PETROLOGY OF THE MALIGNANT COVE DIORITIC COMPLEX

- by -

MICHAEL ALISDAIR MACDONALD

THIS THESIS
IS
SUBMITTED
IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS
FOR THE DEGREE OF
B A C H E L O R O F S C I E N C E
AT
ST. FRANCIS XAVIER UNIVERSITY
May, 1977

This thesis by Michael Alisdair MacDonald
is accepted in its present form by the Department of Geology
as satisfying the thesis requirements for the degree of
Bachelor of Science with Honours.

Date _____ _____
Thesis Advisor

Date _____ _____
Department Head

Approved:

Date _____ _____

ABSTRACT

The Malignant Cove Dioritic intrusion occupies an area of 5 sq km. and is situated on the N. W. shore of Nova Scotia, some 20 km north of Antigonish.

Detailed mapping of a section of this intrusion together with subsequent petrographic work, has shown it to comprise various lithologies ranging from minor lherzolites, clinopyroxenites and peridotites, through intermediate stages of diorite (constituting the bulk of the intrusion) to residual porphyritic phases, quartz diorites, anorthosites and pegmatites. The semi-circular stock intrudes actinolitic hornfels and andesitic lithologies thought to be part of the Cambro-Ordivician Brierly Brook Formation of the Brown's Mountain Group (Benson,1970).

Within the intrusion,the widespread occurrences of rhythmic layering mineralogical banding or cumulate textures implies magmatic fractionation and crystal accummulation within the parent magma. Horneblende, frequently poikilitic in texture is intercumulus to olivine and pyroxene in the ultramafics, and plagioclase in the anorthositic phases and porphyritic quartz diorites.

The various igneous lithogies are thus considered to have formed through fractionation of a single parental melt, for which an intermediate composition is suggested by relative lithological abundances. The mode of emplacement of the ultramafics varies from in-situ segregation to forceful emplacement following differentiation and

settling to form a cumulate sequence. Where forceful emplacement occurred, chilled margins are absent indicating a closed crystal mush system at a temperature similar to that of the melt.

Detailed petrographic descriptions of 20 thin sections are included in the appendix.

ACKNOWLEDGEMENTS

To John Stirling who suggested the study area and helped in all aspects of this thesis I express my extreme gratitude. To Damian Nance who, along with John, donated many hours of help with thin section work and showed me how much I have to learn, my sincere thanks. I would also like to thank the boys, especially Pat Donovan for use of his car and help in the field and Russell Oicle for contribution of ideas and stimulating conversations over the occasional ale.

TABLE OF CONTENTS

LIST OF PLATES

CHAPTER 1 - INTRODUCTION

PREVIOUS WORK

There has been little published literature with respect to this intrusion. The entire region however, was mapped by Hugh Fletcher (1887) as a part of a series of 1 inch to 1 mile maps of Northern Nova Scotia.

The Antigonish highlands was again mapped on a scale of 1 inch to 1 mile by Benson(1970). Benson delineated the approximate extent of the intrusion, named it as a horneblende diorite and noted that the intrusion has been cut by diabase dikes. Benson dated a similar dioritic intrusion near the headwaters of Barney's River, some 30 km South West of the map-area, using K/Ar, and arrived at an age of 411= 20 M.Y.

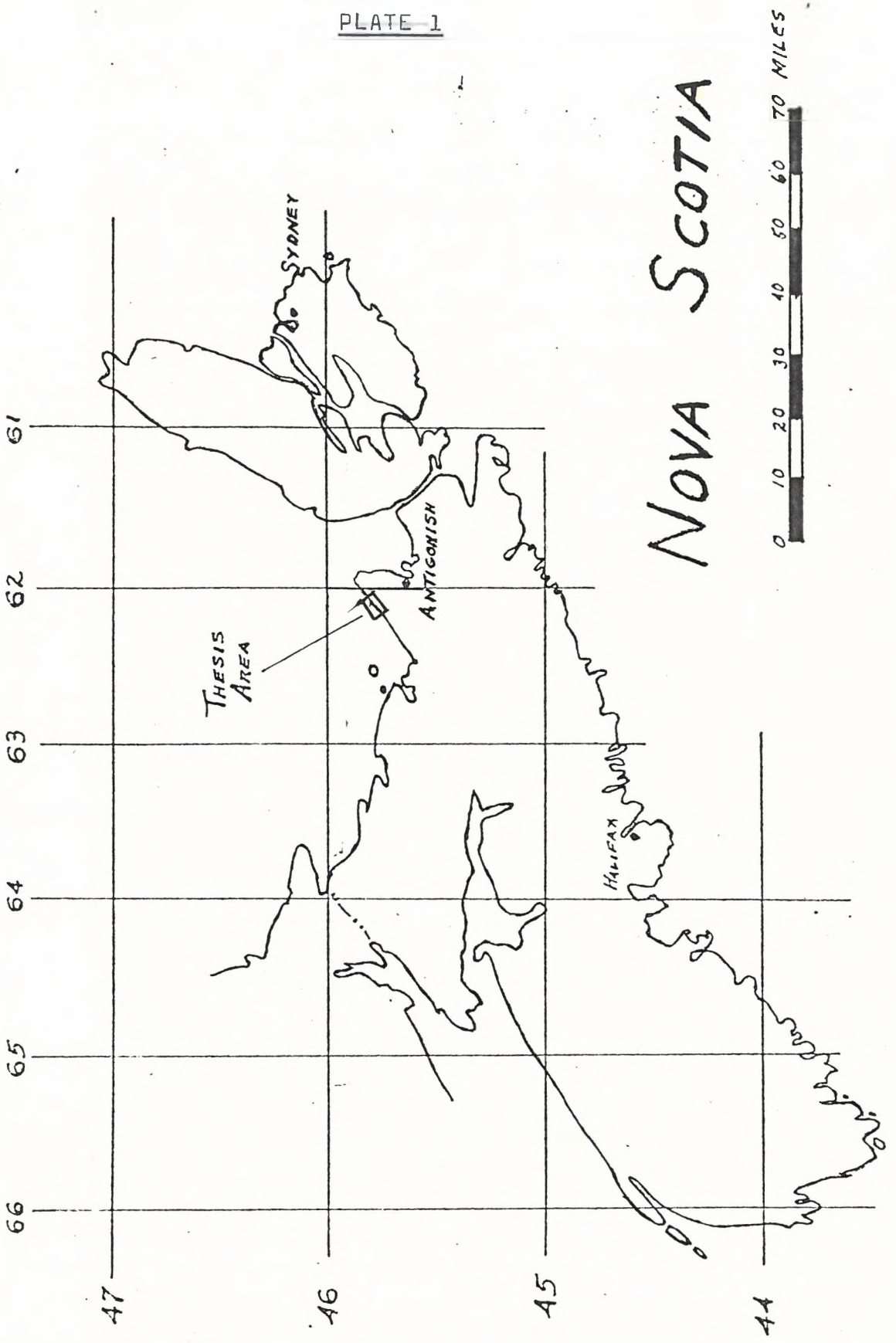
This may represent a minimum age for the dioritic rocks as a result of up-dating by the intrusion of a nearby granite. Benson describes the diorites as dark green, medium greenish grey, dark grey and rarely mottled greenish grey and black, medium to fine grained diorites with porphyritic plases common in the larger bodies. Plagioclase (oligoclase and rarely andesine), and amphibole, (predominantly horneblende) being the main minerals. Amphibole occurs as two types: primary and

to a lesser extent, secondary horneblende. Benson also noted the occurrance of actinolite as a reaction rim of pyroxene (augite) as well as the replacement of hornblende by chlorite and biotite. Benson further noted the common proximity of basic volcanics and the diorite intrusions, and interpreted the diorites as being intruded during late stages of volcanism.

Later more detailed work on the intrusion was carried out by Jodrey (1973) as a Bsc. thesis at Acadia University. Jodrey considered the intrusion consisting of at least three phases; a periodolite, a bojite and a diorite. The peridolite dominantly consisting of poikilitic horneblende enclosing smaller crystals of Olivene or augite. The bojite consisting of plagioclase and horneblende, and the diorite consisting of plagioclase, horneblende, biotite quartz and minor apatile. Jodrey concluded that the presence of amphibole, a hydrated mineral, represents crystallization under a moderately high water pressure.

