Geology of the Northern
Baie Verte Peninsula,
Newfoundland, Canada

A thesis presented to the Faculty
of the State of New York
at Albany
in partial fulfillment of the requirements
for the degree of
Master of Science

College of Science and Mathematics
Department of Geological Sciences

Pamela J. Stella
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ABSTRACT

On the eastern portion of the Burlington Peninsula of northwest central Newfoundland, Canada, there are two different age groups of volcanic and volcaniclastic rocks. There have been arguements in the past as to whether or not these two groups are actually only one group (Cape St. John Group) but with progressive intensity of deformation and metamorphism from south to north. Other workers have divided the rocks into two distinct groups, the Grand Cove Group and the Cape St. John Group based on their differences in deformation style and metamorphic grade. This study ignored previous divisions of the rocks into one group or the other and instead described the lithologies of the rocks in detail. Two distinct groups of rocks were defined, the Northern Group and the Southern Group, based on lithological and structural differences. The Northern Group is Early Ordovician in age and outcrops along the northern coastal areas and inland southwards towards the La Scie Highway. These rocks are complexly deformed and metamophosed to the actinolite - greenschist facies. The Southern Group is Silurian - Devonian in age and outcrops in the southern central portion of the Peninsula. This group is only mildly deformed and metamorphosed to lower greenshist facies. Both Groups were metamorphosed in Late

Devonian/Early Carboniferous (Acadian Orogeny). This study revealed previously unrecognized ductile high strain zones which form a definite restricted belt across the Peninsula separating the Northern Group from the Southern Group.

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My stay in Brents Cove the first year was especially unique thanks to Kevin and Annie Hass and the use of their sons Steve, Jamie and Kevin Jr. for company in the field. The people of Tilt Cove, especially Terry Rideout, Kevin Snooks Jr., Elmo and the entire Snooks family, made me feel very welcome in their tiny village the second year. Bill

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I would especially like to thank my entire family, particularly my mother, Jean, for raising me to understand that there is no such planet in our universe called a "man's world."

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CHAPTER ONE

INTRODUCTION

LOCATION AND ACCESS

The thesis area is located in the Burlington Peninsula of northwest central Newfoundland, Canada, on the Nippers Harbour, Newfoundland map sheet, between latitudes 49°55' - 49°57' and longitudes 55°37' - 55°48' (Figure 1.1). The area is bounded on the west just past the Nippers Harbour Road turnoff, on the north by Confusion Bay, on the east by the Tilt Cove Road and on the south by Red Cliff Pond and a prominent serpentinite belt which separates the Cape St. John Group from the Snooks Arm Group. Minor additional work at Cape St. John and within Cape Cove between Middle Bill and South Bill was also conducted (Figure 1.2). The Cape Cove area is discussed separately and only with reference to a mylonite zone found there (Chapter Four).

Inland outcrops are generally good but scattered and somewhat difficult to reach. A few logging roads facilitated access to the area. Most of the area is covered with thick vegetation, making traverses difficult and somewhat time consuming, so many of the outcrops actually visited were roadcuts, lakeshores, recently cut areas and the coastline. Many key relationships, however, required traverses across black fly-infested swamps and

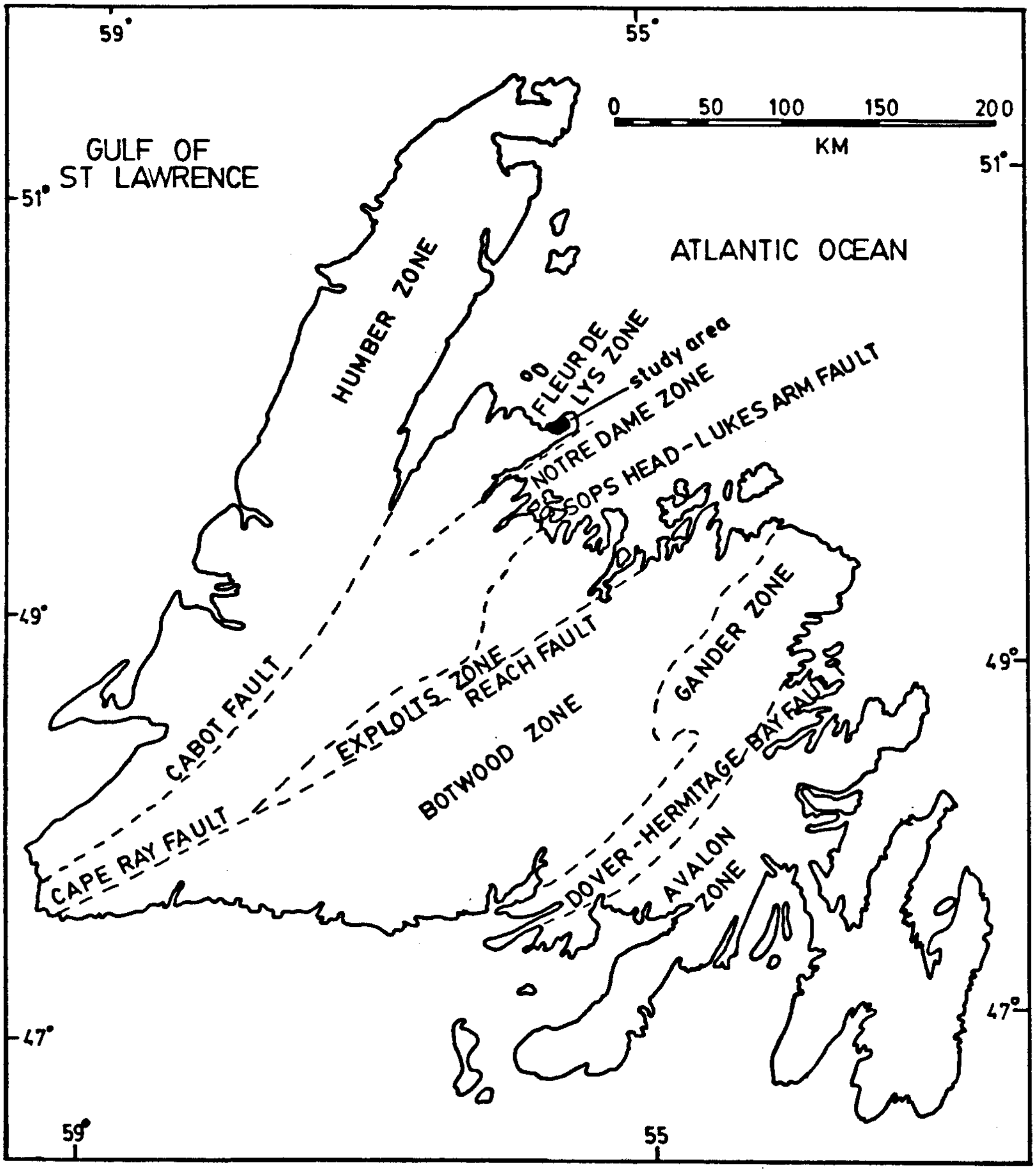

Figure 1.1 Location map of the study area with respect to major tectonic zones of the Newfoundland Appalachians.

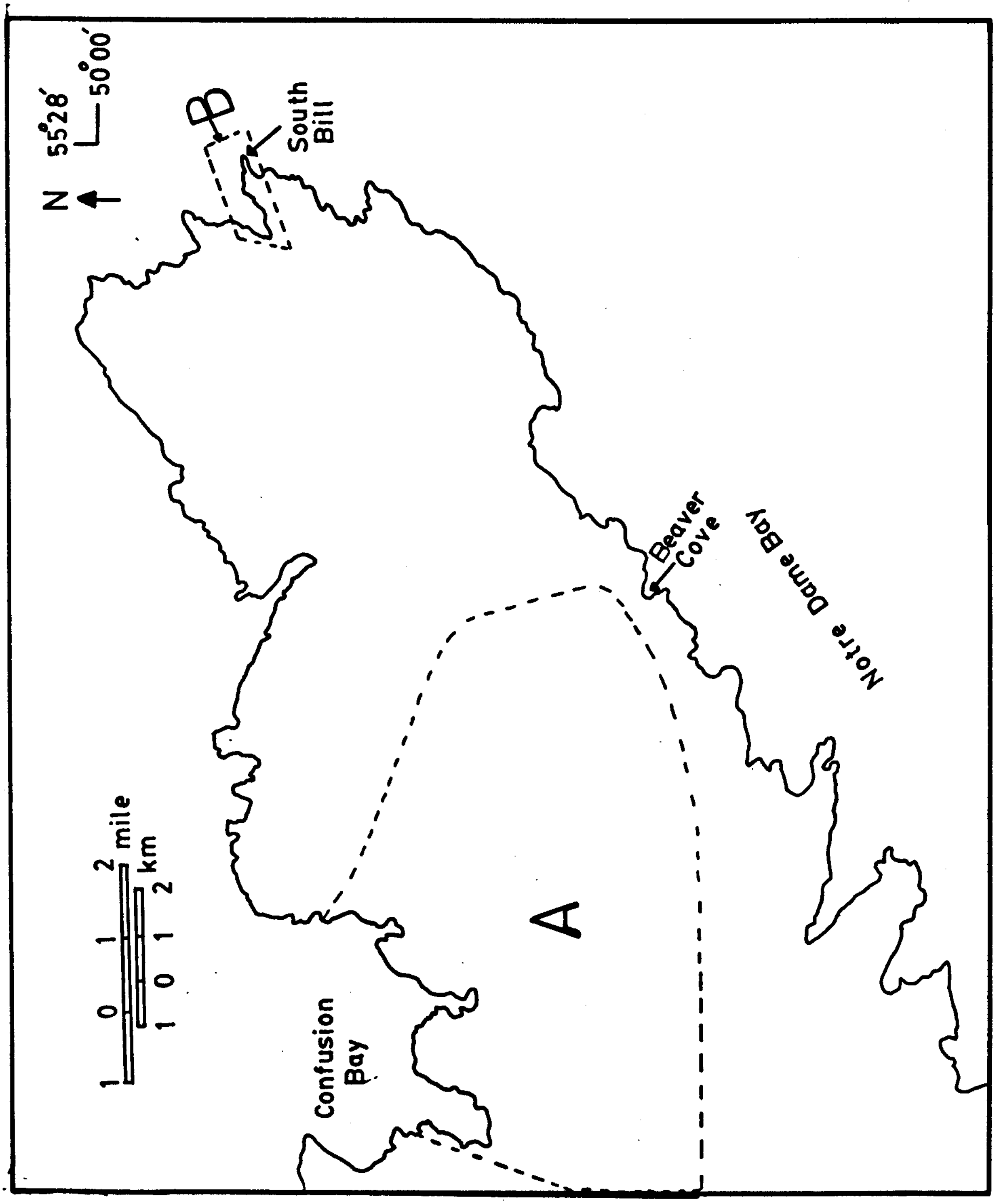

Figure 1.2 Map of field areas.

dense brush. Coastal exposure is excellent but most outcrops can only be reached by a small boat on calm days. Inland the surface forms an irregular plateau sloping gently to the southeast. Parts of the area are rugged with over 200 meter cliffs around Brents Cove, but in general the terrane consists of gently northeast trending rolling hills and swampy valleys. The area has been extensively glaciated showing an east to southeast direction for the last ice movement.

Field Methods

The results of the field mapping in the Cape St. John area are displayed on the map, Plate 1. Field work was conducted for 6 weeks in the summer of 1982 and for 9 mostly rainy weeks during the summer of 1983. Data were collected and recorded in the field on 1:15,840 nominal scale aerial photos purchased from the Canadian Department of Energy, Mines and Resources. The base map was conducted by enlarging a 1:50,000 scale topographical map of the area to the scale of the aerial photos at sea level. The outcrops were transferred directly from the aerial photos to the mylar topographic map. The base map is approximately 1:16,000 scale.

PURPOSE OF STUDY

There have been numerous disagreements over the age of the rocks within the eastern Fleur de Lys Zone, their correlation, and the timing of their deformation and metamorphism. The Cape St. John Group as originally defined by Baird (1953) consists mainly of subaerial calc-alkaline volcanics and related sedimentary rocks that are now known to occur unconformably above the Early Ordovician Snooks Arm Group in the south-eastern most portion of the Fleur de Lys Tectonostratigraphic Zone (Neale et al, 1975). These rocks are, particularly in the more northern and western part of their outcrop, complexly deformed and metamorphosed, obscuring original relationships and correlations. More importantly, these rocks share structures and metamorphism with the Fleur de Lys Supergroup rocks, which were supposed to have been deformed and metamophosed in pre- Silurian times. Consequently there has been and still is much confusion and disagreement over the age and stratigraphy of the Cape St. John Group. Church (1969) separated the more deformed rocks of the original Cape St. John Group into an older Grand Cove Group (to the north) and assigned a Silurian age (based on regional lithic correlation to the Botwood Group) to the less deformed rocks of the Cape St. John Group (to the south). There are no known fossils in either group. Isotopic studies have been conducted for several rock units from both groups (Mattinson, 1975, 1977; Dallmeyer, 1977; Bell and Blenkinsop, 1977, 1978; Pringle, 1978; Dallmeyer and Hibbard, 1984). These dates, however, have been inconsistent and ambiguous with respect to field relationships. The Cape St. John Group is dated at 520+/-40 MA (Bell and Blenkinsop, 1978) and the Grand Cove Group at 355+/-15 MA (Pringle, 1978) using Rb/Sr whole-rock methods. U-Pb dating on zircons obtained an age of 475+/-10 MA (E. Ordovician) for the Grand Cove Group (Mattinson, 1977). These dates, if reliable, require that at least part of the original Cape St. John Group as defined by Baird (1953) is Ordovician in age. Since part of the Cape St. John on the southern edge of this zone is certainly of post-Arenigian, and probably of Siluro-Devonian age, and resting unconformably above folded Arenigian rocks of the Snooks Arm Group, then there must be a structural and/or stratigraphic break between the Grand Cove Group and the southern Siluro-Devonian part of the Cape St. John Group. These arguments still leave two possibilities to resolve: (1) either the rocks all belong to the Grand Cove Group and are all Ordovician but post-Arenigian in age and in part have isotopic ages reset in the Acadian or 2) there is an as yet undetected structural and stratigraphic break between the Ordovician Grand Cove Group and Siluro-Devonian Cape St. John Group. This present study was undertaken in order to attempt a resolution of this problem.

METHOD OF APPROACH

In order to resolve these possibilities, the following objectives were set out:

(1) To carefully distinguish and define as precisely as possible rocks and units belonging to the Cape St. John Group and Grand Cove Group, and their contact and structural relationships to each other.

(2) To carefully trace and map out any highly strained rocks or fault traces that could be separating the Grand Cove Group from the Cape St. John Group.

(3) To collect a suite of samples from both the Cape St. John Group and Grand Cove Group and any highly strained rocks separating them for subsequent thin section examination.

(4) To produce a detailed map (1:16,00 scale) of the Cape St. John area on the Burlington Peninsula, northwest central Newfoundland.

Using field observations, petrology and interpretation from this study it was hoped that an improved understanding of the geology and hence an improved tectonic model for this part of Newfoundland could be obtained.

CHAPTER TWO

REGIONAL GEOLOGY

Introduction

Regional geology is discussed in two parts. The first part covers previous work based primarily on structural and field work. The second part discusses geochronology supported by isotopic ages. The ages of rocks belonging to the eastern division of the Fleur de Lys Supergroup (Church, 1969), their correlation with the Cape St. John Group, and the time of their deformation and metamorphism are the subjects of considerable disagreement. Previous workers included all volcanic and volcaniclastic rocks not belonging to the Pacquet Harbour Group or the Snooks Arm Group on the Burlington Peninsula in the Cape St. John Group. Although the rocks are lithologically similar, their structures are different. Church (1969) divided the Cape St. John Group into two distinct groups because the rocks in the northern part of the Peninsula have typical polyphase Fleur de Lys structures and the rocks in the south do not. Church (1969) included the rocks in the northern part of the peninsula which had previously been assigned to the Cape St. John Group into the eastern division of the Fleur de Lys Supergroup and called them the Grand Cove Group. The review that follows adheres to Church's (1969) division of the Cape St. John Group and refers to the Grand Cove Group as those silicic and mafic metavolcanics in the northern part of the Burlington Peninsula which are presumed to be Ordovician in age. The Cape St. John Group consists of mafic, intermediate and silicic metavolcanics in the southern part of the Burlington Peninsula. This group is at least post-Arenig and possibly as young as Silurian or Devonian in age.

PREVIOUS FIELD WORK

The first study conducted in this area was by Snelgrove in 1931. He found Lower Ordovician graptolites in a group he termed the "Snooks Arm Series". He also interpreted rhyolitic pyroclastic rocks of the "Goss Pond volcanics" to be stratigraphically conformable above the Snooks Arm Series. He interpreted rhyolites and dacites belonging to the "Red Cliff volcanics" to be stratigraphically conformable above the "Goss Pond volcanics". The "Goss Pond" and "Red Cliff" volcanics are now considered to be part of the Cape St. John Group (Baird, 1951).

Baird (1951) called the Cape St. John Group "that sequence of lava flows, with interbedded sedimentary and pyroclastic rocks, that overlies the Snooks Arm Group". He considered the age of the Cape St. John Group to be Ordovician based on its lithological similarities to other Ordovician rocks of the Notre Dame Bay area. Baird (1951) believed that the Cape St. John Group conformably overlay the Snooks Arm Group. He also felt that the entire sequence of rocks from Shoe Cove to the tip of Cape St. John represented one period of volcanic activity, and that it should be considered as one stratigraphic unit.

