THE GEOLOGY AND GEOCHEMISTRY OF THE McKAY RIVER AREA VOLCANIC ROCKS WESTERN LABRADOR

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BY

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ABSTRACT

The McKay River area is situated in the south eastern section of the Labrador Trough on the boundary between the Grenville and Churchill tectonic provinces. Major lithologic subdivisions identified in the area consist of Archean basement gneisses (2500 ma), a sequence of Aphebian supracrustal rocks (2500-1800 ma), composed primarily of the Knob Lake Group, and some Helikian intrusive, extrusive, and sedimentary rocks (1800-1300 ma).

Unique to this region of the Labrador Trough is the occurrence of three distinct mafic volcanic sequences. The first, tentatively named the sub-eruptive suite consists of high level basaltic dykes and associated tuffaceous rocks which are intimately associated with the Sokoman Formation. These rocks are chemically similar to the volcanic rocks of the Nimish Sub Group and formed as a direct result of rifting associated with the development of the Labrador Trough. This is the first time this unit has been recognized in the McKay River area, which has subsequently led to the discovery of new information concerning the tectonic and structural history of the area.

The other two volcanic sequences are separated from the rocks of the Knob Lake Group by a tectonic boundary and are considered to be allocthonous. The first of these, consists

of alkali basalts and associated pyroclastic rocks and is characterized by higher than average TiO_2 and CaO. It has been tentatively named the McKay River formation.

The second sequence, which stratigraphically overlies the McKay River formation has been tentatively named the Rose Bay formation. It consists of a suite of alkaline ultrabasic lavas and associated fragmental and volcanoclastic sedimentary rocks. The petrochemistry of these rocks indicate that they represent primary or near primary magma compositions and exhibit strong chemical affinities with a rare rock type known as olivine melilitite. Similarities are also evident between these rocks and some lamprophyres and carbonatites in the northern Labrador Trough.

Petrochemical and structural evidence suggests that while the McKay River and Rose Bay formations may be synchronous with the Sokoman Formation, they were deposited at some distance from the main rift system and south of their present location. They were transported northward to their present location as a result of the Grenville Orogeny, circa 1000 ma.

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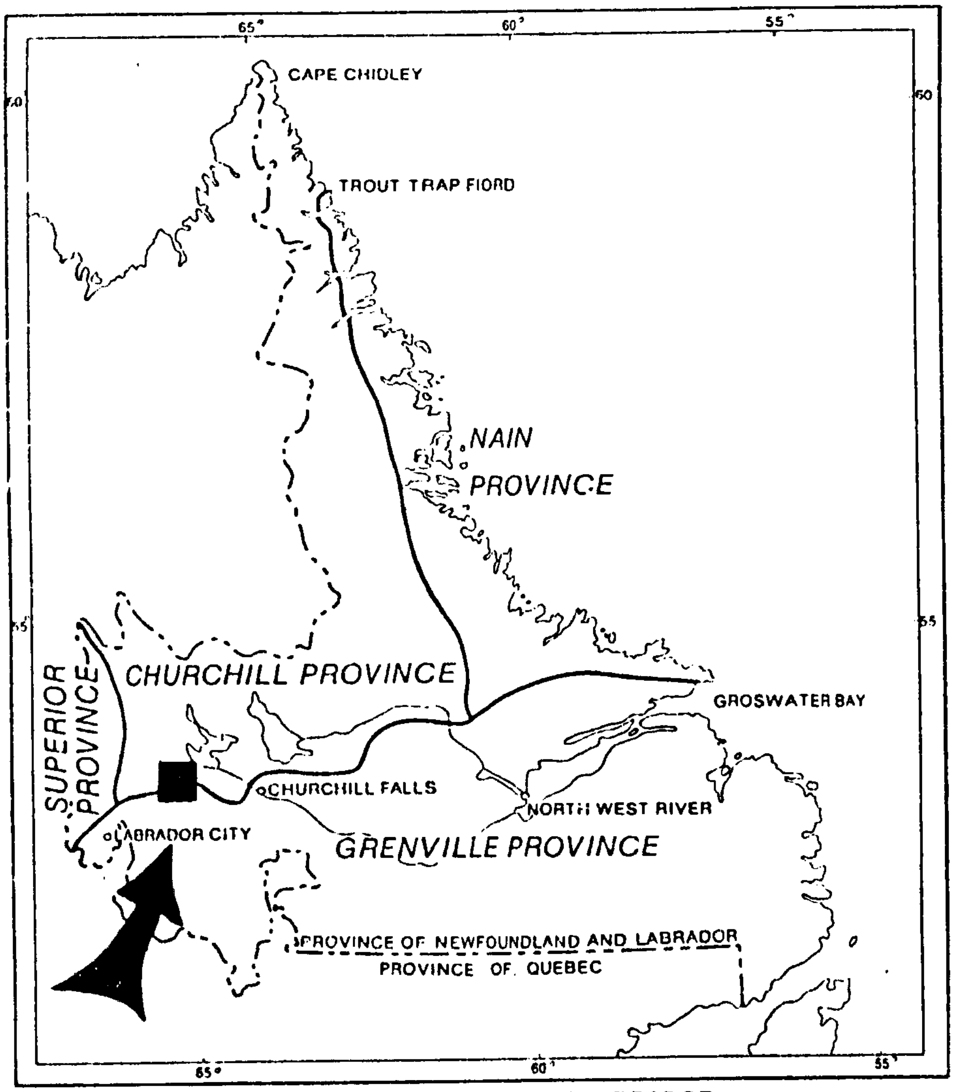
CHAPTER 1

INTRODUCTION

1.1 PURPOSE OF STUDY AND SCOPE

The purpose of this study is to classify and establish the paleotectonic significance of the volcanic rocks found within the study area (figure 1.1), located in the south eastern extension of the Labrador Trough. This will be done by geochemical analysis of various samples of the volcanic rocks using the major, trace, and rare earth elements to determine their chemical characteristics, and pertinent aspects of their petrogenesis. In addition, the stratigraphy and spatial relationships of the volcanic rocks will be clarified. The chemical nature of these rocks will then be compared with younger volcanic suites and other suites found within the Knob Lake Group. These include rocks described by Dressler (1975) and Dimroth (1970, 1978) located in the north central and northern portion of the Trough. A discussion of the significance of these rocks with respect to the development of the south eastern extension of the Labrador Trough is included.



GEOLOGICAL PROVINCES OF LABRADOR

Figure 1.1 Study area location map.

1.2 LOCATION

The study area (figure 1.1) is situated approximately 65 Km due west of Churchill Falls, in the southeast portion of the Labrador Trough. It consists of the McKay River map sheet (NTS 23H/12 and the western half of the Gabbro Lake sheet (NTS 23H11/W) and is bounded by latitudes 53° 30′ and 53° 45′ and longitudes 65° 15′ and 66° 00′. The study area includes an area of approximately 1150 square kilometers of which 1/3 is covered by water. The volcanic and associated rocks which are the subject of this study outcrop sporadically in an east west line across the centre of the area.

1.3 PREVIOUS WORK

Local mapping was first conducted by the Iron Ore Company of Canada (Baird, 1950) and the Labrador Mining and Exploration Company (LM&E) (Beland 1950). Follow up studies included those of Tiphane (1951), Frazer (1952), Jackson (1952), Slipp (1952) and Peach (1952). Reconnaissance mapping was conducted by the Geological Survey of Canada, (Wynne-Edwards, 1961) and theses by Goodwin (1951), Badhroon (1961), Giovanella (1961) and Henderson (1965) also covered various aspects of the geology. The Sims Formation located in the north and western portion of the map area was mapped by the Newfoundland Department of Mines and Energy (Ware, 1979; Ware and Wardle, 1979). The Blueberry Lake group which outcrops in the eastern sections was mapped the same year (Wardle, 1979a,b). Only pertinent information from these most recent studies has been compiled directly onto the map accompanying this thesis (Figure 1.2). Since the fieldwork for this study was completed, work by Brown (1991) has shed new light on the structural geology of the map area. This new information does not significantly change the interpretation and significance of the petrochemistry, which is primarily the subject of this thesis.

1.4 GENERAL GEOLOGY

The McKay River - Gabbro Lake area is proximal to the southwestern junction of the Churchill and Grenville tectonic provinces and lies within the para-autochthonous rocks of the Grenville Front Tectonic Zone (Rivers, 1986). The eastern edge of the Archean gneisses of the Ashuanipi Complex outcrops approximately 50 km to the west while the Helikian granitiods of the Trans Labrador Batholith are found approximately 40 km to the east.

The area is underlain by lithologies of the Knob Lake Group. These form a sequence of interlayered sedimentary and volcanic rocks contained within the Kaniapiskau Super Group, an Aphebian supracrustal sequence which comprises a large portion of the Circum Ungava Geosyncline.

In some locations, these rocks are overlain by Helikian intrusive, extrusive, and sedimentary rocks. Due to the poor exposure and the nature of the terrain within the map area, no contacts were observed. In this portion of the Trough however, all contacts within the Knob Lake Group are believed to be conformable. Unconformities within this sequence have been observed in the northern and central portions of the Trough (Dimroth, 1978).

1.4.1 ARCHEAN ROCKS

The oldest rocks in the region are the granodiorite and tonalitic gneisses of the Eastern Basement Metamorphic complex (Wardle, 1979a,b). These rocks are Archean in age and occur extensively to the north and sparsely to the east of the study area. Outcrops of this unit are found on the eastern edge of the map area, on the northern shores of Way Bay. At this particular location the contact of this unit with the surrounding units is not clearly understood. It has been suggested that this particular occurrence may be a roof pendent or raft within a much younger gabbro body (Noel,1981; Rivers, 1982). Retrograde assenblages observed at this locality are likely to be due to Grenvillian metamorphism.

1.4.2 APHEBIAN ROCKS

The most abundant rocks that are found within the study area are interpreted to be part of the Knob Lake Group. These rocks consist of interbanded shales and greywackes, and their metamorphic equivalents, and are considered to be part of the Attikamagen Formation. The base of this unit is not exposed but the unit is believed to lie unconformably on the Archean basement. To the north, in the central Labrador Trough the Attikamagen Formation lies conformably on basal conglomerates of the Seward formation (Wardle, 1977; Dimroth, 1978) but this unit appears to be absent in the map area.

Overlying the Attikamagen Formation is the Denault Formation. For the purpose of this study the Denault Formation is sub divided into a northern unit and a southern unit. The northern unit, composed of dolomitic and calcitic marble, appears to be relatively devoid of any volcanic material and is interpreted by the author to be a southern extension of the Denault Formation found to the north of the map area. The southern unit which consists of dolomitic and calcitic marble intimately intercalated with volcanic and volcanoclastic rocks is interpreted to be allocthonous. The significance of this interpretation is discussed later in the structural section of this study (see Chapter 6).

The volcanogenic material found associated with the Denault Formation (south) is examined in this thesis. It appears to be, in part, a lateral equivalent to the upper section of the southern unit and in part to overlie it. Prior to the completion of the field work and chemical analysis, all of these rocks were considered to be equivalent to the volcanic rocks of the Nimish Subgroup found in the Dyke Lake area to the north (Evans 1978). Results presented in this thesis, however, indicate that these rocks differ significantly from those of the Nimish Subgroup and have therefore provisionally been given the separate nomenclature status of the McKay River formation (Noel, 1981).

Overlying the Denault Formation is the Sokoman Formation. For the same tectonic reasons as mentioned above, the Sokoman Formation is also subdivided into northern and southern units. The northern unit consists mainly of cherty carbonate, silicate carbonate, greywacke, and cherty oxide facies iron formation. Locally it contains sub-eruptive basaltic dykes (having chemical affinities with the Nimish Sub Group found to the north) and probable tuffaceous equivalents. The southern unit consists of iron formation which has been replaced by or is intimately intercalated with volcanic and volcanoclastic rocks. These volcanic rocks are undersaturated and alkaline in nature and bear a strong resemblance, both chemically, and morphologically to olivine melilitites. Therefore, they have been tentatively named the Rose Bay formation and are discussed in detail in Chapter 3.

Overlying the Sokoman Formation are grey - black schists and slates of the Menihek Formation. It consists of quartz + feldspar + biotite +/- garnet schist and is locally graphitic. Although this unit outcrops throughout the northern and central portions of the study area it is interpreted to correspond tectonically to the northern units of the Denault and Sokoman Formations. Like the Sokoman and Denault Formations (northern units) it is interpreted to be a direct extension of the Knob Lake Group found to the north of the area.

A unit which was initially included in the McKay River formation (Noel, 1981) but has since been shown to structurally overly the rocks of the Knob Lake Group has been informally named the Equus Lake formation (Brown, 1991). It consists of a basal polymictic boulder conglomerate containing clasts of Denault, Sokoman and Menihek Formation and fines upward to a well laminated siltstone. (Brown 1991). The lower contact of this unit is tectonic, preventing its stratigraphic position from being determined, however Brown (1991) suggests that it may be correlative with the Tamarack Formation, a late Aphebian molasse unit found further to the northwest.

1.4.3 HELIKIAN ROCKS

Unconformably overlying the rocks of the Knob Lake Group are the orthoquartzites and granule conglomerates of the Sims Formation. These rocks, which are Helikian in age, have been mapped by the Newfoundland Department of Mines and Energy (Ware, 1979; Ware and Wardle, 1979).

Also believed to be Helikian in age is a group of felsic volcanic and associated sedimentary rocks which outcrop extensively to the east of, and to a lesser extent within, the eastern and northeastern portions of the map area. These rocks, known as the Blueberry Lake group, were the subject of a mapping project by Wardle (1979a,b). They have yielded a Rb-Sr errochron date of 1540 Ma (Wardle 1991, personal communication) but are considered to be slightly older (Wardle 1991, personal communication).

Outcrops of highly deformed monzodiorite outcrop in the southeastern portion of the map area. These are interpreted to belong to the Trans Labrador Batholith which outcrops extensively to the east and north east of the map area. The contact of these rocks with the rocks further to the north appears to be tectonic. The youngest rocks in the area are the gabbroic rocks of the Shabogamo Intrusive Suite (Rivers, 1979). These intrusions appear to form dykes, sills and small laccoliths in the western section of the map area but in the eastern section, the intrusions are extensive and appear to have obliterated the surrounding stratigraphy.

1.5 TECTONIC HISTORY

The region underwent deformation during the Hudsonian Orogeny, circa 1750 Ma. This produced northwest trending upright to slightly overturned open folds and high angle reverse faults. The southern portion of the area was strongly affected by the Grenville orogeny ca.1000 Ma. Brown (1991) completed a structural study of the central portion of the map area and found the structure to be, to say the least, very complex. He defined four structural domains within the central portion based on variations in the morphology of the units and the orientation of the structural elements and their internal geometry. The author refers the reader to Brown (1991) for a detailed structural analysis of the central portion of the map area.

Information gained from Brown (1991) combined with new geochemical data presented in this thesis has suggested some rather interesting conclusions concerning the structural development of the map area as a whole and these are presented in Chapter 6. Figure 1.2 located at the back of this thesis represents a new interpretation of the geology and structural geology based on these implications.

1.6 METAMORPHISM

Metamorphic fabrics attributed to the Hudsonian Orogeny are well developed to the north (Wardle 1978 and others) but are found to be faint and non pervasive in the map area (Brown 1991).

The first notable period of metamorphism in the Aphebian rocks was on a local scale, resulting from the intrusion of the Shabogamo Intrusive Suite during the Helikian. The effects can be seen in the form of contact aureoles and hornfels around some of the larger intrusions and minor contact aureoles around some of the smaller ones.

The next phase of metamorphism was regional in extent, accompanying the Grenvillian orogeny. Metamorphic grades range from sub - greenschist in the north to amphibolite facies in the south. The central, and better exposed portion of the map area, which includes the geochemical sample sites, lies within the greenschist facies.

1.7 METHODS OF MAPPING AND SAMPLE COLLECTION

The area was mapped in order to determine the internal stratigraphy of the volcanic rocks and establish their stratigraphic and structural relationship to the surrounding units of the Knob Lake Group.

Foot traverses were conducted using pace and compass techniques. Traverses were run using a combination of 1:50,000 scale topographic maps and aerial photographs. Geological data was recorded on 1:25,000 scale enlargements of the topographic maps. In the Gabbro Lake and Ossokmanuan Lake areas, shoreline geology was mapped with the aid of a small inflatable boat, while the central portion of the map area was mapped with the aid of a canoe. The peripheral portion of the map area had little outcrop and was therefore mapped with the aid of a helicopter.

Although initial sampling of all the volcanic rocks was completed in 1979 the area was revisited in 1983 and 1985 to selectively sample additional sites containing known occurrences of the Rose Bay formation. Additional samples were collected bringing the total to 71. Sampling was conducted across the volcanic pile both vertically and horizontally, however the complicated structural geology of the area renders any specific interpretation of the results regarding horizontal and vertical geochemical variations somewhat speculative.

1.8 ACCESS

Access to most locations within the map area is easily obtained by helicopter or float plane. It will soon be feasible to gain access by way of the Trans Labrador Highway which is due to pass just south of the map area and cross Ossokmanuan Lake. It is from this location and also the Gabbro Lake control structure that one could gain access to the eastern portion of the map area by boat. When conducting boat work however, one must use extreme caution due to submerged trees, numerous shoals, and high swells in unpredictably stormy weather.

Air services are conducted out of Schefferville to the northwest, Labrador City to the southwest or Churchill Falls to the east.

1.9 PHYSIOGRAPHY

The most prominent topographic features in the area are the 215 m quartzite ridges of the Sims Formation in the northwest portion of the map area. Intrusive and volcanic rocks comprise most of the smaller ridges.

The shapes of many of the lakes and ridges in the central portion of the map area appear to be directly related to geological structures and lithology, and therefore are a product of differential erosion. This relationship is most apparent in the central portion of the map area. Elsewhere, the effects of glaciation are prominent and include such features as eskers, boulder fields, roches moutonées and erratics. Glacial striations indicate ice movement was towards the southeast.

CHAPTER 2

DESCRIPTION OF FORMATIONS

2.1 ARCHEAN

2.1.1 EASTERN BASEMENT COMPLEX

The Eastern Basement Complex which comprises the oldest rocks in the region (Table 1) outcrops extensively to the north but only sparsely in the eastern portion of the map area. Most outcrops are found on the northern shores of Way Bay. Outcrops are predominantly white or grey orthogneiss, consisting of quartz + plagioclase + biotite + hornblende + K-feldspar and are quite distinctive from the banded gneisses of the Ashuanipi Complex described by Rivers and Massey (1979). Retrograde assemblages found in these rocks, indicated by the formation of chlorite from biotite are believed to mark the northern limits of Grenvillian metamorphism. This area of outcrop is interpreted to be fault bounded to the north and west and is in contact with the Shabogamo Intrusive Suite to the south and east.

TABLE 1. TABLE OF FORMATIONS

EON	ERA	GROUP	FORMATION	MAP UNIT	LITHOLOGY
PROTEROZOIC	PALEOHELIKIAN	SHABOGAMO INTRUSIVE SUITE		13	DIABASE, GABBRO, LEUCO GABBRO, MINOR ULTRAMAFITE
			SIMS FM.	12	ORTHOQUARTZITE, ARKOSE,
		TRANS LABRADOR BATHOLITH		11	MONZODIORITE - QUARTZ MONZODIORITE
		BLUEBERRY LAKE GROUP		10	FELSIC-INTERMEDIATE VOLCANICS, ASSOCIATED SEDIMENTS
			EQUUS LAKE FM.	9	CONGLOMERATE - SILTSTONE
ANGULAR UNCONFORMITY					
	APHEBIAN	KNOB LAKE GROUP	MENIHEK FM.	8	GRAPHITIC SLATE- SCHIST PHYLLITE
			SOKOMAN FM.	7	CHERTY CARBONATE AND SILICATE IRONSTONE
			SUB-ERUPTIVE SUITE	6	BASALTIC DYKES TUFFACEOUS EQUIVALENTS
			ROSE BAY FM.	5	ULTRAMAFIC ERUPTIVES
			MCKAY RIVER FM	4	BASALTIC PILLOW LAVA
			DENAULT FM.	3	DOLOMITIC-CALCITIC MARBLE, CHERT
			ATTIKAMAGEN FM.	2	GREYWACKE-SHALE-SLATE SCHIST
ARCHEAN		EASTERN BASEMENT COMPLEX		1	QUARTZO-FELDSPATHIC GNEISS

2.2 APHEBIAN

KNOB LAKE GROUP

2.2.1 ATTIKAMAGEN FORMATION

Outcrops of the Attikamagen Formation are sparsely distributed across the northern and southern portions of the map area. In the north, it is composed of a greywacke - shale sequence. Sub - greenschist metamorphism and deformation has produced a faint slaty cleavage, however primary structures such as cross bedding, graded bedding and sole marks may still be observed. Due to the sparse nature of outcrops, little use could be made of these structures.

In thin section, these rocks are found to consist of an assemblage of quartz - feldspar - muscovite - chlorite - opaque ± tourmaline, biotite and sphene. Only partial alignment of micas can be observed as these rocks are very fine grained.

In the southern portion of the map area the Attikamagen Formation outcrops as a banded quartz - feldspar - biotite - schist ± garnet, chlorite and hornblende. In this area deformation is quite intense with the rocks locally exhibiting augen textures and other high strain features such as quartz ribbons and mortar textures. These structures are more dominant near the most southerly interpreted thrust. The Attikamagen Formation is thought to extend further to the south where it grades into a well banded quartzo-feldspathic, pelitic gneiss. (Wynne-Edwards, 1961). Kyanite has been found in these rocks to the southwest, in the Wabush area. (Rivers, 1979, 1980).

2.2.2 DENAULT FORMATION (northern unit)

The Denault Formation (north) outcrops as a wide but discontinuous band aligned east-west across the central portion of the map area. It is also interpreted (from drill hole data further to the northwest) to form a northwest trending, northeast dipping band which strikes along the southwest shore of McKay Lake. The Denault Formation consists mainly of light brown to buff-grey weathering dolomitic and calcitic marble. It commonly contains highly contorted and recrystallized chert bands and quartz veins. Locally it is stromatolitic. Occasionally tremolite occurs as a reaction product between the carbonate and chert layers and is usually an indication of tectonic displacement within the unit.

In a number of localities, the Denault Formation outcrops as a graphite-bearing, grey weathering banded limestone containing one to two meter diameter lenses of buff weathering dolomite. One such outcrop was found at the southeast end of Dave Lake, the other about two miles southwest of Mobey Lake. Initially the interpretation was that the limestone contained diagenetic concretions (Noel, 1981). Brown (1991) found that these outcrops were in fact mylonites and the lenses of dolomite were augen features.

In a few localities near Four King Lake the Denault Formation outcrops as a dolomite breccia (figure 2.1). Angular to flattened clasts of limestone and chert are surrounded by a dolomite matrix. Some of the chert clasts are up to 30 cm in diameter and contain various amounts of disseminated sulphide. The presence and significance of this occurrence is not clearly understood, however, one possibility is that it may be correlative to the Flemming Formation found further to the north (Dimroth, 1978).

Elsewhere, locally occurring horizons of fine grained pelitic metasediment may be found, the origin of which is not clear. These layers are assumed to represent primary bedding and may therefore indicate a close proximity to the contact with the underlying phyllites of the Attikamagen formation. At this point in time however there is no structural evidence to support this interpretation.

Peculiar to the northern unit is the near absence of volcanic material. Minor occurrences of chloritic material are the only hints of proximal volcanism.

Within the region as a whole, the Denault Formation maintains a consistent relationship with the overlying Wishart and Sokoman Formations. In the map area, the Wishart

Figure 2.1 Photograph of chert breccia in Denault Formation.

Figure 2.2 Interbanded carbonate and actinolite schist.

Formation, a unit which usually consists of white crystalline quartzite, is absent and the Sokoman Formation is in direct contact with the Denault.

DENAULT FORMATION (southern unit)

The Denault Formation (southern unit) appears to have been completely replaced by the abundance of volcanic rocks found in the study area. Thin lenses or discontinuous layers of carbonate are found locally within some of the volcanoclastic rock (figure 2.2). Within the pillow basalts the vertices between the pillows are carbonate filled (figure 2.3). It is not known if this carbonate is indeed dolomitic thereby suggesting a relationship to the Denault Formation or sideritic and thus implying a closer association with the iron formation.

There are some outcrops of volcanoclastic rocks which do contain large oval lenses of dolomite. The initial interpretation (Noel 1981) was that these outcrops represented a gradational contact between the marble and the volcanoclastic rocks and that the dolomite lenses were actually boudonaged layers.

Evidence presented later in this thesis gives an alternate interpretation which suggests that these outcrops may represent a tectonic boundary and that the dolomitic pods are actually "knockers" which have been incorporated into the base of an overriding thrust slice composed of the volcanoclastic rocks.

Figure 2.3 Photograph of carbonate occupying vertices of pillow lava.

Figure 2.4 Photograph of silicate oxide facies Sokoman Formation. Darker layers are hematite rich.

2.2.3 VOLCANIC AND ASSOCIATED ROCKS

Geochemical evidence presented in this thesis demonstrates the presence of three separate suites of volcanic rocks within the McKay River area. These include a suite of pillow basalts and associated volcanoclastic rocks (McKay River formation), a suite of undersaturated alkaline volcanic rocks and their volcanoclastic equivalents (Rose Bay formation) and a more limited suite of sub-eruptive rocks and their tuffaceous equivalents with chemical affinities to the Nimish Sub group. The Rose Bay and McKay River formations are interpreted in this thesis to be allocthonous and correlative with the southern units of the Denault and Sokoman Formations while the third suite, with Nimish affinities, is correlative with the northern unit of the iron formation.

The volcanic rocks within the map area are primarily the focus of this study and will be dealt with in detail in the following chapters.

2.2.4 SOKOMAN FORMATION (northern unit)

The Sokoman Formation overlies the Denault Formation and outcrops in a similar fashion as discontinuous bands in the central portion of the map sheet. It also is interpreted to form a SE-NW trending band overlying the Denault Formation and running through McKay Lake. This interpretation is based on the presence of a continuous linear magnetic anomaly which forms an extension of the iron formation, confirmed by drill hole data to the northwest (Jackson, 1952; Ware, 1979).

In the central portion of the map area, the Sokoman Formation outcrops as a well banded cherty carbonate, cherty oxide (figure 2.4), or greywacke facies iron formation locally containing bands or disseminations of magnetite ± haematite. In some cases the chert and carbonate bands have reacted to produce a grunerite schist (figure 2.5) This is similar in nature to the occurrence of tremolite within the Denault formation and is often indicative of some tectonic displacement. Northwest of Tiphane Lake and east of Four King Lake, pisoliths or carbonate mud balls were found within the iron formation (figure 2.6). These ranged up to 3 cm in diameter and when occurring in the chert bands formed grunerite sphericules. Similar occurrences were found outcropping in the channel between Way Bay and Gabbro Lake. Locally the silicate oxide facies is non-magnetic suggesting the dominant oxide to be haematite.

Greywacke facies iron formation (figure 2.7) outcrops in the northeast, central, and west central portions of the map area. These rocks are banded in appearance and consist of quartz-feldspar-carbonate-haematite-magnetite greywacke. Occasionally thin discontinuous bands containing actinolite or chlorite +/- sphene are found, which are interpreted to be meta

Figure 2.5 Grunerite schist in Sokoman Formation. Note rubbly appearance of outcrop.

Figure 2.6 Grunerite bearing carbonate mud balls, Sokoman Fm.

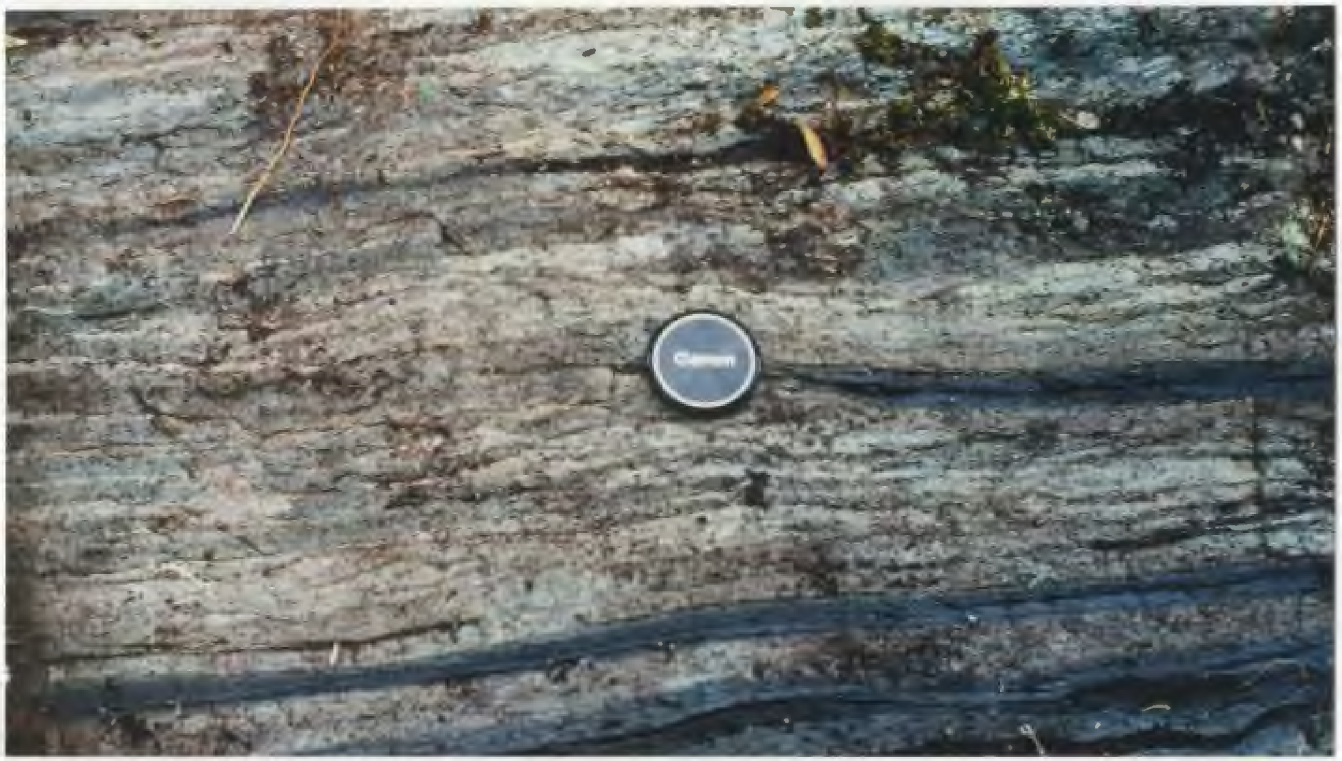


Figure 2.7 Greywacke facies Sokoman Formation. Greenish layrers above lense cap are tuffaceous.

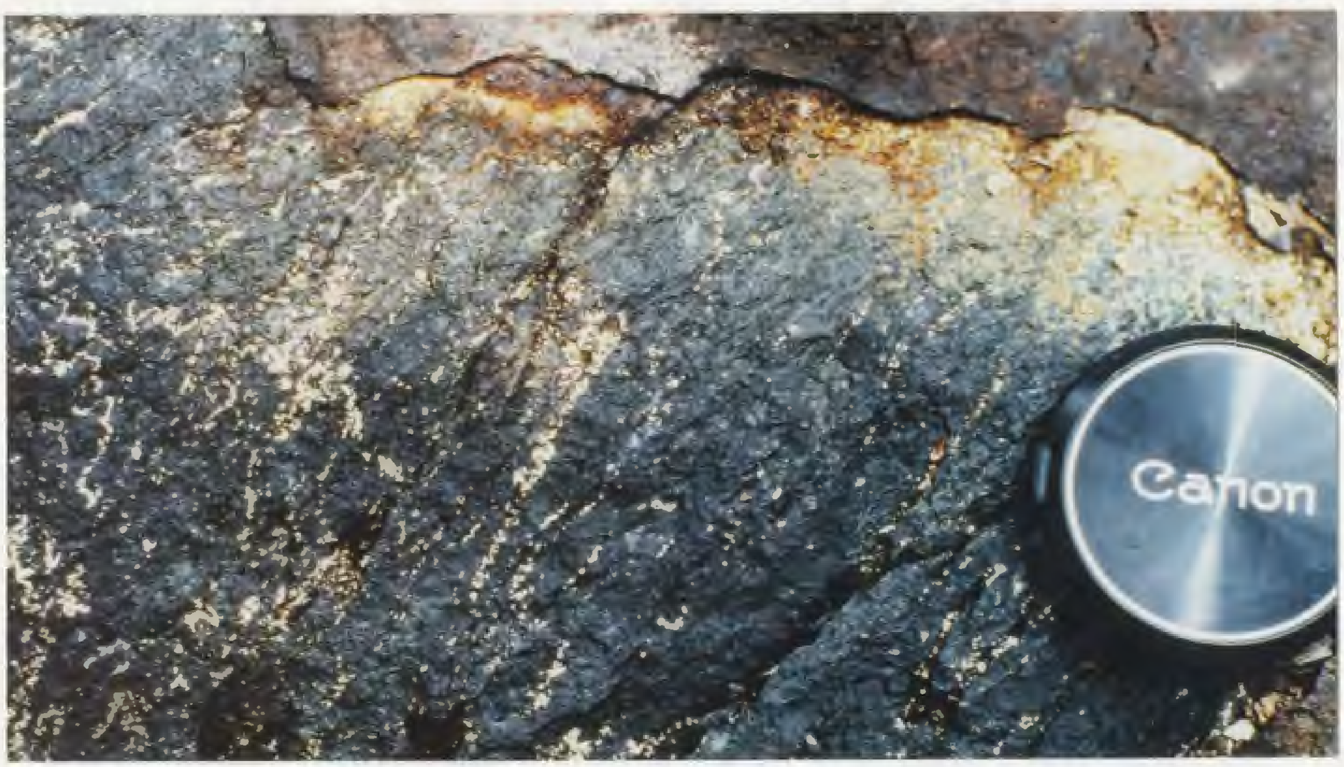


Figure 2.8 Disseminated pyrite mineralization in Menihek Fm.

tuffaceous in origin. The outcrops found in the Mobey Lake area appear to be well banded and may contain layers of siltstone.