Jodrey also recognized crystal fractionation as the main mechanism of differentiation. Jodry considered the dioritic intrusion to have crystallized from a basaltic parent magma which, with removal of peridiotite, enriched the residual magma in the alkalies, silica, and aluminum and depleted it in magnesium, calcium and iron to produce a diorite residual phase.

PLATE 1


NOVA SCOTIA
0 10 20 30 40 50 60 70 MILES
SYDNEY
ANTIGONISH
THESIS AREA
HALIFAX
61
62
63
64
65
66
47
46
45
44

General Geology

This paper deals with the petrography and field relationships of a dioritic intrusion located in the Northeastern Nova Scotia, Malignant Cove area (Plate 1). The location is roughly 20 kilometers North-West of the Town of Antigonish at latitude 45 degrees 4' West and extends from 1 kilometer North east of Malignant Cove to the Maritime Rock Quarry.

The area lies withint the Appalacian Orogen which in this region comprises mixed sedimentary-volcanic and igneous assemblages of lower Paleozoic age which in places are overlain by younger, relatively undisturbed, mainly non-marine, sedimentary rocks of Carboniferous age (Benson, 1970). The intrusion outcrops over an area of 5 square kilometers, is semicircular in shape being truncated by the coastline, and probably represents part of a circular stock or plug. The intrusion consists of various lithologies ranging from minor lherzolites, clinopyroxenites, and peridotites, through intermediate stages of diorite (which make up the bulk of the intrusion) to residual porphyritic phases, quartz diorites, anorthosites, and pegmatites. The stock intrudes actinolitic hornfels, biotite hornfels, and andesitic lithologies (Plate 2) thought to be part

of the Brierly Brook formation of the Brown's Mountain Group (Benson, 1970). This formation as mapped by Benson consists of leucoandesitic porphyry, lapilli crystal tuffs, horneblende and amygdaloidal andesites, purplish and dark grey agglomerates, lithic tuffs and grey wackes. The objective of this paper is the description of field relationships and petrographic details of the Malignant Cove intrusion and country rocks in order to aid the interpretation and petrogenesis of the intrusion.

CHAPTER II - PETROGRAPHY AND FIELD RELATIONS

ULTRAMAFICS

The ultramafic rocks of the Malignant Cove area vary considerably in composition, comprising lherzolites, clinopyroxenites and peridotites (horneblendites). The ultramafics can be further subdivided into two types according to emplacement within the main intrusive body. Type I are found as irregular pods which are inclusions that have reacted with the less mafic melt and are comprised primarily of horneblende. Type II have been forcefully emplaced as dikes following differentiation and settling to form a cumulate sequence.

Type I

Ultramafics of this nature are to be found throughout the entire intrusion, both as small irregular pods 0.3-0.6 meters in size and larger areas 3-6 meters across. They are characterized by large plagioclase and horneblendes developed marginally around the intrusions. as a result of reaction with the more silicous dioritic melt. The outcrop characteristically have a spotted appearance. Where such reactions occur the ultramafics are generally horneblendites, composed primarily of

horneblende with variable composition as shown by a range in pleochroism within individual crystals, secondary amphiboles (tremolite) which are alteration products of the horneblendes, and clinopyroxene which occurs as smaller, commonly twinned crystals. The author considers these rocks to have initially comprised pyroxene and/or olivene which interacted with the adjacent less mafic melt to form the hydrated mineral horneblende.

Type 2

These ultramafics were injected as dikes which are considered to have tapped different levels in a cumulate sequence and therefore vary in composition as follows:

(1) Lherzolites (sample Mal-2 - Appendix 1) consist of clinopyroxene which may show some replacement by horneblende, olivene which occurs as rounded grains altered to serpentine along fractures, orthopyroxene and minor amounts of poikilitic horneblende.

(2) Clinopyroxenites (mal -6 Appendix 1) composed primarily of clinopyroxene (augite or diopside) which are commonly rimmed by tremolite and olivene which is extensively altered along fractures to serpentine and chlorite.

(3) Peridotites (Mal-1,3,41 and M-26 Appendix 1) vary considerably in composition although all exhibit cumulate textures with cumulate crystals of olivene and clinopyroxene and intercumulus poikilitic horneblende.

The contacts between these ultramafics and the diorite are generally sharp. This would suggest that the ultramafics represented a closed system, and were intruded as crystal mushes which were fluid enough to move and form dikes within the diorite but impermeable enough to prevent interaction. No chilling within these dikes indicates that the two systems were at approximately the same temperature.

Lherzolites contain only partially altered olivenes and fresh clinopyroxenes whereas the olivenes in the peridotites are extensively altered and clinopyroxenes are rimmed by tremolite. The peridotites contain a large amount of horneblende whereas the clinopyroxenites and lherzolites do not. Considering these factors the author concludes that a cumulate sequence settled out on the floor of the magma chamber with the lherzolites being the deepest layers, overlain by clinopyroxenites and then peridotites. The peridotites are primarily horneblendites resulting

from interaction with the melt, the deeper layers being shielded from the melt by overlying cumulate layers.

Jodrey (1973) has classed all the ultramafic rocks as peridotites recognizing the presence of two mineral assemblages, horneblende and olivene which he calls a cortlandite and a second assemblage of horneblende, and augite which he calls a horneblende-augite peridotite. However, he did not recognize the possibility of this cumulate layering.

Diorite

Horneblende diorite (e.g. M-21 Appendix 1) comprising approximately equal proportions of brown to green horneblende and andesine, makes up the bulk of the exposed intrusion. However, the diorite is chemically inhomogeneous and variable in grain size showing widespread mineralogical banding (Plate 3) and irregular coarse and fine-grained patches. The vertical banding varies in attitude from 040 degrees in the intrusion outcropping to the west of Chisholm's Brook to 160 degrees in the outcrops between MacDonald Brook and MacNeil Brook. It consists of alternating horneblend-rich and andesine-rich layers, ranging in width from 3-5cm to nearly 0.5m. The layering is thought to parallel the perimeters of the magma chamber

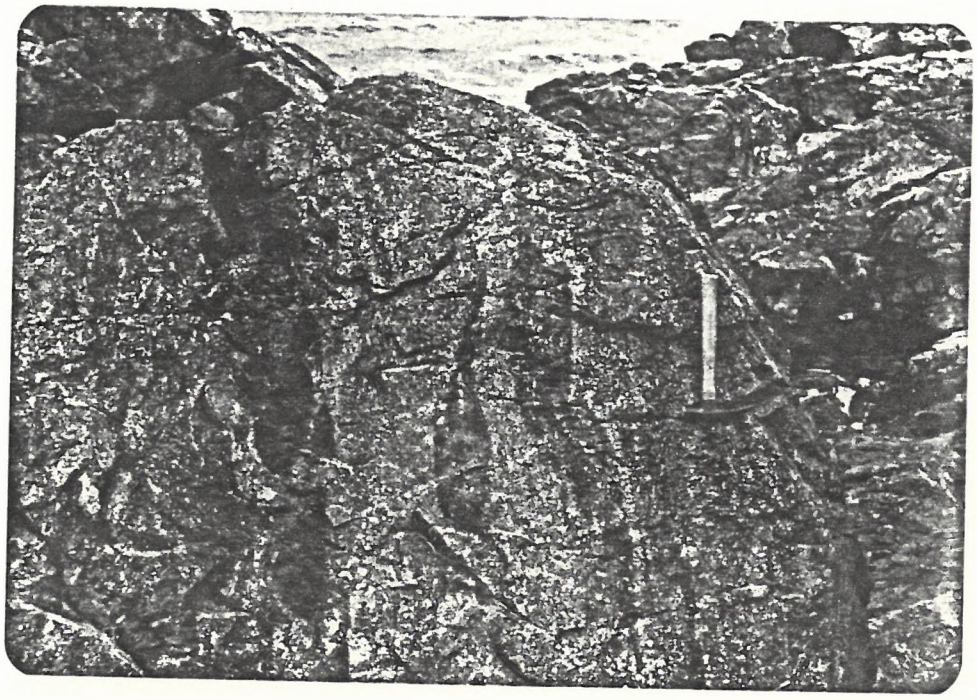


Plate 3 - Mineralogical Banding within the Diorite

from which the intrusion crystallized (Wager and Brown 1967).