Neale (1957) proposed an unconformity based on ultramafic rock fragments and pieces of the ophiolite suite in a Cape St. John Group conglomerate near Kitty Pond in the Betts Cove area. Upadhyay (1973) reinterpreted these conglomerates with the ophiolitic clasts as late diatremes due to their similarities to well established diatremes in the region which may be associated with intrusion of widespread (Silurian/Devonian ?) porphyries. Neale (1957) also claimed to have recognized an angular unconformity at Beaver Cove Head between crossbedded sandstones and purplish-hued, amygdular basalt flows of the Cape St. John Group unconformably overlying sediments belonging to the Snooks Arm Group. However, this was not well documented. Neale (1957) correlated the Cape St. John Group with the (Devonian) Springdale Group to the southeast, and interpreted the Cape Brule Porphyry and the extrusive rocks of the Cape St. John Group to be derived from the same magma. Neale (1958) included deformed mafic and silicic rocks on the north side of the Burlington Peninsula near Brents Cove and Harbour Round in the Cape St. John Group.

Neale and Nash (1963) defined the Fleur de Lys Group as the metamorphic rocks between Baie Verte and White Bay. Williams (1964) correlated the Cape St. John Group with the faunally-dated Middle Silurian Botwood Group. Church

(1969) reaffirmed that the Cape St. John Group unconformably overlies the Snooks Arm Group and therefore must be Silurian or Devonian in age. Church (1969) noted that the Fleur de Lys and northern Cape St. John (in the sense of Neale, 1957) Groups had a similar structural history. This led him to believe that either the main deformation in the rocks was post-Silurian or that the Cape St. John is actually two distinctly different groups, with the northern group being older and more deformed than the southern group.

Church (1969) collectively called the "Fleur de Lys Supergroup" all high grade metamorphic rocks on the Burlington Peninsula which separate the Cambrian-Ordovician platform sedimentary rocks of western Newfoundland from the volcanic and clastic sedimentary rocks of the Central Mobile Belt (Williams, 1977). He divided the metamorphic rocks into two units referred to as the western and eastern divisions of the Fleur de Lys Supergroup. He also introduced the names Pacquet Harbour Group and Grand Cove Group for the high grade metamorphic rocks of the eastern division in the Paquet-Confusion Bay region which were formerly (Baird, 1951) included in the Baie Verte and Cape St. John Groups respectively. The Pacquet Harbour Group consists dominantly of mafic metavolcanic rocks which outcrop between the Burlington Granodiorite inland and Pacquet Harbour on the coast. The Grand Cove Group is essentially silicic flows and metasedimentary rocks which outcrop along the north coast of the Burlington Peninsula around the Confusion Bay area. Church (1969) interpreted the Grand Cove Group as part of the Fleur de Lys Supergroup and suggested a pre-Early Ordovician age for it. He found silicic dacitic rocks of the Grand Cove Group to be in structural conformity with amphibolitic rocks of the Pacquet Harbour Group between Gooseberry and Hollins Cove. Church (1969) included in the eastern division of the Fluer de Lys Supergroup the following groups: Mings Bight, Pacquet Harbour and Grand Cove. He reported deformed silicic volcanic clasts of Grand Cove affinities within the Snooks Arm Group, making the Cape St. John Group pre-Early Ordovician in age.

Coates (1970) mapping an area between Confusion Bay and the Pacquet Harbour Road north of the La Scie Highway agreed with Church (1969) and divided the Cape Brule Porphyry into two different porphyrys, the Cape Brule Porphyry in the north and the Cape St. John Porphyry in the south, based on different structural and metamorphic histories. No contact between the two was noted and Coates proposed that the two porphyrys may actually be part of the same intrusive body but representing different structural levels, an arguement impossible to reconcile with Church's view.

Dewey and Bird (1971) interpreted the Cape St. John Group as pre-Ordovician in age hence making it older than the Betts Cove ophiolite suite and Lower Ordovician (Arenig) Snooks Arm Group basic lavas and oceanic sediments which overlie the ophiolites. This interpretation was based on a `giant raft' of Cape St. John Group within the Snooks Arm Group near Tilt Cove. Deformed mafic volcanic rocks in the northern part of the peninsula were included in the Pacquet Harbour Group (Dewey and Bird, 1971). Douglas et al. (1940) were actually the first to notice `inclusions' of Cape St. John rocks within the serpentinized ultramafic rocks near Tilt Cove. Neale (1957) interpreted these inclusions as tectonic inclusions associated with remobilization of the serpentinite.

Schroeter (1971) found unconformities at two localities near Rogues Harbour which are similar to the unconformity Neale (1958) described at Beaver Cove and Pinnacle Bight (Neale at al, 1975). The rocks which unconformably overlie the ophiolite at Rogues Harbour are lithologically similar to the Devonian Mic Mac Lake Group to the west. The Mic Mac Lake Group is lithologically similar to the sequence at Beaver Cove and Pinnacle Bight (Neale at al., 1975). Neale et al. (1975) also reemphasized the similarities of the Cape St. John Group and the Mic Mac Lake Group to the Springdale Group (about 40 km south-southwest of Betts Cove). The Springdale Group is also lithologically correlated with the Middle Silurian Botwood Group farther to the east (Williams, 1967). Schroeter (1971) believed the Cape Brule Porphyry to be Siluro-Devonian in age based on its lithological similarity to Burton's Pond "Granite" which intrudes the Nippers Harbour Group.

Kennedy et al. (1972) suggested that the Pacquet Harbour Group, Cape St. John Group and the Cape Brule Porphyry are pre-Ordovician in age based on their similar structural histories. Kennedy (1975) suggested that in order for the Cape St. John Group to be pre-Ordovician in age, ophiolitic sheets would have had to have been thrust over or around a pre-existing island arc made up of the Cape St. John Group. Kennedy (1975) was still in agreement with Kennedy et al. (1972) about the Cape St. John Group being pre-Ordovician in age. He also found that the Snooks Arm Group and the southern part of the Cape St. John Group (as defined by DeGrace at al., 1976) both shared an Acadian foliation. He could not explain the contact relationship between the Silurian (?) rocks of the southern Cape St. John Group with the Fleur de Lys deformed rocks in the northern part of the Cape St. John Group. Kennedy (1975) included deformed mafic metavolcanics in the northern part of the Burlington Peninsula with the Pacquet Harbour Group.

DeGrace et al. (1976) suggested that the Cape St. John Group and associated intrusive rocks are all post-Lower Ordovician in age due to major differences in structure, age and lithologies with the Fleur de Lys Group. They found no evidence for a structural or stratigraphic break within the Cape St. John Group and believe that the rocks Church (1969) termed the Grand Cove Group all belong to the Cape St. John Group. They interpreted the more deformed rocks in the northern part of the area (Church's Grand Cove

Group) to be the northern limb of a syncline with the less deformed rocks in the southern portion of the area to be the southern limb of this syncline. They suggested that the terms Eastern and Western Divisions of the Fleur de Lys Supergroup (Church, 1969) be obliterated.

GEOCHRONOLOGY

Geochronology is discussed separately from other previous work because available isotopic ages for rocks on the Burlington Peninsula are too ambiguous to possibly define a unique history of this area. A summary of isotopic ages obtained by various workers is shown in Table 2.1. A compilation map of their obtained isotopic ages and sample collection locations is presented in Figure 2.1. Many authors express their beliefs that most of the ages have been thermally reset. This author warns against the assignment of these ages to individual Groups as the age of their deposition/intrusion based on current age data.

Not all previous isotopic age results from Table 2.1 are discussed. The following discussion is limited to only the more meaningful isotopic ages and their significances.

Rocks belonging to the Cape St. John Group were dated using only the Rb/Sr whole-rock method. Ages of 520+/-40 Ma (Bell and Blenkinsop, 1978) and 444+/-50 Ma (Pringle, 1978) were reported and interpreted as initial cooling ages. A younger age of 350 Ma was reported (Bell and

SUMMARY OF THE GEOCHRONOLOGY OF THE EASTERN FLEUR DE LYS

Unit	Age	Method	Reference
Cape St. John Group	520 ± 40 MA	Rb-Sr whole-rock	5
	441 ± 50 MA	Rb-Sr whole-rock	6
Grand Cove Group	475 ± 10 MA	U-Pb zircon	3
	385 ± 15 MA	Rb-Sr whole-rock	5
	355 ± 15 MA	Rb-Sr whole-rock	6
Cape Brule Porphyry	475 ± 10 MA	U-Pb zircon	3
	336 ± 14 MA	Rb-SR whole-rock	4
	407 ± 25 MA	Rb-Sr whole-rock	6
Burlington Granodiorite	464 ± 6 MA	U-Pb zircon	2
	451 ± 5 MA	Pb-Pb zircon	3
	434 ± 9 MA	U-Pb sphene	3
	345 ± 30 MA	U-Pb apatite	3
	437 ± 40 MA	Rb-Sr biotite,whole-rock	6
	445 ± 24 MA	U-Pb zircon	7
	343-345 MA	40Ar/39Ar biotite	7
	412-414 MA	40Ar/39Ar biotite	7
	464 ± 5 MA	40Ar/39Ar hornblende	7
	413-419 MA	40Ar/39Ar hornblende	7
	494 ± 34 MA	Rb-Sr whole-rock	7
Dunamagon Granite	348 ± 15 MA	K-Ar biotite	1
	435 ± 15 MA	Pb-Pb zircon	3
	425 ± 10 MA	Rb-Sr whole-rock	6
	343 ± 10 MA	Rb-Sr biotite	6
	459 ± 27 MA	U-Pb zircon	7
	344 ± 5 MA	40Ar/39Ar biotite	7
La Scie Granite	486 ± 40 MA	Pb-Pb zircon	3
	462 ± 40 MA	Pb-Pb zircon	3
	488 ± 35 MA	Pb-Pb zircon	3
Seal Island Bight Syenite	421 ± 12 MA	Pb-Pb zircon	3
	414 ± 23 MA	Pb-Pb zircon	3
	336 ± 14 MA	Rb-Sr whole-rock	4

REFERENCES

(1) Wanless et al., 1972
(2) Mattinson, 1975
(3) Mattinson, 1977
(4) Bell and Blenkinsop, 1977
(5) Bell and Blenkinsop, 1978
(6) Pringle, 1978
(7) Dallmeyer and Hibbard, 1984

Table 2.1.

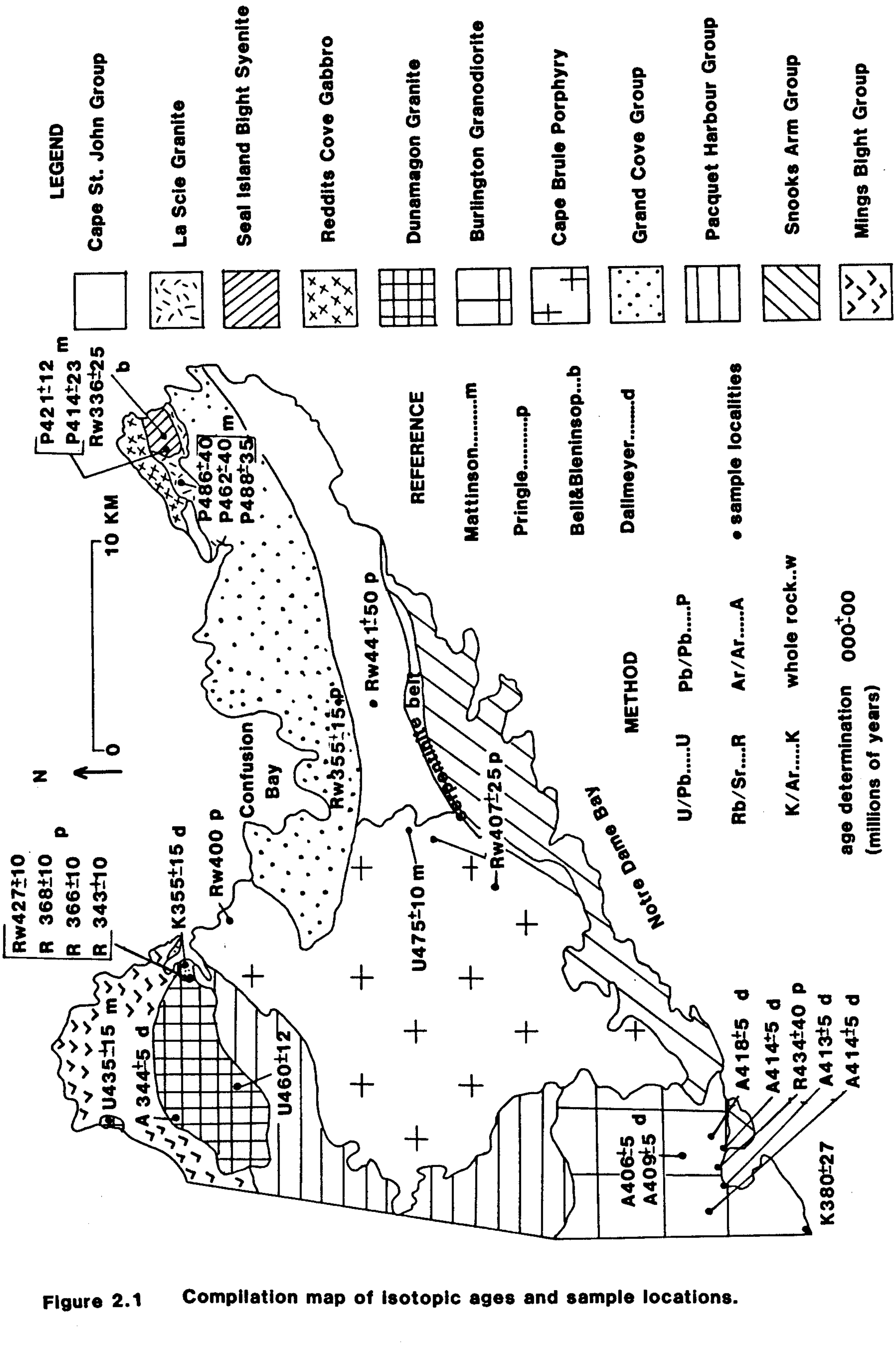

Figure 2.1 Compilation map of isotopic ages and sample locations.

Blenkinsop, 1978) and is believed to represent a thermal resetting event.

Rocks belonging to the Grand Cove Group have been dated using U-Pb (Mattinson, 1977) and Rb-Sr whole-rock (Pringle, 1978) methods. An age of 475+/-10 Ma was obtained by using U-Pb dating of zircons (Mattinson, 1977) and is interpreted to represent the age of primary crystallization of the Grand Cove Group.

The Cape Brule Porphyry was dated using U-Pb and Rb-Sr whole-rock methods. Using the U-Pb method zircons were dated and an interpreted primary crystallization age of 475+/-10 Ma (Mattinson, 1977) was obtained. The Rb-Sr whole-rock method produced inconsistent ages of 407+/-25 Ma (Pringle, 1978) and 336+/-14 Ma (Bell and Blenkinsop, 1977). The younger ages are interpreted to represent the age of a thermal resetting event.

The Burlington Granodiorite was dated using several isotopic dating techniques. U-Pb dating of zircons obtained consistent ages of approximately 445 - 464 Ma (Mattinson, 1975, 1977; Dallmeyer and Hibbard, 1984). This range of ages is interpreted to represent the primary crystallization of the granodiorite. A post-crystallization tectonothermal event is recorded in the other isotopic methods used. U-Pb dating of apatite obtained an age of 345+/-30 Ma (Mattinson, 1977). Apatite is more susceptible to thermal resetting than zircon. Thus, the younger age obtained by dating apatite probably reflects a thermal disturbance in the Late Devonian/Early Carboniferous (Acadian). Rb-Sr whole-rock methods obtained a 437+/-40 Ma age (Pringle, 1977), also reflecting a thermal resetting event. 40Ar/39Ar dating of biotite and hornblende recorded ages ranging as young as 343 Ma to 419 Ma (Dallmeyer and Hibbard, 1984), indicating thermal resetting.

The Dunnamagon Granite was dated by several isotopic methods. Two distinct age groups were obtained. An older group of ages ranges from approximately 425-459 Ma (Mattinson, 1977; Pringle, 1978; Dallmeyer and Hibbard, 1984). These older ages were obtained using Pb-Pb precision techniques on zircons, U-Pb and Rb-Sr whole-rock methods and represent the time of emplacement of the granite. A younger group of ages ranges from approximately 343-348 Ma. These younger ages were obtained by K-Ar (Wanless et al., 1972), Rb-Sr (Pringle, 1978), and 40Ar/39Ar (Dallmeyer and Hibbard 1984) methods. The 343-348 Ma age reflects a thermal resetting event.

The La Scie Granite was consistently dated at 462-488 Ma by Pb-Pb dating of zircons (Mattinson, 1977). These are the only dates and methods reported and probably represent the age of primary crystallization.

The Seal Island Bight Syenite was dated using Pb-Pb techniques on zircons (Mattinson, 1977) and Rb-Sr whole-rock methods (Bell and Blenkinsop, 1977). The Pb-Pb method obtained consistent ages of 414-421 Ma representing the age of primary crystallization. A younger age of 336+/-14 Ma was obtained using Rb-Sr whole-rock methods. This younger age reflects a thermal resetting event.

Summary and Interpretation of Isotopic Ages

It is a well accepted fact that metamorphism effects the parent-daughter relationship if the rocks have been chemically altered (Faure, 1977). If rubidium and/or strontium are either added or lost at any time after their formation, the Rb-Sr method of dating becomes meaningless for dating the age of formation of the rocks. However, the Rb-Sr method is useful for dating the age of metamorphism. Pb-Pb isochrons are useful for dating primary crystallization of metamorphic rocks since they are not affected by recent losses of either uranium or lead (Faure, 1977).

