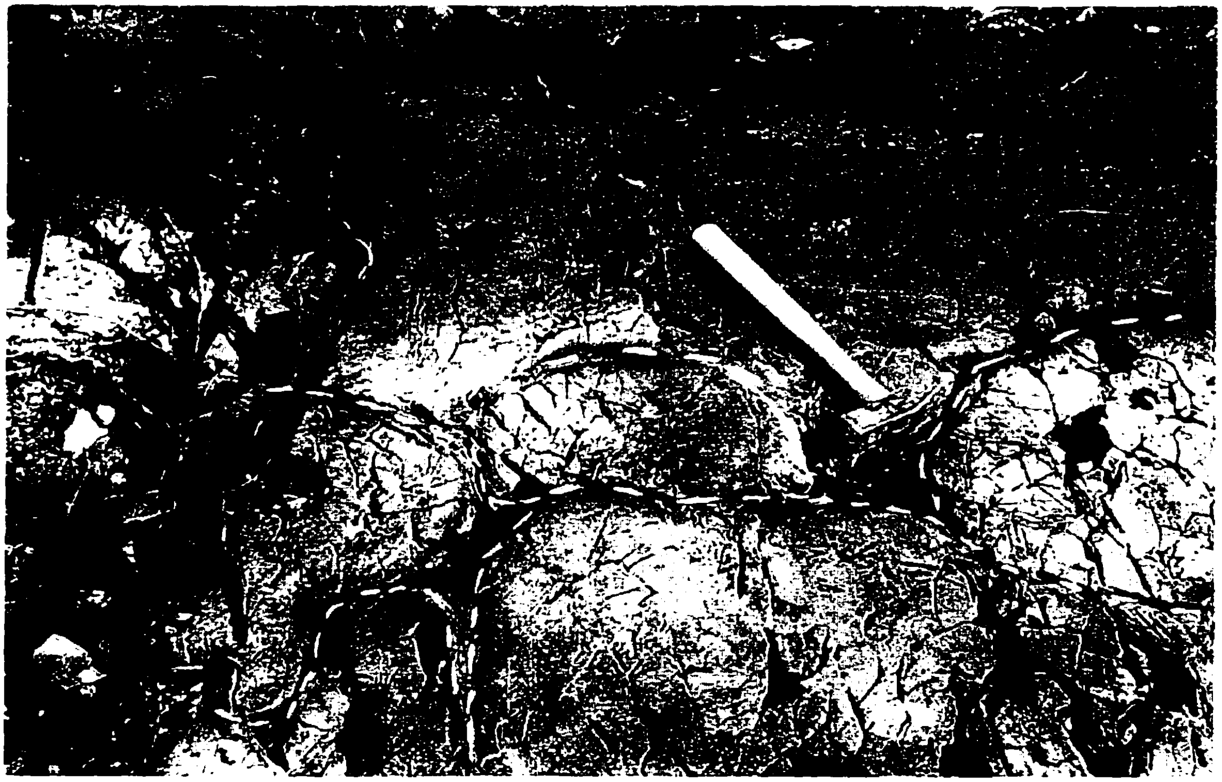

Figure 11: Aphyric pillowed basalt. The pillows have thin selvages with very little hyaloclastite between them. The pillow shape (convex up) indicates the rock outcrop is north facing. (The hammer is orientated N-S with the handle pointing N. Loc. 0800E/3480N)

Stratabound, syn-volcanic alteration has affected a relatively large portion of this Birch Lake basalt unit. These altered rocks are fine-medium grained, pinkish/purple to grey on unweathered surfaces, a pale tan colour on weathered surfaces and of felsic composition. The pillowed texture is still preserved in some locations. This alteration is discussed more in chapter 6.

The Birch Lake basalt rock unit is interpreted to be sub-aqueous massive to pillowed basaltic flows. Along most of its length the Birch Lake basalt is bounded to the NE by the Birch Lake fault (Fig. 5). However, at the NW end of Birch Lake, mafic volcaniclastic rocks overlie the Birch Lake basalt. There is no exposed contact between the Birch Lake basalt rocks and the overlying mafic volcaniclastic rocks but unpublished geophysical data suggests this is a fault contact.

3.2.4 BIRCH LAKE MAFIC VOLCANICLASTIC UNIT

This mafic volcaniclastic unit outcrops at the northwestern end of Birch Lake (Map-A & Fig. 5). The unit is composed of interbedded volcanic conglomerates and fine laminated sediments of mafic composition (Fig.12). The mafic volcanic conglomerates are heterolithic and matrix supported. The clasts in the conglomerate are rounded to sub-angular which are variable in size from mm's up to 50 cm in scale. The clasts are mafic in composition and have the characteristic pseudo pyroxene phenocrysts, which are found in the other mafic volcaniclastic rock units. Interbedded with the conglomerates are fine laminated mafic sediments that form mafic wacke beds up to 40 cm thick. Light and dark coloured bands that range from 0.5mm up to a few centimetres define the laminations in the mafic wacke beds.

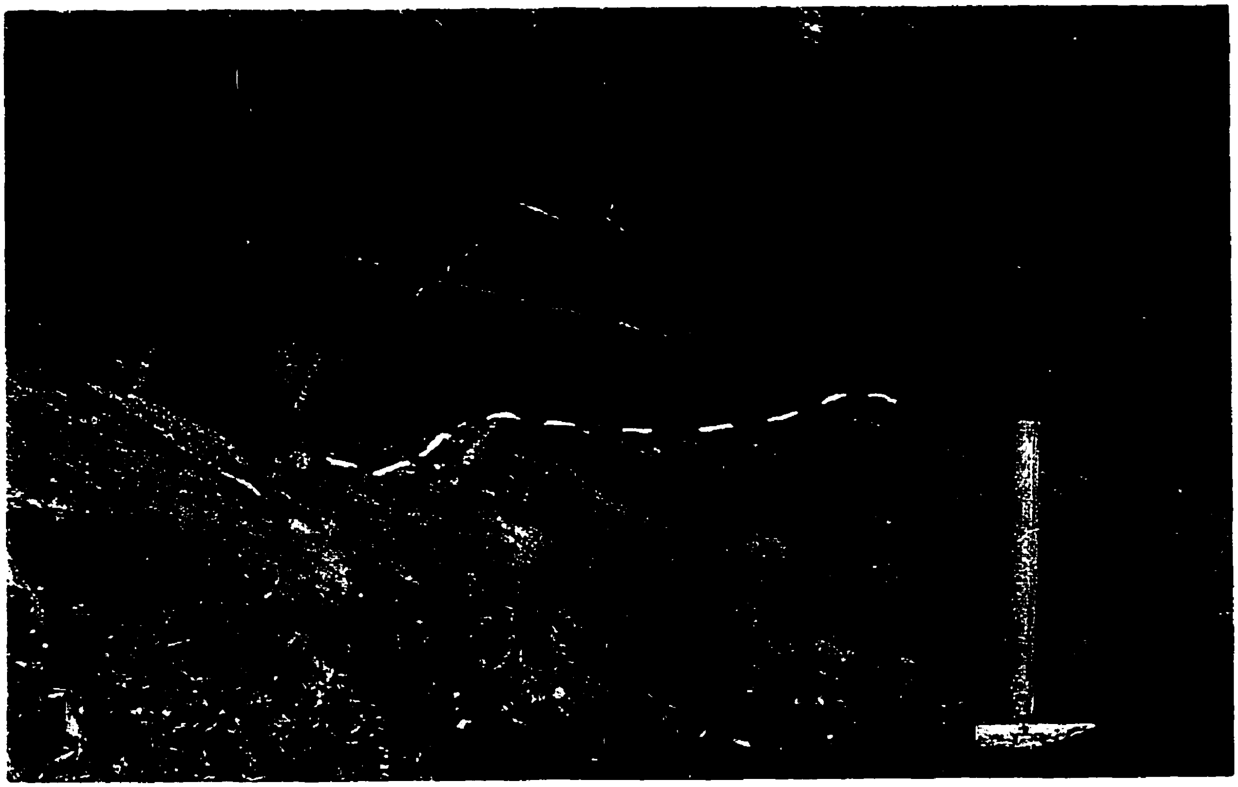

Figure 12: Erosional surface at the base of a finely laminated mafic wacke bed. The erosional surface (E) indicates the younging direction is to the NE (upwards). Also note the relationship between the bedding (B) and the pervasive S_1/S_2 foliation fabric (F). The strike and dip of the mafic wacke bed is $307^0/25^0$N and the strike and dip of the foliation is $340^0/36^0$. This outcrop is located in the Birch Lake mafic volcaniclastic unit at the NW end of Birch Lake. (Loc. 10200E/15320N)

In an outcrop located at the NW end of Birch Lake (10200E/15320N) there is an erosional scour indicating the younging direction to be to the N-NE (Fig. 12). The Birch Lake mafic volcaniclastic rock unit is highly epidotised in comparison to the other mafic volcaniclastic unit in the mapped area. The epidote alteration has affected some clasts and veins. This alteration is discussed further in chapter 6. The Birch Lake mafic volcaniclastic unit is very similar to the other mafic volcaniclastic rocks in the Snow Lake area and is also interpreted to be sub-aqueous debris flows

3.2.5 INTRUSIVE VOLCANIC ROCKS

There are a number of mafic intrusive volcanic rocks of both massive and dyke like nature. These intrusive rocks all occur within the mafic volcaniclastic and felsic rock units of the McLeod Road-Birch Lake allochthon, however none have been found in the Birch Lake Basalt unit (Map-A).

3.2.5.1 PYROXENE-PLAGIOCLASE PHYRIC GABBRO

The pyroxene (Pyx) and plagioclase feldspar (Plag) phyric gabbro outcrops at the Boundary Zone and to the immediate north of the Boundary Zone (Map-A & B). These gabbroic rocks are massive and characterized by the large pseudo-pyroxene crystals, 4-8 mm in size, and feldspar phenocrysts, up to 3 mm in size, both of which have a uniform distribution at the outcrop scale (Fig. 13). The lack of any fragments, bedding and fabric in the massive gabbroic rocks would argue that these rocks are not a crystal tuff. The fragments in the mafic breccias of the mafic volcaniclastic units are of similar character as these gabbroic rocks. The similarity between the fragments in the mafic volcaniclastic units and the pyroxene-feldspar phyric gabbroic rocks, and that no similar rocks are found in the Birch Lake basaltic unit or the Burntwood sediments infer that the massive

Figure 13: Pyx-Plag gabbro. This gabbroic rock is exposed at the Boundary Zone (Map-B) and to the immediate north of the Boundary Zone (Map-A). Clasts in the mafic volcaniclastic rocks are similar in character to this intrusion, which suggests that this is a synvolcanic intrusion. Note the lack of a strong foliation fabric. (Loc. Boundary Zone)

gabbroic rocks are syn-volcanic. Two contacts of the massive gabbroic rock with the mafic volcaniclastic rocks are parallel to the bedding indicating a sill or flow. One of these contacts is exposed at the Boundary Zone (Map-B); the other contact is to the NE of the Boundary Zone (Loc. 20.80E/03.20N, Map-A). Relative to the volcaniclastic rocks, the massive gabbroic rocks only have a weak foliation.

3.2.5.2 HORNBLENDITE

The hornblendite rock is massive, coarse grained, dark green to black in colour with no bedding, layering or foliation evident. The rock is composed of porphyritic amphibolized pyroxene crystals, up to 8 mm in size, in a fine-grained matrix consisting predominantly of hornblende with minor amounts of plagioclase feldspar. Outcrops of this coarse-grained hornblendite intrusion are exposed to the east of the Blood Zone (Map-A). This hornblendite is similar in character to the mafic intrusions seen in the drill core from the New Britannia Mine. No evidence such as crosscutting relationships could be found to indicate the relative age of this intrusion.

3.2.5.3 ANDESITE

A fine to medium-grained, intrusion of intermediate composition is hosted in the felsic rocks at the Boundary Zone (Map-B; Fig. 24). This intrusion forms a single dyke approximately 50cm in thickness and has small, 1-2mm, size garnets throughout the dyke. The Boundary Zone basalt crosscuts this intrusion.

3.2.5.4 BOUNDARY ZONE BASALT

A fine grained, dark green intrusion of mafic composition has been intruded along the faulted contact between the felsic and mafic rocks at the Boundary Zone (Map-B). Irregular flow features and at least two intrusive phases of the intrusion can be recognized. This fine-grained mafic intrusion crosscuts some of the hornblende-biotite-tourmaline dykes and therefore pre- dates them.

3.2.5.5 HORNBLENDE-BIOTITE-TOURMALINE DYKES

Mafic hornblende-biotite-tourmaline dykes outcrop at the Boundary Zone and are hosted in both the felsic rock unit and the mafic volcaniclastic rock unit (Map-B). The dykes are medium to coarse grained, vary in thickness from 10 cm to 50 cm, are parallel to sub-parallel to the pervasive S_1/S_2 foliation and do not have noticeable chilled margins. The dykes are generally black in colour and consist of amphibole, biotite with minor tourmaline, feldspar, quartz and ±garnet. The coarser-grained dykes have pseudo-pyroxene crystals that have been altered to amphibole. Geochemically these mafic dikes at the Boundary Zone show a higher K_2O and Ba values when compared to the other mafic rocks in the mapped area.

3.3 ROCK GEOCHEMISTRY OF THE MCLEOD ROAD-BIRCH LAKE ALLOCHTHON

A number of volcanic rock samples from within the mapped area of the McLeod Road-Birch Lake allochthon were submitted for geochemical analysis using ICP-MS and ICP-AES analytical procedures (Appendix-A). Two samples from fragments in the Three Zone mafic volcaniclastic rock unit, two samples from the Pyx-Plag gabbro, two samples from the hornblendite and six samples from relatively unaltered pillowed, Birch Lake basalt rocks were used to classify and interpret the tectonic setting of the volcanic rocks.

Figure 14 shows that all the selected rock samples plotted in the subalkaline field using the subalkaline/alkaline classification plot of Irvine and Barager (1971). Figure 15 shows that all except for one sample plotted in the tholeiitic field of the tholeiitic/calc-

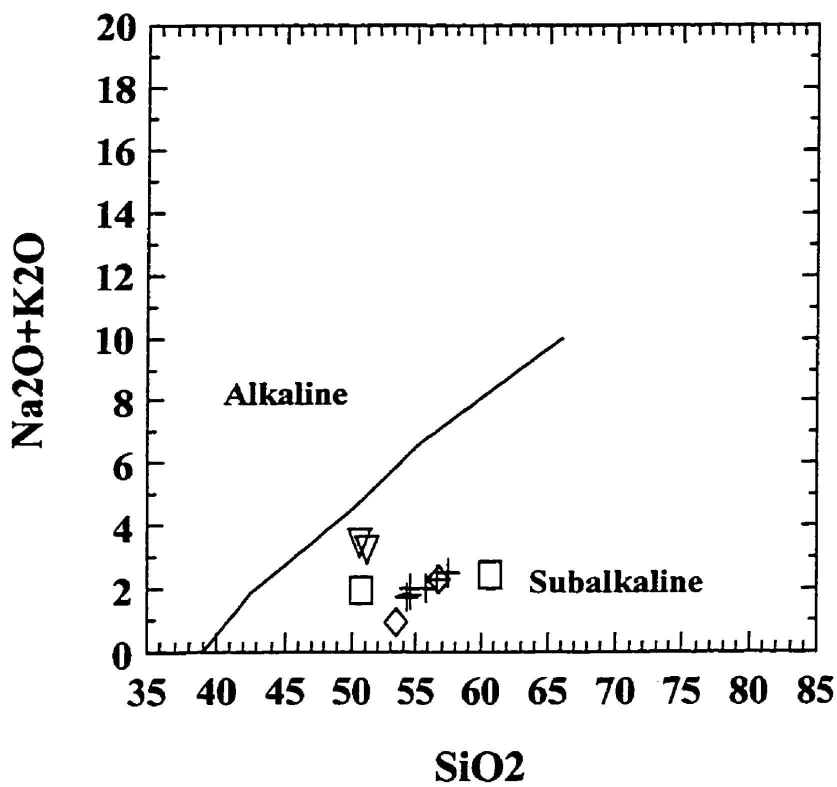

Figure 14: Subalkaline/alkaline plot for selected rock samples. The six samples from the Birch Lake basaltic rock unit (crosses), the two samples of the Three Zone mafic volcaniclastic rocks (squares), the two samples of Pyx-Plag gabbro (triangles) and the two samples of Hornblendite (diamonds) all plot in the subalkaline field. The subalkaline/alkaline plot after Irvine and Barager (1971). The values are all in weight percent. The SiO_2 values were calculated by subtracting the other major oxide values from 100%.

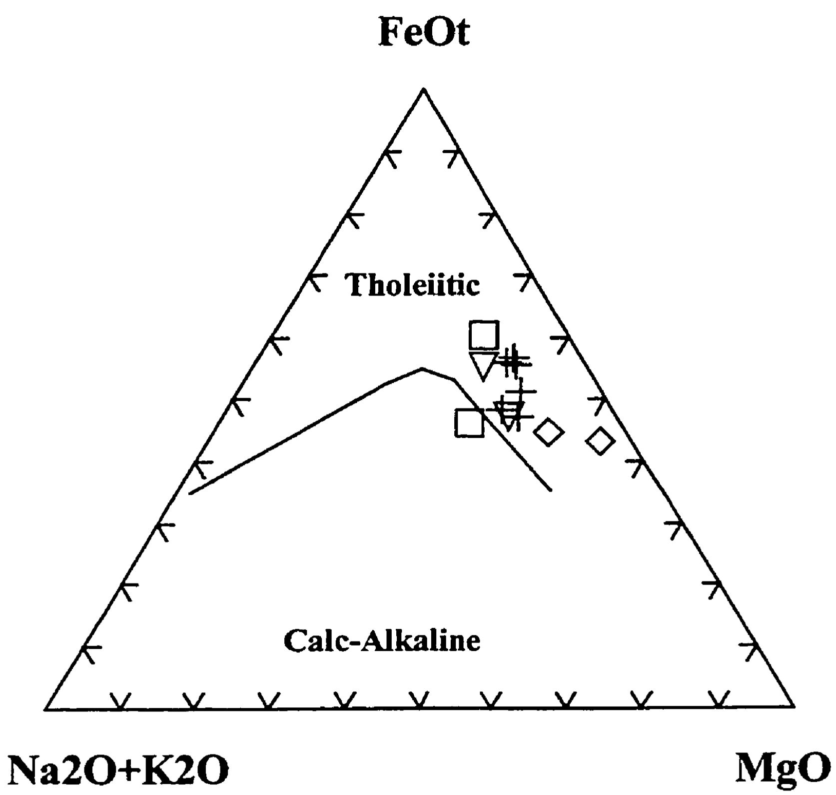

Figure 15: AFM plot for selected rock samples. The six samples from the Birch Lake basaltic rock unit (crosses), one of the samples of the Three Zone mafic volcaniclastic rocks (squares), the two samples of Pyx-Plag gabbro (triangles) and the two samples of Hornblendite (diamonds) all plot in the tholeiitic field. One sample of Three Zone mafic volcaniclastic unit plots in the calc-alkaline field. The AFM plot is based on Irvine and Barager (1971).

alkaline classification plot of Irvine and Barager (1971). This characterizes the volcanic rocks as being predominantly subalkaline tholeiitic. On the Jensen cation plot (1976) the Birch Lake basalts, Pyx-Plag gabbro and one sample of the Three zone mafic volcaniclastic rocks all plot in the centre of the tholeiitic field on the boundary between the high-iron and high-magnesium tholeiitic fields (Fig. 16). One sample of the Three Zone mafic volcaniclastic rocks plotted in the calc-alkaline field. The samples from the hornblendite intrusion plotted in the basaltic komatiite field. A REE plot of these six samples from the Birch Lake basalt rock unit shows that there is light REE depletion, typical of MORB basalts (Fig. 17). A further seven samples from the Birch Lake basaltic unit representing relatively unaltered fine grained (basalt) to medium grained (gabbroic) rocks had very similar REE plots to the pillowed basalt samples, however these are not shown in figure 17 to avoid cluttering the diagram. This suggests that all the rocks in the Birch Lake basalt unit have a similar origin and are related.

The two samples from the Three Zone mafic volcaniclastic rock unit, the two samples from the Pyx-Plag gabbro and the two samples from the Hornblendite all show a slight light REE enrichment and relatively flat High REE (Fig. 17). This suggests a similar origin and this is comparable to the REE patterns of mature arcs in the Snow Lake arc assemblage (Stern et al 1995). These rocks have a very different REE pattern in comparison to the Birch Lake basaltic rocks.

In a Th/Nb – Nb/Y discrimination diagram the Birch Lake basaltic rocks plot in the N-type MORB field and the rest of the volcanic rock samples plot in the Snow Lake Mature Arc field (Fig. 18; after Pearce 1983 and Bailes & Schledewitz 1998)
In comparison to the Birch Lake basaltic rocks the Three Zone mafic volcaniclastic, Pyx-Plag gabbro and Hornblendite the REE patterns and Th/Nb – Nb/Y

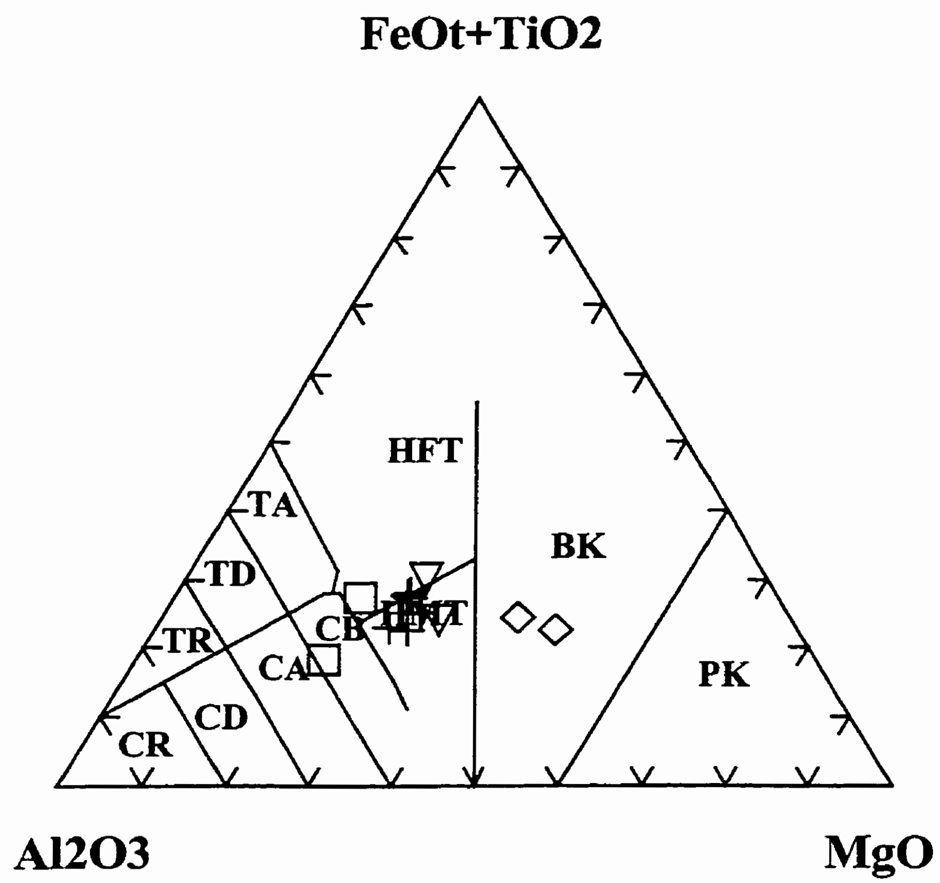

Figure 16: Jensen cation plot for selected rock samples. The six samples from the Birch Lake basaltic rock unit (crosses), one of the samples of the Three Zone mafic volcaniclastic rocks (squares) and the two samples of Pyx-Plag gabbro (triangles) all plot in the tholeiitic field. The two samples of Hornblendite (diamonds) plot in the basaltic komatiite field. The one sample of Three Zone mafic volcaniclastic rock that plots in the calc-alkaline basalt field may have been slightly altered. The cation plot is based on Jensen (1976).

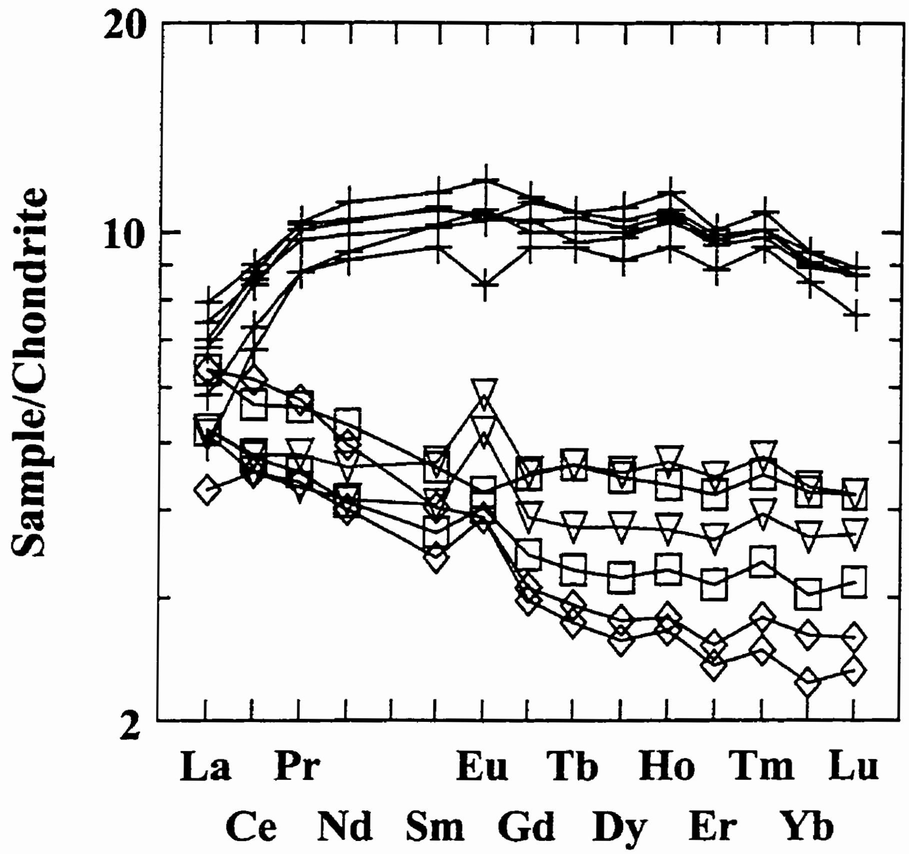

Figure 17: Chondrite normalized REE patterns for selected rock samples. The six samples from the Birch Lake basaltic rock unit (crosses) show LREE depletion. The two samples of the Three Zone mafic volcaniclastic rocks (squares), the two samples of Pyx-Plag gabbro (triangles) and the two samples of Hornblendite show LREE enrichment.

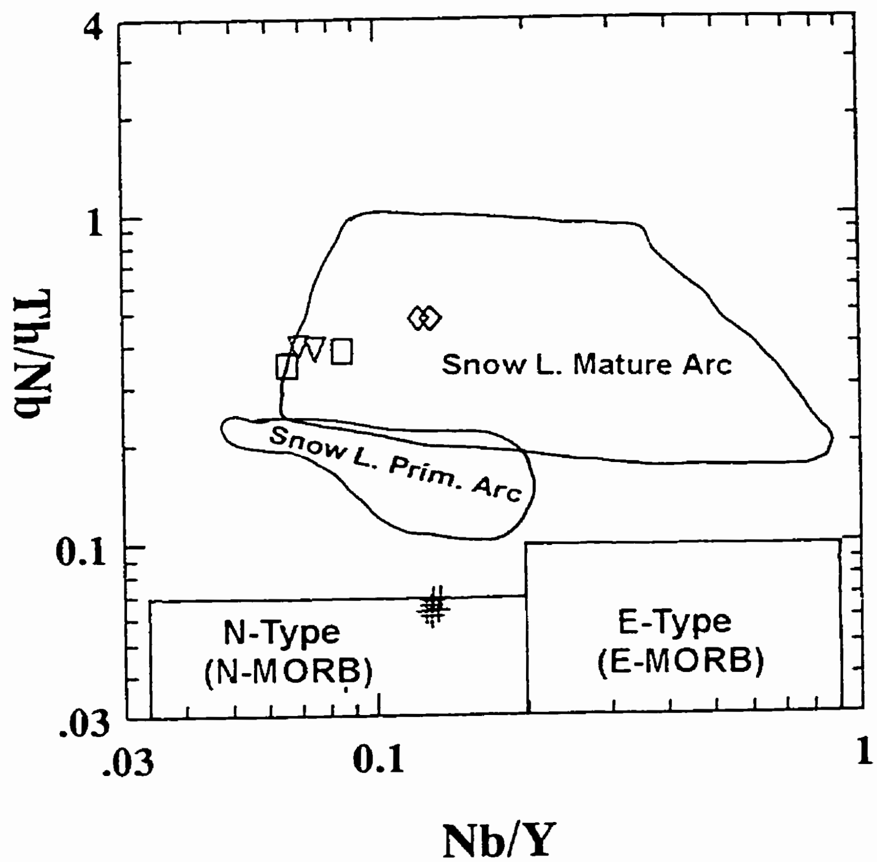

Figure 18: Th/Nb – Nb/Y discrimination diagram. The six samples of relatively unaltered pillowed basalt from the Birch Lake basaltic rock unit (crosses) plot in the N-type MORB field. The two samples of the Three Zone mafic volcaniclastic rocks (squares), the two samples of Pyx-Plag gabbro (triangles) and the two samples of Hornblendite plot in the Snow Lake mature arc field. (after Pearce 1983 and Bailes & Schledewitz 1998)

discrimination diagrams suggest that the Birch Lake basaltic rocks were deposited in a different tectonic setting and are possibly allochthonous relative to the rest of the volcanic rocks in the McLeod Road-Birch Lake allochthon.

3.4 BURNTWOOD SUITE

The Burntwood suite is a sedimentary suite that is located to the south and west of the McLeod Road Thrust (Fig.5). It is composed of interbedded mud and siltstone units which are light to dark grey in colour. The beds are well formed and vary in thickness from a few cm's to meters. The Burntwood suite has been interpreted as a sequence of greywacke turbidites (Bailes 1980). In the Snow Lake area this suite has a high degree of metamorphic mineral overprint and contains varying amounts of staurolite, garnet and biotite. Staurolite is only present in some beds and is typically euhedral, dark brown/red in colour and up to 9 cm long. Garnets are present in almost the whole unit and are typically euhedral, dark red in colour and are generally 2-4 mm in size. Brown-coloured biotite is present throughout the unit and generally occurs as "biotite books" which are 2-4 mm long. The biotite defines a pervasive foliation. A distinctive bed characterized by an abundance of large, up to 1 cm in size, porphyroblastic garnets with little or no staurolite is intersected in minesite drilling and drifts in the New Britannia Mine which penetrate the McLeod Road Thrust fault into the Burntwood sedimentary suite. This garnet-porphyroblastic bed also outcrops on the surface at the roadside to the south east of the Snow Lake police station. This garnet-porphyroblastic bed is similar in character to the Corley Lake member in the File Lake formation (Alan Bailes, pers. com. 1998).

CHAPTER 4
STRUCTURAL GEOLOGY

4.1 PRIMARY FEATURES

A number of primary features such as pillows (Figs. 11 & 59) in the Birch Lake basaltic unit and bedding in the felsic breccias, mafic breccias and fine laminated mafic wacke rocks have been preserved (Figs. 7, 10, 12 & 23). The bedding in the mafic wacke bed at the top of the Three Zone mafic volcaniclastic rocks dips moderately to the N and strikes at 260^0-290^0. The bedding in the mafic volcaniclastic rocks at the Boundary Zone dip moderately to the NNE (strike 300^0-310^0) and at the outcrop at the northwestern end of Birch Lake (Loc. 10200E/15320N) the bedding dips to the NNE and strikes at 307^0.

The younging direction, interpreted from exposures of pillowed basalts and the outcrop at the NW end of Birch Lake, is consistently to the NE. The absence of any reversal in the younging direction infers that this volcanic sequence is a homoclinal structure and any duplication or repetition of the rock units in this volcanic sequence is likely to be the result of reverse thrusting rather than folding.

4.2 ROCK FABRIC

In the volcanic rocks in the area of Map-A there is a pervasive planar fabric that is sub-parallel to the major lithological boundaries and dips moderately to the NE. This foliation fabric is defined by the planar alignment of fragments, clasts and the minerals amphibole, biotite and mica in the rocks (Figs. 6, 7, 9 & 19).

The foliation fabric is recorded to varying degrees of intensity in the various rock types. In the massive intrusions and/or flows, only a weak foliation is prevalent (Fig. 13),

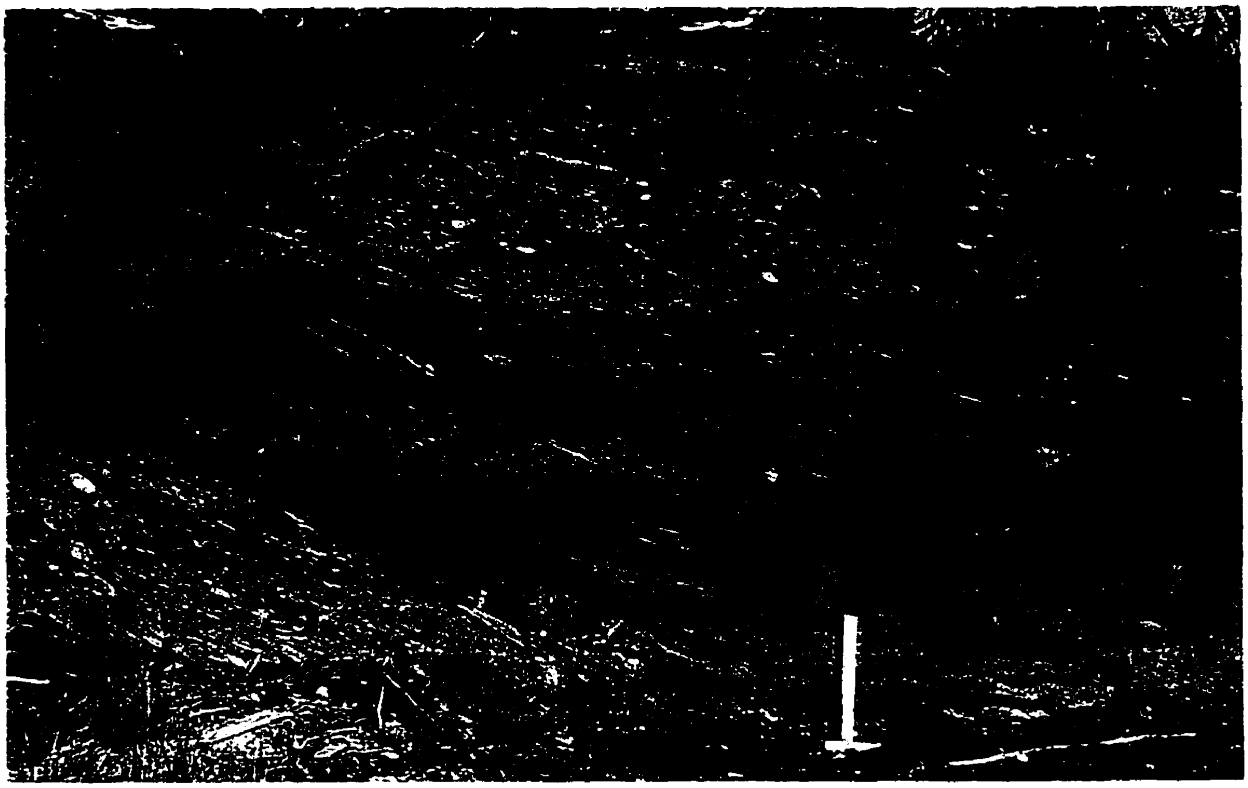

Figure 19: Outcrop clearly showing the bedding (B) and the S_1/S_2 foliation (S). The S_1/S_2 foliation is defined by the alignment of the clasts. This outcrop is also crosscut by NNE-SSW striking faults that are interpreted to be early, pre-metamorphic extensional faults. (Loc. 10200E/15320N)

where as in the "silicified" basalts and volcaniclastic rocks a moderate to very strong planar fabric is recorded (Figs. 6, 7, 9 & 19). This pervasive foliation in the volcanic rocks crosscuts primary S_0 features at a shallow to steep angle (Figs. 7 & 19) and is folded by the Threehouse syncline. In the interests of consistency, the fold terminology outlined by Kraus and Williams (1998) is used in this study. Kraus and Williams (1998) interpreted the Threehouse syncline to be a F_3 fold. This and that the pervasive foliation crosscuts S_0 constrains the pervasive foliation to being S_1 or S_2. There was no unambiguous evidence found in the volcanic rocks of the McLeod Road-Birch Lake allochthon with which to further define the relative age of this pervasive foliation fabric. Thus it is interpreted to be a S_1/S_2 foliation fabric.