East of a fault system which occurs at MacNeil Brook, the horneblende diorite is foliated (130/75W) with a planar fabric defined by the horneblendes and minor, biotites and muscovites, thought to reflect upper marginal deformation accompanying intrusion, Although similar in composition to the diorites west of the fault, those to the east show a more severe tectonic history with numerous faults and brecciated zones. Both the ultramafics and diorites in this area exhibit cataclastic fragments 5-10cm in size and show fractures infilled with a residual plagioclaseish fluid.

Porphritic Quartz Diorite

Outcropping in the Maritime rock quarry, this lithology is composed of andesine plenocrysts in a groundmass of andesine, quartz, horneblende, biotite and muscovite (sample M-53, Appendix 1). The contacts between this unit and the horneblende diorite are sharp but with no signs of chilling. The presence of quartz in this rock suggests that it is a late residual phase which is related to the diorite and was left after the more mafic rocks had crystalized from the magma. The occurrance of biotite and muscovite associated with

horneblende represents a retrograde reaction where horneblende alters to biotite and chlorite which in turn alters to muscovite and chlorite. This retrograde reaction is thought to be due to an interaction of the horneblendes with a more acidic melt in a slow cooling, high temperature environment. (Winkler, 1967)

Pegmatites

Coarse pegmatitic phases with horneblende crystals up to 15 cm long set into a feldspathic matrix were observed at a number of locations East of MacNeil Brook. These pegmatites which are commonly associated with finer grained, sugary textured aplites were found to fill fractures in both the ultramafics and diorites. These pegmatites and aplites are interpreted to represent a volatile phase of the residual melt which may have undergone second boiling (Hyndman, 1972). The pegmatites show a decrease in grain size close to contacts with the ultramafics or diorites, indicating that the latter rocks may have already cooled by the time the pegmatites were intruded. The occurrence of these late residual phases also seems to be restricted to the area East of MacNeil Brook as in the case of the porphyritic quartz diorite.

Anorthosite

A small anorthosite body outcrops 60 meters

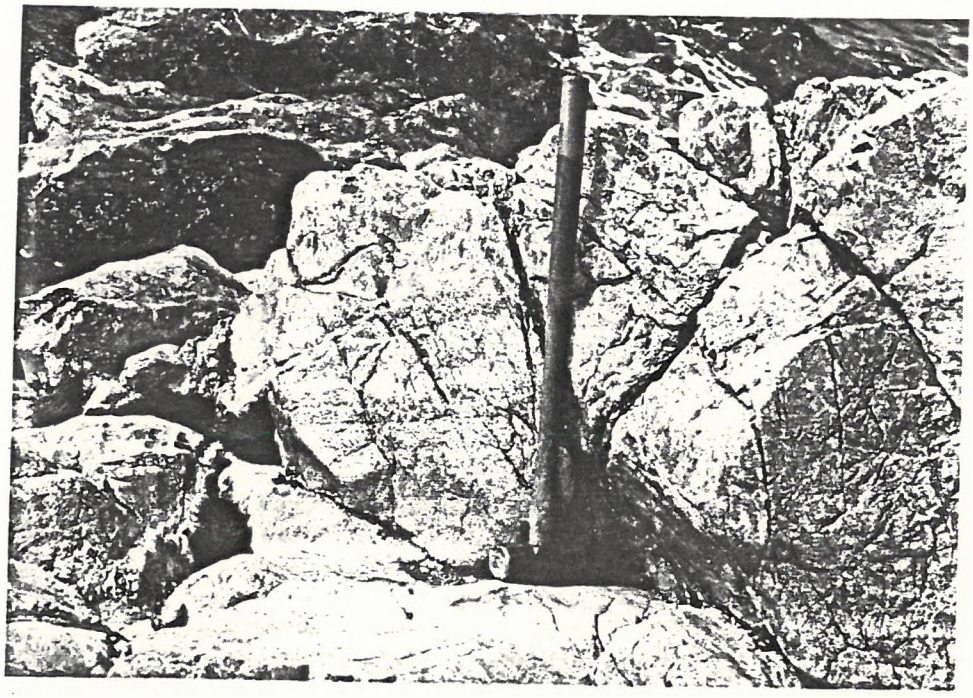


Plate 4 - Anorthosite exhibiting rhythmic layering.

East of the mouth of Chisholm's Brook (sample M-32 Appendix 1). It is composed of highly serecitized plagioclase and minor amounts (5-10%) of intercumulus poikilitic horneblende. The anorthosite exhibits rhythmic layering (Plate 4) which suggests a cumulate settling of plagioclase to form still another phase of the intrusion. The anorthosite is in igneous contact with an underlying ultramafic unit, and was either emplaced at a later stage in the crystalization history of the intrusion, or represents a thin layer of adcumulate growth of plagioclase at the top of a rhythmic layer (Brown 1956)

Metamorphic Rocks

The Malignant Cove stock intrudes a sequence of interrelated andesitic flows and black to dark brown hornfels which outcrop in the vicinity of Chisholm's Brook. The andesites are fractured and calcified to such an extent that thin sections could not be made although one section was made of a meta-andesite from close to the contact with the intrusion. The composition of the meta-andesite is roughly 50% plagioclase (andesine), 25% pyroxene, 15% calcite and 10% magnetite (Sample M-33 Appendix 1). On the shore some 300 meters East of Chisholm's Brook the andesites grade into hornfels.

The composition of the hornfels is variable with metamorphic mineral assemblages varying with the composition of the original rock. The main metamorphic phases are : (1) Actinolite which occurs as radiating free growth. Forms typically in fine grained quartzo-feldspathic matricies (Samples M34,35 Appendix 1). The Actinolites show no sign of preferred orientation indicating a high temperature, low pressure environment. (2) Biotite, which is present in Sample Mal-9 (Appendix 1) as orientated laths as well as larger elliptical inter-growths in a quartzofeldspathic matrix.

The hornfels contain elongate elliptical mineral bands 10-15 mm long and 2-3mm wide which appears in most places to be preferentially orientated to give a banding within the rock. These bands are interpreted as primary clasts which were probably smeared out long before the formation of the Actinolite minerals. It is possibly a tuffaceous unit in which mineral fragments became flattened during deposition. Andesites are found to be interbedded in the hornfels in an outcrop 600 meters East of Chisholm's Brook, supporting a related origin for these two units.

Marbles occur as pods which are interbedded in both the andesites and the hornfels and are commonly finely laminated being marine and sedimentary in origin. The marbles are composed almost entirely of recrystalized calcite (Sample M-44, Appendix 1) indicating metamorphism of a pure limestone. The limestones occur as isolated pods in the andesites but do show a preferential orientation to their bedding direction

It is the author's interpretation that much of the calcification of the andesites could be due to absorption and incorporation of these limestone beds into the flows. The limestones also occur as pods interbedded within the hornfels and the author feels that these carbonates represent periods of quiescence both in volcanic activity and deposition of the hornfelsic lithologies.

Diabase

Cross-cutting the entire map area and all the rocks therein are diabase dikes which are later (? Devonian) in age. The dikes consist of labradorite crystal laths and display ophitic texture encompassing clinopyroxene crystals. Minor amounts of chlorite and magnetite are also present (Sample M-2-B Appendix 1). These dikes are unrelated to the Malignant Cove intrusion and follow a network system of fractures throughout the area.