Primary crystallization ages were obtained using U-Pb and Pb-Pb isotopic techniques. Mattinson (1977) used U/Pb dating to obtain primary crystallization ages of 475+/-10 Ma for volcanic rocks of the Grand Cove Group and rocks of the Cape Brule Porphyry. He also used Pb/Pb dating to obtain primary crystallization ages of 445+/-10 Ma for the Burlington Granodiorite. These isotopic ages agree with and support field evidence for these ages.

The rocks in this study area have all been metamorphosed although to varying metamorphic grades.

Therefore, the Rb-Sr method is clearly not useful for dating the age of formation or primary crystallization of these group of rocks on the Burlington Peninsula. However, the Rb-Sr, K-Ar and 40Ar/39Ar methods proved useful in detecting a major tectonothermal event in the Late Devonian/Early Carboniferous (Acadian) that disturbed these isotopic systems. The Pb-Pb and U-Pb techniques obtained consistent ages and therefore may be considered to be reliable and interpreted to represent primary crystallization ages.

CHAPTER THREE

STRATIGRAPHY

INTRODUCTION

STRATIGRAPHIC PROBLEMS WITH PYROCLASTIC ROCKS

Many problems were encountered when trying to determine the stratigraphy of this area as with many other volcanic terranes. Because different types of volcanic material may be erupted out of different vents and other nearby volcanoes at the same time, interfingering of these different volcanic materials, synchronous erosion and erosional unconformities may result. These all cause lateral discontinuity of the volcanics making rock units difficult to trace and correlate. Particular facies characteristics depend upon the topographical, structural, and environmental factors affecting the volcanic pile during its formation (Fisher and Schmincke, 1984).

Plate 1 shows the distribution of and relationships between the various rock types preserved on the eastern portion of the Burlington Peninsula. It is difficult to separate these rocks into more than one grouping based strictly on lithologies. However, their structures are different and Church (1969) in a general way divided these volcanic and volcaniclastic rocks into two separate groups based on this difference. Rocks in the northern portion of the peninsula have Fleur de Lys type structures (Kennedy, 1975). Church (1969) assigned these more deformed rocks to the Grand Cove Group; they had previously been included in the Cape St. John Group by other workers. Based on the Grand Cove Group's Fleur de Lys type structures and Mattinson's U-Pb age (1978) some authors (Kennedy, 1975; Church, 1969; Dewey et al, 1983) have assigned it an Early Ordovician age. In order to avoid confusion and to try to better understand these rocks and their relationship to each other, the pigeon-holing of these rocks into either the Grand Cove Group or the Cape St. John Group is not used in the description which follows. Instead descriptions of the individual rock units are discussed. Rocks in the northern portion of the area are discussed first, from north to south. It was not possible to determine the direction of younging in the rocks in this area because there are no definitive stratigraphic top indicators found. These rocks are believed to be the oldest rocks preserved in this area and are everywhere separated from rocks in the south-east by one or a series of fault(s) or shear zone(s). Second, the group of rocks in the south-southeast portion of the area is described from its stratigraphic base upwards to the top. Rocks from this group are almost everywhere separated from the structurally underlying sediments of the Arenig Snooks Arm Group by a serpentinite fault belt, although locally there is an unconformity between them, they are believed to be the youngest rocks in this area.

LITHOLOGICAL DESCRIPTION

NORTHERN GROUP

The Northern Group consists of mafic schist, mafic volcaniclastic rocks, and porphyritic and non-porphyritic silicic volcanic rocks that might include both flows and ignimbritic products, most of which are generally north of the La Scie Highway. This group is bounded on the north by Confusion Bay, on the south by a series of faults or mylonite zones, on the east by the La Scie Intrusive Complex and on the west by the Pacquet Harbour Group and a quartz-feldspar porphyry (Cape Brule Porphyry).

MAFIC ROCKS

Mafic Schist

Within the Northern Group are mafic schists rich in biotite and chlorite that in outcrop have a phyllitic sheen. The rock varies in weathered color from dark green to medium dark grey with weathered brown folded calcite pods and discontinuous layers of calcite (Figure 3.1). The rock is locally massive and extremely fine-grained. This unit is seen along the shore of Brents Cove, Harbour Round and Grand Cove with few outcrops of it between these locations.

Figure 3.1 Mafic schist belonging to the Northern Group on west shore of Brents Cove.

Figure 3.2 Northern Group silicics at Brents Cove Harbour.

Along the south shore of Brents Cove the rock appears to have a sandy texture grading into an amygdaloidal mafic rock with flattened, calcite-filled amygdules. These rocks have a strong phyllitic sheen to their surface. A strong mineral lineation defined by biotite is associated with this unit. This outcrop can only be observed during low tide at this location.

In thin section there are irregularly spaced chlorite and biotite-filled clots in a medium to light green, fine-grained sericite-rich matrix. Microscopically, this mafic schist is a poorly layered rock composed of anhedral quartz grains with subhedral yellow-green epidote crystals embedded in and around the quartz grains. Plagioclase grains are subhedral and dusty in appearance. Euhedral sphene crystals are randomly scattered throughout the rock. Blue-green pleochroic platy amphibole (actinolite) is intergrown with biotite and randomly overprints all minerals, with no preferred alignment (to them). This indicates that the actinolite growth post-dates the main foliation in this rock.

SILICIC ROCKS

This unit consists of variably differentiated porphyritic and non-porphyritic silicic volcanics (metarhyolites). These rocks cover a large area around the Harbour Round Pond area, almost the entire length of the

Brents Cove Road and most of the Harbour Round to La Scie Highway traverse. In outcrop this unit is buff white to pinkish white on the weathered surfaces and pinkish grey to light grey on the fresh surfaces. The weathered surfaces enable the structures to be seen more easily (Figure 3.2).

The porphyritic portions are medium-grained to coarse-grained. There are 10-15% sub to anhedral K-spar phenocrysts and pink to grey silicic fine-grained rock fragments. Quartz grains and, rarely, grey basaltic fragments occur. This unit shows folded layering (with axial planar foliation) in outcrops on the hills and roadcuts just south of Brents Cove.

The non-porphyritic sections are usually massive, aphanitic and fine to extremely fine-grained. Muscovite commonly occurs on foliation planes and may help to define a well-defined, fine-grained fabric lineation.

In thin section there are commonly no original textures left. Textures seen are porphyritic with rotated and commonly fractured or recrystallized phenocrysts (? pseudomorphs). There frequently has been new grain growth and extensive recrystallization.

On the west shore of Brents Cove, this unit is strongly foliated and lineated. In thin section this rock appears highly strained and is very fine-grained with only small patches and discontinuous ribbons of tiny polygonal quartz grains with undulose extinction. These patches and ribbons are tightly folded with biotite and even smaller polygonal quartz grains defining an axial planar foliation to these folds. There are no large phenocrysts of quartz.

Thin sections from outcrops at the top of the first hill on the road going south out of Brents Cove show twinned plagioclase and quartz phenocrysts in a fine-grained groundmass of the same minerals and muscovite. The feldspar grains are altered and partially recrystallized with wisps of biotite around their edges.

Thin sections from other localities reveal twinned plagioclase grains and clots of calcite surrounded by streaks of muscovite. There are no large phenocrysts of quartz. The plagioclase is highly altered with muscovite (? sericite) growing throughout it.

SOUTHERN GROUP

The Southern Group is exposed in a belt with northeast trending strata, bounded in the north by the Northern Group, in the south by the Snooks Arm Group, in the east by Notre Dame Bay and in the west by several quartz-feldspar porphyry bodies. Major structural and lithologic trends are northeasterly. The contact with the Northern Group is a series of faults or shear zones. The contact with the Snooks Arm Group is marked by a narrow fault lineament.

MAFIC ROCKS

The base of the Southern Group at Beaver Cove Pond is a series of mafic rocks that includes vesicular flows with amygdaloidal structures, massive sills and minor pillow lavas.

PILLOW LAVAS

The best and only (except for 2 other possibilities) exposure of pillow lavas is on the Tilt Cove Road directly across from the north-west shore of Beaver Cove Pond. Ellipsoidal pillows range in diameter from 8 cm to 1.5 m and are elongated by local flattening (Figure 3.3). Fresh surfaces of the pillows are dark green in color and weather to brownish brick colored red hematite stained surfaces. Chill margins can be identified around the pillows. There are dark chloritized and epidote coated slickensided surfaces in many different orientations around the individual pillows that may be due to rotation of the individual pillows within the matrix during local shearing. Locally, there is a pillow breccia unit associated with these pillows consisting of brecciated angular pillow fragments or clasts in a dark green matrix. Some of the clasts are vesicular. There has been some confusion over which group to put these pillow lavas in. Some authors (Neale and Nash, 1963; DeGrace et al., 1976)

Figure 3.3 Mafic pillow lavas belonging to the Southern Group on Tilt Cove Road directly across from Beaver Cove Pond.

Figure 3.4 Calcareous sandstone unit on the Tilt Cove Road near Beaver Cove Pond.

included them within the Snooks Arm Group. Other authors (Dewey and Bird, 1971) include them within the Cape St. John Group.

In thin section calcite-filled vesicles are rimmed with chlorite. The texture is locally diabasic with flow alignment of plagioclase grains. Yellow, isotropic palagonite (an alteration product of glass) and small patches of minute quartz grains are scattered in the groundmass along with tiny laths of plagioclase exhibiting albite twinning. The groundmass is dominantly sericite, chlorite, calcite and minor magnetite grains.

AMYGDALOIDAL MAFIC LAVAS

In many places throughout the southern part of the field area, best seen along the Tilt Cove Road, are amygdaloidal mafic lavas with quartz and calcite-filled amygdules up to 4 cm long, rimmed by chlorite. The amygdules are mildly flattened and/or rotated into the cleavage. Albite phenocrysts are outlined by skeletal opaques in a diabasic and locally subophitic textured groundmass. The rocks are generally too altered to distinguish original textures and groundmass contents.

CALCAREOUS SANDSTONE

A coarse-grained, crossbedded calcareous sandstone, with prominent crossbedding younging to the north, is well exposed across from Beaver Cove Pond on the Tilt Cove Road. The sandstone is pale beige in colour and well sorted. It consists predominantely of quartz and feldspar clasts and minor red and green altered ultramafic, rhyolite, mafic volcanic and chromite clasts (Figure 3.4).

In thin section the larger quartz grains have undulatory extinction. The quartz also occurs in aggregates of small grains. The feldspar grains exhibit twinning. The matrix is composed of sericite, quartz and feldspar fragments, calcite and chlorite.

Sandstone like this rests unconformably above sediments of the Lower Ordovician Snooks Arm Group at Pinnacle Bight (Neale, 1958; Neale et al, 1975). Crossbedding of this sandstone suggests a shallow water marine/non-marine origin for these beds.

INTERMEDIATE ROCKS

Pyroclastic Volcaniclastics

Intermediate volcanics are massive and vesicular. This unit appears in several forms: (1) a light to dark grey vesicular rock with calcite and chlorite-filled vesicles

(2) a medium grey, massive medium-grained rock with no clasts or vesicles (3) peach colored pumice fragments in a dark grey matrix (Figure 3.5) (4) a yellow/green colored tuff. The volcaniclastic sections of these rocks are generally well foliated as defined by flattened calcite and chlorite amygdules and pumice fragments. The foliation locally exhibits a good crenulation cleavage.

Tuffaceous rocks occur along the La Scie Highway 15 m east of the Brents Cove Road turnoff. The tuffs have a green silty/sandy matrix which weathers buff, and there are pumice fragments which are flattened into planes parallel to the regional foliation (S1). Pyrite is present in this unit.

These intermediate rocks all appear very similar in thin section. A general thin section description (for them) is given. In thin section there are aggregates of twinned plagiclase microlaths, flattened patches of minute quartz grains and calcite. There are minor amounts of chlorite. Alteration products of the plagioclase include sericite, calcite and epidote. Magnetite occurs as an accessory mineral.

SILICIC ROCKS

Silicic rock types include silicic breccias, ignimbrites, accretionary lapilli tuffs, massive rhyolites, and crystalline tuffs.

Figure 3.5 Intermediate pyroclastic rock belonging to the Southern Group.

SILICIC BRECCIA (?Pyroclastic)

This breccia contains angular clasts of various sizes ranging from 0.5 cm to 10 cm. There are small, black, unfoliated clasts and well foliated rhyolite clasts in a dark fine-grained matrix that weathers white. The best exposed example of this unit is in the garbage dump and adjacent roadcut on the east side of the Snooks Arm Road.

WELDED TUFFS

This crystalline tuff is nonfoliated and in outcrop appears lithologically similar to the Cape Brule Porpyry. The locations for this rock type are scattered exposures in low-lying areas around ponds throughout the Red Cliff Hills area and 2 isolated exposures on the Snooks Arm Road. Locally, in sections of the Red Cliff Hills area this unit becomes foliated, cleaved and appears strained. In general, the outcrops of the rock are coarse-grained and buff yellow quite commonly containing angular red and green ultramafic-derived fragments (xenoliths) up to 10 cm in length. The red clasts have weathered green rims. Rounded and angular clear quartz grains and white weathered feldspar crystal fragments are seen in hand samples.

In thin section there are crystal fragments of rounded quartz, feldspar and plagioclase grains with a welded shard texture (eutaxitic). The quartz grains have resorption cavities that are filled with the brown cloudy micaceous groundmass. Flow of plagioclase microlites of the groundmass around crystal fragments can be seen in thin section but not in hand samples. Muscovite and aggregates of small quartz and feldspar grains occur in the matrix.

RHYOLITE

Rhyolites are massive, fine-grained to aphanitic, dark grey to reddish brown in color and are hard, flinty and in a few places fracture conchoidally. Flow banding structures are common and are more easily seen on the weathered surface than on the fresh. This unit appears locally, 500 m south from the La Scie Highway on the Tilt Cove Road, as a dark grey to black, extremely fine-grained pinstriped rock. The pinstripes are continuous and about 0.2 cm thick (Figure 3.6).

Generally in thin section there are only a few distinquishable microphenocyrsts of rounded quartz which show undulatory extinction and small patches of tiny recrystallized quartz grains, sanidine and possibly orthoclase occuring in a dense aphanitic groundmass. There are a few opaque minerals with blood red oxidized rims. The rock is frequently extremely sericitized. Small discontinuous calcite and quartz veins are common. Although spherulites were reported by previous workers, the thin sections examined for this study did not reveal any.

Figure 3.6 Black pinstriped rhyolite unit of the Southern Group on the Snooks Arm Road approximately 100 m south of the La Scie Highway turnoff.

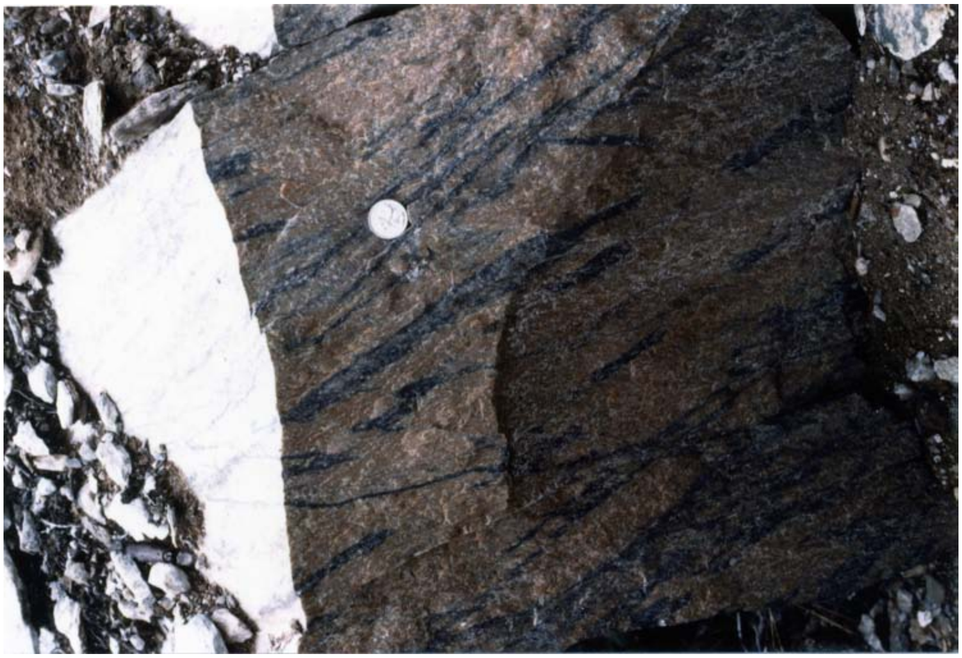

Figure 3.7 Silicic ignimbrite with fiamme flattened into a foliation plane. Rock belongs to the Southern Group on the La Scie Highway approximately 1.2 km west of the Tilt Cove Road turnoff.

These rhyolites are best observed on the La Scie Highway near the Tilt Cove Road turnoff, next to the Snooks Arm Road turnoff, and in the Red Cliff Hills area.

IGNIMBRITES

This unit is very distinctive. It consists of black fiamme (flattened pumice fragments) in a fine-grained peach-colored matrix. This can be seen in a quarry on the west side of the Snooks Arm Road. At the Brents Cove Road turnoff, fiamme are unusually pale within a dark matrix and are flattened into a foliation plane (S1) (Figure 3.7). In a nearby quarry on the north side of the La Scie Highway near the north end of the Snooks Arm Road. There is no well-developed foliation fabric at this location (Figure 3.8).