In places there is a stretching lineation associated with this S_1/S_2 foliation fabric. This is shown in many outcrops by the considerable elongation of clasts, fragments and mineral grains in addition to the flattening which is axial planer to the foliation fabric. Rock fragments exposed at No.3 Zone have been stretched to an approximate ratio of 1:3:10 and plunge moderately in an ENE direction. At the Boundary Zone, quartz grains in a quartz porphyritic rock have been stretched to an approximate ratio of 1:2:10 with the long axis plunging moderately to the NE (Fig. 20). Locally, amphibole crystals show a preferred orientation with their long axis plunging moderately to the NE-ENE. All the long axis of these stretching lineations are contained within the plane of the pervasive S_1/S_2 foliation fabric and are interpreted to be associated with development of this foliation fabric. The rocks that show this stretched fabric are thus SL tectonites. The degree to which these SL tectonites have developed is extremely variable with high strain zones showing considerable stretching.

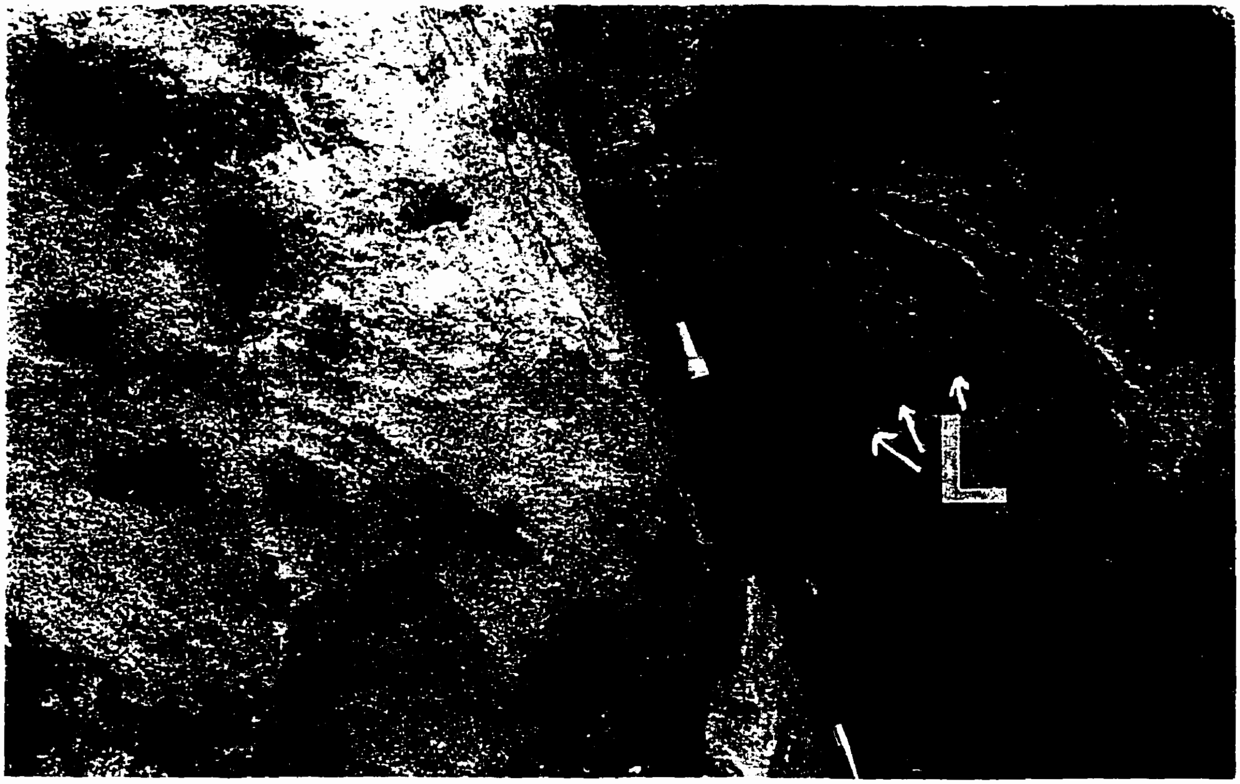

Figure 20: Quartz mineral stretching lineation. The rock surface to the right of the pencil shows L_1/L_2 lineations (L) formed from the stretching of quartz phenocrysts in a quartz porphyritic rock. These lineations plunge moderately to the NE. The rock surface to the left of the pencil is at approximately 90^0 to the surface showing the stretching lineations. In this surface comparatively little deformation of the quartz phenocrysts can be seen. The quartz phenocrysts have been stretched up to a ratio of 1:10. (Loc. Boundary Zone)

Crosscutting and overprinting this S_1/S_2 foliation fabric is a very poorly developed foliation that can only be recognized at the microscopic level. This secondary foliation is only locally developed and is evident in alteration zones such as in the Birch Zone, where a secondary biotite growth overprints the earlier shear fabric (Fig. 22). This foliation is also occasionally found in relatively unaltered rocks where it is defined by a secondary green-brown hornblende growth which overprints the earlier S_1/S_2 foliation fabric, which is defined by actinolite/blue-green hornblende amphiboles (Fig. 21). This secondary green-brown hornblende is orientated at a high angle to the earlier S_1/S_2 foliation fabric. This secondary foliation is tentatively interpreted as S_3 based on its orientation and relative timing.

4.3 FOLDS

The large-scale outcrop pattern of the rocks in the vicinity of Snow Lake is controlled to large degree by the moderately NE plunging, open fold of the Threehouse syncline (Fig. 5). As mentioned in section 4.1 the younging direction in the volcanic rocks in the vicinity of Snow Lake is consistently to the N and NE. This infers there is no repetition of the sequences due to large scale isoclinal folding. This is consistent with the mapped area being on one limb of a larger structure.

Other than the Threehouse syncline, the Nor-Acme anticline and the Three Zone syncline are the only two large-scale folds in the volcanic rocks in the vicinity of Snow Lake (Fig. 5). These two folds form an anticline, syncline fold pair. The Nor-Acme anticline is located near the New Britannia Mine and is defined by the folding of the Howe Sound fault and the contact between the Town Rhyolite and the overlying Golf

Figure 21: Photomicrograph showing blue-green actinolite being replaced by a secondary green/brown hornblende growth. The blue-green actinolite (a) is orientated into the S_1/S_2 foliation (S). The actinolite and S_1/S_2 fabric is overprinted by the later green/brown hornblende (b) that is orientated into the section and at a high angle to the blue-green actinolite. This secondary green/brown hornblende growth infers higher metamorphic temperatures under a very different tectonic regime and is interpreted to be related to D_3. This secondary hornblende growth is only locally developed. (field of view is 0.70 mm)

Figure 22: Photomicrograph showing the two phases of biotitization. This sample is from the Birch Zone. The earlier biotite (a) is comprised of small biotite lathes which are orientated parallel to the "c" shear fabric defined by the compositional banding in the rock. The secondary biotite (b) growth is comprised of large flakes of biotite, which form in the mafic bands. The secondary biotite is orientated at a high angle to the "c" fabric (C) and the earlier biotite growth. This secondary biotite is interpreted to be related to the folding of the shear zone (see section 4.7). (field of view is 0.70 mm)

Course mafic volcaniclastic rocks (Fig. 5). This fold forms an open anticline fold that plunges moderately to the NE. The Three Zone syncline is located near the No.3 Zone mineral occurrence and is defined by the folding of the contact between Three Zone mafic volcaniclastic rocks and the overlying Birch Lake basaltic rocks (Fig. 5 & Map-A). Both these folds have no axial planer foliation developed and are interpreted to be a hanging wall anticline, syncline fold pair related to the development of the McLeod Road Thrust. This is discussed further in chapter 7.

One outcrop scale isoclinal fold is located within a finely laminated mafic wacke bed (loc. 1100E/2720N; Fig. 23). The top limb is cut off by a fine-grained volcanic rock, most likely an intrusive dyke. The bottom limb is also sheared. The fold has an S symmetry and the fold axis plunges moderately to the NE. The S symmetry and isoclinal shape suggests this fold is related to an early period of deformation of D_1 or D_2.

There are a number of very small, cm-scale, folded quartz veins such as those seen at the Boundary and No.3 Zones. Quartz veins form small, monoclinal to closed S-folds (Fig. 24). Also at the Boundary Zone, carbonate impregnation forms synkinematic S-folds in the fault zone between the mafic and felsic rocks (Fig. 25). All the fold axes of these minor folds also plunge moderately to the NE.

In the Birch Zone pit, the planar, shear zone hosted gold mineralization forms one limb of an open, monoclinal fold with Z asymmetry (Fig. 36). The axis of this fold is at the eastern end of the pit and plunges at a moderate angle to the NE. The open nature, Z asymmetry and orientation of this fold suggests that this fold is related to the Threehouse

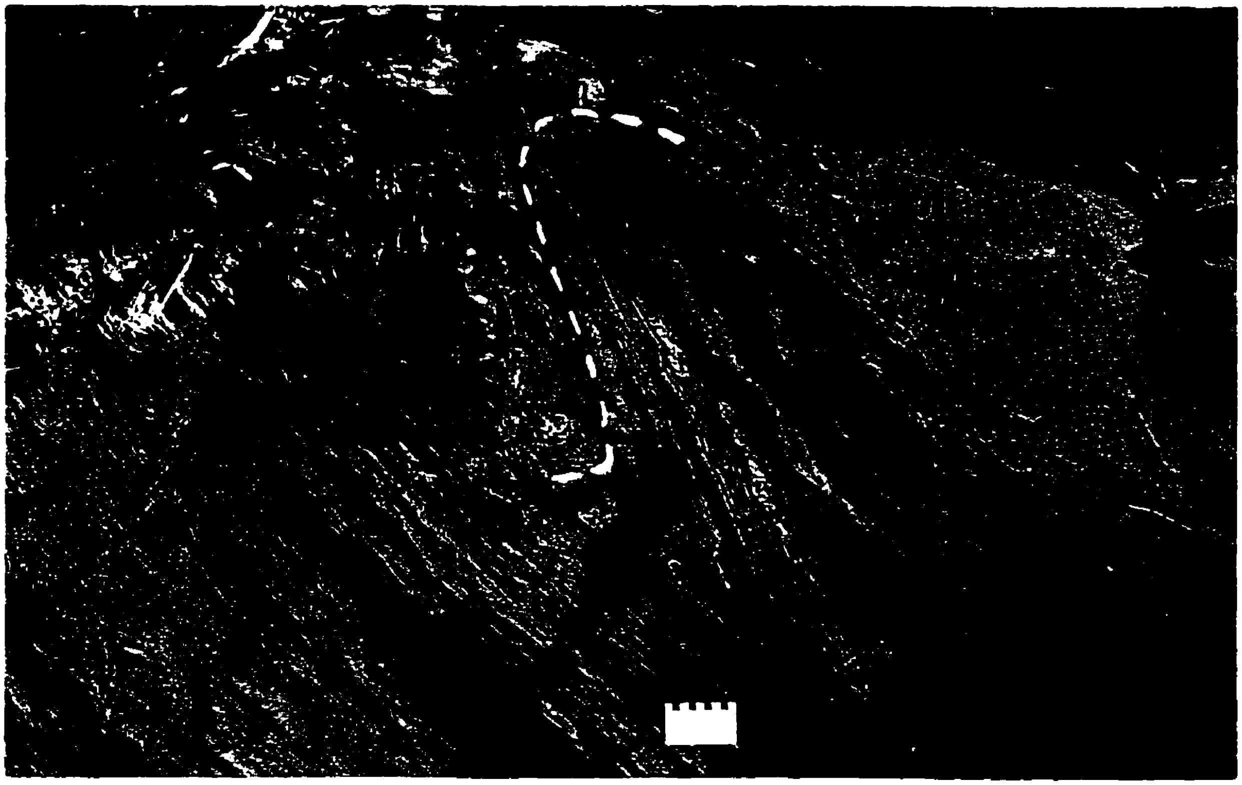

Figure 23: Isoclinal fold in a finely laminated mafic wacke bed. The fold has S symmetry and the fold axis plunges moderately to the NE. A shear (S), parallel to the fold limbs and bedding, crosscuts the nose of the fold. The top limb is cut off by a fine-grained basaltic dyke (a). (Loc. 1100E/2720N)

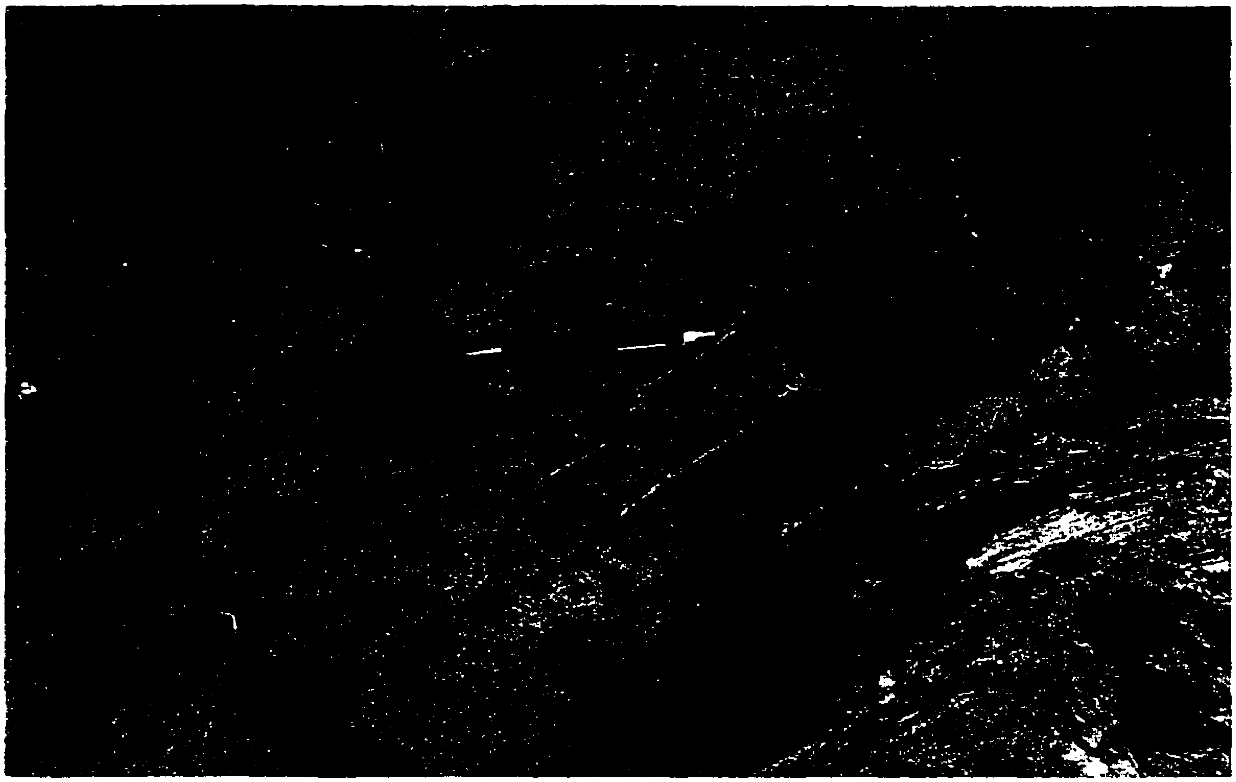

Figure 24: Folded quartz vein. The folded quartz vein (q) has "s" symmetry and the fold axis plunges moderately to the NE. The "s" symmetry indicates a sinistral shear strain that is consistent with the large-scale features such as No.3 Zone. (Loc. Boundary Zone)

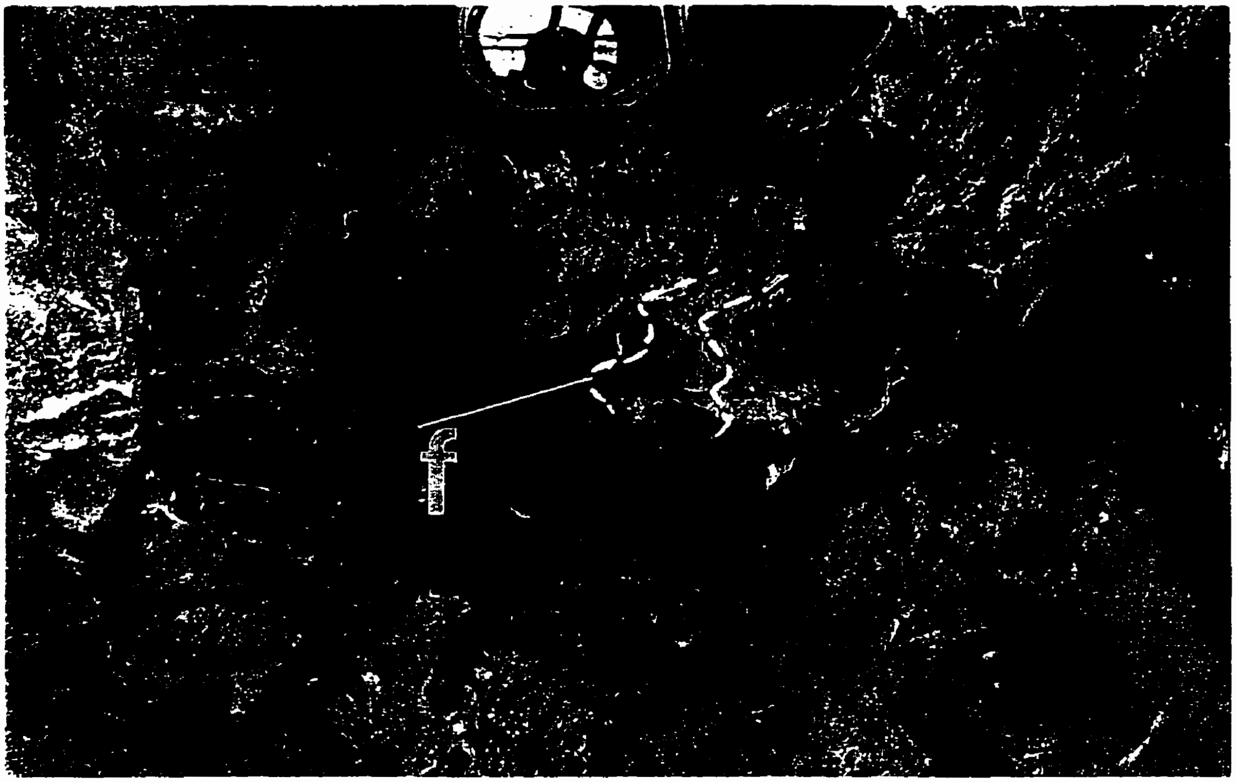

Figure 25: Folding of the synkinematic carbonate impregnation. The fold axis (f) plunges moderately to the NE. This fold is located within the structurally complex fault zone of the felsic/mafic contact at the Boundary Zone (Map-B).

syncline thus be of the same age, i.e. F_3.

The fold axis lineations of all the above-mentioned folds generally all plunge moderately to the NE and ENE. Plotting all the lineations measured in the mapped area, including the fold axis lineations, the long dimensional axis of minerals and the long dimensional axis of the stretched fabrics on to a lower hemisphere, equal area stereographic projection shows that all the lineations have a moderate plunge in the NE to ENE direction (Fig. 26). Figure 26 also shows that the lineations are contained within the S_1/S_2 foliation fabric. There is little difference in orientation between the different types of lineations in a particular area, but there are slight variations between the different areas suggesting subtle structural domains within the mapped area (Fig. 26). The Boundary Zone represents one structural domain that has lineations plunging moderately to the NE, and the Birch Zone area and No.3 Zone represent another structural domain that has lineations plunging moderately to the ENE. The development of the subtle structural domains would be consistent with flexural folding of the S_1/S_2 foliation fabric.

4.4 MCLEOD ROAD THRUST FAULT

The McLeod Road Thrust fault is a prominent, regional scale structural feature in the Snow Lake area (Fig. 5). At Snow Lake the 1.89 Ga volcanic rocks form the hanging wall and the 1.85-1.84 Ga Burntwood suite pelites form the footwall. The McLeod Road Thrust has been folded by the Threehouse syncline. To the SW of Snow Lake the McLeod Road Thrust fault crosscuts the pervasive regional fabric and main lithological rock units in the hanging wall at a moderate to low angle. In the vicinity of the Snow

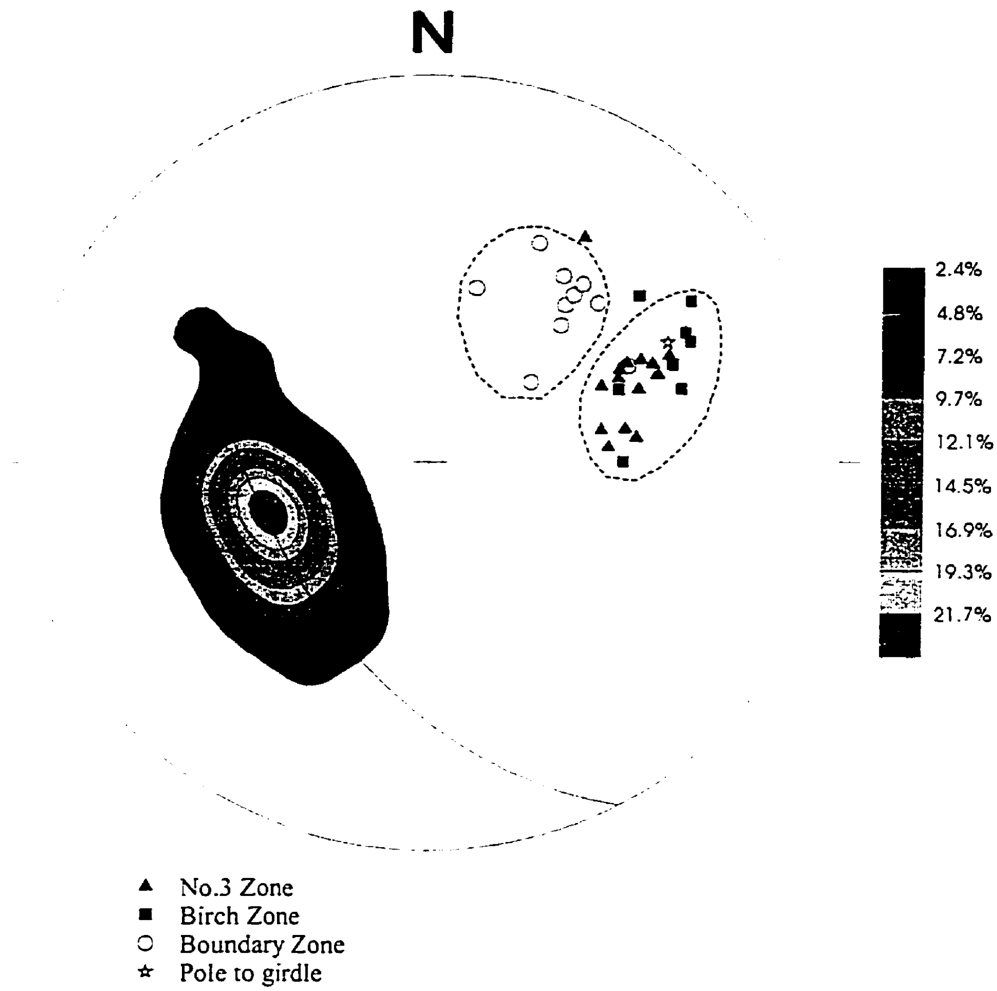

Figure 26: Lower hemisphere, equal area, stereographic projection of lineations and contoured poles of foliations. All the lineations plunge moderately in the NE to ENE direction. Subtle structural domains can be recognized with the lineations taken from the Boundary Zone plunging to the NE were as the lineations from the Birch and No.3 Zones plunge moderately to the ENE. The contours of the poles to the S_1/S_2 foliations show that the poles have an ellipse shaped distribution. The pole to the girdle fitting the elliptical contours also moderately plunges to the NE. This infers that the lineations are contained in the plane of the S_1/S_2 foliation fabric. The development of the subtle structural domains would be consistent with the flexural folding of this foliation fabric.

Lake town and to the NW of the town, the McLeod Road Thrust fault cuts steeply up the hanging wall volcanic rock sequence.

There is no surface outcrop of the McLeod Road Thrust, however, at the New Britannia Mine a drift at the 3000 level and a number of drill holes drilled in a fan array from the 2300 level intersect the fault. This drift and drill core was used to examine the details of the fault zone of the McLeod Road Thrust fault.

At the intersection of the McLeod Road Thrust fault in the 3000 level drift there is considerable alteration of the hanging wall volcanic rocks resulting in siliceous layers parallel to the fault. These siliceous layers have been extended and deformed forming boudinage structures with white milky quartz infilling between the boudins (Figs. 27 & 29). The boudins have been slightly rotated in an anti-clockwise direction. At the McLeod Road Thrust fault in the 3000 level drift the foliation and layering of the volcanic rocks are parallel to the fault contact.

The metamorphosed sediments of the Burntwood suite in the footwall of the McLeod Road Thrust consist of interlayered biotite, garnet-biotite and staurolite-garnet-biotite schists (Figs. 27 & 29). There is also a very distinct garnetiferous unit, characterized by large (~1 cm) euhedral garnet and the absence of staurolite, which is present in the footwall and in close association with the fault. There is relatively less alteration in the footwall pelites than in the hanging wall volcanic rocks. Small "s" folds are evident in the footwall rocks adjacent to the fault (Figs. 27 & 29).

The fault zone is defined by the main faulted contact and anastomosing network of minor splays. The width of this fault zone is quite well constrained and ranges from centimetres to a few metres (Figs. 27 - 29). Within this fault zone there is often a fine-

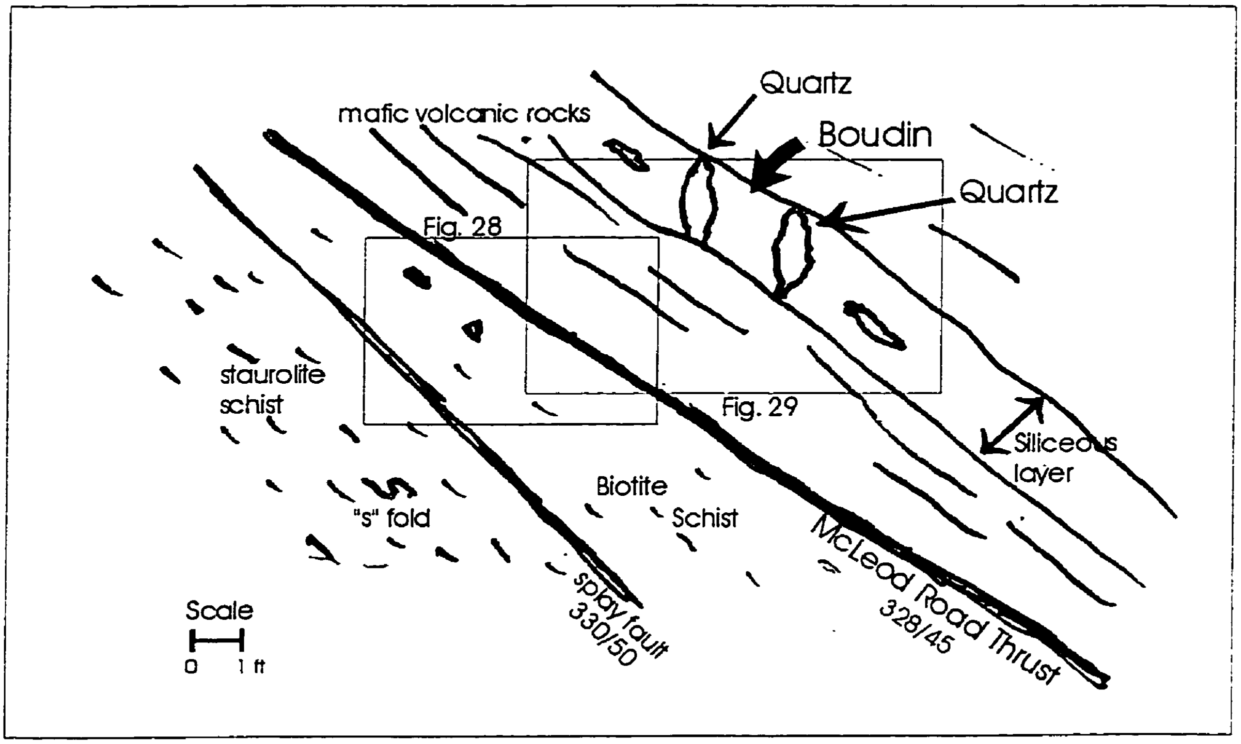

Figure 27: Sketch of the McLeod Road Thrust fault zone. This sketch is of the north wall of a 3000 level drift in the New Britannia Mine were it intersects the McLeod Road Thrust. Photo areas marked are shown in figures 28 & 29. In this sketch of the McLeod Road Thrust fault zone there is one main fault and a single splay fault. In the hanging wall are the mafic volcanic rocks that show considerable alteration. This alteration is heterogeneous and forms siliceous layers parallel to the fault. Some of these siliceous layers have been deformed and form boudins with milky white vein quartz in filling the space between the boudins. The boudins have been rotated slightly in an anti-clockwise direction (photo – B). In the footwall of McLeod Road fault is the Burntwood sediments. Here the Burntwood sediments are composed of biotite schist and staurolite-garnet-biotite schist. There are occasional “s” folds in the sedimentary rocks. There is relatively minor alteration in the footwall compared to the alteration in the hanging wall. The “s” folds and the anti-clockwise rotation of the boudins suggest a left lateral sense of movement.

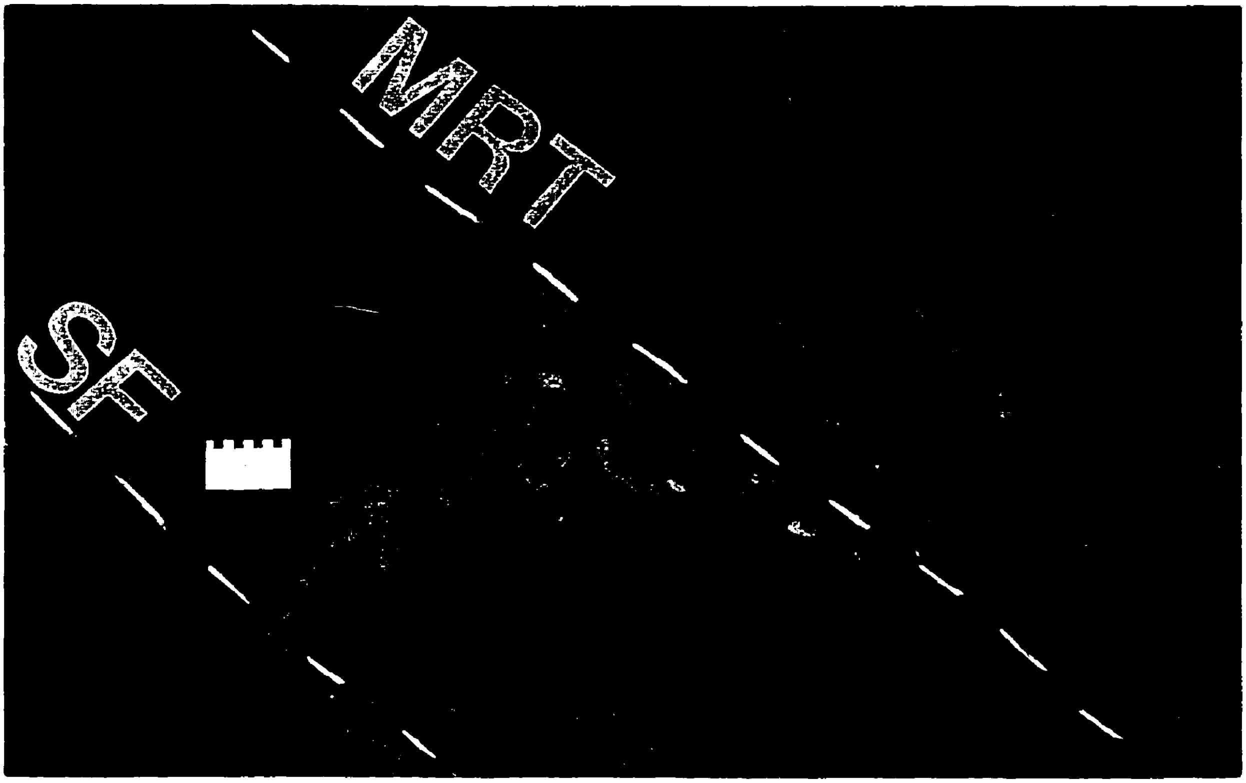

Figure 28: McLeod Road Thrust fault. The McLeod Road Thrust fault (MRT) forms a thin discrete fault only a few cm's thick, as does the single splay fault (SF). The McLeod Road Thrust is interpreted to have formed under brittle-ductile conditions.

