GEOLOGICAL DEVELOPMENT OF THE SOUTHERN LONG RANGE MOUNTAINS, SOUTHWEST NEWFOUNDLAND: A REGIONAL SYNTHESIS

PART 1

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by

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ABSTRACT

The southern Long Range Mountains in southwest Newfoundland are traversed by a major, northeast-trending fault, the Cape Ray Fault. The fault zone is overlain by Emsian-Eifelian terrestrial sedimentary and bimodal volcanic rocks of the Windsor Point Group. Terranes juxtaposed along the fault began their development as an Early Paleozoic(?) ocean basin (Terrane I-NW) and an Ordovician arc volcano-plutonic and sedimentary basin complex at least partly resting on oceanic crust (Terrane II-SE). These terranes were rapidly converted to continental crust through thrusting, production of synkinematic granitoid rocks, and subsequent convergent wrenching (transpression).

The Cape Ray Fault was formerly called a cryptic suture because pre-Windsor Point Group rocks along its northwest side were considered Grenvillian, and along its southeast side Hadrynian(?). The original criteria for calling the fault a cryptic suture are therefore incorrect (above). Nevertheless, the Cape Ray Fault is considered the most significant late tectonic boundary in the area.

A low pressure granulite facies foliation predating regional deformation in the cumulate metagabbro (MOHO) layer of the oceanic crust northwest of the fault is interpreted tentatively as the result of rapid ocean floor spreading. Thrusting, involving all levels of the lithosphere from

depleted upper mantle to sedimentary and volcanic cover rocks, may have occurred before this cumulate sequence had substantially cooled. Voluminous tonalite was apparently produced and emplaced during thrusting. Thrust-stacked ophiolite and synkinematic granitoid rocks were later intruded by mafic to felsic plutons.

The volcano-plutonic centre southeast of the fault contains a high proportion of dacitic and rhyolitic volcaniclastic rocks. After its maturation, recumbent folding tectonically buried distal parts of the volcanic sequence and the adjacent sedimentary basin. Amphibolite facies metamorphism and partial melting to produce voluminous tonalite-granodiorite followed, after which megacrystic monzogranites were emplaced.

Timing considerations suggest that the thrusting in the northwest was an early Taconic event, and the recumbent folding in the southeast was a late Taconic event.

Later 'transpression'-related deformation events were Acadian to Hercynian. They resulted in locally intense, penetrative deformation, the emplacement of leucogranites, the strike-slip repetition of pre-Acadian sequences, fault-controlled deposition of sedimentary and volcanic rocks, and high angle reverse faulting.

Acknowledgements

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This thesis is dedicated to my father, Ronald W. Chorlton.

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CHAPTER 1: HISTORICAL BACKGROUND AND BASIS FOR THE PRESENT STUDY

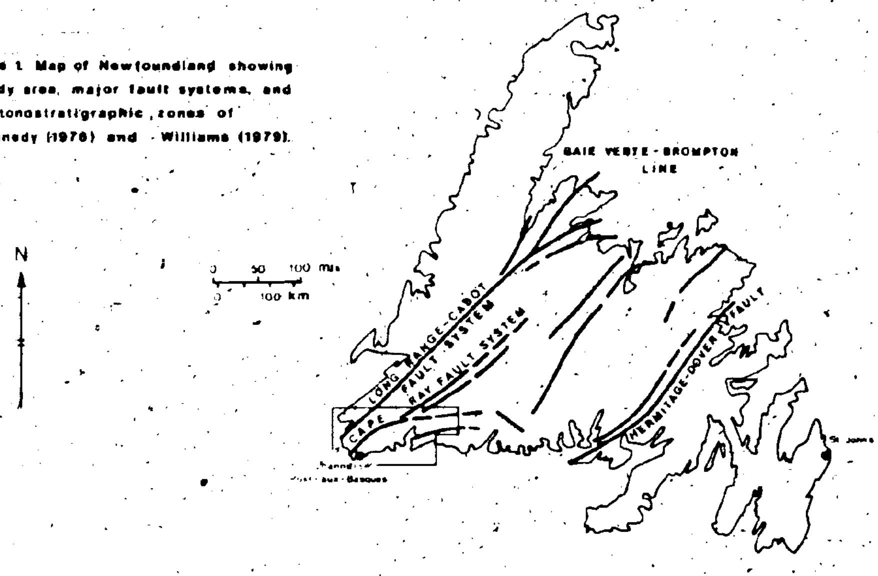
1.1 INTRODUCTION

The southern Long Range Mountains span the southwestern end of the Newfoundland segment of the Appalachian orogenic system (Figure 1a). They form gently undulating, barren uplands which provide fair to excellent exposure of bedrock, enabling field observation of a broad range of rock types over extensive areas, although largely inaccessible by road.

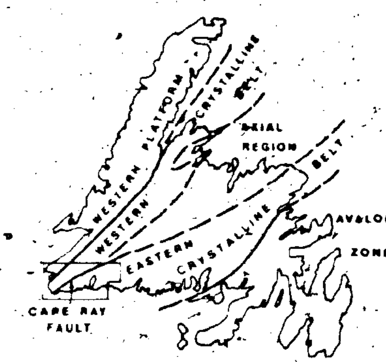
The area has been noted for the alleged presence of an ancient cryptic suture, the Cape Ray Fault, the site of the complete closure of an early Paleozoic proto-Atlantic ocean (Brown, 1973). Gneisses to the southeast of the fault were interpreted as PreCambrian continental crust (Brown, 1972), overlain farther east by Devonian strata (Brown (1975). To the northwest of the fault, exposures of ophiolitic rock have been interpreted as remnants of the early Paleozoic oceanic crust thrust northwestward from the Cape Ray 'suture zone' onto Grenvillian continental crust (Brown, 1976a).

Although very much in tune with contemporary thought, these theories conflicted with prior mapping in two ways. First, there is apparent continuity between the tectonic

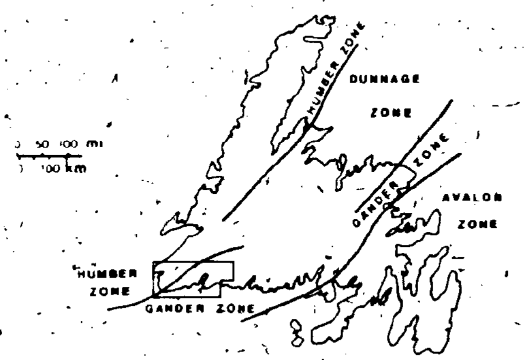
Figure 1. Map of Newfoundland showing study area, major fault systems, and tectonostratigraphic zones of Kennedy (1976) and Williams (1979).



1a: Location of the study area in reference to major fault systems.



1b: Threefold subdivision of the Newfoundland Appalachians as envisaged by Kennedy (1976). Western and Eastern crystalline belts separated by the axial region in Northern Newfoundland are shown juxtaposed along the Cape Ray Fault in Southwest Newfoundland.



1c: Tectonostratigraphic zones of the Newfoundland Appalachians according to Williams (1979). The Humber and Gander Zones are shown juxtaposed across the Cape Ray Fault in Southwest Newfoundland.

fabrics and metamorphic grade between the supposed Precambrian basement southeast of the Cape Ray Fault and rocks previously mapped as Devonian (Cooper, 1954; Power, 1955). To explain this, Brown (1975) invoked intense Acadian microstructural reworking. Secondly, some of the better exposed thrust contacts between ophiolite and supposed Grenvillian crust northwest of the Cape Ray Fault were originally interpreted as intrusive (Phair, 1949). Field and petrographic observations made during this study, while reinforcing many of the observations made prior to Brown as well as recognizing the validity of many of Brown's detailed observations, were impossible to reconcile as a whole with his regional tectonic interpretations. In addition, most of the rocks considered Devonian and used to assign an Acadian age to the regional 'reworking' deformation of Brown (1975) are Ordovician. So intricate were the dilemmas introduced that it was decided that a fresh start in documenting the geology was necessary.

For this purpose, direct field and petrographic observations relating to as many aspects of the geology as possible were gathered, and incorporated into an internally consistent synopsis of deposition, magmatism, and structural and metamorphic history. It is hoped that this synopsis and derivative tectonic models will provide focii for future specialized investigations.

Because of the large volume of observational data considered adequate for this type of regional synthesis, it was considered beyond the scope of the thesis to research many aspects of the metamorphic and igneous petrogenesis; therefore, verification of specific metamorphic reactions inferred from microtextures, or geochemical proof of tectonic affinity or parentage was not attempted. The geological 'scenarios' depicted in this thesis are forwarded only as sensible suggestions compatible with other features of the synopsis and with the concepts of tectonic history of Newfoundland as a whole.

This thesis is separated into two parts. Part I (this volume) contains the main dialogue, from historical background (this chapter) to summary (Chapter 12). Part II contains a systematic documentation of the lithology and petrography of rock units in Chapters 13 through 18, following the arrangement of Chapters 3 through 8 in Part I. Specific observations are drawn from Part II to Part I by means of cross-references. In this way, individual textural or mineralogical details may be utilized more than once without full, descriptive repetition. Part II is also intended as a general background for future studies.

1.2 TECTONOSTRATIGRAPHIC ZONES OF THE NORTHEASTERN APPALACHIANS

1.2.1 Bases for defining tectonstratigraphic zones, and significance of the southern Long Range Mountains in the tectonostratigraphic framework

The general acceptance of plate tectonic processes involving the generation and destruction of oceans or ocean basins as prime factors in the development of several orogenic belts has promoted a growing awareness of the significance of oceanic crust, continental margin and various oceanic sedimentary and volcanic assemblages in the Appalachian orogenic system. After the suggestion by Williams (1964) that Newfoundland could be viewed geologically as a symmetrical system with a central Paleozoic mobile belt of oceanic volcanic and sedimentary rocks separating two continental platforms, Wilson (1966) proposed that the early Paleozoic history of Newfoundland primarily involved the opening and closing of a proto-Atlantic ocean (Iapetus) prior to the Mesozoic opening of the present Atlantic Ocean. Newfoundland was thus partitioned into three geological provinces, the Western platform (Kay, 1966), the Central mobile belt (Williams, 1964), and the Avalon platform (Kay and Colbert, 1965). As plate tectonic models for the evolution of the Appalachians were proposed (Dewey, 1969; Bird and Dewey, 1970; Stevens, 1970), and the plate tectonic affinities of various assemblages, such as ophiolite suites or island arcs were increasingly recognized in Newfoundland (e.g., Church and Stevens, 1971; Upadhyay et al, 1971; Strong, 1972; Strong and Williams, 1972), the northwestern Appalachians were further organized into nine distinct tectonostratigraphic zones, A to I, with contrasting Ordovician or earlier depositional and/or structural histories (Williams et al., 1972, 1974).

On one hand, the authors of this scheme recommended an 'as is' approach to the definition of these zones, i.e., definitions more based on direct observation than on inferences biased by the tectonic theory of the moment. On the other hand, several general hypotheses were offered regarding the nature of the lithospheric crust underlying different zones in the early Paleozoic. Zones A, B, H, and I were founded largely on continental crust, and zones D, E, and F on oceanic crust. It was suggested that zones C and G represent continental margins, where thick continental rise prisms of deformed sedimentary rocks rested unconformably on gneissic and/or migmatitic basement (Williams et al, 1972, 1974).

Developing this theme further, Kennedy (1976) reverted to the earlier threefold system, but distinguished the polydeformed, highly metamorphosed eastern and western marginal zones (zones G and C of the ninefold system) from the weakly metamorphosed, oceanic, axial region of the Central mobile belt (Figure 1b).

Williams (1978, 1979) subsequently reorganized the tectonostratigraphic framework in order to make it more applicable for regional correlation along the whole length of the Appalachian system:

(1) The name Humber Zone was given to zones A, B, and C of the ninefold system, which were underlain in the Early Paleozoic by Grenvillian crystalline rocks belonging to the eastern margin of the ancient North American continent.

(2) The name Dunnage Zone was applied to zones D, E, and F, where Ordovician and older, island arc volcanic and marine sedimentary sequences were deposited on oceanic crust.

(3) The name Gander Zone (Williams, Kennedy, and Neale, 1974) was retained for zone G, where Ordovician and older volcanic and sedimentary sequences were deposited at the eastern margin of the proto-Atlantic ocean on Precambrian? continental crust.

(4) The name Avalon Zone was applied to zone H, formerly the Avalon platform of Kay and Colbert (1965), characterized by Precambrian volcanic and sedimentary sequences related either to rifting and the opening of Iapetus, or to a previous subduction cycle.

(5) The Meguma Zone is occupied by a Cambrian to Ordovician sedimentary assemblage (Meguma Group) possibly related either to ancient northwest Africa (Schenk, 1971), and/or to the Avalon zone.

In this scheme, the latest Precambrian and early Paleozoic history of the Humber, Dunnage, and Gander Zones was implicitly linked to the history of Iapetus, with the major tenet for the separation of the Humber and Gander

Zones from the intervening Dunnage Zone being the transition from continental to oceanic crust (Williams, 1979). A second, more readily observed criterion is the nature of the Ordovician or older supracrustal rocks: continental margin sequences, either of a stable continental shelf or a continental rise clastic prism, in the Humber and Gander Zones, and island arc volcanic and marine sedimentary rocks in the Dunnage Zone. In the Humber Zone, a Cambro-Ordovician carbonate bank of a stable continental shelf gives way eastward to continental rise clastic sequences. The shelf carbonates are absent in the Gander Zone, and quartzofeldspathic sedimentary rocks there are interpreted as part of another clastic wedge (or continental rise prism), presumably derived from the gneissic/plutonic basement terrane on the east side of Iapetus. Volcanic and sedimentary rocks characteristic of the Dunnage Zone probably transgress the oceanic-continental crust boundary in southeastern New Brunswick (Rast and Stringer, 1974; Ruitenberg et al, 1977), and in southeast Newfoundland (Colman-Sadd, 1980), and have led many workers to suggest that the eastern margin of Iapetus was an Andean-type continental margin. Conversely, Blackwood (1980) has suggested the possibility that the continental rise sedimentary rocks of the northeastern Gander Zone partly overlay oceanic crust in the Early Paleozoic.

Broad contrasts in granitoid rock types (sensu lato) have also been used to support the major plate tectonic principles of the tectonostratigraphic framework stated above. In general, potassic granite, quartz monzonite, and granodiorite are more common in the Gander and eastern Humber Zones, whereas intrusions ranging from gabbro to granite, many composite, are more common in the Dunnage Zone, and small trondhjemite and diorite intrusions are associated with both in situ and transported ophiolite suites (Williams et al, 1972, 1974). Megacrystic biotite granite to quartz monzonite, and equigranular, garnetiferous, two-mica leucogranite have been considered diagnostic of the Gander Zone (Kennedy, 1976; Rast et al, 1976), and attributed to anatexis of continental crust (Jayasinghe and Berger, 1976; Strong and Dickson, 1978; Strong, 1980). Intrusions in the Dunnage Zone have, in general, been ascribed to partial melting of the upper mantle and/or island arc magmatism, with local crustal contamination and anatexis (Strong, 1980; Strong and Dupuy, 1982). However, Currie and Pajari (1981) have suggested that some of the peraluminous, two-mica leucogranites characteristic of the Gander Zone were generated in the Dunnage zone by self-heating in a thick pile of Paleozoic metasediments. Strong (1980) has emphasized that the type of granitoid rocks exposed, or the level of emplacement, may strongly depend on volatile content, in addition to original composition, degree of partial melting, and mineral fractionation, i.e., water-saturated, leucogranitic melts would not be able to ascend very far from their source, and would thus be hosted by medium to high grade metamorphic rocks. However, the diapiric rise of such leucocratic granitoid rocks together with their metamorphic envelope due to gravitational instability (c.f. Ramberg, 1967, 1972) after initial emplacement, piercing higher crustal levels as gneiss domes (Eskola, 1949; Thompson et al, 1968; Flood and Vernon, 1978) may complicate interpretation.

It has been generally supposed that the Humber and Gander Zones were juxtaposed in southwest Newfoundland, with the structural omission of the originally intervening Dunnage Zone (Williams, Kennedy, and Neale, 1970; Brown, 1972, 1973, 1975; Brown and Colman-Sadd, 1976; Kennedy, 1976; Williams 1978, 1979). It was the interpretation of the gneissic/plutonic complex to the northwest of the prominent, northeast-trending Cape Ray Fault as Grenvillian crust of the Humber Zone and the gneissic/plutonic complex to the southeast as the Precambrian (Hadrynian?) crust of the Gander Zone (Brown, 1972, 1975) that led to the interpretation of the Cape Ray Fault as the cryptic suture, or locus of the closed-out oceanic tract.

The Cape Ray Fault system forms a wide zone of mylonite, overlain by the presumably Devonian or younger Windsor Point Group (Brown, 1972, 1975, 1977), which was itself intensely deformed by late movements on the fault. Thus, the final activity of the Cape Ray suture, and therefore the final closure of Iapetus, was considered Acadian or younger (Brown, 1976a).

1.2.2 Problems in local interpretation of tectono-stratigraphic zones

The boundaries of the Dunnage Zone with the Humber and Gander Zones on either side are interpreted as transitions from early Paleozoic oceanic crust to sialic crust of the latter zones (Williams, 1979). The Baie Verte-Brompton Line, a narrow belt of serpentinized ultramafic rocks, forms the surface trace of the Dunnage-Humber Zone boundary down the length of the northeastern Appalachians from the north coast of Newfoundland to southeastern Quebec (Williams and St. Julien, 1978, 1982). Another belt of ultramafic rocks, the Gander River Ultrabasic Belt, forms the accepted surface boundary between the Dunnage and Gander Zones in northeastern Newfoundland (Pajari and Currie, 1978; Pickerill at al, 1978; Pajari, Currie, and Berger, 1979; Pajari, Pickerill, and Currie, 1979; Williams, 1978, 1979). However, this line is missing in southeast Newfoundland, where Middle Ordovician marine metasedimentary rocks probably overlap the junction between continental and oceanic crust (Colman-Sadd, 1980). Calc-alkaline arc volcanic rocks of the Dunnage Zone were also deposited on continental crust in New Brunswick (Rast and Stringer, 1974; Ruitenberg et al, 1977). Therefore, it was further suggested that in many areas the true division between the Gander and Dunnage Zones can only be made at the level of the basement (Williams, 1979).

Recognition of Precambrian crust is relatively straightforward in the Humber Zone, except along its eastern side. Well exposed examples of Grenvillian basement rocks are the gneisses and plutonic rocks of the Indian Head Range near Stephenville (Riley, 1962) and the Great Northern Peninsula (Bostock, 1971; Bostock and Cumming, 1973; Bostock et al, 1976). In the west, Grenvillian rocks are locally overlain by plateau basalts (Williams and Stevens, 1969, 1974), cut by mafic dykes dated at about 600 Ma (Stukas and Reynolds, 1974), and overlain by the Cambro-Ordovician carbonate bank of a stable continental margin.

However, in the Gander Zone and the eastern part of the Humber Zone, relationships between basement and cover are obscured by intense deformation, metamorphic recrystallization, migmatization, and plutonism which affect both early Paleozoic cover sequences and rocks which qualify as probable basement. At the eastern edge of the Humber Zone, local gneissic patches surrounded by highly deformed metasedimentary rocks of the Baie Verte Peninsula were interpreted as gneissic inliers resulting from the remobilization of Grenvillian basement (de Wit, 1972, 1974, 1980; Hibbard, in preparation). However, the separation of Gander Zone basement from cover has produced much disagreement. In the northeastern Gander Zone, some workers considered migmatitic gneisses and highly deformed granitoid rocks (Bonavista Bay Gneiss Complex) near the eastern fault boundary as sialic basement to a sedimentary sequence, now exposed further west as medium to low grade metasedimentary rocks (Murray and Howley, 1881; Kennedy and McGonigal, 1972; Blackwood and Kennedy, 1975; Kennedy, 1975, 1976; Blackwood, 1976). On the other hand, Jenness (1963) interpreted the same gneisses as highly metamorphosed equivalents of the metasedimentary rocks further west, an interpretation subsequently re-adopted by Blackwood (1978). As yet, there are no radiometric dates supporting a Precambrian age for any of the gneisses or granitic rocks in this area. In the Bay d'Espoir area of southeastern Newfoundland, basement gneisses (Little Passage Gneisses) have been identified with a tectonic history which predates that of adjacent Middle Ordovician metasedimentary and metavolcanic rocks of the Bay d'Espoir Group (Colman-Sadd 1974, 1980).

Some of the problems of determining ages of the 'basement' gneisses and basement/cover deformation may arise from:

(1) different interpretations of the hiatal significance of local unconformities, such as those near a continental slope or volcanic pile;

(2) difficulty in assessing the meaning of many radiometric age dates on non-fossiliferous gneissic and granitoid rocks, the latter commonly used to place age limits on deformation and deposition episodes;

(3) difficulty in assessing the importance of structural boundaries, either tectonic slides at deep levels in the crust or brittle faults at high levels;

(4) contrasts in deformational style between deepseated and shallow crustal environments (Wegmann, 1965), making difficult the correlation of deformation events between high and low tectonic levels juxtaposed by late

fault movement.

The significance of various ranges in granitoid rock types in the Appalachian system is not yet fully understood, and many exceptions to the previously suggested granitoid zonation were documented during this and other recent studies. For instance, garnetiferous leucogranite, once thought to be confined to the Gander Zone and underlying continental crust, is locally intrusive into metasedimentary rocks within the accepted limits of the Dunnage Zone in northeastern Newfoundland (Currie and Pajari, 1977, 1981).

The age of the deformation and metamorphism which affected both basement and cover rocks of the Gander and the eastern Humber Zones is also a matter of debate. The earliest polyphase deformation was originally thought to have occurred in approximately Cambrian time, prior to the Taconic orogeny, followed by Devonian deformation of the Acadian orogeny (Williams _et al_, 1972, 1974). Medium to high metamorphic grades have traditionally been linked with the early deformation, whereas the Devonian metamorphism in Newfoundland was generally considered low in rank (Williams _et al_, 1972), except very locally in Devonian rocks of southwest Newfoundland (Kennedy, 1976). Kennedy (1975, 1976) proposed that the early deformation was the result of the closure of small, marginal ocean basins in the late Cambrian on the west side of the Dunnage Zone, and in the late Precambrian in the Gander Zone, examples of repetitive processes which might be responsible for much of the structural history of the Appalachian-Caledonian belt as a whole. Subsequent workers have contended that all deformation is mid-Ordovician (Taconic) and younger (Acadian), related to the closure of a much larger 'Iapetus' ocean (Pickerill et al, 1978; Pajari et al, 1979; Williams, 1979; Colman-Sadd, 1980), and most of the deformation and metamorphism in the southeastern Newfoundland Gander Zone is considered Acadian in age (Colman-Sadd, 1980). In the southwestern extension of the Gander Zone (the terrane southeast of the Cape Ray Fault in southwest Newfoundland), deformation related to closure was also considered Acadian, affecting the presumed Devonian Bay du Nord Group of Cooper (1954) and the inferred Devonian or younger Windsor Point Group (Brown, 1976a).

Taking another approach, Hanmer (1981) has attributed the intense, 'polyphase' structures which typify the Gander zone to progressive deformation within a wide Acadian/ Hercynian transcurrent 'megashear' zone. Strong (1980, Figure 2, p.745) has portrayed this 'megashear' system extending across the present Atlantic Ocean to western Europe. Significant involvement of strike-slip deformation, as opposed to simple northwesterly directed head-on closure between the two continental margins of Iapetus, may be responsible for Gander Zone deformation (Hanmer, 1981).

1.3 PREVIOUS WORK IN THE SOUTHERN LONG RANGE MOUNTAINS

1.3.1 History of previous work

First specific mention of the pre-Carboniferous rocks of southwest Newfoundland was made during the nineteenth century (Murray and Howley, 1881), who considered the area to be largely underlain by ?Laurentian granite and gneisses. Early in the twentieth century, metalliferous mineral occurrences (Figure 2a), namely gold in the Diamond Cove quartz vein near Rose Blanche, and Au-Cu (Chetwynd claim) in sheared volcanogenic rocks on Cinq Cerf Brook (Murray and Howley, 1918) drew attention to the area. Activity died down until the 1930's when more gold was discovered in the Diamond Cove quartz vein (Howse, 1934), prospecting in the vicinity of the Chetwynd claim revived (Snelgrove and Howse, 1934; Snelgrove, 1935), and a promising Pb-Zn-Ag and Cu showing (Strickland prospect; Figure 2a) was discovered at the head of La Poile Bay (Howse, 1937; Cooper, 1940a). Since that time, mineral exploration has continued sporadically.

Major contributions to the regional geology of the area were made after the exploration activity of the mid-thirties. The founding contributors were J.R. Cooper, a geologist of the Geological Survey of Newfoundland, and George Phair, a Ph.D. candidate at Princeton University and a temporary employee of the Newfoundland Survey. After

FIGURE 2:

DISTRIBUTION OF MAPPING AND PREVIOUS WORK IN SOUTHWEST NEWFOUNDLAND

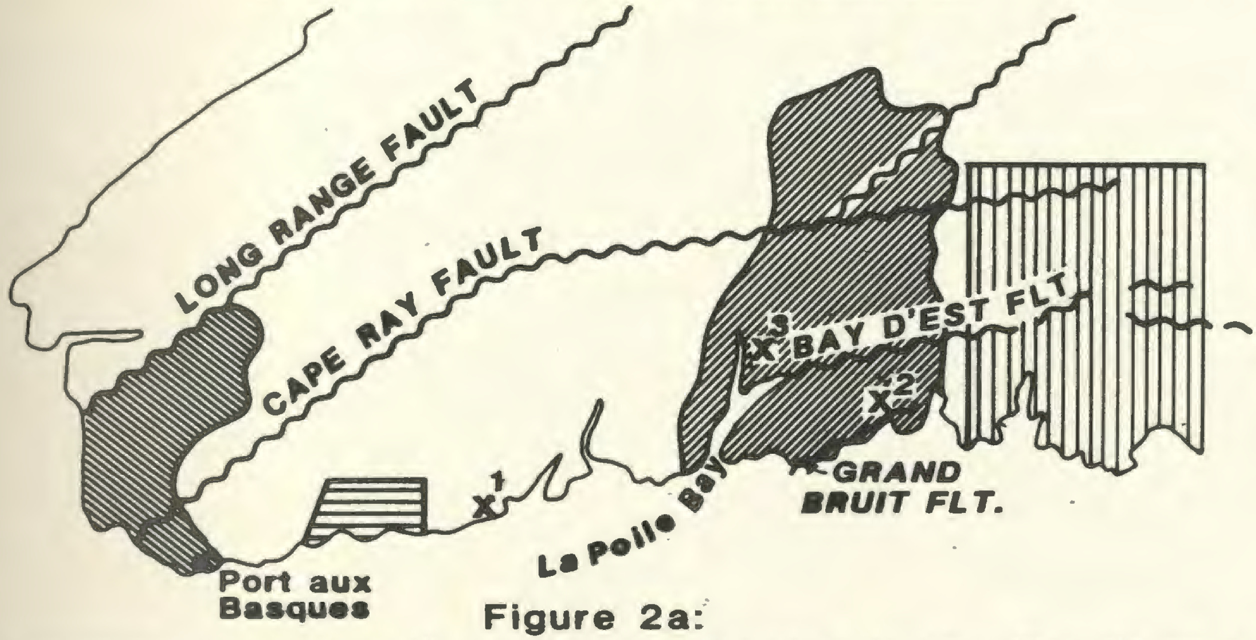


Figure 2a:

Early prospects and early regional mapping in the Southern Long Range Mountains: 1-Diamond Cove quartz vein (Au) 2-Chetwynd Mine (Cu,Au) 3-Strickland Prospect (Pb-Zn-Ag-(Cu))

J.R.Cooper (1954); G.Phair (1949); W.R.Power (1955); G.C.Riley (1959) and Buchans Mining Co. (1957)

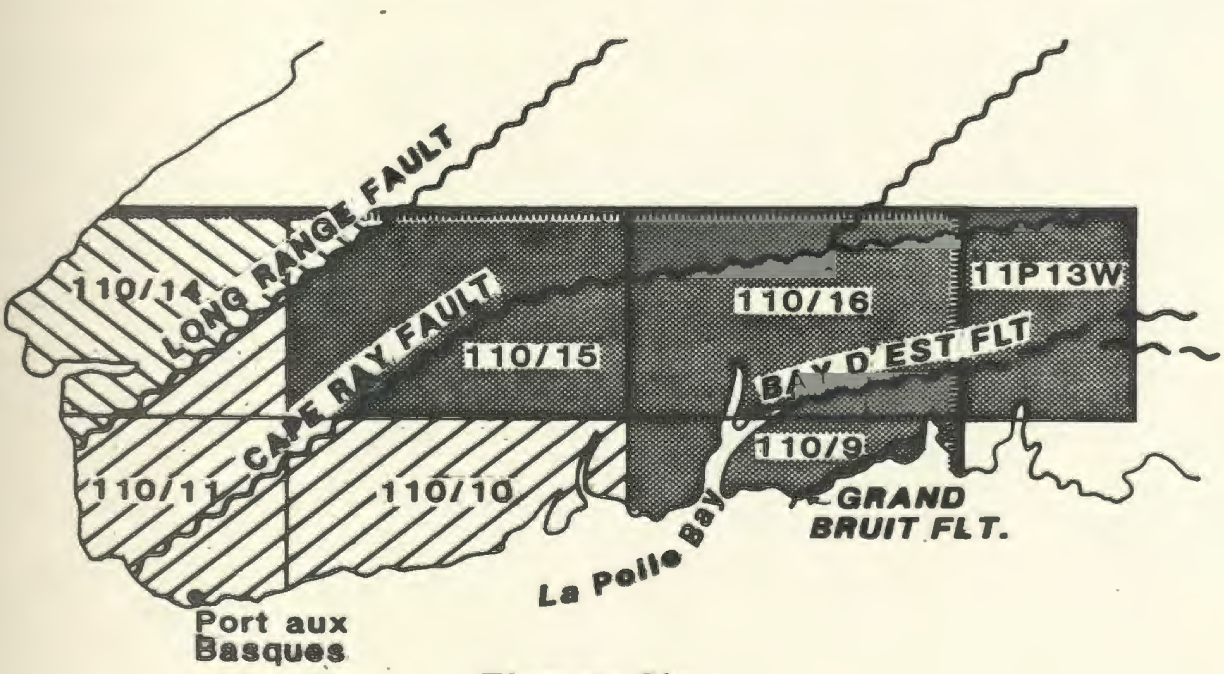


Figure 2b:

Regional mapping of Southwest Newfoundland from which Map 1 was compiled:

P.A.Brown (Brown,1976b,1977; Knight and Brown,1977)

I.Knight (Knight and Brown, 1977; Knight, 1976b)

This study (Chorlton,1978, 1980a, 1980b, 1983 (open file)

The area outlined by hachured line was mapped by Gillis (1972) whose map was not used in compilation mapping a large part of the area now included in the La Poile (11Ø/9) and La Poile River (11O/16) 1:5Ø,ØØØ scale N.T.S. sheets (Figure 2b), Cooper (194Øb, 1954) outlined the basic stratigraphy of rocks underlying the southeastern flanks of the southern Long Range Mountains. The most significant and widely exposed stratigraphic unit defined was the fossiliferous, Early Devonian Bay du Nord Group.

The geology of Cooper (1954) was used as a reference for mapping to the southwest (Power, 1955) and east (Buchans Mining Company, anonymous, 1957). Riley (1959) mapped the area to the east on a larger scale, also referring to the stratigraphy of Cooper (1954).

The major geological components and structure of the pre-Carboniferous terrane exposed in the southern Long Range Mountains east of the community of Doyles were described by Phair (1946, 1949), who also produced a 1:63,36Ø scale map of parts of the Codroy (N.T.S. 11O/14) and Port aux Basques (N.T.S. 11O/11) sheets (Figure 2a). Phair documented an enormous mafic-ultramafic stratiform intrusion with no exposed base. He interpreted this mafic complex to have intruded the overlying metasedimentary rocks pre-tectonically, before the emplacement of synkinematic and post-kinematic granitoid rocks.

J.W. Gillis, who was the first to produce a comprehensive map of the geology of southwest Newfoundland, incorporated the earlier work of Cooper and Phair into his 1:253,44Ø scale reconnaissance map (Gillis, 1972) of the

Port aux Basques map area (Figure 2b). Gillis modified several of Cooper's map units including the Bay du Nord Group, reconciling radiometric K/Ar mineral age dates with lithologic continuities observed in the region. Gillis (1972) was also first to recognize the Cape Ray Fault as a regional fault of major importance.

Another major contributor, P.A. Brown, later drew attention to southwest Newfoundland by incorporating geological features of the area into the plate tectonic framework then being used to interpret the rest of the Newfoundland Appalachians (Brown, 1973, 1976a).

The work of Cooper, Phair, Gillis, and Brown is summarized in Appendix I, with particular reference to field relations and geological interpretations which proved significant during this project. A comparative Table of Formations, including the Table of Formations used in the present study, is given in Table 1.

1.3.2 The ideas of P.A. Brown

Brown (1972) recognized three major geological subdivisions, the Cape Ray Complex (in the west), the Port aux Basques Complex (in the east), and the Windsor Point Group (intervening), in southwest Newfoundland. The first two are separated by, and the third unconformably overlies, the Cape Ray Fault. The Cape Ray Complex occurs northwest of the fault, and comprises a tonalitic leucogneiss with mafic

Table 1: Comparative Table of Formations for the southern Long Ran[...]

this study

PERIOD	GROUP/FORMATION	LITHOLOGY
POST-EARLY CARBONIFEROUS	Leucogranite PLUTON A	Perthite-rich leucogranite
EARLY CARBONIFEROUS	ISLES AUX MORTS BR. GR.	Perthite-rich leucogranite
	dykes	Basalt and dacite dykes
POST-MIDDLE DEVONIAN	Leucogranite PLUTONS B & C	Perthite-rich leucogranite
EARLY-MIDDLE DEVONIAN	WINDSOR POINT GROUP	Terrestial sedimentary and bimodal volcanic rocks; subvolcanic granophyre
	CHETWYND GRANITE	Perthite-rich leucogranite
	PETITES GRANITE?	
	PLUTONS D,E,F,G	
	Leucogranite, pegmatite	Subsolvus leucogranite, pegmatite
	'BURGEO' BATHOLITH	Megacrystic quartz monzonite
	'IRONBOUND' INTRUSION	Megacrystic syenodiorite to granite
SILURIAN?	HAWKS NEST POND PORPHYRY	Porphyritic microgranite
	LA POILE BATHOLITH	Megacrystic granite-granodiorite
	OTTER POINT GRANITE	
	Synmetamorphic granitoid rocks	Migmatite; tonalite, granodiorite, and granite veins and sheets
	CINQ CERF GRANODIORITE	Granodiorite-tonalite with amphibolite inclusions
ORDOVICIAN TO SILURIAN?	Mafic to felsic plutons	Compositionally variable quartz gabbro, diorite, quartz diorite, quartz monzonite, and granite
MIDDLE ORDOVICIAN AND OLDER	LA POILE RIVER GROUP: DOLMAN COVE FM	Massive dacitic crystal tuff
	GEORGES BROOK FM	Mafic, intermediate, and felsic volcanic and volcaniclastic rocks
	HAGGS HILL BR. GR.	Subvolcanic granophyre, granite-trondhj.
	PIGLET BROOK RHY.	Pink rhyolite
	ROTI GRANITE	Subvolcanic porphyry to granite
	Gabbroic to qtz dioritic intrusions	Medium to fine grained gabbro, diorite, qtz diorite, pyroxene cumulates
	ERNIE POND GABBRO	Gabbro-diorite with cumulate wehrlite
	CARROT BROOK FM	Felsic volcaniclastic rocks, feldspathic greywacke, mafic flows (amphibolitized)
	ROUND HILL BR PHYLLITE	Graphitic phyllite with volcaniclastic greywacke beds
	BUNKER HILL BROOK GNEISS	Semipelitic to pelitic schist and gneiss, amphibolite, migmatite
EARLY TO MIDDLE ORDOVICIAN	Tonalite and other synkinematic granitoid rocks	Biotite tonalite, tonalite to granodiorite, tonalite to granite, gneissic, garnetiferous tonalite
EARLY ORDOVICIAN	BLUE HILLS OF COUTEAU 'OLDER' GABBRO	Varietextured, subophitic metagabbro intruded by metadiabase and plagiogranite
EARLY ORDOVICIAN OR OLDER?	LONG RANGE MAFIC-ULTRAMAFIC COMPLEX	Layered peridotite, dunite, feldspathic dunite, troctolite, ol-gabbro, anorthosite; massive, varietextured metagabbro intruded by metadiabase and plagiogranite; mafic volcanic and hypabyssal rocks; semipelitic paragneiss, marble, calc-silicate rocks, siliceous schist, breccia

after Brown (19[...]

PERIOD	GROUP/FORMATION	
CARBONIFEROUS?	ISLES AUX MORTS BR GR	Course [...] granite[...]
CARBONIFEROUS	WINDSOR POINT GROUP OR EARLIER	Ignimbr[...] and con[...]
DEVONIAN OR EARLIER	CAPE RAY FAULT ZONE	Mylonit[...]
	LA POILE BATHOLITH	Course [...] potass[...]
	PETITES GRANITE	Medium [...] potass[...]
	ROSE BLANCHE GRANITE	Medium [...] garnet[...] granod[...]
	BAY DU NORD GROUP	Predomi[...] with in[...] and con[...]
	HARBOUR LE COU GROUP	Pelit[...] with g[...]
CAMBRO-ORDOVICIAN	LONG RANGE MAFIC-ULTRAMAFIC COMPLEX	Layer[...] troctol[...] by mas[...] by dun[...] lherzo[...]
	CAPE RAY GRANITE	Pink, [...] to meg[...] coarse [...] potass[...]
PRECAMBRIAN	LONG RANGE GNEISS	Tonali[...] of ear[...]
	PORT AUX BASQUES GRANITE	Pink, [...] feldsp[...]
	PORT AUX BASQUES GNEISS	Well b[...] melano[...] stauro[...] sillim[...]

1 of

able of Formations for the southern Long Range Mountains, southwest Newfoundland.

after Brown (1976a, 1977)

PERIOD	GROUP/FORMATION	LITHOLOGY
ARBONIFEROUS?	ISLES AUX MORTS BR GR	Course grained, pink, equigranular granite
ARBONIFEROUS	WINDSOR POINT GROUP OR EARLIER	Ignimbrite, rhyolite, shale, tuff, and conglomerate
EVONIAN OR ARLIER	CAPE RAY FAULT ZONE	Mylonitized gneiss and granite
	LA POILE BATHOLITH	Course grained, megacrystic, potassium feldspar-rich granite
	PETITES GRANITE	Medium grained, equigranular, potassiun feldspar rich granite
	ROSE BLANCHE GRANITE	Medium grained, equigranular, garnetiferous leucogranite to granodiorite
	BAY DU NORD GROUP	Predominantly slates and phyllites with interbedded sandstone, grit, and conglomerate
	HARBOUR LE COU GROUP	Pelitic to semipelitic schists with garnet and local sillimanite
AMBRO-RDOVICIAN	LONG RANGE MAFIC-ULTRAMAFIC COMPLEX	Layered sequence of norites, troctolites and gabbros, overlain by massive gabbro and underlain by dunite, harzburgite, and lherzolite
	CAPE RAY GRANITE	Pink, mafic-poor, equigranular to megacrystic quartz monzonite; coarse grained, mafic-poor, potassium feldspar-rich granite
PRECAMBRIAN	LONG RANGE GNEISS	Tonalite gneiss with inclusions of earlier amphibolite and gneiss
	PORT AUX BASQUES GRANITE	Pink, equigranular, potassium feldspar-rich granite
	PORT AUX BASQUES GNEISS	Well banded leucogranitic and melanocratic gneiss with garnet, staurolite, kyanite, and sillimanite

after Cooper (1954)

PERIOD	GROUP/FORMATION	LITHOLOGY
DEVONIAN	CHETWYND GRANITE	Granite
		Derivative dyke rocks
		Porphyritic biotite granite and injection gneiss
		Hornblende-biotite granite
		Pink and grey granite
		Gneissic biotite-hornblende granite, granite porphyry
		Diorite, quartz diorite, gabbro, peridotite, amphibolite, serpentinite
	DOLMAN GNEISS	Fine granitic gneiss, granulite, orthogneiss
	LA POILE GROUP	Rhyolite, trachyte, tuff, minor shale, arkose, conglomerate
		Schist, paragneiss, conglomerate, minor volcanic rocks
LOWER OR EARLY MIDDLE DEVONIAN	BAY DU NORD GROUP	Slate, argillaceous quartzite, greywacke, grit, conglomerate, minor volcanic rocks
PRE-DEVONIAN (PRECAMBRIAN or PALEOZOIC)	NORTHERN GRANITE	Granite, granite-gneiss
	KEEPINGS GNEISS	Granite-gneiss, hornblende gneiss, amphibolite, banded paragneiss

2 of 2

pods (Long Range Gneiss) intruded by deformed and undeformed granitoid rocks (Cape Ray and Red Rocks Granites). The Port aux Basques Complex is composed of banded gneisses which were intruded by granitoid rocks (Port aux Basques Granite) after the first deformational episode and before the second.

The Cape Ray Complex was further correlated with the Grenvillian rocks of the Indian Head Range in the Stephenville area (Riley, 1962) and other Precambrian gneissic/plutonic rocks (Bostock, 1971) forming the sialic basement to the western continental margin of the Newfoundland Central mobile belt (Brown, 1972). Similarly, the Port aux Basques Complex was likened to the Little Passage Gneisses (later named by Colman-Sadd, 1974) of the Bay d'Espoir area, interpreted by Colman-Sadd (1974, 1980) to be the Precambrian (Hadrynian?) continental basement of the eastern margin of the Central mobile belt. This lead Brown (1973) to interpret the Cape Ray Fault as a cryptic suture which juxtaposes the two Precambrian continental gneissic basement terranes from opposite sides of the Early Paleozoic proto-Atlantic Ocean. Devonian sedimentary rocks mapped by Cooper (1954) were considered as sedimentary cover to the eastern continental basement, the Port aux Basques Complex.

Brown (1975) subsequently extended his structural and metamorphic study eastward to the extension of the Bay du Nord Group as mapped by Gillis (1972) around Garia Bay. Microstructural reworking (related to the development of tectonic slide zones) was invoked to explain the structural/metamorphic similarity of the western parts of the Devonian sequence with adjacent 'Precambrian basement' (Brown, 1975), a feature which had earlier lead Gillis (1972) to modify some of the original mapping of Cooper (1954).

The proposed closing-out of the Early Paleozoic proto-Atlantic ocean along the Cape Ray 'suture', as well as the interpretation of the granitoid and gneissic rocks west of the Cape Ray Fault as a Grenvillian crystalline association, provided for a new interpretation of the mafic-ultramafic stratiform complex of Phair (1949). The complex had formerly been likened by Buddington (1939) and Phair (1949) to the Bay of Islands Complex (Smith, 1958), the latter complex later recognized as ophiolite (Church and Stevens, 1971). The southwest Newfoundland mafic stratiform complex was accordingly interpreted as ophiolitic by Brown (1976a), who gave it the name Long Range Mafic-Ultramafic Complex. Brown (1976a, 1977) further suggested that the Long Range Mafic-Ultramafic Complex represented remnants of ophiolitic crust obducted from the Cape Ray Fault zone onto the Grenvillian Long Range Gneiss to the northwest. This proposal implied that the field relations documented by Phair (1946, 1949), namely that the stratiform mafic complex underlies the migmatites and metasedimentary gneisses, are inverted. Mafic meta-igneous rocks of Phair's complex which form rafts within some of the granitoid rocks, and amphibolite which is interlayered with metasedimentary rocks and lit-par-lit granitoid sheets, were included by Brown in the Long Range Gneiss. Other fairly large exposures of Phair's mafic complex were considered thrust-bound ophiolite remnants, and included in the Long Range Mafic-Ultramafic Complex.

1.3.2 Problems introduced during previous work in southwest Newfoundland

There are two major conflicts in field interpretation apparent from the earlier geological studies in southwest Newfoundland. The first conflict concerned which rocks should be included in or correlated with the Early Devonian Bay du Nord Group of Cooper (1954), and the relationships of this group to adjacent injection and/or migmatitic gneisses, and amphibolite (Appendix I). Power (1955) and Riley (1957) both referred to this problem, for which the work of Cooper (1954), Gillis (1972), and Brown (1975) indicated different solutions. Secondly, there was outright disagreement about whether the Long Range Mafic-Ultramafic Complex is tectonically below (Phair, 1946, 1949) or above (Brown, 1976a, 1976c, 1977) the metasedimentary gneisses between the Long Range Fault and the Cape Ray Fault, and also whether the earliest granitoid rocks in that area intrude the mafic complex (Phair, *op. cit*) or tectonically underlie it (Brown, *op. cit.*) (Appendix I).

These controversies relate directly to whether or not Precambrian basement terranes are exposed in southwest

Newfoundland, northwest of the Cape Ray Fault as part of the Humber Zone and southeast of the fault as part of the Gander Zone. The suggestion that the Dunnage Zone has been pinched out along the Cape Ray Fault (Brown, 1973), and that the Long Range Mafic-Ultramafic Complex has been obducted from the vicinity of the Cape Ray Fault (Brown, 1976a) hinges largely on the interpretation of the gneisses on either side of the fault as Precambrian crust. This provided one of the first focii of the present study.

1.4 PRESENT STUDY

1.4.1 General background, aim, and organization of thesis

At the inception of this study, it was thought that the extension of the Gander Zone Precambrian gneissic basement, unconformably overlain by Devonian metasedimentary rocks (Bay du Nord Group of Cooper, 1954), could be found in the La Poile Bay area. Supporting this expectation were both the felsic gneisses (Dolman Gneiss, Keepings Gneiss, and the unnamed schist and gneiss units) and several associated conglomerate bands containing granitoid clasts which were reported by Cooper (1954). In addition, Kennedy (1976) suggested that a partly subaerial volcanosedimentary unit (La Poile Group of Cooper, 1954) which was in fault contact with the Bay du Nord Group might be related to Late Precambrian volcanic rocks of the Avalon zone. If this proved correct, the area would have the additional significance of spanning three tectonostratigraphic zones of the Newfoundland Appalachians, and two faults of major regional significance.

Parts of the Bay du Nord Group were metamorphosed to lower amphibolite facies grade (Cooper, 1954), and probable correlatives to the west were intensely deformed in association with activity of the Cape Ray Fault (Brown, 1975), making substantial Devonian (Acadian) deformation and metamorphism, as well as major Devonian movement on the fault, a certainty in this area. Devonian structural reworking and metamorphism presented the possibility of basement remobilization, producing gneiss domes and several generations of crustally-derived granitoid rocks (c.f., Watson, 1967). The study area might thus be a good place to study the effects of the Acadian orogeny where they were unusually intense.

It became apparent after early field work, that:

(1) Most, if not all, of the conglomerates are intrinsic features of the volcanosedimentary rocks with which they were associated, and do not signify profound unconformities as had once been believed.

(2) There is apparent conformity between the Bay du Nord Group as mapped in its type area and nearby gneisses which had been excluded from the group.

(3) The Dolman Gneiss is not a gneiss, but a dacitic crystal tuff with the same structural and metamorphic history as the surrounding rocks.

(4) The Devonian fossils are not found within the major part of the group, but are confined to strata which occurred within the Cape Ray Fault zone and are possibly distinct from the rest of the group in

lithological makeup and in markedly lower metamorphic grade.

(5) The Bay d'Est Fault, the contact between the Bay du Nord Group to the north and other volcanic and sedimentary rocks to the south, juxtaposed rocks of strikingly similar protoliths but with contrasting metamorphic grade.

None of these observations could be substantiated or refuted without a more widespread, systematic regional investigation, nor could their significance be assessed. The apparent complexity of the area indicated that as many aspects of the geology as possible should be considered. In addition, the large scale of tectonic processes such as those proposed for the Appalachians in general, and for southwest Newfoundland in particular, suggested that it was important to study as wide and varied an area as possible. All constraints, such as paleontological and radiometric ages, levels of granitoid intrusion, approximate deformation-P-T history, and structural development could then be used to develop a generalized tectonic model(s) for more thorough testing at smaller scale.

For this regional synthesis, I separate the geology of the southern Long Range Mountains into its component assemblages in Chapter 2, and describe the nature and internal relationships of each component assemblage in Chapters 3 through 8 (cross-referenced to the more systematic description in Part II). Subsequent chapters are devoted to structural and metamorphic development (Chapter 9), a synopsis of deposition, intrusion, structure and metamorphism (Chapter 10), discussion of various aspects of the outcome of the thesis (Chapter 11), and finally, a summary and suggestions for further work (Chapter 12).

1.4.2 Logistics and mapping

The logistical support gained through employment by the Newfoundland Department of Mines and Energy during 1977-1982 enabled me to map on a 1:50,000 scale an extensive area across the southern Long Range Mountains from the Long Range Fault in the west to the coast in the La Poile-Cinq Cerf area.

Mapping of most of the study area was accomplished by traversing radially from helicopter-positioned fly camps. The La Poile area (N.T.S. 110/9) and the area at the head of La Poile Bay was mapped while based in the communities of Grand Bruit and North Bay, occasionally using a boat. Helicopters were used for final coverage in the 1977 to 1980 field seasons. The use of a helicopter chartered by Cominco in 1975 in order to visit localities within the Cape Ray Fault zone is gratefully acknowledged.

1:20,000 aerial photographs were used in the field as a basis for the final production of 1:50,000 scale maps. MAP 1 is a 1:100,000 scale compilation of three and one half 1:50,000 map sheets produced during the course of this study, in addition to three previous 1:50,000 scale maps (Brown, 1976b, 1977; Knight and Brown, 1976). A few details on Map 1 were extracted from maps by Phair (1949).

1.4.3 Terminology and petrographic techniques employed in this thesis

Modal rock compositions were estimated visually. The nomenclature of Streckeisen (1973) was used for naming the granitoid rocks with the exception of plagiogranite. The term plagiogranite is applied here to granitoid rock made up largely of plagioclase and quartz with minor clinopyroxene or hornblende, and refers specifically to small injections or pods which intrude high level gabbros and diabase of the Long Range Mafic-Ultramafic Complex; the plagiogranite is considered part of the complex. In addition, tonalitic rocks with more than 25 modal percent ferromagnesian minerals are referred to here as quartz diorite, and the term tonalite applied to rocks with under 25 percent ferromagnesian minerals.

The textural terms granophyre and myrmekite follow conventional usage summarized by Barker (1970).

The terminology of Sibson (1977) is applied to fault rocks, mainly of the mylonitic class. Protomylonite, mylonite, and ultramylonite are terms referring to rocks showing gradational increases in degree of strain indicated by an increasing proportion of fine grained matrix to porphyroclasts. Blastomylonite refers to highly strained rock which has undergone substantial new grain growth, rendering it coarser grained. Phyllonite refers to a hydrated, mica-rich mylonite or ultramylonite.

Metamorphic grades are named according to Miyashiro (1973). No detailed metamorphic studies have been undertaken in this area. Therefore, general metamorphic grade was determined from easily recognizable mineral indicators, although their use involves a fair degree of imprecision.

Approximate mineral compositions of plagioclase, olivine, and orthopyroxene were determined optically without the benefit of a universal stage. The anorthite content of plagioclase was determined using the bisectrix method of Winchell (1949), and is reported as a single value, a range of values, or as the plagioclase species (e.g. oligoclase) encompassing the compositional range encountered, whichever appeared most appropriate. Where possible, the forsterite content of olivine and the enstatite content of orthopyroxene were estimated using published curves (Heinrich, 1965). Many thin sections did not yield grains of suitable orientation for these methods.

Hornblendes are designated as blue green, green, brown green, or igneous brown according to their pleochroism:

Blue green: Z = blue green
Y = forest or grass green
X = straw yellow

Green: Z = green, dark green
Y = green, olive green
X = straw yellow

<u>Brown green</u>: Z = grey tan or olive green
Y = tan brown
X = pale tan to colourless

<u>Igneous brown</u>: Deep pinkish brown, with high dispersion which masks pleochroism.

All of the above hornblendes are biaxial negative with moderate to large $2V_X$. Fibrous blue green amphibole, probably actinolite, displays the same pleochroic scheme as the blue green hornblende. Blue green amphiboles which may be either hastingsite or hornblende, and amphiboles with pleochroic schemes other than those listed above, are specified in the text. The brown-green hornblende has a $2V_X$ of 80°-85°, and maximum interference colours in the lower second order.

For the mineral stilpnomelane, the convention of Brown (1967) and Eggleton (1972) which prefixes 'ferri' to ferric-rich varieties and 'ferro' to ferrous-rich varieties is adopted. The former is generally pleochroic in shades of reddish brown to black, the latter in green to yellow.

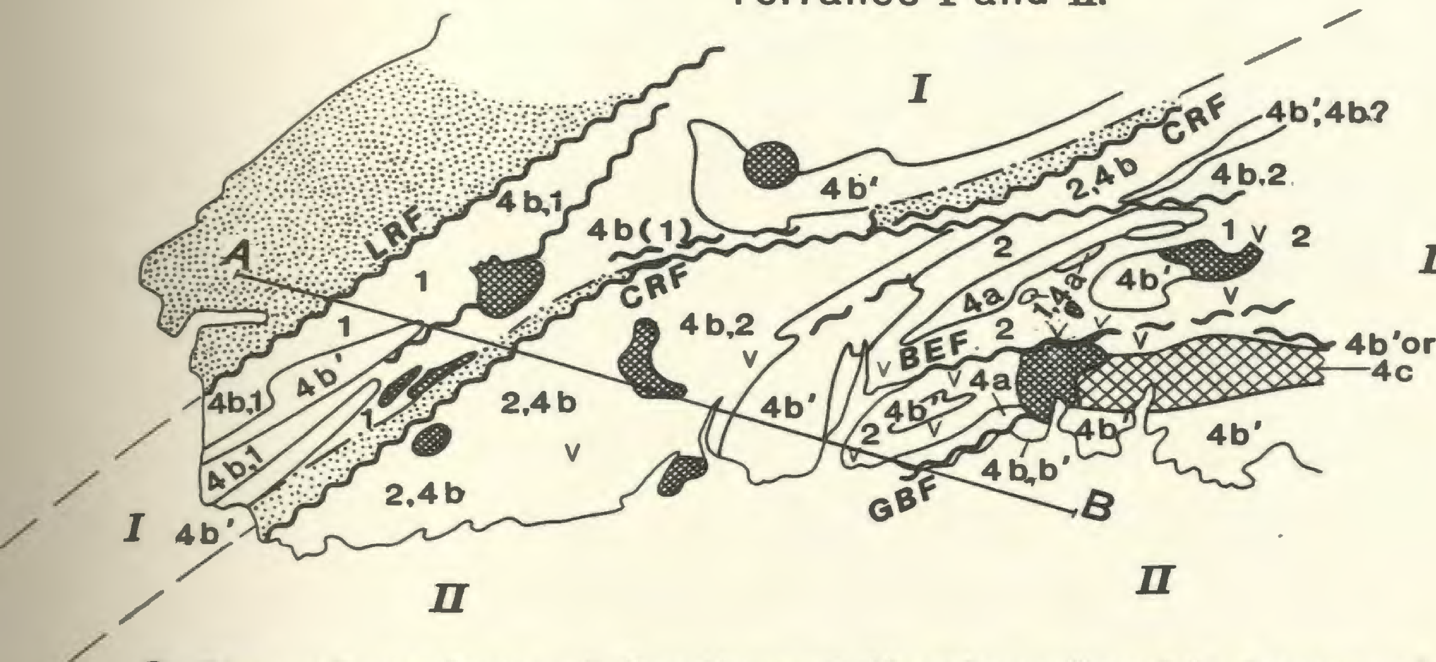
CHAPTER 2: GENERAL GEOLOGY

2.1 COMPONENTS

The geology of the southern Long Range Mountains can be separated into four major geological components (Figure 3): (1) metamorphosed ?Cambro-Ordovician to Early Ordovician mafic plutonic to hypabyssal and extrusive complexes (interpreted by Brown (1976a) and in this study as ophiolitic); (2) ?Early to late Middle Ordovician metavolcanic and metasedimentary rocks belonging to a calc-alkaline volcanic centre and an adjacent submarine sedimentary basin; (3) Devonian terrestrial sedimentary and volcanic rocks; and (4) Ordovician to Devonian granitoid rocks (sensu lato). The granitoid rocks fall into three categories: (4a) metamorphosed Ordovician gabbroic, dioritic, granodioritic, and trondhjemitic subvolcanic intrusions related to the metavolcanic rocks of component 2; (4b) extensive Early Ordovician and Silurian synmetamorphic/synkinematic tonalite and granodiorite generated directly from components (1) and (2), crosscut by quartz gabbro to quartz monzonite plutons (4b') which originated from deeper tectonic levels; and (4c) Devonian 'late' and 'post' tectonic intrusions.

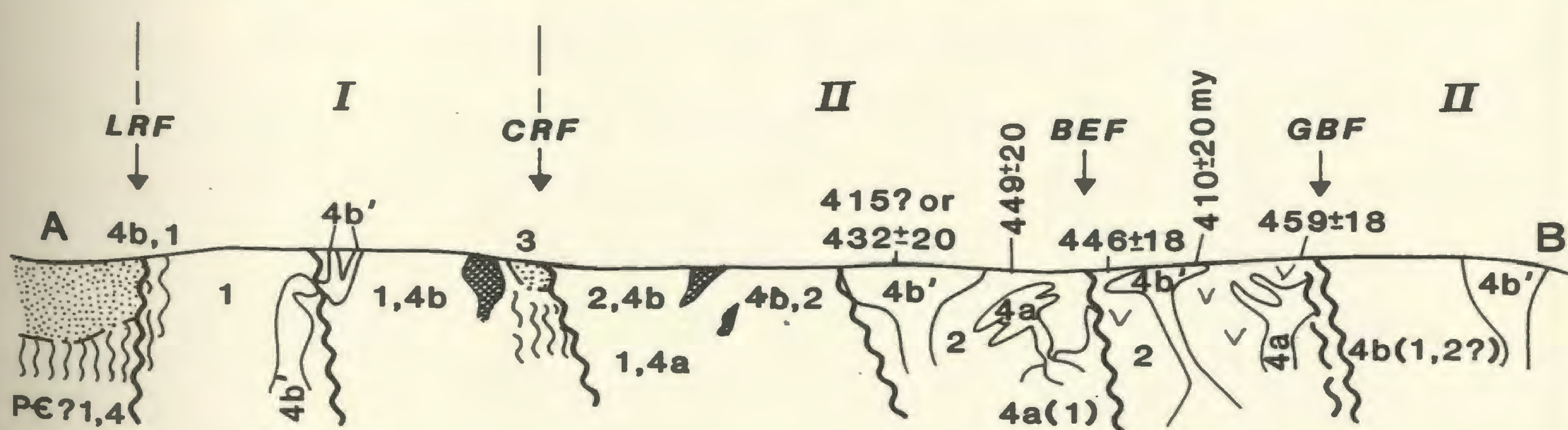
Carboniferous sedimentary rocks west of the southern

FIGURE 3: SOUTHWEST NEWFOUNDLAND TRAVERSED BY MAJOR FAULTS: LRF – Long Range Fault, CRF–Cape Ray Fault, BEF–Bay D'est Fault, GBF–Grand Bruit Fault. Cape Ray Fault System divides the area SE of the Long Range Fault into Terranes I and II.



a. Plan of geology of Southwest Newfoundland in terms of components 1 to 4.

COMPONENT 1–(OPHIOLITIC) Є–ORD MAFIC PLUTONIC EXTRUSIVE COMPLEX
2–Є–M. ORD SED. & VOLC. ROCKS
[stippled]–TERRESTRIAL SEDIMENTARY, VOLCANIC ROCKS
3–DEVONIAN WINDSOR PT. GROUP
4a– ORD. GABBRO–TRONDJ. RELATED TO 2
4b– SYNKINEMATIC/SYNMETAMORPHIC GRANITOID ROCKS
4b'–QUTZ–GABBRO– QUTZ.–MONZ.– MONZOGR.– PLUTONS
4c [dark] –DEVONIAN "LATE" AND "POST" TECTONIC LEUCOGRANITE INTRUSIONS
[cross-hatched] –POSSIBLY A LITTLE OLDER THAN CROSSCUTTING 4c



b Cross-section A–B (with scale expanded) showing geology of SW Newfoundland as components 1 to 4 ignoring deformational effects except for major faults. (Actual configurations are suggested schematically in cross-sections accompanying map 1)

Long Range Mountains (Map 1) probably constitute the successors to Devonian terrestrial sedimentary rocks of Component 3. These have been studied by Knight (1983), and will only be referred to here in the synopsis in Chapter 10 and discussion in Chapter 11 as a constraint on the timing and an indication of the style of the late tectonic activity.

This analysis, used in the organization of this thesis, does not conflict fundamentally with the more limited interpretations of Phair (1949), Cooper (1954), or Gillis (1972), but differs considerably from the broad scale interpretations of Brown (1973, 1975, 1976). In particular, no criteria were found which would identify exposures of Precambrian basement.

2.2 TERRANES AND STRUCTURAL/METAMORPHIC DOMAINS

Southwest Newfoundland is traversed by two major faults, the Long Range Fault and the Cape Ray Fault, which divide the area into three terranes of contrasting litho-stratigraphic makeup. Carboniferous strata completely cover pre-Devonian sequences northwest of the Long Range Fault in the Codroy Valley (Knight, 1983). The pre-Carboniferous rocks which occupy the southern Long Range Mountains southeast of the Long Range Fault are here divided into Terranes I and II along the Cape Ray Fault (Figure 4). Terrane I has traditionally been assigned to the Humber

Zone, and Terrane II to the Gander Zone (Williams, 1978, 1979).

Terrane I, between the Long Range and Cape Ray Faults, is underlain by the metamorphosed (ophiolitic) Long Range Mafic-Ultramafic Complex of Brown (1976a) capped by metasedimentary rocks (included collectively in component 1), cut by extensive early Ordovician synkinematic tonalite (component 4b) and several quartz gabbro, diorite, quartz monzonite, and leucogranite plutons (components 4b' and 4c).

Terrane I is further subdivided into two belts, the Little Codroy Pond and the Dinosaur Pond belts (Figure 4), in contact across another late fault. Early high strain zones of medium to high metamorphic grade overprint both belts: the coalescing Long Range high and Stag Hill high strain zones (LRhsz, SHhsz) in the Little Codroy Pond belt, and the north-central high strain zone (NChsz) in the Dinosaur Pond belt (Figure 4).

Terrane II, southeast of the Cape Ray Fault, is occupied by Ordovician metasedimentary and metavolcanic rocks (component 2) and subvolcanic intrusions (component 4a), augmented by mainly Silurian synmetamorphic granitoid rocks (component 4b) and cut subsequently by Silurian megacrystic granitoid batholiths (component 4b') and Devonian intrusions (component 4c). Component 2 submarine and locally subaerial metavolcanic rocks of a calc-alkaline volcanic complex are exposed largely east of La Poile Bay (Figure 4). Component 2 metasedimentary, mafic metavolcanic, and mafic metaplutonic rocks predominate in the western part of Terrane II, wedging out northeastwards along the southeast side of the Cape Ray Fault. There is a facies transition between the two associations, i.e., from a partly subaerial, partly submarine volcanosedimentary pile to submarine basin facies.

The northwestern boundary of Terrane II is the main Cape Ray Fault. However, a late splay of the Cape Ray Fault system cuts across Terrane II in the eastern half of the area, and is here called the Gunflap Hills fault splay; the area between the Gunflap Hills fault splay and the northeast part of the Cape Ray Fault is referred to in the text as the northeastern wedge (Figure 4). Another major fault, the Bay d'Est Fault, cuts through the metavolcanosedimentary rocks between La Poile Bay and Grandys Brook #2; the terrane north of the Bay d'Est Fault is referred to as the Bay du Nord belt, the terrane to the south of the Bay d'Est Fault as the highlands belt (Figure 4).

On the southeast side of Terrane II, the Grand Bruit Fault juxtaposes a greenschist facies part of the meta-volcanic complex against the Cinq Cerf Complex, which consists largely of amphibolitic mafic meta-igneous rock cut by granodiorite. The granodiorite locally cuts a sub-volcanic granitoid member of the metavolcanic pile, and intrudes amphibolite facies metavolcanic rocks similar to metavolcanic rocks north of the fault. Therefore, the fault may have been much less regionally significant than the Long Range or Cape Ray Faults.

2.3 PREVIEW OF THE STRUCTURAL AND METAMORPHIC DEVELOPMENT

Although it is recognized that a picture of the structural and metamorphic history via field relations and lithological/petrographic features of the rocks has yet to be developed, it is thought that a preview might make it easier to assimilate Chapters 3 through 8 into a tectonic framework.

In the following text, it is suggested that both Terranes I and II were affected early in their history by tectonic stacking due to thrusting or recumbent folding, and that these processes were ultimately responsible for the generation of large volumes of granitoid rock (component 4b). The ophiolitic crust of Terrane I was thrust-stacked during both the intrusion of synkinematic granitoid rocks and the development of several high strain zones exhibiting moderate to high metamorphic grade. Rocks exposed in Terrane II were incorporated into fold nappes, resulting in tectonic burial of part of the terrane before the attainment of a metamorphic peak and *in situ* generation of syn-metamorphic granitoid rocks. The most obvious contrast in early structural and metamorphic development between Terranes I and II is that in Terrane I, high grade metamorphism and early thrusting were approximately contemporaneous (suggesting the involvement of already hot rocks), whereas in Terrane II, metamorphism lagged behind thrusting or recumbent folding. In addition, the only available radiometric evidence suggests that thrusting in Terrane I occurred earlier than the formation of fold nappes in Terrane II.

This early deformation was followed by the development of a long-lived regime of compressive wrench faulting (c f. Wilcox et al, 1973) such as described by Harland (1971) as 'transpression'. This culminated in Devono-Carboniferous strike-slip, horst, and high angle reverse fault systems which were accompanied by the deposition of the Devonian terrestrial sedimentary and volcanic rocks (component 3) and the emplacement of leucogranite plutons (component 4c).

CHAPTER 3: LONG RANGE MAFIC-ULTRAMAFIC COMPLEX AND ASSOCIATED METASEDIMENTARY ROCKS (COMPONENT 1)

3.1 DEFINITION AND FIELD RELATIONS

The Long Range Mafic-Ultramafic Complex (Brown, 1976a) was first interpreted as a large stratiform intrusion emplaced into the metasedimentary rocks which overlay it before deformation and intrusion by granitoid rocks (Phair, 1949). Brown (1976a) suggested alternatively that it was exposed as two thrust sheets resting on the metasedimentary and granitoid assemblage, which he referred to as the Long Range Gneiss (Brown, 1972). The lower sheet of the mafic-ultramafic complex was thought to consist of tectonic pods of highly serpentinized dunite passing upward into amphibolite with relict igneous banding, and the upper sheet was described as grading from feldspathic dunite at its base to well layered troctolite, olivine gabbro, norite, and anorthosite capped by massive coarse and fine grained gabbro. The Long Range Gneiss (Brown, 1972) is a foliated tonalite with abundant inclusions of amphibolite and localized paragneiss. The amphibolite, described as coarse to fine grained and locally thickly banded, was considered the oldest part of the Long Range Gneiss.

During this study, the tonalite of the Long Range Gneiss was observed not only enclosing xenoliths which could be identified as part of the Long Range Mafic-Ultramafic Complex, but intruding much larger tracts of the complex as dykes and apophyses. In the Dinosaur Pond belt, large outcrop areas of massive metagabbro and metadiabase intruded by only minor tonalite grade into outcrop areas where the metagabbro and metadiabase forms xenoliths in tonalite. The tonalite with mafic meta-igneous inclusions passes northward into tonalite with assorted metasedimentary and mafic meta-igneous inclusions. In the Little Codroy Pond belt to the west, similar massive metagabbro and metadiabase grades into layered troctolite, olivine gabbro, anorthositic gabbro, and anorthosite which display granulite facies foliations, resembling the upper sheet as described by Brown (1976a). The massive metagabbro and metadiabase of this belt is overprinted by amphibolite facies tectonic fabrics of the Long Range and Stag Hill high strain zones, where amphibolite of this derivation, mafic metavolcanic rocks, and metasedimentary rocks are intruded by equally deformed and metamorphosed tonalite and related granitoid rocks. Therefore, it is suggested here that it is the Long Range Mafic-Ultramafic Complex that constitutes the oldest, mafic meta-igneous and amphibolitic part of the Long Range Gneiss of Brown (name discarded here), and the tonalite the youngest part.

Therefore, the name Long Range Mafic-Ultramafic Complex is applied here to all of the mafic and ultramafic meta-igneous rocks which predate the intrusion of the tonalite, and which are believed to be parts of the sequence from ultramafic rock to layered metagabbro to massive metagabbro and metadiabase described by Brown (1976a). The complex also includes mafic metavolcanic rocks.

The Long Range Mafic-Ultramafic Complex so defined, and metasedimentary rocks associated with the mafic metavolcanic rocks and dykes and locally (in the LR-SHhsz) proximal to the massive metagabbro and metadiabase, are intruded by the foliated tonalite and related granitoid rocks, and by younger diorite, quartz monzonite, granite, and dykes.

Contacts between the metasedimentary rocks and the mafic meta-igneous complex approximately coincide with, and are obscured by intense deformation within the Long Range and the Stag Hill high strain zones and by the intrusion of voluminous granitoid rock. However, the sequence from layered metagabbro through massive metagabbro and metadiabase to mafic metavolcanic rocks and dykes prior to deformation is consistent throughout the entire area, indicating a 'way up' in the mafic complex. Furthermore, the close spatial association of metasedimentary rocks with mafic metavolcanic rocks and dykes within the LRhsz and metasedimentary rocks with amphibolite in the adjoining SHhsz in the Little Codroy Pond belt, as well as the association of mafic metavolcanic and metasedimentary xenoliths in the granitoid rocks in the NChsz of the

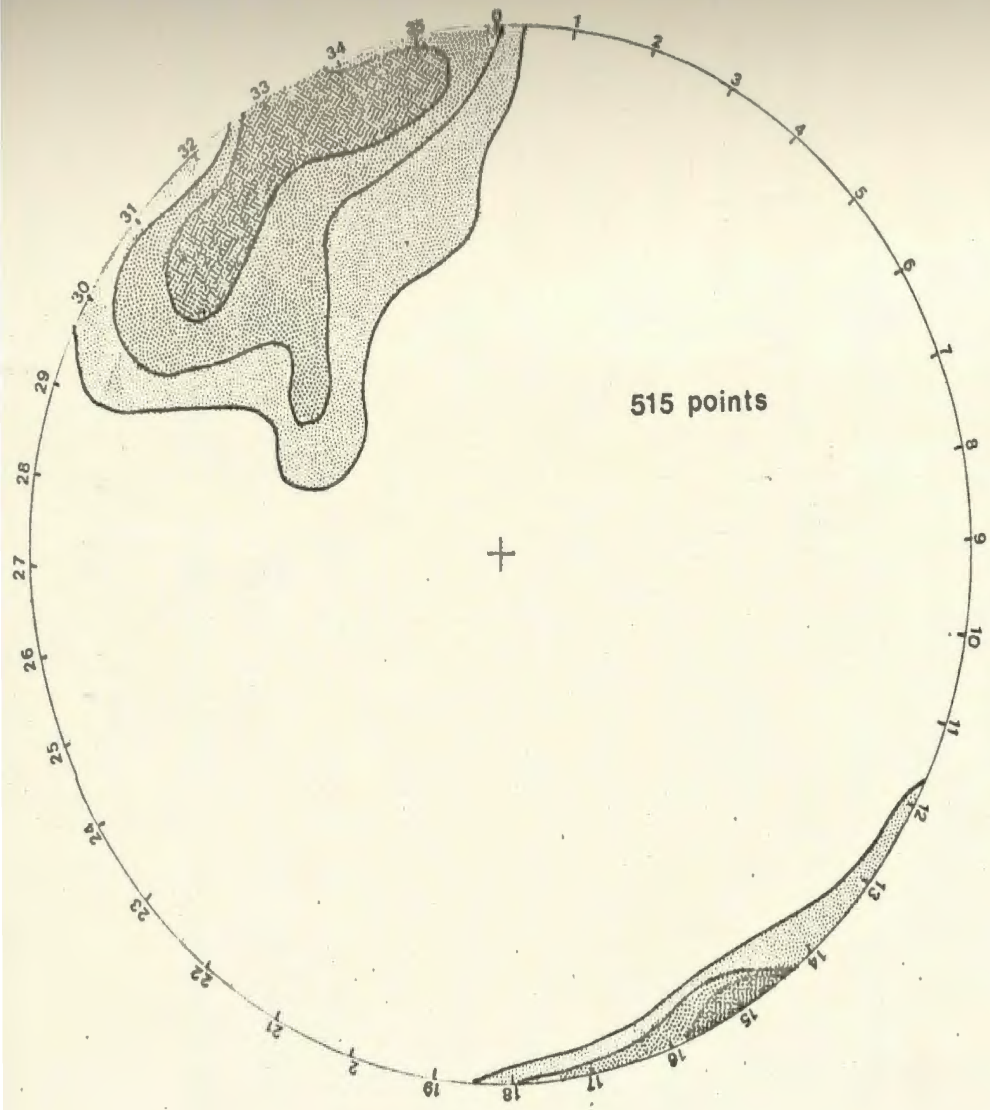
Dinosaur Pond belt is consistent with this 'way up' trend. Because of this, and because of the absence of intrusive contacts or of partly assimilated screens and xenoliths of metasedimentary rock in the mafic meta-igneous rocks, and the lack of hornfels textures in the metasedimentary rocks, it is suggested that the metasedimentary rocks were deposited on top of the Long Range Mafic-Ultramafic Complex. Tentative stratigraphic sequences (without vertical scale) for the Little Codroy Pond and the Dinosaur Pond belts are illustrated in Figure 5.

3.2 MAIN CHARACTERISTICS OF THE LONG RANGE MAFIC-ULTRAMAFIC COMPLEX

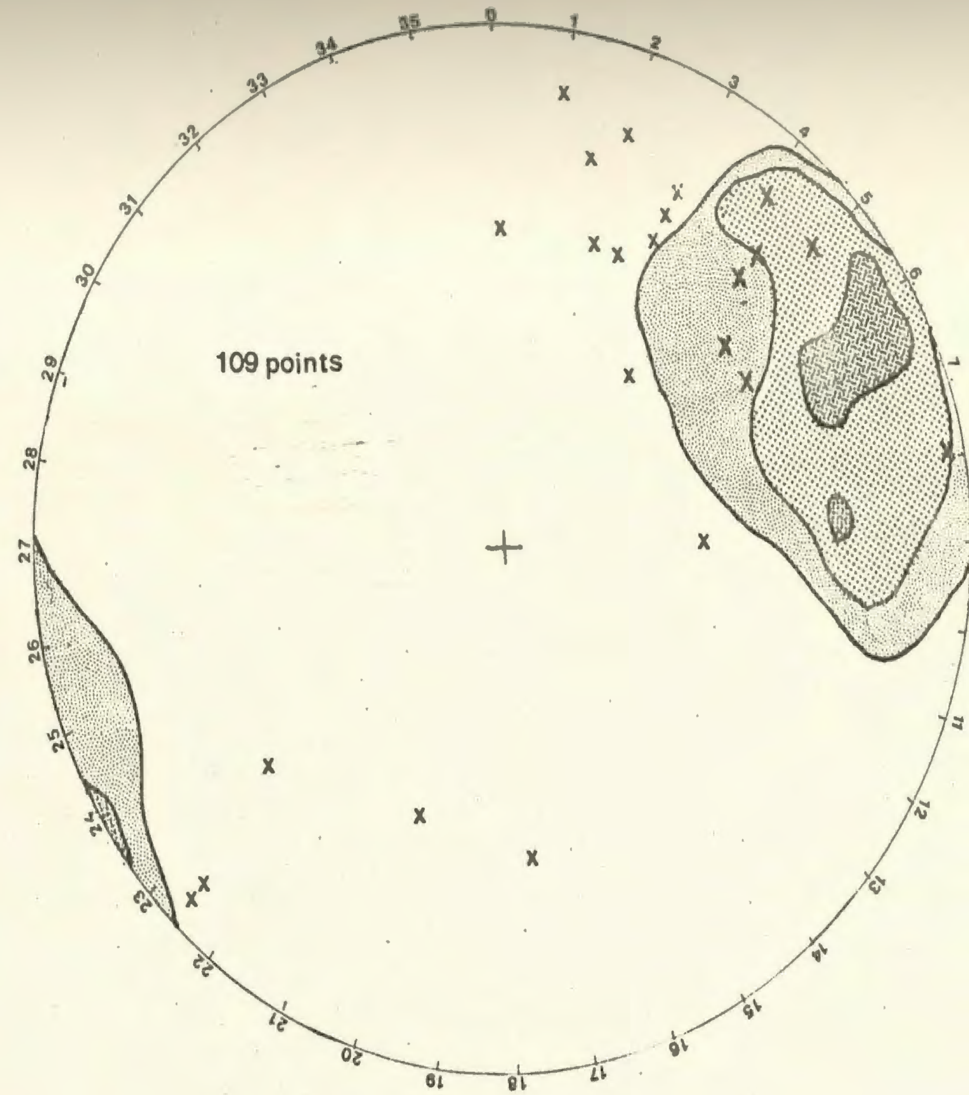
3.2.1 Makeup of the Long Range Mafic-Ultramafic Complex

In the area studied during the project (Grandys Lake: 110/15), the complex includes altered ultramafic rock, layered metagabbro, massive metagabbro and metadiabase, mafic metavolcanic rocks and dykes, and undivided amphibolite. The ultramafic rocks occur as lenses within the layered metagabbro of the Little Codroy Pond belt, as pods or lenses in contact with undivided amphibolite in the Stag Hill high strain zone, and as pods surrounded by the tonalite which also engulfs the massive metagabbro and metadiabase as xenoliths in the Dinosaur Pond belt. In the Little Codroy Pond belt, layered metagabbro grades into massive metagabbro and metadiabase, which is in turn

Figure 10: Predominant fabrics of the Bay du Nord belt.



10a: Poles to predominent foliations.
Contours at 2, 4 and 6% per 1% area.



10b: Extension lineations.
Contours at 2.5, 5 and 10% per 1% area;
23 fold axes (x).

adjacent to mafic metavolcanic rocks and dykes. In the Dinosaur Pond belt, massive metagabbro and metadiabase intruded by and engulfed in synkinematic tonalite (component 4b) passes northward into a tonalite terrane rich in mafic metavolcanic and metasedimentary inclusions, and southwestward into both layered metagabbro and massive metagabbro and metadiabase intruded by or engulfed in tonalite.

All subunits have been subjected subsequently to regional metamorphic conditions, but some of the rocks, particularly the relatively anhydrous layered metagabbro, retain their previous texture and mineralogy. All locally grade into undivided amphibolite, which is exposed most extensively in the Stag Hill and Long Range high strain zones.

Preliminary reconnaissance has shown that these units are continuous into areas mapped by Phair (1949) and Brown (1976c, 1977), and shown on Map 1. However, only rocks mapped during this study are described in Part II.

3.2.2 Ultramafic rocks (Part II, Section 13.1.2)

The ultramafic rocks include metamorphosed feldspathic peridotite, dunite, wehrlite, and harzburgite. The feldspathic peridotite occurs within the layered cumulate metagabbros (next unit), dunite, wehrlite, and harzburgite occur in the Stag Hill high strain zone, and dunite is exposed as pods in the Dinosaur Pond belt. Most of the ultramafic rocks in the Stag Hill high strain zone occur as lenses in contact with amphibolite, with the exception of the harzburgite. The harzburgite occurs near Long Pond as an isolated pod, surrounded by outcrops of garnetiferous granitoid rock and paragneiss. In the Dinosaur Pond belt, ultramafic pods are engulfed by the deformed tonalite which includes rafts of massive metagabbro and metadiabase nearby.

3.2.3 Layered metagabbro (Part II , Section 13.1.3)

Well defined layering, mineral lamination, and the high olivine content distinguish the layered metagabbro from the massive metagabbro and metadiabase (next unit). The layered metagabbro sequence is most voluminously exposed within the core of the Little Codroy Pond belt, and in the part of the Dinosaur Pond belt southwest of the area mapped during this study (N.T.S. 110/11: Brown, 1976a, 1977). The massive metagabbro and metadiabase is in gradational contact with layered metagabbro through a relatively narrow zone of well layered, alternately coarse and fine grained subophitic clinopyroxene metagabbro along both flanks of the core of the Little Codroy Pond belt. Gabbroic and trondhjemitic pegmatites, as well as rare plagioclase porphyry (highly deformed) and tuffisite cut the layered metagabbro sequence.

The 'fresh' layered metagabbros are derived from foliated cumulate olivine gabbro, troctolite, anorthosite, anorthositic olivine-gabbro, and clinopyroxene gabbro. The most obvious macroscopic layering mainly reflects fluctuations in plagioclase content, and occurs on a scale of 1 to over 100 cm. Common plano-linear foliations are defined by lenticular concentrations of ferromagnesian silicate minerals and are parallel to layering. Gabbronorite, lacking the foliation of the layered metagabbros, was observed in one outcrop.

The layered metagabbros contain variable proportions of plagioclase, olivine, clinopyroxene, subordinate orthopyroxene, and minor brown hornblende. The first four minerals show evidence of subsolidus deformation and annealing. Plagioclase (An_{50} to An_{70}) occurs as granoblastic intergrowths which form monomineralic domains, or otherwise as single laths subophitically enclosed in clinopyroxene. Olivine forms lensoid grains, grain aggregates, and polygonized lenses which partly define the foliation and banding. Many plagioclase-olivine contacts are present, however, and the lack of reaction (to form garnet) between them is suggestive of low pressures (relative to other similarly high temperature regional metamorphic rocks) during this deformational and metamorphic recrystallization (e.g. Eskola, 1952; Green and Ringwood, 1967; Miyashiro, 1973, p. 301-3, 313). Clinopyroxene grains generally form large, polygonized, subophitic grains, with smaller subgrains at their boundaries which are rarely strung out along the foliation plane. Orthopyroxene clusters around olivine or clinopyroxene grains in most of the gabbros, and is commonly polygonized.

As evidence for some vapour present in the layered sequence during late crystallization or formation of the early foliation, brown igneous hornblende commonly surrounds large, cuspate magnetite grains, and rare phlogopite with the same habit is locally rimmed by quartz-mica symplectites.

Retrograde overprints on the foliated layered metagabbros within the block are of two main types:

(1) Earlier, moderately high temperature type: Replacement of the ferromagnesian minerals by green hornblende, and development of accessory epidote, sphene, and rare sphene-rimmed rutile. Locally, brown green hornblende, mottled and rimmed with blue green hornblende, occurs in place of blue green hornblende, and the rocks lack sphene.

(2) Later, low temperature type: Pseudomorphous replacement of the ferromagnesian minerals by fibrous blue green amphibole and clinochlore. Thin tremolite coronas surround olivine grains locally. Epidote occurs as single grains and as vermicular coronas on altered clinopyroxene grains. Sphene is absent.

3.2.4 Massive metagabbro and metadiabase (Part II, Section 13.1.4)

These rocks are distinguished from the layered metagabbros by the lack of well developed layering, the variably coarse subophitic texture of the metagabbro, and the abundance of the associated metadiabase intrusions. They are also typically cut by plagiogranite stringers and pods, not present in the layered metagabbro terrane. Altered clinopyroxene is the major ferromagnesian mineral phase, and olivine is absent.

This unit is most extensively exposed in the Dinosaur Pond belt, both as extensive outcrop areas sparingly intruded by equigranular tonalite, and in outcrops that consist of about 30 to 70 percent mafic rock intruded by or enclosed in tonalite. This terrane passes gradationally northward into the north-central high strain zone, where tonalite encloses mafic metavolcanic rocks and dykes, undivided amphibolite, and assorted metasedimentary rocks, as well as local inliers of massive metagabbro and metadiabase.

Plagiogranite cuts the mafic rocks either as vein networks or as the matrix of metagabbro/metadiabase breccias. Segregations of quartz in the core of some of the breccia pods suggests hydrothermal activity accompanying the fracturing and introduction of the plagiogranite. In contrast to the synkinematic biotite tonalites (Unit 7a) which cut the Long Range Mafic-Ultramafic Complex, uralitized clinopyroxene laths are the sole ferromagnesian mineral in the plagiogranite.

In addition, the massive metagabbro with abundant metadiabase intrusions grades through a relatively narrow transition zone into the layered metagabbros in the Little Codroy Pond belt.

In the central part of the Stag Hill high strain zone, medium grained subophitic metagabbro is cut by a magnetite-rich dioritic pegmatite. The metagabbro is mildly deformed, probably buttressed against much of the penetrative deformation of the SHhsz by the massive pegmatite. The magnetite-rich pegmatite contains igneous brown hornblende and colourless clinopyroxene, commonly rimmed or mottled with brown hornblende. The metagabbro contains clinopyroxene and subordinate igneous brown hornblende. Clinopyroxene grains are deformed, and ubiquitously rimmed with igneous brown hornblende which locally forms films along deformational subgrain boundaries, possibly indicating minor deformation at very high, subsolidus temperatures associated with the pegmatite development. Some clinopyroxene was later partly uralitized, and many rocks were subsequently fractured, the fractures filled with fine grained chlorite.

3.2.5 Mafic metavolcanic rocks and dykes (Part II, Section 13.1.5)

Mafic metavolcanic rocks and dykes are spatially associated with marble and semipelitic metasedimentary rocks in the Long Range high strain zone. Mafic metavolcanic and hypabyssal rafts are also concentrated in two outcrop areas in the north-central high strain zone, and grade into the massive metagabbro and metadiabase (intruded by tonalite) to the south, and are bordered to the north, northwest, and northeast by foliated granitoid rocks with both abundant metasedimentary and mafic metavolcanic or amphibolitic inclusions.

The mafic metavolcanic rocks and dykes within the LRhsz comprise massive metabasalts which are cut by equally metamorphosed, aphyric to plagioclase phyric mafic dykes. Thin, partly granitized pillow selvages, pillow junctions and margins with abundant flattened vesicles occur locally.

In the north-central high strain zone, fine grained, amphibolitic metavolcanic rocks display diabasic textures, and plagioclase phenocrysts are preserved in some places. Pillow-like structures, epidosite concentrations, mafic breccias and patches of banded tuffaceous metasediment characterize the two largest outcrop areas. As with the metagabbro and metadiabase complex, exposures with almost no intrusive tonalite pass abruptly into those containing a large proportion of tonalite.

3.2.6 Undivided amphibolite (Part II, Section 13.1.6)

Undivided amphibolite is most extensively exposed within the Stag Hill and Long Range high strain zones, and along the north side of the Cape Ray Fault. Some of the mafic meta-igneous inclusions in foliated tonalite of the north-central high strain zone are also called undivided amphibolite.

Stag Hill high strain zone

Local exposures which display characteristics of the units above (Sections 3.1.2 - 3.1.5), but which grade into well foliated amphibolite, indicate that all units of the Long Range Mafic-Ultramafic Complex contributed locally to undivided amphibolite of this zone.

Hornblendes vary from typically blue green in the Little Codroy Brook to Stag Hill area, to green and rarely brown green in the northeastern part of the SHhsz. The northeastern amphibolites are more intensely foliated and more quartz-rich than the amphibolites further southwest; in the northeastern amphibolites, polygonal grains of clinopyroxene occupying triple junctions in the granoblastic hornblende-plagioclase intergrowth, rather than form pseudomorphs of the subophitic (tan) igneous clinopyroxene which locally persist as relics in the southwest part of the zone. Cummingtonite occurs at the expense of hornblende along microshears.

Long Range high strain zone

Undivided amphibolites in this zone were also derived from mafic metavolcanic rocks and dykes, the massive metagabbro and metadiabase, and mafic metavolcanic rocks and dykes. Amphibolites range from extremely fine grained to extremely coarse grained. Linear to plano-linear foliations are commonly developed in the fine grained amphibolites, whereas fabrics in the very coarse grained rocks are generally planar.

Hornblendes vary from blue green or green to brown green in fine and medium grained amphibolites. Brown green hornblende has so far been observed only near the transition into the layered metagabbro core zone to the east, and is commonly both rimmed and mottled with blue green hornblende.

Mylonitic amphibolites display augen of blue green hornblende and plagioclase in a strong foliation defined by fibrous actinolite, chlorite, epidote, and recrystallized quartz.

North-central high strain zone

Amphibolite xenoliths in the north-central high strain zone are relatively fine grained and, in general, lack pronounced foliation. A pattern of early, amphibolite facies assemblages locally retrograded in patches by greenschist facies minerals matches that of the associated metasedimentary xenoliths (2c, below).

Cape Ray Fault zone

Undivided amphibolite underlying the relatively thin high strain zone along the north side of the Cape Ray Fault occurs as inclusions and rafts in equally deformed, or even more deformed tonalite. These rocks are gradationally more foliated toward the fault, locally passing into chlorite-muscovite phyllonite. They grade away from the fault into tonalite which includes rafts of the massive metagabbro and metadiabase. These amphibolites reflect a peak metamorphic grade in the greenschist facies.

3.3 METASEDIMENTARY ROCKS OF TERRANE I

3.3.1 Subdivision of the metasedimentary rocks

The metasedimentary rocks of Terrane I are variable in nature, and contrast markedly between the Little Codroy Pond and Dinosaur Pond belts. Semipelitic paragneiss and bands of marble occur in the Little Codroy Pond belt, where they are deformed with equally deformed and metamorphosed, lit-par-lit intrusions of foliated to gneissic granitoid rock. In contrast, a wide assortment of metasedimentary rocks, including semipelitic paragneiss, brecciated to nonbrecciated, calc-silicate laminates, microcrystalline garnet-quartz rock, and siliceous schist, accompanied by mafic metavolcanic and/or dyke rock, occur as inclusions in the highly deformed and metamorphosed tonalite in the north-central high strain zone of the Dinosaur Pond belt.

3.3.2 Paragneiss of the Little Codroy Pond belt (Part II, Section 13.2.2)

Stag Hill high strain zone

Semipelitic paragneiss and migmatite, intruded by sheets of synkinematic granitoid rock and deformed under moderate to high grade metamorphic conditions, is exposed within the Stag Hill high strain zone. In the northeast part of the belt, intense deformation and recrystallization preclude the separation of the paragneiss from the granitoid sheets.

The SHhsz paragneiss consists largely of coarsely garnetiferous biotite-muscovite-sillimanite schist with granodioritic to tonalitic veinlets. Metamorphic grades reflected by the paragneisses are higher in the northeastern part of the SHhsz than in the southwest (as for the undivided amphibolite). Sillimanite is commonly present to the exclusion of muscovite in the northeast, although overprinted locally by fine grained muscovite. Similar muscovite replacement of sillimanite is observed locally around Stag Hill and further southwest, and therefore the contrast in grade may be merely one of more complete metamorphic downgrading to the southwest.

Garnetiferous, sillimanite-bearing quartzofeldspathic mylonite can be traced along the Long Range escarpment, and muscovite-bearing siliceous mylonite is exposed in the southeast.

A very strong, east-trending rodding lineation parallel to both the long axes of mineral augen and fold hinges is displayed at Stag Hill.

Paragneiss along the southeastern boundary of the zone is partly retrograded.

Long Range high strain zone

Intensely sheared and commonly mylonitic, garnetiferous carbonate-rich to carbonate-poor semipelitic schists, with local mafic metavolcanic bands or dykes, occur next to the marble (next section) within the Long Range high strain zone. They generally reflect peak metamorphic grade and fabric development to the gneisses in the adjoining Stag Hill high strain zone, although more retrograded overall. Foliated red granite injections are common.

3.3.3 Marble (Part II, Section 13.2.3)

Massive marble and calc-silicate marble with rare impure marble bands or lenses, locally intruded by veins of red granite and pegmatite, occurs as a multipli-folded band following the northwest edge of the Long Range Mountains, and as boudinaged lenses or layers within the Stag Hill high strain zone. It was mapped by Phair (1949) on the hills northeast of Little Codroy Pond and near the source of Trainvain Brook on Table Mountain. Marble also forms rafts enclosed in the foliated granitoid rock with which it is brecciated in the north-central high strain zone. It is spatially associated with either mafic metavolcanic rock or undivided amphibolite in all three areas.

3.3.4 Metasedimentary inclusions, Dinosaur Pond belt (Part II-Section 13.2.4)

The metasedimentary inclusions include nonlaminated and laminated garnetiferous biotite paragneiss, banded calcareous schist, microcrystalline garnet-quartz rock, grey metasandstone, and siliceous schist. Outcrops of gneissified breccia composed of angular fragments of laminated paragneiss were observed locally. The xenoliths and the enclosing tonalite are metamorphosed to upper amphibolite (sillimanite) grade during regional deformation, which involved the formation of both an early schistosity superceded by a second foliation ranging from a strong crenulation to segregated gneissic layering. Some of the inclusions show bimetasomatic reaction rims, formed during or after the most intense deformation since fractures and tension gash boundaries formed during extension of the fragments are also rimmed.

Various degrees of patchy retrogression occurred after the formation of the early gneissic fabric within the zone, preferentially around late microfractures. Rocks along the western fault margin of the NChsz are intensely retrograded. Some of these gneisses were subsequently contact re-metamorphosed by a perthite-rich pluton.

3.4 KEEPINGS GNEISS (Part II, Section 13.3)

The Keepings Gneiss (Cooper, 1954), composed of part quartzofeldspathic metasedimentary, part (?) metavolcanic, and part synkinematic granitoid rock, is exposed to the east around Morg Keepings Brook, and is probably part of a tectonic subdomain not yet defined. At least part of the orthogneiss is related to the highly deformed, synkinematic granodiorite-tonalite intrusion surrounding the Keepings Gneiss to the northwest and northeast. Slightly deformed quartz gabbro-diabase cuts the gneiss to the south.

3.5 PRELIMINARY INTERPRETATION OF THE LONG RANGE MAFIC-ULTRAMAFIC COMPLEX AND ASSOCIATED METASEDIMENTARY ROCKS

Mafic meta-igneous rocks of the Long Range Mafic-Ultramafic Complex exposed in the Grandys Lake area (N.T.S. 110/15), as well those described to the west and southwest (Phair, 1949; Brown, 1976b, 1976c), are remarkably similar to the gabbroic portions of the Bay of Islands Complex (Smith, 1958; Church and Stevens, 1971; Malpas and Stevens, 1979) and the Annieopsquotch Mountains ophiolite complex (Dunning and Herd, 1980; Dunning, 1980). The latter are interpreted as ophiolitic remnants, representing an early Paleozoic oceanic crust and upper mantle Church and Stevens, 1971). The layered metagabbro of the Long Range Mafic-Ultramafic Complex is comparable to the 'critical zone' layered cumulate gabbro of established ophiolite sections, and the massive metagabbro and metadiabase is comparable to the high level, or 'isotropic' gabbro (Cann, 1974; Malpas and Stevens, 1977; Dewey and Kidd, 1977).

Cumulate layered gabbros are thought to have developed in chambers in the crust below a spreading ridge, and the extent of individual chambers to be dependent on the spreading rate of the ridge (Cann, 1974); the greater the spreading rate, the greater the breadth and the cumulate sequence and the smaller the sheeted dyke complex (Cann, 1974; Sleep, 1975; Dewey and Kidd, 1977). Thermal modelling also predicts that rapid spreading, due to rapid convection which would also result in a comparatively high overall geothermal gradient, may enable the newly formed oceanic crust to remain hotter farther from the ridge axis than slow spreading (Sleep, 1975). Kinematic models for accretion of material in the magma chamber predict common shear deformation of the ultramafic and gabbroic cumulates in such a case (Sleep, 1975; Dewey and Kidd, 1977).

These predictions may apply to some of the features of the layered metagabbro of the southern Long Range Mountains. The core of the Little Codroy Pond belt in the study area is occupied by very voluminous layered metagabbro; this may be explained at least partly by structural repetition or by disposition with respect to the present surface, but may also reflect a large thickness and width to begin with. The abundance of anorthosite bands in the metagabbros mapped in the Grandys Lake area probably signify the upper parts of the cumulate sequence. However, both Phair (1949) and Brown (1976a) have reported anorthosite-poor cumulates and highly deformed ultramafic cumulates to the southwest (N.T.S. areas 110/11, 110/14), representing lower parts of the cumulate section. The 'low pressure' granulite facies foliation in the upper levels of the cumulate metagabbro sequence may reflect subsolidus spreading deformation of very hot (near solidus) cumulates during spreading, and the unfoliated gabbronorite a younger injection of mafic magma cutting through deformed cumulates. The obvious coexistence of Ca-plagioclase and olivine in the cumulates suggests relatively low pressures for the granulite facies (Miyashiro, 1973, p. 302-3, 312-3). Submagmatically-deformed 'gneissic' cumulates constitute a significant part of the Mings Bight Ophiolite Complex (Kidd and Dewey, 1978), possibly reflecting a comparable situation further north in the Baie Verte area. Down-graded remnants of foliated cumulates were also observed in the South Lake Igneous Complex much farther east (Lorenz and Fountain, 1982). Similar foliations on a more limited scale have been reported in the cumulate sections of the the Marum Ophiolite of Papua, New Guinea (Jaques, 1981), the Blow-Me-Down ophiolite of the Newfoundland west coast (Smith, 1958; Girardeau and Nicolas, 1981; J. Malpas, personal communication, 1983), the Baltimore (Maryland-Pennsylvania) and Tinaquillo (Venezuela) Complexes (Thayer, 1980), and Semail Nappe of Oman (Smewing, 1981).

It is also likely that some of the pegmatites within the layered metagabbro block may have been generated from the cumulates themselves during this deformation. As well, one exposure of clinopyroxene metagabbro from above the critical zone shows evidence of being disrupted (minor rupturing of clinopyroxene) at near igneous temperatures during the emplacement of a magnetite-rich pegmatite. The numerous coarse grained, hornblende-rich dykes and plagiogranite pods in the massive metagabbro and metadiabase may also be the result of fracturing and introduction of water from above.

Isotropic gabbro is interpreted as the high level product of either inward crystallization of magma at the roof of the magma chamber or magmatic 'underplating' concurrent with spreading, and the injection of subvolcanic feeders through the solidified shell (Cann, 1974; Dewey and Kidd, 1977). Isotropic metagabbro, referred to here as massive metagabbro and metadiabase, is particularly abundant in the Long Range Mafic-Ultramafic Complex in the Dinosaur Pond belt, but well developed sheeted dykes between the massive metagabbro and metadiabase and the extrusive rocks could not be distinguished. This may be either because small exposures as rafts obscure the numerous contacts which would serve to identify a dyke complex, or because they did not constitute a very continuous or thick layer to begin with, as suggested by both Cann (1974) and Sleep (1975) for fast-spreading ridges.

Therefore, the minimal exposure of sheeted dykes (if the second alternative above is correct) combined with the extensive layered metagabbro sequence would suggest that the Long Range Mafic-Ultramafic Complex was formed during a period of rapid spreading.

The ultramafic rocks exposed in the study area are of several types and probably have several origins. The harzburgite near Long Pond and perhaps some of the partly serpentinized dunites in the Stag Hill high strain zone probably represent a depleted harzburgite residue from below the cumulate section (Dewey and Kidd, 1977). In this case, they possibly belong to the lower parts of the thrust sheet originally located above the high strain zone (see Chapter 9). Most of the other ultramafic bands and lenses in the Little Codroy Pond belt are thought to be part of the layered metagabbro sequence because of their intimate association with the layered rocks and because their cumulus minerals, mainly olivine and plagioclase, and rare clinopyroxene, correspond to those of the neighbouring layered metagabbros. Their occurrence as attenuated and locally somewhat folded lenses, even within the slightly downgraded parts of the layered cumulate zone, may be manifestations of the early penetrative deformation which affected the cumulates under granulite facies conditions. The altered dunite pods in the Dinosaur Pond belt could be either rafts or intrusions in the tonalite. If rafts, they possibly represent refractory (monomineralic) dunite remnants from the base of the layered cumulate sequence.

The proximity of relatively deepseated (plutonic) parts of the Long Range Mafic-Ultramafic Complex to meta-sedimentary rocks within the Long Range and Stag Hill high strain zones may partly result from tectonic juxtaposition during early thrust faulting, an effect enhanced by late deformation associated with horsting of the Little Codroy Pond belt (discussed in Chapter 9). However, the occurrence of the only recognizable mafic metavolcanic rocks and dykes next to metasedimentary rocks in both the Long Range and the north-central high strain zones indicate a regular progression from intrusive through hypabyssal to extrusive and sedimentary environments.

The metasedimentary assemblages of the Little Codroy Pond belt and the Dinosaur Pond belt contrast markedly. The occurrence of persistent marble beds with the metasedimentary and metavolcanic sequence in the Little Codroy Pond belt contrasts with the highly variable nature of the metasedimentary and volcanic rocks, which include intraformational breccias, in the Dinosaur Pond belt. The sediments of the Little Codroy Pond belt may have been deposited where topography was much more regular than that of the Dinosaur Pond belt.

Suggested protoliths for the semipelitic and calcareous paragneisses and schists of the Little Codroy Pond belt and similar xenoliths of the Dinosaur Pond belt include greywacke, quartzitic sandstone, siltstone, calcareous mudstone, and shale; for the marble, thickly bedded ?dolomitic limestone. The presence of the carbonate indicates a moderately shallow marine environment, above the calcite compensation depth, as opposed to an extremely deep one. The more exotic metasedimentary inclusions, such as microcrystalline garnet-quartz rock, the cummingtonite- and gedrite- bearing siliceous schist, and calcareous breccias may have been associated with submarine weathering of volcanic rocks and/or sea floor hydrothermal activity to produce clays and chemical sediments. Umber, ochre, red, iron-rich clay, chert, tuff, calcareous to siliceous muds and breccias, as well as shale and sandstone, are possible protoliths for the more exotic metasedimentary inclusions in the north-central high strain zone. Samples of the microcrystalline garnet-quartz rock and the cummingtonite-gedrite siliceous schist are geochemically compatible with origins as marine metasedimentary rocks (Part II, Section 13.2.4, Table 9).

The origin of the Keepings Gneiss is not clear. Metamorphic reconstitution and injection of granite have obliterated most primary features. The pebble lenses and crossbeds observed on Cascade Brook indicate some clastic derivation. Some of the felsic rocks may be derived from felsic volcanic and subvolcanic rocks, and the fine grained amphibolites associated with felsic volcanic or clastic rocks derived from mafic volcanic rocks. Other amphibolites may be plutonic, related to the Long Range Mafic-Ultramafic Complex.

CHAPTER 4: METASEDIMENTARY AND METAVOLCANIC ROCKS (COMPONENT 2), AND THE EARLIEST META-PLUTONIC ROCKS (COMPONENT 4a) OF THE LA POILE RIVER GROUP

4.1 FIELD RELATIONS, FACIES DISTRIBUTION, AND NEED FOR THE DEFINITION OF A NEW GROUP, THE LA POILE RIVER GROUP

4.1.1 Introduction

Relationships among the early assemblages of Terrane II have been the cause of considerable confusion. As suggested in Section 1.3, the main difficulty lay in determining the relationships between the thick sequence of metavolcanic and metasedimentary rocks east of La Poile Bay, the metasedimentary and amphibolitic rocks to the north, east, and west, and the Devonian plant fossil bearing metasedimentary rocks in Billiards Brook. The general concordance of structural attitudes throughout is partly responsible.

Brown (1973, 1975) suggested that the Bay du Nord Group and possibly the La Poile Group of Cooper (1954) were Devonian cover sequences overlying continental crust, namely the Port aux Basques Gneiss of Brown (1972). Intense Paleozoic reworking of the early tectonic fabrics of the

Port aux Basques Gneiss during the earliest deformation of the Bay du Nord Group was invoked to explain the difficulty in finding a mappable structural discontinuity between basement and cover (Brown, 1975). However, during this study: (1) the Devonian fossil bearing strata were removed from Cooper's Bay du Nord Group; and (2) fabrics predating the 'reworking' deformation were observed in the remainder of the group.

In order to summarize recent observations, and explain the basis for the redefinition of these rocks into a new lithostratigraphic framework, the field relationships among the metavolcanic, metasedimentary, and subvolcanic rocks of the Bay du Nord and La Poile Groups of Cooper (1954), Port aux Basques Gneiss of Brown (1972), and unseparated amphibolites and metagabbro lenses are outlined below. Evidence for the nature of the basement to the metavolcanic and metasedimentary rocks is also reviewed.

4.1.2 Bay du Nord Group of Cooper (1954)

The Bay du Nord Group was originally defined as a group of largely metasedimentary rocks exposed in two belts, one extending northeast from La Poile Bay, and the other extending northeast from Garia Bay to meet the first near the headwaters of the La Poile River system (Cooper, 1954). Devonian plant fossils were found in low grade sedimentary rocks in the northern belt in Billiards Brook (Dorf and

Cooper, 1943), suggesting a Devonian age for the Bay du Nord Group.