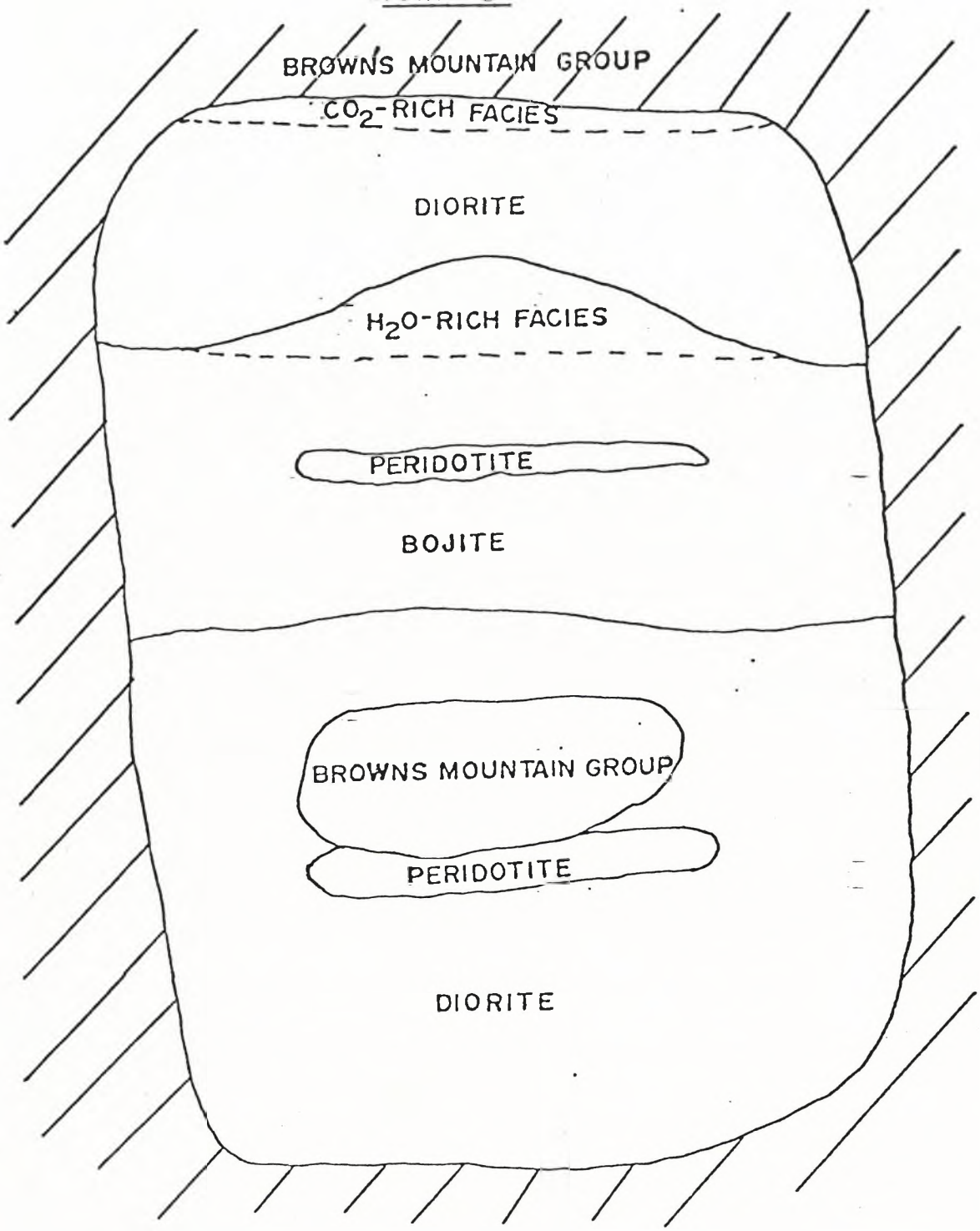
CHAPTER 111 PETROGENESIS

Composition of the Melt

The original composition of the melt could have been andesitic or basaltic as both intermediate and ultramafic material is present within the intrusion. If the parental magma was basaltic, sufficient amounts of ultramafic material must have crystalized and separated in order to deplete the magma in magnesium, calcium and iron and enrich the magma in silicon, aluminum, sodium, and potassium to form an intermediate melt from which the diorite crystalized. If the parental melt was intermediate (andestic) in composition however, then the separation of ultramafic material would have to have been insufficient to change its composition to any great extent as this would have produced an acidic residual melt.

Jodrey (1973) indicates the possibility of creating a residual diorite magma from a parent basaltic magma. Jodrey notes that the crystalization of peridotite material could produce a dioritic residual magma, however, in order to do so there would have to be two-thirds as much peridotite as diorite within the intrusion. Field evidence suggests that the amount of ultramafic material is insufficient for the parental magma to have been basaltic, and that an intermediate (andesitic) composition is the more likely alternative.

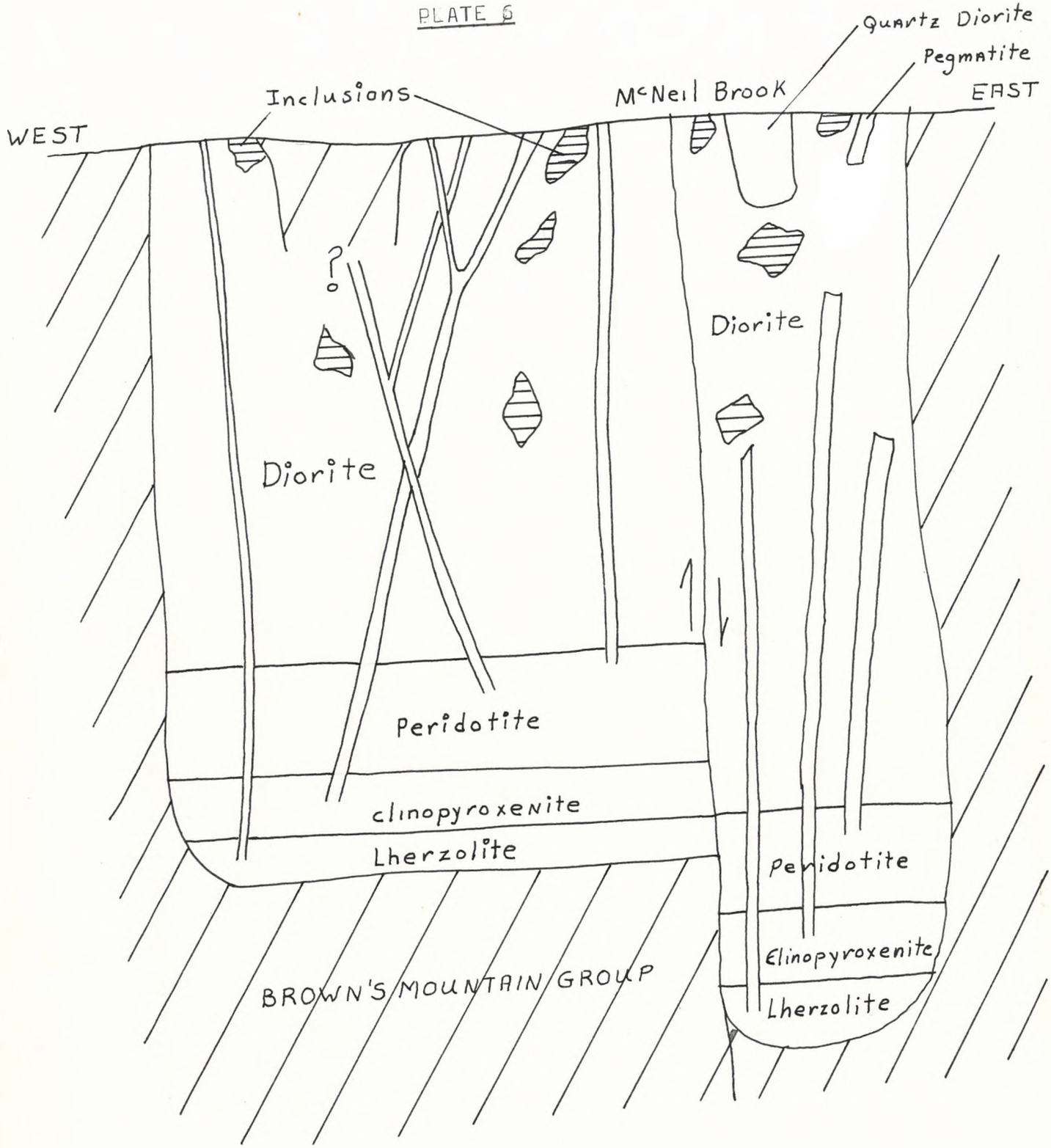
PLATE 5



Sketch of McDonald Brook intrusion in section view before referred tilting.