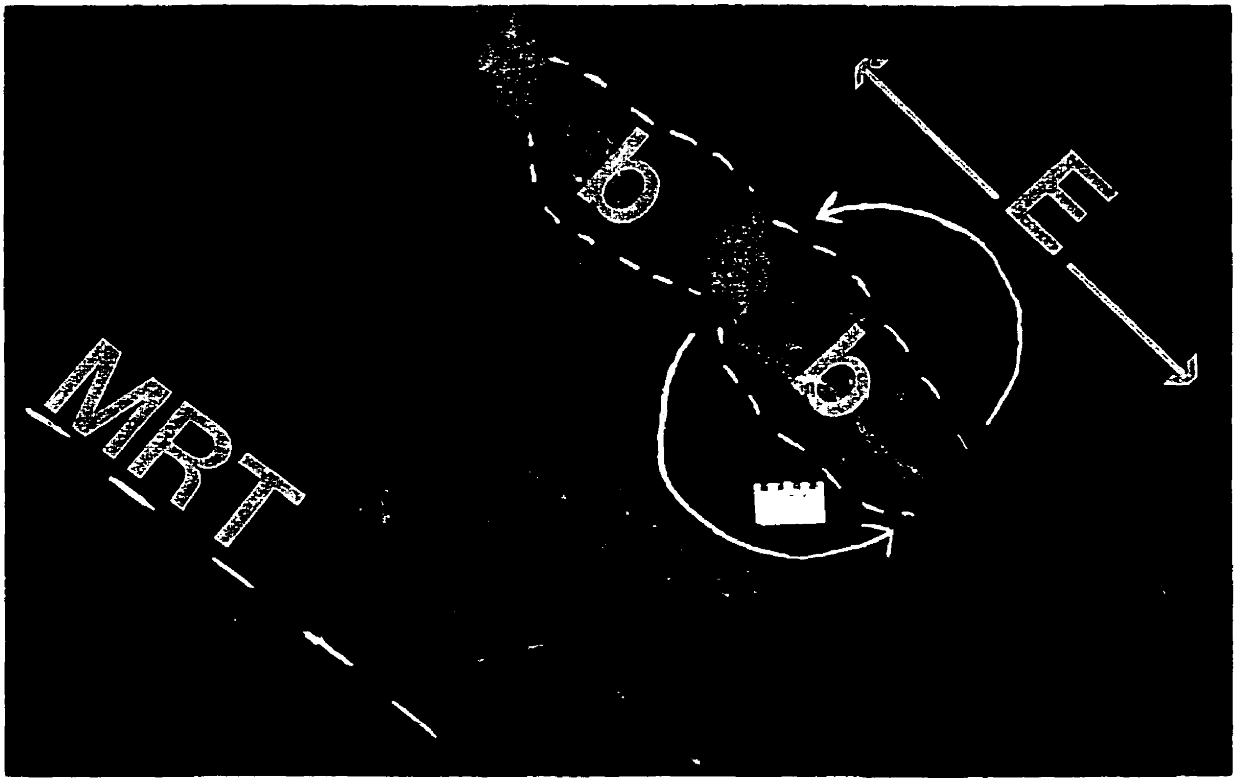

Figure 29: The hanging wall of the McLeod Road Thrust (see figure 27 for location). The McLeod Road Thrust fault (MRT) is in the lower left-hand corner. The fabric of the altered volcanic rocks is parallel to the fault. Extension (E) of a highly altered layer resulted in boudins (b) forming and the space between the boudins being in filled with milky white quartz. These boudins have also been slightly rotated in an anti-clock wise direction. (card has cm gradations)

grained rock which is difficult to assign to either the volcanic rocks or the sediments. A fine, dark grey coloured graphitic schist a couple of cm's wide is often present in the actual fault contact between the hanging wall rocks and footwall rocks, and in the minor splay faults.

4.5 NORTHERN CANADA FAULT

The Northern Canada fault forms a prominent feature on aerial photographs (Fig. 54) and unpublished geophysical maps. This fault is interpreted to splay from the McLeod Road Thrust fault just north of the No.3 Zone (Map-A and Fig. 54) where it forms a prominent curvilinear lineament. From this interpreted splay the Northern Canada fault curves northwards where it forms a straight structural feature striking NNE-SSW. To the west of the Birch Zone the fault is interpreted to lie between the northing gridlines of 7600 and 7800 where it is striking at 020^0. This interpretation extends the McLeod Road Thrust fault system to the north of Herblet Lake. Drill core from drill hole # SN 87-55, which intersects the Northern Canada fault, shows the fault to consist of a wide fault zone with considerable brecciation of the host rocks. Based on the geometry and nature of this fault it is interpreted to be imbricate fault of the McLeod Road Thrust fault. The drill core also indicated that there is no significant gold mineralization of this fault.

4.6 HOWE SOUND FAULT

The Howe Sound fault, also known as the Nor-Acme fault, is located at the northern end of the Snow Lake town (Figs. 2 & 5). The gold mineralization at the New

Britannia Mine is hosted within this fault system. The Howe Sound fault is hosted within the Golf Course mafic volcaniclastic rocks of the McLeod Road-Birch Lake allochthon but is close to, and sub-parallel to the contact between these mafic volcanic rocks and the overlying felsic volcanic rocks (Fig. 5). This curviplanar shear/fault zone forms an anticlinal structure, the Nor-Acme anticline, which plunges moderately to the NE. The Howe Sound fault/shear system consists of a fault zone, varying from a few meters to approximately 30m in width, that has considerable alteration and brecciation of the wall rock and has been infilled in places by a massive to "crack and seal" type quartz-carbonate vein (Figs. 30 & 31). Earlier interpretations of Galley *et al.* (1988) and Hogg (1957) suggested that the Howe Sound fault cut the McLeod Road Thrust at its western end. However there is no evidence to support this interpretation, and a simpler solution is that the Howe Sound fault is cut at its western end by the McLeod Road Thrust and does not extend into the sediments in the footwall of the McLeod Road Thrust (Fig. 5). In plan view the large-scale structure of the Howe Sound Fault can be interpreted to have a "s" asymmetry with the western limb cut off by the McLeod Road Thrust (Fig. 5). The shear/fault structure is open to the east and down dip.

At the surface expression of the Howe Sound fault and in some of the underground drifts there are fabrics which would be consistent with ductile shear zone fabric. This would suggest that Howe Sound fault was a ductile shear zone prior to the overprinting by brittle-ductile features such as the crack and seal type vein. However, because of metamorphism and reactivation of this fault zone through time, its early history and nature are invariably obscured.

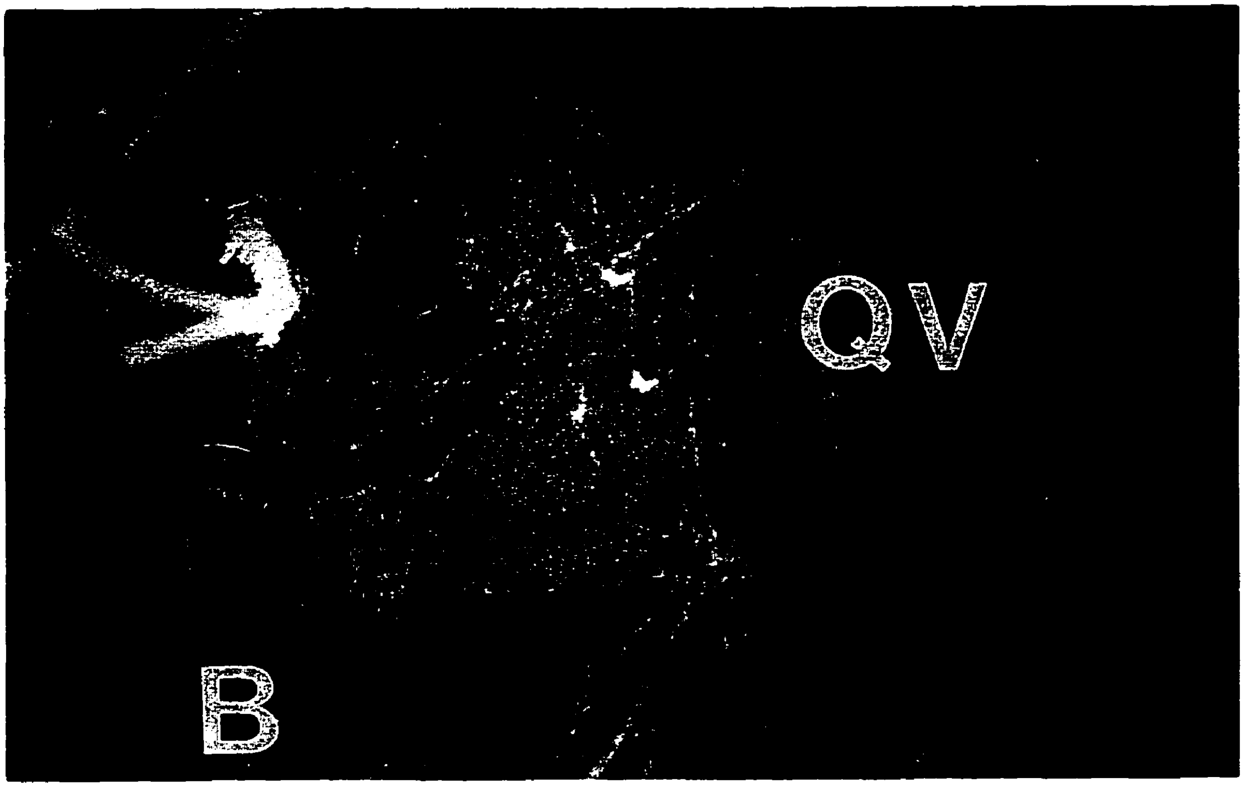

Figure 30: Brecciation (B) of the wallrock on the left-hand side of photo and the gray, quartz-carbonate vein (QV) infilling the Howe Sound Fault. This type of vein hosts the gold mineralization. (Loc. level 495, New Britannia Mine. field of view is approx. 2 m)

Figure 31: Highly brecciated wall rock fragments in the Grey, quartz-carbonate vein. The bright specks in the mafic wallrock are arsenopyrite crystals. (Loc. level 495, New Britannia Mine)

The "Crack and seal" features in the quartz-carbonate veins associated with the Howe Sound fault indicate that the Howe Sound fault is a progressive dilatational opening formed under ductile/brittle conditions such as a shear fracture. The Howe Sound fault is not considered a splay of the McLeod Road Thrust fault, as previously interpreted, but as a tensional, brittle-ductile shear fracture. This fracture has exploited the rheological differences between the felsic and mafic volcanic rocks, and an earlier ductile shear zone.

A number of unmetamorphosed brittle faults, which are sub-parallel to the Howe Sound fault and characterized by pale cream/green fault gouge (Fig. 32), can be seen in the New Britannia Mine. These faults are interpreted to be a late, post-metamorphic reactivation of the Howe Sound fault. These post-metamorphic faults have an important control on the gold mineralization as movement along these late structures displace and terminate ore. There are also a number of late, post-metamorphic faults that are characterized by a N-S orientation and a shallow to steep easterly dip which cross cut the Howe Sound fault system at a high angle. The movement along these N-S faults is relatively minor.

The gold mineralization at the New Britannia Mine is associated with the curviplanar Howe Sound fault system. The main ore bodies at the New Britannia Mine, namely the Hogg, Toots, Dick and Ruttan zones form irregular, lenticular zones within the Howe Sound fault system. The grey coloured, massive to brecciated, quartz-carbonate vein system and the adjacent wall rock, which is typically highly altered, hosts the gold mineralization (Fig. 30 & 31). This quartz-carbonate vein is locally called QCMS. The alteration associated with the mineralization in the wallrock of the Howe Sound fault is

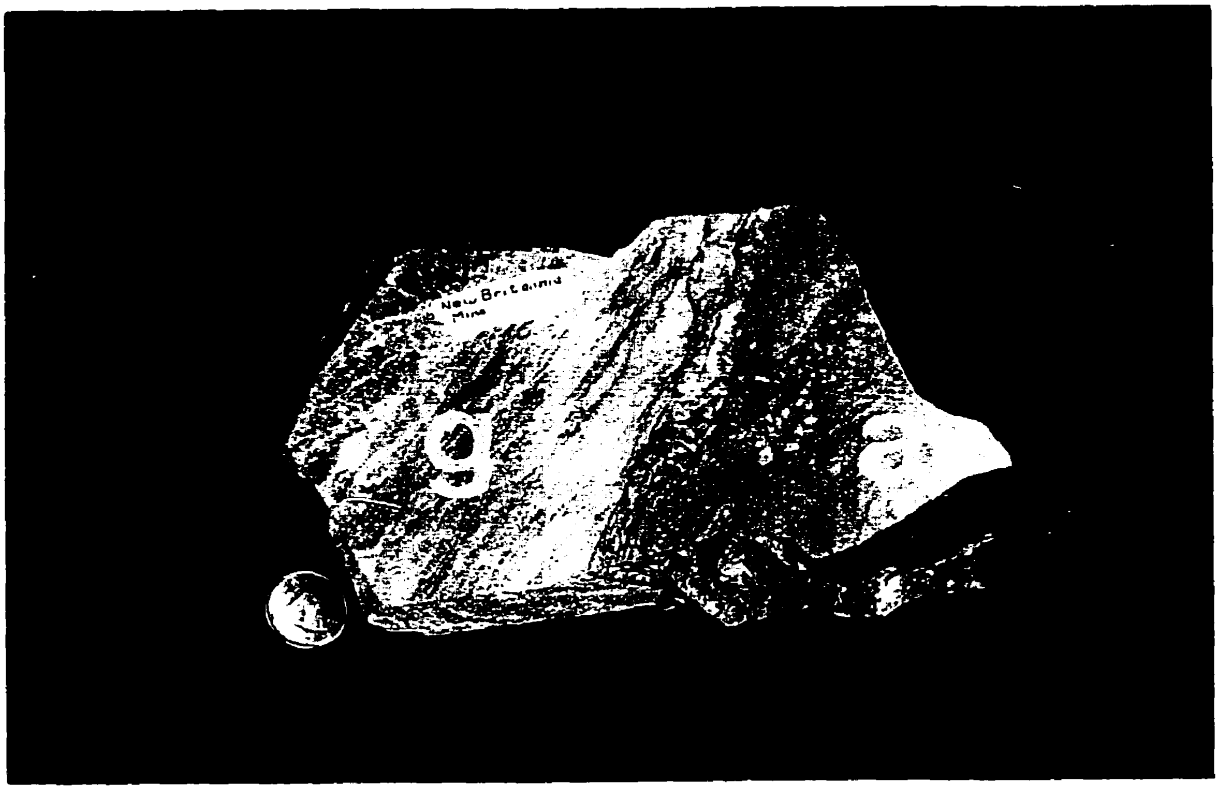

Figure 32: Fault gouge from the late, post-metamorphic reactivation of the Howe Sound fault. The fault gouge (g) is a pale, creamy/green colour that has not been recrystallized, indicating the development of this gouge to be post-metamorphic. These late faults are sub-parallel to and form an anastomosing network along the Howe Sound fault. These late faults crosscut and off set the gold mineralization. The Grey coloured rock (a) is the gold mineralized quartz-carbonate vein. (Sample taken from 2030 level in the New Britannia Mine)

extremely variable and can be almost completely altered and replaced. The typical mineralogical assemblage of the altered and mineralized mafic wall rock is quartz, albite, actinolite, biotite, calcite arsenopyrite and other minor sulphides (Fig. 33). Grab samples of the altered and mineralized wallrock indicate the gold values are very variable with values up to 18g/t. The higher gold values are associated with the higher loss on ignition values and higher Na_2O values. The higher loss on ignition values most likely are a result of a higher CO_2 content of the sample, and the higher Na_2O values indicate an increased albitization, i.e. increased alteration, of the host rock.

At the New Britannia Mine mafic intrusions do not crosscut the Howe Sound fault or the associated mineralization. However, the presence of mafic intrusions near ore bodies does decrease the grade of the ore in its immediate vicinity, (Bill Lewis, personal communication, 1997). At the deeper levels of the mine (level 3000) there is a flattening and different orientation of the ore body compared to the higher levels on the Ruttan side. This is near a large intrusion that suggests the intrusion is affecting the orientation of the Howe sound fault and therefore the orientation of the ore body.

Another factor that affects ore grade is the presence of garnet in the mafic wall rock. In personal communication with the mine geologists at the New Britannia Mine it was noted that as a "rule of thumb", where there are garnets in the mafic host rocks the grade of the gold mineralization decreases. Within the Howe Sound fault and cross cutting the grey quartz-carbonate veins are numerous tension gashes that are infilled with milky white quartz (Fig. 34). These tension gashes are consistent with a late brittle deformational event that post-dates the development and mineralization of the Howe

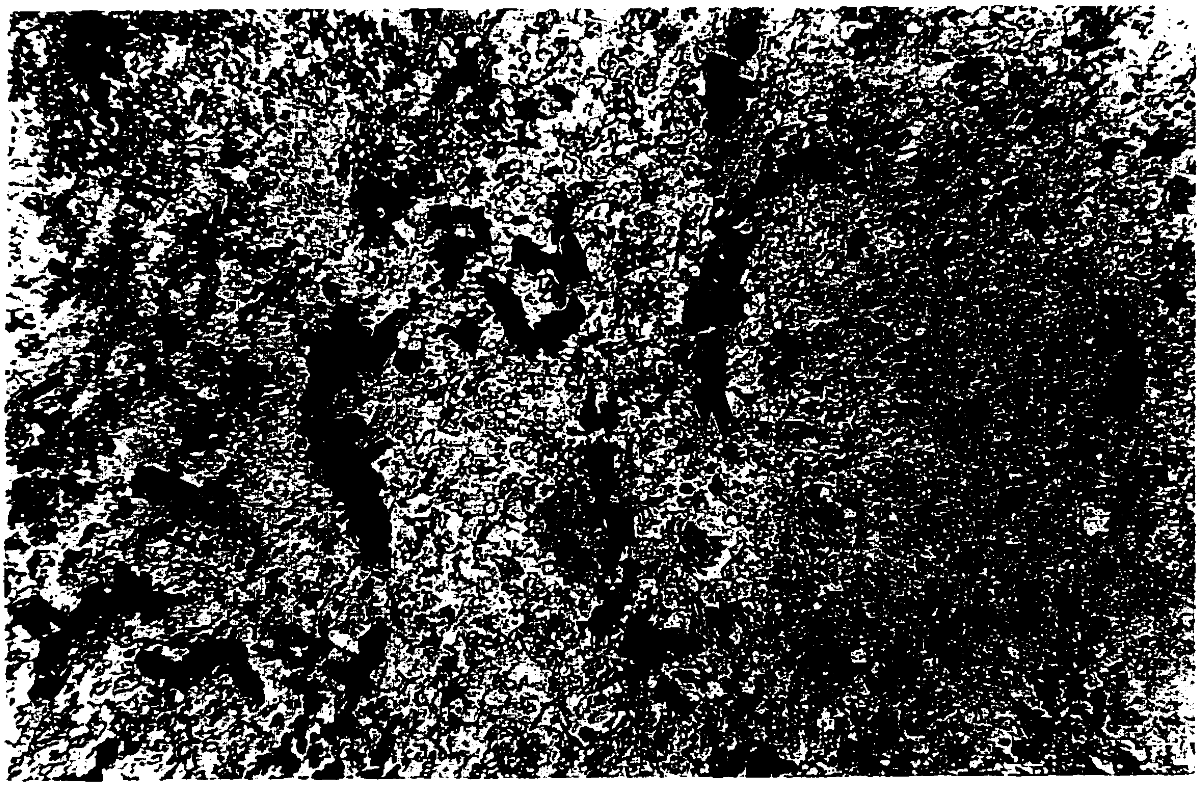

Figure 33: Typical mineralogical composition of altered and gold mineralized mafic wall rock. This sample is from the 2030 level in the New Britannia Mine. Minerals are quartz, albite, calcite, actinolite, biotite, arsenopyrite and other minor sulphides. (field of view is 2.8mm)

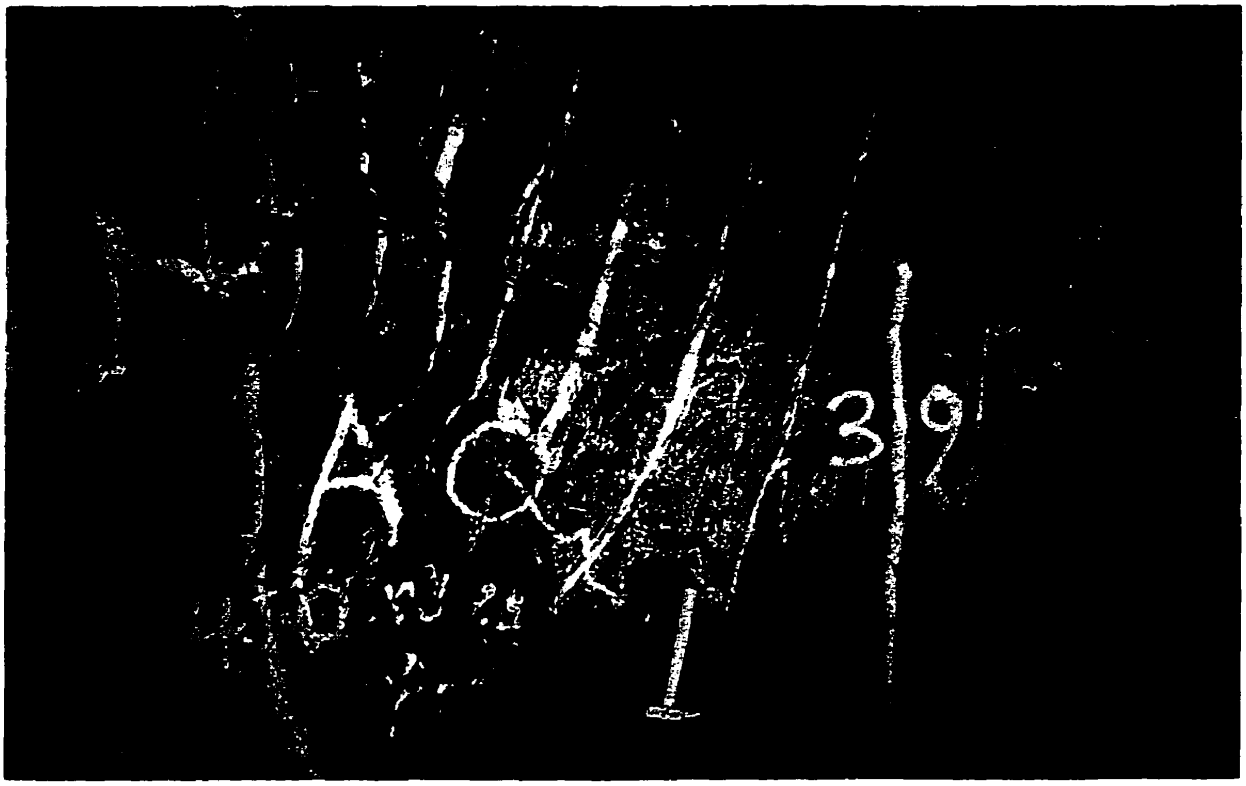

Figure 34: Tension gashes in filled with barren, milky white quartz. These tension gashes are a common feature in all parts of the mine and crosscut the gold mineralization. The tension gashes are interpreted to be a result of a late, brittle deformation event. (Loc. level 495, New Britannia Mine)

Sound fault. These tension gashes, which form numerous stringer are not mineralized and may affect the grade of the ore by dilution of the bulk rock.

4.7 BIRCH ZONE SHEAR

The Birch Zone is located approximately 3 km to the NW of the New Britannia Mine (Map-A & Fig. 2). The Birch Zone is divided into the Upper and Lower Birch zones. Only the Upper Birch zone is exposed at surface in an open pit. This pit, approximately 70 x 70 metres, exposes a shear zone along its southern end. This shear zone is hosted in the Birch Lake basaltic rock unit, crosscuts the earlier S_1/S_2 fabric and at the southeastern edge of the pit the shear zone is also crosscutting the "silicified" basalt rock unit (Fig. 35). At the western side and central areas of the pit the shear zone strikes E-W and dips moderately to the N. At the eastern side of the pit the shear zone has been folded and forms an anticlinal open fold which plunges moderately to the NE. To the east of the pit mapping infers the shear zone is folded again into an open syncline. The anticline and syncline fold pair together form a monoclinal structure that plunges moderately to the NE (Fig. 36).

The rocks in this shear zone are highly deformed, altered and mineralized. Thin lenticular grey quartz-carbonate veins interlayered with the highly altered mafic host rock impart a mylonitic texture to the rock (Fig. 37). These ribboned veinlets have smooth edges that pinch and swell forming lenticular shaped discontinuous ribbons. These ribboned veins are parallel to and part of the "c" fabric of the shear zone. The deformed rocks from this shear zone also show a quartz rodding that plunges to the NE (Fig. 38).

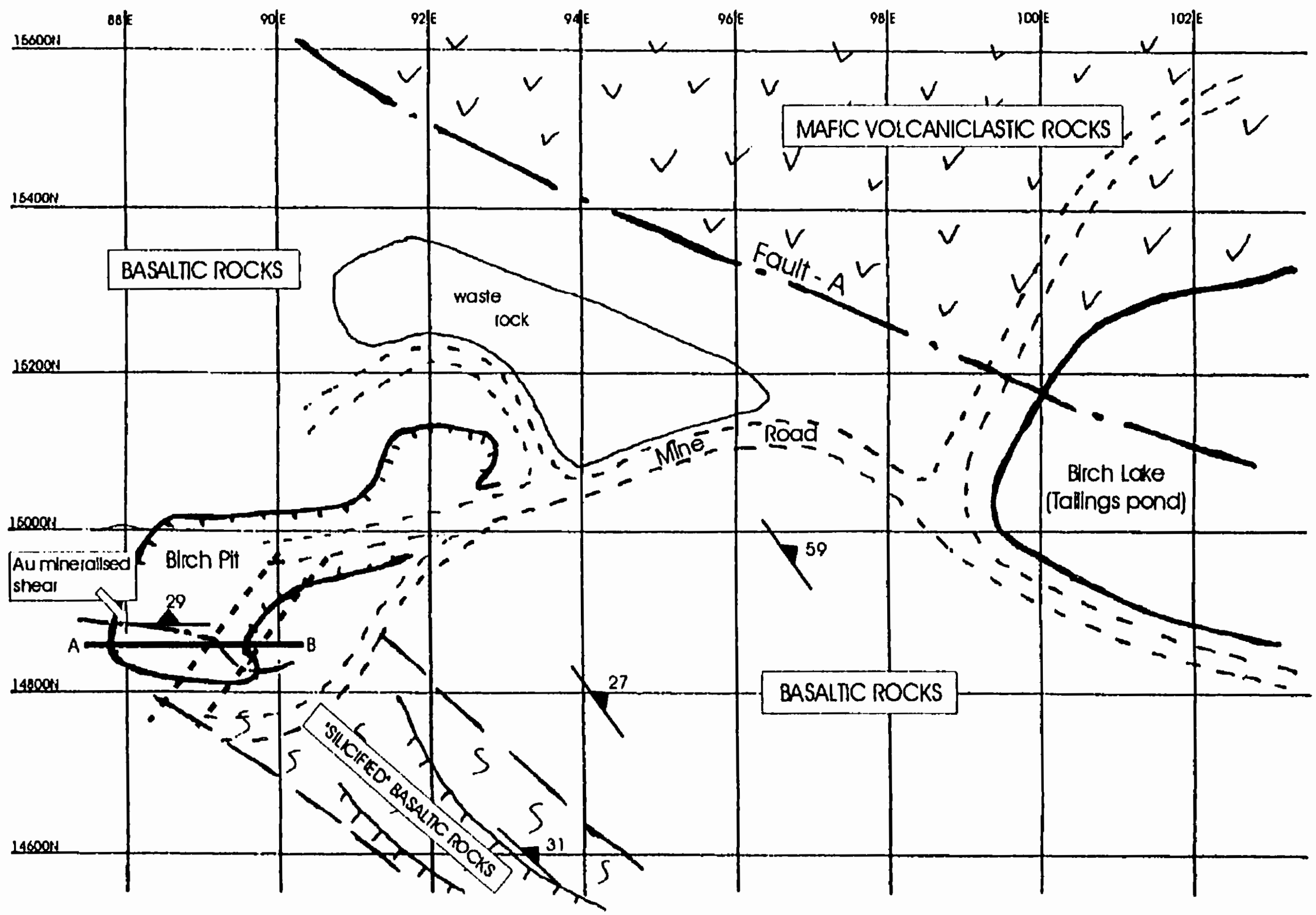

Figure 35: Map of the Birch Zone. The gold mineralized Birch Zone shear is located at the southern end of the Birch Pit. This shear zone is adjacent to a larger fault zone (Fault – A) that forms the contact between the basaltic rocks and the overlying mafic volcaniclastic rocks. The Birch Zone shear crosscuts the "silicified" basaltic rocks and forms a monoclinal structure that plunges moderately to the NE (see cross sectional sketch of A-B in figure 36).

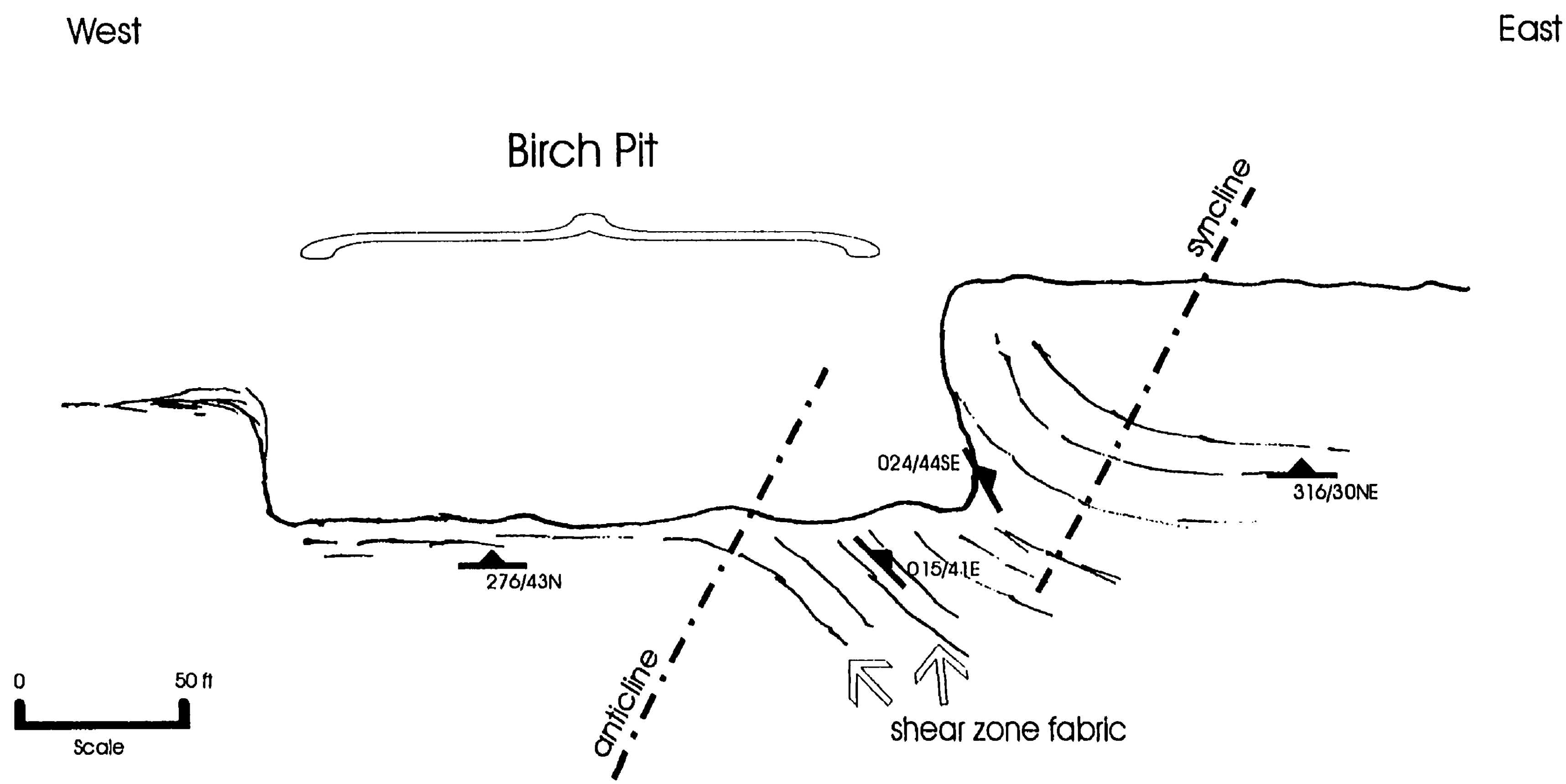

Figure 36: An E-W cross-sectional sketch of the Birch Zone pit. The mineralized Birch Zone shear forms a monoclinal structure plunging moderately to the NE. At the eastern edge of the pit, overlying the Birch Zone shear, there is a 20-30m thick layered sequence of highly altered and deformed rock (Fig. 40). This layered sequence could not be traced onto the western or northern wall of the pit.

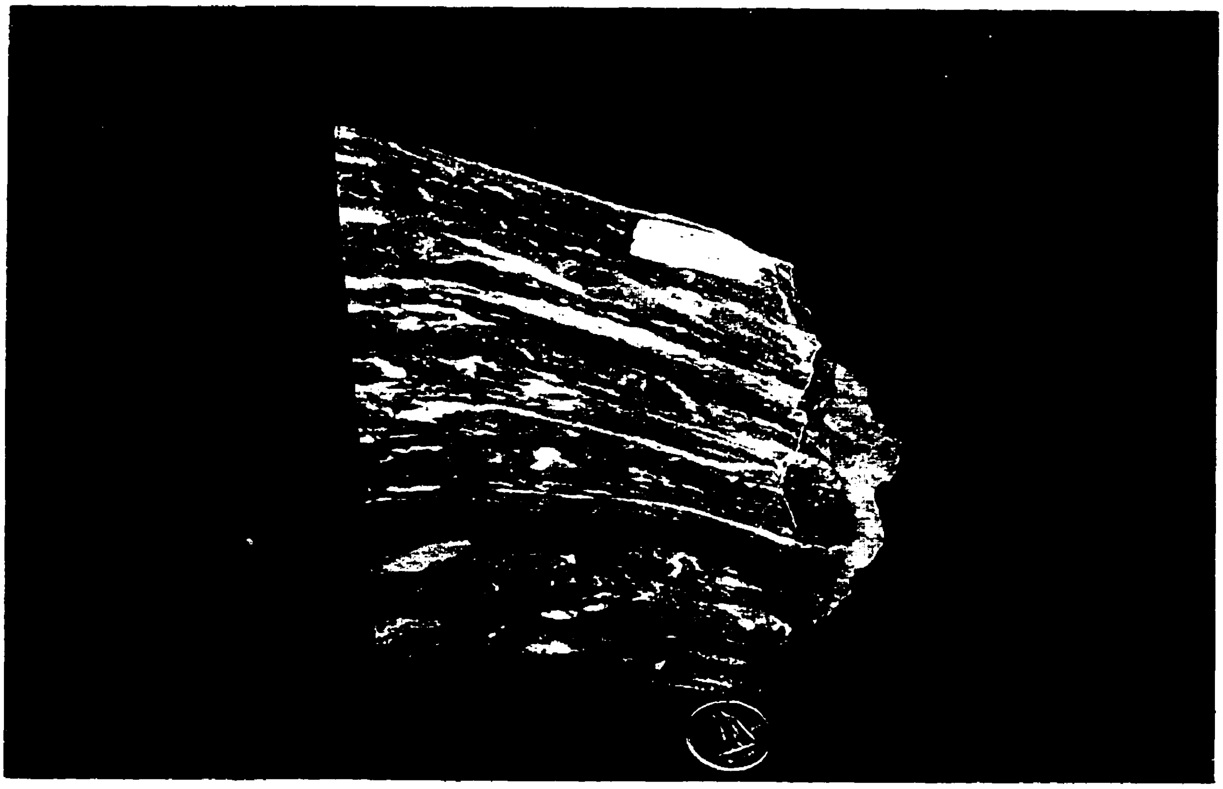

Figure 37: Rock sample from the Birch Zone shear. The deformed quartz veins and mylonitic texture infer this is a ductile shear. The ribboned and mylonitic texture of the mineralized Grey quartz-carbonate veins indicates that this mineralization is pre- to syn-shearing. The mafic host rock is highly altered and is also mineralized.