ACCRETIONARY LAPILLI TUFF

This unit is very distinct with brownish maroon accretionary lapilli rimmed by white quartz in a pale lime green matrix (see Figure 4.27). The undeformed lapilli range in size from 0.5 cm to 1.5 cm and in their most deformed state they are 10 cm in length and 2 mm in width. Accretionary lapilli are known to form as moist aggregates of ash in eruption clouds or by rain that falls through dry eruption clouds (Fisher and Schmincke, 1984) and accumulate

Figure 3.8 Silicic ignimbrite belonging to the Southern Group with no developed foliation. Location is in a nearby quarry on the north side of the La Scie Highway near the north end of the Snooks Arm Road.

Figure 3.9 Porphyry A, a quartz-feldspar porphyry.

only on land or in shallow water (Williams and McBirney, 1979). In thin section the individual lapilli are made up of a calcite core with rims of tiny recrystallized quartz grains in a sericite and quartz matrix. Some lapilli consist entirely of recrystallized quartz grains. Some of the samples from the thrust fault exposed in the quarry off the Snooks Arm Road show that the original concentric structures of the lapilli have been modified by a pressure solution chemical transfer process at the outer boundaries of the lapilli. The best outcrops of this unit are found in quarries at the Snooks Arm Road thrust fault and the La Scie Highway strike slip fault. At the first of these locations the lapilli can be traced from undeformed spherical shapes into very strained elliptical shapes next to the fault surface .

INTRUSIVE ROCKS

QUARTZ/FELDSPAR PORPHYRY

Several small porphyritic bodies occur in this field area. Previous workers (Neale, 1957; DeGrace et al., 1976) have placed all of these bodies into one large unit, the Cape Brule Porphyry. There have been some arguments whether or not prophyries of two different ages exist (Coates, 1970) based on different structural histories. I found all but one of the porphyritic bodies to be very similar in composition with minor variations in percentages of quartz and feldspar. They do, however, vary in structural histories. Some outcrops of porphyry are extremely homogenous, undeformed and are void of any structures (Figure 3.9). At other localities, such as the south shore of Brents Cove Harbour, porphyry is clearly deformed (Figure 3.10). On the La Scie Highway, porphyry is locally mylonitized (see Chapter Four for discussion). Structural differences do not justify dividing these porphyritic bodies into many different units. Porphyritic bodies described below will be divided into two categories. The first, porphyry A, outcrops in many locations along the La Scie Highway on the western edge of this field area. A similar rock type is found locally on the south shore of Brents Cove. The second body, porphyry B, outcrops only in the quarry off the Snooks Arm Road at a thrust fault contact.

Porphyry A

In general, porphyry A is pale to dark grey on fresh surfaces and weathers to buff or light grey. Phenocrysts of up to 35% pink and white feldspars and 25% clear and cloudy quartz stand out in relief in a fine-grained to aphanitic grey groundmass. The quartz phenocrysts are commonly rounded and embayed by the groundmass. Feldspar phenocrysts include both euhedral K-spar and sodic

Figure 3.10 Deformed Porphyry A intruding the Northern Group on the south shore of Brents Cove.

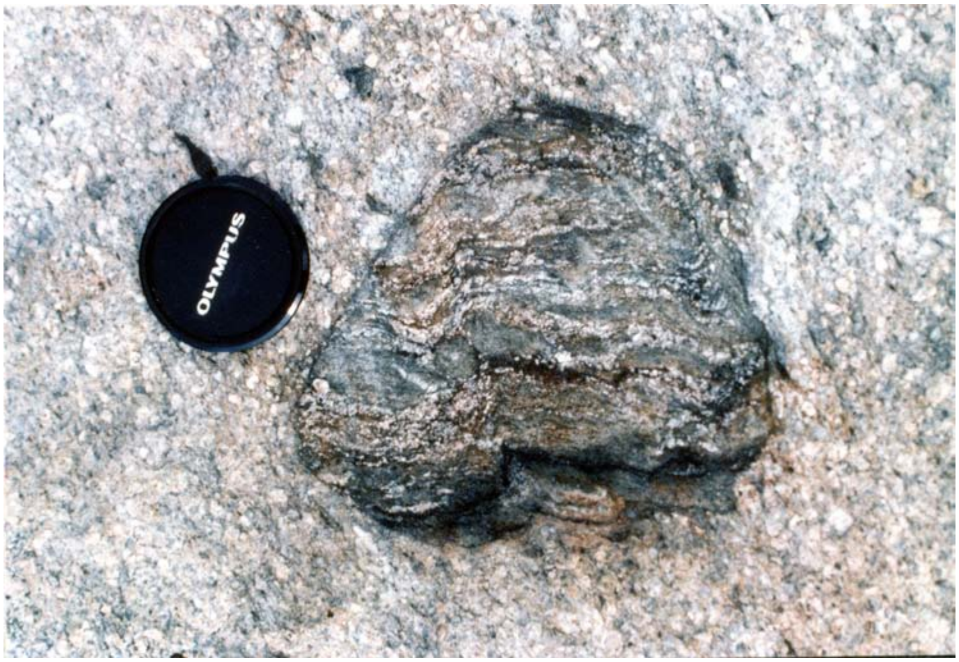

Figure 3.11 Porphyry A with a deformed mafic inclusion.

plagioclase. Inclusions of silicic, mafic and intermediate composition volcanic rocks occur. On a logging road north of the La Scie Highway near Confusion Bay, one mafic inclusion has a predepositional foliation in it (Figure 3.11). The porphyry does not display a crenulation cleavage as well as some of its inclusions. Figure 3.12 shows a mafic clast with a penetrative cleavage which when looked at closely can be seen to penetrate the porphyry also. Adjacent to the mylonite zone on the La Scie Highway near the Nippers Harbour turnoff the porphyry becomes extremely foliated as it approaches the mylonite zone and the quartz and feldspar phenocrysts become rotated in the direction of shear (see Chapter Four for further description).

In thin section, phenocrysts of quartz and feldspar are embayed by a groundmass consisting of quartz, feldspar, chlorite, muscovite, biotite and calcite. Accessory minerals include magnetitie, apatite, zircon, sphene, and sericite. Orthoclase phenocrysts exhibit Carlsbad twinning. Microcline crystals show characteristic grid twinning. Quartz occurs as clear, euhedral crystals with occasional undulose extinction.

Porphyry B

In outcrop, this quartz-feldspar porphyry is coarse-grained, homogenous and purple in color. In thin

Figure 3.12 Porphyry A with deformed clast. Crenulation cleavage also penetrates the porphyry.

Figure 3.13 Deformed mafic dike on the La Scie Highway 2.5 km west of the Nippers Harbour turnoff.

section, clear, rounded quartz and euhedral to subhedral pink feldspar grains occur in a dark grey, black, purple fine-grained matrix.

In thin section there are minor amounts of fine-grained rectangular silicic volcanic fragments with small phenocrysts of feldspar and twinned plagioclase. There are also broken and fractured feldspar grains embayed by the groundmass. Patches of tiny polygonal quartz and large phenocrysts of broken quartz are present. The larger quartz grains are embayed by the groundmass. The fractures in the quartz grains are filled with tiny polygonal quartz grains. Euhedrally outlined twinned plagioclase grains are very altered. The groundmass is spherulitic and consists of seritized quartz and plagioclase. Opaques are scattered throughout the spherulitic groundmass.

DIKES AND SILLS

There are a few mafic dikes and sills within the Southern Group. They are dark grey to black in color and are extremely fine-grained. They are cut by the regional foliation and must therefore be pre or synkinematic (Figure 3.13). Outcrops of these dikes and sills can be seen in several locations: 1) on the La Scie Highway about 1 km east of the Brents Cove Road turnoff; 2) on the Snooks Arm Road about 2 km south from the La Scie Highway turnoff; and 3) on the La Scie Highway about 2.5 km west of the Nippers Harbour Road turnoff.

STRATIGRAPHIC SECTION

STRATIGRAPHIC SUCCESSION IN THE NORTHERN GROUP

The nature of the contact between the mafic schist and an adjacent quartzo-feldspathic porphyry is difficult to establish in the Brents Cove Harbour area. Whether the contact is intrusive, volcanic or tectonic is ambiguous for several reasons: (1) it was difficult to determine if a clear intrusive contact or chill margin could be recognized (Figure 3.14) (2) it was not possible to tell if mafic clasts at the contact are xenoliths or rip up clasts (3) the contact is now faulted in many places (along the south shore of Brents Cove Harbour) and the porphyry is brecciated along the contact (4) the contact is gradational and exhibits gneissic layering in other places (especially along the north west shore of Brents Cove Harbour). Foliated mafic clasts are included in the porphyry (Figure 3.15). These clasts are at various angles to each other and with the foliation of one of the clasts oblique to the foliation of the other clasts. These mafic clasts could represent zenoliths indicating that the porphyry intruded the mafic rocks or the clasts could be rip up clasts along a fault surface. This contact is probably an originally intrusive contact which was later modified by faulting. Figure 3.16 shows a calcite clot with asymmetrical quartz tails indicating a right lateral sense of shear. This is a

Figure 3.14 Contact between mafic schist unit and Porphyry A on south shore of Brents Cove.

Figure 3.15 Foliated mafic clasts incorporated into Porphyry A.

Figure 3.16 Calcite clot in mafic schist with asymmetrical tails indicating right lateral sense of shear.

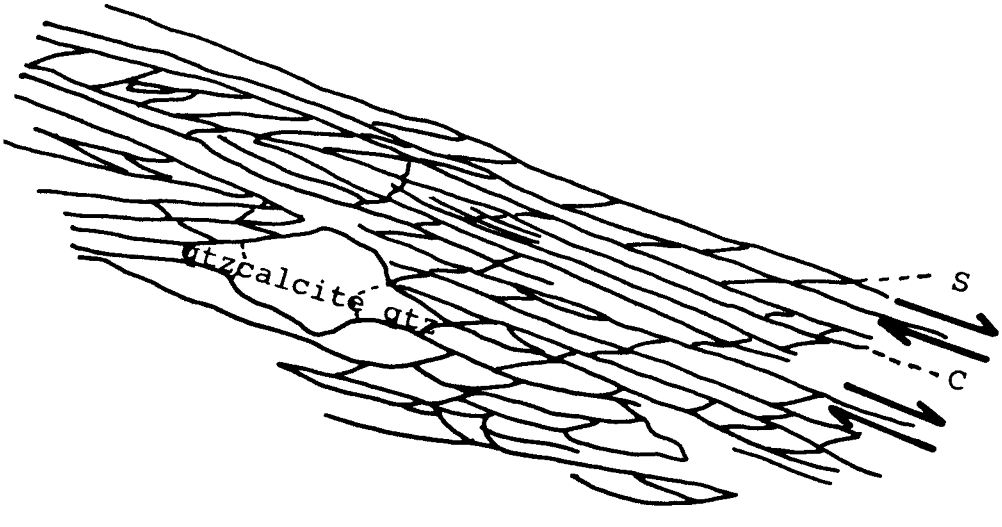

Figure 3.17 Schematic drawing of Figure 3.16.

north over south sense of thrust movement directly at the mafic schist unit and the porphyry contact. The only place that this contact relationship was seen was right on the south shoreline in Brents Cove Harbour and has been severely mechanically weathered by sea water making it impossible to see any slickensides or other fault indicators.

It was not possible to establish the stratigraphic relationship between the mafic units and the silicic units in the Northern Group. Almost the entire length of the Brents Cove Road and the Harbour Round Pond area is undifferentiated porphyritic and non-porphritic silicic rocks with very little outcrop of mafic rocks at all. The shores of Harbour Round Cove, Brents Cove and Grand Cove consist of interbedded silicic, intermediate and mafic flows/pyroclastics and, locally in Harbour Round, metaconglomerate. Figure 3.18 shows the stratigraphy of the Northern Group.

STRATIGRAPHIC SUCCESSION IN THE SOUTHERN GROUP

Figure 3.19 is a stratigraphic column of the Southern Group. The basal unit of the Southern Group is the mafic pillow lavas and associated breccia that occurs directly across from Beaver Cove Pond on the Tilt Cove Road. Continuing northeast along the Tilt Cove Road the pillows

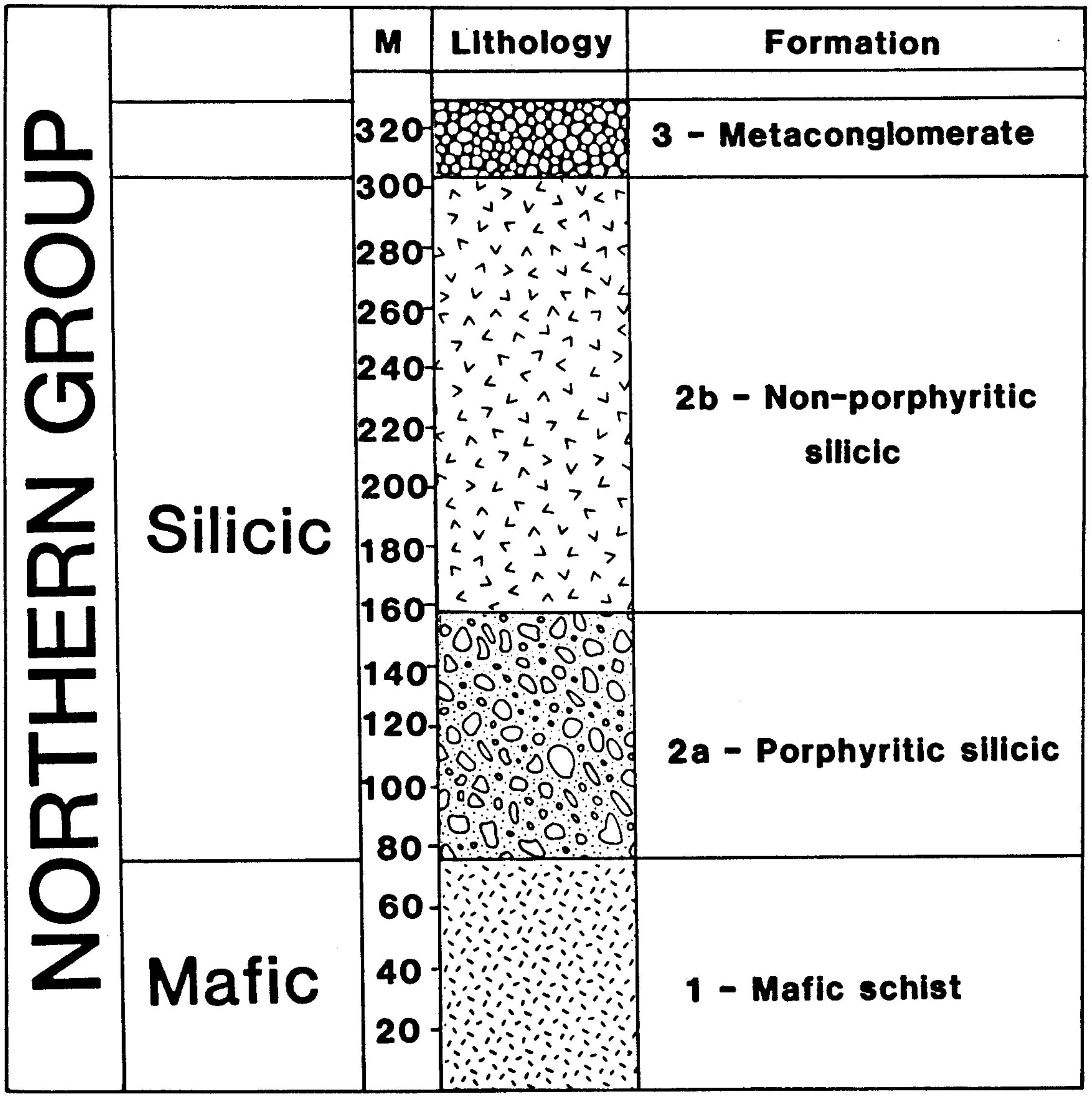

Figure 3.18 Stratigraphic column of the Northern Group.