After Jodrey (1973)

PLATE 6



SKETCH OF A SECTION EAST - WEST
THROUGH THE MALIGNANT COVE INTRUSION

However, the author does not exclude the possibility that there is a large ultramafic body at depth in which case the parental magma could have been basaltic.

Form of the Intrusion

Jodrey (1973) concluded that the intrusion (Plate 5) was tilted at approximately 90 degrees to the northeast based on: (1) Vertical contacts between the wall rock and the diorite (2) presence of volatiles which are concentrated in the northeast section of the intrusion and decrease in abundance in a southwest direction.

The author concludes, however, that the intrusion is essentially in place and that the concentration of porphyritic volatile phases, pegmatites and quartz diorites in the northeast, is due to down faulting of the block east of MacNeil Brook (Plate 6) Steep contacts are not uncommon between wall rocks and stocks due to their discordant and forceful nature of emplacement. The most convincing evidence for the rotation of the intrusion lies in the vertical banding. However, vertical banding is known to occur in other layered intrusions that have suffered no such rotation (e.g. Mount Johnson, Quebec; Currie, 1976) Furthermore, primary vertical layering might be expected to result

from emplacement of a crystal mush system as a small stock, in a manner somewhat akin to the Lizard Complex, Cornwall (Green, 1964) where a vertical foliation is dominant.

Relationship of Andesites to Diorite Intrusion

Benson (1970) concluded that the basic volcanics of the Brierly Brook Formation were the extrusive equivalents of the Malignant Cove Diorite intrusion and similar diorites intrusions throughout the Antigonish Highlands. Benson based his conclusion on the spatial relationship of these intrusions to the basic volcanics, comparative mineralogy and apparently similar age. No conclusive evidence was found by the author to suggest a co-magmatic relationship between the andesites and the diorites. Jodrey (1973) concluded that the andesites and hornfels at Chisholm's Brook were a large xenolith within the diorite.

The presence of marine limestones interbedded in the andesites and hornfels suggests that this volcanic pile was cool when the diorite was intruded. The coarse grained nature of the intrusion tends to rule out hypabyssal crystalization. However, the volcanic pile may

have been thick enough to have cooled on top yet remain hot at depth. With the intrusion of the dioritic magma as a crystal mush system, a coarse grained intrusion at shallow depths could have been produced. Therefore, the volcanics may have been the extrusive equivalents of the diorite and would support the conclusion that the parent melt was andesitic in composition. The depth of emplacement and possible co-magmatic relationship between the andesites and diorites is open to further interpretation.

Conclusion

The Malignant Cove intrusion is highly variable in composition comprising lithologies ranging from minor lherzolites, clinopyroxenites and peridotites, through intermediate stages of diorite (which make up the bulk of the intrusion) to residual porphyritic phases, quartz diorites, anorthosites, and pegmatites. The semi-circular stock intrudes actinolitic and biotitic hornfels and andesites thought to be part of the Cambro-Ordivician Brierly Brook Formation of the Brown's Mountain Group (Benson, 1970). The intrusion has been faulted at MacNeil Brook with downward movement of the east block. As a result of subsequent erosion the porphyritic residual phases found east of the fault are absent to the west of the fault. The composition of the parental

melt is thought to have been andesitic in composition, being differentiated through fractional crystalization to give the present rock assemblages.

The intrusion is thought to be later in age than the Andesites within the area and are magmatically unrelated to them.

APPENDIX 1

Petrographic Descriptions

Sample Mal 1: Cataclastic Hornblende-pyroxenite
Sample location close to mouth of Chisholm brook.

Cataclastic fragments of clinopyroxene and hornblende (ranging from 50M to 2 mm in size) together a few anhedral, poikilitic hornblende crystals up to 6 mm in diameter, are set in a felted groundmass of pale green serpentine and ragged magnetite grains which define a crude planar fabric that encloses larger crystals.

The hornblende shows a pleochroic range from pale brown to reddish brown and typically exhibits undulose extinction. The larger poikilitic chrystals enclose rounded grains of altered olivine up to 1 mm in diameter, and anhedral clinoproxenes(diopside or augite) up to 2 mm in length. The olivines have been completely replaced by mesh-textured serpentine and magnetite, but appear to preserve a pyroxene reaction rim with the enclosing hornblende. Relatively unstrained clinopyroxene forms the dominant inclusions and occurs as partially corroded subangular crystals or highly ragged grains showing extensive replacement by hornblende. The cataclastic clinopyroxenes are likewise relatively unstrained and show similar patterns of hornblende replacement.

Poikilitic hornblendes enclosing clinopyroxene and olivine are also present in sample M-26 (Plate 7)

Visual modal estimate: Hornblende 45%, clinopyroxene 20%, serpentine 30%, magnetite 5%.

Sample Mal-2: Serpentinized lherzolite, sample location- close to mouth of Chisholm's Brook.

Composition - Olivene (Forsterite), clinopyroxene, orthopyroxene, serpentine and minor amounts of brown hornblende, chlorite and magnetite.

Clinopyroxene (augite or diopside) occurs as enhedral to subhedral grains up to 5mm in length, show frequent twinning and show some replacement by horneblende giving ragged grains. Olivenes occur as rounded grains, and vary in size from 1mm - 5mm. Olivenes show partial to complete serpentization and minor chloritization with alteration proceeding along fractures in the grains. (Plate 8) Orthopyroxene occurs as enhedral crystals 1-2mm in size. Minor amounts of amphibole are poikilitic with inclusion of altered olivenes. Magnetite's occurrance is confined along fractures within the olivenes. Rock may have cumulate texture with cumulate crystals of clinopyroxene, olivene, orthopyroxene and intercumulus serpentine and hornblende.

Visual Modal estimate: Clinopyroxene 30%, olivene 25%, serpentine 30%, orthopyroxene 5%, brown hornblende 3%, chlorite 2%, and magnetite 5%.

Plate 7 Poikilitic horneblende enclosing Clinopyroxene and Olivenes

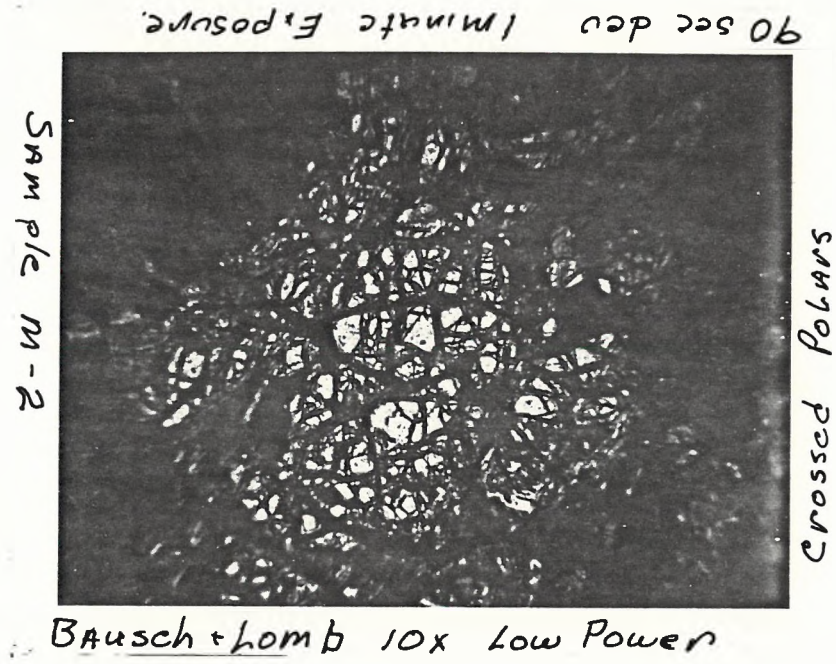


Plate 8 Olivene showing partial to complete serpentenization and chloritization with alteration proceeding along fractures in grains.