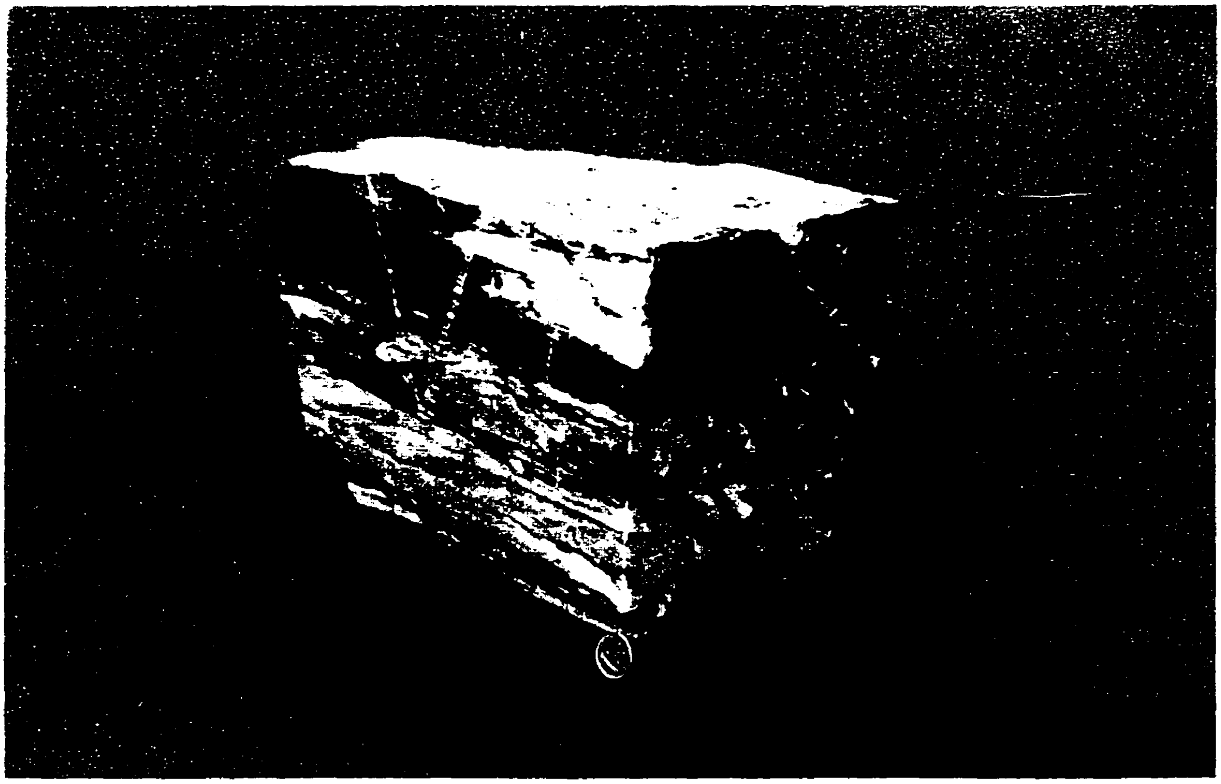

Figure 38: Quartz rodding in the shear zone at the Birch Zone. This rock sample is cut to show the highly deformed rocks where the white quartz veins have been deformed and stretched to form rods that plunge to the NE.

Metamorphism and recrystallization of these rocks have obscured much of the fine microscopic textures and fabric in this shear zone, however figures 22 & 39 shows the "c" fabric, mineralogical composition and metamorphic recrystallization evident in this shear zone. The "c" fabric is defined by the felsic/mafic bands and the alignment of the early, small biotite crystals. The mafic bands consist of highly altered amphibole, biotite and metal oxides. The mineralogy of the felsic bands is essentially quartz and carbonate.

A late, post-metamorphic fault, which is characterized by a pale green coloured fault gouge a couple of cm's thick, is found parallel to and within the Birch Zone shear fabric. The fault gouge consists of fine grained quartz and carbonate and is similar in character to the late post-metamorphic faults seen in the New Britannia Mine (Fig. 32).

Above this shear zone at the eastern edge of the pit there is a 20-30 m thick, layered sequence of highly deformed and altered rocks (Fig. 40). The layers are lenticular, have a thickness varies from a few cm's to 50 cm thick and are composed of very fine grained greenish/black rocks interfingered with fine grained dark purple coloured siliceous rock. There is also a thin graphitic layer within this layered sequence. This layered sequence of deformed and altered rocks could not be traced onto the western wall of the pit. The nature of the termination of this layered sequence could not be established, posing further, unresolved structural complexities associated with the Birch Zone shear.

The Birch Zone shear is located close to and below a structural contact between the Birch Lake basaltic rocks and the overlying Birch Lake mafic volcaniclastic rock unit (Fig. 35). This contact forms a shear zone that is well defined on unpublished VLF

Figure 39: Photomicrograph showing recrystallization of quartz. This recrystallization overprints an earlier shear fabric defined by the opaque oxides. This recrystallization has affected all the mineralized zones. This sample is from the Birch Zone. (field of view is .70 mm)

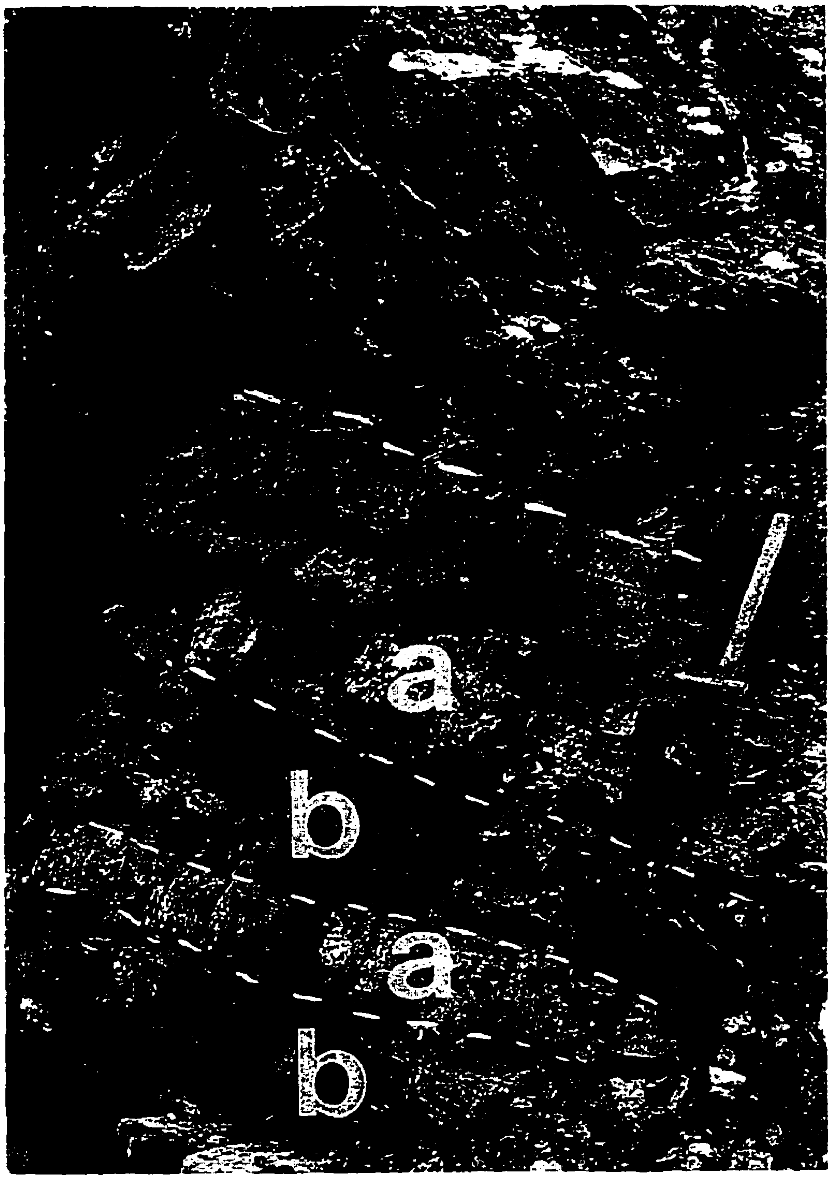

Figure 40: Outcrop on the eastern side of Birch pit. The lens shaped layers of the dark purple coloured siliceous rock (a) and the dark black coloured mafic rock (b) form a thick sequence. These rocks could not be traced onto the western or northern wall of the pit suggesting further structural complexities in this zone.

geophysical surveys and is interpreted to be a splay of the Birch Lake fault. The Birch Zone shear is interpreted to be a pre-metamorphic, ductile shear that is related to and connected to the splay of the Birch Lake fault. The Birch Zone shear is interpreted to be terminated to the west by the Northern Canada fault.

The gold mineralization at the Upper Birch Zone is associated with the ductile Birch Zone shear. The thin, lenticular ribboned grey quartz-carbonate veins that impart a mylonitic texture to the rock are mineralized with arsenopyrite and gold (Fig. 37). The pale green alteration and associated mineralization of the mafic host rocks also forms thin lenticular shaped layers with irregular edges in the shear zone. The typical mineralogical assemblage of the altered mafic host rock is quartz, albite, actinolite, biotite, calcite arsenopyrite and other minor sulphides (Fig. 41). From a number of grab samples the degree of gold mineralization is very variable and irregular with values up to 85.38 g/t being recorded in some samples.

4.8 BOUNDARY ZONE FAULT

The Boundary Zone fault that is located approximately 1.5 km to the NW of the New Britannia Mine is defined as the structural contact between felsic and mafic rocks at the Boundary Zone mineralized occurrence (Fig. 2 & Map-A). The Boundary Zone fault is exposed only at the Boundary Zone (Map-B & Fig.42) and at an outcrop located to the south east of the Boundary Zone, (across and adjacent to the mine road), known as the South outcrop. The Boundary Zone fault zone is structurally very complex and records a long history of multiple reactivation and ductile to brittle deformation. The felsic rocks are to the south of the fault and the mafic rocks to the north (Figs. 42 & 43). The exposed

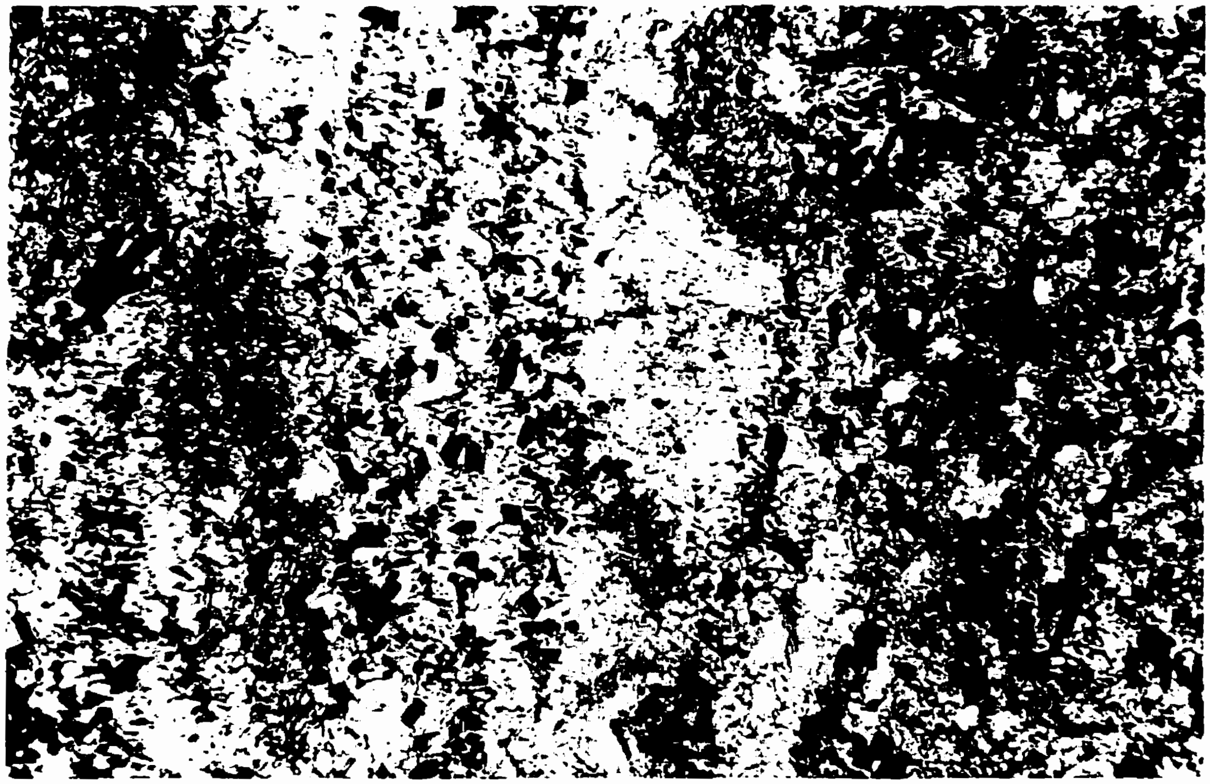

Figure 41: Typical mineralogical composition of altered and mineralized mafic wall rock. This sample is from the Birch Zone. The white minerals are quartz, albite and calcite; the green mineral is actinolite; the brown mineral is biotite; and the opaque minerals are arsenopyrite and other minor sulphides. Arsenopyrite is spatially associated with the biotite. (Field of view is 2.8mm)

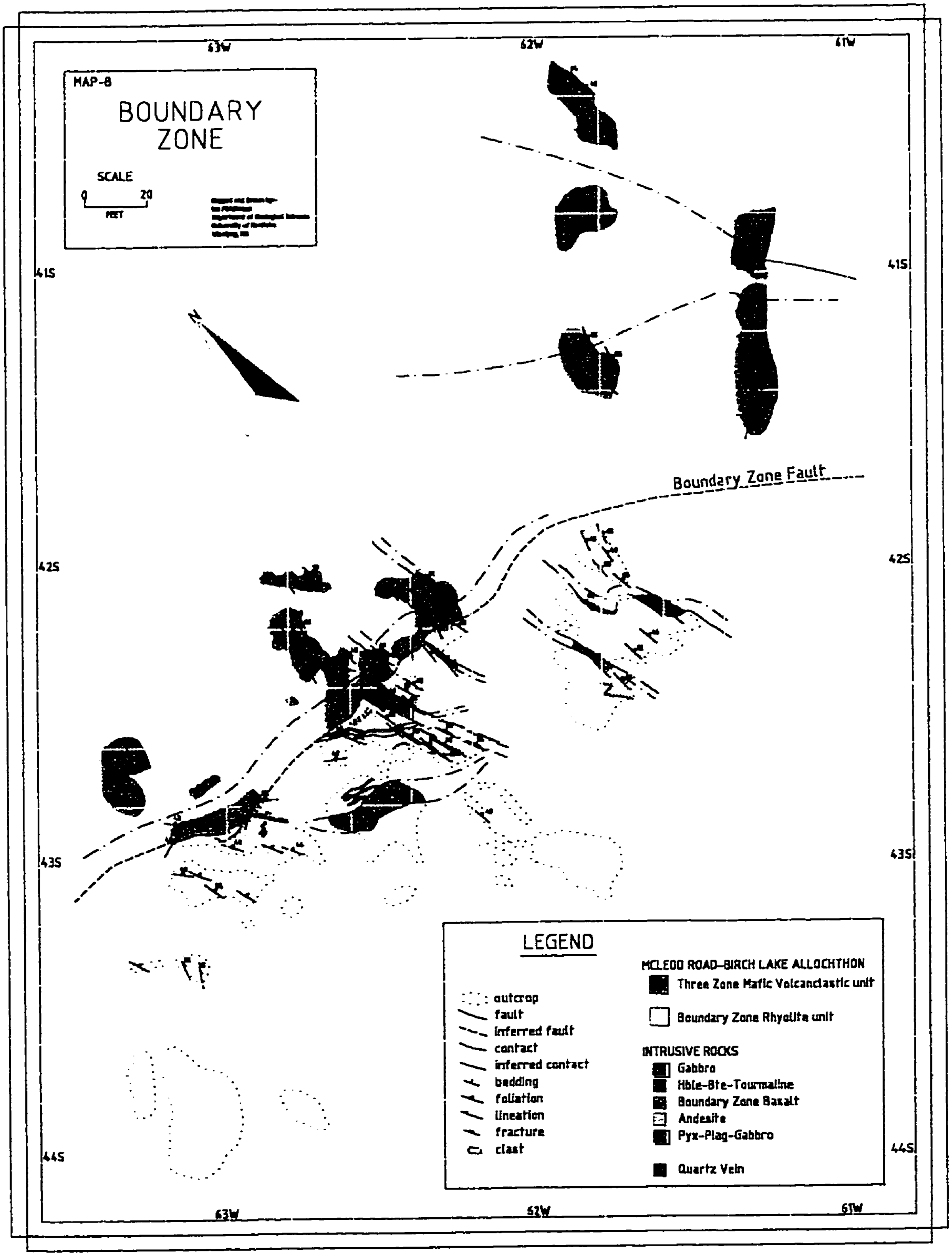

Figure 42: Map of the Boundary Zone fault. For fine details see Map-B in back pocket.

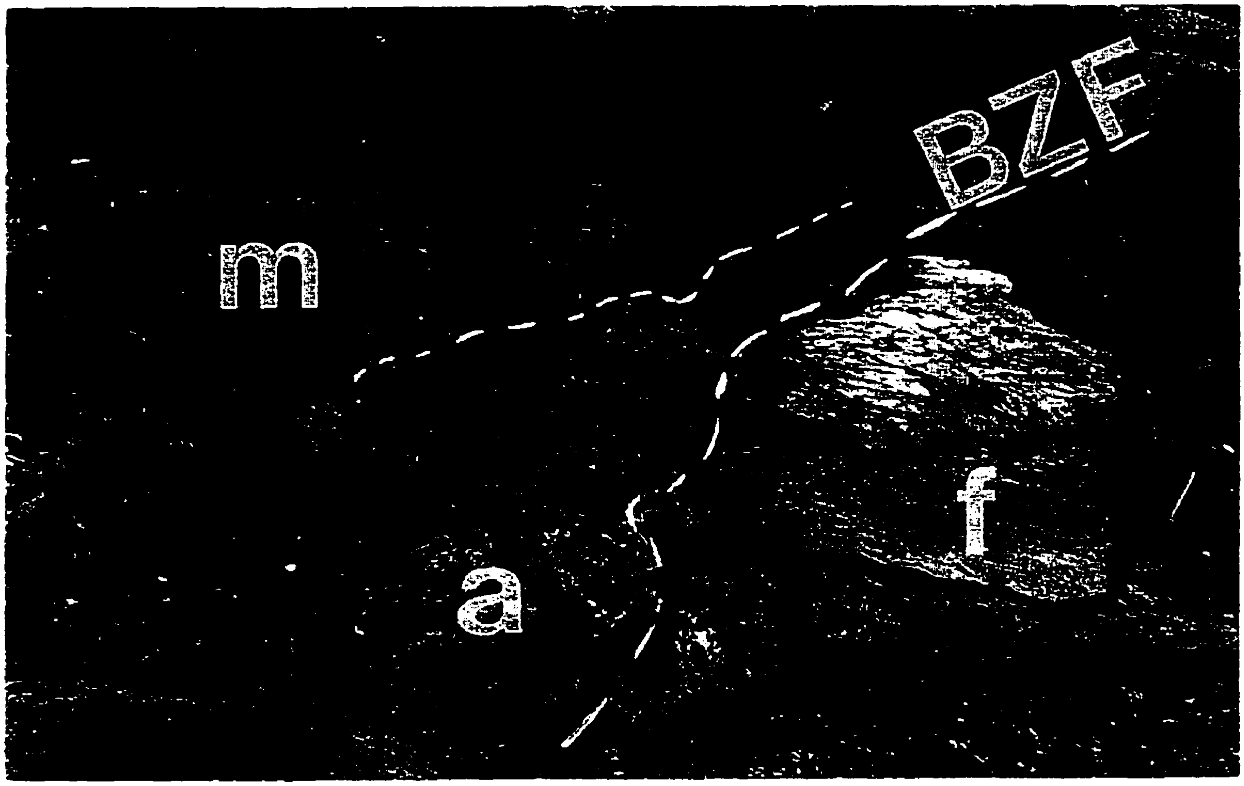

Figure 43: Boundary Zone fault. The Boundary Zone fault (BZF) is a structural contact between the felsic rocks (f) and the mafic rocks (m) at the Boundary Zone. This fault has a step like trace and records multiple phases of deformation. In places this fault has been intruded by at least two phases of fine-grained mafic intrusion (a).

faulted contact describes a step like trace that steps up the volcanic sequence to the east (Map-B). In one outcrop adjacent to the fault, felsic clasts exhibit extremely high strain suggesting a period of early ductile deformation (Fig. 44). The foliation fabric and clasts are deflected into this high strain area suggesting this is an early crosscutting, ductile shear zone. The nature of the deflection indicates this ductile shear to have had a left lateral sense of movement. This ductile shear is only locally preserved and is crosscut at a low to moderate angle by a brittle fault (Map-B). Further, this fault has been intruded by at least two phases of fine-grained basalt (Map-B; Fig. 45). A number of coarse grained, pyroxene phyric, mafic dykes are found on both sides of the faulted felsic/mafic contact (Map-B & Fig. 42). In places, these coarse grained dykes can be seen to crosscut the fine grained basalt intrusions in the fault zone, but cannot be traced across the whole fault zone as later deformation in the fault zone has offset and obscured details (Fig. 45). Part of this later deformation is a carbonate impregnation and synkinematic folding within the fault zone (Fig. 25). There is a deflection of the foliation and the coarse grained dykes adjacent to the fault zone, which infers a right lateral sense of movement (Map-B). Spatially associated with the Boundary Zone fault are a number of brittle to brittle-ductile deformational features of different ages. In the mafic rocks en echelon sigmoidal tensional fractures in filled with quartz-carbonate veins indicate a left lateral sense of shear. A fracture in the felsic rocks is infilled with a "crack and seal", quartz vein (Fig. 46). Fracture networks, defined by numerous thin quartz filled fractures with no displacement of the rock pieces, are found in the felsic volcanic rocks at both the Boundary Zone and at the South outcrop (Fig. 47). At the South outcrop the thin quartz filled fractures in the breccia zones form two differently orientated fracture sets (Fig. 47).

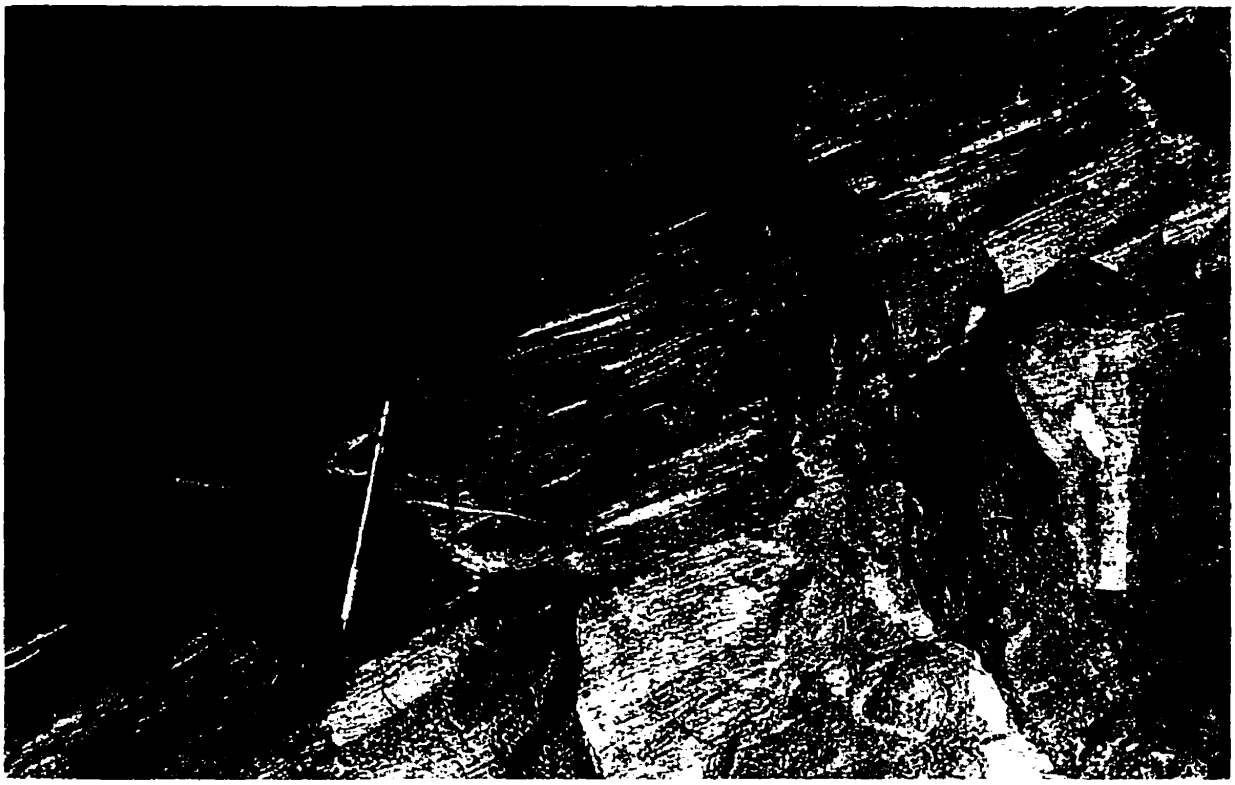

Figure 44: Ductile shear at the Boundary Zone. Felsic clasts near the felsic/mafic contact showing high degree of strain. Clasts defining the S_1/S_2 foliation are deflected into this ductile shear indicating a left lateral sense of movement.

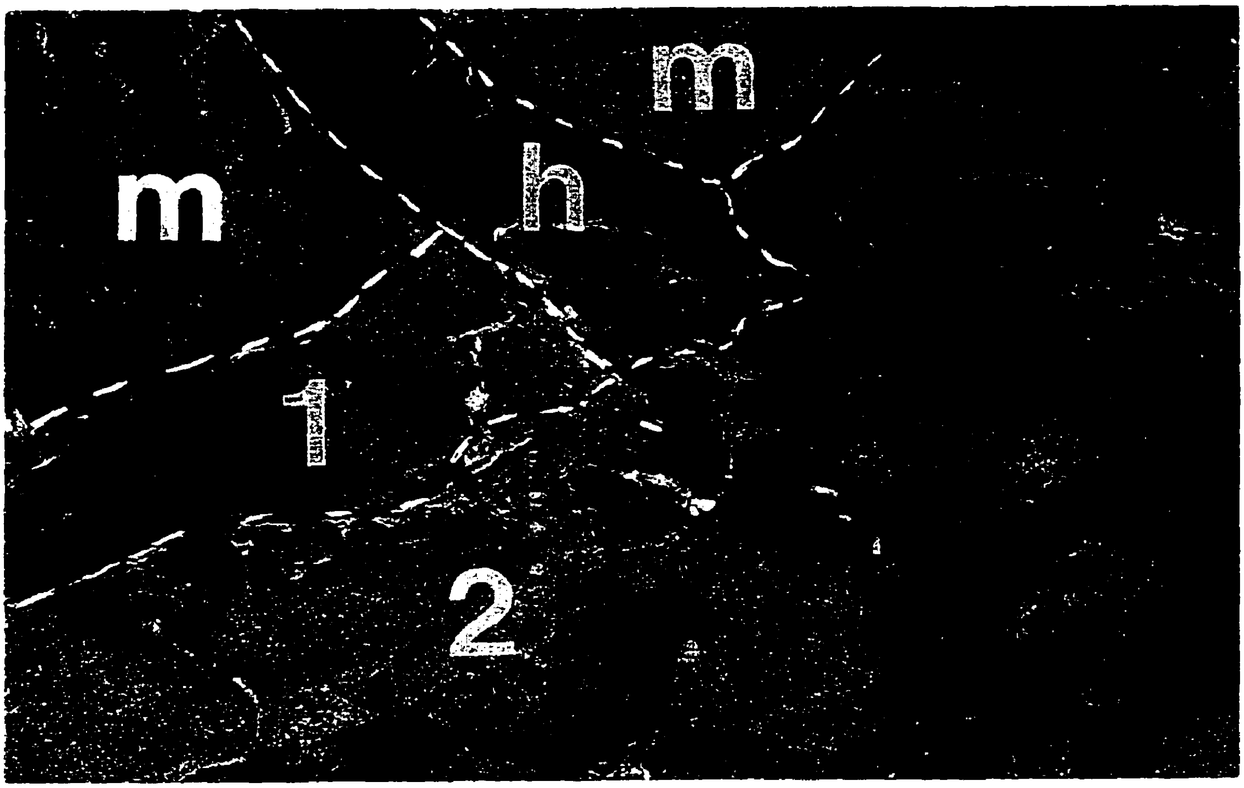

Figure 45: Basaltic intrusion of the fault zone at the Boundary Zone. This fault zone has been intruded by at least two phases (1 & 2) of a fine-grained basaltic rock. The mafic volcaniclastic rocks (m) and at least the first phase of the basaltic intrusion are cross cut and intruded by a coarse grained Hble-Bte tourmaline dyke (h). Further deformation of the fault zone resulted in synkinematic carbonate impregnation and folding in the basaltic intrusions.

Figure 46: "Crack and seal" type vein at the Boundary Zone. The vein is hosted in the felsic volcanic rocks and contains gold mineralization.

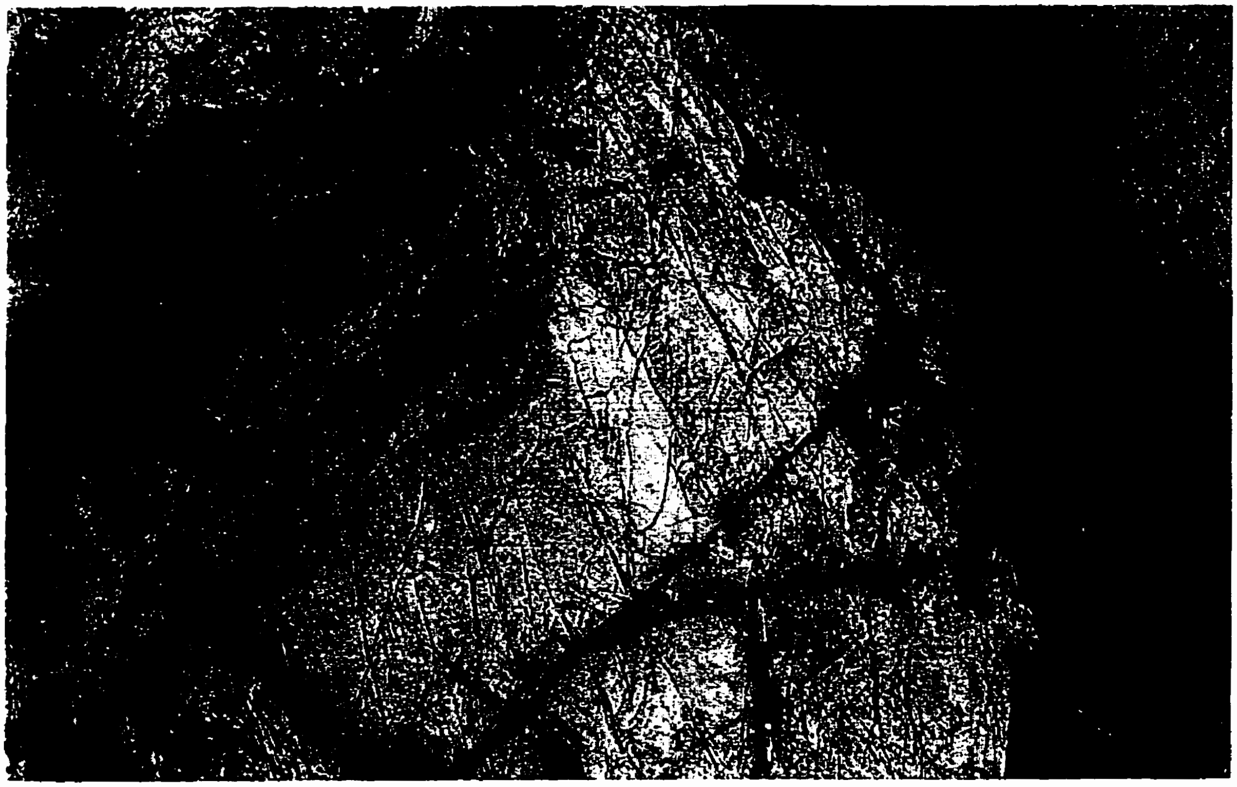

Figure 47: Fracture network at the South outcrop (near the Boundary Zone). The breccia zone has numerous parallel veins that form two sets of fractures. One set is striking in N-S direction and the other set in a NNW-SSE direction. This brecciation is only hosted in the felsic rocks and terminates against the faulted felsic/mafic contact. (Pencil is orientated N-S)

One fracture set strikes in a NNW-SSE direction and the second set strikes in an N-S direction, which together form a rhombohedral pattern of veins.

Gold mineralization at the Boundary Zone is primarily associated with the felsic/mafic fault contact. The gold mineralization at the Boundary Zone is hosted mostly within the fault and felsic volcanic rocks. In the felsic rocks the gold mineralization is associated with brittle-ductile features such as the "crack and seal" vein (Fig. 46) and the network fractures (Fig. 47). These brittle-ductile fractures do not form a single continuous structure and thus the gold mineralization is expected to be very erratic.

Brittle tension fractures, filled with milky white quartz, occur in both the mafic and felsic rocks. These fractures are interpreted to be a result of a late deformational event. Based on hand sample observations, there appears to be no gold mineralization associated with these late brittle fractures.