Unique to the northern unit are the sub eruptive volcanic rocks of Nimish affinity. These were found approximately one kilometre east of Tiphane lake, three kilometers west southwest of Mobey Lake and on the west shore of Limestone Bay in the eastern portion of the map area. Based on these findings similar occurrences are suspected to have the same relationship in sporadic outcrops of iron formation found in the south central portion of the map area near Isa Lake. Tuffaceous layers associated with the greywacke facies, mentioned previously, are interpreted to be derivatives of these rocks and not related to the other volcanic suites in the map area.

SOKOMAN FORMATION (southern unit)

Like the southern unit of the Denault formation, the Sokoman Formation appears to have been replaced by the volcanoclastic rocks. Evidence for this is discussed in more detail in the geochemical section which follows. Petrographic evidence is mainly restricted to noticeable increases in the presence of magnetite or disseminated magnetite and chert within the volcanoclastic rocks, or the presence of thin sideritic looking carbonate bands in some outcrops (figure 2.2).

The Sokoman Formation in general provides a good marker bed for deciphering the structural geology since it can be traced through areas of poor exposure by its strong aeromagnetic signature which in most cased is much stronger than that of mafic intrusive rocks. In the central and southern portions of the map area however, the volcanic and gabbroic rocks appear to have a much stronger magnetic signature. In these areas the Sokoman Formation is only useful as a marker horizon when found in close association with the underlying Denault Formation. This also provides useful information on bedding orientations for structural purposes.

2.2.5 MENIHEK FORMATION

In the northern portion of the map area the Menihek Formation outcrops north of the most northerly, east-west trending, band of iron formation and also overlies the interpreted band of iron formation which crosses McKay Lake. Other occurrences are limited to the west central and south central portions of the map area and in the immediate vicinity of Tiphane Lake. Exposure of this unit is limited and its actual extent is largely interpretive, however the outcrops that can be positively identified play an important role in the structural interpretation presented later. It occurs mainly as a fine grained quartzo-feldspathic slate, schist or phyllite, with or without coarser grained quartzo-feldspathic bands. Often it is graphite-bearing. Southwest of Rose Bay it outcrops as a fine grained, black graphitic schist/slate. Brown (1991) has interpreted similar rocks found in the Tiphane Lake area as belonging to the McKay River formation, however the structural interpretation presented in chapter 6, combined with geochemical evidence, suggests that these rocks are indeed part of the Menihek formation and that they stratigraphically overly the northern unit of the Sokoman Formation.

Sulphide gossan can commonly be found in these rocks as a result of disseminated pyrite mineralization, however, it is most pronounced in the vicinity of the intrusive rocks present in this area (figure 2.8).

2.2.6 EQUUS LAKE FORMATION

This unit described by Brown (1991) was originally interpreted by Noel (1981) to be part of the McKay River formation. It consists of a basal polymictic boulder conglomerate containing clasts of the Denault, Sokoman, and Menihek Formation and fines upwards into a well laminated siltstone (Brown, 1991). Brown (1991) reported that the contact of this unit (figure 2.9) with the surrounding rocks is tectonic, thereby preventing its stratigraphic position from being determined. He does however suggest that it may be correlative with the Tamarack River Formation which comprises a late Aphebian molasse unit which also contains clasts of Knob Lake lithologies (Ware 1979). The significance of this unit occurring as a 'klippe' structure is

Figure 2.9 Bedded silt-sandstone of the Equus Lake formation.

Figure 2.10 Photograph of augen gneiss from highly deformed monzodiorite.

discussed in the structural section (Chapter 6).

2.3 HELIKIAN

2.3.1 BLUEBERRY LAKE GROUP

The Blueberry Lake Group (Wardle, 1979b) is a sequence of felsic volcanic and associated sedimentary rocks found locally in the eastern portion of the map area. These rocks outcrop extensively to the east and have been the subject of a study by Wardle (1978, 1979 a, b). The Blueberry Lake Group outcrops as a sequence of felsic and intermediate volcanic rocks, greywackes, feldspathic sandstones and polymictic conglomerate. Clasts in the conglomerates consist of quartzite, black slate, foliated leucogranite, and blue quartz-bearing felsic tuff (Wardle, 1979). An errochron date of 1550 Ma has been obtained for these rocks by Rb/Sr dating methods Wardle (personal communication) however the true age is probably slightly older.

2.3.2 GRANITIC INTRUSIVE ROCKS

Outcrops of highly deformed quartz monzodiorite outcrop on the southern shore of Ossokmanuan Lake and in the south central portion of the map area. These rocks are strongly foliated, biotite-bearing and appear to have been metamorphosed to amphibolite facies.

A few relict k-spar megacrysts were observed, however in most cases the rock is essentially an augen gneiss (figure 2.10). It is thought that these rocks are equivalent to rocks of the Trans Labrador Batholith which outcrops sporadically to the west (Rivers 1979,80) and extensively to the east and northeast (Wardle,1979 and others).

2.3.3 SIMS FORMATION

The Simms Formation, consisting of orthoquartzite and granule conglomerate, forms the high ridges in the northwest portion of the map area. Like the Blueberry Lake Group, this too lies unconformably on the Knob Lake Group, and has been intruded by gabbros of the Shabogamo Intrusive Suite. The Simms Formation was the subject of a detailed mapping project by Ware (1979) and is also described in the report by Ware and Wardle (1979).

2.3.4 SHABOGAMO INTRUSIVE SUITE

The Shabogamo Intrusive Suite (Rivers, 1980) is the name given to a suite of intrusive rocks, found quite extensively in the region, which range in composition from gabbro to diorite, with minor occurrences of ultramafite and quartz monzodiorite. They range from fine to coarse grained with some of the larger intrusions being pegmatitic in grain size (figure 2.11).

In the map area, compositions fall mostly within the gabbro-leucogabbro range; however, there are a few occurrences of ultramafic and granodioritic rocks which are believed to be part of the suite.

All of these rocks commonly exhibit relict igneous texture, despite widespread development of sub-greenschist to amphibolite grade metamorphic mineral assemblages.

Typically, the mineralogy is chlorite - albite - actinolite epidote - sphene +/- pyrite, garnet, and magnetite. In the southern portion of the map area, actinolite and chlorite may be replaced by biotite and hornblende. For the most part, primary mineralogy is only found in the northern portions of the map area; however, local occurrences can be found in some of the larger intrusions slightly further south. In the western half of the map area, intrusions occur as dykes, small sills and laccoliths. In the east, the intrusions are often so extensive that it is difficult to distinguish between large xenoliths and surrounding country rocks, and it appears that indivual intrusions may coalesce into a large intrusion at depth.

A few gabbroic bodies which are presently included in the Shabogamo Intrusive Suite may actually be intrusive equivalents

Figure 2.11   Pegmatitic leucogabbro, Shabogamo Intrusive Suite

Figure 2.12   Primary igneous layering in Shabogamo gabbro.

of the volcanic rocks, and further study is required to investigate this possibility. Metamorphic corona textures are characteristically found in the Shabogamo gabbro (Rivers, 1978 1979) and may be of some use for distinguishing between the two in the field. Also associated with these rocks are minor occurrences of granitic pegmatite and ultramafite. Primary igneous layering was observed in one of the larger intrusions on the west shore of Rose Bay and in the larger bodies in Ossokmanuan Lake (figure 2.12).

The age of the Shabogamo Gabbro has been determined to be approximately 1400 my (Brooks et al. 1981).

CHAPTER 3

VOLCANIC ROCKS

3.1 INTRODUCTION

Prior to 1979 the volcanic rocks of the McKay River area were assumed to be a southern, lateral equivalent of the Nimish Sub Group, a suite of basaltic volcanic rocks found further to the north (Evans, 1978). This assumption was based on early field descriptions and the fact that the outcrop pattern of the volcanics combined with the structural interpretations of that time indicated a strong stratigraphic correlation with the Sokoman Formation as was the case with the Nimish Sub Group (Evans 1978). Preliminary work conducted by Noel (1981), which included random geochemical analysis of the volcanic rocks indicated that there were two separate volcanic suites present and neither were related to the Nimish . These were subsequently named the McKay River formation and the Rose Bay formation. The area was revisited briefly in 1983 and more extensively in 1985 and additional samples of the volcanic rocks were collected. Of particular interest were samples of ultramafic rocks found to be intrusive into silicate oxide, silicate carbonate and greywacke iron formation. Field evidence suggests that these rocks are dykes which were intruded into the iron formation while it was still a "soft" sediment and are therefore contemporaneous. For the purpose of this study these rocks and their tuffaceous equivalents will be called the sub-eruptive suite. Geochemical evidence presented later demonstrates that these rocks have no affinity with either the McKay River formation or the Rose Bay formation but do bear a strong resemblance to those of the Nimish Sub Group found to the north. Combining this new information with work completed by Brown (1991) and Noel (1981) has made it necessary to reinterpret the structural geology of the area and reexamine the volcanic units described by Noel (1981). Evidence presented in this thesis suggests that while the flow rocks of the McKay River and Rose Bay formations are distinctive, volcanoclastic derivatives of the two may be intercalated. Furthermore new structural evidence suggests that the contact between these units and the surrounding rocks of the Knob Lake Group may actually be tectonic. Without a good stratigraphic correlation between the volcanic rocks and the marker units of the Denault and Sokoman Formations, the internal stratigraphy of the volcanoclastic rocks is less certain and more dependant on their geochemical and petrographic signatures. Metamorphism has destroyed most of the primary textures in the finer grained rocks making it difficult to distinguish between specific volcanoclastic units on a local scale. Subdivisions have therefore been made mostly on the basis of field evidence (often discreet but sometimes circumstantial) and petrography supported by geochemical evidence wherever possible.

3.2 MCKAY RIVER FORMATION

Rocks of the McKay River formation outcrop in the central and eastern portion of the map area. These consist primarily of mafic pillow lava (figure 3.1) and pillow breccia with a few minor occurrences of pyroclastic rocks. Epiclastic rocks, including polymictic conglomerate and tuffaceous conglomerate which are in part derivatives of the basalts, have been included in the Rose Bay formation.

3.2.1 FLOW ROCKS

Flow rocks of the McKay River formation outcrop as relatively narrow belts extending in an east-west fashion across the lower portion of the map area. The largest and by far the thickest of these belts lies about three kilometers south of Mobey Lake. The thickness here is estimated to be a minimum of 600-800 m. The belt is interpreted to extend intermittently eastward as far as Four King Lake where it appears to thin out. These rocks consist of green weathering, fine to medium grained amygdaloidal to massive pillow lava and contain variable amounts of carbonate occupying the interstices of the pillows (figure 3.2). This carbonate is generally coarsely crystaline calcite and is

Figure 3.1 Pillow lava in McKay River formation. Outcrop is located on south side of Four King Lake.

Figure 3.2 Photograph showing carbonate in vertices of pillows.

probably the result of hydrothermal fluid circulation just after the time of eruption. Pillows observed at the eastern extension of the band show few effects of deformation and are thus the best preserved. These vary in size from 1 - 2 m across and show good facing directions. The cores of the pillows are homogeneous and coarser grained than the rims and exhibit relict igneous texture. The finer grained rims are thought to represent chill margins and a slight discoloration around the rims could reflect metamorphism of mineral assemblages resulting from sea water interaction at the time of eruption. Facing directions determined from the orientation of these pillows indicate that tops are up.

Westward along this belt the pillows begin to show the effects of strain by an increase in the intensity of deformation. Pillows show varying degrees of flattening and shearing with the result being a net reduction in size. The edges of the pillows take on a slatey cleavage and veins of calcite and quartz become more pervasive (figure 3.3). At the western end of the belt, pillows are barely recognizable and the rocks have a well developed linear metamorphic fabric.

The other band of recognizable pillow lava outcrops south and east of Dragon Lake and is believed to connect with similar outcrops found along strike on the eastern shores of Rose Bay. The band contains a mixture of pillow lava and pillow breccia and is poorly exposed. Locally it is strongly deformed.

Figure 3.3 Deformed pillows near thrust fault south of Mobey Lake.

Figure 3.4 Feeder dyke intruding McKay River basalt.

In thin section these rocks are found to be microphyric with feldspar being the porphyritic phase. They are completely retrogressed to a greenschist assemblage of chlorite - albite - actinolite - epidote - sphene - opaques. Amygdales are filled with calcite. In the highly deformed lavas, muscovite is found along some of the shear planes. No primary ferromagnesium phases have been observed in these rocks.

3.2.2 INTRUSIVE ROCKS

Only one example of an intrusive equivalent of the McKay River formation lavas has been found. A sill located on the eastern shore of Rose Bay intrudes the pillow lava which forms the dominant lithology at this location (figure 3.4) The chemistry of this sill is essentially identical to the surrounding pillow lava and it is therefore considered to be an offshoot of a feeder dyke.

Brown (1991) reported gabbroic clasts in some outcrops of polymictic conglomerate. These could conceivably be derived from intrusive equivalents of the basalts subsequently exposed by erosion.

Based on field observations few if any of the gabbroic bodies within the map area appear to represent intrusive equivalents of the lavas, although it is conceivable that some may. At the time of mapping, however, a comprehensive geochemical sampling program of the intrusive rocks was impractical due to time restrictions. All mafic intrusive rocks have therefore been included in the Shabogamo Intrusive Suite which outcrops extensively in the region.

3.2.3 PYROCLASTIC ROCKS

Pyroclastic rocks, which appear to be primarily associated with the McKay River formation, outcrop in the Sydney Lake area. These consist of small angular clasts of aphyric basalt with occasional vesicular basalt in a tuffaceous matrix and may actually represent an explosive breccia (figure 3.5) Unique to this rock is the lack of highly vesicular material characteristic of the Rose Bay formation. Supporting the interpretation that this rock is a member of the McKay River formation is the fact that it appears to underlie and therefore predate the polymictic conglomerates of the Rose Bay formation.

3.3 ROSE BAY FORMATION

Rocks of the Rose Bay formation outcrop in the central portion of the map area. These consist of sporadic occurrences of highly vesicular lava, fragmental rocks (some of which may represent diatremic material or pipe breccia), and associated epiclastic rocks. Derivatives of the McKay River formation, seen mostly as clasts in conglomerate,

Figure 3.5 Explosive breccia composed of McKay River basalt

Figure 3.6 Possible pipe breccia, Rose Bay formation.

are interbedded with tuffaceous and reworked tuffaceous material. All rocks of the Rose Bay formation have been retrogressed to a greenschist assemblage of actinolite + chlorite + opaque + carbonate + feldspar + quartz + sphene.

Petrographic analysis and preliminary microprobe work have identified the presence of three opaque phases within the volcanic rocks of the Rose Bay formation. These include titanium- rich euhedral-subhedral lath shaped ilmenite, a finer grained anhedral ilmenite which appears to be exsolving from pseudomorphs of Ti-clinopyroxene (titanaugite), and coarser euhedral-subhedral magnetite octahedra which may be related in part to an external source.

3.3.1 FLOW ROCKS

Flow rocks of the Rose Bay formation outcrop sporadically throughout the central portion of the map area. These include outcrops of highly amygdaloidal and porphyritic ultramafic lava. The extent of any particular occurrence is measured on an outcrop scale and they are always closely associated spatially with an abundance of fragmental/tuffaceous rocks. In thin section actinolite is the dominant mafic phase and in the porphyritic rocks appears to be pseudomorphing clinopyroxene. Amygdales are filled with calcite and their abundance suggests that the magma was extremely volatile.

Missing from these rocks is the coarser Fe-oxide opaque phase. The significance of this is discussed in the petrochemistry section.

3.3.2 INTRUSIVE ROCKS

Although no definite intrusive rocks were found, a number of outcrops composed of brecciated equivalents of the above, are considered to be likely candidates for pipe breccia (figure 3.6). In most cases fragments in these rocks are angular however a few occurrences contain elliptical clasts (figure 3.7). Since these clasts are found in rocks showing little evidence of subsequent reworking or deformation they are interpreted to have formed as a result of gas streaming in the pipe during eruption episodes. This process is reported to be common in this style of eruption (Boyd and Meyer, 1979). This interpretation is supported by the fact that the clastic rocks of known sedimentary origin, are without fail, polymictic, while the clasts in the suspected pipe breccia consist primarily of vesicular lava (material) much like that of the extrusive rocks.

Figure 3.7 Photograph of elliptical (? gas streamed) clasts in pipe breccia. Note that the long axis of the clasts are sub-aligned.

3.3.3 FRAGMENTAL ROCKS

AGGLOMERATE

Should the rocks mentioned above not represent pipe breccia then they are most likely an agglomeratic phase of the Rose Bay formation. In outcrops containing angular fragments, the rocks are largely clast supported and there is essentially no evidence of reworking . Although in most cases metamorphism has all but destroyed primary textural features in the matrix they appear to be essentially the same as the clasts.

TUFFACEOUS ROCKS

Tuffaceous rocks constitute the most abundant member of the Rose Bay formation and although in some cases these rocks have a pervasive metamorphic fabric they are still quite recognizable. Rocks belonging to this sub-division include recognizable tuffs composed of material indicative of an airfall origin. They also have a welded appearance as opposed to tuffs and tuffaceous sediments containing rounded lithic fragments and matrix material believed to represent some reworking. Petrographic analysis shows that the latter often contains considerable carbonate and quartz (meta chert ?) and abundant magnetite.

Occasionally within tuffs exhibiting little evidence of reworking, lithic fragments may be coated by magnetite. Initially this was thought to indicate synchronous deposition of the tuffaceous rocks and the Sokoman Formation. Upon closer examination it is clear that the magnetite is the result of exsolution of iron from ferro-magnesian phases during metamorphism. In one particular specimen the opaque was concentrated close to but not on the rims of the fragments. In these cases the magnetite crystals are also very fine grained unlike those seen within the matrix of the reworked tuffaceous rocks where occasionally magnetite crystals up to 5 mm in diameter are observed.

On the south shore of Four King Lake tuffaceous rocks of the Rose Bay formation are stratigraphically interleaved with pillow basalts of the McKay River formation. Although this is the only outcrop which clearly exhibits a contact relationship between the two formations, a close spatial association is clearly evident wherever outcrops of the basaltic rocks are found.

3.3.4 EPICLASTIC ROCKS

CONGLOMERATE

Conglomerates comprise the bulk of the epiclastic rocks and may be subdivided into two groups consisting of

1) orthoconglomerates of definite sedimentary origin and 2) paraconglomerates likely of sedimentary and/or airfall origin and/or their reworked equivalents.

Polymictic orthoconglomerate (figure 3.8) outcrops mainly in the Dave Lake and Sydney Lake areas. Although the outcrops are not large enough to observe features such as cross bedding and graded bedding, some minor tuffaceous layers believed to represent primary bedding may be found. Sorting is poor with clasts ranging up to 30 cm in diameter. Most clasts are subrounded and consist of amygdaloidal and aphyric lava which is identical to the pillow lavas of the McKay River formation. Other clasts consist of pumice, scoria, marble, quartz (possibly metachert), and reworked volcanoclastic sediment. Most important is the presence of highly vesicular lava clasts of the Rose Bay formation (figure 3.9) It is this association along with that previously mentioned which supports the conclusion that the Rose Bay formation is stratigraphically equivalent to and slightly younger than the top of the McKay River formation. In most outcrops the matrix consists of volcanogenic sandstone and reworked tuffaceous material and comprises less than 50% of the rock.

Polymictic paraconglomerate outcrops throughout the map area. Outcrops are coarsely bedded and often contain layers of fine grained tuffaceous or reworked tuffaceous material (figure 3.10).

Figure 3.8 Polymictic orthoconglomerate of the Rose Bay fm. Clasts are aligned parallel to schistosity.

Figure 3.9 Clast of highly vesicular ultramafic lava (left) beside clast of aphyric basalt. (under camera lens).

Clasts usually consist of fine grained aphyric or amygdaloidal lava and scoria and sometimes redeposited silty sediment. Clasts in these rocks are on the average smaller than those of the orthoconglomerates. They are often flattened or crescent shaped suggesting that they were initially derived directly from parental ejecta. In some instances subsequent deformation may be, for the greater part, responsible for the flattened appearance of some of the clasts. The matrix in these rocks usually comprises greater than 50% of the rock, is believed to be predominantly of a tuffaceous nature and often shows evidence of reworking. It is quite possible that the paraconglomerates represent a more distal facies of the orthoconglomerates. Although the petrography of the matrix of these rocks is similar to that of the orthoconglomerates and both units commonly contain magnetite in the matrix, the paraconglomerates often contain noticeably more magnetite. It is suspected that the conglomerates are time equivalent to the Sokoman Formation and have been enriched in iron.

SILT AND SANDSTONES

Interbanded volcanogenic silt-sandstone (figure 3.11) outcrops sporadically in the Tiphane Lake area and immediately west of Rose Bay. These rocks consist of fine grained interbanded meta-silt-sandstone occasionally containing some

Figure 3.10 Polymictic paraconglomerate of the Rose Bay fm.

Figure 3.11 Finely bedded volcanogenic silt-sandstone.

reworked sediment clasts believed to be the result of soft sediment slumping. Tuffaceous fragments have also been observed although they are rare. Magnetite has been found in varying abundance in these rocks suggesting, as with the conglomerates, a possible chronological link with the iron formation. This is supported by the presence of outcrops at Rose Bay which appear to stratigraphically overly fragmental rocks of the Rose Bay formation. It is important to note that while outcrops of this unit are few and given the complicated structural interpretation presented later in this thesis, there is a suspicious association of this unit with the northern units of the Sokoman and Menihek Formations. The tectonic boundary between the two (figure 1.1) is largely interpretive and an alternate interpretation could put some of the occurrences of the siltstones with the northern units thereby supplying a possible link between the northern and southern units (see chapter 7).

In thin section these rocks have mineral assemblages closely resembling the matrix material observed in the paraconglomerates and they may represent a distal facies equivalent.

3.4 NIMISH EQUIVALENTS

3.4.1 SUB-ERUPTIVE DYKES

This is a new unit which was until recently included in the Rose Bay formation. Examples outcrop to the east of Tiphane Lake, west of Mobey Lake and on the western shores of Way Bay. Other similar outcrops were found on the west side of Isa Lake.

At these locations ultramafic dykes are found to be intruding into carbonate and greywacke facies iron formation. Contact relationships between the magma and the iron formation indicate that the magma was intruded into soft sediment and is therefore contemporaneous (figure 3.12). In the western outcrops, the rocks are relatively fine grained ultramafic/mafic dykes whose contacts define mushroom shapes possibly indicative of protopillow structures. Lorenz (1980) describes similar structures in basaltic volcanic rocks found to be intruding soft sediments of the Dunnage Zone in Newfoundland. In thin section they appear to have been retrogressed to a very fine grained assemblage of actinolite and opaques. A particularly interesting feature about these rocks is the fact that they represent the only noted occurrences of volcanic rocks seen to be in direct contact with recognizable iron formation which is relatively void of volcanoclastic material.

Outcrops in the Way Bay area consist of highly porphyritic

Figure 3.12 Photograph of basaltic plug intruding cherty greywacke iron formation.

Figure 3.13 Phyllitic-looking actinolite-chlorite schist.

intrusive rocks which appear to be sills within the iron formation. Although these rocks are highly retrogressed, some relict olivine crystals are still visible in thin section. Although these rocks are surrounded by iron formation, contact relationships are not visible and conclusive field evidence for their direct association with the western occurrences is not available. Geochemical evidence presented in this study does however show a good correlation.

3.4.2 TUFFACEOUS ROCKS

Tuffaceous rocks believed to be the eruptive equivalents of the sub-eruptive dykes occur within the northern unit of the iron formation and are noticeably prevalent in the vicinity of the sub-eruptives. They occur as thin layers of actinolite-opaque schist and commonly contain small tuffaceous fragments. Occasionally they are crystal lithic. At the southeast corner of Tiphane Lake, crystal fragments of orthoclase were observed. Elsewhere white weathering crystals are found in thin section to be composed mostly of tremolite-actinolite and probably represent retrogressed mafic phases such as olivine or clinopyroxene.

3.4.3 ROCKS OF UNKNOWN AFFINITY

ACTINOLITE SCHIST

Outcrops of fine grained green weathering actinolite-chlorite phyllitic schist (figure 3.13) occur throughout the map area. Often they contain thin discontinuous bands of carbonate (most commonly calcite) however thicker bands are rusty weathering and could be equivalent to the carbonate bands of the iron formation. Because of the similarities, both in the field and petrographically, between actinolite schists of the proposed Nimish equivalents and the tuffaceous rocks of the Rose Bay formation, problems arise when assigning these rocks to a particular unit. Their spatial association with the Sokoman Formation along with the results of this study suggest that these rocks are in fact tuffaceous equivalents of the sub-eruptives. It should be noted however that only two samples of this rock type were geochemically analyzed. This problem is addressed later in the discussion of the petrochemistry.

CHAPTER 4

PETROCHEMISTRY

4.1 INTRODUCTION

Initial sampling of the volcanic rocks in the map area was carried out in 1979 with the results of a study by Noel (1981) determining the presence of two distinct volcanic suites. It was also concluded that neither of the two suites were chemically affiliated with the rocks of the Nimish Subgroup. The area was then revisited briefly in 1983 and more extensively in 1985 in an attempt to collect additional samples of the Rose Bay formation for further study. The interpretation at that time was that the Rose Bay formation was time equivalent to the Sokoman Formation and therefore, sampling sites were chosen based on the close proximity of actinolite schists, fragmental, and meta tuffaceous rocks to known outcrops of iron formation. It was at this time that the ultramafic sub-eruptives were found associated with the northern units of the iron formation and these were thought to be a good candidate for intrusive equivalents of the Rose Bay formation. Ultramafic-looking tuffaceous rocks, in close proximity to the iron formation (northern units) were also sampled. In addition, known occurrences of Rose Bay volcanic rocks and conglomerate clasts were sampled as well as some new outcrops of pillow basalts found on the eastern shore of Rose

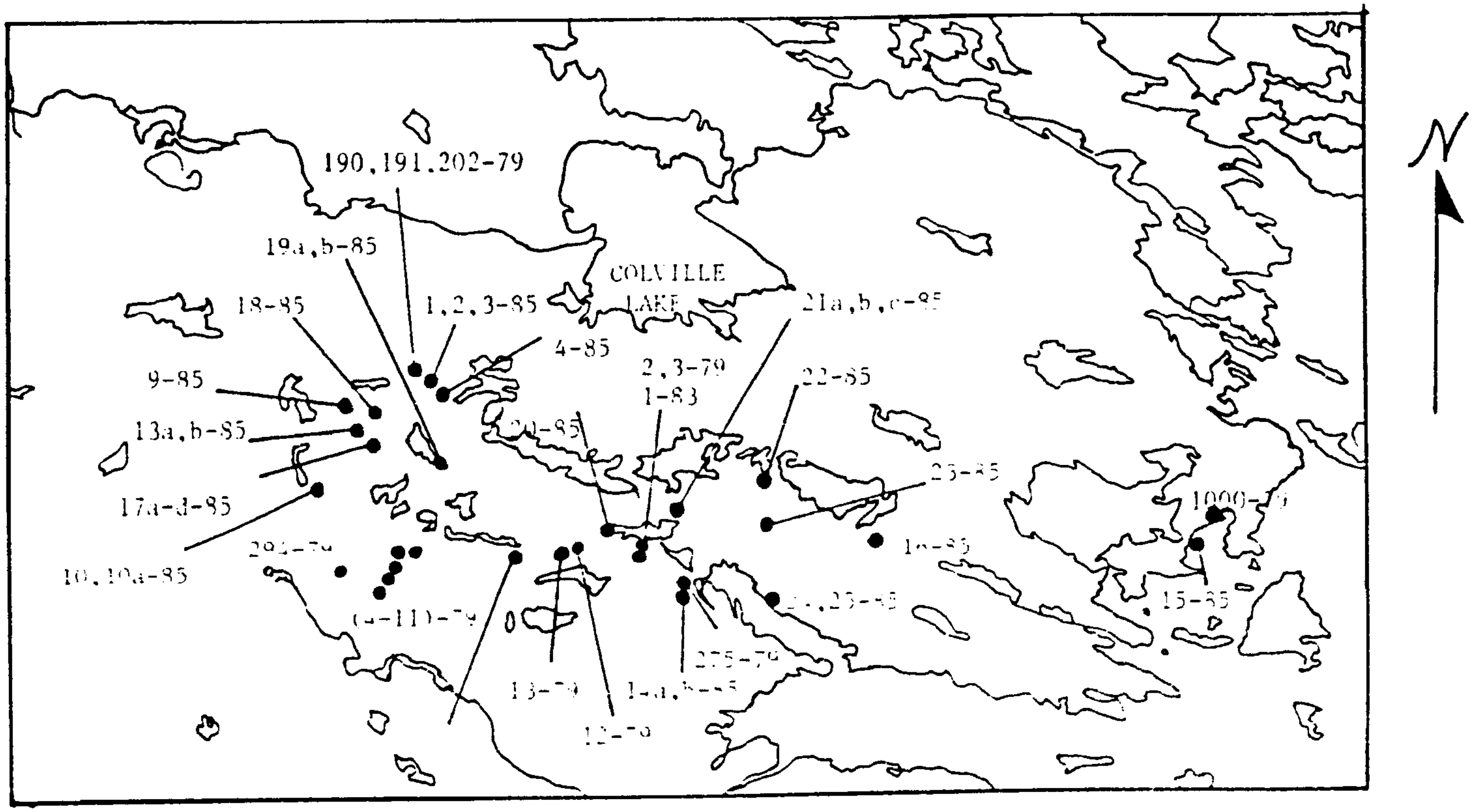


FIGURE 4.1 SAMPLE LOCATION MAP

Bay. Presented in this section are the results of the geochemical analyses of all samples taken to date.

Table 2 (see appendix) lists the chemical data for the volcanic rocks. Samples have been grouped according to the findings of this thesis.

Figure 4.1 is a location map for all the geochemical samples taken. Sample locations are also indicated on the large map, figure 1.2 found at the back of this thesis.

4.2 SAMPLE PREPARATION

A total of 53 samples were collected and analyzed. Most of the magmatic or near magmatic samples studied, ie. lavas, (?) pipe breccia or agglomerate, show little sign of deformation except the basalt samples taken from the A-Lake area. Deformation in these samples is moderate for NN-4 to NN-7-79 while NN-294-79 is strongly deformed. A few samples of the fragmental tuffaceous rocks show slight degrees of flattening however most samples were relatively undeformed. All samples have been completely retrogressed to greenschist facies except sample NN-1000-79 from Way Bay. Although this rock exhibits greenschist mineralogy it still contains recognizable relict olivine and orthopyroxene.

Although most of the volcanic rocks within the map area possess a pervasive metamorphic fabric, samples were collected from outcrops showing minimal fabric development. The least deformed lavas as well as the larger clasts in both the fragmental rocks and conglomerates still exhibit relict igneous texture. The matrix of some of the tuffaceous rocks sampled is best described as a fine grained schist. Samples NN-16-85 and NN-18-85 have no recognizable fragments and are also classified as fine grained schist.

In order to minimize the effects of metamorphic modification, these rocks were first slabbed and carefully trimmed in order to prevent any contamination by alteration products. Then the samples were carefully dissected in order to exclude any secondary vein material. A jaw crusher reduced the rock chunks into 1 cm chips which were then powdered in a tungsten carbide pulverizer.