During recent mapping, it was discovered that the fossiliferous rocks were significantly younger than most of the Bay du Nord Group as previously mapped by Cooper (1954). Dykes which fed mafic flows interbedded with the fossiliferous rocks were observed truncating the foliation of the synkinematic granitoid rocks which have in turn intruded higher grade, predeformed Bay du Nord rocks south of the fossil locality (Chorlton, 1980a). The fossiliferous sequence and associated bimodal volcanic suite were accordingly separated from the Bay du Nord Group and informally named the Billiards Brook formation (Chorlton, 1980a). They were correlated with, and are now included in the Windsor Point Group of Brown (Chorlton, 1983).

The pre-Devonian rocks of the of the group near its type area of North Bay was found to be more volcanogenic than originally suggested. At the Strickland Prospect east of North Bay (Figure 2a), felsic bands hosting polymetallic massive sulphide mineralization (Pb-Zn-Ag and Cu) and originally considered to be silicified sedimentary bands (Howse, 1937; Cooper, 1940a) were re-interpreted as felsic volcanic rocks, interbedded with lapilli tuff, agglomerate, tuffaceous greywacke, and conglomerate (Chorlton, 1980a). Granule conglomerate containing mainly felsic volcanic clasts is interbedded with graphitic phyllite and semipelitic schist to the northwest of the volcanic and volcaniclastic rocks.

Several other volcanic-related units southeast of the phyllite were deposited within the Bay du Nord depositional interval. The informally named Dolman formation (Chorlton, 1980a), a massive, highly deformed and metamorphosed dacitic volcaniclastic unit previously referred to by Cooper (1954) as the Dolman Gneiss, overlies Bay du Nord Group metasedimentary and early volcanic rocks in this area but is overlain by them to the east of the area, i.e., metaconglomerate devoid of Dolman clasts occurs consistently along both exposed contacts here (Chorlton, 1980a), but metaconglomerate at the contact of a correlative unit along the Burgeo Highway contains Dolman equivalent clasts (W.R. Smyth, personal communication, 1978). The Baggs Hill Granite (Cooper, 1954; modified by Chorlton, 1980a), a subvolcanic granite varying from equigranular, fine grained granite to porphyritic, locally miarolitic granophyre, intruded parts of the Bay du Nord volcanic and sedimentary sequence near the Strickland Prospect, but contributed clasts to Bay du Nord conglomerates near north and south contacts of the Dolman formation. The Piglet Brook Rhyolite (Chorlton, 1980a) may have been emplaced as flows within the Bay du Nord metasedimentary rocks. It also occurs locally as clasts in conglomerate near the Dolman formation contact. Mafic dykes cut the Bay du Nord metasedimentary and metavolcanic schists and the Baggs Hill Granite, but have not been observed cutting the Dolman formation.

In the eastern part of the area, highly deformed and metamorphosed felsic lapilli tuff is locally interbedded with amphibolitized mafic tuffs or flows near the Bay d'Est Fault, and is associated with metagreywacke, volcaniclastic conglomerate, crystal tuff, and tuffaceous metasediment further north. Deformed and metamorphosed boulder to pebble conglomerate, with semipelitic schist lentils or interbeds, contains rhyolite, subvolcanic granite, metabasalt, and metasiltstone clasts, and is cut by equally deformed and metamorphosed mafic dykes toward Grandys Brook #2 in the southeast (Chorlton, 1980b). Metaconglomerate interbedded with semipelitic schist and tuffaceous greywacke associated with Piglet Brook Rhyolite and capped by Dolman formation continues almost as far as Grandys Brook #2; the Dolman formation can be mapped farther east.

Metasedimentary rocks away from the metavolcanic pile are semipelitic to pelitic schists and migmatite, with identical rock types found locally in the Phillips and Couteau Brook areas. These rocks locally contain thin, convolutely-folded layers of microcrystalline quartz and pink garnet (the coticules of Clifford, 1960).

A persistent band of laminated phyllite follows the northern margin of the Strickland volcaniclastic rocks and Baggs Hill Granite between the head of La Poile Bay and the northeastern corner of the study area. Rhyolite granule metaconglomerate and metamorphosed felsic volcanic/ feldspathic grit beds occur within interbedded graphitic phyllite and semipelitic schist in the North Bay area. The phyllite is also interbedded with coarse metagreywacke in the northeast corner of the area.

The metaconglomerate of the Bay du Nord Group (above) is concentrated as a broad halo around the metavolcanic rocks. It varies from clast to matrix supported, the matrix resembling the associated tuffaceous, relatively feldspathic metagreywacke. Around the Strickland Prospect, the metaconglomerate contains clasts of rhyolite, siltstone, greywacke, and black argillite. Along the north contact with the Dolman formation and between the south contact of the Dolman formation and the Bay d'Est Fault, metaconglomerate contains fragments of rhyolite, Baggs Hill Granite, siltstone, greywacke, Piglet Brook Rhyolite (local), and vein quartz (local) in contrast to the metaconglomerate away from the Dolman formation.

The occurrence of volcanic detritus, and/or interbeds of felsic lapilli tuff, in the metasedimentary rocks away from the main concentration of volcanogenic rocks, and the incestuous relationships among the metavolcanic, subvolcanic, and associated metasedimentary units suggests a facies transition from a complex subaqueous/subaerial meta volcano-sedimentary terrane to a partly contemporaneous metasedimentary basin.

4.1.3 La Poile Group of Cooper (1954) and Chorlton (1978)

The name La Poile Group (Cooper, 1954) was originally applied to a group of sedimentary and volcanic rocks, the base of which was defined by an east-trending, steeply dipping conglomerate band that was interpreted as an important unconformity. Coarse clastic rocks, varying from vent facies pyroclastic to epiclastic or alluvial facies breccias and conglomerates are present within many volcanic terranes (Parsons, 1969), providing an alternative explanation for the occurrence of the conglomerate and associated sandstone in this terrane. Therefore, the group was redefined to include all of the low grade metavolcanic, subvolcanic, and metasedimentary/volcaniclastic rocks on both sides of and including this band (Chorlton, 1978). Pyroclastic rocks, mudflows, and breccias are also present in the area on either side of the conglomerate band.

The redefined La Poile Group originally consisted of three formations: (i) the Georges Brook Formation, (ii) the Roti Granite, and (iii) the Hawks Nest Pond Porphyry. The Georges Brook Formation (Chorlton, 1978) included all of the mafic and felsic volcanic, volcaniclastic, and sedimentary rocks of the group, and contains unseparable subvolcanic mafic dykes and sills. The Roti Granite was emplaced within the depositional interval of the Georges Brook Formation, cutting some of the rocks as sills or dykes and also occurring as clasts in volcaniclastic conglomerate and sandstone. The granite ranges from a medium grained, equigranular granodiorite/ tonalite in its core to locally porphyritic microgranite or rhyolite at its margins and in sills. Sills of Roti Granite intrude interbedded felsic and mafic to intermediate pyroclastic rocks of the Georges Brook Formation around Cinq Cerf Brook, and interbedded felsic tuffs and metasedimetary rocks near Grand Bruit. It is cut by numerous mafic to intermediate dykes, and breaks up in an intrusion breccia with a relatively mafic igneous/clastic matrix northwest of Grand Bruit. Subrounded Roti Granite cobbles and boulders occur in the prominent conglomerate band along Cinq Cerf Brook. The Hawks Nest Pond Porphyry is a porphyritic microgranite sill and/or dyke system which intrudes the Georges Brook Formation; it has since been removed from the group because it has been dated as 410±20 Ma (U/Pb$_{zircon}$: Dallmeyer, 1979), significantly younger than the upper part of the Georges Brook Formation (446±18 Ma: Dallmeyer, 1981).

Largely on the basis of the relationships of the Roti granite, mafic dykes, and conglomerates with the rest of the volcanic and sedimentary rocks, a crude temporal succession of volcanic products in the Georges Brook Formation was recognized within the La Poile area (Chorlton, 1978), and a variation of the sequence was noted in the Peter Snout area (Chorlton, 1980b). The most striking similarity between the two outcrop areas of La Poile Group was the presence of Roti Granite in both, and the occurrence of the thick, massive, dacitic crystal tuff at the exposed top of each sequence. The temporal succession of volcanic products in both areas is included below as part of Table 2 in Section 4.1.8, and is described in part in Section 4.3.4.

4.1.4 Bay du Nord-La Poile Group boundary

The Bay d'Est Fault, a prominent late stage, east-trending fault, juxtaposes the penetratively deformed, lower to middle amphibolite facies rocks to the north with the inhomogeneously deformed, middle greenschist facies Georges Brook Formation to the south. However, the Dolman formation north of the fault bears a striking resemblance to the massive, dacitic crystal tuff of the Georges Brook Formation south of the fault. In the Peter Snout area, volcaniclastic rocks of the Georges Brook Formation apparently pass northward into rocks with similar protoliths, uninterupted by the break implied by the metamorphic transition from middle or upper greenschist facies to lower amphibolite facies and the increase in the degree of strain coincident with the fault zone. It was therefore postulated that the metamorphic contrast may reflect early tectonic burial of the northern rocks, with readjustment brought about by late vertical movement on the Bay d'Est Fault (Chorlton, 1978, 1980a). The late vertical movement of the Bay d'Est Fault was greatest in the west, where it is brittle, and less in the east, where it passes into ductile shear zones. The possible equivalence of the metamorphosed crystal tuffs on either side of the fault has recently been supported by radiometric dates (U/Pb_{zircon}) of 449±20 Ma and 446±18 Ma on the Dolman formation and the Georges Brook upper crystal tuff respectively (Dallmeyer, 1979, 1981; Chorlton, Dallmeyer, and Odom, in preparation).

4.1.5 Port aux Basques Gneiss, Bay du Nord and Harbour le Cou Groups of Brown (1972, 1975)

Brown (1975, 1976a) considered it unlikely that Devonian rocks such as the Bay du Nord Group could have become as structurally and metamorphically complex as the Port aux Basques Gneiss, and accordingly suggested that the Bay du Nord Group was a cover sequence to the Port aux Basques Gneiss. The amphibolite facies Harbour le Cou Group (Brown, 1975) shared recognizable primary sedimentary features with the Bay du Nord Group in the Rose Blanche map area (N.T.S. 110/10), and was considered its high grade equivalent. The Harbour le Cou Group is exposed as two tectonic slivers faulted between slivers of the Port aux Basques Gneiss in a series of slide zones (ductile shear zones or faults) near the community of Rose Blanche. Brown (1975) invoked microstructural reworking of the Port aux Basques Gneiss eastward from the community of Isle aux Morts toward these slide zones, with the resultant destruction of the evidence for a 'pre-slide' tectonic history, to explain why the Port aux Basques Gneiss could not be separated from the cover rocks in the field on the basis of tectonic fabrics by Power

(1955) or Gillis (1972). Since it was subsequently discovered that the belt of Devonian fossiliferous sedimentary and associated volcanic rocks within the Cape Ray Fault zone are actually younger than the main part of the Bay du Nord Group of Cooper (1954) and Brown (1975, 1976b), the Bay du Nord Group (minus the fossiliferous strata) and the equivalent Harbour le Cou Group are thus considered pre-Devonian.

In addition, the metamorphic and structural history of the Bay du Nord Group in the La Poile River map area outlined by Chorlton (1980a) is the same as that proposed for the Port aux Basques Gneiss by Brown (1975, 1976a, 1977) (Chorlton, 1983). What Brown referred to as the 'composite gneissic banding' of the Port aux Basques Gneiss can be correlated for the most part with primary layering and the earliest fabric (S_1) of the Bay du Nord Group; however, the gneissic banding corresponds to D_2 of the Port aux Basques Gneiss in some places. The Port aux Basques Gneiss of Brown apparently corresponds to the metasedimentary, amphibolitic, and migmatitic portions of the 'Bay du Nord Group', and is continuous with these rocks. Brown's Harbour le Cou Group locally contains fine grained siliceous siltstone layers similar to the graphitic phyllite described above, and garnet-quartz stringers (Brown, 1975) such as the coticule bands in the 'Bay du Nord Group' farther north. The 'reworked Port aux Basques Gneiss' that is caught up in the Rose Blanche slide zone at Diamond Cove also contains graphitic phyllite septa (Snelgrove, 1935). It is therefore suggested that the Port aux Basques Gneiss, the Harbour le Cou Group, and Bay du Nord Group are equivalent in age.

4.1.6 Metamorphosed mafic plutonic rocks and unseparated amphibolites

Lenticular bodies of metamorphosed mafic plutonic rock are exposed along a belt stretching northeastward between East Bay and the Blue Hills of Couteau. Most of the smaller lenses are enclosed as rafts in the Baggs Hill Granite. The larger ones are generally tectonic 'slide' (Hutton, 1980) or shear-bounded megaboudins surrounded by metavolcanic and metasedimentary schists. The metagabbros exposed at the Blue Hills of Couteau are successively intruded by equally metamorphosed, fine to medium grained quartz metagabbro or metadiorite, metamorphosed mafic dykes, and Baggs Hill Granite, and are directly overlain by metagreywacke, tuffaceous metasediment, volcaniclastic metaconglomerate, and dacitic crystal metatuff. Dykes of Baggs Hill Granite enclosing angular boulders of the quartz metagabbro or metadiorite are exposed with the metagabbro/diorite in a stream section east of the largest of the Blue Hills.

These metagabbros have been inhomogeneously foliated and metamorphically recrystallized at amphibolite grade. However, texturally well-preserved igneous remnants in the Blue Hills of Couteau are typical of the isotropic gabbro layer of many ophiolites, consisting largely of coarse to medium grained, subophitic metagabbro with local nebulous layering, intruded by irregular bodies of subophitic metadiabase and by veins or pods of plagiogranite. The fine grained quartz metagabbro or metadiorite (above) which intrudes the ophiolitic metagabbro of the Blue Hills of Couteau resembles a diorite which cuts the Annieopsquotch Mountains Ophiolite Complex and is interpreted to be subvolcanic to volcanic rocks of Victoria Lake Group (G.R. Dunning, personal communication, 1981). The highly deformed mafic bodies to the southwest of the Blue Hills of Couteau apparently once consisted of metagabbro and metapyroxenite similar to both the Ernie Pond Gebbro of Chorlton (1978) and the medium grained, subvolcanic metagabbro plugs near Grandys Brook #2. Metapyroxenite similar to metamorphosed clinopyroxenite patches in the Ernie Pond Gabbro, and medium grained, quartz-hornblende metagabbro or metadiorite are enclosed as rafts in the early synkinematic granitoid rocks west of the La Poile Bay area (Chorlton, 1983).

Amphibolites with strong S-L fabrics and variable mineralogy are exposed as extensive wedges without intercalations of metasedimentary rock, and as bands interlayered with semipelitic schist. Large tracts of amphibolite along the southeast side of Big Otter Pond, and extensive wedges of amphibolite near the Cape Ray Fault in the southwest (Grandys Brook #1 and Isles aux Morts Brook area), locally show relict subophitic textures and/or layering reminiscent of coarse grained metagabbros.

It is possible some of the amphibolites represent masses of mafic volcanic rock, since fine grained amphibolite is interlayered with recognizable felsic lapilli tuff with a concentration of other metavolcanic rocks near the Bay d'Est Fault. To the west of La Poile Bay and the main concentration of metavolcanic rocks, thin, sharply-bounded layers of very fine grained amphibolite within a mainly metasedimentary terrane are probably metabasalts and sills or dykes. In addition, a northeastward continuation of the amphibolite wedge northeast of Big Otter Pond passes into pillowed metabasalts of the Victoria Lake Group, a sequence of pre-Caradocian island arc volcanic rocks (Kean et al, 1981; Kean and Jayasinghe, 1981; Kean, 1983).

It is therefore conjectured that the majority of these amphibolites originated partly as metagabbro and metadiabase similar to the oldest components of the Blue Hills of Couteau, and partly as plutonic rocks related to the nearby volcanic activity like the younger, dioritic intrusions at the Blue Hills of Couteau and in the south between Grand Bruit and Grandys Brook #2. Some of the fine grained amphibolites showing no evidence of relict plutonic textures could alternatively have mafic metavolcanic protoliths.

4.1.7 Basement to the Ordovician metasedimentary and metavolcanic rocks

The nature of the crust or basement in this area cannot be demonstrated. There are no exposures representing convincing Precambrian basement with a structural and metamorphic history demonstrably predating that of the Ordovician rocks, or with protoliths incompatible with the Ordovician metasedimentary-metavolcanic-metaplutonic association. The Port aux Basques Gneiss, in particular, has failed to meet these criteria. Therefore, two indirect approaches were persued for evidence which might relate to the nature of the early basement: (i) xenoliths and rafts in the pretectonic and early syntectonic granites were examined as possible examples of crustal material not related to material derived from their immediate hosts, and (ii) field and petrographic inspection of the conglomerates was undertaken in order to identify fragments obviously deformed prior to their incorporation and/or of obviously deepseated plutonic origin.

Inclusions in the subvolcanic Roti and Baggs Hill Granites, the Cinq Cerf granodiorite (Chorlton, 1978) south of the Georges Brook Formation, and the La Poile batholith suggest a predominance of mafic meta-igneous rocks, of whatever affinity, at depth. The Baggs Hill Granite and Roti Granite enclose huge rafts of mafic plutonic rock and include little else, although a few screens of the surrounding volcaniclastic schist were noted in the former. The Cinq Cerf granodiorite (Section 5.4), exposed south of the Grand Bruit Fault, intrudes the Roti Granite at least locally (Cooper, 1954), so that it cannot itself be considered basement predating the volcanosedimentary pile. However, it encloses a variety of xenoliths and rafts, mostly amphibolite with a few very large tracts of metagabbro and mafic dykes. Within the Grand Bruit Fault zone, screens of siliceous mylonite, felsic agglomerate, siliceous arenite, fine grained amphibolite, and migmatite possibly represent the juxtaposed Georges Brook Formation, intruded by granodiorite either during and/or after the first phase of regional deformation, or after tectonic activity associated with volcanism. Alternatively, the screens might qualify as much older sialic crust. Platy fragments of mylonitized amphibolite and biotite schist (either biotite tonalite or metasediment), as well as rounded ultramafic cobbles, are brought up in some of the late dykes which cut the foliation of rocks within the Grand Bruit Fault zone. The megacrystic La Poile batholith includes only amphibolitic inclusions in its core, but encloses xenoliths and screens of the neighbouring metasedimentary schist and foliated granodiorite hosts close to its margins.

No deepseated granitoid clasts were found in the conglomerates of the Georges Brook Formation or in conglomerates underlying the Dolman formation. Granitoid clasts in these conglomerates apparently belong mainly to the Roti and Baggs Hill Granites, although quartz diorite and gabbro clasts are locally abundant in some of the Georges Brook conglomerates. Sparse, small, silicic mylonite clasts found in conglomerate and mudflows of the Georges Brook Formation around Roti Bay and Cinq Cerf could have been derived either from the cataclastic deformation of silicic volcanic or subvolcanic rocks at depth during volcanic instability, or from pre- or synvolcanic shearing of ensialic crystalline basement.

These observations, and the field relations of the pretectonic mafic masses to the Ordovician metavolcanic rocks, suggest that the basement in this area is largely metamorphosed mafic to intermediate igneous rock, most of which could possibly be attributed to magmatism related to the volcanic complex and hosted by oceanic crust. However, the possibility that some of these mafic rocks belong to significantly older ensialic crust and/or that the volcanic rocks in the south are sited on a partly mylonitized ensialic sliver engulfed by synvolcanic magmas should also be considered.

4.1.8 Evolutionary model for the volcanic pile

The field relationships outlined above are consistent with the development of a thick sequence of volcanic and related rocks which built up in the southeast part of

Terrane II, adjacent to a sedimentary basin filled with greywacke, shale, and interbedded mafic volcanic rocks overlying plutonic amphibolite. Simplified facies relationships prior to regional deformation are shown schematically in Figure 6.

The volcanic and related units are polydeformed and metamorphosed. Tectonic transposition and substantial faulting are characteristic of the terrane, and regional metamorphism has obliterated much evidence concerning the primary nature of many of the volcaniclastic units. However, using the relationships observed among the subvolcanic granites, mafic dykes, conglomerates, and the rest of the volcanic and sedimentary rocks, a tentative sequence of deposition is proposed. In the following, it is not intended to imply that the felsic subvolcanic Baggs Hill and Roti Granites are either equivalent or contemporaneous; this would be an artifice stemming from the use of the subvolcanic intrusions as marker units.

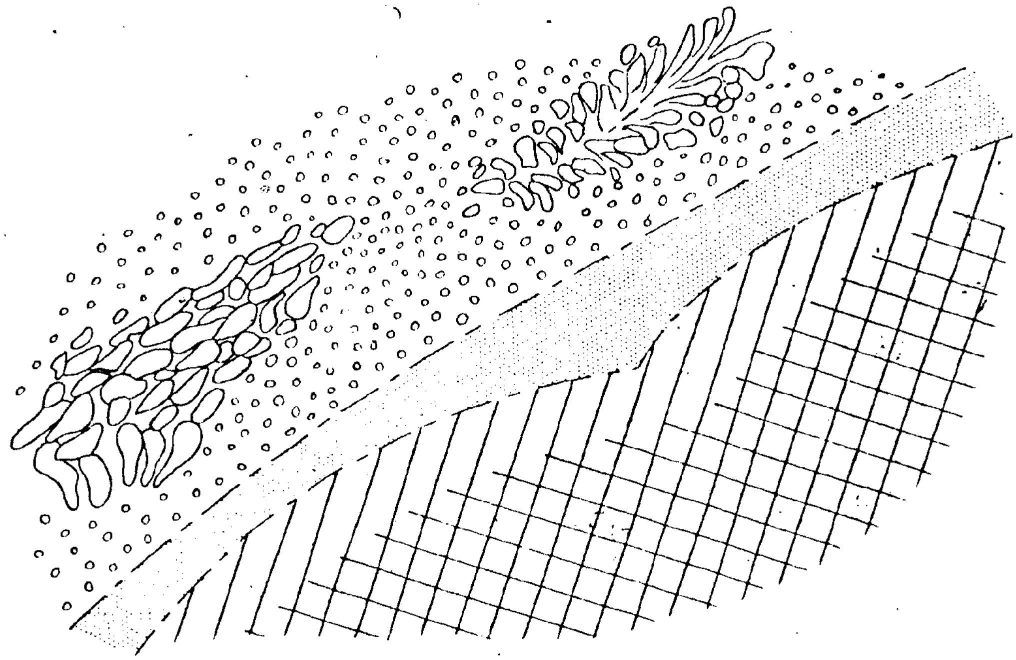
The volcanosedimentary pile has been divided into four separate areas, A through D. Four stages of volcanic, sedimentary, and intrusive activity are tabulated for these areas (Table 2).

Several observations stem from this exercise:

(1) The felsic volcanic and associated rocks around the Strickland Pb-Zn-Ag and Cu prospect are the products of an early stage of volcanism relative to the Baggs Hill Granite.

(2) The most voluminous mafic to intermediate volcanic activity is exposed along the southeast side of the

FIGURE 6: POSSIBLE FACIES DISTRIBUTION OF OLDER ROCKS OF TERRANE II BEFORE REGIONAL DEFORMATION



a - Plan of facies variations, La Poile Bay area, SW Newfoundland

Volcanic and volcanoclastic rocks proximal to volcano magmatic centre

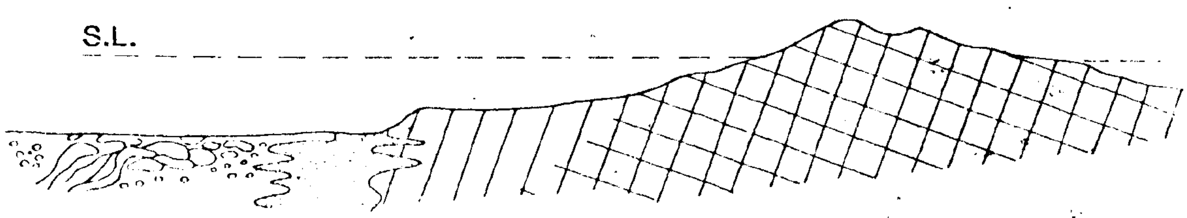
Largely reworked volcanoclastic rocks and greywacke more distal from the volcano-magmatic centre

Argillite with interbeds of greywacke and reworked tuff

Greywacke with minor marl, clay and quartz wacke

Mafic volcanic rock

--- Gradational boundary



b - Exaggerated cross section from ULH corner to LRH corner of 6a symbols as in 6a

Table 2: Sequence of volcanic and sedimentary deposition in Stages 1-4 in four areas of exposed volcanic centre: A) Carrot Brook area; B) Blue Hills of Couteau area; C) La Poile Bay to Cinq Cerf River area; and D) east half of Bay d'Est Fault to Grandys Brook #2 area.

	A	B	C	D
STAGE 1	Finegrained felsic tuff and agglomerate inter edded with tuffaceous, locally conglomeratic greywacke. Conglomerates contain clasts of rhyolite, quartz, siltstone and black argillite. Adjacent phyllite with beds of quartzofeldspathic tuff; semipelitic schist with tuffaceous interbeds.	Graphitic phyllite, greywacke, and possibly felsic tuff overlie the mafic plutonic rocks of the Blue Hills of Couteau.	Rhyolite tuff, siltstone, and greywacke with local pebble conglomerate lenses. Latter contains clasts of rhyolite, rhyolite tuff, vein quartz, and siltstone. Interbedded, felsic to mafic tuff near Cinq Cerf Brook.	Interbanded felsic lapilli tuff and mafic flows or tuffs (now epidote amphibolites) in west, within and near Bay d'Est Flt. Mafic flows and subvolcanic gabbro plug, associated with rhyolite.
STAGE 2	Baggs Hill Granite (BHG) and Piglet Brook Rhyolite (PHR). BHG cuts Stage 1 rocks near Baggs Hill, and includes mafic plutonic rafts and rare screens of volcanosedimentary schist.	Baggs Hill Granite and Piglet Brook Rhyolite. BHG cuts mafic plutonic rocks as dykes, and includes it as large rafts.	Roti Granite (RG) cuts Stage 1.	Roti Granite in southeast (contact obscured).
STAGE 3	Conglomerate with clasts of BHG, rhyolite, siltstone, vein quartz (local), and PBR (local) near Dolman Cove Fm contacts; accompanied by rhyolite granule conglomerate, tuffaceous greywacke, semipelitic schist and migmatite. Mafic dykes cut BHG and volcanic, volcaniclastic, and sedimentary rocks.	Lapilli tuff, crystal-rich greywacke-tuff, conglomerate, and local black argillite. Conglomerate with clasts of rhyolite, siltstone, and PBR, restricted to west side of area.	Voluminous mafic flows and dykes/sills; volcanic breccia; hackly ignimbrite bands; mudflows. Mafic dykes/sills cut RG and Stage 1 rocks.// Quartzofeldspathic tuff with well graded beds.// Conglomerate, siltstone, and coarsely crossbedded sandstone. Conglomerate contains clasts of RG, rhyolite, siltstone, basalt/andesite, 'jasper'(oxidized rhyolite tuff:local), vein quartz (local), and silicic mylonite (local).	Mafic dykes cut RG. Thickly bedded conglomerate, lapilli tuff, coarsely crossbedded sandstone, local argillite lenses, mafic flows and/or dykes. Conglomerate contains clasts of rhyolite, RG, siltstone, basalt/andesite, vein quartz, and gabbro. Conglomerate/ sandstone in Grandys Brook more reworked (well bedded, graded) than farther west.
STAGE 4	Dolman Cove Fm: massive, thickly bedded crystal tuff with minor thinly bedded siliceous tuff, hackly welded tuff, rare porphyry, and local black pebbly siltstone lenses and rhyolite pebble bands.	Dolman Cove Fm: massive, streaky, grey, feldspathic crystal tuff.	Sparsely porphyritic rhyolite dome underlies Eastern Point and is autobrecciated to northeast.// Flowbanded rhyolite underlies ridge through Dinnerbox Hill and clings to face of Highlands of Grand Bruit, autobrecciated to north.// Reversely graded lapilli tuff interbedded with laminated siliceous ash, and rhyolite blocks in dacite tuff matrix from Withy Gulch Hill south of Old Man Pond to Black Duck Br.// Thickly bedded volcaniclastic rocks and banded siltstone with intraformational breccia and dunelike crossbeds, associated with hackly, indurated, felsic tuff and minor volcanic breccia and flowbanded rhyolite underlies Highlands of Grand Bruit.// Dolman Cove Formation: massive, thickly bedded crystal tuff with minor pebble lenses, sedimentary bands, and bands of hackly indurated rhyolite tuff.	Dolman Cove Fm: massive crystal tuff grading to streaky, grey, feldspathic schist.

volcanosedimentary terrane, i.e. south of the Highlands of Grand Bruit in area C and from within to southeast of the Bay d'Est Fault zone in area D.

(3) Later (STAGE 3) mafic volcanism was concentrated in the middle to southwest part of area C. Dykes related to this stage probably extended to the margins of the volcanosedimentary pile, and are possibly related to those cutting metagabbro and metadiorite at the Blue Hills of Couteau.

(4) The latest phase of activity produced the Dolman formation and the analogous, thickly bedded crystal tuffs of the Georges Brook Formation, which are spread over all four areas, and further east. Rhyolite plugs, domes, flows, and a wide variety of felsic pyroclastic rocks of much more restricted extent occur in area C between La Poile Bay, Dinner Box Hill, and Inside Gull Pond.

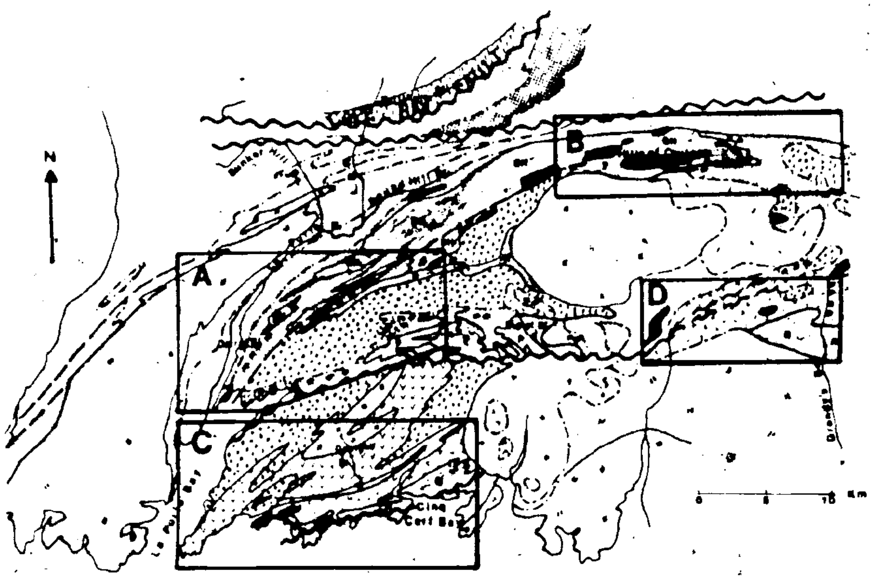
A schematic outline of the development of the volcanic centre (Figure 7) was constructed from Table 2. The gradual build-up of the centre into a thick, locally subaerial volcanic island (?arc) complex is envisaged here.

4.2 REVISED NOMENCLATURE AND THE DEFINITION OF THE LA POILE RIVER GROUP

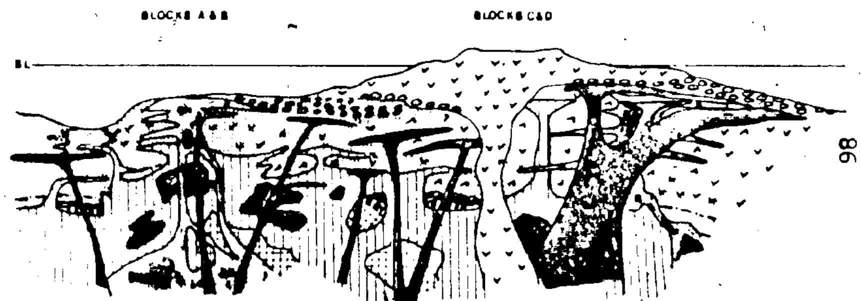
It is suggested that the stratigraphic nomenclature can be revised to provide a more valuable stratigraphic framework for this and future studies in the area (included in Table 1). The main changes introduced here are as follows:

(1) The names Bay du Nord and La Poile are dropped, since the volcanogenic rocks of these two groups are related. The name Port aux Basques Gneiss, which refers to amphibolite and metasedimentary gneisses

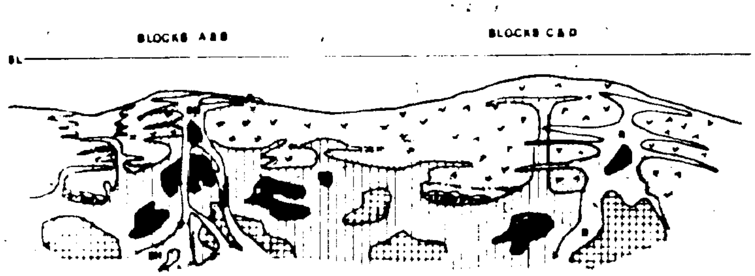
Figure 7: Development of the volcanosedimentary complex east of La Poile Bay for areas A – D in stages 1 to 4.



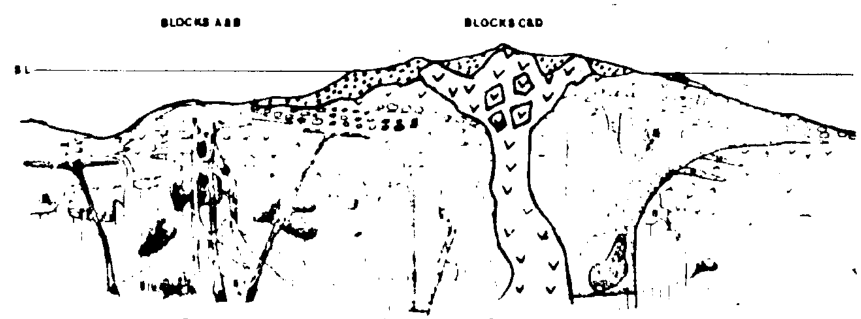
7a: Map of volcanosedimentary complex, showing areas A – D. Legend for map and rest of diagram on opposite page



7c: Stage 3 from Table 2. Emergence of a central volcanic island



7b: Stages 1 and 2 from Table 2. Mafic and felsic submarine volcanism.



7d: Stage 4 from Table 2. Possible development of a caldera complex. ?

LEGEND

WINDSOR POINT GROUP (Emsian - Eifelian)

SILURIAN AND DEVONIAN GRANITOID ROCKS:

- Perthite-rich leucogranite
- Two-feldspar leucogranite
- Megacrystic syenodiorite-granite
- Megacrystic monzogranite; porphyry

ORDOVICIAN METAVOLCANIC, METASEDIMENTARY, AND METAPLUTONIC ROCKS:

- Largely dacitic crystal tuff
- Largely felsic volcanic and volcaniclastic rocks
- Abundant matrix-supported conglomerate
- Subvolcanic granite stocks and rhyolite sheets:
  BH - Baggs Hill Granite; P - Piglet Brook Rhyolite;
  R - Roti Granite
- Cumulate dunite, wehrlite, and clinopyroxenite
- Subvolcanic to plutonic quartz metagabbro, metadiorite, and metadiabase, including local remnants of ophiolite
- Ophiolitic metagabbro and metadiabase
- Black shale - graphitic phyllite
- Greywacke sandstone

continuous with those of the Bay du Nord Group of Cooper (1954), is also dropped. Substantial revision to the boundaries to any of these units precludes the use of any of these established names.

(2) The name La Poile River Group is proposed for all of the roughly coeval metasedimentary and metavolcanic rocks plus inseparable amphibolite of the former Bay du Nord and La Poile Groups, and the former Port aux Basques Gneiss. The Georges Brook Formation, Roti Granite, Piglet Brook Rhyolite, and Baggs Hill Granite are included in the La Poile River Group. The La Poile River is a major river which empties through North Bay into La Poile Bay, and thence into the Gulf of St. Lawrence. It traverses metasedimentary, migmatitic, and amphibolitic rocks, and runs for some distance along the northwest side of the metavolcanic units, and thus exposes, or is proximal to, more lithologies of the group than any other topographic feature in the area.

(3) The recently separated Billiards Brook formation (Chorlton, 1979, 1980a) is omitted from the La Poile River Group, although it was originally included by Cooper (1954) in the former Bay du Nord Group. The Billiards Brook formation is now included as part of the Windsor Point Group, and contains Devonian fossils (Dorf and Cooper, 1943; W.R. Forbes, personal communication, 1980; D.C. MacGregor, personal communication, 1981).

(4) The Hawks Nest Pond Porphyry is not included in the La Poile River Group. This by no means conflicts with field relations, although the unit was originally assumed to be a late porphyry laccolith or sill related to the volcanic pile (Chorlton, 1978).

(5) The informal name Dolman formation is changed to Dolman Cove Formation. The Dolman Cove Formation is a massive, crystal-rich, dacitic tuff with interbedded hackly, welded rhyolite tuff and small sedimentary lenses, which passes northeastward from Dolman Cove into massive, streaky, grey, feldspathic schist. The formation is expanded to include the equivalent, low grade, dacitic crystal-rich tuff of the Georges Brook Formation, which occurs along the north side of the rest of the Georges Brook Formation. The Georges Brook Formation is redefined with this omission. The Dolman Cove Formation is included in the La Poile River Group.

The volcanic and related rocks are separated from the predominantly non-volcanic metasedimentary schists within the La Poile River Group. This is done by applying formation names to the metasedimentary schists, and also giving previously unnamed but mappable volcanogenic units formation status. Several new formation names are proposed below. The significance of measured sections is questionable and estimated thicknesses unreliable because of extreme polyphase deformation and tectonic transposition. General descriptions are given in Part II. The new formation names applied are as follows:

(1) Bunker Hill Brook Gneiss is the name applied to the abundant semipelitic to pelitic schist, amphibolite, and migmatite that occurs west of North Bay, along the La Poile River, and along Bunker Hill Brook, another tributary of the La Poile River. This unit is apparently voluminously exposed both to the west and to the east of the study area, and includes the Port aux Basques Gneiss of Brown (1972). Amphibolite is not generally separated from this formation at present, pending criterion for distinguishing amphibolite of different origins.

(2) Round Hill Brook Phyllite is the name proposed for the graphitic phyllite which occurs along the northwest to north boundary of the volcanogenic rocks of the Carrot Brook Formation. Round Hill Brook, a tributary of the La Poile River, follows this unit to its downstream junction.

(3) Carrot Brook Formation is a name proposed primarily for the felsic metavolcanic bands and associated metavolcaniclastic and metasedimentary rocks which occur east of North Bay and extend norteastward beyond the boundary of the study area. Carrot Brook is a small, precipitous stream which plunges westward into North Bay from the vicinity of the Strickland Prospect. Mafic and felsic volcanic and volcaniclastic rocks between the Blue Hills of Couteau and the Bay d'Est Fault, and metasedimentary

schists, conglomerate and migmatite from Northeast Arm to the Couteau Brook area are apparently continuous with the Carrot Brook Formation.

4.3 MAIN CHARACTERISTICS OF THE LA POILE RIVER GROUP

4.3.1 Subdivisions and field relations of the La Poile River Group

The La Poile River Group (above) is composed of the Bunker Hill Brook Gneiss, the Round Hill Brook Phyllite, the Carrot Brook Formation, the Georges Brook Formation, unnamed mafic and intermediate plutonic and hypabyssal metaigneous rocks, the Roti Granite, the Piglet Brook Rhyolite, the Baggs Hill Granite, and the Dolman Cove Formation.

The Round Hill Brook Phyllite along the southeast side of the La Poile batholith (Map 1) is in gradational contact with the Bunker Hill Brook Gneiss to the northwest and locally infolded with it, and is likewise interfingered with the northwest side of the Carrot Brook Formation. Exposures of graphitic phyllite correlated with the Round Hill Brook Phyllite proximal to both reworked volcaniclastic rocks tentatively correlated with the Carrot Brook Formation and metasedimentary rocks of the Bunker Hill Brook Gneiss occur west of the La Poile batholith (Map 1). The Georges Brook Formation is believed to be gradational into the Carrot Brook Formation, contrasting with the latter mainly because of greater volcanic and plutonic buildup near a volcanic centre.

The Piglet Brook Rhyolite, and the Roti and Baggs Hill Granites were emplaced within the depositional cycle of the volcanic and sedimentary rocks. Some of the mafic and intermediate meta-igneous rocks predate the metasedimentary and metavolcanic rocks exposed, whereas others were emplaced during the volcanic cycle and are subvolcanic to mafic and intermediate flows.

The Dolman Cove Formation caps the metavolcanic, metaplutonic rocks and metasedimentary rocks of the rest of the La Poile River Group exposed within the study area.

The nature of the contacts between Bunker Hill Brook metasedimentary rocks and meta-plutonic rocks has been obscured by intense deformation; most are tectonic 'slides' (usage of Huuton, 1979, 1980).

Where rocks of the La Poile River Group have attained amphibolite facies metamorphic grade, they are commonly migmatitic and/or intruded by veins and sheets of foliated granitoid rock (Section 5.3).

4.3.2 Description of subdivisions of the La Poile River Group

Subdivisions of the La Poile River Group, as outlined above, are described in Part II, Chapter 14 of this thesis.

References for each unit, with unit number on Map 1 in parentheses, are as follows:

Bunker Hill Brook Gneiss ----------- Section 14.2:

Metasedimentary rocks (3a) ----- Section 14.2.1

Amphibolitic rocks (3c) -------- Section 14.2.2

Round Hill Brook Phyllite (3b) ----- Section 14.3

Carrot Brook Formation (4a, b, d) -- Section 14.4

Georges Brook Formation (4c) -------- Section 14.5

Intermediate, mafic, and ultramafic plutonic rocks (4e, f) ------ Section 14.6

Intermediate and mafic dykes (not shown) - Section 14.7

Baggs Hill Granite (5a) ----------- Section 14.8

Piglet Brook Rhyolite (5b) --------- Section 14.9

Roti Granite (5c) ------------------ Section 14.10

Dolman Cove Formation (6a, 6b) ----- Section 14.11

4.4 INTERPRETATION OF THE LA POILE RIVER GROUP

The oldest rocks in Terrane II are included in the Paleozoic (Ordovician and possibly older) La Poile River Group, which includes the former Port aux Basques Gneiss of Brown (1972, 1975), La Poile Group of Cooper (1954), and, with the exception of Devonian fossiliferous strata along the Cape Ray Fault zone, the former Bay du Nord Group of Cooper (1954).

Although it has been disrupted by several deformational episodes, the La Poile River Group displays the general configuration of a marine to locally subaerial, mafic to felsic, dominantly calc-alkaline (Appendix II; Chorlton, 1980a, Appendix I) volcanic centre and adjacent sedimentary basin with subordinate mafic volcanic rocks and hypabyssal intrusions. Submarine fans may have formed around the volcanic edifice, and are proposed as the most likely derivation for the conglomerate-rich metasedimentary halo in this area. Some of the conglomeratic rocks in the central part of the Georges Brook Formation north of Grand Bruit and along the south side of the Highlands of Grand Bruit may be fluviatile in origin.

The Carrot Brook, Georges Brook, and Dolman Cove Formations, the mafic hypabyssal rocks, the Piglet Brook Rhyolite, and the Baggs Hill and Roti Granites are all components of the volcanic centre, which rests on partly ophiolitic crust, represented in the Blue Hills of Couteau mafic complex. The Dolman Cove Formation appears to cap the volcanogenic rocks as a thick and relatively homogeneous sequence of dacitic crystal tuff. The adjacent Round Hill Brook Phyllite, with its reworked volcaniclastic interbeds, probably represents a narrow, starved trough at the edge of the volcaniclastic pile. The phyllite passes northwestward and westward into the metasedimentary part of the Bunker Hill Brook Gneiss, the regionally metamorphosed product of two main components: (1) a thick cover of interbedded greywacke and shale with thin layers of both clay (represented now by profusely garnetiferous layers and by coticules), and marl (now calc-silicate bands), and interdigitated mafic volcanic rocks (now sharply bounded layers of amphibolite); and (2) an underlying mafic basement, perhaps similar in makeup either to the Blue Hills of Couteau mafic complex and/or the Long Range Mafic--Ultramafic Complex. The Bunker Hill Brook metasedimentary rocks are, on the whole, much less feldspathic than the metagreywackes of the Carrot Brook Formation, which are intermingled with felsic metavolcanic rocks. Locally high contents of garnet and biotite, and lack of alkali feldspar in the Bunker Hill Brook metasediments suggest that the original sediments contained high proportions of detrital chlorite or montmorillonite (Mg-, Fe-, and Al-rich) as opposed to illite and kaolinite (Al-rich). Sedimentary rocks of this composition are particularly common in marine environments near island arc terrane (Bjorlykke, 1974).

The nature and facies distribution of the metavolcanic rocks, together with the adjacent, predominantly metasedimentary sequences, are remarkably similar to generalized 'volcanic island - sedimentary basin' models proposed for calc-alkaline volcanic complexes of the Canadian Shield (Ayres, 1982; Dimroth et al, 1982). Elements of similarity include the central, highly pyroclastic and volcaniclastic calc-alkaline (Appendix II; Chorlton, 1980a, Appendix I) volcano-plutonic complex, the dacitic tuff 'cap', 'aprons' of conglomeratic sedimentary rocks, and subordinate mafic metavolcanic units which extend far from the central volcano-plutonic complex into the adjacent marine sedimentary basin. The abundant subvolcanic granitoid to gabbroid intrusions which are abundant in the central complex can be likened to plutonic arc-core complexes documented elsewhere.

Many of these features, in addition to the geochemically calc-alkaline nature (with minor tholeiite) of the volcanic rocks (Appendix II; Chorlton,1980a), suggest a possible island arc centre, founded at least peripherally on an oceanic type crust. However, the high proportion of felsic volcanic rocks in the Georges Brook Formation argues for a foundation of at least partly sialic crust in the central area. As previously noted in section 4.1.7, there is no firm evidence for such a crust, although it is certainly considered a possibility.

CHAPTER 5: SYNKINEMATIC/SYNMETAMORPHIC GRANITOID ROCKS OF THE SOUTHERN LONG RANGE MOUNTAINS (COMPONENT 4b)

5.1 INTRODUCTION

Foliated, equigranular granitoid rocks intrude the Long Range Mafic-Ultramafic Complex and associated meta-sedimentary rocks of Terrane I and the La Poile River Group in Terrane II. They occupy at least half the surface exposure and are intimately associated with their hosts on outcrop scale. In both terranes, tonalitic and grano-dioritic compositions predominate, and have been involved in either some or all of the intense deformation which has affected their hosts.

The Cinq Cerf Complex south of the Grand Bruit Fault is predominantly composed of granodiorite which intrudes and engulfs abundant mafic meta-igneous rock, as well as locally intruding the Roti Granite of the La Poile River Group (Section 4.1.7). It has also undergone penetrative deform-ation which probably reflects a major stage of regional deformation north of the Grand Bruit Fault (Section 9.3).

5.2 TONALITE AND OTHER SYNKINEMATIC GRANITOID ROCKS OF TERRANE I

5.2.1 Rock types, field relationships, and distribution

The synkinematic granitoid rocks of Terrane I fall into the general mineralogical categories, biotite tonalite, garnetiferous biotite tonalite, garnetiferous tonalite-granodiorite, and leucogranite-tonalite.

The biotite tonalite and garnetiferous biotite tonalite form the granitoid component of the mega-agmatite terrane in the Dinosaur Pond belt (Section 3.1) and grade into one another near the transition into the north-central high strain zone[1]. The gradation involves: (i) increased development of tectonic fabric, (ii) increased metamorphic grade during the development of the prominent fabrics, and (iii) local high proportion of metasedimentary xenoliths in the latter. The biotite tonalite is hosted mainly by massive metagabbro and metadiabase of the Long Range Mafic-Ultramafic Complex, although layered metagabbro as well as massive metagabbro is intruded by the biotite tonalite southwest of the area mapped during this study.

The garnetiferous tonalite-granodiorite and leucogranite-tonalite occupy the Little Codroy Pond belt, coinciding in general with the development of the Long Range and Stag Hill high strain zones. The garnetiferous tonalite-granodiorite occurs as _lit-par-lit_ veins and as gneissic sheets in mainly metasedimentary rocks, whereas the leucogranite-tonalite is mainly hosted by amphibolitic rocks.

although it cuts metasedimentary rocks in places. There are no crosscutting relationships between the two types even though they occur very close together, possibly because they are both of the same general age and have not moved far from their source.

5.2.2 Biotite tonalite (Part II, Section 15.1.2)

The biotite tonalite intrudes and encloses variable sized rafts of the massive metagabbro and metadiabase, the proportions of tonalite to metagabbro varying between all extremes from outcrop to outcrop. Flattened polygonized quartz and mica aggregates define a schistosity which intensifies toward the Cape Ray Fault. Next to the fault, biotite is chloritized, quartz is recrystallized into fine grained stringers, plagioclase is highly sericitized, and secondary epidote and carbonate are abundant. A muscovite-chlorite-quartz phyllonite southwest of Windowglass Hill and in several other places along the length of the fault reflects the most thorough retrogression and development of this fabric.

Several minor, discontinuous shear zones occur near the transition to the north-central high strain zone, and coincide with the development of a strong, flattening schistosity which is crenulated by an even stronger foliation defined by red brown biotite interlayered with muscovite. Biotite of the neighbouring, less deformed tonalite also changes from olive green to red brown.

5.2.3 Garnetiferous biotite tonalite (Part II, Section 15.1.3)

The garnet content of this tonalite varies from nil where the granitoid rock encloses only amphibolitic xenoliths to exceedingly abundant where garnetiferous and locally calcareous metasedimentary xenoliths are abundant.

The garnetiferous biotite tonalite displays composite fabrics which vary from gneissosity to schistosity; in most places, a gneissosity defined by segregations of biotite and garnet is apparently crenulated by a second foliation, although this order may not apply everywhere. In general, the second fabric is easier to measure since it is more regular in orientation, and is responsible for the predominant northwesterly striking foliations shown on the map. Gently northwesterly to southeasterly plunging rodding and mineral lineations, and folds in the first fabric are also related to the development of the second fabric. In the north part of the NChsz, garnets overprinting biotite of the early gneissosity are fragmented, and the fragments strung out in the second foliation.

The tonalite is patchily retrograded throughout the

NEhsz, with very local partial chloritization of biotite and saussuritization of plagioclase. Retrogression is intense along the western fault boundary of the zone (described in Section 3.2.4).

5.2.4 Garnetiferous tonalite-granodiorite (Part II, Section 15.1.4)

The garnetiferous tonalite-granodiorite is everywhere associated with semipelitic paragneisses, and occurs as veins, sheets, and structurally concordant masses in the Stag Hill and Long Range high strain zones.

The segregation of micaceous minerals and garnet defines an early gneissosity, which is crenulated to tightly folded. Micas are aligned parallel to both the gneissic banding and the crenulation schistosity. Garnets accompanying the gneissic biotite are commonly fractured and fragments displaced along the second fabric, and plagioclase tends to form porphyroclasts. The second fabric is particularly intense and locally mylonitic in the northeastern end of the Stag Hill high strain zone. Younger, steep, northeast-striking foliations occur along the southeast boundary of the SHhsz and along the Long Range escarpment in the LRhsz. The granitoid rocks along the southeast fault margin of the Stag Hill high strain zone and along some of the shear zones next to the Long Range escarpment are thoroughly retrograded.

5.2.5 Leucogranite-tonalite (Part II, Section 15.1.5)

The foliated, pink leucogranite-tonalite intrudes amphibolite or encloses it as rafts in several places within the Stag Hill and Long Range high strain zones of the Little Codroy Pond belt. These rocks possess tectonic fabrics which vary from schistosity (composite) to gneissosity. Differences in modal mineralogy, particularly ratio of alkali feldspar to plagioclase, are common within individual outcrops. Microcline is most commonly clear and nonperthitic, but may locally show exsolution of hair perthite. Plagioclase is highly altered, with corroded margins; it is commonly embayed or overprinted by clear microcline.

Small pods of quartz syenite intrude amphibolite and metagabbro of the Long Range Mafic-Ultramafic Complex along the west side of the layered metagabbro core.

5.2.6 Granitoid rocks between Deep and Fox Hole Brooks (Part II, Section 15.1.6)

These granitoid rocks consist of tonalite, leucotonalite, and granodiorite. Like the tonalite of the Dinosaur Pond belt, amphibolite inclusions are common. The more granodioritic rocks of the unit surround the Keepings Gneiss, and grade into the veins which intrude tracts of more deformed felsic rocks (Section 3.4, 13.3).

5.2.7 Preliminary interpretation of the tonalite and other synkinematic granitoid rocks of Terrane I

Large volumes of trondhjemite and tonalite, remarkably similar to these granitoid rocks, occur in Archean grey gneiss terranes, where they have been interpreted as resulting from partial melting of metamorphosed mafic rocks (e.g., Arth and Hanson, 1972; Hanson and Goldich, 1972; Barker and Arth, 1976; Collerson and Fryer, 1978; Arth, 1979; Gower et al, 1982). Granulite facies foliated, layered metagabbros underneath the massive metagabbro and metadiabase unit, hydrated under amphibolite facies temperatures along the base of a thrust sheet, are possible mafic sources. In this context, the timing of the early granulite facies metamorphism of the layered metagabbros relative to the regional tectonic events involving the formation of the amphibolite facies high strain zones might be highly significant.

In addition, lower Paleozoic trondhjemite and quartz diorite suites associated with metamorphosed mafic rocks in northwestern and northeastern Newfoundland, the Little Port Complex and the Twillingate Trondhjemite respectively, have been tentatively interpreted as the results of partial fusion of metamorphosed oceanic crust (Malpas, 1979; Payne and Strong, 1979), either in an oceanic island arc environment an oceanic fracture environment (Karson and Dewey, 1978; for the Little Port Complex only). Both interpretations imply the involvement of plate tectonic processes; in this context also, the timing of emplacement and deformation is important.

The granitoid rocks of Terrane I show no evidence of derivation by the fractional crystallization of more mafic magma, and were probably derived by partial melting of either the component 1 ophiolitic metagabbros voluminously exposed in southwest Newfoundland or other mafic metamorphic rocks. There is no evidence that high level metagabbro or hypabyssal and extrusive metavolcanic rocks of the Long Range Mafic-Ultramafic Complex exposed here or their metasedimentary cover reached metamorphic temperatures and pressures adequate for the onset of either hydrous or anhydrous partial melting <u>much</u> <u>before</u> the emplacement of granitoid magmas, although the veined semipelitic paragneisses and the garnetiferous tonalite-granodiorite sheets in the Stag Hill high strain zone may represent <u>in</u> <u>situ</u> partial melting during deformation and metamorphism in the zone. This is not true for the massive metagabbro and metadiabase which hosts the biotite tonalite in the Dinosaur Pond belt, and there is no evidence that this occurred in the garnetiferous tonalite and enclosed metasedimentary xenoliths in the north-central high strain zone. The tonalite of the Dinosaur Pond belt was therefore generated at <u>deeper</u> tectonic levels than those represented by the host terrane now exposed. A model for the generation of these rocks incorporating the structural and metamorphic development of Terrane I will be given in Section 9.1.4 and illustrated in Figure 8.

Post-emplacement polyphase regional deformation under middle to upper amphibolite facies metamorphic conditions has played a significant role in the present textures and mineralogical composition of the gneissic garnetiferous granitoid rocks of the high strain zones. The non-gneissic biotite tonalite intruding the massive metagabbro of the Dinosaur Pond belt was partially recrystallized during deformation under lower amphibolite or upper greenschist facies conditions at most. It is suggested here that the transition from biotite tonalite to garnetiferous biotite tonalite corresponds to an increase in post-emplacement regional shearing and metamorphic grade, and also to contamination by metasedimentary inclusions, some of which consisted of highly ferruginous and aluminous claystone and marl. The siting of a major component of early thrusting above the level of the mafic meta-igneous/ metasedimentary rocks interface in the north-central part of the area may be responsible for the structural and metamorphic contrast (Cross-sections Sheet 1; Section 9.2.4).

The pink leucogranite-tonalite is sited primarily in amphibolitic rocks of the Stag Hill and Long Range high strain zones and in proximity to the major, steep, northeast-trending faults which may be primarily associated with the activity of the Long Range Fault system. These may have been derived and/or may have undergone much of their subsequent tectonometamorphic recrystallization with unlimited access to volatiles and alkalis. Consequently, alkali metasomatism may have been an important influence on present composition. In general, microcline appears to have been stable and repeatedly recrystallizing during deformation and metamorphism; plagioclase is corroded by microcline or myrmekite, and commonly highly sericitized. In contrast, the mafite-hosted biotite tonalite which was not emplaced into either a major high strain zone or deformed and metamorphosed under the influence of the major fault, acted as a relatively closed system with respect to volatiles and alkali elements during emplacement and subsequent metamorphism.

5.3 SYNMETAMORPHIC/SYNKINEMATIC GRANITOID ROCKS, PEGMATITES, AND VEINS OF TERRANE II

5.3.1 Rock types and field relations

Foliated, equigranular granitoid rocks occur as veins, sheets, and rarely thicker intrusions in the metasedimentary rocks and amphibolites of the La Poile River Group. They are normally present wherever their hosts have reached metamorphic grades adequate, or nearly adequate, for partial melting to occur. The granitoids were emplaced after the first regional deformation and the subsequent attainment of the metamorphic peak, and before the second deformation and the superposition of the prominent regional tectonic fabrics.

These synmetamorphic granitoid rocks can be described in terms of two mutually gradational end member phases, Rose Blanche and Port aux Basques phases, which can be broadly correlated with the Rose Blanche and Port aux Basques Granites of Brown (1975) (see Appendix I). The Rose Blanche phase consists of massive, foliated granodiorite to tonalite with veined metasedimentary, or locally amphibolitic, screens, normally gradational into veined host rocks. The Port aux Basques phase is hosted mainly by amphibolite, and is restricted to two broad wedges next to the Cape Ray Fault, in the southwest half of the study area, and in the northeastern wedge between the Cape Ray Fault and Gunflap Hills fault splay.

Boundaries with the gneisses and amphibolites of the La Poile River Group are indicated on the map as gradational. They were positioned on the basis of approximate proportions of granitoid to host rocks observed in the field, as well as by air photo interpretation.

The synmetamorphic granitoid rocks are in fault contact with the Windsor Point Group in most places, but evidence in the La Poile River area suggests that they were deformed (D_2) prior to the eruption of the Windsor Point Group mafic volcanic rocks (Chorlton, 1980).

The deformation and metamorphism during which the granitoid rocks were emplaced affected volcanic rocks to the southeast dated as middle or late Ordovician (446$\pm$20 and 449$\pm$20 Ma; Dallmeyer, 1979, 1982), and predates the latest Early Devonian or earliest Middle Devonian Windsor Point Group. It is cut by the La Poile batholith (432$\pm$20 Ma OR emplaced at approximately approximately 415 Ma (Dallmeyer, 1982). Thus, the granitoid rocks are probably Silurian in age (cf, Odin, 1982).

Numerous pegmatites occur in the areas also occupied by the synmetamorphic granitoid rocks. Kyanite-quartz veins are exposed in a zone along the southeast side of the Cape Ray Faultin both the southwest and northeast parts of the study area. Thick quartz veins are also located along 'slide zones' within five kilometers of the Cape Ray Fault.

5.3.2 Rose Blanche phase Part II, Section 15.2.2)

The Rose Blanche phase consists largely of schistose tonalite to granodiorite with minor granite. The least foliated granitoid rocks generally contain small, sparsely distributed, zoned plagioclase phenocrysts. Broad veins of foliated, muscovite-rich leucogranite cut schistose granodiorite-tonalite near the transition to the Port aux Basques phase in the west part of the terrane.

These granitoid rocks display a penetrative schistosity which is weak in many exposures, but intense near shear zones associated with the Cape Ray Fault and the Gunflap Hills fault splay, and northeast side of the La Poile batholith. A prominent segregation gneissosity is developed where the granitoid rocks are intricately interlayered and deformed with metasedimentary gneisses west of Northwest Brook.

Mylonitic to blastomylonitic granitoid rocks with similarly foliated metasedimentary and amphibolitic screens are exposed from the the east trending portion of the Cape Ray Fault to the Gunflap Hills fault splay and in the broad, 'northeastern' wedge north of the splay in the northeast corner the area. Alkali feldspar porphyroclasts are a centimetre or more in maximum diameter in the west, but much smaller in the east. In the northeastern wedge, fine, medium, and coarse grained granitic schist and porphyroclastic granitic schist alternate in bands.

Rare, sharply bounded, angular xenoliths of both equigranular hornblende quartz diorite and feldspar porphyritic granitoid rock are enclosed in the foliated granodiorite-tonalite exposed on Northwest Brook. These may be either Paleozoic or older granitoid phases from the meta-igneous crustal foundation of the La Poile River Group.

5.3.3 Port aux Basques phase (Part II, Section, 15.2.3)

The Port aux Basques phase varies from tonalite to true granite, samples of the entire compositional range commonly occurring in a single outcrop. A strong gneissic fabric is characteristic of this phase. In the western part of the Bay du Nord belt, the fabric is tightly to moderately folded. It is little folded in the northeastern wedge, but contains a prominent linear component defined by lenticular aggregates of mafic minerals plunging moderately to the southeast in the plane of the southeast-dipping foliations. Some exposures of the Port aux Basques phase near the coast are relatively unfoliated and conspicuously coarse grained; these are cut by pegmatite. Lenticular leucocratic domains resembling feldspar augen are present in many gneissic exposures.

The leucocratic minerals are conspicuously deformed, and in places recrystallized. Plagioclase (unzoned oligoclase-andesine) comprises between 20 and 60 modal percent of the rock, its proportion decreasing with increasing amounts of alkali feldspar. In some samples, the plagioclase grains are bent and fractured; in others, optically continuous but slightly bent fragments are separated by infillings of quartz. Alkali feldspar occurs both as domains of hair perthite passing into irregular rims of nonperthitic, gridiron-twinned microcline, and as interstitial microcline. Myrmekite is abundant in the presence of microcline.

The ferromagnesian minerals also appear to have recrystallized in response to deformation. Biotite flakes and minor local muscovite appear to overprint the leucocratic assemblage, as do traces of fibrolite.

5.3.4 Pegmatites and veins (Part II, Section 15.2.4)

The pegmatites range from several centimetres to over a metre thick, and were generated along and across foliation planes. A conjugate set of thin quartz-feldspar-mica pegmatite veins traverse the foliations of the synmetamorphic granitoid rocks and the La Poile batholith east of Garia Brook.

Most of the pegmatites are composed of albite, microcline, quartz, and apatite. Thick kyanite-quartz bands exposed on the hillside overlooking Grandys Brook are similar in grain size to the pegmatites. Pegmatites nearby contain kyanite, and mylonitized granitoid sheets exposed along strike from the most prominent veins consist of quartz, muscovite, kyanite, and sillimanite. Extension gash fillings of kyanite and quartz were also noted in the northeastern wedge.

5.3.5 Preliminary interpretation of the synmetamorphic granitoid rocks of Terrane II

The Rose Blanche and Port aux Basques phases were emplaced while metamorphic conditions were sufficient to bring about partial melting in the hydrous metasedimentary and amphibolitic rocks that they intrude, and therefore partial melting of the La Poile River Group is considered the most likely origin for these granitoid rocks. Dingwell (1980) used geophysical evidence to suggest that the granitoid sheets were emplaced close to source. The fairly thick sheets or bodies of granitoid rock were probably generated and collected at slightly greater depth in the metamorphic pile, and emplaced upward to the present exposure level. The transition from the more aluminous Rose Blanche phase to the Port aux Basques phase may partly reflect an increase in the proportion of amphibolitic to metasedimentary parent.

In addition, the occurrence of the Port aux Basques phase in the highly deformed rocks within 5 km of the Cape Ray Fault, and its more highly strained, recrystallized nature suggest that its tectonic position may be an important influence on post-emplacement modification. Petrographic textures exhibited by most samples collected in this map area and by several samples collected near the Rose Blanche highway to the south suggest that relatively large feldspar grains have been fragmented during deformation in many rocks. At least short range metasomatic activity within the shear zone south of the fault, probably responsible for several generations of alkali feldspar, locally abundant microcline, and myrmekite in samples from this map area and also local hydrothermal chequered albite in samples to the south (Dingwell, 1980), also chemically altered the granite during deformation and recrystallization. The movement of Na, K, ~~Ca~~, and mobile trace elements in the Port aux Basques phase southwest of the map area has been demonstrated (Dingwell, 1980; Dingwell and Strong, 1981).

It is suggested here that the quartz-kyanite veins and the aluminosilicate-bearing, felsic blastomylonite in the southwest formed by hydrothermal leaching of pegmatites and granitoid sheets, respectively. Similar processes have been described by Gresens (1971) for pegmatite and quartz kyanite deposits in northern New Mexico, and by Vernon (1979) for the production of late sillimanite in some high grade gneisses. The circulation of hydrothermal fluids required for this process may be related to hydrothermal activity associated with the Cape Ray Fault zone.

5.4 CINQ CERF COMPLEX

5.4.1 Field relations and distribution

The name Cinq Cerf Complex (Chorlton, 1978) refers to an extensive granodiorite intrusion which includes rafts and xenoliths of massive amphibolite and subordinate amphibolite facies metavolcanic and metasedimentary screens, all of which are cut by intermediate and mafic dykes. The complex exposed along the south side of the Grand Bruit Fault in the Roti to Cinq Cerf Bay area, and continues eastward as roof pendants in the Chetwynd Granite and huge screens or rafts in the megacrystic quartz monzonite intrusion. It is possible that the complex is also exposed between the north contact of the latter intrusion and several shear zones across Grandys Brook #2 which affect the Roti Granite.

The Cinq Cerf granodiorite intrudes or encloses screens of highly deformed metavolcanic and metasedimentary schist and mylonite which may be part of the Georges Brook Formation near the Grand Bruit Fault, and metavolcanic rocks along strike from the rest of the Georges Brook Formation in the roof pendants. A fine grained phase of the granodiorite, containing the characteristic xenoliths of amphibolite, intrudes the more intensely deformed Roti Granite southwest of the Chetwynd Granite contact (Cooper, 1954; this study).

5.4.2 <u>Main characteristics of the Cinq Cerf Complex</u> (Part II, Section 15.3)

The Cinq Cerf Complex is most commonly represented by equigranular granodiorite containing amphibolite inclusions in various stages of assimilation. Metavolcanic and metasedimentary rocks occur near the Grand Bruit Fault west of Cinq Cerf Bay. Many of the felsic screens have been mylonitized prior to incorporation into the complex.

The granodiorite is penetratively foliated much more intensely near the Grand Bruit Fault than away from it, and simple shear zones are common. The foliation is commonly composite. The granodiorite is retrograded around shear zones, <u>ie</u>., the ferromagnesian minerals are replaced by chlorite-biotite intergrowths, and epidote is abundant.

Dykes are concentrated within 100 m of the Grand Bruit Fault. The dykes vary in composition from nearly-ultramafic to intermediate. They are either simple or composite, and may intersect. Although some dykes are foliated with the granodiorite, others truncate the penetrative foliation and thus may be substantially younger. The former are weakly to strongly deformed, with foliations continuous with the fabrics of the granodiorite, but generally sigmoidal in arrangement.

5.4.3 Preliminary interpretation of the Cinq Cerf Complex

Without knowing the full extent of the Cinq Cerf granodiorite south of the Grand Bruit Fault, or spatial variations in the pre-granodiorite components of the Cinq Cerf Complex, here largely amphibolite xenoliths and rafts, it is hard assess the affinities of the complex. Present evidence suggests vaguely that the granodiorite is synmetamorphic and occurs in roughly the same regional tectonic interval (post-D_1 and pre-D_2) as the other synmetamorphic/synkinematic granitoid rocks of Terrane II. The amphibolite might be a component of the mafic crustal basement underlying the La Poile River Group.

Since the most intense deformation of the Cinq Cerf granodiorite, and phenomenon of dyke emplacement are proximal to the Grand Bruit Fault, it is likely that both phenomena are related to its development.

5.5 COMPARISON OF THE SYNKINEMATIC/SYNMETAMORPHIC GRANITOID ROCKS IN TERRANES I AND II

The voluminous foliated granitoid rocks in both Terranes I and II are largely tonalitic and granodioritic in composition. In both terranes, granitoid rocks intimately associated with migmatitic sedimentary gneisses and minor amphibolite show compositional variations between tonalite and granodiorite within small areas. In Terrane I, large tracts of tonalite with mafic meta-igneous rocks and local metasedimentary rocks as xenoliths are solely tonalitic. The tonalites of Terrane I lack zoned plagioclase and small phenocrysts, whereas the tonalite and granodiorite of Terrane II contain both. However, the Cinq Cerf granodiorite, which includes mainly amphibolite rafts and xenoliths rather than metasedimentary rocks, contains zoned plagioclase.

Compositional variations and textures of the Port aux Basques phase are remarkably similar to the schistose to gneissic pink leucogranite in the Little Codroy Pond belt. Both vary from tonalite to true granite and show evidence of the crystallization of potassium feldspar at the expense of plagioclase. These granitoid units both occur within zones influences by two major fault systems, the Long Range Fault and the Cape Ray Fault (to be discussed in Chapters 9 and 11); however in Terrane I, the influence of the earlier activity of a major, amphibolite facies high strain zone may be equally significant.

There is no evidence that, except for the layered cumulate metagabbros, the oldest rocks of Terrane I were penetratively deformed in a separate episode long before the introduction of the granitoid rocks, although the granitoid rocks of the Little Codroy Pond belt may have been deformed with their hosts during generation and emplacement. Both the granitoid rocks and their hosts in the Stag Hill, Long Range, and north-central high strain zones were subsequently deformed under amphibolite facies conditions, producing strong composite fabrics.

Field and petrographic evidence in Terrane II indicates that at least the semipelitic metasedimentary rocks of the Bunker Hill Brook and Carrot Brook Formations were brought to amphibolite facies metamorphic grades following an early penetrative regional deformation episode (D_1) prior to granitoid emplacement. The granitoid rocks were thus synmetamorphic, and were emplaced close to their source as structurally concordant, lit-par-lit sheets which show no chill or contact effects. This has been supported by gravity data for the synmetamorphic granitoid sheets near Port aux Basques (Dingwell, 1980). The granitoid rocks were later deformed with their hosts under amphibolite facies conditions throughout most of the area.

South of the Grand Bruit Fault in Terrane II, granodiorite of the Cinq Cerf Complex displays both the field appearance and contact relations of the synkinematic tonalites of the Dinosaur Pond belt in Terrane I, and the largely tonalitic to granodioritic composition of the synmetamorphic granitoid rocks of Terrane II north of the Grand Bruit and Bay d'Est Faults. Although the granodiorite was emplaced after the formation of a strong, locally mylonitic foliation of several screens, it is not certain whether these rocks were deformed: (a) during the La Poile

River Group volcanic activity, (b) during the earliest regional deformation which affected the group, or (c) during some very much older tectonic event. If either the first or third possibility proves correct, the granodiorite might be related to magmatism connected with volcanic activity rather than regional metamorphic conditions.

The relative ages of the synkinematic/synmetamorphic granitoid rocks on either side of the Cape Ray Fault is uncertain. The age of the synmetamorphic rocks of Terrane II is poorly bracketed by a U-Pb zircon concordia-discordia age of 432±20 Ma (or more likely, a 415 Ma emplacement age suggested by a nearly concordant zircon separate) on the cross-cutting La Poile batholith (Dallmeyer, 1982), and U-Pb zircon ages of 449±20 and 446±18 Ma for the La Poile River Group metavolcanic pile. A Rb-Sr isochron giving an age of 415±15 Ma for the Rose Blanche Granite of Brown (Brown, 1976b, quoting R. Cormier, personal communication), as well as K-Ar ages of 410±20 Ma (Gillis, 1965) and 415±20 Ma (Neale, 1963) for muscovites from syntectonic pegmatites are tentatively interpreted as reflecting late Silurian to early Devonian deformation (D_2) and regional metamorphism southeast of the Cape Ray Fault. The Cinq Cerf granodiorite is cut by the megacrystic Otter Point Granite, an intrusion very similar to the La Poile batholith. Both are apparently affected by the penetrative deformation culminating in movement on the Grand Bruit Fault, and truncated by the

Chetwynd Granite ($Ar^{39/40}$ biotite cooling age of 372±5 Ma: Dallmeyer, 1979).

The granitoid rocks of Terrane I are presently considered somewhat older than those south of the fault (Chapter 10). This is partly because plutons which cut the foliation of the tonalite further northeast have given fairly old minimum (K-Ar mineral) ages: hornblende from one pluton which yielded a K-Ar age of 455±65 Ma (Herd, 1982), and biotite from another yielded a K-Ar age of 447±8 Ma (Herd, 1982). Gillis (1972) also reported K-Ar biotite dates of 445±18 Ma for either the cross-cutting quartz diorite-megacrystic granite pluton (Component 4b') or a sheared tonalite screen in the north part of the study area; if these reflect cooling of biotite below the closure temperature for argon, they are useful minimum ages.

CHAPTER 6: 'LATE SYNKINEMATIC' GRANITOID PLUTONS OF THE SOUTHERN LONG RANGE MOUNTAINS (COMPONENTS 4b')

6.1 INTRODUCTION

Various types of granitoid (sensu lato) intrusion were emplaced after the development of the early, component 4b synkinematic/synmetamorphic rocks (Chapter 5), but before regional deformation culminated in major movement on the Cape Ray and related faults. In Terrane I, these plutons range from gabbro to granite, many of latter megacrystic; some plutons show pronounced internal compositional variation. In Terrane II, the most voluminous intrusions of this class are megacrystic monzogranites. Other Terrane II varieties include megacrystic syenodiorite-granite, and quartz feldspar porphyry.

6.2 MAFIC TO FELSIC PLUTONS OF TERRANE I

6.2.1 Rock types and field relationships

Compositionally-variable plutons cut the early synkinematic granitoid rocks of Terrane II after the formation of the early tectonic fabric, but before the deposition of the Windsor Point Group along the Cape Ray Fault. Granitoid rocks of this category include quartz gabbro, quartz diabase, quartz diorite, quartz monzonite, and granite. Norite, in addition, has been reported in Terrane I to the north of the study area (Carew, 1980). Three such intrusions from the southern Long Range Mountains will be described below, with emphasis on those investigated during this study. One is a megacrystic quartz monzonite to granite exposed in the southwest part of Terrane I. The others consist of (a) quartz diorite to megacrystic granite and quartz monzonite and (b) quartz gabbro to quartz diabase, and are exposed in the north and northeast parts of the study area.

The intrusion(s) in the southwest correspond mainly to the late components of the Cape Ray Complex, defined by Brown (1972) as a tonalite gneiss complex, the former Long Range Gneiss (see Sections 3.2.1 and 4.2.1), cut by later granite bodies, the Cape Ray and Red Rocks Granites. The Cape Ray Granite was originally described by Brown (1972, 1975) as a megacrystic, pervasively deformed granite exposed at Cape Ray on the southwest coast; the name Red Rocks Granite was applied to a locally sheared, but largely unfoliated equigranular granite exposed at Red Rocks. The name Cape Ray Granite was later used by Brown (1977) to refer to a granite/quartz monzonite that varies from medium or coarse grained and equigranular to coarse grained and megacrystic in texture. The equigranular granite at Red

Rocks was then included in the Cape Ray Granite, a correlation supported by Wilton (1981). The Cape Ray Granite as mapped by Brown (1977) apparently also includes a demonstrably younger, perthite-rich, biotite leucogranite exposed at the southwest corner of the Grandys Lake map area. Therefore, the name is not used here, although in general, the megacrystic quartz monzonite to granite described below can be correlated with the Cape Ray Granite as defined by Brown (1972). Preliminary helicopter reconnaissance has indicated that equigranular phases similar to the Red Rocks Granite grade into the megacrystic phase elsewhere in the southwest part of Terrane I.

The contact relation between the quartz gabbro-diabase and the quartz diorite-megacrystic granite is uncertain. Apophyses of quartz monzonite or porphyroblastic quartz granodiorite which possibly belong to the quartz diorite-granite cut the quartz gabbro around Nitty Gritty Brook.

Brown (1972, 1975) has reported clasts of Cape Ray Granite in conglomerate of the Windsor Point Group. The Devonian Windsor Point Group also unconformably overlies the high level parts of the the quartz gabbro-diabase in the northeast part of the study area. There is no direct field evidence to indicate the age of the quartz diorite-megacrystic granite intrusion to the west relative to the Windsor Point Group, although a strikingly similar pluton in the King George IV area (12A/4) is overlain unconformably by the group (Kean, 1983). Therefore it is assumed that the quartz diorite-megacrystic granite also predates the eruption and deposition of the Windsor Point Group along the fault.

The compositionally variable intrusions are cut by smaller, perthite-rich leucogranite plugs and late, mafic and felsic dykes of Component 4c, presently considered mainly younger than the Windsor Point Group.

6.2.2 Megacrystic quartz monzonite to equigranular granite (Part II, Section 16.1.2)

Inhomogeneously deformed, coarse grained, megacrystic quartz monzonite represents the bulk of the unit within the area mapped. It is inhomogeneously deformed, locally intensely. Medium to coarse grained, equigranular granite or granodiorite patches are common to the southwest (Brown, 1977). The rocks probably occur as several separate intrusions, which typically either enclose rafts of metagabbro and screens of equigranular granitoid rock or project as dykes into Long Range Mafic-Ultramafic Complex and the tonalite.

6.2.3 Quartz diorite to megacrystic granite (Section 16.1.3)

This intrusion is characterized by widely varying composition, the abrupt transition in some outcrops from medium grained quartz diorite to megacrystic granite or quartz monzonite with large orthoclase megacrysts, and randomly oriented hornblende and biotite. Many screens of the tonalite and its mafic meta-igneous inclusions are enclosed in the body, and patches of diorite occur away from the main pluton, making the precise boundary of the pluton difficult to define in the field. All rock types contain many small, partly assimilated mafic xenoliths.

The intrusion includes quartz diorite, megacrystic granite, quartz monzonite, and quartz monzodiorite, the latter limited in exposure. Quartz diorite is the predominant phase in the west, and in some outcrops grades abruptly into orthoclase megacrystic granite or quartz monzonite. The transition from quartz diorite into plagioclase and orthoclase-porphyritic quartz monzonite is more subtle. The latter is characterized by a variable abundance of rectangular, pink alkali feldspar porphyroblasts (perthitic 'orthoclase') several centimetres long, which overprint medium grained quartz diorite in which the plagioclase is heavily sericitized.

The intrusion is more highly fractured and altered to the east and southeast than it is to the northwest. Carbonate patches may be present in some of the highly sheared rocks, and plagioclase is saussuritized next to the Cape Ray Fault. It is largely unfoliated, but a strong cleavage grading to schistosity is evident near the Cape Ray

Fault. Several sheared outcrops of the granite or quartz monzonite within the Cape Ray Fault zone in Garia Brook are leached of almost all mafic constituents.

Contact effects, such as muscovitization and/or fibrolitization of plagioclase, patchy microclinization of plagioclase, and chloritization of biotite and amphibole, occur in the tonalite and mafic meta-igneous association at the boundary and extend for an unknown distance to the west. It is uncertain whether the contact aureole overprints or is the cause of some of the alteration in the highly sheared rocks in the north-central high strain zone. The exposure of sporadic patches of the intrusive quartz diorite away from the western boundary of the main surface exposure of the body could mean that the intrusion is either continuous in the subsurface or occurs as smaller, separate bodies for some distance to the west. It is therefore difficult at present to assess whether such a width of altered rocks could reasonably be related to this intrusion, whether the emplacement of the intrusion provided a source of heat, causing convection along a previously existing hydrothermal pathway, or merely caused hydrothermal degradation.

6.2.4 Quartz gabbro-diabase (Part II, Section 16.1.4)

The main body of the gabbro consists of medium grained, subophitic hornblende-clinopyroxene gabbro with small, coarse grained pegmatite pockets. Dykes and other fine grained phases generally display a doleritic texture. Mafic metamorphic or meta-igneous xenoliths which may be either finer or coarser grained and either more or less mafic than the host, are found in many exposures. On a hill overlooking the headwaters of Billiards Brook, a fine grained phase of the gabbro is in contact with a breccia of diabase or basalt, medium grained gabbro, pyroxenite, feldspar-phyric gabbro, and diorite, all apparently belonging to the quartz gabbro-diabase unit, and the older, component 4b foliated tonalite and pegmatite; this is a basal breccia of the Windsor Point Group (Chapter 7). Diabase sheets cut through highly altered and brecciated, synkinematic granitoid rock northeast of the breccia outcrops.

6.2.5 Preliminary interpretation of mafic to felsic plutons of Terrane I

Some of these intrusions show internal compositional variations which may be attributed to both differentiation processes and hydrothermal or pneumatolytic activity.

Pneumatolitic activity is probably best represented in the quartz diorite-megacrystic granite which possibly intersected the early, north-central high strain zone. In the megacrystic granite phase of this intrusion, the matrix of diorite is overprinted by alkali feldspar crystals and plagioclase crystals are high sericitized. Mafic and felsic dykes cutting the quartz diorite are straight-sided and very fine grained. The intrusion must have been cooled, and possibly uplifted with its host terrane (during activity on the Cape Ray Fault?) before the emplacement of the dykes. However, the feldspathic dykes cutting the quartz diorite-megacrystic granite have apparently been affected by hydrothermal alteration, suggesting that hydrothermal activity was still active, either associated with the original system or connected with the Cape Ray Fault, when they were emplaced. As suggested at the beginning of this section, the contact relationship between the quartz gabbro-diabase and the quartz diorite-megacrystic granite is not clear. The major distinctions between the quartz diorite and the quartz gabbro/diabase to the east are: (i) the local presence of brown rather than green igneous hornblende or amphibole, coarse crystals of sphene, and abundance of magnetite in the quartz gabbro; (ii) the exceptional abundance of apatite in the quartz diorite-megacrystic granite; and (iii) the gradation of the quartz gabbro from medium grained, subophitic gabbro to relatively fine grained diabase. These variations could actually be reflections of compositional zonation, late magmatic hydrothermal activity, or the contrasting levels of emplacement with respect to the present erosion surface rather than separate origin. Pending further investigation, the quartz diorite to megacrystic granite intrusion is presently considered to have been emplaced during the same tectonic interval as the quartz gabbro/diabase, but not necessarily related to the same magma chamber.

Without petrochemical study, little can be said about the affinities of these intrusions, but several features are noteworthy. First, the ubiquitous presence of partly assimilated amphibolite (in the q.d.) and other mafic meta-igneous xenoliths (in the q.g.) may in part reflect the source terrane. Secondly, the intense sericitic alteration of plagioclase, and possibly the chloritization of biotite, apparently accompanies the growth of clear orthoclase megacrysts in the quartz diorite to produce the megacrystic granite, suggesting interaction of the crystalline solid with hydrothermal fluids just after the final crystallization of the quartz diorite body. Similar activity may be responsible for the development of alkali feldspar porphyroblasts in the quartz gabbro.

6.3 MEGACRYSTIC GRANITOID PLUTONS AND PORPHYRY OF TERRANE II

6.3.1 Rock types and field relations

Three large granitoid plutons, two of megacrystic monzogranite and one of syenodiorite, were emplaced after the first regional deformation event and local partial melting of their amphibolite grade host rocks, and before at least the culmination of the second regional deformation episode. Several smaller bodies of quartz feldspar porphyry were emplaced into greenschist facies rocks during the same tectonic interval.

The megacrystic monzogranite plutons are the most voluminous. The megacrystic La Poile batholith (Cooper, 1954) and Otter Point Granite (Chorlton, 1978) are very similar in appearance, and intrude the synmetamorphic granitoid rocks. The La Poile batholith has been dated by U-Pb zircon discordia-concordia methods as 432 ± 20 Ma (Dallmeyer, 1981), however, a nearly concordant zircon fraction suggests that the age of emplacement may be near 415 Ma, and that some of the zircons may be inherited from either source or host. Both plutons have been affected by the second regional deformation (D_2) of Terrane II, and precede the development of the Cape Ray and Grand Bruit Faults.

The La Poile batholith intruded the Rose Blanche <u>phase</u>, which itself intruded the La Poile River Group after D_1.

Patches of little foliated Rose Blanche phase are enclosed in the batholith near its northwestern margin. Rarely, thin pegmatite sheets that cut the Rose Blanche phase in the Garia brook area also cut the La Poile batholith after the formation of the regional D_2 fabric.

The Otter Point Granite cuts the Cinq Cerf Complex along the south coast between Roti Bay and Connoire Bay. Partly assimilated inclusions of Cinq Cerf granodiorite and rafts of both the granodiorite and amphibolite are common locally. The foliation of the Otter Point Granite is truncated by a more mafic, undeformed megacrystic quartz monzonite (Unit 13 on Map 1), and by the even younger Chetwynd Granite.

The Hawks Nest Pond Porphyry (Chorlton, 1978) is a porphyritic microgranite which intrudes the Georges Brook and Dolman Cove Formations as a thick sill or laccolith in the centre of the highland plateau around Hawks Nest Pond, and as lenses or thin sheets to the south and southwest. Small dykes or sills of similar porphyry occur around the Bay d'Est Fault zone near Grandys Brook #2. The foliation of the Hawks Nest Pond Porphyry is truncated by the unfoliated Chetwynd Granite and by the Bay d'Est Fault.

A more unusual pluton underlies the peaks around Ironbound Hill and the source of Couteau Brook. The rocks range from syenodiorite to granite, and intrude the synmetamorphic granitoid rocks, and both suites are deformed during the D_2 event. The dominant foliation (S_1-S_2) of the

Dolman Cove Formation is warped around the contact with the quartz monzonite near upper Côteau Brook and mineral and mineral aggregate lineations plunge steeply inward toward it, the configuration suggesting an originally mushroom or funnel-shaped intrusion. The Ironbound complex was cut by equigranular, two-feldspar leucogranite (Peter Snout leucogranite, Section 8.2).

6.3.2 La Poile batholith (Part II, Section 16.2.2)

The La Poile batholith is a large body of porphyritic monzogranite which varies slightly (but continuously) from granite to granodiorite in composition (Appendix III). The most abundant rock type in the widest part of the batholith is a coarse, white to pink weathering megacrystic quartz monzonite to granodiorite. Pegmatites are locally abundant. Sheets of fine grained garnetiferous aplite are exposed in the centre of the highland between Deep Brook and the La Poile River.

Partially assimilated xenoliths of amphibolite can be found in the core of the batholith, whereas xenoliths and screens of metasedimentary country rock and synkinematic granitoid rock occur near the margins.

6.3.3 Otter Point Granite (Part II, Section 16.2.3)

Most exposures consist of coarse grained, alkali feldspar and plagioclase megacrystic granite. Several thick pegmatites and copious pink aplite are associated with the batholith.

The phenocrysts may be aligned, giving the rock a planar fabric which is noticeably stronger toward the Grand Bruit Fault, and not at all obvious to the southeast on the offshore islands and Otter Point. Specimens collected near the fault are intensely deformed, and contain polygonized quartz with strong undulose extinction, quartz-filled tension gashes across feldspar megacrysts, and brittle fractures with offsets in phenocrysts originally oriented at a high angle to the foliation.

6.3.4 Hawks Nest Pond Porphyry Part II, Section 16.2.4)

The Hawks Nest Pond Porphyry contains phenocrysts of plagioclase, alkali feldspar, quartz, and biotite, set in a fine grained leucocratic matrix. Deformation of the thickest body of Hawks Nest Pond Porphyry is very inhomogeneous. A single fracture cleavage is developed along the southeast side of the body, whereas a strong flattening schistosity is developed in the relatively thin sills or dykes. The fabric is attributed to regional D_2 of Terrane II.

6.3.5 Ironbound syenodiorite-granite (Part II, Section 16.2.5)

The intrusion contains two major phases: an unfoliated, porphyritic (or porphyroblastic) syenodiorite restricted to the western part, and strongly to moderately foliated, porphyritic granite in the east and southeast. Aplite and pegmatite are associated with the most granitic, southeastern part of the pluton.

The most interesting aspect of this intrusion, aside from its peculiar compositional variation, is deformational. The pluton itself is little deformed in its syenodioritic western part, but becomes increasingly foliated to the southeast and east. Megacrysts of microcline are disaggregated and recrystallized as much finer grains along the foliation in some of the eastern exposures.

6.3.6 Preliminary interpretation of the megacrystic granitoid rocks and porphyry of Terrane II

Hypotheses for the origin of the megacrystic granites of Terrane II vary from remobilization of sialic crust (e.g., Strong and Dickson, 1978; Strong, 1980; Jayasinghe and Berger, 1976) to production of calc-alkaline magmas above an east-dipping subduction zone (Strong et al, 1974). Geochemical modelling of several plutons from the northeastern Gander Zone suggests that these plutons, which indeed show a calc-alkaline affinity, originated from partial melting of greywacke (volcanogenic sediment) (Jayasinghe, 1979).

This mode of origin might explain their emplacement after recumbent folding, tectonic burial, and granitizationin Terrane II, some perhaps existing as magmas at depth in the crust for some time before deformation provided a trigger or escape route for upwards emplacement. High level emplacement could result in a coarsely feldspar-phyric microgranite like the Hawks Nest Pond Porphyry, dykes and/or sills of which are numerous in the Highlands belt.

However, it may be significant that the megacrystic granitoid rocks in southwest Newfoundland are more mafic than those studied by Jayasinghe (1979). They are calc-alkaline in composition like the northeastern Gander Zone megacrystic granites, although also very similar to both the late volcanic magmas of their La Poile River Group hosts, and the megacrystic granitoid rocks of Terrane I. Therefore, similar petrogenesis for both the megacrystic granites of Terrane II and the volcanic magmas of Terrane II as well as the megacrystic granitoid rocks of Terrane I should be considered.

The Ironbound syenodiorite-granite is unusual in petrology and composition. Unpublished analyses of the more mafic phase show it to be Cr and Ni rich and high in K and incompatible trace elements, but not peralkaline. No interpretation is offered here.

6.4 COMPARISON BETWEEN COMPONENT 4b' PLUTONS OF TERRANES I AND II

Megacrystic granitoid rocks, generally considered characteristic of the Gander Zone, occur in both terranes. However, the megacrystic granitoid rocks of Terrane I generally show more internal textural and compositional variation; many are associated with significantly more mafic counterparts. In contrast, the megacrystic granitoid batholiths in Terrane II (except for the syenodiorite-granite) are remarkably uniform internally in composition and texture.

The more mafic component 4b' granitoid rocks in Terrane I show a remarkable resemblance, though less deformed and metamorphosed, to some of the plutons (component 4a) related to the development of the La Poile River Group and its basement (see discussion, Section 11.2).

CHAPTER 7: WINDSOR POINT GROUP SEDIMENTARY AND VOLCANIC ROCKS (COMPONENT 3)

7.1 DEFINITION, DISTRIBUTION, AND FIELD RELATIONS

The Windsor Point Group (Brown, 1972, 1975, 1976a, 1977) is an assemblage of nonmarine sedimentary and volcanogenic rocks which is exposed along the trace of the Cape Ray Fault from the southwest tip of Newfoundland (Brown, 1975) for at least 125 Km inland to King George IV Lake (Kean and Jayasinghe, 1981). The informally named Billiards Brook formation of the La Poile River area (Chorlton, 1980a) is now included in this group. Plant fossils indicate a Devonian age for the latter strata (Dorf and Cooper, 1943).

Specimens collected recently by W.R. Forbes from the original fossil locality and from a new locality 35 Km to the northeast include *Drepanophycus gaspianus*, *Taeniocrada*, *Psilophyton*, *Trimerophyton* (tentative), and *Pertica*, and confirm an Emsian-Eifelian (late Early Devonian or early Middle Devonian) age for the group (W.R. Forbes, personal communication, 1981). Palynmorphs collected from the northeastern locality suggest the same age (W.C. MacGregor, personal communication, 1982).

The Windsor Point Group is folded, refolded, and faulted by activity along the Cape Ray Fault system, but generally faces south within the map area. The group is bounded to the northwest by the tonalite (component 4b) and included mafic rocks (component 1) and locally by compositionally-variable granitoid rocks (component 4b') of Terrane I upon which it rests unconformably. Fragments of all three components occur as clasts in Windsor Point Group conglomerates (Brown, 1975, 1977; Chorlton, 1980a; Kean and Jayasinghe, 1981). Siliceous mylonite derived largely from the tonalite also occurs as clasts in volcaniclastic rocks. Tuffisite dykes, probably related to combined fault and volcanic activity, occur along the mylonitic banding of siliceous mylonite in Isles aux Morts Brook. Aphyric rhyolite dykes of the group cut the tonalite complex northwest of the main fault zone.

Mylonite zones along the main curvilinear trace of the Cape Ray Fault mark the contact of the Windsor Point Group with highly metamorphosed rocks of the La Poile River Group and synmetamorphic granitoid rocks in the southwest and northeast segments of the Cape Ray Fault zone. In the central inflection of the fault zone, relations are more complicated. As well as being faulted against the synmetamorphic granitoid rocks of Terrane II, mafic feeders to Windsor Point mafic volcanic rocks cut the already deformed, synmetamorphic granitoid rocks along the southern side of the fault zone, and Windsor Point Group clastic rocks rest unconformably on mylonite and phyllonite within the fault zone. Northeast of the study area, the group contains deformed clasts derived from both sides of the fault zone and was therefore originally deposited unconformably on both (Kean and Jayasinghe, 1981); there, the southeastern contact was later faulted and the rocks near the southern margin face northwest in contrast to the general southeasterly facing direction.

Thus bounded, the Windsor Point Group is best exposed in the northeast-trending sections of the Cape Ray Fault zone, and pinched out in the east-trending inflection of the fault, where the Gunflap Hills fault splay coalesces with the main fault. Several intensely deformed boudins of Windsor Point volcanic rocks were recognized along the east-trending fault segment.

Small, subvolcanic granophyre pods (or rhyolite domes), the Nitty Gritty Brook Granite (Chorlton, 1980a) and the Windowglass Hill Granite (Bucknell, Mackenzie, and Wilton, 1980), are coeval with the extrusive volcanic rocks. The Nitty Gritty Brook Granite intrudes Windsor Point Group sedimentary and volcaniclastic rocks as well as component 4b' quartz diorite to the northwest, but is autobrecciated and intermixed with hematitic siltstone, or 'iron formation' along its southern margin. There, the Nitty Gritty Brook Granite is overlain by sedimentary and volcaniclastic rocks which contain Nitty Gritty Brook clasts. The Windowglass Hill Granite cuts the Windsor Point Group southwest of Isles aux Morts Brook; similar rhyolite or microgranite occurs as flows or hypabyssal intrusions of the Windsor Point Group to the northeast of the brook. Some of the rhyolite or microgranite/granophyre clasts in nearby volcaniclastic rocks may have been derived from the Windowglass Hill Granite or similar rock.

All of the rocks of the Windsor Point Group within the boundaries of the study area have been both metamorphosed to greenschist facies grade and deformed by activity within the Cape Ray Fault system. Therefore, the prefix meta has been dropped below. However, it should be noted that the degree of penetrative deformation and metamorphism decreases dramatically in the King George IV Lake area to the northeast (Kean, 1983).

7.2 MAIN CHARACTERISTICS OF THE WINDSOR POINT GROUP

The volcanogenic rocks of the Windsor Point Group are strongly bimodal, and structurally as well as depositionally interfingered with nonvolcanogenic sedimentary rocks. Among the latter are coarse basal breccias containing clasts largely derived from Components 1, 4b, and 4b' of Terrane I. Descriptions of the volcanic and sedimentary rocks of the Windsor Point Group, as well as the subvolcanic granophyre bodies, are given in Part II, Chapter 17 as follows:

7.3 PRELIMINARY INTERPRETATION OF THE WINDSOR POINT GROUP

Exposure of the Windsor Point Group is apparently restricted to the Cape Ray Fault zone. Basal breccias are common along the northwest side of the fault zone. Bimodal volcanic activity along the Cape Ray Fault is an essential element in the group. Rapid deposition possibly linked with faulting and volcanic instability is reflected by the angularity of matrix, and lack of imbrication and sorting within individual beds in the coarse clastic rocks. Therefore, a genetic link between the activity of the Cape Ray Fault and the deposition of the Windsor Point Group is suggested here.

Parts of the sequence are fluviatile, with paleocurrent directions from the southwest (Chandler, 1982). Red beds associated with felsic and mafic volcanic rocks occur northeast of the map area (Kean and Jayasinghe, 1981), and are perhaps the source for red siltstone clasts in the sedimentary rocks and intraflow breccia in the study area.

The fault and the overlying Windsor Point Group stretch from the southwest tip of Newfoundland at least as far as King George IV Lake, and the case for its interpretation as a wrench fault will be presented through considerations of structural development and timing of fault activity with respect to other events (Section 9.4).

CHAPTER 8: 'LATE' OR 'POST' TECTONIC INTRUSIVE ROCKS OF THE SOUTHERN LONG RANGE MOUNTAINS (COMPONENT 4c)

8.1 INTRODUCTION

Intrusions in this category generally truncate the regionally penetrative tectonic fabrics of their hosts. Most common are relatively small, potassic, either two-feldspar (wholly subsolvus) leucogranites or perthite-rich (transolvus) leucogranites. The two-feldspar leucogranites were emplaced solely in hosts which were intensely deformed under amphibolite facies conditions in Terrane II. The more widespread, perthite-rich leucogranites are found in host rocks deformed under either greenschist or amphibolite facies conditions in both Terranes I and II; however, where emplaced in the higher grade terranes, there are indications that the hosts were uplifted, partly eroded, and partly cooled before intrusion.

A larger, megacrystic monzogranite batholith which extends east of Grandys Brook #2 near Burgeo crosscuts the foliation of the Otter Point Granite. It may be more related in origin to the foliated megacrystic granitoid rocks, which it markedly resembles, than the potassic leucogranites. The megacrystic monzogranite was cut by one of the perthite-rich leucogranite plutons and by rhyolite dykes.

Each terrane is cut by distinctive late dyke suites. Dykes in Terrane I apparently intruded along regional east-northeast and northwest-trending fracture sets (Phair, 1949). A pattern has not yet been demonstrated southeast of the Cape Ray Fault. This is partly because many of the dykes may not have been identified as a suite distinct from the La Poile River group dykes, and partly because at least some of them have been deformed under deepseated conditions during the prolonged deformational events which affected much of the present exposure of Terrane II.

8.2 LATE MEGACRYSTIC MONZOGRANITE, BURGEO AREA (PART II, SECTION 18.2)

The 'Burgeo' megacrystic monzogranite is remarkably homogeneous in composition and generally megacrystic to its margins, although a megacrystic-poor contact zone is exposed locally in Grandys Brook #2. It is coarse grained and mafic-rich, and intrudes previously foliated, metamorphosed volcanic-related rocks of the La Poile River Group.

8.3 TWO-FELDSPAR (WHOLLY SUBSOLVUS) LEUCOGRANITES (PART II, SECTION 18.3)

8.3.1 General characteristics

The subsolvus leucogranites occur as small lensoid pods which commonly cut across the strong, regional structural grain of Terrane II, and as larger, poorly defined intrusion zones of similar geometric aspect which enclose huge rafts and pendants of the previously foliated, synkinematic granitoid rocks and La Poile River Group amphibolite facies schists. All were emplaced into amphibolite facies rocks, and none have contact metamorphic aureoles. The leucogranites are concentrated in three main areas: (i) the Northwest Brook-Garia Brook area, (ii) the Piglet Brook-Couteau Brook area, and (iii) the Peter SnoutGrandys Brook #2 area, but are fairly common as pods throughout the amphibolite facies terrane (Map 2).

These leucogranites are largely unfoliated and nearly equigranular, but are penetratively schistose near the Cape Ray and Bay d'Est Faults and the Gunflap Hills fault splay, and are also foliated in the numerous, small scale faults and shear zones observed in continuous exposures on Northwest Brook.

8.3.2 Northwest Brook-Garia Brook leucogranite Part II, Section 18.3.2)

This leucogranite consists largely of fine grained, pink, equigranular subsolvus leucogranite, with local patches of medium grained granite, and minor alkali feldspar-quartz pegmatite in the main intrusion zone around Northwest Brook. Biotite (2-5 modal percent) is the main macroscopic ferromagnesian phase, and forms randomly oriented flakes. Muscovite predominates over biotite locally.

The Northwest Brook-Garia Brook leucogranite is associated with locally intense internal and external alteration, carbonate fracture and cavity fillings, and brecciation. Brecciated patches and highly fractured outcrops are accompanied by patchy yellow, red, and black alteration. Carbonate-filled fractures and cavities are common around brecciated and fractured zones. A tuffisite dyke is exposed in the middle of the intrusion zone on Northwest Brook. Hematitic alteration also affects the host rocks, both in the main intrusion zone and around smaller pods.

8.3.3 Piglet Brook-Couteau Brook leucogranite (Part II, Section 18.3.3)

The leucogranite west of Couteau Brook forms anastomosing dikes and interlocking networks. Deformed La Poile River Group hosts are commonly included as rafts or screens in the centre of the intruded zone. This leucogranite is medium grained and largely equigranular.

8.3.4 Peter Snout-Garia Brook leucogranite (Part II, Section 18.3.4)

Medium grained, unfoliated leucogranite is exposed mainly in a large intrusion zone and several smaller pods. The leucogranite also projects across the foliated synmetamorphic granitoid rocks (component 4b) and the Ironbound syenodiorite-granite as straight-sided dykes to the west of the main intrusion zone. The leucogranite is equigranular to slightly plagioclase-porphyritic, and contains both biotite and muscovite.

8.3.5 Preliminary interpretation of the two-feldspar (subsolvus) leucogranite

Several features may be relevant to the origin of the two-feldspar leucogranites in general:

1. Occurrence as lenses oriented across the regional fabric of hosts (dominantly granodioritic, tonalitic, or migmatitic), and as elongate central intrusion zones in areas also dominated by voluminous older synkinematic granitoid rock.

2. Very homogeneous, almost haplogranitic composition (Appendix III), suggesting a minimum melting compositon under uniform melting conditions of T, P(H_2O), and P(total).

3. The occurrence of potassic feldspar and sodic plagioclase in clearly separate grains. This suggests that the feldspars crystallized from the magma at temperatures below the alkali feldspar solvus, i.e. intersection of the solidus (near the minimum) with

the solvus which would occur at $P(H_2O) = P(total)$ greater than about 2.5 Kb (Luth et al, 1976), or deeper than 8 Km.

4. Relatively uniform equigranular or sub-porphyritic textures within each zone of leucogranite, e.g. the Northwest Brook- Garia Brook leucogranite is fine grained and nonporphyritic, whereas the Peter Snout Garia Brook leucogranite is medium grained with incipient development of feldspar phenocrysts.

5. Muscovite and some of the biotite in the highly deformed and metamorphosed synkinematic granitoid rocks universally exhibits marginal fibrolite development. Muscovite and biotite flakes exhibit incipient fibrolite development in the leucogranite as well.

Features particular to the Northwest Brook-Garia Brook leucogranite are:

1. Generally uniform, fine grained texture, except for subordinate medium grained patches around Northwest Brook, and its lack of phenocrysts, suggesting rapid crystallization under nearly the same conditions as those under which partial melting took place.

2. The occurrence of a tuffisite dyke in the core of the main intrusion zone.

3. The abundance of carbonate, and other alteration within and around the leucogranite suggests that CO_2 was active during and after its crystallization.

Generation of the leucogranite magma by partial melting of the synmetamorphic granitoid rocks during deformation under amphibolite facies conditions (D_2 and possibly early D_3), and collection of the magma in tensional zones across the regional structural grain seems likely. The partial dehydration of muscovite to form fibrolite occurs extensively in the host rocks, and has probably proceeded to a greater degree at depth. This process might have provided a temporary source of hydrous fluid which would facilitated limited partial melting under amphibolite facies and higher temperatures. Since the main effect of the presence of CO_2 in the vapour phase would be to counter the depression of the solidus produced by H_2O, it is assumed that the partial pressure of CO_2 was very low during the generation of the granitoid magma.

Subsequently, a sudden influx of CO_2 into zones of tension or weakness would provide a quenching mechanism for the fine grained, Northwest Brook leucogranite at conditions of T and P(total) under which it was generated, since the effects of both H_2O release and CO_2 addition would raise the temperature of the solidus (cf. Wyllie and Tuttle, 1959; Holloway, 1976; Wyllie, 1977; Eggler and Kadik, 1979). The fluxing of CO_2, as well as the H_2O released from the rapidly solidified magma, through the Rose Blanche phase and the leucogranite itself, particularly in fracture zones, was responsible for the characteristic alteration.