4.9 NO.3 ZONE SHEAR FRACTURE

The No.3 Zone is an example of a shear fracture system (Fig. 48) and is located approximately 2 km to the NW of the New Britannia Mine (Map-A & Fig. 2), part of which is exposed at the surface (Fig. 49). This shear fracture system consists of a main shear fracture, splay fracture and numerous tension fractures (Fig. 48) which have been infilled by a quartz-carbonate vein that has "crack and seal" characteristics (Fig. 50), and a milky white quartz vein. The No.3 Zone shear fracture system is hosted in the Three Zone mafic volcaniclastic unit. The main fracture is at least 150 metres long and along most of its length it varies from 50-150 centimetres wide (Fig. 48). The main fracture strikes between 100^0 and 105^0 and dips 45^0 to 50^0 to the north. At the eastern end of the

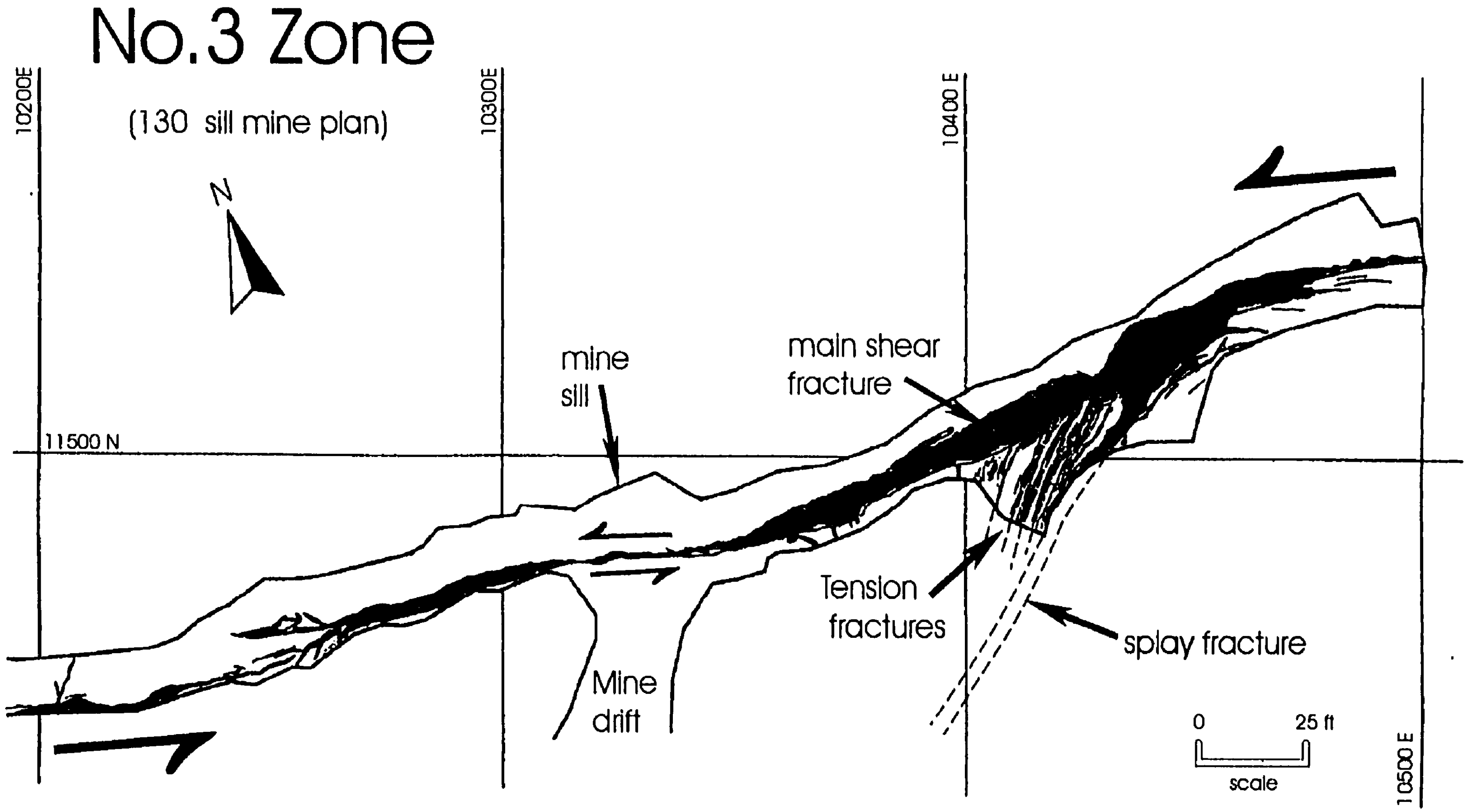

Figure 48: Mine plan of the 130 sill at the No.3 Zone. This mine plan shows the "s" asymmetry and sigmoidal nature of the main shear fracture. The "s" asymmetry of the main fracture indicates a left lateral sense of shear. There is one major splay fracture at the eastern end that splays off to the SE. Between the main shear fracture and a major splay fracture there is a dilation zone in which numerous tension fractures have extensively brecciated the wallrock. This part of the fracture/vein system is exposed at the surface and is shown in figure 49. The shear fracture has been infilled with a gold mineralized Grey quartz-carbonate vein.

Figure 49: Surface exposure of the shear fracture at the No.3 Zone. Ladder veins (L) and extensive brecciation of the wallrock are to a large degree contained between the main vein (M) and a major splay vein (S). This forms the zone of dilation in the sigmoidal fracture system. The wall rock in the brecciated zone is highly mineralized. (field of view is approximately 50 feet)

Figure 50: "Crack and seal" mineralized vein at No.3 Zone. A gold mineralized quartz-carbonate vein that has "crack and seal" characteristics has in filled the shear fracture at No.3 Zone. The extensive brecciation of the wall rock can also be seen to the left of the vein.

fracture system the main fracture has a sigmoidal shape with "s" asymmetry which plunges moderately to the northeast. Associated with this sigmoidal structure of the main fracture is a smaller but significant splay fracture that splays off to the southwest. In between the main and the splay fractures there is considerable brecciation of the host rock as a result of numerous northeast striking parallel fractures (Figs. 48 & 49). These parallel fractures terminate against the main fracture at a high angle and are interpreted to be tension fractures. This part of the fracture-vein system is exposed at the surface (Fig. 49). The "s" asymmetry and the formation of the tension fractures indicate a sinistral shear movement across the main fracture. The No.3 Zone fracture occurs where there is an open fold of the contact between the basaltic and mafic volcaniclastic rocks (Map-A). A stress analysis based on the main shear fracture, the tension fractures and the intersection of these fractures indicated the orientation of the principle stresses as being $45^0/204^0$, $40^0/040^0$ and $15^0/308^0$ for sigma 1, 2 and 3 respectively. The milky white quartz vein adjacent to the quartz-carbonate "crack and seal" vein in the shear fracture indicate that fracture has been reactivated at different times in the past. The milky white quartz vein post-dates the quartz-carbonate "crack and seal" vein and is interpreted to be a reactivation of the fracture during a later brittle deformational event. In addition to this, tension fractures associated with the No.3 Zone shear fracture crosscut an earlier, small, irregular, deformed quartz-carbonate vein (Fig. 51). This indicates the rocks at No.3 Zone have a long history of deformation.

The gold mineralization at the No.3 Zone is associated with a large shear fracture/vein system. The grey quartz-carbonate "crack and seal" vein and the wall rock immediately adjacent to the vein are both mineralized and formed the bulk of the ore. The mineralization and associated alteration of the host rock is generally confined to within a

Figure 51: Mineralized ladder veins (L) crosscutting an earlier, folded quartz-carbonate vein (C) at the No.3 Zone. This points to a long history of deformation and quartz mineralization at the No.3 Zone.

metre of the vein, except between the minor splays of the vein and where the wall rock has been brecciated. In these brecciated zones and in between the minor splays of the main vein the wall rock is considerably more altered and mineralized. The mineralogical assemblage of the altered and mineralized mafic host rock is quartz, albite, actinolite/hornblende, biotite, calcite, garnet, arsenopyrite and other minor sulphides (Fig. 52). The arsenopyrite crystal enclosed within a garnet crystal suggests that there has been a metamorphic event post dating the mineralization (Fig. 52). At the eastern end of the shear fracture/vein system, where the main vein has a sigmoidal shape, the quartz-carbonate veins and brecciated wallrock between the veins forms the thickest ore zone, being up to 8 metres wide. There is less alteration of the wall rocks at the No.3 Zone when compared to the wall rocks at the New Britannia Mine. The upper part of fracture/vein system has been mined out, however the structure and mineralization are still open at depth.

4.10 MINOR FAULTS AND SHEARS

4.10.1 NNW-SSE FAULTS AND SHEARS

In the field there is evidence for a number of NNW-SSE striking shears in the form of exposed shears, lithological changes and topographic features. A major NNW-SSE lineament forms a topographic low that runs from approximately the North Zone, SSE to immediately north of the Blood Zone (Map-A and Fig. 54). To the west of this lineament the finely laminated mafic wacke bed is absent from the top of the mafic volcaniclastic unit. This lineament also offsets the contact between the Birch Lake basaltic rock unit and the underlying mafic volcaniclastic rocks and infers a left lateral movement.

Figure 52: Inclusion of acicular arsenopyrite in a poikilitic garnet. The arsenopyrite is the opaque mineral and the garnet is marked G. This suggests that gold mineralization occurred prior to porphyroblast growth of the garnet and metamorphism. (Loc. No.3 Zone; field of view is 2.5mm)

The North Zone and three isolated shear zones coincide or are along strike from this major NNW-SSE lineament. Trenches at the North Zone expose a number of minor shears which have ductile shear fabrics and minor alteration and mineralization associated with them.

The three isolated shear zones are exposed on isolated outcrops at L1380E/2820N, L3000E/1000N & L3450E/0920N. These shear zones are a few metres wide and have a NNW-SSE, (334^0-344^0) strike and dip moderately, (39^0-45^0), to the NE. The shear zones are characterized by a finer grain size than the surrounding rock and a very strong "c" shear fabric suggestive of a ductile shear. Thin section analysis shows the "c" shear fabric is defined by bands of biotite, which is interpreted to an alteration product of the amphibole minerals. There is also a variable amount of disseminated sulphides, which consists mostly of pyrrhotite. Recrystallization and metamorphism has overprinted and obscured most of the shear zone fabric. Rock samples from these three isolated ductile shears were submitted for geochemical analysis and the results indicated that there is no significant gold mineralization associated with these ductile shears.

In addition to the NNW-SSE shears described above, there is also a number of thin discrete shears, which strike at approximately 350^0 and dip to the east, and further topographic lows that form NNW-SSE lineaments. These thin discrete shears lineaments infer additional NNW-SSE shears that are not well exposed or developed. All of these NNW-SSE shears in the mapped area are sub-parallel to the nearby McLeod Road Thrust fault and are tentatively interpreted to be related to it. Drilling has indicated that gold mineralization occurs where these NNW-SSE shears intersect the NNE-SSW shears (next section).

4.10.2 NNE-SSW SHEARS AND FAULTS

In the mapped area there are numerous inferred minor shears which strike approximately NNE-SSW (Map-A & Fig. 54). These shears are particularly evident to the west of the Birch Zone and in the northeastern part of the mapped area. The NNE-SSW shears have strikes that range from 000^0 to 030^0 and an easterly dip that ranges from 25^0 to 65^0. These NNE-SSW faults/shears are not exposed but are inferred from topographic features, NNE-SSW orientated foliations and offsets in lithological contacts. Linear NNE-SSW orientated topographical features such as steep sided gullies and muskegs suggest an inherent structural geological control. NNE-SSW orientated foliation in association with the linear topographical features are consistent with these features being NNE-SSW striking shears.

The lithological boundaries, in particular the Three Zone mafic volcaniclastic rock unit contact with the over lying Birch Lake basaltic unit, are found to be laterally discontinuous and are interpreted to be offset by NNE-SSW shears. This offset often coincides with the NNE-SSW orientated foliations and topographical features. The resultant outcrop pattern indicates a predominantly right lateral, with an occasional left lateral sense of movement (Map-A).

In addition to the above described shears, there are a number of relatively thin, carbonatized faults with a NNE-SSW strike and moderate to steep easterly dip which outcrop in the mapped area. These faults form narrow, weathered out discrete faults and are interpreted to be late, post-metamorphic faults (Fig. 53).

These NNE-SSW shears and faults have a similar orientation as the Northern Canada Fault. This suggests they may be related to this prominent fault.

Figure 53: Carbonatized NNE-SSW faults in basaltic rock unit. This fault is interpreted to be a late post-metamorphic fault, which is more readily weathered than the surrounding rock. (Loc. 0820E/3380N)

4.10.3 OTHER MINOR SHEARS

There are a number of small discrete mineralized zones in the vicinity of the New Britannia Mine. These are namely, but not inclusive, the Blood Zone, East Zone, Sherry Zone, North Zone, No.2 Zone, Kim Zone, No.4 Zone, Centre Zone and a number of unnamed shear zones across which shallow trenches have been dug to expose them (Map-A). These mineralized zones typically consist of a minor linear shear, localized alteration and gold mineralization. The strike of these shears is varied from N-S, such as the Blood Zone to E-W such as the East Zone. The shears are generally moderately to steeply dipping. No.2 Zone is anomalous as it forms a shallow dipping structure to the east. These minor zones generally appear as isolated mineralized shears. Drilling of these minor shears indicates significant gold mineralization. A barren milky white quartz vein is often present in the minor shear zones infilling a tension fracture. These tension fractures are generally sub-parallel to the earlier shears, up to a meter in width and are interpreted to be result of reactivation of the shear zone during a late, post-metamorphic deformation period.

4.11 AERIAL PHOTOGRAPH INTERPRETATION

The air photos A20043-162 to 165, from 1967, were used for the aerial photograph interpretation, as they were the best trade-off between quality and anthropological disturbances. Structural details from the area near the mine and town sites have been obscured by these anthropological activities. The following description refers to the interpretation seen in figure 54.

The lineaments are interpreted to be largely a result of glacial action that has preferentially eroded geological and structural weaknesses in the bedrock. These

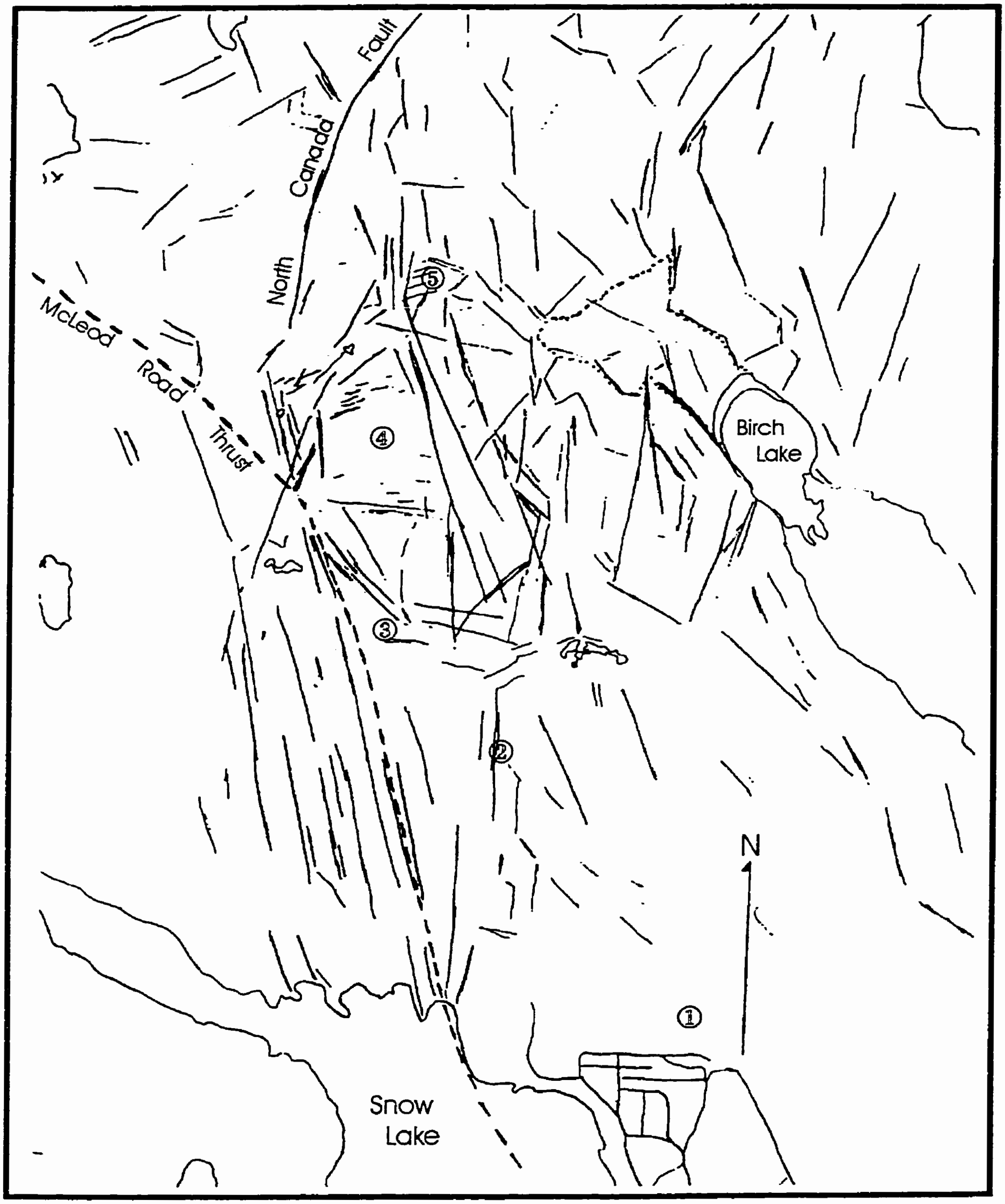

Figure 54: Aerial photograph interpretation. 1-New Britannia Mine; 2-Boundary Zone; 3-No.3 Zone; 4-No.2 Zone; 5-Birch Zone. Aerial photos 20043 162-165 (1967).

lineaments are categorized according to their orientations. In general the NNW-SSE to NNE-SSW lineaments are more pervasive and dominant in the Snow Lake area. This may be a result of the direction in which the glacier moved.

Immediately north of the lake, within the Burntwood suite peletic rocks, there are a number of lineaments forming a very pervasive fabric striking at approximately 345^0. In this area, there are also very few crosscutting lineations. This linear fabric coincides with the strike of the bedding and the McLeod Road Thrust fault in this area.

Within the volcanic rocks there are a number of NNW-SSE orientated lineations. A few particularly strong lineaments, which strike at approximately 337^0, correspond to the lower lying areas that extend from the North Zone to the Blood Zone. This also coincides with the strike of shear zones found in the field (see section 4.10.1) and the point of offset of the contact between the basaltic rock unit and the underlying rocks (Map-A).

N-S to NNE-SSW lineaments are also seen in the aerial photos and often corresponds to shears and gullies seen in the field. One of these is the Northern Canadafault, which forms a prominent and continuous lineament all the way from the McLeod Road Thrust to the north of Herblet Lake. This is interpreted to be an imbricate fault of the McLeod Road Thrust.

Shorter, less prominent NW-SE orientated lineaments form a fabric between the other more prominent shears. These correlate to the regional fabric and/or earlier shears. In some localities, such as along the SW shore of the tailings pond, this NW-SE fabric has been cut and displaced by the more prominent NNE-SSW lineaments. E-W lineaments can be seen that correspond to the geological contact and E-W foliations that extend eastwards from the No.3 Zone. Short, less prominent, E-W lineaments can also be seen in the vicinity of the Birch, No.2 and Centre Zones. The area that contains both the No.2 and Centre Zones is anomalous in that it has no major NNE-SSW orientated lineaments.

CHAPTER 5
METAMORPHISM

5.1 GENERAL COMMENT

In general, the Snow Lake area has been affected by lower amphibolite grade of metamorphism. The meta-volcanic rocks do not show a marked textural change with increasing metamorphic grade, as do the meta-sediments in the Snow Lake area. However, the mafic volcanic rocks do show a significant metamorphic mineralogical change. The mafic meta-volcanic rocks record at least two prograde metamorphic events and one late heating event. These metamorphic events have resulted in a total recrystallization of the original rock and the amphibolitization of pyroxene phenocrysts.

5.2 METAMORPHIC MINERAL GROWTH

The mafic rocks have a metamorphic mineral assemblage consisting essentially of actinolite/hornblende amphibole and plagioclase feldspar. Primary pyroxene crystals in the mafic rocks have been almost totally amphibolitized and replaced by hornblende (Fig. 55). In the mafic volcanic rocks the actinolite/hornblende crystals typically have an irregular lath like shape and are generally orientated parallel to the $S_1 \backslash S_2$ foliation fabric, particularly in high strain domains (Fig. 21). This amphibole growth and development of the $S1/S_2$ foliation fabric is interpreted to represent a regional prograde metamorphic event.

Locally this $S_1 \backslash S_2$ foliation fabric and the associated amphibole growth are overprinted by a secondary hornblende growth (Fig. 21). The secondary green/brown

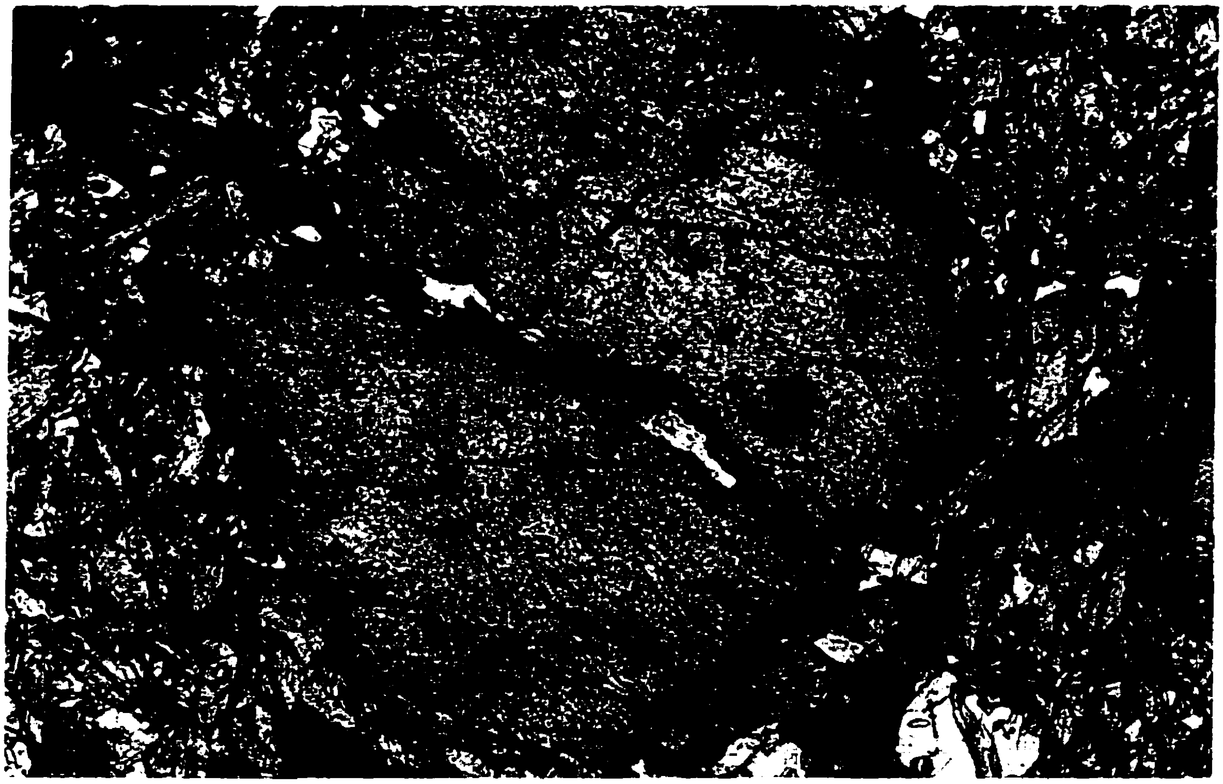

Figure 55: Photomicrograph showing an amphibolitized pyroxene phenocryst. There is almost a total amphibolitization of the mafic rocks with remnants of pyroxene crystal being found in thin sections only occasionally. (field of view 0.70 mm)

hornblende growth is orientated at a high angle to the earlier $S_1 \backslash S_2$ fabric, defined by the actinolite/blue-green hornblende growth (Fig. 21). This is important as it infers another metamorphic event, at slightly higher temperatures and under a different tectonic stress regime, that post-dates the development of the $S_1 \backslash S_2$ foliation fabric.

In zones where alteration has occurred as a result of hydrothermal fluids, biotite replaces amphibole as the main ferro-magnesium mineral. The amount of quartz generally increases in these altered zones. At the Birch Zone two separate biotite growths are recorded (Fig. 22). The first resulted in small, blade like biotite crystals that are orientated parallel to the c-fabric in the shear zone and are associated with the felsic components of the rock. The secondary biotite growth resulted in considerably larger flakes of biotite forming biotite "books". This secondary biotite growth forms thin biotite layers which constitutes the c-fabric of the shear zone. The secondary biotite growth is orientated at a high angle to the earlier c-fabric of the shear zone. The biotite "books" can be identified in hand samples from altered zones.

Metamorphism also resulted in a local garnet growth. The garnet growth is spatially associated with alteration zones. Stratigraphically above the "silicified" basalts there is a patchy distribution of small (2 mm) euhedral garnets. At No.3 Zone the garnets are sub-euhedral to euhedral and are poikiloblastic. Small quartz inclusions in these garnets record one early fabric that is the regional $S_1 \backslash S_2$ foliation (Fig. 56). There is no rotation of the garnet evident. This infers that the garnet growth post-dates the development of the regional S_1/S_2 fabric.

One sample with radiating, fibrous sillimanite growth indicates that post-dating the alteration and D_1/D_2 deformational fabric there must have been a late heating event

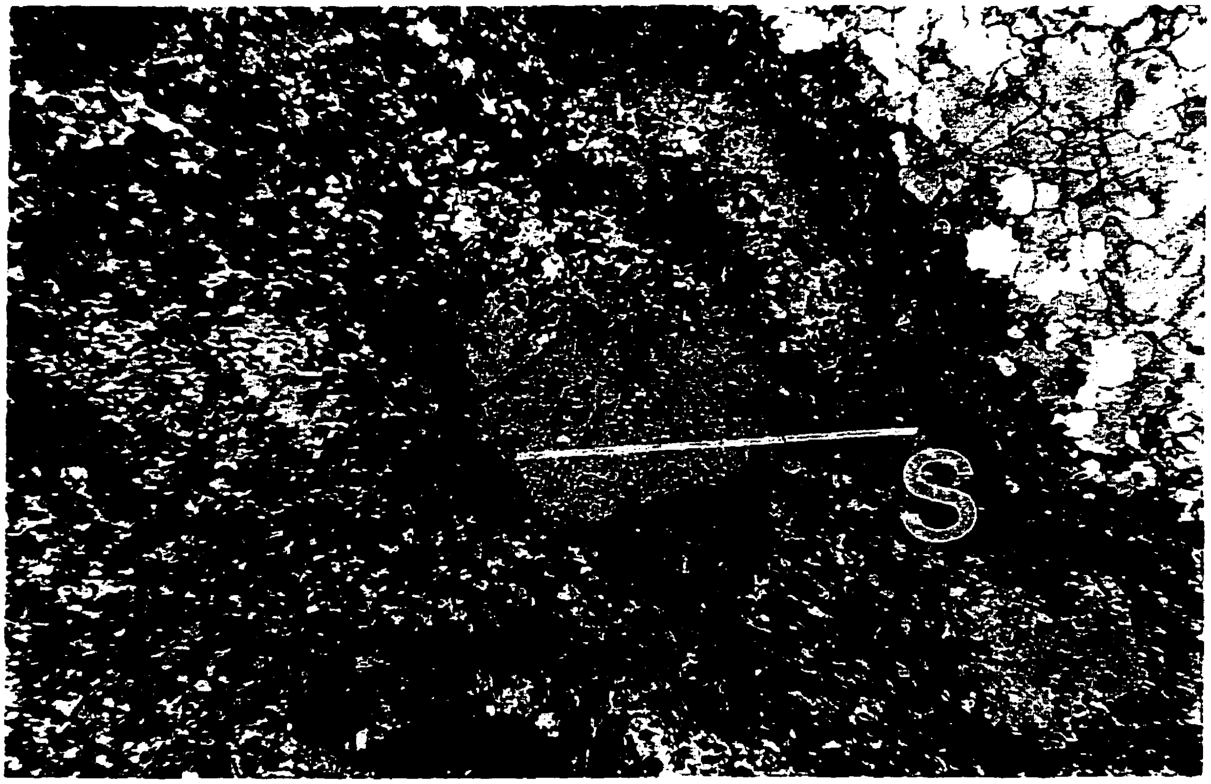

Figure 56: Photomicrograph showing a poikiloblastic garnet. The fabric recorded by the inclusions of quartz is the S_1/S_2 foliation (S). There is no rotation of the garnet during its growth. This sample was taken from the No.3 Zone surface exposure, adjacent to the mineralized vein. (field of view is 2.8 mm)

under static pressure conditions (Fig. 57).

All the volcanic rocks in the study area indicate they have been recrystallized. This is particularly evident in the altered zones such as the Birch Zone. Figure 39 shows the recrystallization of quartz overprinting the earlier shear fabric.

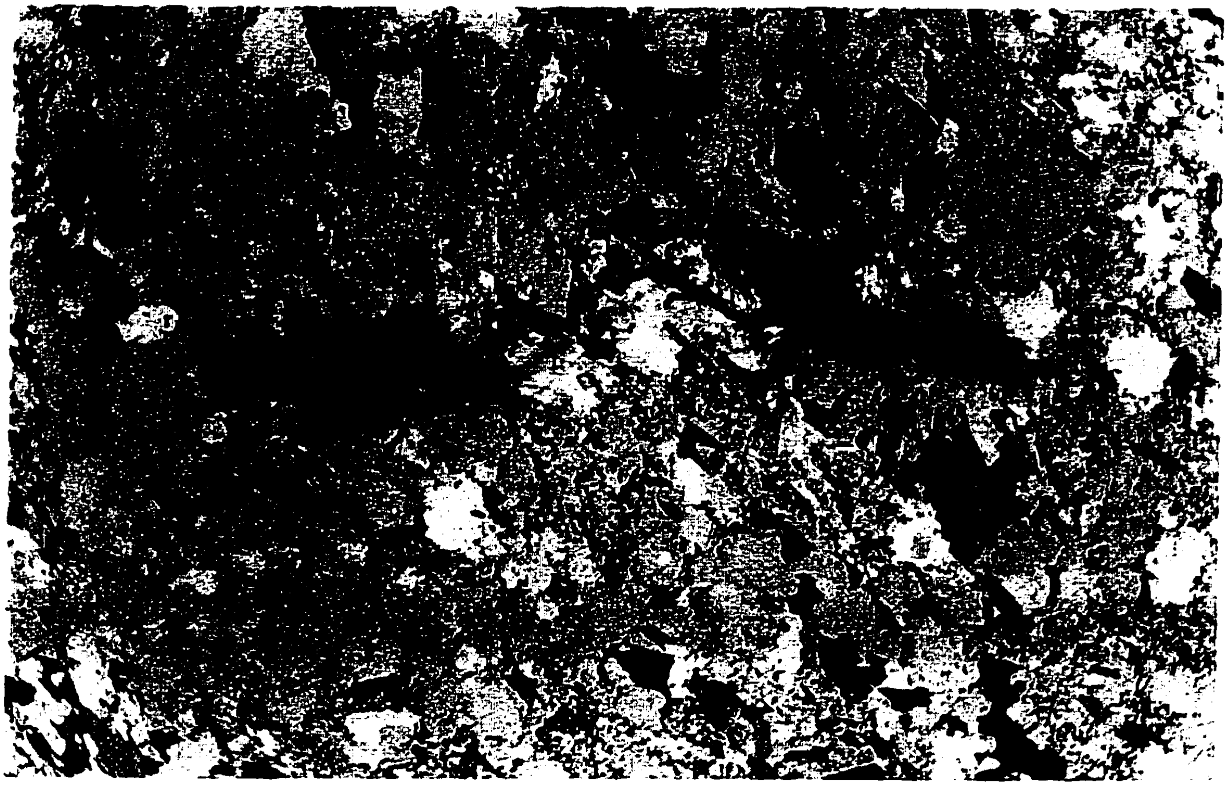

Figure 57: Photomicrograph showing a radiating fibrous sillimanite growth. This indicates that post-dating the S_1/S_2 foliation fabric and alteration there was a metamorphic heating event with static pressure conditions. This sample is from an altered zone at loc. L1800E/3770N. (field of view is 2.8 mm)

CHAPTER 6
ALTERATION

6.1 INTRODUCTION

There are a number of different types of alteration events that have affected these volcanic rocks. They can be broadly divided into three main categories: -

1) syn-volcanic alteration,

2) alteration associated with faults and or shears and,

3) alteration associated with the gold mineralization.

In this chapter only the syn-volcanic alteration is discussed as the other rock alterations observed have been discussed in the chapters and context with which they are associated. The syn-volcanic alteration is further separated into silicification and epidote alteration.

6.2 "SILICIFICATION"

In the volcanic rocks of the Snow Lake arc assemblage there is considerable, so called "silicification", alteration evident in both drill core and in the surface outcrop. There is a problem, particularly in the logging of drill core, in distinguishing mafic rocks that have under gone this "silicification" alteration from felsic volcanic rocks as both the altered mafic rocks and the felsic volcanic rocks can look the same.

In the Birch Lake basaltic unit there is a considerable area of altered basalts, which are locally known as the "silicified" basalts. This alteration is stratabound within the Birch Lake Basalt, laterally continuous and appears to have originally been formed as a stratiform layer. The boundaries of this alteration, seen both in the field, (Fig. 58), and

Figure 58: Outcrop showing a sharp contact between the dark coloured, unaltered basaltic rocks and the light coloured altered basaltic rocks. In both the field and drill core the contacts between the highly altered and unaltered mafic rocks can be both very sharp, as shown here, or gradational. In areas where there is both highly altered mafic rocks and felsic volcanic rocks it is problematic to distinguish between the two rock types, particularly in drill core. This has led to misnaming and misinterpretation of rock types in the past. (Loc. 10700E/14300)

in drill core are very variable from sharp to gradational. In some localities where alteration of the basaltic rocks has occurred, the primary structures of pillows can still be recognized (Fig. 59). These altered basaltic rocks are generally fine grained, pinkish/grey in colour and often have a very strong cleavage defined by biotite. On weathered surfaces these rocks appear bleached and are a pale tan colour. The mineralogy of these altered rocks is quartz, feldspar, biotite, muscovite with varying amounts of disseminated pyrrhotite (0-2%). Spatially associated with these altered basalts, and in most places stratigraphically above, are basaltic rocks which have a patchy distribution of small 1-2 mm size garnets.

In a comparison of the Fe and Mg oxide values from samples of altered basalt with samples of basaltic pillows, which are considered least altered basalts, it can be seen that the altered basalts have consistently much lower Fe and Mg oxide values (Table 1). The lower Fe and Mg oxide values in the altered basaltic rocks are consistent with leaching of Fe and Mg from the rock. This leached alteration of the basaltic rocks is not associated with any large structures and is interpreted to be a result of pervasive syn-volcanic hydrothermal alteration.

This alteration of the mafic volcaniclastic rocks is seen in drill core from the New Britannia Mine and other areas, such as the Boundary Zone. These "silicified" rocks which are found in zones from centimetres to meters wide in drill core, are often not expressed at the surface. In the absence of clear contact relationships, the timing and process of this siliceous alteration is not clearly defined and could be the result of metamorphism, deformation and / or synvolcanic hydrothermal fluids.

Figure 59: Outcrop showing bleached, "silicified" basaltic pillows. These rocks were originally basaltic in composition and have been considerably altered with Fe and Mg being leached from the rock. Along the southwestern shore of Birch Lake these bleached basaltic rocks form a more or less conformable layer which is stratabound within the Birch Lake basalt unit. The bleaching is interpreted to be a result of a pervasive synvolcanic hydrothermal alteration. (Loc. 3550E/3580N)

Table 1: Comparison of Fe_2O_3 and MgO chemical analysis results between the least altered pillow basalts and altered basalts. The Fe and Mg oxide values are considerably lower in the altered basalt rocks.