4.3 ANALYTICAL TECHNIQUES

Major element analyses were determined by atomic absorption while trace element analyses were performed by X-ray fluorescence. REE analysis was completed by ICP-MS. For a complete description of analytical techniques involved the reader is referred to Longerich et al. (1990).

4.4 RESULTS

(variation diagrams)

A selection of variation diagrams for all samples of the volcanic rocks collected in the McKay River area are presented below. The intention here is to illustrate the basic differences in composition of the parental magmas from which these rocks were derived. Due to the nature of these rocks with regards to metamorphism and deformation most plots will only include elements considered to be relatively immobile. Although the trace element data which follows is more useful for differentiating between the volcanic suites, some peculiar variations in the major element chemistry of the volcanic rocks must first be accounted for.

Figures 4.2a-d plot TiO_2, MgO, CaO and total Fe against SiO_2. Noticeably absent in the area are intermediate and felsic members of either of the three suites. Two samples of actinolite schist, NN-16-85, and NN-18-85 (shown as triangles) do have SiO_2 values just less than 65.00% Although these samples, (one from the Tiphane Lake area and the other from the Marny Lake area), are some distance apart, they are compositionally nearly identical. The trace element data which follows suggests that these rocks are derivatives of the Nimish sub-eruptives, which

FIGURE 4.2 a (SIO2 VS TIO2)

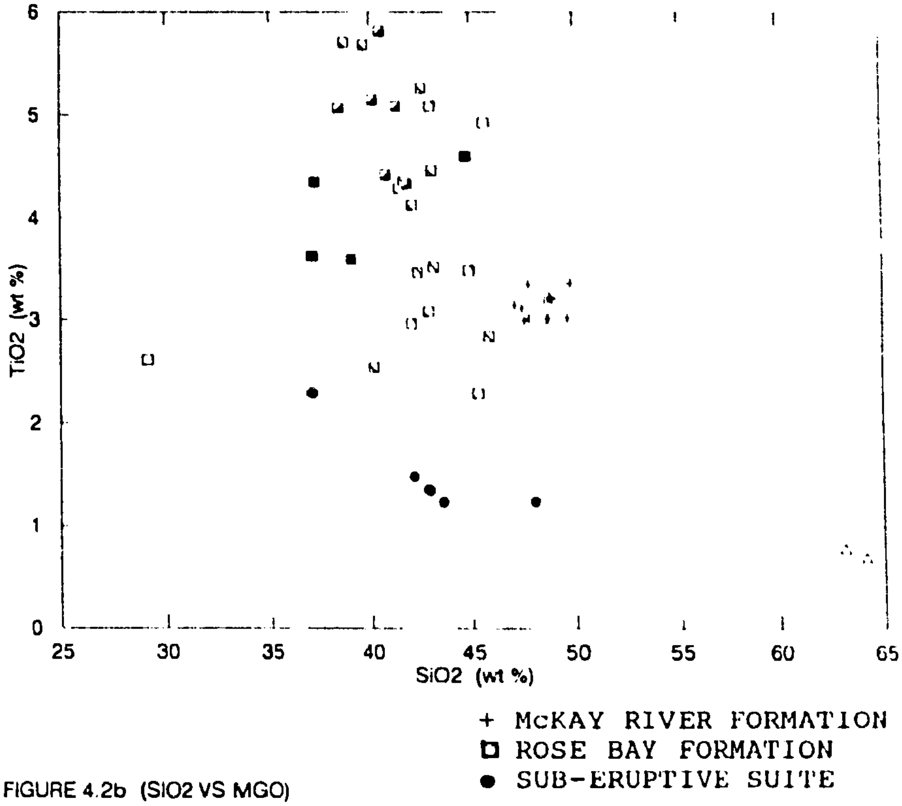


FIGURE 4.2b (SIO2 VS MGO)

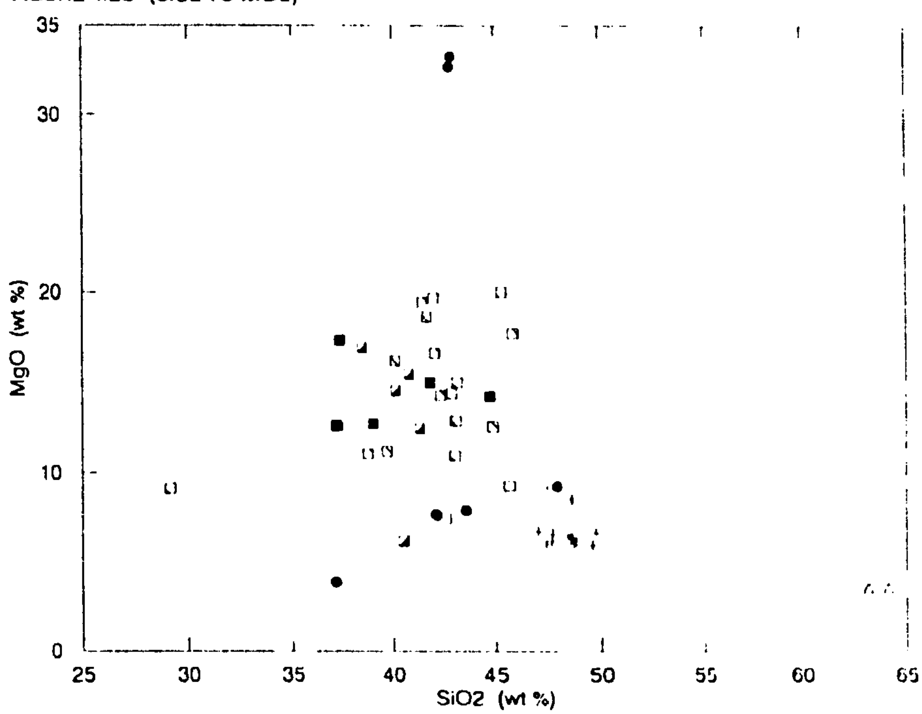
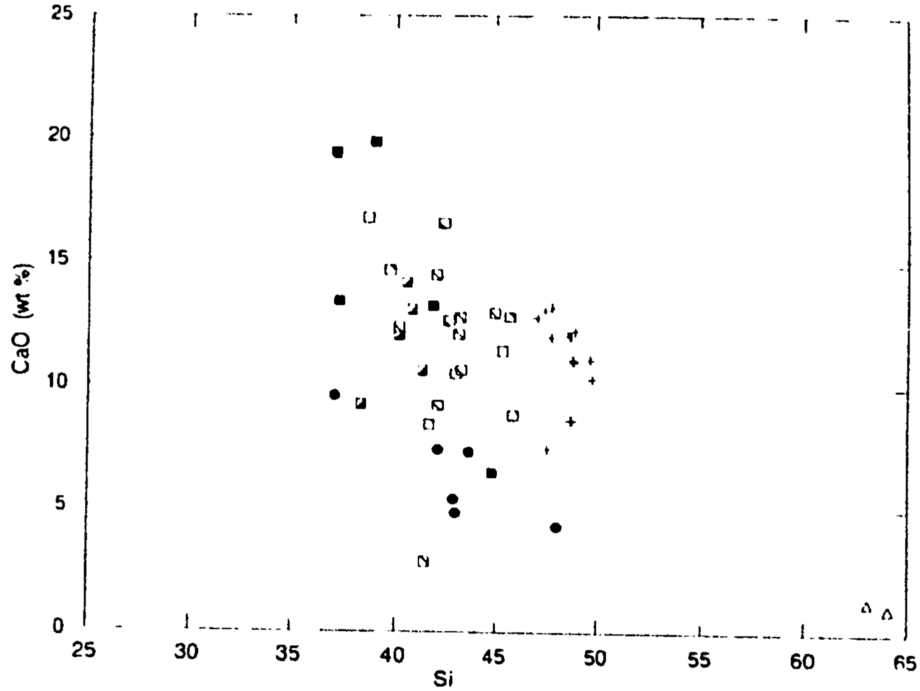
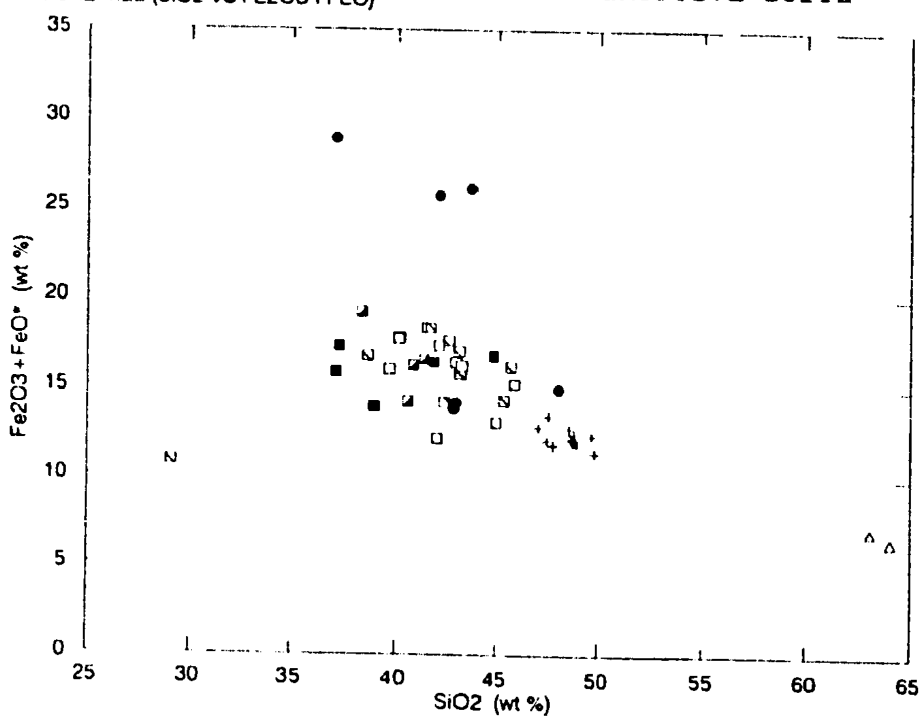


FIGURE 4.2c (SIO2 VS CAO EXCL 1-85)



+ McKAY RIVER FORMATION
□ ROSE BAY FORMATION
● SUB-ERUPTIVE SUITE

FIGURE 4.2d (SIO2 VS FE2O3 + FEO)



are interbedded with the northern unit of the iron formation. Proportionately depressed total Fe, MgO, TiO_2, CaO, MnO, P_2O_5 concentrations, (see appendix) suggests that these rocks have been diluted by syn-depositional chert, (accounting for the high SiO_2 content), and a minor input of pelitic material to account for normal Al_2O_3 and elevated K_2O and Na_2O values. Their significance is discussed later.

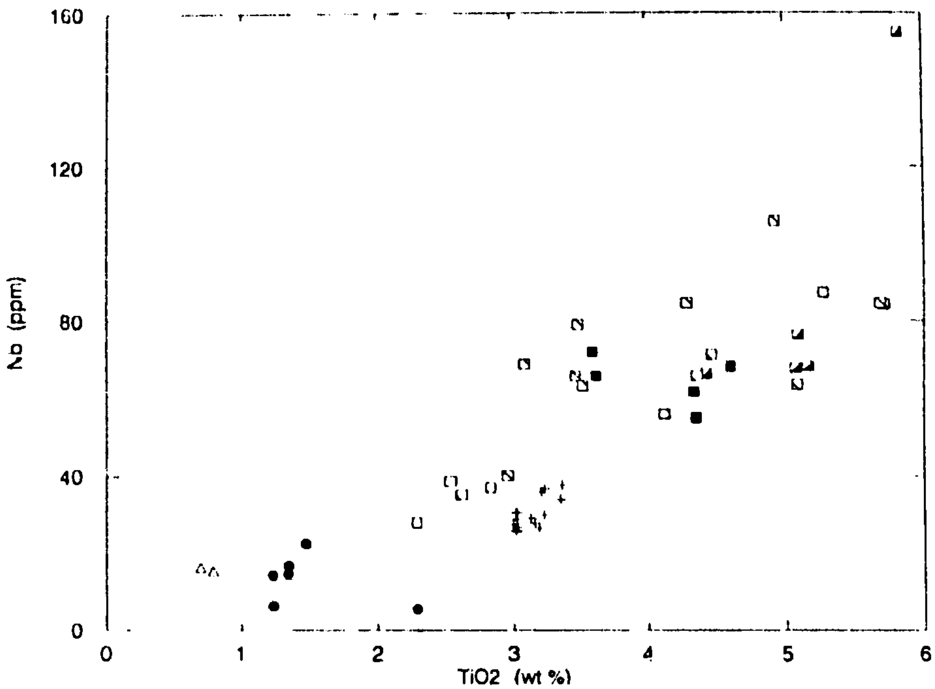
Of the sub eruptive rocks, two samples NN-15-85 and NN-1000-79 consist mostly of cumulate olivine and orthopyroxene resulting in lower SiO_2, TiO_2, and very high MgO. Samples NN-4, 10, and 10a - 85 are enriched in Fe at lower vanadium values (see appendix) suggesting contamination from the iron formation (host rock) with subsequent dilution of SiO_2. This is supported by sample NN-9-85 which has only slightly higher than expected values for Fe and a more normal value for SiO_2. Assuming a value of total FeO = 16.00 (as in the sample NN-9-85) for the enriched samples NN-4-85, NN-10-85, and NN-10a-85 SiO_2 values rise by approximately 5.00% It is therefore possible that the liquids from which these rocks were derived were actually basaltic or at the most, mildly ultrabasic in composition. Even after adjusting SiO_2 and FeO values for the sub eruptive rocks, comparisons with the McKay River formation basalts show noticeably higher TiO_2, and CaO contents in the latter.

In a later section it is shown that the Rose Bay formation is a suite of volcanic rocks having strong affinities to present day olivine melilitites. These rocks are undersaturated, strongly alkaline and often show extreme values with respect to their chemistry. The following plots which are best suited for the normal spectrum of basaltic rocks are therefore intended only to show general differences between these rocks and the other rocks of the McKay River area. A separate section of this thesis is devoted to the Rose Bay formation and includes a comparison to similar rocks and a discussion of their chemical nature and significance.

All diagrams exhibit clear differences between the McKay River basalts and the Rose Bay formation. The solid squares represent samples of lava or lava clasts taken from the conglomerates, while the open squares are fragmental tuffs. Squares half-filled represent samples of agglomerate and possible pipe breccia. Although most samples of the Rose Bay formation are ultrabasic, the tuffaceous samples in general are slightly higher in SiO_2 with samples NN-2-79 and NN-191-79 crossing into the field of basic rocks. Sample NN-1-83 is located close to NN-2-79 and NN-190-79 close to NN-191-79 and both are undersaturated thereby suggesting that some of the fragmental tuffaceous rocks may have been slightly enriched in SiO_2 from external sources during deposition. Sample NN-1-85 has anomalously low silica and high CaO (37.92%) values and has there for been excluded from figure 4.2c to allow for a more meaningful comparison of the other samples. In thin section this sample was found to contain an abundance of carbonate sphericules which accounts for the anomalously high CaO value. Values for the other oxides appear to be proportionately depressed when compared with the other samples suggesting CaO has been enriched by an external source, possibly carbonate sedimentation.

Figures 4.2e-g are bivariate scattergrams plotting immobile trace elements Nb, Y, and Zr against TiO_2. These elements have been shown to be generally immobile (Pearce and Cann, 1973; Pearce and Norry, 1979; and others) under conditions of low to medium grade metamorphism and are therefore considered to be useful for studying the volcanic rocks of the McKay River area. These diagrams confirm the results of the previous major oxide plots that the Rose Bay formation and the McKay River formation constitute two separate volcanic suites. Parallel but separate differentiation trends indicate that the suites were derived from two distinct parental magmas formed as a result of two separate mantle melting episodes. In these diagrams the affinity of the sub-eruptives (solid circles) is less clear. A paucity of samples along with the effects of dilution makes the data presented here less reliable. Rough trends can be seen in the plots of Nb and Y however these are inconclusive. Of particular interest however are the similarities between the actinolite schists (open triangles) and the sub eruptive rocks and their relatively tight grouping as shown in these and the following

FIGURE 4.2e (TIO2 VS Nb)



+ McKAY RIVER FORMATION
□ ROSE BAY FORMATION
● SUB-ERUPTIVE SUITE

FIGURE 4.2f (TIO2 VS Zr)

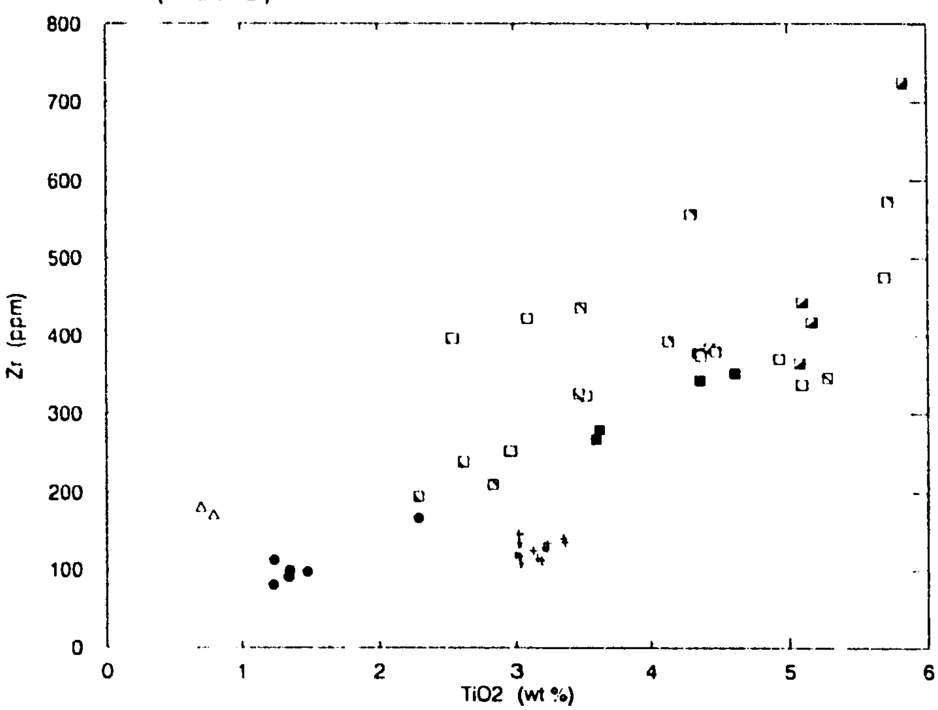
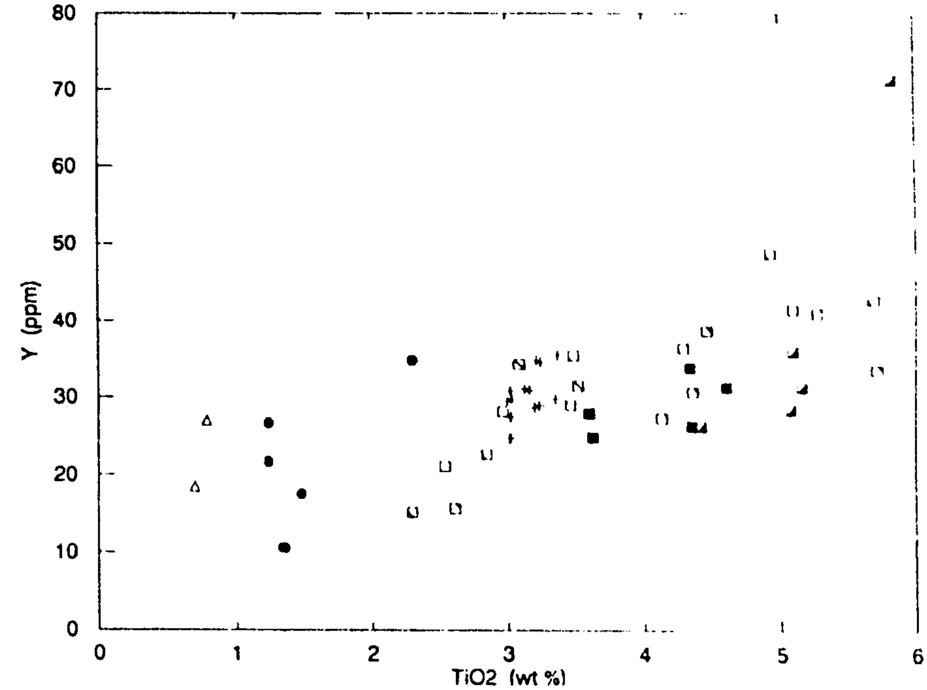
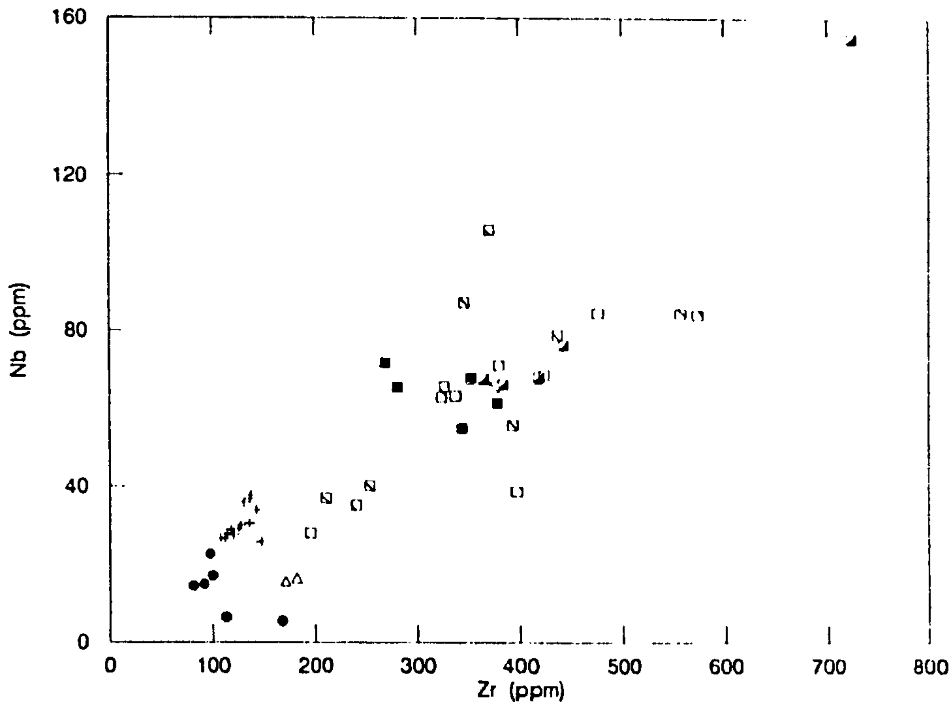


FIGURE 4.2g (TIO2 VS Y)



+ McKAY RIVER FORMATION
☐ ROSE BAY FORMATION
● SUB-ERUPTIVE SUITE

FIGURE 4.2h (Zr VS Nb)



diagrams. This significance of this observation is discussed later in this chapter.

Figures 4.2h-i which plot Zr against Nb and Nb against Y clearly show parallel but separate trends for both the McKay River and Rose Bay formations. The sub-eruptive rocks show similar rough trends (almost vertical) and grouping as in the previous diagrams and again the actinolite schists show an affinity to these rocks.

4.5 AFM DIAGRAM

Included in figure 4.3 are all the volcanic rocks of the McKay River area. Due to a lack of chemical variation the rocks of the McKay River formation do not show a trend. Although it will be demonstrated later that the Rose Bay formation is a strongly alkaline suite, the tholeiitic trend exhibited here is simply reflecting the high MgO and FeO content of these rocks.

The sub-eruptive rocks also exhibit a tholeiitic trend however this is believed to be a function of Fe-enrichment for some samples or the cumulate nature of others.

4.6 TRACE ELEMENT DISCRIMINATION DIAGRAMS

Figures 4.4a-b are trace element discrimination diagram

FIGURE 4.2i (Nb VS Y)

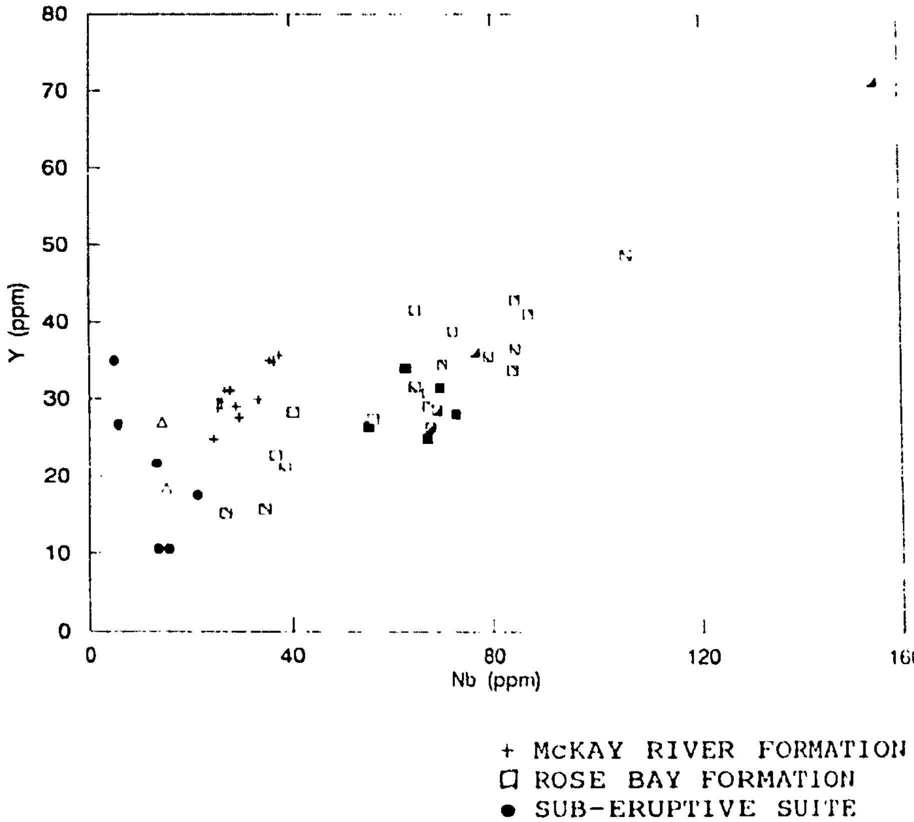
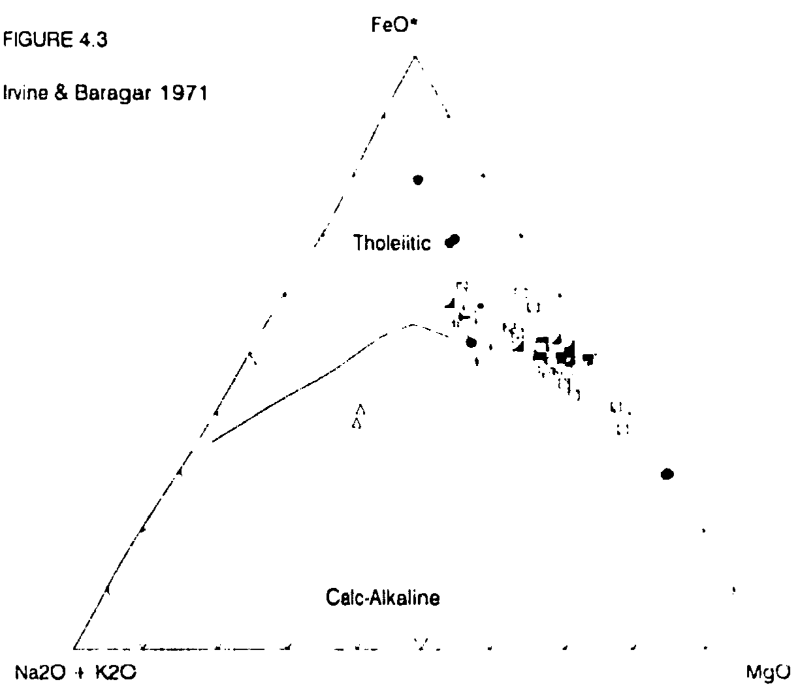


FIGURE 4.3

Irvine & Baragar 1971



developed by Winchester and Floyd (1977) for discriminating between different magma series. In figure 4.4a log Zr/TiO_2 is plotted against log Nb/Y. It has been shown that the Zr/TiO_2 ratio of a magma series increases with differentiation and can therefore be used as a differentiation index while Nb/Y is used as an alkalinity index only (Winchester and Floyd, 1977). In this diagram the basalts of the McKay River formation plot well within the field of alkali basalts and show a slight but noticeable trend towards the trachyandesite field.

The ultrabasic rocks of the Rose Bay formation, although falling mostly within the alkali basalt field lie closer to the field for basanites and nephelenites. The sub-eruptives have considerable horizontal scatter.

In figure 4.4b which plots SiO_2 against Zr/TiO_2 the McKay River formation basalts plot within the sub-alkaline field due to anomalously high TiO_2 at given values of SiO_2. Although the grouping is not as tight as that seen in the previous diagram a positive trend towards the trachyandesite field is evident.

The Rose Bay formation which contains elevated amounts of Zr even at high TiO_2 plots within the basanite/nephelenite field.

The sub-eruptive rocks plot within a narrow range with respect to Zr/TiO_2 having consistent values for both. Adjusting for SiO_2 dilution by FeO would place most samples closer to the field of alkali basalts and also form a tight cluster around NN-9-85.

4.7 Zr-Ti-Y DIAGRAM

Figure 4.5 utilizes a diagram developed by Pearce and Cann (1973) for discriminating between different geotectonic regimes. The position of points for the McKay River basalts which plot within the field of within plate basalts reflects their higher than normal TiO_2 values and lower values for Zr.

The Rose Bay formation which has elevated values for both Zr and TiO_2 plots on the extreme left hand side of the within plate basalt field.

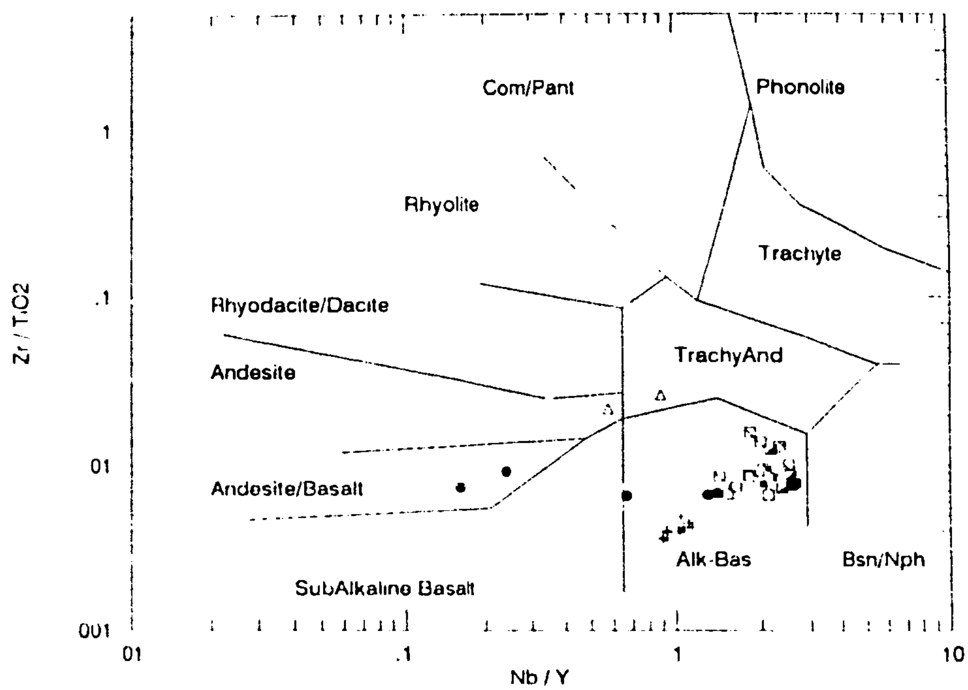
The sub-eruptive rocks exhibit a certain amount of scatter however these to fall within or close to the field of within plate basalts.

4.8 Zr/Y - Zr DIAGRAM

Figure 4.6 is a diagram developed by Pearce and Norry (1979) to distinguish between mid ocean ridge basalts, island arc basalts and within plate basalts. As with the previous diagram the basalts of the McKay River formation plot well within the field of within plate basalts as represented by higher Zr with respect to Y.