Abundant secondary calcite and indications of high CO_2 activity are not uniquely linked with the leucogranite. Patches of late stage calcite replacement, especially along late fractures, is a very common phenomenon in most of the rocks in the Grandys Lake (110/15) N.T.S. area. South of the

Grandys Lake area, pods of amphibolite breccia with a massive carbonate matrix cut across the Bunker Hill Brook Gneiss near Port aux Basques. In addition, CO_2 is considered to have been an important volatile phase during structurally-controlled, subsolidus metasomatic alteration of the Port aux Basques phase to the southwest (Dingwell, 1980; Dingwell and Strong, 1981).

The relationship of these leucogranites to the structural and metamorphic history of the amphibolite facies terrane (Section 9.3 and Chapter 10) suggest that they were emplaced in the tectonic interval following the later stages of regional deformation (D_2) responsible for the prominent structural grain in Terrane II, but before the last stages of deformation associated with the Bay d'Est, Cape Ray Fault and Gunflap Hills fault systems.

8.4 PERTHITE-RICH LEUCOGRANITE (PART II, SECTION 18.4)

8.4.1 Individual plutons and their field relations

Perthite-rich leucogranite was emplaced as discordant, generally ovoid plutons in both Terranes I and II. These plutons include the Chetwynd Granite (Cooper, 1954), the Petites Granite (Brown, 1975), and Isles aux Morts Brook Granite (Brown, 1976b) of Terrane II, and several bodies in Terrane I, here referred to as plutons A to G (Map 2). Many lineaments or shear zones in Terranes I and II. Composition and internal textural variations are remarkably similar in all of the plutons, although some are modified somewhat by local features such as fracture zones and associated hydrothermal activity. The presence of coarse perthite, with or without oligoclase, and under 5 percent biotite as the sole ferromagnesian silicate mineral are diagnostic. The leucogranites are associated with extensive rhyolite dyke systems, also remarkably similar in both terranes.

The perthite-rich leucogranites intrude all but the late dykes (8.5 below). Narrow, low pressure contact aureoles occur against several of the plutons, but are imperceptible or absent in the pre-metamorphosed hosts surrounding others. Some of the leucogranites enclose rafts of previously deformed granitoid rock.

These intrusions probably vary in age. Field constraints on their ages are listed below:

Pluton A: Pluton A spans the boundary between the Little Codroy Pond and Dinosaur Pond belts, although it is apparently deformed by late movement on this boundary. The deformation is penetrative on the northwest side of the pluton, where a deeper level of the pluton plus some of its roots or 'emplacement tracks' are exposed. Late uplift of the Little Codroy Pond belt affected Carboniferous (Visean and possibly younger) rocks.

Plutons B and C: These bodies cut the foliated tonalite and both phyllonite and mylonite along the Cape Ray Fault zone before activity ceased on the Cape Ray Fault. A projection from Pluton C cuts the Emsian-Eifelian Windsor Point Group, and aplitic apophyses, possibly related to the leucogranite, intrude the fault zone and are brecciated with the Windsor Point volcanic rocks.

Plutons D, E, F, and G: These bodies, and associated chilled rhyolite dykes, truncate the strong regional foliation of the tonalite which they intrude, and also intrude the quartz diorite-megacrystic granite and the quartz gabbro-diabase. Their hosts must have cooled somewhat before the introduction of the rhyolite dykes, since the dykes are extremely fine grained (mostly spherulitic). They are somewhat more deformed than most of the other plutons. Although they have shed absolutely no detritus into the main volume of Windsor Point Group clastic rocks between Nitty Gritty Brook and Billiards Brook, they may nevertheless be the source for the perthite granite boulders of a unique oligomictic conglomerate exposure south of Billiards Brook (Section 17.2.2). If this is correct, and if the oligomictic conglomerate is the same age as the rest of the Windsor Point Group, the plutons are Emsian-Eifelian at maximum, and probably older.

Isles aux Morts Brook Granite: This pluton has intruded the La Poile River Group kyanite grade metasedimentary schists, amphibolite, and synkinematic granitoid rocks after the formation of the penetrative tectonic fabrics. Andalusite in a local contact zone has been reported by Derek Wilton of Memorial University (D. Wilton, personal communication, 1982). The terrane must have been uplifted and eroded somewhat before the emplacement of the leucogranite and the development of andalusite. Uplift in this area may have accompanied reverse faulting of the La Poile River Group against the Windsor Point Group, suggesting an Emsian-Eifelian minimum age for the Isles aux Morts Brook Granite (recently dated by Rb-Sr as 352 Ma: Wilton, 1983).

Petites Granite: This granite apparently cuts La Poile River Group sedimentary rocks of comparatively low grade, which may belong to the greenschist facies highland belt south of the Bay d'Est Fault east of La Poile Bay. It truncates strong fabrics and refolded folds, probably of D_2 generation (Brown, 1975), but is affected later by inhomogeneous deformation associated with the Bay le Moine fault which may have displaced parts of the pluton (Map 1).

Chetwynd Granite: The Chetwynd Granite truncates D_2 fabrics of the greenschist facies highland block, the Grand Bruit Fault, and the partly retrograded Cinq Cerf Complex. It is cut by the Bay d'Est Fault.

8.4.2 General characteristics (Part II, Section 18.4.2)

The leucogranites are remarkably uniform in whole rock chemical composition (Appendix III) and are essentially haplogranitic (low CaO). They vary internally from hypersolvus to subsolvus; the hypersolvus granite could be classified modally as alkali feldspar granite (Streckeisen, 1973). Proportions of plagioclase to alkali feldspar microperthite vary from almost nil to just under one. Plutons generally display both medium grained equigranular granite to coarse grained subequigranular textures. Many also display marginal patches of relatively fine grained, quartz and feldspar porphyritic granite or rapikivi granite.

8.4.3 Individual characteristics (Part II, Section 18.4.3)

Although the perthite-rich leucogranite plutons are remarkably uniform in major element geochemistry and overall mineralogy and texture, they show subtle differences in accessory and secondary mineral content as well as in trace element geochemistry.

For instance, Plutons B and C contain unusually abundant, coarse sphene and allanite relative to the other plutons, whereas magnetite is the main accessory mineral in the nearby Isle aux Morts Brook Granite. In Plutons B and C, chequered albite locally replaces the potassic feldspar portion of microcline ribbon perthite grains or rims them, an effect also observed in the Windowglass Hill Granite in the same area of the Cape Ray Fault zone. Therefore, hydrothermal activity along the fault zone might be a factor in dictating late or post-magmatic hydrothermal effects. In contrast, the Isles aux Morts Brook Granite contains late muscovite poikiloblasts and lacks the secondary chequered albite of its neighbours to the northwest.

As another example, the Petites Granite is the only pluton showing substantial hydrothermal alteration in the field. The most profound effects are silicification and fine grained sericite/kaolinite alteration associated with molybdenite showings sited around fracture sets related to the Bay le Moine Fault or shear zone (Brown, 1975). In addition, the presence of fairly patchy, rather than ribbon-like microcline perthite and of relatively abundant myrmekite may indicate substantially higher volatile content at least during late crystallization.

8.4.4 Preliminary interpretation of the perthite-rich leucogranites

The perthite-rich leucogranites were emplaced as discordant plutons at relatively high crustal levels at a late stage in the tectonic development of the area. The quartz-sanidine porphyry dykes are chilled and display uniformly developed spherulitic textures, resulting from intrusion into relatively cool hosts. In one case, if the dykes next to the Isles aux Morts Brook Granite in Terrane II were emplaced in a cool, high level environment, then they must have been emplaced after the third deformation which culminated in uplift and post-metamorphic cooling of the Bay du Nord belt. Near the contact of the Isles aux Morts Brook Granite, andalusite porphyroblasts overprinting highly deformed kyanite grade rocks also suggest emplacement after uplift and at least limited erosion.

The perthite-rich leucogranites are mafic-poor and calcium-poor, and range from granite to alkali granite according to the modal classification of Streckeisen (1973), and plot almost entirely within the potassic half of haplogranite (alkali feldspar-quartz) system (Appendix III). They display the physical and chemical characteristics of the late orogenic 'alkali' granites described by Rodgers and Greenberg (1981), who discussed a number of derivations, including fractional crystallization of calc-alkaline magmas. They also resemble, mineralogically and chemically, the anorogenic A-type granites of Collins et al (1982), who suggested derivation by dry partial melting of granulites containing quartz and feldspar components. According to the results of the hydrous to anhydrous partial melting experiments of Whitney (1975), partial melts formed at high temperatures and total pressures in water-poor granitic charges are richer in alkali feldspar components than those formed at lower temperatures and equivalent total pressures in water saturated granitic charges, supporting water-undersaturated partial melting at depth as a suitable source for the relatively potassic, perthite-rich leucogranite magmas. Since there is no evidence of more mafic, coeval calcalkaline differentiates associated with the leucogranites in southwest Newfoundland, and since there is a high probability that granulites were present at depth at the time of their emplacement, the partial melting of granulites is favoured as a source. However, these leucogranites cannot be regarded as truly anorogenic, as many were emplaced before a late regional deformation stage.

Although the perthite-rich leucogranites may have begun their ascent as relatively water-poor melts crystallizing large, K- and Na-rich, now perthitic but formerly hypersolvus alkali feldspars, their petrography in detail suggests that most plutons came in contact with relatively hydrous environments at a late stage in their crystallization history. Although water-saturated haplogranites can crystallize hypersolvus alkali feldspar at $P(H_2O) = P(total)$ less than 2.5 Kb, or approximately 8 Km depth, (Luth et al, 1973), dry haplogranites can only precipitate two separate alkali feldspars at greater depth. For a compositionally and mineralogically similar perthitic leucogranite from central Rhode Island, it was estimated that crystallization began under water undersaturated conditions at temperatures above 775°C and was completed at temperatures of greater than 665°C at total pressures of less than 3 Kb, corresponding to less than 10 Km depth (Day and Fenn, 1982).

Thus, the existence of hypersolvus and perthite-rich subsolvus granite in the same pluton could reflect a number of alternative crystallization histories. For instance:

(1) The entire crystallization of the pluton may have occurred at high levels with P(total) spanning 2.5 Kb under water-saturated conditions.

(2) Crystallization may have begun under relatively water-poor conditions before final emplacement and completed under hydrous conditions, possibly variable throughout the body, at higher tectonic levels.

(3) Another scenario.

Anorogenic hypersolvus and subsolvus leucogranite associations, in many ways similar to the perthite-rich plutons, are thought to have been derived from water-poor melts emplaced at high level, locally coming in contact with water-rich environments (Martin and Bonin, 1976). The effects of late water saturation may vary from late, subsolidus secondary hydrothermal activity (if the temperature is below the depressed, water-saturated solidus) to actual remelting to produce a younger, subsolvus leucogranite (if the temperature is still high enough) (Martin and Bonin, 1976). There is no evidence of the latter extreme within the study area, but it is noteworthy that a roughly circular, perthite-rich leucogranite pluton at Francois further east on the south coast is cut by a smaller, central body of fine grained, subsolvus leucogranite (R.H. Flood, personal communication, 1981).

Many of the perthite-rich leucogranites in southwest Newfoundland appear to have been emplaced along or near a lineament or fault zone. Many also show signs of having been influenced by volatiles at late, possibly late to post-magmatic stages in their history, perhaps because of hydrothermal activity persisting around these lineaments. For example, Plutons B and C show chequered albite replacement of microcline in fractured rocks, an effect shared by the nearby Windowglass Hill Granite in the Cape Ray Fault zone. Similarly, a few dykes cutting the north-central high strain zone have been affected by muscovite-producing alteration processes (Section 18.4.3), and were therefore probably intruded while fluids were still present in the NChsz.

8.5 LATE DYKES OF TERRANES I AND II (PART II, SECTION 18.5)

Terranes I and II contrast in their late dyke suites, apart from the rhyolite dykes related to the perthite-rich leucogranites (above). Mafic and felsic dykes predominate in Terrane I, and intermediate to mafic, mica-amphibole dykes are recognized as a suite characteristic of Terrane II. The latter include those dykes associated with the Cinq Cerf Complex.

Terrane I dyke sets cut across the foliation of the synkinematic granitoid host rocks of component 4b and the quartz diorite-megacrystic granite. Mafic dykes also intrude perthite-rich Pluton C. Dacite dykes intrude the layered gabbro and metagabbro of the Long Range MaficUltramafic Complex. Most of these dykes strike either east-northeast or north-northeast, or rarely northwest, and dip vertically. Phair (1949) convincingly demonstrated the correspondence between dyke orientions and late fractures and minor faults.

Dykes in the main part of Terrane II were not as readily isolated as in Terrane I, partly because of the confusion with dykes of the metavolcanic complex. A north-trending mafic dyke cuts the component 4b synmetamorphic granitoid rocks, and may have: (1) cut, (2) formed a screen in, or (3) intruded coevally with the fine grained subsolvus leucogranite exposed on Northwest Brook. Similar, more deformed dykes cutting the same synmetamorphic granitoid rocks parallel to their foliation were noted along the Port aux Basques-Rose Blanche highway during this study, and dykes with ultramafic cobbles cut granitoid and host fabrics near Foxroost (P.A. Brown, personal communication, 1974). The latter are remarkably reminiscent of the dykes which intrude the Cinq Cerf Complex near the Grand Bruit Fault (Section 5.4).

The dykes are described in Part II as part of the general attempt to characterize suites, and for limited reference in Chapter 9.

CHAPTER 9: STRUCTURAL AND METAMORPHIC DEVELOPMENT OF THE SOUTHERN LONG RANGE MOUNTAINS

9.1 INTRODUCTION

At the onset of this study, it was accepted that the structural trends and patterns exhibited by metamorphic rocks of Terranes I and II (namely the Long Range Gneisses and former Port aux Basques Gneiss of Brown (1972)) were largely the products of Grenvillian deformation, and of Precambrian structures with Acadian reworking, respectively (Brown, 1973, 1975, 1976a). Near the end of the reconnaissance, it was realized that the exposed pre-Devonian rocks (the bulk of the outcrop area) were probably not themselves Precambrian in age, and were affected by Paleozoic deformation both before and after the deposition of the Devonian Windsor Point Group along the Cape Ray Fault (Chorlton, 1983). Thus, a map of prominent structural trends (Map 2) suggests a more coherent pattern of structural trends than originally expected, particularly within the Bay du Nord belt (Figure 4) from Port aux Basques through the Peter Snout N.T.S. area.

The first sound link between the orogenic histories of Terranes I and II is provided by deformation which affects the Devonian Windsor Point Group, although deformation related to fault zone activity before deposition of the group can tentatively be correlated on either side. Deformation affecting the Windsor Point Group correlates well with the late stages of deformation in Terrane II, and provides a significant time constraint. Therefore, the Windsor Point Group and the Cape Ray Fault zone along which it is exposed is treated as a separate structural terrane in Section 9.4.

The developmental histories of Terranes I and II are dealt with in turn in this chapter. In Sections 9.2 (Terrane I), 9.3 (Terrane II), and 9.4 (Windsor Point Group-Cape Ray Fault zone), the effects of deformation and metamorphism on each domain are first summarized, and then followed by a discussion of the tectonic development of the terrane as a whole.

9.2 EFFECTS OF DEFORMATION AND METAMORPHISM ON TERRANE I

9.2.1 INTRODUCTION

Terrane I has been subdivided into the Little Codroy Pond and Dinosaur Pond belts along a steep, north-northeasterly trending fault (Figure 4), as much because of differences in the metasedimentary and synkinematic granitoid rocks (Chapters 3 and 5) as contrasting structural development between the two belts. The Long Range and Stag Hill high strain zones of the Little Codroy Pond belt and the north-central high strain zone of the Dinosaur Pond belt represent zones of distinct early structural and metamorphic overprint on components 1 and 4b. A simplified sequence of structural events for Terrane I is summarized in Table 3.

In Terrane I, northwesterly to westerly, gently plunging lineations and fold axes and moderately to gently dipping foliations are characteristic of the high strain zones (SHhsz, LRhsz, and NChsz: Figure 4), and merge into variably to northeasterly trending foliations outside these zones. Northeasterly-trending foliations predominate along late faults and shear zones both in Terrane I and the Carboniferous rocks northwest of the Long Range Fault; northwesterly-trending faults are subordinate.

The Keepings Gneiss and synkinematic tonalite-granodiorite of the Deep Brook-Morg Keepings Brook area cannot be defined as part of any specific tectonic domain until their extension to the north and northeast can be mapped.

Both the Little Codroy Pond and Dinosaur Pond belts of Terrane I expose domains dominated by ophiolitic metagabbro which pass laterally into broad high strain zones occupied mainly by high level ophiolitic metagabbro and metadiabase, metavolcanic rocks, and metasedimentary rocks; and by subordinate ultramafic rock and layered metagabbro. These belts are characterized in particular by strong, composite tectonic fabrics formed under medium to high grade metamorphic conditions. In the Little Codroy Pond belt, the

Table 3: Deformational events of Terrane I

Event	Main effects	Local interpretation
D_5(TI)	Faults, shear zones, rotation of earlier fabrics with local refolding of earlier structures. Deformation of Codroy Group on west side of Long Range Fault.	Long Range fault activity, uplift of Little Codroy Pond belt between Long Range Fault and southeast fault margin of belt.
D_4(TI)	Faults, shear zones, fractures, particularly near Cape Ray Fault. Local fault gouge. ($\equiv D_2$(WPG))	Wrench faulting on Cape Ray Fault with new displacement path.
D_3(TI) late	Fractures, faults and shear zones particularly common along Cape Ray Fault. ($\equiv D_1$(WPG))	Wrench movement, mainly strike-slip, along Cape Ray Fault continues.
D_3(TI) early	Development of major mylonite and phyllonite zones along Cape Ray Fault. Faults, shear zones, fractures, and local rotation of earlier fabrics away from fault.	Compressive wrench faulting on Cape Ray Fault, with differential uplift of Terrane I (southwest end up).
D_{22}(TI)	Mineral extension lineations, tight folds, strong crenulation, gently dipping shear zones.	Thrusting, with zone of high strain (NChsz) sited near major decollement.
D_{21}(TI)	Formation of schistosity to gneissosity in syn-kinematic tonalite and its inclusions in NChsz.	
D_{12}(TI)	Formation of mylonites. Strong crenulation, tight folding, rotation of schistosity/gneissosity, rodding, and mineral extension lineations.	Thrusting, with zone of high strain and mylonite development sited in LR-SH hsz's either underneath, or spanning a major decollement.
D_{11}(TI)	Formation of schistosity to gneissosity spans generation and emplacement of synkinematic granitoid rocks in LRhsz and SHhsz.	
pre-D_1(TI)	Formation of granulite facies foliation in layered cumulate metagabbro. Pegmatites in both massive and layered metagabbro. Fracturing, plagiogranite pods, and coarse grained gabbroic pegmatite dykes with comb layering in massive metagabbro. Breccias in extrusive volcanic and sedimentary rocks of Dinosaur Pond belt.	Oceanic spreading deformation?

greater exposure of layered, granulite facies foliated metagabbro of the ophiolitic 'transition zone' (3.2.3 and 13.1.3) in the core of the belt contrasts with the Dinosaur Pond belt, where the metagabbroic portion is occupied mainly by high level massive metagabbro and metadiabase (3.2.4), only grading to layered metagabbro southwest of the study area (Brown, 1977). In addition, the high strain zones of the Little Codroy Pond belt contain silicic mylonite zones of medium to high metamorphic grade, which are apparently lacking in the north-central high strain zone of the Dinosaur Pond belt, although scaly, rusty shear zones are present in the latter.

The high strain zones have undergone patchy retrogression after the development of the early composite fabrics. In some cases, it is difficult to tell whether or not muscovite was present at the metamorphic peak. In addition, the geochemical systems of certain areas may have been open to fluxes of fluid during and after the main period of deformation and regional metamorphism, an effect which merits consideration. Since the early history of these belts is obviously complex, and correspondingly complex P-T paths are envisaged, it was decided that only generalizations about the metamorphic history are warranted at this time.

The orogenic development of these domains is summarized below from structural, textural, and metamorphic features of these rocks described in Part I, Sections 3.2 and 3.3, and

Part II, Sections 13.1, and 13.2.

9.2.2 LITTLE CODROY POND BELT

The Little Codroy Pond belt is exposed as a horst occupied mainly by layered metagabbro passing northwestwards into the Long Range high strain zone and in all other directions into the Stag Hill high strain zone (Figure 4). Although the Stag Hill and Long Range high strain zones were initially treated separately (3.2.6, 3.3.2, 13.1.6 and 13.2.2) so that possible breaks in structural and metamorphic history would emerge naturally during petrographic description, no abrupt breaks were found. Since these zones merge northeast of the layered metagabbro core and both grade into the core, they are treated here as one unless otherwise specified. Perthite-rich leucogranite Pluton A, whose deformed roots are exposed in the Stag Hill high strain zone, cuts across the southeast fault boundary of the belt (Figure 4; Map 2).

Toward the Stag Hill/Long Range high strain zone, the layered metagabbro is interlayered with clinopyroxene metagabbro typical of the massive metagabbro and metadiabase (Unit 1c). Within the high strain zone, layered metagabbro, massive metagabbro and metadiabase, and mafic metavolcanic rocks are transformed to undivided amphibolites, which drape the central layered metagabbro zone together with semi-pelitic paragneiss, silicified mylonite, marble, ultramafic lenses, and synkinematic granitoid rocks (Cross-sections, Sheet 1). It is noteworthy that the marker horizon of marble is exposed in most parts of this belt (Plate 9.1), although only scattered erosional remnants are preserved on the topographically highest ground of the Stag Hill high strain zone. As well as being exposed in the Grandys Lake area (this study), the marble is exposed near Little Codroy Pond and next to the Trainvain Brook fault lineament (Phair, 1949) in areas exhibiting westerly structural trends (Map 2).

The layered metagabbro displays a strong L-S to S-L fabric (Plate 9.2) defined by the recrystallization of the anhydrous mineral assemblage: cpx + opx + ol + calcic plag, probably under conditions of very high grade, submagmatic temperatures and relatively anhydrous conditions (Miyashiro, 1973, page 313). The coexistence of olivine and calcic plagioclase, in particular, suggests low pressures, as well as high temperatures (Green and Ringwood, 1967). The early foliation is reflected macroscopically by the lenticular nature of polygonized or recrystallized olivine, clinopyroxene, and orthopyroxene aggregates, which contrast in colour with bands of granoblastic calcic plagioclase (13.1.3, Plates 13.4-13.6), and is parallel or near parallel to the igneous compositional layering, which was probably developed before the onset of regional deformation. As mentioned in Section 3.5, the high temperature foliation most likely represents deformation associated with a rapidly spreading oceanic ridge.

The low-pressure granulite facies assemblages of the layered metagabbro are locally overprinted retrogressively by amphibolite facies minerals toward the Stag Hill/Long Range high strain zone (13.1.3), whereas in these zones rocks higher in the ophiolite section are metamorphically upgraded to amphibolite facies (13.1.6 and 13.2.2). The earliest overprint occurred locally at higher temperatures within the area gradational to the layered metagabbro block, since the igneous/granulite facies ferromagnesian minerals of the cumulate metagabbro were locally replaced by recrystallized aggregates of brown green hornblende, before being mottled locally by the blue green hornblende more characteristic of the high strain zone. Brown green hornblende is generally thought to signify higher metamorphic temperatures than green or blue green varieties (Miyashiro, 1973, page 254), although in some cases attributed particularly to the comparatively low $P(H^+)$ or $P(H_2O)$ associated with high metamorphic temperatures (Engel and Engel, 1962). Therefore, although the low-pressure granulite facies foliation may have been developed prior to the events which formed the high strain zone, the latter events occurred before the layered cumulate zone had cooled below upper amphibolite facies temperatures.

In the Long Range/Stag Hill high strain zone, partial melting occurred early, and composite S>L to L>S fabrics were developed under middle to upper amphibolite facies conditions, producing composite foliations (below) and local extension lineations such as quartz rods, elongate trails of fragmented garnets in the paragneisses (13.2.2) and orthogneisses (15.1.4), and a strong plano-linear fabric in the amphibolites (13.1.6). The composite fabrics consist of an early, penetrative schistosity, here referred to as S_{11}(TI) (corresponding to event D_{11}(TI) in Table 3), defined in part by flattened quartz domains and micas in the quartzofeldspathic rocks and by flattened quartz and plagioclase domains in some of the amphibolites, which was crenulated or transposed by a more widely spaced foliation or gneissosity, here called S_{12}(TI) (corresponding to event D_{12}(TI) in Table 3). The development of sillimanite in the paragneisses both preceded and accompanied the development of the second foliation, along which it is commonly segregated; rarely, large crystals of sillimanite form augen in this fabric (13.2.2).

No evidence of deformation prior to metamorphism, such as inclusion trails inside porphyroblasts, was observed in the metasedimentary rocks of the high strain zone. The transitional overprint of the high strain zone on the layered metagabbro core domain indicates that the early amphibolite 'retrograde' overprint affecting the layered metagabbro is related to the early development of the zones.

Early fabrics and structures were gently to moderately inclined in many places. Minor folds around Stag Hill are variably reclined and verge both ways about gently east-plunging hinges parallel to strong rodding lineations which are very well developed at the top of the hill (Plate 9.3); this area is not penetratively affected by late, northeast-striking structures which transpose (and partly retrograde) the early structures nearer the southeast boundary of the belt. Beneath the summit of the hill, a gneissified tectonic breccia horizon dips gently eastward (Plate 9.4). Near the Long Range escarpment, rodding and stretching lineations parallel to fold hinges are highly rotated by late deformation associated with activity in the high angle faults which also affected Carboniferous rocks.

The Stag Hill/ Long Range high strain zone contains several siliceous mylonite horizons (13.2.2), especially next to the marble marker horizon. These mylonites exhibit metamorphic grades equivalent to those displayed by neighbouring gneiss, schist, marble, and amphibolite. Local juxtapositions of layered metagabbro, ultramafic rocks and metasedimentary rocks, with very little of the usually intervening massive metagabbro and metadiabase near the mylonite just southwest of the head of South Branch River probably represents early attenuation and perhaps faulting in the high strain zone. In fact, local synmetamorphic faulting may be responsible for the gneissified breccia zones at Stag Hill and on hills to the northeast (Plate 9.4; Section 13.2.2). Movement within such high temperature shear zones would be accommodated largely along any mylonite bands present (White et al, 1980), and it is suggested here that the mylonites within the LR-SHhsz may have served this function.

The early, amphibolite facies D_{11}-D_{12} (TI) fabrics of the high strain zones were subsequently tightly folded, truncated, and commonly rotated by later deformation which superimposed northeast trends and steepened foliation inclinations (Cross-sections, Sheet 1). It is suggested here that the outcrop pattern, when mapped in detail, will likely illustrate interference between early, gently to moderately reclined, easterly plunging folds and later, upright folds with steep axial planes.

This late deformation is associated with partial, greenschist facies retrogression, especially intense along the southeast tectonic boundary of the belt and along some of the lineaments within the Stag Hill high strain zone. Late shear zones between the base of the Long Range escarpment next to the marble and the Long Range Fault itself are characterized by a locally mylonitic, greenschist facies fabric (13.1.3). The layered metagabbro block as a whole underwent sporadically-distributed partial retrogression under greenschist facies conditions, e.g. retrogression to fibrous intergrowths of actinolite and chlorite (13.1.3), and it is suggested here that local percolation of fluids along zones of weakness in the relatively competent 'dry' block governed the distribution of alteration away from the major lineaments and faults. The retrograde metamorphic assemblages are similar to those formed in shears within the Long Range Fault zone and the southeast fault boundary of the Stag Hill high strain zone, e.g., development of chlorite and muscovite and destruction of garnet and sillimanite (13.2.2). Consequently, it is likely that the development of late shear zones and lineaments, the rotation of early amphibolite grade tectonic fabrics, and the associated retrogression probably occurred in response to Carboniferous uplift between these faults (Cross-sections-Sheet 1: Fault movement 5).

Component 4b pink leucogranite-tonalite, which is intimately associated with amphibolite within the high strain zone, shows signs of metasomatic alteration during deformation and recrystallization (5.5). Most obvious is the generally fresh nature of the alkali feldspar and its continued recrystallization with quartz during deformation, and the occurrence of plagioclase as corroded, cloudy porphyroclasts (sericitized and occluded with Fe-oxide) overprinted by clear microcline patches and as intensely sericitized grains surrounded by microcline (15.1.5). Because plagioclase appears to have been more unstable than microcline in the environment of the high strain zone, it seems likely that these rocks have undergone microclinization to some degree. This is mimiced by extreme compositional variation of these rocks in general, particularly local variation from pink, muscovite-biotite - (albite) granite to grey tonalite containing minor amphibole rimmed with biotite. Microcline-bearing granitoid rocks in this zone are also characterized by the presence of myrmekite, attributed by many authors to metasomatic alteration processes involving feldspars, H_2O, H^+, and alkali cations (e.g. Barker, 1970; Ashworth, 1972; Phillips, 1974, Hibbard, 1979).

9.2.3 DINOSAUR POND BELT

The Dinosaur Pond belt is occupied by high level, ophiolitic metagabbro and metadiabase and overlying mafic metavolcanic and metasedimentary rocks, all engulfed as rafts and xenoliths in biotite tonalite. This domain could thus be referred to as an extensive agmatite belt. Both tonalite and inclusions or hosts have been deformed and metmorphosed together, and in most cases the tonalite appears more strained than its hosts.

The Dinosaur Pond belt can be divided into the massive metagabbro zone and the north-central high strain zone, which are in gradational contact (Figure 4). An increase in metamorphic grade from upper greenschist facies to middle or upper amphibolite facies accompanied by the development of pronounced composite fabrics (below), and a change in structural orientations from predominantly northeasterly to predominantly northwesterly trends signify the transition. In the massive metagabbro zone, hosts to the biotite tonalite are mainly the massive metagabbro and metadiabase with plagiogranite pods. In the north-central high strain zone, foliated, commonly garnetiferous tonalite encloses metasedimentary and mafic metavolcanic and amphibolitic inclusions from the top of the Dinosaur Pond ophiolite sequence (Figure 5).

The massive metagabbro zone was deformed weakly, and metamorphosed to upper greenschist or lower amphibolite grade before uplift, shearing, and local middle greenschist facies retrogression due to movement on the Cape Ray Fault. At the southwest end of the zone the tonalite displays only irregularly oriented and poorly developed cleavage or schistosity away from the Cape Ray Fault. Steeply to moderately southeast-dipping schistosity is developed with increasing intensity toward the fault, a fabric most likely related to the fault itself (Brown, 1972).

The maximum metamorphic grade increases with more intense overall strain toward the central and northeastern part of the massive metagabbro zone. West and northwest of Grandys Lake, several discrete very schistose zones display the development of a strong secondary foliation, here called S_{22}(TI) (corresponding to D_{22}(TI) in Table 3), crenulating an early flattening foliation S_{21}(TI) (corresponding to D_{21}(TI) in Table 3), forming a composite fabric similar in nature to that in the high strain zones of the Little Codroy Pond belt. Discontinuous, wavy, muscovite-biotite schist zones characterize several outcrop areas. These are pictured as discontinuous sites of ductile shearing beneath the more penetratively deformed NChsz (Cross-sections, Sheet 1, B-B', C-C'). In these zones, the tonalite contains the red brown biotite typical of higher grade tonalitic rocks in the north-central high strain zone, interlayered with muscovite (15.1.2).

The granitoid rocks and their inclusions well within the north-central high strain zone have undergone deformation involving the formation of an early schistosity ($S_2{}^1$(TI) defined by micas and locally by quartzofeldspathic lenses, rotated or crenulated by an $S_2{}^2$(TI) which in some places appears gneissic. The second foliation was accompanied by the development of gently plunging lineations and minor fold hinges. The lineations are defined by sillimanite, elongate aggregates of biotite or hornblende, trails of fragmented garnet, and a strong lineation resulting from the intersection of the early penetrative schistosity ($S_2{}^1$) with the more widely spaced second foliation (S_{22}) (13.2.2, 15.1.3). The sillimanite is aligned as single, prismatic grains in some rocks and segregated within a gneissosity where it is also linearly aligned in others (13.2.2). The lineations and fold axes plunge gently to the northwest and southeast (Map 2). Throughout most of the domain, the most prominent gneissosity/schistosity strikes predominantly northwest and dips moderately to the southwest, although within a small belt across the centre of the zone the main foliation is gently dipping and east-striking. Near the south and southeastern margins of the zone, the northwest-trending fabrics merge into the northeast trends characteristic of the adjacent, massive metagabbro zone.

Deformation took place under middle to upper amphibolite facies conditions. Assemblages of garnet, sillimanite, biotite, plagioclase, quartz and rare local cordierite characterize the semipelitic paragneisses (13.2.2). The granitoid rocks, locally containing partially assimilated paragneiss remnants, contain red brown biotite, garnet, and locally, fibrolite or sillimanite (15.1.3). Kyanite was found locally in rocks also containing fibrolitic sillimanite in the belt of east-striking schistosity. Muscovite occurs as secondary poikiloblasts or as fine grained sericitic mats, and is present most abundantly in (1) the southeastern part of the high strain zone, where the early, amphibolite facies regional metamorphic recrystal-lization is accompanied by features which may reflect at least local metasomatism and assimilation (5.2.7), and (2) in highly retrograded rocks which are especially common around late fracture and fault zones (3.2.4, 5.2.3).

Effects which may related to metasomatic activity are are the local fibrolitization of plagioclase, replacement of plagioclase by coarse muscovite poikiloblasts, the overgrowth of most minerals by quartz, the 'leaching' of biotite to a pale pseudomorph accompanied by exsolution of fine grained rutile, and the local production of abundant, red, poikilitic to skeletal garnets (15.1.3 and 13.2.4). Oxidation and leaching of sulphides in a few rusty, schistose exposures, and locally profuse, fine grained magnetite are also characteristic of this zone (3.3.4).

Greenschist facies retrogression linked with uplift along the north side of the Cape Ray Fault (Cross-sections, Sheets 1, 2: Fault movement 3) is shown by both domains of the belt, but is most obvious in the amphibolite grade north-central high strain zone. Patchy retrogression to greenschist facies minerals affects most of the zone, but rocks adjacent to the western margin and around some of the prominent lineaments are more thoroughly retrograded. The most common forms of retrogression are the patchy sericitization and carbonatization of feldspar and the formation of fibrous blue green amphibole around earlier metamorphic hornblende, and patchy, local chloritization of biotite (13.2.4 and 15.1.3). Partial chloritization around the margins of garnets, the occurrence of epidote/allanite aggregates, and patchy carbonate are concentrated around late microfractures and near lineaments (13.2.4 and 15.1.3). The thoroughly retrograded rocks at the western margin locally show the later contact metamorphic effects of perthite-rich leucogranite Pluton A.

The intense, northeast-striking foliation which occurs in the massive metagabbro zone toward the Cape Ray Fault grades through a wide zone of phyllonite into the fault zone mylonite in the southwest part of the area.

9.2.4 DEEP BROOK - MORG KEEPINGS BROOK AREA

The rocks of the Deep Brook - Morg Keepings Brook area (Map 1) are similar to those of the Dinosaur Pond belt in that the Keepings Gneiss is surrounded by the intrusive, component 4b synkinematic tonalite-granodiorite; metagabbro also occurs as rafts just north of the map area. In contrast to the Dinosaur Pond belt, the foliated granitoid rocks in this area are partly granodioritic rather than exclusively tonalitic, and both deformed and later undeformed granitoid veins cut the Keepings Gneiss.

The Keepings Gneiss displays an early schistosity grading locally to a nonpersistent differentiated layering. The latter consists of gneissic segregations of ferro-magnesian constituents which occurred prior to their peak metamorphic reconstitution to biotite and garnet during the peak of metamorphism (13.3). The synkinematic granitoid rocks likewise display planar fabrics varying from schistosity to gneissosity (15.1.6).

The early foliations are folded with varying intensity. Folds vary from mild warps with variable hingelines to tight, upright folds with east-northeast trending hinges and axial planes. The latter prevail toward the Cape Ray Fault zone, in addition to numerous, east-northeast striking fractures and ductile shear zones.

The rocks attained at least upper greenschist, if not amphibolite grade after the development of the earliest fabric. Garnet commonly occurs along the layering. Biotite and muscovite (locally partly converted to fibrolite) are randomly oriented in areas of open folding, but are aligned parallel to the axial plane foliation in areas of tight folding; thus, biotite must have been stable during the folding event.

Localized retrogression is obvious in east-northeasterly striking shear zones near the Cape Ray Fault.

9.2.5 PRELIMINARY INTERPRETATION OF THE DEFORMATION AND METAMORPHISM OF TERRANE I

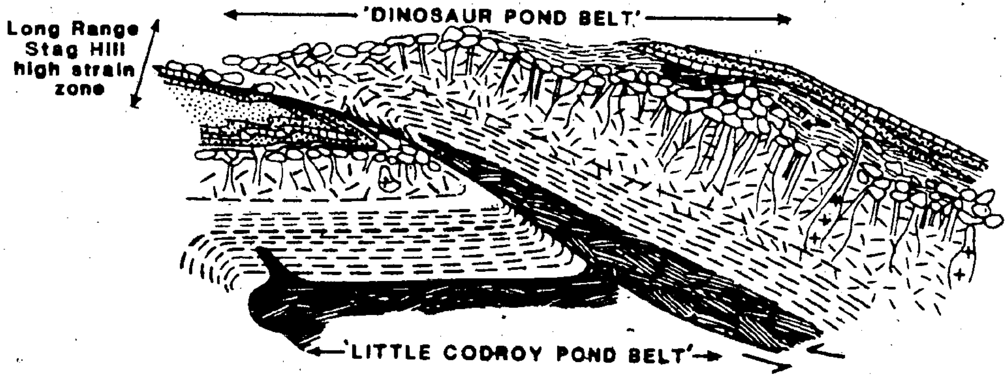
The early structural development of Terrane I is noteworthy for the development of the broad, high strain zones sited in the upper parts of both the Little Codroy Pond and Dinosaur Pond sequences as depicted on the Cross-sections, Sheet 1. Since ophiolitic rocks, generally accepted in the framework of Appalachian geology as implicitly Early Paleozoic in age (e.g., Church and Stevens, 1971), are affected, the high strain zones must also be Paleozoic at maximum.

As implied by the term high strain zone, a high degree of strain allowed by metamorphic recrystallization of the rocks within these zones produced intense, composite plano-linear and locally linear fabrics assigned to D_{11-12}(TI) and D_{21-22}(TI) in Table 3. High strain zones of both belts display extension lineations which are parallel to the axes of coeval, somewhat chaotic minor folds, trending at high angles to the northeasterly 'Appalachian' structural grain (Map 2). The composite foliations, S_{11}-S_{12} of the LR-SHhsz and S_{21}-S_{22} of the NChsz, are gently to moderately dipping where they have not been transposed and steepened by the later fault movements, e.g., steepening is common in the relatively narrow Little Codroy Pond belt which is bounded by steep, northeast-striking Carboniferous faults. Silicic mylonite zones are found in the Little Codroy Pond belt, and several gently inclined, rusty shear zones are exposed in the Dinosaur Pond belt. The zones of intense strain are concentrated within lithological horizons high in the ophiolite section (Figure 5), whereas this penetrative deformation decreases downward in the section. The high strain zones are also characterized by tectonic fabrics gently inclined to the profile of the high strain, and are accordingly interpreted as originally shallow ductile thrust zones (e.g. Cross-sections, Sheet 1, fault movement 1).

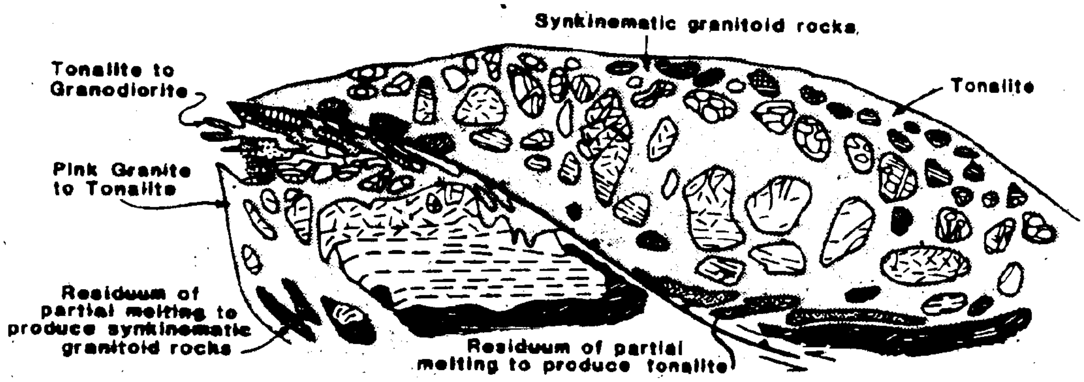
The gently dipping foliations and the shallowly plunging stretching lineations and fold hinges that characterize these high strain zones are oriented transverse to the predominantly northeasterly Northern Appalachian structural trend; this has also been recorded in thrust zones of the southeastern Appalachians, and the linear structures interpreted as indications of transport direction (Bryant and Reed, 1969) and in the Caledonian nappe and thrust complexes of Norway and northern Scotland (Kvale, 1953; Johnson, 1957, 1960, 1965; Zwart, 1974; Williams and Zwart, 1977). It has been suggested that fold axes which form initially at high angles to the direction of thrust transport are rotated toward the direction of transport at the bases of the nappes by combinations of progressive simple shear and pure shear (Escher and Watterson, 1974) or pure shear alone (Sanderson, 1973). Thus, the high strain zones may correspond to zones of particularly intense deformation across the interfaces between three ductile thrust sheets: the Little Codroy Pond belt, the Dinosaur Pond belt, and a now eroded upper sheet (Figure 8).

The early fabrics which identify the high strain zones were developed for the most part under medium to high grade metamorphic conditions. If the high level rocks (e.g., metasedimentary rocks and upper parts of the ophiolite) were originally near the surface at the onset of this deformation event, they were upgraded rapidly by the overriding nappe. In the Little Codroy Pond belt, the synkinematic granitoid sheets and veins which so far appear to coincide spatially with the overprint of the high strain zone, were generated early enough to have developed the same fabrics as the host amphibolites and metasedimentary rocks. In the Dinosaur Pond belt, the agmatitic nature of the rocks both within and away from the high strain zone suggests that the tonalite was emplaced before the belt was overridden by another ophiolite-based nappe and deformed under high

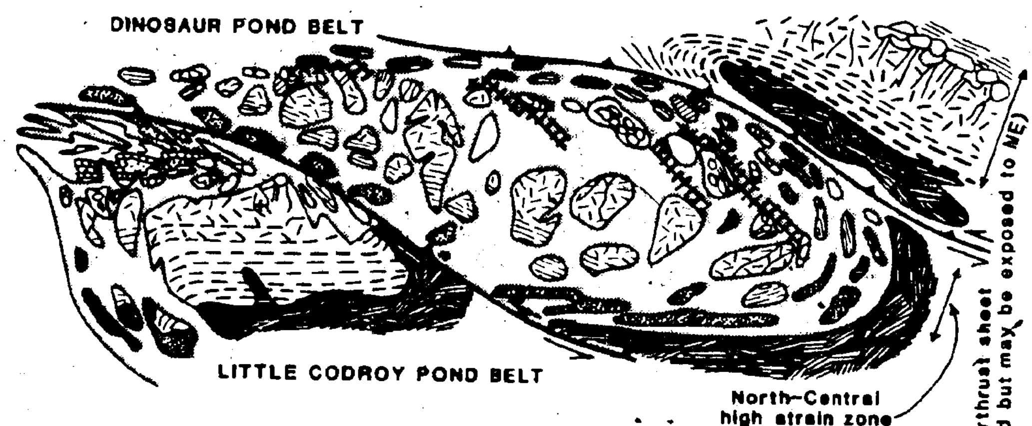
FIGURE 8: SUGGESTED (TENTATIVELY) EARLY ORDOVICIAN DEVELOPMENT OF THE OPHIOLITE / TONALITE TERRANE NORTHWEST OF THE CAPE RAY FAULT



a - Initiation of ophiolite imbrication in terrane northwest of the Cape Ray Fault, Grandys Lake area. Symbols as in Figure 5. Note relative positions of the 'Little Codroy Pond' and 'Dinosaur Pond' belts, and the intervening Stag Hill high strain zones (This activity may have occurred well below the surface)



b - Generation and emplacement of tonalite, granodiorite, and minor granite: Tonalite (4a) is generated from layered metagrabbro?) near the sheared base of the 'Dinosaur Pond belt' and lit par lit tonalite and granodiorite (4c) is generated in the metasedimentary and metavolcanic rocks underneath the thrust (in the Stag Hill and Long Range high strain zones). The granitic to tonalitic synkinematic granitoid rocks (4d) are generated still deeper in the mafic meta-igneous column intersected by another (postulated) high strain zone.



c - The 'Dinosaur Pond belt' is overridden by yet another (postulated) thrust unit, and is highly deformed and metamorphosed in the north-central high strain zone temperature conditions. The north-central high strain zone was thus formed as a ductile shear zone either in the still hot, newly solidified tonalite or near the base of the still hot, upper mantle-lower crustal level of the overriding ophiolitic nappe. In summary, high temperatures were imposed early during nappe development, and maintained during thrusting during the formation of the lineation and composite foliations in the ductile shear, or high strain zones. This suggests that rocks at the bases of overthrust sheets, or, alternatively, involved in thrusting were very hot, perhaps because thrusting occurred before the cumulate and deeper sections of the ophiolite had cooled in response to displacement from the spreading centre.

In this context, it is noteworthy that the deformational overprint of the Long Range/Stag Hill high strain zone on the underlying layered metagabbro occurred while the temperature of the latter was still high enough to produce metamorphic brown green hornblende when fluid was introduced; brown green hornblende only later became partly replaced by blue green hornblende more characteristic of the high strain zone. If layered, transition zone metagabbro underlying the massive metagabbro and metadiabase as part of a normal ophiolitic crustal sequence was also very hot when it was intersected by a thrust beneath the Dinosaur Pond belt, and water introduced into these hot metagabbros, both syndeformational metamorphic upgrading of the rocks overridden by the thrust sheet, and partial melting (due to the rise of $P(H_2O)$ and depression of the min mum melting curve, or solidus (Figure 9)), with upward intrusion of the melt into the overlying, more brittle sheet would probably result. This suggests a source for the tonalite in the Dinosaur Pond belt, and an explanation for its agmatitic nature (Figure 8).

Two questions now arise:

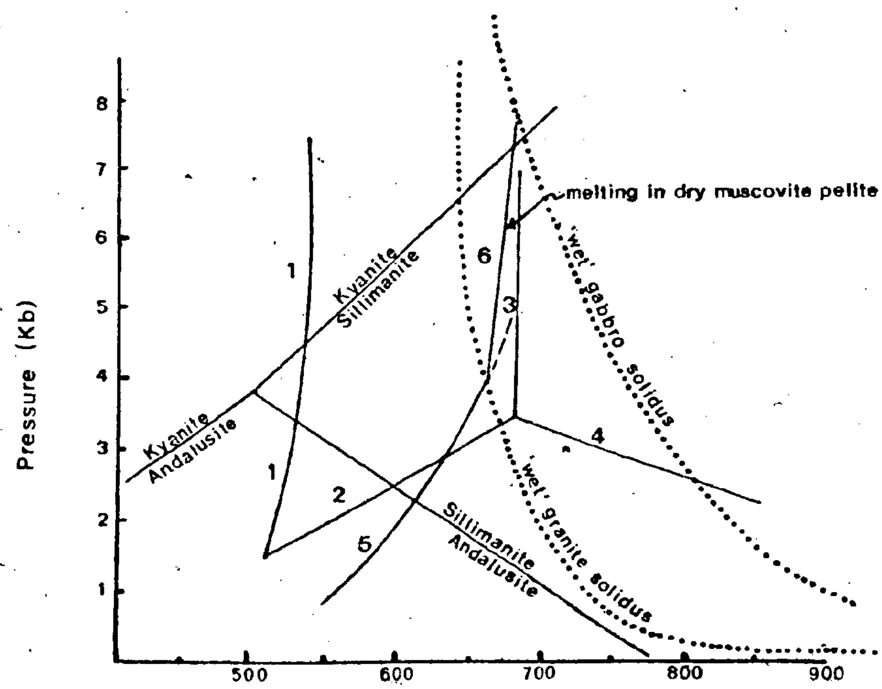
(1) What would cause the ophiolitic crust to become thrust-stacked so soon after its development?

(2) If thrusting was toward the west or northwest, why does the movement pattern which appears to explain the widespread tonalite as well as the high temperatures in the high strain zones suggest that displacement occurred earlier in the west than the east? Is the latter a facet of subduction?

Late deformation in Terrane I (D_3(TI) to D_5(TI), Table 3) involved uplift and retrogression associated with the major northeast-trending faults. Retrogression in the Dinosaur Pond belt is concentrated around internal shear fractures and the fault boundaries. The superposition on early igneous and regional metamorphic textures of penetrative fabrics associated with this late deformation occurred to a substantial degree only near the Cape Ray Fault. Thus, early movement on the Cape Ray Fault ($D_3(TI)_{early}$) is tentatively linked to the uplift and cooling of Terrane I. $D_3(TI)_{late}$ and D_4(TI) (Table 3) are linked to continued movement on the fault, which will be justified later by considering the deformation sequence affecting the Windsor Point Group and Cape Ray Fault zone.

Figure 9: P – T diagram showing approximate stability fields of staurolite, aluminosilicates, muscovite and partial melt.

(curves taken from Turner, 1982)



Reactions shown:*

1 chloritoid + al-silicate ⇌ staurolite + quartz

2 staurolite + quartz ⇌ cordierite + al-silicate

3 staurolite + quartz ⇌ almandine + sillimanite

4 almandine + sillimanite ⇌ quartz + cordierite

5 quartz + muscovite ⇌ K-feldspar + al-silicate + vapour

6 quartz + muscovite + Na-feldspar ⇌ K-feldspar + al-silicate + melt

* numbers on side of reactants

More dramatic effects were associated with late uplift of the Little Codroy Pond belt, and are here assigned to D_5(TI) (Table 3). Early fabrics were folded, and commonly reoriented into steep attitudes during a deformational event which culminated in the horst-like uplift of the belt between the Long Range Fault and the southeast margin of the Stag Hill high strain zone. Movement was also accommodated on many shear/fracture zones within the boundaries of the belt, such as those along the Long Range escarpment. This event was Visean or younger in age, since Codroy Group sedimentary beds are steepened and even locally overturned near the fault (Ian Knight, personal communication, 1981; Knight, 1983), and preceded the deposition of the Pennsylvanian Barachois Group unconformably on Terrane I near the southwest tip of the island (Map 1).

Although uplift is the most obvious component of late movement acting on the belt, the Long Range Fault and other faults in the Carboniferous Codroy Valley have long been interpreted as wrench faults (Wilson, 1962; Webb, 1969; Belt, 1969), and their continuing history linked to the development of the Carboniferous sedimentary basin (Hyde, personal communication, 1982; Knight, 1983). The strike-slip sense of the most recent activity is dextral, as demonstrated by dextral en echelon folds of the Carboniferous sedimentary rocks between the prominent, northeast-trending master faults. Minor southeast-trending block faults are antithetic to the system (Knight, 1983).

The axial traces of these folds, taken from Knight and Brown (1977), are shown on Map 1. It is noteworthy that high angle reverse faulting affects the Carboniferous strata along the west coast of Newfoundland (Knight and Brown, 1977), suggesting that westerly-directed convergence may have been coeval with strike-slip movement on the faults.

9.3 EFFECTS OF DEFORMATION AND METAMORPHISM ON TERRANE II

9.3.1 Relationships between domains

Terrane II is subdivided into structurally and metamorphically coherent domains along the three main faults, the Grand Bruit Fault, the Bay d'Est Fault, and the Gunflap Hills fault splay (Figure 4). The amphibolite facies terrane bounded by the Bay d'Est Fault, the Cape Ray Fault and the Gunflap Hills fault splay is referred to here as the Bay du Nord belt, and the amphibolite facies terrane between the Cape Ray Fault and the Gunflap Hills fault splay the northeastern wedge. The greenschist facies terrane between the Grand Bruit and Bay d'Est Faults is referred to below as the highlands belt. The La Poile River Group occupies all three domains, although the calc-alkaline metavolcanic rocks of the group are concentrated in the highlands belt and the Bay du Nord belt. The rocks of the

Bay du Nord belt and northeastern wedge were metamorphosed to amphibolite grade, veined with partial melt and locally intruded by sheets of component 4b synmetamorphic granitoid rocks before further deformation.

South of the Grand Bruit Fault, the metamorphic rocks and foliated granodiorite have already been named the Cinq Cerf Complex, and the existence of a break in occupancy is still uncertain. It is conceivable that the oldest rocks in the complex are related to the La Poile River Group, and were deformed and intruded by granodiorite after the metamorphic peak in the same manner as the La Poile River Group in the Bay du Nord belt and northeastern wedge (5.5).

Throughout Terrane II, main foliations, stretching lineations, fold axes (Map 2), and trends interpreted from air photos (not shown) define a smoothly varying, northeasterly- to easterly-trending structural grain. Foliations dip steeply and extension lineations and fold hinges plunge gently, and merge into the steeply dipping regional shear zones and faults.

The structural history of Terrane II as a whole is divisible into three major and one minor regional deformation episodes, here denoted as D_1(TII) to D_4(TII) (Table 4). Although the same tectonic events affected all domains in this terrane, clear differences in style of deformation, grade of metamorphism, and levels of intrusion, particularly between the highlands belt and the other three domains, suggest that the response to deformation depended

Table 4: Deformational events in Terrane II

Event	Main effects	Local interpretation
D_4((TII)	Minor block faulting, chevron and kink folding especially along major fault zones, widely spaced local crenulation cleavage.	Minor regional adjustment.
D_3(TII)	Shear zones, mylonites, shear fractures, local refoding and rotation of earlier foliations, lineations, fold hinges, local crenulation, schistosity. ($\equiv D_2$ (WPG))	Dextral oblique uplift of Bay du Nord belt between Cape Ray Fault, Gunflap Hills fault splay, and Bay d'Est Fault. Displacement on Cape Ray Fault in northeast.
D_2(TII) late	Continued development of fabrics, mylonite zones along Cape Ray Fault, and folds, foliations, shear zones away from fault. ($\equiv D_1$(WPG))	Continued deformation and movement on Cape Ray Fault.
D_2(TII) early	Development of Cape Ray Fault, fault zone mylonites, ductile shear zones. Formation of prominent foliations, extension lineations, folds.	Intense deformation (transpression) culminates in development of Cape Ray Fault as a convergent wrench fault.
D_1(TII)	Locally preserved, gently dipping schistosity to segregation banding parallel bedding. Rare early fold closures. Local, gently dipping mylonites.	Recumbent folding, possible thrusting.

largely on the tectonic level during each event of rocks now exposed.

9.3.2 Effects on individual domains of Terrane II

D_1(TII): Bay du Nord belt and northeastern wedge

The first stage of regional deformation resulted in the production of recumbent folds, the hinges of which were observed only locally. The overturned limb of a major F_1 northerly or westerly facing recumbent fold was recently observed east of the study area near the Burgeo highway (Sean O'Brien, personal communication, 1982). An early micaceous schistosity (S_1) subparallel to primary layering occurs locally, although generally reoriented by later deformation (D_2). In most areas, it is now preserved only as planar inclusion trails in almandine garnet and in staurolite of the metasedimentary rocks (14.2.2); the inclusion trails are parallel to both pre-porphyroblast schistosity (S_1) and compositional layering (either $S_\emptyset$ and/or S_1). In addition, quartzitic and migmatitic veinlets tend to follow S_1/S_o, and their generation appears to have coincided with the development of a coarse micaceous schistosity parallel $S_1/S_\emptyset$.

However, S_1 is the foliation predominant in a few outcrop areas. For instance;

(1) S_1 is locally visible as an isoclinally folded micaceous schistosity in the west part of the belt near the Cape Ray Fault, and is locally the main schistosity in central parts of the belt between Peter Snout and Grandys Brook #2 in the easternmost part of the area.

(2) From the Bay d'Est Fault to (and locally beneath) the Dolman Cove Formation contact around Phillips and Cinq Cerf Brooks, S_1 is represented by a tightly to moderately folded differentiation layering subparallel to the bedding planes defined by calc-silicate layers. The differentiated layering is locally overprinted mimetically by post-D_1 pre-D_2 garnets (Plate 9.5).

(3) In the northeastern wedge along Billiards Brook, a possible S_1 differentiated layering is locally crinkled and subsequently overprinted mimetically by garnets (14.2.2; Plate 9.6).

(4) Gently inclined intense schistosity and proto-mylonitic foliations of the Dolman Cove Formation from the source of Piglet Brook through Couteau Brooks may also represent structural elements imposed during the first deformation event.

(5) Pinstripe banding in highly strained amphibolites (14.2.3) may have originated either as syntectonic D_1 fabrics or as minerals mimetic after S_1.

D_1: highlands belt

The effects of D_1 are inhomogeneously developed in this belt. Bedded metatuffaceous and metasedimentary rocks of the Georges Brook Formation commonly display a schistosity that parallels bedding. Some of these beds are overturned in limbs of folds related to the later second cleavage (S_2) (but this could have been the result of primary volcanic disruption rather than F_1 folding). Early schistosities refolded by the second phase of folding were also observed in outcrops on the northern shores of La Poile Bay and north of the first falls on Cinq Cerf Brook. Gently reclined, isoclinal folds with a strong axial plane schistosity are refolded (F_2) between the two lobes of the Hawks Nest Pond Porphyry (Plate 9.7). Now easterly plunging (possibly D_2 rotated), gently reclined isoclines were observed locally along the Highlands of Grand Bruit (Plate 9.8).

The early deformation was responsible for some of the high strain zones exposed in the highlands belt. For instance, mylonite zones and ductile simple shear zones are refolded by D_2 along the shores of Roti Bay and La Poile Bay. Folded, gently dipping, mylonitic foliation west of Gooseberry Brook, and the earliest ultramylonitic fabric along the southeast side of the Bay d'Est Fault near the northwest-facing shore of La Poile Bay may also have developed during the D_I episode. In the eastern part of the belt, D_1 resulted in the development of openly folded, gently to moderately dipping, Fe-mineralized shear zones in the metavolcanic rocks extending from the Bay d'Est Fault zone southward.

D_1: Cinq Cerf Complex

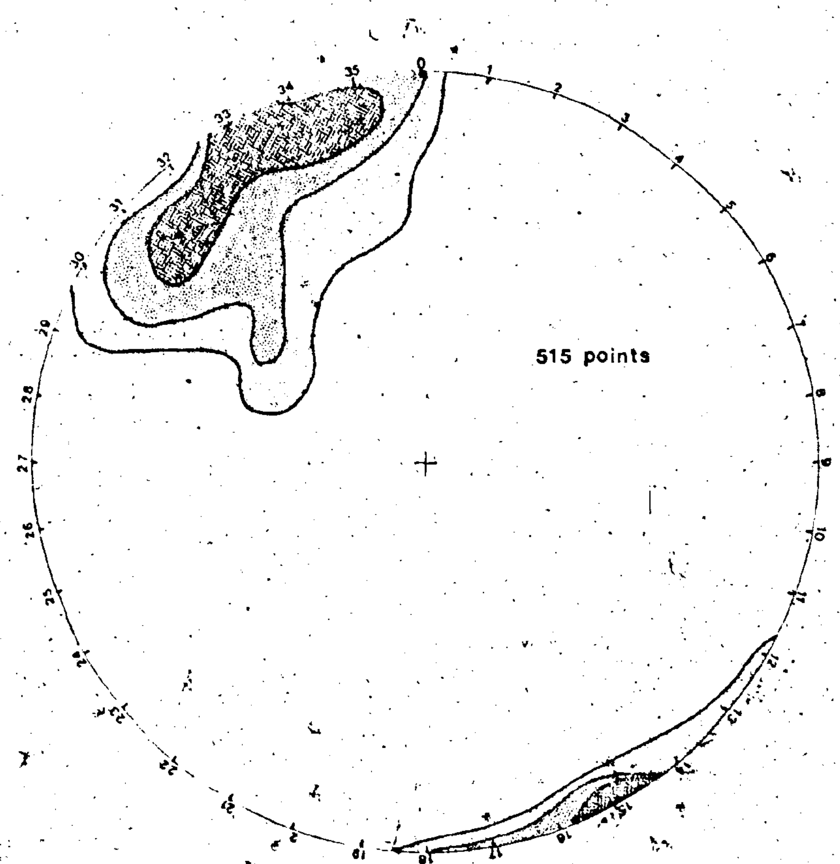
The numerous amphibolite xenoliths and metagabbro rafts show no fabrics which can clearly be attributed to deformation predating the foliation assigned to D_2 in the Cinq Cerf granodiorite. On the other hand, siliceous schists within the Grand Bruit Fault zone display pre-granodiorite, cataclastic to mylonitic foliations, and the huge raft or inlier of amphibolite and felsic schist on Harbour Island is traversed by numerous, gently inclined shear zones which are not concordant with any of the probable D_2 fabrics (below) in the surrounding younger rocks.

D_2: Bay du Nord belt

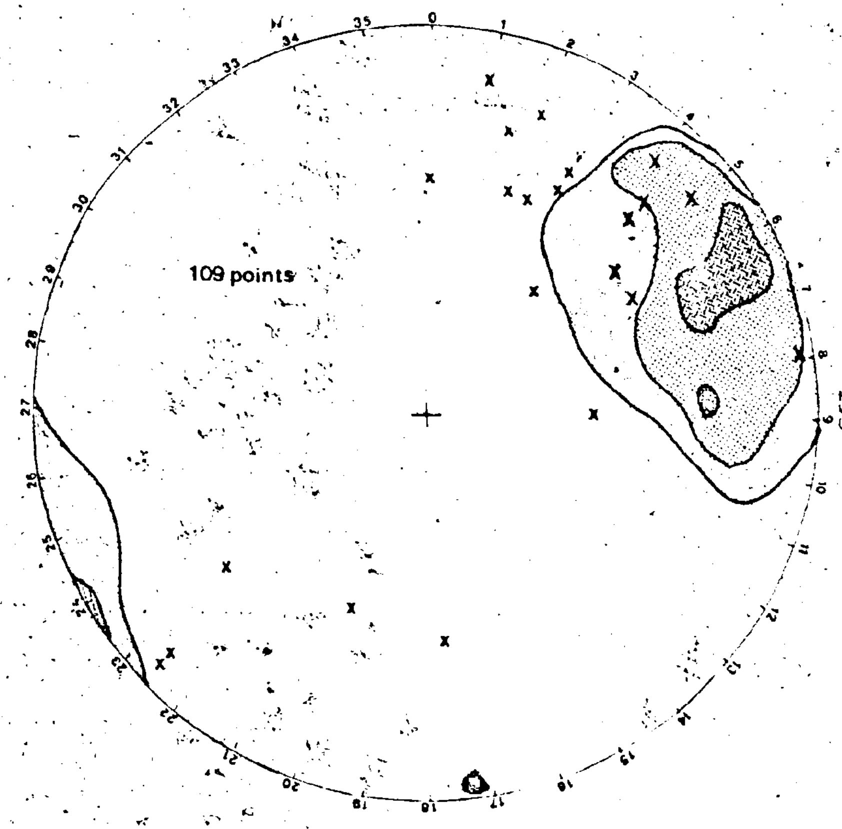
Throughout most of the belt, the second deformation was responsible for the predominant regional foliation of the La Poile River Group and the component 4b synmetamorphic granitoid rocks, and resulted locally in moderate to tight folding. The foliation strikes easterly to northeasterly, and in most places dips moderately to steeply southeast to east (Figure 10a). In some areas this foliation was rotated during D_3, such as near the southeast side of the Cape Ray Fault where it dips gently to moderately northwest, and along Gunflap Hills fault splay where it is near vertical. Next to the Bay d'Est Fault, it is actually crosscut by a stronger S_3 in some outcrops.

An intense schistosity parallel to a local, weak, gneissic segregation (S_2) was developed in the granitoid sheets of the western part of the zone. In the metasedimentary schists near the southwestern Cape Ray Fault zone, S_1/S_0 is isoclinally folded and commonly completely

Figure 10: Predominant fabrics of the Bay du Nord belt.



10a: Poles to predominant foliations.
Contours at 2, 4 and 6% per 1% area.



10b: Extension lineations.
Contours at 2.5, 5 and 10% per 1% area;
23 fold axes (x).

transposed parallel to S_2 during the second deformation.

Linear fabrics defined by elongated fragments in conglomerates (14.4, Plate 14.19), by preferred dimensional orientation of polygonized amphibole in metagabbros and amphibolites (14.2.3), and ferromagnesian and feldspathic clots in the Dolman Cove Formation (14.10) are attributed largely to this stage of deformation. As seen from Map 1 and Figure 10b, these lineations most commonly plunge gently to horizontally northeast to east. However, they plunge southwest locally along the southeast side of the Cape Ray Fault and along the north side of the Bay d'Est Fault, and plunge from southwest to gently southeast where the S_2 foliation dips moderately to gently northwestward.

F_2 folds are generally either upright or inclined with steeply to moderately southeast-dipping axial planes, and plunge gently to moderately northeast, nearly parallel to the linear fabrics (Plate 9.9), although they show a slightly more diverse scatter of orientations (Figure 10b). Fold hinges plunge southwestward in areas where southwest to gently southeast plunging lineations and moderately to gently northwest-dipping S_2 foliations are also present (Map 1).

D_2 occurred under approximately the same amphibolite facies metamorphic conditions achieved after D_1. Although some dehydration reactions accompanied and/or followed the D_2 deformation, these possibly signify gradients in volatile fugacity (below) rather than increases in temperature or changes in total pressure. Biotite and muscovite are the main minerals defining the strong foliation. Sillimanite also defines the foliation east of Garia Brook. In the semipelitic schists, staurolite and almandine porphyroblasts form augen in the S_2 foliation (14.2.2), and therefore predate D_2. A slight curvature of the quartz inclusion trails near the margins of many staurolite grains (14.2.2) suggests that staurolite growth overlapped the onset of D_2. It is uncertain whether gedrite of the gedrite amphibolites and schists crystallized before or during D_2: crystals appear to form very weak augen in S_2 and are traversed by quartz-filled intracrystalline tension gashes, although they are crudely aligned along S_2 (14.2.3). In the amphibolites, hornblende is polygonized and somewhat flattened parallel to S_2 (14.2.3).

Late D_2 reactions which appear to involve a net volatile loss are indicated in many rock types throughout the Bay du Nord belt. In the coarse grained, layered amphibolites of the west part of the terrane, polygonized blue green hornblende grains are overprinted by poikiloblasts of little deformed clinopyroxene (salite or diopside); this may have occurred during the late stages of D_2 or afterwards. In silicified mylonite zones in Grandys Brook #1, grains of kyanite aligned in the foliation are partially altered to muscovite, whereas other muscovite grains are partly altered to fibrolitic sillimanite. Fibrolite locally overprints and fringes fabric-forming muscovite in some of the synmetamorphic granitoid rocks, and may be either late- or post-D_2 in age. Brown (1975) similarly mentioned textures representing both the production of fibrolite knots from muscovite, and their conversion back to muscovite in some of the (?D_2) slide zones along the Rose Blanche Highway. Since no alkali feldspar is visible as a reaction product, reactions involving transfer of H^+, K^+, and H_2O are suggested here (c.f. Eugster, 1970; Gresens, 1971; Vernon, 1979). It will be suggested later that the necessary fugacity gradients may result from the propagation of dilational zones and localization of granitic partial melt during D_2.

The synmetamorphic granitoid rocks of the Port aux Basques phase (Unit 10c on Map 1) show signs of substantial recrystallization of feldspar and quartz during the formation of the D_2 fabrics. This recrystallization may have been accompanied by the replacement of plagioclase by alkali feldspar. The latter appears to have recrystallized in the form of microcline throughout the penetrative deformation, whereas plagioclase, generally altered and corroded, was never observed as fresh new grains. The Port aux Basques phase shows considerable variation in normative, as well as modal, feldspar content (Appendix III).

Pegmatites and small quartz veins were probably emplaced during this period. Massive, northeast-trending quartz veins, which appear to lie along D_2 shear or slide zones, may have developed afterwards by introduction of silica-enriched fluids along mylonite zones.

<u>D_2: northeastern wedge</u>

D_2 resulted in gently northeast-plunging, upright folds and strong, moderately to steeply, southeast-dipping foliations (Map 1, Map 2), associated with the development of numerous, northeast-trending shear to mylonite zones in the northeastern wedge. S_2 is the predominant fabric in this domain.

Tight, similar D_2 folds are best displayed in the semipelitic schists north of Big Otter Pond and Tarzan Brook, where they plunge gently northeast and are associated with a steep, northeast-striking axial plane foliation. Large porphyroblasts of almandine and staurolite (now pseudomorphously replaced by fine grained white mica), form augen in this foliation.

Polygonization of blue green hornblende in the amphibolites is attributed to D_2. Hornblende underwent dynamic recrystallization in the hinges of several angular F_2 folds northeast of Big Otter Pond (14.2.3). Single crystals and sheaves of gedrite developed within or along the D_2 foliation (14.2.3) during this stage. East of Wiggly Pond near the Gunflap Hills fault splay, acicular gedrite overprints the blue green hornblende-plagioclase pinstripe banding and defines the strong foliation axial planar to F_2 isoclinal folds of pinstripe banding. Much of the amphibolite was also under the influence of the post-D_2 Gunflap Hills Fault splay, so that folding of pinstripe banding here tentatively attributed to D_2 might instead be the result of later deformation associated with the splay.

Some of the mylonite zones along the southeast side of the Cape Ray Fault show retrograded D_2 mylonitic foliations defined by white mica and chlorite as well as strained and commonly microcrystalline quartz (Plate 9.10), and in some, equant garnet augen are marginally corroded (Plate 9.11) and locally totally replaced pseudomorphously by chlorite. In some of these rocks, chlorite has extensively replaced porphyroclasts of all compositions 'post-tectonically' (Plate 9.12). Other mylonites in the same area show no evidence for substantial retrogression; biotite and blue green hornblende are developed along S_2, and polycrystalline garnet forms lenses strung out along the foliation. In mylonitized amphibolites exposed on the brook, blue green hornblende is corroded by khaki brown biotite and fibrous actinolite. Cryptocrystalline, hairlike diopside fringes hornblende in less deformed amphibolites (14.2.3).

In the eastern part of the wedge, a wide belt of protomylonites to ultramylonites belongs to a very broad shear zone passing through Rocky Ridge Pond. The belt encompasses multiple, steeply dipping, sinistral simple shear zones (Maps 1, 2). These shear zones formed mainly under amphibolite facies conditions with little or no retrogression. Biotite is present in the least deformed rocks. In more deformed rocks, muscovite buttons along some of the mylonitic foliations are marginally altered to sillimanite, and trails of sillimanite follow the mylonitic foliation. Garnets are fragmented, and the fragments strung out in the foliation without any sign of the chlorite replacement common in the mylonites near the Cape Ray Fault (proper) and Gunflap Hills fault splay.

D_2: highlands belt

The second deformation affected both the La Poile River Group rocks and the Hawks Nest Pond Porphyry. It was responsible for the development of the main, regionally penetrative schistosity (shown on Maps 1 and 2), axial planar to tight upright folds of bedding and local earlier schistosity, and numerous shear or fracture zones. Most D_2 fold hinges plunge moderately east or gently south. The strong, northeast-trending, steeply-dipping foliations consist of fracture cleavage in nonmicaceous felsic volcanic rocks and well developed schistosities in platy or fibrous mineral-rich mafic volcanic and other volcaniclastic rocks. Some of the more massive mafic units were not penetratively foliated, but fractures and local D_2 shear zones are present in these rocks as well as in foliated exposures. Cobbles and boulders which are flattened in the southeast-dipping foliation plane are somewhat elongated in the northeast direction and similarly deformed granodioritic (Roti Granite) boulders display transverse tension gashes filled with fibrous quartz in the Georges Brook conglomerate exposed on Cinq Cerf Brook. Quartz-filled tension gashes also occur locally in the Georges Brook ash flows and in the Hawks Nest Pond Porphyry.

D_2 shear zones and minor faults are abundant. These dip subvertically, and trend both east-northeast (dominant) and north-northeast (subordinate). They are most numerous along the south side of the Highlands of Grand Bruit and toward the Grand Bruit Fault. A particularly persistent shear zone extends from Little Roti Bay through the main shaft of the Chetwynd Mine on Cinq Cerf Brook and is truncated by the undeformed Chetwynd Granite.

The rocks of the highland belt were deformed under middle greenschist facies conditions. The grade is a little higher in the east near Grandys Brook #2, and the high grade is reflected by the first appearance of biotite. Randomly oriented and fabric forming, khaki coloured biotite occurs with both chlorite and muscovite in intermediate to felsic volcaniclastic rocks, and actinolite and chlorite occur in the mafic metavolcanic rocks and associated metagabbro.

D_2 fabrics and shear zones were subsequently truncated by the Chetwynd Granite, as was the Grand Bruit Fault. Chetwynd rhyolite dykes were emplaced along the shear and fracture zones.

$\underline{D_2}$: Cinq Cerf Complex

The Cinq Cerf Complex displays an inhomogeneously developed D_2 schistosity which increases in intensity toward the Grand Bruit Fault and intensifies into minor conjugate simple shear zones (c.f. Ramsay and Graham, 1970). The fabric is defined by flattened quartz domains and by biotite, the biotite locally defining a composite foliation consisting of the early foliation plus an asymmetric crenulation foliation. In some of the shear zones, biotite-chlorite intergrowths occur along the secondary foliation planes and epidote is abundant. The emplacement of dykes apparently spans the deformation, since some possess foliations passing continuously from dyke to granodiorite, whereas other mineralogically-identical dykes are completely unfoliated.

The Otter Point Granite was also affected by D_2 deformation near its margin, where an S_2 fabric is defined by matrix quartz and biotite, and by partially realigned microcline phenocrysts. Effects vanish further from the fault zone.

$\underline{D_3}$: Bay du Nord belt

The third event was initiated under the ambient amphibolite facies conditions of the Bay du Nord belt, and ended with local retrogression along shear zones near the

Cape Ray Fault in the west part of the area, the Gunflap Hills fault splay, the Bay d'Est Fault, and easterly trending to east-northeasterly trending shear or fracture zones within the Bay du Nord belt. Vermicular rims of epidote on clinopyroxene in the coarse grained, layered amphibolites, and patches of secondary calcite near transverse fractures are the only retrogressive effects consistently noted away from these lineaments (14.2.3).

Inhomogeneously-developed crenulation cleavage axial planar to small scale, asymmetric folds affecting the pre-Devonian terrane are developed especially along the southeast side of the Cape Ray Fault zone. In the same general area, less crenulated S_2 of the Bay du Nord belt is locally folded on a larger scale to dip northwest along the southeast side of the fault zone (Map 1). D_2 lineations and fold hinges are rotated with the foliation to plunge southwest, or locally gently southeast (Map 2 and Figure 10b).

D_3 fault movement produced mylonite zones in the Bay du Nord belt along the fault contact with the Windsor Point Group. The strong, blastomylonitic to mylonitic fabrics in the synkinematic granitoid rocks along the easterly trending segment of the Cape Ray Fault are related to movement of the Gunflap Hills fault splay and the fault which defines the southeast contact of the Windsor Point Group. East-trending shear or fracture zones well within the Bay du Nord belt cut across the unfoliated subsolvus leucogranite around

Northwest Brook.

Along the north side of the Bay d'Est Fault, a strong D_3 schistosity to crenulation cleavage or foliation, defined by muscovite and subordinate biotite which is altered partly to chlorite, overprints the D_2 fabric at a low angle. Earlier lineations and schistosities may have been rotated to plunge moderately to steeply SE to SW and strike EW to SE and dip steeply, respectively, next to the fault.

$\underline{D_3\text{: northeastern wedge}}$

The most noticeable effects of the third deformation event on the northeastern wedge are asymmetric folding north of Tarzan Brook (see Section 9.4, Figure 12), faulting along the southeast side of the Windsor Point Group, and the reactivation of mylonite zones near both the fault and the Gunflap Hills fault splay. The F_3 dragfolds plunge very steeply northeast, and locally refold F_2 folds. Much of the deformation along the splay is associated with more penetrative, widespread retrogression in all rock types, and, most noticeably, complete breakdown of gedrite and amphibole of gedrite amphibolites.

$\underline{D_3\text{: highlands belt and Cinq Cerf Complex}}$

Neither the highlands belt nor the Cinq Cerf Complex are very much affected internally by this deformational event, although it is possible that some of the deformation effects attributed to D_4 (below) might have occurred earlier. D_3 is reflected only by movement on the Bay d'Est Fault, which brecciated and kaolinitized the Chetwynd Granite, and is expressed as a mylonite zone along the southeast side of La Poile Bay and Northeast Arm. The dacitic crystal tuffs to the southeast of this mylonite zone are affected by minor simple shear zones which are spaced several centimetres apart.

D_4: All subdomains

The fourth deformation event resulted in the development of crenulation cleavage and kink bands. Kink bands and chevron folds of D_2 mylonitic foliations are particularly well developed along the Cape Ray Fault. In addition, small scale faults and fractures both crosscut and follow the regional grain southeast of the fault.

9.3.3 Preliminary interpretation of the regional deformation of Terrane II

The effects of deformation on Terrane II (Table 4) are generalized as follows:

D_1: The first deformation involved recumbent folding, probably associated with the development of fold and/or thrust nappes.

This resulted in tectonic burial, leading to crustal thickening in respeonse to which the metamorphic grade increased, and amphibolite facies assemblages, anatectic veining, and the emplacement of sheets of synmetamorphic granitoid rocks collected from slightly deeper in the tectonic pile occurred at tectonic levels represented by the Bay du Nord belt and northeastern wedge.

D_2: The second deformation resulted in the moderately to vertically southeast dipping regionally predominant foliations, subhorizontal lineations and gently-plunging, moderate to tight folds. It is associated with numerous northeast-trending sinistral shear zones, at least in the northeastern wedge.

The second deformation took place under approximately the metamorphic conditions achieved after D_1 throughout most of Terrane II, except for the northeastern wedge where it is associated with retrogression localized in D_2 mylonite zones within and near the Cape Ray Fault zone.

The Windsor Point Group was deposited along the Cape Ray fault zone after the formation of the mylonites. It was possibly itself deformed during waning stages of the fault activity (below), forming open folds which may have been later tightened next to the southeast fault boundary.

Several metamorphic reactions involving loss of volatiles from rocks of the Bay du Nord belt may be late- or post-D_2. The introduction of subsolvus leucogranite into tensional zones across the structural grain of the Bay du Nord belt is pre-D_3.

D_2 in the Cinq Cerf Complex resulted in the development of shear zones which appear to be more numerous toward the Grand Bruit Fault. Retrogression is displayed in some of the shear zones near the fault.

D_3: The third deformation episode is associated with the development of localized fabrics and folds beginning under the ambient metamorphic conditions throughout most of the Bay du Nord belt and partial to complete retrogression localized along major shear zones or faults, particularly along the margins of the belt. It involved late faulting, reactivation of shear zones, and local folding in the northeastern wedge.

D_4: The effects of the fourth deformational episode were

> only minor, and may not everywhere have been contemporaneous. Local, high level chevron and kink folding and minor faulting was concentrated mainly along pre-existing fault and shear zones.

From the summary above, it appears that D_1 of Terrane II resulted in crustal thickening and burial of part of the La Poile River Group now exposed in the Bay du Nord belt and the northeastern wedge, and possibly also the oldest components of the Cinq Cerf Complex. D_2 culminated at least partly in differential uplift of the tectonically-buried, amphibolite facies northeastern wedge, as well as being responsible for the development of the regional S-L fabrics and most of the folds in the other domains. D_3 was responsible for local refolding of earlier structures, and culminated with the uplift of the Bay du Nord belt. The major fault and shear zones obviously played an important role in these deformational events; as a consequence, they now form the boundaries of metamorphically coherent domains within the same complex of rocks. Conversely, the regional stresses causing penetrative deformation on a regional scale would ultimately lead to faulting if they are of sufficient magnitude. Therefore, it is pertinent to consider the geometric pattern of these deformation events compared to that of major faults.

D_2 was the most regionally significant of the two post-nappe deformation events. D_2 structures have been somewhat affected by D_3, especially near the Cape Ray Fault zone in the southwest, and near the Gunflap Hills and Bay d'Est Faults. In the amphibolite facies Bay du Nord belt and northeastern wedge, where D_2 left the largest imprint, the main characteristics of D_2 are:

(1) a steep schistosity which strikes in an undulating northeasterly to easterly direction,

(2) extension lineations which plunge gently to subhorizontally northeast to east,

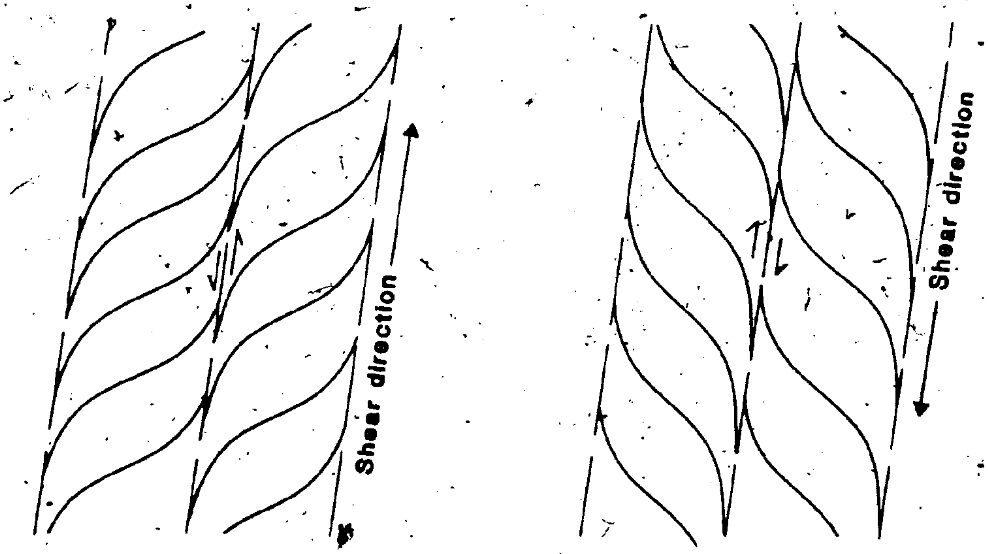
(3) fold hinges which plunge gently northeast to east, a little more scattered in orientation than the extension lineations.

All of these characteristics can be easily accounted for by a process of regional simple shear (strike-slip) plus compression, a process termed 'transpression' by Harland (1971). A subvertical shear belt with a lateral strike-slip direction would fit the observations for Terrane II. Such a simple shear couple would result in both steeply dipping foliations and extension lineations with strikes and trends ranging from 45° (at low strains) to nil (at high strains) from the simple shear direction. Where shearing was substantial, as in Terrane II, angles between the foliation and the shear direction would be mainly in the lower part of this range. Fold hinges would initiate parallel to the intersection of S_1/S_o and planes perpendicular to the maximum shortening, approximated by the local foliation in deepseated domains. Fold hinges, foliations, and extension lineations would rotate into the shear direction during progressive deformation (e.g. Escher and Watterson, 1974; Hobbs, Means, and Williams, 1976, pages 286-288). Because of originally greater diversities due to variations in S_1 and S_0 orientation, fold axes may not cluster as tightly as the stretching lineations.

Progressive, heterogeneous simple shear results in a sigmoidal asymmetry of pre-existing and contemporaneous fabric elements with respect to the shear direction (Ramsay and Graham, 1970). Since foliations, shear zones, and faults in Terrane II trend largely northeast to east, the general direction of strike-slip must be either approximately northeast or approximately east (ignoring the D_3 effect), and the rotation either sinistral or dextral. These four arrangements are shown in Figure 11. From Figure 11b and 11c, the combinations northeasterly dextral shear and easterly sinistral shear can immediately be rejected because they would produce dominant trends not observed in Terrane II (Map 2; Figure 10). The other combinations, northeasterly sinistral shear and easterly dextral shear (Figure 11a, 11d) would both produce the structural array displayed by the deepseated parts of Terrane II. However, the presence of sigmoidal shear zones with a sinistral sense in the northeastern wedge and the predominance of northeasterly striking D_2 shear and mylonite zones makes the combination 'northeasterly sinistral shear' the most attractive choice for D_2.

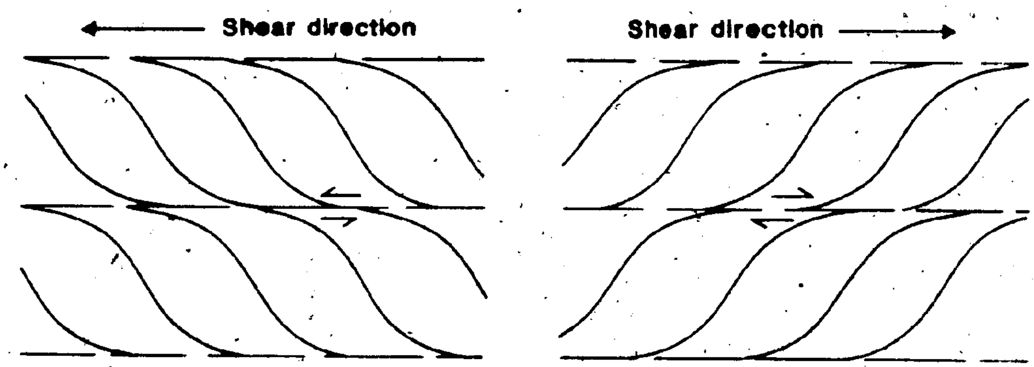
The subsequent D_3 event resulted in uplift of the Bay du Nord belt against the Windsor Point Group by a combination of high angle reverse faulting on the southeast side of the

FIGURE 11: ALTERNATIVE NORTHEASTERLY AND EASTERLY TRENDING, SUBHORIZONTAL SHEAR SYSTEMS, WITH SUBVERTICAL SHEAR PLANES



a. Sinistral sense of shear with north east-striking, subvertical shear plane and northeasterly, subhorizontal shear direction

b. Dextral sense of shear with northeast-striking, subvertical shear plane and northeasterly, subhorizontal shear direction



c. Sinistral sense of shear with east-striking, subvertical shear plane and easterly, subhorizontal shear direction

d. Dextral sense of shear with east-striking, subvertical shear plane and easterly, subhorizontal shear direction

Cape Ray Fault zone in the southwest and by dextral oblique slip on the Gunflap Hills fault splay. D_3 uplift of the Bay du Nord belt was also accommodated by largely vertical adjustment along the Bay d'Est Fault. Minor subhorizontal dextral movement along the southeast side of the northeastern end of the Cape Ray Fault, causing small fault offsets and subvertically plunging asymmetric folds on both sides, was probably related to the dextral displacement of the splay (by accommodating space problems at the tip of the wedge). The penetrative effects of D_3 are generally concentrated near internal D_3 shear zones and domain boundaries; pre-existing structural elements are rigidly rotated more than redeformed plastically. Comparable rocks span both the Gunflap Hills fault splay and the Bay d'Est Fault, so it was unlikely that these domain boundaries originated as really old faults, although either may have had minor pre-D_3 movement.

Although northeasterly sinistral and easterly dextral shear regimes (D_2 and D_3 respectively) would produce the same variations in structural attitude, the strains produced would not be everywhere coaxial. Therefore, D_2 structures might be folded or otherwise reoriented by D_3. The scale of interference would depend on the regional distribution, density and relative intensity of principle shear planes of each deformation stage. F_2- F_3 fold interference patterns affecting the gently dipping $S_{1/\emptyset}$-planes potentially vary from Type 0 of Ramsay (1967, page 531), where the principle strain directions are coaxial, to Ramsay's Type I, where maximum shortening and extension directions are at high angles to one another. The striking, bulls-eye patterns shown by the synmetamorphic granitoid sheets (Map 1) emplaced along S_1 in the Port aux Basques (110/11) and Rose Blanche (110/10) map areas (Brown, 1977, 1976b) are examples of Type 1 or Type 1(-2) (Figure 10-13E of Ramsay, 1967).

Where progressive simple shear has proceeded to an advanced degree, even rocks which have been deforming in a ductile manner may produce en echelon dilational structures which propagate at 45° to the shear direction and perpendicular to the instantaneous stretching direction (see Ramsay, 1967, page 84; Ramsay and Graham, 1970; Durney and Ramsay, 1973). Sigmoidal quartz-filled and pegmatite-filled veins were observed in several places, but their geometry was not documented during this study; both small, east-trending, dextral tension gash arrays as well as larger, pegmatite-filled gashes were noted.

On a sightly larger scale, numerous thin sheets of little deformed, garnetiferous leucogranite traverse the foliations of the synmetamorphic granitoid rocks, its La Poile River Group hosts, and the La Poile batholith east of Garia Brook. These were also noted within the Gunflap Hills shear zone during this study (Plate 9.14). Brown (1975) noted similar garnetiferous leucogranite dykes crisscrossing shear and slide zones further west. It is noteworthy that the Bay du Nord belt underwent the intense D_2 deformation (and initial D_3) under amphibolite facies temperatures and pressures within the range of the water-saturated granite solidus. During late D_2, metamorphic assemblages in the Bay du Nord belt appear to have been dehydrating; the fluid probably migrated toward dilational zones and thence upward. Local increases in $P(H_2O)$ may have been adequate for minimum melting of the pre-existing granitoid rocks and gneisses, and the segregation of melt into volatile-rich dilational zones. Therefore, the deformational development of dilational zones could have caused volatile fugacity gradients and localized partial melting. Partial melting may in turn have provided a 'sink' for K^+ ions which may have been produced during the local replacement of muscovite by sillimanite (c f., Eugster, 1970).

This process in general could explain both the generation of the garnetiferous leucogranite dykes and the larger masses of subsolvus leucogranite that were passively emplaced into intrusion zones and lenses at high angles to the regional structural grain (7.3; Map 2). It is thus most likely that these leucogranites segregated after D_2 had produced substantial regional strain, and before the rocks were uplifted and cooled as the ultimate result of D_3.

As stated earlier, there is an implicit link between the regionally active strain field and the development of the fault systems. In general, for the orogenic level now exposed at the present erosion surface, ductile deformation preceded and probably culminated in failure along faults.

The Gunflap Hills fault splay and its extension along the southeast side of the Cape Ray Fault, and the Bay d'Est Fault resulted from D_3. The Grand Bruit Fault and the Cape Ray Fault precede the D_3 faults: the Grand Bruit Fault was crosscut by the undeformed Chetwynd Granite which was itself cut by the Bay d'Est Fault, and the Cape Ray Fault was offset dextrally by the Gunflap Hills splay.

The patterns of the shear zones, dykes, and dyke foliations would undoubtedly provide much information on the major movement on the Grand Bruit Fault. Fault zone lineations plunge moderately to steeply southwest, indicating at least a component of sinistral movement, if vertical movement was south side up as implied by the shear zone retrogression superimposed on the higher overall metamorphic grade of the Cinq Cerf Complex. Cooper (1954) also suggested that the fault was sinistral. Alternatively, either sense of strike-slip displacement may have been succeeded by high angle movement which produced the lineations and the metamorphic contrast.

The Cape Ray Fault, prior to D_3 warping, formed a straight, steep fault zone which can be traced northeastward for at least 125 km from Cape Ray to the Annieopsquotch Mountains. From there, one fault component passes along the Lloyds River on the northwest side of the Annieopsquotch Mountains through Red Indian Lake, another on the southeast side through Victoria Lake. The mylonites which mark the original fault zone belong to the set of D_2 mylonite and shear zones which probably resulted from sinistral 'transpression'. The Cape Ray Fault may thus have originated as a master fault from the ultimate brittle failure along some of the major ductile shear zones (c.f. White *et al*, 1980), and may be classified as a sinistral wrench fault (*c.f.* Anderson, 1951) of compressional type (*c.f.* Wilcox *et al*, 1973).

9.4 EFFECTS OF DEFORMATION AND METAMORPHISM ON THE WINDSOR POINT GROUP AND THE CAPE RAY FAULT ZONE

9.4.1 Effects of deformation and metamorphism recorded during this study

The Windsor Point Group in southwest Newfoundland was affected by three stages of deformation, here denoted as D_1(WPG), D_2(WPG), and D_3(WPG) (Table 5). The effects of these deformation stages on the Windsor Point Group differ somewhat between the southwestern and northeastern segments of the Cape Ray Fault zone, and therefore these areas will be treated separately below.

In the northeastern segment, D_1(WPG) resulted in the development of northeasterly- to easterly-trending, gently to horizontally plunging, upright folds and foliations of variable intensity. The folds are relatively open in the

Table 5: Deformational events affecting Windsor Point Group and Cape Ray Fault zone

Event	Main Effects	Local Interpretation
D_3 (WPG)	Kink bands, chevron folds, crenulation cleavage	Minor late activity along fault, late regional adjustment
D_2 (WPG)	Refolding, strike-slip faulting, weak to very strong foliation, locally pronounced stretching of clasts, mineral lineations.	Late movement on Cape Ray Fault with reversed displacement sense.
D_1 (WPG)	Open to tight (en echelon?) folding, weak to strong schistosity.	Continuation of the Cape Ray Fault activity which controlled the deposition of the group.
pre-WPG	Formation of a major zone of mylonites, phyllonites along Cape Ray Fault, and to the southeast.	Initiation of the Cape Ray Fault as a major sinistral? wrench fault.

north, and are tight in the south (where they may have been tightened by D_2(WPG)). Some of the conglomerates show easterly-trending, moderately to gently plunging stretching lineations defined by elongate clasts lying within the pervasive foliation. These clasts locally possess east-trending, fibrous pressure fringes. East of the Fox Hole Brook-Billiards Brook junction, elongate pebbles without pressure fringes or extension gashes define a steeply plunging linear fabric; this may be the result of primary imbrication of elongate pebbles (long axes generally perpendicular to the direction of flow in fluviatile regimes, and parallel the flow direction in turbidite sequences (Walker, 1981, p.96-97)), combined with the folding of bedding into steep attitudes as well as possible tectonic extension.

D_2(WPG) is related to faulting along the southeast boundary of the Windsor Point Group, and resulted in a crenulation foliation which is most evident in the sandstones and siltstones, and in local asymmetric folding. In the upper Billiards Brook, easterly verging, asymmetric folds (F_2(WPG)) of the layering and schistosity (S_1(WPG)) about subvertical axes have the shorter, southern limbs truncated by northeast-striking, subvertical minor faults This geometry suggests some dextral offset along the faults (Figure 12). The latter become more numerous toward the southeast fault boundary of the group. In the northeastern wedge of Terrane II, steeply plunging F_3 dragfolds of S_2

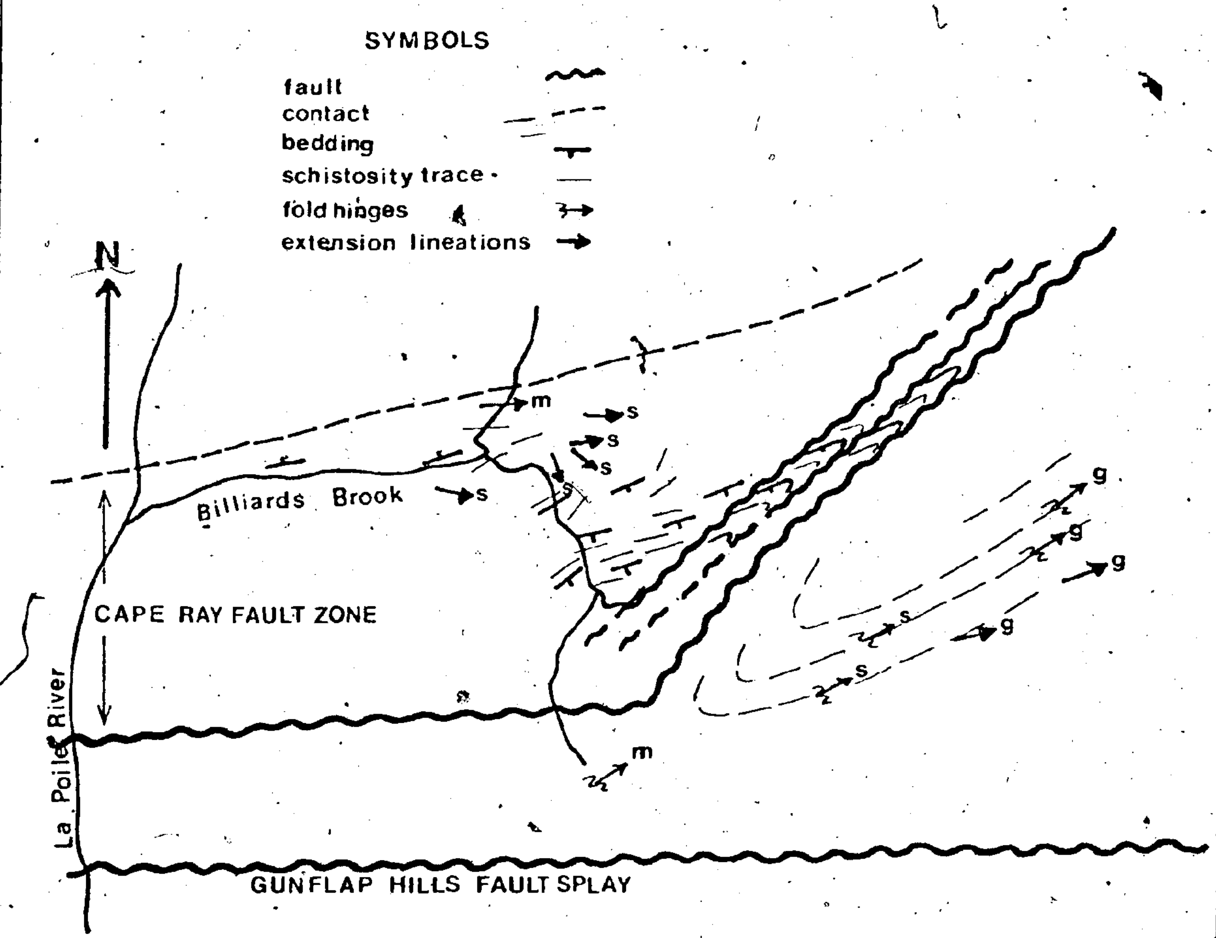


Figure 12: Asymmetrical folds (F_2(WPG)–F_3(TII)) in Billiards Brook area, Cape Ray Fault zone.

between Tarzan Brook and the fault contact (Figure 12) also reflect a dextral couple acting across the southern fault contact of the Windsor Point Group. Dextral fault movement linked to D_2(WPG) is also supported by the pronounced pinching-out of the Windsor Point Group along the east-trending flexure of the Cape Ray Fault, where the Gunflap Hills fault splay merges with the Cape Ray Fault.

The Windsor Point Group possesses an intense schistosity in the south part of Nitty Gritty Brook, where it is tightly interleaved with older mylonites and blastomylonites of the fault zone. The latter contain remnants of earlier metamorphic minerals, such as corroded garnet fragments and muscovite 'fish' (Plate 9.13) typical of the D_2 mylonites of the northeastern wedge. In contrast, the Windsor Point Group rocks are metamorphically overprinted by relatively fine grained muscovite or sericite, although muscovite-rich mylonite clasts and coarse detrital muscovite flakes are abundant in some of the grits. Large, relatively competent cobbles and pebbles in the conglomeratic rocks form elongate augen plunging moderately southwest within the strong foliation (Plate 9.15), and have southwest-trending fibrous quartz and calcite pressure fringes (17.2; Plate 9.16). Other, incompetent clasts are flattened parallel the foliation, and are commonly barely distinguishable from the matrix (17.2). Since these rocks are located near the junction of the Gunflap Hills fault splay and the main Cape Ray Fault zone, it is thought that the intense deformation in this area may be attributed to a combination of D_2(WPG) and D_1(WPG). Further north on Nitty Gritty Brook, away from the late splay and the most severe penetrative deformation, steeply dipping dykes of Nitty Gritty Brook Granite which cut the quartz gabbro-diabase show sinistral offsets across steep, northeast-trending minor faults.

In the part of the southwestern segment mapped during this study (110/15), the Windsor Point Group displays strong, northeast-trending foliations, gently northeast-plunging folds, and a local, moderately southeast-plunging mineral lineation. The foliations and early folds can be attributed to either D_1(WPG) or D_2(WPG) or both, since farther southwest in the fault zone, northeast-plunging folds and foliations are refolded about northeast-plunging axes with a northeast-striking axial plane foliation next to the southeast margin of the fault zone, and are thus attributed to D_2(WPG) (Brown, 1975: 9.4.2 below). The development of northeast-trending foliations intensify toward the southeast side of the fault, and is attributed more to D_2(WPG) than D_1(WPG), although it is realized that this is highly subjective. The southeast-plunging mineral lineations are here assigned to D_2(WPG), and are concordant with similar lineations in the Bay du Nord belt rocks nearby which are attributed with D_2(TJI) northwesterly-directed reverse faulting of the Bay du Nord belt against the Windsor Point Group.

Steeply-dipping, northeast-striking foliations both predate and post-date the Windsor Point Group along the northwest side of the fault zone. The relatively intense, northeast-striking foliation which occurs along the fault in the massive metagabbro zone of Terrane I grades through a wide zone of phyllonite into the fault zone mylonite in Isles aux Morts Brook (5.2.2; 9.2.3). Tuffisite dykes locally cut the mylonite parallel to the mylonitic layering, and fragments of mylonite and tuffisite are found in the volcaniclastic rocks of the overlying Windsor Point Group. Southeast-dipping shear and fracture zones affect both the Windsor Point Group resting unconformably on the mylonite, and slightly younger perthite-rich leucogranite Plutons B and C which cut both the fault zone mylonite and phyllonite. In addition, a northeast-trending zone of fault gouge occurs within the Windsor Point Group, and affects the southern margin of perthite-rich Pluton B.

In both segments, the rocks were metamorphosed to lower or middle greenschist facies assemblages prior to the development of the 'S_2(WPG)' schistosity near the southeast side of the fault zone. Actinolite grains and epidote knobs which crystallized in the mafic metavolcanic rocks during this metamorphism form augen within the schistosity (17.2.1). Recrystallization during deformation resulted in the development of sericite (all rocks), the production of coarse flakes of graphite (mudstones only), and the introduction or redistribution and precipitation of calcite (all rocks).

The Windsor Point Group is affected similarly in both northeastern and southwestern segments of the fault zone by D_3(WPG). D_3(WPG) resulted in chevron, conjugate, and kink folds across the regional grain. D_4(TII) described in the previous section includes the same deformation of the pre-Windsor Point Group rocks deformed within the fault zone.

9.4.2 Deformation sequences proposed by other workers

The structure of the Windsor Point Group in the southwestern segment was studied by Brown (1972, 1975) and Wilton (1981) in more detail southwest of the area mapped during this study. Both report three phases of deformation, and the existence of early, northeasterly plunging fold hinges. However, Wilton (1981) denied the existence of an unconformable relationship between the Windsor Point Group and the early fault zone mylonites observed by Brown (1975) and reported here, and interpreted by us to mark the early development of the Cape Ray Fault zone. The deformation history suggested by Brown (1975), which corresponds closely to the deformation sequence found along the rest of the fault zone during the present study, is summarized below; this is followed by the alternative sequence proposed by Wilton (1981).

According to Brown (1975), the Windsor Point Group in this area was affected by three phases of deformation, which he denoted as D_1(cover), D_2(cover), and D_3(cover). Steeply southeast-dipping cleavage, axial planar to open folds in the northwest side of the fault zone were attributed to D_1(cover). This cleavage intensifies into a strong tectonic banding close to the southeast side of the fault zone. Pebbles form augen in this fabric in conglomeratic rocks. D_1(cover) also formed isoclinal to sub-isoclinal, northeast-plunging folds of the banding in the mylonite that is unconformably overlain by the Windsor Point Group. D_2(cover) was coaxial with D_1(cover), and although the effects of D_2 diminish away from the southeastern fault boundary, D_2 cleavage was developed locally subparallel to the earlier cleavage. Near the southeast fault boundary, D_1 banding was isoclinally folded. D_2(cover) also resulted in open, northeast-plunging folds of the isoclinally folded older mylonites. Conjugate folds and kinks were attributed to D_3(cover), as for D_3(WPG) of the present study. Brown (1975) did not attempt to relate the deformation resulting in the formation of the Cape Ray Fault with any of the deformation stages to the southeast, although he later suggested that late activity of the fault may be related to Devonian or younger antithetic thrusting and microstructural reworking affecting correlatives of the Bay du Nord Group of Cooper (1954) (Brown, 1976a).

Wilton (1981) separated the deformation history of the Windsor Point Group, as well as parts of Terranes I and II adjacent to the Cape Ray Fault, into the same three stages.