Sample Mal - 3: Serpentinized pyroxene-hornblende periodotite, sample location close to mouth of Chisholm brook.

Composition - primary poikilitic brown hornblende up to 17 mm in length, olivene, clinopyroxenes and their alteration products.

The hornblende shows a pleochroic range from very pale to dark brown and anhedral. Enclosed within the poikilitic horneblendes are rounded subhedral grains of olivene up to 6mm in size and are partially to completely replaced by mesh textured serpentine and fine grained magnetite which proceeded along fractures. Clinopyroxenes, which also are enclosed within the poikilitic horneblende, are more angular and subhedral range up to 2mm in size, are occasionally twinned and are relatively unaltered. Cumulate texture with cumulus clinopyroxene and serpentinized olivene and intercumulus poikilitic horneblende is exhibited in this rock. Visual modal estimation: Clinopyroxene 30%, olivene 15%, horneblende 30%, and serpentine after olivene 22%, magnetite 2%.

Sample Mal-4 Olivene-pyroxene horneblendite, sample location - close to mouth of Chisholm brook.

Composition - poikilitic horneblendes, clinopyroxene and highly altered olivenes.

The horneblendes show a pleochroic range from pale brown to reddish brown, and occur as anhedral crystals

which are very large 25-30 mm, and show alteration to secondary anphibole (tremolite, pale green pleochroism) along grain boundaries. Clinopyroxene occurs as angular subhedral crystals up to 9mm in length and exist both as individual crystals and cumulate crystals within the poikilitic horneblendes and may exhibit orthopyroxene exsolution. Both horneblendes and pyroxenes exhibit stained extinction and curved cleavage planes. Olivenes also occur within the poikilitic horneblendes as rounded anhedral crystals 1-2mm in size and are highly altered along fractures to magnetite and serpentine and in the interior portions to an orange brown, low birefringent mineral possibly vermicularite.

Visual modal estimate : horneblende 50%, clinopyroxene 40%, olivene alteration products 10%.

Sample Mal-6 Clinopyroxenite, sample location near the mouth of Chisholm brook.

Composition - clinopyroxene, a few altered olivenes and their alteration products set in a groundmass comprising angular clinopyroxene fragments, serpentine, chlorite, and tremolite. The clinopyroxemes occur as subhedral crystals up to 4mm in size, are commonly rimmed by tremolite, are commonly twinned, exhibit undulose eatinction and usually exhibit a mottled surface being altered to tremolite, chlorite and serpentine and show corroded grain boundaries. The olivenes are up to 10mm in size and are extensively altered along fractures to serpentine and chlorite. The matrix is

highly fractured and comprises angular clinopyroxene grains set in a felted groundmass of tremolite, serpentine and chlorite.

Visual Modal estimate: Clinopyroxene 65%, olivene 10%, combined serpentine chlorite and tremolite 25%.

Sample Mal -7 Diorite, sample location near mouth of Chisholm brook.

Composition - plagioclase (albite), Clinopyroxene, olivene, amphibole, chlorite and serpentine which is alteration after amphibole.

The Albite occurs as subhedral crystal laths up to 3mm in length and are highly serecitized showing a "dusty", mottled surface. The clinopyroxene occurs as subhedral crystals o.5-1mm in size, are commonly twinned and exhibit a parting in addition to cleavage (?diallage). There is a small amount of unaltered brown amphibole although most has been partially or completely altered to serpentine and/or chlorite) which has replaced subhedral crystals. Crystals showing ragged grain boundaries up to 4mm in length and 2mm in width. The olivenes have been completely altered to serpentine which occurs in its fibrous form along original olivene fractures. Veinlets of chlorite cross-cut the section.

Visual Modal estimate - Plagioclase (albite) 50%, chlorite and serpentine which are alterations of amphibole and olivene 20%.

Sample Mal - 8 Amphibolitic Hornfels

Sample location, roughly 600 meters East of mouth of Chisholm's brook.

Composition - amphibole (hornblende - actinolite) crystals in a quartzofeldspathic matrix. The amphiboles occur as subhedral diamond and lath shaped porphyroblasts roughly 0.2mm in size (up to 0.5mm) that are confined to mineralogical bands and as small acicular crystals in the matrix that define a planor fabric parallel to the mineralogical layering. There are a smaller number of subhedral orthoclose laths up to 1mm in length which are also present. The matrix comprises alternately coarse and fine layers. The coarser layers show elliptical outlines which may represent the outlines of the original clasts. They are composed of strained quartz up to 0.1mm in diameter. The finer areas of the matrix have a grain size 0.01mm and are composed of quartz and feldspor. chlorite veinlets cut across the bands. Minor magnetite is also present occuring in bands parallel to the mineral banding.

Sample Mal-9 Biotite hornfels

Sample location roughly 600 meters east of mouth of Chisholm's brook.

Composition - shows a similar texture to sample Mal-8 but lacks amphibole and phenocrysts of orthoclose. The quartzofeldspathic matrix is banded on a 0.1 mm

scale and contains small orientated laths of biotite. Large elliptical intergrowths of biotite and muscovite are also present and comprise subhedral 0.05-0.1mm crystals or random orientation.

Sample M-2-B Diabase, sample was taken by field camp students in Spring of 1976 located on Chisholm's brook just below road.

Composition - Plagioclase (labiodorite,Ab50), pale brown clinopyroxene, pale green chlorite, magnetite and minor amounts of amphibole.

The plagioclase occurs as subhedral laths 0.5-1mm in length and exhibits ophitic texture with clinopyroxene. The clinopyroxenes are anhedral and 0.5mm in size. Magnetite occurs both in intersticies between plagioclase crystals and in larger blotches up to 1mm across. There are a few veinlets of chlorite cross cutting the section. Visual modal estimate - plagioclase 65%, clinopyroxene 20%, chlorite 5%, magnetite 5% and minor amounts of amphibole .

Sample M-15A- Amphibolite/Horneblende Diorite contact, Sample location - 700 meters West of mouth of Chisholm's brook on shoreline.

Amphibolite - Composition - large anhedral brown horneblende crystals, show plecchroism from pale brown to reddish brown and a few subhedral clinopyroxene crystals and minor magnetite.

The horneblende occurs as crystals 3-4mm in size and have been altered to secondary amphibole (?tremolite-pale green to green pleochroism).

Pleochroism is not constant throughout the horneblende with areas that are essentially colorless grading to brownish red, with cleavage transecting both varities suggesting a compositional variation within the horneblende. Clinopyroxene is commonly twinned and occurs as crystals 1-2mm in size.

Diorite - Composition horneblendes of same composition as in amphibolite, plagioclase (andesine) minor magnetite.

The horneblende shows pale brown to reddish brown pleochroism although as in amphibolite cores may be pale to deep green to colorless and occurs as anhedral crystals 2-3mm in size with rounded irregular grain margins. The horneblendes have been altered to secondary horneblende and contains small enhedral hexagonal crystals of apatite. The andesine is highly serecitized and has a mottled appearance.

Visual Modal estimate - andesine 50%, horneblende 35%, Tremolite 10%, magnetite 3%, apatite 2%.

Sample M-21 Horneblende Diorite

Sample location 820 meters west of mouth of Chisholm's Brook on shoreline.

Composition - Subhedral plagioclase (andisine) crystals up to 5mm long. Primary amphibole (basaltic horneblende) which occurs as brown to green, highly pleochroic, anhedral crystals up to 10mm in size and some crystals have cores which are colorless to pale green (and higher

birefringence) suggesting some sort of compositional variation, as cleavage transects both varities. Minor amounts of Opaques (Magnetite or Ilinenite) as well as small amounts of euhederal apatite crystals averaging o.1mm in size which are contained in the horneblendes. The Andesine shows alteration to Serecite, Chlorite, and Muscovite (? also Epidote).