Again the Rose Bay formation shows extreme values, plotting

FIGURE 4 4a Winchester & Floyd 1977



+ McKAY RIVER FORMATION
□ ROSE BAY FORMATION
● SUB-ERUPTIVE SUITE

FIGURE 4 4b Winchester & Floyd 1977

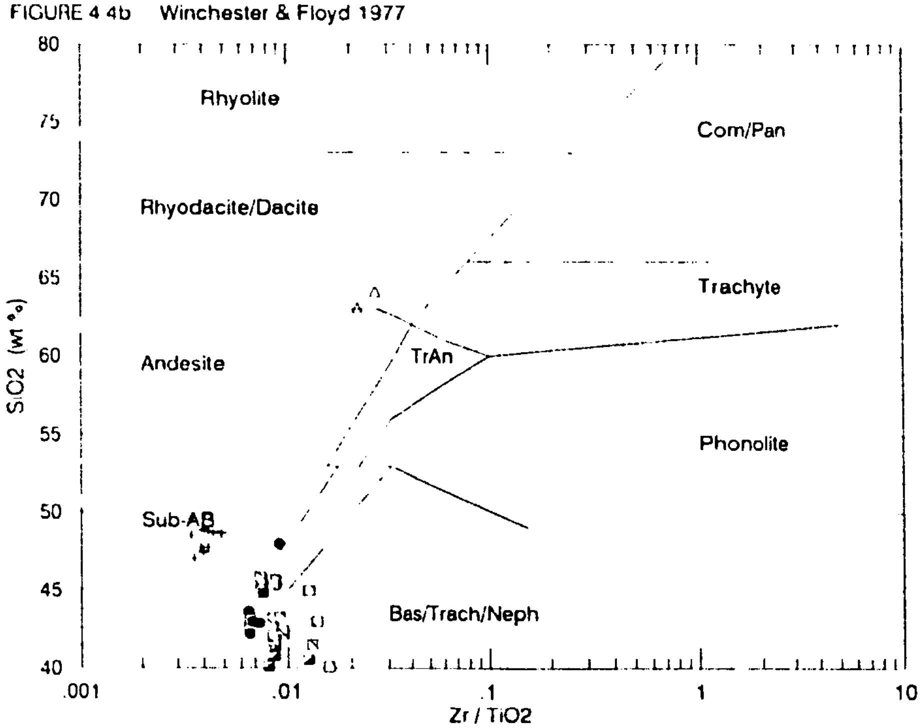


FIGURE 4.5

Pearce & Cann 1973

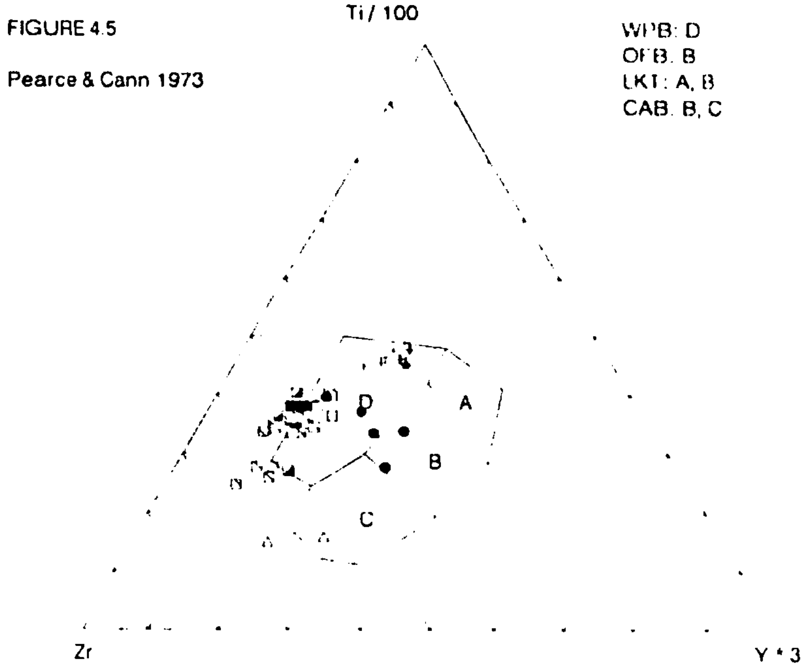
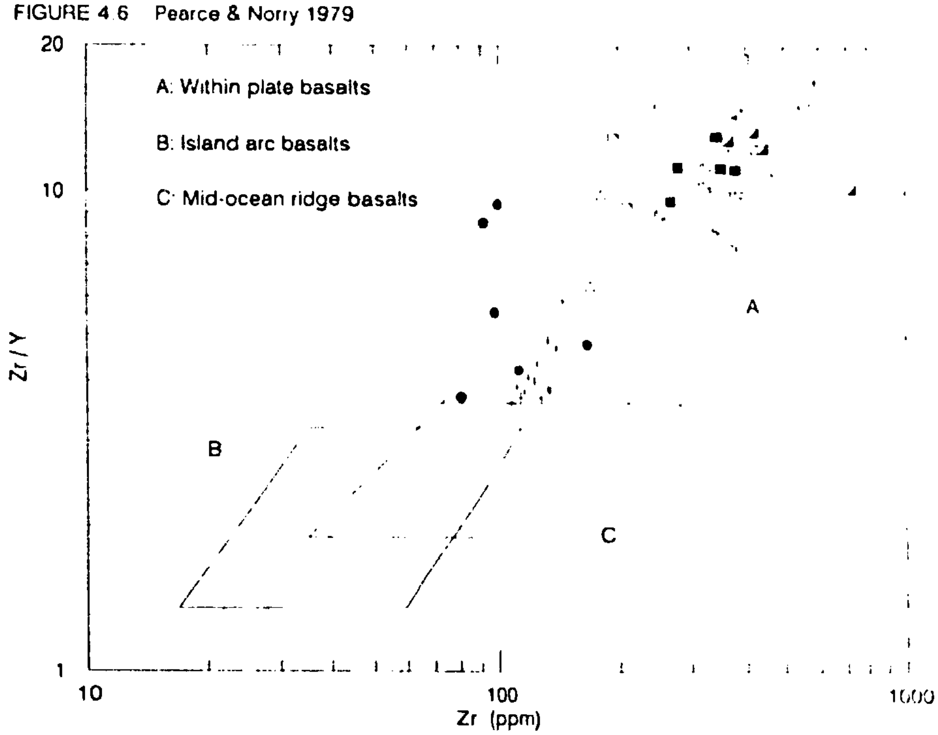


FIGURE 4.6 Pearce & Norry 1979



mostly outside or slightly inside the within plate field.

The sub-eruptive rocks although possessing some degree of scatter maintain an affinity for the same field.

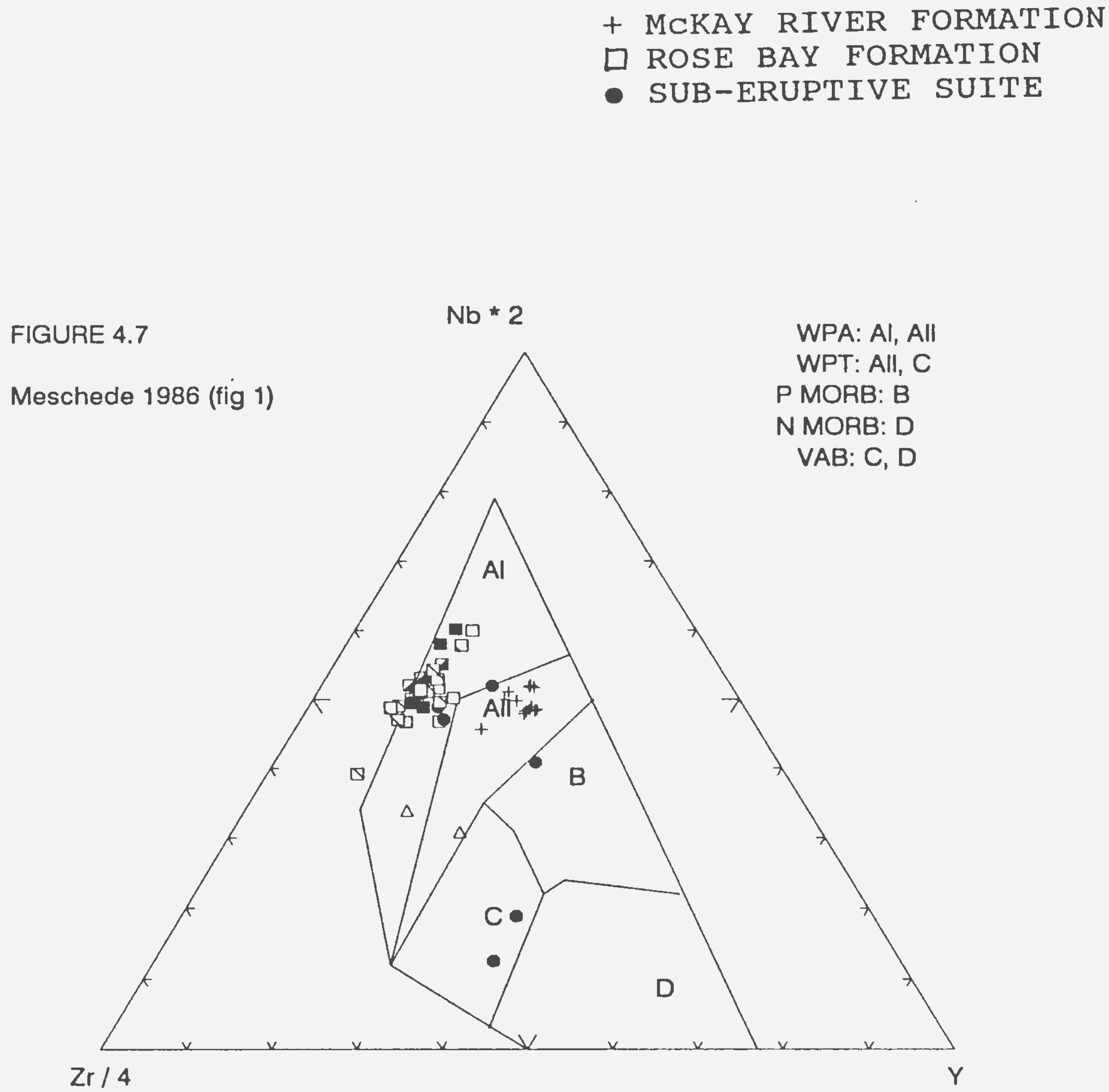
4.9 Nb*2 - Zr/4 - Y DIAGRAM

Figure 4.7 is a discrimination diagram developed by Meschede (1986) for distinguishing between both tectonic setting and magma series. The McKay River basalts and the Rose Bay formation plot well within the fields for within plate alkali basalts supporting the results of the previous magmatic and tectonic discrimination diagrams. Again the Rose Bay formation plots to the extreme edge of this field. The sub-eruptive rocks show a similar scatter as before. Samples NN-4-85 and NN-9-85 plot within the field for within plate tholeiites field due to very low Nb values as compared to the other members of this group.

4.10 RARE EARTH PLOTS

Figures 4.8a-c are REE plots (normalized to primitive mantle) of selected samples for the McKay River formation (figure 4.8a), the Rose Bay formation (figure 4.8b) and the sub-eruptive rocks,(figure 4.8c).

Figure 4.8a shows a standard REE pattern for alkali basalts being moderately enriched in the light-REE with a slightly


+ McKAY RIVER FORMATION
□ ROSE BAY FORMATION
● SUB-ERUPTIVE SUITE
FIGURE 4.7
Meschede 1986 (fig 1)
Nb * 2
WPA: AI, AII
WPT: AII, C
P MORB: B
N MORB: D
VAB: C, D
AI
AII
B
C
D
Zr / 4
Y

sloping profile for the heavy-REE. Values compare well with results for alkali basalts presented by Clague and Frey (1982) and Chauval and Jahn (1981). A slight positive Eu anomally is best explained by the presence of microphenocrysts of plagioclase observed in thin section. It should be noted however that samples NN-24-85 (pillow lava) and NN-25-85 (interpreted to be a feeder dyke) were collected from the same outcrop and may not be representative of the McKay River basalts as a whole.

Figure 4.8b shows REE data for some selected samples of the Rose Bay formation and an assortment of olivine melilitites using data from Alibert et al. (1983)

From the profiles shown here it is evident that the Rose Bay formation is strongly enriched in the light-REE, a feature shown by Frey et al.(1971) and Alibert et al. (1983) to be characteristic of olivine melilitites, carbonatites and kimberlites. Low degrees of partial melting which is suggested to be responsible for the formation of these rock types is interpreted by some to cause the enrichment factors in these rocks to be quite variable. It is also evident that the pattern shown for the selected olivine melilitites matches that of the Rose Bay formation.

Figure 4.8c shows REE data for the sub-eruptive rocks. In general these rocks too exhibit a pattern characteristic of

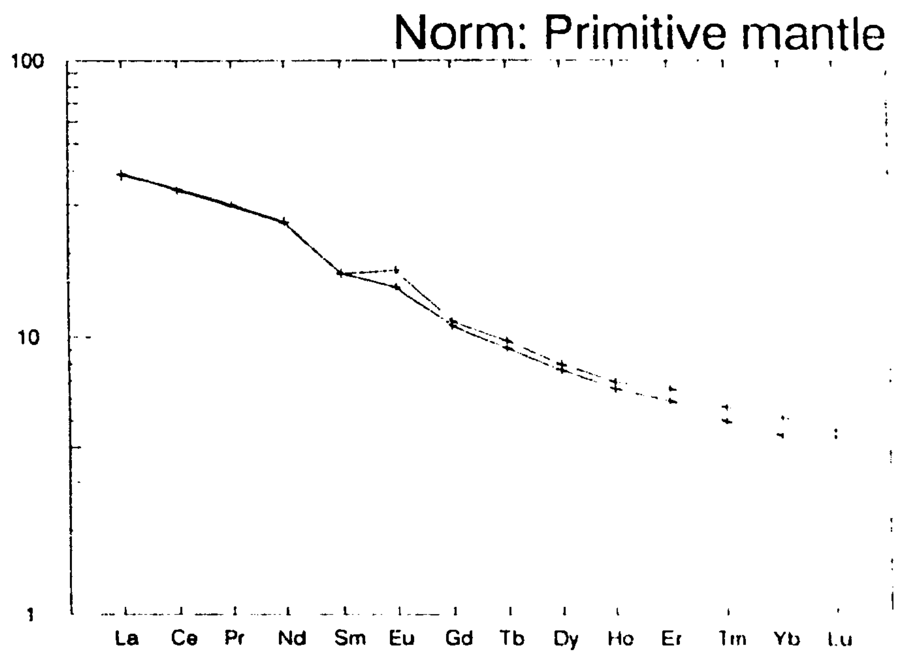


Fig. 4.8a McKay River formation

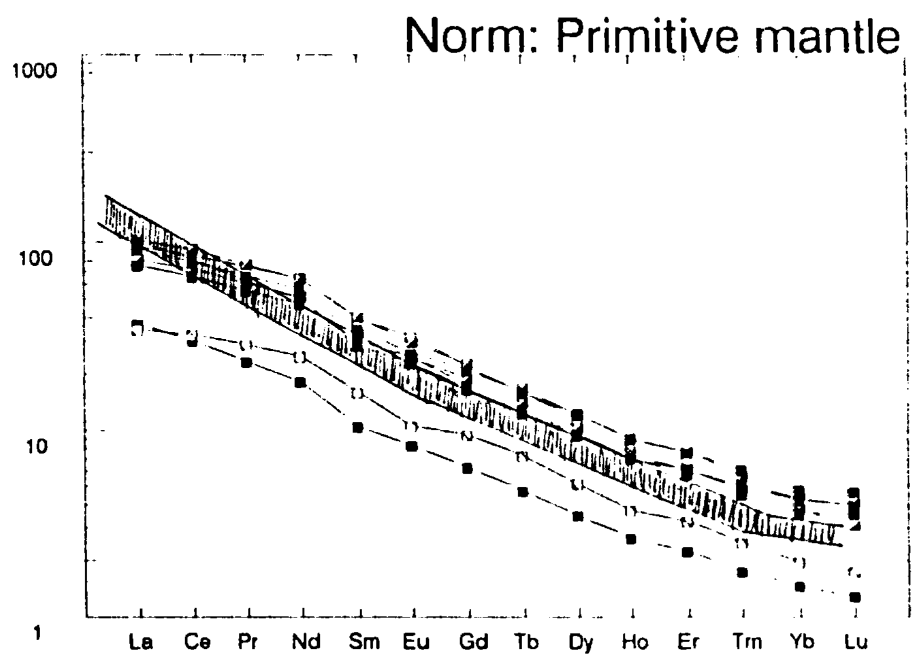


Fig. 4.8b Rose Bay formation

SELECTED SAMPLES OF OLIVINE MELILITITES

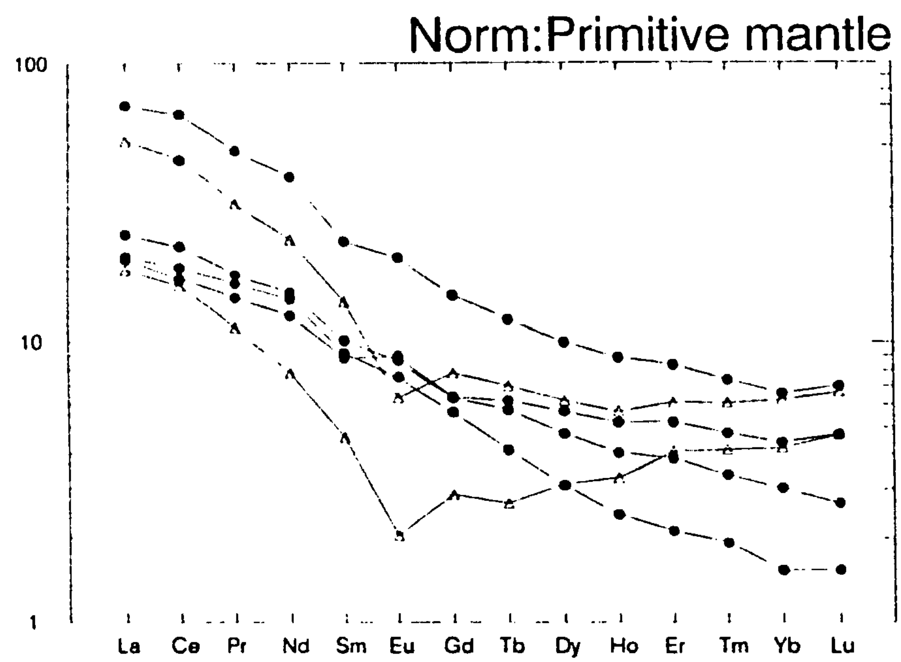


Fig. 4.8c Sub-eruptive suite

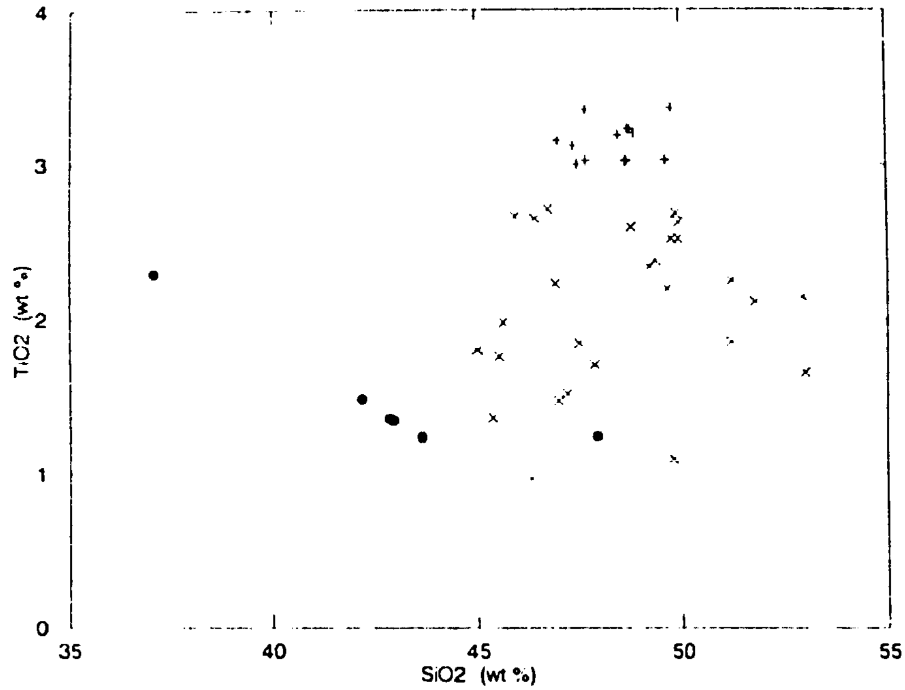
alkali basalt. While crossing profiles are usually considered to be due to metamorphism in rocks such as these the patterns exhibited here are interpreted to be more likely due to these rocks having undergone a greater degree of fractionation as noted by Evans (1980). The actinolite schist samples NN-16-85 and NN-18-85 (triangles) do show parallel trends and possess a noticeable negative Eu anomally. This is possibly due to fractionation of plagioclase from the magma from which these rocks were originally derived but is more likely the result of later alteration.

4.11 COMPARISON OF THE BASALTS WITH THE NIMISH SUB GROUP

The following diagrams compare the basaltic rocks (SiO_2 = 45 - 52%) of the McKay River formation with equivalents of the Nimish Subgroup found to the north. Included for comparison are the sub-eruptive rocks found in the McKay River area. Evans (1978) reported some of the Nimish rocks to have SiO_2 values less than 45% but goes on to mention that silica loss is suspected in those rocks. To allow for a more meaningful comparison, data for the Nimish Subgroup presented here has been recalculated volatile free and for the purpose of this study only those analysis having SiO_2 values > 45% have been used.

Figures 4.9a-d plot TiO_2, MnO, CaO, and total FeO against

FIGURE 4.9a (SIO2 VS TIO2)



+ McKAY RIVER FORMATION
● SUB-ERUPTIVE SUITE
x NIMISH SUBGROUP

FIGURE 4.9b (SIO2 VS MnO)

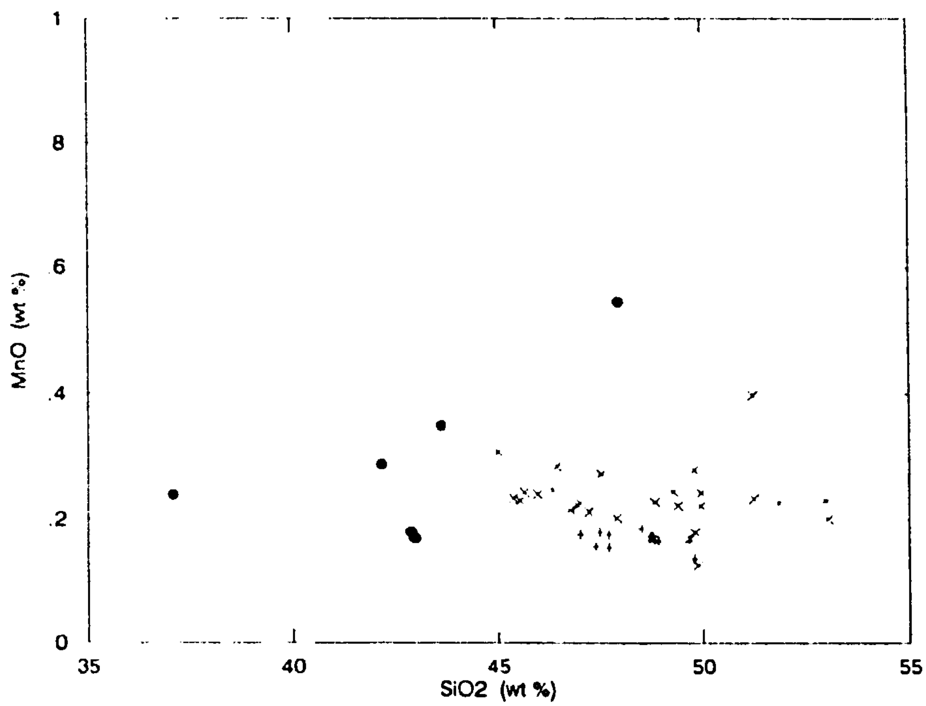
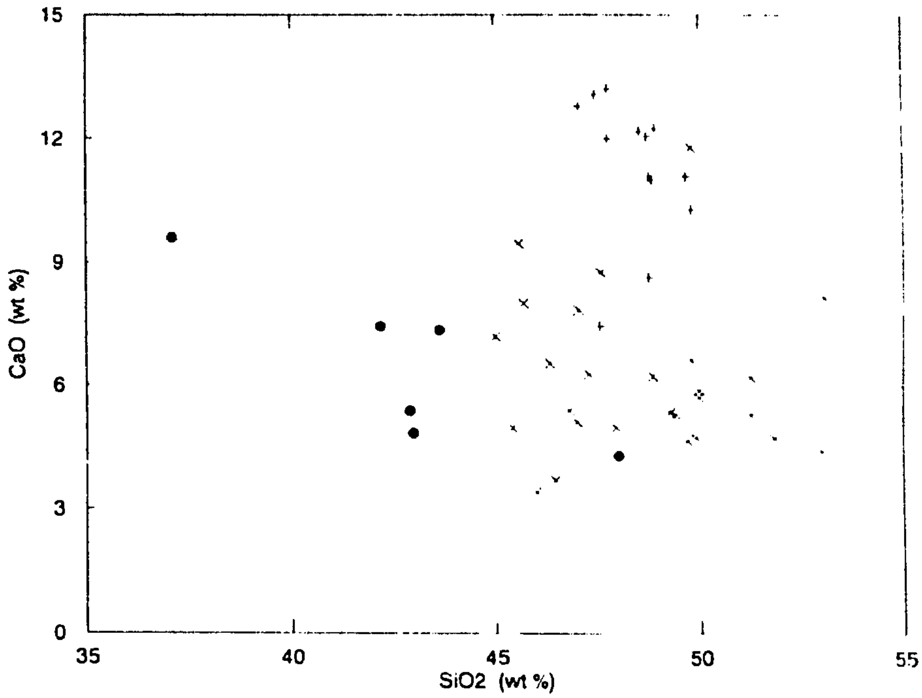
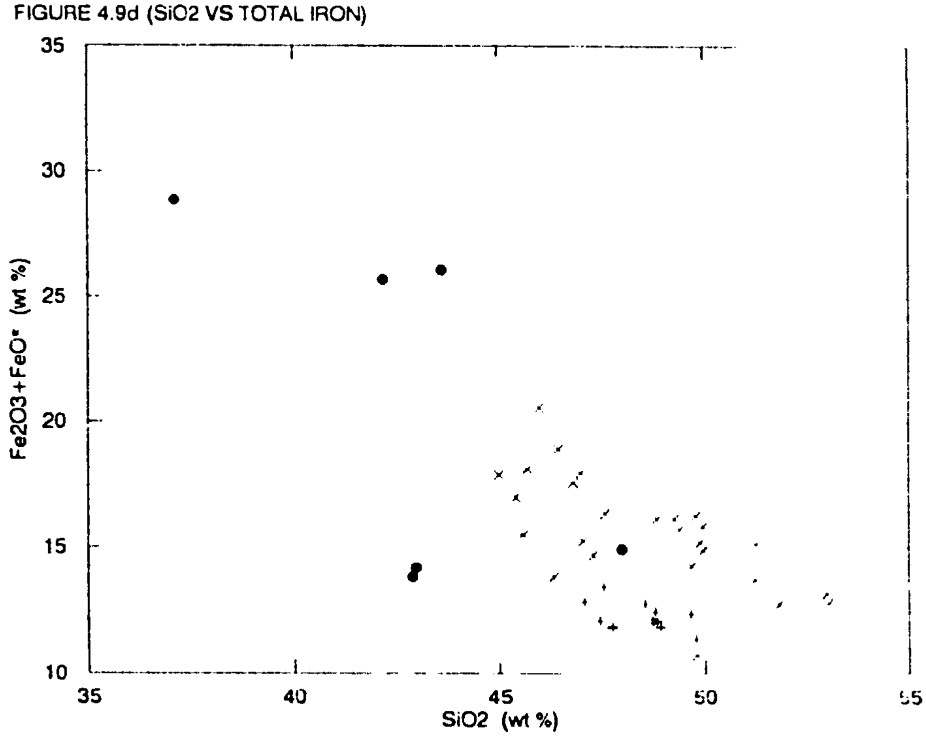


FIGURE 4.9c (SIO2 VS CaO)



+ McKAY RIVER FORMATION
● SUB-ERUPTIVE SUITE
x NIMISH SUBGROUP

FIGURE 4.9d (SIO2 VS TOTAL IRON)



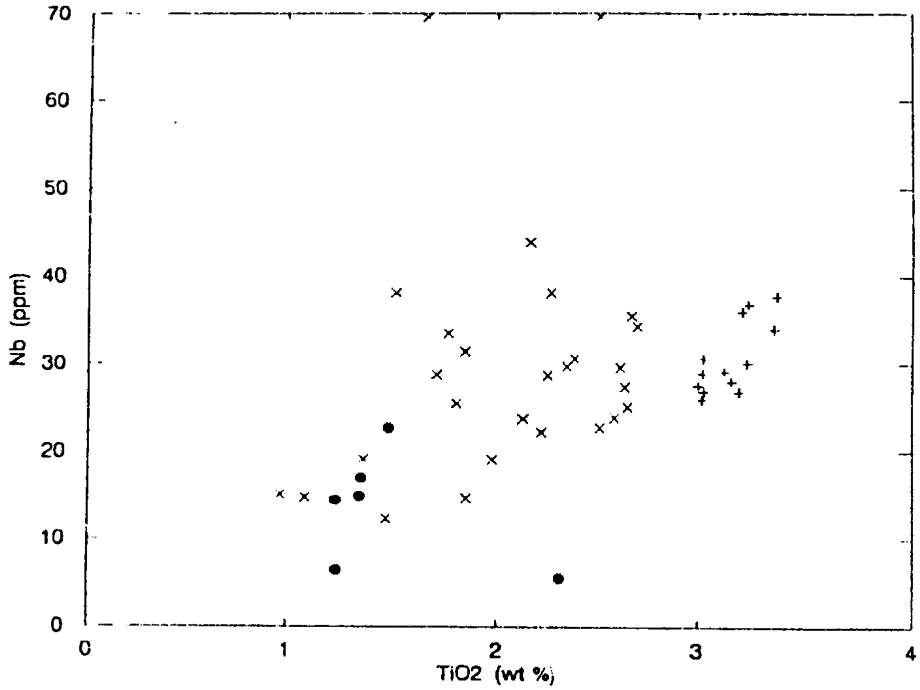
SiO_2. From these diagrams it can be seen that while the Nimish basalts and the McKay River formation have similar MgO and Al_2O_3 values, (see appendix) the McKay River formation basalts have higher TiO_2 and CaO, and lower MnO and total Fe than the Nimish rocks. Also of interest is the similarity of the sub-eruptive rocks to the Nimish basalts. Sample NN-9-85 which is considered to be the least affected by FeO dilution plots well within the field of the Nimish basalts except for MnO. Excluding the cumulate rocks, the other samples plot the same if SiO_2 values are adjusted to account for the effects of Fe dilution.

Figures 4.9e-h are Nb vs TiO_2, Zr vs TiO_2, Y vs Zr and Nb vs Zr plots for the McKay River formation, the sub-eruptives, and the Nimish basalts. In figures 4.9e - f parallel but separate fields are evident for the Nimish basalts and the McKay River basalts while the sub-eruptives plot in close association with the Nimish rocks.

Figures 4.9g-h plot Nb vs Zr and Y vs Zr. Again two distinct fields are evident for the Nimish and McKay River basalts with a continued association of the sub-eruptives with the Nimish Sub Group. Common to all diagrams is the tendency of the sub-eruptive rocks to plot with those Nimish samples having the lowest abundances of the elements graphed.