According to Wilton (1981), the first event produced a southeast-dipping flattening foliation which is axial planar to isoclinal folds, and a southeast-plunging mineral lineation. The second produced open folds, asymmetric to the northwest, and a local crenulation cleavage. Both of these events he attributed to shortening and consequent high angle thrusting from the southeast. Wilton (1981) suggested that the Cape Ray Fault was formed within the Windsor Point Group or along its northwestern contact, and relates to the first deformation of the group.

9.4.3 Correlation of D_1(WPG), D_2(WPG), D_3(WPG) with deformation in Terranes I and II

It is suggested here that deformation which affected the Windsor Point Group (Table 5) can be correlated in time with the deformation of the adjacent terranes (Tables 3 and 4):

(1) Cape Ray Fault zone mylonites, on top of which the Windsor Point Group was deposited unconformably, are thought to have developed after the formation of the flat-lying D_1-D_2(TI) high strain zones of Terrane I and the emplacement of component 4b' plutons which intersect them, and as a result of the D_2(TII) deformation in Terrane II.

(2) The latest event, D_3(WPG), corresponds to the latest deformation, D_4(TII).

(3) D_1(WPG) and D_2(WPG) are linked to the major stages of activity within the Cape Ray Fault zone; since these movements are reactions to regional stress fields, they are undoubtedly linked to deformation away from the fault prior to D_4(TII)-D_3(WPG).

(4) D_2(WPG) relates to the southeast fault boundary of

the Windsor Point Group with the Bay du Nord belt and northeastern wedge, and thus corresponds with D_3 of Terrane II. Differences in structural effects between the southwestern and northeastern segments of the Cape Ray Fault zone may reflect the contrasts in the D_3-Terrane II deformation between the Bay du Nord belt, which is adjacent to the southwestern segment, and the northeastern wedge, which is adjacent to the northeastern fault segment.

(5) D_1(WPG), which resulted in open folds away from the southeast boundary of the fault zone and in foliations of variable intensity, may correspond to either an early stage of D_3 which is unseparated in Terrane II or the waning stages of D_2. The second suggestion is presently considered the most likely.

The Windsor Point Group, consisting of fluviatile sedimentary rocks and alluvial conglomerates (Chandler, 1982) and basal breccias, and a bimodal volcanic suite (Chapter 7), is exposed the length of the Cape Ray Fault from Cape Ray to the foot of the Annieopsquotch Mountains (Map 2). Mylonitic clasts are common in some of the coarse sedimentary rocks and volcaniclastic rocks along the fault. In the southwest part of the fault (this study area), nonmylonitic detritus was derived from the plutonic/metamorphic rocks now exposed along the northwest side of the fault, whereas in the northeast part (northeast of the study area), coarse nonmylonitic metamorphic detritus was derived from rocks now exposed on both sides (Kean, 1983). Paleocurrent directions northeast of the study area suggest flow from the southwest (Chandler, 1982), compatible with a general downhill trend from the uplifted southwest part of Terrane I. Differential vertical displacement such as this is characteristic of wrench faults (Wilcox et al, 1973), and is referred to as scissors faulting (Moody and Hill, 1956).

The Windsor Point Group was deposited after the initiation of the fault. Since en echelon folds and faults typically develop in sedimentary strata deposited along wrench fault basins or scarps during continued lateral movement (Wilcox et al, 1973), it is likely that the upright, early folds in the Windsor Point Group represent en echelon folds resulting from waning stages of D_2(TII). The dextral oblique-slip movement and high angle thrusting of D_3(TII) ended this activity, but may have heralded the formation of wrench fault basins further west (see Chapter 10, Figure 14 and Section 11.1.2).

9.1 Thickly layered marble which is asymmetrically folded against the Long Range escarpment. (looking northeast)

9.2 Linear tectonic fabric in layered metagabbro.

9.3 Fold hinges and quartz rods in quartzofeldspathic veinlets parallel the gently east-plunging linear fabric. (summit of Stag Hill)

9.4 Syn-metamorphic tectonic breccia with coherent blocks of amphibolite and migmatite in chaotic migmatic matrix. (western slope of Stag Hill)

9.1

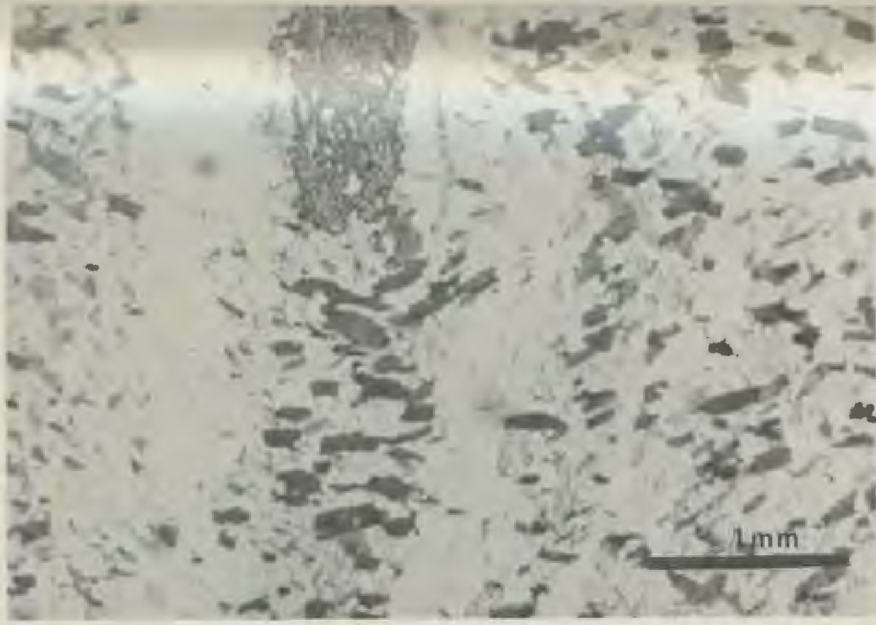
9.2

9.5 Photomicrograph of tabular garnet with planar S_1 inclusion trails, overprinting S_1 pinstripe segregation and forming augen in S_2 biotite fabrics, Cinq Cerf Brook north of Bay d'Est Fault. (76-LC-155, plane polarized light)

9.6 Photomicrograph of garnet overprinting crinkled biotite segregation (S_1?), Cape Ray Fault zone. (76-LC-237, cross polarized light)

9.7 Photomicrograph of highly deformed felsic tuff with strong S_1 fabric and possible F_1 folds, north of Highlands of Grand Bruit. (76-LC-226, plane polarized light)

9.8 Near recumbent isoclinal fold (F_1?) in volcanigenic sedimentary rocks of Georges Brook Formation, northeast of Highlands of Grand Bruit.



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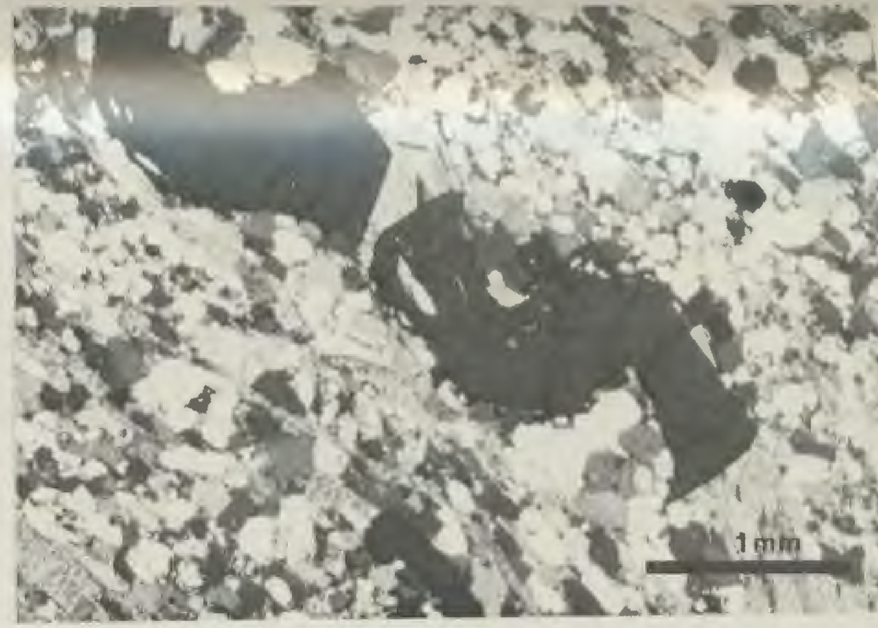

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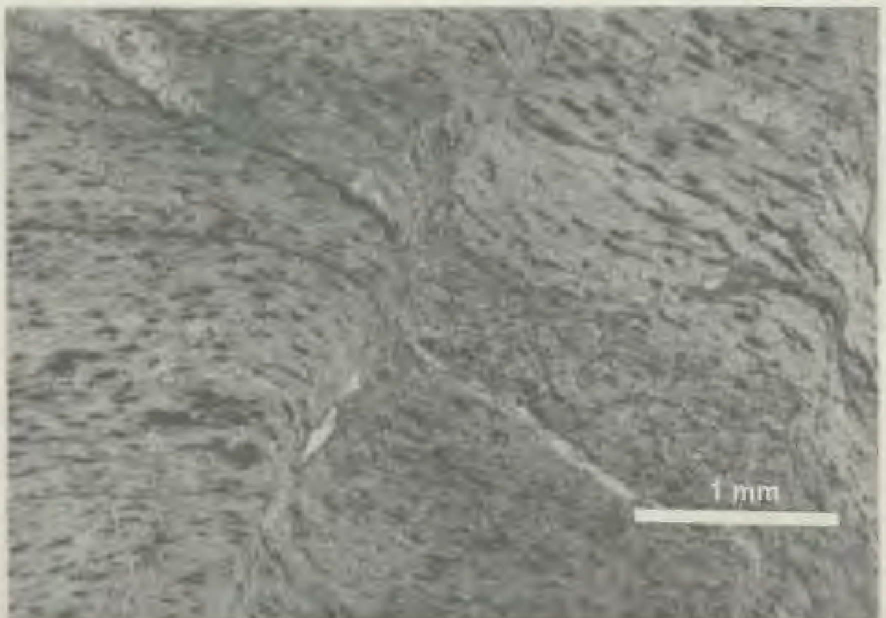

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9.9 Gently east-plunging folds in migmatitic veinlets, La Poile River.

9.10 Photomicrograph of strained and recrystallized quartz wrapping around feldspar porphyroclasts in mylonite of northeastern wedge. (76-LC-208, cross polarized light)

9.11 Photomicrograph of a corroded garnet porphyroclast with planar S_1 inclusion trails in a partly retrograded mylonite zone, northeastern wedge. (76-LC-208, plane polarized light)

9.12 Photomicrograph of chlorite overprinting porphyroclasts post-tectonically, northeastern wedge. (76-LC-208, plane polarized light)

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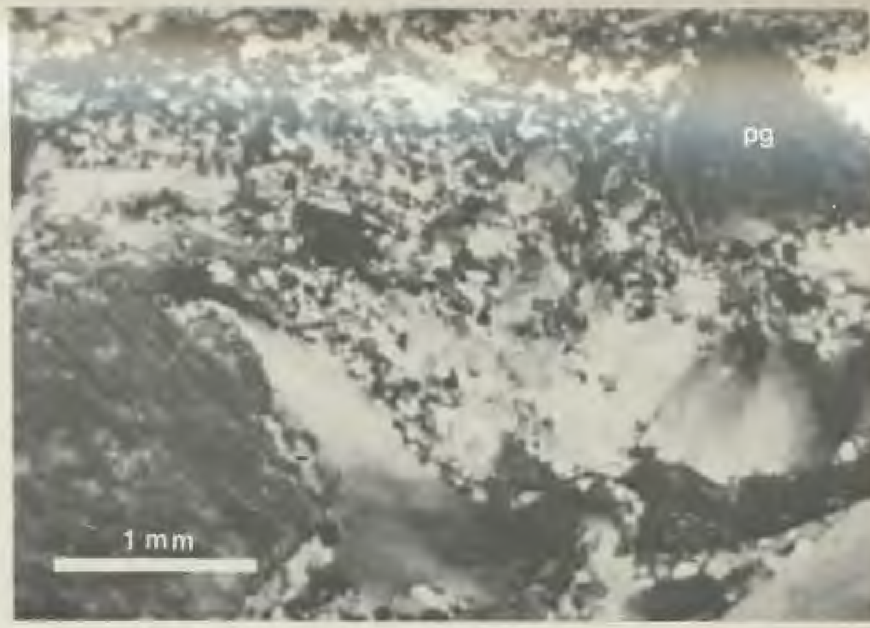

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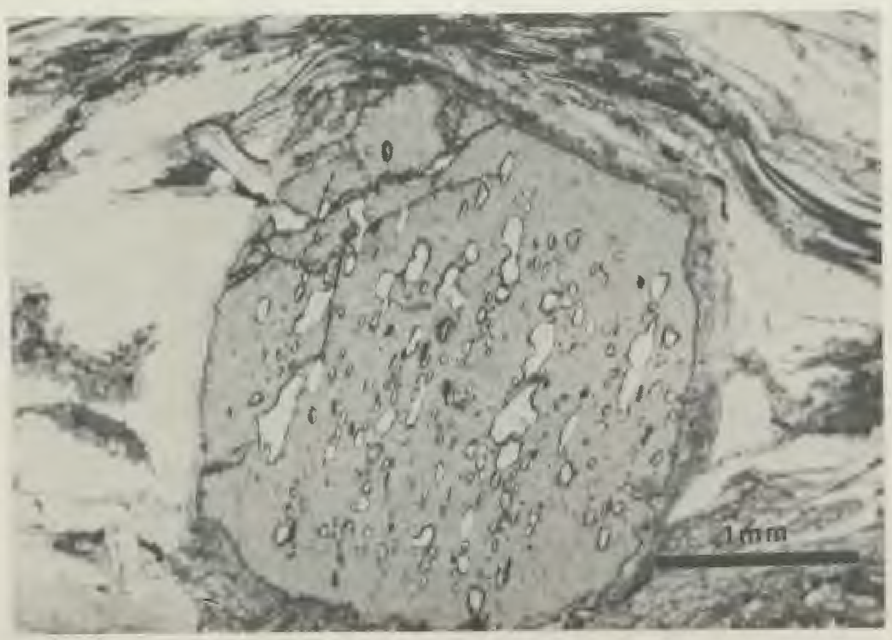

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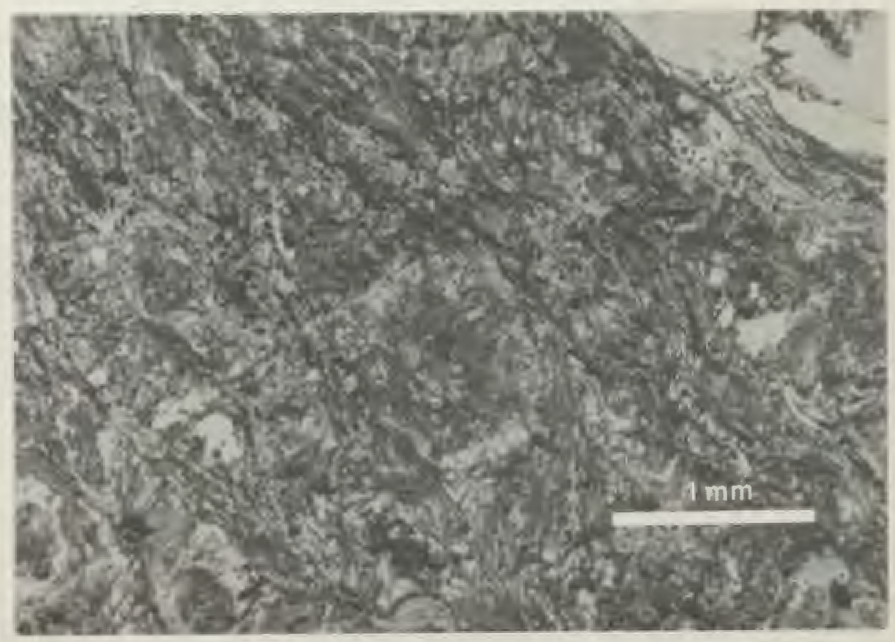

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CHAPTER 10: SYNOPSIS

An amalgamation of the field and petrographic data now collected from southwest Newfoundland provides the basis for a coherent picture of the tectonic development of the area. A synopsis of the timing of deposition or emplacement, structural development and metamorphism for each domain is given in Table 6, and Table 7 summarizes the various isotopic and fossil ages used as a time framework for this synopsis in reference to the time scale of Odin (1982). Table 8 represents an attempt to synthesize this information in a semi-diagramatic form.

The timing of major tectonic and magmatic events in southwest Newfoundland apparent from these syntheses is as follows:

(1) Early thrusting and/or recumbent folding in Terranes I and II: Preliminary K/Ar ages of biotite and hornblendes from the mafic to felsic plutons (Table 7) which cut the tonalite of Terrane I after the formation of the high strain zones are comparable to U/Pb$_{zircon}$ and Rb/Sr ages of late products of the calc-alkaline volcanic pile in the La Poile Bay area. This suggests that the postulated thrusting in Terrane I (responsible for the

Table 6: Synopsis of deposition or emplacement, structural development, and m

Bay St. George sub-basin		TERRANE I							
		Little Codroy Pond belt			Dinosaur Pond belt			Bay du Nord bel	
Deposition	Structural Development	Depositions Emplacement	Structural Development	Metamorphism	Depositions Emplacement	Structural Development	Metamorphism	Depositions Emplacement	Structural Development
Barachois [Westphalian] Group				Cooling and inhomogeneous retrogression		Minor faulting			D_4(TII), minor
	Activity on Long Range and related faults	Pluton A intrudes SE margin	Final uplift of L.C.P. belt on Long Range Flt. System		Pluton A intrudes NW margin		Contact metamorphism next to Pluton A		
Codroy Gp. [Visean] Anguille Group [Tournaisian]	Deformation				Late dykes?	Deformation near Cape Ray Fault (D_2WPG)		Isles aux Morts Br. Gr. [352]	D_3(TII) dextral oblique uplift
			Partial uplift together with D.P.belt?		Plutons B and C Windsor Pt. Gr. [377-393]	Cape Ray Fault defmtn (D_1WPG) Cape Ray Fault, wrench faulting plus uplift	Cooling and inhomogeneous retrogression	Windsor Pt.Gp.	Late D_3(TII)= D_1(WPG) Formation of Cape Ray Flt. as sinistral wrench fault
								Subsolvus leucogr.	
								Second partial melting?	
								pegmatites [410-415] La Poile batholith Synmetamorphic granitoid rocks & migmatites: 1st partial melting	D_2(TII)-sinistral 'transpression'
									Tectonic burial D_1(TII) recumbent folds, slides, thrusts
		Mafic to felsic plutons?			Mafic to felsic plutons [e.g. 445, 447 and younger minimum ages]		Hydrothermal circulation renewed near some plutons		
								Dolman Cv. Fm [446-449]	
						Composite fabric, folds, rodding. Overthrusting, producing MChez.	U. amphibolite facies in MChez, U. greenschist-L. amphibolite facies in massive metagabbro zone	Carrot Br. Fm, other volc. & sed.rocks of L.P.R.Gp	
		Synkinematic granitoid rocks, partial melting	Composite fabrics rodding, folds Thrusts, forming high strain zones between slices, mylonite	Amphibolite facies metamorphism in high strain zones Upper amphibolite facies in transition to layered metagabbro	Tonalite intrudes L.R.M-Um Complex			Diorite, gabbro, tonalite? cuts oceanic crust.	
		Pegmatites			pegmatites			Generation of oceanic basin crust	
					plagiogranite	Instability, local fracturing	Local introduction of seawater, submarine weathering, ocean floor metamorphism		
		Generation of oceanic crust [488-498 Ma or older]	Ductile defmtn in layered metagabbro. Local fracturing of rocks above	Granulite facies in layered metagabbro	Generation of oceanic crust [488-498 Ma or older]				

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Table 5: Synopsis of deposition or emplacement, structural development, and metamorphism for Terranes I and II, and the Bay St. Georges sub-basin of Knight (1983).

I Dinosaur Pond belt			TERRANE Bay du Nord belt			II Northeastern wedge			Highlands belt	
Depositions Emplacement	Structural Development	Metamorphism	Depositions Emplacement	Structural Development	Metamorphism	Depositions Emplacement	Structural Development	Metamorphism	Depositions Emplacement	Structural Development
	Minor faulting			D_4(TII), minor			D_4(TII), minor			D_4(TII), minor
Pluton A intrudes NW margin		Contact metamorphism next to Pluton A								Bay d'Est Fault
Late dykes?	Deformation near Cape Ray Fault (D_2WPG)		Isles aux Morts Gr. [[illegible]2]	D_3(TII) dextral oblique uplift	Cooling, innomogeneous retrogression near domain margins		D_3(TII)-D_2(WPG) dextral faults & shear zones			
Plutons B and C	Cape Ray Fault defmtn (D_1WPG)			Late D_2(TII)= D_1(WPG)			Late D_2(TII)= D1(WPG)			
Windsor Pt. Gr. [377-393]	Cape Ray Fault, wrench faulting plus uplift	Cooling and innomogeneous retrogression	Windsor Pt.Gp.	Formation of Cape Ray Flt. as sinistral wrench fault		Windsor Pt. Gr. along Cape Ray F.	Differential uplift as part of movement on Cape Ray Fault	Local greenschist facies retroression along mylonites, shears	Chetwynd Gr.spans G.B. Flt [min.372]	Grand Bruit Flt
			Subsolvus leucogr. Second partial melting?		Local dehydration reactions (fluid migration toward (i)mylonite zones, (ii) dilational zones?)	Garnetiferous leucogr. veins				
				D_2(TII)-sinistral 'transpression'			D_2(TII)-sinistral 'transpression'			D_2(TII)-'transpression'
			pegmatites [410-415] La Poile batholith Synmetamorphic granitoid rocks & migmatite: 1st partial melting		Amphibolite facies attained	Synmetamorphic granitoid rocks, 1st partial melting		Amphibolite facies attained	Hawks Nest Pd. Porphyry [418]	
					Rapid metamorphic upgrading			Rapid metamorphic upgrading		
				Tectonic burial			Tectonic burial			
Mafic to felsic plutons [e.g.445,447 and younger minimum ages]		Hydrothermal circulation renewed near some plutons		D_1(TII) recumbent folds, slides, thrusts	Greenschist facies or lower grade		D_1(TII) recumbent folds, slides, thrusts	Greenschist facies or lower grade		D_1(TII)-recumben folds, slides, thrusts
			Dolman Cv. Fm [446-449]						Dolman Cove Fm [446-449]	
	Composite fabric, folds, bedding. Overthrusting, producing MCnas.	U. amphibolite facies in MCnas, U. greenschist-L. amphibolite facies in massive metagabbro zone	Carrot Br. Fm, other volc. & sed.rocks of L.P.R.Gp			(Victoria Lake Gr.)			Georges Br Fm	
Tonalite intrudes L.H.M-Um. Complex			Diorite, gabbro, tonalite? cuts oceanic crust.			Diorite, gabbro, tonalite? cuts oceanic crust.			Diorite, gabbro, tonalite cuts oceanic basin crust or continental sliver	
pegmatites			Generation of oceanic basin crust			Generation of oceanic basin crust				
plagiogranite	Instability, local fracturing	Local introduction of seawater, submarine weathering, ocean floor metamorphism								
Generation of oceanic crust [488-490 Ma or older]										

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...morphism for Terranes I and II, and the Bay St. Georges sub-basin of Knight (1983).

TERRANE	II Northeastern wedge			Highlands belt			Cinq Cerf Complex		
...morphism	Depositions Emplacement	Structural Development	Metamorphism	Depositions Emplacement	Structural Development	Metamorphism	Depositions Emplacement	Structural Development	Metamorphism
		D_4(TII), minor			D_4(TII), minor			D_4(TII), minor	
					Bay d'Est Fault	Local kaolinztn of Chetwynd Gr. next to Bd'E.Flt.			
...ng, inhomo- ...us retrog- ...on near ...n margins		D_1(TII)-D_2(WPG) dextral faults & shear zones							
		Late D_2(TII)= D1(WPG)							
	Windsor Pt. Gr. along Cape Ray F.	Differential uplift as part of movement on Cape Ray Fault	Local greenschist facies retrogression along mylonites, shears	Chetwynd Gr. spans G.B. Flt [min. 372]	Grand Bruit Flt.		Chetwynd Gr spans G.B. Flt.	Uplift assoc. w. movement on Grand Bruit Fault	Cooling, local retrogression near G.B.Flt.
... dehydration ...ions (fluid ...tion toward ...ylonite zones, ...dilational ...?)	Garnetiferous leucogr. veins	D_2(TII)-sinistral 'transpression'			D_2(TII)- 'transpression'			D_2(TII)- 'transpression'	
				Hawks Nest Pd. Porphyry [418]			Otter Pt. Granite		
...bolite facies ...ned	Synmetamorphic granitoid rocks, 1st partial melting		Amphibolite facies attained				Cinq Cerf Granodiorite		Amphibolite facies
... metamorphic ...ading			Rapid metamorphic upgrading			Greenschist facies			
		Tectonic burial						Tectonic burial?	
...nschist facies ...ower grade		D_1(TII) recumbent folds, slides, thrusts	Greenschist facies or lower grade		D_1(TII)-recumbent folds, slides, thrusts	Greenschist facies or lower grade		D_1(TII)-thrusting?	
				Dolman Cove Fm [446-449]					
	(Victoria Lake Gr.)			Georges Br Fm					
	Diorite, gabbro, tonalite? cuts oceanic crust.			Diorite, gabbro, tonalite cuts oceanic basin crust or continental sliver					
	Generation of oceanic basin crust								

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Table 7: Radiometric dates and chronostratigraphic time scale, southern Long Range Mountains, southwest Newfoundland.

Radiometric (Ma) or fossil ages (stage)	Unit dated	Method	Reference	Interpretation (this study)	Time scale correlation (Odin, 1982)
Westphalian	Barachois Group	microspores	Bacquebard et al, 1961	Age of group.	300 - 310 Ma
Visean	Codroy Group	microspores	"	Age of group.	315 to 300 - < 350 Ma
Tournaisian or older	Anguille Group	microspores	Cote, 1964	Age of group.	< 350 - 350 to 365 Ma
346±20 & 344±16	Biotite and muscovite, resp., from La Poile Batholith in Bay du Nord belt	K/Ar	Gillis, 1967	Post-metamorphic cooling after D_3 (TII) uplift of Bay du Nord belt.	Lower Carboniferous
353±5, 350±5 & 345±5	Biotite from semipelitic schists, Bunker Hill Br. Gneiss & Phillips Br. Fm. of Bay du Nord belt	$Ar^{40/39}$	Dallmeyer, 1979	"	"
350±5 & 361±5	Biotite and hornblende, resp., from Ironbound syenodiorite-granite, Bay du Nord belt	$Ar^{40/39}$	Dallmeyer, 1979	Post-metamorphic/magmatic cooling after D_3(TII) uplift of Bay du Nord belt.	"
352±5.6	Isles aux Morts Br. Granite	Rb/Sr W.R.	Wilton, in press	Granite emplacement (during or following D_3(TII) uplift of Bay du Nord belt).	"
360±5 & 377±5	Biotite and hornblende, resp., from La Poile batholith, sourthern part	$Ar^{40/39}$	Dallmeyer, 1981	Post-magmatic cooling of La Poile batholith (where emplaced at high level of highlands belt?)	Middle through late Devonian
368±12	Windowglass Hill Granite (subvolcanic to Windsor Point Group)	Rb/Sr W.R.	Wilton, in press	Age of granophyre stock? Probably also reflects sodic hydrothermal alteration after emplacement.	Middle to late Devonian
372±5	Biotite of Chetwynd Granite	$Ar^{40/39}$	Dallmeyer, 1979	Post-magmatic cooling of granite, close to age of emplacement (see 8.4)	"
377.3±21	Ignimbrite of Windsor Point Group	Rb/Sr W.R.	Wilton, in press	Age of ignimbrite. Probably affected by synkinematic metasomatic alteration.	Middle Devonian
Emsian-Eifelian (E. to M. Devonian)	Black, silty mudstone of Windsor Point Group	Vascular plants & trilete spores	W.H.Forbes, p.c., 1980; C. MacGregor, p.c., 1981	Age of group.	377-393 Ma
(a)374±5 & 378±5; (b)378±5 & 388±5	Biotite and hornblende, resp., (2 samples) from very sheared granitoid rocks, northeastern wedge	$Ar^{40/39}$	Dallmeyer, 1979	Rapid, post-metamorphic cooling due to late D_2(TII) uplift of northeastern wedge.	Early-Middle Devonian
384±5 & 385±5	Biotite and hornblende, resp., from blastomylonite of Cape Ray Fault next to northeastern wedge	$Ar^{40/39}$	"	Very rapid post-metamorphic cooling resulting from scissors-like uplift along Cape Ray Fault,	"
410±20	Muscovite from syntectonic pegmatite, Bay du Nord belt	K/Ar	Gillis, 1965	Age of syn-D_2 (TII) pegmatite.	Silurian?
415±20	Muscovite from syntectonic pegmatite, Bay du Nord belt	K/Ar	Neale, 1963	"	"
410±20	Hawks Nest Pond Porphyry	U/Pb_{zircon}	Dallmeyer, 1979	Emplacement age prior to end of D_2(TII).	"
436±8 & 426±20	Biotite and hornblende from synkinematic tonalite and amphibolite inclusion, resp. of agmatite terrane in TI northeast of stduy area	K/Ar	Herd, 1982	Post-metamorphic cooling after uplift of TI	"
432±20	La Poile batholith	U/Pb_{zircon}	Dallmeyer, 1981	Discordia 'age' derived from new and inherited zircons?	Late Ordovician or Silurian?
445±18	Biotite from quartz diorite-megacrystic granite of TI 'late' synkinematic suite	K/Ar	Gillis, 1972	Ar blocking age of biotite gives minimum age for pluton.	Middle Ordovician
449±20 & 446±20	Dolman Cove Fm., north and south of the Bay d'Est Flt. resp.	U/Pb_{zircon}	Dallmeyer, 1979, 1981, resp.	Age of tuff, La Poile River Group volcanic activity.	Middle Ordovician
447±8	Biotite from 'late' synkinematic leuconorite cutting synkinematic tonalite in TI northeast of study area	K/Ar	Herd, 1982	Post-magmatic or post-metamorphic cooling of pluton; minimum age of pluton.	"
449±8 & 449±14	Biotite from synk. biotite tonalite and hornblende from hb-tonalite (early OR 'late' synkinematic) in TI northeast of study area	K/Ar	"	Post-magmatic or post-metamorphic cooling.	Middle Ordovician
455±65	Hornblende form 'late' synkinematic hb diorite/gabbro in TI northeast of study area	K/Ar	"	Post-magmatic or post metamorphic cooling.	"
459±18	Georges Brook Fm. metavolcanic rocks	Rb/Sr W.R.	R.K.Wanless, p.c., 1979	Age of La Poile River group volcanic activity? superimposed with effects of synvolcanic and/or regional synkinematic hydrothermal alteration.	"
Documented Newfoundland ophiolites from outside the study area:					
$485.7^{+1.9}_{-1.2}$	Bay of Islands Complex	U/Pb_{zircon} precise ages	Dunning and Krogh, 1983	Ages of oceanic crustal remnants.	Early Ordovician
$488.6^{+3.1}_{-1.8}$	Betts Cove Complex				
$477.5^{+1.3}_{-1.0}$	Annieopsquotch Mountains Complex				

TABLE 8: Geological development of southwest Newfoundland in stages one through four and Carboniferous

KEY: Fault movements – major ~~~~~ discontinuous or minor ~ ~ ~ unconformity - - - - - emplacement of perthite-rich leucogranite plug

Stage	Long Range Fault	Terrane I	Cape Ray Fault # 1	Cape Ray Flt # 2 to Gunflap Hills Fault Splay	Terrane II (SE)	Stage
Carbon-iferous	Codroy Group	Minor deformation			Minor deformation	Carbon-iferous
Stage 4	Anguille Group	Mafic and felsic dykes			Uplift of polydeformed, amphibolite facies tectonic level (Bay du Nord belt) via reverse faulting	Stage 4
Stage 3		Uplift of thrust-stacked tonalite-ophiolite terrane	Windsor Point Group		Sinistral transpression and deformation of Bay du Nord belt under prevailing amphibolite facies metamorphic conditions and northeastern wedge under changing metamorphic conditions (Episodic, diapiric emplacement of large plutons)	Stage 3
Stage 2		Emplacement of compositionally variable quartz gabbro to granite plutons Continued thrusting Production of synkinematic tonalite and 'dynamothermal' metamorphism during thrusting Initiation of thrusting and tectonic stacking possible formation of a 'subduction complex'	Contact ?		Metamorphism to amphibolite facies and partial melting to produce migmatite and synmetamorphic tonalite to granite Premetamorphic recumbent folding and thrusting resulting in tectonic burial of predominantly sedimentary and more distal parts of volcanic terrane	Stage 2
					Island arc volcano-plutonic activity and sedimentation in adjacent marine basin Development of interarc sedimentary basins and beginning of arc magmatism Generation of oceanic or marginal basin mafic crust	Stage 1
Stage 1		Generation of oceanic mafic crust				

development of the high strain zones) took place in the early Ordovician while these volcanic centres were in their early stages, and before recumbent folding in Terrane II. This may support a subduction-like or proto-subduction model for early thrusting in Terrane I, and perhaps a time link between the tonalite generation and earliest volcanic activity. In contrast, the fold nappes in Terrane II, which developed after the maturation of the volcanic centre could have resulted from gravitational spreading away from an upwelling arc terrane, a popular model for many nappe complexes (e.g. Price, 1973; Elliot, 1976; Ramberg, 1977). This event must have occurred between middle or late Ordovician and the onset of the D_2(TII) event, which affected post-D_1(TII) synmetamorphic granitoid rocks.

(2) Stages of compressive wrench faulting ('transpression'): The 'transpression' regimes in southwest Newfoundland belong to three sequential episodes:

(a) D_2 (TII) - Cape Ray Fault - Grand Bruit Fault systems, which must have begun in late Silurian times and culminated in Early Devonian faulting. The Grand Bruit Fault was sealed by the Chetwynd Granite ($Ar^{40/39}$ biotite cooling age of 372±5 Ma), after which activity ceased. The Cape Ray Fault zone mylonites were unconformably overlain by the Emsian-Eifelian Windsor Point Group (377-393 Ma of Odin, 1982), and activity of the early deformation regime may have continued in that area a little after the deposition of the group. It seems likely that many of the syntectonic pegmatites in the amphibolite facies Bay du Nord belt (410-415 Ma) may have coincided with earlier D_2(TII) deformation.

(b) D_3 (TII) - Gunflap Hills fault splay - Bay d'Est

Fault systems, which must have begun after the depositional and initial deformation (above) of the Windsor Point Group. $Ar_{40/39}$ post-metamorphic cooling ages (Dallmeyer, 1979) suggest that cooling resulting from uplift took place in the 345-350 Ma range (earliest Carboniferous); therefore stage (b) might have been active from middle or late Devonian to earliest Carboniferous. This might coincide with the initial development of the sedimentary basin into which the Anguille Group was deposited (Knight, 1983).

(c) Long Range Fault system, which must have been active after the deposition of the Visean Codroy Group, but may have been active as a fault system earlier. All but minor faulting had ceased by the time the late Carboniferous Barachois Group was deposited.

(3) Emplacement of the granitoid rocks: The general sequence of granitoid emplacement in Terrane I begins with the emplacement of synkinematic tonalite, followed by mafic to felsic plutons, and ends with perthite-rich leucogranite plugs and a bimodal dyke suite. In Terrane II, the first granitoid rocks to intrude ophiolite are mafic to felsic plutons associated with the La Poile River Group volcanic pile and its basement. Voluminous synmetamorphic granodiorite and tonalite were then generated, followed by the emplacement of megacrystic monzogranite batholiths, and finally, the relatively potassic leucogranites and mafic to intermediate dykes. The pattern of granitoid evolution in southwest Newfoundland is thus comparable to the general pattern of granitoid evolution which accompanied the cratonization of many shield areas (e.g., Anhausser *et al*, 1969; Anhausser, 1973; Glikson and Sheraton, 1972; Bridgewater *et al*, 1974; Glikson and Lambert, 1976;

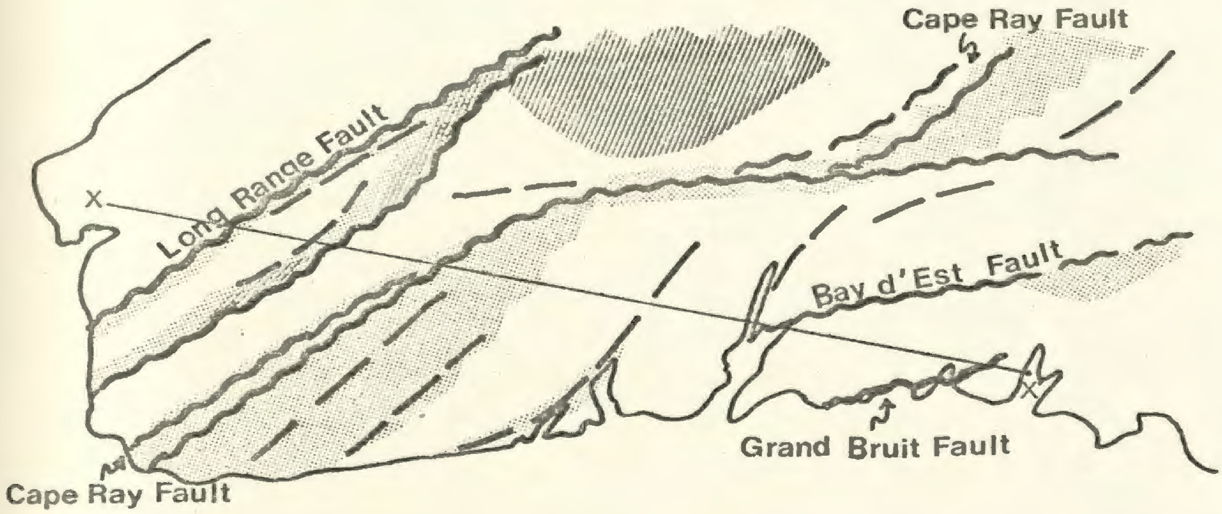
Collerson and Fryer, 1978).

The synopsis suggests that early stage of regional deformation in each terrane, involving either thrusting or recumbent folding, was ultimately responsible for the generation of the component 4b synkinematic/ synmetamorphic granitoid rocks in each terrane, whereas ages of emplacement of various post-ophiolitic gabbros, diorites, monzonites and granites comprising the similar components 4b' and 4a may relate to several deformation episodes. For the component 4c leucogranite intrusions and dyke suites, correlation between time of emplacement of each pluton or dyke suite and a specific late, 'transpression'-related tectonic event affecting the host structural/metamorphic domain is also indicated.

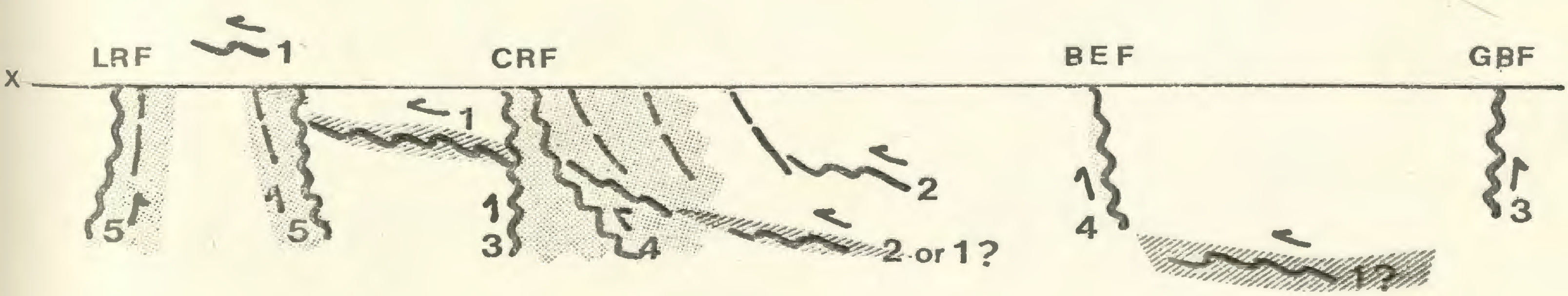
For instance, the perthite-rich leucogranites (not all the same age, e.g. Chetwynd and Isles aux Morts Brook Granites: Table 4) and the dykes both appear to have been emplaced at high tectonic levels; where the host domain is characterized by peak metamorphism in the (medium pressure) amphibolite facies, this implies that an uplift stage preceded or accompanied intrusion.

A deformation plan and cross-section shows fault movements and shear systems chronologically (Figure 13). Figure 14 illustrates in plan the 'transpression', or

Figure 13: Timing of major faults in SW Newfoundland, showing speculative vapour phase transport zones.

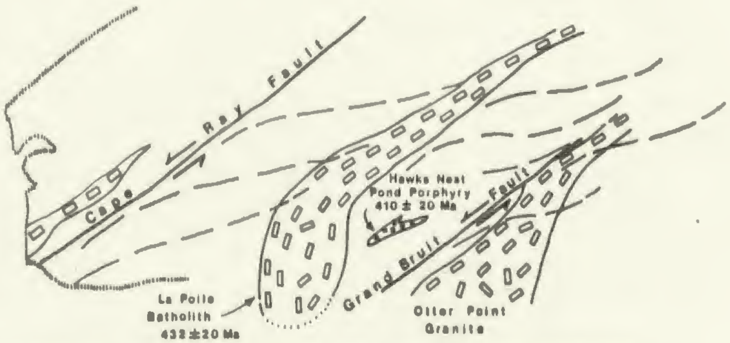


13a: Plan view showing major faults and proposed hydrothermally active zones, which initiated (1) ▨ during early thrusting, possibly with seawater and hydrous, semiconsolidated sediment available, and (2) ☐ during late, oblique-slip faulting, with metamorphic fluid available.

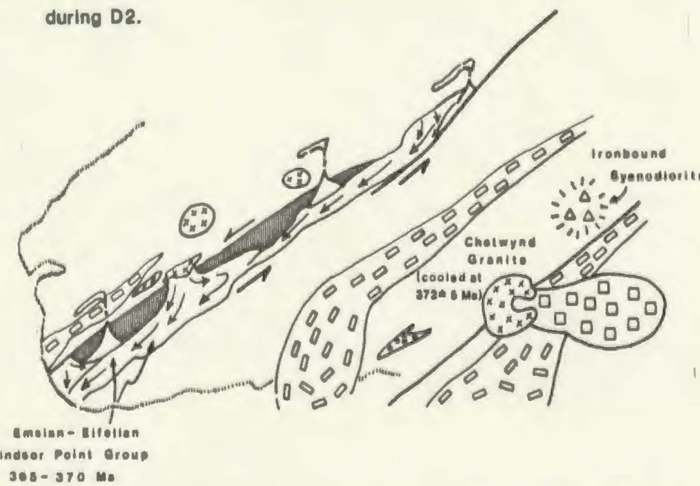


13b: Expanded cross-section, with numbers showing relative timing of faults.

Figure 14. Earliest Devonian to Carboniferous 'transpression' stages following early thrusting and recumbent folding.

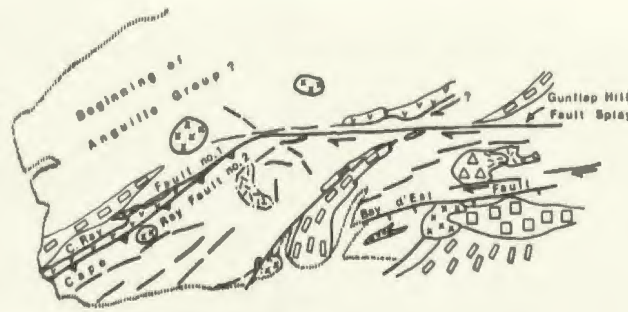


14a: Initiation of the Cape Ray Fault in the early Devonian, culminating from the D2 deformation episode of Terrane II. Megacrystic granitoid batholiths, and porphyritic microgranite are deformed during D2.



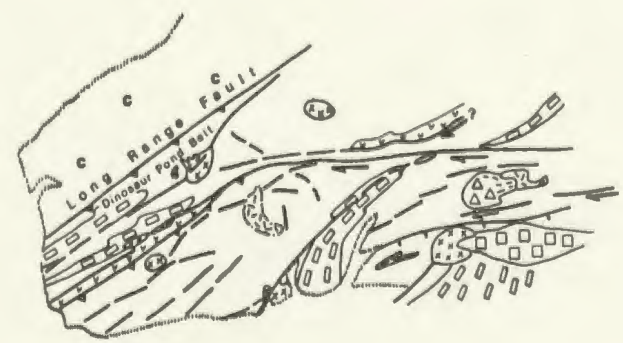
14b: The deposition of fluviatile sedimentary rocks and volcanic activity of the Windsor Point Group either accompanies or follows movement on the Cape Ray Fault. Emplacement of granitoid plutons locally.

Perthite-rich leucogranite   Ironbound syenodiorite



14c: Uplift of the deepseated 'Bay du Nord belt' against the Windsor Point Group in the southwest via high angle thrusting, block, and strike-slip faulting between Cape Ray Fault#2 and the Bay d'Est Fault.

Two-feldspar leucogranite



14d: Uplift of the Little Codroy Pond between its southeast boundary and the Long Range Fault, affecting Carboniferous rocks on it's northwest side.

compressive wrenching, stages which follow the early thrusting and recumbent folding in southwest Newfoundland.

CHAPTER 11: DISCUSSION

11.1 TIMING, CORRELATION, AND IMPLICATIONS OF DEFORMATION

Three main deformation regimes of contrasting style have been postulated for the development of southwest Newfoundland. The first two, corresponding to thrusting and recumbent folding in Terrane I and II, respectively, are probably related to the Taconic Orogeny. The third, involving several stages of compressive wrench faulting (transpression), is related to the Acadian Orogeny.

11.1.1 <u>'Taconic' events</u>

Thrust-stacking of ophiolitic crust of Terrane I probably preceded the maturation of the volcano/plutonic arc sequence in Terrane II (Chapter 10). The development of recumbent fold nappes in Terrane II occurred after the maturation of the arc complex but before the longlasting late Silurian? to Middle Devonian D_2(TII) deformation event. Whether the early TI thrusting is recorded at depth in Terrane II and/or the early TII recumbent folding caused reactivation of early thrusting in Terrane I is uncertain.

The timing of these two events corresponds roughly to stages of emplacement of ophiolite slices on the eastern continental margin of North America during the early Paleozoic, the first producing initial decollement and the associated development of the dynamothermal aureole rocks west of the continental margin, and the second, gravitational spreading (Elliot, 1976) which may have caused the final westward transport of the allochthons onto the margin (cf. Williams and Smyth, 1973). $Ar^{40/39}$ hornblende post- metamorphic cooling ages of 460±5 Ma for the Bay of Islands dynamothermal aureole (Dallmeyer, 1975) and 480±5 Ma for Hare Bay aureole (Dallmeyer, 1977) possibly reflect the earlier event. The final emplacement of the Humber Arm Allochthon was accomplished before the Early Caradocian after a depositional hiatus in the neoautochthonous Long Point Formation (Bergstrom et al, 1974). If the recent time correlation scale of Odin (1982) is correct, the final emplacement of the Humber Arm Allochthon, at least, corresponds to an allowable age for the Terrane II recumbent folding event. If this is true, the intervening Terrane I was probably affected by this event although it has not been distinguished in the area presently mapped; presumably, this is the tectonic process which thrust correlatives of the Middle Ordovician Buchans Group (age discussed below) westward toward Grand Lake (Whalen and Currie, 1982) northeast of the map area.

Although these two early deformational events roughly correspond in age with distinct obduction-related processes in western Newfoundland, it is hard to correlate the later fold nappe phase to the late stages of obduction rigorously. Movements along various northeast-trending strike-slip faults such as the dextral faults affecting the Carboniferous Codroy and Deer Lake basins and complex displacement path (first sinistral, then dextral) of the Cape Ray Fault may make such a correlation tenuous at most. Furthermore, it has not yet been suggested that the final obduction stage was in any way related to the development of fold nappes affecting the Middle Ordovician arc terrane of central Newfoundland. However, a conceptual attraction to the link would be that both the final obduction process and recumbent folding are thought to be gravity driven (e.g. Elliot, 1976, and Ramberg, 1977 in general; Malpas and Stevens, 1977 for the Newfoundland allochthons), the southwest Newfoundland fold nappes by gravitational spreading after the maturation of the calc-alkaline volcano/plutonic arc complex. In addition, the Pipestone Pond ophiolite in south-central Newfoundland appears to form the upper sheet of a large scale thrust nappe in central Newfoundland (Colman-Sadd and Russell, 1982), and its emplacement possibly relates to the development of large scale recumbent folds in Terrane II.

However, the thrust sheet assemblage of Terrane I is not equivalent to the allochthonous slices assembled before final emplacement on the western continental margin described by Williams (1975). Cumulative studies in western Newfoundland (Stevens, 1970; Williams, 1971; Williams and

Smyth, 1973; Williams, 1975; Jamieson, 1979; and many others) illustrate a sequence of slices stacked with ophiolite on top, downward through dominantly sedimentary and/or metavolcanic slices representing facies progressively more proximal to the continental margin (Stevens, 1970; Williams, 1975). It has been inferred here that ophiolite-based sliçes in southwest Newfoundland were stacked on top of each other, unlike any of the obducted slice assemblages. This probably means that the thrust sheets in southwest Newfoundland are not comparable to the far-travelled Taconic allochthons of Williams (1975).

Nevertheless, the development of the flatlying high strain zones in Terrane I might reflect the initial metamorphic history of dynamothermal aureoles. According to Malpas (1979), the high metamorphic temperatures recorded by rocks in the dynamothermal aureoles of western Newfoundland ophiolite allochthons are the ultimate result of unusually high geothermal gradients in the over-riding ophiolite sheet, which would be likely only in three oceanic environments: (1) at spreading ridges, (2) in marginal basins, or (3) above hot spots.

The southwest Newfoundland ophiolite remnants possibly corroborate the unusually high geothermal gradients which must have characterized the western Newfoundland ophiolite remnants (Malpas, 1979). The pre-regional deformation granulite facies foliations of the layered cumulate metagabbros have tentatively been attributed here to shearing throughout an extensive zone of high geothermal gradient associated with rapid spreading of an oceanic ridge (see Section 3.5). The ocean crust so generated could belong to either a marginal or interarc basin. On the basis of the rapid upgrading of the surficial rocks in the high strain zones and the presence of shear zones of slightly higher grade in the transition to layered cumulates beneath the Long Range/Stag Hill high strain zone, it has been suggested that thrusting occurred before the southwest Newfoundland ophiolitic crust had cooled substantially. As one suggestion, the early decollement might have occurred along simple shear zones or zones of decoupling that developed earlier within or at the base of the cumulate sequence (Sleep, 1975; Girardeau and Nicolas, 1981; Girardeau and Mevel, 1982) if plate movement dictated sudden compression or subduction of relatively young ocean crust. Molnar and Atwater (1978) have proposed that the cause of Andean-type orogenies involving extensive deformation in the overriding slab may be the attempted subduction of relatively young buoyant ocean crust rather than subduction beneath continental crust. Nicolas and le Pichon (1980) have also suggested that compression resulting in thrust imbrication of oceanic crust with a relatively high geothermal gradient will result from the subduction of young oceanic crust, although in their model it occurs in thin oceanic crust on the other side of the trench; the thrust sheets then accrete to the overriding slab.

It has been speculated here that thrusting and localized partial hydration of hot ophiolitic crust (9.2.4) is responsible for the early production of tonalite. This resembles the synthrusting tonalite-generation model proposed by McGregor (1979) for the production of the largely tonalitic, Archean Nuk Gneisses of Greenland. Similarly, Sleep and Windley (1981) propose a model for the production of voluminous tonalite from subduction (=thrusting?) of Archean marginal basin oceanic crust, which has relatively thick cumulate sequences and high spreading rates because of higher Archean geothermal gradients.

11.1.2 Acadian/Hercynian events

The third style is represented by the several later episodes of compressive wrench faulting, or 'transpression' (Harland, 1971), which began in the ?late Silurian and persisted until the late Devonian or Carboniferous, and which culminated in wrench faults and differential uplift. It is noteworthy in a general context that the wrench faults resulting from 'transpression' do not necessarily imply plate boundaries, although they may follow earlier, suitably oriented zones of structural weakness, such as old transform faults, and may have reactivated old decollement horizons in the process of high angle reverse faulting.

Extensive sinistral displacement on the prominent northeast-trending faults was first suggested by Wilson (1962), who correlated the Long Range-Cabot Fault system with the sinistral Great Glen Fault of Scotland (W.Q. Kennedy, 1946). Although the early evidence for demonstrating displacement on the Great Glen Fault, in particular, was later shown ~~to be~~ weak (e.g. Marston, 1967; Munro, 1973), analysis of many of the large faults has supported major sinistral shear in northern Ireland and northern Scotland, normally accompanied by substantial dip-slip movement (Pitcher, 1969). Evidence for the displacement and timing of the most prominent and continuous faults of the northeastern Appalachians was reviewed by Webb (1969). In this review, most of the Carboniferous faults of the Long Range - Cabot Fault system earlier referred to by Wilson (1962) were described as having dextral combined with dip-slip displacements. It was pointed out that many faults between southwest Newfoundland to Notre Dame Bay have undergone polyphase movements, both sinistral and dextral. Webb (1969, Figure 3, pages 771 and 774) correctly projected the Cape Ray Fault from Cape Ray through Red Indian Lake to Badger Bay.

As summarized by Pitcher (1969), the major Paleozoic activity along the northeast-trending faults of northern Scotland and Ireland occurred in several early to middle Devonian stages, i.e., before and after Old Red Sandstone deposition; some were also reactivated in the Carboniferous. It is therefore noteworthy that the deposition of the terrestrial Windsor Point Group occurred in late Early or early Middle Devonian, post-dating the early development of the fault and predating late activity. The fault timing in northern Ireland and Scotland is therefore very similar to the timing of the Cape Ray and Long Range Fault systems of southwest Newfoundland.

Hamner (1981) has proposed that most or all of the deformation of the Gander Zone of northeastern Newfoundland relates to a major Acadian/Hercynian (sinistral) megashear zone, and concludes that with no evidence for continental marginal deformation there are few grounds for equating the Gander Zone with the eastern margin of Iapetus. Significant in the timing of early 'megashear' is the Early Devonian age bracket for major movement on the Dover Fault (Dallmeyer et al, 1981). It is perhaps also significant that this corresponds to the approximate age of the Cape Ray Fault, and the two might indeed be related to the same pre-Atlantic fault system. It was concluded in this study that compressive wrench fault deformation post-dates fold nappe deformation in southwest Newfoundland, in disagreement with Hamner (1981). Despite this reservation, the caution of Hamner (1981) about equating polydeformed, metamorphosed, and granitically-intruded terranes with the eastern continental margin, as well as his idea of an important Acadian/Hercynian 'megashear zone', is highly appropriate.

Post-nappe wrench faulting is partly supported by geophysical evidence. First, the paleomagmatic reconstructions offered by Morris (1976) for the northern Appalachians and the British Isles indicate substantial sinistral transcurrent displacement between Silurian-Early Devonian and Late Devonian times. This agrees with the early sinistral strike-slip along the Cape Ray Fault, here thought to have begun in the Early Devonian and persisted through the deposition of the Emsian-Eifelian (approximately Middle Devonian) Windsor Point Group (Chapter 10, Tables 6, 7, and 8). Secondly, Lefort and Haworth (1978) illustrate trans-Atlantic continuity of Hercynian dextral movement from the east-west trending South Armorican shear zone of France to the an east-west trending linear magnetic anomaly north of the Avalon Peninsula of Newfoundland and from another in northern Spain and southeastern France to the Cobequid-Chedabucto fault system of Nova Scotia. The fracture offset of seismic and magnetic anomalies extending from the Atlantic offshore over the Avalon Zone also illustrate this Hercynian dextral displacement (Haworth and Lefort, 1979). Although these east-west systems apparently post-date the late Devonian to earliest Carboniferous movement on the Gunflap Hills fault splay and the Bay d'Est Faults, the latter southwest Newfoundland faults might be related to the Hercynian east-west fault systems, at least as precursors.

Discussions of Webb (1969) were centred on the significance of the dip-slip movement (Brown and Helmstaedt, 1969; with reply by Webb; Lock, 1969; with reply by Webb). Dip-slip movement is easier to deduce than strike-slip movement, especially within a limited area. Chorlton (1980a) also realized that there were substantial dip-slip components to the Cape Ray Fault, but did not recognize the importance of strike-slip movement. Therefore, a significant result of this study is the link between the regionally intense ductile deformation of the pre-Devonian rocks southeast of the Cape Ray Fault with the polyphase activity of the fault itself. Further structural, metamorphic and isotopic studies (dating and cooling history) on the metamorphic rocks and the late granites may assist in putting this type of analysis on a firmer footing.

It is interesting that D_2(TII) and D_3(TII) are mutually conjugate in aspect, and that both are associated with localized uplift, the actual vertical displacements of which are concentrated largely at structural/metamorphic domain margins. As suggested by Harland (1971), the sense would depend on the angle of locus of movement with respect to the orientation of rigid plate margins, and two cases may apply:

(1) Orthogonal closure between irregular or oblique margins.

(2) Oblique closure between straight margins.

In the first case, the deformation pattern of southwest Newfoundland could be the result of compression (due to plate convergence) from the southeast against an oblique or irregular margin, which resolved into conjugate ductile simple shear zones, with sinistral shear initially favoured over dextral (see Ramsay, 1980). Since deformation produced by differently oriented shear sets can accommodate any overall regional shape (Ramsay, 1980), or shape change, the later and subordinate dextral shear regime may have been a final adjustment of the relatively rigid cratonic masses to the northwest and southeast to achieve a best 'fit'. This would only reflect an alteration of regional finite strain, not an alteration in the locus of interplate movement.

In the second case, a change in the sense and orientation of regional compression from northwest to west can be invoked to explain the change of strike-slip regimes. A switch in compression direction toward the west might have caused the reactivation of some of the major northeast trending faults, this time resulting in dextral displacement. This could be the cause of some of the large scale dextral faults and associated <u>en echelon</u> folds in the Carboniferous Bay St. Georges sub-basin (Knight, 1983). The east-west dextral D_3 regime also mimics the more prominent Cobequid-Chedabucto fault system of Nova Scotia (Eisbacher, 1969, 1970), and may be a precursor to movement there. Carboniferous movement on the latter in turn heralded the Triassic opening of the present Atlantic ocean along fractures determined by the pre-existing structural grain and plate rotations (Swanson, 1982).

Possibly both explanations apply.

11.2 GRANITOID EVOLUTION

11.2.1 Granitoid rocks associated with La Poile River Group (Component 4a)

Rocks ranging largely from gabbro to granite or trondhjemite, but with subordinate cumulate pyroxenite, belong to this class. The subvolcanic Baggs Hill and Roti Granites, which display both intrusive and unconformable contacts with the La Poile River Group metavolcanic rocks, were emplaced around the volcanic centre. Metadiorite, quartz metadiorite, and metapyroxenite are more widespread; they were observed during this study as texturally preserved inclusions in synkinematic granitoid rock intruding the Bunker Hill Brook Gneiss, and east of the map area as a quartz diorite intrusion unconformably overlain by La Poile River Group oligomictic (diorite) conglomerate (S.J. O'Brien, personal communication, 1982). Baggs Hill Granite intrudes quartz gabbro/diorite cutting ophiolitic isotropic metagabbro, includes rafts of metagabbro and metapyroxenite, and is itself cut by metagabbro and metadiabase dykes; the Roti Granite also both intrudes and is intruded by mafic rocks, suggesting a comagmatic relationship between mafic and felsic magmas.

Perhaps the most significant feature of Component 4a granitoid rocks is their similarity to some of the mafic to felsic plutons (Component 4b') of Terrane I (below). It is therefore noteworthy that granitoid rocks which range from gabbro to granite have traditionally been associated with the Dunnage zone (Williams et al, 1972; 1974). In the western Notre Dame Bay area, Lorenz and Fountain (1982) have reported quartz diorite, trondhjemite, and granophyre engulfing ophiolitic crustal remnants, and have interpreted this complex (South Lake Igneous Complex) to represent basement to the central Newfoundland volcanic island arc. Rock types and intrusive relationships in the South Lake Igneous Complex are similar to those of the Blue Hills of Couteau, except that ophiolitic layered gabbros occur in place of the ophiolitic high-level gabbros of the latter.

11.2.2 Synkinematic/synmetamorphic tonalite and granodiorite (Component 4b)

It has been speculated here that the voluminous tonalites and granodiorites in southwest Newfoundland have originated in two ways:

(1) Partial melting of mafic oceanic crust and minor sedimentary rocks during early imbrication, while parts of the oceanic crust were relatively young and still hot (Terrane I).

(2) Partial melting of amphibolite and metasedimentary rocks after tectonic stacking and rising metamorphic grade following recumbent folding (Terrane II).

Similarly synkinematic/synmetamorphic, commonly potassium feldspar- or locally albite-enriched granitoid rocks are hosted by amphibolites in areas under the influence of two major wrench fault systems, the Long Range and Cape Ray Fault systems (Figure 13). Both the Port aux Basques phase and the synkinematic granitoid rocks near the Long Range Fault grade locally from true granite into tonalite. The distribution of this type in Terrane II (Port aux Basques phase) may have something to do with the abundance of D_2 (or D_3) mylonite, or 'slide' zones between the Cape Ray Fault and Isles aux Morts. Alternatively, they may reflect different source levels and volatile activity. Tonalites are apparently very abundant along the northwest side of the Cape Ray Fault far to the northeast of the study area, e.g. agmatite terranes consisting of ophiolitic metagabbro blocks engulfed in tonalite and diorite have been reported in west-central Newfoundland (Dunning *et al*, 1982).

11.2.3 'Late' synkinematic plutonic rocks (Component 4b')

In Terrane I, this generation of granitoid rocks includes quartz gabbro, diorite, quartz diorite, quartz monzonite, and granite. The granites and quartz monzonites are commonly megacrystic. Compositional variability both within and among the plutons is characteristic, perhaps because of combined igneous fractionation, tonalite and possibly amphibolite assimilation, and magmatic to subsolidus hydrothermal activity. Barker *et al* (1981) suggested the production of compositionally variable mafic to felsic 'batholiths' could be accomplished by the introduction of the partial melt from a subducted slab into overlying mantle and crust, and assimilation of overlying material, a model which is consistent with at least the field relations, setting, and petrographic variability of the component 4b' plutons of Terrane I.

In Terrane II, this generation of granitoid rocks includes megacrystic monzogranite batholiths (La Poile batholith and Otter Point Granite), the Ironbound syenodiorite-megacrystic granite, and porphyritic microgranite of dacitic composition (Hawks Nest Pond Porphyry and other minor intrusions in the highlands block). The undeformed megacrystic 'Burgeo' monzogranite possibly belongs to this suite though it apparently cuts the Otter Point Granite, and thus may have been placed mistakenly in Chapter 8 (Component 4c). As mentioned previously, it is probable that some of these plutons existed as magma chambers at depth until gravitational instability and/or deformation, particularly the development of southwest Newfoundland terrane II as a longlived ductile 'megashear zone' (Section 11.1.2), triggered their emplacement (c f., Hutton (1982) for granitoid plutons of Northern Ireland, and Davies (1982) for calc-alkaline granitoid intrusions in northern Saudi Arabia). There are commonly several generations of megacrystic granite where they are abundant (Williams, 1973; Jayasinghe and Berger, 1976; Blackwood, 1978; Colman-Sadd, 1980).

Coarse megacrystic granitoid rocks which have traditionally been identified with the Gander zone (Kennedy, 1976) occur on both sides of the Cape Ray Fault, and their appearance in the Newfoundland Appalachians may depend more upon the Paleozoic tectonic level exposed than the tectonostratigraphic zone. High level emplacement could result in a coarsely feldspar-phyric microgranite like the Hawks Nest Pond Porphyry.

11.2.4 Late potassium-rich leucogranites (Component 4c)

The late leucogranites and probably also the dykes may mark definitive local structural environments during the late stages of deformation. The emplacement of perthite-rich leucogranite plugs apparently correlates in time to local uplift; if a pluton spans two subdomains, the emplacement correlates with uplift of one of them (the source area). Emplacement also appears to have occurred at relatively high tectonic levels (8.4.4).

The proposed origin of granites of this sort as water-poor partial melts (Martin and Bonin, 1976) derived by partial melting of granulite (Collins et al, 1982), together with their emplacement associated with uplift suggests decompression-controlled partial melting resulting from both the increase in gravitational potential of the source (i.e., decrease in density on uplift) and decrease in confining pressure due to combined uplift of the source and erosion of the overlying rock column. These magmas would be highly viscous, particularly if relatively dry, and emplacement would be greatly facilitated by a lineament or deep fracture.

Exposures of wholly subsolvus leucogranites are restricted to belts displaying intense amphibolite facies deformation after the generation of the early synkinematic granitoid rocks. Since leucogranites of this composition would likely be emplaced in dilational zones at an advanced stage of an episode of intense deformation under these conditions (e.g. as in the Maydan shear zone, Afghanistan (Nicolas et al, 1977; Mehnert, 1971, page 20), this has been speculated here. Some of the aluminous minerals such as the partly fibrolitized muscovite and biotite may be xenocrystic relics of the metamorphic/igneous parent. These intrusions and subordinate syntectonic pegmatites may therefore date a period of longlived deformation.

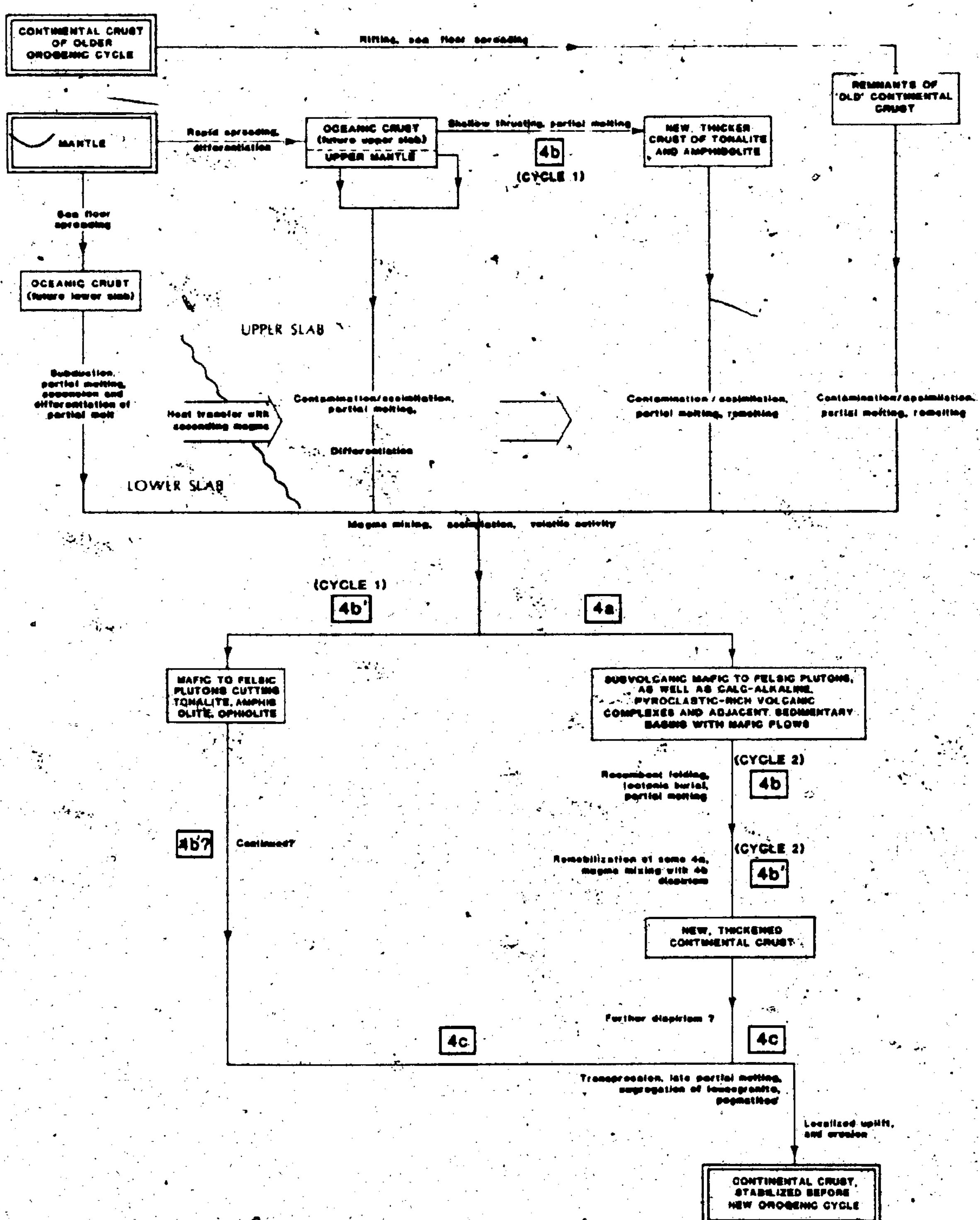
Dykes may have been emplaced at any stage during the compressive wrenching episodes. A mafic suite post-dating most, if not all, of the larger intrusions in Terrane I were emplaced in a high level environment and are Middle Devonian or younger. At least some of the mafic to intermediate dykes in Terrane II appear to have undergone regional deformation and/or alteration at depth, and were probably emplaced between the late stages of D_2 and the end of D_3 at a guess. Further work may link specific suites with specific tectonic activity.

11.2.5 Summary of granitoid evolution

In summary, Figure 15 is a flow chart showing the proposed evolution of the granitoid rocks and addition or recycling of crustal material. It has been concluded that anatexis of older continental crust is not absolutely necessary for the generation of the voluminous granitoid rocks found in southwest Newfoundland, either in Terrane I or Terrane II. Early formation of thrust and/or fold nappes combined with intense transpressive deformation may provide a very efficient 'crustal differentiation' mechanism.

Crustal differentiation here means a decrease of average density and thickening of the Early Paleozoic upper crust, first through the building of topographic relief by creating a calc-alkaline volcanic pile which promotes thick sedimentation in an adjacent basin (discussed below), and then by tectonic thickening via structural stacking and partial melting at depth. During subsequent intense, possibly polyphase 'transpression', local volume changes may occur through the siting of late granitoid rocks (diapiric emplacement of previously formed magma chambers plus second partial melting in dilational zones) along the deformed belt. Uplift and eventual erosion may be one result of the local density changes. Upper parts of the early recumbent nappe sequence which have not been equally metamorphosed and granitized are likely to have been intruded by diapirs of

FIGURE 15: FLOW CHART SHOWING POSSIBLE DERIVATION OF GRANITOID ROCKS (COMPONENTS 4a to 4c) OF SW NEWFOUNDLAND



the underlying granitoid rocks with their gneissic mantles, an effect which has been observed in central Newfoundland (Colman-Sadd, 1983). Density inversion may also provide a driving force for the emplacement of the megacrystic granite batholiths.

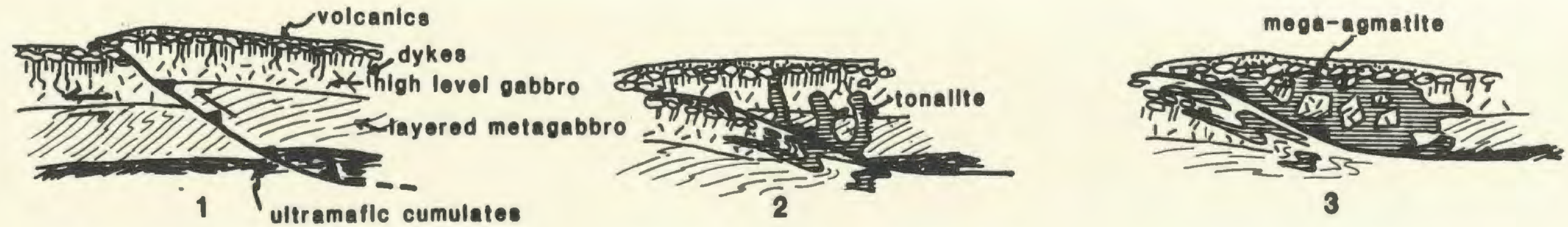
11.3 LA POILE RIVER GROUP AND ITS RELATION TO THE THE GANDER AND DUNNAGE ZONES

Precambrian crustal exposures which would definitively place Terrane II in the Gander Zone (cf. Brown, 1973; Brown and Colman-Sadd, 1976) have not been confirmed, although it is conceivable that some of the amphibolite now included as xenoliths in the La Poile batholith or the Cinq Cerf granodiorite and mylonite fragments in some of the volcaniclastic rocks belong to a previous orogenic cycle. However, exposures around the Blue Hills of Couteau indicate the presence of ophiolitic crust (assumed early Paleozoic), cut by or rafted in a mafic to felsic intrusive suite. Some of these intrusions are unambiguously related to the volcanic complex east of La Poile Bay, although the suite as a whole is not at all restricted to the volcanic centre. Despite the high degree of regional metamorphism which affected these intrusions, some have less metamorphosed analogues which cut the early tonalite of Terrane I, also founded on ophiolitic crust. Diorites in the Annieopsquotch Mountains Ophiolite Complex (Dunning, 1981, personal communication), and the South Lake Igneous Complex in western Notre Dame Bay (Lorenz and Fountain, 1982) display the same relationships as observed in the the Blue Hills of Couteau complex. The crust in Terrane II at least locally resembles early Paleozoic crust exposed in the Dunnage Zone.

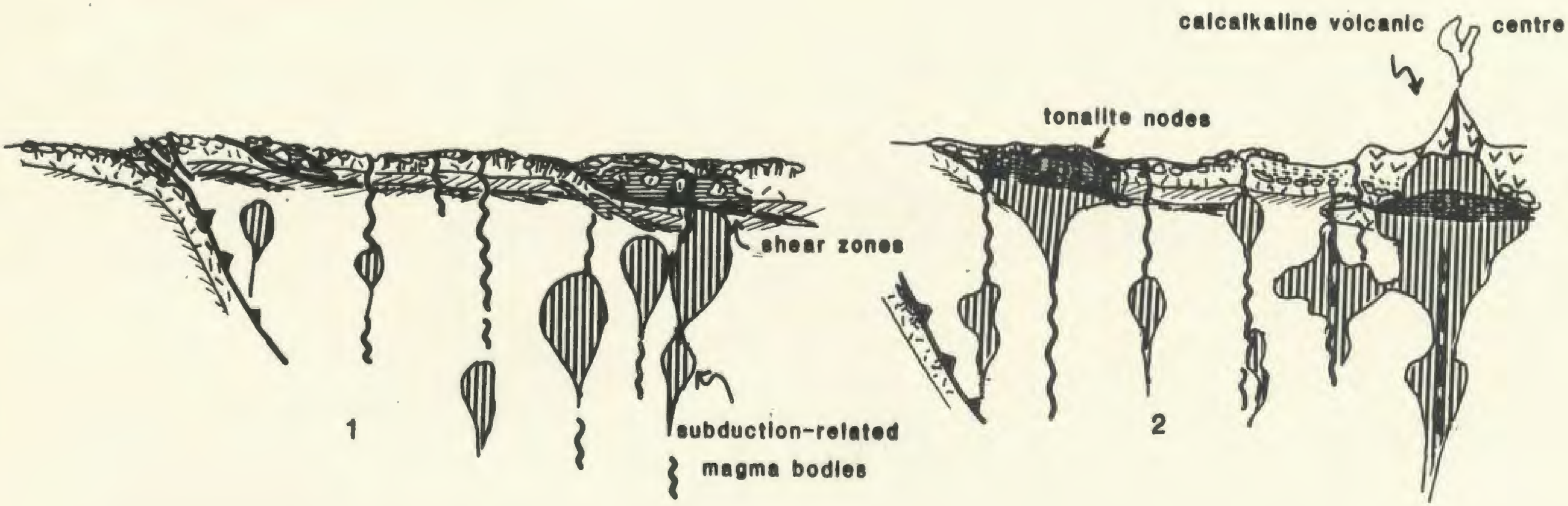
Nevertheless, involvement of continental-like crust at least in the most proximal part of the La Poile River volcanic complex is suggested by the large volume of calc-alkaline dacite and rhyolite east of La Poile Bay. As mentioned at the end of Chapter 4, this continental-like crust could represent a pre-existing sialic sliver rifted from a continental margin during oceanic spreading.

An alternative to older continental sialic crust may be the early production of tonalite from thrusting of relatively young ophiolitic crust as proposed in Terrane I (5.2.7, 9.2.4). Substantial tonalite production could only occur locally, where the thrust-stacked oceanic crust was sufficiently hot and maintained at high temperature for long enough for partial melt to coalesce and intrude upward; it may appear in megalenses along imbricate overlaps (Figure 16). Because of the apparent abundance of calc-alkaline plutons, some of which are Ordovician, in both Terranes I and II, and because of the calc-alkaline volcanic pile in Terrane II, it is speculated here that more conventional subduction established itself west or southwest of the map area. If so, melts rising from the subducted slab might assimilate tonalitic crust at these nodes, producing hydrous

Figure 16: Speculative model for the development of calcalkaline volcanic centres above early tonalite nodes.



16a: Development of tonalite nodes.



16b: Subduction and subduction-related magmas locally intersect tonalite nodes, with resulting development of calcalkaline plutons and volcanic centres.

felsic, intermediate, and mafic calc-alkaline magmas (see Burnham, 1979, pages 96-101, for the production of voluminous intermediate to felsic calc-alkaline magmas). Possibly, only mafic, intermediate, and minor felsic arc volcanic rocks would be erupted away from the tonalitic nodes, such as the mafic metavolcanic rocks to the west of the La Poile Bay area or 'early arc' examples of Strong (1977). In calculating the theoretical mechanism for producing these calc-alkaline melts, estimates of temperature gradient and heat content of the sialic amphibolite/tonalite mass underlying the arc should be adjusted upward because the terrane might still be hot. In addition, ascending melts may locally traverse hydrothermally active, high temperature shear zones (Figure 16) such as that which may have affected the north-central high strain zone, providing access to an active volatile pathway, and causing explosive eruption; the heat of ascending magmas could also reactivate these hydrothermal pathways.

The calc-alkaline nodes would tend to build up into edifices composed mainly of subaerially ejected volcaniclastic materials, and the areas exhibiting more mafic (possibly tholeiitic) and less hydrous volcanism in between the nodes would tend to become sedimentary basins.

Isotopic U/Pb ages for the Dolman Cove Formation (449±20 Ma and 446±17 Ma) and Georges Brook Formation (459±18 Ma) are essentially the same as isotopic ages for the Roberts

Arm Group (447±7 Ma Rb/Sr: Bostock et al, 1979; discussion by Nelson and Kidd, 1979; Dean and Kean, 1980) and the Buchans Group (Bell and Blenkinsop, 1981) in the Dunnage zone. Comparison of the geochemistry of the Georges Brook Formation mafic flows (Chorlton, 1980a, APPENDIX) with trace element geochemistry of the Roberts Arm and Buchans Groups (Strong, 1977) shows very little difference. Kean et al (1981) indicate that the Roberts Arm and Buchans Groups represent post-arc volcanic activity, both because field relations (facing directions) suggest that the volcanics lie above an extensive Caradocian shale (Dean, 1977, 1978; Kean et al, 1981) and because the isotopic age dates imply post-Caradocian age according to some time correlations (e.g. Ross et al, 1978) or late Caradocian age by others (Van Eysinga, 1978). However, the validity of using facing directions across various faults has been disputed (Nelson, 1977; Nelson and Casey, 1978), and a recent revised time scale (Odin, 1982) permits the isotopic dates of the Roberts Arm and Buchans Group (Roberts Arm belt) to be Llandeilan, or pre-Caradocian.

The problem of the large proportion of calc-alkaline intermediate and felsic magmas was a conceptual problem in considering the Roberts Arm belt to be an island arc sequence in the Dunnage zone, since an oceanic crustal basement for early Paleozoic sequences in the Dunnage zone has been inferred and at least locally demonstrated. Other confirmed, anomalously felsic Pre-Caradocian volcanic sequences, the Victoria Lake Group and the Isles Galet Formation of central and southeastern Newfoundland have been interpreted instead to be founded on transitional or continental crust of the southeastern margin of the proto-Atlantic Ocean rather than on the oceanic crust of the Dunnage zone (Swinden, 1982). Bostock et al (1979) instead assume that the Roberts Arm Group of the Dunnage island arc sequence indeed resting on a continental sliver. This is also suggested for possible correlatives of the Roberts Arm belt by Whalen and Currie (1982).

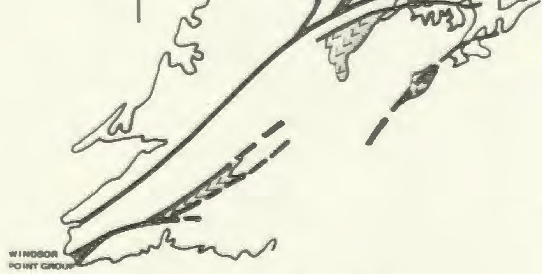
It is speculated here that the Roberts Arm, Buchans, Victoria Lake, La Poile River, and Isles Galet calc-alkaline volcanic sequences may originate from much the same process, whatever the origin of the continental-like 'sliver'. If they originally formed part of a continuous chain, it would have been highly modified first by recumbent folding, and later by strike-slip displacement. The distribution of these rocks, taken from Kean et al (1981), Colman-Sadd and Swinden (1982), Swinden and Collins (1982), and this study is shown in Figure 17. The broad wedge of terrane shown as the Gander Zone (Fig 1) in southwest and central Newfoundland may represent a first thrust and later strike-slip imbricated island arc terrane, with either a lower Paleozoic basement or older basement rifted from either continental margin.

Figure 17: Proposed distribution of island arc and post arc volcanic sequences in Newfoundlandland compared with previously proposed distribution of early and late or post arc sequences.

17a: Ordovician island arc sequences of the Newfoundland Central Mobile Belt as suggested in this study:

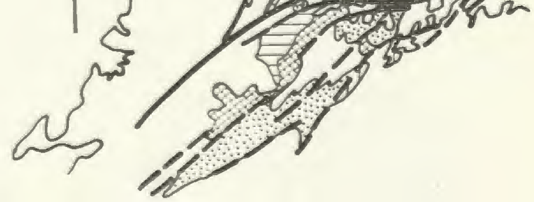
Largely calcalkaline arc sequences Non-calcalkaline arc sequences

Diagram modified from Dean (1977,1978), Kean *et al* (1981), Colman-Sadd and Swinden (1982), and Swinden (1982).



17b: Post-arc or intracontinental arc volcanic sequences modified after Dean(1977,1978), Kean *et al* (1981) , and this study:

Post-arc, or intracontinental sequences



17c: 'Early' and 'late' arc sequences as defined by Dean (1977,1978) and Kean *et al* (1981) for the Notre Dame Bay region:

'Early' arc sequences 'Late' arc (or post arc) sequences

Springdale belt

Roberts Arm belt

Botwood belt

11.4 GEOPHYSICAL SIGNATURES

The terranes on either side of the Cape Ray Fault contrast in three main features which partly explain the gradual change from positive to negative gravity anomalies from northwest to southeast (Weaver, 1967; Miller, 1977), and the change in aeromagnetic pattern (Geological Survey of Canada, 1971) which slightly overlaps the Cape Ray Fault system. These are:

(1) Metagabbros of the Long Range Mafic-Ultramafic Complex are prominent in Terrane I (Map 1), whereas metagabbros are subordinate to other rock types at the surface in Terrane II.

(2) A greater extent, and probably original thickness, of metasedimentary rock is exposed in Terrane II. These rocks consist largely of interlayered semipelitic to pelitic schist, gneiss, and migmatite with minor marl, or calc-silicate layers, and pass gradationally southeastward into a thick, marine to locally subaerial volcanosedimentary pile. No correlation can be made with metasedimentary rocks of Terrane I, which include semipelitic schists and gneiss, quartzofeldspathic metasandstone, marble, laminated calc-silicate rock, metamorphosed clay, metachert, and metavolcanic rock.

(3) In Terrane II, the rocks were intensely deformed under amphibolite facies conditions after the formation of the earliest, penetrative regional fabrics, and the latter largely transposed parallel to the regionally predominant, northeast-trending structural grain before uplift and post-metamorphic cooling. In Terrane I, regional tectonic fabrics in the plutonic part of the mafic-ultramafic complex were inhomogeneously developed; early, penetrative, amphibolite facies tectonic fabrics in rocks highly reconstituted by deformation, such as amphibolite and paragneiss within the high strain zones, were uplifted to higher tectonic levels and cooled post-metamorphically before they underwent late deformation. Therefore, early northwest- to west-trending fabrics which were concentrated in the high strain zones were only locally transposed or

overprinted by late, northeast-trending structures.

11.5 APPLICABILITY OF TECTONOSTRATIGRAPHIC ZONES

At the beginning of this study, the juxtaposition along the Cape Ray Fault of the Gander and Humber Zones in southwest Newfoundland was accepted. The study of the contact relations between the Precambrian basement inferred by this phenomenon and its early Paleozoic cover was the original intent. At the end of the study, it was realized that the tectonostratigraphic zones were not easy to define in this area and neither was their basement, let alone basement-cover relations.

First, there is nothing to suggest that the ophiolitic rocks northwest of the Cape Ray Fault were obducted onto the western continental margin during the Taconic Orogeny, since neither continental margin clastic slices nor autochthonous carbonate bank are in evidence. Although some of the Grenvillian crust may have been overthrusted by the dominantly Paleozoic terranes during late Paleozoic transpression, this would not really justify assigning Terrane I to the Humber Zone. The Dunnage Zone would seem more appropriate. The western boundary of the Dunnage Zone cannot be defined on the basis of present knowledge. The Carboniferous Long Range Fault does not follow the boundary, since it traverses the Grenvillian Steel Mountain Anorthosite north of the study area and since there may be Grenvillian components in the Cormacks Lake Complex east of the anorthosite (Herd and Dunning, 1979).

Terrane II might also be assigned to the Dunnage Zone on the basis of the presence of at least local remnants of ophiolitic crust southeast of the Cape Ray Fault and of metavolcanic/plutonic complexes which are here equated with several exposed near Notre Dame Bay. The sialic crust necessary to produce the pyroclastic-rich, calc-alkaline volcanic centre and adjacent basin before deformation and syn to post-kinematic granitoid production could have been produced either in early Paleozoic or Precambrian times; it probably also forms a portion of the basement for the other calc-alkaline volcanic centres to the north. The backbone of southwest and central Newfoundland may be the recumbently folded, thrust, and strike-slip repeated arc volcanic complexes and associated sedimentary basins (Figure 17). Only the greater exposure of granitoid rocks and the intensity of deformation and metamorphism suggest Gander Zone affinities. But as stated above, much of the granitoid exposure is due to the deformation and regional metamorphism of the arc-basin and its crust, as well as the tectonic level now exposed, and does not confirm the presence of Precambrian sialic basement.

The criteria for the definition of northern Appalachian tectonostratigraphic zones are difficult to apply in southwest Newfoundland. However, they have provided a useful focus for investigation, which was the intent in organizing Newfoundland geology 'as is' into tectonostratigraphic zones originally (Williams et al, 1972). It is also obvious that some of the tectonostratigraphic zones generally do reflect broad contrasts in tectonic level after Acadian/Hercynian Orogeny, when the area was fully 'cratonized' before the opening of the present Atlantic Ocean. Until the roles of different tectonic stages are confirmed by more specialized structural and metamorphic studies, and recognized for broad areas of Newfoundland, perhaps it would be productive to shift the focus to crustal development at different levels.

CHAPTER 12: SUMMARY AND SUGGESTIONS FOR FURTHER WORK

12.1 GENERAL FIELD RELATIONS AND TECTONIC HISTORY

Several significant modifications to previously accepted field relations were made during the course of this study. First, Devonian fossil-bearing strata in the Cape Ray Fault zone, formerly thought to signify a Devonian age for all of the metasedimentary and metavolcanic rocks of the La Poile Bay - North Bay area, were separated as younger than the penetrative foliation which affected the latter. The older rocks are Ordovician in age and have been included in the newly defined La Poile River Group, which extends northeastward from Port aux Basques through the Burgeo highway east of the study area. The Devonian plant fossil bearing rocks are included in the Windsor Point Group of Brown (1972, 1975), exposed along the Cape Ray Fault zone.

Secondly, gneissic tonalite with numerous mafic inclusions, formerly considered Grenvillian continental crust upon which remnants of early Paleozoic ophiolite were obducted from the vicinity of the Cape Ray Fault, instead intrudes the ophiolite. The basis for the Cape Ray cryptic suture of Brown (1973), which was the juxtaposition of the Precambrian Port aux Basques Gneiss in the southeast against the Grenvillian Long Range Gneiss in the northwest, is no longer valid. However, unexposed Grenvillian rocks had probably underthrust the Paleozoic complexes to some extent by late Paleozoic time.

The early geology of Terrane I can be more readily envisaged as that of a rapidly spreading ocean or ocean basin. Sequential thrusting is the first regional deformational tectonic event recognized, and resulted in the development of discrete high strain zones and probably the immediate production of largely tonalitic partial melt. The granitoid rocks were themselves deformed in the lower high strain zone, and intruded into the overlying slab before being overriden by another thrust slice. The deformed tonalitic rocks and their enclaves were then intruded by compositionally variable plutons (Component 4b') before the development of the Cape Ray Fault.

The early history of Terrane II involves a volcanic/plutonic arc complex and adjacent metasedimentary basin founded on disrupted ophiolite, or partly on an either early Paleozoic or Precambrian sialic sliver. In this terrane, mafic (and ultramafic?) to intermediate plutons (Component 4a) and mafic volcanic rocks also occur within the sedimentary basin adjacent to the volcanic centre, comprising an edif ce of mafic to felsic calc-alkaline volcanic rocks capping similar plutonic, volcanic, and sedimentary rocks. Some of the calc-alkaline volcanic rocks were probably erupted subaerially, and redeposited in a relatively shallow marine environment around the subaerial part of the pile proximal to the main eruptive centre. Subsequent recumbent folding in Terrane II affected the volcanic centre and the adjacent basinal rocks; the metamorphic peak was achieved only after tectonic burial, generating voluminous synmetamorphic granitoid rocks, followed by the emplacement of large megacrystic granitoid intrusions.

Isotopic age constraints (Table 7), admittedly meagre, suggest that the early imbrication and tonalite production in Terrane I occurred before the late stages of calc--alkaline volcanism in Terrane II. The tentative model of thrusting in Terrane I (9.2.4) is similar to shallow subduction, but may not correspond to subduction in a strict sense. In contrast, the formation of recumbent fold nappes occurred after the construction of the calc-alkaline volcanic centre in Terrane II, and it is speculated that these are due to gravitational spreading associated with the thickened crust of mature volcanic centres, possibly themselves the result of earlier subduction.

Thrusting and nappe development was followed by the type of deformation here referred to as 'transpression' (Harland, 1971), which culminated in the formation of convergent wrench faults. Wide zones of folds, thrusts, and penetrative deformation preceding strike-slip, oblique slip, and high angle reverse faulting are characteristic of convergent wrenching (Wilcox et al, 1973). Therefore, vertical movements and the reactivation of previous decollement surfaces are both likely, although the latter have not been recognized on the surface. The transpression episodes in southwest Newfoundland were accompanied by the emplacement of potassic leucogranites (Component 4c) and dykes.

It is proposed here that the first episode of this type consisted of long-lasting sinistral shear plus northwest-directed compression and shortening, which began to imprint Terrane II at least by Late Silurian time. It culminated in the development of the Cape Ray Fault as a sinistral wrench fault associated with differential uplift of the southwest part of Terrane I and part of northeastern Terrane II. Terrestrial sedimentary rocks and a strongly bimodal volcanic suite of the Windsor Point Group were deposited along the fault during the continuation of its activity.

Subsequently, the area was affected by late Devonian or earliest Carboniferous dextral transpression, also accompanied by differential vertical movement. In Terrane II, this produced the uplift of the deeply-buried Bay du Nord belt by oblique strike-slip and high angle reverse fault motions directed from the east.

In Terrane I, reactivation of the old faults, perhaps the beginning of the sedimentary basin in which the Anguille Group was deposited west of the study area accompanied this deformation. Later, wrench faulting, again with significant vertical components, affected the Visean Codroy Group and resulted in the final uplift of the Little Codroy belt.

The geological history of southwest Newfoundland reflects the evolution of a crustal segment from the late stages of opening an ocean basin, through imbrication and the production of an arc complex followed by obduction, to transpression and final cratonization. A high geothermal gradient and subhorizontal shear zones inherited from spreading may have been the cause of unusually rapid creation of continental-like, tonalitic-amphibolitic crust and partial recycling of this crust locally to produce calc-alkaline volcano-plutonic centres unusually enriched in felsic components compared with modern intra-oceanic arcs. Recumbent folding and tectonic burial of part of this terrane began a further cycle of granitoid production which lasted through the late transpression, using materials largely recycled from the newly-developed crust. Hydrothermal pathways were probably also inherited from the early oceanic, imbrication stage, and re-utilized throughout transpression.

This rapid, multistage, continentalization plus the strike-slip effects of the late deformation has made it difficult to apply the present definitions of tectono-stratigraphic zones in many areas in terms of the development of the early Paleozoic Iapetus Ocean. However, if they are outlined with an 'as is' approach they provide useful guides for the investigation of crustal processes.

12.2 SUGGESTIONS FOR FURTHER WORK

The scope for future work in southwest Newfoundland appears almost endless to the writer. Since the tectonic history involves many complexly interacting systems, it would probably be wise to investigate the structural and metamorphic development early on, while also determining age and source constraints on units or suites affected least by these complexities. The following initial investigations are suggested:

(1) Field-based structural and metamorphic studies in order to assess the intricacies and scale of late tectonic development, and applicability of the tectonic model that was proposed here on a best-fit basis.

(2) The application of $Ar^{40/39}$ incremental release dating techniques along with studies of metamorphic development to place constraints on the uplift components of this development, and comparison of these constraints with those provided by fossiliferous units.

(3) U/Pb_{zircon} and $Ar^{40/39}$ dating of the perthite-rich leucogranites, and comparison of the latter results with those of their hosts if they are amphibolite or higher grade. Geochemical investigation and comparison of possible sources of these granites, as well as late hydrothermal overprint which should also locally affect hosts, might also provide some interesting information about the nature of the lower crust at that stage.

(4) Regional mapping followed by a thorough investigation of the ophiolitic sequences northwest of the Cape Ray Fault.

(5) Precise U/Pb_{zircon} dating of the southern Long Range tonalite and the earlier oceanic plagiogranite where they are not affected by high temperature high strain zones.

(6) Investigations of hydrothermal or metasomatic activity within the early high strain zones and along the major wrench fault zones.

Undoubtedly, more work will result in useful revisions to the tectonic outline proposed here, from whence new directions will be taken.

PART II

CHAPTER 13: DESCRIPTION OF THE LONG RANGE MAFIC-ULTRAMAFIC COMPLEX AND ASSOCIATED METASEDIMENTARY ROCKS (TERRANE I)

13.1 LONG RANGE MAFIC-ULTRAMAFIC COMPLEX

13.1.1 Subdivisions of the Long Range Mafic-Ultramafic Complex

For the purpose of producing Map I, the complex was subdivided into altered ultramafic rock (Unit 1a), layered cumulate metagabbro (Unit 1b), massive metagabbro and metadiabase (Unit 1c), mafic metavolcanic rocks and dykes (Unit 1d), and undivided amphibolite (Unit 1e).

13.1.2 Ultramafic rocks (Unit 1a)

Definition and distribution:

The term ultramafic rock is used here to refer to rocks which contain over 90 percent ferromagnesian minerals on an outcrop scale, but some of which contain gradational lenses of rock with over 10 percent plagioclase.

Altered ultramafic rocks form sharply-bounded, discontinuous bands or boudinaged lenses within the layered metagabbro sequence, and within the amphibolites of the Stag Hill high strain zone. One of the pods near Long Pond in the SHhsz is instead completely surrounded by exposures of migmatitic metasedimentary rock and garnetiferous granite.

Isolated ultramafic pods up to 30 meters in diameter are exposed in the Dinosaur Pond Belt.

Lithology:

Ultramafic rocks within the layered metagabbro sequence consist of partly altered feldspathic peridotite. Ultramafic rocks within the Stag Hill high strain zone and the Dinosaur Pond belt include altered dunite and peridotite, some so altered that their primary nature has been obliterated. One of the pods in the northeastern part of the Stag Hill high strain zone was recognized as wehrlite, and the pod near Long Pond as harzburgite.

In general, fresh surfaces of both highly altered and little altered ultramafic rock are black with resinous to earthy lustre. Weathered surfaces are rubbly, and brown to grey. Laths of clinopyroxene or orthopyroxene, if present, stand out as shiny cleavage surfaces. Single grains and disseminated patches of magnetite, the most common macroscopic spinel, are barely visible. Weathered specimens of partly serpentinized dunite from the Stag Hill high strain zone and Dinosaur Pond belt commonly display aggregates of pale green olivine grains overprinted by a fine black web of serpentine and magnetite. Enstatolite veins characterize the harzburgite near Long Pond.

In feldspathic peridotite of the layered metagabbro, resistant, white plagioclase aggregates less than 1 mm in width are concentrated as blebs or networks surrounded by black, partly serpentinized perodotite.

Petrography:

The feldspathic peridotite within the layered sequence is composed of olivine, plagioclase, clinopyroxene, hornblende, rare orthopyroxene, and minor opaques with accessory brown phlogopite and olive green spinel. Secondary serpentine and fine grained magnetite are abundant. Olivine is the predominant mineral in all ultramafic phases, and forms anhedral, ovoid domains of uniform extinction from 1 to 7 mm in diameter which are criss-crossed by a network of serpentine and fine grained magnetite wisps (Plate 13.1). Olivine compositions vary between Fo_{90} and Fo_{65}. Plagioclase (labradorite in several specimens) occurs mainly as lens-shaped clusters or interconnecting stringers of anhedral, fractured grains of up to 1 mm in diameter (Plate 13.1), but was found as large grains poikilitically enclosing olivine in one thin section. Clinopyroxene commonly occurs as large, pale brown grains of diallage which poikilitically enclose olivine and plagioclase. It rarely occurs as polycrystalline aggregates, a possible result of the deformation and annealing recrystallization of larger grains. Brown igneous hornblende occurs as rims around cuspate opaque oxide grains, and as single anhedral crystals. Orthopyroxene displays pale pink and green pleochroism, and occurs as small grains clustered around either clinopyroxene or plagioclase. Coronas of tremolite-actinolite between olivine and plagioclase are common, and double coronas on olivine with tremolite inside and actinolite outside were observed locally.

The harzburgite near Long Pond consists of an aggregate of large (up to 7 mm) and very small (less than 0.15 mm) domains of optically continuous olivine in a network of serpentine and fine grained magnetite, accompanied by ragged, bent, and twinned crystals and crystal aggregates (up to 1 cm in maximum diameter) of orthopyroxene (now clear bastite). Some of the orthopyroxene crystals enclose tiny, anhedral olivine grains. Secondary calcite patches and a few isometric opaque grains are accessory constituents.

Other ultramafic rocks within the SHhsz now consist largely of serpentine net-veined with fine, wispy magnetite, but alteration assemblages locally include talc, chlorite, and tremolite. Poikilitic uralitized clinopyroxene and relict olivine were observed in a strongly sheared, serpentinized wehrlite pod in the northeast.

Ultramafic pods in the Dinosaur Pond belt are composed mainly of olivine net-veined by serpentine and wispy magnetite, and overprinted by patches of secondary calcite. Optically continuous, polygonal domains of olivine (Fo_{90}

approximately) up to .7 mm in diameter composed of several fragments engulfed in serpentine are common.

13.1.3 Layered metagabbro (Unit 1b)

Definition and distribution:

Well defined layering, mineral lamination, and the high olivine content distinguish the layered metagabbro from the massive metagabbro and metadiabase. The term 'fresh' is applied here to layered metagabbro which possesses an early tectonic fabric produced under dry, granulite facies conditions, and which lacks the hydrous, greenschist or amphibolite facies mineral assemblages locally superimposed by regional metamorphism. 'Fresh' metagabbro and regionally metamorphosed metagabbro are in gradational contact.

The layered metagabbro sequence is most voluminously exposed within the core of the Little Codroy Pond belt, and in the Dinosaur Pond belt to the southwest of the area mapped during this study (Brown, 1976a,c, 1977). Massive metagabbro and metadiabase is in gradational contact with layered metagabbro through a comparatively narrow zone of well layered, alternately coarse and fine grained subophitic clinopyroxene metagabbro along the west and east sides of the Little Codroy Pond belt, and in a position described by Phair (1949) as along the flanks of a major antiform in the mafic-ultramafic complex in the southwest half of this belt. According to Brown (1976a), the transition occurs near the top of the layered cumulate sheet in extensive outcrops which lie within the southwest end of the Dinosaur Pond belt.

Pegmatites cut the layered metagabbro in the centre of the well preserved part of the sequence, and within the adjacent high strain zones.

Lithology:

The 'fresh' layered metagabbros consist of foliated, interbanded cumulate olivine gabbro, troctolite, anorthosite, anorthositic olivine gabbro, and clinopyroxene gabbro. Olivine-bearing phases predominate in the centre of the layered 'core', whereas coarse, subophitic clinopyroxene metagabbro interlayered with relatively fine grained metagabbro is along its flanks. Gabbronorite, lacking the foliation of the layered metagabbros, was observed in one outcrop.

The most obvious macroscopic layering mainly reflects fluctuations in plagioclase content, and occurs on a scale of 1 to over 100 cm (Plate 13.2). The gabbroic and troctolitic layers are generally black to grey on weathered surfaces; the anorthosite and anorthositic gabbro layers white to light grey; local patches unrelated to the layering weather silvery brown. Graded bedding is most visible in troctolite bands. An L-S foliation due to the lenticular concentration of mafic minerals parallel to the layering is displayed in most outcrops (Plates 13.2, 13.3). An anorthosite layer with subparallel? foliation apparently truncated by another anorthositic layer and subparallel? foliation was observed locally (Plate 13.3). This could either represent truncated bedding, or, alternatively, attenuated isoclinal folds related to the foliation. Grey clinopyroxene with tiny, subophitically-enclosed grey plagioclase laths, dark olivine, and rims of brown hornblende around opaque grains can be observed on fresh surfaces of the 'fresh' metagabbro. Some of the clinopyroxene metagabbros display sparse lenses of clino-pyroxene, locally up to 5 cm in maximum diameter.

Biotite-plagioclase-quartz pegmatites and subordinate gabbroic hornblende-plagioclase pegmatites cut the layered metagabbros. Fine grained plagioclase porphyry dykes (11b?) and one thin tuffisite dyke were also observed cutting the layered sequence.

<u>Petrography:</u>

The **'fresh' layered metagabbros** contain variable proportions of plagioclase, olivine, clinopyroxene, subordinate orthopyroxene, and minor brown hornblende (Plates 13.4, 13.5. 13.6). Opaque minerals, emerald green spinel, and rare biotite are accessory minerals. Plagio-clase generally ranges in composition between An_{50} and An_{70}, but grains as sodic as An_{45} were found in clinopyroxene gabbro. It occurs as granoblastic intergrowths which show a tendency to form monomineralic domains with straight to slightly curved or irregular intergrain boundaries (Plate 13.5). Most grains are either of similar size or larger than olivine, and some are subophitically enclosed in clinopyroxene. Olivine, ranging in composition between Fo_{90} and Fo_{65}, forms lozenge shaped grains, grain aggregates, and polygonized lenses which partly define the foliation and banding. Clinopyroxene grains are beige under transmitted light, and display very thin exsolution lamellae. They generally form large, polygonized to recrystallized, subophitic grains (Plate 13.6), with smaller subgrains at their boundaries which are rarely strung out along the foliation plane. Diallage partings are decorated with fine opaques. Orthopyroxene is weakly pleochroic, clusters as rims around olivine or clinopyroxene grains in most of the gabbros, and is commonly highly polygonized. Anhedral, pinkish brown igneous hornblende is ubiquitous, though not abundant. It commonly surrounds cuspate magnetite grains Plate 13.4), and rarely forms separate grains. Deeply pleochroic, red brown phlogopite or biotite is common but even less abundant than hornblende, and is locally rimmed by symplectites of biotite or phlogopite and quartz. Magnetite is the predominant opaque phase in all of the layered metagabbros. Fine grained magnetite and emerald green spinel generally occur together, and are relatively abundant accessory minerals in some rocks.