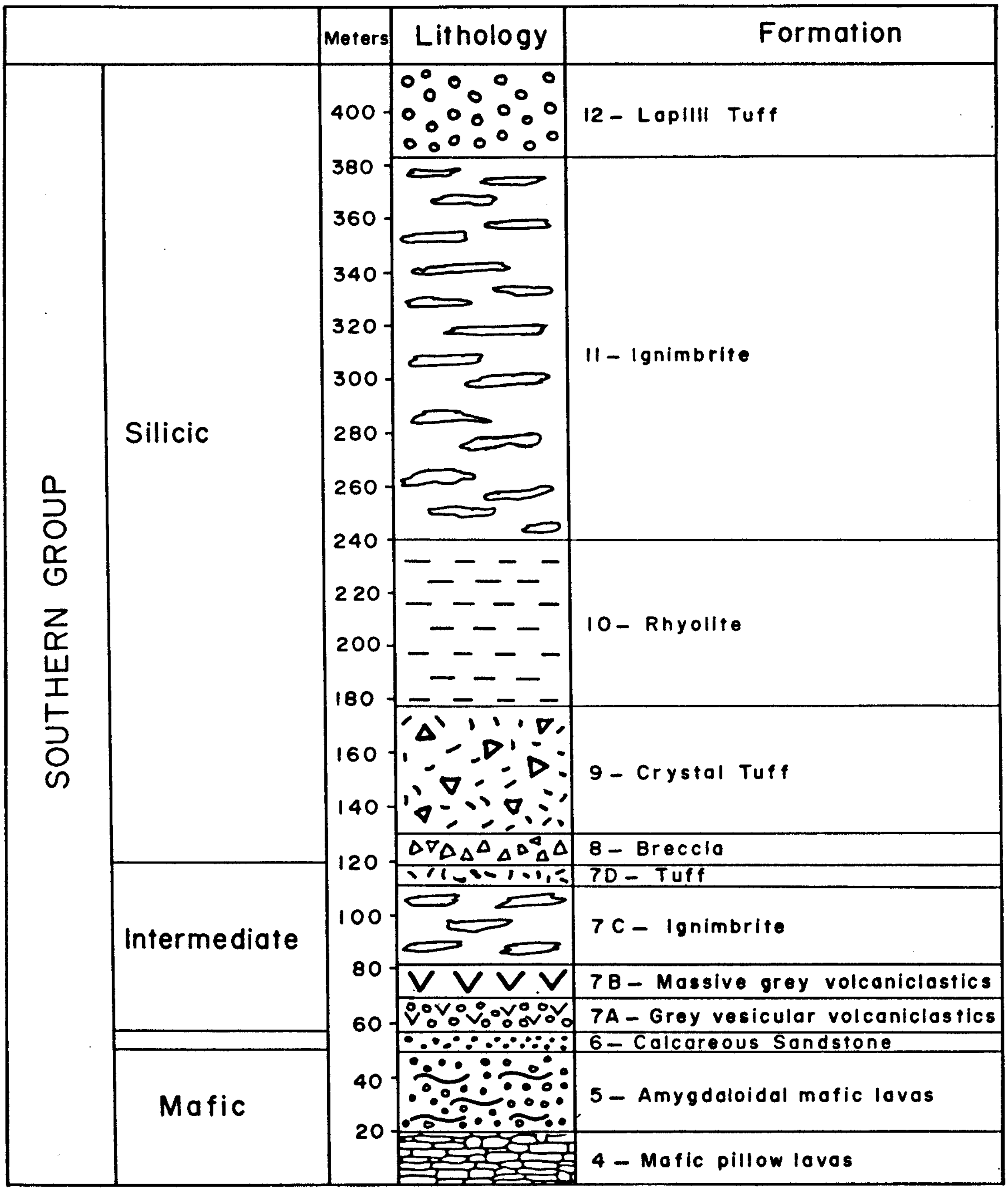

Figure 3.19 Stratigraphic column of the Southern Group.

become well cleaved and almost phyllitic in appearance with a dark sheen to them. There is a lack of continuous outcrop here with a change in cleavage orientation when the exposure reappears. The rock locally becomes so well cleaved that it is broken into small pencil sized pieces. The next unit is a calcareous sandstone. No contact with the basalt unit is seen. The contact may be a fault. Along the rest of the Tilt Cove Road to the La Scie Highway are interbedded mafic lavas with intermediate composition lavas. Right at the north end of Tilt Cove Road are silicic flows (rhyolites).

The base of the Southern Group at Red Cliff Pond is mafic vesicular flows. The next unit is a silicic crystalline tuff. From here to just past the Brents Cove Road turnoff silicic flows and tuffs, and minor mafic and intermediate pyroclastic flows interfinger each other.

CHAPTER FOUR

STRUCTURE

In the description which follows DO refers to structures which formed in unlithified rocks. The subsequent deformations are referred to as Dl, D2, etc. Superscripts S, F and L refer to schistosity, folds and lineations related to the deformations identified by their accompanying numbers.

PENECONTEMPORANEOUS SOFT SEDIMENT DEFORMATION OR FLOW STRUCTURES IN VOLCANICS = DO

Structures, such as contorted layers and brecciated beds, which formed prior to the consolidation of the clastic material, are called penecontemporaneous deformation structures, SO. DO structures were only observed south of the La Scie Highway and within the Southern (Cape St. John Group). These structures vary from convoluted laminations in thinly bedded rhyolitic and other silicic rocks, to box folds, FO, in intermediate composition pyroclastic rocks and banded rhyolites (Figure 4.1). The convoluted lamination consists of folded layers sandwiched between undeformed layers. Two main explanations for the development of these laminations are: (1) gravity sliding of sloping water-saturated pyroclastic

Figure 4.1 Box fold (D0) in a banded rhyolite on the Snooks Arm Road.

Figure 4.2 Volcaniclastic rock with individual clasts exhibiting tectonic fabric.

material and (2) shear deformation caused by an overriding base surge flow (Fisher and Schmincke, 1984). The box folds were most likely formed by the downward sliding of the unlithified pyroclastic rocks on a slope. Reverse and normal grading are common in the pyroclastic rocks of the Southern Group in the southern portion of the area. A sandstone unit at the base of the Southern Group on the Tilt Cove Road west of Beaver Cove Pond is prominently cross-bedded and youngs to the north. The only D0 structures observed within the Grand Cove Group consisted of D0 flow banding structures and igneous textures within individual volcanic clasts that were later incorporated into sediments (Figure 4.2). Other than that no D0 structures were observed within the Grand Cove Group, despite careful examination.

D1

It was difficult to separate S1 from S2. S1 could be related to flattening (compaction) of pumice fragments creating a planar fabric or the result of tectonism. Regardless of the origin of these structures, they were labelled as S1 on Plate 1. S1 is an east-west trending, moderately (55^{o}-70^{o}) north dipping planar schistosity or flattening foliation. It is the most commonly developed structure and is, subject to the assumption stated below, pervasive throughout the entire field area. The foliation is defined by planes into which the clasts and fiamme (pumice fragments) are flattened and aligned (Figure 4.3). Figure 4.4 is a Wulff stereonet projection of the poles to S1. Fabrics with this style and orientation occur in both the Northern and Southern Groups, and are therefore could be correlated as S1. Another possibility is that the S1 fabric in the Northern Group is older, relative to the Southern Group. The S1 fabrics for both groups, however, are discussed together for two reasons: (1) the S1 fabric is similar in style and orientation in both groups and (2) S1 is the oldest foliation recognized in the Northern Group. S1 is best displayed in the volcaniclastic rocks of mafic or intermediate composition. The silica-rich rocks either lack S1 or it is poorly developed within them. No F1 folds were noted within either group.

D2

F2 folds are angular, tight to isoclinal, upright to moderately plunging (45°-60°) and trend roughly east-west (Figure 4.5). Their hinge lines are horizontal to subvertical. Their axial surfaces dip moderately to the north. F2 folds S1 (Figure 4.6). There is a penetrative axial planar foliation associated with these F2 folds. Some F2 folds are cut by shear planes which are sub-parallel to the F2 fold limbs. This shearing could either be contemporaneous with D2 or it may post-date the

Figure 4.3 Flattened pumice fragments defining S1 in a silicic volcaniclastic rock of the Southern Group in the garbage dump on the Snooks Arm Road.

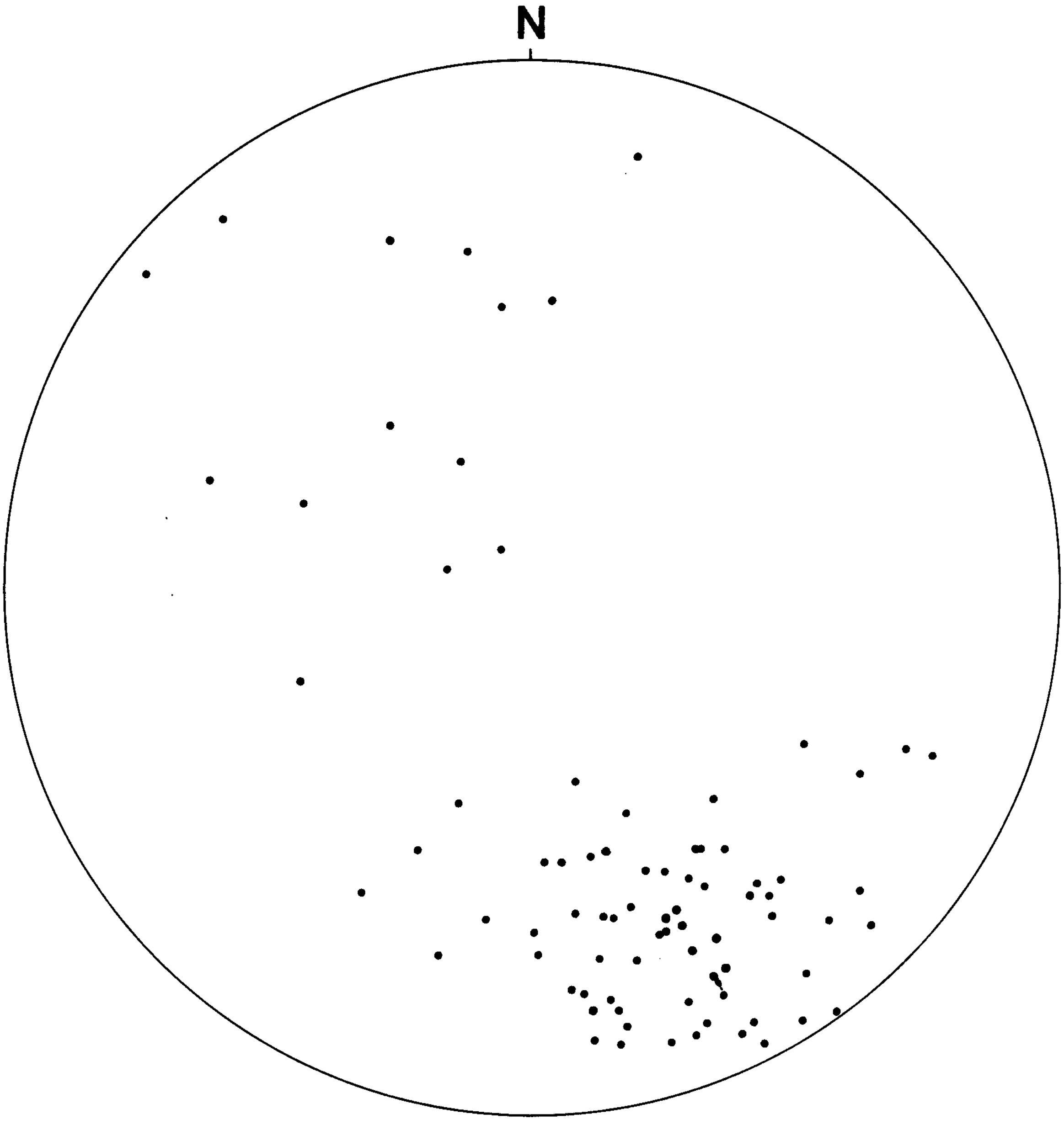

Figure 4.4 A stereographic projection of poles to S1

Figure 4.5 A moderately inclined tight fold (F2) with north dipping axial planar foliation. There are shear surfaces sub-parallel to the fold limbs. View is looking west. Location is on the La Scie Highway, 1 km west of the Snooks Arm Road.

Figure 4.6 A flattened pumice fragment in the S1 foliation plane folded tightly (F2). View is looking west. Location is on the north side of the La Scie Highway 30 m west of Brents Cove Road.

Figure 4.5

Figure 4.6

formation of the F2 folds. D2 folds are pervasive within the Grand Cove Group. No D2 folds were observed in outcrop within the Cape St. John Group but S1 changes orientation on the outcrop scale and examination of the map pattern indicates that the Cape St. John Group is folded on a regional scale by folds with geometries similar to the outcrop scale F2 folds.

A small synform that DeGrace et al (1976) suggested was the major structural feature controlling the map pattern on the entire Baie Verte Peninsula can only be clearly observed at a single coastal exposure at South Bill of Cape St. John. This synform could be a F2 syncline, or less likely it may represent the reorientation of layering as it approaches a mylonite zone which truncates an earlier, originally recumbent syncline at this outcrop (see mylonite discussion to follow). DeGrace et al (1976) following Baird (1955) envisioned this syncline as extending along the entire length of the peninsula in a generally east northeast-west southwest direction. Several careful and detailed north-south traverses were conducted across the peninsula and no evidence of this lengthy syncline was noted, other than the one at South Bill. DeGrace et al (1976) claimed to have used sedimentary way-up indicators, cleavage-bedding intersections and inferred regional relationships to define the axial plane trace of their major fold. This author found graded bedding and other stratigraphic top indicators to be rare, and when found, to be in most cases ambiguous.

Elongate biotite and muscovite crystals within mafic rich rocks define a mineral lineation (L2) which is vertically pitching (Figure 4.7) and lies within the S2 foliation plane. The lineation is at the intersection of the S3 conjugate crenulation planes.

D3

The relative ages of D3 and D4 are not understood since they are not observed to cross-cut each other. They could represent the same progressive deformation episode or two different and distinct episodes of deformation. The structures are arbitrarily assigned to either D3 or D4 and this does not indicate that D3 structures necessarily formed prior to D4 structures.

S3 are conjugate crenulation planes which were observed in outcrop in the central part of the field area, especially along the Brents Cove Road and the north-south traverse from Harbour Round to the La Scie Highway. The stereonet projection of the crenulation cleavage displays the orientation of this conjugate cleavage (Figure 4.8). S3 was observed only within the Grand Cove Group. Conjugate crenulation cleavages are common in areas where tight or isoclinal folds with well-developed axial planar foliation predates the crenulation cleavages (Hobbs, Means

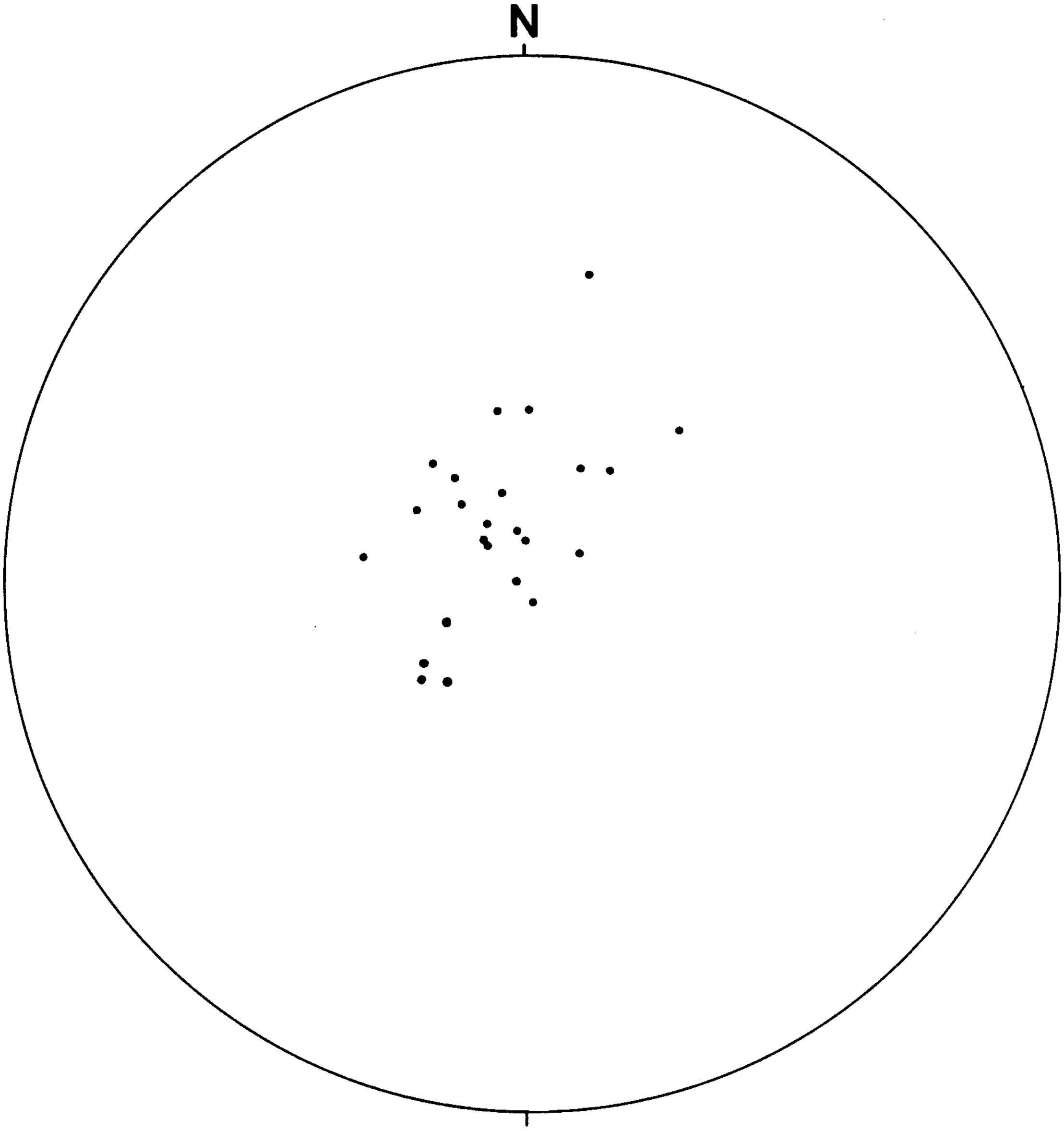

Figure 4.7 A stereographic projection of stretching lineation (L2).