Visual modal estimate - Adnesine 50%, horneblende 45%, Opaques 3%, Apatite 2%

Sample M-23 Serecitized Anorthosite, sample was taken from a light colored feldspathic rich mineralogic band 640 meters west of the mouth of Chisholm's Brook.

Composition - highly sericitized feldspors, a few relict amphiboles (? horneblendes) minor quartz showing undulatory extinction and minor opaques.

The feldspors show faint signs of polysynthetic twinning but are too highly serecitized to measure the composition. The amphiboles are long prismatic subhedral crystals 3-4mm long and are completely altered to Chlorite, serpentine and secondary amphibole (? Fibrous high birefringence.

Visual modal estimate - plagioclose 90%m amphibole and alteration products 5%, quartz 2%, opaques 3%.

Sample M-26 Olivene-pyroxene - horneblendite

Sample location 400 meters West of mouth of Chisholm's Brook.

Composition - primary poikilitic amphibole (horneblende), secondary amphibole (tremolite) after horneblende, clinopyroxene, olivene, magnetite and chlorite.

The poikilitic horneblendes show pleochioism ranges from pale brown to reddish brown and pale green to dark green, occur as anhedral, intercumulus crystals up to 10mm in size, and commonly have jagged corroded grain boundaries being altered to fibrous acicular tremolite, and Chlorite.

Horneblendes commonly show brown pleochroism in unaltered cores and green pleochroism on altered edges suggesting a compositional variation. Clinopyroxenes occur as colorless, high birefringent crystals which show partial replacement by horneblende resulting in a mottled texture. Enclosed within the large poikilitic crystals of horneblende are subhedral to anhedral angular crystals of clinopyoxene (diopide or augite) 1-2mm in size and rounded anhedral crystals of olivene up to 2mm in size. The olivenes have been completely replaced by carbonate (?calcite), chlorite and along fractures to magnetite yet they retain their primary rounded shape, the grain boundaries are solid and show no corrosion (Plate 6) Visual Modal estimate - Poikilitic horneblende 40%, clinopyroxene 35% and 25% combined carbonate, chlorite, and magnetite after olivene.

Sample M-30 -Hornfels, sample location - 180 meters West of mouth of Chisholm's brook.

Composition - a very fine grained, highly brecciated quartzo feldspathic matrix with an average grain size 0.01 mm. A rough layering is formed by microscopic veinlets of magnetite which are preferentially orientated within the section. The angular breciated fragments are cemented by chlorite and calcite which also form cross-cutting veinlets.

Sample M-32 Serecitized anorthosite, sample location 90 meters East of mouth of Chisholm's brook. Sample was taken from a small anorthisitic body exhibiting cumulate layering. (See plate).

Composition - plagioclase which has been highly serecitized - no determination of composition could be made, poikilitic amphibole, calcite, and serpentine after amphibole.

The poikilitic amphiboles have a pleochroism ranging from very pale brown to orange brown and pale green to light green, show undulatory extinction and are partially or completely altered to serpentine, and high birefringence mineral (chlorite) and are 3-4mm in length, 1-2mm in width. Enclosed within the poikilitic amphiboles are highly serecitized, rounded anhedral crystals of plagioclase 0.2-0.5 mm in length, some showing relict polysynthetic twinning. Calcite occurs as

a few elliptical pods 2-3mm in length. This rock shows cumulate texture with cumulate serectized plagioclase within intercumulus poibilitic amphibole. Visual modal estimate - plagioclase 90%, poikilitic amphibole 7%, calcite 3%.

Sample M-33 - Meta-andesite, sample location 90 meters East of mouth of Chisholm's brook and very close to the contact with ultra mafic rocks.

Composition - plagioclase (andesine), pyroxene which is now totally altered to chlorite, calcite and opaques.

The andesine occurs as crystal laths of anhedral to subhedral crystals 0.5-1 mm in length which show minor serecitization and in some cases contain rounded inclusions of chlorite. Opaques are composed of equal proportions of pyrite, magnetite and leucoxene after ilmenite and together make up an interwoven network of veinlets and irregular pods within the rock. Calcite occurs in much the same way and is commonly related to the opaques. Visual Modal estimate - Andesine 40%, chlorite (after pyroxene) 25%, calcite 15%, combined opaques 20%

Sample M-34 Actinolite Hornfels,
sample location 520 meters East of mouth of Chisholm's Brook.

Composition - radiating free growth forms of actinolite set in a fine grained recrystalized quartz-ofeldspathic groundmass.

The Actinolite occurs as euhedral, bladded aggregates showing pleochroism from light green to green, (Plate 9) with crystals up to 3mm long and 0.1 mm wide.

The granular matrix has a grain size not exceeding 0.1 mm in coarse layers and not exceeding 0.05mm in finer bands and is composed of anhedral equigranular grains of quartz showing undulose extinction. anhedral groins of feldspor with minor amounts of magnetite (? and ilmenite) as well as minor amounts of feldspor alteration products (muscovite and epidote). Remnants of primary structure in the form of mineralogical banding is present with bands up to 2mm wide and 10-15 mm in length. There are some larger plagioclose (oligocene) crystals in the matrix. Also suggesting original variation in the composition within the rock is the restriction of the growth of actinolite by mineralogical banding.
Visual modal estimate - Actimolite 40%, quartzofeldspothic matrix 60%.

Sample M-35 - Actinolite Hornfels
Sample location 700 meters East of mouth of Chisholm's brook on shoreline.

Composition - much the same as sample M-34 with actinolite in a quartzofeldspathic matrix with cross cutting veinlets of calcite and (? epidote)

The actinolite occurs as green bladded aggregates of crystals up to 2.5mm long and 0.2mm wide, are less pleochroic than ones in M-34 showing pleochroism from pale green to light green and are alligned parallel to the mineralogic banding rather than radiating free growth forms. The matrix shows a much greater variation in grain size consisting of coarse bands with anhedral equigranular grains up to 0.1mm in size and finer bands being sub-microscopic in size. Quartz shows undulatory extinction. The extent of mineralogic banding is much greater than in M-34 with individual bands up to 10mm wide and cross cutting the entire slide.

Visual Modal estimate - 30% actinolite, 70% quartzo-feldspathic matrix.

Sample M-44 Marble - sample location - 1 Kilometer East of mouth of Chisholm's Brook along shoreline.

A fine grained rock composed 100% by recrystalized calcite. Crystals form an equigranular mosaic showing a granoblostic polygonal tenture with equangle (120 deg.) triple points with the average grain size being 0.1mm with some crystals up to 0.3mm

Sample M-53 Porphyritic Quartz Diorite

Sample location - 120 meters East of the end of Maritime rock quarry road.

Composition - Plagioclose (andesine) set in a medium grained groundmass of andesine quartz, horneblende, biotite and muscovite.

Andesine Phenocrysts are subhedral, up to 10mm

long and 3mm wide and show selective serecetization (Plate 10) of calcic cores, the cores are also altered to chlorite. The andesine in the groundmass occurs as subhedral crystal laths up to 1mm long. Quartz occurs as anhedral crystals 0.5-2mm in size exhibiting undulose extinction. Combined together and interwoven in approximately equal proportions are anhedral horneblende, biotite and muscovite crystals 0.5-1mm in length, comprising clusters up to 4-5mm long.

Visual modal estimate - Andesine plenocrysts 20%, andesine 40%, quartz 20%, combined horneblende, biotite and muscovite 20%.