The gabbronorite is characterized by orthopyroxene, plagioclase, and phlogopite as cumulus phases, enclosed in partly uralitized, intercumulus clinopyroxene (Plate 13.7). Orthopyroxene occurs as large and small, subhedral, colourless grains with exsolution lamellae. The gabbronorite lacks the penetrative, granulite facies foliation of the rest of the layered sequence.

Retrograde overprints on the layered metagabbros within the block are of two main types:

The first type is characterized by the replacement of the ferromagnesian minerals by coarse, polygonized grains (Plate 13.8) to recrystallized, fine grained, lensoid aggregates (Plate 13.9) of blue green hornblende, and by accessory epidote, sphene, and rare sphene-rimmed rutile. Core and mantle texture is common. Granoblastic plagioclase (calcic andesine to labradorite) intergrowths are preserved. Locally, fine grained aggregates of brown green hornblende, mottled and rimmed with blue green hornblende, occur instead of blue green hornblende, and the rocks lack sphene.

The second type is characterized by pseudomorphous replacement of the ferromagnesian minerals by fibrous blue green amphibole and clinochlore (Plate 13.10), although brown igneous hornblende is commonly preserved. Thin tremolite coronas surround olivine grains in a few sections. Symplectite rims and lobes of pale blue green, fibrous actinolite are also common locally. Some of the rocks display remnants of clinopyroxene pseudomorphously replaced by pale amphibole rimmed with more deeply pleochroic, blue green amphibole. Epidote occurs as single, prismatic euhedra, and as vermicular coronas on altered clinopyroxene grains. Type 2 retrograded metagabbros lack sphene.

13.1.4 Massive metagabbro and metadiabase (Unit 1c)

Definition and distribution:

These rocks are distinguished from the layered metagabbros by the lack of well developed layering, the coarse to medium grained subophitic texture of the metagabbro, and the abundance of the associated metadiabase intrusions. They are also typically cut by plagiogranite stringers and pods, not present in the layered metagabbro terrane. Altered clinopyroxene is the major ferromagnesian mineral phase, and olivine is absent.

This unit is most extensively exposed in the Dinosaur Pond belt, both as extensive outcrop areas sparingly intruded by equigranular tonalite, and in outcrops that consist of about 30 to 70 percent mafic rock intruded by or enclosed in tonalite. This terrane passes gradationally northward into the north-central high strain zone, where tonalite encloses mafic metavolcanic rocks and dykes, undivided amphibolite, and assorted metasedimentary rocks, as well as local inliers of massive metagabbro and metadiabase.

In addition, the massive metagabbro with abundant metadiabase intrusions grades into the layered metagabbros in the Little Codroy Pond belt. This transition occurs through a sequence of well layered clinopyroxene metagabbro on the northwest side of the layered metagabbro block and is overprinted by the Long Range high strain zone. The same gradation occurs on the eastern side of the layered metagabbro terrane near Sandy Pond, where it is intersected by the Stag Hill high strain zone.

Lithology:

Several rock types characterize this unit. The most common phase is clinopyroxene metagabbro which varies from coarse to medium grained in texture, and from plagioclase-rich to ferromagnesian-rich in composition. The clinopyroxene metagabbro is commonly cut by irregular metadiabase dykes, and locally by very coarse grained hornblende metagabbro (Plate 13.11). Straight-sided dykes of the latter display comb layering (Moore and Lockwood,1973). All of the rocks are intruded in places by plagiogranite pods and stringers, and also by pegmatites composed of quartz, plagioclase, biotite, and hornblende.

Outcrops of clinopyroxene metagabbro weather dark grey to black, and are characterized by a well developed subophitic to ophitic texture.

Metadiabase forms small, irregular intrusions, and is typically fine grained with a poorly preserved diabasic texture. It is locally plagioclase-phyric.

Plagiogranite veins and pods are white in colour and sugary in texture, and in places contrast sharply with the mafic plutonic rocks (Plate 13.12). Green ferromagnesian laths and small, brown zircons were observed in many plagiogranite specimens. Many of the pods contain angular inclusions of their hosts (Plate 13.12). Many also have quartz-rich core segregations.

In the central part of the Stag Hill high strain zone, medium grained subophitic metagabbro is cut by a magnetite-rich dioritic pegmatite. The rock is mildly deformed, but was probably butressed against much of the penetrative deformation of the high strain zone by the massive pegmatite.

<u>Petrography</u>:

The **clinopyroxene metagabbro** is composed of altered clinopyroxene, plagioclase, brown igneous hornblende, and accessory magnetite and pyrite. Secondary minerals include blue green amphibole (after clinopyroxene), rare chlorite, clinozoisite (after plagioclase), minor brown biotite, and rare rutile associated with opaque minerals. Pale brown clinopyroxenes, which make up between 30 and 70 percent of the rock, subophitically enclose plagioclase. They are partly to completely altered to blue green amphibole, and many pseudomorphs have pale green cores and t[illegible], more intensely pleochroic rims. Planar arrays of very fine opaque grains mark remnant diallage partings. Plagioclase, partly to totally replaced by clinozoisite and zoisite, occurs as subhedral laths ranging from andesine to bytownite in composition. Brown igneous hornblende is very minor in most of the rocks. It ordinarily surrounds large, cuspate, magnetite grains, but in some thin sections, flakes of deep brown, pleochroic biotite occur with this habit. Locally, pale brown to brown green hornblende forms large, subophitic grains in conjunction with clinopyroxene. Magnetite forms both separate disseminated grains, commonly oxidized around the rim, and cuspate, hornblende-rimmed grains. Pyrite is locally present, but is subordinate to magnetite.

The metadiabase varies in texture. A granoblastic intergrowth of prismatic blue green amphibole and altered plagioclase with abundant accessory magnetite and fine grained secondary epidote is common. Altered dykes locally contain epidote or clinozoisite pseudomorphs of plagioclase, and some contain rare flakes of brown biotite oriented parallel to a weak foliation. Plagioclase porphyritic dykes contain recrystallized plagioclase phenocrysts in a matrix of fine grained, blue green, prismatic hornblende, subordinate fine grained plagioclase, and accessory apatite and opaque grains. The recrystallized phenocrysts are composed of granoblastic clots of plagioclase (approximately An_{70}), some of which are partly replaced by coarse grained zoisite and muscovite.

The plagiogranite veins are composed of about 60 percent plagioclase, 20 percent quartz, and 20 percent uralitized clinopyroxene with accessory zircon and secondary minerals. The rock is generally fractured, with coarse epidote and subordinate sphene concentrated along the fractures. Plagioclase (labradorite) occurs as altered to unaltered grains up to, but generally smaller than, 1.5 cm in length. Many grains are bent as well as fractured. Quartz forms interstitial polygonized and recrystallized networks. Clinopyroxene forms anhedral patches up to 1.5 cm long, and is completely uralitized, or rarely chloritized. Zircon occurs as large, clear, prismatic crystals.

The **magnetite-rich pegmatite** is composed of igneous brown hornblende (several centimetres in maximum diameter) and equally large grains of colourless clinopyroxene interstitial to coarse, lightly sericitized plagioclase (An_{40}), and abundant anhedral magnetite (up to 25 modal percent). Clinopyroxene, where fresh, is commonly rimmed or mottled with brown hornblende. Many clinopyroxene grains are uralitized, and rimmed with more deeply pleochroic blue green hornblende. **The associated clinopyroxene metagabbro** consists essentially of plagioclase poikilitically enclosed in clinopyroxene with less abundant igneous brown hornblende and igneous, brown hornblende-rimmed magnetite. Clinopyroxene grains in this rock were deformed, and ubiquitously rimmed with igneous brown hornblende, which locally forms very fine films along some deformational subgrain boundaries, possibly indicating minor deformation at very high, subsolidus temperatures associated with the pegmatite development. Clinopyroxene was later partly uralitized, and rimmed with more deeply pleochroic, blue green amphibole.

The rocks as described above were heavily fractured at a later stage (from cross-cutting relationships), and the fractures lined with fine grained chlorite.

13.1.5 Mafic metavolcanic rocks and dykes (Unit 1d)

Definition and distribution:

Mafic metavolcanic rocks and dykes or sills form a wedge within the Long Range high strain zone where they are spatially associated with marble and semipelitic metasedimentary rocks. They are intruded by sheets and veins of red, foliated granite and subordinate white trondhjemite, and adjacent to massive metagabbro and metadiabase to the southeast, although several late stage shear zones cross the latter transition.

Rafts of mafic metavolcanic and hypabyssal rocks are concentrated in two outcrop areas in the north-central high strain zone of the Dinosaur Pond belt, and grade into the massive metagabbro and metadiabase intruded by tonalite to the south. The rafts are bordered to the north, northwest, and northeast by foliated granitoid rocks with both abundant metasedimentary and mafic metavolcanic or amphibolitic inclusions.

Lithology:

The mafic metavolcanic rocks and dykes within the Long Range high strain zone comprise massive metabasalts which are cut by equally metamorphosed mafic dykes. Outcrops of metabasalt weather black to dark grey, are generally highly fractured, and locally break up into ovoidal masses. Thin, partly granitized pillow selvages, pillow junctions and margins with abundant flattened vesicles were observed locally. The dykes are massive and aphyric to plagioclase porphyritic, and are inseparable from mafic metavolcanics in most places. Plagioclase phenocrysts in porphyritic dykes are abundant, 3 to 10 mm in diameter, and display oscillatory zoning. The ferromagnesian minerals of both metavolcanic rocks and dykes have been metamorphically recrystallized into fine, acicular amphibole which defines a pronounced foliation.

In the north-central high strain zone, fine grained, amphibolitic metavolcanic rocks display diabasic textures, and plagioclase phenocrysts are preserved locally. Pillow-like structures with 2 to 4 cm thick, weathered-out rims, epidosite lenses or pods, mafic breccias (Plate 13.13) and patches of green to buff, colour-banded, tuffaceous metasediment characterize the two largest outcrop areas. As with the metagabbro and metadiabase complex, exposures with almost no intrusive tonalite pass abruptly into those containing a large proportion of tonalite.

Petrography:

Plagioclase-phyric and aphyric metabasalts in the LRhsz are composed mainly of hornblende and plagioclase with accessory epidote minerals, sphene or leucoxene, and magnetite. Hornblende is most commonly blue green, but some sections contain the brown green variety. A few relics of pale green clinopyroxene are present in some thin sections. Secondary actinolite and chlorite associated with the hornblende occurs locally. Plagioclase phenocrysts, where present, are almost completely replaced by coarse intergrowths of prismatic zoisite, which is also abundant in the matrix (Plate 13.14).

Mafic metavolcanic rocks or dykes from the NChsz are composed of blue green hornblende (60 to 70 percent) and plagioclase (up to 30 percent) with minor quartz and magnetite (1 to 4 percent). Relics of pale green pyroxene were observed in several thin sections. Traces of cummingtonite form an incipient alteration of hornblende in the metabasites of the northern outcrop area. Secondary clinozoisite or epidote replaces plagioclase grains of some samples in the southern outcrop area.

One plagioclase porphyry sample consists of a network of small prismatic hornblende crystals encasing coarse aggregates of one to several grains of plagioclase up to 1 mm in diameter and rare rounded crystals of quartz. Plagioclase varies between bytownite and andesine.

13.1.6 Undivided amphibolite (Unit 1e)

Definition and distribution:

Deformed and metamorphically recrystallized mafic meta-igneous rocks for which a protolith is not recognizable in outcrop or hand specimen were mapped as undivided amphibolite.

Undivided amphibolite is most extensively exposed within the Stag Hill and Long Range high strain zones, and along the north side of the Cape Ray Fault. Some of the mafic meta-igneous inclusions in foliated tonalite of the north-central high strain zone have also been referred to as undivided amphibolite. The term amphibolite refers to mafic metamorphic rocks composed largely of amphibole and plagioclase, which may form under a wide range of metamorphic conditions. These conditions might be expected to differ in different parts of the area, so the undivided amphibolites will be described according to location.

Stag Hill high strain zone

Well foliated amphibolites from this zone grade north and westward into the transition zone between the layered metagabbro and massive metagabbro and metadiabase, and therefore may have been derived from both. Since metasedimentary rocks also occur in this zone, it is possible that some of the amphibolite is derived from the mafic metavolcanics and dykes which have been observed next to paragneiss and marble locally. Around Little Codroy Brook, medium grained amphibolite accompanied by lenses of very fine grained amphibolite may represent highly recrystallized metagabbro and metadiabase. Halfway between Sandy Pond and Long Pond, mylonitic, quartz-poor feldspathic rock characterized by ferromagnesian augen in a mylonitic, plagioclase-rich matrix probably represent cumulate layers of anorthositic metagabbro. Nearby, medium grained metagabbro cut, and probably buttressed by, a thick magnetite-hornblende-clinopyroxene-plagioclase pegmatite has preserved the subophitic igneous texture characteristic of the clinopyroxene metagabbro; these have been described with the massive metagabbro and metadiabase.

Most of the amphibolites weather black to dark green or grey in outcrop, and show strong S or L-S fabrics. Pinstripe banding, formed by the segregation of light from dark coloured minerals on a scale of one to several grains thick, is well developed. The alternation of fine and coarse grained layers, and of dark coloured hornblende with lighter green, diopside-rich layers, is developed in some exposures. Amphibolites which originally contained coarse ferromagnesian grains and are slightly to highly enriched in plagioclase, are characterized by polycrystalline ferromagnesian augen.

The foliation of amphibolites at the northeast end of the zone is particularly strong. In many outcrops west of South Branch River and the late, perthite-rich granite pluton, they are pervasively interlayered with blasto-mylonitic to mylonitic, red granitoid rocks. Several ultramafic lenses or pods accompany these amphibolites.

Highly deformed, recrystallized layered metagabbros are exposed as a wedge to the northeast of the main layered metagabbro block. They display colour banding, reflecting variations of modal plagioclase, on the same scale as the layered metagabbros to the southwest. Bands of altered ultramafic rock occur within the highly strained, layered metagabbro wedge. Outcrops weather black, dark to pale green, and grey. Steeply plunging mineral lineations and steep foliations characterize these rocks.

Petrography:

Amphibolites in the southwestern SBhsz consist of a well foliated and layered homeoblastic intergrowth of blue green hornblende, diopside, plagioclase, local cummingtonite, clinozoisite or epidote, and sparse local quartz, with accessory apatite and local opaque minerals. The blue green hornblende is moderately to strongly pleochroic. Moderately pleochroic hornblende forms abundant prismatic crystals, and subordinate, strongly pleochroic hornblende occurs either as thin, patchy rims or fracture linings on the other ferro-magnesian silicates, or rarely as single grains. Diopside is generally pale green, and may be either concentrated in selected layers or lenses or disseminated throughout the rock (Plate 13.15). It occurs as equant anhedral grains, commonly rimmed with thin coronas of epidote or clinozoisite. In a few samples, tan clinopyroxene patches with remnant diallage, surrounded by clear, pale green diopside grains, are probably the remnants of igneous augite grains. Plagioclase (andesine to labradorite) clusters in planar to lensoid aggregates with curved to sutured intergrain boundaries. Some of the plagioclase is partly to completely replaced by epidote or clinozoisite. Colourless, polysynthetically-twinned cummingtonite is locally present, and apparently replaces blue green hornblende in particularly highly strained layers. Magnetite is the predominant accessory opaque mineral, but minor partly oxidized pyrite was observed in some specimens. In amphibolites around Little Codroy Brook, tiny quartz domains (0 to 1 modal percent) occupy plagioclase-plagioclase boundaries.

Amphibolites in the northeastern SHhsz consist of hornblende, plagioclase, diopside, quartz (0 to 5 modal percent) and accessory opaque minerals, apatite, clinozoisite or epidote, and rare sphene. Hornblende is blue green to locally green. Diopside is pale green and nonpleochroic, and may occur either as part of the hornblende intergrowth or as small ovoid grains at plagioclase triple junctions; it is rimmed with epidote in a few places. Plagioclase (An_{70} in one rock) occurs as fine grained, granoblastic domains with irregular intergrain boundaries. Remnant, normally zoned grains are common in this intergrowth. Plagioclase is locally replaced by zoisite. Magnetite is the main opaque mineral. Sphene-rimmed anhedral opaque grains were noted in one thin section.

Amphibolite east of South Branch River is composed of plagioclase (labradorite), brown green hornblende, partly preserved pale green clinopyroxene, and blue green amphibole. Magnetite, apatite, and pyrite are accessory minerals. Hornblende and uralitized pyroxenes are rimmed with blue green amphibole, which also occurs as fibrous clots. Abundant disseminated magnetite occurs both alone and as rims on subordinate pyrite.

The feldspathic rocks between Sandy Pond and Long Pond contain highly pleochroic blue green hornblende and blue green hornblende rimmed, beige clinopyroxene porphyroclasts which form augen in a mylonitic, plagioclase-rich matrix. Blue green hornblende locally forms poikiloblasts which enclose fine grains of quartz. In the mylonitic matrix, it is partly replaced by olive green biotite in places. Plagioclase occurs as very fine grained granoblastic aggregates which form ribbonlike bands and lenses. Minor muscovitization of the plagioclase is common. Epidote (or clinozoisite) and apatite are abundant accessory minerals. Accessory sphene and epidote-rimmed allanite also occur locally.

The foliated, layered metagabbros are composed largely of blue green, prismatic hornblende and plagioclase

(An_{60-65}). A segregation foliation is defined by flattened clots of the blue green hornblende alternating with granoblastic aggregates of plagioclase. Coarse grained zoisite overprints plagioclase (An_{45} to An_{60}) in some layers.

Long Range high strain zone

Lithology:

Amphibolites in the Long Range high strain zone are gradational into the massive metagabbro and metadiabase in some cases and the mafic metavolcanic rocks and dykes in others. Dark grey, very fine grained amphibolite predominates along the northeast end of the zone in association with mafic metavolcanic rocks. Medium to fine grained amphibolite with coarse grained layers occurs locally in the southwest part of the fault zone in this area, and grades into metagabbro. Black to dark grey or green weathering, medium to fine grained amphibolite occurs near the fault contact with Carboniferous rocks along South Branch River.

Many of the fine grained amphibolites display a pronounced linear fabric, produced by the alignment of fine grained acicular amphibole crystals. Strong planar fabrics resulting from the deformation of large ferromagnesian grains are developed in the banded, coarse to medium grained amphibolites which grade into massive and layered metagabbros in the southwest part of the high strain zone. Planar fabrics defined by flattened, stubby hornblende grains typify the very mafic-rich, black amphibolite exposed along South Branch River.

Petrography:

Amphibolites in the LRhsz vary from fine to very coarse grained, and are composed largely of hornblende and plagioclase with or without minor quartz. Epidote minerals, sphene, magnetite, and apatite are common accessory minerals. Hornblendes vary among deeply pleochroic green to blue green and brown green varieties, the latter found in the transition into the layered metagabbro block. Two types may occur in the same rock, either as separate grains or as blue green rims on green or brown green cores, the last-mentioned commonly mottled with blue green. Hornblende generally defines at least two intersecting S-L fabrics, and monomineralic domains are polygonized and annealed. Many of the large domains in very coarse grained amphibolites display dark, occluded patches inherited from igneous diallage. Plagioclase forms polycrystalline, granoblastic, stringer-like domains which appear to be tightly folded or crenulated. Strained quartz domains also form tiny patches or stringers in some rocks. Dark brown, pink brown, or orange brown sphene forms very fine grained, polycrystalline, crenulated stringers, and is associated with sparse, very fine grained magnetite.

Less deformed, medium to coarse grained amphibolites (transitional to easily recognizable metagabbros) are composed of blue green amphibole and plagioclase with rare, relict brown igneous hornblende surrounding anhedral opaque grains, and late secondary epidote, chlorite, and green biotite. Sphene, apatite, and abundant opaques are accessory minerals. Some large ferromagnesian clots show subophitic texture and relict diallage, and have cores of highly birefringent, pale green amphibole and rims of more deeply pleochroic, blue green amphibole. Otherwise the amphibole occurs as bladed, polycrystalline clots and fibrous bundles. Epidote is relatively coarse grained.

Mylonitic **amphibolites along late lineaments** contain sparse plagioclase and blue green hornblende porphyroclasts which form augen in a strong planar fabric defined by fibrous blue green amphibole (probably actinolite), lenses of leucoxene or sphene, epidote, chlorite, and ribbons of very fine grained recrystallized quartz.

North-central high strain zone

Lithology:

Most of the undivided amphibolite xenoliths and rafts are fine grained, and weather dark grey to black. Many lack a regional metamorphic fabric, but several inclusions in the eastern part of this terrane are strongly foliated. Few were collected for thin section.

Very highly sheared and retrograded amphibolite containing large, feathery, highly altered anthophyllite or gedrite crystals was observed near the western fault boundary of the zone on North Branch River.

Petrography:

One **amphibolite/metabasalt xenolith in the southeast-central part of the MChsz** is composed mainly of hornblende, cummingtonite, plagioclase, biotite, and quartz in homeoblastic intergrowth, with accessory magnetite and pyrite. Chlorite pseudomorphously replaces some of the amphibole, and partly replaces some of the biotite. Biotite is red brown, hornblende pale brown, and cummingtonite colourless. Plagioclase and quartz are clustered together as minor constituents. Pyrite either occurs alone or is rimmed by magnetite. This assemblage abruptly grades into a clear-looking subdomain consisting of a fine grained intergrowth of cummingtonite and plagioclase (bytownite) with accessory red brown biotite, magnetite, and pyrite.

A highly foliated **(rare) amphibolite xenolith** is composed largely of tremolite/actinolite with between 5 and 10 percent interlayered biotite and chlorite, and about 5 percent combined quartz and plagioclase. Sphene and secondary calcite and muscovite are the main accessory minerals. The tremolite-actinolite is very pale green, acicular, and defines a pronounced L-S tectonic fabric. Quartz and plagioclase are very fine grained and interstitial to the amphibole. The biotite/chlorite intergrowth is aligned and segregated along late cleavage planes that crosscut the penetrative foliation. Some of these cleavages also site late muscovitization. (This xenolith could either have been tectonically foliated before incorporation into the tonalite, unlike most of the xenoliths, or alternatively, represent primary flow structures of some of the volcanic rocks.)

The retrograded anthophyllite schist is composed of plagioclase, anthophyllite or gedrite pseudomorphs, epidote, magnetite-ilmenite, and accessory pyrite. Serpentine and chlorite replace anthophyllite or gedrite crystals up to 3 cm long. Plagioclase is clear, and exhibits mottled extinction. Coarse grained epidote overprints all minerals, and occurs particularly at plagioclase triple junctions.

Cape Ray Fault zone

Lithology:

Undivided amphibolite underlying the relatively thin high strain zone along the north side of the Cape Ray Fault occurs as inclusions and rafts in equally deformed, or even more deformed tonalite. These rocks pass gradationally toward the fault in the southwest corner into a thick band of chlorite-muscovite phyllonite, and away from the fault into tonalite which includes rafts of the massive metagabbro and metadiabase.

The amphibolite along the northwest side of the Cape Ray Fault weathers black, and is fine to medium grained. It lacks the pronounced mineral alignment typical of the other amphibolites of the map area, but displays an anastomosing, inhomogeneously developed schistosity which increases in intensity toward the fault.

Petrography:

These rocks consist of inequigranular, greenschist facies assemblages of actinolite, epidote, chlorite, altered plagioclase, minor quartz, and accessory magnetite, pyrite, zircon, and apatite. Actinolite and chlorite define the foliation. The amphibole is fibrous to bladed in many rocks, but may occur as clots of stubbly, prismatic grains in relatively unfoliated rocks. Rare flakes of partly chloritized red brown biotite occur in the latter. As in the massive clinopyroxene metagabbros in gradational contact nearby, the plagioclase is partly to totally replaced by coarse epidote minerals and flakes of muscovite. Pyrite is partly oxidized.

13.2 METASEDIMENTARY ROCKS OF TERRANE I

13.2.1 Subdivision of the metasedimentary rocks

The metasedimentary rocks of Terrane I have been subdivided into paragneisses of the Little Codroy Pond belt

(Unit 2a), marble (Unit 2b), and metasedimentary inclusions of the Dinosaur Pond belt (Unit 2c).

13.2.2 Paragneiss of the Little Codroy Pond belt (Unit 2a)

Definition and distribution:

Semipelitic paragneiss and migmatite, intruded by sheets of synkinematic, equigranular granitoid rock, and deformed under moderate to high grade metamorphic conditions, is exposed within the Stag Hill high strain zone as outliers or wedges. It is also folded and possibly faulted with the marbles above the mafic metavolcanic rocks and dykes and undivided amphibolite within the Long Range high strain zone.

Lithology:

Coarsely garnetiferous biotite-muscovite-sillimanite schist with granodioritic to tonalitic veinlets comprising a well segregated paragneiss predominates. In the northeast part of the belt, intense deformation and recrystallization preclude the separation of the paragneiss from the granitoid sheets. Multiply folded, well bedded, dark grey-green metasiltstone occurs among the paragneiss, migmatite, and foliated granitoid sheets in the southwest. Paragneiss along the southeastern boundary of the zone, particularly the metasiltstone, is partly retrograded with the development of chlorite and fine grained muscovite, and the local diminution of garnet.

Banded carbonate-rich and garnetiferous semipelitic schists, with local mafic metavolcanic bands or dykes, occur within the Long Range high strain zone. The rocks are intensely sheared and commonly mylonitic. Red, foliated granite injections are common. Retrogression is not as intense southeast of the Long Range escarpment, and garnets are visible in many exposures. Garnetiferous quartzofeldspathic mylonite can be traced along the southern margin of the marble band, and was also observed in the southwest part of the Stag Hill high strain zone north of Clambake Pond.

All of the rocks possess a strong micaceous fabric within which fractured garnets form augen. Migmatitic quartzofeldspathic veins are attenuated along this schistosity. Both schistosity and veins are buckled by a crenulation foliation in the south, and largely transposed by it in the north; pieces of garnet apparently fragmented within the early foliation are locally offset by the crenulation.

At Stag Hill, pronounced east-trending rodding lineations, long axes of mineral augen, and fold axes are parallel, and plunge gently eastward (Chapter 9, Plate 9.3). A metamorphosed breccia of veined paragneiss and amphibolite blocks (Chapter 9, Plate 9.4) is also exposed at Stag Hill. An en echelon row of hills northeast of Stag Hill also exposes folded, veined paragneiss as a megabreccia. The axial planes of the folds strike northwest in some blocks, northeast in others, suggesting that the veining and folding of the paragneisses predated the brecciation.

Petrography:

Semipelitic paragneisses of the SHsz are generally composed of biotite, muscovite, garnet, sillimanite, quartz, plagioclase, and local microcline and myrmekite with accessory zircon, graphite, and other opaque minerals, mainly magnetite. In the northeast and central parts of the zone, biotite, muscovite, fibrolitic sillimanite, and thin quartz-feldspar stringers define a strong, penetrative schistosity within which garnet and rare, large sillimanite crystals form augen. Minerals defining the schistosity are either rotated into a pronounced crenulation foliation at high angles to the penetrative schistosity, or transposed by the crenulation at low angles to the early schistosity. // Biotite is red brown, encloses coarse zircon with intense metamict haloes, and is fringed with fine opaque grains. Graphite is commonly interlayered with biotite. // Muscovite occurs as poikiloblastic flakes overprinting leucocratic domains, as fine grained flakes oriented parallel to, but locally cutting across, the penetrative foliation, and as ovoid to rectangular domains of matted sericite which possibly replace aluminosilicate crystals. (Because of obvious local replacement by muscovite, it is not certain whether muscovite was present in all of the rocks during the metamorphic peak.) // Garnets are generally elongated within the foliation plane, and may be over 5 mm in maximum diameter. They contain random arrays of plagioclase, quartz, biotite, and magnetite inclusions; rare staurolite inclusions were observed in the garnets of the northeast part of the high strain zone. Quartz inclusions generally occur as tiny lobes overprinting larger, slightly rounded, rectangular plagioclase inclusions. Where the inclusions are more voluminous than the enclosing garnet, as in some of the quartzofeldspathic gneisses, the garnets have a dendritic aspect. Garnets form augen within the schistosity, and quartz, biotite, and local fibrolite or muscovite fill tension gashes and pressure shadows. Many of the garnet fragments thus produced are offset along the second fabric. // Sillimanite generally forms mats and torpedo-shaped aggregates of fibrolite crystals, or loosely packed schools of single fibrolite crystals associated with quartz in pressure shadows. In the northeastern part of the high strain zone, sillimanite commonly predominates over muscovite in many rocks. In some samples, remnant single crystals of sillimanite several millimeters in diameter are bent and fractured; fibrolite crystals occur along the margins and along fractures. // Feldspar and quartz occur together in thin veinlets with minor muscovite and fibrolite. Plagioclase is ubiquitous, and is subordinate to quartz in the more pelitic rocks but predominates over quartz in quartzofeldspathic rock types. Plagioclase crystals are corroded by large and small quartz grains. Relatively large microcline grains, observed in a few samples, are either rimmed or corroded by myrmekite.

Retrograded garnetiferous schists along the southeast margin of the SHhsz contain chlorite and muscovite rather than biotite. The retrograded metasiltstones in the southwest are composed mainly of muscovite, epidote, and chlorite with abundant accessory magnetite, sparse pyrite, and a few garnet remnants. Muscovite occurs both as coarse poikiloblastic mica flakes and as thick matted intergrowths with epidote or clinozoisite. Chlorite occurs as coarse sheaflike aggregates or as clots, and is enriched along some layers. Pyrite occurs in chlorite-rich layers.

Calcareous metasedimentary schists associated with the marble are very inhomogeneous. They contain, in addition to calcite and detrital quartz, vesuvianite, red brown biotite, scapolite, actinolite, tourmaline, sphene, and graphite.

Retrograded semipelitic schists in the LRhsz are composed of garnet, muscovite, biotite, quartz, and plagioclase with accessory opaque minerals and coarse zircon. Micas and quartzofeldspathic veinlets parallel an early foliation, isoclinally folded or rotated by a strong crenulation cleavage. Fine grained muscovite and less abundant chlorite is developed locally along either the crenulation or a later strain-slip fabric; however, brown biotite flakes are preserved between these planes. Some of the muscovite occurs as relatively coarse grained clots.

Garnets are intensely fractured and form augen that are slightly rotated by the widely spaced crenulation cleavage, but lack the quartz-filled tension gashes typical of the rocks within the SHhsz. Inclusions of quartz, biotite, chlorite, and pyrite are common, and those of plagioclase rare. Plagioclase forms porphyroclasts in a matrix of flaser quartz in the quartzofeldspathic domains. Magnetite is the major opaque mineral.

The quartzofeldspathic mylonite along the ridge is composed of quartz, alkali feldspar, sillimanite, biotite, and garnet with accessory opaque minerals and coarse zircon. The mylonitic foliation is defined by ribbons of recrystallized quartz, deep red brown biotite, fibrolitic sillimanite, elongate grains of alkali feldspar, and acicular or platy opaque grains. Garnet grains form augen within the foliation, and some grains appear to be fragments strung out in the foliation plane (Plate 13.16). Quartz inclusions in the garnets are large and locally coalesce with the external matrix, imparting a dendritic appearance to the garnet. Both twinned and untwinned alkali feldspar grains occur as elongate to equant grains embayed by quartz. Many of the elongated grains are crosscut by curved fractures marked by red brown iron oxide in some grains and a high relief, colourless to pale green mineral (fibrolite?) in others. **The quartzofeldspathic mylonite north of Clambake Pond** lacks sillimanite, and instead contains abundant muscovite.

13.2.3 Marble (Unit 2b)

Definition and distribution:

Massive marble and calc-silicate marble with rare impure marble bands or lenses occur as a multiply folded band following the northwest edge of the Long Range Mountains, and as boudinaged lenses within the Stag Hill high strain zone. It was mapped by Phair (1949) on the hills northeast of Little Codroy Pond and near the source of Trainvain Brook on Table Mountain (Map I). Marble also forms rafts enclosed in the foliated granitoid rock in the north-central high strain zone.

The marble is spatially associated with either mafic metavolcanic rock or undivided amphibolite in all three areas, and is locally intruded by veins of red granite (Plate 13.17) and pegmatite.

Lithology:

Marble occurs as thick, layered units composed largely of smooth, white, finely crystalline calcite with bands and lenses of resistant, yellow weathering, intensely fractured, coarsely crystalline calcite. Grey weathering diopside-rich bands are present in many exposures. Other exposures of buff to grey weathering marble contain abundant macroscopic brown mica and dark, shiny, prismatic crystals of diopside projecting from the weathered surface. Quartz and possibly detrital plagioclase are common, and are most noticeable as resistant fragments along with quartzofeldspathic veins on very weathered surfaces. Minute disseminated graphite flakes, or alternatively, equally small red hematite grains, are visible in the white weathering marble, and white mica flakes are visible on freshly broken surfaces.

The calc-silicate rich layers, and the differentially weathered bands and lenses, probably represent tectonically transposed bedding; contrasting grain size among layers is interpreted to be the result of inhomogeneous recrystallization during deformation. Layering is openly to isoclinally folded near the base of the Long Range Fault escarpment, and steeply dipping at the top. It is folded and boudinaged within the Stag Hill high strain zone.

Marble inclusions are brecciated with the intrusive granitoid rock in the north-central high strain zone.

Petrography:

The white marble is composed mainly of calcite with accessory white mica, graphite, and less commonly, hematite (oxidized pyrite?). Calcite is coarse to fine grained, and displays profuse deformation lamellae. Detrital quartz and/or plagioclase is a common minor constituent; the latter is generally at least partly altered to scapolite...

The grey marble is composed dominantly of calcite with bands rich in diopside with the local addition of sphene. White mica, oriented parallel to the schistosity, and detrital quartz are ubiquitous. Graphite is the main accessory mineral.

The buff-weathering marble is composed largely of calcite with less abundant diopside, red brown biotite or phlogopite, and scapolite (replacing plagioclase) with accessory graphite and tourmaline (dravite).

13.2.4. Metasedimentary inclusions of the Dinosaur Pond belt (Unit 2c)

Definition and distribution:

The varied assemblage of metasedimentary inclusions in the garnetiferous tonalite of the north-central high strain zone, with the exception of marble, are included in this category.

Lithology:

The xenoliths include nonlaminated and laminated garnetiferous biotite paragneiss, banded calcareous schist, microcrystalline garnet-quartz rock, grey metasandstone, and siliceous schist. Outcrops of gneissified breccia composed of angular fragments of laminated semipelitic to slightly calcareous paragneiss were observed locally. The xenoliths and the enclosing tonalite are metamorphosed to upper amphibolite (sillimanite) grade during regional deformation, which involved the formation of composite fabrics, i.e., crenulated schistosity or gneissosity. Some of the inclusions have formed bimetasomatic reaction rims. This occurred during or after the late deformation, since fractures and tension gash boundaries, formed during boudinage of the fragments, are also rimmed.

The garnetiferous paragneiss is generally enriched in biotite relative to the enclosing granitoid rock, and is locally layered or more fine grained than the granitoid. Coarse to fine grained red garnets are ubiquitous in the paragneiss, but also occur in the granitoid rock. Laminated varieties typically contain fine grained garnet-rich layers reminiscent of the microcrystalline garnet-quartz rock (described below). In many places, sillimanite is visible in hand specimen. In some outcrop areas, the garnetiferous paragneiss inclusions neither display textures that contrast greatly with those of their hosts, nor contrast sufficiently in mineralogy, to enable an assessment of the proportion of paragneiss to granitoid present.

The grey metasandstone is slightly calcareous, and contains about 40 percent fine grained quartz which is visible on weathered surfaces.

The microcrystalline garnet-quartz rock occurs as pink to red, chunky xenoliths of up to fist size, and lacking internal structure.

The calcareous schists are laminated or banded, and associated with granitoid rocks particularly rich in red garnet.

The siliceous schist shows no recognizable primary features. It weathers white, and exhibits a strong planar fabric.

The southeast part of the north-central high strain zone is locally highly sheared and (metasomatically?) altered, resulting in the destruction of plagioclase and leaching of ferromagnesian components from biotite, and augmentation by quartz and almandine garnet. Garnets are typically over a centimeter in diameter, commonly dendritic and surrounded by biotite-free patches, indicating that they may have grown at the expense of ferromagnesian phases. Many schistose outcrops in this area have weathered after mineralization with Fe sulphide or oxide, and form scaly, rusty mounds. Similar weathered showings occur within the same rock assemblage near the western margin of the north-central high strain zone.

Intense retrogression is displayed along the western fault margin of the zone, and varying degrees of patchy retrogression is displayed within the zone. Retrogression occurred after the formation of the early gneissic fabric during movement along the fault. Some of the retrograded gneisses, or alternatively similar gneisses from the adjacent Stag Hill high strain zone, were subsequently contact metamorphosed by the late, perthite-rich leucogranite pluton.

Petrography:

The garnetiferous paragneiss inclusions are composed of garnet, biotite, quartz, plagioclase, sillimanite, and local cordierite with accessory opaque minerals and zircon. Secondary muscovite, chlorite, and carbonate occur locally. A crude segregation of biotite and sillimanite defines a weak to strong schistosity or gneissosity (Plates 13.18) which is folded in many samples. Garnets occur either as anhedral grains about 2 mm and greater in diameter with inclusions of quartz and magnetite, or as abundant, euhedral, inclusion-free grains between less than 0.5 mm in diameter. Locally, the garnets form augen in a planar gneissic fabric defined by sillimanite segregation. Biotite is red brown, and is commonly annealed in the hinges of the microfolds to produce the effect of variable orientation. Quartz forms large, weakly strained domains with a tendency to embay plagioclase. Plagioclase (andesine) is slightly to heavily sericitized. Sillimanite forms clusters of well formed acicular prisms and is locally aligned to impart a linear fabric; it occurs less commonly as fibrolite bundles. It is mainly, but not solely, associated with the ferro-magnesian segregations. Cordierite, where present, occurs as large grains which poikilitically enclose the small, euhedral garnets. Secondary muscovite occurs as ragged porphyroblasts, and is generally associated either with chlorite as an alteration of biotite or with carbonate patches as an alteration of plagioclase. Sericite or muscovite alterations of sillimanite aggregates were observed in a few thin sections. Anhedral, rounded and skeletal magnetite is the most common opaque phase, followed by slightly oxidized pyrite. Zircons are found as large, clear single crystals, and as inclusions in biotite.

The banded calcareous schist contains quartz, vesuvianite, calcite, chlorite, and minor rutile with accessory apatite and zircon. Quartz occurs as amoebic to cuspate grains, and as lenselike domains parallel to the banding.

The microcrystalline garnet-quartz rock (analysis below) consists of about 70 percent pink to red garnet and about 20 percent quartz with minor biotite, muscovite, ferristilpnomelane, and abundant magnetite. Garnets form solid to loose aggregates of rounded grains well under 0.05 mm in diameter, and quartz forms an interstitial polygonal intergrowth. Flakes of muscovite and chlorite, and fine grained ferristilpnomelane patches occur in the quartz network. Brown biotite flakes form loose clusters. Anhedral magnetite grains are disseminated throughout.

The grey metasandstones consist essentially of quartz, plagioclase, ?clinopyroxene, and amphibole with abundant accessory magnetite, xenotime, sphene, zircon, and pyrite. Clinozoisite, zoisite, coarse muscovite, and patchy carbonate overprint plagioclase, especially near late fractures. There may be several varieties of amphibole present, but the predominant variety is a very pale green, fibrous tremolite. Clear, high relief ?clinopyroxene is preserved as remnants within patches of amphibole.

The siliceous schist (analysis below) is composed of quartz, biotite, cummingtonite, and gedrite with accessory fine grained opaque minerals and apatite. Quartz is most abundant, and forms ribbon-like, polygonized stringers parallel to the schistosity. Red brown biotite, polysynthetically twinned cummingtonite, and well cleaved, high relief, biaxial positive gedrite occur in subequal proportions as oriented segregations between the quartz domains. Magnetite is disseminated sparsely.

Sheared rocks in the southeast contain muscovite, epidote minerals, and local kyanite, as well as garnet additional to the above assemblage. The most highly deformed rocks, which form the scaly mounds, are very fine grained. Quartz is very fine grained, and overprints all minerals. Biotite is completely leached to pale coloured unidentified mica decorated with abundant, powdery, brown ilmenite grains. Muscovite porphyroblasts and fibrolite bundles are common locally. Plagioclase is partly sericitized, muscovitized, or fibrolitized in many places. Rare crystals of kyanite occur in rocks also containing fibrolite bundles. Large skeletal to poikilitic garnets with quartz inclusions are common, and are commonly surrounded by zones lacking ferromagnesian constituents. Opaque minerals are either highly oxidized or leached. Less highly deformed rocks in this area are medium to coarse grained. Garnets are much larger than in the 'nonmetasomatized' rocks, and contain abundant inclusions of quartz, plagioclase, biotite, opaque minerals, fibrolitic sillimanite, and rare ferristilpnomelane aggregates. Where these inclusions coalesce with the matrix, the garnets are dendritic, a feature shared by the enclosing granitoid rock. Polycrystalline garnet clots, similar to the microcrystalline garnet-quartz rocks described above, appear in a few samples. Plagioclase is largely replaced by muscovite or locally overprinted by clinozoisite, or both. Quartz generally forms large grains marginally overprinting both plagioclase and micas in many places.

Retrograded gneisses next to the SBhsz display chlorite and muscovite replacing the biotite-sillimanite segregations. Chlorite also replaces the margins and fractures in garnet grains. Epidote is abundant.

Table 9: Geochemistry of two metasedimentary inclusions, Dinosaur Pond belt.

<u>Analyses of microcrystalline garnet-quartz rock (80 LC 186) and cummingtonite and gedrite bearing siliceous schist (80 LC 198)</u>

(wt.%)	SiO_2	Al_2O_3	Fe_2O_3	FeO	MgO	CaO	Na_2O	K_2O	TiO_2	MnO	P_2O_5	LOI
80LC186	58.2	12.90	10.23	10.83	2.09	2.31	.13	.10	1.28	,78	.22	nil
80LC198	82.0	6.25	.13	2.90	3.12	1.57	.22	.85	.38	.07	.11	1.89

(ppm)	Ba	Sr	Rb	Cr	V	F	Cu	Zn	Ni	Li	Mo	Pb
80LC186	58	29	3	34	127	156	11	144	35	4	3	nd
80LC198	177	54	20	521	67	1255	6	47	91	18	3	2

13.3 KEEPINGS GNEISS

Definition and distribution:

The Keepings Gneiss (Cooper, 1954) is a mainly felsic paragneiss and orthogneiss exposed in Terrane I around Morg Keepings Brook. At least part of the orthogneiss is related to the highly deformed, synkinematic granodiorite-tonalite intrusion surrounding the Keepings Gneiss to the northwest and northeast. Little deformed quartz gabbro-diabase cuts the gneiss to the south.

Lithology:

The prevalent rock type in this unit is banded quartzo-feldspathic gneiss or schist. Quartzofeldspathic layers 1-4 cm thick, alternating with thinner layers enriched in ferromagnesian minerals and muscovite, are the most common form of banding. Such bands may persist for several metres, but neighboring outcrops may display only gradational changes in mineral proportions. Pinstripe banding marked by biotite stringers occurs locally, especially where the layering is tightly buckled. Some exposures consist exclusively of very fine grained, granular, quartzo-feldspathic rock which contains small quartz lenticles and resembles deformed felsic volcanic rocks. In Cascade Brook, crossbeds and quartzofeldspathic pebble lenses indicate that at least some of these rocks are sedimentary in origin. The rocks are locally cut by granitic stringers of several ages, giving them a migmatitic appearance.

Amphibolite is infolded with the felsic rocks along Morg Keepings Brook and is included as xenoliths and rafts in the Northern Granite and younger plutonic rocks. Medium to fine grained amphibolites exposed in a tributary of Fox Hole Brook and inliers in the felsic rocks along Morg Keepings Brook are mafic in composition; isolated outcrops of coarse grained amphibolite are either amphibolitized pyroxenite or hornblendite.

The early layering in the felsic gneisses may record an early structural event, although no evidence of associated folding of an even earlier layering was observed in outcrop. The main fabric in outcrop is the gneissic segregation of melanocratic minerals, which is randomly oriented in areas of open folding, but tends to be aligned parallel to axial planes in areas of tight folding. In several places, mica flakes lie parallel to the plane of segregation, producing a well defined parting. Many of the felsic rocks exhibit only crude parting or fracture cleavage.

Petrography:

The felsic paragneisses consist of varying proportions of quartz, plagioclase (oligoclase-andesine), biotite, and garnet, with accessory tourmaline (schorl) and opaque minerals. Felsic orthogneisses contain microcline and muscovite as well as the above assemblage. Fibrolite has locally been developed inside muscovite flakes. Chlorite occurs as a alteration of biotite in some specimens.

The amphibolites consist of a granoblastic intergrowth of green hornblende and plagioclase (andesine) with minor interstitial quartz, and accessory apatite and garnet. The andesine is locally saussuritized, and randomly oriented flakes of biotite overprint hornblende in places. Late fractures commonly contain epidote.

13.1 Photomicrograph of feldspathic peridotite showing folded stringers of granoblastic plagioclase. (DD-80-358, plane polarized light)

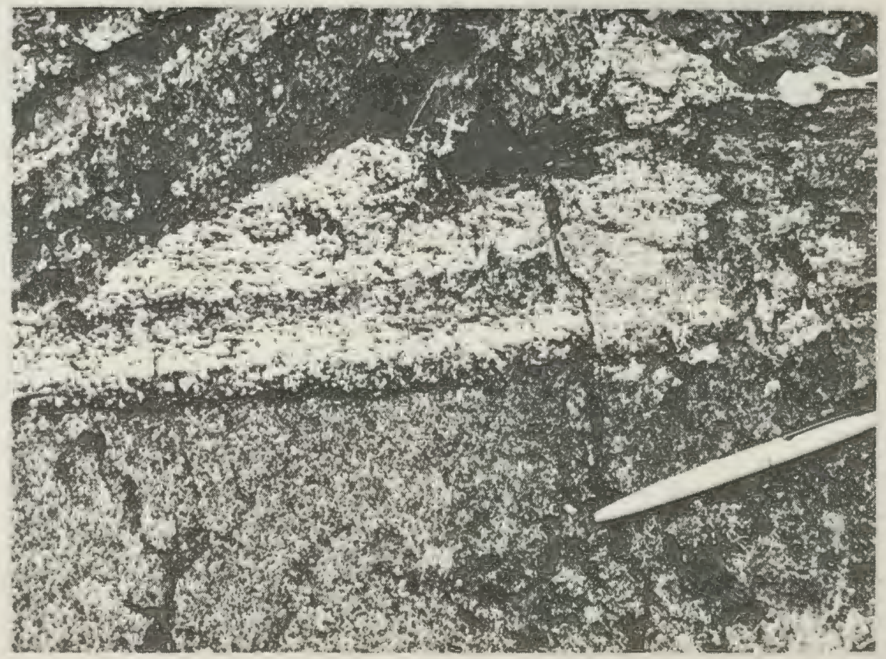
13.2 Layered metagabbro showing plagioclase-rich layers.

13.3 Layered metagabbro showing possible truncated layering or attenuated nose of tight fold.

13.4 Photomicrograph of olivine metagabbro of layered metagabbros, showing deformed and recrystallized clinopyroxene (cpx) and olivine (ov). Also showing grains of magnetite (mag) and Mg-spinel rimmed with brown hornblende (h). (80-LC-17, plane polarized light)

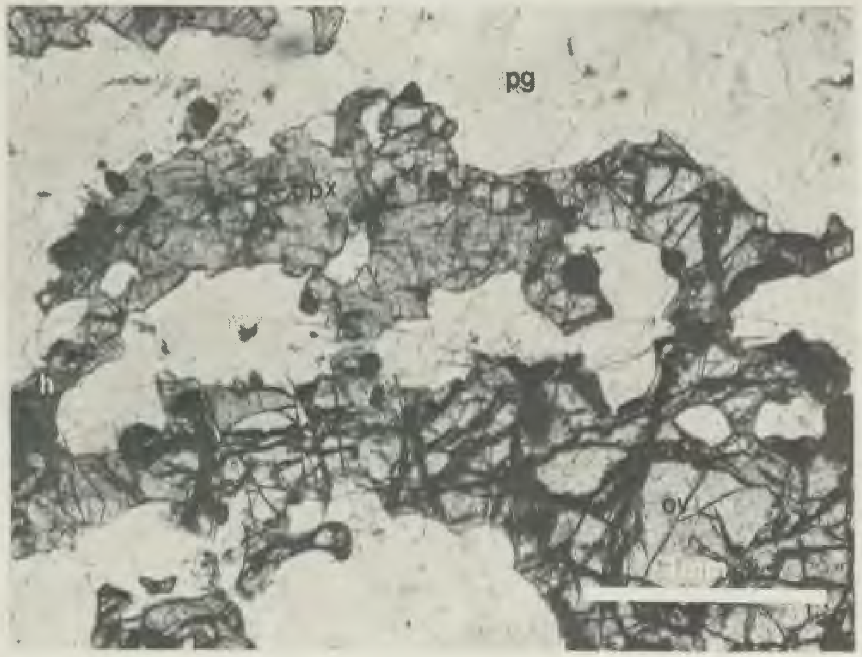
13.2

13.1



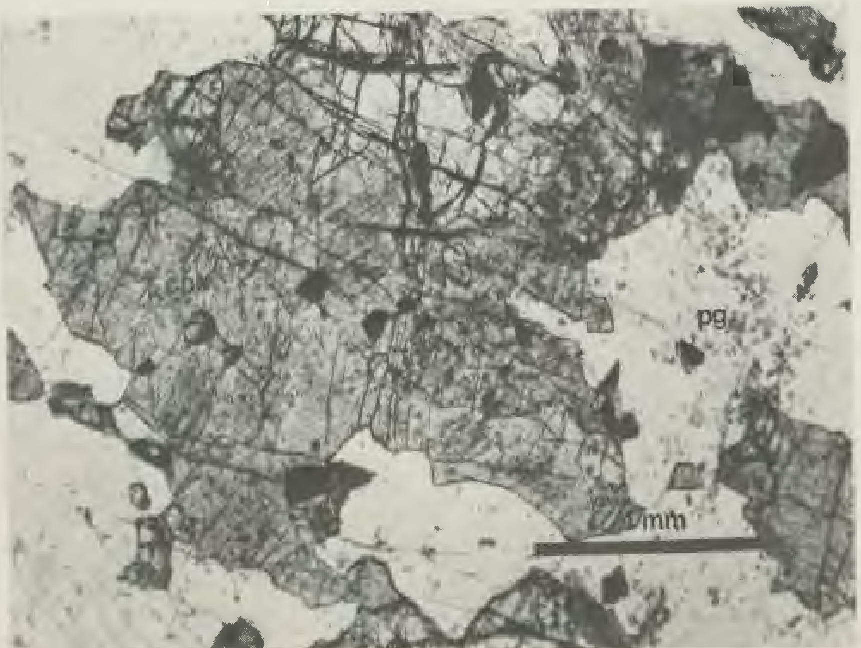
13.5 Photomicrograph of olivine metagabbro showing foliation defined by deformed and recrystallized olivine (ov), clinopyroxene (cpx), brown hornlende (h), and granoblastic plagioclase (pg). (80-LC-12, 13.5a: plane polarized light;
13.5b: cross polarized light)

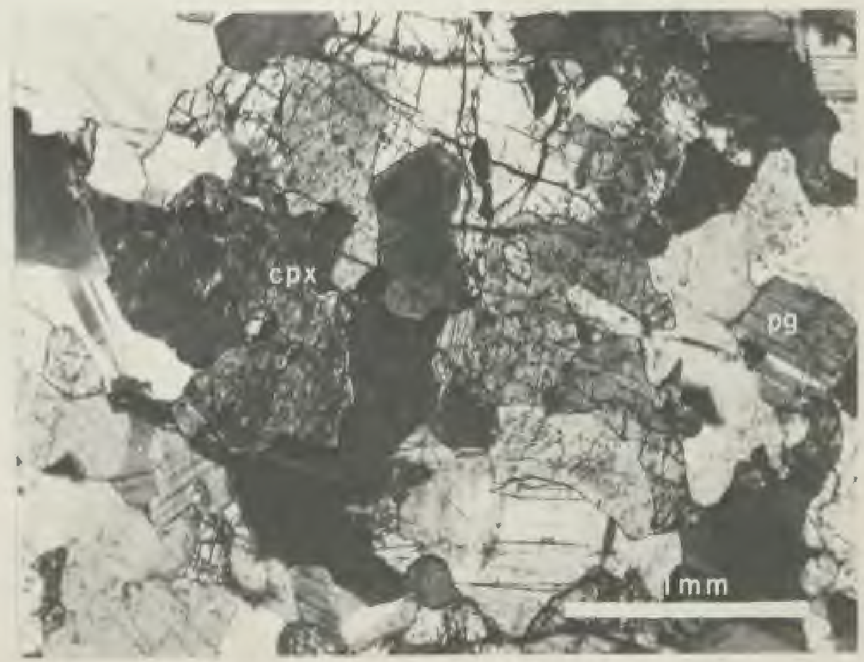
13.6 Photomicrograph of recrystallized clinopyroxene aggregate (centre) in layered metagabbro. (80-LC-17, 13.6a: plane polarized light;
13.6b: cross polarized light)



13.5a

13.5b



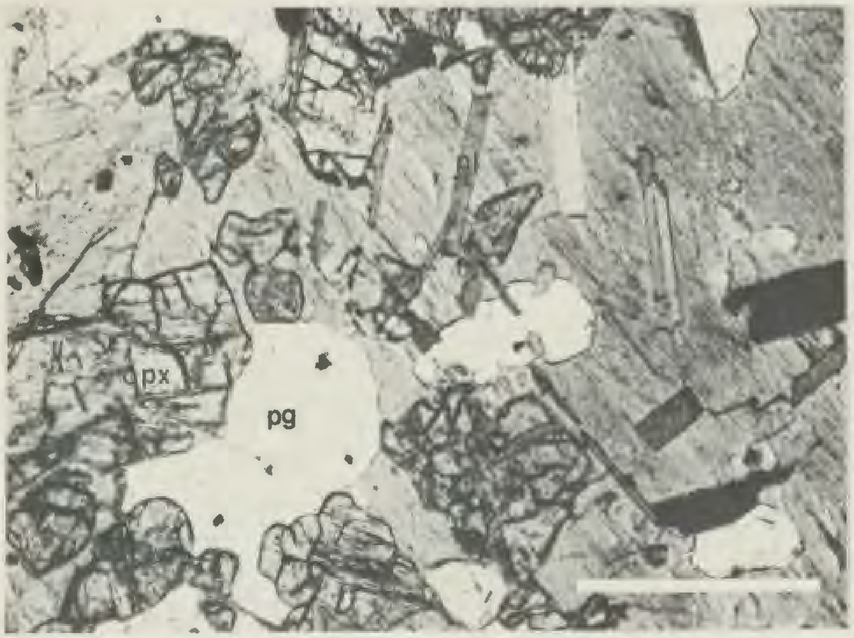


13.7 Photomicrograph of gabbronorite with cumulus grains of orthopyroxene (opx), phlogopite (pl) and plagioclase (pg) ophitically enclosed in intercumulus clinopyroxene (cpx). (DD-80-359, plane polarized light).

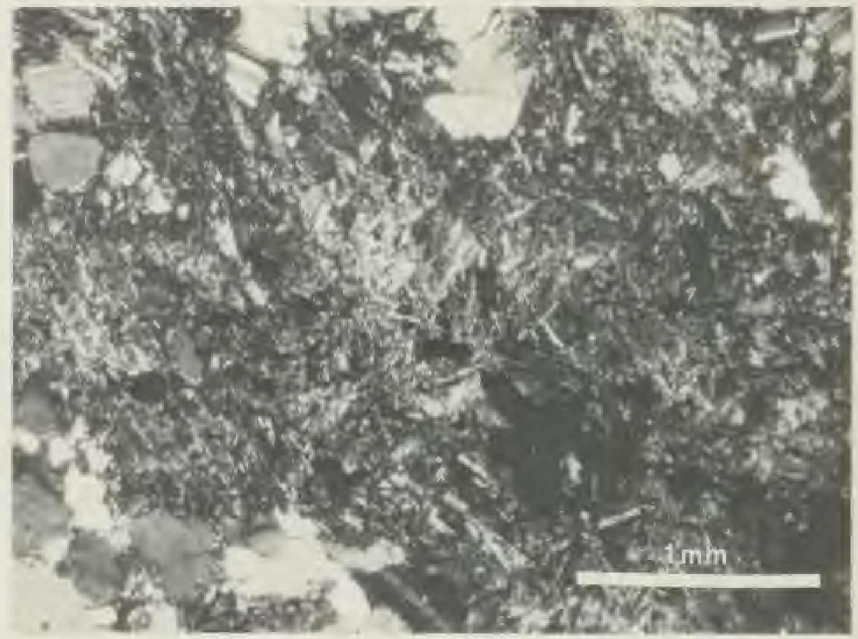
13.8 Photomicrograph showing effect of type 1 amphibolite facies retrogression in layered metagabbro. Coarsely polygonal blue-green hornblende has replaced ferromagnesian minerals. (DD-80-343, plane polarized light)

13.9 Photomicrograph of a ferromagnesian patch in the layered metagabbro; recrystallized fine grained polygonal blue-green hornblende. (DD-80-342, plane polarized light)

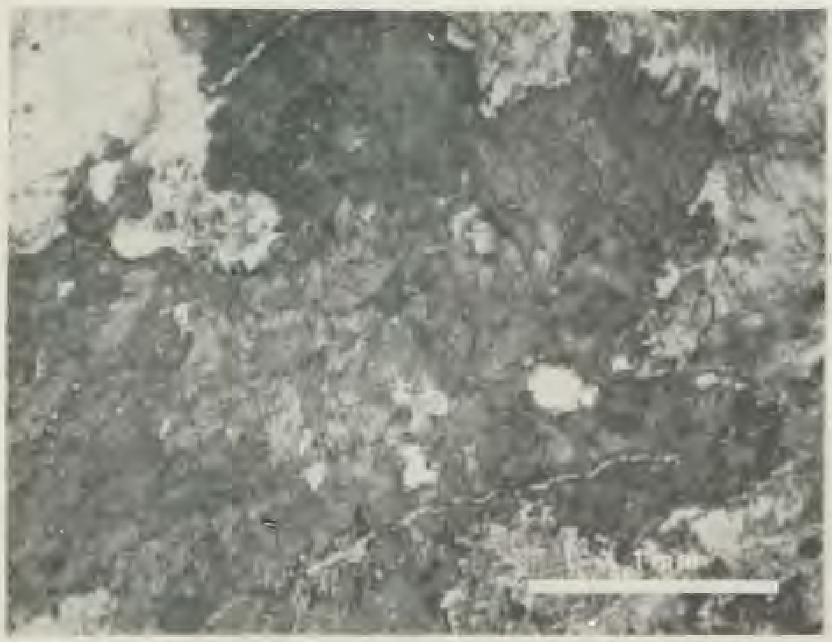
13.10 Photomicrograph showing type 2 greenschist facies retrogression in layered metagabbro. (DD-80-357, cross polarized light)

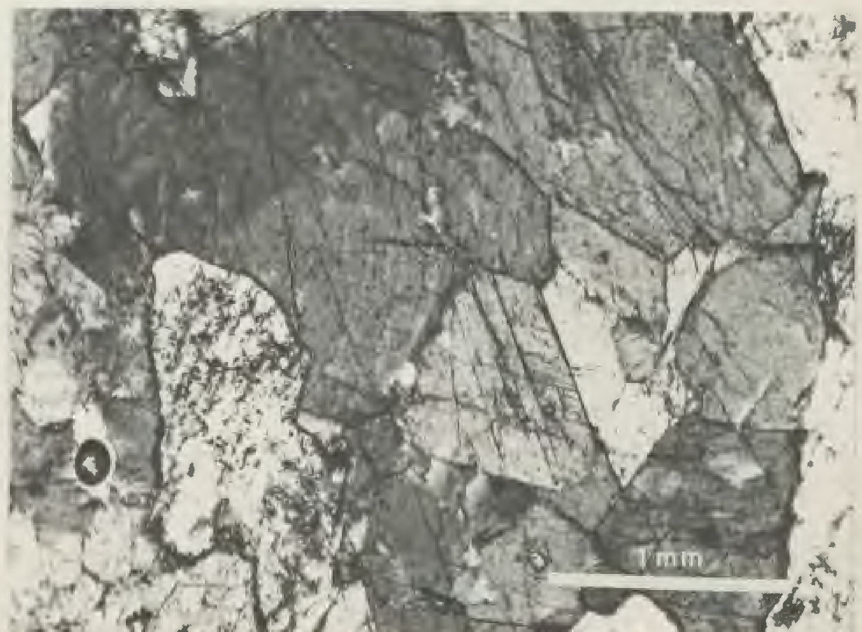


13.7



13.8





13.11 Varitextured subophitic metagabbro southwest of Doughball Pond.

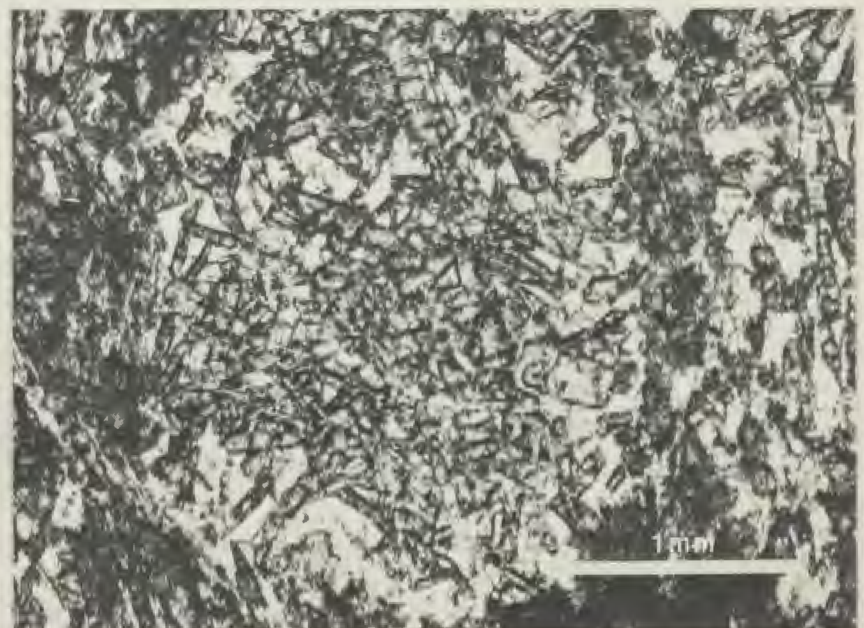
13.12 Plagiogranite veining southwest of Doughball Pond.

13.13 Mafic metavolcanic and hypabyssal rocks veined with tonalite. Relatively competent patch in north-central high strain zone.

13.14 Photomicrograph of plagioclase phenocryst replaced by prismatic zoisite in metabasalt from Coal Brook. (81-LC-25, plane polarized light)

13.11

13.12

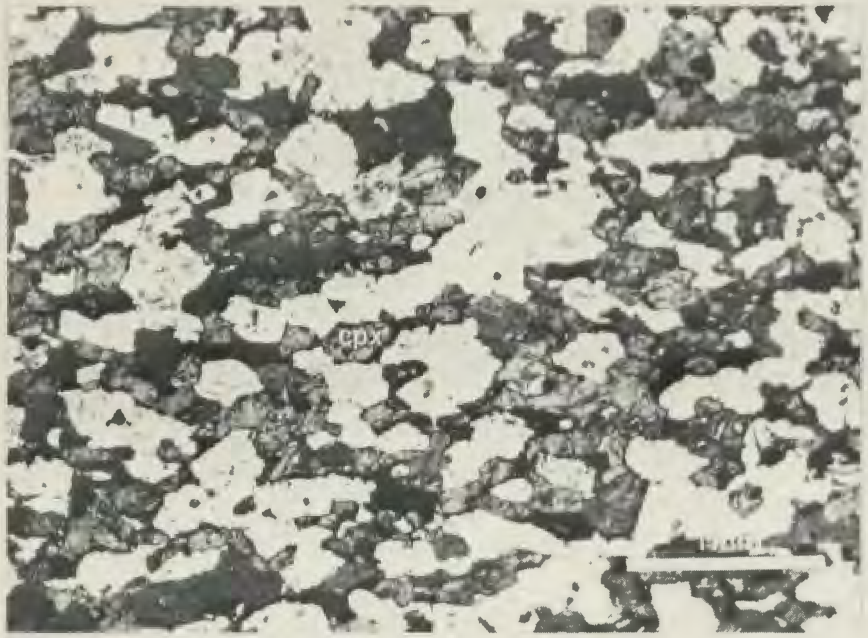


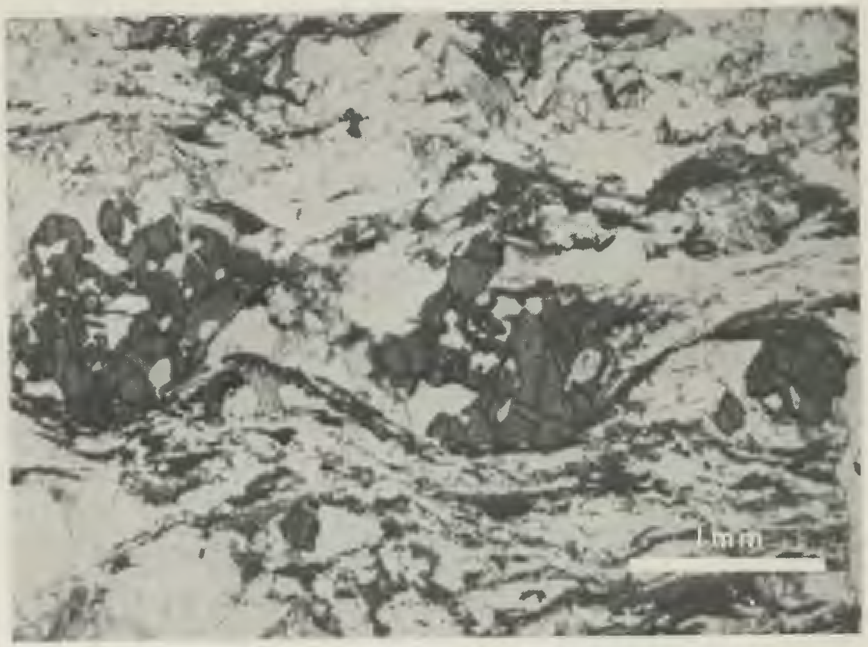
13.15 Photomicrograph of fine grained clinopyroxene (cpx)-bearing amphibolite near Litte Codroy Brook. (80-LC-419, plane polarized light)

13.16 Photomicrograph of fragmented garnet augen offset in crenulation of leucocratic mylonite next to marble band, Stag Hill-Long Range high strain zones. (80-LC-349, plane polarized light)

13.17 Boudinaged red granite (unit 7d) vein in marble, South Branch River.

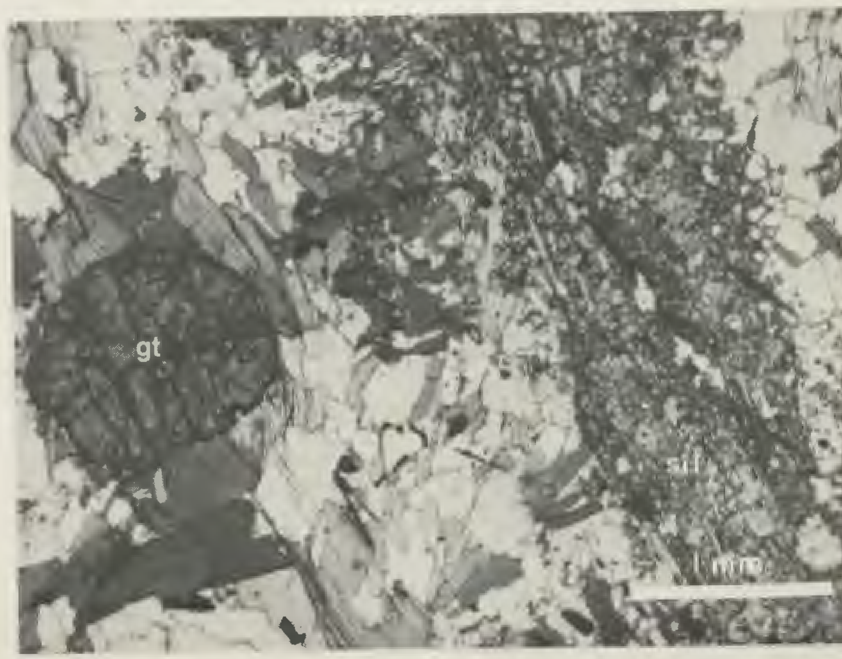
13.18 Photomicrograph of garnet (gt) and sillimanite (sil)-bearing gneiss, north-central high strain zone. (80-LC-223, plane polarized light)





13.15

13.16



CHAPTER 14: LA POILE RIVER GROUP

14.1 SUBDIVISION OF THE LA POILE RIVER GROUP

The La Poile River Group is subdivided on Map 1 into the largely metasedimentary and amphibolitic Bunker Hill Brook Gneiss (Unit 3a and 3c) and Round Hill Brook Phyllite (Unit 3b), and the metavolcanic Carrot Brook Formation (Unit 4a), Georges Brook Formation (Unit 4c), and Dolman Cove Formation (Unit 6). Other metasedimentary and volcanic rocks (Unit 4b) between Northeast Arm and Grandys Brook #2 are continuous with the Carrot Brook Formation, and are probably also related to the easternmost part of the Georges Brook Formation.

Subvolcanic diorite, gabbro, and pyroxenite (Unit 4e), unnamed dykes (thick dashed lines), Baggs Hill Granite (Unit 5a), Piglet Brook Rhyolite (Unit 5b), and Roti Granite (Unit 5c) are also included in the La Poile River Group, and constitute important components of the volcanic centre. Metagabbro like that exposed on the Blue Hills of Couteau (Unit 4f) and some of the subvolcanic mafic metaplutonic rocks of Unit 4e) may constitute, in metamorphically and structurally reconstituted form, important components of the basement of the metasedimentary rocks away from the centre.

14.2 BUNKER HILL BROOK GNEISS (Units 3a,c)

14.2.1 Makeup of the Bunker Hill Brook Gneiss

The Bunker Hill Brook Gneiss encompasses the polydeformed metasedimentary and amphibolitic schists, gneisses, and migmatites exposed between the Port aux Basques-Rose Blanche coastline and the northeast corner of the study area. The metasedimentary rocks (3a) are largely semipelitic and pelitic. The amphibolites (3c) vary from largely metagabbroic rocks which form extensive outcrop areas interrupted only by the granitoid sheets, to fine grained amphibolite which forms thin bands, lenses, or boudins interdigitated with metasedimentary rock.

The Bunker Hill Brook Gneiss is traversed by the Gunflap Hills fault splay, which separates like rock assemblages showing contrasting degrees of retrograde metamorphism associated with second deformation (D_2(TII): Section 9.3) and later deformational effects.

14.2.2 Metasedimentary rocks (Unit 3a)

Lithology:

The metasedimentary rocks consist largely of: (a) sparsely to profusely garnetiferous 'salt and pepper' biotite schists, and (b) garnet, staurolite, and kyanite and/or sillimanite bearing, micaceous schists. Both varieties are migmatitically veined in the centre and northeast part of the study area (Plate 14.1). In veined rocks, kyanite is absent, sillimanite is present locally, and fine grained muscovite pseudomorphs of staurolite are recognizable in some rocks.

Bedding in the 'salt and pepper' schists is reflected by gradations in garnet and/or biotite content, and locally by calc-silicate layers splotched with dark green amphibole. Bedding in the staurolite schists is reflected by varying proportions and grain size of staurolite, garnet, kyanite (if present), and muscovite; bedding is also indicated by pink coticules, thin layers of microcrystalline garnet-quartz rock which probably originated as clay bands.

In general, the earliest schistosity (S_1) is parallel to the compositional banding, and in many places is only preserved in the cores of large staurolite and garnet porphyroblasts. The predominant foliation is S_2, which either transposes both the compositional banding and S_1, or is related to tight F_2 folds. S_2 is cataclastic, and locally mylonitic in the northeastern wedge. S_2 is locally transposed, crenulated, folded, or crosscut by a later regionally developed foliation, S_3, which has different styles and intensities in different places. Large porphyroblasts form augen in S_2 in most areas, and are variably rotated or fractured by S_3.

Quartzitic sweats, and anatectic veins transitional to synmetamorphic granitoid sheets, post-date the first deformation, and are generally concordant (and multiply-folded) with the bedding and early foliation.

Petrography:

The 'salt and pepper' schist is composed largely of quartz, plagioclase, biotite, muscovite, local garnet, and local sillimanite with accessory apatite, zircon, magnetite, and rare graphite. Tourmaline is absent, or at least rare, west of Garia Brook, but is an abundant accessory mineral near the Round Hill Brook Phyllite and the volcanic pile. Leucocratic veins consist of coarse grained quartz, plagioclase (oligoclase), muscovite, and rare fibrolite. The veins, and a strong foliation (S_1 11 S_0)*, defined by preferred orientation of micas and the dimensional preferred orientation of quartz and feldspar, are either buckled or crosscut by a later, oblique foliation (generally S_2, but locally S_3) along which new micas have developed. // Strained to unstrained grains of quartz are associated with unaltered plagioclase (oligoclase-andesine). Intergrain boundaries are generally curved to irregular. Plagioclase in the veins is heavily occluded, and both quartz and plagioclase are intensely deformed. // Biotite in most of the schists is dark olive brown, but is red brown near the Cape Ray Fault and the high strain zones around Garia Brook

* 11 means parallel to - see also page 343.

and the upper reaches of the La Poile River. // Muscovite occurs in some rocks as a fabric-forming intergrowth with biotite, but in others as large, ragged porphyroblasts and polycrystalline clots. In several samples, the muscovite is partly converted to fibrolitic sillimanite. // Very small, euhedral to subhedral almandine garnets generally overprint the biotite, and some display a weak tendency to form augen within the S_2 schistosity. Garnets are either inclusion-free or contain small inclusions of quartz, biotite, and fine opaque grains, some displaying a poorly developed planar alignment. // Fibrolite occurs locally in both the quartzofeldspathic intergrowth and veins, and tends to follow the main foliation.

The **calc-silicate bands** contain quartz, plagioclase, biotite, blue green hornblende, and zoned epidote and allanite with accessory sphene, apatite, zircon, and pyrite. Sphene constitutes a minor, rather than an accessory, phase in some layers. Biotite is red brown in colour. Blue green hornblende is concentrated in patches and forms inclusion-free to poikilitic prisms which are locally crosscut by biotite. Epidote forms large, colourless, prismatic grains, many with cores of brown allanite. Rare poikiloblasts of plagioclase were also observed. Zircon occurs both as inclusions in the biotite and as large, single prismatic crystals in most of the schists.

The **staurolite schists** are composed largely of quartz, biotite, staurolite, almandine garnet, kyanite, plagioclase, muscovite, and minor fibrolitic sillimanite (Plates 14.2--14.8). Minor chlorite occurs as a late secondary mineral south of the Gunflap Hills fault splay. Zircon, magnetite, apatite, rutile, and rare tourmaline are accessory minerals. In the southwest, the main schistosity (S_2, or S_1 transposed or isoclinally folded parallel S_2) is defined mainly by brown biotite in most of the rocks, but by biotite, muscovite, and kyanite or fibrolite in others. Strained quartz and subordinate plagioclase (oligoclase-andesine) also define this fabric. S_2 is axial planar to tight folds of the earlier compositional fabric or banding ($S_0 \parallel S_1$).* // Staurolite grains several centimeters long enclose abundant, planar to slightly curved inclusion trails of quartz and minor magnetite, and locally enclose single euhedral garnets (Plate 14.2) or numerous tiny garnets. Large grains are generally surrounded by mafic poor rims of flaser quartz, and have asymmetric, quartzitic to quartzo-feldspathic extension fracture fillings and pressure shadows apparently developed during D_2, and possibly D_3 (Plate 14.2). They form augen within the main fabric (S_2) which is steeply to gently inclined to the plane of the internal inclusion trails (S_1). Near Grandys Brook #1, they are also rotated, bent, and annealed in segments by the D_3 crenulation (Plate 14.3). // Garnets are up to several millimeters in diameter, and the largest contain planar inclusion trails of quartz and subordinate magnetite. As in staurolite, the inclusion trails are oriented at negligible

* see page 341

to high angles to the external schistosity (S_2) within which the garnets form augen. // Kyanite, with few irregular quartz inclusions, occurs as locally twinned, elongate grains oriented along the main schistosity (S_2) (Plate 14.4). Where the main fabric is folded or crenulated, the kyanite grains are fractured and the fragments rotated by the crenulation (S_3). Local muscovite/fibrolite fringes occur at the ends of deformed grains. // Very fine fibrolite also radiates locally from late fractures in the quartzofeldspathic intergrowth in rocks near the Cape Ray Fault.

In **the northeastern wedge**, secondary muscovite and chlorite define the S_2 fabric in intensely sheared to mylonitic rocks. S_2 is conspicuously crenulated to openly folded (F_3) locally. Many of the garnets are rimmed or replaced with chlorite.

The coticules are thin, contorted bands, and rarely balls, composed of between 35 and 80 percent very fine (less than .005 mm in diameter) garnet in a matrix intergrowth of quartz with traces of biotite (Plates 14.5, 14.6). The garnets in the surrounding schist are also very fine, and large numbers are locally included in both kyanite and staurolite. Thus, they crystallized before the formation of these minerals and the amphibolite facies metamorphic peak.

Migmatites are derived from both 'salt and pepper' and the more pelitic schists. In most places, leucocratic veins consist either solely of quartz and plagioclase or of coarse grained quartz, plagioclase (oligoclase), muscovite, and rare fibrolite. Some of the veins in sillimanite-rich migmatites of the Gunflap Hills area are composed of quartz, plagioclase (oligoclase), microcline, biotite, muscovite, and almandine garnet. The residual schists are generally composed of biotite, muscovite, plagioclase (sodic oligoclase, An_{15}), and quartz with or without tiny almandine garnets. Tourmaline, apatite, sphene, zircon, clinozoisite, and opaque minerals are common accessory minerals; some are exceptionally abundant in the wide shear zone of the Gunflap Hills fault splay. Nobs of matted fine grained to very coarse muscovite may represent staurolite pseudomorphs. Biotite and muscovite generally defined the earliest penetrative foliation, along which the quartzofeldspathic veinlets developed, and both are singly or multiply-folded or buckled. Sillimanite at the expense of muscovite accompanies coarse biotite along the prominent foliation in some of the Gunflap Hills migmatites.

14.2.3 Amphibolite (Unit 3c)

Lithology:

Amphibolites of the Bunker Hill Brook Gneiss include massive, well foliated amphibolite of uncertain origin, layered, coarse grained amphibolitic metagabbros, and fine grained amphibolite bands, lenses, or boudins. Also included here are gedrite-bearing schists, some of which are not true amphibolites.

The massive amphibolites weather black to dark green in outcrop, and show a strong S-L tectonic fabric. Pinstripe banding, formed by the segregation of light from dark coloured minerals on a scale of one to several grains thick, is well developed in some outcrops. Small, red, subhedral garnets locally overprint the melanocratic layers. The banding is conspicuously chevron to tightly folded (D_3?) in the northeast part of the study area, and relatively large garnets with coronas of plagioclase, and veins of tonalite are common locally.

Metagabbros near Grandys Brook #1 are layered on a scale of 1 cm up to 0.50 m. The layering partly reflects fluctuations in plagioclase content, and partly the hornblende to clinopyroxene ratio. Coarse, dark green hornblende clots are flattened within a weak to strong fabric, but generally appear interstitial to plagioclase. Slightly flattened, corroded, pale green clinopyroxene grains occur both alone and within hornblende-rich aggregates in many samples. In addition, highly contorted, garnetiferous to anthophyllitic, layered metagabbro is exposed along the north side of the Gunflap Hills fault splay; however, these are possibly related to the gedrite-bearing amphibolite and schist (below).

The very fine grained amphibolites weather almost black. A strong planar foliation is developed on a very fine scale.

The gedrite-bearing amphibolite and schist includes gedrite- hornblende-plagioclase and, gedrite-plagioclase amphibolite, and gedrite-garnet-biotite-amphibole-plagioclase schist. Spectacular sheaves of acicular, pale brown gedrite crystals up to 4 cm long overgrow the foliation defined by amphibole and/or plagioclase, but generally are oriented with their long axes parallel to the foliation plane. Some of the gedrite crystals appear dark green due to minor alteration around the margins; this is particularly evident in the northeast, between the Cape Ray Fault and the Gunflap Hills fault splay. Garnets within the gedrite-garnet-biotite-amphibole-plagioclase schist are large in contrast with those contained in the garnet amphibolite. In partly retrograded garnet-gedrite schists along the Cape Ray Fault in Billiards Brook, garnets form fist-sized aggregates, flattened in the cataclastic foliation of the fault. In some of the gedrite schists in the Gunflap Hills fault splay, gedrite crystals have been cataclastically fragmented and altered, imparting pale green hue to the entire rock.

Petrography:

The **massive amphibolites** are generally composed of blue green hornblende and plagioclase with minor local garnet or local salite, and accessory zircon, apatite, and local opaque minerals, local sphene, or local rutile. Polygonized blue green hornblende and plagioclase (andesine to labradorite) occur in variable proportions as medium to very fine grained, pinstripe granoblastic intergrowths. Near the Cape Ray Fault around Grandys Brook #1, the hornblende is more deeply pleochroic and defines a stronger fabric than away from it, and either sphene or rutile takes the place of opaque minerals. Tiny, inclusion-free garnets have either overprinted or crystallized with the hornblende and plagioclase intergrowth in the garnet amphibolite.

In the northeastern wedge, massive amphibolites also locally contain either salite or garnet. Salite, where present, forms tiny, corroded and fragmented augen in the foliation. Garnet occurs as small grains overprinting the hornblende pinstripe fabric, and displays plagioclase-rich rims locally near the Cape Ray Fault. Blue green hornblende-plagioclase boundaries are fringed with cryptocrystalline clinopyroxene hairs in many rocks.

The layered metagabbros near Grandys Brook #1 are composed of variable proportions of plagioclase, blue green hornblende, and clinopyroxene with minor sphene and accessory apatite, zircon, and rare opaque grains. Secondary carbonate patches are concentrated along late fractures which crosscut the foliation at high angles. Plagioclase occurs as granoblastic lenses or networks (depending on its abundance in the rock) (Plate 14.7b), and ranges widely in composition between andesine and labradorite. Hornblende and clinopyroxene occur as segregations parallel to the foliation plane and banding, but some clinopyroxene grains occur alone (Plate 14.7a).

Blue green hornblende predominates as polygonized grains or grain aggregates (Plate 14.7). Clinopyroxene grains are large or small in proportion to their abundance. They are relatively clear and pale green to colourless, lack remnant diallage, and, if large, poikilitically enclose hornblende, sphene and rare plagioclase but otherwise overprint them. Plagioclase commonly forms marginal embayments in the ferromagnesian minerals. Clinopyroxene crystals are commonly surrounded by thin rims of epidote. Large, euhedral grains of sphene occur outside the pyroxene crystals, and many are recrystallized aggregates.

The layered metagabbro on the north side of the Gunflap Hills Fault splay contains several rock types. Of the three samples sectioned, one consists of deeply pleochroic blue green hornblende, epidote, quartz, and plagioclase; another consists of magnesian anthophyllite, quartz, and plagioclase with several large pink garnets; a third consists of conspicuously poikiloblastic, highly pleochroic blue-green hornblende, plagioclase (anorthite), quartz, and coarse opaques. Apatite is an abundant accessory mineral.

One **sample of the fine grained amphibolite** is composed of plagioclase (20 to 30 modal percent), blue green hornblende (about 40 percent), quartz (about 10 percent) with minor opaque minerals (about 2 percent), and abundant late secondary epidote and biotite. Apatite is a common accessory mineral. Blue green hornblende occurs as intensely pleochroic, acicular, prismatic grains up to 0.7

mm in length, which are aligned parallel to the strong foliation. Plagioclase grains are completely sericitized, and occur in bands several grains thick which are overprinted by tiny, clear quartz grains and stringers. The fabric is randomly overprinted by flakes of olive green biotite and abundant, coarse, patchy yellow to colourless epidote crystals.

The gedrite-bearing amphibolites and schists are variable in mineralogy. **Gedrite amphibolites** consisting largely of gedrite, blue green amphibole, local biotite, minor local quartz, and plagioclase with accessory sphene (Plate 14.8) and apatite grade locally into those consisting solely of gedrite, plagioclase, quartz, and accessory hematite (Plate 14.9). A strong planar fabric (S_1-S_2) is defined by the inequigranular intergrowth of plagioclase (oligoclase), subordinate quartz, and highly acicular, locally kinked, blue green amphibole. Gedrite occurs as large, euhedral crystals which poikilitically enclose quartz inclusions, which cut across acicular amphiboles defining the earliest planar fabric (S_1) (Plate 14.8). In one section, the quartz inclusions occur in planar arrays. The gedrite locally forms weak augen within the S_2 schistosity in some rocks (Plate 14.10), and is affected by the crenulation S_3. It is colourless to weakly pleochroic (Z=purplish tan; Y=smokey tan; X=yellowish tan), and is biaxial positive. The hornblende commonly contains (001) exsolution lamellae, indicating the presence of another amphibole phase.

Gedrite amphibolites of late cataclastic zones (D_3 in the southwest and both D_2 and D_3 in the northeastern fault wedge) are particularly altered, generally with the partial destruction of the distinctive, feathery texture. In one specimen of gedrite amphibolite collected from a mylonite zone along the south side of the Cape Ray Fault near Grandys Brook #1, the plagioclase and gedrite form porphyroclasts in feldspathic, mylonitic banding (S_3), and the gedrite crystals are partly replaced by fibrous chlorite, khaki green biotite, and traces of ferristilpnomelane. Several unaltered gedrite fragments are isolated along the foliation. In the Gunflap Hills, gedrite crystals show all degrees of alteration to fine grained serpentine and/or chlorite. Highly altered rocks are commonly interlayered with rocks composed largely of actinolite and plagioclase, probably retrograded amphibolite. In a few gedrite-rich layers near Wiggly Pond, coarse, kinkbanded, black to brown biotite or phlogopite forms a strong foliation, apparently overprinted by gedrite, and also fractured and kinked. Fractures and grain boundaries are serpentinized.

Gedrite-bearing schist consists of blue green amphibole, gedrite, biotite, plagioclase, garnet, and quartz with accessory hematite and secondary chlorite (Plate 14.11). Large, euhedral gedrite crystals crosscut the strong planar fabric defined by red brown biotite and abundant, acicular, blue green amphibole, and display quartz-filled tension gashes and form very weak augen within S_2 (Plate 14.11). They are rotated and slightly displaced by the crenulation cleavage (S_3) which affects the penetrative fabric. Garnets are generally large and are also affected by the crenulation cleavage. The blue green amphibole is highly acicular, commonly bent or kinked, and shows moderate pleochroism (Z=blue green; Y=grass green; X=colourless); it may be actinolite rather than hornblende. Plagioclase is slightly more abundant than quartz, is both pericline and albite twinned, and approximates andesine in composition.

14.3 ROUND HILL BROOK PHYLLITE (Unit 3b)

Lithology:

The Round Hill Brook Phyllite consists of laminated, graphitic phyllite with interbeds of coarser psammitic and semipelitic schist, and locally abundant felsic volcaniclastic lenses and thin amphibolite bands.

Sedimentary structures in the phyllite are best displayed in the North Bay-Round Hill Brook and Grandys Brook #1 areas, but is intensely strained in the intervening area, probably because the phyllite has sited a high strain zone which has been overprinted by intense deformation associated with the Gunflap Hills fault splay.

Around North Bay and Grandys Brook #2, graphite--bearing biotite-muscovite phyllite with thin, very fine grained, graded, quartzitic siltstone beds contains interbeds of greywacke, about 6 cm thick, and lenses of quartz-feldspar-rhyolite granule conglomerate. Outcrops of the phyllite in the high strain zone consist of highly foliated and crenulated, shiny, dark gray mica schist without visible primary laminations or bedding, although boudins of metasiltstone with sandy lenses are preserved locally.

Petrography:

The phyllite is generally composed of biotite, muscovite, and quartz with or without graphite in layers which alternate with fine grained, quartz-rich layers containing either biotite porphyroblasts or actinolite sprays with minor calcite. Accessory minerals include anhedral opaque minerals, tourmaline, local epidote, and rare garnet. In many of the rocks, muscovite and/or biotite and/or graphite define an early schistosity parallel to banding. Small porphyroblasts of biotite, and rarely muscovite, are crosscut by a crenulation cleavage defined by biotite-chlorite intergrowths or muscovite. Elongate opaque grains in many samples are reoriented along this crenulation cleavage, producing a pinstripe segregation. Conjugate crenulation cleavage was noted, especially in early (F_1) fold hinges.

Phyllite between Two Way and Mouse Pond Brooks consists of highly foliated tourmaline-biotite-muscovite-graphite-quartz schist (Plate 14.12). Tourmaline (schorl) constitutes from 10 to 20 percent of the rock. The alignment of tourmaline, muscovite, and biotite-chlorite intergrowths defines the main schistosity, which forms augen around rare porphyroblasts of garnet and is markedly crinkled.

14.4 CARROT BROOK FORMATION (Units 4a,b)

Makeup of the Carrot Brook Formation:

Regionally metamorphosed volcanic and related rocks east of North Bay, and lateral equivalents, are assigned to the Carrot Brook Formation. The formation includes felsic metavolcanic to volcaniclastic rocks and interbedded metasiltstone, and metagreywacke or semipelitic schist from the terrane around Carrot Brook to Mouse Pond. It also includes mafic volcanic amphibolites around the Blue Hills of Couteau south to the Bay d'Est Fault. Quartzofeldspathic sandstone and siltstone with interbeds of felsic lapilli tuff, agglomerate, and conglomerate are exposed on the north shore of Northeast Arm and the west shore of La Poile Bay, and these rocks apparently continue west of the La Poile batholith around Garia Bay (Map 1). The tuffaceous component in the latter rocks decreases eastward from Northeast Arm, and semipelitic schists and metaconglomerate are prevalent around the Phillips Brook and Couteau Brook areas, and are migmatitic from Couteau Brook eastwards.

Metaconglomerate near contacts with the overlying Dolman Cove Formation contains clasts derived from the unroofed, subvolcanic Baggs Hill Granite, and is thought to represent the top of the Carrot Brook Formation. This 'datum plane', also marked by the Piglet Brook Rhyolite, includes the conglomeratic metasedimentary or volcaniclastic rocks which are exposed as a thin band along the northwest side of the Dolman Cove Formation at its southwest end and as the broader wedge of semipelitic schist and metaconglomerate between Northeast Arm and Couteau Brook. The volcaniclastic rocks from the Blue Hills of Couteau towards the east and southeast probably also belong to this horizon.

Lithology:

The felsic metavolcanic rocks consist of massive, indurated rhyolite tuff and pyroclastic rock, which occur as 10 to 100 m thick bands of cream coloured, fine grained tuff, lapilli tuff, agglomerate, and flowbanded rhyolite or laminated tuff. Faint outlines of rhyolite fragments, crystal clasts, and small mafic-rich patches are discernable in many outcrops, and flowbanding and globular pockets 5 to 10 mm across, which may have originated as spherulites, were observed locally in one rhyolite band. Intensely deformed, grey to pink weathering quartz keratophyre, with abundant, indistinct, phenocrysts of feldspar and quartz, is found near the northwestern contact of the Dolman Cove Formation.

Mafic volcanic rocks between the Blue Hills of Couteau and the Bay d'Est Fault consist of either metabasalt with calc-silicate filled vesicles interbedded with felsic tuff and mafic volcaniclastic rocks, or massive, very fine grained amphibolite.

The volcaniclastic rocks consist of lapilli tuff and agglomerate intercalated with poorly stratified rhyolite cobble and pebble conglomerate (Plate 14.13) and tuffaceous graywacke. These rocks contain lenses rich in rhyolite and quartz and feldspar crystal clasts, with rare black slate and siltstone clasts. The matrix may be either garnet and biotite or actinolite and biotite bearing quartzofeldspathic schist, the higher ferromagnesian content of which serves to distinguish these rocks in the field from the massive felsic volcanic rocks. Finely speckled, garnet-biotite and actinolite-biotite schists without macroscopic rock fragments are prevalent locally, and probably represent metasiltstones and metasandstones (described below).

The metasandstones and metasiltstones of western shore of La Poile Bay and north shore of Northeast Arm (Plate 14.14), are quartzofeldspathic to siliceous in composition, and are interbedded with reworked rhyolite tuff. Ungraded beds of coarse to medium grained, tuffaceous metasandstone, with clasts of quartz, feldspar, and rhyolite, vary in thickness from approximately 10 to 35 cm. Ovoid carbonate concretions were observed in these beds just south of Broad Cove in La Poile Bay. The siltstone beds are 3 to 5 cm thick, and show parallel lamination and rare, indistinct scours.

The semipelitic schists, metaconglomerate and migmatite exposed in the Phillips Brook-Couteau Brook area, and locally north of the Dolman Cove Formation contact, resemble the metasedimentary portion of the Bunker Hill Brook Gneiss, apart from the presence of metaconglomerate. The schists similarly vary from sparsely garnetiferous, 'salt and pepper' biotite schists to staurolite schists. The migmatitic rocks are staurolite-free, and contain veins of white trondhjemite to granodiorite. The 'salt and pepper' schists commonly display thin, calc-silicate bands and pods or boudins. The polymictic metaconglomerate varies from clast-supported to matrix-supported, containing pebbles, cobbles, and rarely boulders, of siltstone, rhyolite, subvolcanic Baggs Hill granite and granophyre, and rare vein quartz in a matrix of either 'salt and pepper' schist or feldspathic crystal tuff. The fragments are highly strained, and elongated parallel to the prominent regional trend and fold axes.

Polymictic cobble to boulder conglomerate thickly interbedded with felsic to mafic lapilli tuff and greywacke, cut locally by mafic (amphibolite) dykes, is exposed just east of Grandys Brook #2; this unit is apparently a highly strained, amphibolite facies equivalent of the greenschist facies Georges Brook volcanic metaconglomerate and metasandstone south of the Bay d'Est Fault in the same area. The clasts in the metaconglomerate include rhyolite or microgranite porphyry, aphanitic rhyolite, felsic to intermediate tuff, pink felsite (Piglet Brook Rhyolite?), vein quartz, and metabasalt in variable proportions. The quartzofeldspathic matrix contains biotite, muscovite, rare garnet, and abundant fine grained magnetite. The boulders and cobbles are stretched.

Petrography:

The massive felsites consist mainly of a very fine grained intergrowth of quartz, plagioclase, microcline, and muscovite with sparsely distributed crystals of embayed, polygonized quartz and plagioclase (oligoclase-andesine), and rare flakes of normally red-brown, but locally khaki-colored, biotite and/or actinolite, and/or local rutilated chlorite. Coarse zircon and sphene are abundant accessory minerals in places, apatite in others; garnet, tourmaline, and epidote are rare. Coarse grained, quartz patches and stringers are ubiquitous in highly deformed rocks. In these domains, hematitic staining is common, especially near sulphide showings; also, cordierite was observed near one showing near Big Pond (Stackhouse, 1976). The thin flow bands and globular spherulites northwest of Complicated Pond are comparatively fine grained and enriched in muscovite (Plate 14.15).

The quartz keratophyre contains phenocrysts of feldspar and quartz in a matrix of fine grained plagioclase, checkered albite, and quartz with minor biotite, blue green hornblende, and accessory opaque minerals. The feldspars are more abundant than quartz. Plagioclase (albite, An_5) is locally the sole feldspar phenocryst phase and occurs as laths elongated parallel to [100] with narrow marginal fringes of checkered albite. Finely crosshatched microcline, present in some samples, internally encloses small, amoebic quartz patches. The quartz phenocrysts are rounded, with volcanic embayments. In highly strained, altered rocks, the feldspars are fractured, quartz exhibits well developed extinction bands, and chlorite appears in place of hornblende.

The, volcaniclastic metasedimentary rocks are petrographically similar to the massive felsites, but the fragmental lenses contain a wider variety of clasts and the matrix is relatively enriched in ferromagnesian components. Clasts of rhyolite, siltstone, crystals of quartz, plagioclase, and rare alkali feldspar, and very fine grained oxide-peppered siltstone or mudstone are common. The matrix consists of quartz, plagioclase, biotite, muscovite, and scarce to abundant, skeletal to rounded almandine garnets. Zircon, sphene, and tourmaline are accessory minerals. Poikiloblastic red-brown biotite is present locally; khaki green biotite porphyroblasts with cores occluded with tiny opaque inclusions were also recorded. Abundant poikiloblastic epidote, though not common, is found lcally in highly deformed and metasomatically altered rocks.

The volcaniclastic metasedimentary rocks without macroscopic rock fragments consist essentially of plagioclase (andesine), quartz, muscovite, biotite, and local almandine garnet with accessory, very fine grained apatite and tourmaline. The proportion of quartz to feldspar varies between 10:1 and 1:3. Radiating actinolite clusters were observed in many outcrops.

Mafic metavolcanic rocks are composed of a coarse to fine grained, pinstripe intergrowth of hornblende and plagioclase, with minor epidote and sphene and locally concentrated platy opaques. The hornblendes are polygonized, and the pinstripe banding is locally crenulated. In some rocks along the north of the Bay d'Est Fault zone, biotite has developed along discrete bands, whereas along the south side of the fault zone chlorite has formed instead.

The metavolcanic and related rocks were variably affected by the regional deformation. Polygonization of quartz crystals, quartz-filled tension gashes, pressure shadows and fringe structures around quartz, feldspar, and rhyolite augen, and veinlets of coarsely recrystallized quartz randomly criss-crossing the regional grain are evidence of strain in the competent felsite bands. Only in the flow banded rhyolite was a micaceous schistosity observed. The crystal and rock fragments of the volcaniclastic rocks form augen in a locally developed, anastomosing micaceous schistosity. No fabric was observed locally in some of the volcanogenic siltstones, and biotite or actinolite porphyroblasts are preserved intact. Large clasts in the agglomerate are highly stretched, imparting a prominent linear fabric, approximately parallel to locally observed fold hinges and the regional linear fabric.

The 'salt and pepper' schist of the Phillips Brook-Couteau Brook consists of garnet, biotite, quartz and muscovite with accessory sphene and tourmaline (schorl). Almandine garnet and red-brown biotite porphyroblasts have formed augen within a weak to strong S_2 biotite or biotite-muscovite fabric, and in some places, fragments of garnet and sphene are strung out in this foliation. The garnets are commonly tabular, possibly due to replacement of an early, fabric-forming biotite segregation (S_1); some thin sections display garnet partly overprinting biotite tablets.

The staurolite schist contains porphyroblasts of staurolite, garnet, and biotite in addition to the mineral assemblage of the 'salt and pepper' schist. The porphyroblasts form augen in a strong muscovite-biotite fabric, also defined locally by acicular or platy opaque minerals. Locally, the staurolite-bearing schists contain kyanite which also forms augen in the foliation, and sparse fibrolite at the edges of large biotite grains. Garnet and the cores of staurolite grains contain planar quartz inclusion trails, generally bent near staurolite grain margins. Both the garnet and staurolite have S-shaped inclusion trails within shear zones north of the Dolman Cove Formation contact, and biotite and garnet are partly chloritized with chlorite flakes also overprinting the matrix.

The calc-silicate bands are composed of an inner zone of epidote and quartz, and an outer zone rich in poikiloblastic actinolite and quartz. Minor plagioclase is intergrown with quartz, and sphene is a particularly abundant accessory mineral.

14.5 GEORGES BROOK FORMATION (Unit 4c)

Makeup of the Georges Brook Formation:

The Georges Brook Formation is a slightly bimodal mafic to felsic metavolcanic suite, with abundant pyroclastic to volcaniclastic and associated epiclastic metasedimentary rocks, which may have been deposited in a partly subaerial and partly shallow marine environment.

The Georges Brook Formation is exposed from the point between La Poile and Roti Bays at least as far east as Grandys Brook #2. The temporal succession of volcanic products and hypabyssal intrusions from place to place can be used to illustrate the evolution and facies relations in the volcanic centre (Table 2, Part I). It is impossible to do justice to the wide variety of rock types in the formation in such a broad regional reconnaissance, so this is left for an independent future study and only a cursory description of a few prominent rock types is presented below.

All of the rocks in the Georges Brook Formation are metamorphosed to greenschist facies; therefore, the prefix meta will be dropped in the following descriptions.

Lithology:

The oldest rocks of the Georges Brook Formation in the southwest consist of fine grained rhyolitic tuff, well bedded felsic to mafic volcaniclastic rocks, flow banded rhyolite, siliceous siltstone, arkose, and rhyolite pebble conglomerate. The oldest rocks in the eastern extension of the Georges Brook Formation are mixed mafic to intermediate flows and felsic volcanic rocks including fine grained rhyolite tuff and quartz feldspar porphyry.

Volcanism following the emplacement of the subvolcanic Roti Granite produced both mafic and felsic volcanic rocks, and associated well bedded sedimentary rocks. The felsic volcanic rocks include flow banded rhyolite, rhyolite breccia, ashflow tuff, and thickly bedded, normally and reversely graded volcaniclastic rocks including laminated ash (Plate 14.16), lapilli tuff, agglomerate, and reworked agglomerate with dune-like crossbeds. Tough, hackly, white weathering, rhyolite ashflow tuff is common, and is locally associated with pebbly tuff and conglomeratic sedimentary rocks. Oxidized layers at or near the flow tops are brick red to scarlet in colour.

Synchronous mafic volcanic rocks include thin vesicular basalt flows, massive and generally thick sills or flows, flow breccias, bedded mafic volcaniclastic rocks, and diabase dykes. Massive and crudely stratified breccias and volcanic conglomerates contain angular fragments of rhyolite, diabase, siltstone, and vein quartz, as well as vesicular basalt bombs (Plate 14.17, 14.18). The flows and dykes are commonly, but not universally, porphyritic, with phenocrysts of plagioclase (Plate 14.19) and less abundant, altered hornblende or clinopyroxene. Gabbro is generally associated with voluminous dykes and/or flows.

Sedimentary rocks are interdigitated with the volcanic and volcaniclastic rocks. A particularly persistent sedimentary belt possibly extends across the southwest part of the area; the same or a similar belt is exposed around Grandys Brook #2, where it directly underlies the Dolman Cove Formation and is cut by numerous mafic dykes, sills or interbedded flows. This unit consists of quartzitic siltstone, arkosic and lithic sandstone, and conglomerate. The siltstone lentils are thinly bedded to locally laminated, and some show basal scours. The sandstones are locally graded, some with pebbly lenses at the base, and many are coarsely crossbedded (Plate 14.20). Crossbeds vary from trough like to planar. The conglomerates are clast to matrix supported; clasts vary in size from pebbles to boulders. The large fragments include microgranite porphyry (Roti Granite), fine grained to medium grained trondhjemite and/or granodiorite (Roti Granite), rhyolite, rhyolite tuff, andesite, basalt, intermediate tuff, siltstone, local fine grained gabbro and black shale, and vein quartz. Angular fragments of grey and red hackly (welded?) tuff predominate where the conglomerate is associated with the hackly weathering ashflow. Coarse conglomeratic rocks in the sedimentary section decrease markedly in abundance east of Grandys Brook #2, and finally disappear, along with coarse volcaniclastic components.

Also noteworthy are small, black pelitic lenses in well bedded volcanic conglomerate, and lapilli tuff just west of Grandys Brook, which display white, retrograded andalusite porphyroblasts (Plate 14.21). Nearby, relatively quartzo-feldspathic siltstones display porphyroblastic, chloritic rosettes.

Sparsely porphyryitic rhyolite, hackly ignimbrite, agglomerate, and sedimentary lenses are among the youngest members of the Georges Brook Formation in the southwest. The sparsely porphyritic rhyolite underlies much of the peninsula between La Poile and Roti Bays, and is characterized by small, greenish plagioclase and fewer, tiny quartz phenocrysts. Flow banded rhyolite, locally autobrecciated is exposed along the highland ridge further east.

Rocks of the Georges Brook Formation are inhomogeneously deformed and display as wide a variety of tectonic fabrics as of lithological makeup. A well developed micaceous schistosity is present in chlorite and sericite rich tuffaceous rocks; a less penetrative slaty cleavage is present in some of the siltstones. Clasts in the conglomerates are commonly boudinaged within their foliated matrix, and many display quartz and calcite filled extension gashes. Vesicular basalts are commonly schistose, whereas thick sills or flows show only anastomosing shear fractures. Mylonite zones occur locally.