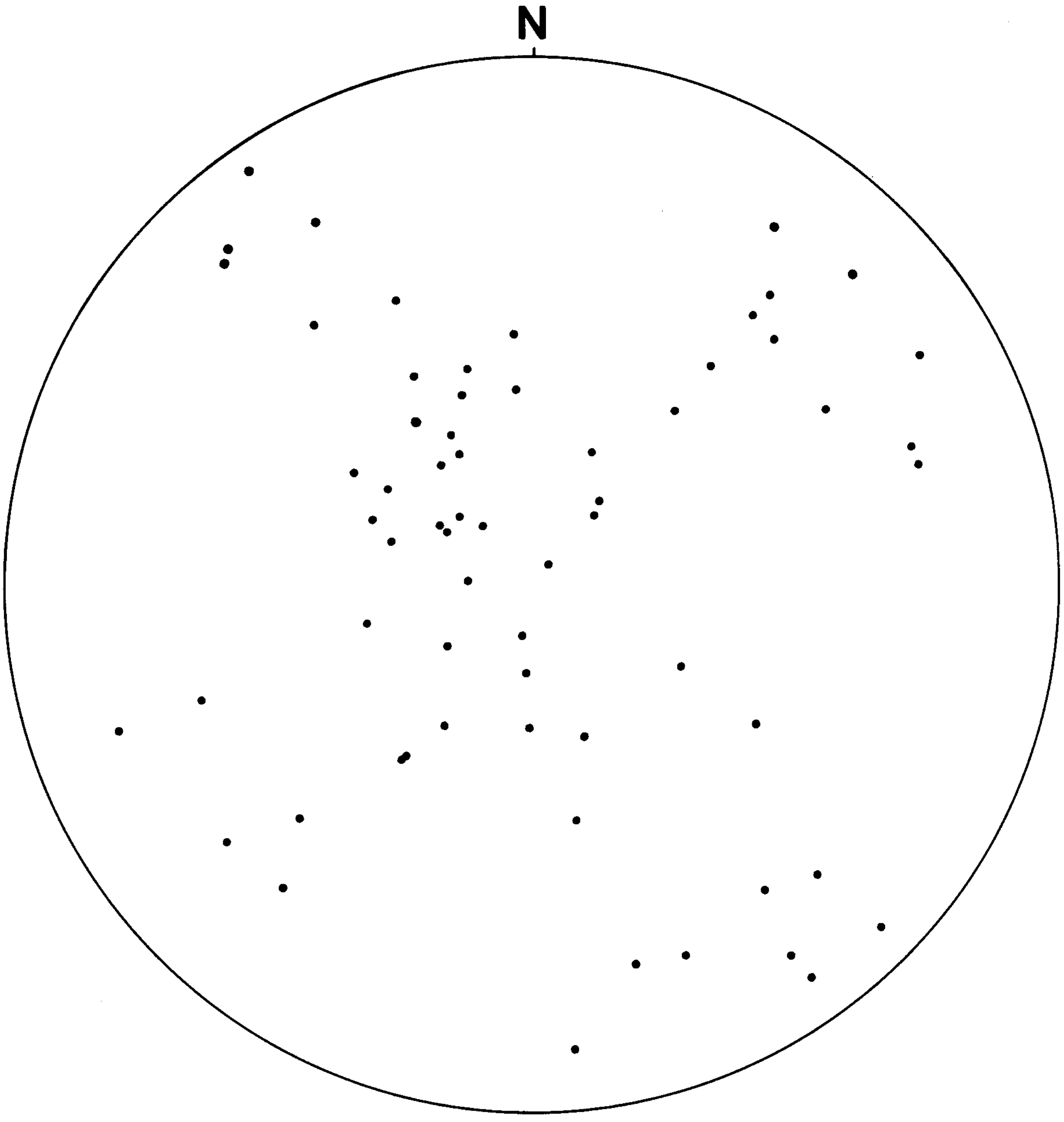

Figure 4.8 A stereographic projection of poles to S3.

and Williams, 1976). S2 is the axial planar foliation associated with the F2 isoclinal folds which predate S3. S3 becomes less intense and dies out in a southeast direction. In the Cape St. John Group S3 is a weak, poorly developed single crenulation cleavage plane. No large F3 folds are found in association with S3.

The only evidence that S3 could be older than D4 is seen in a single thin section taken of a mafic rich rock from the south shore of Brents Cove Harbour. In this thin section the S3 as defined by biotite grains is slightly openly folded. Nowhere else in thin sections or in outcrop is S3 seen affected by D4 structures. Sense of shear along the crenulation planes was carefully looked for in thin section and handsamples but none were found consistently developed.

D4

East-west trending F4 folds refold F2 folds and layering into southward diminishing recumbent open to tight folds (Figure 4.9), with amplitudes of up to 600 m near Brents Cove Head. At Brents Cove, S4 is a flat lying axial planar crenulation cleavage to the F4 folds (Figure 4.10) and becomes poorly developed and eventually dies out in a southeast direction. The spacing between the cleavage planes is up to 8 mm in places. D4 was recognized only within the Grand Cove Group despite careful examination of the Cape St. John Group.

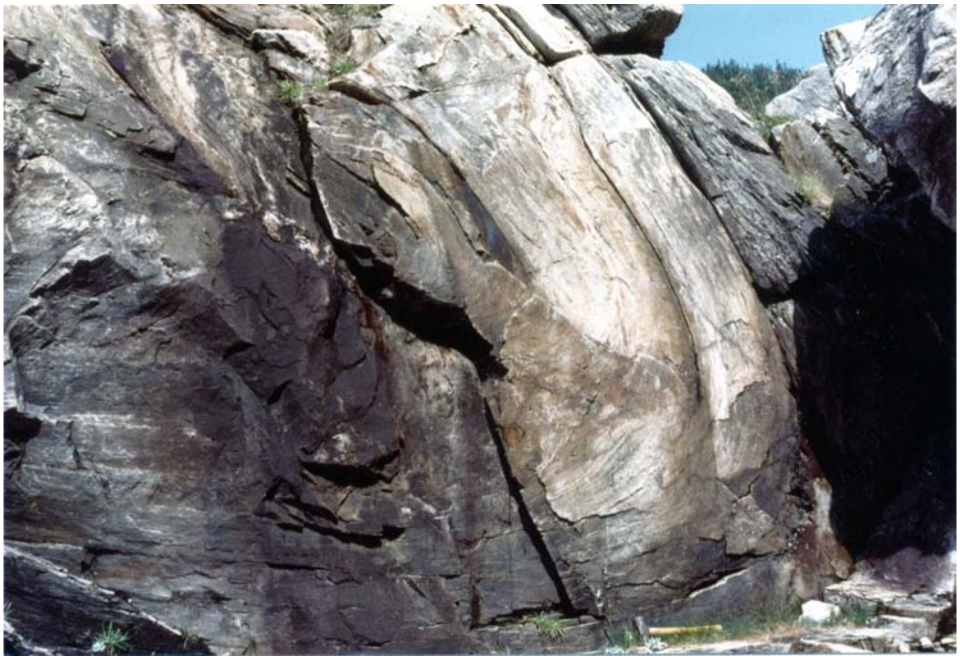

Figure 4.9 A south-facing F4 fold on the north-east shore of Brents Cove. View is looking east.

Figure 4.10 Flat-lying axial planar crenulation cleavage (S4) to F4 folds on the north-east shore of Brents Cove. View is looking east.

MYLONITE ZONE

Highly strained or mylonitic rocks can be observed in several localities on the eastern Burlington Peninsula. The best example is a northeast-southwest striking, steeply southeast dipping zone at a coastal exposure at South Bill (Figure 4.11). Deformed vesicular mafic rocks lithologically similar to the Cape St. John Group along with other rhyolitic rocks lie to the north of the mylonite. Banded dark purplish-black rhyolites are immediately south and grade structurally northward into the mylonite. The foliation within the rhyolite is transposed and vertically plunging rootless folds in the east-west trending foliation are abundant (Figure 4.12). The stretching lineation in and around the mylonite is vertically plunging. Mullion structures (Figure 4.13) and boudinaged quartz veins also (Figure 4.14) have their long axes vertically plunging. The mylonite formed before regional cleavage (S1) development as it is cross cut by it (Figure 4.14). There is a small synform exposed at the base of the cliffs at Middle Bill that folds the mylonite and the surrounding volcanics and volcaniclastic rocks. Figure 4.15 is a detailed map of the Middle Bill area.

It was originally hoped that the rocks on either side of the mylonite zone in thin section would reveal different metamorphic grades and belong to the two different groups. Upon microscopic examination, however, the rocks were found

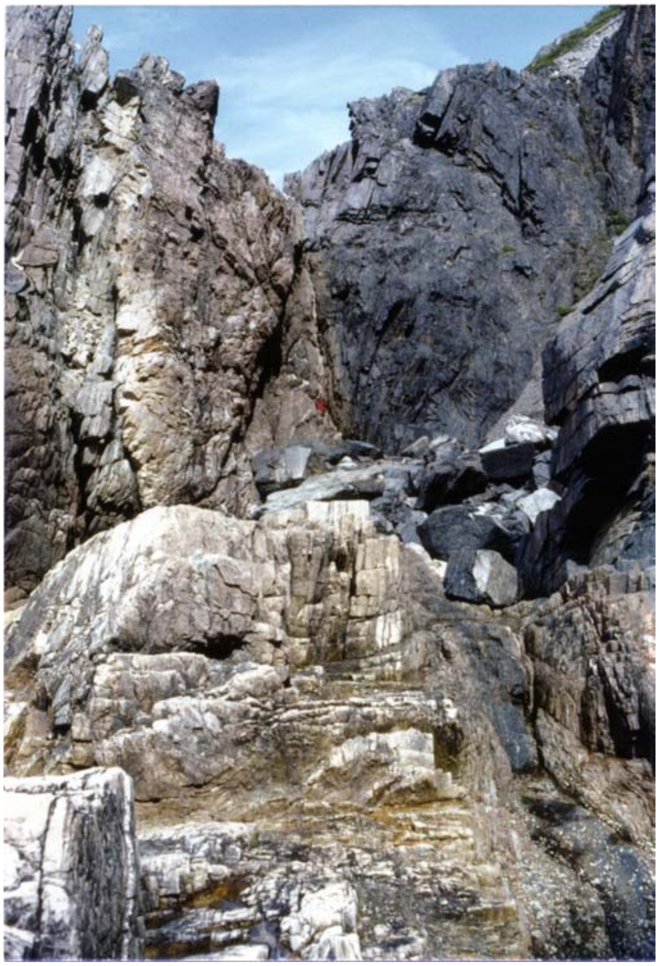

Figure 4.11 Mylonitic rocks separating mafic rocks from silicic rocks at South Bill (person in red jacket for scale) View is looking east-north-east (Photo courtesy of W.S.F. Kidd).

Figure 4.12 Transposed foliation and rootless folds in banded rhyolite within a mylonite zone at South Bill. Rootless folds are east-west trending and vertically plunging within the foliation. View is looking north-north-west (Photo courtesy of W.S.F. Kidd).

Figure 4.13 Mullion structures with long axes vertically plunging. Location is South Bill (Photo courtesy of W.S.F. Kidd).

Figure 4.12

Figure 4.13

Figure 4.14 Boudinaged quartz veins with the boudin long axes vertically plunging. Regional cleavage (S1) cross cuts the mylonitic foliation. Location is South Bill (Photo courtesy of W.S.F. Kidd)

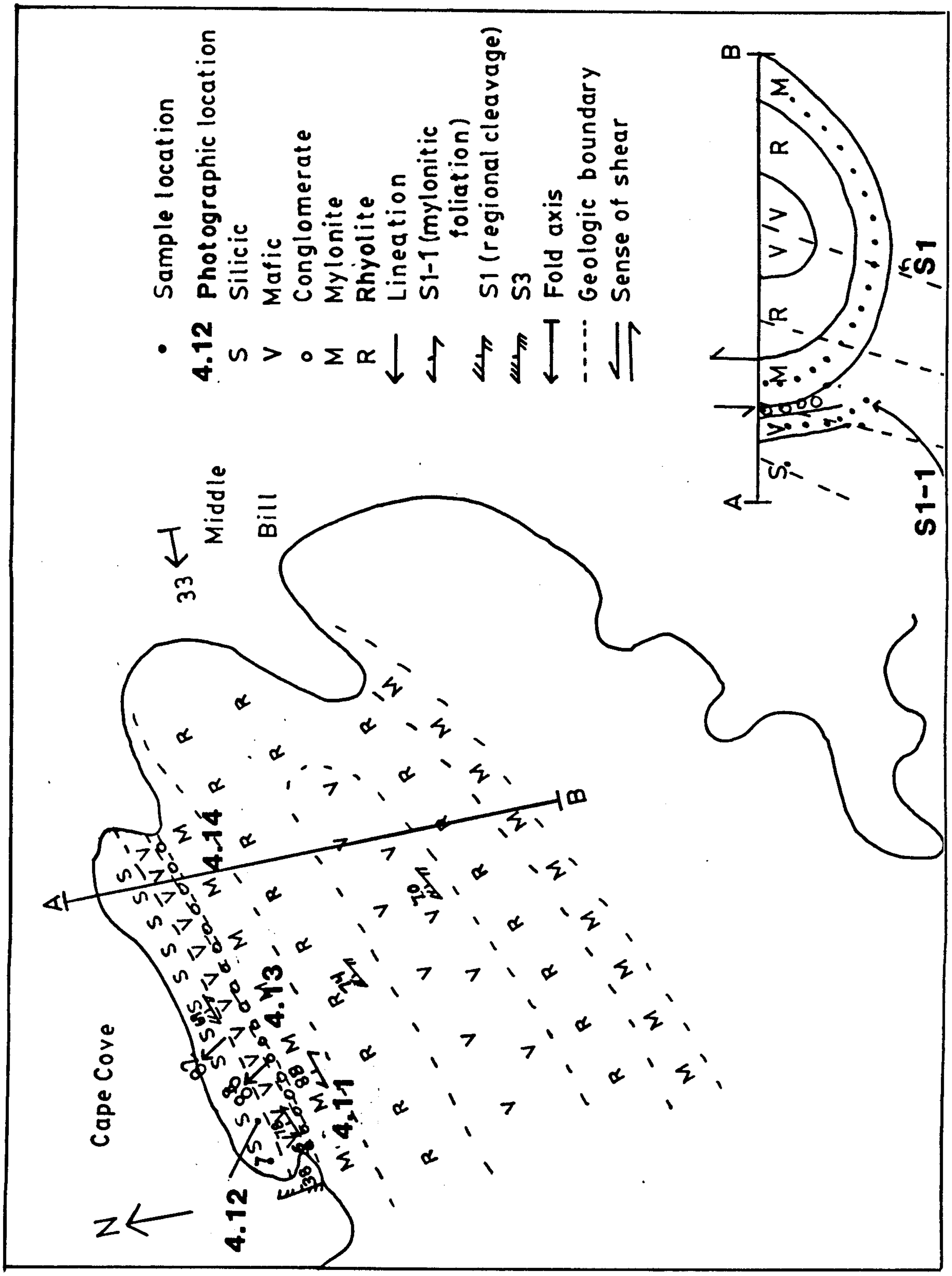

Figure 4.15 Detailed map of Middle Bill area.

to all be recrystallized and of lower greenschist facies assemblages so that it was not possible to determine by this method which group to assign them to. If the rocks on either side of the mylonite in fact do belong to the same group then this mylonite does not represent a good dividing line between the Cape St. John and Grand Cove Groups. If, however, the rocks on either side of this mylonite zone do prove to belong to the Cape St. John Group on the south and the Grand Cove Group on the north this mylonite would represent a significant structural break between the two groups.

On the north shore of Cape Cove, opposite the location described above, there are highly strained rocks. Around the North Bill area samples of mafic rock taken revealed an upper greenschist facies assemblage. It is possible that there is a high strain zone between North and Middle Bill which separates the Grand Cove Group on the north from the Cape St. John Group on the south. More concentrated work along the coast from North Bill to Mother Burke Rock would need to be done to determine this with any certainty.

C and S surfaces as defined by Berthe et al. (1979) are prominent in outcrop at the junction of the La Scie Highway and Tilt Cove Road (Figure 4.16). C planes (cisaillement) are shear planes which are planes parallel to the shear zone boundaries and contain the shear direction (Berthe et al, 1979). S planes are schistosity planes which anastomose in and out of the C planes (Lister and Snokes,

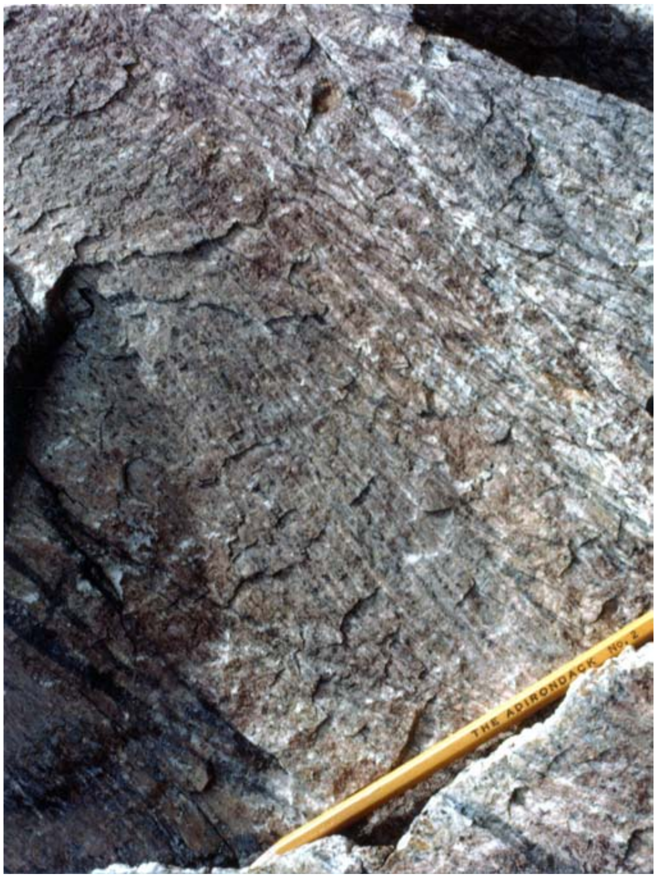

Figure 4.11 Mylonitic rocks separating mafic rocks from silicic rocks at South Bill (person in red jacket for scale) View is looking east-north-east (Photo courtesy of W.S.F. Kidd).