Figures 4.9i-j are tectonic discrimination diagrams from Meschede (1986) and Pearce and Cann (1973) respectively which

FIGURE 4.9e (TiO2 VS Nb)



+ McKAY RIVER FORMATION
● SUB-ERUPTIVE SUITE
x NIMISH SUBGROUP

FIGURE 4.9f (TiO2 VS Zr)

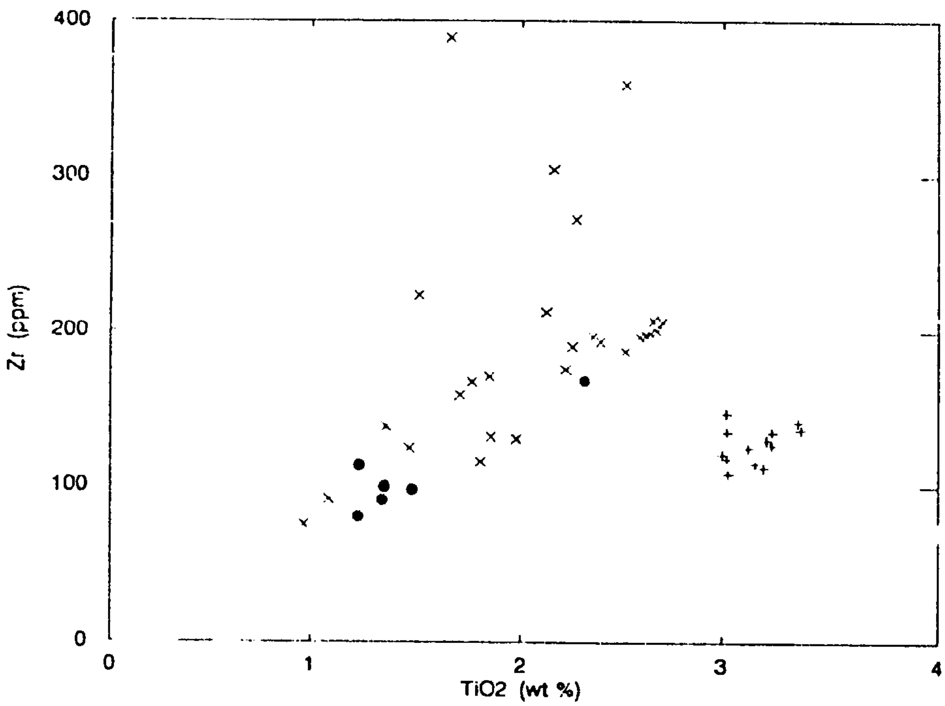


FIGURE 4.9g (Zr VS Nb)

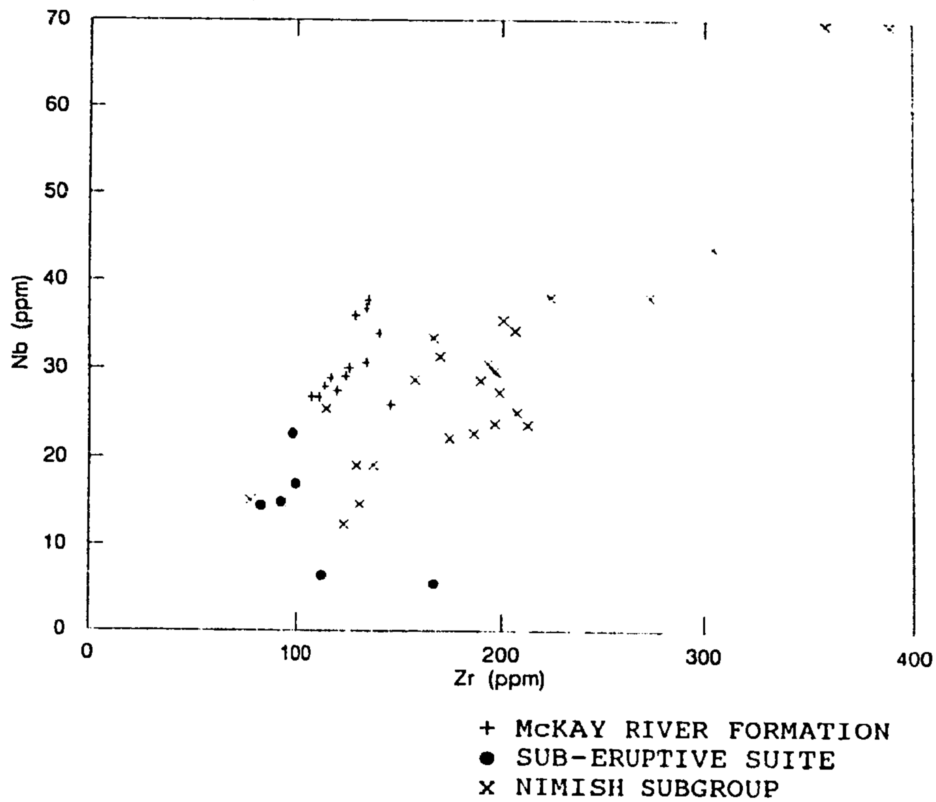


FIGURE 4.9h (Zr VS Y)

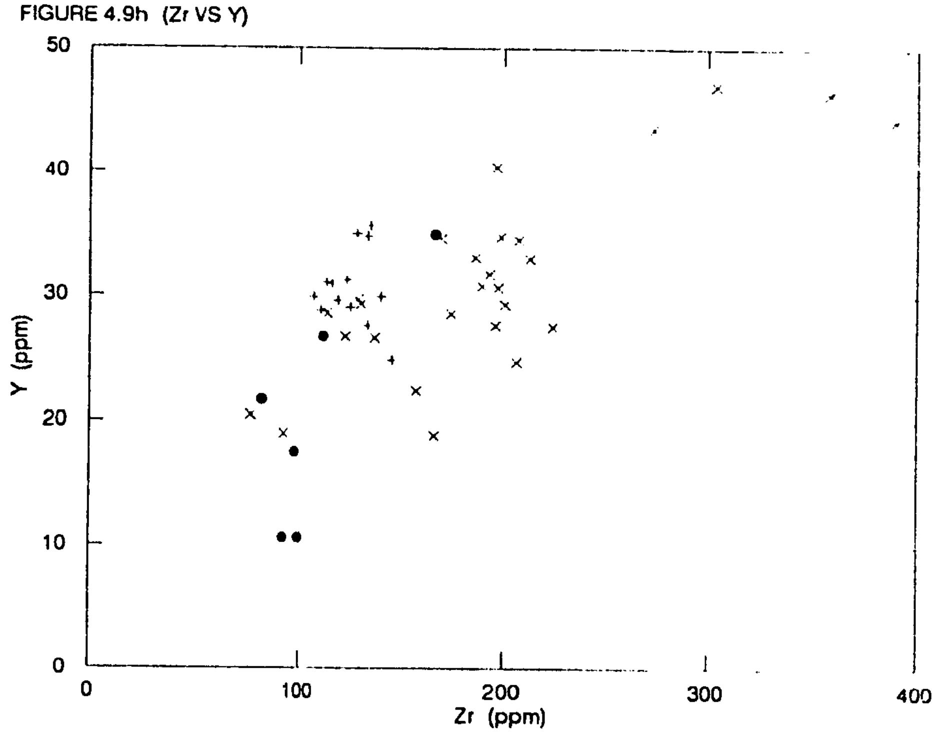
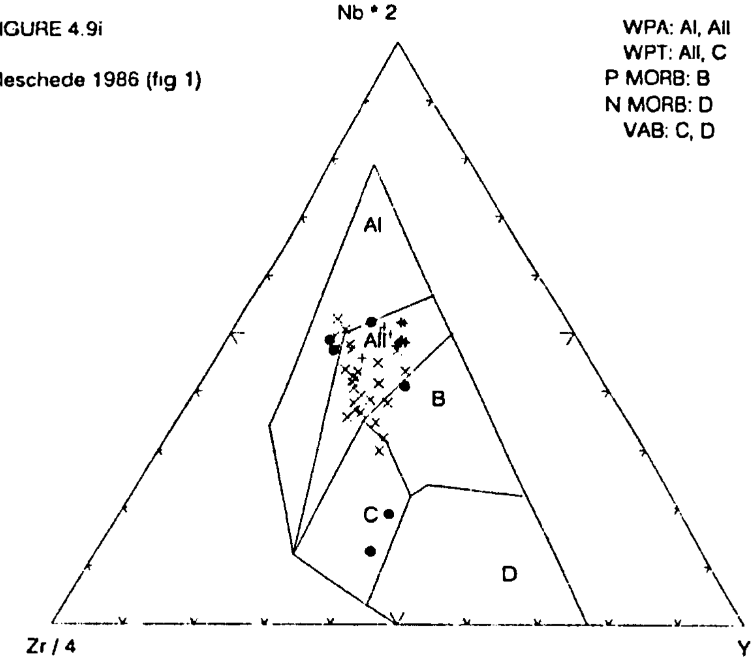


FIGURE 4.9i

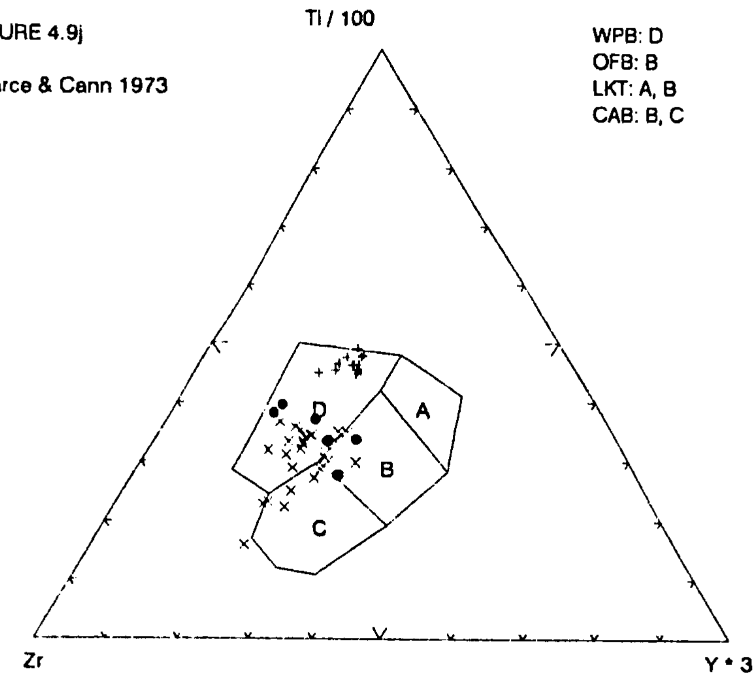
Meschede 1986 (fig 1)



+ McKAY RIVER FORMATION
● SUB-ERUPTIVE SUITE
x NIMISH SUBGROUP

FIGURE 4.9j

Pearce & Cann 1973



again show distinct differences between the McKay River basalts and those of the Nimish. Evans (1978) concluded that the Nimish rocks were a suite of within plate alkali basalts, a conclusion supported by figures 4.9i and 4.9j. In both instances the Nimish basalts plot within the fields for within plate basalts and again there is a strong correlation between the Nimish rocks and the sub-eruptives. Of particular interest is the fact that even the degree of scatter of both units is very similar. The McKay River formation on the other hand has considerably higher TiO_2.

CHAPTER 5

DISCUSSION AND PETROGENESIS

5.1 INTRODUCTION

Previously presented data demonstrates the presence of three distinct volcanic suites within the McKay River map area. The first consists of a suite of sub-eruptive alkali basalts and associated tuffaceous rocks which are stratigraphically equivalent to the Sokoman Formation. The second, a suite or alkali basalts and associated sedimentary rocks comprises a distinct unit called the McKay River formation. The third, a suite of alkaline ultrabasic rocks has been tentatively named the Rose Bay formation.

Evidence presented in the structural section, which follows, suggests that both the McKay River and Rose Bay formations are allocthonous, and their location in the stratigraphy is less certain than that of the sub eruptives. With no obvious field evidence linking them to any particular unit within the Knob Lake Group, determining their position within the stratigraphy has been attempted by way of the petrochemistry and is therefore largely interpretive.

5.2 PETROGENESIS

Kesson (1973), Brey (1978), Brey and Green (1975, 1976) Frey et. al; (1978) and Wass (1980) conducted experimental work concerning the origins of primary magmas and their chemical characteristics. Their results outlined three basic criteria for recognizing and classifying primary or near primary basaltic magmas.

(1) The presence of high pressure, mantle-derived lhertzolitic inclusions indicative of a mantle source for the magma and a rapid accent, enough to support and propel the inclusions to the surface.

(2) Mg values (molecular proportions of MgO/MgO + FeO) greater than 65. This suggests that the magmas have not undergone significant fractionation and therefore could possibly be in equilibrium with upper mantle olivine compositions believed to be in the range of Fo 89- Fo 92.

(3) High Ni values, > 300 ppm, would also indicate that the magma could be in equilibrium with the mantle, predicted to contain approximately 2000 ppm Ni (Kesson, 1973)

In addition, parameters were constructed for the abundances of various trace elements relative to the degree of magmatic fractionation. While the results obtained by Wass (1980) differ slightly from those of Kesson (1973) they are not contradictory. All values obtained refer mainly to primary or evolved alkali basalts, along with basanites and nephelenites.

Table (3) outlines trace element values for the three volcanic suites found within the study area along with available data from the Nimish Sub Group for comparison with that of primary and evolved magmas. Rocks of cumulate or possible cumulate origin have been excluded. Only those elements found useful by Wass (1980) and Kesson (1973) are used, and two of these Ba, and Rb, are highly susceptible to alteration thereby limiting their value for comparison.

Uranium, vanadium, barium and rubidium values for primary and evolved magmas overlap to some degree, however primary compositions generally have low uranium, rubidium and barium and high vanadium values. While the petrogenetic nature of the Rose Bay formation makes a direct comparison of this nature inconclusive, the findings of this study are consistent with those of Wass (1980) and Kesson (1973). In order to facilitate a more meaningful comparison two sets of numbers are shown for the Rose Bay formation. The top set represents the range of all analyses listed in Table 2 including the fragmental and tuffaceous rocks while the numbers in parenthesis include only those samples believed to be primarily magmatic. These include vesicular lava, lava clasts in the conglomerates and samples taken from single fragments

TABLE 3

	NIMISH SUB GROUP	SUB- ERUPTIVES	McKAY RIVER FM	ROSE BAY FM	PRIMARY	EVOLVED
U	nd	0-1	0-1.5	0-3	1-15	1-22
V	62-383	160-293	312-468	225-490	234 (H) -	62 (L)
Ba	213-2682	115-768	45-689	16-2706	305-740	> 3359
				(48-811)		
Rb	14-135	2-81	0-18	0-79	10 (L) -	50(H)
				(1-30)		
Y	19-47	10-34	25-34	8-70	21-35	21-38
				(23-42)		
Zr	75-387	78-163	105-146	193-714	206-315	129-528
				(210-373)		
Cr	0-60	0-75	112-260	2-4003	>445	>14
				(242-3406)		
Ni	0-70	1-156	75-121	11-1062	> 300	>14
				(137-960)		
Mg#	20-56	35-52	46-56	43-74	> 65	<60
	most- 35			most- >60		

(H) indicates values usually in high end of range

(L) indicates values usually in low end of range in the fragmental rocks.

While the major and trace element data for both the sub-eruptive and Nimish rocks exhibits consistent and similar patterns with regards to the evolution of their respective magmas, results obtained for the McKay River basalts are somewhat contradictory. An explanation for this is included in the discussion which follows.

5.2.1 ROSE BAY FORMATION

Table 3 shows that the Rose Bay formation fits most of the criteria for being primary or near primary in composition and in some cases exhibit extreme values with regards to some trace element concentrations. While most samples have Mg #'s around 60 (see figure 5.1a) it is suspected that the Rose Bay formation may have received some iron input as a result of intruding into and being deposited synchronously with the Sokoman Formation. Evidence for this is in the presence of thin discontinuous layers composed of euhedral magnetite within the conglomerates which are interpreted to represent a volcanoclastic equivalent of oxide facies iron formation. Considerable variations in SiO_2 in this unit and considerably higher values of both SiO_2 and Fe (tot) for the tuffaceous rocks (figure 4.2d) indicate synchronous deposition of the tuffs with silicate oxide facies Sokoman Formation. In addition the clasts in the conglomerates in question are consistently small indicating that they are somewhat distal. This would presumably provide enough time for iron formation sediments depositing at the time to form distinct layers as seen by the previously mentioned magnetite-rich bands. An input of iron would also suppress the Mg #'s of these rocks enough to make them appear to be less primitive.

5.2.2 COMPARISON WITH OLIVINE MELILITITES

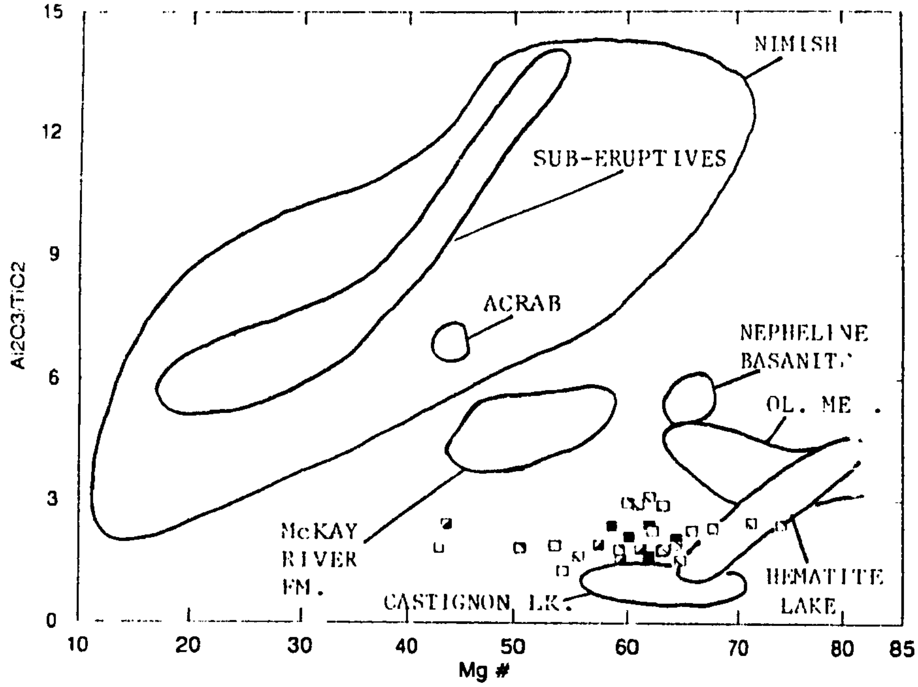
Olivine melilitites are generally defined as larnite-normative olivine and melilite bearing basaltic rocks found on oceanic islands and continents, but they are generally found to be absent at mid ocean ridges and island arcs (Brey 1978). Studies of olivine melilitites are few, resulting in only a limited amount of analytical data being available. The majority of these consist of major element data while trace element and rare earth element data are rare or non existent for most samples. Work carried out by Brey (1977;1978), Frey and Green (1974), Frey et al. (1978), Wass (1980), Kesson (1973) Frey, Green and Roy (1977), Eggler and Mysen (1976) and others has shed some light on the relationship between olivine melilitites and other primary magmas, implications concerning their petrogenesis, and geotectonic significance. Brey (1978) reports that continental olivine melilitites are almost exclusively found at or near zones of major crustal rifting. He notes that extreme chemical variations between proximal occurrences requires that each vent or vent complex be examined independently. Although the chemistry of this rock type is quite variable, when comparing one vent complex to another, they form quite a distinct suite in contrast to other undersaturated alkalic rocks, such as basanites, phonolites and nephelenites. This is evident from their lower Al_2O_3, higher MgO, and higher TiO_2. MgO contents commonly range between 10 and 20 percent even when samples are void of porphyritic phases such as olivine or clinopyroxene. Mg #'s commonly fall between 65 and 80. These rocks have been suggested by Brey (1978) and others to represent magmas of primary composition. They are commonly found in the form of pipes and diatremes due to their high volatile contents (mostly CO_2 and H_2O) and they erupt in a very explosive manner. Few actual flows have been found, with the majority of the extrusive products being in the form of melilite-bearing fragmental and tuffaceous rocks concentrated near or around the vent. Characteristically they appear late in the stratigraphy found in rift basins. Volumetrically they are small compared to the relatively large volumes of alkalic volcanics formed in the initial stages of continental rifting. Overall the chemical nature of these rocks suggests strong affinities with kimberlites and carbonatites. Their volatile nature is believed to be responsible for a quick ascent to the surface thereby excluding the formation of high level magma chambers and minimizing low pressure fractionation. The major and trace element chemistry of the magma is thought to be representative of the initial mantle melt and is therefore considered to be a useful tool for studying the nature of the source material.

A considerable amount of work has been done regarding the formation of mantle-derived melts which lead to the eruption of such rocks. Models designed to account for their variable and often extreme chemistry include melting episodes in the order of 1 - 5% and/or the involvement of mantle metasomatic fluids (MMF). These models are discussed by Menzies and Murthy (1980), Watson (1981 and 1982), Spera (1981) and others. The application of these models to the rocks of the Rose Bay formation or the McKay River basalts is beyond the scope of this thesis.

Figures 5.1a-c are diagrams from Brey (1978) which plot weight % ratios of oxides against Mg # (Mg /Mg + Fe * 100) for the Rose Bay formation. Also shown on the diagrams are fields for primary nepheline basanites (Wass 1980), an array of occurrences of olivine melilitites from various parts of the world, (Brey 1978, Alibert et al. 1983) and some lamprophyric, carbonatitic and melilititic rocks from the northern Labrador Trough included in studies of the Hematite Lake area by Dressler (1975), and the Castignon Lake area by Dimroth (1978)

Most of the melilitite samples shown here are associated with continental rifting with only one sample being from an oceanic island, that being Hawaii (Brey 1978). No significant

FIGURE 5.1a (Mg# VS AL2O3/TIO2)



ROSE BAY FORMATION

FIGURE 5.1b (Mg# VS CaO/AL2O3

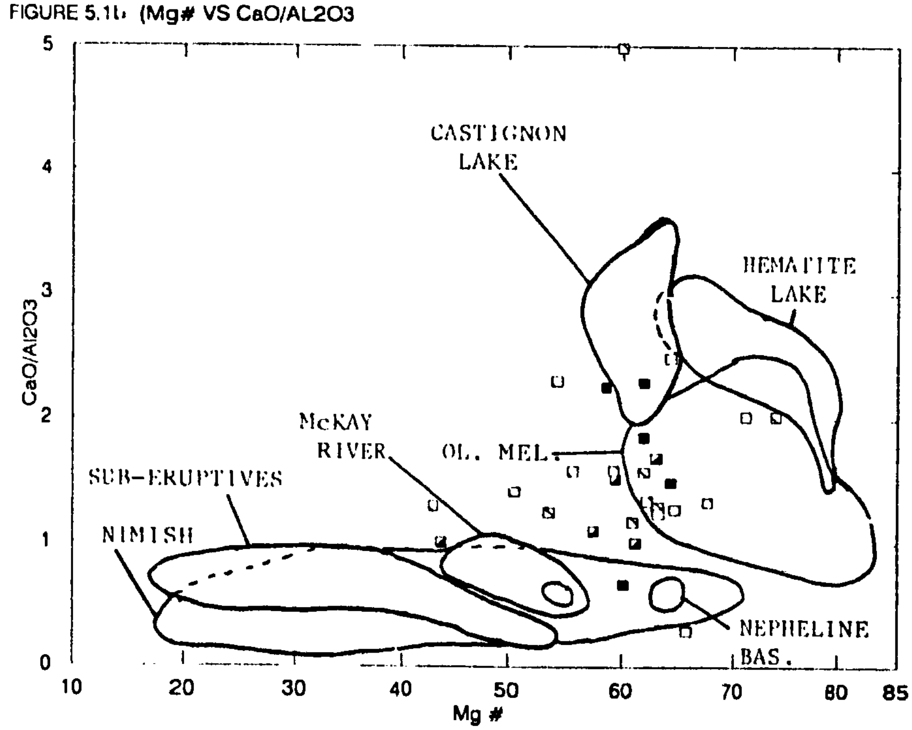
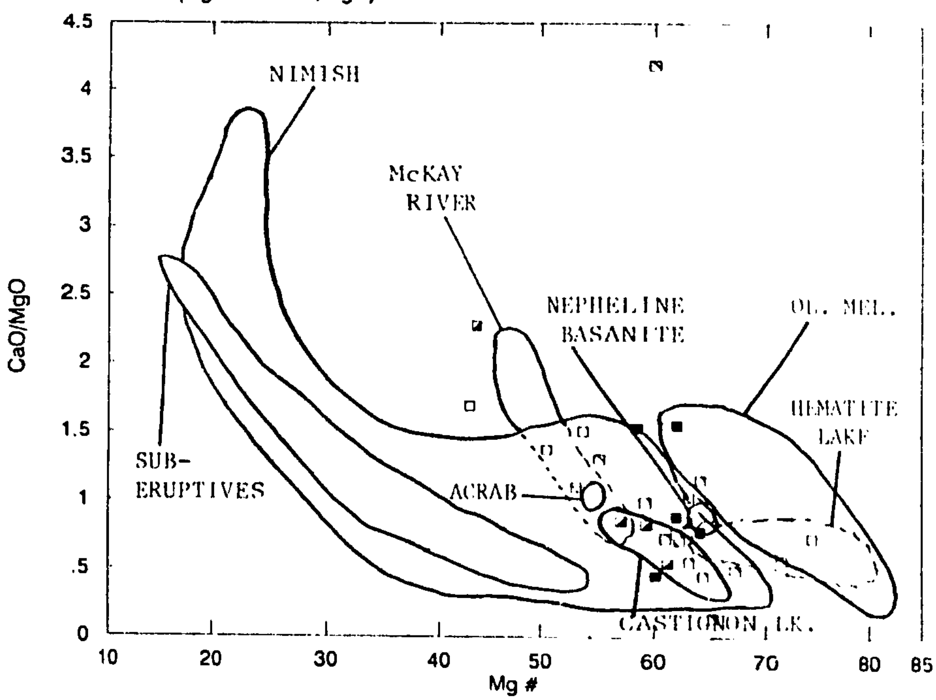
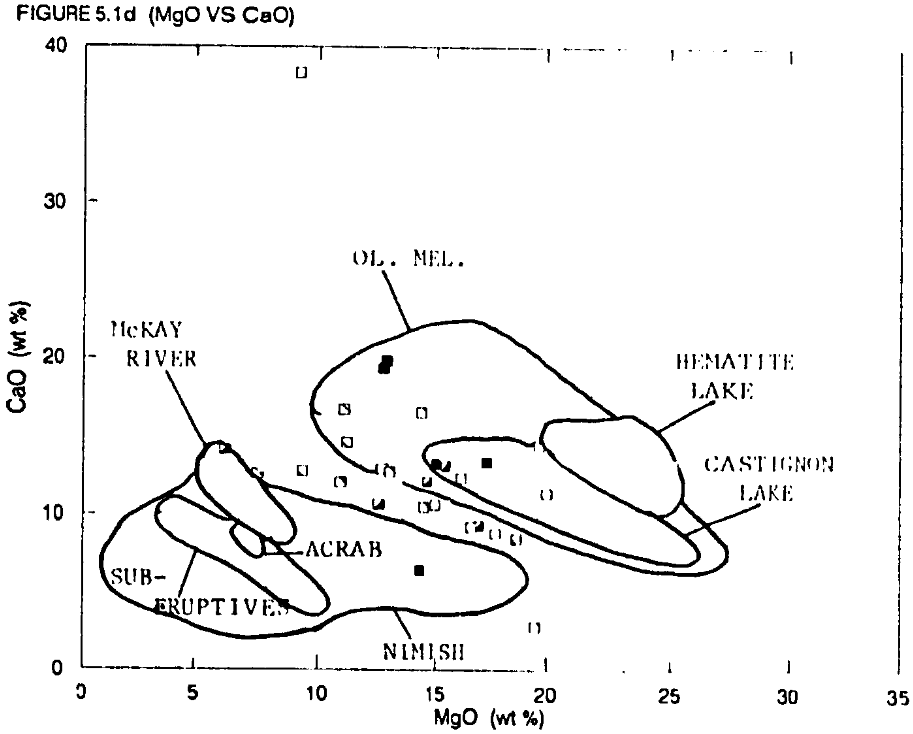


FIGURE 5.1c (Mg# VS CaO/MgO)



ROSE BAY FORMATION

FIGURE 5.1d (MgO VS CaO)



differences in major element abundances were noted between the two and in figures 5.1a - c the Hawaiian samples plot centrally in the field for melilitites. Fields for the basalts of the Mckay River formation, the Nimish Sub group and average values for continental alkali basalts (Windley, 1978), have been included for comparison.

Most apparent from these diagrams is the similarity of the Rose Bay formation data with the relatively tight fields of the rocks of the northern Labrador Trough and olivine melilitites.

Figure 5.1a shows a loose horizontal scattering of the Rose Bay formation which is suspected of having undergone Fe addition, especially in the tuffaceous rocks, thereby lowering the Mg #. This is supported by the relatively narrow range found for those samples thought most likely to represent lavas which have Mg #'s between 60 and 65. The two samples with Mg #'s over 70 are fragmental and therefore more likely to be closely representative of a lava composition. Low Al_2O_3/TiO_2 ratios for the Rose Bay formation are due to higher TiO_2 (ave. RBf=4.1% olivine melilitites = 2.75%) at slightly lower than average Al_2O_3 (RBf=8.3% while olivine melilitites = 9.96%). Rocks of the Castignon Lake Complex (Dimroth (1978) have a consistent TiO_2 average of 4.4% with Al_2O_3 averaging 4.4%, considerably lower than that of the olivine melilitites. The field for nepheline basanite reflects Al_2O_3 values averaging

13.5% (considerably higher than melilitites) at similar TiO_2 values.

The field for the sub-eruptive rocks shows a very strong correlation with the rocks of the Nimish Subgroup while the McKay River basalts are distinctive from all other units. The McKay River basalts, the sub-eruptive rocks, and the rocks of the Nimish Subgroup cluster around a point representing the average composition of continental rift alkali basalts (Windley, 1978 listed on table 4).

Figure 5.1b which plots CaO/Al_2O_3 vs Mg# once again illustrates similarities between the Rose Bay formation and melilitites with some of the flow samples and fragmental rocks plotting well within the field. Sample NN-1-85 which plots at the top of the graph possesses an anomalously high value for CaO (37.05%). It is possible that $CaCO_3$ was assimilated during its ascent through the country rock, possibly the Denault Formation, which would explain the low SiO_2,(28.76%) value and the loss on ignition of 21.81% attained for this sample. However, it is also possible that this sample could have carbonatitic affinities, as is the case with the Castingnon Lake rocks of Dimroth (1978). Dimroth (1978) postulates that chemical and lithological variations in the Castignon Lake Complex can be explained by unmixing of a kimberlitic magma at depth to form two immiscible magmas consisting of carbonatized meimechite and biotite-ankerite

TABLE 4

* OXIDE/ * ELEMENT	NIMISH SG	SUB ERUPTIVE SUITE (NN-9-85)	McKAY RIVER BASALTS	ACRAB AVE. CONT. RIFT ALKALI BAS.
SiO_2	48.29	47.21	48.23	48.7
TiO_2	2.32	1.22	3.16	2.2
Al_2O_3	14.79	16.61	14.45	15.3
Fe (tot)	17.23	16.34	12.5	12.4
MgO	6.21	9.11	6.59	7.0
CaO	5.2	4.23	11.47	9.0
Na_2O	3.1	3.93	2.59	2.85
K_2O	3.04	.62	.56	1.31
Cr	30	75	172	400
Ni	30	156	90	100
V	281	203	402	?
Rb	35	4	4	200
Sr	nd	0	469	1500
Ba	1400	115	174	700
Zr	190	111	120	800
Ce	nd	24	36	95
U	nd	0.29	.5	.5
Th	nd	1.47	4	4

* ALL VALUES ARE MEAN CONCENTRATIONS. OXIDES = WT% TRACE ELEMENTS = PPM

carbonatite. It is possible that large swings in CaO in the rocks of the Rose Bay formation could also be the result of liquid immiscibility within the magma prior to eruption. The carbonatites of the Castignon Lake Complex and sample NN-1-85 have LOI values > 20% and Cr and Ni concentrations greater than 1000ppm and 200ppm respectively. In sample NN-1-85 such high concentrations of Cr and Ni would tend to contradict the possibility of CaO dilution. Other samples ie. NN-19a-85, NN-19b-85 and NN-21a-85 which have CaO > 16% and LOI values of approximatly 10% are similar in this respect and could also have carbonatitic affinities.

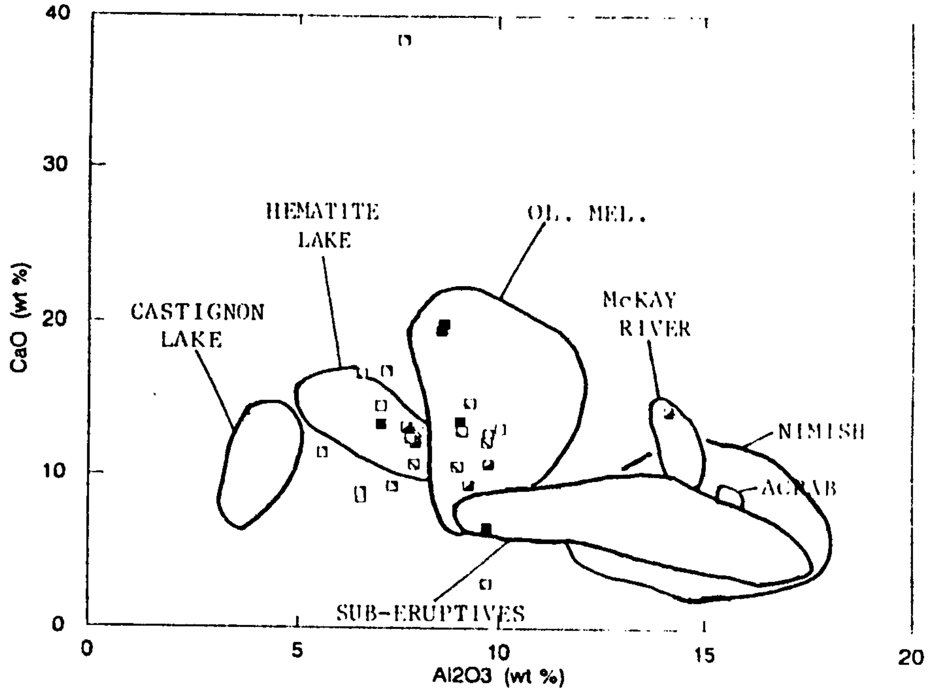
Values obtained for other trace elements in these samples such as V, Zr, Nb, and Y support such a hypothesis in that they are still consistent with the other samples of the Rose Bay formation and show no evidence of dilution. Sample NN-2-85 which possesses a low ratio for CaO/Al_2O_3, has an SiO_2 value of 44.00%, and total Fe of 20.00%. In general the kimberlite-carbonatite spectrum of rocks does not contain more than 12% total iron. Therefore high Fe and SiO_2 are better explained by contamination of the magma during its ascent through a silicate oxide facies of the Sokoman Formation. Support for this can be seen in figure 4.2d (page 64) which shows that the Rose Bay formation contains considerably more total Fe (ave. = 18%)than normal for olivine melilitites. The Castignon Lake Complex and Dressler's rocks which would also have had to intrude iron formation show a similar enrichment.