Sample #	Fe_2O_3	MgO
least altered pillow		
SG/10	9.09	6.28
SG/13	12.29	6.70
SG/23	12.17	6.64
SG/24	11.92	6.74
SG/25	9.25	6.94
SG/26	10.06	7.11
altered basalts		
SG/18	1.24	0.86
SG/21	1.77	1.80
SG/30	2.82	1.89
SG/57	5.27	1.44
SG/58	4.73	1.97

6.3 EPIDOTE ALTERATION

An epidote alteration has been observed both in the field and in drill core. This alteration has a patchy distribution and occurs only in the mafic volcaniclastic rocks and in particular the Birch Lake mafic volcaniclastic unit. In the mafic volcaniclastic rocks, the epidote alteration is both in the clasts and veins (Fig. 60). The S1/S2 foliation fabric deforms the epidote veins. This constrains the timing of the epidote alteration to pre-D_1/D_2. This pre- D_1/D_2 timing and that no epidote alteration has been observed in the Birch Lake basaltic unit suggests this epidote alteration to be syn-volcanic.

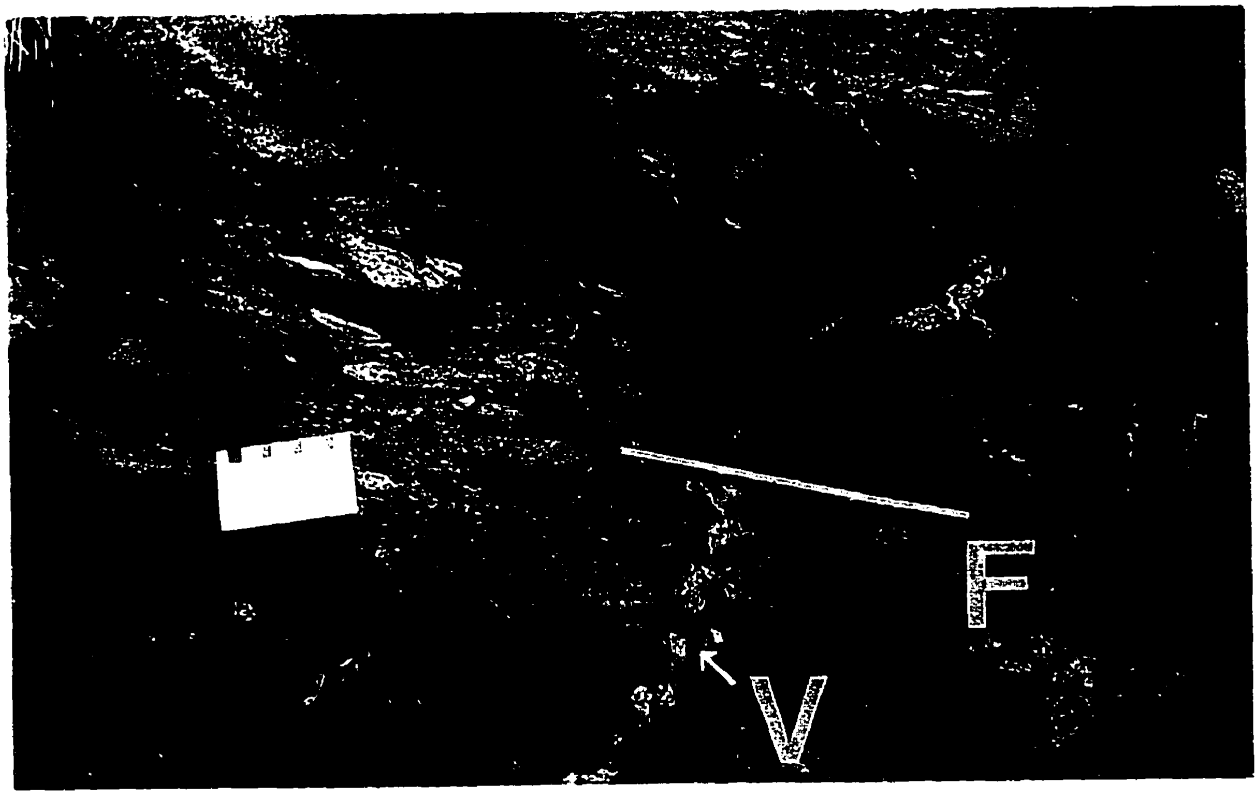

Figure 60: Epidote alteration in the Birch Lake mafic volcaniclastic rocks. The pale green/yellow epidote alteration has affected some clasts and is crosscutting the rocks in a deformed vein (V). This vein has been deformed by the S_1/S_2 fabric (F) indicating an early timing of epidote alteration. This epidote alteration is very prevalent in the mafic volcaniclastic rock unit at the NW end of Birch Lake. (Loc. 10200E/15320N. Card has cm gradations)

CHAPTER 7
SYNTHESIS AND CONCLUSIONS OF THE VOLCANIC SEQUENCE, STRUCTURES AND GOLD MINERALIZATION

7.1 CHARACTER OF THE MCLEOD ROAD-BIRCH LAKE ALLOCHTHON VOLCANIC SEQUENCE

The McLeod Road-Birch Lake allochthon is composed of a number of distinct lithostratigraphic rock units forming a volcanic sequence. This volcanic sequence consists of mafic volcaniclastic rock units, felsic rock units and mafic flow rock units that are intercalated with one another through the McLeod Road-Birch Lake allochthon (Fig. 5). The pillowed basalts and erosion scour at the one outcrop at the northwestern shore of Birch Lake indicates a consistent younging direction to the NE. The pillows and sedimentary features such as the fine laminated mafic wacke beds suggest that the whole volcanic sequence was deposited sub-aqueously.

Mafic volcaniclastic rocks make up a considerable portion of the volcanic sequence in the Snow Lake area. All of these mafic volcaniclastic units are somewhat similar in character and are composed of mafic volcaniclastic breccias with minor mafic wacke beds. The pyroxene and feldspar phyric gabbroic intrusions have a similar character to the fragments in the mafic breccias. This is consistent with the gabbroic intrusions being synvolcanic and the breccias being proximal to their source. Even though the contacts between the felsic rock units and the overlying mafic volcaniclastic rocks are often structural, the stratigraphic progression is interpreted to be conformable and a result of bimodal volcanism. This is because felsic clasts from the under lying felsic units are often found in mafic volcaniclastic rocks that immediately overlie these felsic rock units. The volcanic sequence of the mafic volcaniclastic (and associated mafic flows), gabbroic intrusions, and the felsic volcanic rocks is interpreted to be the product of cyclic, bimodal volcanism that was deposited on the slopes of an emerging volcanic volcano.

The Birch Lake basaltic unit is interpreted to have been deposited in a different tectonic setting from the rest of the volcanic rocks in the McLeod Road-Birch Lake allochthon. The pillows indicate the Birch Lake basaltic unit was deposited sub-aqueously and the geochemical analysis indicates an ocean floor affinity. The difference in sedimentological character, geochemical affinity and the absence of mafic dykes in the Birch Lake basalt unit infer that the contact between the Birch Lake basalt unit and the rest of the volcanic rock sequence is an unconformable contact. Further, the abrupt termination of the fine laminated mafic wacke bed at the top of the mafic volcaniclastic unit suggests that this contact to be a structural contact, however this is inconclusive.

The Birch Lake mafic volcaniclastic unit is bounded by major faults and is similar in character to the other mafic volcaniclastic rocks that are lower down in the volcanic sequence, such as the Three Zone mafic volcaniclastic rock unit. This and very different geochemical and sedimentological character of the Birch Lake basalts suggest that the Birch Lake mafic volcaniclastic unit is allochthonous and structurally interdigitated above the Birch Lake basalt unit.

7.2 STRUCTURE OF THE MCLEOD ROAD-BIRCH LAKE ALLOCHTHON

The younging direction was found to be consistently to the N-NE which indicates that there are no large-scale isoclinal folds in the McLeod Road-Birch Lake allochthon.

This infers that the volcanic sequence is on one limb of a large-scale structure and that the outcrop pattern is a result of faulting, shearing and displacement of "fault blocks". The same pervasive deformational fabric is seen throughout the volcanic rock pile suggesting that the assembly of all the volcanic rocks occurred early in the deformational history. This is consistent with structural emplacement of the volcanic pile along early ductile shears.

The earliest deformational fabric recorded in the volcanic rocks in the Snow Lake area is a pervasive foliation, which is interpreted to be a S_1/S_2 foliation fabric. In the volcanic rocks this S_1/S_2 foliation fabric is sub-parallel to the strike of the major lithological units. A stretching lineation, which plunges moderately to the NE-ENE, is associated with and contained within the plane of this S_1/S_2 foliation. This forms a SL-tectonite in places. The degree of strain is very variable with high strain areas having extremely flattened and stretched clasts. The penetrative S_1/S_2 foliation, SL-tectonite fabric and the lower amphibolite facies minerals associated with the foliation fabric infer the D_1/D_2 metamorphic event to have had medium to high pressure, with moderate temperatures. The ductile shears exposed at the upper Birch Zone and the Boundary Zone also exhibit this SL-tectonite deformational fabric suggesting that these ductile shears are early and were formed during the D_1/D_2 deformational period.

The ductile D_1/D_2 deformational fabric is interpreted to be the result of simple shear. The transport direction and compressive stress are interpreted to be from the NE to the SW. Figure 61 shows this interpretation in the form of a block diagram.

Post-dating and in places crosscutting this early D_1/D_2 fabric are a number of brittle-ductile features. The largest of these brittle-ductile structures is the McLeod Road

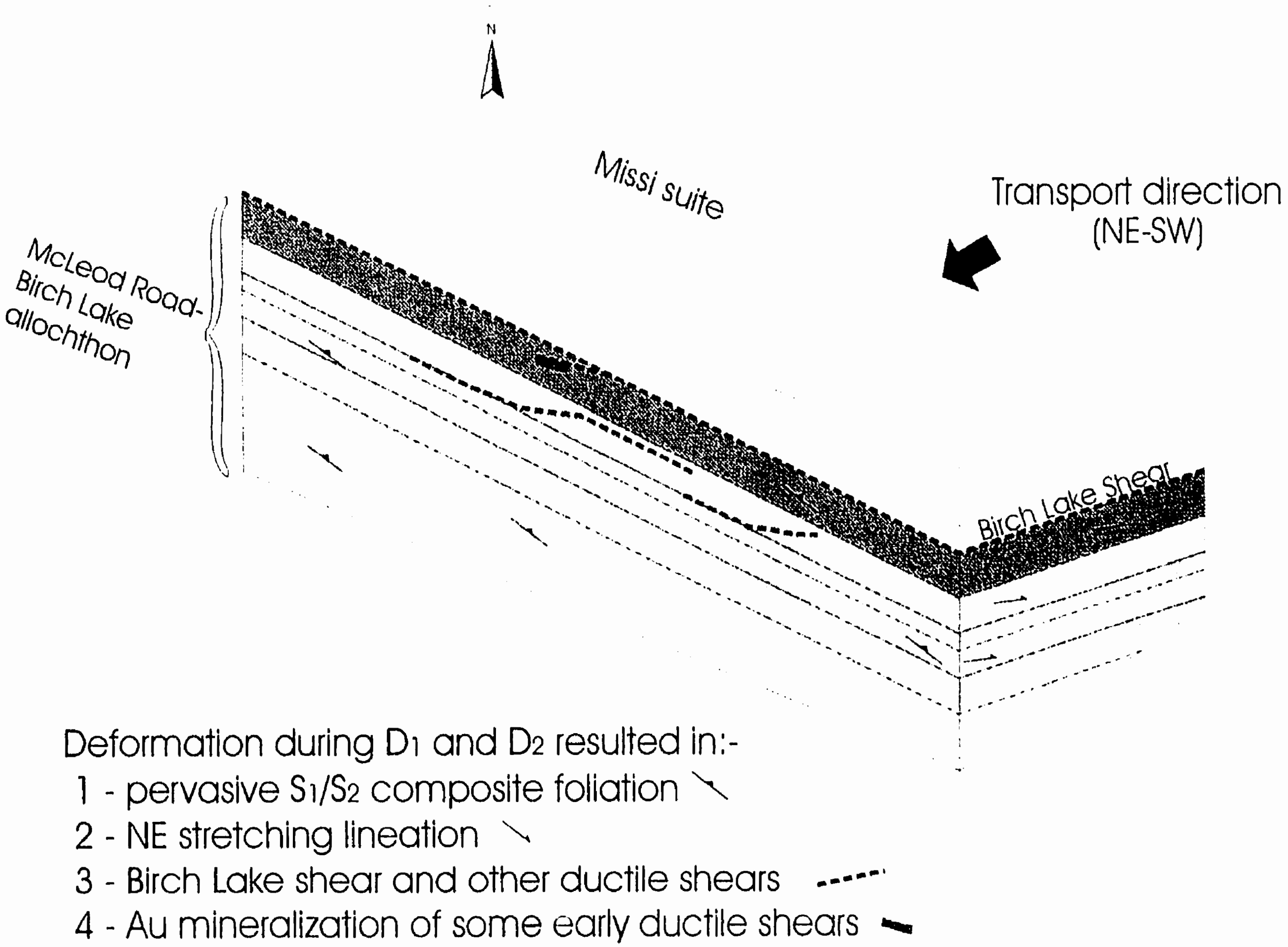

Figure 61: Block diagram showing the relationships of the D_1/D_2 deformational fabrics.

Thrust fault. In the vicinity of Snow Lake the McLeod Road Thrust places the older, McLeod Road-Birch Lake volcanic sequence over younger turbidites of the Burntwood suite. In the hanging wall the trace of the McLeod Road Thrust cuts up the volcanic sequence progressively to the northwest in a step like manner. Thus the McLeod Road Thrust is in structural discordance with the hanging wall volcanic rocks.

The Nor-Acme anticline and the Three Zone syncline are located in the hanging wall of the McLeod Road Thrust. These folds are spatially associated with variations in the angle of structural discordance between the trace of the McLeod Road Thrust and the lithological layering in the volcanic rock sequence. These two folds are interpreted to be rootless folds associated with the development of the McLeod Road Thrust. Rootless folds are generated by translation of a hanging wall block up a thrust with a staircase trajectory (Suppe 1983; Fig. 62) or smoothly curving trajectory (Cooper and Trayner 1985). In addition to this, the McLeod Road Thrust fault zone has characteristics of a brittle-ductile fault zone rather than that of a ductile shear zone. These brittle-ductile features and the crosscutting nature suggest that the McLeod Road Thrust post-dates the D_1/D_2 ductile deformation period. The McLeod Road Thrust fault is folded by the F_3 Threehouse syncline and so pre-dates the F_3 folding deformation. The Northern Canada fault, which has a brittle-ductile character, is interpreted to be an imbricate of the McLeod Road Thrust.

A number of other significant brittle-ductile structures also post-date the early D_1/D_2 deformational fabric and are spatially associated with the McLeod Road Thrust. These are the Howe Sound fault, No.3 Zone shear fracture and Boundary Zone fault.

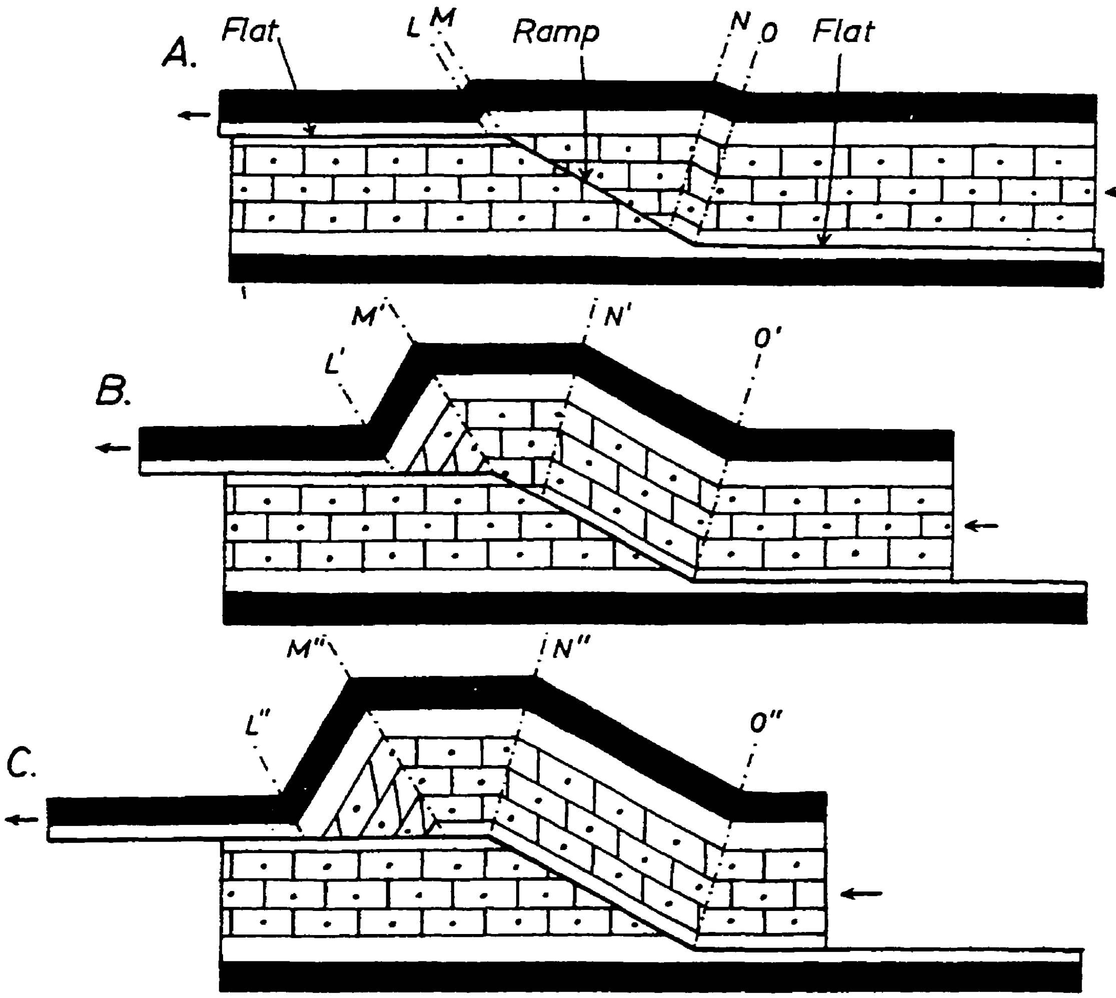

Figure 62: Development of rootless folds and their relationship to thrust faults. A, B and C illustrate successive geometric modifications of the thrust sheet with increasing displacement. The Three Zone syncline and Nor-Acme anticline are interpreted to be the equivalent of L[ii] and M[ii] respectively. (after Suppe 1983)

These brittle-ductile structures are often controlled and use planes of weakness in the previously deformed rock such as the S_1/S_2 foliation fabric and earlier ductile shears, for example the Boundary Zone fault. The Howe Sound fault is close to a felsic/mafic rock contact and overprints the S_1/S_2 foliation fabric. The Howe Sound fault describes a curviplanar structure, the Nor-Acme anticline, which plunges to the NE. The sigmoidal shear fracture at the No.3 Zone crosscuts the S_1/S_2 foliation fabric. This shear fracture has "s" asymmetry, plunges to the NE and is spatially associated with the Three Zone syncline. The Boundary Zone fault also crosscuts the S_1/S_2 foliation fabric and is superimposed on an earlier ductile shear. The "crack and seal" nature of the veins that infill these fractures are typical features associated with brittle-ductile deformation.

The Howe Sound fault, Boundary Zone fault and No.3 Zone shear fracture are all spatially associated with the McLeod Road Thrust fault and all have "s" symmetry. Thus the Howe Sound fault, Boundary Zone fault and No.3 Zone shear fracture are interpreted to be imbricate structures linked to the development and movement of the McLeod Road Thrust fault. In addition to this, the spatial association of the Howe Sound fault and No.3 Zone shear fracture with the Nor-acme anticline and the Three Zone syncline respectively suggest that the development of the imbricate structures are linked to the development of the rootless folds (Fig. 62).

All the large scale structures and many of the minor structures in the Snow Lake area all plunge moderately to the NE, thus the large scale outcrop pattern exposed on the approximate horizontal surface at Snow Lake can be regarded as an oblique section through these structures. A diagrammatical sketch of this oblique section, with the effects of the F_3 folding and minor faults removed, is shown in figure 63. The rootless folds,

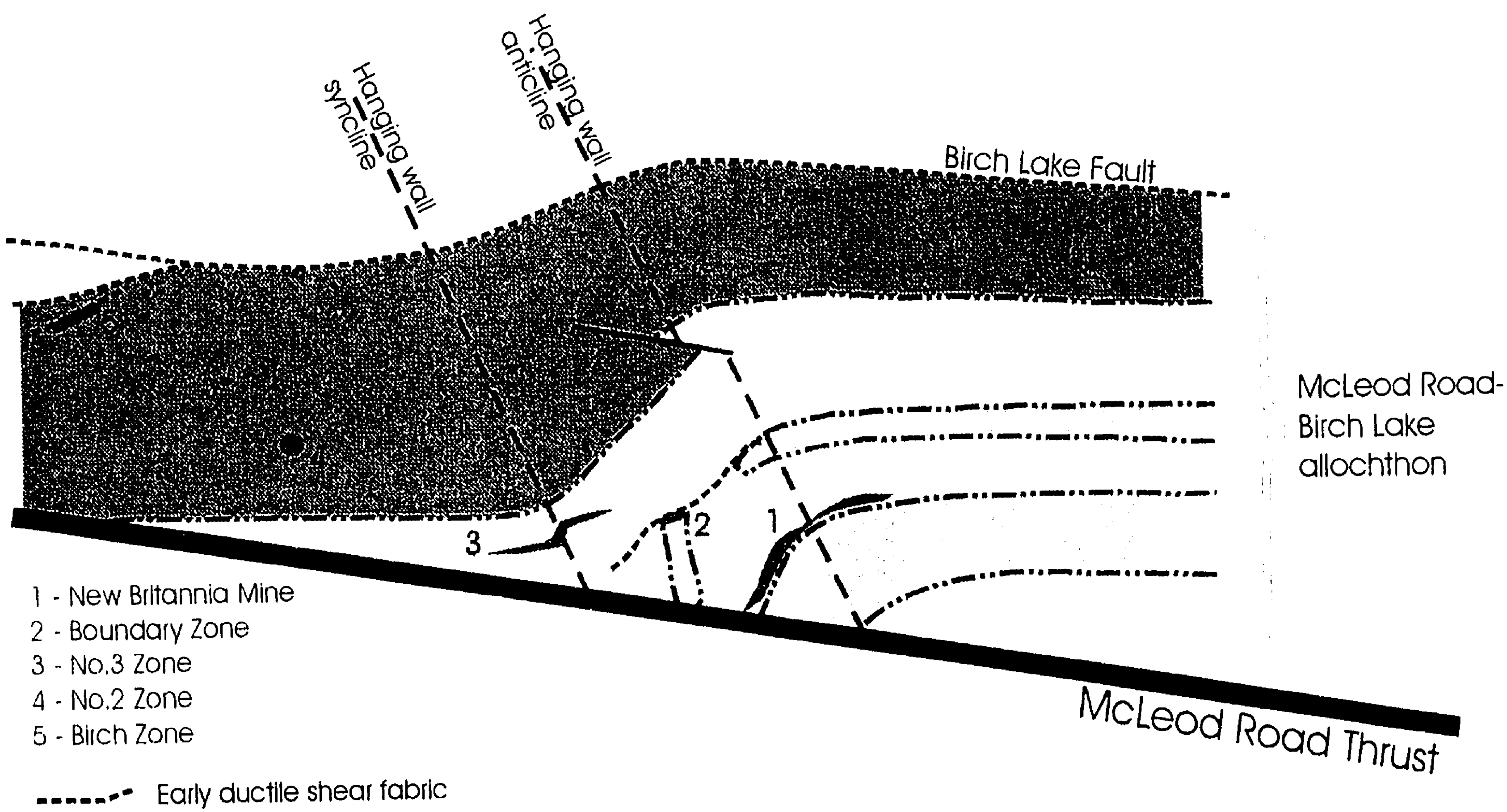

Figure 63: Diagrammatical sketch of the outcrop pattern in the Snow Lake area with the affects of the F_3 folding and minor faults removed. All the major structures plunge moderately to the NE and so this large-scale outcrop pattern is an oblique section through these structures.

constant "s" symmetry and step like nature of the McLeod Road Thrust suggest that this large-scale outcrop pattern is an oblique section through a ramp or sidewall structure of a thrust sheet. The direction of movement of the McLeod Road-Birch Lake allochthon during this ductile-brittle thrusting is not resolved due to the lack of decisive evidence.

The recrystallization evident in all the altered zones, the secondary biotite growth in the Birch Zone shear, poikilitic garnet growth at No.3 Zone, the replacement of actinolite with hornblende all suggest a prograde metamorphic event which post-dates the mineralization and the early D_1/D_2 penetrative fabric. The hornblende overgrowth and secondary biotite are orientated almost perpendicular to the S_1/S_2 foliation fabric suggesting that the growth of these minerals is synchronous to a compressive deformational event with the principle compressive stress approximately perpendicular to those that formed the early S_1/S_2 foliation fabric. This would be consistent with a regional prograde metamorphic event accompanying the F_3 folding of the Threehouse syncline. The radiating sillimanite growth indicates a late heating event during which pressure conditions were static. There is considerable post-metamorphic brittle deformation evident that resulted in many features such as tension gashes infilled with the barren milky white quartz, and the reactivation of the earlier shears and faults.

7.3 GOLD MINERALIZATION

The gold mineralization is primarily structurally controlled and occurs within and immediately adjacent to shear zones, fault zones and shear fractures that have been discussed in the above section and in chapter 4. The gold mineralization consists of the simple to complex quartz-carbonate vein systems and associated alteration. The gold occurs as fine dissemination's in the quartz-carbonate veins and in the immediately adjacent altered wall rocks. Visible gold is rare but does occur at No.3 Zone and in increasing amounts in the deeper levels of the New Britannia Mine. The host rocks of the gold mineralization is predominately mafic volcanic rocks, with occasional exceptions such as the Boundary Zone. Invariably associated with the gold mineralization are arsenopyrite and an intense alteration of the host rocks. The arsenopyrite commonly occurs as fine acicular needles, but also occurs locally as coarse acicular needles, anhedral grains or "blebs" and as thin stringer veins. The higher gold values tend to be associated with arsenopyrite where it occurs as fine acicular needles, especially where these fine arsenopyrite needles have a mesh or felt like appearance.

The alteration of the host rocks associated with the gold mineralization is consistently an intense silicification, carbonatization, albitization and biotitization. The typical mineralogical composition of altered and mineralized mafic wallrock is actinolite, biotite, albite, quartz, calcite, and minor sulphides (Figs. 22, 33 & 41). The biotite in the altered wall rock of the mineralized zones is formed by the replacement of amphibole and is a dark reddish brown colour. The degree of biotitization is variable. The quartz in the alteration zones has a sugary texture. The sulphide minerals that are associated with the gold mineralization are pyrite, pyrrhotite, (generally < 1% each) and in particular arsenopyrite (1-5 %). In thin section the arsenopyrite, and presumably the gold, is spatially associated with the biotitic alteration in the rock (Figs. 33 & 41).

7.4 TIMING OF THE GOLD MINERALIZATION

To constrain the timing of the gold mineralization it is necessary to look at the relative timing and relationships between the different structural features associated with the gold mineralization. The gold mineralization at the Birch Zone is associated with a ductile mylonitic shear zone that crosscut the early S_1/S_2 foliation fabric at a low angle. The character and style of this shear indicates it is an early D_1/D_2 shear. The nature of the gold mineralization hosted within this shear consistent with the gold mineralization being coeval with the development of the shear. This zone records the earliest gold mineralization of the volcanic sequence. Post-dating and crosscutting the D_1/D_2 structures are a number of brittle-ductile structures, such as the Howe Sound fault and No.3 Zone shear fracture. The gold mineralization of these imbricate structures is consistent with hydrothermal fluids remobilizing gold from earlier mineralized ductile shears, such as the Birch Zone, and being deposited into these later dilatational structures during the initial stages of their development.

A rock sample (sample # N307) taken from the No.3 Zone shows inclusions of acicular arsenopyrite crystals in a sub-euhedral poikilitic garnet (Fig. 52). The gold content of this sample is very low, being only 60 ppb, however it suggests that gold mineralization occurred prior to the metamorphic growth of the garnet as in this area arsenopyrite is invariably associated with gold mineralization. In addition to this, all the mineralized zones and associated altered wall rocks show evidence of recrystallization as a result of metamorphism (Figs. 22, 56, 57, 39, 33 & 41). This further constrains the timing of the gold mineralization to pre-date the last metamorphic event.

CHAPTER 8

REGIONAL CONSIDERATIONS

8.1 STRUCTURE

Four deformational events, D_1-D_4, are now recognized in the Snow Lake region (Kraus and Williams 1994 & 1998 & Kraus and Menard 1996 & 1997). An interpreted north-south convergence during the forming Trans-Hudson Orogen resulted in the southwest movement of the Kisseynew sedimentary basin over the Flin Flon terrane. This is interpreted to have produced the first two phases of deformation during which isoclinal folding, related thrusting and tectonic imbrication of the major rock units occurred (Kraus and Williams 1994b & 1998, Kraus and Menard 1996, Connors 1996 & David *et al.* 1996). Kraus and Williams (1993) considered the F_1 and F_2 folds to be indistinguishable in terms of their style or orientation and are indicated by the presence of both S- and Z-shaped minor folds on the same limb of macroscopic F_1 structures. D_1 produced transposed, tight to isoclinal folds at all scales at ca. 1.842-1.835 Ga (Kraus and Williams 1993 & 1994b, David *et al.* 1996, & Kraus and Menard 1997). The F_1 fold axes have a moderate to steep plunge mainly to the northeast and an axial plane that is inclined at moderate to steep angle towards the north at Snow Lake (Kraus and Williams 1993). An S_1 foliation, defined by the alignment of biotite and amphibole is well developed axial planar to F_1 folds in Amisk rocks (Kraus and Williams 1993). Kraus and Menard (1997), and Kraus and Williams (1998), interpreted that during F_2 the tectono-stratigraphy was folded into southwest-verging tight to isoclinal curviplanar structures, e.g. McLeod Lake fold. These F_2 fold axes have a moderate to steep plunge, mainly to the northeast, with their axial planes inclined at moderate to steep angles towards the north at Snow Lake

(Kraus and Williams 1993 & Kraus and Menard 1997). This regional fabric and deformation during D_1 and D_2 is consistent with the penetrative S_1/S_2 fabric and ductile shears described in the McLeod Road-Birch Lake allochthon.

There are three major faults in the Snow Lake area which are of regional significance, these being the McLeod Road Thrust, Snow Lake and Birch Lake faults (Fig. 64). These faults interleave the different lithological units of the Snow Lake area on a regional scale. The McLeod Road Thrust and Snow Lake faults form a sub-parallel fault pair which coalesce east of Snow Lake (Fig. 64). Sandwiched in between these faults are the isoclinally folded pelites of the Burntwood suite (Fig. 64). To the northwest of Snow Lake, along the McLeod Road fault there is a triple junction that puts the Burntwood meta-pelites, the McLeod Road-Birch Lake meta-volcanic rocks and Missi meta-sedimentary rocks in contact with each other. Here, earlier work, (Russell 1957 & Froese and Moore 1980) interpreted the McLeod Road Thrust fault trace to turn very sharply and trend to the northeast as the contact between the meta-volcanic and Missi suite rocks. D. Schledewitz (1997 & 1998) however, interprets the McLeod Road Thrust to continue to the NW as the contact between the Missi and Burntwood rocks (Fig. 64). Schledewitz (1997 & 1998) also interprets that the McLeod Road Thrust has been cut by later faults and displaced such that very little of the original McLeod Road Thrust is left immediately north of the town of Snow Lake.

At Snow Lake, and potentially regionally, the McLeod Road Thrust is in structural concordance with the footwall sedimentary rocks. This statement is based on the presence of the garnetiferous rock unit in the footwall rocks adjacent to the McLeod Road Thrust fault. This garnetiferous rock unit is adjacent to the fault at the 3000 level

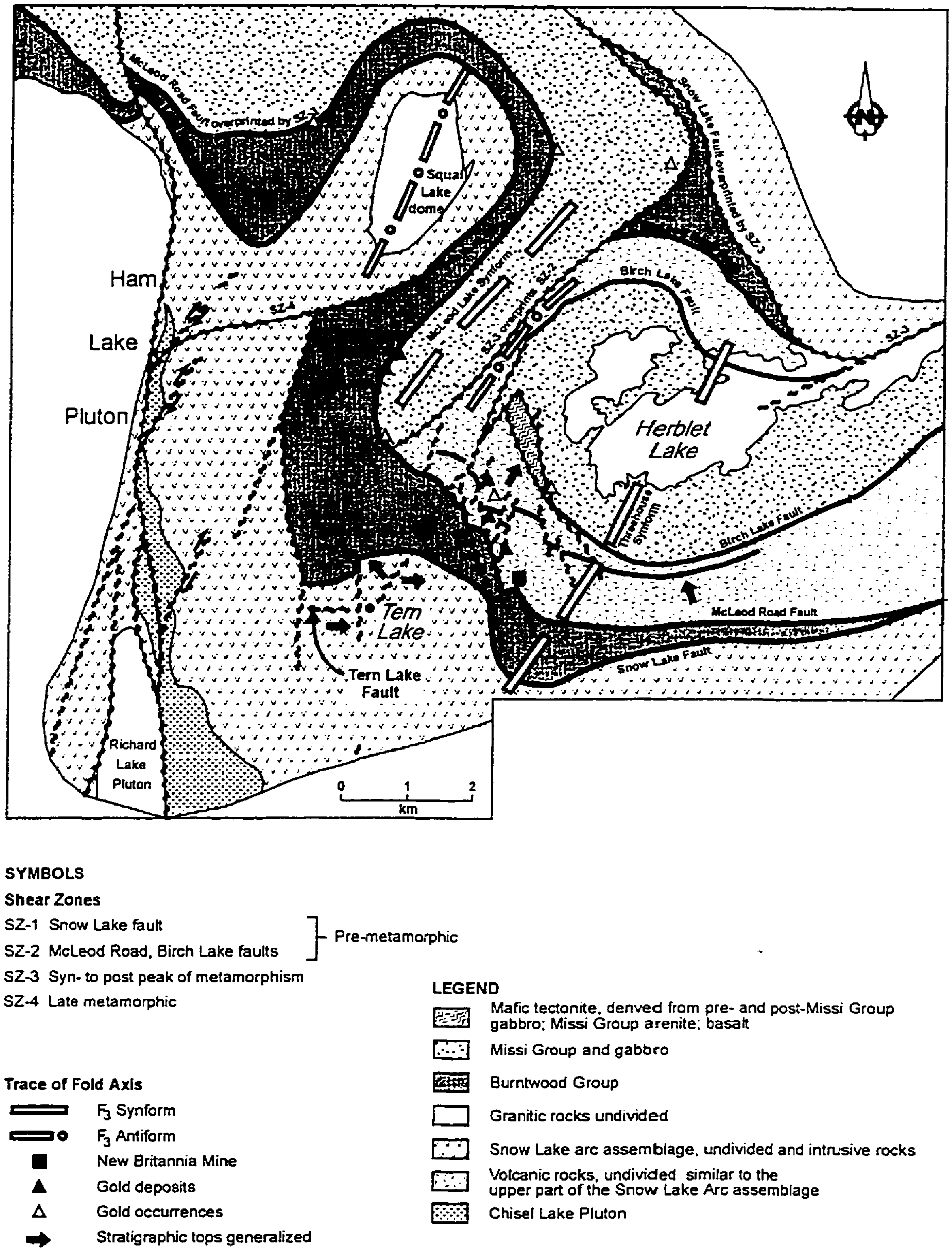

Figure 64: A simplified structural map of the Snow Lake area. This map shows the major tectonic assemblages and the reinterpreted fault and fold trends by D. Schledewitz (1998). The study area is within the volcanic rocks on the NW-limb of the Threehouse syncline.

and also outcrops approximately 1km directly south of the New Britannia Mine, where it has the same character and spatial association to the McLeod Road Thrust. On a regional scale, it has the same characteristics as Corley Lake member in the File Lake formation (Alan Bailes, personal communication, July 1998). The Corley Lake member has been mapped over a considerable strike length and at the north end of Squall Lake it is near the top of the File Lake formation, i.e. not far from the unconformable contact between the File Lake formation and the overlying Missi suite (Bailes 1980). Lineaments in aerial photos and unpublished satellite imagery indicate that the McLeod Road Thrust in the Snow Lake area, and the unconformable contact between the Burntwood and Missi suites in Squall Lake and File Lake areas form a continuous structural feature. This continuous structural feature is interpreted to be the basal thrust plane of the McLeod Road Thrust. The structural concordance of the Corley Lake member with the basal thrust plane of the McLeod Road Thrust is consistent with this fault being a low angle thrust which is using particular bedding planes within the Burntwood pelites as a slip surface.