Petrography:

In general, the volcanic rocks of the Georges Brook Formation are altered to greenschist facies mineral assemblages. The feldspars in either mafic or felsic rocks are too altered to determine composition, although faint albite and Carlsbad twinning can be observed in some plagioclase. The alkali feldspars are heavily occluded. Ferromagnesian crystals, mostly biotite, in the felsic to intermediate pyroclastic rocks in the southwest are replaced by chlorite, sphene, and epidote; ferromagnesian crystals in similar rocks near Grandys Brook #2 are replaced more commonly by chlorite and biotite. Actinolite is a common replacement for other ferromagnesian crystals, particularly in mafic rock.

The mafic flows or sills are generally composed of phenocrysts of altered plagioclase and less abundant altered clinopyroxene and/or hornblende set in a matrix of actinolite, epidote, clinozoisite, albite, local quartz with accessory opaques and sphene. Magnetite is locally profuse. Vesicles are filled with calcite and epidote. Mafic tuffs are composed largely of chlorite, epidote, calcite, sericite, and quartz.

The sandstones and siltstones are composed largely of angular grains of quartz, feldspar, and rhyolite in a matrix of fine grained chlorite, sericite, epidote, clinozoisite, and rare sphene. The matrix of the conglomerate includes angular, unsorted fragments of quartz, feldspar, rhyolite, chlorite, epidote, clinozoisite, sericite, and opaques.

The **black pelitic lenses west of Grandys Brook #2** are composed of sericitized pseudomorphs of andalusite (Plate 14.21), in a quartzofeldspathic chlorite, muscovite, and magnetite rich matrix which locally contains cordierite. Heavily mineralized tuffs nearby contain abundant coarse, euhedral magnetite, patchy chlorite, and exceptionally abundant apatite and tourmaline (schorl).

14.6 MAFIC METAPLUTONIC ROCKS: ERNIE POND GABBRO, BLUE HILLS OF COUTEAU MAFIC COMPLEX, AND OTHER METAGABBROIC AND METADIORITIC ROCKS (Units 4e, 4f)

Makeup and distribution:

Mafic metaplutonic rocks are exposed in two main belts. The southern belt extends from Roti Bay (Ernie Pond Gabbro, and others) northeast to the Grandys Brook #2 area, following the Georges Brook Formation mafic to intermediate metavolcanic rocks and the subvolcanic Roti Granite. The northern belt extends from Dolman Cove northeastward to the Blue Hills of Couteau (Blue Hills of Couteau mafic complex).

The Ernie Pond Gabbro and smaller metagabbro to metadiorite plugs in the southern belt are clearly related to the mafic metavolcanic rocks, and some project into composite dykes or sills. Although some patches appear to be rafts in the Roti Granite, the Roti Granite is undoubtedly intruded by some of the metagabbros, and is very commonly cut by mafic dykes.

The mafic metaplutonic rocks of the northern belt show diachronous relationships with the subvolcanic Baggs Hill Granite even more clearly. Baggs Hill dykes locally cut the mafic rocks, which are either enclosed in the subvolcanic Baggs Hill Granite as rafts, or show through the Round Hill Brook and Carrot Brook Formations as inliers. However, many of the mafic dykes (following section) cutting the Baggs Hill Granite, the neighbouring volcaniclastic rocks, and the mafic metaplutonic rocks are similar in composition and texture to the younger parts of the metaplutonic complex, and may be related in source. Several tectonically-bounded bodies of metagabbro in the Carrot Brook area are probably inliers, but are similar both to the late component of the Blue Hills of Couteau Complex and to the mafic dykes of the following section.

The mafic metaplutonic rocks may by no means be restricted to the volcanic centre, but may be the protoliths of some of the massive amphibolite of the Bunker Hill Brook Gneiss. In addition, rafts of metapyroxenite similar to cumulate patches in the Ernie Pond Gabbro (below) and metadiorite similar to late components of the Blue Hills of

Couteau complex are enclosed in the synmetamorphic granodiorite around Northwest Brook. East of the study area, a coarse grained quartz diorite is unconformably overlain by La Poile River Group conglomerate containing metadiorite and amphibolite cobbles (S.J. O'Brien, personal communication, 1982).

14.6.1 Southern belt

Lithology:

The mafic metaplutonic rocks of the southern belt occur as small, irregular medium to fine grained metagabbro plugs which are continuous in places with metadiabase dykes or sills and thick flows. The medium grained metagabbros are characterized by stubby, altered clinopyroxene laths.

Two larger plutons, the Ernie Pond Gabbro and an equivalent on an island in Roti Bay, consist of medium to fine grained metagabbro and metadiorite enclosing patches of coarse grained metaperidotite and metapyroxenite characterized by large, shiny uralitized clinopyroxene laths. Hornblende pegmatite intrudes the latter, and may be continuous with the medium grained rocks.

The metagabbros of the southern belt were inhomogeneously deformed under greenschist facies conditions, and do not possess penetrative tectonic fabrics.

Petrography:

Medium grained phases of the Ernie Pond and Barasway Island metagabbros consist of saussuritized plagioclase, uralitized clinopyroxene and hornblende, actinolite, rare minor quartz and alkali feldspar. Epidote, calcite, and abundant opaques are accessory minerals. The ultramafic patches are cumulates of very coarse, uralitized clinopyroxene laths which poikilitically enclose serpentinized olivine (Plate 14.22) and minor, interstitial, saussuritized plagioclase.

The medium grained metagabbro near Grandys Brook #2 consists of 1 to 4 mm diameter, actinolite-rimmed, uralitized clinopyroxene laths, individual acicular actinolite grains, and chlorite patches in a matrix of fine grained albite, quartz, epidote, and remnant, occluded igneous plagioclase.

14.6.2 Northern belt

Lithology:

In the northern belt, the Blue Hills of Couteau best exposes the metaplutonic rocks and their internal contact relations. The oldest rocks in this complex are remarkably similar to the high level, massive metagabbro and metadiabase of the Long Range Mafic-Ultramafic Complex, and consist of subophitic to ophitic metagabbros with variable grain size and modal content of ferromagnesian minerals. Small intrusions of metadiabase cut the coarse to medium grained metagabbro. Both are fractured or brecciated, the fractures filled with white plagiogranite. Coarse, ophitic clinopyroxene crystals are common, and nebulous layering, reflecting variable proportions of plagioclase to mafic minerals, particularly the large clinopyroxene grains, is displayed locally (Plate 14.23). The oldest part of the complex was intruded by locally voluminous, fine grained metadiorite of more uniform texture, composition, and grain size. Peculiar to the metadiorite are irregular dark green, amphibole-rich patches (Plate 14.24). In one stream exposure, the metadiorite occurs as megabreccia blocks hosted in Baggs Hill granite which intrudes the older metagabbro (Plate 14.25); elsewhere, the metadiorite is cut by very fine grained, mafic or intermediate dykes which also enclose it as fragments, and both are profusely veined with plagiogranite (Plate 14.26).

The plagiogranite is white weathering, and contains pale green amphibole as its sole ferromagnesian constituent.

All of these rocks were inhomogeneously deformed under amphibolite facies conditions, and anastomosing shear zones are common. The femic minerals are replaced by blue green hornblende, which defines strong, east- to northeast-trending, moderately plunging lineations in many places. Amphibolites locally contain red garnets.

The metagabbro pods further southwest in the belt are more penetratively deformed and recrystallized, so that their original textures are not easily recognized. Most consist of fine to coarse grained metagabbro to metapyroxenite and metadiabase, with small pockets of hornblende pegmatite and stringers of white plagiogranite. Discontinuous layering was noted locally. These pods may be equivalent to the Blue Hills of Couteau complex and/or the subvolcanic metagabbros of the southern belt.

Petrography:

The older metagabbros are largely composed of uralitized clinopyroxene, plagioclase, and brown hornblende with accessory magnetite. Epidote, bladed blue green hornblende, sphene, and rare local garnet and ferristilpnomelane are secondary minerals. The clinopyroxene grains are uralitized, with very fine grained sphene along remnant cleavages, and markedly subophitic to ophitic in texture (Plate 14.27). Many ophitic grains grade into patches of equally ophitic brown hornblende. Unaltered plagioclase is labradoritic, lath-shaped, and twinned on Carlsbad, albite, and pericline laws; it is generally overprinted by a few epidote patches or locally very occluded. In highly strained rocks, plagioclase forms very fine grained intergrowths with epidote, and clinopyroxene grains were replaced by aggregates of bladed, blue green hornblende which also overprints the matrix. Sparse magnetite forms coarse, cuspate to irregular opaques, rimmed with sphene in highly deformed rocks. In one locality, the altered rocks contain patches of fine grained, euhedral garnet and matrix patches of red brown biotite or stilpnomelane.

The **metadiorite** is composed of blue green hornblende, plagioclase, minor quartz, minor biotite with accessory apatite, magnetite, and zircon. Sphene locally rims magnetite. Plagioclase is somewhat patchily occluded, displays patchy extinction, and occurs as ragged remnants in an anastomosing, very fine grained, leucocratic mesostasis. The blue green hornblende forms ragged crystals probably pseudomorphous after clinopyroxene, which may be coarsely to finely polygonized and are much like the blue green hornblende crystals of the mafic dykes (next section). An original subophitic texture is possible in some of the amphiboles. The matrix varies in proportion, and apparently consists largely of very fine grained quartz, probably accompanied by at least some fine grained feldspar, forming what may be a protoclastic texture. Red brown biotite and additional bladed hornblende also occur in the mesostasis. **The amphibole-rich patches** are composed of concentrations of hornblende crystals, accompanied by minor interstitial, cloudy plagioclase, red brown biotite, and abundant accessory magnetite.

The **plagiogranite** consists almost solely of plagioclase, subordinate quartz, and less blue green amphibole with accessory zircon. Plagioclase locally exhibits a peculiar graphically-mottled extinction.

The **mafic plutonic pods southwest of the Blue Hills of Couteau** are more intensely deformed and recrystallized on a penetrative scale. They are mainly composed of blue green hornblende and plagioclase. Some of the rocks are very rich in amphibole, approaching ultramafic composition, and may be similar in origin to the amphibole-rich patches in the metadiorite of the Blue Hill of Couteau complex or the mafic-rich parts of the Ernie Pond Gabbro of the southern belt. The hornblende most commonly occurs as bladed aggregates, defining an S-L fabric. Altered clinopyroxene grains, with dusky cores displaying relict schiller texture and clear, blue green hornblende rims, locally form porphyroclasts in the strong foliation defined by the more acicular amphibole. Some of the clinopyroxene pseudomorphs possibly show relict subophitic texture. The plagioclase is generally clear, and generally recrystallized to very fine grained intergrowths similar to the metadiorite matrix above. Accessory apatite and anhedral magnetite are abundant, and epidote occurs locally. Tourmaline and garnet are generally rare, but abundant in some shear or fracture zones.

14.7 MAFIC DYKES

Distribution:

Metamorphosed mafic dykes intrude the Carrot Brook Formation metavolcanic and clastic rocks, and the Baggs Hill Granite. (It is possible that some of dykes in the granite may be confused with screens; this has not yet been resolved.) Dykes and sills are so common in the Georges Brook Formation that they are treated with that unit. No dykes have been observed cutting the Dolman Cove Formation. It is considered likely that most of the dykes were emplaced within the Ordovician volcanic cycle. However, some may be significantly younger, but may have been emplaced before the third regional deformation event, which culminated in uplift and cooling of the Bay du Nord belt, to account for a metamorphic state which is compatible with that of the host schists.

Lithology:

The dykes vary in composition from extremely mafic to moderately felsic, with or without chilled margins. They are mildly to highly deformed, and many are laterally persistent for up to several kilometres, then disappear, only to reappear along strike several kilometres away; this might be attributed to large scale boudinage.

Petrography:

The dykes are largely composed of blue green hornblende, clinopyroxene pseudomorphs, plagioclase, minor local quartz, minor local biotite, secondary epidote and accessory magnetite, apatite, and sphene. Many are characterized by ragged, uralitized clinopyroxene phenocrysts (or porphyroclasts) in a very fine grained leucocratic matrix. Blue green hornblende occurs either as individual bladed to prismatic grains or as rims on dusky grains of altered clinopyroxene. Fibrous actinolite is also present in many samples. Plagioclase is recrystallized to polycrystalline aggregates with fine grained epidote and local fine grained quartz in many places, but may occur as very altered remnants. Biotite, where present, is red brown. Sphene is an abundant accessory mineral, but may be classified as a major phase where it occurs as overgrowths on magnetite grains. A few samples, otherwise similar to the above, contain abundant sagenitic intergrowths of magnetite and ilmenite. Rarely, chilled phases contain profuse, fine grained magnetite.

The dykes vary in overall composition from moderately enriched in plagioclase to very hornblende-rich. The more mafic dykes are generally medium grained with chilled margins, and locally display polycrystalline blue green hornblende pseudomorphs of primary ferromagnesian phenocrysts. The more feldspathic rocks are fine grained throughout and contain phenocrysts of zoned plagioclase. The mesostasis of fine grained dykes consist mainly of intergrowths of columnar plagioclase (mainly calcic andesine) and acicular to stubbly blue-green hornblende in varying proportions.

14.8 BAGGS HILL GRANITE (Unit 5a)

<u>Definition and distribution:</u>

The name Baggs Hill Granite was given by Cooper (1954) to three bodies of deformed granite which underlie a series of low ridges trending northeast from Baggs Hill. These bodies exposed on Baggs Hill, Rocky Ridge, and Eight Mile Hill Prong are now thought to be part of the same subvolcanic stock and network of dykes or sills extending to the east of the Blue Hills of Couteau.

The Baggs Hill Granite intruded the Carrot Brook felsic volcanic and clastic rocks at a fairly high tectonic level, indicated by the locally preserved miarolitic cavities, and the fine grained porphyritic, aphanitic, and granophyric textures of the marginal phases. It was unroofed to contribute clasts to the volcanic conglomerate near the top of the Carrot Brook Formation.

Lithology:

The Baggs Hill Granite consists of pale gray to white weathering porphyritic granite and granophyre which grades into medium grained, equigranular, leucocratic biotite granite in the central portion of the thickest exposure area. The marginal phase to the northwest has an aphanitic to quartz phyric texture; however, the most common lithology displayed along the southern margin and in the numerous dikes or sills is fine grained to aphanitic granophyre with local quartz and feldspar phenocrysts. Quartz feldspar porphyry and aphanitic microgranite or granophyre is most common around the Blue Hills of Couteau. Miarolitic cavities, some containing arsenopyrite, are common locally.

Petrography:

The medium grained granite consists of quartz, plagioclase, microperthite, and biotite. Accessory minerals generally include zircon, apatite, and hematite; rarely, epidote and zoisite. The quartz occurs in polycrystalline aggregates, of which individual domains are undulose. The feldspars comprise mainly plagioclase (An_{30} to An_{40}), ribbon to patch microperthite, and chequered albite, and are rarely altered. Many of the plagioclase grains are rimmed by microperthite; however, rims of chequered albite on microperthite were observed in several thin sections. The biotite occurs as shapeless, fine grained, red brown or blackish green aggregates, altered to chorite locally.

The fine grained granophyre (Plate 14.28) is slightly more diverse mineralogically. Quartz, plagioclase (An_{30} to An_{40}), microperthite, granophyre, chequered albite, and biotite are present as major phases. Zircon, epidote, apatite, deep green amphibole or chlorite, and tourmaline are present in variable amounts as accessory minerals. Quartz occurs as a granophyric intergrowth with alkali feldspar and the plagioclase occurs as phenocrysts locally mantled by coarse microperthite. The microperthite occurs as phenocrysts, commonly with plagioclase or chequered albite rims and in granophyric intergrowth with quartz in the matrix (Plate 14.28). In addition, chequered albite may occur as discrete grains in the matrix, accompanied by finely divided biotite, amphibole, and other accessory minerals. Several specimens, especially near the margin of the body, contain abundant epidote, probably resulting from either pneumatolitic or later metasomatic activity.

The Baggs Hill Granite is highly deformed in many places. Domains of quartz are polygonized and annealed, and individual crystals show undulose extinction and curved intracrystalline grain boundaries. Plagioclase crystals are bent, fractured and, in several sections, recrystallized into aggregates along fractures and at grain boundaries. Anastomosing stringers of recrystallized quartz and fine grained aggregates of red brown biotite are common. Lenticular segregations of fine grained quartz are present in the very highly deformed rocks.

14.9 PIGLET BROOK RHYOLITE (Unit 5b)

Distribution:

The Piglet Brook Rhyolite occurs consistently within the Carrot Brook Formation near the basal contact of the Dolman Cove Formation, and its distribution seems to be linked to the (probably coaeval) Baggs Hill Granite to the northwest. It contributed clasts to metaconglomerate at the top of the Carrot Brook Formation.

Lithology:

The rhyolite is cream to salmon pink in colour, and very fine grained with a granular texture. Sparse phenocrysts of orange feldspar, and rarely quartz, can be seen in hand specimen. Tiny brown specks are commonly present, representing a weathered, unidentified oxide mineral. The rock is more coarsely crystalline around Piglet Brook and contains macroscopic muscovite. East of Couteau Brook, tiny red garnets are also visible. Numerous pegmatites hosted by the coarsely recrystallized rhyolite are exposed just north of the Bay d'Est Fault in the hills east of Piglet Brook.

Petrography:

The **Piglet Brook Rhyolite** is composed largely of a very fine grained quartzofeldspathic intergrowth enclosing small feldspar phenocrysts, many of which are occluded plagioclase. Other feldspar phenocrysts are either chequered albite or very finely gridiron-twinned microcline, and are intergrown with clear granophyric quartz or partly replaced by coarse muscovite. Individual muscovite flakes were observed in some samples. The more coarsely crystalline phase which occurs around Piglet Brook consists mainly of quartz, plagioclase, microcline, muscovite, blackish brown biotite, and rare, tiny red garnet grains. The muscovite generally occurs as poikilitic flakes, and east of Couteau Brook, locally displays incipient fibrolite development. The pegmatites hosted by these rocks in the southeast are composed of microcline, quartz, and muscovite, and lack the garnet and tourmaline common in other pegmatites in the area.

14.10 ROTI GRANITE

Definition and distribution:

The Roti Granite (Cooper, 1954) is a subvolcanic granitoid body which intrudes parts of the Georges Brook Formation as sills or dykes and is markedly phaneritic away from its contacts with the extrusive rocks. However, it is found as cobbles and boulders in a prominent band of Georges Brook metaconglomerate in the southwest, and in similar metasedimentary rocks around Grandys Brook #2. Mafic dykes related to the metavolcanic pile cut the Roti Granite, although rafts of mafic plutonic rocks ranging from metagabbro to metadiorite and metadiabase, also related to the metavolcanic pile, are enclosed in the granite.

Lithology:

The Roti Granite ranges from a medium grained tonalite to granodiorite, and locally quartz diorite, in its thickest parts to fine grained microgranite or rhyolite porphyry near its contacts with the Georges Brook volcaniclastic rocks. The hypabyssal intrusions generally consist of quartz-feldspar porphyry.

The granite displays an indistinct to pronounced cleavage or schistosity, and bluish quartz augen are common. In one area near the Grand Bruit Fault, intensely foliated granite has developed a gneissic segregation of leucocratic from melanocratic minerals.

The eastern exposure of the Roti Granite near Grandys Brook #2 is largely quartz phyric, and is intensely strained, the phenocrysts forming augen in a strong quartzo-feldspathic foliation. The rocks are also partly to completely leached of ferromagnesian silicate minerals. Reddened patches of oxidized, fine grained, disseminated pyrite and less abundant magnetite occur locally.

Petrography:

The medium grained Roti Granite consists of plagioclase, quartz, local alkali feldspar, chlorite, and epidote with accessory zircon. The feldspars are very highly altered, generally sericitized. Quartz occurs as strainbanded, polygonal aggregates. Chlorite aggregates, replacing biotite and possibly subordinate hornblende, were in turn replaced by khaki coloured biotite patches near the contact with the Chetwynd Granite and along the contact with the Cinq Cerf Complex along the northeast part of the Grand Bruit Fault. In the porphyritic hypabyssal phases, strained, polygonized, rhombic quartz phenocrysts outnumber those of plagioclase.

The highly foliated granite near the Grand Bruit Fault consists of segregations of microcline and quartz alternating with chlorite and epidote.

The highly foliated quartz phyric granite near Grandys Brook #2 consists mainly of finely recrystallized quartz and highly altered feldspar with variable amounts of secondary muscovite, chlorite, and epidote. Muscovite porphyroblasts commonly replace or overprint feldspars, and fibrolite is developed locally in the muscovite flakes and throughout the quartzofeldspathic matrix. Most of these rocks are mafic-poor, but chlorite-epidote lenses or stringers occur in some.

14.11 DOLMAN COVE FORMATION

Makeup and distribution:

The Dolman Cove Formation is a laterally extensive, deformed and metamorphosed dacitic crystal tuff which overlies the Carrot Brook Formation and may be coeval with or just younger than the upper part of the Georges Brook Formation. The formation is exposed in two main areas: a broad belt extending northeast from Dolman Cove to the hills overlooking Couteau Brook, where it has been deformed under amphibolite facies conditions; and the highland plateau southeast of Northeast Arm to the Cinq Cerf Brook area, where it has been deformed under greenschist facies conditions. Other outcrop areas on either side the Bay d'Est Fault in the Grandys Brook #2 area are probably remnants of the eastern extension of these main exposures. An outlier of similar, greenschist facies, dacitic crystal tuff is exposed around Little Roti Bay and on Jacques Island.

Zircons from the Dolman Cove Formation north of the Bay d'Est Fault have yielded U/Pb dates of 449$\pm$20 Ma (Dallmeyer, 1979), and zircons from the formation south of the fault have yielded U/Pb ages of 446$\pm$18 Ma (Dallmeyer, 1980). These dates would suggest an approximate Llandeilan (Odin, 1982) or Caradocian (Van Eysinga, 1978) age.

Lithology:

The Dolman Cove Formation consists largely of variably deformed and metamorphosed dacitic crystal tuff, which includes local metasedimentary lenses and rhyolitic ignimbrite, the latter most common in the southwest around the main volcanic centre.

In general, the dacite tuff forms rounded, grey weathering outcrops which reveal variable proportions of intact and broken quartz and feldspar crystals on close inspection. These rocks are crudely bedded in many places, the thick, ungraded beds reflecting variations in abundance and size of clasts. Conglomeratic or agglomeratic lenses with a makeup similar to that of the surrounding tuff are fairly common; in the southwest, some lenses contain angular blocks of preconsolidated crystal tuff in a similar matrix. Subrounded to subangular clasts of Baggs Hill granophyre and quartz porphyry are peculiar only to the tuff north of Northeast Arm, near the Baggs Hill Granite. The sedimentary lenses include metagreywacke, black or grey metasiltstone, and pebbly metaconglomerate, which may display graded bedding and crossbedding.

North of the Bay d'Est Fault, the rocks have been penetratively deformed (largely D_2) under amphibolite facies conditions. As well as quartz and white to cream coloured plagioclase and alkali feldspar crystals, the tuff contains tiny, flattened, black mafic clots, mostly biotite, which originated as ferromagnesian crystals and/or black shale fragments. In the northeastern part of the belt, the rocks have been intensely strained and more thoroughly recrystallized to form massive, grey 'pencil gneiss or schist' with a strong L-fabric defined by biotite aggregates. Rare porphyritic microgranite also occurs within the exposure area north of the fault. Although internally dacitic in composition, the metatuff or 'pencil gneiss' contains a larger proportion of mafic minerals near contacts with the underlying metasedimentary rocks, the transition commonly marked by a gradations through relatively biotite-rich crystal-lithic tuff or gritty, feldspathic sandstone.

The formation south of the fault has been inhomogeneously deformed under greenschist facies conditions. The plagioclase crystals are pale green and well zoned, ferromagnesian crystals are dark green. Very schistose rocks are pale green due to the chlorite-sericite alteration along S-planes, generally S_2. East and west of Phillips

Brook, patches of very fine grained, fissile felsic rock with quartz laminae parallel the gently dipping prominent foliation which is axial planar to early isoclinal folds, may represent local (D_1) shear or thrust zones within the dacite tuff unit.

Petrography:

The greenschist facies dacitic crystal tuff consists of intact and broken crystals of quartz, plagioclase, alkali feldspar, biotite, and opaques in a leucocratic matrix with accessory sphene, zircon, and apatite. Severe alteration of the plagioclase crystals gives them the green color in hand specimen; color zoning in some crystals is reflected by the concentration of green epidote in the cores and paler sericite in the rims. The alkali feldspars consist of simply twinned orthoclase laths which are locally sericitized and dusted with opaques, giving them the cream to pink hues in hand specimen. The biotite is pseudomorphously replaced by chlorite, epidote, and leucoxene.

Fine grained tuffs are composed of sparse crystals of quartz, plagioclase, and alkali feldspar in an oxide-peppered, very fine grained leucocratic matrix.

A sericitic foliation (S_2) is the main foliation developed in most of the rocks. In both coarse and fine grained tuffs, the crystal clasts are strained and fractured, and locally boudinaged in the S_2 foliation.

The amphibolite facies dacitic crystal tuff consists of phenocrysts of quartz, orthoclase and plagioclase, clasts of felsite, and patches of biotite and sphene, in a fine grained quartzofeldspathic matrix containing minor biotite, sericite, sphene, apatite, tourmaline, allanite, and epidote. Scattered patches of granophyre and relatively fine grained quartzofeldspathic intergrowths may represent incorporated rhyolite fragments. Quartz phenocrysts have volcanic embayments, are commonly polygonized and annealed (Plate 14.29a) and some also display strain bands and undulose extinction. Orthoclase (or anorthoclase) occurs in euhedral, simply twinned laths (Plate 14.29a), which show a characteristic woven texture under crossed polarizers due to very fine gridiron twinning and perthitic exsolution. Plagioclase phenocrysts, not as numerous as those of alkali feldspar, are albite twinned, and so highly altered that their composition could not be determined optically. The mafic clots are generally composed of flakes of biotite and rounded grains of sphene, but may contain apatite, opaques and rarely, epidote.

In the **'pencil gneiss'**, quartz phenocrysts are polygonized and annealed, and have lobate intracrystalline domain boundaries, strain bands, and undulose extinction. Ragged-edged, cross-hatched microcline crystals are present instead of orthoclase laths; these are commonly fragmented, with clusters of small, newly formed grains along the fractures (Plate 14.29b) and around the edges. Plagioclase crystals are fractured and recrystallized likewise. Biotite clots are rodlike, trending east-northeast and plunging gently to the east or northeast; some resemble hornblende pseudomorphs in cross-section (Plate 14.31). Many of these rocks contain thin quartz stringers which anastomose across the main fabric, defined by streaks of fine grained, recrystallized quartz and by biotite clots.

Amphibolite facies dacitic crystal tuff from the Grandys Brook #2 area contain crystal clasts of microcline-rimmed orthoclase, bleb antiperthite (35 percent exsolved alkali feldspar), and strained quartz in a matrix of fine grained quartz, feldspar, and biotite with less abundant muscovite and accessory apatite, opaques, sphene, and epidote. The opaques are concentrated in tiny lenticular patches. The very deformed, streaky rocks are composed of trails of the quartzofeldspathic intergrowth separated by segregations of fine grained biotite and sphene, accessory apatite, and opaque clots. Some specimens contain augen of polygonized to totally recrystallized, sutured quartz and ovoid porphyroclasts of microcline and ribbon antiperthite.

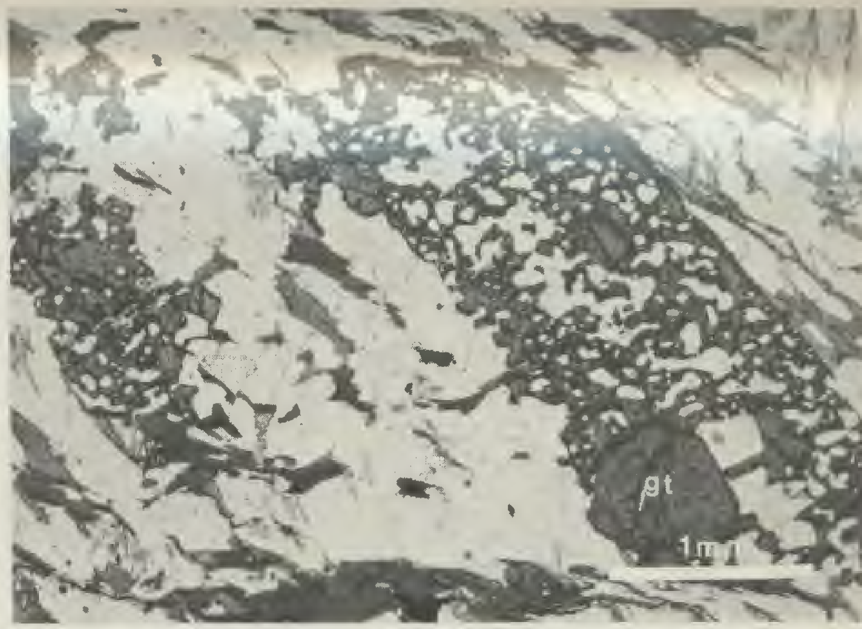
14.1 Migmatite of Bunker Hill Brook Gneiss, La Poile River.

14.2 Photomicrograph of Bunker Hill Brook schists showing staurolite (st) with slightly curved inclusion trails and single garnet inclusion, forming pulled apart augen in S2. (79-LC-266b, plane polarized light)

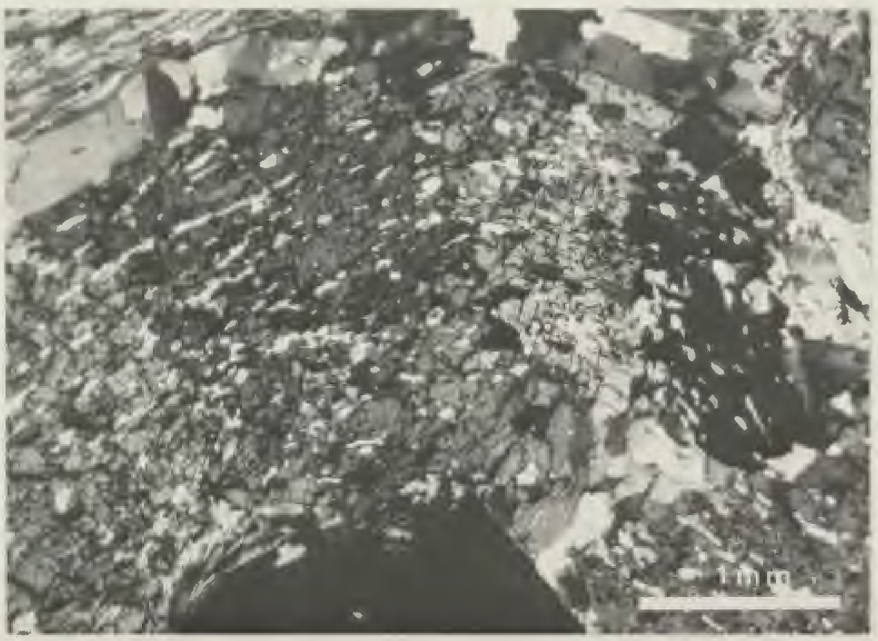
14.3 Staurolite in Bunker Hill Brook Gneiss re-oriented in segments by D_3. (79-LC-276, plane polarized light)

14.4 Photomicrograph of garnet-staurolite-kyanite schist showing layering and S_1 tightly folded (F_2), as well as later micaceous shistosity (S_2) Kyanite overprints S_2. (79-LC-276, plane polarized light)

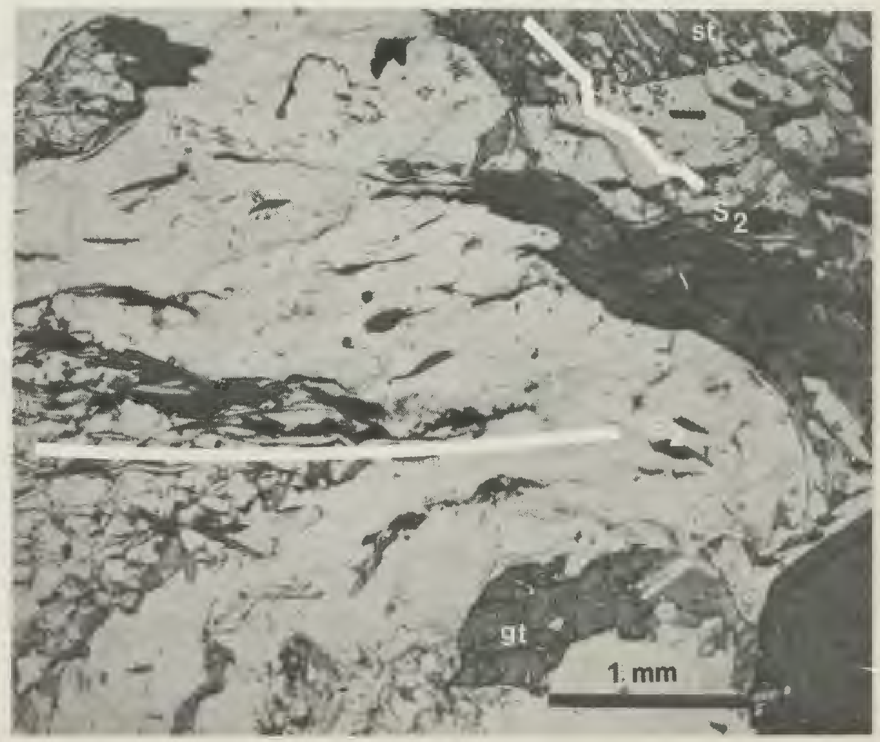
14.1



14.2



14.3

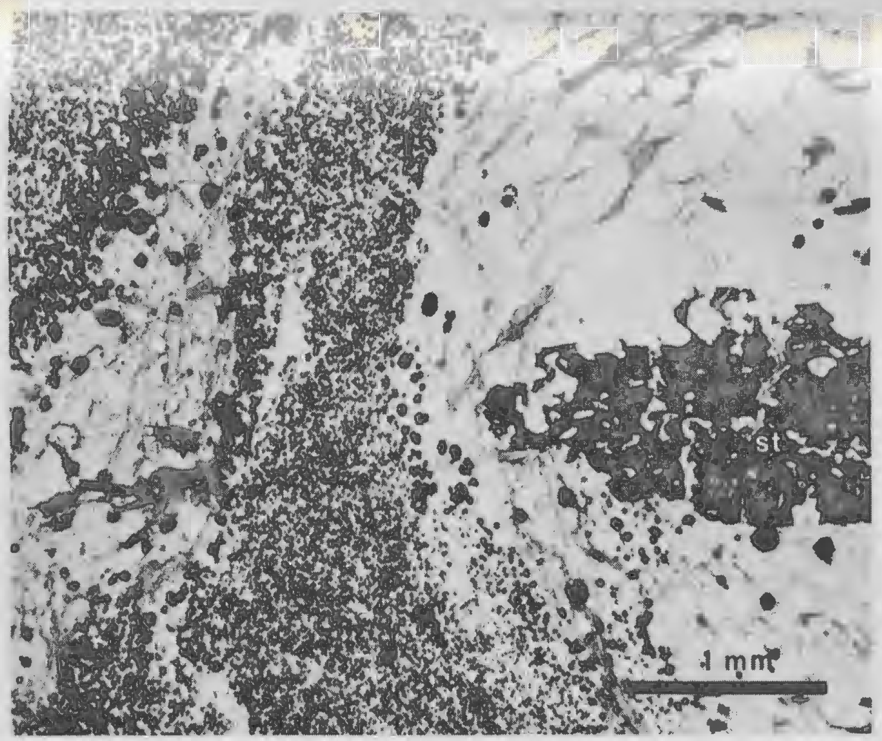


14.4

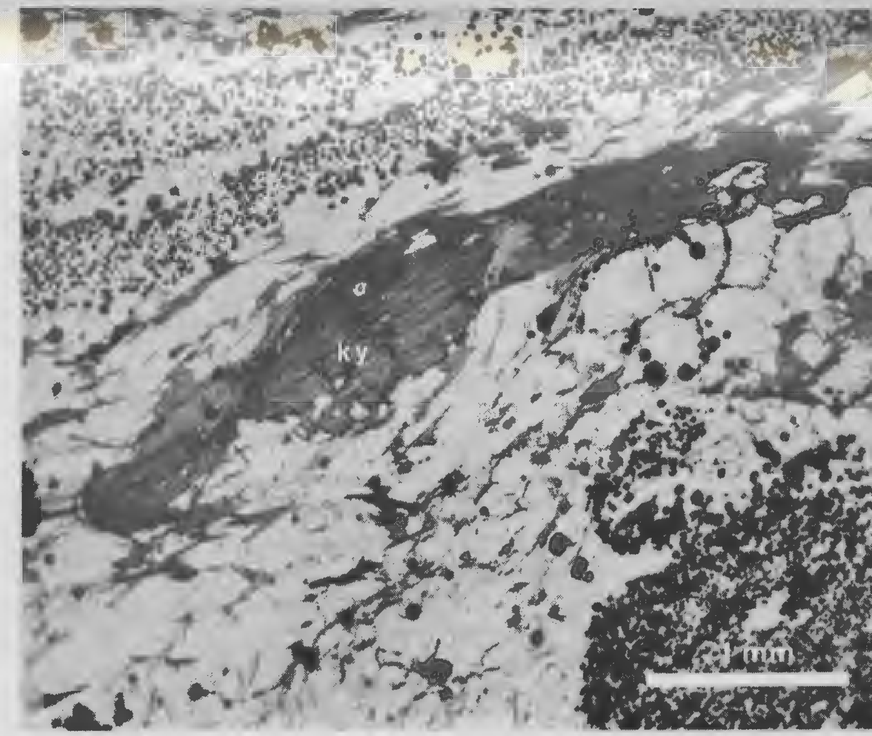
14.5 Photomicrograph of tightly folded (F_2) coticules in staurolite-garnet-kyanite-muscovite-biotite schist. Coticules reflect S_o, quartz inclusion trails in staurolite (st) reflect S_1, and staurolite forms augen in S_2. (79-CW-179a, plane polarized light)

14.6 Photomicrograph of kyanite-garnet-biotite schist showing coticule bands and corner of coticule ball (clay pellet?): kyanite overprints biotite along S_1 (transposed parallel S_2). (79-CW-179a, plane polarized light)

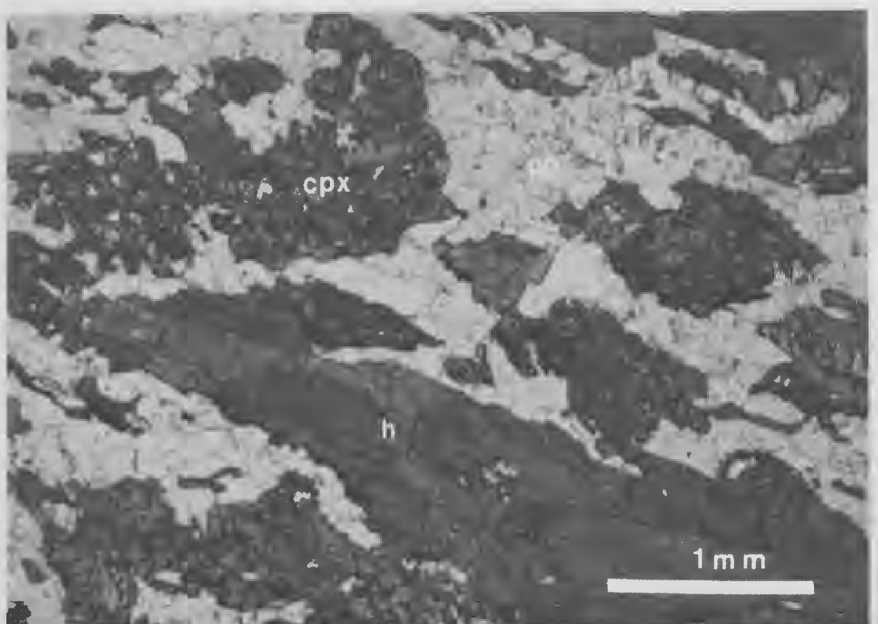
14.7 Photomicrograph of clinopyroxene-bearing, layered metagabbro showing cpx overprinting deformed and recrystallized blue-green hornblende and granoblastic plagioclase.
(80-LC-408a, 14.7a: plane polarized light;
14.7b: cross polarized light)



14.5



14.6



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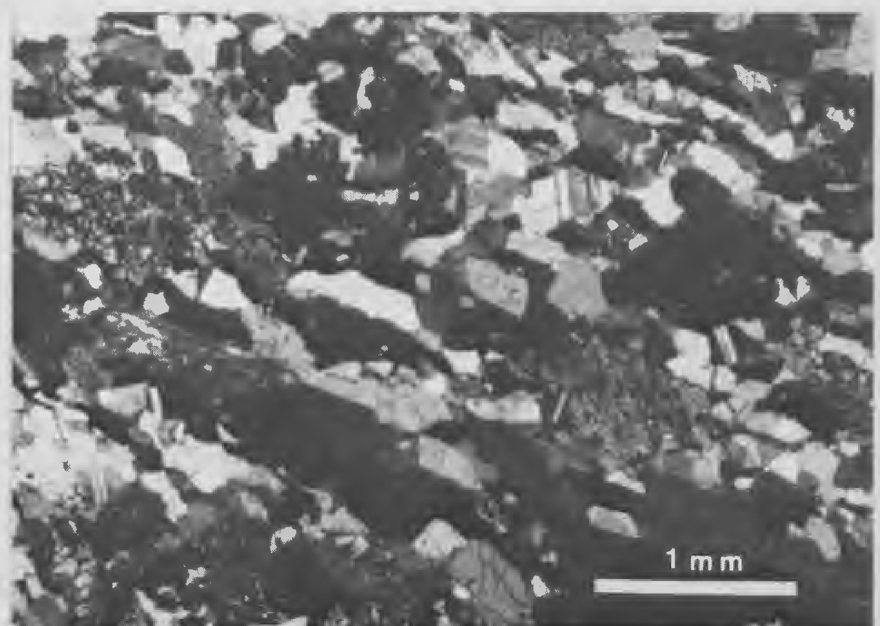


14.7b

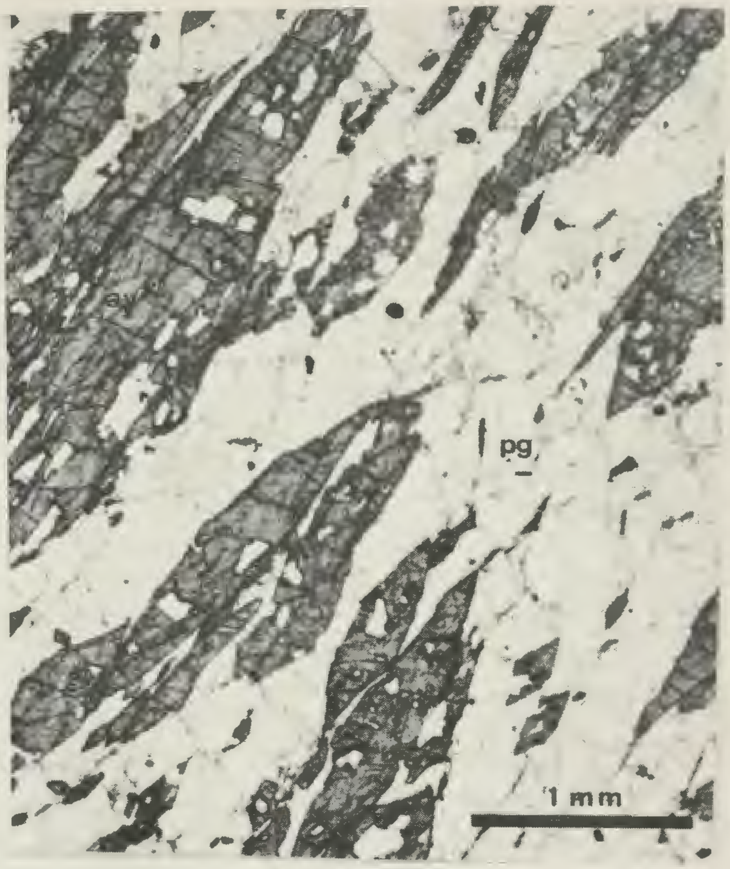
14.8 Photomicrograph showing gedrite (ay) overprinting the planar fabric defined by blue-green amphibole and red-brown biotite. (79-CW-161, plane polarized light)

14.9 Photomicrograph of gedrite-plagioclase amphibolite. (80-LC-413, plane polarized light)

14.10 Photomicrograph showing gedrite crystal fragmented and extended in S_2. (79-CW-161, plane polarized light)

14.11 Photomicrograph of garnet-gedrite-biotite-amphibole schist. (79-CW-161, plane polarized light)

14.8



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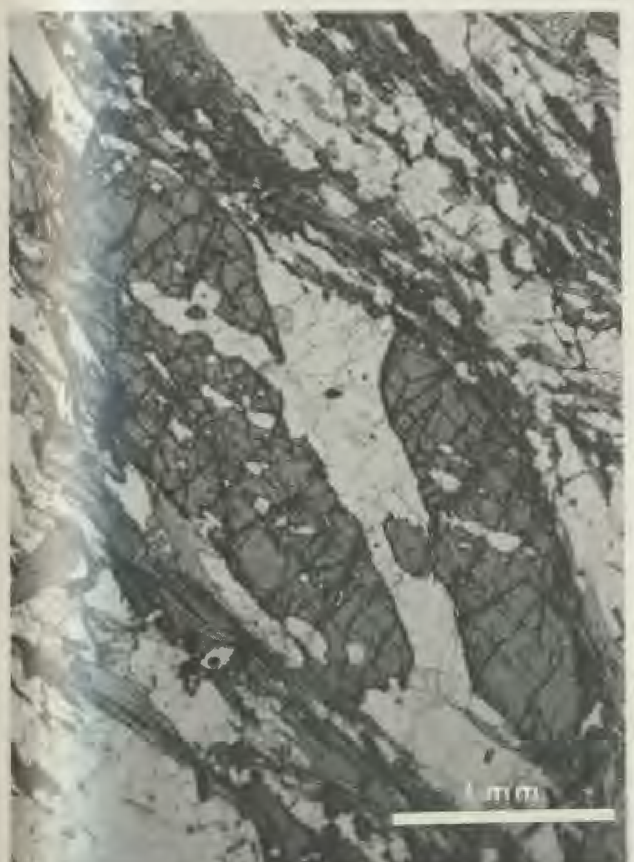


14.10

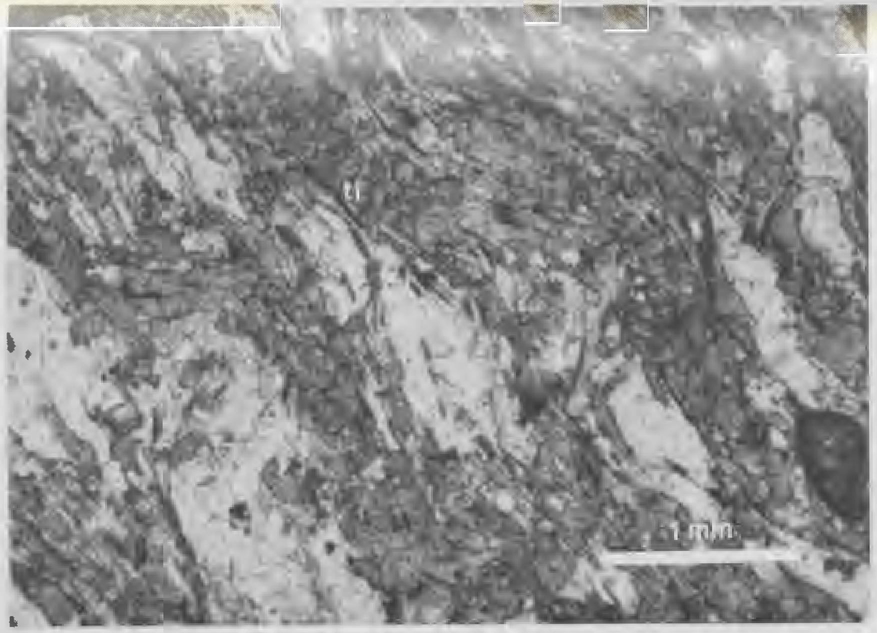
14.11

14.12 Photomicrograph of tourmaliniferous (tl) Round Hill Brook Phyllite, Mouse Pond Brook. (79-LC-113, plane polarized light)

14.13 Volcanic conglomerate of the Carrot Brook Fm., showing moderately northeast-plunging pebble elongation.

14.14 Bedded siltstone of Carrot Brook Fm. on north shore of East Bay.

14.15 Photomicrograph micaceous "flowbanding" in metarhyolite of Carrot Brook Fm. (78-LC-464, cross polarized light)



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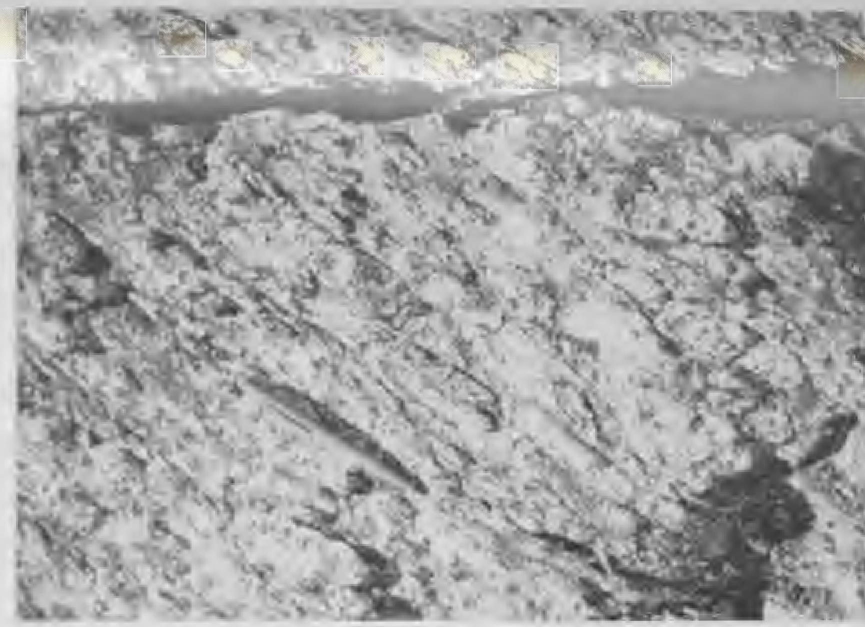

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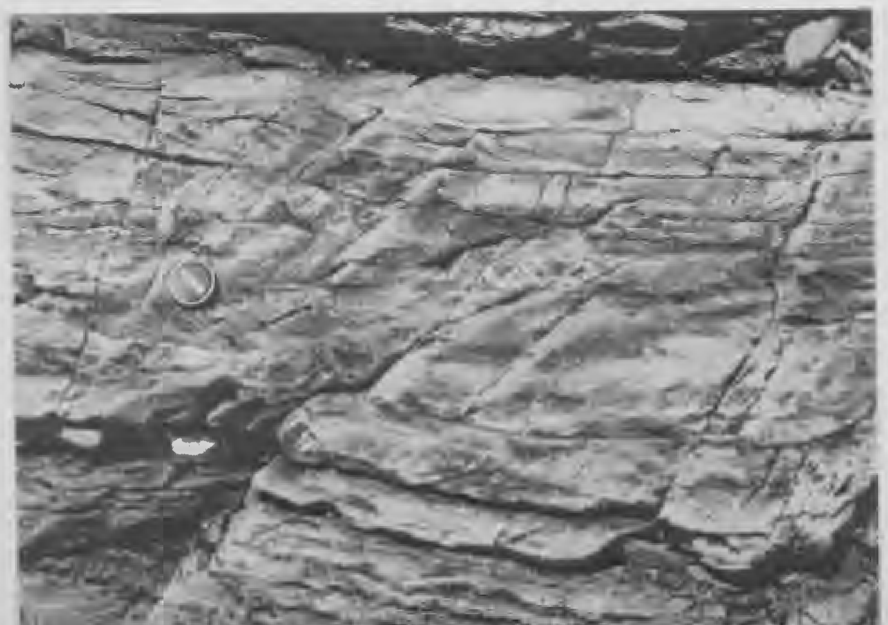
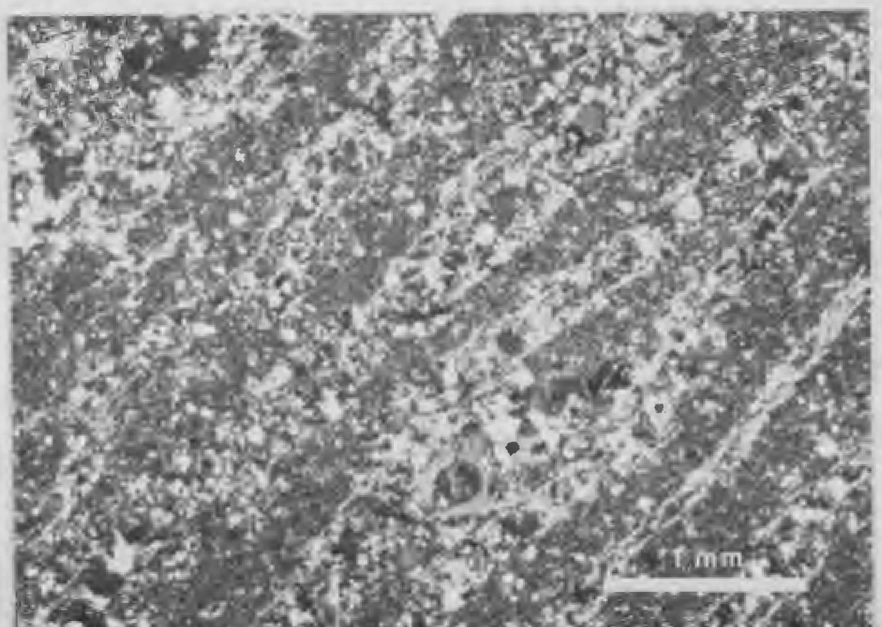




14.16 Bedded felsic tuffs with finely laminated ash layers, Georges Brook Fm. Pen is 14 cm long.

14.17 Agglomerate with vesicular andesitic fragments, Geroges Brook Fm.

14.18 Lapilli tuff with largely felsic fragments, some with fluidal outlines. Pen is 14 cm long.

14.19 Photomicrograph of plagioclase porphyritic basalt of Georges Brook Fm. (77-LOC-27-2, cross polarized light)

14.16

14.17

14.18

14.19

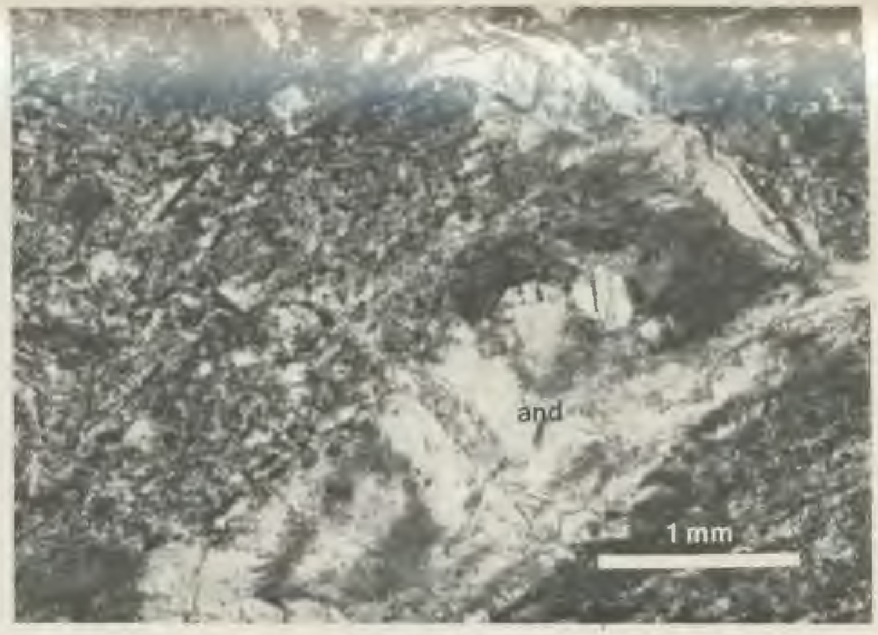
14.20 Crossbedded sandstone with pebbly layer at base, Georges Brook Fm. Pen is 14 cm long.

14.21 Photomicrograph of corner of andalusite porphyroblast retrograded to white mica in black siltstone lense in volcaniclastic rocks of Georges Brook Fm. near Grandys Brook. (79-LC-159, cross polarized light)

14.22 Photomicrograph of altered wehrlite patch in Ernie Pond Gabbro. (74-GB-110, plane polarized light)

14.23 Nebulous layering inoldest metagabbro component of Blue Hills of Couteau.

14.20



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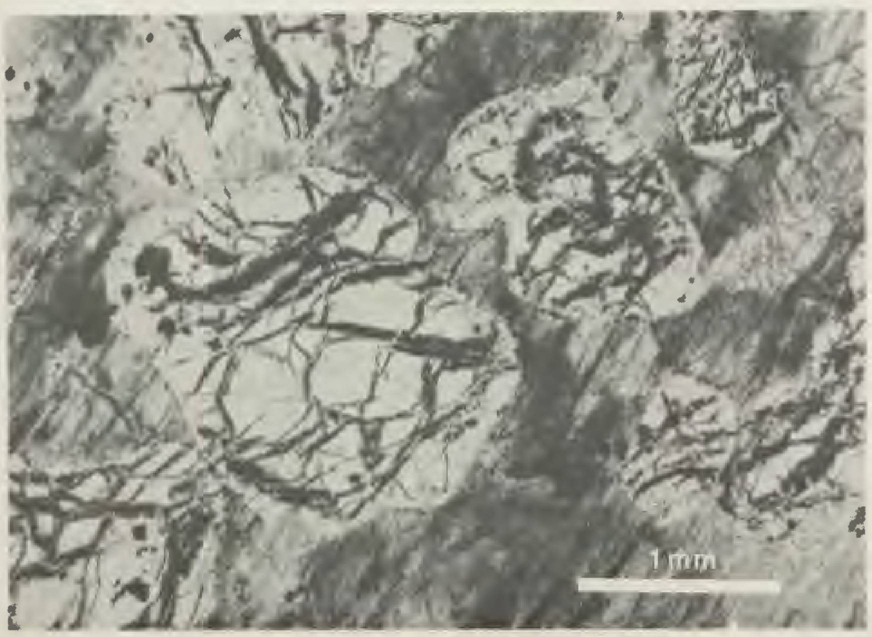

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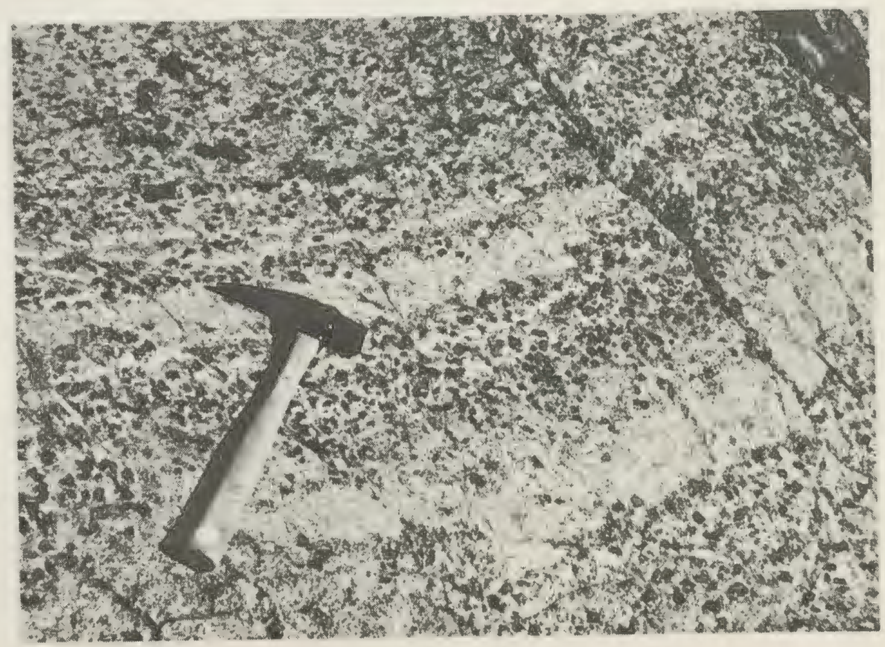


14.23

14.24 Mafic-rich (amphibole) patches in quartz metagabbro/diorite in Blue Hills of Couteau complex.

14.25 Blocks of quartz metagabbro are engulfed in Baggs Hill Granite (center photo) that cuts through older metagabbro, Blue Hills of Couteau.

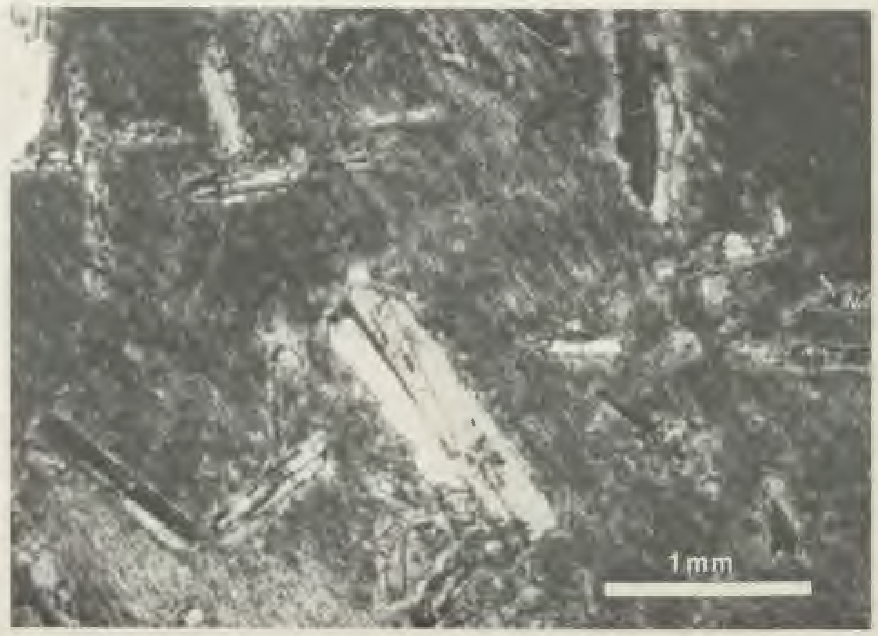
14.26 Xenoliths of quartz metadiorite in mafic dyke, all veined by plagiogranite. Pen is 14 cm long.

14.27 Photomicrograph of plagioclase laths ophitically enclosed in altered clinopyroxene in subophitic metagabbro, oldest component of the Blue Hills of Couteau complex. (79-LC-222, cross polarized light)

14.24

14.25

14.26



14.27

14.28 Photomicrograph of Baggs Hill granophyre, Baggs Hill. (79-LC-127, cross polarized light)

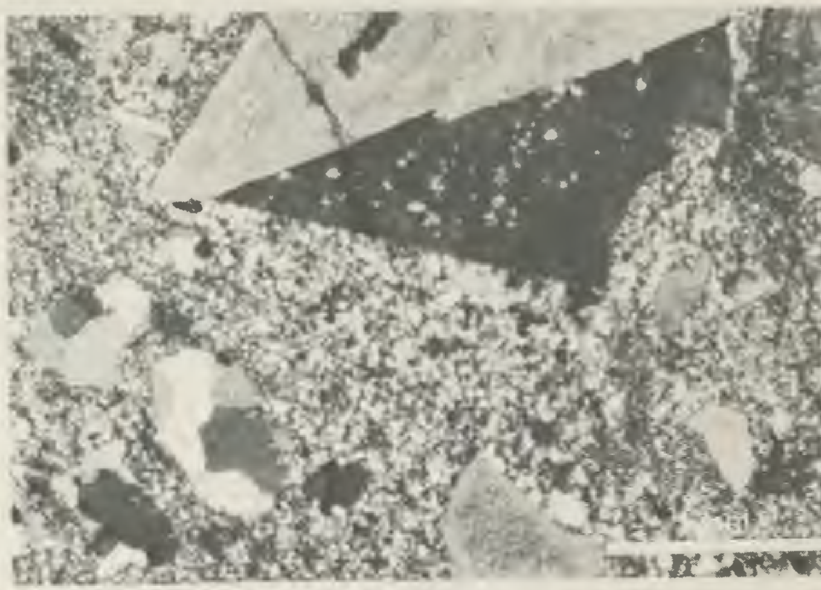
14.29a Photomicrograph showing simply-twinned alkali feldspar crystal fragments and polygonized and annealed quartz in amphibolite facies Dolman Cove Fm. (77-LOC-17, cross polarized light)

14.29b Photomicrograph showing clast of alkali feldspar which was disaggregated during regional deformation in highly deformed, amphibolite facies Dolman Cove Fm. (77-LC-119, cross polarized light)

14.30 Angular fragment of dacite crystal tuff among fragments of dacite and rhyolite in dacitic crystal tuff matrix, greenschist facies Dolman Cove Fm.

14.31 Photomicrograph showing hornblende? pseudomorphously replaced by fine grained biotite, epidote, and sphene.

14.28



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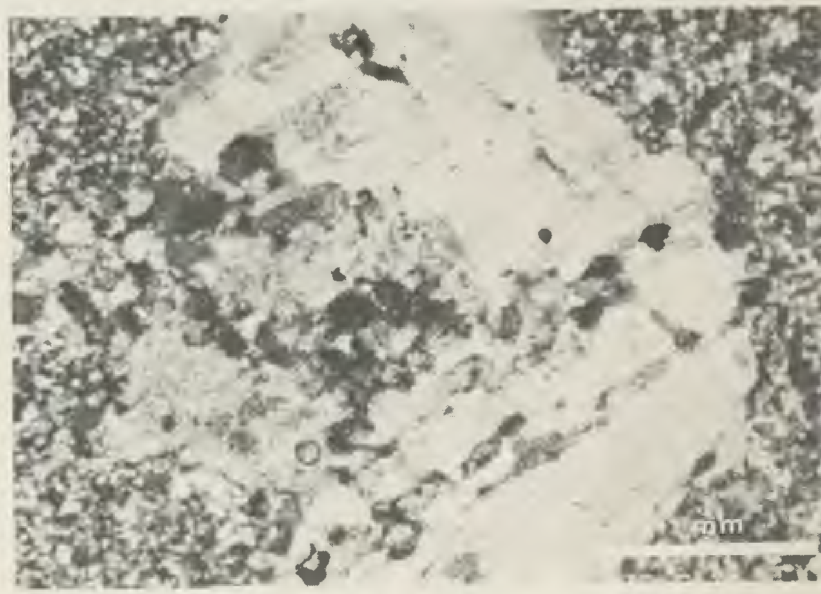


14.29b

CHAPTER 15: SYNKINEMATIC/SYNMETAMORPHIC GRANITOID ROCKS OF THE SOUTHERN LONG RANGE MOUNTAINS

15.1 TONALITE AND OTHER SYNKINEMATIC GRANITOID ROCKS OF TERRANE I (UNIT 7)

15.1.1 Subdivisions and general characteristics of Unit 7

These granitoid rocks include biotite tonalite grading to garnetiferous biotite tonalite in the Dinosaur Pond belt, and both garnetiferous tonalite to granodiorite and pink leucogranite to tonalite in the Little Codroy Pond belt. Tonalite to granodiorite is exposed in the northeastern part of the study area between Deep Brook and Fox Hole Brook.

All varieties are characterized either by abundant inclusions, rafts, and screens of host rock, or by a lit par lit style of intrusion into the host terrane, and each subunit is associated with its own typical host material. The biotite tonalite (Unit 7a on Map 1) is hosted mainly by massive metagabbro and metadiabase with which it commonly forms a large to small scale agmatite. The garnetiferous biotite tonalite (Unit 7b) contains both assorted metasedimentary rocks and mafic metavolcanic or hypabyssal rocks as xenoliths. The garnetiferous tonalite-granodiorite

(Unit 7c) is mainly hosted by semipelitic paragneiss with which it is interlayered as lit par lit sheets. The pink leucogranite-tonalite (Unit 7d) is mainly hosted by the undivided amphibolite and the mafic metavolcanic rocks and dykes which it includes as xenoliths and screens, but was observed locally cutting metasedimentary rocks and mylonite. The tonalite-granodiorite in the Deep Brook area (7e) contains mafic meta-igneous and sedimentary xenoliths like those of the Dinosaur Pond belt, whereas further east it is related to the migmatitic veins of the tract of Keepings Gneiss which it encloses.

These granitoid rocks are also characterized by penetrative fabrics concordant with the earliest recognized fabrics of their inclusions or hosts, produced under the same metamorphic conditions.

Variably deformed pods of red quartz syenite along the Long Range Fault are here included with the pink leucogranite-tonalite (Unit 7d), but may be of another generation.

15.1.2 <u>Biotite</u> <u>tonalite</u> (Unit 7a)

<u>Distribution:</u>

The biotite tonalite intrudes massive metagabbro and metadiabase, undivided amphibolite, and subordinate mafic metavolcanic rocks and dykes of the Long Range Mafic-ltramafic Complex of the Dinosaur Pond belt. In many areas, the tonalite occurs only as apophyses in the massive metagabbro and metadiabase (Plate 15.1), but grades into tonalite with between 30 and 70 percent equant to elongate mafic meta-igneous inclusions. This complex passes continuously but abruptly into garnetiferous biotite tonalite north of Grandys Lake. The transition is more gradual in the northeast part of the belt.

Lithology:

This unit consists mainly of medium grained, equigranular, biotite leucotonalite, and grades locally into biotite tonalite with over 10 percent biotite. It is equigranular, medium grained, and grey weathering. Quartz domains range from several millimetres to over 1 cm in maximum diameter, and are characteristically blue grey in colour. Biotite forms black, interstitial aggregates. Both biotite and flattened quartz domains define a weak to strong schistosity, generally composite and more intense in the central and northeastern part of the Dinosaur Pond belt where it locally constitutes a gneissic segregation. The tonalite in the extreme northeast part of the area displays a weak gneissosity due to the segregation of biotite. North of Grandys Lake, veins of relatively undeformed, coarse grained trondhjemite locally cut obliquely across the schistosity of the tonalite. Metagabbro and metadiabase inclusions are commonly much less deformed than the surrounding tonalite in the southwest part of the belt.

The biotite tonalite along the northwest side of the Cape Ray Fault has been intensely deformed by activity of the fault. Quartz domains form augen in the strong, chloritic foliation. This makes the separation of highly strained, 'quartz eye' tonalite from equally strained quartz porphyry of the Windsor Point Group difficult in a few places along the fault.

Several outcrops of very schistose, locally weathered tonalite (almost phyllonite) shown on the map west and northwest of Grandys Lake probably represent minor, early high strain or shear zones associated with the more regionally penetrative, intense deformation further north in this area.

The tonalite around the late quartz diorite-megacrystic granite in the northeast corner of the area is highly altered. The effects are not as obvious in outcrop or hand specimen as in thin section (below).

Petrography:

The biotite tonalite is largely composed of plagioclase, quartz, biotite, minor muscovite, and minor to trace amounts of magnetite with accessory zircon, apatite, and pyrite. Modal quartz is inversely proportional to modal biotite, reflecting the variation from trondhjemite (under 10 percent biotite) to tonalite (over 10 percent biotite). In the most highly deformed rocks, the planar orientation of micas and flattened, sinuous quartz domains defines the penetrative schistosity, commonly crenulated or crosscut by a locally predominant secondary foliation. Plagioclase comprises 40 percent of the tonalite, and occurs as clear, unzoned, subhedral albite (?) grains in rocks that are not retrograded. Minor, patchy sericitization affects plagioclase locally. Quartz generally occurs as large, weakly strain-banded, polygonized grains, slightly embaying plagioclase in places. Some of the larger grains form polygonized stringers up to 5 mm long. Biotite occurs mainly as coarse, olive green flakes which form interstitial aggregates, locally interlayered with minor muscovite. Ragged muscovite porphyroblasts overprint plagioclase in many places.

The tonalite along the north side of the Cape Ray Fault contains abundant secondary chlorite, epidote, carbonate, and sericite. Plagioclase is largely sericitized. Quartz is strained, polygonized, and locally completely recrystallized into lenses and discontinuous stringers. Biotite is completely chloritized at the southwest end of the belt, and partly chloritized elsewhere along the fault.

Tonalite in the minor high strain bands west and north of Grandys Lake contains red brown, partly chloritized biotite interlayered with muscovite, profuse accessory apatite, and rare patches of orthoclase perthite and myrmekite overprinting the plagioclase. The dominant fabric in these shear zones is the crenulation schistosity, defined by oblate domains of polygonized quartz and the segregation of partly chloritized biotite and muscovite.

Tonalite around the quartz diorite-megacrystic granite (Unit 8) body contains secondary muscovite, epidote, local chlorite, allanite, profuse apatite, and fibrolite. Plagioclase is either finely sericitized or overprinted by muscovite and locally by fibrolite.

15.1.3 Garnetiferous biotite tonalite (Unit 7b)

Distribution:

The garnetiferous biotite tonalite is a foliated to gneissic granitoid rock with a highly variable garnet content, which encloses abundant diverse metasedimentary and metabasic rocks as xenoliths. It occupies the north-central high strain zone, and grades into the biotite tonalite with mafic meta-igneous inclusions to the south and southeast.

Lithology:

The garnetiferous tonalite forms white to light grey weathering outcrops, with macroscopic red garnets being generally more abundant and larger in the south half of the area. The metasedimentary inclusions are commonly also garnetiferous, and are difficult to separate from granitoid rock in some exposures. A weak gneissosity to penetrative schistosity is defined mainly by biotite segregation, and tightly folded or crenulated. The combined fabric is responsible for the northwesterly structural trends typical of this zone. Fine grained disseminated magnetite occurs in most of the rocks, and pyrite occurs locally. Magnetite lenses occur locally in sheared tonalite in the southeast part of this zone.

The garnetiferous tonalite and its inclusions are locally intensely sheared and leached in the southeast part of the north-central high strain zone, and locally along the western margin of the zone. Here, garnets commonly attain diameters of several centimetres (Plate 15.2).

Petrography:

The garnetiferous tonalite is composed of plagioclase, quartz, biotite, almandine garnet, local microcline, local myrmekite, and very rare, blue green amphibole. Secondary carbonate, epidote minerals, muscovite, and chlorite also occur locally. Magnetite and zircon are ubiquitous accessory minerals, and pyrite occurs in some places. The earliest foliation is defined by a weak segregation of biotite, which is also crystallized along the crenulation or second schistosity. The second schistosity predominates in the most highly deformed rocks. // The quartz to plagioclase ratio is normally less than one. In the least foliated rocks, large, anhedral grains of weakly deformed quartz embay plagioclase. In very foliated rocks, quartz appears as coarse, polygonized lenses which partly define the crenulation or second foliation, and as tiny, unstrained grains overprinting plagioclase. Plagioclase (andesine) is commonly lightly sericitized, and locally displays mottled extinction. // Biotite forms interstitial clusters of red brown flakes which enclose accessory magnetite and zircon. // Garnets vary widely in size. Very small, inclusion-free garnets overprint the biotite in some of the tonalites, especially in the north half of this zone, whereas many granitoid rocks further south contain medium to coarse, subhedral garnets with few to abundant inclusions (quartz, biotite, magnetite, zircon). They tend to cluster with biotite. In highly deformed rocks, skeletal, inclusion-rich garnets are broken and the fragments strung out along the second foliation; this is prevalent in the north half of the area. Rare nodules of very fine grained, inclusion-free garnets probably represent partly assimilated inclusions of microcrystalline garnet-quartz rock of Unit 2c (13.2.4).

The highly altered tonalite in the southeast has a quartz to plagioclase ratio commonly exceeding one. Highly sericitized plagioclase is diminished by replacement by quartz, and is overprinted by muscovite flakes and rare carbonate patches (Plate 15.3). Fibrolitic mats occur locally instead of muscovite, and myrmekite is developed in some samples. Acicular epidote crystals align with biotite in some very foliated rocks. Biotite in the most highly sheared and altered rocks is either leached and fine grained rutile exsolved, or it is partly chloritized. Large, dendritic garnets are particularly common. Disseminated, fine to coarse grained magnetite is concentrated locally.

15.1.4 Garnetiferous tonalite to granodiorite (Unit 7c)

Distribution:

The garnetiferous tonalite to granodiorite is intimately associated with paragneiss and subordinate lenses or layers of amphibolite. It occurs as numerous veins, sheets, and thicker structurally concordant masses interleaved with host rock in the Stag Hill high strain zone, and locally accompanies less extensive metasedimentary rocks of the Long Range high strain zone.

Lithology:

The tonalite to granodiorite is gneissic to schistose, and normally weathers light grey. The gneissosity is due to the segregation of micaceous minerals and garnet, and is either crenulated or tightly folded. Micas define a schistosity parallel to both the gneissic banding and the crenulation schistosity.

In the northeast part of the Stag Hill high strain zone, the very intense and locally mylonitic second fabric transposes the early gneissic fabric. Garnetiferous granitoid and garnetiferous paragneiss are generally inseparable in outcrop, especially in zones of silicic or quartzofeldspathic mylonite.

The granitoid rocks in the central part of the Stag Hill high strain zone contain coarse biotite, muscovite, and garnet. Coarse garnet crystals occur within biotite-rich layers, and overprint the schistosity defined by biotite in some exposures. A strong rodding lineation is displayed by the hybrid granitoid and metasedimentary rocks which underlie Stag Hill. Southeast of Long Pond, numerous reddened patches occur in the white weathering granitoid rock and paragneiss. Veins and patches of medium grained, red granite crosscutting the foliation in some places may be partly responsible for the red colouration. Ilmenite-quartz sweats occur locally in these rocks.

Along the southeast margin of the Stag Hill high strain zone, and also within the Long Range Fault zone, the granitoid rocks are highly retrogressed. Biotite is chloritized, and the garnets are commonly corroded and partly replaced by chlorite. Muscovite is particularly abundant near the western boundary of the map area.

Petrography:

The tonalite to granodiorite generally contains plagioclase, quartz, biotite, almandine garnet, muscovite, local microcline and myrmekite, and sparse, local fibrolite. Secondary chlorite, sericite, and epidote minerals occur in some of the rocks. Zircon, relatively scarce apatite, and sphene are ubiquitous accessory minerals. Accessory opaque minerals consist mainly of magnetite in the north, and both magnetite and ilmenite in the south. The gneissosity reflects the segregation of biotite and muscovite and/or fibrolite, and is generally crenulated or transposed. The overall grain size of the rock decreases with the increasing development of the second foliation. // Plagioclase (calcic oligoclase to sodic andesine) tends to form porphyroclasts. It occurs as relatively large grains with ragged, corroded boundaries where it constitutes up to 50 percent of the rock, but occurs as small grains overprinted by both large and small grains of quartz where it is subordinate in proportion to quartz. // Quartz occurs as polygonized to unstrained grains and grain aggregates which display ribbon-like and amoebic outlines in highly deformed rocks. // Biotite, intergrown with less abundant flakes of muscovite, is red brown to olive green in colour, and is locally, partly to completely chloritized. Platy opaque grains (probably ilmenite) in contact with chloritized biotite are generally rimmed with fuzzy sphene or leucoxene. // Garnets are mainly rounded to flattened, but are locally dendritic. Small garnets are free of inclusions, but large garnets commonly contain randomly-arranged inclusions of quartz and plagioclase. // Muscovite occurs as ragged porphyroblasts either associated with biotite or overprinting plagioclase, and as matted sericitic intergrowths. // Microcline (if present) forms small, clear, interstitial grains where it is least abundant. Where present in larger amounts, it forms large, clear, ragged grains with inclusions of quartz and optically continuous remnants of sericitized plagioclase. Myrmekite lobes embay the microcline. // Fibrolite occurs as bundles or sprays overprinting feldspar or radiating from feldspar grain boundaries, and as needles within muscovite, particularly in blastomylonitic rocks in the northeast.

The granitoid rocks along the southeast margin of the SHhsz and in late shear zones in the LRhsz contain abundant secondary chlorite, epidote, sphene, and sericite or porphyroblastic muscovite.

15.1.5 Pink leucogranite to tonalite (Unit 7d)

Distribution:

The foliated, pink leucogranite-tonalite encompasses several separate, lithologically distinct intrusions. However, lithological differences are mainly those of grain size, and gneissic banding versus schistosity, which may be due to differences in subsolidus deformation and recrystallization.

Mylonitic, pink granite intrudes amphibolite where the Stag Hill and Long Range high strain zones merge. Fine grained, pink granite is also exposed near Long Pond in the central part of the SHhsz, and foliated to gneissically-banded, pink granite intrudes amphibolite around Little Codroy Brook.

Schistose to gneissic, pink leucogranite (Plate 15.4) with local, grey tonalite patches cuts deformed mafic metavolcanic rocks, dykes, and undivided amphibolites, and to a lesser degree metasedimentary rocks, in the Long Range high strain zone.

Small pods or lenses of quartz syenite intrude amphibolite and metagabbro of the Long Range Mafic-Ultramafic Complex near the western boundary of the map area.

Lithology:

In the northeast part of the Stag Hill high strain zone, fine grained, mylonitic, pink leucogranite intrudes the amphibolites with which it is deformed. Biotite schlieren and subordinate muscovite are typical of this phase, although biotite-rich granite grades locally into leucogranite lacking ferromagnesian silicate minerals. Some exposures of the mylonitic granite display medium to coarse feldspar porphyroclasts or flattened, finely recrystallized feldspathic lenticles, and may be related to the roots of the nearby perthite-rich granite pluton. Pegmatites are associated with the foliated leucogranite northeast of South Branch River.

The fine grained, pink granite near Long Pond is homogeneously equigranular. It appears unfoliated on many weathered surfaces, but a composite penetrative schistosity defined by fine grained biotite is obvious in hand specimen.

The intrusion which cuts amphibolite around Little Codroy Brook varies from fine grained, equigranular, schistose, pink granite south of the brook to fine grained, gneissically-banded, pink granite north of the brook. Alternating biotite-rich and biotite-poor bands, a centimetre or more in thickness, form the gneissosity. Pegmatite is associated with schistose red granite in the brook.

Voluminous, pink leucogranite along the southeast side of the Long Range Fault intrudes the amphibolite and the mafic metavolcanic rocks and dykes as sheets, and the marble and associated metasedimentary rocks as veins. Larger intrusions enclose screens of amphibolite. In several places, leucogranite grades into grey weathering, gneissic tonalite. The pink leucogranite is locally red due to patchy hematization. In many places, it displays a penetrative schistosity and a strong crenulation cleavage defined by fine grained biotite or chlorite, and locally muscovite. In other places, openly to tightly folded gneissic banding is developed.

Pods of red weathering quartz syenite and microcline-quartz pegmatite contain coarse, green chlorite patches. They are less intensely foliated than the other rocks near the fault.

Petrography:

The mylonitic pink granite in the northeast end of the SHhsz is composed of an allotriomorphic granular intergrowth of quartz, microcline, plagioclase, myrmekite, biotite, and muscovite with accessory epidote, apatite, magnetite (locally completely oxidized), and large single crystals of zircon. The schistosity, defined by micas and quartzo-feldspathic layers, is penetratively crenulated. The grain size is highly variable, and dependent on the degree of deformation. Schlieren of olive green biotite and epidote grains, the latter commonly enclosing cores of allanite, partly define the early schistosity and pass unchanged into the crenulation cleavage. Quartz occurs as large polygonized domains and tiny, strain-free interstitial grains. Microcline forms clear, ragged grains, commonly embayed by abundant myrmekite. It locally displays minor, hairlike perthitic exsolution and encloses tiny, rounded quartz grains. Plagioclase is subordinate to microcline, and forms either small, bent, corroded grains or large grains with mottled extinction overprinted with small microcline patches. It is commonly occluded with iron oxide. Muscovite forms clusters of coarse flakes which display an internally vermicular texture which may be due to quartz or fibrolite development. In biotite-free rocks, muscovite also occurs as fine grained flakes aligned along the schistosity.

The fine grained, pink granite near Long Pond is composed of quartz, microcline, plagioclase, myrmekite, and biotite with accessory apatite, zircon, and magnetite. Two well developed biotite schistosities intersect at a high angle. Microcline occurs as interstitial grains partly enclosing highly strained quartz and subordinate plagioclase (oligoclase). Myrmekite lobes are concentrated in patches with the microcline. Biotite with a few zircon inclusions occurs as flakes interlayered with small amounts of muscovite.

The gneissically-banded leucogranite around Little Codroy Brook is composed of alternating leucocratic and biotite-rich bands. The biotite-rich bands consist of plagioclase, hair perthitic microcline (very minor perthitic exsolution), quartz, and about 10 to 15 percent olive brown biotite with accessory epidote, magnetite, sphene, and large prismatic zircons. Quartz is polygonized, and flattened quartz combined with oriented biotite define a schistosity that is parallel to the gneissosity. The leucocratic bands are not foliated and are more coarse grained. They are composed of microcline braid perthite, subordinate corroded plagioclase, polygonized quartz, local myrmekite, and minor muscovite. The perthitic microcline contains about 10 to 15 percent exsolved plagioclase, and large grains commonly enclose tiny sericitized plagioclase inclusions. Plagioclase is generally overprinted by crystallographically aligned flakes of muscovite. Myrmekite lobes associated with microcline appear to cluster near the margins of biotite-rich bands.

Leucogranite from the LRhsz consists of an allotrio-morphic inequigranular intergrowth of polygonized quartz, microcline, plagioclase, local myrmekite, and local biotite, chlorite, and/or muscovite. Accessory minerals include epidote, local allanite, sphene, zircon, local apatite, magnetite, and iron oxide. Flattened to ribbon-like quartz domains, and shear zones composed of fine grained microcline and quartz define an early foliation which is strongly microfolded or crenulated. Microcline is clear and generally nonperthitic. It occurs as very coarse to very fine irregular grains, many of which are internally strained and recrystallized in slightly different crystallographic orientations. Quartz occurs as very fine to coarse polygonized grains, many of which are highly undulose or strain banded, with rare curved deformation lamellae. Quartz embays plagioclase in many highly sheared rocks. The plagioclase (calcic oligoclase, locally albite) is lightly occluded with iron oxide, and commonly forms fractured, corroded porphyroclasts in the early schistosity, the fragments of which are displaced by the crenulation schistosity. Myrmekite rims plagioclase locally. Biotite and secondary chlorite comprise less than 5 percent of the rock. Biotite forms irregular dark brown or green flakes, largely pseudomorphed by deeply pleochroic, green chlorite intelayered with sphene and epidote. In biotite-free rocks, muscovite is abundant and magnetite is the sole mafic phase.

Gneissic tonalite from the LRhsz is composed of plagioclase, quartz, biotite, chlorite, and amphibole with abundant accessory apatite and epidote. A strong, crenulated foliation is defined by quartz lenticles, plagioclase porphyroclasts, and biotite/chlorite.

Plagioclase (andesine) comprises up to 50 percent of the rock, and is generally unzoned. Quartz is highly strained, and makes up about 30 modal percent. Brown biotite is generally partly replaced by deeply pleochroic, green chlorite, and the intergrowths associated with abundant epidote and apatite. Corroded grains of highly pleochroic, blue green amphibole surrounded by deep brown biotite also occur in the ferromagnesian intergrowths.

The quartz syenite is composed of mesoperthite (commonly over 75 modal percent), quartz (less than 15 modal percent), plagioclase, myrmekite, chlorite and muscovite. Ferri-stilpnomelane, magnetite, epidote, zircon, and abundant sphene are accessory minerals. The mesoperthite is occluded with iron oxide, and forms large, fractured, grains embayed by a fine grained mesostasis of alkali feldspar, plagioclase, and myrmekite. Chlorite occurs in matted, polycrystalline patches which are veined with ferri-stilpnomelane. Fine grained quartz and rare grains of magnetite are associated with the chlorite clots. Muscovite flakes overprint all minerals, and other accessory minerals are randomly dispersed.

15.1.6 Granitoid rocks between Deep and Fox Hole Brooks

Distribution:

A deformed granitoid intrusion which lies north of the Cape Ray Fault zone appears to extend beyond the northern boundary of the project area. The tonalite encloses equally deformed xenoliths of amphibolite, metagabbro, and calc-silicate bearing metasedimentary rocks west of Deep Brook, and merges eastward into the migmatitic veins and dykes which cut the largely felsic Keepings Gneiss (Section 13.4).

Lithology:

This intrusion is composed of grey equigranular tonalite, trondhjemite, and granodiorite, which appear weakly schistose and/or gneissose in some exposures. The schistosity is defined by flattened quartz domains and the gneissic banding by the presence of discrete, relatively fine grained layers; they are mutually parallel. In many areas, the entire exposure is very fine grained, and large patches of contrasting mafic content (color index) and small gneissic schlieren are common.

Petrography:

Both **tonalite and trondhjemite** consist of quartz, plagioclase (An_{30}), blue green hornblende, and dark brown biotite, with accessory opaque minerals and zircon. Minor amounts of microcline were observed in some of these rocks. **The granodiorite** consists of quartz, plagioclase, microcline, myrmekite, biotite, and muscovite. Several muscovite-bearing specimens also contain fibrolite. Chlorite and epidote, replacing ferromagnesian minerals, appear locally in all three rock types. The quartz contains strainbands, and is recrystallized along the strain-band boundaries and grain edges to form lenticular domains composed of large strained and small unstrained grains. The plagioclase is unzoned and unaltered, but is generally fractured. Tiny grains of both plagioclase and quartz have developed along intergrain boundaries and along fractures (mortar texture) and the fine grained phases observed in outcrop may represent rocks in which this process is relatively advanced. Quartz-plagioclase boundaries are generally curved, and are convex toward plagioclase. The hornblende is commonly dendritic, and some poikiloblastically enclose small grains of quartz and plagioclase. The micas occur as single grains or in clots; many grains appear to have selectively grown along grain boundaries and fractures in the leucocratic minerals. The fibrolite, where present, occurs in and around muscovite clots.

15.2 COMPONENT 4b SYNMETAMORPHIC/SYNKINEMATIC GRANITOID ROCKS, PEGMATITES, AND VEINS OF TERRANE II (UNIT 10)

15.2.1 Subdivision and main characteristics of Unit 10:

These synmetamorphic granitoid rocks can be described in terms of two mutually gradational end member phases, Rose Blanche and Port aux Basques phases, which can be broadly correlated with the Rose Blanche and Port aux Basques

Granites of Brown (1975).

The Rose Blanche phase consists of massive foliated granodiorite to tonalite with veined metasedimentary, or locally amphibolitic, screens normally gradational into veined host rocks. The Port aux Basques phase is hosted mainly by amphibolite, and is restricted to a broad wedge next to the Cape Ray Fault in the west part of the Bay du Nord belt and the northeastern wedge.

Numerous pegmatites occur in the areas also occupied by the synmetamorphic granitoid rocks. Kyanite-quartz veins are exposed in a zone along the southeast side of the Cape Ray Fault, and thick quartz veins are also located within five kilometers of the fault.

15.2.2 Rose Blanche phase (Unit 10a,b)

Lithology:

The Rose Blanche phase is characterized by schistose tonalite to granodiorite with minor granite. Granitoid rocks of different composition are mutually gradational. Outcrops are characteristically grey to white weathering, although pink weathering exposures were observed locally along Rose Blanche Brook and near small intrusions of late, fine grained, pink leucogranite. Pink weathering veins of foliated, muscovite-rich leucogranite also cut the grey weathering granitoid near the transition to the Port aux Basques phase in the west part of the terrane.

The least foliated granitoid rocks generally contain small, sparsely distributed, zoned plagioclase phenocrysts. The granodiorite and tonalite contain between 5 and 15 percent ferromagnesian minerals, mainly biotite. Muscovite-rich granite was observed principally in the shear zone adjacent to the Cape Ray Fault, the Gunflap Hills shear zone, and along the northwest side of the La Poile batholith. In the latter area, it forms coarse grained, almost pegmatitic sheets interlayered with more foliated, medium grained, biotite-rich granite or granodiorite. Garnets are small and scarce, except in the muscovite-rich granites.

These granitoid rocks display a penetrative schistosity defined by the planar orientation of micas and flattened quartzofeldspathic domains. The schistosity is weak in many exposures, but intense near shear zones associated with the Cape Ray Fault and the Gunflap Hills fault splay, and northeast side of the La Poile batholith. A prominent segregation gneissosity is developed where the granitoid rocks are intricately interlayered and deformed with metasedimentary gneisses west of Northwest Brook. The gneissosity is folded in many outcrops, especially in the central part of the area, but is merely transposed parallel to a regional northeast-trending structural grain in others. Small, openly to tightly folded quartz veins are displayed in many exposures in the southwestern part of the area, and are probably tension gash fillings variably deformed after their formation.

Mylonitic to blastomylonitic granitoid rocks with similarly foliated metasedimentary and amphibolitic screens are exposed from the the east trending portion of the Cape Ray Fault to the Gunflap Hills fault splay and in the adjacent northeastern wedge. Alkali feldspar porphyroclasts are a centimetre or more in maximum diameter in the west, but much smaller to the east. In the northeastern wedge, fine, medium, and coarse grained granitic schist and porphyroclastic granitic schist alternate in bands. Rare, sharply bounded, angular xenoliths of both equigranular hornblende quartz diorite and feldspar porphyritic granitoid rock are enclosed in the foliated granodiorite-tonalite exposed on Northwest Brook. These may be either Paleozoic or older granitoid phases from the meta-igneous crustal foundation of the La Poile River Group.

Petrography:

The Rose Blanche phase is normally composed largely of plagioclase, quartz, biotite, and minor muscovite. Alkali feldspar and minor myrmekite occur locally as principal constituents. Accessory minerals include zircon, magnetite, apatite, epidote, local sphene, local allanite, local fibrolite, and local garnet. A penetrative schistosity, generally conjugate in aspect, is defined in thin section by flattened quartz domains, weakly porphyroclastic plagioclase, and micas. In many areas, one of the conjugate schistosities is developed preferentially. // Plagioclase (An_{20}-An_{40}) occurs as zoned, subhedral laths which form porphyroclasts in relatively deformed rocks. It comprises 40 to 60 modal percent of the rock. // Quartz (25 to 35 modal percent) occurs as polygonized grains with irregular to sutured domain boundaries. It is generally interstitial to plagioclase, but locally forms small, little strained grains, which both overprint and occupy grain margins of plagioclase. In highly deformed rocks, quartz forms very fine grained aggregates interstitial to plagioclase porphyroclasts. // Alkali feldspar generally comprises from 0 to 10 percent of the rock, but locally comprises up to 30 percent. Large grains commonly consist of untwinned orthoclase or microcline hair perthite (under 5 percent exsolved plagioclase) rimmed with gridiron-twinned microcline. Microcline also appears interstitially. Very small, lightly sericitized plagioclase inclusions occur in some of the large grains. Myrmekite (if present) embays the microcline, occurs alone, or rarely rims plagioclase. // Biotite (5 to 10 modal percent) is mainly olive green, but is locally red brown around major shear zones. It is associated with subordinate muscovite and most of the accessory minerals. Mica flakes generally occupy and slightly embay grain boundaries in the quartzofeldspathic assemblage. Minor fibrolite is developed around the micas in some of the rocks, and may also overprint leucocratic domains, especially near the Cape Ray Fault. Brown (1975) also reported fibrolite nodules replacing muscovite and vice versa in slide zones. Biotite in synkinematic granitoid rocks next to the Bay d'Est Fault is partly altered to rutilated chlorite in places. Allanite and sphene are unusually abundant in some of the tonalitic rocks near the headwaters of Garia Brook (within the Cape Ray Fault zone). Apatite is ubiquitous, but variable in abundance.

The **garnetiferous muscovite granite** consists mainly of quartz, microcline, myrmekite, plagioclase, biotite, muscovite, and garnet with accessory, coarse apatite, and zircon. The quartz occurs interstitially as polygonized grains with numerous smaller grains along their margins, forming lenticular domains that in part define the schistosity (mortar texture). Microcline is interstitial, and plagioclase occurs in zoned, subidiomorphic laths. Mica flakes overprint the leucocratic minerals to impart a well developed schistosity, but some are oriented at random angles to the fabric. Garnets occur as small, idiomorphic to rounded, inclusion-free grains. Biotite is scarce to absent in the coarse grained, garnet- and muscovite-rich granite band northwest of the La Poile batholith; in these rocks, sillimanite is found in the cores of some large muscovite grains, and lenticular quartz domains are the only fabric forming elements.

Gneissically-banded tonalite to granodiorite (west of Northwest Brook) is characterized by sharply to gradationally bounded, alternating melanocratic and leucocratic layers 1 to several centimetres thick (Plate 15.5). The melanocratic bands in the well segregated gneisses are largely composed of olive brown to red brown biotite and muscovite which may together define a planar foliation or occur as coarse, randomly oriented flakes, and flattened plagioclase domains overprinted by the micas. Accessory opaque minerals, zircon, apatite, and rare euhedral garnet are concentrated in the melanocratic bands. The leucocratic bands are composed mainly of unzoned to weakly zoned plagioclase (oligoclase) and strained quartz with minor biotite and accessory zircon. Muscovite porphyroblasts overprint plagioclase locally. Poorly-banded, gneissic rocks are composed of gradational layers alternately enriched and depleted in biotite. The strong, micaceous schistosity displayed by mica-rich bands is continuous with gently curved, S-shaped foliations in the leucocratic segregations in some of the rocks.

Granitoid rocks near the Cape Ray Fault in the west locally contain augen of feldspar and abundant coarse muscovite. The augen in most rocks consist of coarse to medium grained, corroded to highly embayed crystals of zoned plagioclase (oligoclase-andesine). However, large myrmekite-rimmed porphyroblasts of microcline, and smaller porphyroclasts of hair perthite, are locally abundant. The microcline porphyroblasts consist of hair perthite (2 to 5 percent exsolved plagioclase) with non-perthitic microcline rims. Highly polygonized, sutured quartz domains and flattened, interstitial microcline occur as part of the foliated matrix to these augen. Finely recrystallised quartz ribbons occur in mylonitic layers. These rocks are also characterized by very coarse, generally red brown, but locally blackish green, biotite with abundant zircon and coarse apatite inclusions. Very coarse muscovite buttons were formed in microcline-free rocks. Fibrolite is locally developed within muscovite and plagioclase grains.

The granitoid rocks in the shear zones of the northeastern wedge have strong planar, protomylonitic to ultramylonitic fabrics (Sibson, 1977), and enclose similarly foliated screens of semipelitic schist and amphibolite. Fine, medium, and coarse grained granitic schist and coarse grained augen schist alternate in bands. The more coarse grained rocks are composed of quartz, plagioclase, and alkali feldspar with less than ten percent biotite and local muscovite with or without accessory allanite, zircon, and garnet. The alkali feldspar consists of hair perthite (less than 5 percent exsolved plagioclase) with oval quartz inclusions and microcline around rims and fractures. Rare ribbon perthite (10 to 25 percent coarse plagioclase) and myrmekite lobes were observed locally. The quartz in all samples forms recrystallized domains with sutured intergrain boundaries, defining a schistosity which locally forms augen around corroded, bent feldspar grains. In the most deformed rocks, the alkali feldspar and plagioclase augen are isolated in the foliated matrix and display thin quartz-filled tension cracks. Coarse muscovite buttons occur within the foliation planes instead of biotite, and have partly reacted to produce sillimanite around their margins and tips; trails of fibrolite needles occur along the button-bearing foliation planes. Sparse, red, tabular garnet grains are oriented parallel to the foliation and fragmented within it. Less deformed biotite-bearing rocks contain rare muscovite, but contain abundant accessory opaque, euhedral allanite, and large, clear, prismatic zircons.

15.2.3 Port aux Basques phase (Unit 10c)

Lithology:

The Port aux Basques phase consists of pink to white, medium grained, largely equigranular granitoid rock which varies in composition from tonalite to true granite. Samples of the entire compositional range can commonly be obtained from a single outcrop. It contains five to fifteen percent ferromagnesian minerals and muscovite. Biotite is the predominant ferromagnesian mineral, but hornblende occurs in some rocks.

The Port aux Basques phase is characterized by a strong gneissic fabric. This fabric is largely planar in the southwest, and is tightly to moderately folded in many outcrops. In the northeastern wedge, the fabric commonly has a prominent linear component, the lineation defined by lenticular aggregates of mafic minerals plunging moderately to the southeast in the plane of the southeast-dipping foliations. Some exposures of the Port aux Basques phase near the coast are relatively unfoliated and conspicuously coarse grained; these are cut by pegmatite veins and larger pegmatites. Coarse grained gneissic bands in some of the gneissic granite further northeast on Rose Blanche Brook (Plate 15.6) may represent either remnants of the coarse grained granite or pegmatite veins. Lenticular leucocratic domains resembling feldspar augen are present in many gneissic exposures.

Petrography:

The Port aux Basques phase is largely composed of allotriomorphic inequigranular intergrowths of plagioclase, quartz, local alkali feldspar, local myrmekite, biotite, local chloritized biotite, local muscovite, and local blue green amphibole. Zircon, apatite, epidote, allanite, magnetite (local), sphene (local), garnet (local), and fibrolite (local) are accessory minerals. A very strong, crenulated to tightly folded foliation is due to flattened quartz domains, dimensional preferred orientation of feldspar grains, and preferred orientation of biotite, muscovite, and amphibole. Biotite and amphibole are concentrated along the crenulation schistosity in many rocks. // Plagioclase comprises between 20 and 60 modal percent of the rock, its proportion apparently decreasing with increasing amounts of alkali feldspar. It consists mainly of clear, unzoned, corroded anhedra of oligoclase-andesine (Plate 15.7). Rare grains with oscillitory zoning occur locally. In some samples, the plagioclase grains are bent and fractured; in others, optically continuous but slightly bent fragments are separated by infillings of quartz. // Quartz (30 to 40 modal percent) forms a strained and annealed network which engulfs and embays plagioclase. Fine grained quartz occurs along quartzofeldspathic grain boundaries, and also as small, rounded 'inclusions' locally in grains of plagioclase, alkali feldspar, and amphibole. // Alkali feldspar (if present) occurs both as domains of hair perthite (very minor exsolved plagioclase) passing into irregular rims of nonperthitic, gridiron-twinned microcline, and as interstitial microcline. Rare bleb perthite was observed in samples from the northeastern wedge. Some of the partly perthitic domains form aggregates of anhedral grains which may represent fragmented larger crystals that were fractured and rotated slightly during deformation; nonperthitic, twinned microcline now borders the fracture boundaries and represents an annealing phase. Simple or composite porphyroclasts of microcline over 1 cm long occur locally. Myrmekite, up to 5 modal percent in the presence of microcline, either embays microcline or appears alone as part of the leucocratic intergrowth. // Biotite (2 to 15 modal percent) is generally dark brown in colour, but is locally green, and contains abundant zircon inclusions.

Rarely, the biotite is partly altered to rutilated chlorite. Biotite flakes and minor local muscovite appear to overprint the leucocratic assemblage, as do traces of fibrolite. // The amphibole, where present, exhibits intense blue green pleochroism, and has a negative 2V, varying from 50 degrees to considerably less in different specimens. On the basis of optical properties, it could be either blue green hornblende or ferrohastingsite. The grains are anhedral to subhedral and prismatic in habit, and many poikilitically enclose grains of quartz, plagioclase, and biotite (Plate 15.8). It is generally clustered with biotite, particularly in the northeastern wedge. // Accessory zircon, epidote, and apatite are common. Magnetite is abundant in many samples, but is locally absent. Very dark coloured sphene occurs in the absence of magnetite. Zoisite prisms up to 2 mm long, as well as epidote rimmed allanite, occur locally. Tiny, subhedral, inclusion-free garnets were also observed in a few specimens.

15.2.4 Pegmatites and veins

Lithology and petrography:

The pegmatites range from several centimetres to over a metre thick, and were generated along and across foliation planes. Many are composed mainly of quartz, feldspar, muscovite, and biotite, with some containing garnet, tourmaline, apatite, and rarely, beryl, in addition. A conjugate set of thin veins of quartz-feldspar-mica pegmatite traverse the foliations of the synmetamorphic granitoid rocks east of Garia Brook. Thick pegmatites associated with the Port aux Basques phase near the south coast locally contain abundant magnetite and chalcopyrite. Others situated in metavolcanic and associated rocks in the Bay d'Est Fault zone consist of graphic granite, quartz, tourmaline, magnetite, and, in one locality, rare beryl, pyrite, chalcopyrite, molybdenite, and fluorite. Pegmatites developed in the Piglet Brook Rhyolite are composed only of alkali feldspar, quartz, and muscovite.

Thick bands of blue or green, colour zoned kyanite and quartz exposed on the hillside overlooking Grandys Brook #1 are similar in grain size to the pegmatites. Pegmatites nearby contain kyanite, and mylonitized granitoid sheets exposed along strike from the most prominent veins consist of quartz, muscovite, kyanite, and sillmanite. Extension gash fillings of kyanite and quartz were also noted in the northeastern wedge.