Figure 5.1c again shows that a good correlation exists between the Rose Bay formation and the melilitites with both fields overlapping with the northern Labrador Trough rocks.

In figures 5.1b and 5.1c overlapping fields of the Nimish Subgroup and the sub-eruptive rocks provide further evidence for their close association. Fields for the Mckay River basalts in figure 5.1a-c reflect the higher than average TiO_2 (figure 5.1a) and CaO (figure 5.1b and 5.1c) present in these rocks.

Figures 5.1d-g are plots using various oxides excluding Fe. Without involving Fe, the correlation of the Rose Bay formation with olivine melilitites become even stronger especially with regards to the samples of lava (solid squares) and fragmental rocks (half filled squares) which are considered to better represent the original magma. Except for the plots involving Al_2O_3 the northern Labrador Trough rocks also plot within the fields for olivine melilitites. This is probably a reflection of the carbonatitic nature of the northern rocks which tend to have lower Al_2O_3 values.(approx. 2-4%)

FIGURE 5.1e (AL2O3 VS CAO)



□ ROSE BAY FORMATION

FIGURE 5.1f (AL2O3 VS MGO)

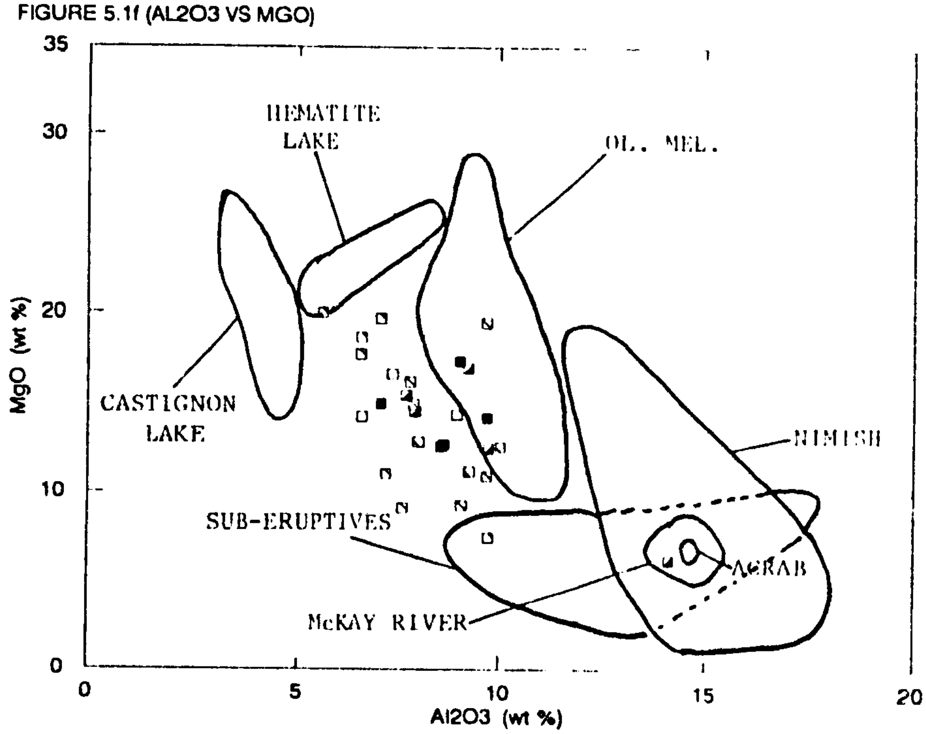
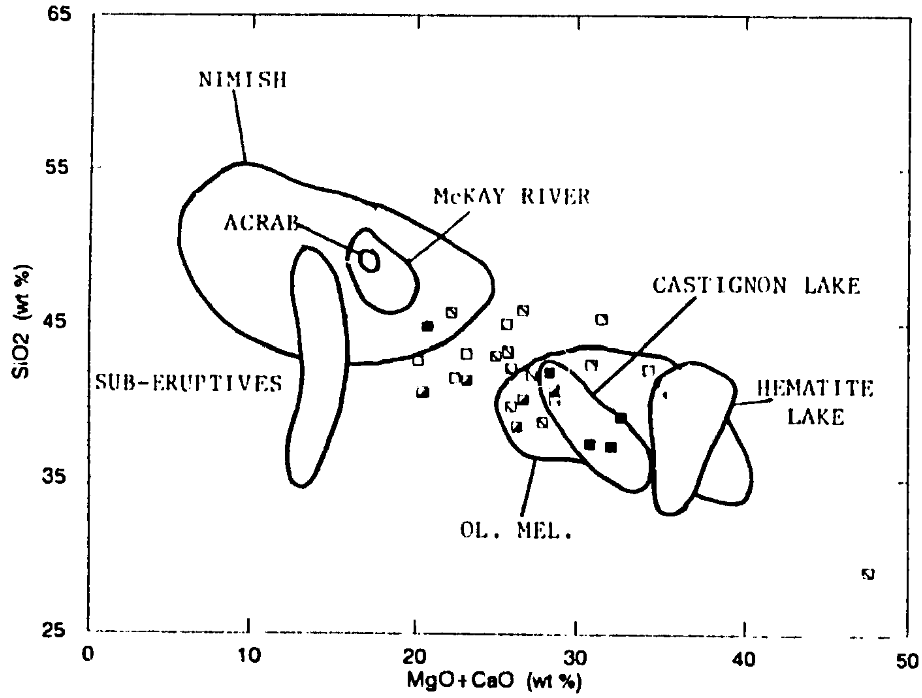


FIGURE 5.1g (MGO+CAO VS SIO2)



5.3 MCKAY RIVER BASALTS

The limited data scatter and the reasonably well defined differentiation trends of the McKay River formation basalts (figures 4.1-4.7), suggest that the effects of metamorphism and alteration on these rocks has been minimal. It is therefore suggested that except for some mobility of K_2O and Na_2O, the chemistry closely approximates their original composition.

Figures 4.5 - 4.7 show the McKay River basalts to be a suite of alkali basaltic rocks associated with a continental rifting environment. Comparing the major element compositions of these rocks to Windley's average continental rift alkali basalt (ACRAB) (table 4) shows them to have higher TiO_2 and CaO and slightly lower MgO. Table 4 shows the MRB to have lower values for Cr and Ni and Mg#'s between 46 and 56, suggesting that these rocks are derived from an evolved magma which has undergone some olivine fractionation. This combined with an average MgO value of 6.59% would classify these rocks as strictly alkali basalts as opposed to alkali olivine basalts which have higher Cr and Ni values, MgO values of approximately 9.00% and are usually olivine porphyritic. The absence of clinopyroxene (titanaugite) as a porphyritic or cumulate phase is reflected by lower than average Al_2O_3 suggesting that the higher than average values for CaO and TiO_2 are a reflection of the abundance of sphene as was seen to be the case in thin section. This would indicate that the CaO and TiO_2 concentrations observed in these rocks are primary and are either a reflection of the composition of the initial mantle source from which the magma was derived or possibly due to a lack of fractionation of Ti-bearing minerals such as Ti-phlogopite or kaersutite. This is supported by lower concentrations of Zr, Ba, Rb, Sr, U, and La for these rocks which are usually indicative of primitive magmas. High vanadium with respect to Fe_2O_3 indicates that magnetite has not been a fractionation product and further supports a primitive nature for these rocks. Frey et al. (1978) have shown that magmas of this composition are derived from slightly lower degrees of partial melting than for normal alkali basalts and have a higher volatile content which enables the liquid to reach the surface without the formation of high level magma chambers where low pressure fractionation might occur. The quick ascent of the magma from its source might also explain the lack of any porphyritic phases such as olivine or clinopyroxene since there would be relatively little time in which the phenocrysts could develop. Low Mg values along with low Cr and Ni would then have to be related to processes occurring at the source rather than olivine fractionating during ascent of the magma or immediately prior to eruption.

At this point in time, the stratigraphic position of the McKay River Formation is based on interpretation and association rather than on field evidence. One outcrop from which samples NN-1-79, NN-2-79, and NN-3-79 were collected suggests that the upper portion of the McKay River basalts are in part synchronous with the Rose Bay formation as the two were found to be interbedded. The likelyhood of the Rose Bay formation being syn or post Sokoman Iron Formation and the fact that the conglomerates of the Rose Bay formation contain clasts of the MaKay River basalts, suggests that the basaltic rocks of the McKay River formation erupted just before the Rose Bay suite. The McKay River formation would therefore be stratigraphically equivalent to the top of the Denault Formation. Of some possible significance is the fact that all representative rocks of the McKay River formation indicate sub-aqueous deposition, suggesting that the McKay River formation may have provided a volcanic pedestal upon which the Rose Bay formation was able to erupt sub-areally.

5.4 NIMISH SUBGROUP / SUB-ERUPTIVES

Evidence presented earlier in this thesis it was tentatively concluded that petrochemically the sub-eruptive rocks are correlative with the volcanic rocks of the Nimish Subgroup and stratigraphically they are both synchronous with the Sokoman Formation.

The sub-eruptive rocks will therefore be discussed in terms of the findings of Evans (1978; 1980) who completed a comprehensive study of those rocks to the north, including their relationship with the Sokoman Formation. With field evidence demonstrating conclusively that like the Nimish rocks, the sub eruptives are synchronous at least in part with the Sokoman Formation, contamination from the iron formation is possible if not probable. Since these rocks are not voluminous, the effects of contamination would be enhanced since a small amount of magma would not be able to buffer the effects of assimilating high concentrations of iron or silica. The conclusion that they are Nimish equivalents is therefore based on figures (4.9e-i) and figure(4.9j,) and oxide ratios shown on the Y axis in figures (5.1a-c) which exclude the effects Fe and Si. It is likely that only these elements would be affected since studies by Fryer (1977) show the Sokoman Formation to be void of index elements where input of a volcanic nature is not evident. With this in mind it is possible to provide a plausible explanation for chemical variations in these rocks with respect to Fe and Si and also explain the overall low trace element and rare earth element concentrations observed. It is suggested that the anomalously low values are the result of dilution of the magma by Fe in the case of samples NN-4-85, NN-10-85 and NN-10a-85 and by SiO_2 in samples NN-16-85 and NN-18-85. It appears that all element concentrations have been affected proportionately thereby being consistent with results of Fryer (1977). This is supported by sample NN-9-91 which contains a considerably lower value for Fe and higher value for SiO_2 and likewise has expected values for the less mobile elements as well. Both the Nimish rocks and the sub-eruptive rocks (sample NN-9-91) have higher than expected values for total Fe as indicated on table (5B). Windley (1978) shows the average total Fe for continental alkali rift alkali basalts to be approximately 12.4%. The Nimish rocks have total Fe ranging from approximately 15% to 22% averaging approximately 17%. This would suggest that the Nimish rocks have also absorbed some Fe. Evans (1978) makes no mention of this and appears to attribute higher Fe to fractionation and differentiation of the parental magma. It is interesting to note that K_2O and Na_2O show some erratic variations but tend to be considerably higher than expected. Evans (1978) described similar trends in the Nimish rocks and attributed the enrichment of alkalis to metasomatic alteration. Considering the findings of this study it is quite possible the sub-eruptive rocks have undergone the same process.

Table 3 strongly suggests that both the Nimish rocks and the sub-eruptives (based on sample NN-9-85) represent evolved magmas having undergone significant fractionation of ferromagnesian phases, as indicated by low Cr and Ni, and Mg #'s mostly in the range of 25 - 50. A few samples which contain high Ni and Cr and Mg #'s of 55 - 69 are suspected of being cumulate in nature. This is supported by their very low values for Zr, TiO_2, Nb and Y. Evans (1978) describes these rocks as intrusive and reports the presence of some cumulate textures. The chemistry of these particular samples in fact bears a strong resemblance to samples NN-1000-79 and NN-15-85 which are cumulates of the sub eruptive rocks. Evidence previously mentioned concerning probable dilution of the magma by Fe suggests that a comparison such as that shown in table 4 would be inconclusive. Except for sample NN-9-85, Fe concentrations in the non cumulate rocks suggests that substantial amounts of Fe have been assimilated by the magma thereby suppressing the Mg #'s. Dilution by Fe would have some effect on the trace element concentrations, (generally a lowering effect) but the extent of this is presently unknown. If sample NN-9-85 closely approximates the composition of the magma in terms of the major element and immobile trace element chemistry, then it closely resembles the Nimish rocks (evolved magma) with low Cr and Ni, yet slightly higher than expected vanadium and an Mg # of 50.

Figures (4.9i - j) show the sub-eruptive rocks to be consistent with the findings of Evans (1978) in that they are within plate alkali basalts associated with a continental rifting. Sample NN-9-85 is considered to best represent the original magma and with an Mg# of 53 for this sample along with overall low concentrations of Cr and Ni, it is probable that there has been considerable fractionation of olivine and/or orthopyroxene from the magma. Samples NN-15-85 and NN-

1000-79 which consist primarily of cumulate olivine and orthopyroxene certainly indicate that crystal fractionation did take place. REE plots (figure 4.8c) show a noticeable depletion of Eu in samples NN-16-85 and NN-18-85. While this can easily be explained by magmatic fractionation of plagioclase the other samples show a very slight positive Eu anomaly. It is therefore possible to conceive a second hypothesis which because of the tuffaceous nature of these rocks could involve secondary processes. As mentioned previously these particular rocks contain few if any fragments and tnose present are very small. It is therefore possible that these rocks represent tuffaceous material which has travelled some distance from its point of eruption. This may have caused plagioclase present as a porpyritic phase to be separated by sorting of the tuffaceous material during deposition.

The only noticeable difference between the Nimish rocks and the sub-eruptives as a whole, is the absence of felsic volcanic rocks associated with the sub-eruptives. The nature of their occurrence ie. as sub-eruptive dykes and tuffaceous extrusive rocks combined with an absence of flow rocks suggests that the area was slightly less proximal to the main conduits (presumably tensional faults) by which the bulk of the Nimish rocks were extruded and that fractionation or assimilation which would develop a felsic component did not get a chance to happen in this area.

CHAPTER 6

STRUCTURE

6.1 INTRODUCTION

This section examines the implications of the stratigraphic information determined in this study on the interpretation of the structural geology of the area. A detailed analysis of the structural geology is beyond the scope of this thesis. Such a study was recently completed by Brown (1991) based on a comprehensive structural examination of a relatively well exposed corridor through the central portion of this study area. (Figure 6.1). Also included in Brown's thesis is an overview of the post-depositional structural and orogenic history of the region as a whole, as well as a comprehensive summation of previous structural studies conducted in, and adjacent to, the study area including the most recent work by Rivers and others. For this and further information the reader is directed to Brown (1991).

Brown (1991) attempted to define the internal stratigraphy of the volcanic rocks found in the area and establish their relationship from a stratigraphic point of view with the surrounding rock types as well as determine the structural history of the area. He concluded that the area was divided structurally into a number of domains each possessing its own structural style that could be worked out on an internal basis but that is was difficult if not impossible to correlate from

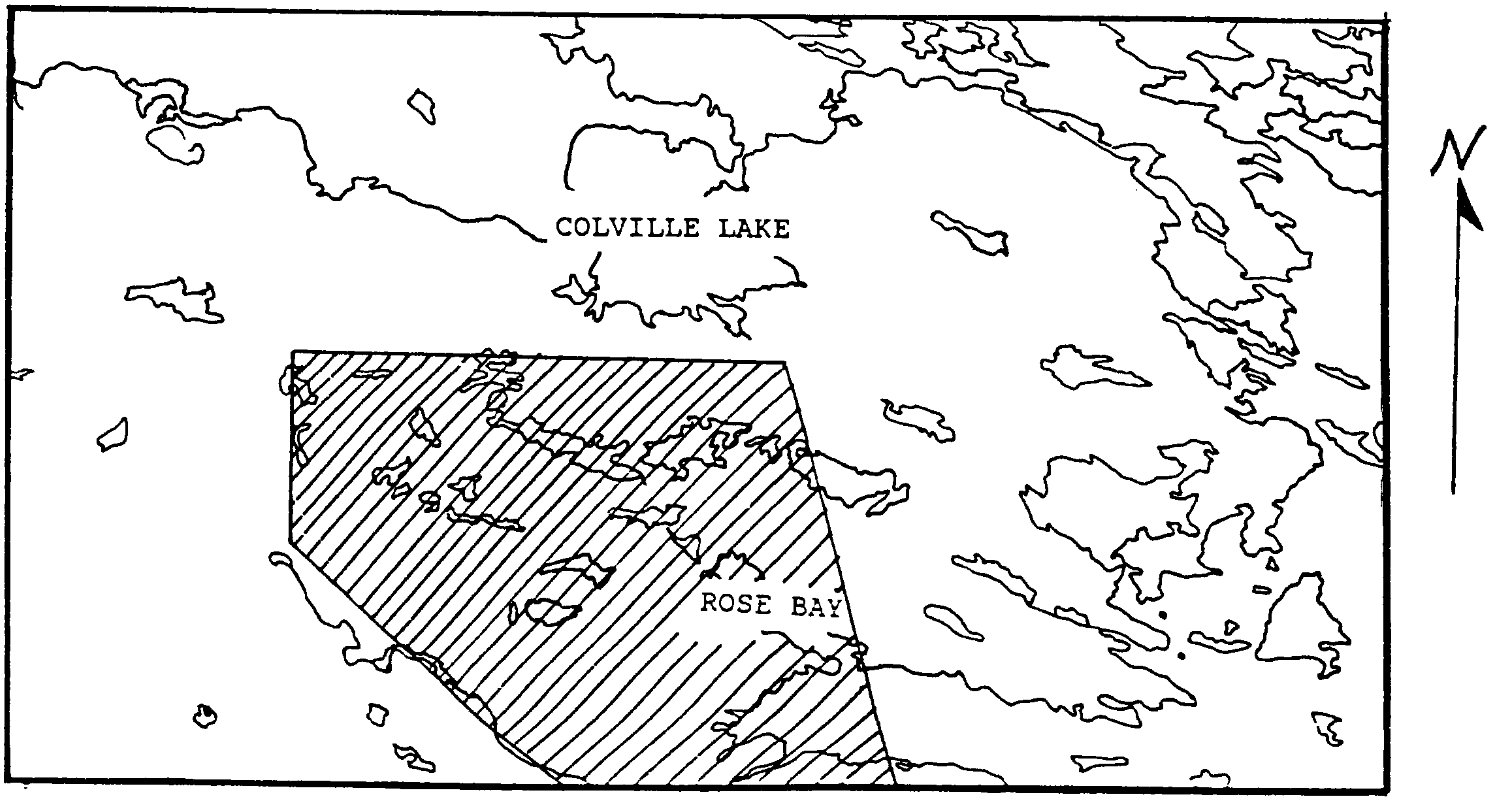


FIGURE 6.1 FIGURE SHOWING AREA COVERED BY BROWN (1991)

domain to domain.

The chemo and litho-stratigraphy of the volcanic rocks defined in this study clarify some problematic aspects of the structural model provided by Brown (1991). It should be noted that the pertinent results of this study were only recognized after the study by Brown (1991) was completed. In areas requiring a structural interpretation based on the internal stratigraphy of the volcanic rocks Brown did not have this information.

The aim of this section is to provide an alternate interpretation to that advanced by Brown (1991) using the additional information provided by this study. It is felt that this interpretation provides a better explanation of both the present geology and the geological development of the area and simplifies certain aspects of the structural geology modelled by Brown (1991). The interpretation includes a number of diagrams which are compared with the existing structural and stratigraphical framework presented by Brown (1991) and others.

Figure 6.2 summarizes the general geology of the study area as mapped and interpreted by Noel and Rivers (1979) and Rivers (1982) including compiled data from Wardle (1979b) and Ware and Wardle (1979). Most interpretive modifications of the structural geology by Brown (1991) were of a local nature and confined specifically to the north central portion of the map. Since they did not significantly change the overall appearance

FIGURE 6.2 McKAY RIVER FM. DENAULT FM. SOKOMAN FM.
EQUUS LAKE FM. SHABOGAMO INTRUSIVE SUITE

of the map, they are not included in figure 6.2. The klippe comprised of the Equus Lake formation which was defined by Brown (1991) is shown. It should be noted that this map is based on the interpretation that the contacts between the volcanic rocks within the map area and the paraautochthonous units of the Knob Lake Group are stratigraphic and conformable.

Geochemical evidence presented in this thesis has demonstrated the presence of a third suite of volcanic rocks within the map area. This new unit which has been shown to be petrogenetically and stratigraphically associated with the Nimish Sub Group consists of sub-eruptive basaltic dikes and associated tuffaceous rocks which are interbanded with the Sokoman Formation and possibly the upper portions of the Denault Formation (see previous chapters). Previously these rocks were assumed to be equivalent to the other volcanic units found in the area. This led to the misinterpretation that the other volcanic rocks in the area were interbanded with the autochthonous or para autochthonous stratigraphic units (northern units) of the Knob Lake Group (Noel and Rivers 1979, Noel 1981, Rivers 1982, Brown 1991). A re-examination of the field data (this study) indicates that while the sub eruptive rocks can be clearly shown to be interbedded with the northern Knob Lake units, the McKay River and Rose Bay formations comprise a separate allochthonous tectonic slice which was emplaced during the Grenville Orogeny and structurally overlies the para autochthonous sequences (northern units) of the Knob Lake Group. The map at the back of this thesis portrays this interpretation.

Figure 6.4 models the structural history of the area based on the new interpretation and combines certain aspects of the tectonic framework defined by Brown (1991) and Rivers (1983a) with the findings of this study. Evidence favoring this model is presented as follows.

6.2 STRATIGRAPHIC EVIDENCE

Figure 6.3a is a schematic map showing the interpreted geology adjacent to and beneath the overlying thrust slice. In order to simplify the diagram, rocks belonging to the Shabogamo Intrusive Suite are not shown since it is still unclear as to which units, north or south , they belong.

The heavy solid lines represent stratigraphic contacts between units of the Knob Lake Group, namely the Denault, Sokoman, and Menihek Formations which are well defined or not obscured by the overlying volcanic material. Dashed lines represent interpreted boundaries beneath the thrust slice based on extrapolation of adjacent structural data. Figure 3b (overlay) shows the outcrop pattern of the McKay River and Rose Bay formations and also includes the Equus Lake klippe defined by Brown (1991). It is evident from this diagram and figure 2 that there are numerous occurrences within the map

Figure 6.3a Schematic diagram showing allochthonous rocks

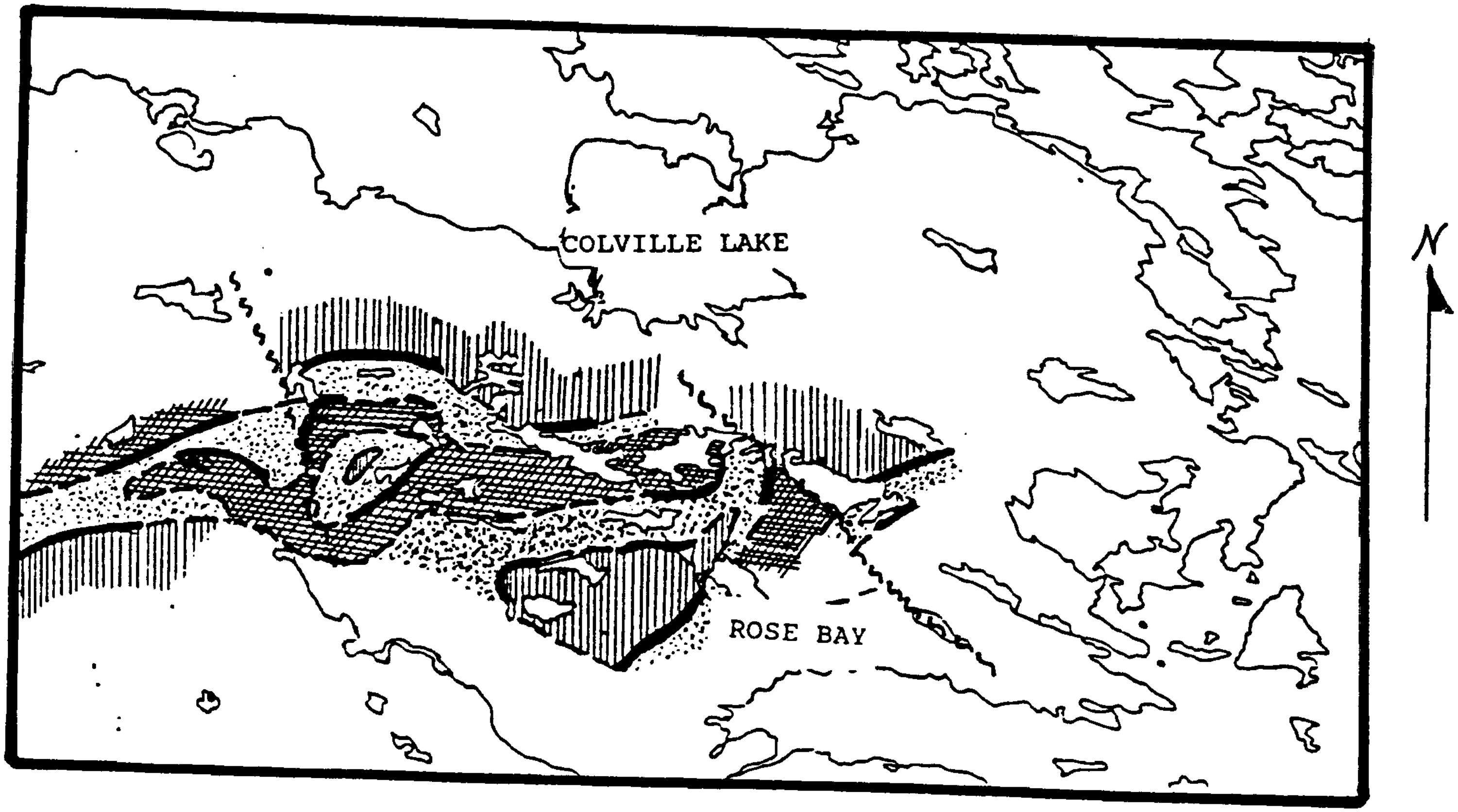
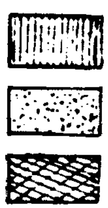


Figure 6.3 Schematic diagram showing interpretation of study area geology with allochthonous rocks removed.



Menihek Formation.

Sokoman Formation.

Denault Formation.

area, especially in the Tiphane Lake, Dave Lake, and Sydney Lake areas, where the Sokoman Formation and the Denault Formation, both essentially void of any volcanic material, clearly form a continuous st··atigraphic sequence. Figure 6.2 however shows that the two units are interpreted to stratigraphically confine large thicknesses of McKay River and Rose Bay formation only a few hundreds of meters away.

In the outcrops of the Sokoman Formation which exhibited evidence of volcanoclastic input, the material is found to be without exception, thin layers of extremely fine grained tuffaceous material. The host rock is always clearly recognizable, and the dominant lithology present. Such occurrences are often found to be proximal to, or associated with, the sub eruptive dikes described earlier.

Also, it is found that in most outcrops consisting of volcanic material that clearly belongs to the McKay River or Rose Bay formations, neither the Sokoman Formation nor the Denault Formation are detected. In a few outcrops the presence of these units is problematic, (see chapter 3). What is observed are a few thin carbonate, silicate, or magnetite rich layers and in most cases the presence of the Sokoman of Denault Formations can only be inferred by geochemical variations or textures observed in thin section.

Brown (1991) described most of the contacts between the

Sokoman Formation and the McKay River formation as interpretive. Instances where gradational contacts are described coincide with occurrences of the newly identified sub-eruptive rocks and are therefore believed by the author not to involve the McKay River formation at all. The two locations, Equus Lake (west side) and Dave Lake (south side), where Brown (1991) describes a stratigraphic contact between the McKay River formation and the Denault Formation actually coincide with major thrust zones described by Brown (1991). It is suggested that these contacts are actually mylonite zones associated with the sole thrust formed by the structural slice comprised of the volcanic rocks overriding the Denault Formation (northern unit). Lenses of dolomite described as boudonaged layers of Denault within the volcanic units are thought to be "knockers" which were incorporated tectonically into the volcanic rocks and subsequently flattened during the second phase of deformation. Similar outcrops described by Noel (1981) can be found in the areas of Sydney Lake, and west and southwest of Mobey Lake. In all cases these outcrops are in close proximity to or associated with mylonite zones found at the contacts between the volcanic units and the Denault Formation.

The interpretation portrayed in figure 6.2 along with the that described by Brown (1991) interprets numerous occurrences of graphite-bearing pelitic schist found throughout the map area to be part of the McKay River formation. New evidence resulting from further thin section work (this study) along with the discovery of proximal outcrops of Sokoman Formation (northern unit) suggest that these outcrops best fit descriptions of the Menihek Formation (northern unit) as described by Rivers (1980) in the area to the southwest It is therefore probable that these occurrences represent areas where erosion has removed the overlying thrust sheet which appears to form the topographic highs in the central portion of the map area thereby providing structural windows through the allocthonous slice. The most notable of these occurrences is that found in the area of Isa Lake where the Menihek Formation appears to be preserved in a synformal structure surrounded by outcrops of the Sokoman Formation. In the centre of this structure and forming the cap of a topographical high are outcrops of the Rose Bay formation.

6.3 STRUCTURAL EVIDENCE

Also shown on figure 6.3b (overlay) are thrust faults identified or interpreted by Brown (1991) that coincide with faults identified by Noel (1981) and Rivers (1982). Faults identified by the re-interpretation of field data along with new information (this study) are highlighted in purple. The remaining boundaries cannot be accounted for due to lack of exposure. They have been extrapolated using information gained from aeromagnetic maps and air photographs and are also interpreted to be tectonic.

Outcrops described by Brown (1991) as exhibiting evidence of deformation possibly related to the Hudsonsian Orogeny coincide only with northern units described in this study. Some of the outcrops described by Brown (1991) occur in the south central portion of the map area but they coincide with areas interpreted in this study to represent structural windows through the overlying allochthon. The lack of Hudsonian fabrics can be explained by the interpretation provided in this study which suggests that the McKay River and Rose Bay formations were located further to the south west and were therefore unaffected by Hudsonian deformation or suffered greater Grenvillian deformation.

The development and emplacement of the thrust sheet is believed to be synchronous with the first phase of deformation associated with the Grenville Orogeny (figure 6.4a-c). The fact that thrust- related fabrics on both the leading and trailing edges of the defined klippe dip mostly to the south (Brown 1991) can best be explained by folding of the thrust plane (figure 6.4b) during the second phase of deformation associated with the Grenvillian Orogeny. This style and sequence of deformation is similar, to and in agreement with, studies by Connelly et al (1989), Rivers (1978), Rivers and Massey, (1979) Rivers, (1983a) and others to the southwest.