The Snow Lake fault is very poorly exposed and is mainly inferred from regional mapping (Kraus and Williams 1993). It forms the contact between the Snow Lake arc assemblage meta-volcanic rocks to the south and the Burntwood meta-pelites to the north. It contains synkinematic carbonate veins and has lineations plunging to the northeast (Kraus and Williams 1993 & 1994a). Kraus and Williams (1994a) interpret the Snow Lake fault to be older than the McLeod Road Thrust and to have been overridden by the McLeod Road Thrust at Snow Lake thereby leading to the disappearance of the Burntwood meta-pelites (Fig. 64).

The Birch Lake fault runs sub-parallel to the McLeod Road Thrust and forms the contact between the inferred older meta-volcanic rocks and the unconformably overlying rocks of the younger Missi suite (Fig. 64). The Birch Lake fault is interpreted to be folded by F_3 and F_4 (Kraus and Williams 1994a).

F_3 folding is interpreted to have been produced during a broadly east-west shortening at ca. 1.8 Ga (Connors 1996 & Kraus and Williams 1998). This produced the large scale, open too tight, upright folds such as the Threehouse syncline, which plunge to the north- northeast (Fig. 64; Kraus and Menard 1997, Kraus and Williams 1998 & Schledewitz 1998). The Threehouse syncline controls the geological outcrop-pattern to a large degree in the Snow Lake area (Fig. 64). F_1, F_2 and F_3 folds are coaxial, with F_3 folds having axial-planes that are oblique to F_1/F_2 axial-planes (Kraus and Williams 1993). F_3 folds are interpreted to refold F_1/F_2 axial planes, F_2 shears and deform F_2 porphyroblasts (Kraus and Williams 1993).

F_4 produced east-west trending cross folds north of Snow Lake which overprint large scale F_3 folds resulting in dome and basin to mushroom interference patterns (Kraus and Menard 1997).

8.2 METAMORPHISM

The regional metamorphic grade in the Flin Flon-Snow Lake belt generally increases northwards from greenschist to amphibolite facies, towards the Kisseynew gneiss belt (Fig. 4; Harrison 1949, Froese and Gasparrini 1975, Bailes and McRitchie 1978, Froese and Moore 1980 & Bailes 1980a). The grade of metamorphism in the Snow Lake area is generally higher than elsewhere in the Flin Flon-Snow Lake belt. In the

Snow Lake region the isograds and metamorphic zones have been mapped based on the mineralogy of the pelitic rocks (Froese and Gasparrini 1975 & Froese and Moore 1980). Four separate metamorphic zones have been recognized these are the chlorite-biotite, chlorite-biotite-staurolite, biotite-staurolite-sillimanite and biotite-sillimanite-almandine zones (Froese and Gasparrini 1975 & Froese and Moore 1980).

Regional metamorphism began after the deposition of the Missi Group and during F_1 (Froese and Moore 1980). Peak metamorphic conditions are interpreted to have occurred at around 1.81 Ga (Machado and David 1992). Kraus and Williams (1995) established a peak metamorphic temperature of 536 ± 11^0 C with a pressure of approximately 4 kbar from a pelitic sample taken from the Snow Lake town site. This grade of metamorphism is consistent with the mineralogical assemblages observed in the volcanic rocks from the McLeod Lake allochthon.

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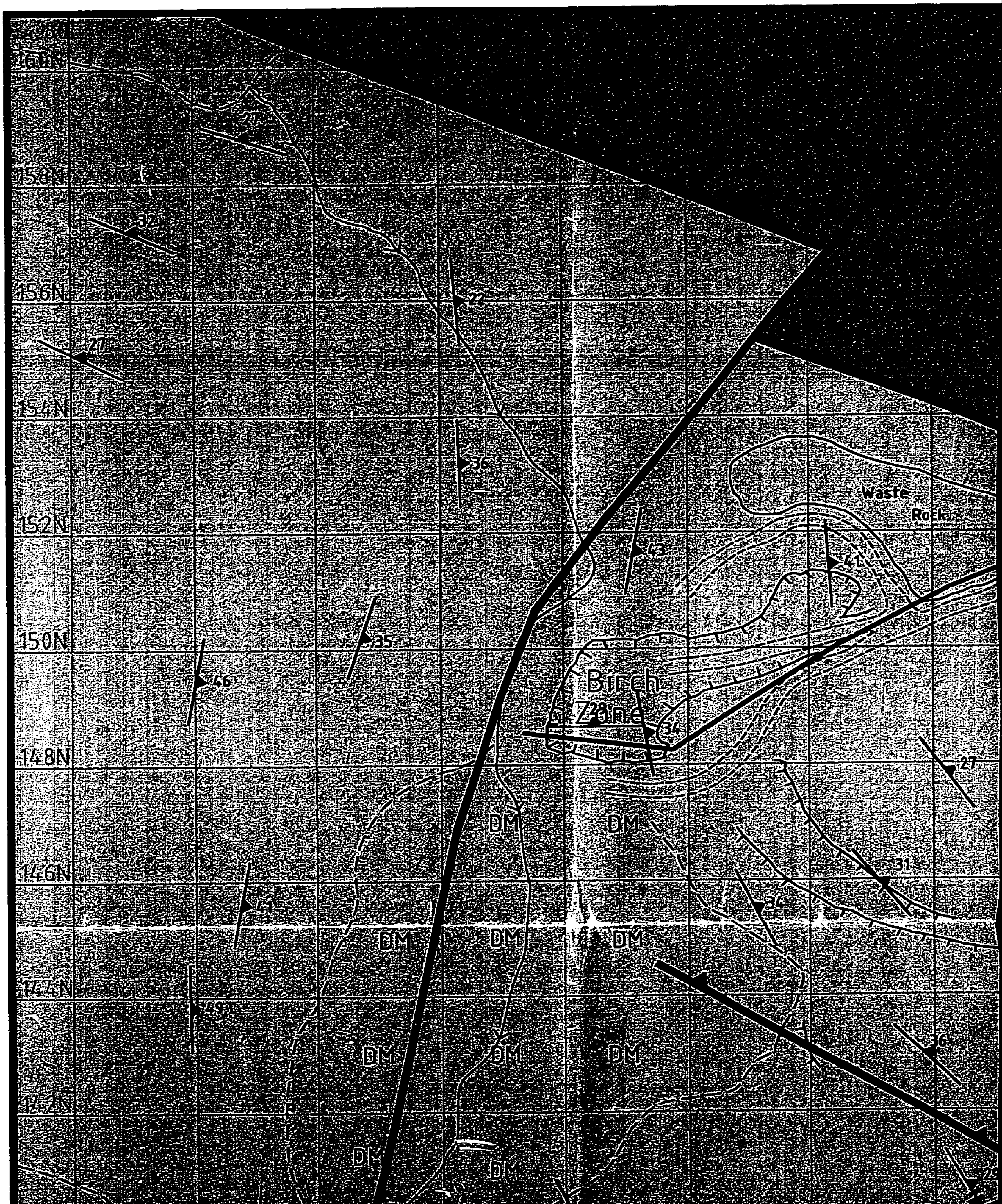
APPENDIX A - ROCK GEOCHEMISTRY

All data are in ppm.

		Birch Lake Basalts						Hornblendite		Pyx-Plag Gabbro		No.3 Zone mafic	
		SG/10	SG/13	SG/23	SG/24	SG/25	SG/26	SG/09	SG/12	SG/50	SG/63	SG/68	SG/69
Test Code													
IMT-101	La	2.51	1.82	2.72	2.92	2.57	2.15	1.57	2.34	1.88	1.91	2.34	1.91
IMT-101	Ce	8.07	6.50	8.18	8.59	8.41	6.98	4.34	5.88	4.32	4.61	5.42	4.54
IMT-101	Pr	1.38	1.20	1.34	1.40	1.42	1.20	0.60	0.79	0.59	0.66	0.77	0.62
IMT-101	Nd	7.35	6.68	7.07	7.39	7.84	6.48	2.84	3.53	2.94	3.27	3.77	2.92
IMT-101	Sm	2.50	2.37	2.34	2.48	2.64	2.20	0.79	0.93	0.94	1.08	1.06	0.86
IMT-101	Eu	0.91	0.94	0.91	0.92	1.03	0.73	0.34	0.34	0.45	0.51	0.37	0.35
IMT-101	Gd	3.39	3.06	3.19	3.15	3.44	2.92	0.95	0.91	1.20	1.39	1.37	1.06
IMT-101	Tb	0.62	0.58	0.56	0.61	0.62	0.55	0.17	0.16	0.22	0.27	0.27	0.19
IMT-101	Dy	4.14	3.82	3.75	3.87	3.98	3.47	1.06	0.99	1.44	1.72	1.70	1.22
IMT-101	Ho	0.97	0.88	0.89	0.90	0.92	0.81	0.24	0.23	0.32	0.40	0.37	0.28
IMT-101	Er	2.52	2.42	2.39	2.43	2.47	2.20	0.64	0.60	0.90	1.11	1.05	0.78
IMT-101	Tm	0.38	0.36	0.35	0.36	0.36	0.34	0.10	0.09	0.14	0.17	0.16	0.12
IMT-101	Yb	2.33	2.25	2.21	2.23	2.32	2.10	0.66	0.56	0.91	1.07	1.05	0.75
IMT-101	Lu	0.33	0.33	0.33	0.33	0.34	0.29	0.10	0.09	0.14	0.16	0.16	0.12
IMT-101	Rb	0.78	1.37	1.59	1.50	0.71	1.87	2.56	3.26	1.40	34.06	0.91	9.21
IMT-101	Sr	144.4	150.5	154.8	171.4	112.9	101.9	118.7	191.9	310.0	236.5	157.8	243.7
IMT-101	Nb	3.22	3.15	3.05	3.09	3.08	2.86	0.81	0.75	0.61	0.79	0.72	0.65
IMT-101	Cs	0.02	0.09	0.04	0.05	0.02	0.02	0.08	0.10	0.03	1.45	0.02	0.24
IMT-101	Hf	0.60	0.68	0.74	0.62	0.52	0.45	0.58	0.52	0.47	0.56	0.48	0.44
IMT-101	Ta	0.68	0.54	0.53	0.46	0.52	0.48	0.67	0.23	0.50	0.31	0.37	0.16
IMT-101	Th	0.20	0.19	0.21	0.21	0.20	0.18	0.39	0.36	0.24	0.31	0.25	0.25
IMT-101	U	0.12	0.07	0.06	0.07	0.07	0.06	0.18	0.18	0.18	0.19	0.44	0.17
IMT-101	Y	25.70	24.64	22.94	23.96	23.99	21.71	6.25	6.12	8.78	10.47	10.95	7.63
IAT-100	Al	71692	69703	69615	69256	70424	66936	51088	49785	73099	71376	71716	75246
IAT-100	Ba	49	44	54	57	32	65	399	104	50	514	33	80
IAT-100	Ca	70366	71181	77640	76144	73953	75940	66803	85831	74214	64297	86704	110732
IAT-100	Cd	17	23	21	22	16	20	21	21	21	28	11	22
IAT-100	Co	54	52	48	47	48	47	55	52	54	60	43	42
IAT-100	Cr	158	148	141	138	153	139	573	567	150	187	117	72
IAT-100	Cu	9	123	108	127	185	41	0	61	145	132	116	125
IAT-100	Fe	63559	85962	85096	83371	64675	74151	78578	79091	83246	105873	43766	83111
IAT-100	K	1283	1575	1264	1453	1272	1779	2024	2841	2228	12451	1046	4124
IAT-100	Li	19	22	11	9	20	13	11	20	13	34	18	29
IAT-100	Mg	37884	40390	40045	40657	41868	42874	61014	74133	52489	46163	24908	30494
IAT-100	Mn	1157	1311	1296	1325	976	1307	1284	1422	1722	1974	1127	1205
IAT-100	Na	17369	13707	11707	11808	15712	13249	15439	4668	21950	14212	17378	10963
IAT-100	Ni	108	108	101	101	104	95	103	110	41	45	36	35
IAT-100	P	745	715	694	689	696	666	621	626	714	756	761	701
IAT-100	S	224	254	271	247	252	241	222	290	249	212	261	337
IAT-100	Sc	39	39	38	38	39	37	65	63	47	55	55	43
IAT-100	Ti	5625	5551	5408	5401	5398	5007	1664	1554	2159	3143	2333	2054
IAT-100	V	318	321	315	315	318	307	305	265	329	398	345	316
IAT-100	Zn	92	99	101	97	88	92	89	72	85	129	55	84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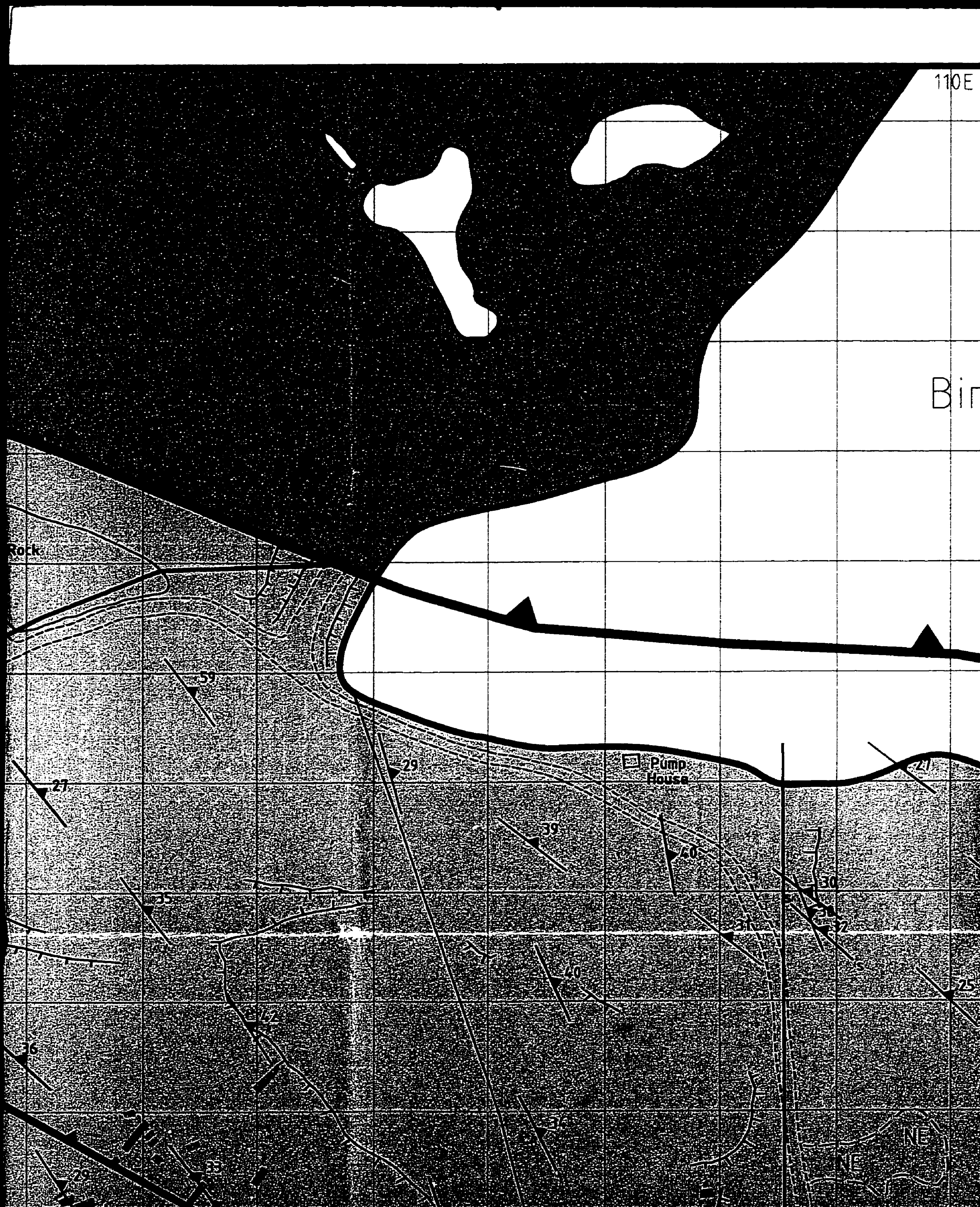
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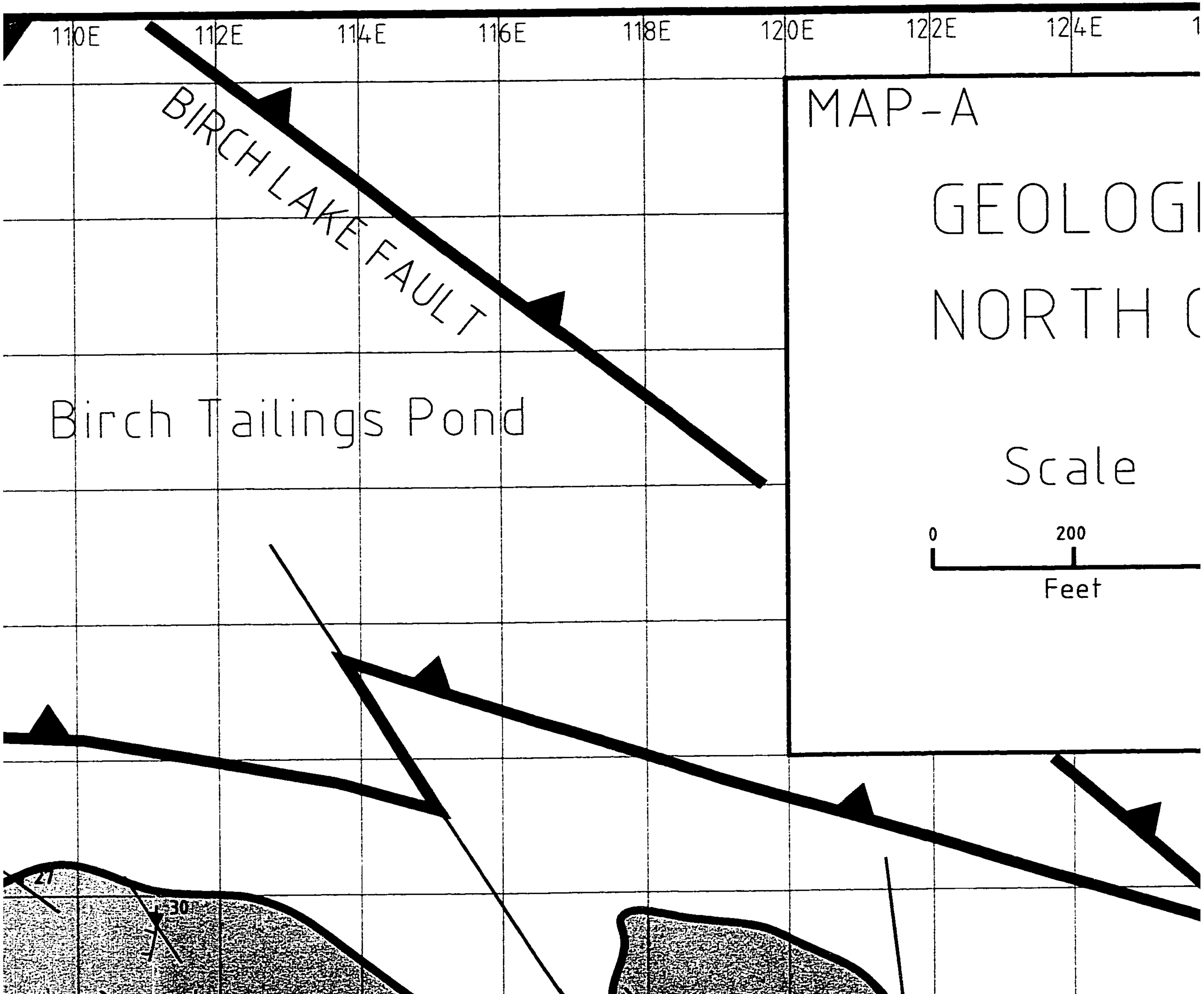
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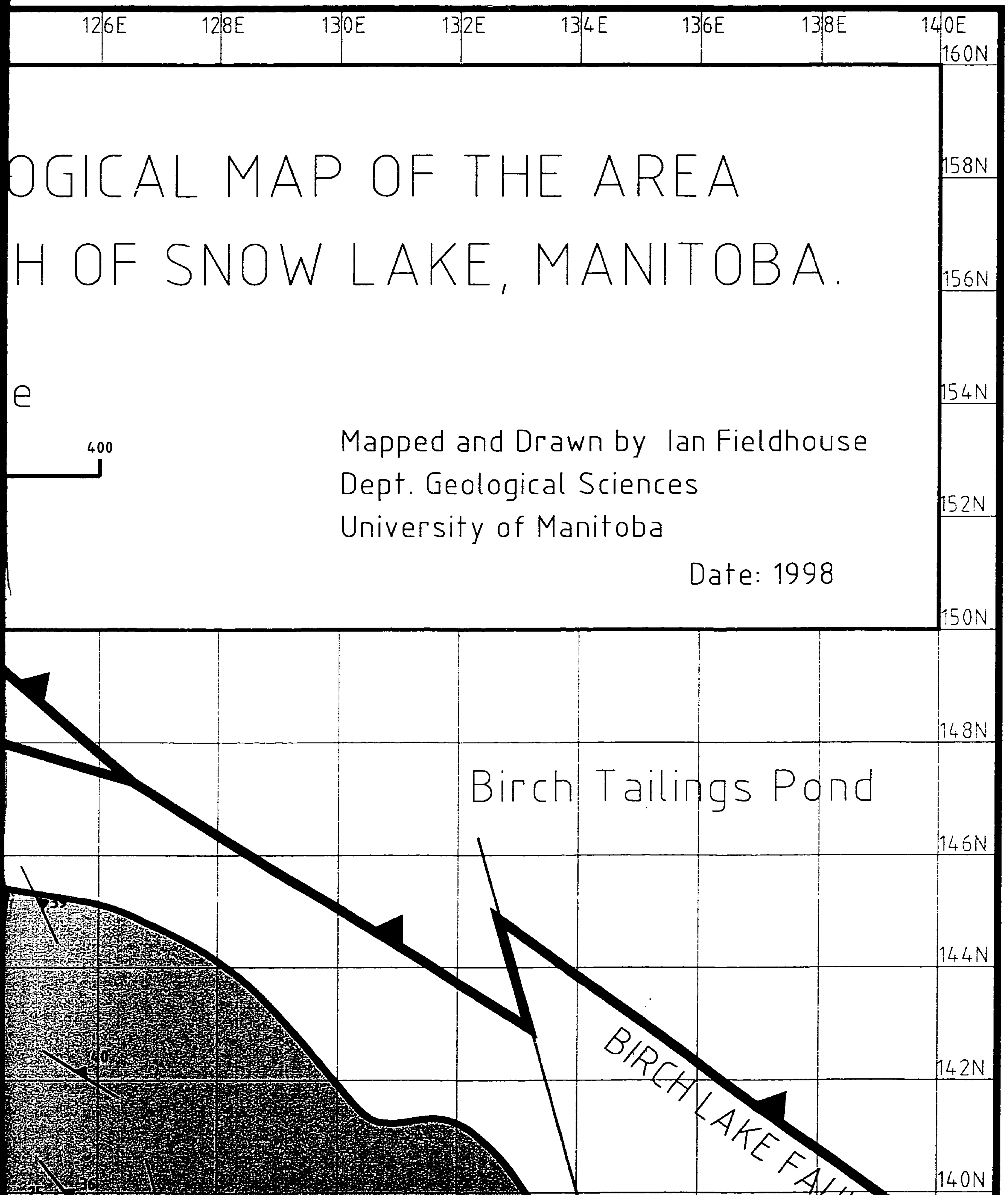
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Dept. Geological Sciences
University of Manitoba
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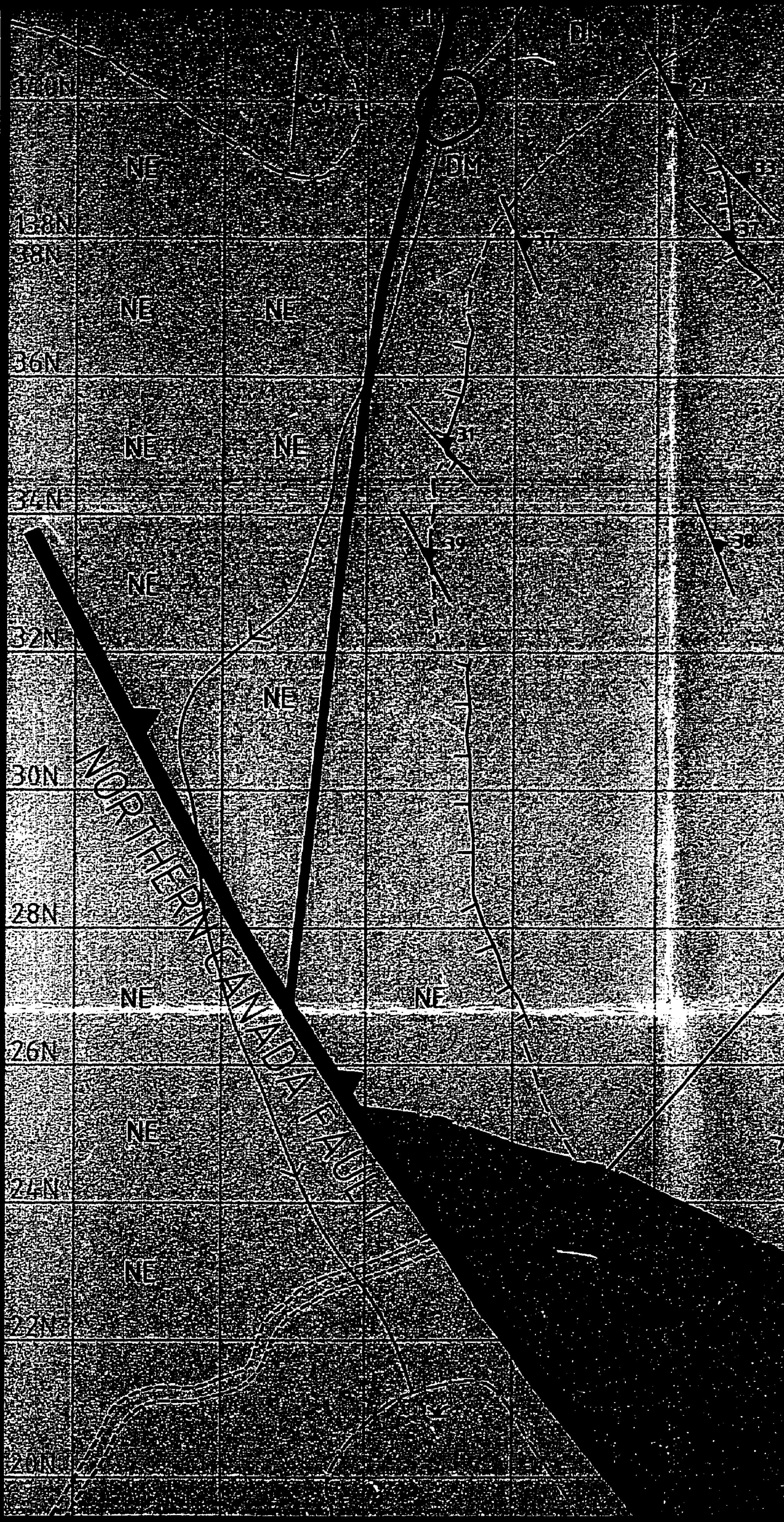
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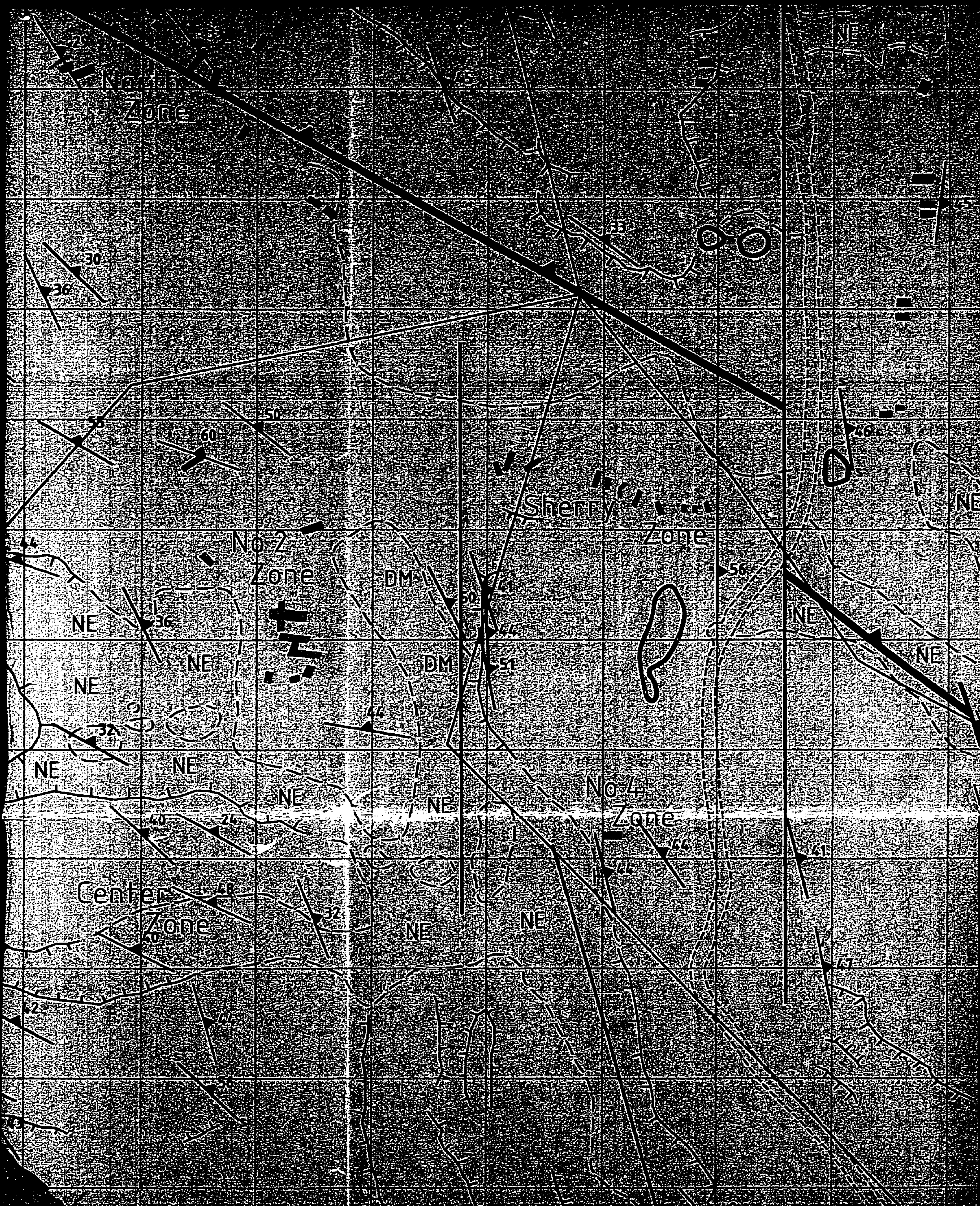
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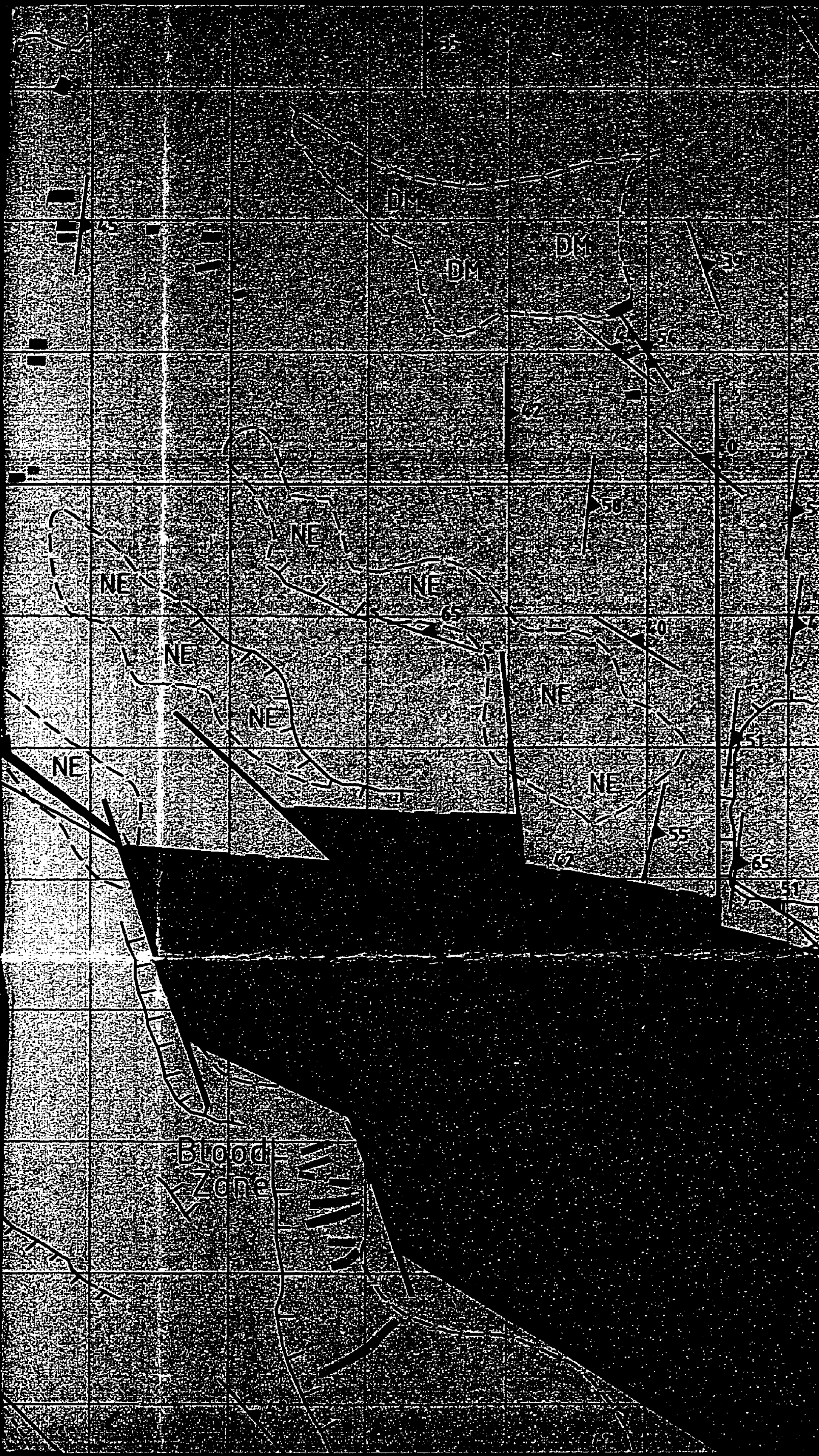
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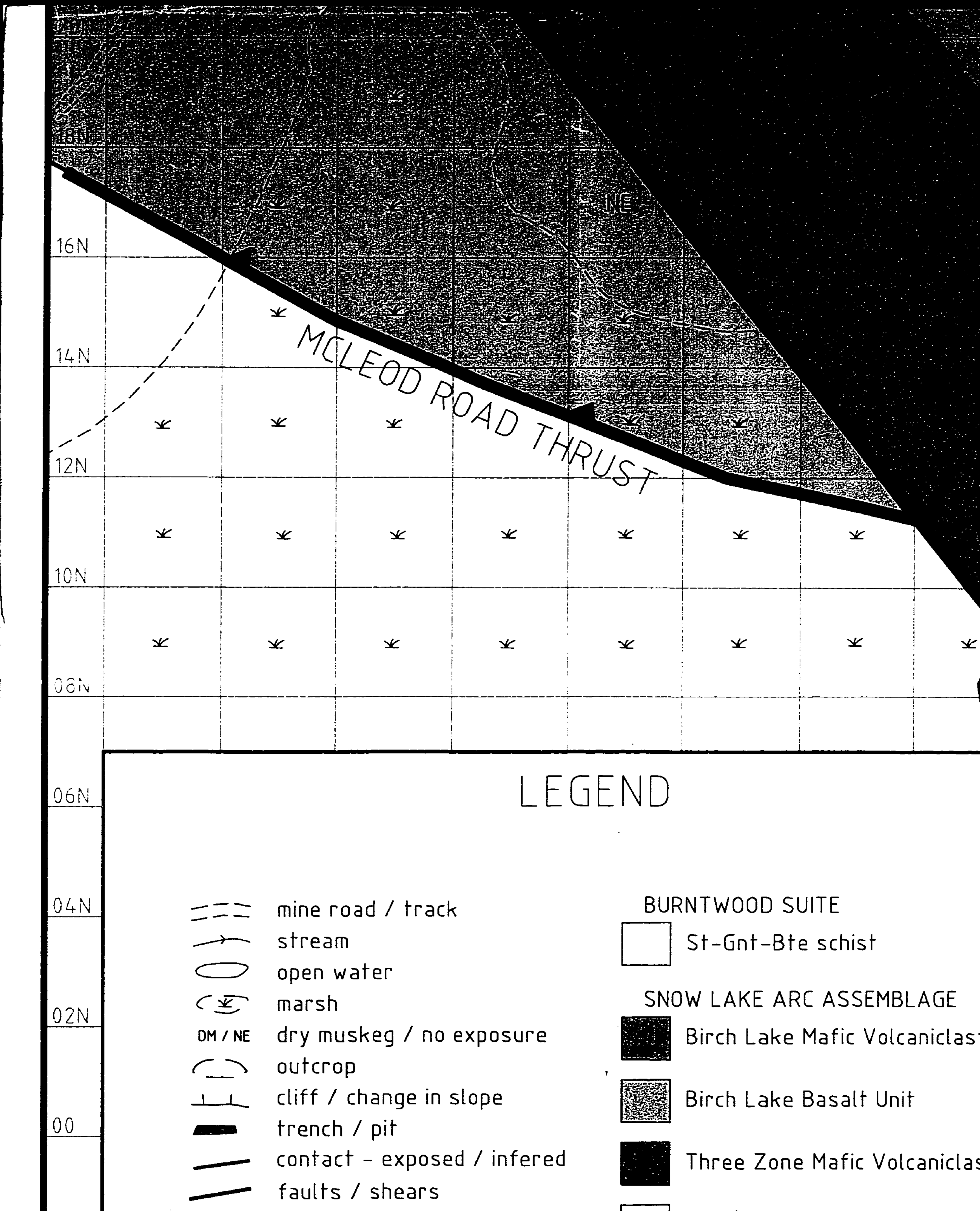