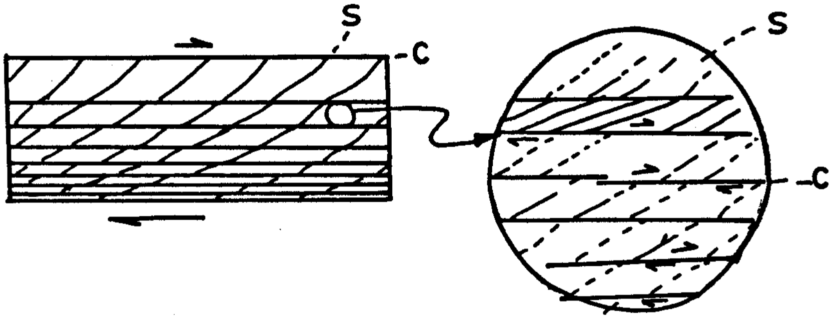

Figure 4.17 The evolution of C and S planes during simple shear.

1984). As deformation intensifies, the S planes rotate into parallelism with the C planes and develop a sigmoidal shape. The angular relationship between the C and S planes define the sense of shear (Berthe et al, 1979; White et al., 1980; Simpson and Schmid, 1984) as shown in Figure 4.17. Sense of shear from the outcrop is ambiguous because it was difficult to distinguish which surfaces are the C-surfaces and which ones are the S-surfaces. Oriented hand samples were cut parallel to lineation and perpendicular to foliation. In thin section it was possible to distinguish between the C and S surfaces and a right lateral strike-slip sense of shear was obtained.

At another mylonite location (near the Nippers Harbour/La Scie Highway intersection) the mylonitic foliation is gently inclined to the north and the lineation is nearly horizontal trending and east-west (Figure 4.18). Convoluted quartz veins cross cut the mylonitic foliation at a 30^{o} angle (Figure 4.19).

Other unequivocal sense of shear indicators are found in thin section. Broken and displaced hard grains in a ductile matrix within a shear zone can be used to deduce the overall sense of shear in the zone (Choukroune and Lagarde, 1977). Etchecopar (1974, 1977) presented this idea with a sheared stack of cards (Figure 4.20). Figure 4.21 shows a broken and displaced feldspar grain within a mica rich ductile matrix. The displacement along the microfaults between the feldspar pieces, which are oriented

Figure 4.18 Mylonitic rocks with gently inclined mylonitic foliation. The lineation is within the foliation plane and is gently plunging. Location is 1/2 km west of the Nippers Harbour Road on the La Scie Highway.

Figure 4.19 Mylonitic foliation cross cuts thin convoluted quartz veins at a 30° angle. Location is on the La Scie Highway 1/2 km west of the Nippers Harbour Road.

Figure 4.18

Figure 4.19

Figure 4.20 A) A model of a sheared stack of cards (Etchecopar, 1977). B) A model of a broken and displaced brittle grain in a ductile matrix. Displacements along the microfaults are opposite to the bulk sense of shear in the cards and rock (Simpson and Schmid, 1984).

Figure 4.21 A broken and displaced feldspar grain in a micaceous matrix indicating an overall right lateral sense of shear. Displacements of the microfaults, however, are left lateral.

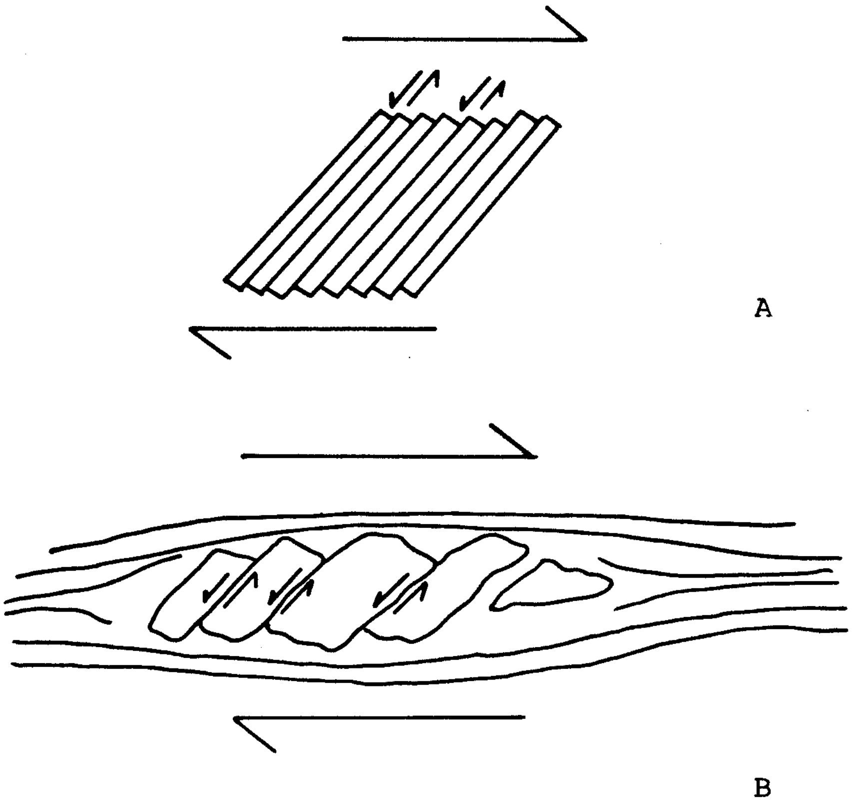

Figure 4.20

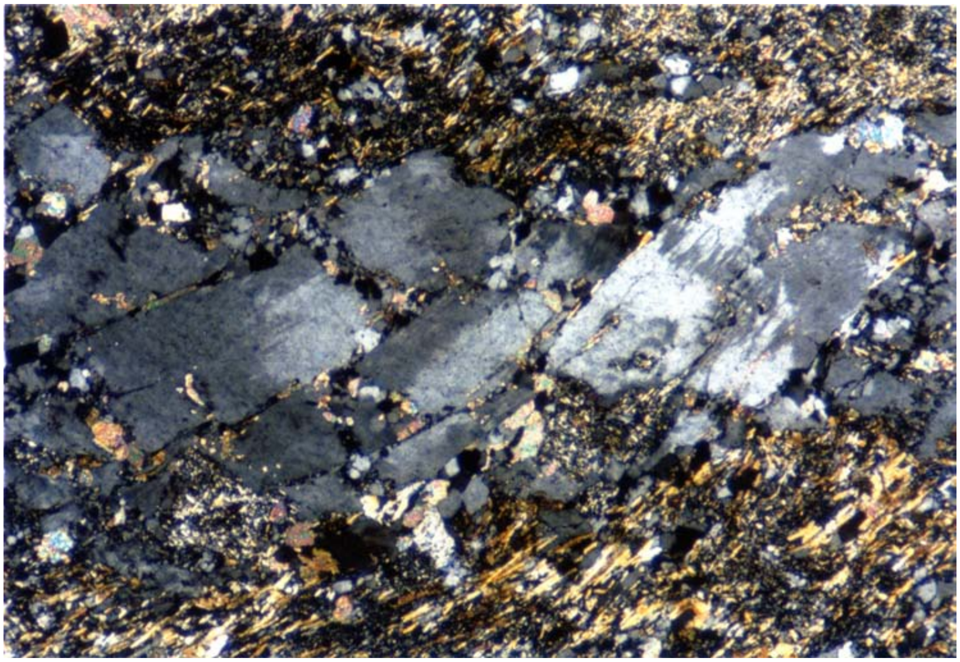

Figure 4.21

oblique to the mylonitic foliation, is a left lateral strike-slip sense of shear and is opposite to the bulk sense of shear of the rock which is right lateral.

Asymmetric augen structures were also used to determine sense of shear. When porphyroclasts are present within a fine-grained ductile matrix, the foliation planes surrounding the porphyroclasts will have fine-grained dynamically recrystallized material of the same composition as the host grain in the shape of tails extending along the foliation plane indicating the direction of shear (Simpson and Schmid, 1984) (Figure 4.22). A rotated quartz porphyroclast with recrystallized asymmetrical tails (Figure 4.23) indicates a right lateral sense of shear using Simpson and Schmidt's (1984) model.

The point of maximum curvature of the foliation where it enters the porphyroclast records the direction of crystal rotation (Simpson and Schmidt, 1984) and was also used to determine sense of shear. For a right lateral sense of shear, the foliation is closely spaced in the upper left-hand and lower right-hand corners (Figure 4.24). Using this criteria, the foliation in Figure 4.25 indicates a right lateral sense of shear as well.

One thin section from the Brents Cove Road and the La Scie Highway junction revealed opposite sense of shear indicators using asymmetrical pressure shadows on pyrite crystals. A cut and polished slab of the rock that the thin section was made from uncovered small tight folds

Figure 4.22 A model showing a porphyroclast within a fine-grained ductile matrix. The foliation planes surrounding the porphyroclasts will have fine-grained dynamically recrystallized material of the same composition as the host grain in the shape of tails extending along the foliation planes indicating the direction of shear (after Simpson and Schmid, 1984).

Figure 4.23 A rotated quartz porphyroclast with asymmetrical tails indicating a right lateral sense of shear (plain light).

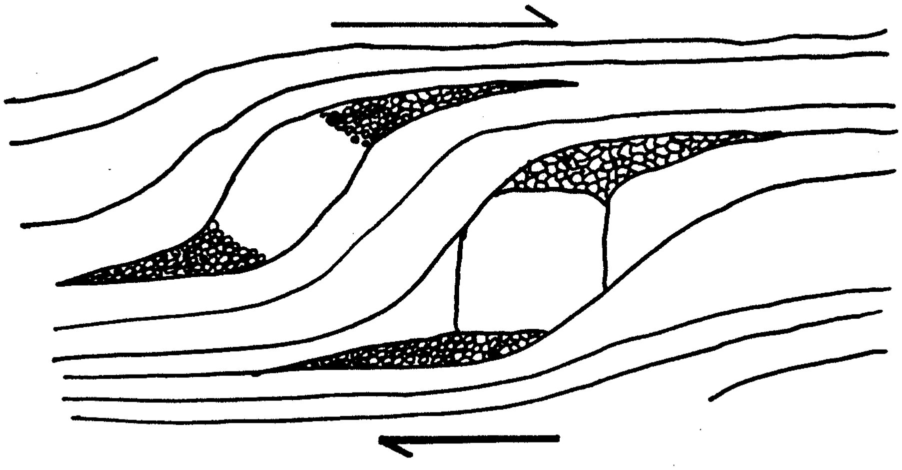

Figure 4.22

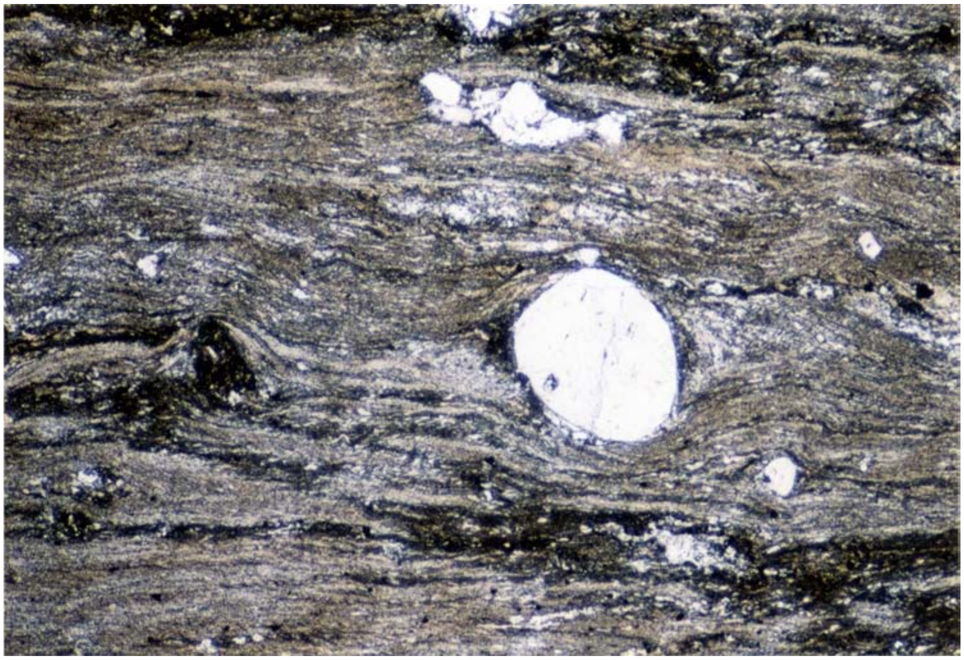

Figure 4.23

Figure 4.24 A model of a rotated porphyroclast showing closely spaced microfolds of the foliation at position A and broadly spaced microfolds of foliation at position B indicating a right lateral sense of shear (after Simpson and Schmid, 1984).

Figure 4.25 Closely spaced microfolds of the foliation as defined by quartz and mica layers entering the upper left-hand corner (position A of the model) of a rotated quartz porphyroclast. The sense of shear is right lateral (polarized light).

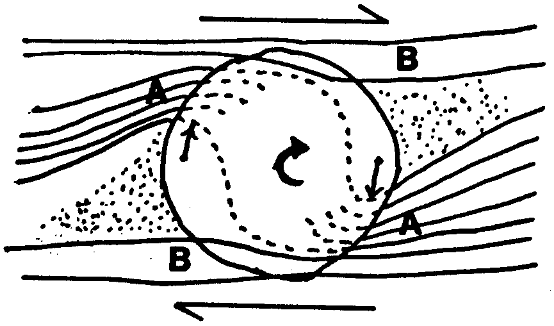

Figure 4.24

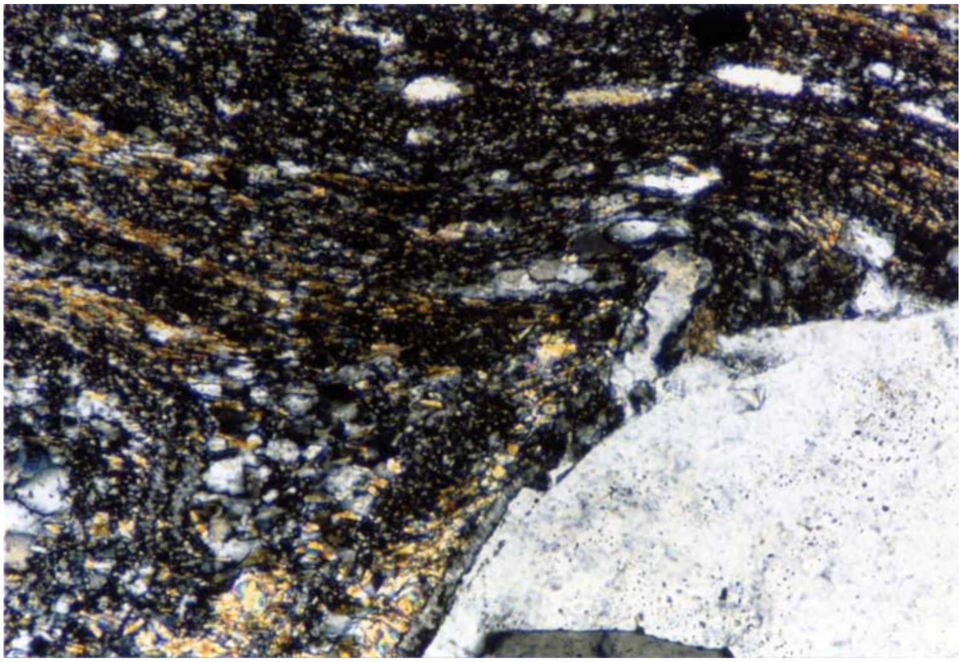

Figure 4.25

which were not seen in the thin section or at the outcrop.

These folds fold the foliation planes in which the pyrite crystals are located. There may be two generations of pyrite crystals since some of them have pressure shadows and others do not. The crystals that lack pressure shadows appear to be scattered haphazardly throughout the rock and do not lie within foliation planes and may be overgrowths. The foliation and folds are cut at an 80° angle by a crenulation cleavage. Some of the pyrite crystals lie directly within the crenulation planes and are affected by slip along these planes.

This slip may be responsible for opening spaces which have allowed the crystals to grow in asymmetrical tails. Some of the tails consist of green biotite and are aligned parallel to the shorter limbs of the asymmetrical kink bands. Some of the pyrite crystals have two mineral phases (quartz and green biotite) composing the tails. Others have only one mineral composing their tails. The two mineral tails could represent two phases of deformation, the first episode pre-crenulation and the second one syn-crenulation. These asymmetrical pressure shadows were not used to determine sense of shear due to the uncertainty of their origin and the effect of the crenulation planes on them.

LATE FAULTING

South of the La Scie Highway the area has also been affected by late faulting. A prominent fault in the area is in a quarry adjacent to the Snooks Arm Road 1/2 km south of the La Scie Highway (Figure 4.26). This is a north over south thrust fault. On the north side of the fault are ignimbrites and volcaniclastic rocks; these are thrust over a weakly-foliated quartz-feldspar porphyry. At the thrust contact accretionary lapilli in a tuff layer become increasingly deformed as the thrust is approached (Figure 4.27). Figure 4.28 is a close-up view of the fault to emphasize the foliation and its change in orientation as it curves into the fault zone. The foliation change is consistent with a north over south motion of thrust. This thrust may be related to the Acadian Orogeny that caused a general north-south shortening across the Newfoundland Appalachians.

Another late fault in the area is in a garbage dump south of the La Scie Highway between the Brents Cove Road and the Tilt Cove Road. It is an east-west striking, steeply north dipping, right lateral strike slip fault (Figure 4.30). There are kink bands in rocks near the fault which show a north side down sense of rotation (Figure 4.31); these were probably formed during shortening in the Acadian Orogeny or if related to the fault, they indicate an early history of north side down motion. The

Figure 4.26 Thrust fault with volcanics on the north (left) thrusted over porphyritic rocks on the south (right). View is looking east. Location is a quarry off the Snooks Arm Road 1/2 km south of the La Scie Highway.