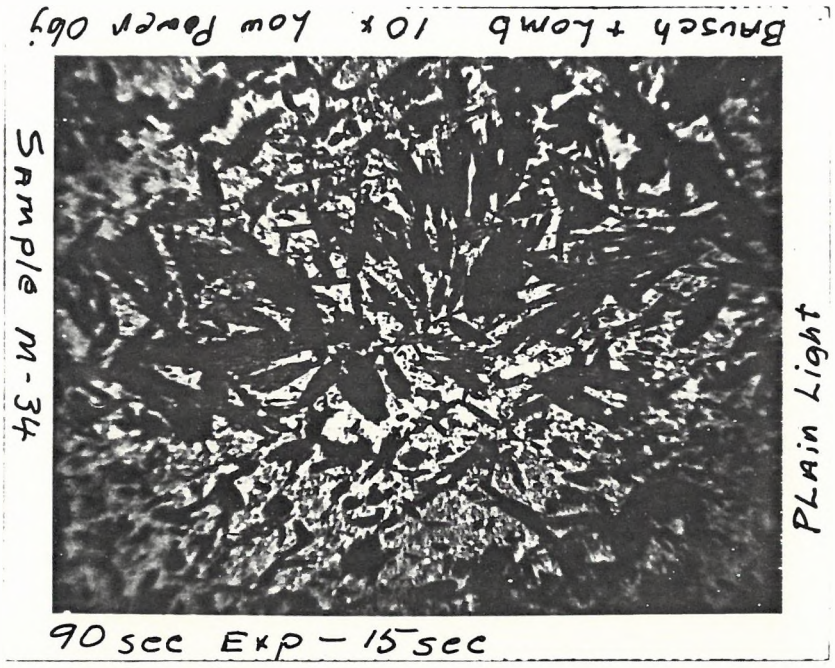


Plate 9 Actinolitic hornfels - radiating free growth forms of actinolite set in a fine grained quartzofeldspathic matrix.

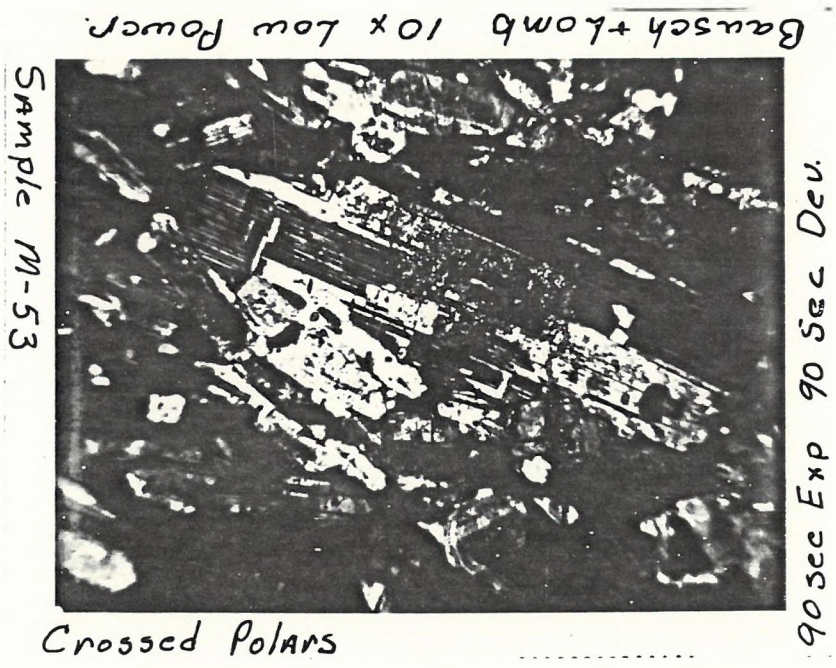
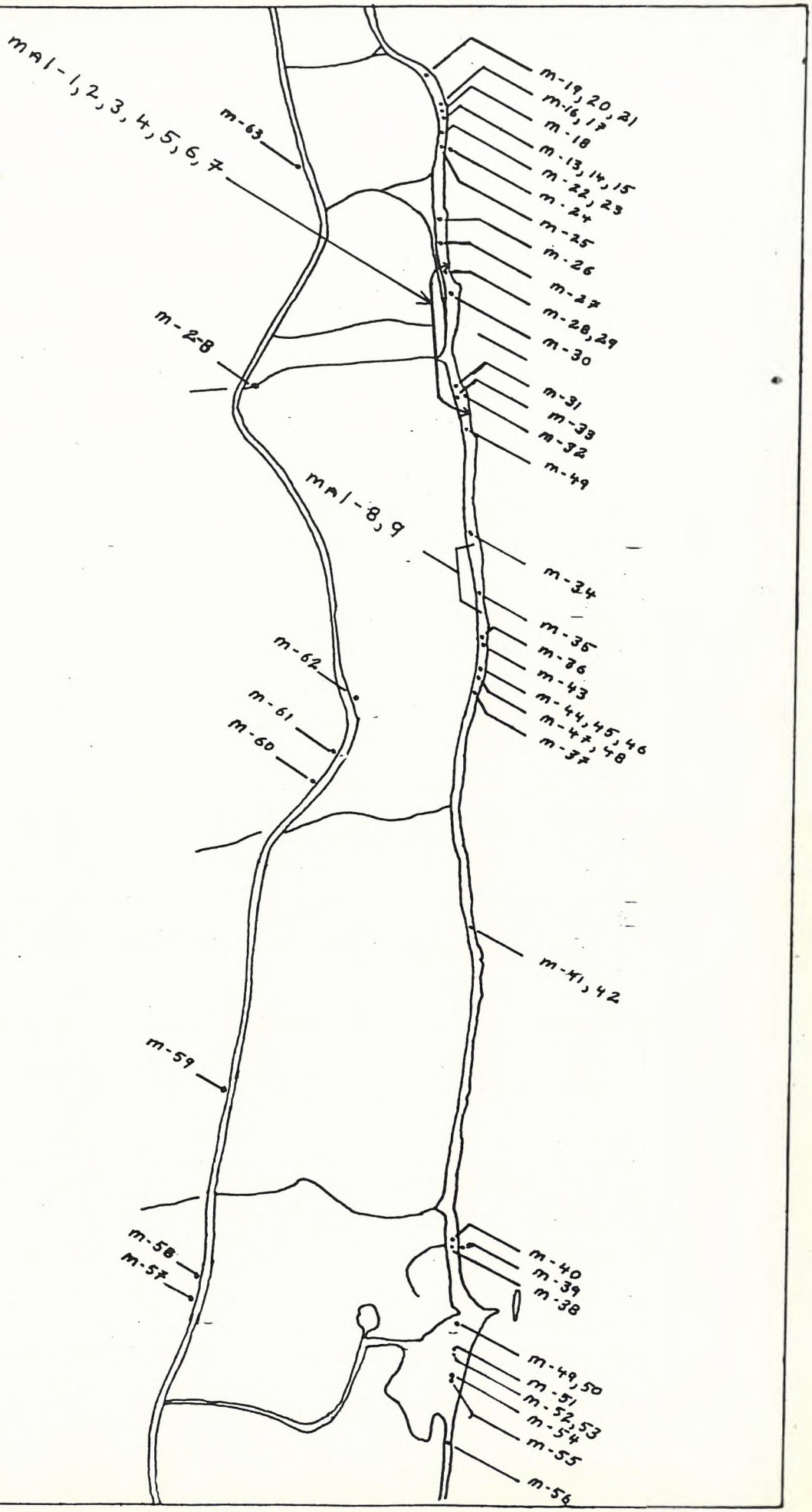


Plate 10 Porphyritic quartz diorite showing selective serecitization of calcic cores.

Plate 11

SAMPLE LOCATION MAP

MALIGNANT COVE NOVA SCOTIA



REFERENCES

Benson, D. G., 1970
Notes to Accompany Maps of the Geology of Merigomish and Malignant Cove Map Area, Nova Scotia: Geological Survey Can., Paper 70-9

Brown, G. M. , 1956
The Layered Ultrabasic rocks of Rhum, Inner Hebrides. Phil. Trans. Roy. Soc. Land Ser. B

Currie, K. L., 1976
The Alkaline Rocks of Canada. Geol. Surv. Can., Bulletin 239

Green, D. H., 1964
The Petrogenesis of the High-Temperature Peridotite Intrusion.

Hyndman, D. W. 1972
Petrology of Igneous and Metamorphic Rocks. McGraw-Hill Book Company.

Jodrey, J. M. 1973
Petrology of the Composite MacDonald stock, Antigonish County, Nova Scotia Unpub. Bsc. thesis.

Wagner, L. R., Brown, G. M., 1967
Layered Igneous Rocks. W. H. Freeman and Company, San Francisco