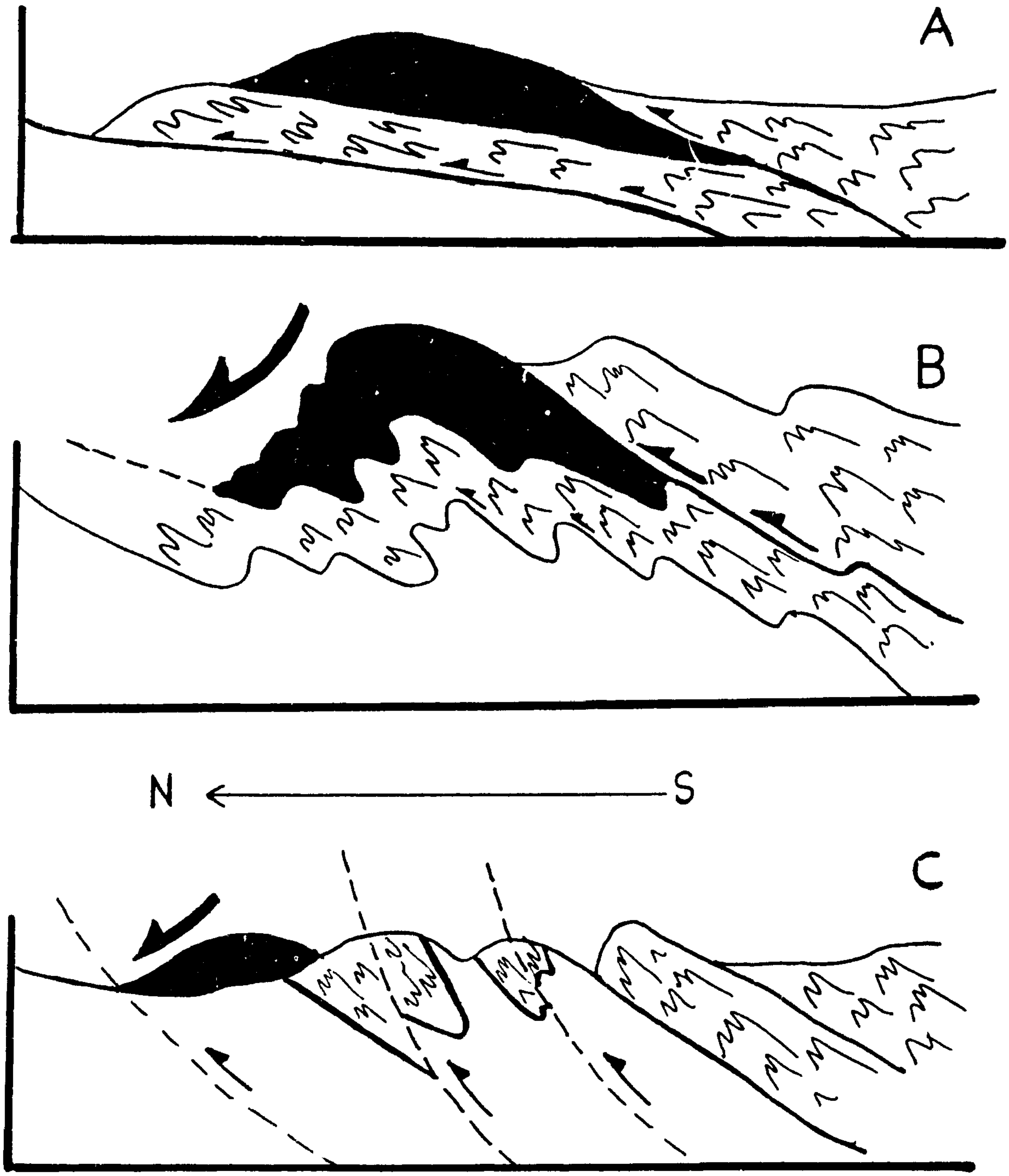


FIGURE 6.4 DIAGRAM SHOWING TECTONIC EMPLACEMENT OF ALLOCHTHONOUS ROCKS.

EQUUS LAKE FORMATION

3 McKAY RIVER VOLCANIC ROCKS

2 KNOB LAKE GROUP

1 ATTIKAMAGEN FORMATION

The sequence was then cut by high angle reverse faults (figure 6.4c) associated with the third phase of Grenvillian deformation which cut both the underlying rocks and the overlying thrust slice. Such faults are described in detail by Brown (1991) and will not be dealt with here. Brown (1991) interprets the Equus Lake klippe to be the result of a gravity slide. At this time there is no evidence to suggest otherwise.

CHAPTER 7

7.1 TECTONIC HISTORY AND BASIN DEVELOPMENT

Work by Dimroth (1978), and Wardle (1977, 1978, 1979) to the northwest and Rivers (1978, 1979, 1980) and others to the southwest has established a model depicting the formation of the Labrador Trough. This model describes the Knob Lake Group as a sequence of supracrustal rocks which were deposited into a major rift system formed as the result of rifting within the proto-North American continent. It has generally been concluded that the portion of the Labrador Trough which lies to the north of the study area represents a " failed " continental rift. Alkaline type basaltic volcanism (Nimish Sub-Group) related to the rifting occupies a stratigraphic level coeval with the middle stages of the developing basin.

Although rifting failed to generate oceanic crust in the region east of the Nimish rocks, tholeiitic activity (Doublet Group) formed a thick sequence of pillow basalts and associated sheeted dykes in the latter stages of the basin's development. Further rift-related activity terminated with the onset of the Hudsonian orogeny ca. 1800 ma.

According to this model the Nimish rocks, being interbedded with the shallow water sequences of the Knob Lake Group, occupy the paleomiogeosyncline, while the Doublet Group was deposited in the corresponding eugeosyncline as proposed by Dimroth (1978). Figure 7.1 shows the extent of these units as two elongate parallel volcanic belts. If it is reasonable to assume that the orientation of these belts along with the surrounding units of the Knob Lake Group represent the general geometry of the basin at the time of development, then the trend of these rocks point to a NW-SE oriented rift system. The trend of both the Nimish rocks and the Doublet Group suggests that the main zone of rifting passed through a point somewhere to the east of the study area. The southern extension of the Doublet Group terminates in the Andre Lake area where it is thrust bounded by the Eastern Basement Complex to the east or in contact with the Trans Labrador Batholith to the south (Wardle 1978,1979a). The Nimish rocks which outcrop abundantly to the west of the Doublet Group can be traced further south and south eastward to an area immediately east of the northern end of Simms Lake, which is approximately 50 km due north of the study area. South of this, and immediately west of the central section of Simms Lake, drill hole data has revealed the presence of thin layers of meta tuffaceous material lying stratigraphically between the quartzite of the Wishart Formation and the Sokoman Iron Formation.

Before the completion of this study, these rocks were interpreted to represent the southernmost limit of the Nimish Subgroup. The findings of this thesis suggest that rocks

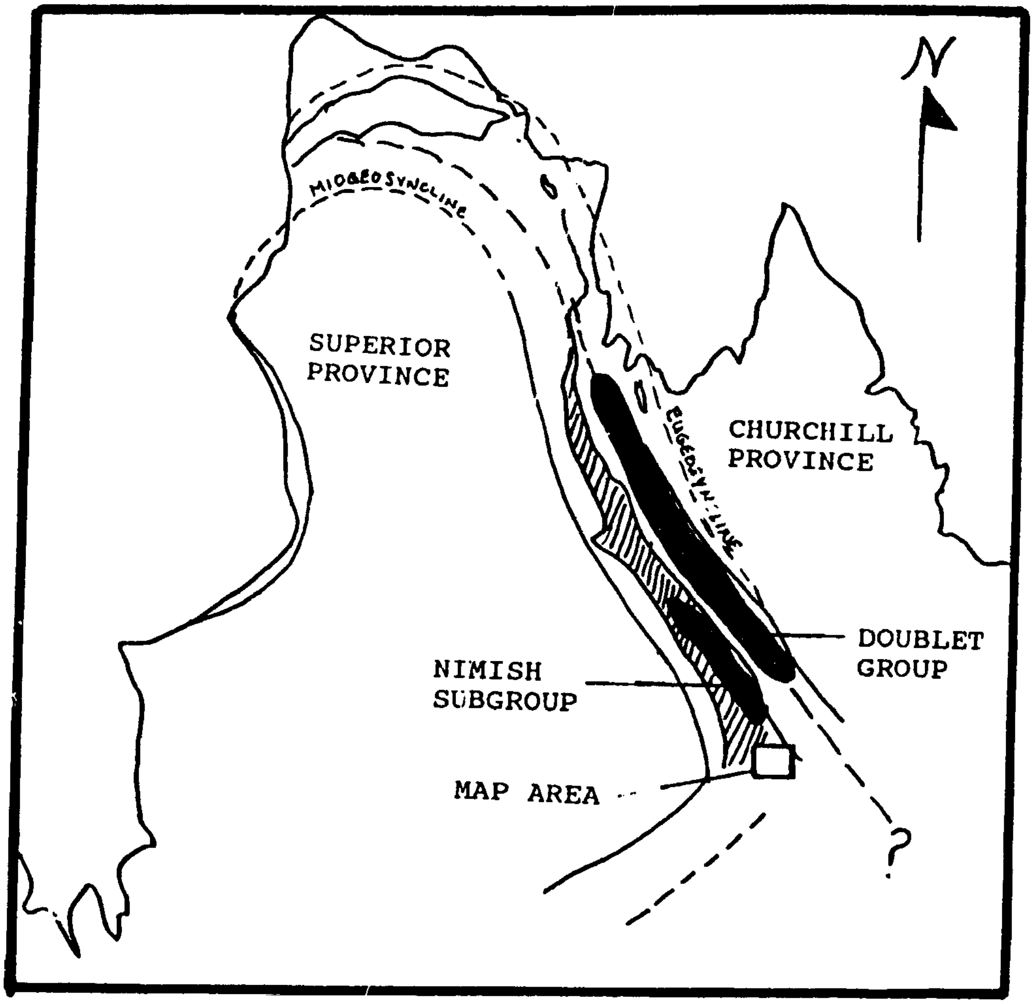


FIGURE 7.1 DIAGRAM OF LABRADOR TROUGH SHOWING ORIENTATION OF MAJOR VOLCANIC BELTS.

related to the Nimish can now be traced at least to the south central portion of the study area as seen by the presence of sub-eruptive dykes and tuff layers in outcrops of the Sokoman Formation immediately west of Isa Lake. South of this point, major east-west trending Grenvillian thrust faults are interpreted to place deeper rocks of either the Attikamagen Formation or McKay River and Rose Bay formations against the northern units (figure 1.2). Fine grained chlorite-actinolite schist and meta tuffaceous rocks found associated with Sokoman Formation in the western portion of the study area are also interpreted to be Nimish equivalents. Flow rocks or large volumes of volcanic derivatives belonging to this unit are noticeably absent in the study area, and to the west. This supports the idea that while rifting in this region was indeed occurring, the main axis of rifting and therefore the bulk of the volcanic rocks lay further to the east. Some of the tuffaceous rocks found interbedded with the top of the Denault Formation and the Sokoman Formation could have been derived from a limited number of dykes reaching the surface as would appear to have been the case in the Tiphane Lake area. This matches the interpretation of the geology of the Nimish rocks to the north by Evans (1980) who found that the majority of the tuffaceous rocks found there predate the bulk of the lava. This suggests that the initial eruptive phases of the volcanic activity were of a tuffaceous nature possibly caused by phreatic eruptions. This then gave way to the formation of pillow lava after the volcanic activity intensified. In the study area however, the volcanic activity ceased.

It is also possible that the sub-eruptive dykes did not reach the surface and that, with the bulk of the volcanic activity occurring to the east, the tuffaceous rocks in the study area represent distal tuffs. This suggestion is supported by the fact that the meta tuffaceous rocks have a very fine grained matrix and contain only small tuff fragments. They appear to have been enriched with silica which could indicate syndeposition with a cherty facies of the Sokoman Formation.

In either case the nature of the sub-eruptive suite along with the absence of an associated volcanic pile in this area indicates that, tectonically speaking, the area represents a less active portion of the miogeosynclinal platform during the time of rifting and subsequent formation of the northern trough (figure 7.2).

South, and southwest of the study area the development of the basin is less clear. It is the conclusion of this study that the McKay River and Rose Bay formations have been tectonically transported from that direction to their present setting. Although they may yet be considered allocthonous on a local scale they correspond to, and fall within, the structural setting of the parauthocthonous Molson Lake Terrain

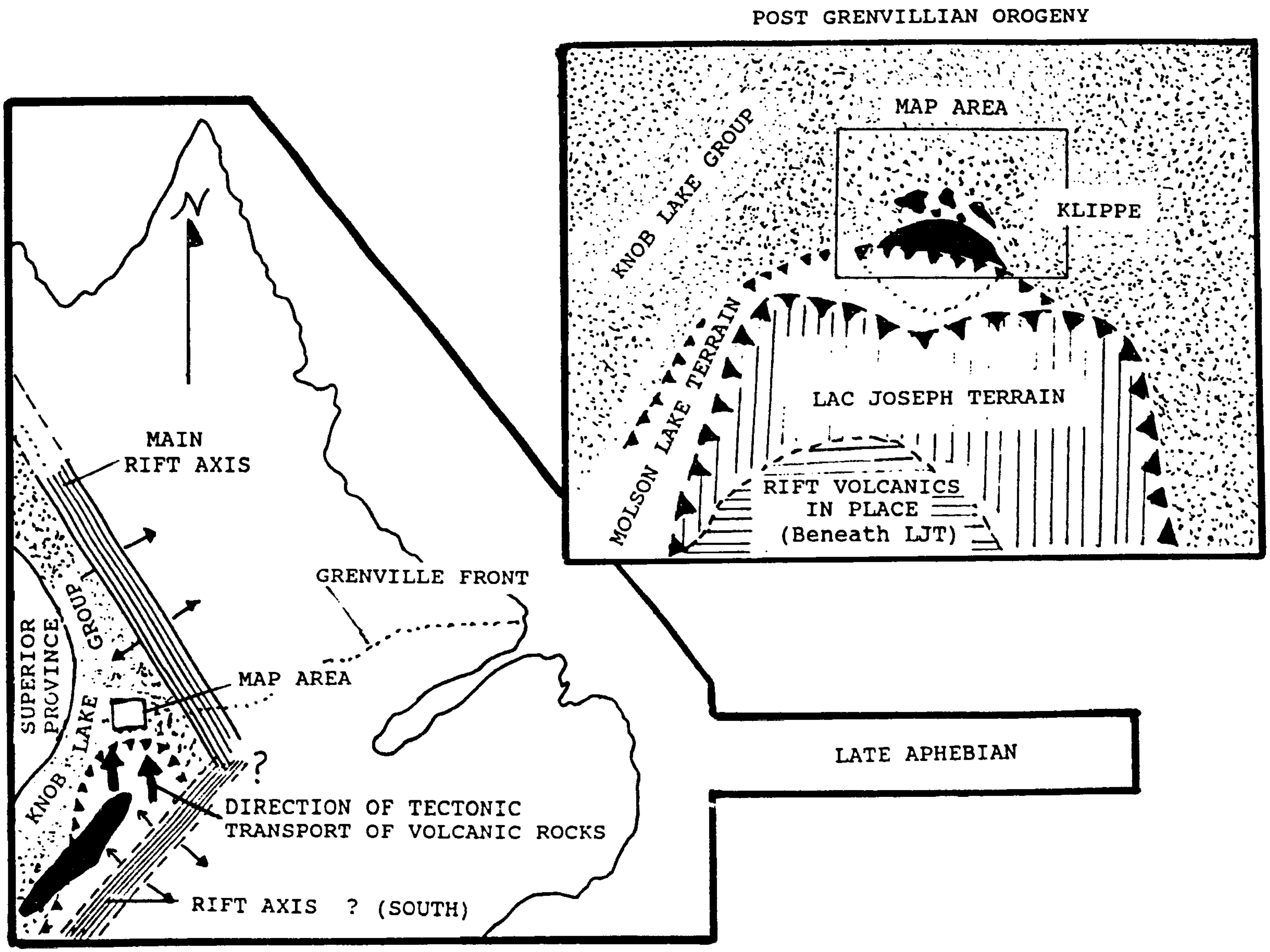


FIGURE 7.2 SCHEMATIC DIAGRAM SHOWING POSSIBLE ORIENTATION OF EASTERN AND SOUTHERN RIFT SYSTEMS IN THE LABRADOR TROUGH REGION.

outlined by Connelly et al. (1989). While the stratigraphic evidence collected to date is inconclusive, geochemical and petrographic evidence suggests that the McKay River and Rose Bay formations are syndepositional with the Denault and Sokoman Formations, respectively. The lack of any noticeable amount of these units occurring within the volcanoclastic rocks presumably indicates that the McKay River and Rose Bay formations were voluminous enough so as to completely replace the other sediments. It is also possible that they were deposited at some distance from edge of the craton and therefore distal to where the bulk of Denault and Sokoman sedimentation was occurring, presumably in deeper water, and, in a relatively short period of time.

The chemical nature of the volcanic rocks especially the Rose Bay formation suggests that they were associated tectonically with a tensional environment but that they erupted at a considerable distance from the point of intense rifting (Brey, 1977). It is therefore possible that they were a function of the northwest-southeast trending rift system associated with the Nimish and Doublet Groups. It is also possible that they represent volcanic activity associated with a major rift system located further to the south (figure 7.2). Studies by Rivers (1979, 1980) to the southwest show a general absence of volcanic rocks interbedded with the miogeosynclinal sediments of the Knob Lake Group. He describes some amphibolite bodies which are found just east and south of the southern end of Wabush Lake, as possible meta tuffaceous rocks. Although the occurrence of these rocks is limited, they are found in the same position relative to the leading edge of the Molson Lake Terrain (see Brown 1991) as the McKay River and Rose Bay formations.

These occurrences along with the McKay River and Rose Bay formations may represent the northern most edge of significant Aphebian volcanic activity occurring south of the Grenville Front in this region which has since been buried by allocthonous terrains of the Grenville Orogeny.

CHAPTER 8

CONCLUSIONS

The following conclusions, in point form, summarize the principal findings of this study.

1. A volcanic sequence, described in this report as the sub-eruptive suite, was recognized for the first time within the study area. It was concluded that this unit represented a southern extension of the Nimish Sub Group, a volcanic sequence, found to the north of the study area.

2. The sub-eruptive suite comprises the only volcanic sequence that can clearly be shown to occupy a position in the stratigraphy Knob Lake Group in this area, specifically the Sokoman Iron Formation.

3) Two other volcanic suites, the Mckay River formation and Rose Bay formation, previously thought to be interbedded with the stratigraphy of the Knob Lake Group comprise an allocthonous sequence which is separated by a tectonic contact from the rocks of the Knob Lake Group.

4) The internal stratigraphy of the McKay River and Rose Bay formations has been described and refined. It is concluded that the bulk of the volcanogenic sedimentary rocks are part of the Rose Bay formation.

5) The Rose Bay formation is stratigraphically equivalent to the top of, and also overlies the McKay River formation.

6) Chemically, the McKay River formation is a distinct suite of continental rift related alkali basalts possessing considerably higher than average CaO and TiO_2.

7) The Rose Bay formation is a sequence of strongly alkaline ultramafic volcanic rocks with strong chemical affinities for a rare rock type known as olivine melilitite.

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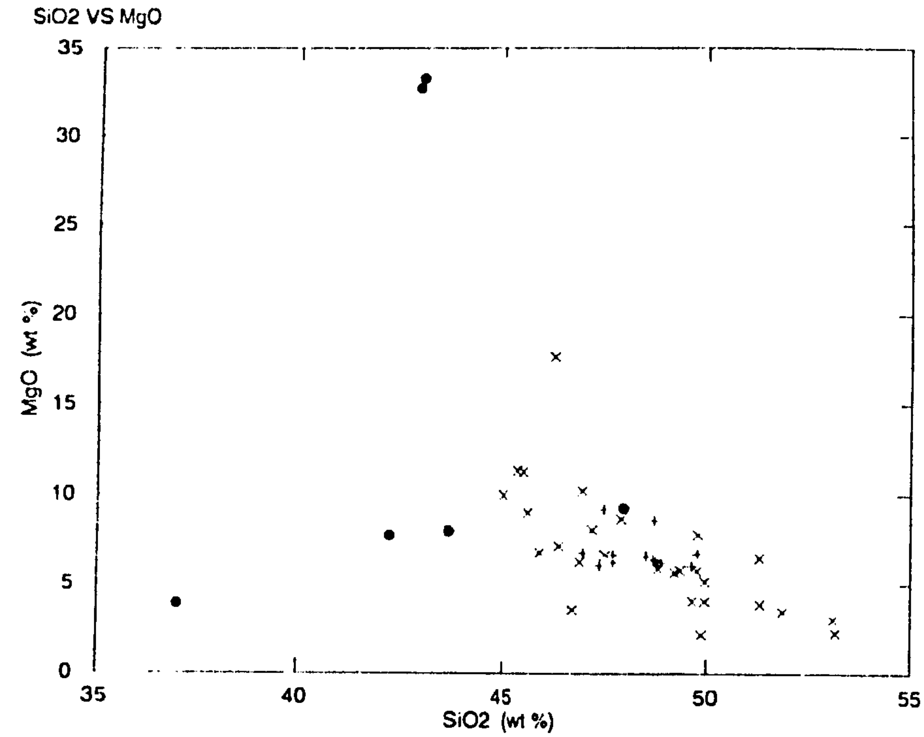
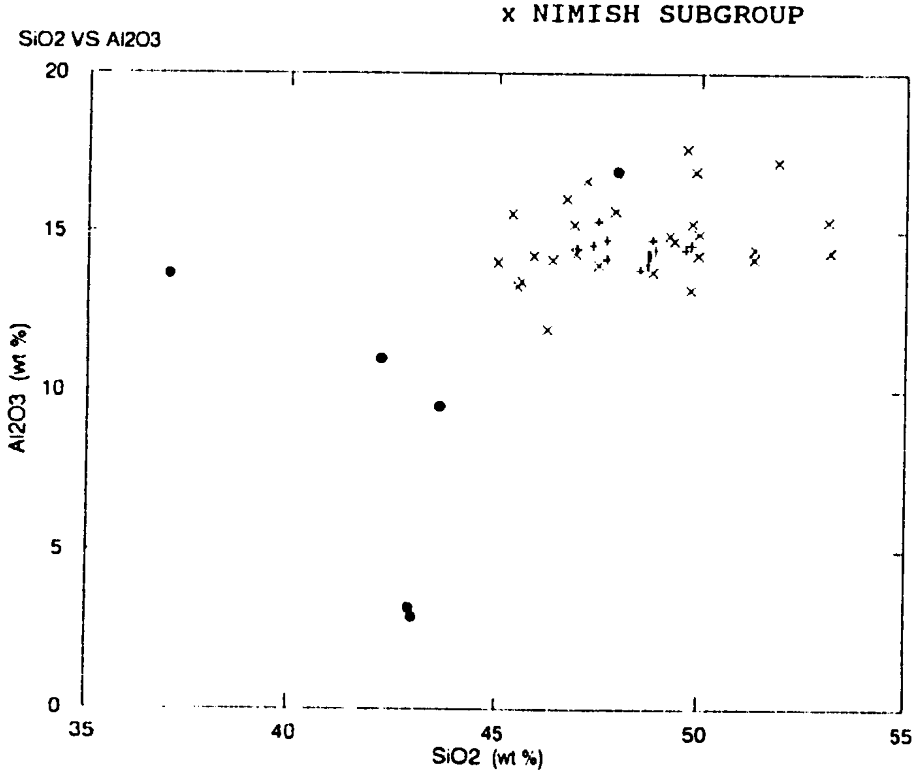


+ McKAY RIVER FORMATION
● SUB-ERUPTIVE SUITE
x NIMISH SUBGROUP



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Locality 2										
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Plot Colour	10	10	10	10	10	10	10	10	10	10
Rock Type	basalt	basalt	basalt	basalt	basalt	basalt	basalt	basalt	basalt	basalt
SiO2	46.30	47.10	48.20	45.60	45.00	47.70	47.50	47.20	47.50	45.50
TiO2	2.93	3.11	2.94	3.00	2.84	3.16	3.21	3.10	3.11	3.05
Al2O3	13.70	14.20	14.00	14.00	14.50	13.90	13.90	13.40	14.00	14.00
Fe2O3	3.46	2.57	2.89	2.85	3.37	3.44	0.56	3.22	1.05	2.13
FeO	8.39	9.34	9.40	9.05	9.69	9.06	10.37	9.49	10.57	10.49
MnO	0.17	0.16	0.16	0.15	0.17	0.17	0.13	0.18	0.16	0.17
MgO	6.41	5.85	5.82	5.80	8.71	6.20	6.37	6.37	6.03	6.53
CaO	12.81	10.62	10.77	12.57	7.07	10.85	9.82	11.84	11.89	12.38
Na2O	2.46	2.57	2.59	2.45	3.02	2.51	2.77	2.04	2.05	2.10
K2O	0.36	0.97	0.37	0.72	0.39	0.83	0.51	0.46	0.54	0.36
P2O5	0.31	0.22	0.22	0.24	0.24	0.32	0.33	0.26	0.33	0.24
Total	97.30	96.71	97.36	96.43	95.00	98.14	95.47	97.56	97.23	96.95
LOI	1.84	1.63	1.64	2.70	4.08	1.61	2.58	1.73	2.35	2.15
Mg #	49.82	47.22	46.36	47.09	54.95	47.61	51.07	47.82	48.27	48.40
Sc	-	-	-	-	-	-	-	-	-	
V	375	399	406	382	445	408	429	401	411	393
Cu	30	-	4	22	-	26	-	-	-	
Pb	1	2	5	21	6	4	4	1	6	5
Zn	94	98	106	132	11	98	88	98	95	89
Bi	-	-	-	-	-	-	-	-	-	
W	-	-	-	-	-	-	-	-	-	-
Mo	-	-	-	-	-	-	-	-	-	-
Rb	-	10	-	4	2	10	5	3	4	-
Cs	-	-	-	-	-	-	-	-	-	-
Ba	109	277	35	276	125	367	196	156	231	45
Sr	650	429	387	695	239	455	235	471	463	429
Tl	-	-	-	-	-	-	-	-	-	-
Ga	14	10	11	14	13	10	11	12	15	11
Li	-	-	-	-	-	-	-	-	-	-
Ta	-	-	-	-	-	-	-	-	-	-
Nb	28.0	29.0	26.0	28.0	26.0	36.0	36.0	26.0	35.0	27.0
Zr	114	122	105	120	114	132	130	109	126	111
Y	30	28	29	30	28	34	34	28	34	30
Th	-	3.00	4.00	2.00	3.00	5.00	5.00	6.00	5.00	6.00
U	-	-	-	-	-	-	-	-	-	-
La	-	-	-	-	-	-	-	-	-	-
Ce	-	-	-	-	-	-	-	-	-	-
Pr	-	-	-	-	-	-	-	-	-	-
Nd	-	-	-	-	-	-	-	-	-	-
Sm	-	-	-	-	-	-	-	-	-	-
Eu	-	-	-	-	-	-	-	-	-	-
Gd	-	-	-	-	-	-	-	-	-	-
Tb	-	-	-	-	-	-	-	-	-	-
Dy	-	-	-	-	-	-	-	-	-	-
Ho	-	-	-	-	-	-	-	-	-	-
Er	-	-	-	-	-	-	-	-	-	-
Tm	-	-	-	-	-	-	-	-	-	-
Yb	-	-	-	-	-	-	-	-	-	-
Lu	-	-	-	-	-	-	-	-	-	-
Be	-	-	-	-	-	-	-	-	-	-
Density	2.71	2.69	2.69	2.71	2.71	2.69	2.70	2.72	2.72	2.74

File Name	A:\MRVOLRCK.ROC									
Sample	nn-294-79	NN-24-85	NN-25-85	NN-1-85	NN-13A-85	NN-14A-85	NN-17A-85	NN-17B-85	NN-17C-85	NN-17D-85
Locality 1										
Locality 2										
Plot Symbol	13	13	13	4	4	4	5	5	5	5
Plot Colour	10	10	10	4	4	4	4	4	4	4
Rock Type	basalt	BASALT	basalt	TUFFACEOUS	FRAGMENTAL	TUFF/FRAG	FRAGMENTAL	FRAGMENTAL	FRAGMENTAL	FRAGMENTAL
SiO2	46.30	47.10	47.70	22.30	41.20	44.30	36.30	38.80	38.30	39.00
TiO2	3.25	2.92	2.96	2.00	2.96	3.44	4.80	4.20	4.92	4.80
Al2O3	14.30	13.50	14.00	5.89	8.59	9.89	8.73	7.38	7.61	9.18
Fe2O3	1.78	13.18	13.22	9.27	17.50	14.36	20.15	17.15	18.85	17.35
FeO	9.87	-	-	-	-	-	-	-	-	-
MnO	0.15	0.16	0.17	0.24	0.20	0.15	0.24	0.23	0.23	0.22
MgO	6.02	6.18	8.36	7.02	13.82	12.40	16.05	14.70	13.90	11.76
CaO	11.64	11.66	8.46	29.40	10.08	12.80	8.76	12.46	11.52	10.04
Na2O	2.96	2.66	2.69	0.92	2.00	1.74	0.58	1.14	1.26	1.88
K2O	0.49	0.34	1.41	0.28	0.81	0.57	0.54	0.21	0.18	1.17
P2O5	0.40	0.41	0.36	0.22	0.48	0.35	0.45	0.50	0.54	0.61
Total	97.16	98.11	99.33	77.54	97.64	100.00	96.60	96.77	97.31	96.01
LOI	2.07	1.47	0.67	21.81	0.73	0.78	3.93	4.03	2.21	4.24
Mg #	48.33	48.15	55.60	60.00	61.00	63.10	61.20	62.93	59.36	57.31
Sc	-	36	36	26	34	31	33	26	35	32
V	377	302	405	176	355	330	345	331	385	377
Cu	87	-	-	-	-	-	-	-	-	-
Pb	1	20	21	13	13	13	12	10	15	13
Zn	89	-	-	-	-	-	-	-	-	-
Bi	-	0.06	0.05	0.06	0.05	0.10	0.06	0.04	0.06	0.06
W	-	0.87	3.21	18.07	2.35	54.96	7.30	3.22	1.32	0.55
Mo	-	0.16	0.27	0.61	0.22	1.25	1.12	1.15	0.90	0.18
Rb	4	2	18	4	25	11	17	2	1	39
Cs	-	0.13	2.15	1.87	0.72	0.76	0.39	0.08	0.09	0.84
Ba	95	125	676	203	303	172	640	174	66	234
Sr	703	443	327	393	194	518	174	316	334	333
Tl	-	0.00	0.10	0.06	0.06	0.10	0.03	0.02	0.04	0.08
Ga	15	-	-	-	-	-	-	-	-	-
Li	-	20.36	35.83	18.93	23.26	18.34	31.72	20.65	23.44	23.37
Ta	-	0.01	0.07	1.70	0.05	3.34	0.44	0.14	0.15	0.04
Nb	33.0	25.0	30.0	27.0	66.0	78.0	64.0	63.0	65.0	72.0
Zr	137	142	132	184	406	431	345	365	399	418
Y	29	24	27	12	33	35	27	25	30	34
Th	3.00	1.83	1.83	1.78	4.59	6.94	4.74	3.86	4.54	5.02
U	-	0.46	0.38	0.40	0.91	2.06	0.93	0.81	0.91	1.12
La	-	23.77	23.71	24.67	57.15	50.62	47.97	40.59	53.37	60.84
Ce	-	52.11	53.52	55.39	130.43	131.01	108.80	90.97	117.42	138.33
Pr	-	7.20	7.41	7.38	17.99	17.81	14.46	12.36	15.81	18.09
Nd	-	30.22	30.94	29.40	75.24	70.83	59.16	52.04	67.36	73.46
Sm	-	6.58	6.63	6.03	15.16	13.48	12.60	11.11	13.95	15.07
Eu	-	2.21	2.58	1.63	4.57	5.80	3.45	3.28	3.96	4.16
Gd	-	5.67	5.98	4.66	11.15	10.09	9.53	8.23	10.23	11.36
Tb	-	0.86	0.93	0.65	1.49	1.39	1.30	1.22	1.41	1.54
Dy	-	4.87	5.18	3.36	7.42	7.47	6.45	6.05	6.95	7.64
Ho	-	0.94	1.00	0.59	1.18	1.29	1.05	1.00	1.13	1.27
Er	-	2.46	2.77	1.45	2.89	3.38	2.51	2.45	2.60	3.15
Tm	-	0.33	0.37	0.17	0.34	0.43	0.31	0.28	0.31	0.36
Yb	-	1.91	2.22	0.98	1.82	2.39	1.59	1.38	1.53	1.88
Lu	-	0.28	0.30	0.13	0.25	0.33	0.19	0.18	0.16	0.26
Be	-	0.25	0.85	1.30	2.66	2.92	2.39	1.79	2.93	3.24
Density	2.71	2.61	2.59	2.91	2.70	2.68	2.77	2.75	2.75	2.71