15.3 CINQ CERF COMPLEX, TERRANE II (Unit 10d)

General characteristics and distribution:

The Cinq Cerf Complex is an extensive granodiorite intrusion which includes rafts and xenoliths of massive amphibolite and subordinate amphibolite facies metavolcanic and metasedimentary screens, all of which are cut by intermediate to mafic dykes concentrated within 100 m of the Grand Bruit Fault. The complex is exposed along the south side of the Grand Bruit Fault in the Roti to Cinq Cerf Bay area, and continues eastward as roof pendants in the Chetwynd Granite (Unit 18a on Map 1) and huge screens or rafts in the megacrystic quartz monzonite intrusion (Unit 13 on Map 1). It is possible that the complex is also exposed between the north contact of the latter intrusion and several shear zones across Grandys Brook #2 which affect the Roti Granite.

Lithology:

The Cinq Cerf Complex is most commonly represented by grey weathering, equigranular granodiorite containing amphibolite inclusions in various stages of assimilation. These inclusions are more abundant near large rafts of amphibolite facies metagabbro and metavolcanic and metasedimentary rocks near the Grand Bruit Fault west of Cinq Cerf Bay. Many of the felsic screens have been mylonitized prior to incorporation into the complex. The granodiorite is penetratively foliated much more intensely near the Grand Bruit Fault than away from it, and simple shear zones are common. The foliation is commonly composite. In highly deformed exposures, the amphibolite inclusions are flattened, whereas elsewhere they are fairly equant. The granodiorite was intruded along bedding planes, schistosities, and fractures in the schist and mylonite screens near the Grand Bruit Fault, and these injections folded.

The dykes vary in composition from nearly ultramafic to intermediate, and commonly contain small ferromagnesian and/or plagioclase phenocrysts. Dykes are simple or composite, and may intersect. They vary from weakly to strongly deformed, with foliations continuous with the fabrics of the granodiorite, but generally sigmoidal in arrangement. In one area, east-trending shear zones and mafic dykes, many with numerous highly deformed xenoliths of silicic granodiorite, amphibolite, and metagabbro, appear to truncate the prominent fabrics of the granodiorite (Plate 15.9). One dyke set next to the main fault trace crosscuts the intense foliation of the pre-granodiorite screens, contains equant ultramafic cobbles, and is foliated parallel to the dyke margins (Plate 15.10).

Petrography:

The granodiorite consists of an allotriomorphic granular intergrowths of plagioclase, microcline, quartz, green brown biotite, and blue green hornblende, with accessory opaque minerals and sphene. Some of the rocks are actually more tonalitic than granodioritic. The plagioclase (largely andesine) is commonly zoned, and more abundant than microcline. Alignment of biotite and hornblende, together with lenticles of strained and polygonized quartz, constitute the tectonic foliation. The granodiorite is retrograded around shear zones, so that the ferromagnesian minerals are replaced by chlorite-biotite intergrowths, and epidote is abundant.

Amphibolite and metagabbro rafts consist largely of medium grained blue green hornblende and saussuritized andesine with abundant accessory opaque minerals.

The dykes are variable in makeup, and have not been studied particularly. **One typical intermediate dyke** contains equant, euhedral, simply twinned ?clinopyroxene phenocrysts (now replaced by blue green hornblende) in a matrix of plagioclase, blue green hornblende, and biotite with accessory epidote, apatite, and opaque minerals. Biotite, matrix hornblende, and quartz define a strong foliation which is weakly crenulated. **Another, chilled dyke** is composed mainly of interlocking acicular (basaltic) plagioclase and fibrous actinolite, with a few uralitized mafic and smaller plagioclase phenocrysts, and accessory epidote, quartz, and abundant magnetite.

15.1 Biotite tonalite intruding massive metagabbro, Dinosaur Pond belt.

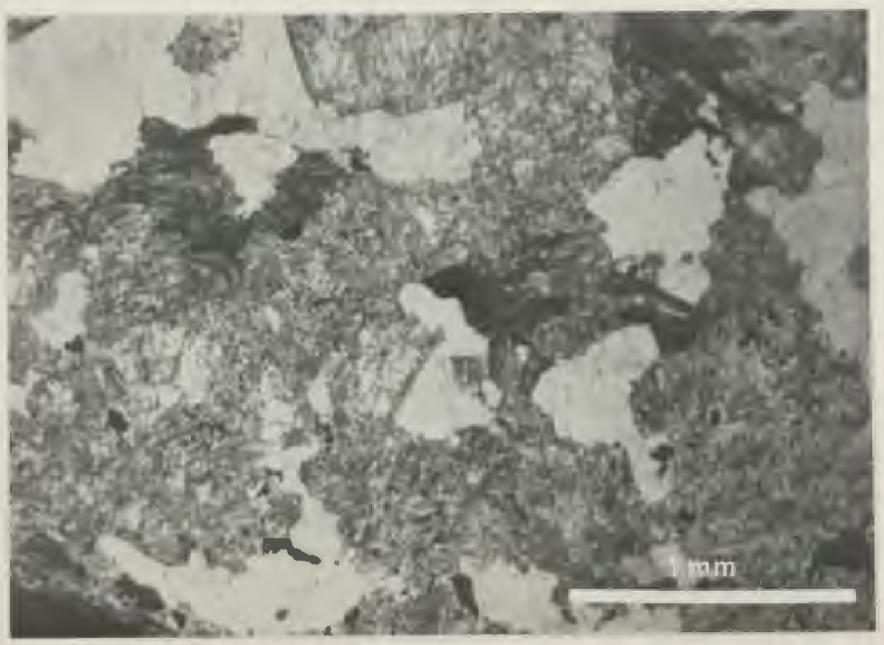
15.2 Garnet-biotite tonalite with abundant metasedimentary inclusions in southeastern part of north-central high strain zone. Note large garnets.

15.3 Photomicrograph of highly altered tonalite of the north-central high strain zone, with feldspars altered to white mica and the biotite bleached. (80-MS-004, plane polarized light)

15.4 Highly deformed pink granitoid 'gneiss' near South Brand River.

15.1

15.2



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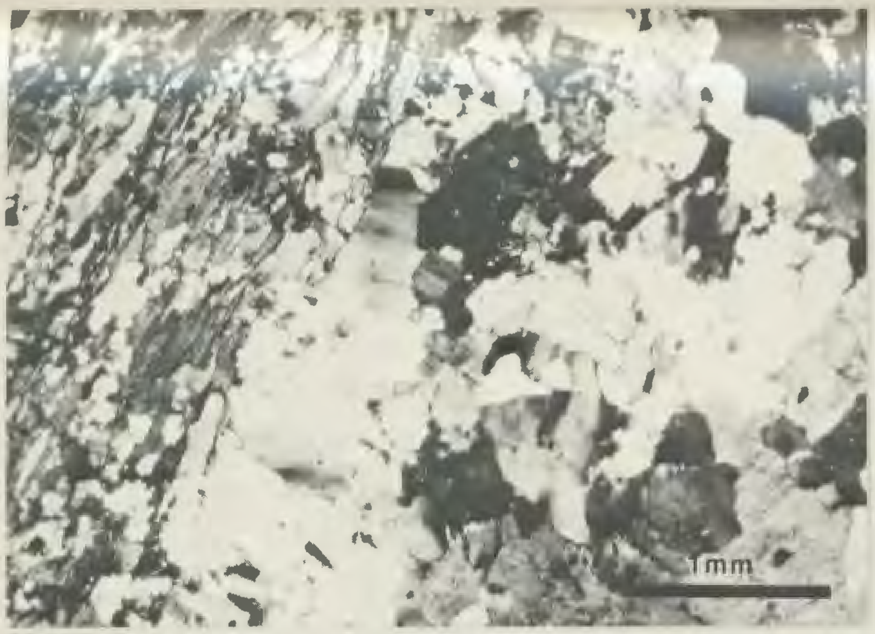
15.4

15.5 Photomicrograph of gneissic Rose Blanche phase, west of Northeast Brook. (80-LC-306, cross polarized light)

15.6 Gneissic granitoid of Port aux Basques phase, Rose Blanche Brook.

15.7 Photomicrograph showing corroded plagioclase in matrix of fine grained, fragmented plagioclase and recrystallized quartz, Port aux Basques phase. (79-LC-257, cross polarized light)

15.8 Photomicrograph of poikilitic amphibole (centre). (79-LC-257, plane polarized light)



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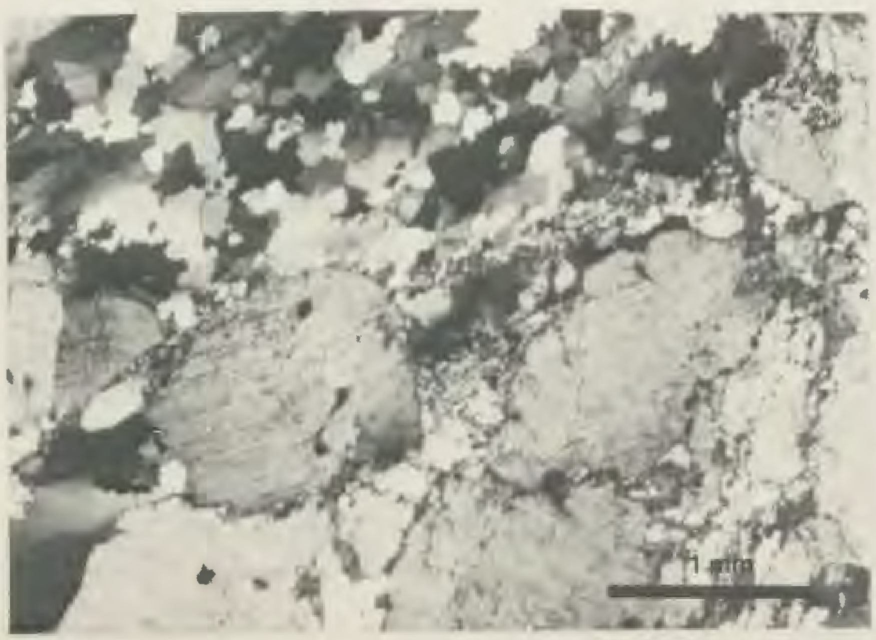

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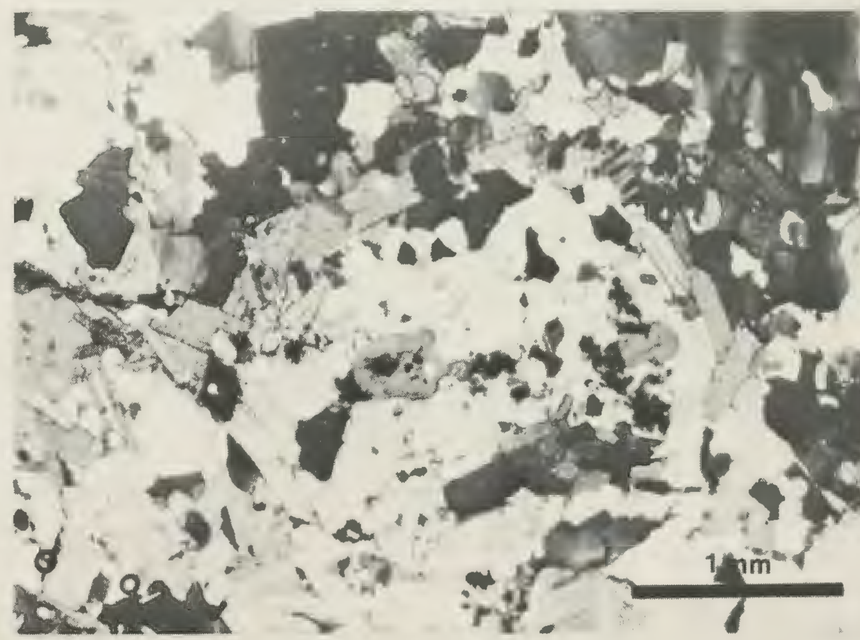


15.8

15.9 Foliated dykes with numerous platy country rock xenoliths cutting more massive amphibolite of Cinq Cerf Complex.

15.10 Intermediate lamprophyric dykes with local ultramafic xenoliths (LH-centre) cutting across foliated amphibolite and granitoid gneiss of Cinq Cerf Complex, Grand Bruit Fault zone.

15.11 Mafic dyke cuts Cinq Cerf granodiorite, Grand Bruit Fault zone.

15,9

15.10

15.11

CHAPTER 16: 'LATE SYNKINEMATIC' GRANITOID PLUTONS OF THE SOUTHERN LONG RANGE MOUNTAINS

16.1 LATE SYNKINEMATIC GRANITOID ROCKS OF TERRANE I (UNIT 8)

16.1.1 General characteristics of Unit 8

These plutons range from gabbro to granite, many of the latter megacrystic. Some plutons display pronounced internal compositional and textural variation on the surface, whereas others show relatively uniform composition but vary in texture. Granitoid rocks of this category include quartz gabbro, quartz diabase, quartz diorite, quartz monzonite, and granite. Norite, in addition, has been reported in Terrane I to the north of the study area (Carew, 1980). Three such intrusions from the southern Long Range Mountains will be described below, with emphasis on those investigated during this study. One is a megacrystic quartz monzonite to granite (Unit 8a) exposed in the southwest part of Terrane I. The others consist of a quartz diorite to megacrystic granite and quartz monzonite (Unit 8b) and an adjoining, if not cogenetic, quartz gabbro to quartz diabase (Unit 8c) exposed in the north and northeast parts of the study area.

16.1.2 Megacrystic quartz monzonite to equigranular granite (Unit 8a)

Lithology:

Inhomogeneously deformed, coarse grained, megacrystic quartz monzonite represents the bulk of the unit within the area mapped. Medium to coarse grained, equigranular granite or granodiorite patches are common to the southwest (Brown, 1977). The rocks probably occur as several separate intrusions, which typically either enclose rafts of metagabbro and screens of equigranular granitoid rock or project as dykes into Long Range Mafic-Ultramafic Complex and the tonalite.

Megacrysts of plagioclase and microcline are generally 0.5 to 1 cm, and locally over 2 cm, in maximum diameter. The megacrysts make up around 35 percent of the rock, and stand out as resistant, pink or white laths against the matrix of quartz, feldspar, mica, and epidote. The proportion of dark minerals apparent in hand specimen varies from about 5 to 20 percent. Patches of non-porphyritic to megacryst-poor, coarse to medium grained quartz monzonite or granodiorite occur near the margins of the intrusions in a few places. Aplite and pegmatite are common.

The equigranular granite in the southwest varies from weakly deformed, white weathering two-mica granite (Red Rocks Granite: see Section 6.2.1) to highly deformed, pink weathering, two-mica granite. The Red Rocks Granite locally contains disseminated sulphides.

The megacrystic quartz monzonite is inhomogeneously deformed, locally intensely. Megacrysts are flattened to lenticular augen, and some crystals are fractured and strung out in the foliation. The foliation is defined by stringers of ferromagnesian minerals and recrystallized quartzo-feldspathic matrix. The release of epidote from plagioclase and possible leaching are the effects of alteration during deformation. The highly deformed megacrystic dykes have been tightly folded by at least the second deformation which has affected their hosts.

Petrography:

The quartz monzonite contains megacrysts of plagioclase and microcline in a fine grained matrix of quartz, biotite, epidote, and minor local microcline or plagioclase. Accessory sphene is exceptionally abundant, and magnetite is less abundant. Muscovite and minor interstitial chlorite occur locally. Plagioclase megacrysts predominate in some samples, microcline in others. The large plagioclase (oligoclase) crystals are bent, fractured, and commonly show kinkbands. Many of these plagioclase domains are intact, with optically-disoriented fragments separated by fractures lined with tiny plagioclase neoblasts. Other plagioclase domains consist of bent and slightly rotated fragments separated by thin layers of fine grained quartz, biotite and epidote. Microcline forms larger, ragged-edged augen, and consists largely of string perthite (under 5 percent exsolved plagioclase) in which gridiron twinning is developed to a variable degree. Grain margins are locally embayed by myrmekite lobes. Large grains are criss-crossed by fractures lined with very fine grained quartz, epidote, and biotite. Smaller, optically-misoriented microcline grains adjoin the larger crystals at the elongated corners of the augen. The matrix quartz is microcrystalline, and stringers of quartz and very fine grained, olive green biotite define the anastomosing foliation. Muscovite, most abundant in very highly deformed rocks, either forms small flakes which overprint plagioclase along crystallographic planes or occurs as coarse buttons which form augen in a biotite-depleted mylonitic foliation defined by quartz ribbons. Epidote and sphene are coarse grained, and the latter is brown to dark yellow brown in colour.

The Red Rocks Granite is generally composed of plagioclase, alkali feldspar, and quartz with minor biotite and muscovite. Epidote, sphene, zircon, and fine grained opaques are accessory minerals. Plagioclase (oligoclase-andesine) is sericitized in patches. The alkali feldspar in most rocks occurs as interstitial gridiron-twinned microcline with cores of untwinned, locally hair perthitic orthoclase or microcline. In other rocks, it is present as elongate, zoned, Carlsbad-twinned microcline phenocrysts with tiny inclusions of sericitized plagioclase; gridiron twinning occurs in patchwork subdomains that commonly transgress zone boundaries.

16.1.3 Quartz diorite to megacrystic granite (Unit 8b)

Lithology:

This intrusion is characterized by widely varying composition, the abrupt transition in some outcrops from medium grained quartz diorite to megacrystic granite or quartz monzonite with large orthoclase megacrysts, and randomly oriented hornblende and biotite. Many screens of the tonalite and its mafic meta-igneous inclusions are enclosed in the body, and patches of diorite occur away from the main pluton, making the precise boundary of the pluton difficult to define in the field.

The intrusion includes quartz diorite, megacrystic granite, quartz monzonite, and quartz monzodiorite, the latter limited in exposure. Quartz diorite is the predominant phase in the west, and in some outcrops grades abruptly into orthoclase megacrystic granite or quartz monzonite. The transition from quartz diorite into plagioclase and orthoclase porphyritic quartz monzonite is more subtle. Patches of equigranular, pink granite were observed near the Cape Ray Fault. Pink aplite patches occur within some of the highly altered tonalite/ amphibolite screens, and pegmatite was observed locally.

The quartz diorite is uniformly medium grained, and fresh surfaces show subhedral plagioclase, and about 30 percent randomly-oriented, dark green hornblende and dark brown biotite. The megacrystic granite or quartz monzonite is characterized by a variable abundance of rectangular, pink alkali feldspar porphyroblasts several centimetres long, which overprint the medium grained quartz diorite. The porphyritic quartz monzonite contains sparse to abundant, zoned plagioclase phenocrysts and white to pink weathering orthoclase megacrysts with tiny plagioclase inclusions in a medium grained granodiorite or quartz diorite matrix. Sparse, white feldspar porphyroblasts overprint clinopyroxene-bearing diorite in the quartz monzodiorite. All rock types contain many small, partly assimilated mafic xenoliths.

The intrusion is more highly fractured and altered to the east and southeast than it is to the northwest. It is largely unfoliated, but a strong cleavage grading to schistosity is evident near the Cape Ray Fault. Several sheared outcrops of the granite or quartz monzonite within the Cape Ray Fault zone in Garia Brook are leached of almost all mafic constituents. Sheared and altered tectonic lenses of 'quartz eye' granitoid rock similar in appearance to leached apophyses which occur along the fault zone to the east, and may be slivers of the basement to the Windsor Point Group. [If so, a component of sinistral displacement on the fault may be indicated.]

Contact effects, such as alteration of feldspar and chloritization of biotite, occur in the tonalite complex at the boundary and extend for an unknown distance to the west. The affected rocks typically appear highly weathered. It is uncertain whether the contact aureole overprints, or is the cause of, some of the alteration in the highly sheared rocks in the north-central high strain zone. The exposure of sporadic patches of the intrusive quartz diorite away from the western boundary of the main surface exposure of the body could mean that the intrusion is either continuous in the subsurface or occurs as smaller, separate bodies for some distance to the west. It is therefore difficult at present to assess whether such a width of altered rocks could reasonably be related to this intrusion, whether the emplacement of the intrusion provided a source of heat which caused renewed convection along previously existing hydrothermal pathways, or whether the intrusion itself was the sole cause of hydrothermal degradation.

Petrography:

The quartz diorite, megacrystic granite, and quartz monzonite are composed essentially of plagioclase, amphibole, biotite, and quartz, with locally abundant alkali feldspar. Augite is found in the quartz monzodiorite. Epidote, chlorite, and coarse sericite are locally present as late magmatic or secondary phases. Carbonate patches may be present in some of the highly sheared rocks. Accessory minerals include sphene, zircon, epidote, pyrite, and exceptionally abundant apatite. // Plagioclase (andesine) is the most abundant mineral, making up 35 percent or more of the quartz diorite and less of the other phases. It forms zoned, subhedral laths with cores of calcic andesine and sharply bounded rims of sodic andesine. Phenocrysts of plagioclase over a centimetre long are developed only rarely in the quartz diorite, but are relatively abundant in the quartz monzonite. Plagioclase varies from totally unaltered to patchily or completely sericitized. Saussuritization of the more calcic cores occurs mainly in the highly sheared rocks to the south. // Alkali feldspar, if present, is largely perthitic orthoclase (about 10 percent exsolved albite) which is converted to finely gridiron-twinned microcline along grain fractures and rims. The perthitic orthoclase is distinct from other perthites found in the area in that the domains of exsolved albite are very fine, forming short, diffusely-bounded stringlets which generally wrap around cleavage intersections. It forms large, clear, ragged-edged laths (Plate 16.1) which enclose small, rectangular inclusions of highly sericitized plagioclase and fewer inclusions of biotite, amphibole, epidote, and chlorite. In the presence of orthoclase, plagioclase is commonly totally sericitized. Myrmekite is not common, occurring as lobes along alkali feldspar grain margins in some rocks. // Quartz occurs in sporadic patches interstitial to, but weakly embaying, plagioclase. Polygonization and irregular, curved deformation lamellae are locally developed. // The amphibole displays a normal blue green pleochroic scheme, has a low $2V_x$, and is commonly twinned. It may be either true hornblende or hastingsite. // Khaki brown biotite and amphibole in reciprocal proportion form interstitial clusters. Together they constitute about 40 percent of the quartz diorite and less in the other rock types. Both biotite and amphibole enclose unusually abundant apatite crystals. Biotite is locally slightly to largely chloritized. In some of the more altered rocks, large prismatic grains of deeply pleochroic, yellow epidote, some with cores of allanite, cluster with ferromagnesian clots, and biotite is largely altered to chlorite with lenticles of sphene along old cleavage traces.

The aplite is composed of a fine grained, hypidiomorphic intergrowth of alkali feldspar, plagioclase, and quartz in subequal proportions, with minor amounts of myrmekite, biotite, chloritized biotite, and muscovite. Zircon, opaque minerals, sphene, and minor apatite are accessory minerals which are generally enclosed in biotite or chlorite. Alkali feldspar consists largely of orthoclase perthite similar in texture and composition to that of the megacrystic quartz monzonite. Microcline rims some of the grains, and occurs in fractured or deformed areas within perthite grains and at multiple grain junctions. Plagioclase (oligoclase) occurs as elongate laths which are generally partly altered to coarse sericite or muscovite flakes. Chloritized biotite contains sphene and epidote, but the other accessory minerals are very sparse. Rare myrmekite occurs as rounded lobes, and as fringes along feldspar grain boundaries.

The petrographic contact effects have not been systematically studied. In general:

Contact effects on the tonalitic host rocks include muscovitization and/or patchy microclinization of plagioclase, the local production of epidote in plagioclase and along fractures, the local production of fibrolite knots (in tonalite screens), the pervasive alteration of biotite to rutilated chlorite (still enclosing large zircons), and the overgrowth on plagioclase grain boundaries of networks of coarse, slightly strained quartz. Muscovite occurs as flakes which are commonly oriented along cleavages, and as dense intergrowths of matted acicular flakes. The mats resemble retrograded fibrolite knots, commonly preserved without retrogression in tonalitic screens. One sample of garnetiferous gneiss from very near the mapped contact shows a similar effect (Plate 16.2): the sample contains coarse, subrounded garnets concentrated in coarse, biotite-rich (now rutilated chlorite) gneissic bands which are crosscut at a high angle by bands of matted sericite or muscovite. Some patches of sericite have square cross sections reminiscent of prismatic sillimanite. Networks of very coarse, undeformed quartz in the plagioclase-rich domains of the original gneissosity are elongated parallel to the sericite bands.

Contact effects on the amphibolite include the development of randomly oriented, scattered chlorite flakes overgrowing well preserved blue green amphibole, and the extensive replacement of plagioclase by coarse epidote minerals and flakes of muscovite. Magnetite, if present, is not altered, but the more sparsely developed pyrite is rimmed with iron oxide.

The pluton is locally highly deformed toward the Cape Ray Fault zone. Plagioclase laths are fractured and bent, and the quartz displays numerous kink bands and curved deformation lamellae. Within the main fault zone, the granite has developed a penetrative foliation, and quartz domains have been polygonized and further strained to produce flat lenticles (ribbon-texture) in a very altered, occluded, feldspathic matrix.

16.1.4 Quartz gabbro-diabase (Unit 8c)

Lithology:

The main body of the gabbro consists of medium grained, subophitic hornblende-clinopyroxene gabbro with small, coarse grained pegmatite pockets. Dykes and other fine grained phases generally display a doleritic texture. A few outcrops in Fox Hole Brook possibly display igneous layering 5 to 10 cm thick. Mafic metamorphic or meta-igneous xenoliths which may be either finer or coarser grained and either more or less mafic than the host, are found in many exposures. Felsic patches and veinlets are common, especially where the rocks are deformed. In western outcrop areas, large patches of gabbro are slightly reddened and contain few, sparse porphyrblasts of alkali feldspar, perhaps due to the assimilation of felsic material or to late magmatic or hydrothermal alteration. On a hill overlooking the headwaters of Billiards Brook, a fine grained phase of the gabbro is in contact with a breccia that contains subangular blocks and smaller fragments of diabase or basalt, medium grained gabbro, pyroxenite, feldspar-phyric gabbro, diorite, and foliated granite, probably a basal breccia of the Windsor Point Group below. Diabase sheets cut through highly altered and brecciated, synkinematic granitoid rock northeast of the breccia outcrop.

The gabbro is sheared and fractured locally. In a few outcrops, thin shear fractures, spaced from several centimetres to several metres apart, appear darker in color and finer grained than the host rock. Cataclasis along the Cape Ray Fault system transforms the gabbro into a fine grained, highly foliated greenschist near Garia Brook.

Petrography:

The medium grained gabbro contains plagioclase (An_{40-50}), hornblende, actinolite, and minor interstitial quartz, with accessory opaque minerals, sphene, and apatite. The plagioclase grains are lath-like, normally zoned, and commonly highly saussuritized, especially in their cores.

The modal proportion of clinopyroxene varies; it occurs as large, subophitic grains, rimmed with hornblende and/or actinolite. Smaller, subophitic grains of hornblende are generally rimmed with actinolite; actinolite also occurs as separate, anhedral grains. Magnetite is the major opaque mineral, although pyrite is especially abundant in shear zones. Leucoxene or sphene rims small oxide grains, and locally forms individual crystals. Some phases of the gabbro contain biotite, enclosing a sagenitic array of exsolved rutile needles, as a major ferromagnesian constituent. Secondary chlorite and epidote replace ferromagnesian minerals locally. The opaque minerals are generally oxides; however, pyrite is ubiquitous in sheared rocks.

The diabase generally consists of a doleritic intergrowth of plagioclase and acicular actinolite, with abundant accessory epidote, chlorite and opaque oxides.

16.2 LATE SYNKINEMATIC GRANITOID ROCKS OF TERRANE II (UNITS 11-12, 14)

16.2.1 General characteristics of Units 11, 12, 14

In Terrane II, the most voluminous intrusions of this class are megacrystic monzogranites. Other Terrane II varieties include megacrystic syenodiorite-granite, and quartz feldspar porphyry.

The megacrystic monzogranite plutons (Unit 11) are the most voluminous. The megacrystic La Poile batholith (Unit 11a) and Otter Point Granite (Unit 11b) are very similar in appearance, and intrude the synmetamorphic granitoid rocks. The Hawks Nest Pond Porphyry (Unit 12) is a porphyritic microgranite which intrudes the Georges Brook and Dolman Cove Formations as a thick sill or laccolith in the centre of the highland plateau around Hawks Nest Pond, and as lenses or thin sheets to the south and southwest. Small dykes or sills of similar porphyry occur around the Bay d'Est Fault zone near Grandys Brook #2.

A more unusual, megacrystic syenodiorite to granite pluton (Unit 14) underlies the peaks around Ironbound Hill and the source of Couteau Brook.

16.2.2 La Poile batholith (Unit 11a)

Lithology

The La Poile batholith is a large body of porphyritic monzogranite which varies slightly but continuously in composition. The most abundant rock type in the widest part of the batholith is a coarse, white to pink weathering megacrystic quartz monzonite to granodiorite, containing tablets of plagioclase up to 5 cm long which are crudely aligned in a northeast direction. Microcline megacrysts are common near the margins of the body. Pegmatite lenses, containing crystals of garnet, apatite, and tourmaline are locally abundant; such pegmatites are found as boudins as far as 12 km along strike from the main batholith. Sheets of fine grained garnetiferous aplite are exposed in the centre of the highland between Deep Brook and the La Poile River.

Partially assimilated xenoliths of amphibolite can be found in the core of the batholith (Plate 16.3), whereas xenoliths and screens of metsedimentary country rock and synkinematic granitoid rock occur near the margins.

Evidence of deformation in the south is restricted to the margins of the body, where the megacrysts occur as augen in a planar fabric defined by the ribbon texture of quartz and the alignment of biotite. The foliation is strong in the northeastern lenses of the granite within the Gunflap Hills shear zone. Isolated pegmatite stringers on the west side of the batholith are boudinaged and locally folded.

Petrography

The rock varies between granite and granodiorite in composition (unpublished geochemical data), and consists essentially of plagioclase (An_{25-30}), microcline, quartz, biotite, and hornblende with abundant, coarse accessory sphene, epidote, allanite, apatite and opaques. Deformed, marginal granitic phases in the south also contain chlorite. Megacrysts include corroded phenocrysts of zoned, twinned plagioclase and in some rocks large poikilitic crystals of microcline enclosing grains of quartz, plagioclase, and biotite. The plagioclase laths are polysynthetically twinned according to both albite and pericline twin laws, and the twin laminae are bent locally. Weakly strained quartz forms polycrystalline domains in the matrix, accompanied by intergrowths of biotite, hornblende, and accessory minerals. The mafic minerals locally make up 30% of the rock.

16.2.3 Otter Point Granite (Unit 11b)

Lithology:

Most exposures consist of coarse grained, alkali feldspar and plagioclase megacrystic granite which weathers pink. The phenocrysts may be aligned, giving the rock a planar fabric which is noticeably stronger toward the Grand Bruit Fault, and not at all obvious to the southeast on the offshore islands and Otter Point.

Several thick pegmatites which locally contain garnet, tourmaline, and beryl, and copious pink aplite are associated with the batholith.

Petrography:

The Otter Point Granite contains megacrysts of alkali feldspar and plagioclase in a medium grained matrix of quartz, plagioclase, biotite, and amphibole with accessory sphene, zircon, and apatite. The alkali feldspar megacrysts are larger than those of plagioclase, and consist of orthoclase inverted in patches to gridiron-twinned microcline, and locally rimmed with plagioclase. Specimens collected near the Grand Bruit Fault display polygonized quartz with strong undulose extinction, quartz-filled tension gashes across feldspar megacrysts, and brittle fractures with offsets in phenocrysts originally oriented at a high angle to the foliation.

16.2.4 Hawks Nest Pond Porphyry (Unit 12)

Lithology:

The Hawks Nest Pond Porphyry forms cream to pink-weathering, massive, blocky exposures. Altered phenocrysts, particularly the greenish saussuritized plagioclase tablets and long, white orthoclase laths, stand out clearly against the matrix.

Deformation of the thickest body of Hawks Nest Pond Porphyry is very inhomogeneous. A single fracture cleavage is developed along the southeast side of the body, whereas a strong flattening schistosity is developed in the relatively thin sills or dykes. The fabric is attributed to the regional D_2 deformational event of Terrane II.

Petrography:

Phenocrysts of plagioclase, alkali feldspar, quartz, and biotite are set in a fine grained leucocratic matrix. Plagioclase is more abundant and occurs in smaller, more equant laths than orthoclase, which occurs as elongate, simply twinned crystals. The feldspars are extremely altered, particularly the plagioclase. Biotite is replaced pseudomorphously by chlorite, epidote, leucoxene, and opaque oxide.

16.2.5 Ironbound syenodiorite-granite (Unit 14)

Lithology:

The intrusion contains two major phases: an unfoliated, porphyritic (or porphyroblastic) syenodiorite restricted to the western part, and strongly to moderately foliated, porphyritic granite in the east and southeast. Outcrops of the more mafic rocks weather dark grey, with grey alkali feldspar laths standing out against a dark green matrix, speckled with white and pink. Biotite, hornblende, and clinopyroxene are visible on fresh surfaces. The granitic phase weathers deep red to grey, and contains ragged phenocrysts/blasts of alkali feldspar and smaller phenocrysts of plagioclase. Aplite and pegmatite are associated with the most granitic, southeastern part of the pluton.

The most interesting aspect of this intrusion, aside from its peculiar compositional variation, is deformational. The pluton itself is little deformed in its syenodioritic western part, but becomes increasingly foliated to the southeast and east. Megacrysts of microcline are disaggregated and recrystallized as much finer grains along the foliation in some of the eastern exposures.

Petrography:

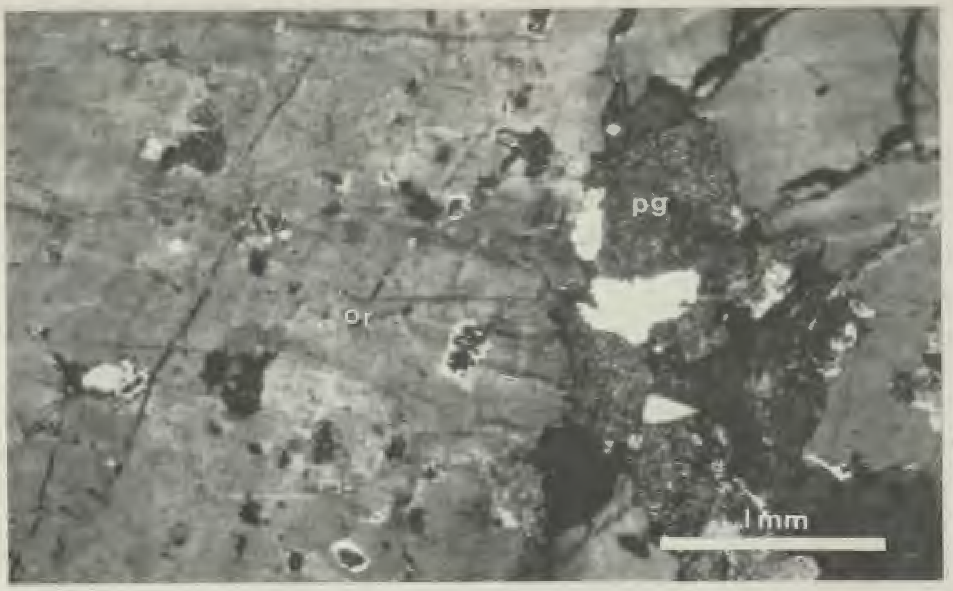
The syenodiorite has a nonequigranular, subidiomorphic texture. Both large phenocrysts or poikiloblasts of alkali feldspar enclosing small grains of augite and plagioclase, and smaller phenocrysts of zoned plagioclase are surrounded by a coarse grained matrix consisting of plagioclase, biotite, augite and local secondary actinolite with accessory fine grained opaque minerals and apatite. The alkali feldspar grains are nonperthitic to hair perthitic, and locally zoned. The composition of the matrix plagioclase is in the andesine range. The augite occurs as colourless, stubby subhedra, many multiply twinned and some with well developed diallage. Sphene is present as coatings on opaque grains where secondary actinolite is present.

The granitic phase is composed of large, ragged poikiloblasts of microcline and fewer, altered, zoned plagioclase phenocrysts in a matrix of quartz, microcline, myrmekite, plagioclase, actinolite, and biotite with exceptionally abundant accessory sphene, apatite, epidote, tourmaline, zircon, and allanite. The microcline encloses plagioclase, quartz, and biotite inclusions; lobes of myrmekite locally project into the grain margins, and some grains contain small cores of hair perthite. Biotite and poikilitic actinolite form lens shaped clusters associated with concentrations of accessory minerals.

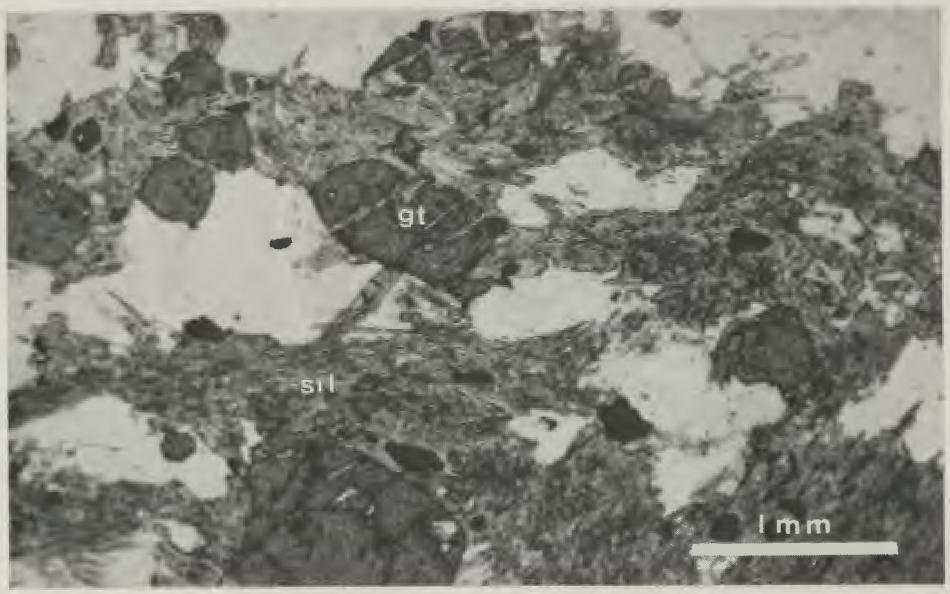
16.1 Photomicrograph showing alkali feldspar megacrysts overprinting highly altered plagioclase, quartz, chloritized biotite, and hornblende of quartz dioritic matrix. (80-LC-366, cross polarized light)

16.2 Photomicrograph of highly altered, garnetiferous quartz diorite near quartz diorite contact, showing alteration of plagioclase to sillimanite, bleached biotite, and garnet relicts. (DD-80-200, plane polarized light)

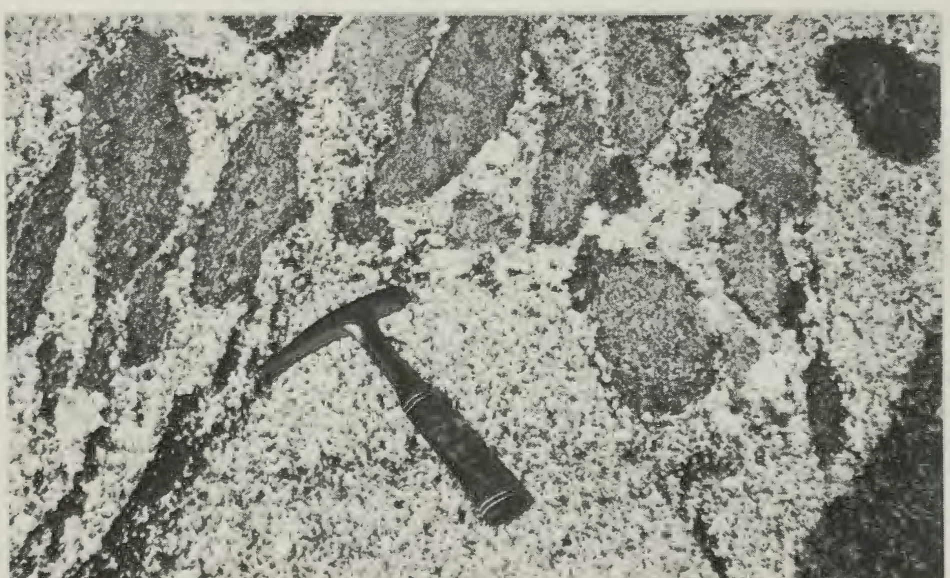
16.3 Partly assimilated amphibolite xenoliths in La Poile batholith west of Western Point.



16.1



16.2



16.3

CHAPTER 17: WINDSOR POINT GROUP SEDIMENTARY AND VOLCANIC ROCKS (UNIT 16), AND RELATED SUBVOLCANIC GRANOPHYRE (UNIT 15)

17.1 ROCK TYPES

The Windsor Point Group (Unit 16) includes both nonmarine sedimentary assemblages and a bimodal volcanic suite. Sedimentary rocks predominate in several areas, whereas in others, bedded (reworked) volcaniclastic rocks with mafic and felsic flows and/or sills predominate over nonvolcanic sedimentary rocks. Felsic volcanic rocks predominate over mafic volcanic rocks near the southwest coast, and generally occur in the lower parts of the succession. Mafic flows appear further northeast near Isles aux Morts Brook, continue as pinched out lenses in the east-trending fault splay, and reappear as flows, sills, and dykes in the upper parts the sequence in the northeast part of the study area.

Rock types are very diverse and cannot be treated systematically here. Descriptions of the Windsor Point Group in different segments of the fault zone are found in Brown (1972, 1975, 1977), Chorlton (1980a), Kean and Jayasinghe (1981), Kean (1983), and Wilton (in preparation).

An attempt is made only to portray the range of volcanic rock types, the general nature of the sedimentary sequence, and features that bear upon the structural and metamorphic history of the group.

Two subvolcanic granophyres (or rhyolite domes) are associated with the Windsor Point Group, the Windowglass Hill Granite (Unit 15a), and the Nitty Gritty Brook Granite (Unit 15b).

All of the rocks of the Windsor Point Group within the boundaries of the study area have been metamorphosed to greenschist facies grade. Therefore, the prefix meta has been dropped below.

17.2 WINDSOR POINT GROUP (UNIT 16)

17.2.1 Predominantly volcanic rocks

Felsic volcanic and related volcaniclastic rocks of the Windsor Point Group include rhyolite porphyry, ashflow tuff, aphyric rhyolite or rhyolite tuff, flowbanded rhyolite, rhyolite breccia, quartz crystal tuff, bedded siliceous tuff or siltstone, and polymictic volcanic conglomerate. The rhyolite porphyry weathers pink to pale grey with rounded phenocrysts of quartz and, less commonly, feldspar. Ashflow tuffs are either black or pale grey to pink, and contain glassy to devitrified, rhyolitic, agglomerate and lapilli size fragments. In the southwest corner of the Grandys Lake (N.T.S. 110/15) area, ashflows are closely associated with quartz crystal tuff and siliceous siltstone. The siliceous siltstone weathers white; differentially-weathered, bedded units range from several millimeters to 15 cm in thickness. Fragments in the breccias vary: examples are boulder-size blocks of rhyolite, quartz porphyry, foliated tonalite, and lapilli of flowbanded and aphanitic rhyolite, and broken crystals. Unsorted, angular fragments of silicic mylonite and either pink rhyolite or Windowglass Hill/Nitty Gritty Brook-type microgranite occur in volcaniclastic rocks associated with brecciated felsic and mafic flows exposed in the brook near the mylonite zone tuffisite.

The rhyolite varies from aphyric to porphyritic. Highly strained, polygonized, and locally recrystallized quartz phenocrysts predominate over altered alkali feldspar phenocrysts in porphyritic varieties. Very fine grained magnetite is commonly the sole mafic phase. Silicic pyroclastic rocks contain rare chlorite patches and associated khaki green biotite as well as magnetite. Rhyolitic fault gouge locally contains fluorite and abundant quartz stringers.

A devitrified glassy rhyolite dyke northwest of the main outcrop area weathers greenish grey, and contains rod-like spherulites plunging gently to the northeast. Radial devitrification textures (perpendicular to the 'spherulite-rod' lineation) are obvious in thin sections where sericitization is not intense.

Mafic volcanic and related rocks include mafic flows and/or dykes, and mafic tuffs. Several thick, green weathering mafic flows have many epidosite knobs and stringers. Calcite and chlorite-filled vesicles and small red orange spots (pseudomorphous after olivine?) occupy dark purplish weathering horizons in the massive flows. Interflow sedimentary rocks, consisting of dark red siltstone and polymictic conglomerate or breccia, occur in the northeast part of the study area. Although the mafic flows are commonly intensely deformed in the southwest part of the fault zone, carbonate and chlorite filled vesicles are locally still recognizable. Fine grained mafic tuffs are interlayered with brecciated felsic volcanic rocks. Chlorite schists along the south side of the belt contain abundant carbonate, and are believed to represent highly deformed mafic volcaniclastic rocks.

Mafic flows in the southwest are largely composed of actinolite, albite, quartz, epidote minerals, and magnetite. Actinolite occurs as deeply pleochroic (Z= blue green, Y=green, X= pale green), fibrous sheafs, which only locally lie parallel to the schistosity. The leucocratic minerals are very fine grained. Tiny, poorly formed plagioclase phenocrysts are present in some of the basalts. Magnetite is finely disseminated, and is generally concentrated along foliation planes. Minor secondary chlorite was observed locally.

Mafic tuffs contain detrital quartz and either muscovite or sericitized patches, relatively coarse grained opaque and epidote minerals, chlorite, and abundant patches of carbonate in addition to the above assemblage.

Mafic flows in the northeast segment of the fault zone consist of very fine grained intergrowths of chlorite, albite, epidote, pyrite, leucoxene and/or magnetite, with larger fragmented grains of actinolite and locally abundant secondary calcite. Epidote occurs as coarse polycrystalline knobs and stringers, as well as small fine grained clusters in the groundmass. Leucoxene occurs as separate grains or encloses cores of opaque oxide. Some specimens contain coarse calcite and chlorite filled vesicles (Plate 17.1), some of which have partial rims or marginal patches of fine grained epidote plus fine grained, disseminated hematite. Small, equant, orange knobs of the fine grained epidote mixture, apparently replacing an even more fine grained fibrous intergrowth, are very abundant in the vesicular basalt. Patchy carbonate replacement in the matrix of vesicular and nonvesicular rocks is common. The cores of some flows have a well developed doleritic, locally pilotaxitic, intergrowth of elongate plagioclase crystals, subophitic actinolite, and actinolite-rimmed hornblende grains, with accessory epidote, leucoxene and, locally, pyrite. A strong schistosity defined by sericite overprints the matrix intergrowth, and anastomoses around actinolite porphyroclasts and epidote knobs. Carbonate vesicles are flattened parallel to this fabric; many elongate grains of plagioclase are bent and fractured across the cleavage planes.

17.2.2 Predominantly sedimentary sequences

The Windsor Point Group is represented by predominantly sedimentary rocks in several places within the fault zone. Two such areas are described briefly below: (i) the area from the La Poile River-Morg Keepings Brook junction to Fox Hole Brook and upper Billiards Brook; and (ii) the Deep Brook-Nitty Gritty Brook area.

(i) La Poile River-Fox Hole Brook-Billiards Brook

Black siltstone, sandstone, and conglomerate are exposed along the lower part of Fox Hole Brook and to the west along the banks of Billiards Brook. The most northerly exposures of the sedimentary sequence in Fox Hole Brook begin in black silty mudstone with thin, graded, quartzitic laminations. Coarse grained interbeds are more common as the black mudstone passes southward into grey sandstone with interbeds of pebble conglomerate and black silty mudstone, a sequence which locally displays flame structures and load casts. The pebble conglomerate contains clasts of mafic and felsic volcanic rocks and grey siltstone. From the Fox Hole-Billiards Brook junction westward, interbedded cobble conglomerate, pebble conglomerate, granule conglomerate, sandstone, and black silty mudstone are exposed as ungraded beds 5 to 25 cm thick. The conglomerates contain many types of clasts, including rhyolite, basalt, fine grained granite, and red, grey, and black siltstone. The siltstone beds contain local lenses of coarse sand, fragmented plant fossils, and fossil algae. These rocks pass southward toward the junction of Two Way Brook into well graded quartzitic sandstone, laminated siltstone, and conglomerate. Thick, crossbeds indicating facing directions to the south occur in a sandstone and conglomerate unit at the contact with a basaltic flow (below).

Mafic flows and tuffaceous rocks, dark red siltstone, volcanic conglomerate, grey calcareous quartz sandstone, and chloritic carbonate rocks are both interbedded and structurally repeated above the quartz arenites.

From Two Way Brook eastward, the mafic volcanic rocks are associated with impure limestone, flaggy sandstone, and cobble conglomerate. The limestone consists of chlorite-carbonate schist, with dark green chlorite-sericite laminae 1 to 2 mm thick alternating with thicker bands of yellowish quartzitic carbonate rock. This schist contains several discontinuous 3 to 7 cm thick beds of pure white limestone near the mouth of Tarzan Brook. The limy rocks grade into flaggy grey sandstone and siltstone, and apparently pass laterally through pebbly sandstone into clast-supported, polymictic conglomerate with sandy lenses. The conglomerate contains subrounded to subangular clasts of grey siltstone, felsic volcanic rock, basalt, red siltstone, epidote, vein quartz, black or silty mudstone, and carbonate in an unsorted matrix of smaller angular clasts of the same lithologies (Plate 17.2). Basalt clasts associated with trondhjemite pebbles are relatively abundant on the hill between Billiards Brook and Fox Hole Brook, where the conglomerate passes laterally into a breccia of mafic igneous rocks at the contact with the fine grained phase of the quartz diabase/gabbro on a hillside overlooking the headwaters of Billiards Brook. The breccia contains subangular blocks and smaller fragments of diabase or basalt, medium grained gabbro, pyroxenite, feldspar-phyric gabbro, diorite and foliated tonalite in an at least partly clastic matrix; it grades southward and laterally into the crudely bedded, imbricated agglomerate which also contains felsic volcanic clasts, and thence into the polymictic conglomerate near the fossil locality.

The black, silty mudstone is composed of particles of quartz, plagioclase, pyrite, and very occluded, unidentified mineral or rock? fragments in a matrix dominated by sericite and graphite. The silicate particles are equant and angular, the pyrite subhedral. Graphite and sericite form a weak schistosity.

The sandstones are of variable composition and grain size. Most consist of poorly sorted, angular fragments of quartz, orthoclase perthite, chequered albite, plagioclase, basalt, rhyolite, pyrite, quartz-plagioclase intergrowths, and oxide-peppered siltstone (red siltstone). Intact basaltic plagioclase laths were noted in specimens from the

Billiards Brook fossil locality (Plate 17.3). Large quartz grains display curved deformation lamellae.

A unique oligomictic boulder conglomerate near the source of Woody Brook is almost exclusively composed of pink weathering, medium grained granite with prominent quartz domains; the granite may either represent the perthite-rich leucogranite plutons north of the Cape Ray Fault zone (plutons D-F of Section 8.3 and Map 2), or the Nitty Gritty Brook Granite. [If they were derived from Plutons D-F, then the emplacement of the plutons must have occurred before the cessation of Windsor Point Group deposition. Re-examination of the outcrop would be helpful.]

(ii) Deep Brook to Nitty Gritty Brook area

Highly deformed cobble, pebble, and granule conglomerate, or volcanic tuff and conglomerate, chlorite-carbonate schist, coarse pebbly sandstone, black silty mudstone, and mafic and felsic flows or sills occur in this area.

The conglomerates or volcaniclastic rocks contain predominantly angular clasts of rhyolite and high level granite, in addition to red siltstone, basalt or diabase, black siltstone, granophyre, trondhjemite or leucotonalite, and quartz and feldspar crystal fragments. Clasts are extended parallel the foliation, and some possess calcite and quartz-filled tension gashes and fibrous quartz pressure fringes.

The sandstone is grey, and commonly contains rounded, fine grained granite and rarer siltstone pebbles. It locally contains coarse muscovite clasts probably derived from the unconformably underlying phyllonites. The matrix is an intergrowth of sericite and very fine grained leucocratic minerals, overprinted by patches of secondary carbonate. The coarse fragments form augen aligned parallel to a strong schistosity which is defined by sericite and flattened, less competent clasts. Tension gashes and pressure shadows in and around the more competent grains are filled with calcite and/or quartz fringes.

The black silty mudstone is similar to that in the Morg. Keepings-Fox Hole Brook sequence, but is more restricted in extent.

The mafic flows or sills are thin, and occur with large volumes of felsic pyroclastic or conglomeratic rocks not far from the southern contact of the belt. Only one flow or sill of quartz-feldspar porphyry was observed. Thin mafic dykes, altered to chlorite schist with epidote pods and stringers, cut cataclastically deformed synmetamorphic granitoid rocks on the hill between the two brooks and along the banks of Deep Brook near the southern contact.

The chlorite-carbonate schists form highly kinked and chevron folded outcrops near the centre of the belt, and are similar to those in the La Poile River-upper Billiards Brook area, but lack the pure limestone beds and commonly contain pebbles of red siltstone, comparable to both the red siltstone between mafic flows (above) and the hematitic siltstone near the roof of the Nitty Gritty Brook Granite.

17.3 WINDOWGLASS HILL GRANITE (UNIT 15a)

Lithology:

The Windowglass Hill Granite is fine grained, and in some places, tiny, sparse, quartz phenocrysts are visible. It is commonly weakly cleaved, and locally traversed by quartz-filled fractures which are mineralized with base metal sulphides. It lacks the small fractures, miarolitic cavities, and autobrecciated patches which characterize the Nitty Gritty Brook Granite.

Petrography:

The Windowglass Hill Granite consists of a granophyric intergrowth with phenocrysts of plagioclase, alkali feldspar, and embayed, volcanic quartz with local secondary carbonate patches and rare sericite. Alkali feldspar phenocrysts consist mainly of elongate, Carlsbad-twinned laths of checkered albite.

17.4 NITTY GRITTY BROOK GRANITE (UNIT 15b)

Lithology:

The main body is composed of fine grained, pink, porphyritic to nonporphyritic leucogranophyre, with local drusy, miarolitic cavities. Many outcrops are highly fractured. In some places, the latest generation of fractures and some of the cavities are filled with purple and green fluorite, with less common calcite, siderite, quartz, and barite. The rock surrounding these veins is intensely altered locally to yellowish clay minerals. Several vuggy quartz veins at the southern margin in Nitty Gritty Brook contain traces of tetrahedrite, malachite, and weathered iron oxide minerals. A deep red, hematitic, silicic dike or screen was also noted near the southern margin, where the granite is autobrecciated and partly recrystallized to white and red, porcelain-like rock.

Petrography:

The Nitty Gritty Brook Granite consists essentially of an intergrowth of granophyre domains (Plate 17.4), with variably abundant phenocrysts of plagioclase, orthoclase microperthite, and quartz. The plagioclase may be either chequered albite or twinned sodic plagioclase in well formed laths, locally rimmed with microperthite or micropegmatite. Orthoclase microperthite forms euhedral Carlsbad-twinned laths, and also constitutes the feldspar component of the micropegmatite. Quartz phenocrysts, are rounded and embayed. Anhedral opaque oxides occur interstitially, usually in clusters accompanied by rare euhedral zircons, apatite, and fluorite. Fractures, which in places cut across and separate individual crystals, contain fluorite which is generally colourless, but locally purple or green under plane transmitted light.

17.1 Photomicrograph showing vesicles in metabasalt now filled with calcite (top) and epidote/Fe-oxide (bottom), Windsor Point Group near Billiards Brook. (77-LC-324, cross polarized light)

17.2 Clast-supported conglomerate of Windsor Point Group, Billiards Brook.

17.3 Photomicrograph showing angular fragments of acicular basaltic plagioclase, quartz, and granophyre in matrix of Windsor Point Group conglomerate, Billiards Brook. (77-LC-342, cross polarized light)

17.4 Photomicrograph of Nitty Gritty Brook granophyre with phenocrysts of quartz and alkali feldspar cryptoperthite. (78-LC-300, cross polarized light)

17,1


17.2

17.3


17.4

CHAPTER 18: 'LATE' OR 'POST' TECTONIC INTRUSIVE ROCKS OF TERRANES I AND II (UNITS 13, 17, AND 18)

18.1 ROCK TYPES

The most significant rock types in this category are potassic leucogranites, which have been classified as either two-feldspar (wholly subsolvus) leucogranites (Unit 17) or perthite-rich leucogranites (Unit 18). A megacrystic monzogranite, the 'Burgeo batholith' (Unit 13), has been included in this chapter because it truncates the foliation of an earlier megacrystic granitoid intrusion, the Otter Point Granite (Chapter 16), to which it may be more akin.

Several late dyke suites also belong in this category, and are characterized below (Section 18.5).

18.2 LATE MEGACRYSTIC MONZOGRANITE, BURGEO AREA (Unit 13)

Lithology and petrography:

The 'Burgeo' megacrystic monzogranite is remarkably homogeneous in composition and generally megacrystic to its margins, an anomalously megacrystic-poor contact zone is exposed in Grandys Brook #2.

The megacrystic monzogranite is coarse grained and mafic-rich. Large alkali feldspar laths (3 cm maximum diameter) and smaller, zoned plagioclase phenocrysts are set in an inequigranular, medium grained mesostasis of plagioclase (An_{25}), quartz, biotite, actinolite, chlorite, and abundant accessory sphene, apatite, opaque minerals, and epidote. Alkali feldspar megacrysts consist of rod or hair perthitic microcline (very minor exsolved plagioclase) with zonally-arranged inclusions of plagioclase and quartz. Quartz occurs as unstrained to weakly strained single crystal domains. Cores of zoned plagioclase phenocrysts are weakly saussuritized. Ferromagnesian minerals are loosely clustered. Both actinolite and sphene are poikilitic; actinolite is commonly zoned, with pale green, patchy cores and more highly pleochroic blue green rims.

18.3 TWO-FELDSPAR (WHOLLY SUBSOLVUS) LEUCOGRANITES

18.3.1 Individual intrusion zones

The leucogranites are concentrated in three main areas: the Northwest Brook-Garia Brook area, the Piglet Brook-Couteau Brook area, and the Peter Snout-Grandys Brook #2 area, but are fairly common as pods throughout the amphibolite facies terrane (Map 2).

The subsolvus leucogranites occur as very small, lensoid pods which commonly cut across the strong, regional structural grain of Terrane II, and as larger, poorly-defined intrusion zones of similar geometric aspect which, enclose huge rafts and pendants of the previously foliated, synkinematic granitoid rocks and La Poile River Group amphibolite facies schists. They are largely unfoliated, but are penetratively schistose near the Cape Ray and Bay d'Est Faults and the Gunflap Hills fault splay, and are also foliated in small scale faults and shear fracture zones.

18.3.2 Northwest Brook-Garia Brook leucogranite

Lithology:

This leucogranite consists largely of fine grained, pink, equigranular leucogranite, with local patches of medium grained granite, and minor alkali feldspar-quartz pegmatite in the main intrusion zone around Northwest Brook. Uniformly pink weathering surfaces are due to abundant pink alkali feldspar grains, but freshly fractured surfaces of both medium and fine grained varieties display equally abundant white plagioclase laths. Biotite is the main macroscopic ferromagnesian phase, and makes up 2 to 5 percent of the rock. It forms randomly-oriented flakes, similar in maximum diameter to the feldspar grains. Muscovite evidently predominates over biotite in some of the medium grained leucogranites.

The Northwest Brook-Garia Brook leucogranite is associated with locally intense internal and external alteration, carbonate fracture and cavity fillings, and brecciation. Brecciated patches and highly fractured outcrops are accompanied by patchy yellow, red, and rarely black alteration along the banks of Northwest Brook. Carbonate-filled fractures and cavities are common around brecciated and fractured zones. The carbonate is platy in habit. A tuffisite dyke with pink and grey weathering felsic fragments in a green-grey weathering matrix is exposed in the middle of the intrusion zone on Northwest Brook. Reddish, hematitic alteration also affects the host rocks, both in the main intrusion zone and locally around smaller pods.

Petrography:

The fine grained leucogranite (Plate 18.1) is composed of quartz, plagioclase, alkali feldspar, myrmekite, biotite, and muscovite with small amounts of accessory zircon, epidote, apatite, opaque oxide, and local fibrolite. Despite the general lack of macroscopic foliation, late deformation has affected most of the rocks. // Quartz (20 to 25 modal percent, rarely more) forms both highly strained, locally polygonized or annealed, interstitial domains, and small, subrounded, prismatic inclusions in both feldspars. // Plagioclase (25 to 55 modal percent, approximately inversely proportional to microcline) occurs as lightly sericitized, subrounded oligoclase laths with rims of slightly different optical orientation and degree of sericitization. Fractured and weakly kinked grains occur locally. // Alkali feldspar occurs largely as ragged-edged, Carlsbad-twinned laths of rod or hair perthite (5 to 10 percent exsolved plagioclase) which grades into local internal patches and rims of nonpert gridiron-twinned microcline. Interstitial microcline is also common in a few rocks. Myrmekite forms lobes which overprint microcline grain margins. // Biotite (2 to 5 modal percent) is dark olive brown to olive green, and is locally partly chloritized. In unfoliated rocks, it forms randomly oriented, anhedral flakes with included zircon and local muscovite and/or fibrolite fringes. Biotite is chloritized and rutile exsolved in some of the pods around Garia Brook. // Muscovite occurs as small, ragged flakes accompanying biotite, and as larger poikiloblasts. Fibrolite is locally developed inside muscovite flakes as vermicular domains, and around them as fringes.

Fine grained leucogranites near the Cape Ray Fault system are foliated. They contain porphyroclasts of orthoclase perthite and plagioclase, which form augen in an anastomosing foliation defined by biotite, muscovite, and recrystallized quartz.

The medium grained leucogranite differs little from the finer grained leucogranite. Muscovite is more abundant and biotite less abundant than in the fine grained phase.

Contacts between fine and coarse grained phases are abrupt, even in hand specimen, but are microscopically gradational.

The tuffisite contains angular, highly deformed fragments of tonalite/trondhjemite, 'graphic granite', quartz, plagioclase, chlorite, and possibly muscovite, in a dusty, quartzofeldspathic, comminuted matrix. The 'graphic granite' fragments consist of optically continuous, cuneiform quartz overgrowths on large grains of sericitized plagioclase, and on aggregates of rod perthite and plagioclase; the feldspars are probably derived from the both the leucogranite and its granitoid host. Altered granitoid rocks near the tuffisite are characterized by bleb-like overgrowths of quartz on mottled-looking plagioclase (An_{60}), and contain excessive amounts of apatite. Unusual abundances of apatite, as well as magnetite and carbonate were also noticed in a thin section of fractured, synmetamorphic tonalite outcropping nearby.

18.3.3 Piglet Brook-Couteau Brook leucogranite

Lithology and petrography:

The body west of Couteau Brook is composed of white to pale pink weathering, medium grained, equigranular leucogranite which forms anastomosing dikes and interlocking networks. Deformed La Poile River Group hosts are commonly included as rafts or screens in the centre of the intruded zone.

This leucogranite is composed mainly of plagioclase, microcline, quartz, biotite, and muscovite, with accessory garnet, apatite, and zircon. Plagioclase occurs as relatively large, zoned, and partly saussuritized laths which are rimmed with clear albite. The microcline is nonperthitic and interstitial in habit. Quartz forms interstitial polycrystalline domains and small rounded inclusions in the feldspars. Flakes of muscovite and biotite are preferentially developed over leucocratic grain boundaries, and together make up less than 5 percent of the rock.

18.3.4 Peter Snout-Garia Brook leucogranite

Lithology:

Medium grained, unfoliated leucogranite is exposed mainly in a large intrusion zone and several smaller pods. The leucogranite also projects across the foliated synmetamorphic granitoid rocks (component 4b) and the Ironbound syenodiorite-granite as straight-sided dykes to the west of the main intrusion zone. The leucogranite is equigranular to slightly porphyritic, and weathers cream to pale gray in outcrop.

This granite lacks widespread alteration, although local 'greisen zones' occur around late ductile shear or fault zones at its northwestern and southern margins. Local garnet-bearing, muscovite-rich patches are foliated in these areas. Fine, red-and-white mottling was noted in several northwestern outcrops.

Petrography:

Most of the leucogranite is composed of alkali feldspar, quartz, plagioclase, myrmekite, biotite, and muscovite with accessory garnet, apatite, and zircon. Alkali feldspar occurs largely as interstitial to porphyrblastic microcline with hair perthite cores. Individual grains may reach up to 7 mm in diameter in porphyroblastic rocks and are embayed at their margins by abundant, ovoid myrmekite domains. Plagioclase grains are simply and normally zoned with cores of about An_{35} in composition. The biotite is dark brown to greenish brown, encloses numerous zircons, and is partly chloritized in some samples. An unknown, acicular, colorless, high relief mineral with low birefringence and inclined extinction occurs along the basal cleavage of many biotite grains.

18.4 PERTHITE-RICH LEUCOGRANITE

8.4.1 Individual plutons and definitive characteristics

These plutons include the Chetwynd Granite (Cooper, 1954), the Petites Granite (Brown, 1975), and Isles aux Morts Brook Granite (Brown, 1976b) of Terrane II, and several bodies in Terrane I, here referred to as plutons A to G (Map 2). Many of the plutons appear to have been emplaced along lineaments or shear zones in Terranes I and II.

Composition and internal textural variations are remarkably similar in all of the plutons, although some are modified somewhat by local features such as fracture zones and associated hydrothermal activity. The presence of coarse perthite, with or without oligoclase, and under 5 percent biotite as the sole ferromagnesian silicate mineral are diagnostic. The leucogranites are associated with extensive rhyolite dyke systems, also remarkably similar in both terranes.

Narrow, low pressure contact aureoles occur against several of the plutons, but are imperceptible or absent in the pre-metamorphosed hosts surrounding others. Some of the leucogranites enclose rafts of previously deformed granitoid rock.

18.4.2 <u>General characteristics</u>

<u>General lithology</u>:

The leucogranites vary from hypersolvus to subsolvus; the hypersolvus granite could be modally classified as alkali feldspar granite (Streckeisen, 1973). Proportions of white weathering plagioclase to pink-weathering alkali feldspar microperthite vary from almost nil to just under one. They are remarkably uniform in overall composition

(this study, Appendix III), and generally vary from medium grained, equigranular granite to coarse grained, subequigranular granite, although most plutons display local marginal patches of relatively fine grained, quartz and feldspar porphyritic granite or rapakivi granite. The alkali feldspar of the coarse grained granite tends to be subhedral and a bit larger than the other mineral grains, imparting a weakly feldspar-megacrystic aspect. Quartz forms equant domains which stand out on weathered surfaces, and generally makes up about one third of the rock. Biotite is the major ferromagnesian mineral, and commonly constitutes much less than 5 modal percent. Minor muscovite, coarse crystals of sphene, and allanite are also visible in hand specimen locally. The quartz-sanidine porphyry dykes weather white, cream, or pink, and contain sparsely distributed, very tiny phenocrysts of rounded quartz and rhombic feldspar in an aphanitic matrix. Ferromagnesian minerals are essentially absent.

General petrography:

The coarse and medium grained leucogranites in general are composed of microcline perthite, plagioclase, and quartz with minor biotite or chloritized biotite, and muscovite. Epidote, sphene, allanite, zircon, apatite, and iron oxide are common accessory minerals. The porphyritic marginal phase is characterized by granophyre. // Microcline perthite (Plate 18.2) contains ribbons of 10 to 20 percent exsolved albite evenly distributed throughout the grains, and is gridiron-twinned. Small, lightly altered plagioclase laths with clear rims commonly form inclusions in the microcline (Plate 18.2). Fringes of plagioclase occur locally along boundaries between microcline perthite grains. // Plagioclase (oligoclase) forms subhedral, zoned laths with ovoid, lightly altered cores, surrounded in some rocks by a thin oscillitory band inside a thicker sodic rim. Microcline locally mantles plagioclase. // Quartz (approximately 35 modal percent) forms large polygonized and annealed domains with irregular boundaries towards the feldspars. Fine grains of quartz are distributed along feldspar grain boundaries in some of the granites. Quartz phenocrysts occur locally in fine grained marginal phases. // Biotite, as anhedral flakes, constitutes less than 5 percent of the rock, and may be virtually absent. It is commonly dark green in colour, but partly chloritized flakes are khaki brown. // Muscovite is much finer grained than the biotite, and generally appears to be a later or secondary mineral. It either fringes the biotite or forms clusters nearby. Tiny, irregular flakes commonly overprint feldspar grains.

The quartz sanidine porphyry dykes are composed of moderately fine to very fine grained, and generally sparse phenocrysts of volcanic quartz, sanidine, and plagioclase set in a spherulitic quartzofeldspathic matrix (Plate 18.3). Muscovite is generally the only other phase present, and is very sparse.

18.4.3 Individual characteristics

Pluton A:

In this pluton, coarse grained leucogranite, with microcline perthite grains several centimetres in diameter, predominates over medium grained leucogranite. Medium to fine grained quartz and feldspar porphyry occurs locally near the northeastern margin. The pluton is cut by rare, feldspathic dykes chock-full of alkali feldspar tablets over a centimetre in maximum diameter; these dykes locally project into the host rocks at the eastern margin. Several east-northeast striking, fine grained quartz-sanidine porphyry dykes cut the tonalite terrane to the east, and contain more fine grained secondary muscovite than equivalent dykes intruding other areas.

In the south and southeast, the pluton is undeformed and truncates the regional structures of the host rocks. The central part of the body displays a northeast-trending fracture set, which passes northwestward into an extensive zone of penetrative ductile shearing, where coarse alkali feldspars form augen within the northeast-striking foliation plane. Screens of the older granitoid and amphibolite are interfingered with the granite in this area, and grey weathering patches relatively enriched in plagioclase, biotite, and locally muscovite reflect local tonalite assimilation. Apophyses of 'augen' granite with northwest-striking foliations extend northwestward into the Stag Hill high strain zone.

Rocks in the centre of the pluton are fractured; fractured and annealed crystals of plagioclase and perthite are common, and generally accompanied by myrmekite. Myrmekite fringes commonly occupy alkali feldspar-plagioclase contacts. Some of the muscovite flakes display vermicular textures. Graphic intergrowths of quartz and microperthite were observed in the matrix of the chilled margin phase.

The tonalite-contaminated rocks are characterized by very coarse flakes of muscovite and locally by an abnormal abundance of green biotite, epidote, and myrmekite. Plagioclase, at least partly andesine, is the predominant feldspar. The alkali feldspar in the latter rocks, where present, is either string perthite or microcline.

Highly sheared host rocks along the southern margin of Pluton A were not substantially contact metamorphosed. However, the chlorite and muscovite of highly retrograded gneissic tonalite and included mafic rocks at the boundary between the Stag Hill and North-Central high strain zones have been replaced by abundant almandine garnet and coarse, prismatic sillimanite along the eastern contact.

Small muscovite flakes abundantly overprint the feldspars in some of the rhyolite dykes intruding the north-central high strain zone to the east.

Plutons B and C:

These bodies are composed largely of medium grained leucogranite to the east and southeast, and coarse grained leucogranite to the west. Quartz porphyritic microgranite, with bluish, bipyramidal quartz crystals, occurs locally along the southeastern margins of both plutons. Allanite and sphene are particularly abundant accessory minerals, and iron oxide, mainly magnetite or hematite, is very sparse. Spectacular, rhombic crystals of sphene and long, thin prisms of zircon occur around the biotite. Epidote also tends to concentrate with the mafic minerals.

Discretely spaced, northeast-trending shear zones related to late activity of the Cape Ray Fault in the south, and a northeast-trending fracture system in the northwest related to late uplift of the Little Codroy Pond belt, affect these bodies. Fracturing and synchronous recrystallization has produced anatomosing, very fine grained quartzofeldspathic stringers, and larger domains of highly recrystallized, strainbanded, and locally flaser quartz. Plagioclase is very commonly fractured and kinkbanded.

In addition, they are affected by late metasomatic activity associated with hydrothermal events around the Cape Ray Fault zone. Chequered albite either replaces the microcline portion of entire ribbon perthite grains or forms rims around them. Secondary carbonate and hematite are common in some of the highly deformed rocks within the Cape Ray Fault itself.

Plutons D, E, F, and G:

These plutons range from typical medium grained and coarse grained leucogranites to rapikivi granites. They have been weakly but penetratively deformed, and are traversed by many shear zones probably linked to Cape Ray Fault activity. Plagioclase is fractured, and quartz displays kink bands and nonplanar deformation lamellae. Plagioclase is lightly to heavily sericitized, and tiny overgrowths of quartz occur in most feldspar crystals. Chlorite alteration of biotite is common, and many biotite grains are rimmed with secondary muscovite. Secondary muscovite is locally visible in outcrop.

ISLES AUX MORTS BROOK GRANITE:

The Isles aux Morts Brook Granite has been visited only briefly. It displays the medium to coarse grained texture typical of these perthite-rich leucogranites. However, it contains more abundant secondary muscovite as ragged muscovite poikiloblasts which overprint feldspar and locally occur in clots with chloritized biotite. Plagioclase cores are commonly occluded with iron oxide and overprinted with small flakes of muscovite rather than ~~sericite.~~ Accessory magnetite is unusually abundant compared with the other perthite-rich leucogranites, whereas sphene is subordinate and very fine grained. Small cubes of pyrite were noticed in one of the nearby dykes cutting pyrite-bearing felsic blastomylonite on Grandys Brook #1.

PETITES GRANITE:

The texture of the Petites Granite is much more irregular and variable than the other perthite-rich leucogranite. Atypically high, late magmatic volatile contents may be indicated by the presence of myrmekite embaying microcline, and microcline perthite with less exsolved albite in comparatively uneven, even patchy, distribution. Biotite is chloritized and rutilated in some specimens. Plagioclase is very fractured, and quartz displays both strain bands and curved deformation lamellae.

According to Brown (1975), two sets of steeply dipping fractures related to activity on the Baie le Moine Fault affect the Petites Granite, one set trending northeast and the other northwest. The northwest-trending set is silicified, and associated with both alteration of the leucogranite and molybdenite showings.

CHETWYND GRANITE

The main rock type is medium to coarse grained, equigranular, mafic-poor, biotite leucogranite, but rapakivi leucogranite phases, hypersolvus leucogranite, and quartz porphyry dykes are present in the south. Many rafts of Cinq Cerf granodiorite and possibly Otter Point Granite were noted in the southern part of the intrusion, the latter hard to discern from coarse grained leucogranite. Fine grained, khaki coloured biotite occurs instead of chlorite in the host dacitic tuffs in a narrow contact aureole along the western margin of the pluton.

The biotite is largely to partly altered to chlorite. Actinolite is present locally. In the rapakivi textured phase, phenocrysts of plagioclase are rimmed with microcline and vice versa. Locally, the mesoperthite of hypersolvus granite is fringed with myrmekite. Accessory minerals such as sphene, magnetite, and allanite are exceptionally abundant and show euhedral crystal forms in some specimens.

Numerous rhyolite dykes cut along the prominent east-northeast trending cleavage and schistosity west of the pluton. These dykes generally weather pink, but have turned grey where they traverse zones rich in disseminated sulphides.

18.5 LATE DYKES OF TERRANES I AND II

18.5.1 Dyke suites

Terranes I and II contrast in their late dyke suites, apart from the rhyolite dykes related to the perthite-rich leucogranites (previous section). Mafic and felsic (largely dacite) dykes predominate in Terrane I, and intermediate to mafic, mica-amphibole dykes are recognized as a suite characteristic of Terrane II. The latter include those dykes associated with the Cinq Cerf Complex (Section 5.4).

18.5.2 Terrane I basalt dykes

The dykes weather dark grey to black, and are very fine grained. Small pits due to weathered-out carbonate were observed in many hand specimens. Coarse phenocrysts are lacking, although small tabular plagioclase phenocrysts, about 1 mm or less in maximum diameter are common, and anhedral, green, ferromagnesian clots, 1 mm or less in diameter are less common. Some of the dykes display a marginal foliation.

The mafic dykes are composed of plagioclase, clinopyroxene, local brown hornblende, other ferromagnesian alteration products, and minor carbonate with accessory leucoxene, opaque oxide, and rare pyrite. Plagioclase forms a felted microlitic matrix intergrowth. Plagioclase phenocrysts display oscillitory zoning, and some are highly sericitized in altered rocks. The predominant ferromagnesian mineral is stubby, subophitic, pale brown augite with high dispersion, generally partly altered to pale actinolite or chlorite. Brown hornblende occurs either as acicular prisms or as rims on clinopyroxene, and is commonly altered to deeply pleochroic, fibrous blue green amphibole. Spherical vesicles are filled with carbonate and locally contain chlorite. Chlorite, actinolite, blue green amphibole, epidote, and minor biotite are the most common secondary minerals. Margins of the mafic dykes which cut Pluton B are highly enriched in leucoxene, epidote, biotite, and sericite or muscovite, and the micaceous minerals define a marginal foliation. Very fine grained, disseminated magnetite is the most abundant opaque mineral, and in altered rocks is coated with fuzzy leucoxene. A platy opaque mineral (ilmenite?) and rare cubes of pyrite were observed locally.

An anomalous diabase dyke near Dinosaur Pond contains an interlocking network of acicular plagioclase crystals enclosed in a matrix composed largely of pale brown clinopyroxene and extremely abundant opaque minerals. Clinopyroxene is partly altered to chlorite and feathery amphibole, the plagioclase is lightly saussuritized, and patches of secondary carbonate are common. The macroscopic, pale green, ovoid patches are composed of a very fine, pale green, fibrous intergrowth, probably amphibole.

18.5.3 Terrane I felsic dykes

The felsic dykes are of two main types: dacitic dykes containing plagioclase and biotite phenocrysts, and more leucocratic dykes containing quartz and plagioclase phenocrysts. One anomalous dacitic dyke cutting foliated granitoid rock and paragneiss south of Stag Hill is fine grained, but lacks phenocrysts. The more quartzofeldspathic dykes occur mainly near the quartz diorite-megacrystic granite.

The dacite dykes generally weather pale grey, and contain phenocrysts of white to pink feldspar (plagioclase), flakes of biotite, and other green ferromagnesian clots in a microcrystalline quartzofeldspathic matrix. Rare, weathered-out carbonate pits were also observed. Most of these dykes are undeformed, but some have a primary foliation defined by the alignment of biotite.

Several of the dykes which cut the layered metagabbro block site minor ductile shear zones, and have a very strong foliation. These dykes possibly do not belong with the others in this late suite.

The plagioclase and biotite porphyritic dacite dykes are composed of phenocrysts of plagioclase and biotite in a microgranitic matrix of quartz, feldspar, muscovite, and biotite with accessory epidote, sphene, fine grained opaque grains, and zircon. Rare quartz phenocrysts with volcanic embayments were observed. Secondary carbonate patches are common. Plagioclase phenocrysts (approximately calcic oligoclase) display pronounced oscillatory zoning, and commonly form glomeroporphyritic aggregates. Some of the phenocrysts have cloudy cores and sharply bounded, clear, reequilibrated rims. Biotite phenocrysts are brown, and contain inclusions of zircon, epidote, and opaque. In some rocks, the biotite is partly to completely chloritized. Epidote is particularly abundant in highly altered rocks, and may locally form coarse crystals.

The nonporphyritic dacite dyke south of Stag Hill is composed of interlocking networks of about 70 percent tabular to acicular plagioclase (andesine) in a matrix of very fine grained quartz, with up to 5 percent anhedral magnetite and about 5 percent each of olive brown biotite and chlorite flakes overprinting the feldspathic assemblage.

The more leucocratic quartz-feldspar porphyritic dykes weather cream or pink, and quartz and white feldspar phenocrysts are embedded in a ferromagnesian-poor, porcelainous matrix. These quartz-feldspar porphyries are petrographically more variable due to varying degrees of metasomatic alteration. They generally contain quartz and feldspar phenocrysts, and local muscovite porphyroblasts set in a very fine grained matrix of quartz, feldspar, and muscovite or sericite with rare accessory magnetite (local), biotite (local), and sphene (local). Biotite and magnetite are mutually exclusive. Monomineralic fracture fillings of plagioclase, quartz, or mica were noticed in various specimens. Plagioclase phenocrysts are generally unzoned, and are variably altered. Many are partly to completely converted to chequered albite, and others are lightly sericitized or overprinted with carbonate patches.

18.5.4 Terrane II mafic to intermediate dykes

The late dykes in this terrane are characterized mainly by small phenocrysts of amphibole and biotite, and vary from mafic to intermediate in overall composition. Most are deformed to some degree, particularly near dyke margins. The fabrics vary from a strong anastomosing schistosity to weak, conjugate fracture cleavages.

The north-trending dyke on Northwest Brook is relatively mafic and coarse grained. It weathers black, and is characterized by a fine grained, phaneritic intergrowth of equant, green amphibole clots 1 to 3 mm in diameter, fine grained biotite, and pinkish orange weathering feldspar. An inhomogeneous, weak, anastomosing fabric is crudely parallel to its north-striking margin.

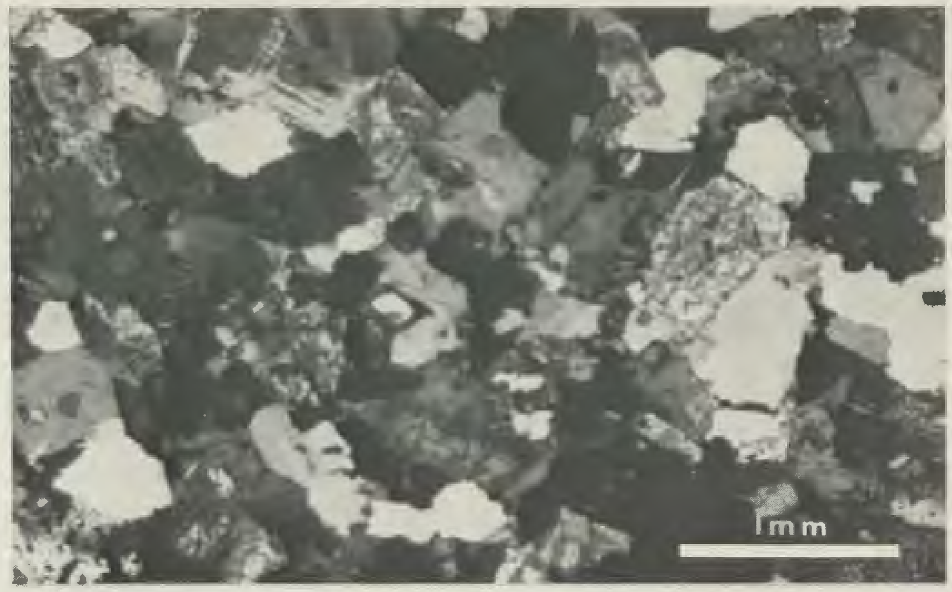
This north-trending dyke is composed of blue green amphibole, biotite, plagioclase (15 percent), orthoclase (10 percent), and quartz (up to 5 percent) with accessory zircon, epidote, and exceptionally abundant apatite and sphene. The amphibole is ordinary blue green hornblende, and is associated with dusky patches of relict deep brown hornblende. It forms stubby crystals and polycrystalline clots several millimeters long, which are elongated parallel to the weak foliation. Biotite is approximately equal in abundance to hornblende, olive green in colour, and contains zircon inclusions. It defines the weak conjugate foliation. Plagioclase is highly sericitized, and clusters with orthoclase and strained quartz. Orthoclase grades from nonperthitic to weakly perthitic (rod or hair perthite). Leucocratic minerals are interstitial to ferromagnesian phases.

The dykes which cut the component 4b synkinematic granitoid rocks along the Rose Blanche highway are intermediate in composition and exhibit a strong foliation. Small, flattened mafic 'phenocrysts' define the foliation which is particularly intense near the dyke margins. The dykes are composed of blue green amphibole, green biotite, plagioclase, and quartz with very abundant accessory sphene, apatite, epidote, and allanite. Plagioclase is more abundant than quartz and is lightly sericitized in patches. The marginal phases contain a higher ratio of biotite to amphibole than the cores, and display very coarse, poikilitic sphene and allanite.

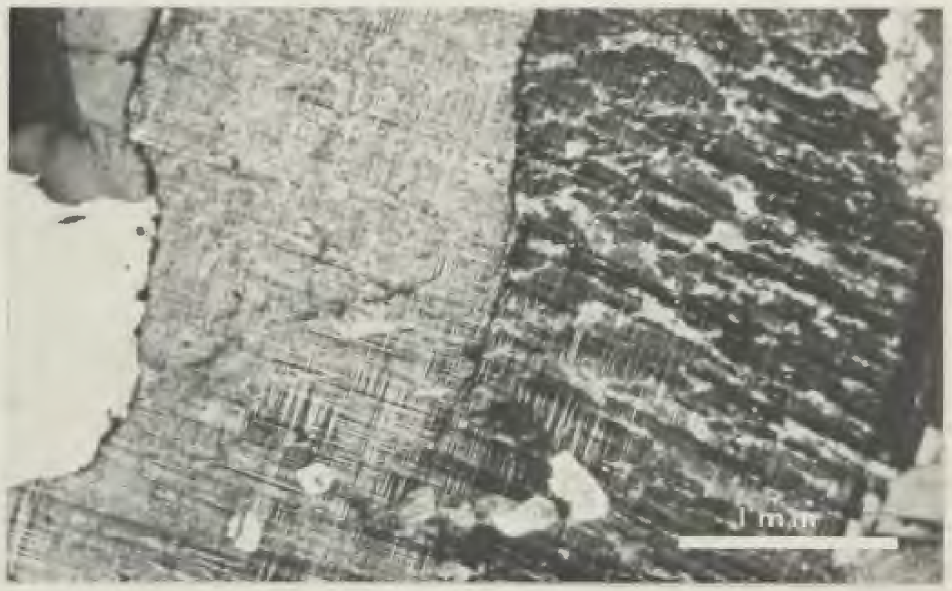
18.1 Photomicrograph of fine grained, two-feldspar leucogranite, Northwest Brook. (80-LC-320, cross polarized light)

18.2 Photomicrograph showing ribbon perthite with tiny plagioclase inclusions in perthite-rich leucogranite Pluton A. (78-LC-320, cross polarized light)

18.3 Photomicrograph showing typical leucorhyolite dyke associated with perthite-rich leucogranite, from near plutons D, E, F. (80-LOC-2, cross polarized light)



18.1



18.2

18.3

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APPENDICES

APPENDIX I: MAJOR CONTRIBUTIONS TO THE GEOLOGY OF SOUTHWEST NEWFOUNDLAND SIGNIFICANT TO THE PRESENT STUDY

1. J.R. COOPER

Cooper (1940b, 1954) separated the metamorphic, sedimentary, and volcanic rocks in the area into three main units: the Keepings Gneiss, the Bay du Nord Group, and the La Poile Group. Rocks which showed some similarities to either the La Poile Group or the Bay du Nord Group, but which could not readily be assigned to these units, were designated as uncategorized schist and gneiss. The Keepings Gneiss, composed largely of orthogneiss with local paragneiss and amphibolite, was considered to be possibly Precambrian in age, older than the Bay du Nord Group from which it was separated by a dioritic intrusion. South of the intervening diorite, Early to Early Middle Devonian plant fossils (Dorf and Cooper, 1943) found in low grade stata in Billiards Brook were used to assign a Devonian age to the Bay du Nord Group, a largely sedimentary sequence. Most of the Bay du Nord Group as defined by Cooper was metamorphosed to higher metamorphic grade than the fossiliferous strata; a wide band of schists and gneisses with injections of granitoid rocks is exposed between the fossiliferous zone and the type area of Bay du Nord (now called North Bay). The La Poile Group was defined as younger than the adjacent uncategorized schists and gneisses and inferred to be younger than the Bay du Nord Group.

Two major faults, the Bay d'Est Fault and a fault along the coast between Roti Bay and Cinq Cerf Bay, were also delineated. The Bay d'Est Fault is a steep fault which forms the northern boundary of his La Poile Group, and which post-dated the Chetwynd Granite. The coastal fault (later named the Grand Bruit Fault; Chorlton, 1978) is a 50 to 100 m wide shear zone which forms the faulted boundary between granodiorite-intruded uncategorized schists and gneisses and the Roti Granite. Cooper suggested that fault displacement was sinistral.

After the publication of Cooper's map and memoir, an attempt to extend map units to the southwest was made on behalf of the Geological Survey of Newfoundland (Power, 1955). Medium to high grade schist and gneiss, traced continuously into the Bay du Nord Group of Cooper (1954), were concluded by Power to be granitically-intruded Devonian and older metasedimentary schists and amphibolites which had undergone the same 'Acadian' orogenic events as the Bay du Nord Group.

The area east of the La Poile-Cinq Cerf area was mapped for Buchans Mining Company at about the same time, with the result that along-strike correlatives of the La Poile Group of Cooper (1954) of slightly higher metamorphic grade were mapped as passing into schist and amphibolite around the eastern extension of the Bay d'Est Fault, and sedimentary rocks of Cooper's Bay du Nord Group were recognized north of a predominantly granitic belt. After 1:253,440 scale reconnaisance mapping of this and neighbouring areas, Riley (1957) also mentioned two belts of metasedimentary and metavolcanic rock on either side of a predominantly granitic belt, both of which he correlated with the Early Devonian Bay du Nord Group. He likewise indicated that there could be continuity between these recognizable sedimentary and volcanic rocks and adjacent, more highly deformed and metamorphosed acidic and basic gneisses with local clearly metasedimentary lenses. In addition, contacts between the gneisses and the granitic rocks were described as varying between extremes of sharp to gradational.

2. GEORGE PHAIR

A study of the western side of the southern Long Range Mountains (Phair, 1949) was undertaken at the suggestion of A.F. Buddington of Princeton University, who had visited the area in 1939. Phair defined the main geological components of his study area in terms of a pre- to post-orogenic calc-alkaline igneous series and a roof zone of metasedimentary gneiss, migmatite, and marble of possible Early Paleozoic age. Included in the calc-alkaline series were: (1) a pretectonic mafic to ultramafic stratiform igneous complex, grading from nonlayered gabbro at the top through layered cumulate mafic and ultramafic rocks to massive ultramafic rocks at the base, and exposed in two areas separated by an east-west belt of stratigraphically overlying gneiss, schist, and granite; and (2) granitic rocks which intruded the gabbroic part of the stratiform complex after its consolidation, and were emplaced into the metasedimentary schists as lit-par-lit sheets. Bands of amphibolite in the roof zone of schists and gneiss were interpreted as sills emanating from the mafic stratiform complex. It was noted that the mafic rocks were mainly intruded by pink and red granite, the metasedimentary rocks by white granite, with locally gneissic texture. Phair suggested that the emplacement of the granitic rocks occurred largely during, but locally after, the intense regional deformation prior to the Carboniferous, and that they were unroofed during the deposition of the adjacent Pennsylvanian strata.

In addition, Phair (1946, 1949) suggested that the structural development of the area occurred in two distinct orogenic periods: before and after the deposition of the Carboniferous strata. The early phase was characterized by folding about northeast-southwest trending axes, the development of a northeast- and east- trending pattern of shears and fractures, and the invasion of granite and pegmatite into pre-existing fractures. Thus, the mafic-ultramafic stratiform intrusive complex, roofed by the metasedimentary and gneissic rocks, was thought to be exposed in several anticlinal cores which were later disrupted by faulting. Uplift and erosion into the adjacent Pennsylvanian Barachois Group followed. Post-Pennsylvanian deformation involved movement along numerous reverse faults, thought by Phair to represent a major schuppen structure transecting the island from Cape Ray to White Bay.

3. J.W. GILLIS

Gillis (1972) described the rocks of southwest Newfoundland as belonging to two contrasting terranes separated by the Long Range Fault: (1) little metamorphosed Carboniferous rocks exposed northwest of the fault, and (2) older metamorphic and intrusive rocks southeast of the fault. The latter terrane is trisected by two other major faults, the Cape Ray Fault (Gillis, 1972) and the Bay d'Est Fault (Cooper, 1954).

Mafic and ultramafic intrusions associated with granitoid rocks and gneisses were shown northwest of the Cape Ray Fault, and thought to be probably Ordovician but possibly partly older. Biotite from one granitoid intrusion near the northern margin of the map area was dated at 445±18 Ma using the K/Ar technique.

Southeast of the Cape Ray Fault, amphibolite facies metamorphic rocks grade into less metamorphosed Devonian sedimentary rocks, part of the Bay du Nord Group of Cooper (1954), in fault contact with ?Silurian volcanic and sedimentary rocks along the Bay d'Est Fault. K/Ar mineral ages on pegmatites (400±20 Ma: Gillis, 1965; and 415±20 Ma: Neale, 1963) and sheared granitoid rocks (346±20Ma and

344$\pm$20 Ma: Gillis, 1967) suggested Silurian to early Devonian and late Devonian regional metamorphic events (Gillis, 1972). Gillis differed from Cooper (1954) in separating the schists and gneisses in the west, which host the pegmatites with Siluro-Devonian mineral radiometric dates, from both the well-bedded Bay du Nord Group in Billiards Brook (where Cooper had found plant fossils), and well-bedded, locally conglomeratic, sedimentary rocks around the type area of Bay du Nord and around Garia Bay.

4. P.A. BROWN

Brown (1972) initially studied the structural and metamorphic history of the gneissic rocks near Port aux Basques as part of an M.Sc. thesis. He recognized three major subdivisions, which he named the Cape Ray Complex, the Port aux Basques Complex, and the Windsor Point Group. The first two are separated by and the third unconformably overlies the Cape Ray Fault. The Cape Ray Complex was thought to be the oldest, and comprises a tonalitic leucogneiss with mafic pods (Long Range Gneiss) intruded by deformed and undeformed granitoid rocks (Cape Ray and Red Rocks Granites). The Port aux Basques Complex is composed of banded gneisses which were intruded by granitoid rocks (Port aux Basques Granite) after the first deformational episode and before the second.

The Cape Ray Complex was further correlated with the

Grenvillian rocks of the Indian Head Range in the Stephenville area (Riley, 1962), and other Precambrian gneissic/plutonic rocks (Bostock, 1971) forming the sialic basement to the western continental margin of the Newfoundland Central mobile belt (Brown, 1972). Similarly, the Port aux Basques Complex was likened to the Little Passage Gneisses (Colman-Sadd, 1974) of the Baie d'Espoir area, interpreted by Colman-Sadd (1974, 1980) to be the Precambrian (Hadrynian?) continental basement of the eastern margin of the Central mobile belt. This lead Brown (1973) to interpret the Cape Ray Fault as a cryptic suture, which juxtaposes the two Precambrian continental gneissic basement terranes from opposite sides of the Early Paleozoic proto-Atlantic Ocean. The Devonian sedimentary rocks mapped by Cooper (1954) were considered as sedimentary cover to the eastern continental basement, the Port aux Basques Complex.

Brown (1975) subsequently extended his structural and metamorphic study eastward to the extension of the Bay du Nord Group as mapped by Gillis (1972) around Garia Bay. Microstructural reworking (related to the development of tectonic slide zones) was invoked to explain the structural/metamorphic similarity of the western parts of the Devonian sequence with adjacent 'Precambrian basement' (Brown, 1975), a feature which had earlier lead Gillis (1972) to modify some of the original mapping of Cooper (1954).

The proposed closing-out of the Early Paleozoic proto-Atlantic ocean along the Cape Ray 'suture', as well as the interpretation of the granitoid and gneissic rocks west of the Cape Ray Fault as a Grenvillian crystalline association, provided for a new interpretation of the mafic-ultramafic stratiform complex of Phair (1949). The complex had formerly been likened by Buddington (1939) and Phair (1949) to the Bay of Islands Complex (Smith, 1958), the latter complex later recognized as ophiolite (Church and Stevens, 1971). The southwest Newfoundland mafic stratiform complex was accordingly interpreted as ophiolitic by Brown (1976), who gave it the name Long Range Mafic-Ultramafic Complex. Brown (1976, 1977) further suggested that the Long Range Mafic-Ultramafic Complex represented remnants of ophiolitic crust obducted from the Cape Ray Fault zone onto the Grenvillian Long Range Gneiss to the northwest. This proposal implied that the field relations documented by Phair (1946, 1949), namely that the stratiform mafic complex underlies the migmatites and metasedimentary gneisses, are inverted. Mafic meta-igneous rocks of Phair's complex which form rafts within some of the granitoid rocks, and amphibolite which is interlayered with metasedimentary rocks and lit-par-lit granitoid sheets, were included by Brown in the Long Range Gneiss. Other fairly massive exposures of Phair's mafic complex were considered thrust-bound ophiolite remnants, and included in the Long Range Mafic-Ultramafic Complex.

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APPENDIX II: GEOCHEMISTRY OF THE LA POILE RIVER GROUP METAVOLCANIC ROCKS

INTRODUCTION

Metavolcanic and subvolcanic rocks of the Georges Brook Formation were analysed for major and trace elements mainly in order to characterize the suite for comparison with other volcanic piles (Chorlton, 1980a, Appendix I). Analyses included mafic flows and dykes, felsic flows, and fine grained tuffs. The Dolman Cove Formation was also analysed. An exploratory attempt was made to assess their tectonic setting using some of the graphical geochemical techniques suggested by various workers: eg., Irvine and Baragar, 1971: Pearce and Cann, 1973; Winchester and Floyd, 1977).

Analytical techniques and tabulated data are contained in Chorlton (1980a, Appendix I).

ALTERATION

The La Poile River Group volcanic and subvolcanic rocks were affected by multiple deformation under up to greenschist facies metamorphic conditions, circumstances which are likely to produce significant chemical migration, hydration, and oxidation. Enrichment in K_2O and H_2O, and depletion in Na_2O, with additional mobility of SiO_2, Ba, Rb, and Sr have been documented in many equally metamorphosed volcanic terranes (Hughes and Malpas, 1971: Kerrich et al, 1977; Morrison, 1978). The rocks may also have been previously affected by interaction with seawater or connate water during burial, causing mobility of Na_2O, K_2O, CaO, SiO_2, FeO, and MgO (Vallance, 1969; Walker et al, 1972; Hughes, 1973; Hart et al, 1974; Hermann et al, 1974; Andrews, 1977; Seyfried and Bischoff, 1979). The nature and relative importance of these factors is difficult to assess. Since alkalis and fluids are particularly mobile in both environments, metasomatism should be most evident in alkali diagrams, the total alkalis versus silica diagram, and the 'loss on ignition' versus silica diagram.

Pyroclastic rocks predominate among the intermediate and felsic members of the Georges Brook Formation, although rhyolite flows were preferred for analysis. Some of the fine grained felsites labelled as flows may be instead fine grained tuffaceous rocks. The pyroclastic rocks (distinguished by separate symbols on all diagrams on which they are plotted) should display a larger scatter of chemical parameters than the flows. Instead, they appear to reflect the same geochemical trends and scatter (Harker diagrams shown in Figures 27 and 28 of Chorlton, 1980a).

Weight percent Na_2O+K_2O was plotted against $K_2O/(Na_2O+K_2)X100$ (Figure AII-1). These diagrams are contoured with the empirically derived data envelope for most relatively fresh volcanic rocks, the 'Igneous Spectrum' (Hughes, 1973). According to Hughes (1973), samples which plot outside the 'Igneous Spectrum' can be considered metasomatic. Many of the La Poile River Group analyses fall outside of the boundaries. Because several combinations of alkali exchange and bulk transport processes may cause analyses to fall inside the spectrum boundaries fortuitously, it is considered likely that most of the La Poile River metavolcanic rocks are metasomatized to some degree (see discussion in Chorlton, 1980a).

The appropriate combination of alkali metasomatic processes cannot be unambiguously inferred from this diagram, especially for a suite that varies widely in initial composition. Hughes (1973) suggests that feldspar alteration may be the main reaction process involved in low grade alkali metasomatism in these terranes. Felsic volcanic rocks are generally rich in sodium and potassium, contained mainly in alkali feldspar and plagioclase. Therefore, alteration should proceed in the form of alkali cation exchange in the feldspars due either to chemical

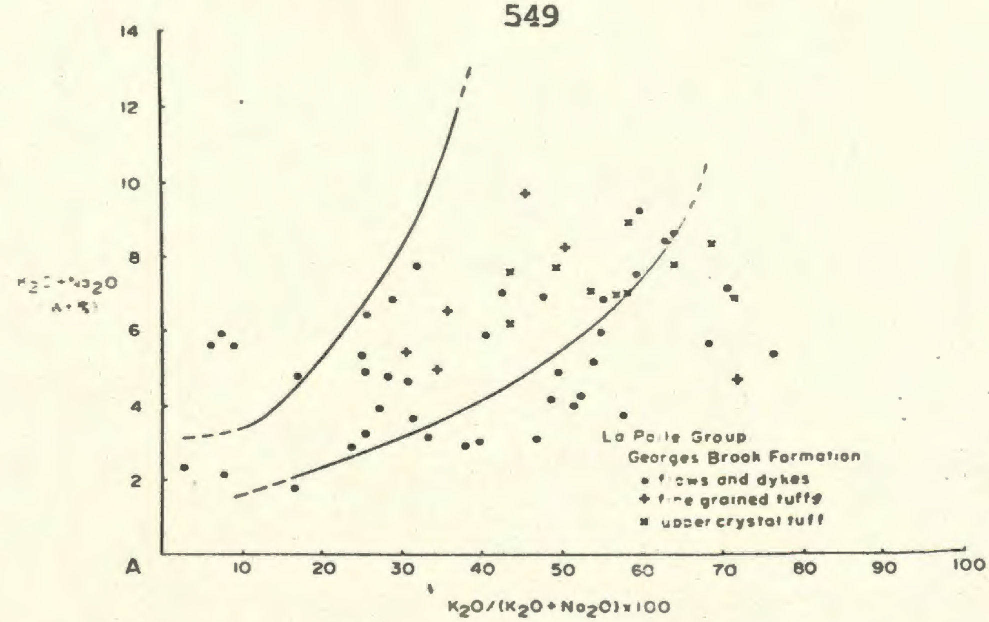


Figure AII-1: (Na2O - K2O) vs. K2O/(Na2O - K2O) x 100 for volcanic rocks of the La Poile River Group plotted on the Igneous Spectrum diagram of Hughes (1973). Lines show envelope of data gathered from well known fresh volcanic rocks world-wide.

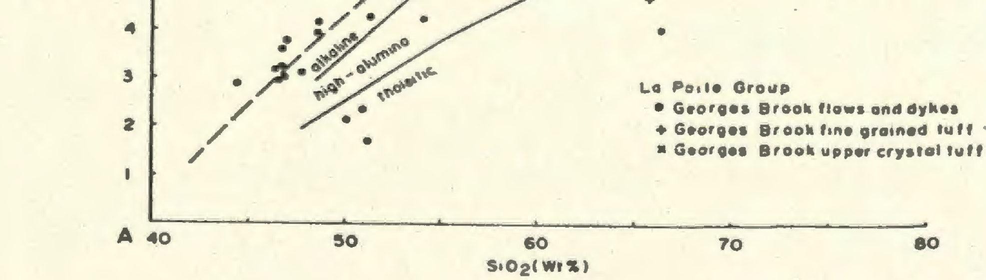


Figure AII-2: (Na2O - K2O) vs. SiO2 for volcanic rocks of the La Poile River Group. Dashed line divides the alkaline and tholeiitic fields of Irvine and Baragar (1971). Solid line separates alkaline, high alumina, and tholeiitic fields of Kuno (1968).

potential, pressure, and/or temperature gradients (Orville, 1963), or to the fluxing of hot brines (Ellis et al, 1964, Walker et al, 1972), or alternately by means of sericitization of the plagioclase feldspars with the consequent removal of Na^+ under greenschist facies conditions. Thus, they should exhibit a high potential for potassium for sodium exchange, which would result in a shallow spread of points to the right or left in the 'Igneous Spectrum' diagram. Basic rocks are originally low in potassium, but high in calcium contained partly in intermediate to calcic plagioclase, and thus should exhibit a high potential for sodium enrichment at low grade through the albitization of plagioclase, possibly accompanied by the addition of silica and release of calcium (as epidote) into the many veins and fractures abundant in these rocks. Basic rocks affected in this way should plot above the upper left margin of the 'Igneous Spectrum'.

Many of the Georges Brook metavolcanic rocks fall to the right of the 'Igneous Spectrum' (Figure AII-1). Therefore, they appear to be dominantly affected by potassium for sodium substitution, although this could alternatively reflect variable alkali depletion. The former is supported by the ubiquitous sericitization of the feldspars. Some data points fall above the left margin of the spectrum, probably representing mafic rocks enriched in sodium. However, potassium enrichment might also be expected because of the common sericitization of plagioclase in many mafic rocks. Some of the low silica rocks also plot in the alkaline field of the Na_2O+K_2O versus SiO_2 diagram of Irvine and Baragar (1971), in contrast to the intermediate and felsic rocks which remain in the tholeiitic field.