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MCLEOD ROAD THRUST
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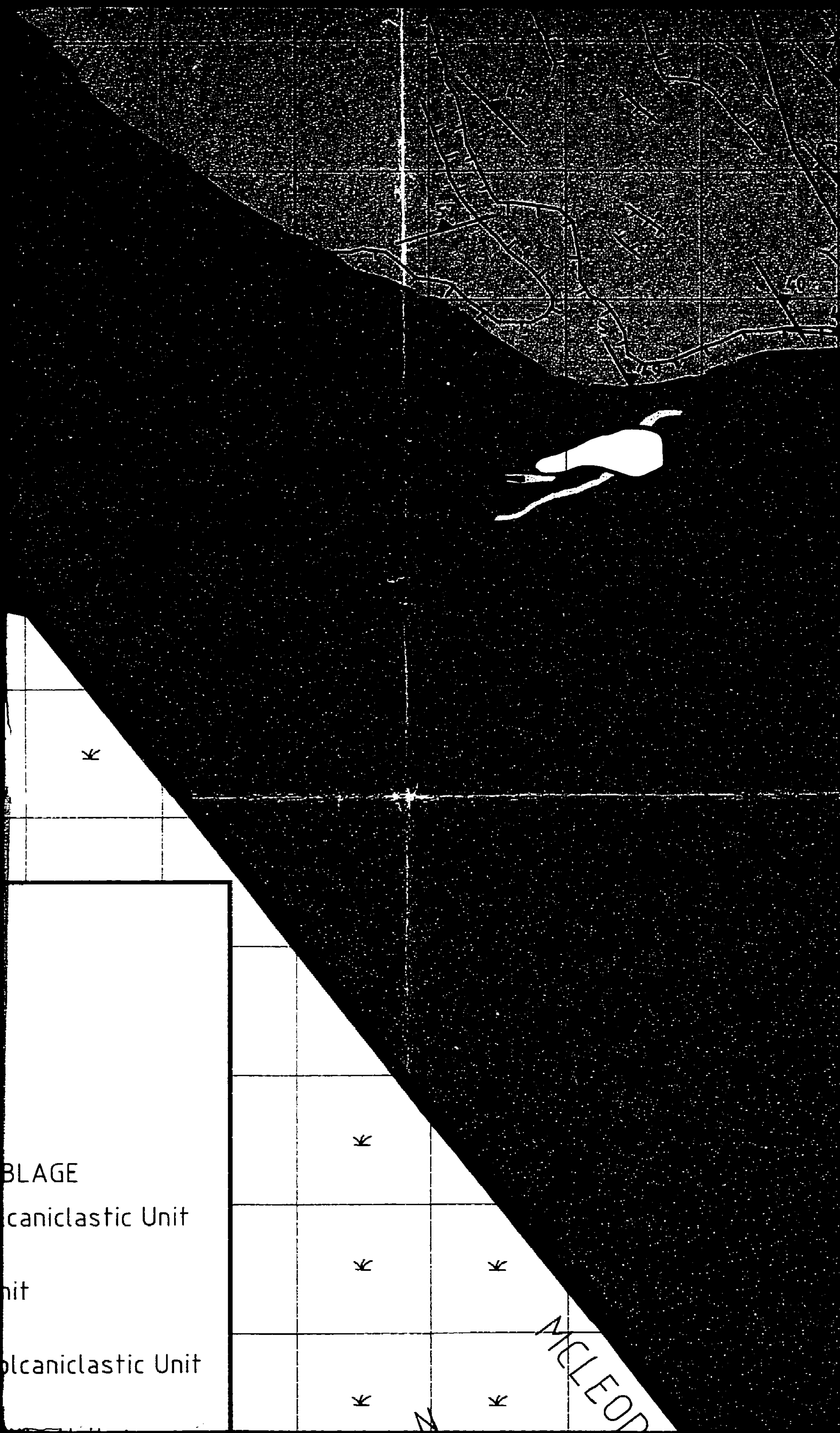
cliff / change in slope
trench / pit
contact - exposed / infered
faults / shears
BURNTWOOD SUITE
St-Gnt-Bte schist
SNOW LAKE ARC ASSEMBLAGE
Birch Lake Mafic Volcaniclas
Birch Lake Basalt Unit
Three Zone Mafic Volcaniclas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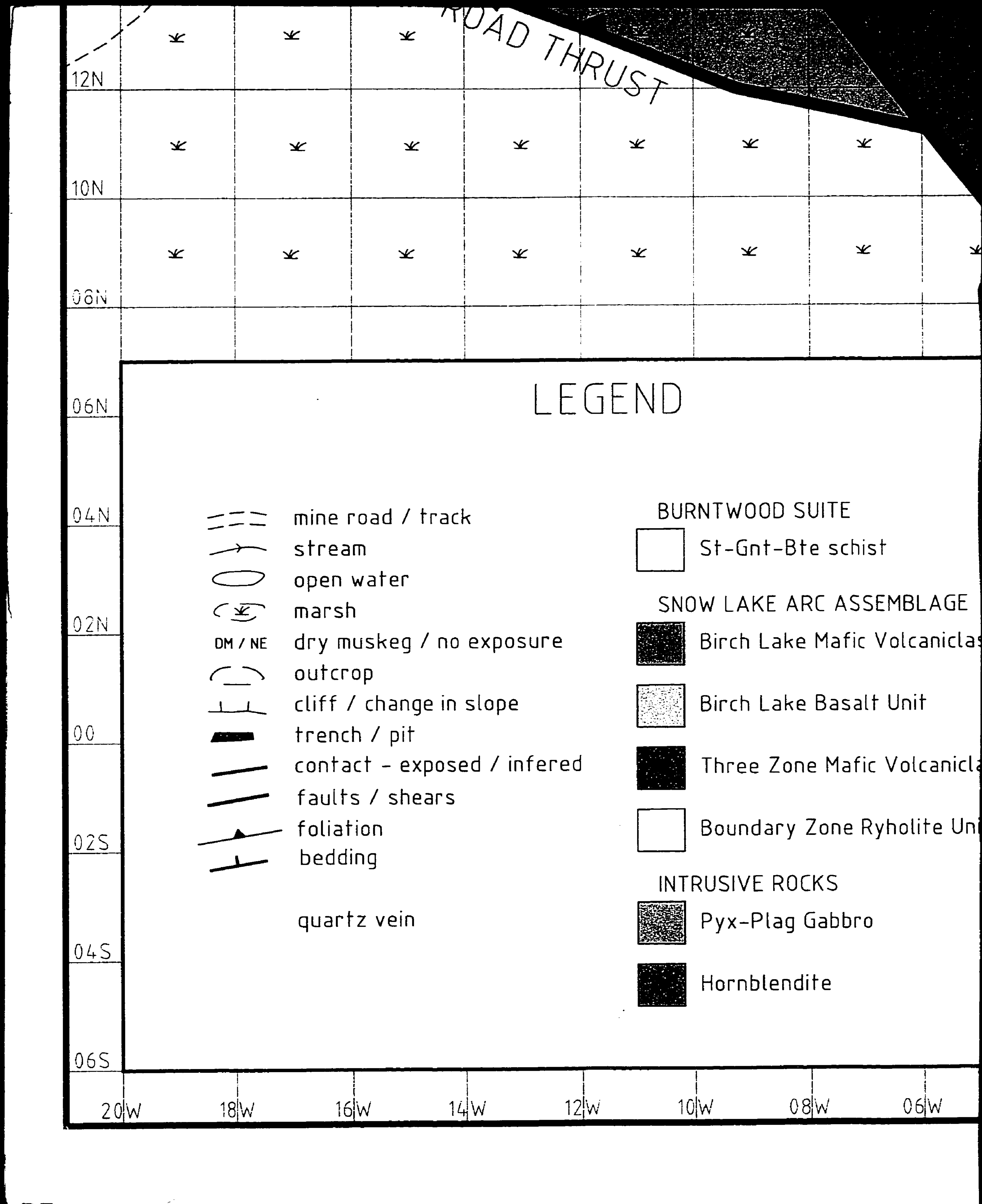
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LEGEND
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stream
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faults / shears
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quartz vein
BURNTWOOD SUITE
St-Gnt-Bte schist
SNOW LAKE ARC ASSEMBLAGE
Birch Lake Mafic Volcanicla
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Three Zone Mafic Volcanicla
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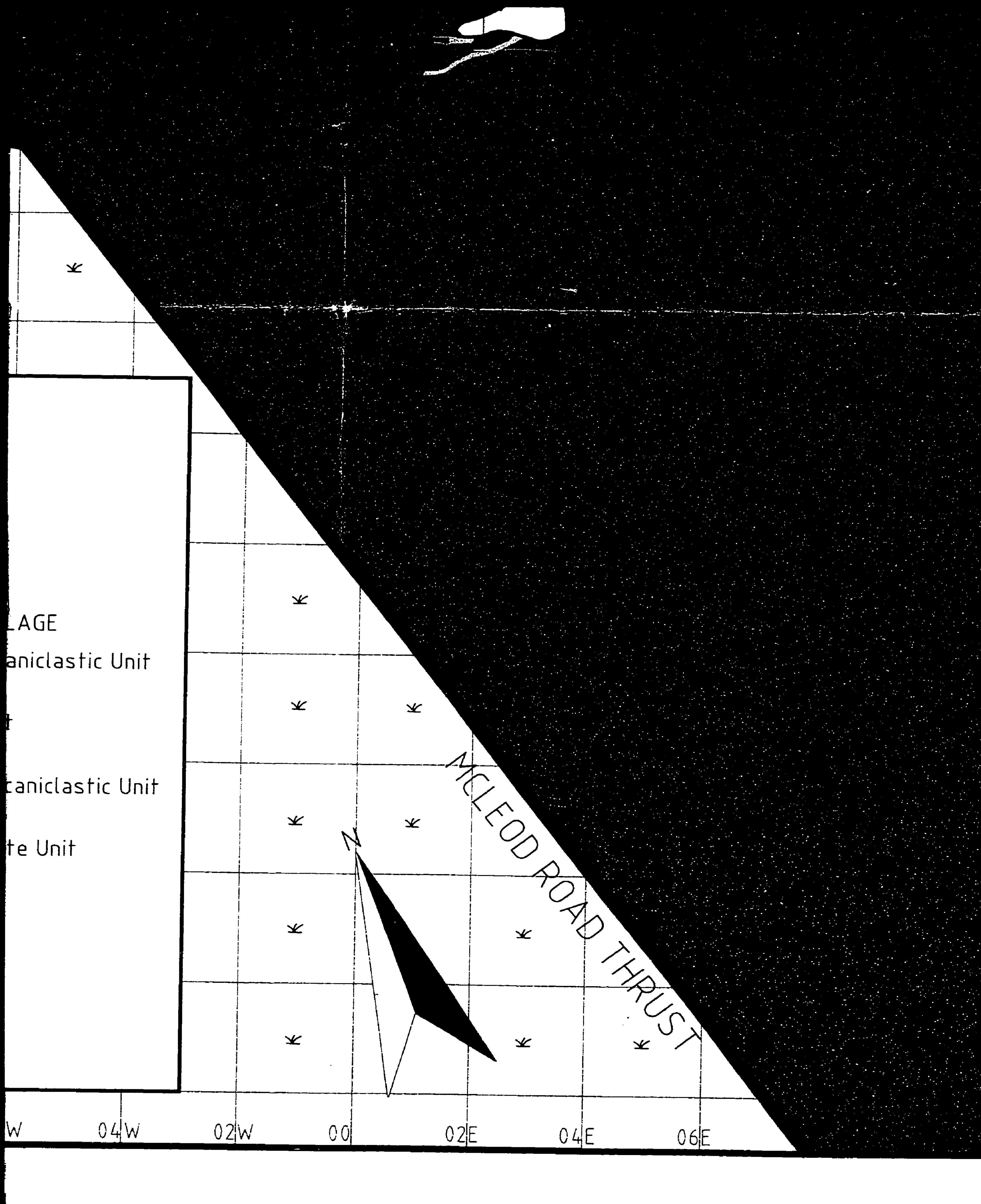
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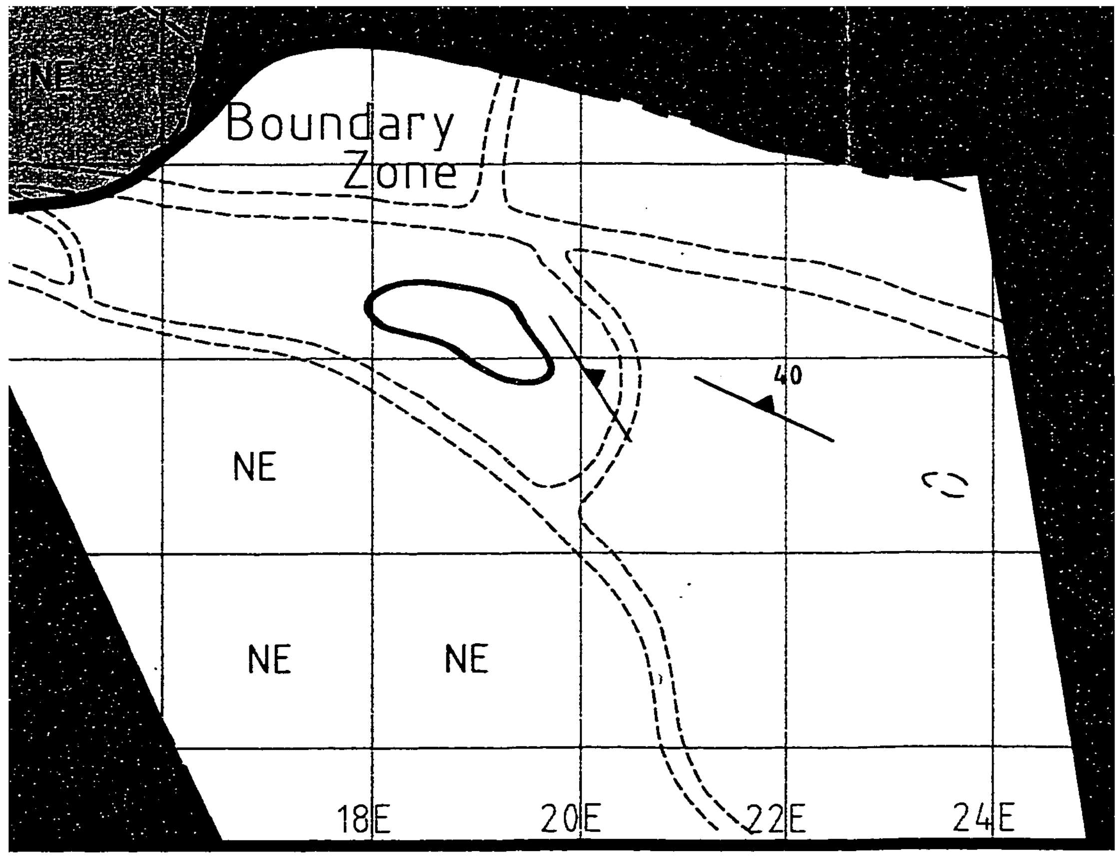
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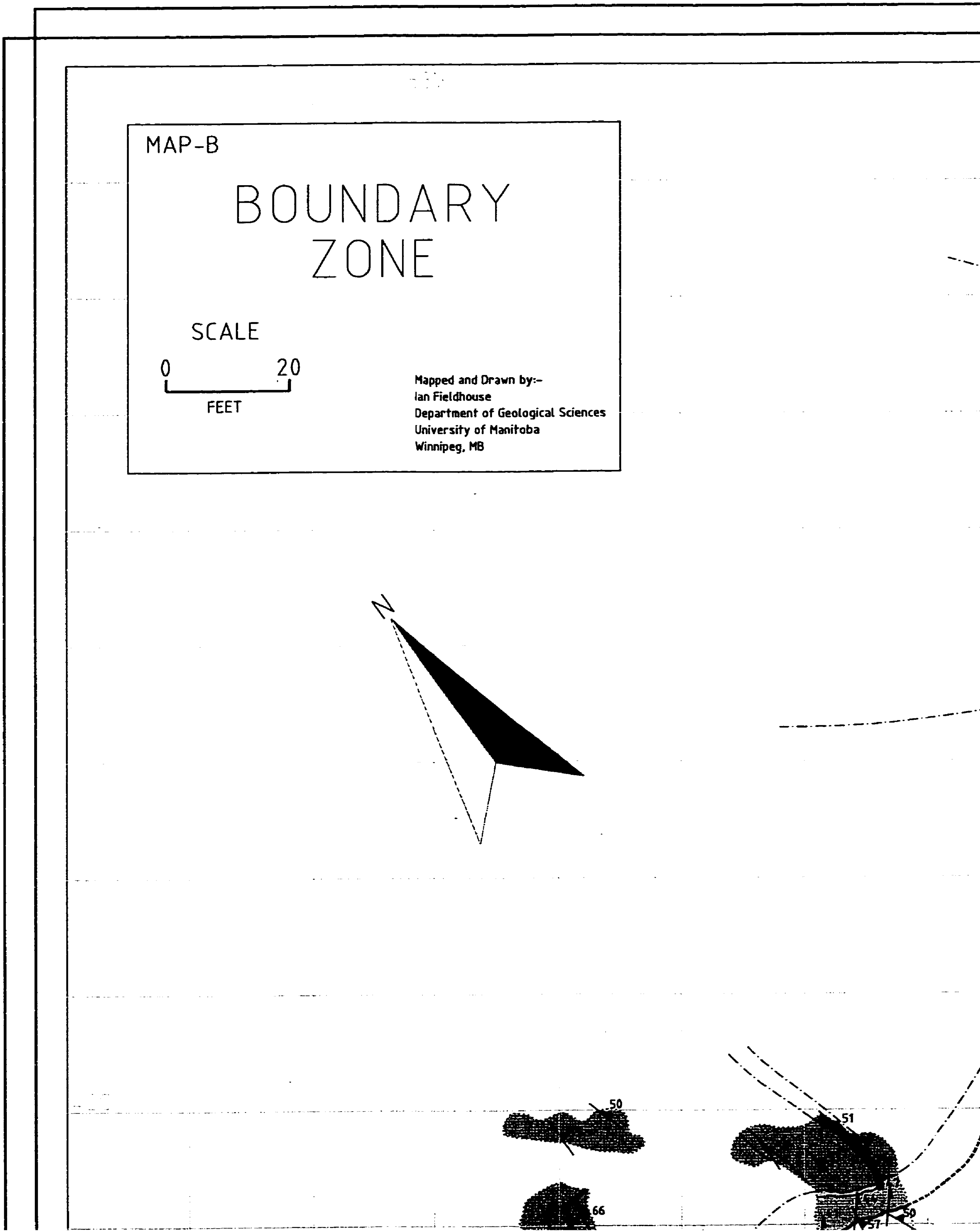
NOTE TO USERS

Oversize maps and charts are microfilmed in sections in the following manner:

LEFT TO RIGHT, TOP TO BOTTOM, WITH SMALL OVERLAPS



MAP-B
BOUNDARY ZONE
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Mapped and Drawn by:-
Ian Fieldhouse
Department of Geological Sciences
University of Manitoba
Winnipeg, MB
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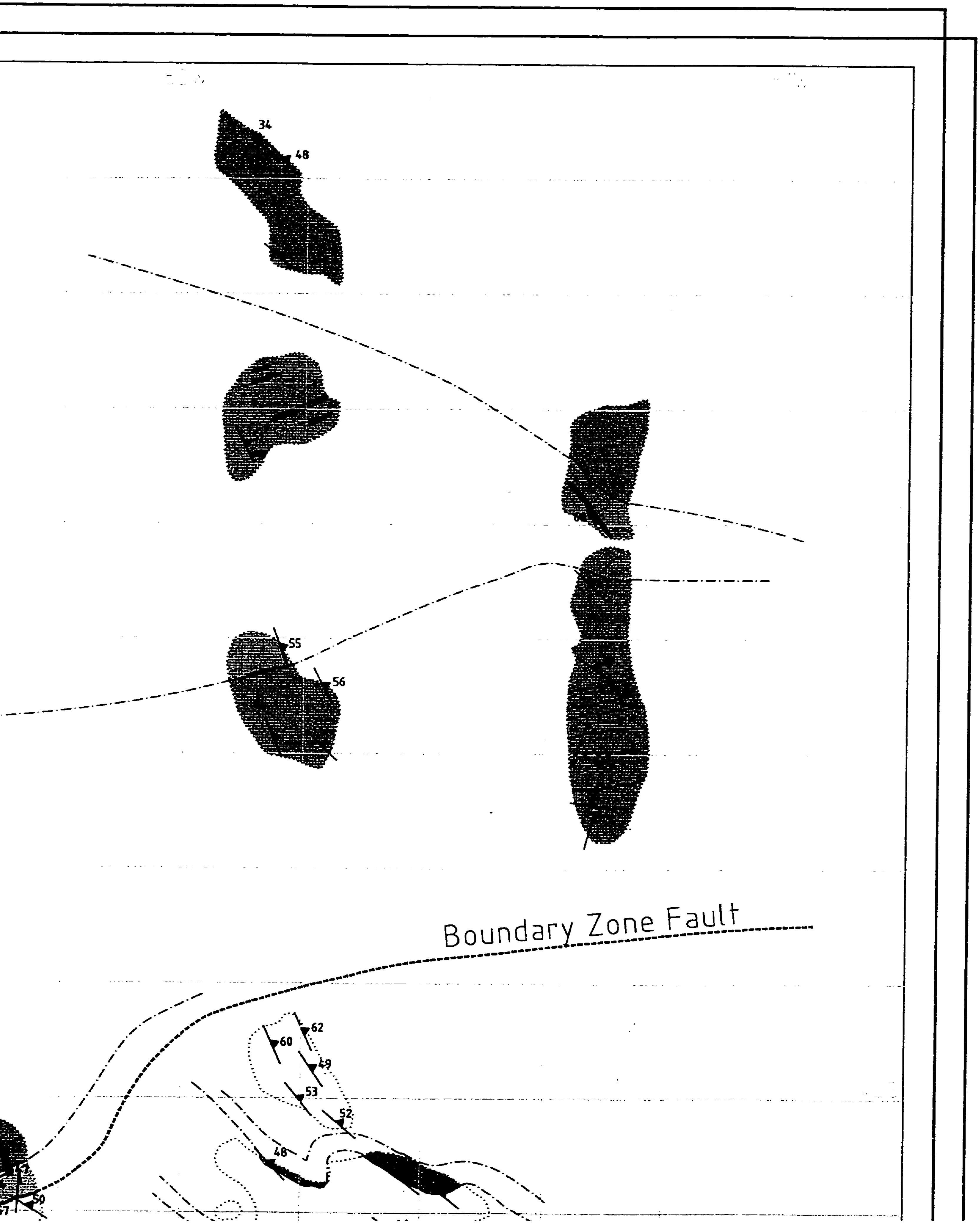
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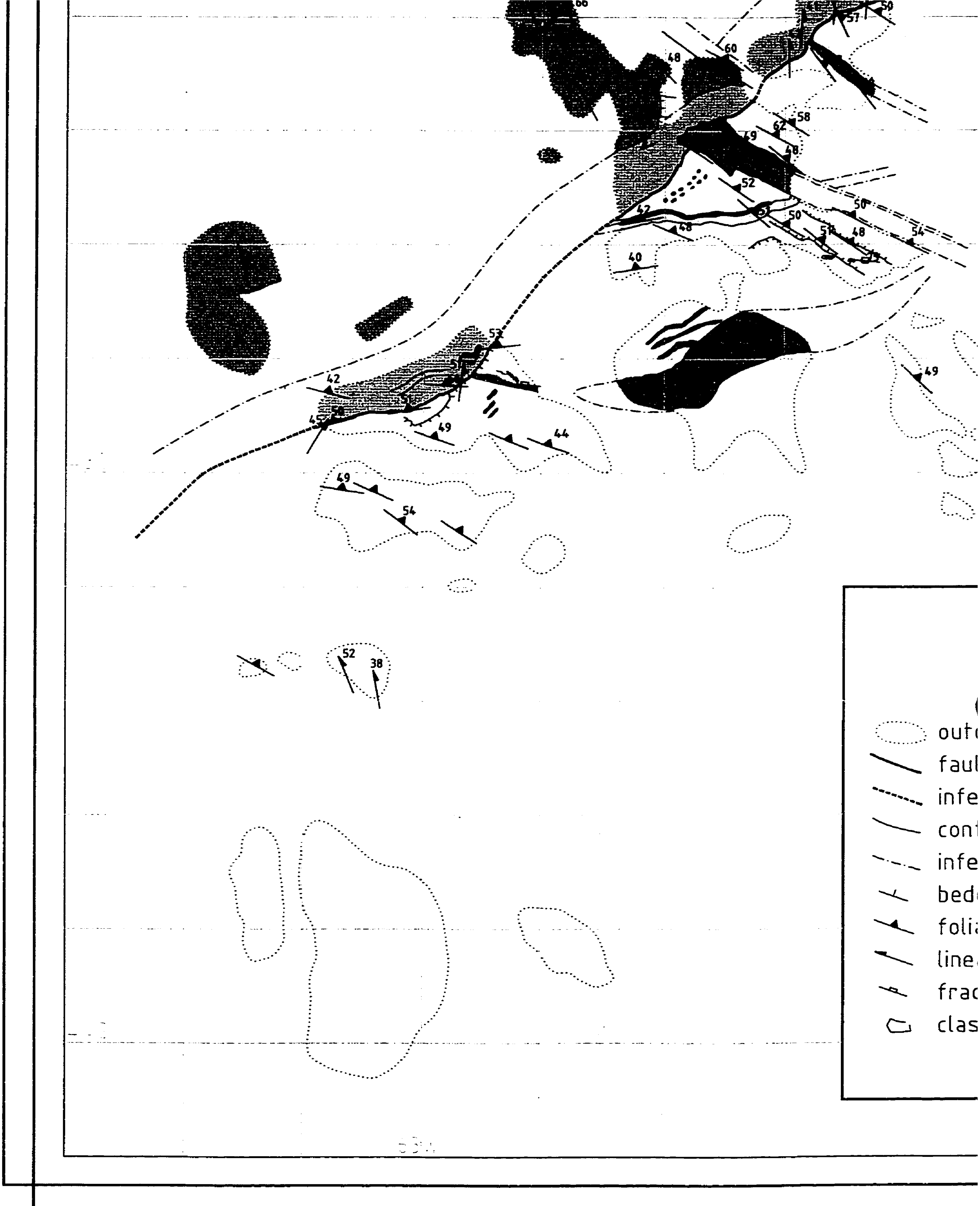

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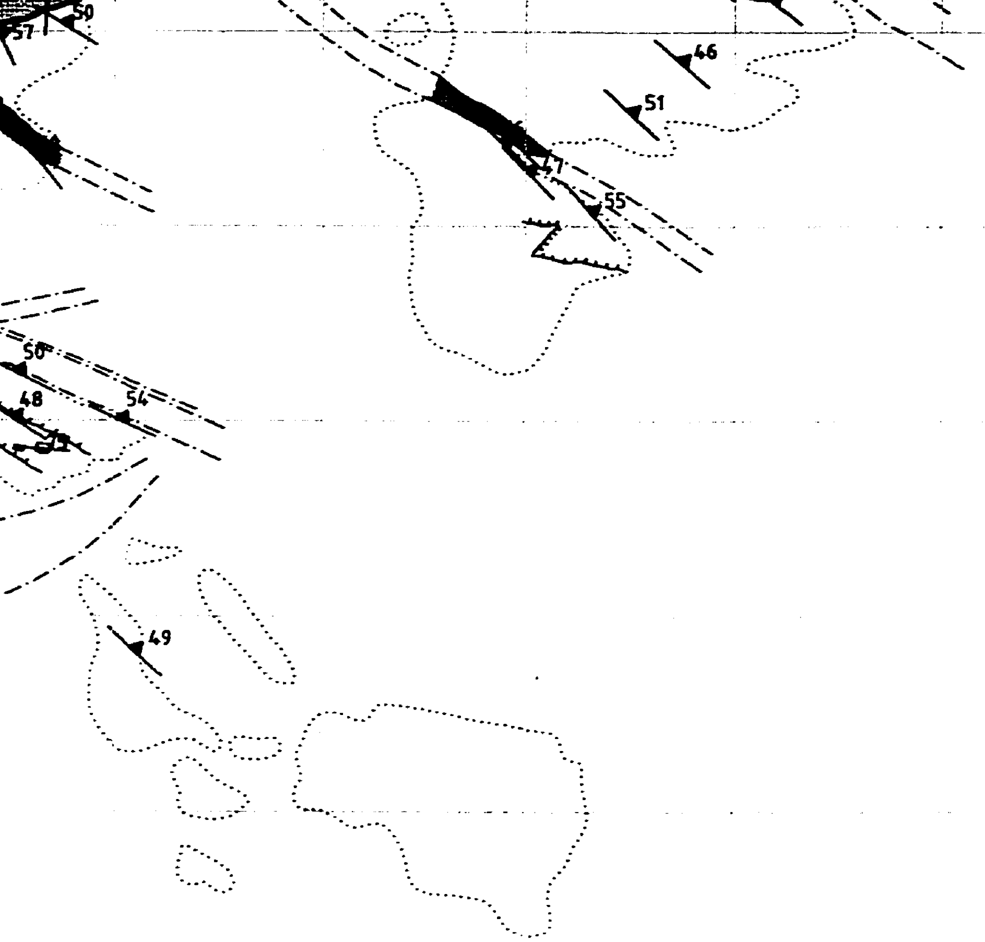

LEGEND

outcrop
fault
inferred fault
contact
inferred contact
bedding
foliation
lineation
fracture
clast

MCLEOD ROAD-BIRCH LAKE ALLOCHTHON

Three Zone Mafic Volcanclastic unit

Boundary Zone Rhyolite unit

INTRUSIVE ROCKS

Gabbro
Hble-Bte-Tourmaline
Boundary Zone Basalt
Andesite
Pyx-Plag-Gabbro

Quartz Vein