File Name	A:\MRVOLRCK.ROC									
Sample	NN-19A-85	NN-19B-85	NN-19C-85	NN-2-85	NN-20-85	NN-21A-85	NN-22-85	NN-23-85	NN-3-85	NN-1 83
Locality 1										
Locality 2										
Plot Symbol	6	6	8	6	4	4	4	4	6	4
Plot Colour	4	4	14	4	4	4	4	4	4	4
Rock Type	META MAGMA	META MAGMA	SHABOGAMO	CLAST VESI	ACTINOLITE	CHECK OC 3	CHECK OC 6	BOULDER OF	UNBRECC VE	TUFFACEOUS
SiO2	32.80	34.70	45.60	42.80	38.70	34.40	40.50	41.90	33.90	41.50
TiO2	3.20	3.20	2.20	4.40	4.00	5.08	5.00	2.12	3.96	4.90
Al2O3	7.60	7.70	15.20	9.26	9.03	6.48	9.24	5.21	8.21	9.33
Fe2O3	15.61	13.80	16.33	17.85	19.00	16.59	18.59	14.72	17.50	18.20
FeO	-	-	-	-	-	-	-	-	-	-
MnO	0.21	0.18	0.19	0.17	0.19	0.20	0.23	0.16	0.21	0.20
MgO	11.15	11.35	6.72	13.61	18.18	9.86	7.10	18.52	15.80	10.55
CaO	17.15	17.65	7.48	6.18	2.64	14.92	12.02	10.56	12.22	11.66
Na2O	0.66	0.55	3.15	2.04	1.06	1.94	2.49	0.45	0.45	1.09
K2O	1.08	0.79	1.05	0.52	1.62	0.69	0.93	0.04	0.09	0.23
P2O5	0.45	0.44	0.35	0.49	0.71	0.46	0.69	0.23	0.38	0.43
Total	89.91	90.36	98.27	97.32	95.13	90.62	96.79	93.91	92.72	98.09
LOI	9.79	9.40	1.34	2.63	4.61	8.08	3.21	5.99	7.94	0.94
Mg #	58.58	61.96	44.90	60.16	65.46	54.07	43.06	71.36	64.13	53.44
Sc	20	9	27	33	29	32	20	26	44	-
V	316	305	242	473	241	272	455	257	454	378
Cu	-	-	-	-	-	-	-	-	-	-
Pb	12	5	12	13	18	15	14	10	54	-
Zn	-	-	-	-	-	-	-	-	-	-
Bi	0.07	0.06	0.02	0.10	0.09	0.05	0.06	0.03	0.06	-
W	1.79	2.86	13.36	23.15	1.14	8.52	5.17	3.27	8.41	-
Mo	0.37	0.75	0.89	1.49	0.30	0.20	0.25	1.15	1.05	-
Rb	37	26	21	11	60	22	28	2	1	3
Cs	1.97	0.33	0.36	3.14	4.10	1.41	1.02	0.04	0.40	-
Ba	567	132	503	271	66	2453	919	15	44	57
Sr	504	343	310	92	117	1164	278	212	252	58
Tl	0.11	0.05	0.12	0.12	0.27	0.09	0.07	0.03	0.07	-
Ga	-	-	-	-	-	-	-	-	-	-
Li	38.62	10.83	21.82	22.33	73.60	20.99	28.31	15.96	30.31	-
Ta	0.10	0.22	0.37	2.38	-0.00	0.05	0.53	0.11	3.02	-
Nb	58.0	64.0	7.0	65.0	79.0	75.0	83.0	26.0	50.0	61.0
Zr	248	239	193	337	520	511	329	181	313	325
Y	22	25	36	30	34	30	39	14	24	40
Th	6.42	2.41	2.03	4.60	7.59	3.66	6.94	1.97	3.09	-
U	1.30	0.50	0.31	0.97	1.34	0.36	1.69	0.44	0.62	-
La	56.15	20.69	20.43	55.72	87.42	66.46	72.10	20.23	43.48	-
Ce	114.74	42.70	45.23	120.26	179.68	151.16	146.77	47.76	95.90	-
Pr	13.87	5.20	6.06	15.95	21.07	19.27	19.33	6.66	12.68	-
Nd	54.26	19.70	25.22	65.76	79.38	75.78	77.29	27.89	52.21	-
Sm	10.02	3.74	5.76	13.29	14.64	14.50	15.44	5.92	10.97	-
Eu	3.03	1.11	1.77	3.71	4.61	3.59	4.15	1.46	3.33	-
Gd	7.83	3.00	5.66	10.71	11.79	11.22	11.24	4.66	8.50	-
Tb	1.07	0.41	1.01	1.49	1.56	1.51	1.58	0.66	1.15	-
Dy	5.48	2.05	6.14	7.75	7.70	7.32	8.42	3.16	5.80	-
Ho	0.93	0.35	1.22	1.28	1.31	1.11	1.43	0.51	0.96	-
Er	2.33	0.87	3.56	3.15	3.19	2.51	3.54	1.31	2.28	-
Tm	0.30	0.11	0.48	0.40	0.40	0.28	0.45	0.16	0.28	-
Yb	1.64	0.57	2.95	2.04	2.11	1.50	2.47	0.80	1.46	-
Lu	0.23	0.08	0.46	0.30	0.31	0.18	0.33	0.11	0.21	-
Be	3.38	1.03	0.71	1.58	3.25	2.49	3.65	-1.08	3.42	-
Density	2.78	2.77	2.59	2.68	2.71	2.76	2.68	2.73	2.80	2.71

File Name	A:\MRVOLRCK.ROC									
Sample	NN-2-83	NN-3-83	NN-3A-83	NN-4-83	NN-5-83	NN-2-79	NN-12-79	NN-13-79	NN-190-79	NN-191-79
Locality 1										
Locality 2										
Plot Symbol	4	13	6	4	4	4	4	4	4	4
Plot Colour	4	10	4	4	4	4	4	4	4	4
Rock Type	META TUFF	BASALT? OC	MAGMA? UB	FRAGMENTAL	CLAST IN F	FRAGMENTAL UB		FRAGMENTAL	FRAGMENTAL	FRAGMENTAL
SiO2	40.00	36.90	39.50	41.20	37.00	43.10	41.10	36.20	40.70	44.50
TiO2	3.92	5.30	4.09	4.26	5.30	4.65	3.35	2.29	4.25	2.76
Al2O3	7.05	12.80	6.74	7.68	8.63	8.56	7.55	7.09	6.49	6.44
Fe2O3	18.26	14.40	17.22	16.75	16.60	3.08	7.13	7.43	6.70	4.07
FeO	-	-	-	-	-	12.51	9.00	9.31	11.85	11.14
MnO	0.18	0.21	0.25	0.22	0.18	0.19	0.16	0.22	0.24	0.21
MgO	15.80	5.66	14.15	12.30	10.45	8.77	14.25	14.63	18.20	17.23
CaO	8.76	12.90	12.50	12.20	13.68	12.09	10.13	11.17	8.27	8.59
Na2O	1.12	3.06	0.99	1.76	1.78	1.05	1.13	0.76	0.56	0.74
K2O	1.17	0.43	0.15	0.33	0.74	0.23	1.63	1.57	0.48	1.57
P2O5	0.47	0.80	0.39	0.39	0.53	0.40	0.36	0.30	0.44	0.21
Total	96.73	92.46	95.98	97.09	94.89	94.63	95.79	90.97	98.18	97.46
LOI	2.61	6.42	4.48	3.26	5.16	2.09	3.09	6.95	1.97	2.41
Mg #	63.15	43.77	61.94	59.25	55.49	50.56	62.23	61.98	64.46	67.47
Sc	-	-	-	-	-	-	-	-	-	-
V	338	208	320	351	367	401	388	312	190	286
Cu	-	-	-	-	-	-	-	-	-	-
Pb	-	-	-	-	-	-	-	-	-	-
Zn	-	-	-	-	-	-	-	-	-	-
Bi	-	-	-	-	-	-	-	-	-	-
W	-	-	-	-	-	-	-	-	-	-
Mo	-	-	-	-	-	-	-	-	-	-
Rb	35	14	2	1	25	-	65	72	40	69
Cs	-	-	-	-	-	-	-	-	-	-
Ba	104	263	778	78	220	21	223	510	120	384
Sr	118	3060	595	350	674	77	195	377	143	150
Tl	-	-	-	-	-	-	-	-	-	-
Ga	-	-	-	-	-	-	-	-	-	-
Li	-	-	-	-	-	-	-	-	-	-
Ta	-	-	-	-	-	-	-	-	-	-
Nb	53.0	141.0	58.0	68.0	79.0	100.0	60.0	35.0	64.0	36.0
Zr	374	660	357	363	444	350	308	359	366	205
Y	26	65	32	37	40	46	30	19	30	22
Th	-	-	-	-	-	-	-	-	-	-
U	-	-	-	-	-	-	-	-	-	-
La	-	-	-	-	-	-	-	-	-	-
Ce	-	-	-	-	-	-	-	-	-	-
Pr	-	-	-	-	-	-	-	-	-	-
Nd	-	-	-	-	-	-	-	-	-	-
Sm	-	-	-	-	-	-	-	-	-	-
Eu	-	-	-	-	-	-	-	-	-	-
Gd	-	-	-	-	-	-	-	-	-	-
Tb	-	-	-	-	-	-	-	-	-	-
Dy	-	-	-	-	-	-	-	-	-	-
Ho	-	-	-	-	-	-	-	-	-	-
Er	-	-	-	-	-	-	-	-	-	-
Tm	-	-	-	-	-	-	-	-	-	-
Yb	-	-	-	-	-	-	-	-	-	-
Lu	-	-	-	-	-	-	-	-	-	-
Be	-	-	-	-	-	-	-	-	-	-
Density	2.72	2.68	2.74	2.71	2.74	2.83	2.81	2.86	2.89	2.82

File Name A:\MRVOLRCK.ROC

Sample	NN-202-79	NN-275-79	NN-10-85	NN-15-85	NN-16-85	NN-18-85	NN 4-85	NN-9-85	NN-1000-79	NN-10A-85
Locality 1										
Locality 2										
Plot Symbol	4	4	3	3	7	7	3	3	3	3
Plot Colour	4	4	15	15	4	4	15	15	15	15
Rock Type	FRAGMENTAL	FRAGMENTAL	MAGMA INTR	CUM WBAY ?	PHYLONITE/	PHYLONITE/	MAGMA INTR	NMSHBAS IN	PORPH WBAY	BASALT INT
SiO2	38.70	39.40	42.30	40.50	62.70	60.80	35.60	44.90	40.50	41.00
TiO2	2.73	3.22	1.20	1.28	0.68	0.76	2.20	1.16	1.27	1.44
Al2O3	6.57	6.19	9.21	3.00	16.50	16.40	13.10	15.80	2.72	10.73
Fe2O3	3.20	4.25	28.10	14.52	7.10	7.61	30.80	15.54	4.87	27.75
FeO	8.34	9.40	-	-	-	-	-	-	8.99	-
MnO	0.19	0.21	0.34	0.17	0.10	0.12	0.23	0.51	0.16	0.28
MgO	18.13	13.28	7.67	30.90	3.52	3.47	3.74	8.66	31.35	7.49
CaO	13.33	15.40	7.14	5.08	1.02	1.24	9.22	4.02	4.57	7.24
Na2O	0.26	0.97	0.60	0.21	2.75	2.83	1.99	3.74	0.15	0.84
K2O	0.48	0.61	2.91	0.08	4.02	3.70	1.54	0.59	0.06	1.06
P2O5	0.35	0.35	0.32	0.15	0.16	0.20	0.68	0.18	0.10	0.19
Total	92.28	93.28	99.79	95.89	98.55	97.13	99.10	95.10	94.74	99.99
LOI	7.46	4.88	0.74	5.31	2.32	3.41	0.24	6.37	5.39	0.67
Mg #	74.22	64.15	35.09	80.82	49.54	47.45	19.39	52.46	80.69	34.83
Sc	-	-	13	18	14	17	18	17	-	-
V	271	277	164	173	149	154	194	193	164	160
Cu	-	-	-	-	-	-	-	-	-	-
Pb	-	-	10	13	21	22	21	11	-	
Zn	-	-	-	-	-	-	-	-	-	-
Bi	-	-	0.04	0.05	0.17	0.19	0.08	0.04	-	-
W	-	-	81.50	20.68	26.56	28.91	6.94	25.05	-	-
Mo	-	-	1.60	1.74	2.04	1.88	2.14	1.12	-	-
Rb	28	33	81	2	120	134	8	4	2	81
Cs	-	-	5.62	0.75	2.39	4.29	12.98	1.24	-	-
Ba	63	235	596	18	723	635	560	110	5	768
Sr	289	1015	46	36	162	130	13	-23	28	37
Tl	-	-	0.13	0.05	0.62	0.80	0.34	0.13	-	-
Ga	-	-	-	-	-	-	-	-	-	3
Li	-	-	15.20	9.84	35.51	43.22	50.17	37.74	-	-
Ta	-	-	0.36	0.08	0.09	0.09	0.22	0.27	-	-
Nb	37.0	61.0	14.0	16.0	16.0	15.0	5.3	6.0	14.0	22.0
Zr	233	303	78	94	178	165	161	106	86	95
Y	26	27	21	10	18	26	34	25	10	17
Th	-	-	1.42	1.02	11.04	12.49	4.30	1.40	-	-
U	-	-	0.17	0.27	2.51	4.14	1.26	0.28	-	-
La	-	-	14.77	11.93	11.07	31.74	42.54	11.51	-	-
Ce	-	-	33.66	27.43	24.59	69.24	99.72	24.88	-	69.00
Pr	-	-	4.21	3.82	2.76	7.53	11.60	3.37	-	-
Nd	-	-	17.52	16.16	9.23	26.96	45.09	14.00	-	-
Sm	-	-	3.92	3.45	1.79	5.33	8.72	3.28	-	-
Eu	-	-	1.25	1.07	0.30	0.92	2.88	1.25	-	-
Gd	-	-	3.28	2.84	1.49	4.00	7.49	3.19	-	-
Tb	-	-	0.54	0.38	0.25	0.66	1.12	0.56	-	-
Dy	-	-	3.02	1.93	2.02	3.96	6.33	3.52	-	-
Ho	-	-	0.58	0.34	0.48	0.81	1.26	0.72	-	-
Er	-	-	1.62	0.86	1.72	2.55	3.46	2.10	-	-
Tm	-	-	0.22	0.12	0.27	0.40	0.48	0.30	-	-
Yb	-	-	1.30	0.64	1.82	2.66	2.80	1.82	-	-
Lu	-	-	0.17	0.10	0.30	0.42	0.45	0.29	-	-
Be	-	-	3.65	0.86	2.31	2.32	7.33	0.94	-	-
Density	2.86	2.85	2.65	2.78	2.40	2.41	2.69	2.58	2.90	2.65

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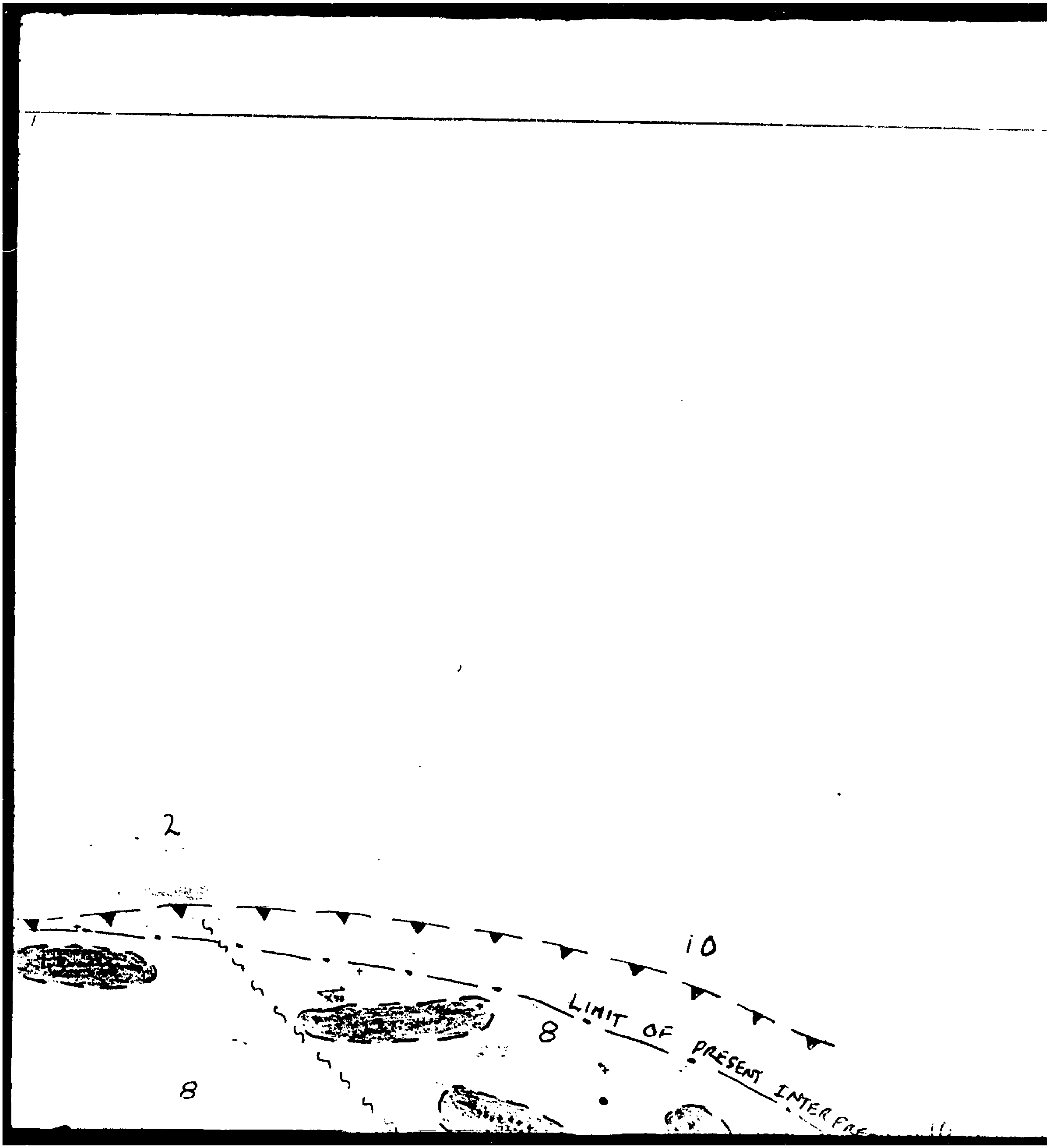
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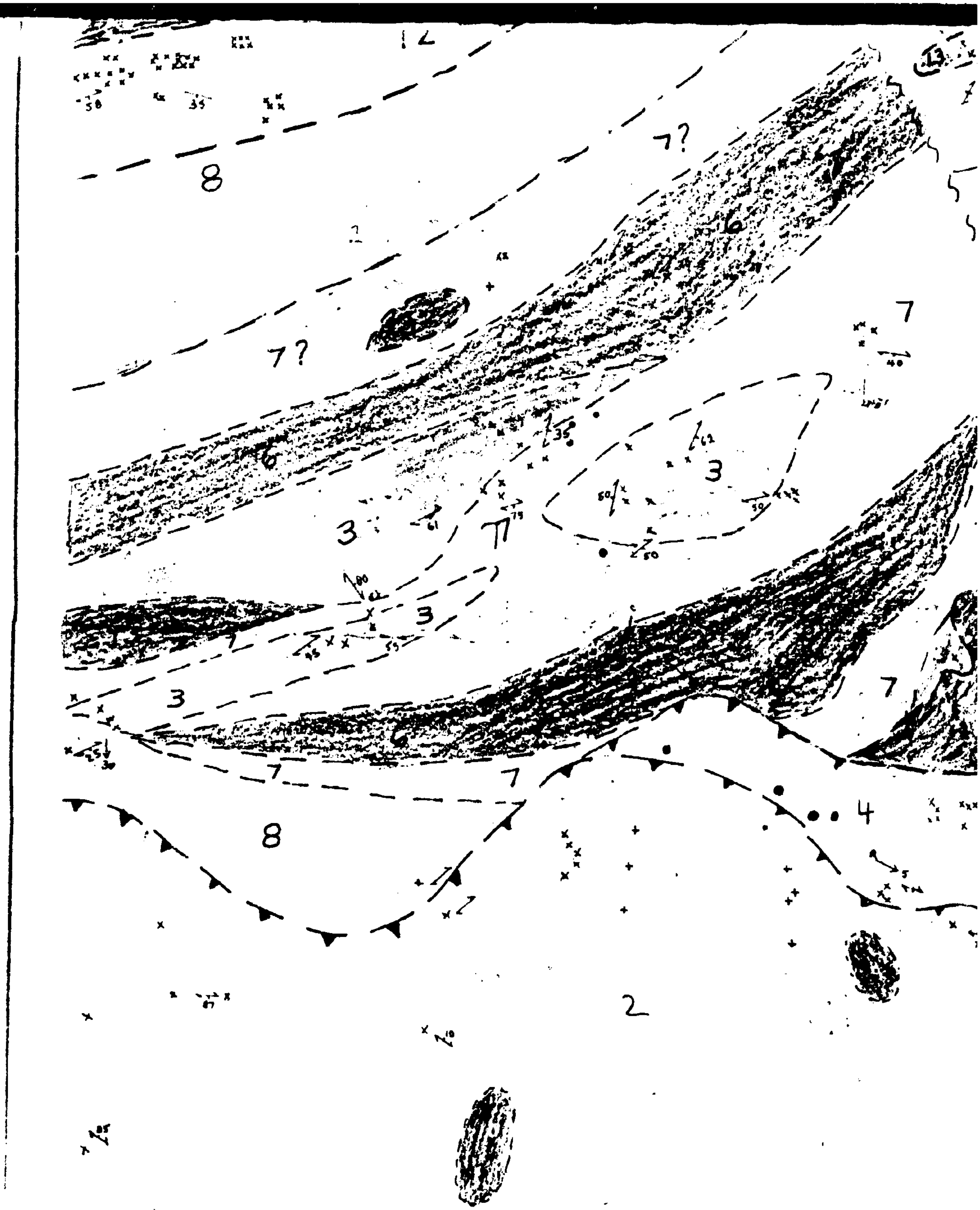
LIMIT OF PRESENT INTERFE



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PRESENT INTERPRETATION
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4a,b,c-85
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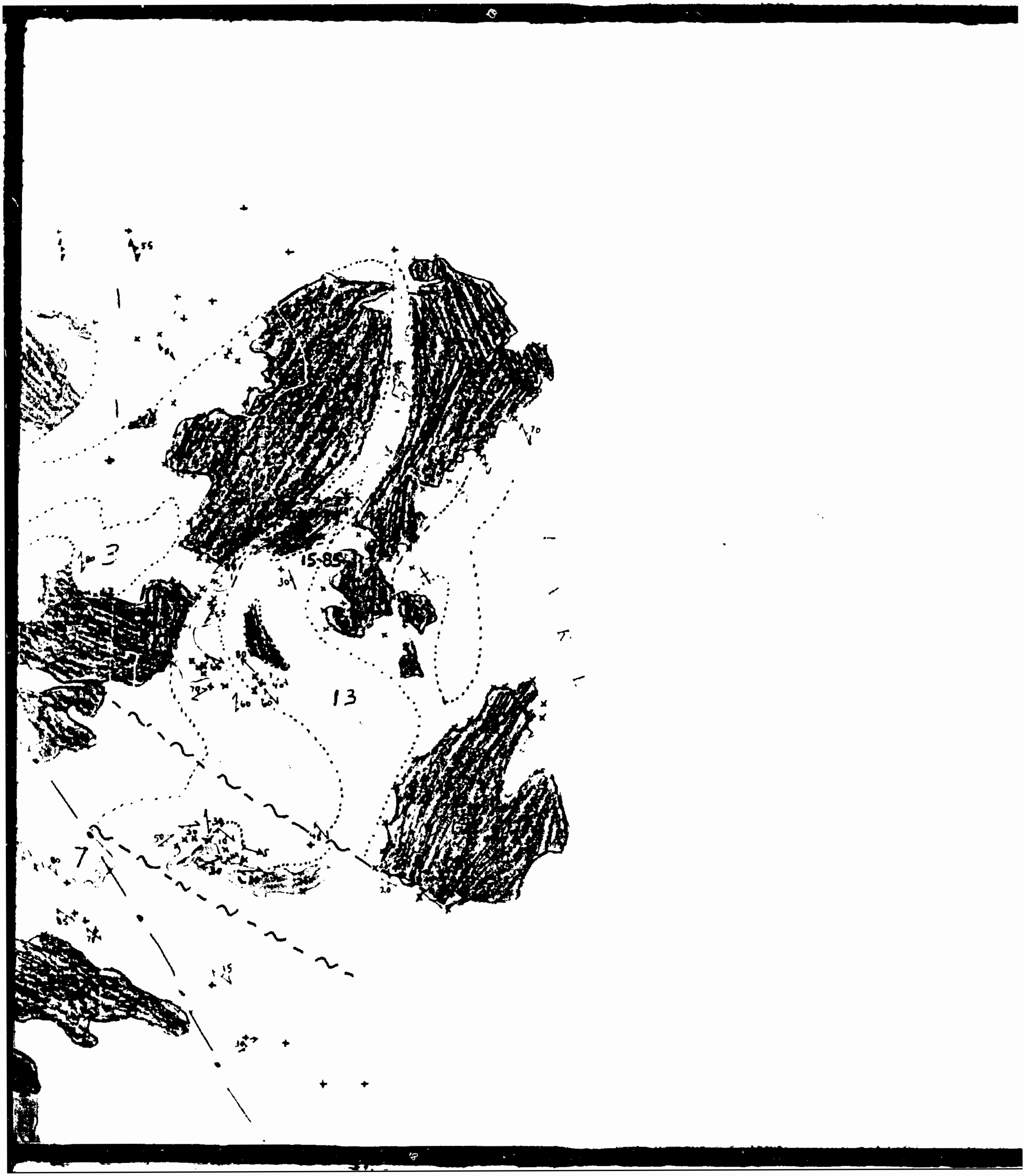

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KEY

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...INTERPRETATION ....
...LE .... ●

GEND

INTRUSIVE SUITE..... GABBRO - LEUCOGABBRO

...TION............... ORTHOQUARTZITE
ARKOSE

...OR BATHOLITH .... QUARTZ MONZODIORITE

LAKE GROUP.... FELSIC-INTERMEDIATE
VOLCANICS ASSOCIATED
SEDIMENTS

...AKE fm......... CONGLOMERATE
SILT-SANDSTONE

...FORMATION....... GRAPHITIC SLATE
PHYLLITE SCHIST

FORMATION...... CHERTY CARBONATE +
SILICATE IRONSTONE
MAY BE TUFFACEOUS

...IVE SUITE........ BASALTIC DYKES
TUFFACEOU EQUIVALENTS

...Y FORMATION...... ULTRAMAFIC ERUPTIVES
MELILITITE TUFFS

...ER FORMATION..... BASALTIC PILLOW LAVA
MINOR PYROCLASTICS

FORMATION ..... DOLOMITIC + CALCITIC
MARBLE. MINOR TUFF

... FORMATION ....KE - SHALE - SLATE

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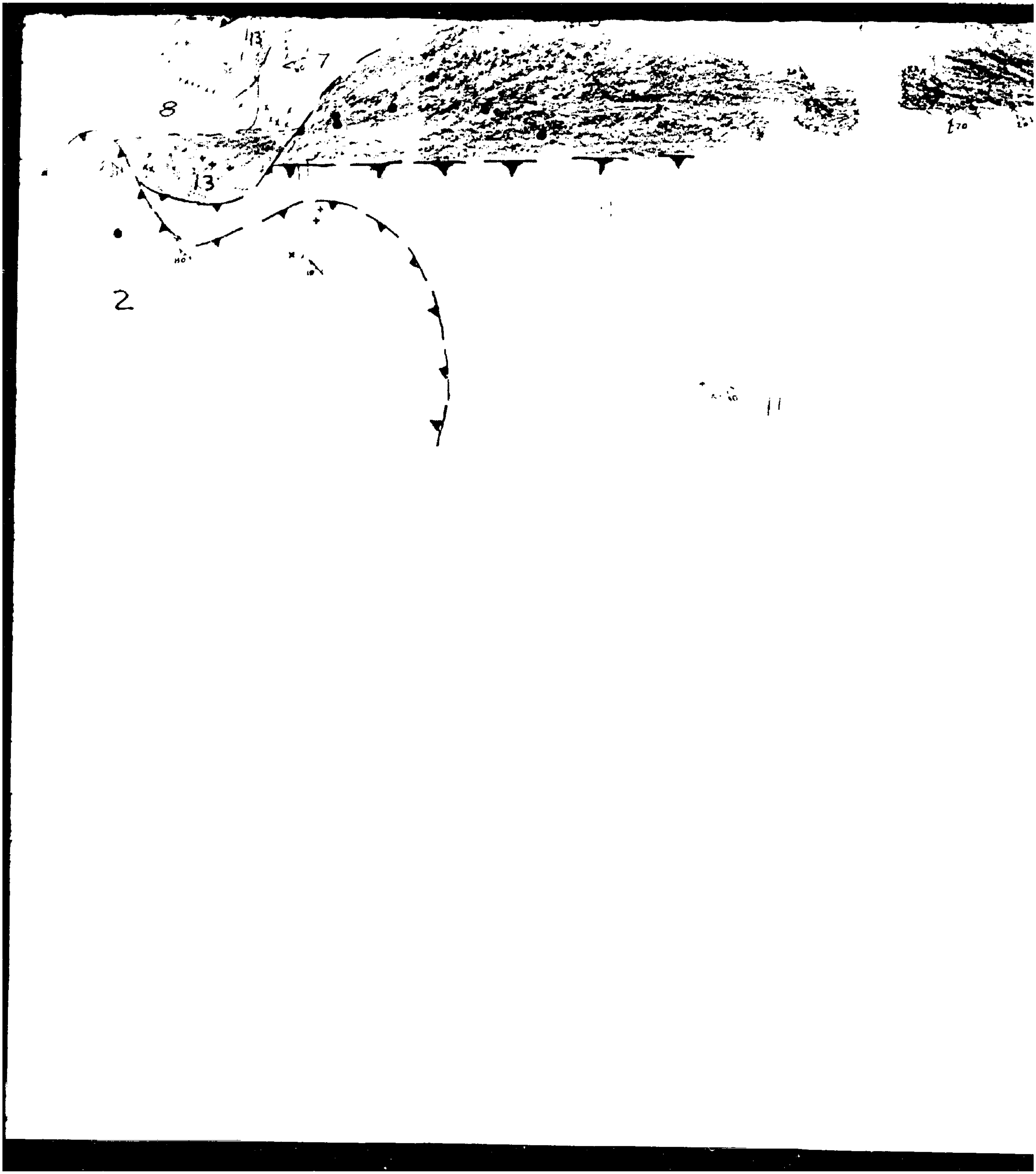
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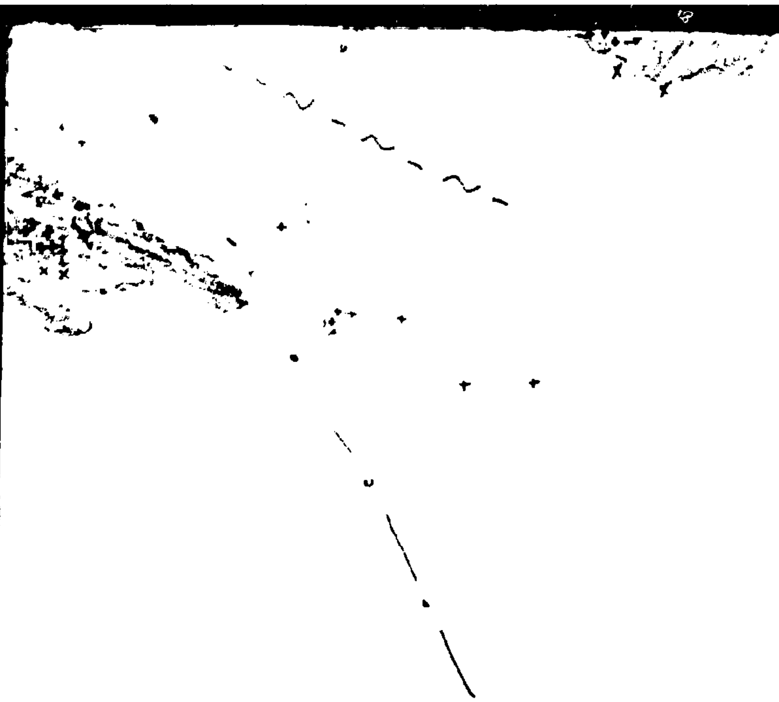

MAY BE TUFFA[illegible]
BASALTIC DYKES
TUFFACEOU EQUIVALENTS

...... ULTRAMAFIC ERUPTIVES
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..... BASALTIC PILLOW LAVA
MINOR PYROCLASTICS

... DOLOMITIC + CALCITIC
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.. GREYWACKE-SHALE-SLATE
QUARTZO-FELDSPATHIC GNEISS

.. ORTHOGNEISS