Figure 4.27 Accretionary lapilli-bearing rocks from the thrust fault in above Figure 4.26. Bottom rock was sampled 1.5 m north from the thrust surface. The top rock was taken directly from the fault surface. Both samples were cut perpendicular to the foliation and parallel to lineation. Ruler is scaled in inches.

Figure 4.26

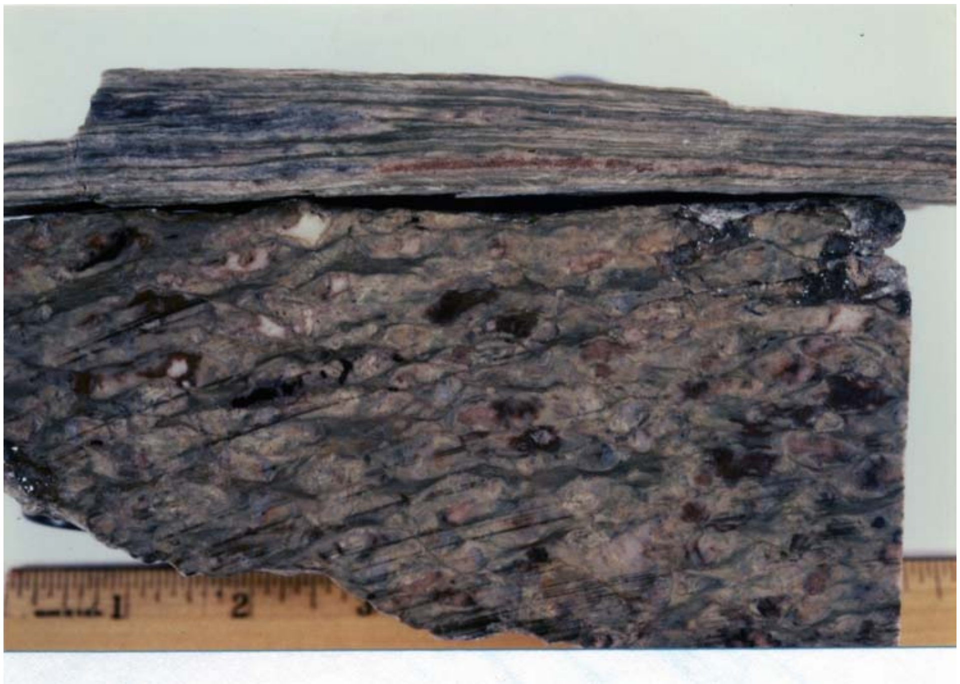

Figure 4.27

Figure 4.28 Close-up view of the thrust fault in Figure 4.26. with a sketch of the foliation changes due to shearing. The foliation change indicates a north over south sense of thrust.

Figure 4.29 Schematic sketch of Figure 4.28.

Figure 4.28

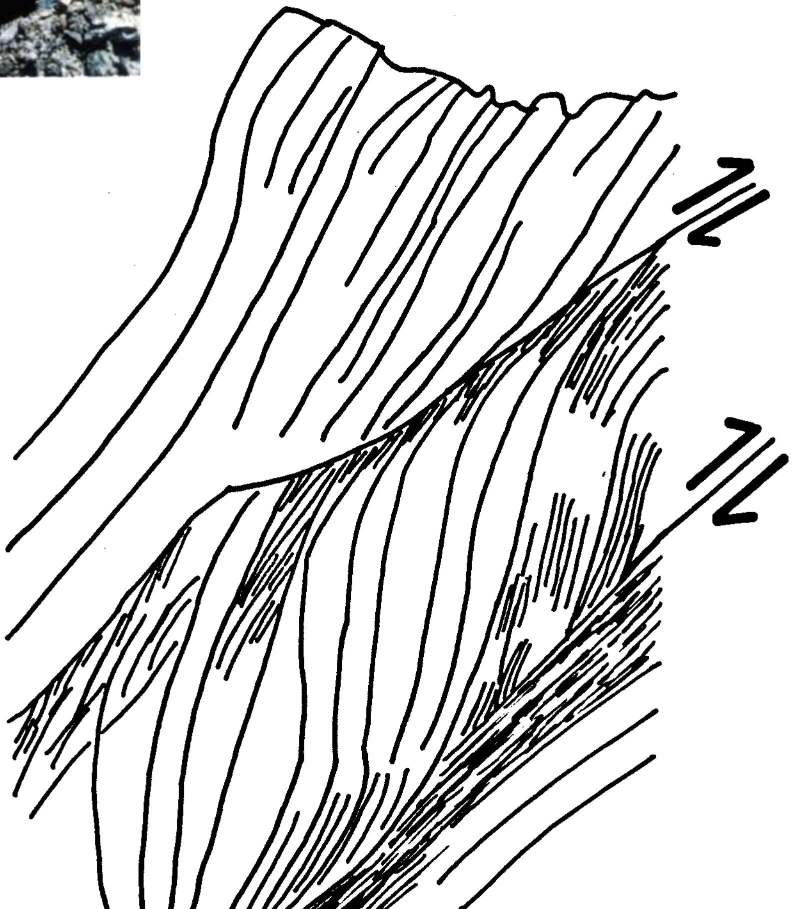

Figure 4.29

Figure 4.30 A right lateral strike slip fault. View is looking east. Location is a quarry off the La Scie Highway halfway between the Brents Cove Road and the Tilt Cove Road.

Figure 4.31 Kink bands from rocks 2 m north of the fault surface in above Figure 4.30. Orientation of the kink bands indicates a south over north direction of movement (north to the left of the photo). Horizontal slickensides are perpendicular to this surface. View is looking east.

Figure 4.30

Figure 4.31

strike slip motion along this fault is probably later than these kinks. Horizontal slickenside steps in fibrous veins of chlorite and quartz indicate a right lateral component of shear. The fault separates volcaniclastic rocks and flows on the north side from silicic lapilli-bearing rocks on the south both belonging to the Cape St. John Group. A narrow zone of fault gouge occurs between these two distinct units (Figure 4.32). The long axes of the individual lapilli are elongated in the foliation (S1) at an angle to and cut by the strike slip fault so shortening must have occurred before strike slip faulting. This fault is parallel to the nearby Carboniferous right lateral Green Bay Fault and I suggest that the displacement in it is also probably Carboniferous, or at least post-Mid Devonian (the age of the Acadian S2 cleavage).

SUMMARY OF STRUCTURES

Figure 4.33 is a sketch map of the various structures found in this area. Although mylonitic rocks could not be traced continuously for any great distance (due to lack of outcrop), they do form a definite restricted belt with thrust faults and strike-slip faults also within the belt. This belt is Zone II in Figure 4.33. Zone I consists of D3 and D4 structures found within the Northern Group rocks. Zone III shows D0 and D1 structures seen in the Southern Group of rocks. No D3 or D4 structures are in Zone III.

Figure 4.32 Fault gouge from the strike slip fault in Figure 4.30.

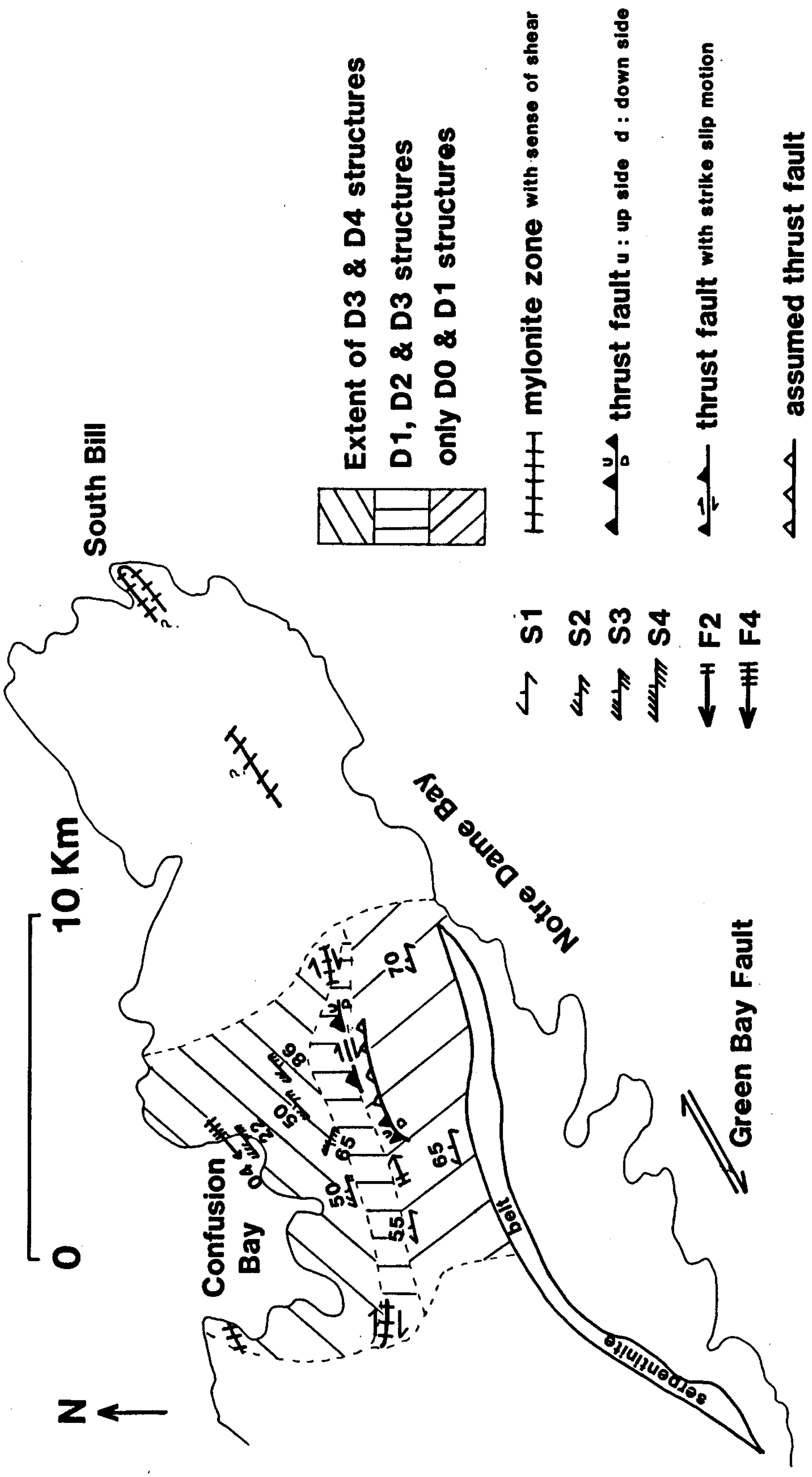

Figure 4.33 Sketch map with summary of structures.

Zone II is a transition zone in which D1, D2, and D3 structures, but no D4 structures can be recognized. This zone includes ductile high strain zones, thrust, and strike slip faults, and represents a dividing zone between the Northern Group and the Southern Group.

METAMORPHISM

Direct evidence of the age of the metamorphic rocks in this area is lacking. The mineral assemblage in the mafic schist unit belonging to the Northern Group consists of: chlorite + actinolite + epidote + albite + calcite and corresponds to the actinolite-greenschist facies (Miyashiro, 1973) which is formed by the low-temperature metamorphism of basic rocks. There is also biotite present in this unit, placing this in the biotite-zone subfacies (Miyashiro, 1973).

It was once thought that metamorphism in this area was pre-Acadian (Church, 1969). This idea was based on the fact that the Pacquet Harbour Group is intruded by the Burlington Granodiorite and that Siluro-Devonian Cape St. John volcanic rocks (Neale and Kennedy, 1967; Neale and Nash, 1963) unconformably overlie the granodiorite. Isotopic studies, however, rule out a post-Acadian age formetamorphism (Bell and Blenkinsop, 1977, 1978; Pringle, 1977; Dallmeyer and Hibbard, 1984). The Rb-Sr data can be interpreted as evidence of a strong thermal event about 350

Ma ago (Late Devonian-Early Carboniferous, Acadian) causing resetting of some of the Rb-Sr isochron ages. In thin section, actinolite is intergrown with biotite and overprints the main foliation and axial planar foliation to folds in the mafic schist unit belonging to the Northern Group. This relationship indicates that some metamorphism must have occured after regional deformation and supports the idea of an Acadian age metamorphism having affected the rocks.

The mineral assemblage in the mafic pillow lava unit in the Southern Group is:

chlorite + albite + epidote + sericite

and corresponds to a sub-greenschist facies and the chlorite-zone subfacies (Miyashiro, 1973). There thus appears to be a gradual increase in metamorphic grade from south to north in this area.

CHAPTER FIVE

CONCLUSIONS

PROBLEMS FOR FUTURE STUDY

It was originally hoped that the questions set forth in the beginning of this thesis could all be answered. The more closely the problems were examined, however, the more questions and problems arose. Previous workers (Neale, 1957; DeGrace et al., 1976) had grouped all the rocks in the area into mafic, intermediate or silicic composition with no subdivisions. During mapping, many other differences were noted between the rocks in the area, and between those in the northern part of the area from rocks to the south.

Rocks south of the La Scie Highway generally have only a flattening foliation in them. Original volcanic structures, such as graded pyroclastic deposits and flow banding in flows, are still clearly recognizable in these rocks. The grade of metamorphism is lower greenschist facies and strain is generally of moderate to low intensity.

Rocks generally north of the La Scie Highway are complexly deformed with little or no original volcanic structures or textures remaining. They have structures, such as conjugate crenulation cleavage planes and recumbent folds, that are not found in rocks further to the south. Metamorphic grade is slightly higher for these rocks in the Northern Group than in the Southern Group.

For the above reasons and reasons already discussed in the Regional Geology section, it seemed that a structural break should exist between the Southern Group and the Northern Group. Ductile high strain zones were found in several locations in this area. These zones had not been recognized by any previous workers. Although these zones could not be traced laterally for any great distances (due to lack of outcrop) and could not be seen to clearly divide rocks belonging to one group on one side of the shear zone from rocks belonging to another group on the other side of the shear zone, they could represent a structural break between these two groups of rocks. Another problem involved several key areas around the La Scie Highway where it was hoped to find rocks of different lithologies and structures on either side of highly strained rocks. These key areas have an abundance of silicic rocks and a lack of mafic and intermediate rocks. The silicic rocks are fine-grained and do not display structures very well. The mylonite zone at South Bill is folded; the mylonitic rocks inland might also be folded, explaining why after several careful traverses the mylonite could not be traced laterally.

A useful project would be to reexamine the mylonitic outcrops and attempt to trace it laterally and determine if it continuously divides rocks with diffferent lithologies and structures. The silicic rocks along the Brents Cove Road and on either side of some of the mylonite exposures should be carefully examined in thin section to look for any differences in microstructures.

Another approach to solving the question of the different ages for the rocks in this area would involve an extensive and careful isotopic study. Since all the 40 Ar/39 Ar and Rb/Sr isotopic ages are thermally reset it might prove more useful to use high precision U/Pb dating of zircons (Krough, T, 1978a; 1978b). The selection of previous sample locations for isotopic dating is questionable. Areas tht might prove useful for future sample locations are: (1) volcanic rocks of the Southern Group along the southern portions of the Tilt Cove Road or the Snooks Arm Road where the structures are well defined and the rocks are of lower greenschist facies (2) the porhyritic body on the south shore of Brents Cove Harbour (3) the porhyritic body in the quarry off the Snooks Arm Road (4) silicic rocks around either Brents Cove or Harbour Round and (5) porhyritic bodies further south on the Nippers Harbour Road than where previous workers have collected samples (See Figure 2.1).

TECTONIC INTERPRETATION

It is believed that during late PreCambrian - early Cambrian times rifting of the passive North American continental margin began (Dewey, 1969; Dewey and Bird, 1971; Dewey et al., 1983), resulting in sea-floor spreading and the formation of the Northern Appalachian Ocean (Iapetus). East dipping subduction of oceanic lithosphere generated the `eastern Fleur de Lys volcanic-arc' during ? Late Cambrian to Early Ordovidian (Dewey et al., 1983). This island arc system collided with the passive continental margin of North America during the medial Ordovician (Caradocian). This orogenic event was responsible for the polyphase deformation and regional metamorphism of the eastern Fleur de Lys Supergroup that occurred at this time and whose effects (uplift, cooling) extended into the Silurian. Extensive plutonism also occurred during this time based on U/Pb and Pb/Pb isotopic dates from zircons in rocks from this area.

The medial to late Devonian Acadian Orogeny involved a continental (Avalonia) collison with the Taconic modified margin of North America (Dewey and Bird, 1971; McKerrow and Ziegler, 1971; Bradley, 1983; Dewey et al., 1983). The younger ages recorded in the minerals in most of the rocks in the eastern Fleur de Lys Supergroup by 40 Ar/39 Ar and Rb/Sr methods of dating are thermally reset, during this younger collision and emplacement of plutons (for example, those in the western Fleur de Lys). As Gondwanaland started to move away from North America (Medial Devonian to L. Carboniferous), it rotated counter-clockwise with respect to North America (McKerrow and Ziegler, 1972) causing right lateral strike-slip faulting in central parts of the system (Bradley, 1983) and Newfoundland during this time. Strong evidence for Carboniferous activity in this area is the Green Bay Fault. This right lateral strike-slip fault cuts and offsets the Snooks Arm Group by about 25 km (Upadhyay et al., 1971). The right lateral strike-slip fault in the garbage dump off the La Scie Highway is parallel to the Green Bay Fault and because of its slip sense is also inferred to be Carboniferous.

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