MAGMA TYPE AND TECTONIC SETTING USING BOTH MOBILE AND IMMOBILE ELEMENTS

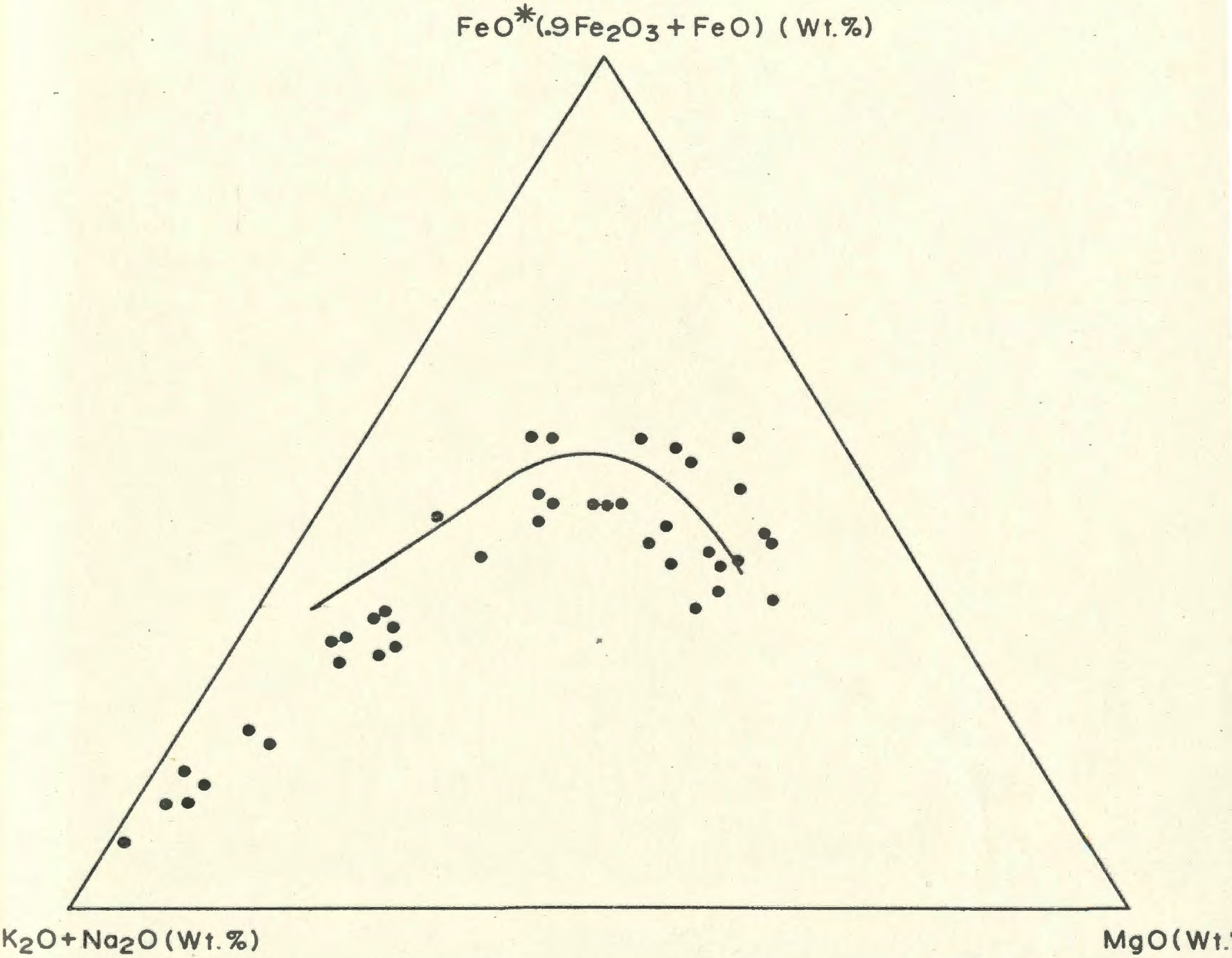
1. Na_2O+K_2O versus SiO_2, and AFM diagrams (Irvine and Baragar, 1971)

Despite the alkali metasomatism indicated above, analyses were plotted on the bulk geochemical discrimination diagrams of Irvine and Baragar (1971). On the Na_2O+K_2O versus SiO_2 diagram (Figure AII-2), analyses fall mainly within the subalkaline field of Irvine and Baragar (1971), but span the alkaline, tholeiitic, and high alumina fields of Kuno (1965). Several of the mafic rocks analyses plot within the alkaline field, possibly because of alkali enrichment as noted above. The spread of data is similar to the distribution shown by several well-known calc-alkaline suites (Irvine and Baragar, 1971, Figure 3e).

The Georges Brook flows and dykes were plotted on an AFM diagram (Figure AII-3). The analyses follow a calc-alkaline trend, and most fall on the calc-alkaline side with some of the mafic rocks on the tholeiitic side of the calc-alkaline-tholeiitic dividing line of Irvine and Baragar (1971). Rocks plotting in the alkaline field in Figure AII-2 were not omitted from this diagram.

2. Magma type using the TiO_2, Zr, and P_2O_5 content of the mafic rocks (Winchester and Floyd, 1976; Floyd and Winchester, 1975)

Ti, Zr, and P_2O_5 are blieved to be less mobile than the alkalis during metamorphism (Pearce, 1975; Floyd and Winchester, 1976; Morrison, 1978; Smith and Smith, 1976). Therefore, TiO_2, Zr, and P_2O_5 values for suitable mafic volcanic rocks were plotted on the TiO_2 versus Zr/P_2O_5 and TiO_2 versus Zr discrimination diagrams of Floyd and Winchester (1975). On the TiO_2 versus Zr/P_2O_5 diagram, all but one of the analyses fall in the tholeiitic plus calc-alkaline field (Figure AII-4); most lie within the oceanic field. On the TiO_2 versus Zr diagram, most of the analyses fall within the field of oceanic tholeiites with a



AII-3: AFM projection for Georges Brook Fm. mafic and felsic flow and dykes with the calc-alkaline/tholeiitic dividing line of Irvine and Baragar (1971).

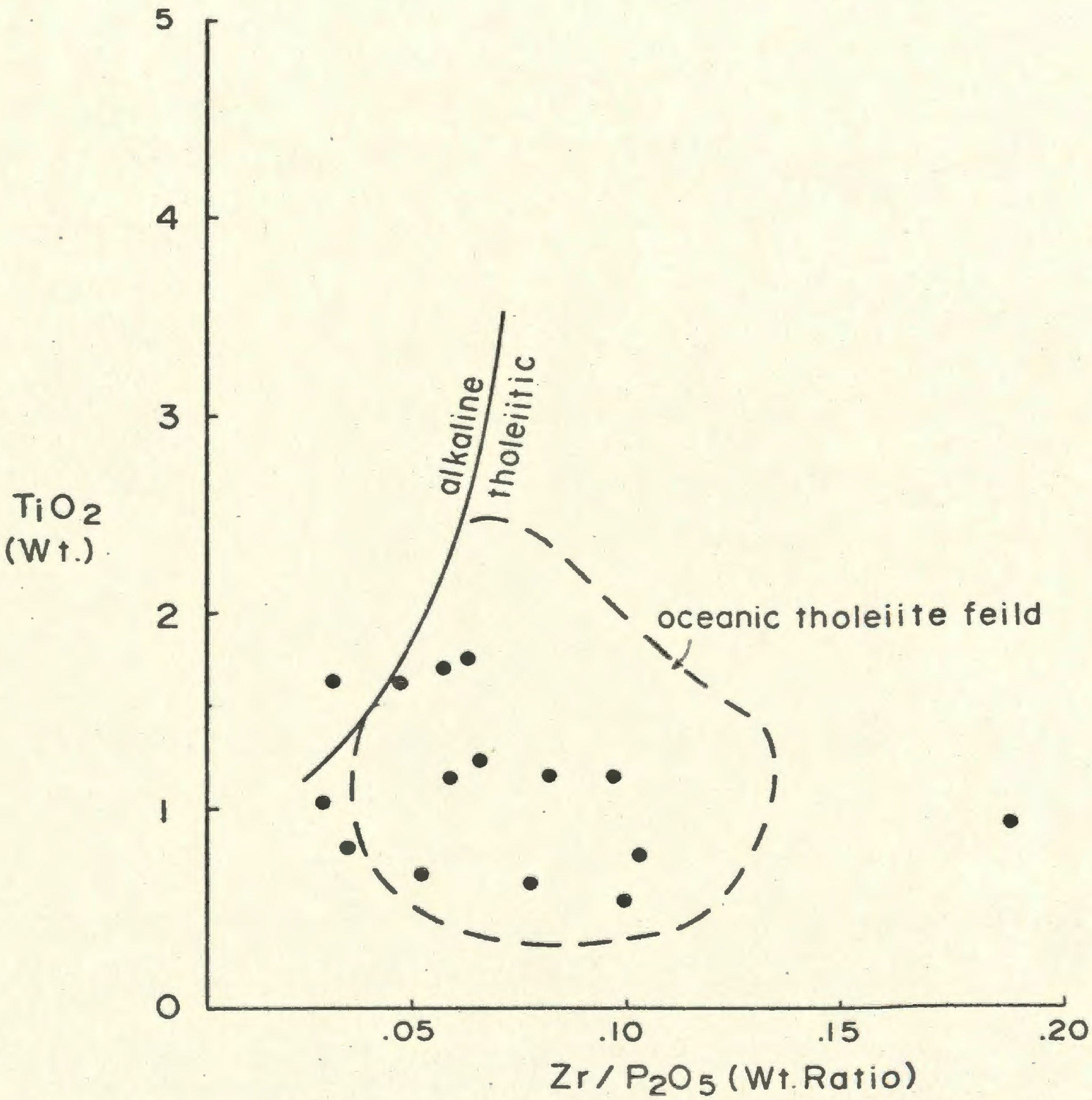


Figure AII-4: Magma type using TiO2 vs. Zr/P2O5 for suitable Georges Brook volcanic rocks. Solid line separates alkaline from tholeiitic plus calc-alkaline fields, and dashed line delineates approximately overlapping oceanic field (Winchester and Floyd, 1975).

few inside the entirely overlapping continental tholeiite field (Figure AII-5).

3. Magma Series using Zr, TiO_2, and SiO_2 (Winchester and Floyd, 1977)

SiO_2 versus Zr/TiO_2 data were plotted on the magma series discrimination diagram of Winchester and Floyd (1977) (Figure AII-6). The analyses are spread along the calc-alkaline high alumina basalt - andesite - dacite - rhyolite trend.

4. Tectonic setting using Ti, Zr, and Y of the mafic rocks (Pearce and Cann, 1973)

Diagrams using Ti, Zr, and Y to discriminate between nonalkaline basalts of within-plate and plate marginal tectonic environments were presented by Pearce and Cann (1973), and applied to altered rocks (Pearce, 1975). Analyses of suitable Georges Brook metabasalts (Pearce and Cann, 1973, page 294) were plotted on the Ti/100-Zr-3Y triangular discrimination diagram (Figure AII-7). A few metabasalt samples from the younger Windsor Point Group were also plotted for comparison. Most of the Georges Brook

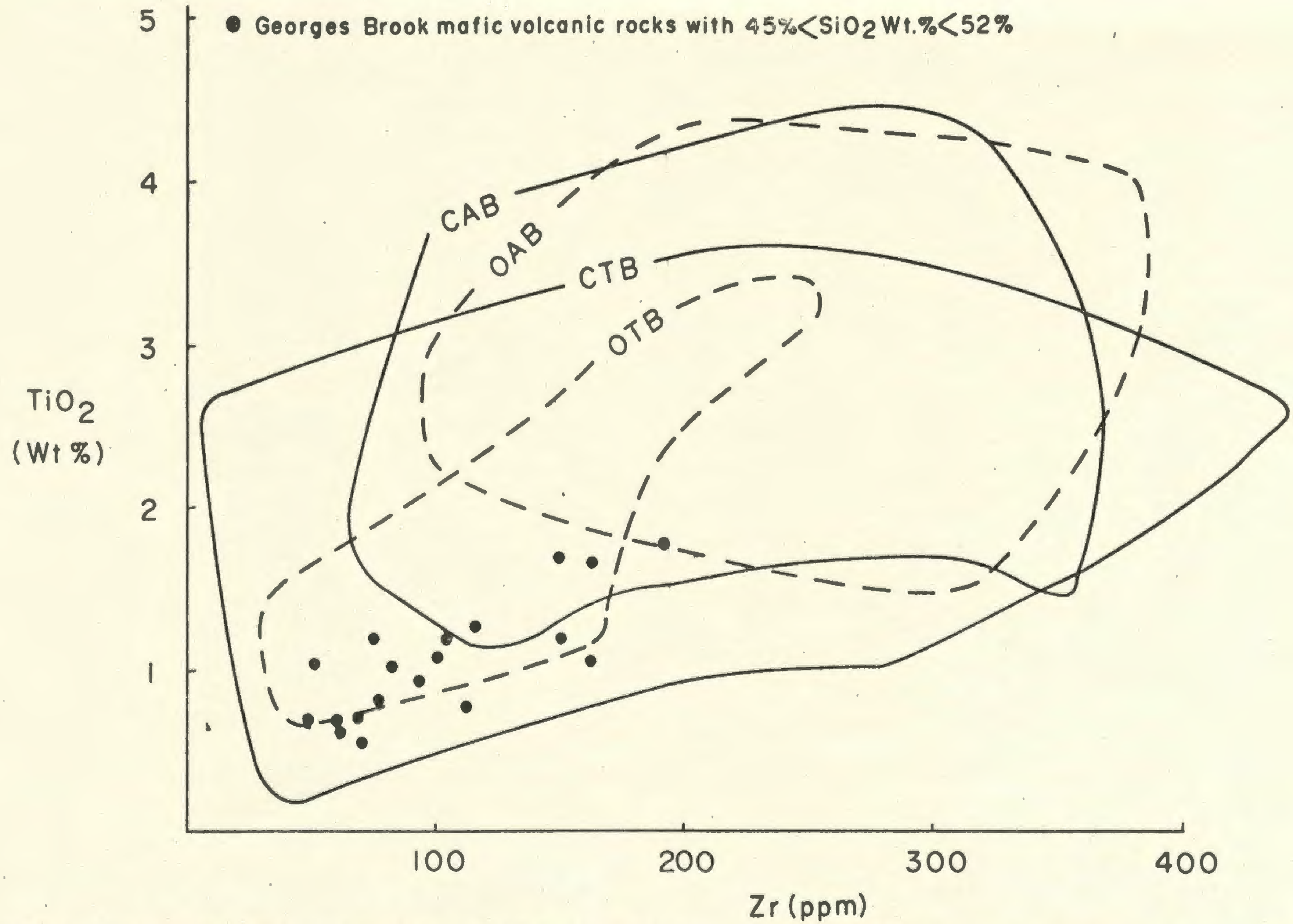


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Figure AII-5: Magma type using TiO2 vs. Zr for suitable Georges Brook volcanic rocks. Solid lines labelled CAB and CTB refer to continental alkaline and tholeiitic fields respectively; dashed lines labelled OAB and OTB refer to oceanic alkaline and tholeiitic fields respectively (Winchester and Floyd, 1975).

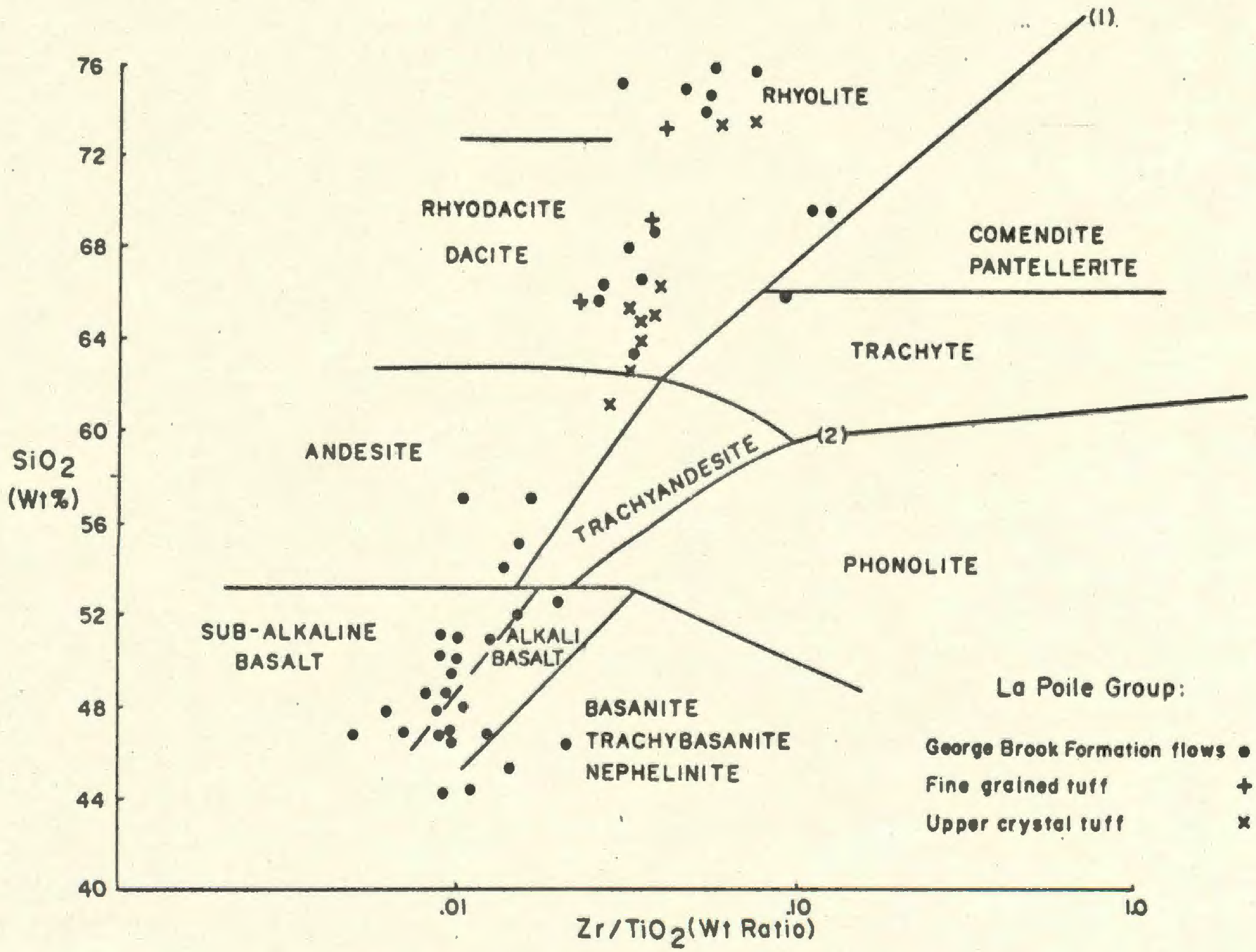

Figure AII-6: Magma series using SIO2 and Zr/TIO2 for volcanic rocks of the La Poile River Group (Winchester and Floyd).

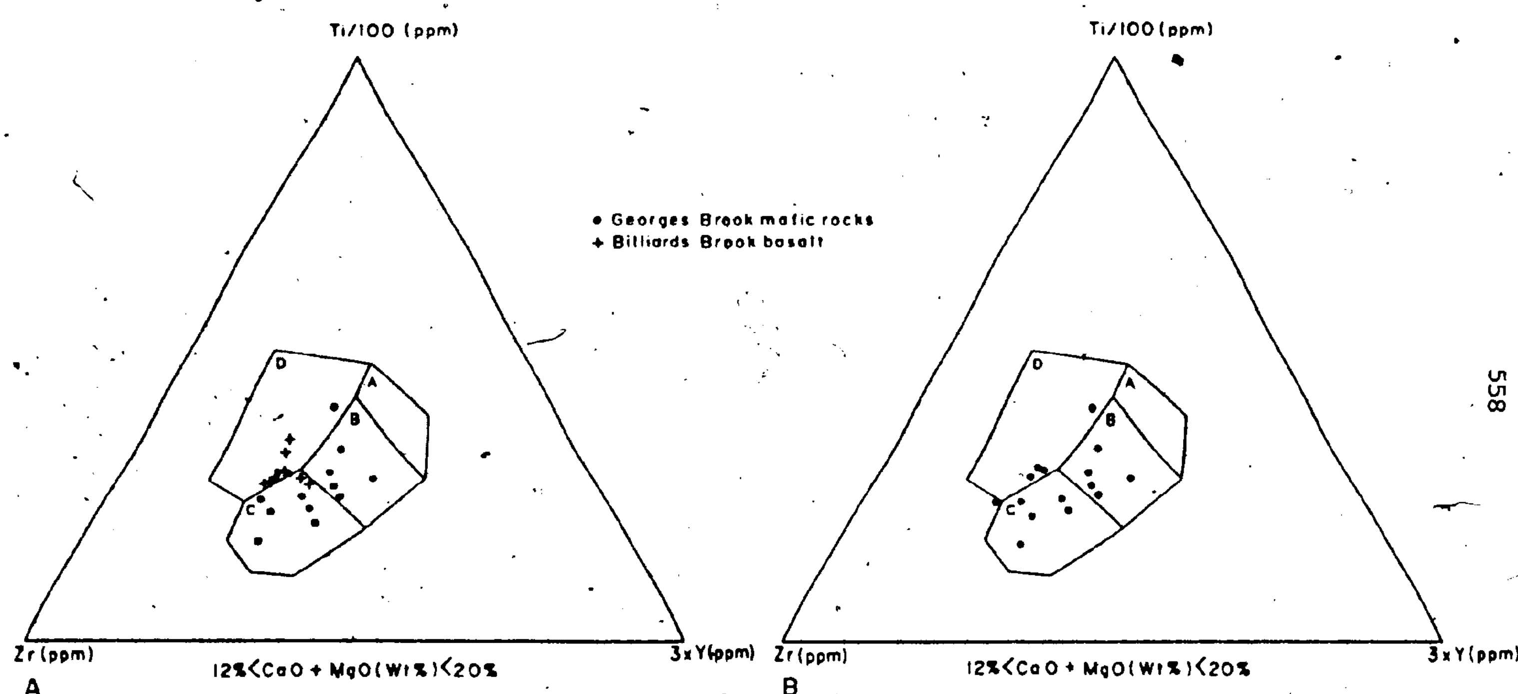

Figure AII-7: Tectonic setting of suitable Georges Brook and Windsor Point Group mafic volcanic rocks using TiO/100 - Zr - 3Y discrimination diagram of Pearce and Cann (1973). Within-plate ocean floor basalts in field B, plate-marginal low potassium tholeiites in fields A and B, and plate-marginal calc-alkaline basalts in fields B and C.

metabasalts fall within fields B and C (Figure AII-7b), indicating a calc-alkaline affinity in a plate marginal environment. The few Windsor Point Group metabasalts plot within and near field D (Figure AII-7a), suggesting a within-plate setting (Pearce and Cann, 1973).

Ti was plotted against Zr for suitable Georges Brook metabasalts on a discrimination diagram separtating ocean floor tholeiitic basalts, low potassium tholeiites, and calc-alkaline basalts (Figure AII-8). The analyses plot largely within fields B and C, the fields occupied by plate marginal calc-alkaline basalts (Pearce and Cann, 1973).

5. Summary

The graphical geochemical techniques employed here indicate that the metavolcanic rocks of the Georges Brook Formation belong to a calc-alkaline suite generated in a plate marginal setting, either oceanic or continental.

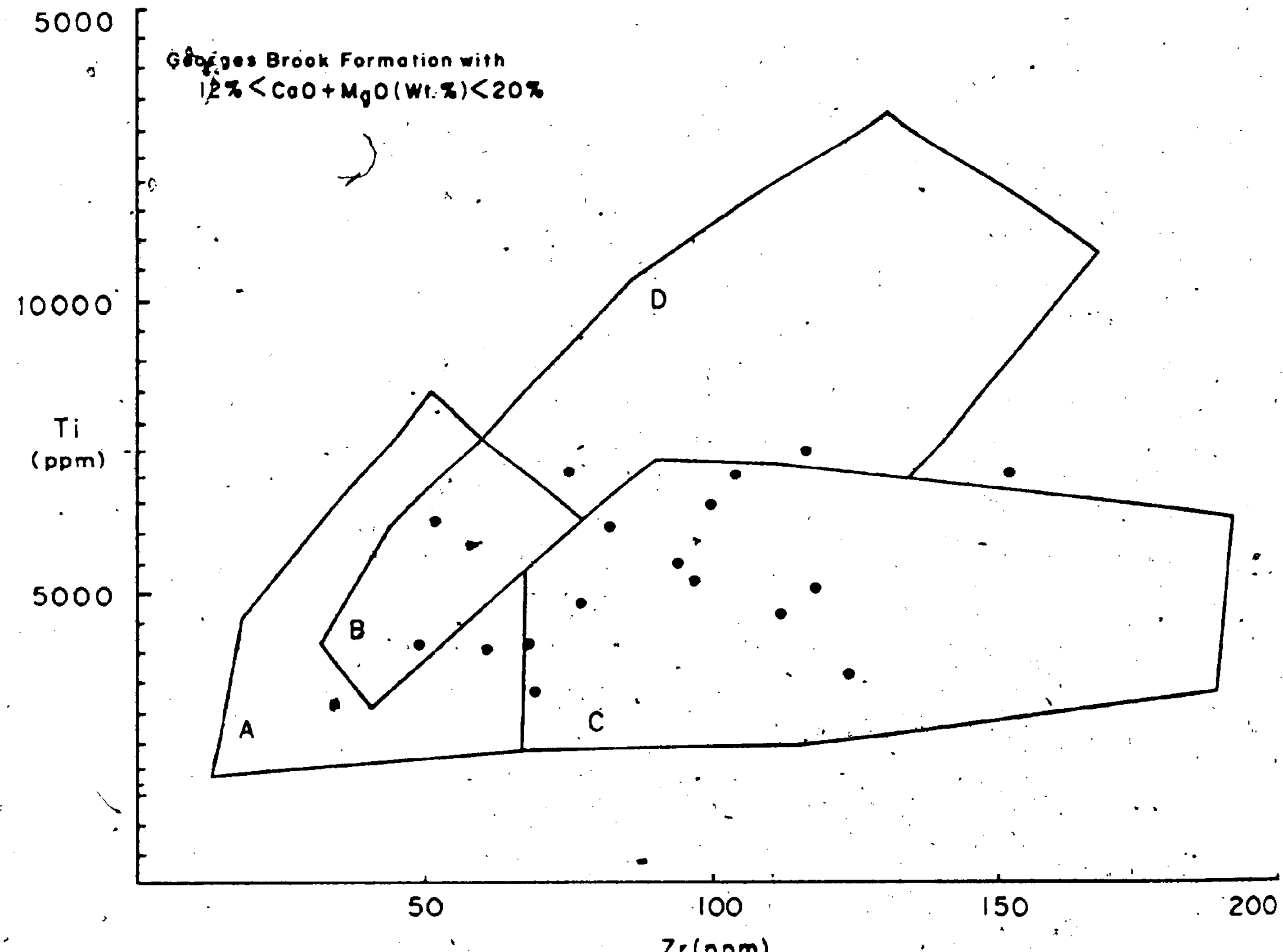

Figure AII-8: Tectonic setting using the Ti vs. Zr discrimination diagram of Pearce and Cann (1973) for suitable Georges Brook volcanic rocks. Ocean floor basalts plot in fields D and B, low potassium tholeiites of plate margins in fields A and B, and calc-alkaline basalts in fields B and C.

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APPENDIX III: NORMATIVE GEOCHEMISTRY OF COMPONENT 4 GRANITOID ROCKS

INTRODUCTION

C.I.P.W. and hornblende-biotite mesonorms were computed from major element analyses of the granitoid rocks. Most analyses were performed at the Newfoundland Department of Mines and Energy geochemical laboratory; analytical techniques are reported by Wagenbauer et al (1983) and precision and accuracy by Dickson (1983). Some of the granitoid rocks were collected prior to the DREE project, and analyzed by the writer at Memorial University of Newfoundland (see Appendix II).

The granitoid rocks were categorized in the main body of the thesis using visual estimates of modal mineralogy (Section 1.4.3, p.28), rather than on the basis of their geochemistry (cf. le Maitre, 1976). Because of the difficulty of discriminating between the Ab component of the plagioclase Ab-An solid solution and the albite component on either mixed alkali feldspar or partly unmixed alkali feldpsar perthite, it is impractical to compare geochemical and mineralogical classifications directly. For example, geochemistry alone cannot distinguish between many alkali feldspar granites and leucocratic adamellites. However, the reader may wish to compare the names applied to the component 4 granitoid rocks with average normative compositions of several types of granitoid rock compiled by le Maitre (1976), and listed here in Table AIII-1.

Table AIII-1: C.I.P.W. NORMS (Wt. %) of average granite, adamellite, granodiorite, tonalite, diorite and gabbro (le Maitre, 1976).

mineral	GRANITE	ADAMELLITE	GRANODIORITE	TONALITE
Q	29.06	25.17	22.36	16.62
C	0.92	0.28	0.26	--
Or	24.50	23.66	16.11	12.24
Ab	31.13	29.36	31.73	30.67
An	8.04	11.55	17.34	22.58
Di	--	--	--	1.49
Hy	3.37	5.66	7.40	9.68
Mt	1.75	1.79	2.00	2.66
Il	0.58	1.03	1.03	1.40
Ap	0.28	0.44	0.42	0.58
Cc	0.12	0.20	0.19	0.33
Fe/Fe+Mg	0.41	0.43	0.35	0.27

mineral	MONZONITE	DIORITE	GABBRO
Q	14.02	10.28	0.71
C	--	--	--
Or	24.00	10.42	5.49
Ab	31.56	29.96	20.26
An	13.97	24.40	28.60
Di	3.78	4.67	13.70
Hy	6.01	12.56	22.13
Mt	2.78	3.63	4.36
Il	1.48	1.80	2.13
Ap	0.60	0.68	0.56
Cc	0.17	0.23	0.17
Fe/Fe+Mg	0.30	0.32	0.28

Hornblende-biotite norms are more applicable to granitoid rocks than C.I.P.W. norms because they reflect the ferromagnesian mineralogy more accurately. The main difference in calculated normative leucocratic minerals is that in the hornblende-biotite norm, the proportion of orthoclase is slightly lower because some potassium is allocated to biotite. However, the difference is so slight that only C.I.P.W. norms are tabulated below.

Component 4c leucogranites

Tables AIII-2 and AIII-3 contain C.I.P.W. norms for subsolvus and perthite-rich leucogranites, respectively. Both granitoid rock types are poor in normative anorthite and femic minerals compared to average granite. Normative Q-Ab-Or triangular projections (Figure AIII-1) show that both types also cluster tightly in the lower centre of the Q-Ab-Or diagrams, and approximate water-undersaturated 'minimum melt' compositions (cf. Wyllie et al, 1976). Both types are concentrated near the Or-Ab side of normative Or-Ab-An triangular projections, the subsolvus leucogranites showing a linear spread toward approximately An_{20} on the Ab-An sideline and the perthite-rich leucogranites showing a linear spread parallel the Or-Ab sideline (Figure AIII-2).

Table AIII-2: C.I.P.W. norms for component 4c subsolvus leucogranites.

	(Spoon Br)	(Garia Br)		(Peter Snout area)			
	7c157	8c389	8c391	9c111	9c112	9c117	9c119
Q	31.28	28.87	31.85	31.01	25.34	31.56	34.70
C	0.84	1.82	0.87	0.13	0.08	0.61	0.57
Or	26.05	28.48	24.36	29.66	28.94	27.65	28.91
Ab	33.76	35.10	31.78	32.05	32.75	33.10	29.61
An	6.05	3.48	6.62	5.68	9.06	5.77	4.79
Di	--	--	--	--	--	--	--
Hy	1.27	1.67	3.22	0.89	2.95	0.75	1.18
Ru	--	--	--	--	--	--	--
Mt	0.44	0.13	0.57	0.40	0.28	0.38	0.10
Il	0.29	0.17	0.59	0.17	0.50	0.12	0.13
Hm	--	--	--	--	--	--	--
Ap	0.02	0.26	0.14	--	0.02	0.05	--
D.I.	91.08	92.46	87.99	92.73	87.09	92.32	93.22

	(Peter Snout area)						
	9c121	9c123	9c124	9c142	9c145	9c399	9w020
Q	33.41	31.00	27.79	26.66	28.47	27.87	30.91
C	1.24	1.74	0.98	1.06	1.04	0.61	0.93
Or	24.74	37.08	29.38	29.06	28.32	29.49	29.94
Ab	35.56	24.01	31.59	32.54	35.92	31.70	30.20
An	4.03	2.98	5.73	6.46	3.86	7.43	5.64
Di	--	--	--	--	--	--	--
Hy	0.54	2.20	3.92	3.63	1.49	1.71	1.87
Ru	--	--	--	--	--	--	--
Mt	0.38	0.45	0.03	0.06	0.52	0.68	0.16
Il	0.08	0.46	0.53	0.53	0.37	0.45	0.29
Hm	--	--	--	--	--	--	--
Ap	0.02	0.09	0.05	--	--	0.05	0.07
D.I.	93.71	92.08	88.76	88.26	92.72	89.07	91.05

continued

Table AIII-2: continued

	(Peter Snout area)						
	9w028	9w036	9w038	9w041	9w047	9w050	9w051
Q	34.45	27.04	31.60	31.29	30.98	34.34	33.91
C	0.29	0.43	0.48	0.42	1.18	0.92	0.48
Or	30.09	39.30	34.28	28.85	28.24	27.48	29.35
Ab	28.76	25.73	29.42	32.47	36.13	33.13	29.23
An	4.99	4.38	3.63	6.06	2.54	3.41	5.49
Di	--	--	--	--	--	--	--
Hy	1.11	2.30	0.15	0.31	0.67	0.18	0.53
Ru	--	--	0.07	--	--	0.06	0.14
Mt	0.07	0.25	--	0.38	0.16	--	--
Il	0.23	0.45	0.02	0.12	0.08	0.04	0.04
Hm	--	--	0.33	--	--	0.43	0.80
Ap	--	0.12	0.02	--	0.02	0.02	0.02
D.I.	93.30	92.08	95.29	92.61	95.35	94.94	92.49

	(Peter Snout area)					(Northwest Br)	
	9w122	9w135	9w209	9w217	9w222	0c254	0c266
Q	31.43	29.54	25.74	30.53	30.50	31.76	30.26
C	0.43	0.63	0.62	0.52	0.46	1.78	2.03
Or	26.06	26.54	32.59	28.24	27.58	28.16	26.21
Ab	36.51	31.37	33.78	34.87	34.76	32.07	33.04
An	4.80	7.49	4.55	4.96	5.95	3.77	4.14
Di	--	--	--	--	--	--	--
Hy	0.23	3.56	2.16	0.57	0.55	1.16	2.65
Ru	0.06	--	--	--	--	--	--
Mt	--	0.19	0.07	0.02	--	0.14	0.19
Il	0.04	0.54	0.29	0.13	0.12	0.34	0.56
Hm	0.43	--	--	--	--	--	--
Ap	--	0.19	0.07	0.02	--	0.14	0.19
D.I.	94.00	87.44	92.11	93.65	92.84	91.99	89.50

continued

Table AIII-2: continued

	(Northwest Br. area)						
	0c281	0c286	0c298	0c304	0c320	0c328	0c374
Q	27.77	32.77	24.56	25.92	30.18	32.91	31.11
C	1.98	1.75	--	1.55	2.20	2.65	1.61
Or	33.04	24.37	18.12	35.30	27.07	25.85	21.73
Ab	30.39	32.20	36.05	27.34	32.28	31.37	35.10
An	2.95	6.01	13.62	3.98	4.45	3.79	6.78
Di	--	--	4.28	--	--	--	--
Hy	1.01	1.46	1.16	1.36	2.05	1.59	3.04
Ru	--	--	--	--	--	--	--
Mt	1.96	0.81	1.13	3.07	0.93	1.02	0.41
Il	0.56	0.54	0.85	0.94	0.65	0.61	0.45
Hm	0.10	--	--	0.25	--	--	--
Ap	0.24	0.09	0.23	0.28	0.19	0.21	0.14
D.I.	91.21	89.34	78.74	88.56	89.54	90.13	87.77

Table AIII-3: C.I.P.W. norms for component 4c perthite-rich leucogranites.

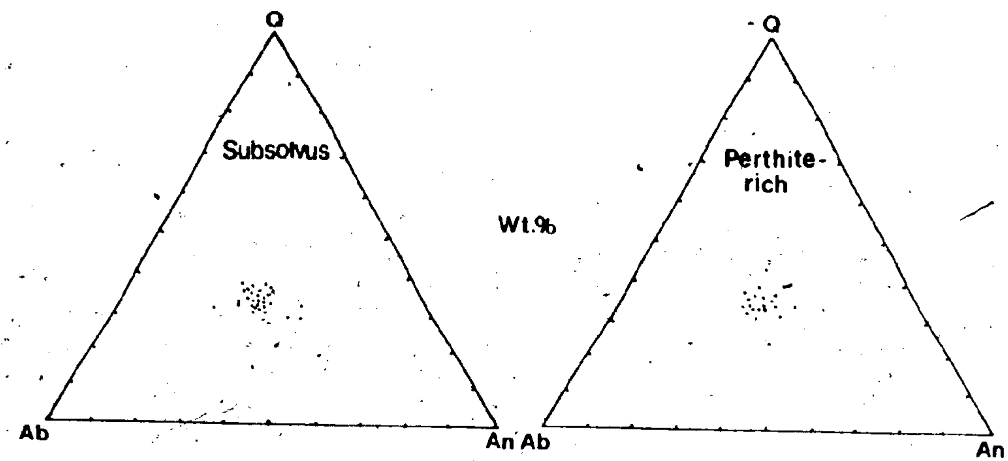
	(Chetwynd Granite)							
	7c317	7c322	9c039	9c445	9c446	9c447	9c459	9c035
Q	32.3	35.9	35.0	33.3	37.0	36.8	34.8	32.0
C	0.29	1.39	0.63	0.46	0.49	0.54	1.02	0.44
Or	32.94	24.68	31.30	31.8	31.3	31.24	26.9	37.1
Ab	28.7	33.75	28.28	29.3	24.5	28.1	29.5	25.26
An	2.94	2.01	2.07	2.88	4.25	2.00	3.80	2.36
Di	--	--	--	--	--	--	--	--
Hy	1.06	1.49	1.08	0.95	1.24	0.74	1.74	1.84
Ru	--	--	--	--	--	--	--	--
Mt	0.97	0.38	0.95	0.81	0.71	0.32	1.35	0.37
Il	0.63	0.29	0.60	0.50	0.48	0.21	0.70	0.59
Hm	--	--	--	--	--	--	--	--
Ap	0.09	0.02	0.05	--	--	0.70	0.14	0.05
D.I.	94.0	94.3	94.6	94.4	92.8	96.1	91.2	94.4

continued

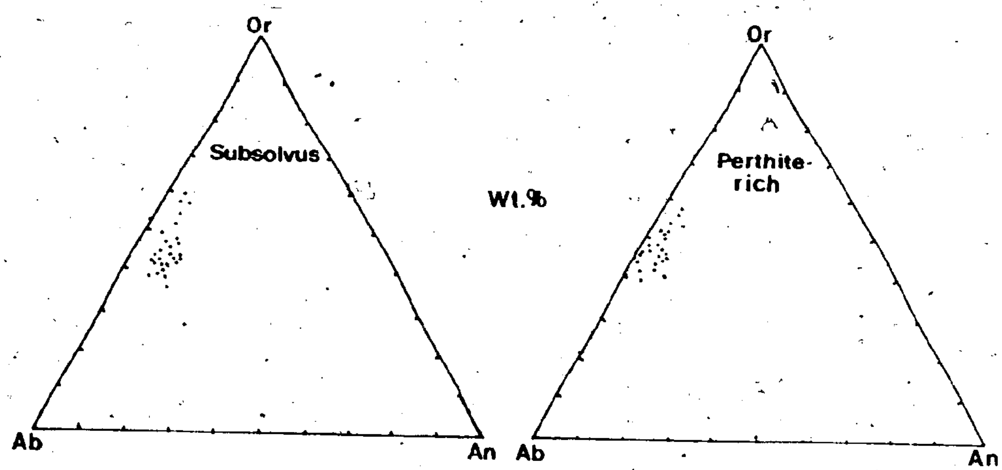
Table AIII-3: continued

	(Chetwynd Granite)			(Petites)	(Is.aux Morts)		(Pluton A)	
	9c036	9c038	9c448	0c417	9c308	9c260	9c301	0c400
Q	29.0	42.1	37.4	31.99	30.50	32.5	31.2	28.32
C	0.17	0.43	0.40	1.75	1.04	0.92	0.53	1.00
Or	36.4	26.2	33.65	25.84	27.49	25.63	28.76	26.74
Ab	29.1	28.3	23.8	32.44	27.49	25.63	28.76	26.74
An	2.40	1.82	2.98	4.06	4.18	2.99	5.18	6.17
Di	--	--	--	--	--	--	--	--
Hy	0.99	0.48	0.48	2.39	2.06	0.30	1.79	1.80
Ru	--	--	0.18	--	--	0.06	--	--
Mt	1.22	0.44	--	0.80	0.71	--	0.91	1.04
Il	0.70	0.25	0.04	0.59	0.62	0.41	0.48	0.62
Hm	--	--	0.92	--	--	0.52	--	--
Ap	0.02	--	0.19	0.14	--	0.05	0.14	0.16
D.I.	94.5	96.6	94.8	90.3	91.38	95.12	90.97	89.20

	(Pluton A)		(Plutons B and C)					
	0c801	0c802	0c054	0c058	0c075	0c089	0c107	9c337
Q	21.38	31.08	33.60	35.58	35.5	33.62	28.71	31.84
C	1.04	0.84	1.02	1.39	1.26	0.48	1.07	1.03
Or	36.44	28.91	28.47	28.06	27.26	28.28	30.26	28.57
Ab	36.65	31.37	30.08	31.57	33.52	34.97	35.48	31.86
An	3.59	4.97	3.72	1.41	0.72	1.11	1.33	3.55
Di	--	--	--	--	--	--	--	--
Hy	0.30	1.36	1.88	0.85	0.85	0.85	1.53	2.14
Ru	--	--	--	--	--	--	--	--
Mt	0.42	0.82	0.73	0.71	0.56	0.59	1.10	0.61
Il	0.15	0.54	0.38	0.38	0.28	0.31	0.42	0.39
Hm	--	--	--	--	--	--	--	--
Ap	0.02	0.12	0.12	0.05	0.02	--	0.09	--
D.I.	94.47	91.36	92.15	95.21	96.28	96.86	94.46	92.27



a: Q- Ab- An projection.



b: Or–Ab–An projection.

Figure AIII-1: Subsolvus and perthite-rich leucogranites plotted on Q-Ab-An sides of the salic tetrahedra.

Component 4b granitoid rocks

The Rose Blanche and Port aux Basques phases of Terrane II were the most extensively sampled for geochemistry. C.I.P.W. norms for these units are presented in Tables AIII-4 and AIII-5.

Both the Rose Blanche and Port aux Basques phases range broadly in composition, generally spanning the average normative compositions of granite, adamellite, granodiorite, and tonalite (Table AIII-1). The Port aux Basques phase in particular appears to be enriched in normative albite compared to some of the average values, although this may beinsignificant in view of the wide range in composition documented for each granitoid rock type (le Maitre, 1976). Norm ratios of the Rose Blanche phase are concentrated in a broad, elongate array on the albite-rich side of the Q-Ab-Or projection between about 30 and 35 percent quartz (Figure 3a) and are more diffusely scattered on the Or-Ab-An projection (Figure 4a). Norm ratios of the Port aux Basques phase are more diffusely scattered on the Q-Ab-Or diagram (Figure 3b), but define a strong linear trend between the Or_{60} position on the Or-Ab sideline and An_{20} on the Ab-An sideline of the Or-Ab-An plot (Figure 4b). These features might be explained by metasomatic alteration during deformation, particularly variable silicification (reflected by the variable and locally abundant normative and modal quartz, and the common appearance of quartz overgrowths in thin section) and alkali feldspar - plagioclase exchange (reflected by the well-defined trend on the Or-Ab-An diagram and the multiple generations of feldspar commonly observed in thin section).

Table AIII-4: C.I.P.W. norms for the component 4b Rose Blanche phase.

	7c299	8c418	9c041	9c069	9c305	9w139	0c250	0c251
Q	24.52	20.15	28.92	31.37	29.53	32.14	27.61	18.31
C	0.28	2.17	1.19	1.30	1.18	0.94	1.45	1.65
Or	21.53	12.24	23.43	24.17	9.15	28.47	14.11	12.42
Ab	36.89	37.53	37.04	39.70	48.97	31.44	38.15	41.07
An	10.27	13.40	6.10	2.10	6.94	4.89	12.33	17.13
Di	--	--	--	--	--	--	--	--
Hy	4.23	9.31	1.19	0.87	3.11	0.71	4.42	6.85
Ru	--	--	0.24	--	--	0.09	--	--
Mt	1.00	2.60	--	0.15	0.44	--	0.92	1.27
Il	0.92	1.82	0.06	0.04	0.48	0.09	0.77	0.84
Hm	--	--	1.66	--	--	1.09	--	--
Ap	0.35	0.79	0.16	--	0.21	0.14	0.24	0.47
D.I.	82.94	69.92	89.39	95.24	87.65	92.06	79.97	71.80

continued

Table AIII-4: continued

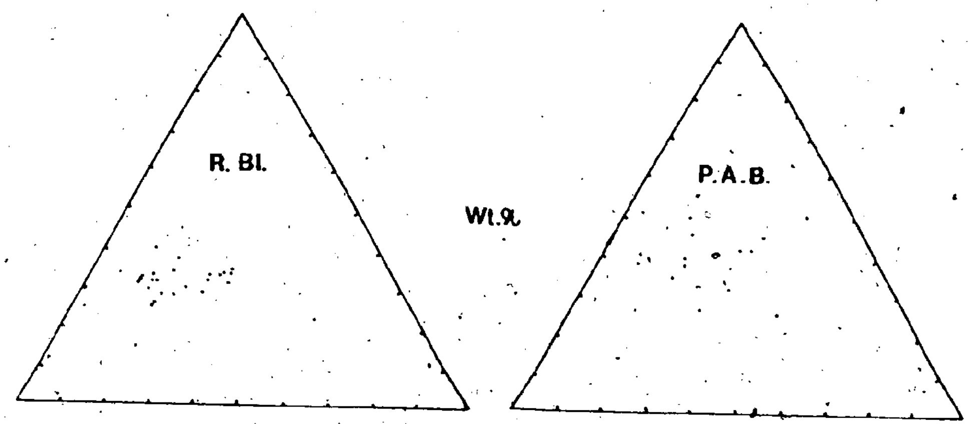
	0c252	0c253	0c261	0c267b	0c268	0c296	0c367	0c368
Q	32.39	26.51	31.14	25.61	23.59	25.88	21.61	25.21
C	1.05	1.08	1.86	--	2.23	2.26	2.02	2.07
Or	26.93	8.34	27.33	24.90	11.40	11.70	16.32	10.12
Ab	34.70	44.10	31.08	28.98	42.90	31.55	33.09	38.89
An	4.00	15.08	4.60	13.93	12.24	15.23	14.96	15.07
Di	--	--	--	3.36	--	--	--	--
Hy	0.26	2.82	1.96	0.37	4.34	10.62	7.99	5.62
Ru	0.07	--	--	--	--	--	--	--
Mt	--	1.15	1.09	1.84	2.09	1.00	1.83	1.45
Il	0.02	0.61	0.73	0.73	0.81	1.23	1.54	1.04
Hm	0.48	--	--	0.06	--	--	--	--
Ap	0.10	0.30	0.21	0.22	0.42	0.53	0.63	0.52
D.I.	94.02	78.96	89.55	79.49	77.88	69.12	71.02	74.23

	0c369	0c370	0c371	0c376
Q	22.27	23.48	30.13	18.79
C	2.38	2.38	1.70	3.45
Or	10.73	10.98	8.39	16.51
Ab	38.89	37.82	39.17	20.07
An	16.49	15.00	14.86	21.65
Di	--	--	--	--
Hy	7.43	6.82	6.67	14.86
Ru	--	--	--	--
Mt	1.26	0.99	0.40	2.42
Il	1.17	1.09	0.87	1.71
Hm	--	--	--	--
Ap	0.45	0.09	0.26	0.55
D.I.	70.82	73.63	75.23	55.38

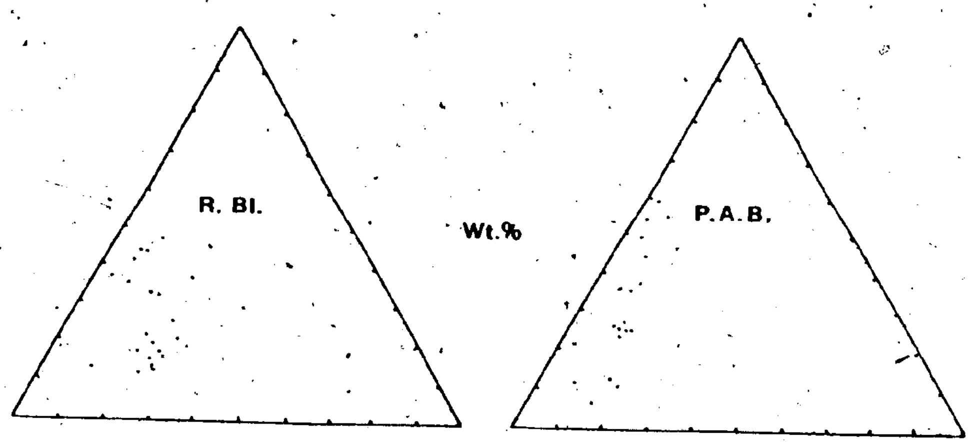
Table AIII-5: C.I.P.W. norms for the component 4b Port aux Basques phase.

	9w198	9c214	9c270	9c390	0c402	0c406	0c407	0c409
Q	44.76	42.22	39.93	40.09	22.32	34.98	44.43	31.86
C	1.26	0.52	2.72	0.82	1.12	1.20	1.43	1.33
Or	12.80	30.16	13.28	30.14	24.85	15.16	3.37	5.86
Ab	32.20	21.05	32.63	24.45	40.17	38.84	40.64	41.66
An	7.29	3.53	6.90	1.47	6.68	6.13	7.32	10.94
Di	--	--	--	--	--	--	--	--
Hy	1.18	0.33	2.79	0.75	2.64	1.26	0.47	6.77
Ru	--	--	--	--	--	--	--	--
Mt	0.34	0.75	1.08	1.87	1.05	1.08	0.64	0.36
Il	0.17	0.42	0.54	0.38	0.89	0.65	0.64	0.99
Hm	--	--	--	--	--	--	0.02	--
Ap	--	--	0.12	0.05	0.28	0.12	0.02	0.24
D.I.	89.76	93.44	85.84	94.67	87.34	88.97	88.44	79.39

	0a001	0a002	0a004	0a005a	0a005b	0a006a	0a006b
Q	28.50	37.44	34.99	34.39	29.95	39.93	24.13
C	0.08	1.07	0.59	0.38	1.08	0.23	0.27
Or	28.95	7.03	7.17	16.90	15.43	28.35	43.53
Ab	32.62	40.91	48.47	39.78	40.35	27.21	28.20
An	5.20	8.60	4.89	6.87	7.42	2.58	1.79
Di	--	--	--	--	--	--	--
Hy	2.83	3.77	3.12	0.73	4.84	1.14	0.92
Ru	--	--	--	0.15	--	--	--
Mt	1.03	0.46	0.17	--	0.09	0.31	0.65
Il	0.64	0.64	0.48	0.04	0.68	0.25	0.33
Hm	--	--	--	0.83	--	--	--
Ap	0.14	0.09	0.12	0.02	0.16	--	0.19
D.I.	90.07	85.38	90.63	90.97	85.73	95.50	95.86



a: Q-Ab-An projection



b: Or-Ab-An projection.

Figure AIII-2: Rose Blanche and Port aux Basques phases plotted on Q-Ab-Or and Or-Ab-An sides of the salic tetrahedron.

Table AIII-6: C.I.P.W. norms for the component 4b Cinq Cerf granodiorite.

	4c037*	4c054*	4c130*	4c227*	7c045	7c068
Q	16.97	15.08	20.53	19.84	20.65	19.31
C	--	--	--	--	--	0.61
Or	19.62	11.64	19.89	17.27	22.22	18.91
Ab	31.45	28.53	31.88	30.30	31.95	33.51
An	19.17	23.14	16.43	18.95	15.73	16.95
Di	1.24	8.66	1.68	3.21	--	--
Hy	5.10	1.83	3.78	4.10	6.05	7.08
Sp	1.07	2.01	0.83	1.01	--	--
Mt	--	--	--	--	2.16	2.17
Il	0.22	0.28	0.22	0.21	0.96	1.12
Hm	5.16	8.82	4.75	5.12	--	--
Ap	na	na	na	na	0.28	0.33
D.I.	68.04	55.25	73.31	67.41	74.82	71.93

* $FeO+Fe_2O_3$ analysed as Fe_2O_3, significantly affecting norms.

Component 4b' granitoid rocks

C.I.P.W. norms of component 4b' granitoid bodies in both Terranes I and II for which there are more than one chemical analysis are given below (Table AIII-7 and AIII-8, respectively). Because the megacrystic monzogranite batholith near Burgeo is very like the megacrystic granitoid batholiths included in component 4b' (Terrane II), it is included here (Table AIII-9) although it was placed in the Component 4c section on grounds of foliation (see discussion, Section 11.2.3)

Table AIII-7: C.I.P.W. norms for some of the component 4b' granitoid rocks from Terrane I.

	('Cape Ray Granite')			(Qtz diorite-monz-grandiorite)				
	9c307	0c097	0c391	0c357	0c428	0c366	0c365	0d217
Q	26.50	25.69	20.39	14.40	10.44	16.99	12.77	0.94
C	1.68	0.64	0.85	--	--	0.74	0.83	0.01
Or	26.22	18.96	17.30	14.65	17.66	20.26	13.50	13.98
Ab	37.07	35.70	41.17	23.62	26.04	24.62	22.82	28.40
An	3.20	13.02	12.57	26.54	24.73	21.11	27.85	34.11
Di	--	--	--	1.83	1.95	--	--	--
Hy	2.50	3.82	4.51	13.16	13.81	11.10	15.25	16.24
Ru	--	--	--	--	--	--	--	--
Mt	1.58	1.31	0.97	3.44	3.01	3.34	4.80	4.12
Il	1.02	0.59	0.88	1.50	1.54	1.27	1.50	1.21
Hm	--	--	--	--	--	--	--	--
Ap	0.24	0.28	0.38	0.85	0.82	0.57	0.67	1.04
D.I.	89.78	80.34	78.86	55.67	54.14	61.87	49.10	43.32

	(Qtz diorite-gabbro)	(Red Rocks Granite)
	7c192	9c008
Q	8.63	25.56
C	--	0.66
Or	3.91	26.47
Ab	23.42	31.76
An	33.69	11.62
Di	11.95	--
Hy	12.10	2.20
Ru	--	--
Mt	3.50	1.09
Il	1.41	0.47
Hm	--	--
Ap	0.39	0.17
D.I.	35.96	83.79

Table AIII-8: C.I.P.W. norms for component 4b' granitoid rocks from Terrane II.

	(Otter Point Granite)						(La Poile bth)	
	4c141*	4c144*	4c253*	9c418	9c449	9c456	5c078*	5c087*
Q	22.22	23.05	32.95	27.50	22.59	22.56	13.65	19.22
C	0.81	3.20	0.23	0.41	0.34	0.07	--	--
Or	32.12	31.05	33.09	36.61	26.83	25.20	21.44	26.45
Ab	33.85	31.35	24.88	22.85	31.00	31.74	31.38	28.55
An	5.95	2.05	6.22	8.24	11.08	11.26	17.54	14.36
Di	--	--	--	--	--	--	--	--
Hy	2.63	4.65	0.97	3.47	4.36	4.53	6.45	5.38
Ru	--	0.67	0.41	--	--	--	--	0.58
Mt	--	--	--	0.33	2.19	2.54	--	--
Il	0.18	0.18	0.04	0.47	1.23	1.55	0.20	0.20
Hm	3.58	3.81	1.21	--	--	--	5.92	4.54
Ap	na	na	na	0.12	0.48	0.54	na	na
							sp 2.38	sp .58
D.I.	86.19	85.45	90.91	86.97	80.33	79.50	66.46	74.22

	(La Poile batholith)						(L.P.margin)	
	7c278	7c279	7c280	7c282	7c285	7c298	7c801a	7c801b
Q	19.19	16.92	13.85	14.35	17.09	18.76	21.45	20.23
C	0.36	--	0.10	--	--	--	1.67	1.86
Or	12.81	21.79	21.37	19.98	21.98	27.46	26.11	27.28
Ab	35.19	30.78	35.18	33.29	30.03	28.65	30.88	31.29
An	17.23	14.57	16.42	17.20	16.00	11.66	9.18	8.83
Di	--	--	--	--	--	--	--	--
Hy	10.88	9.44	8.87	10.66	8.54	3.78	7.38	7.42
Ru	--	--	--	--	--	--	--	--
Mt	1.76	1.69	2.00	1.85	2.21	1.41	1.48	1.24
Il	1.80	1.86	1.50	1.73	1.74	1.18	1.34	1.35
Hm	--	--	--	--	--	--	--	--
Ap	0.78	0.87	0.69	0.82	0.77	0.42	0.53	0.50
D.I.	67.20	69.49	70.39	67.62	69.09	74.86	78.43	78.80

continued

Table AIII-8: continued

	(Hawks Nest Pond Porphyry)					(HNP-type)	
	4c03*	4c74b*	7c039	7c046	7c050	9c089	9c090
Q	26.87	23.98	25.41	25.31	24.51	24.44	46.20
C	--	0.47	1.13	0.64	0.94	1.16	0.92
Or	26.93	28.76	21.72	26.72	28.91	26.83	9.99
Ab	28.16	28.51	36.80	25.94	25.19	24.77	28.10
An	11.80	10.68	5.82	12.42	11.22	12.34	11.23
Di	1.23	--	--	--	--	--	--
Hy	1.42	3.16	2.36	5.30	5.60	6.22	1.48
Ru	--	0.58	--	--	--	--	--
Mt	--	--	4.67	2.03	1.99	2.26	1.48
Il	0.20	0.18	1.16	1.26	1.29	1.54	0.54
Hm	2.73	3.69	0.55	--	--	--	--
Ap	na	na	0.36	0.38	0.40	0.45	--
Sp	0.67						
D.I.	81.96	81.24	83.94	77.98	78.60	76.04	84.35

	Ironbound syenodiorite-granite)			
	6c167	7c190	9w216	9c384
Q	7.31	21.76	16.71	24.08
C	--	--	--	0.38
Or	35.83	35.91	36.30	29.20
Ab	19.26	25.11	21.51	31.50
An	9.20	7.57	9.87	7.41
Di	8.97	0.31	3.10	--
Hy	13.78	5.98	7.92	5.35
Ru	--	--	--	--
Mt	2.16	1.42	2.18	0.72
Il	2.23	1.25	1.67	0.96
Hm	--	--	--	--
Ap	1.21	0.68	0.76	0.40
D.I	62.40	82.78	84.79	74.52

* Fe_2O_3+FeO analysed as Fe_2O_3

Table AIII-9: C.I.P.W. norms for the Burgeo monzogranite.

	9c060	9c441	9c442	9c444	9c454	9c455	9c463
Q	15.26	6.72	6.31	8.56	11.55	12.14	8.81
C	0.87	0.17	0.08	--	2.07	0.11	--
Or	25.14	26.63	24.97	23.24	19.21	17.82	26.13
Ab	30.39	27.82	28.98	27.85	28.60	29.18	
An	15.59	20.27	20.48	20.32	19.55	21.04	20.06
Di	--	--	--	0.64	--	--	0.28
Hy	8.16	12.75	13.27	13.36	11.58	12.64	9.82
Ru	--	--	--	--	--	--	--
Mt	0.50	0.86	0.83	0.89	1.09	1.05	0.62
Il	1.37	2.32	2.30	2.62	2.68	2.59	1.92
Hm	--	--	--	--	--	--	--
Ap	0.50	0.86	0.83	0.89	1.09	1.05	0.62
D.I.	70.80	61.17	60.26	59.66	59.26	58.56	64.12

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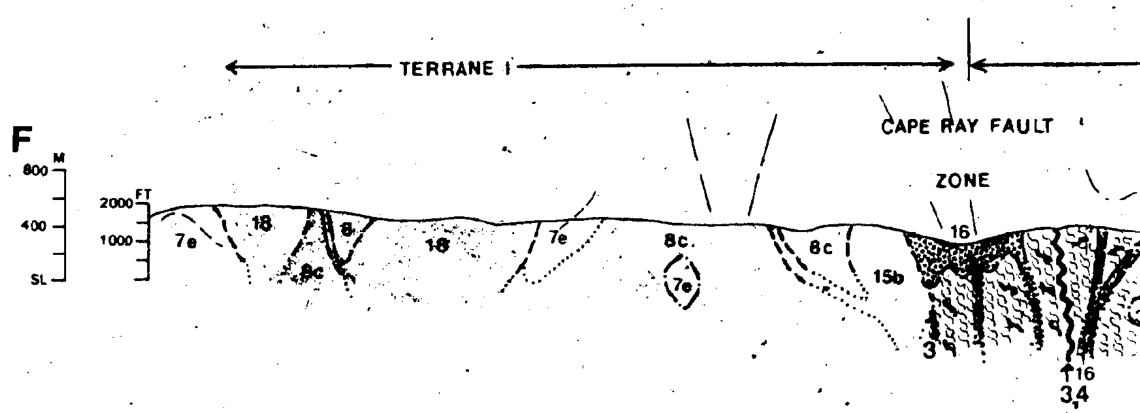
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INTERPRETIVE CROSS-S

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2 of

CROSS-SECTIONS

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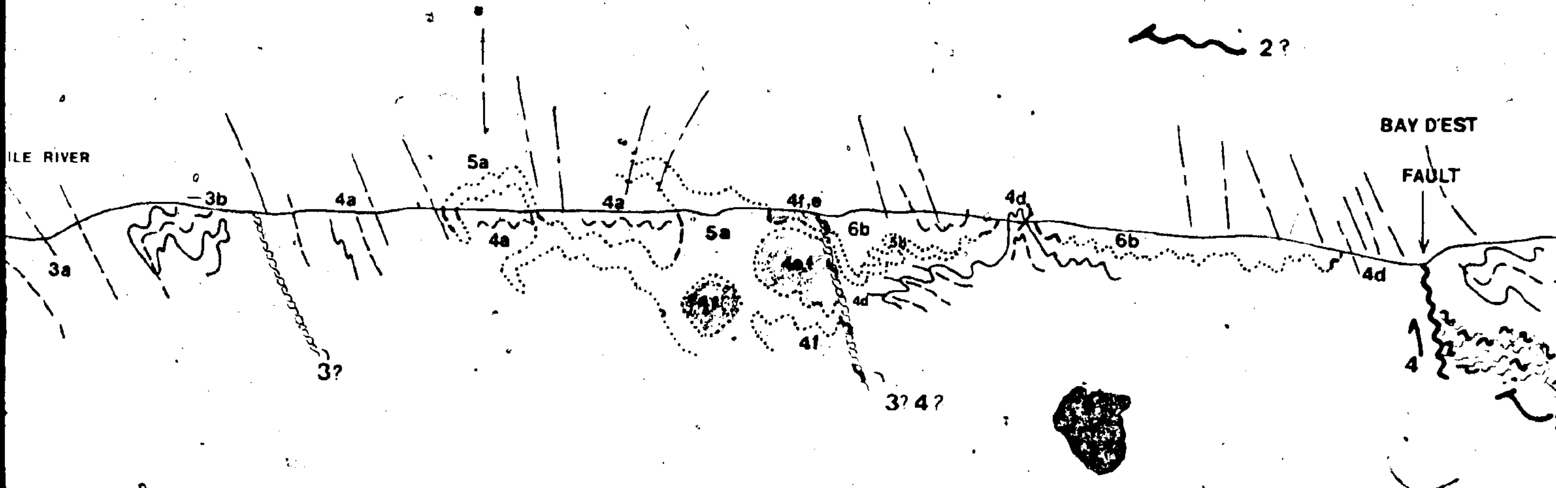

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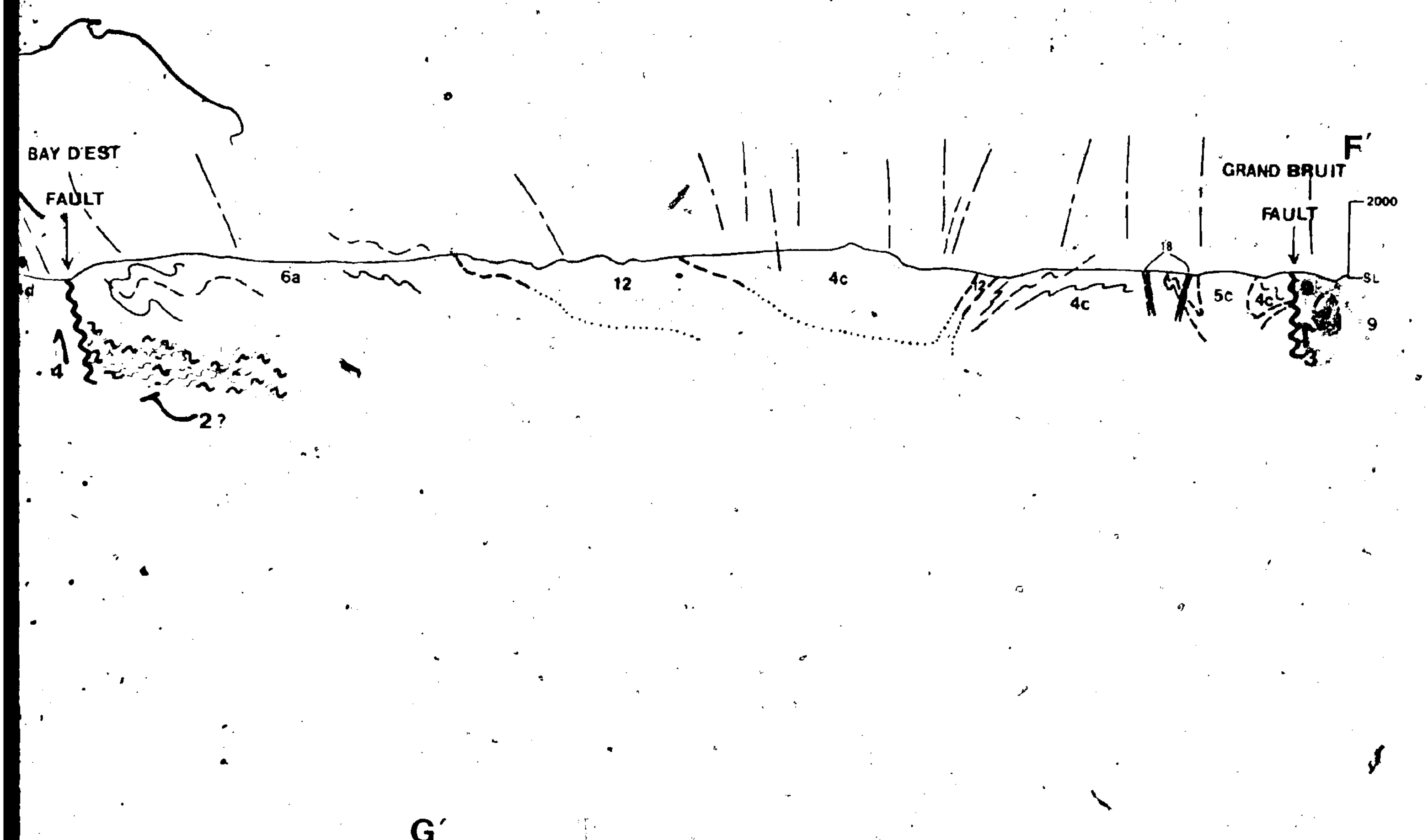
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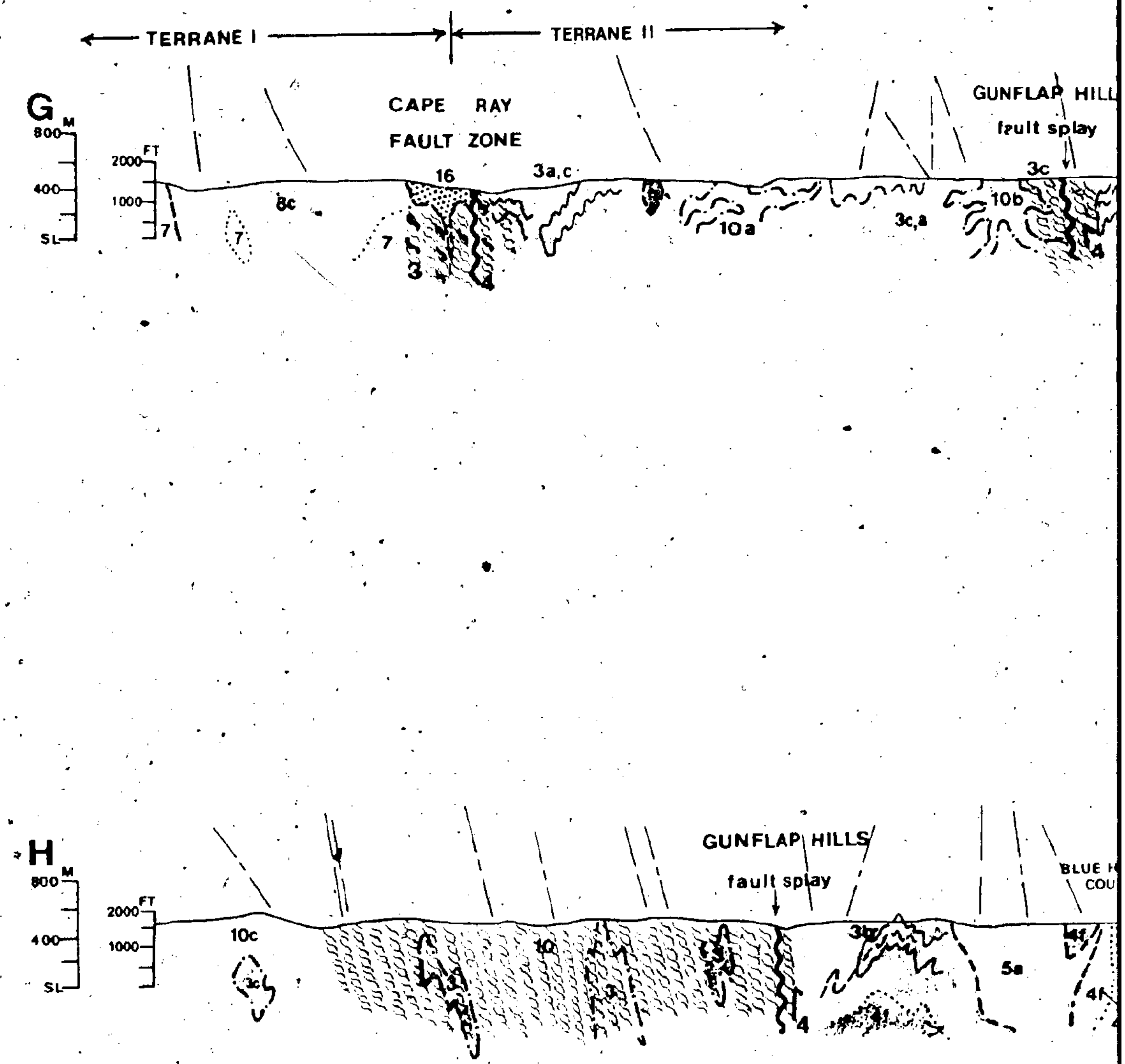
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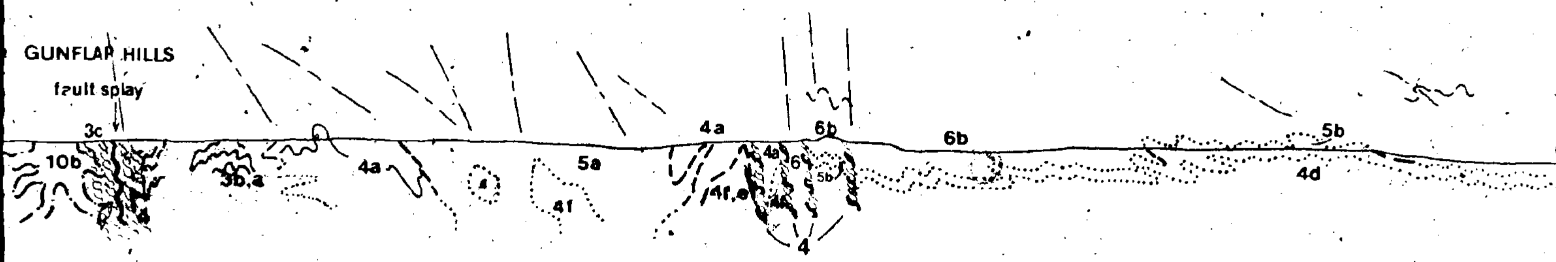
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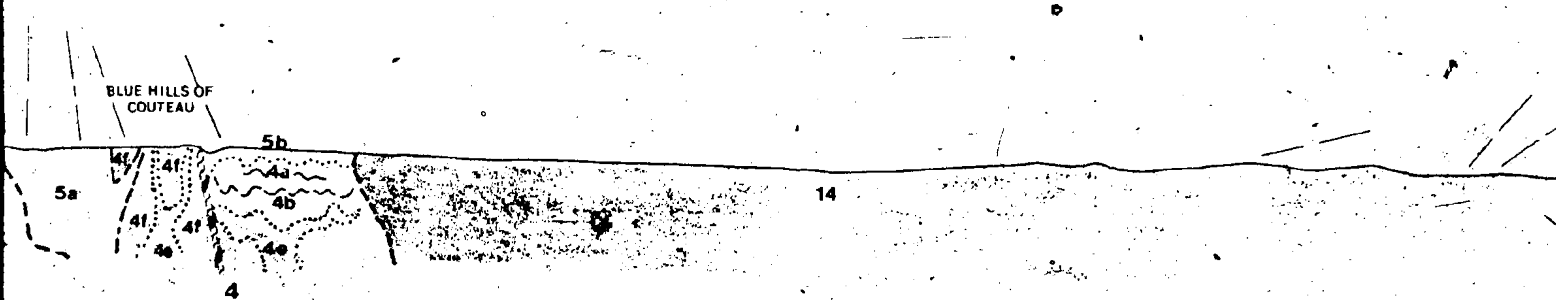
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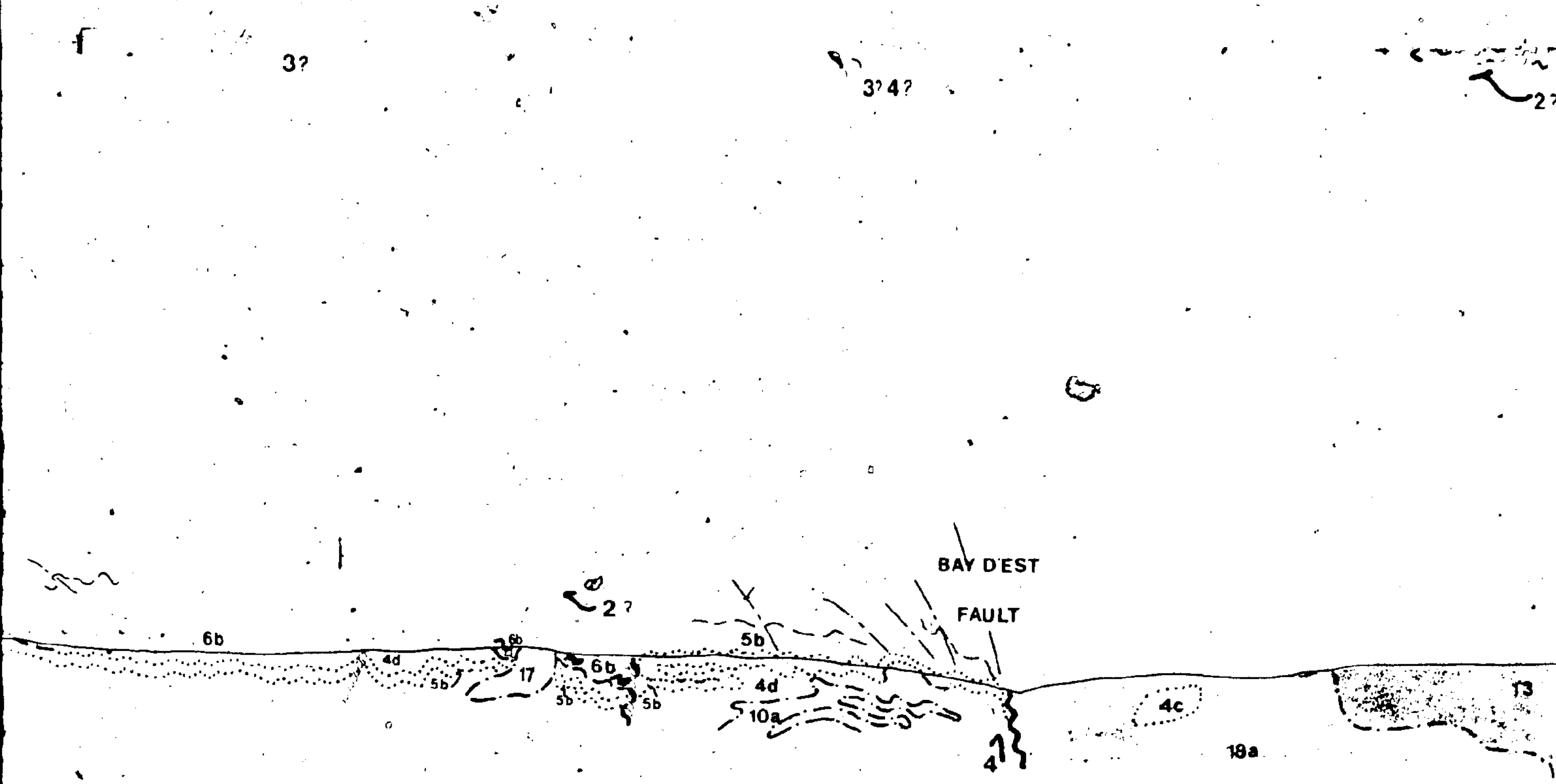
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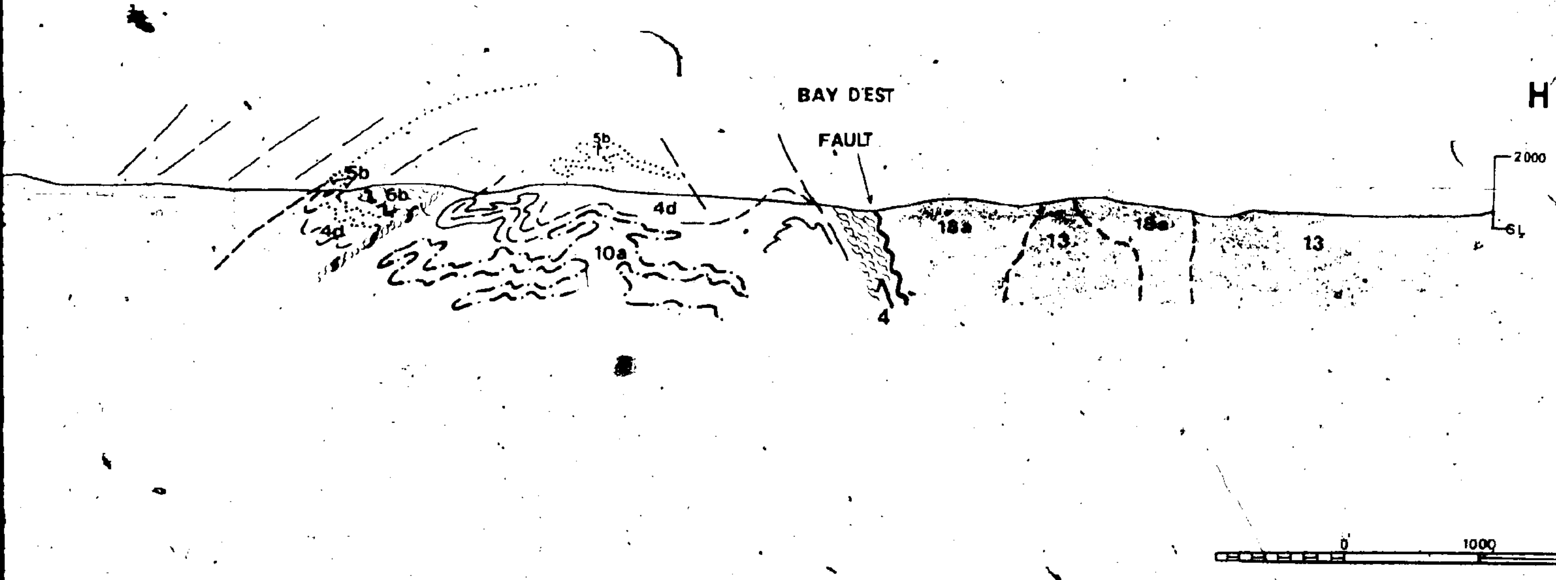
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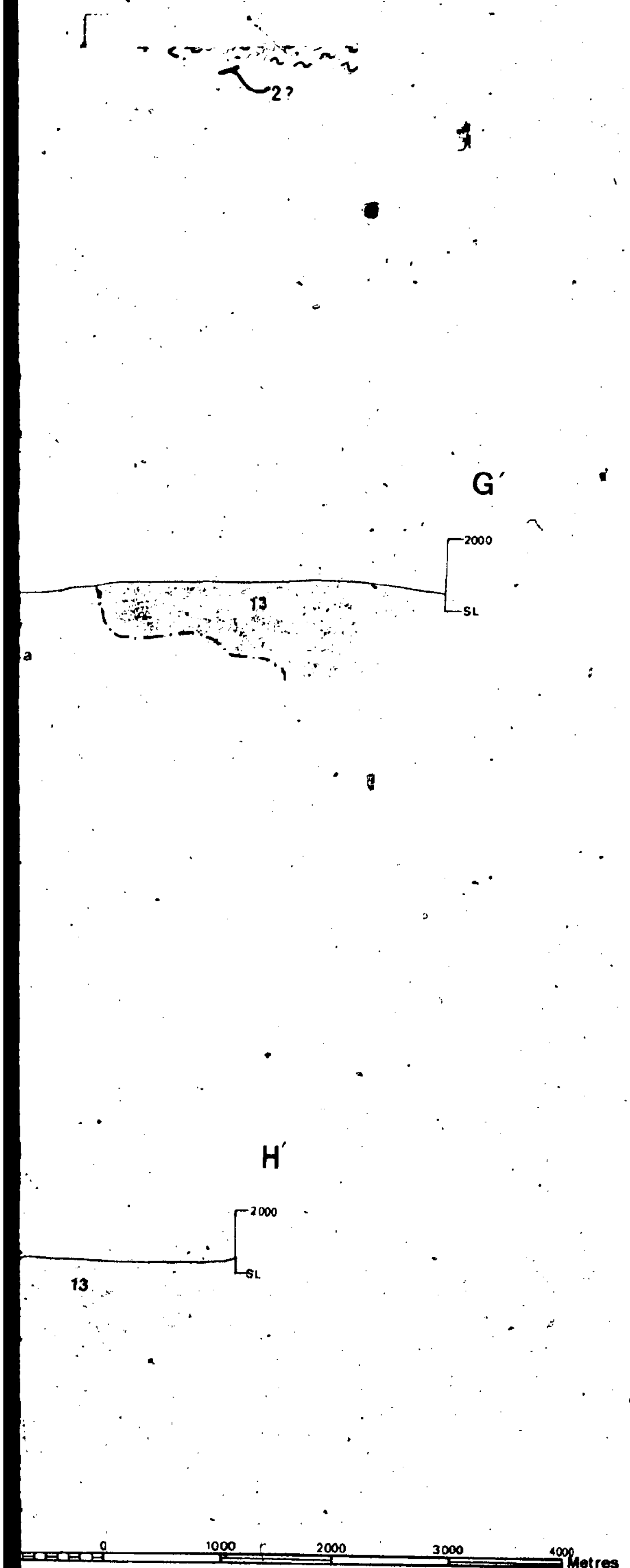

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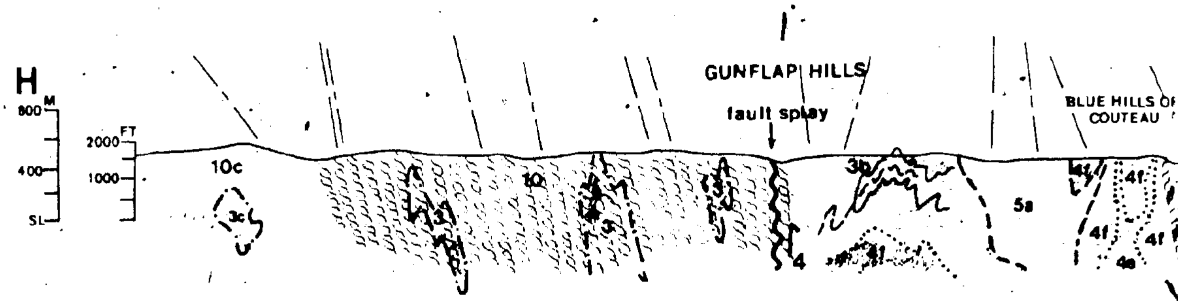
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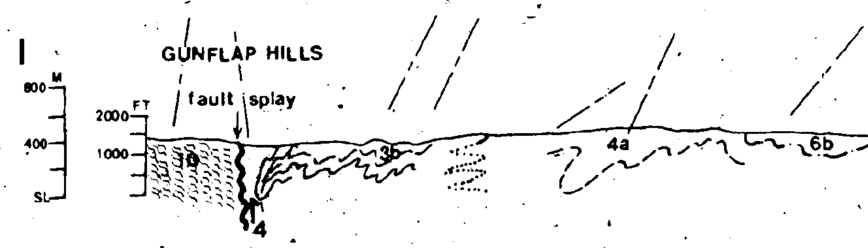
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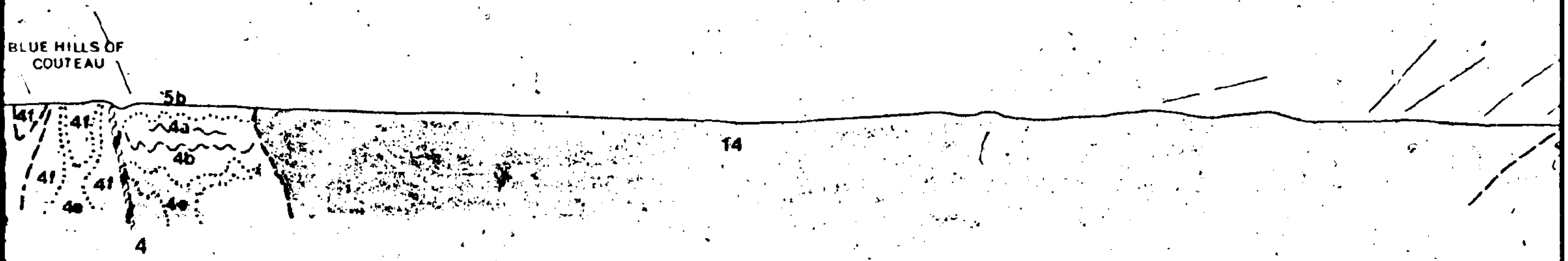
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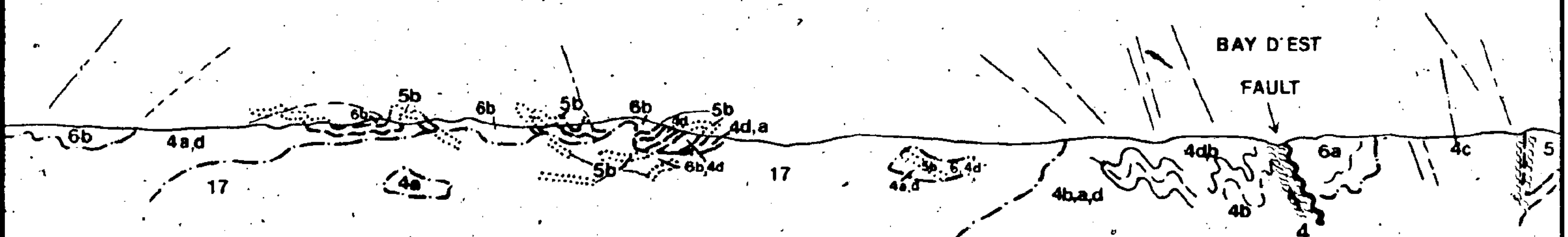
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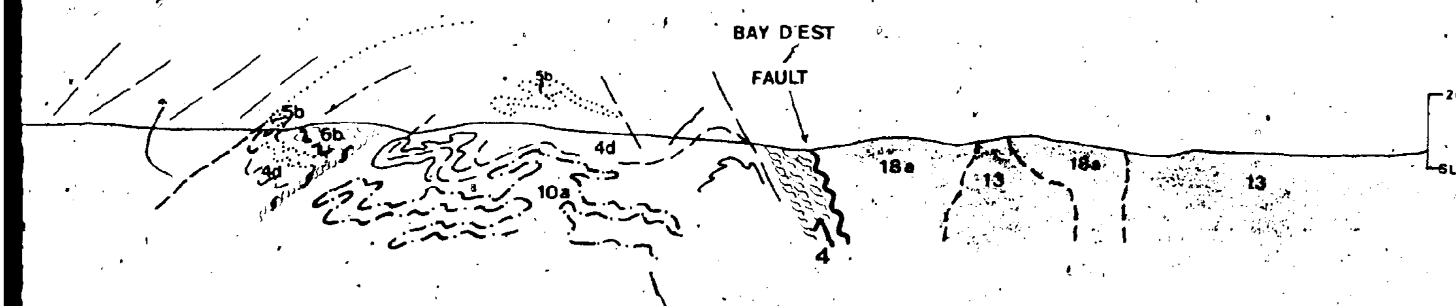
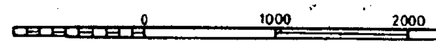
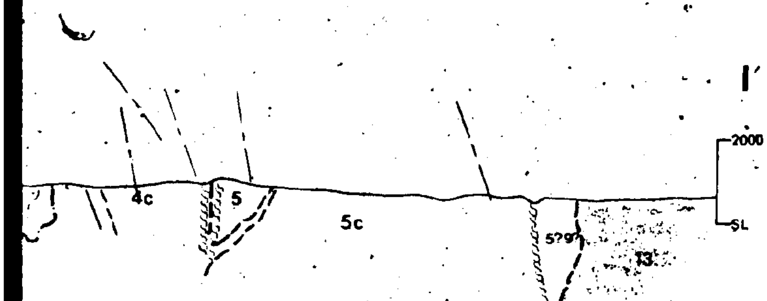
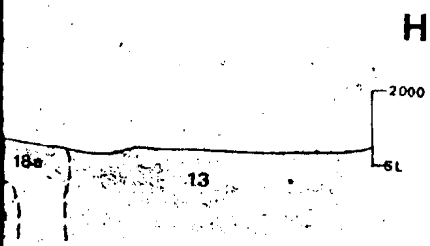


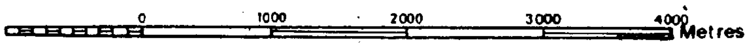




Symbols as o

11 of

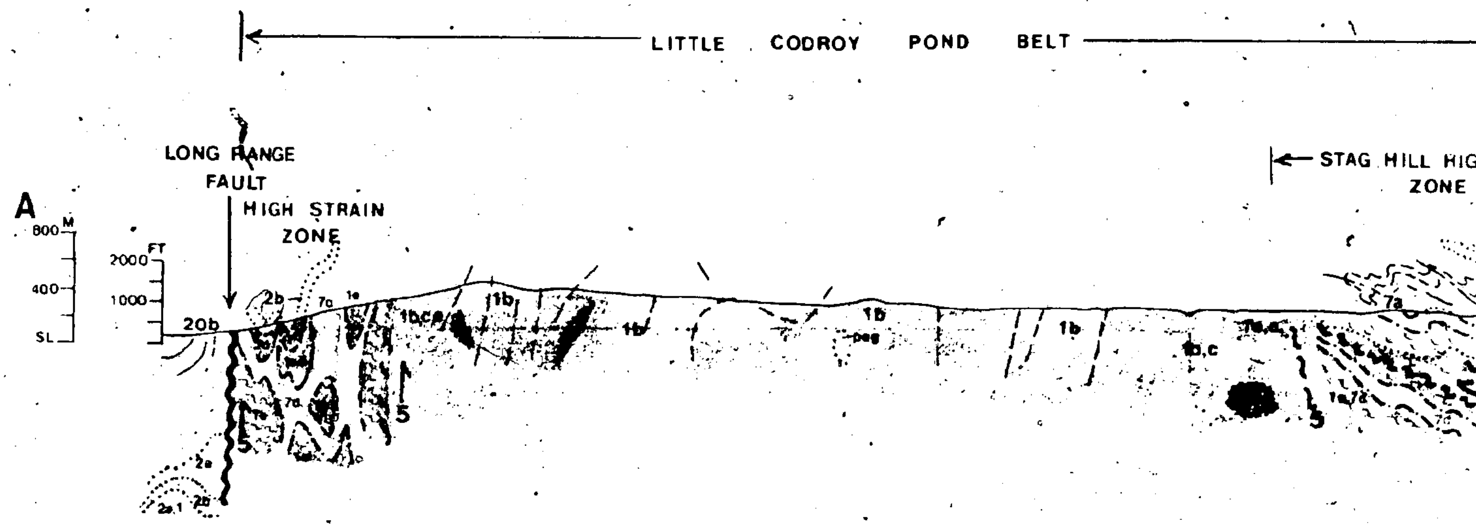




Symbols as on Sheet I

12 of 12

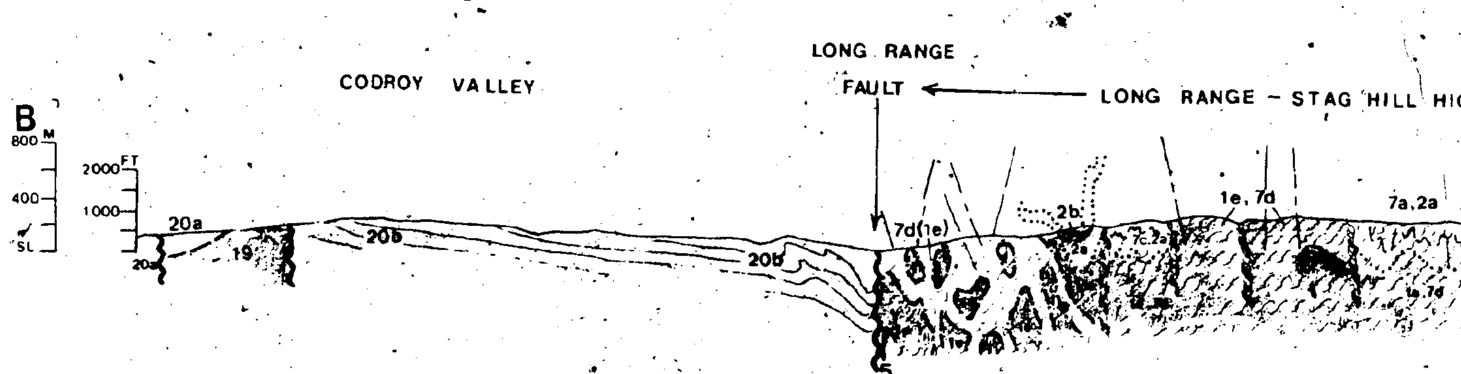
A



LITTLE CODROY POND BELT
LONG RANGE FAULT
HIGH STRAIN ZONE
STAG HILL HIG
ZONE
800 M
400
SL
2000 FT
1000
20b
2b
7a
1e
1b,c,e
1b
peg
1b,c
7a
7d
5
2a
2b

10

B

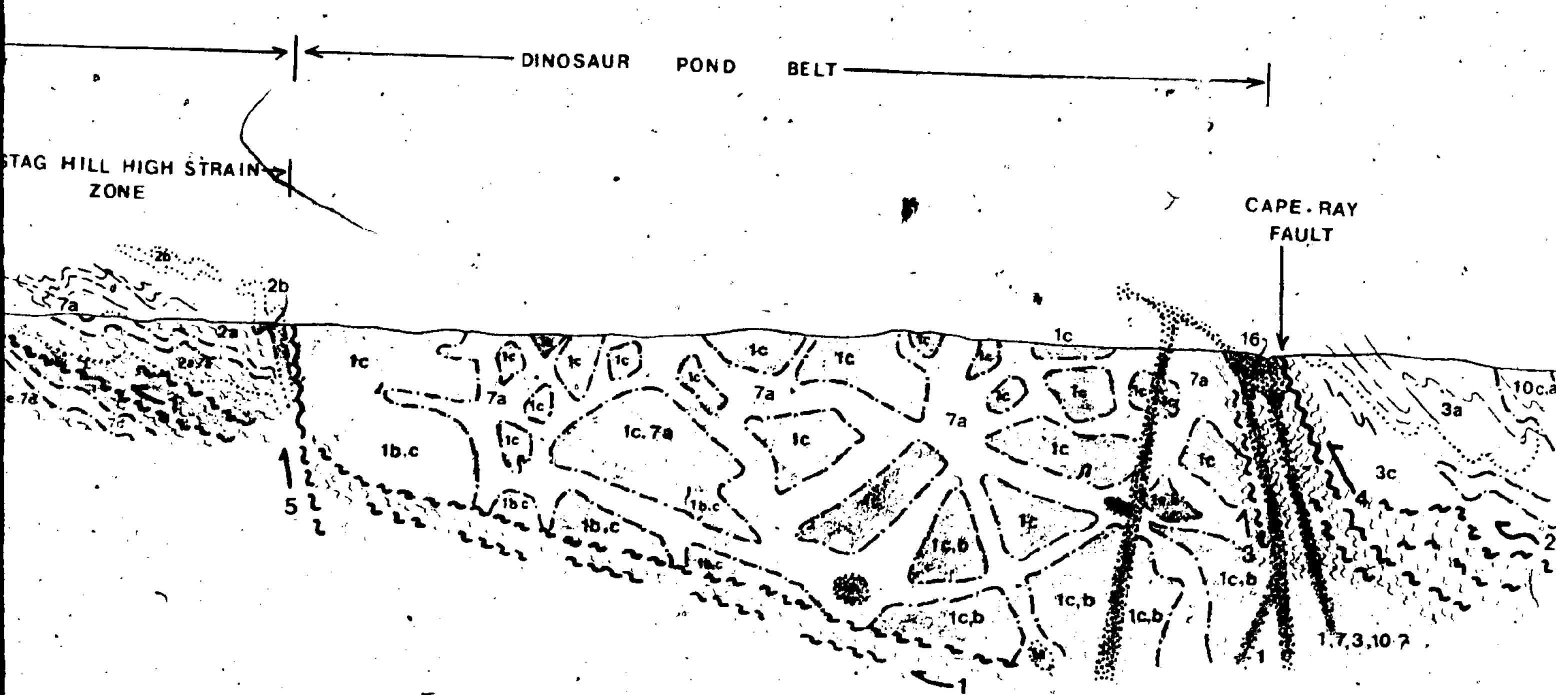


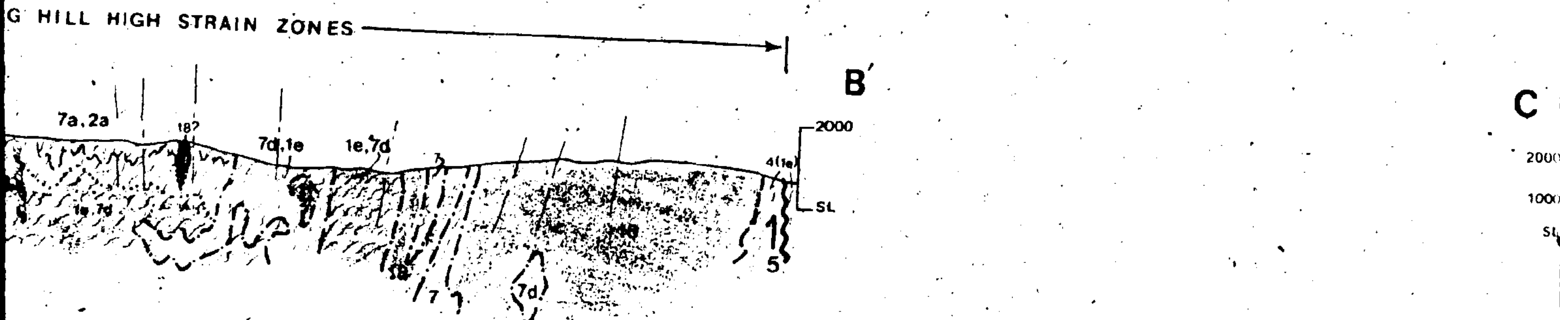
CODROY VALLEY
LONG RANGE FAULT
LONG RANGE – STAG HILL HIG
800 M
400
SL
2000 FT
1000
20a
19
20b
7d(1e)
2b
1e, 7d
7a, 2a
5

INTERPRETIVE CROSS-SECTIONS

SHEET I

2 of

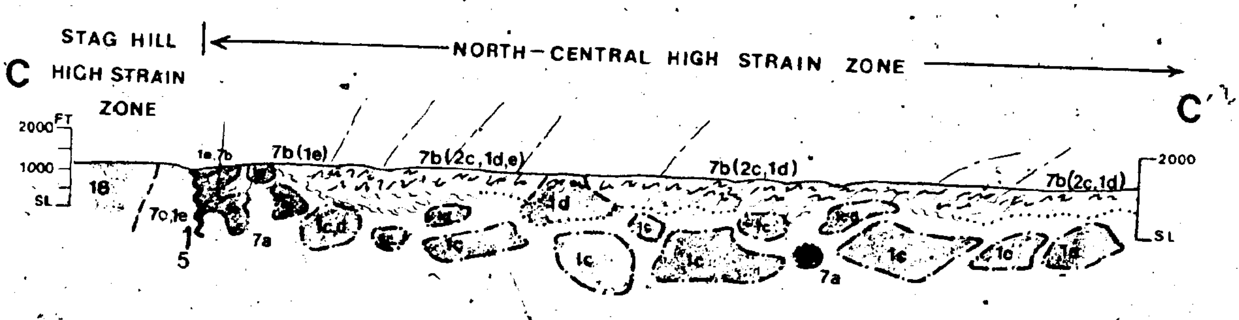


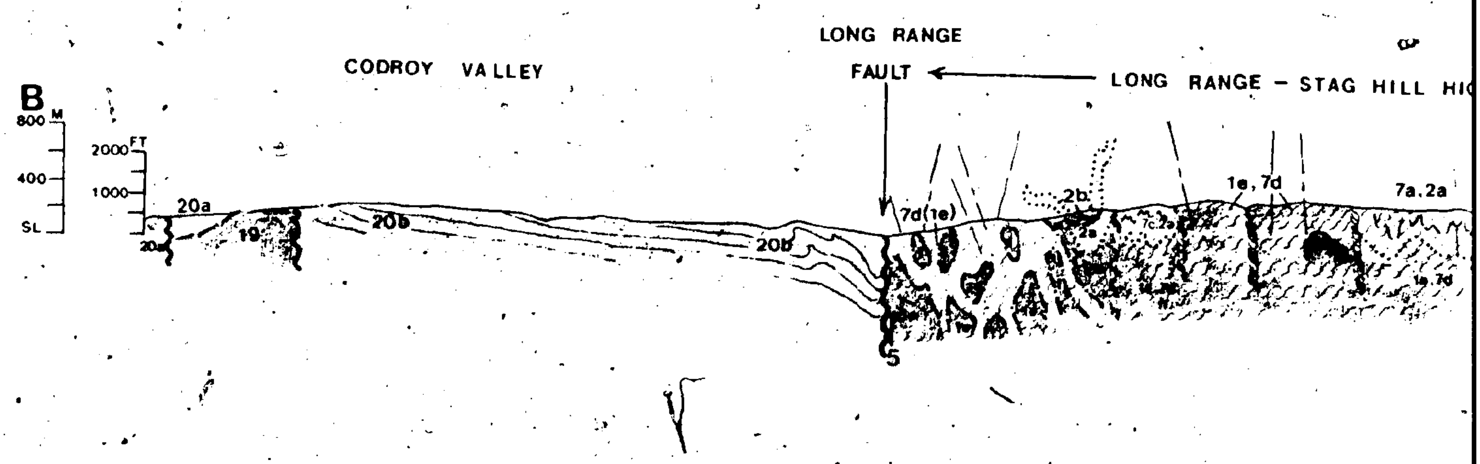


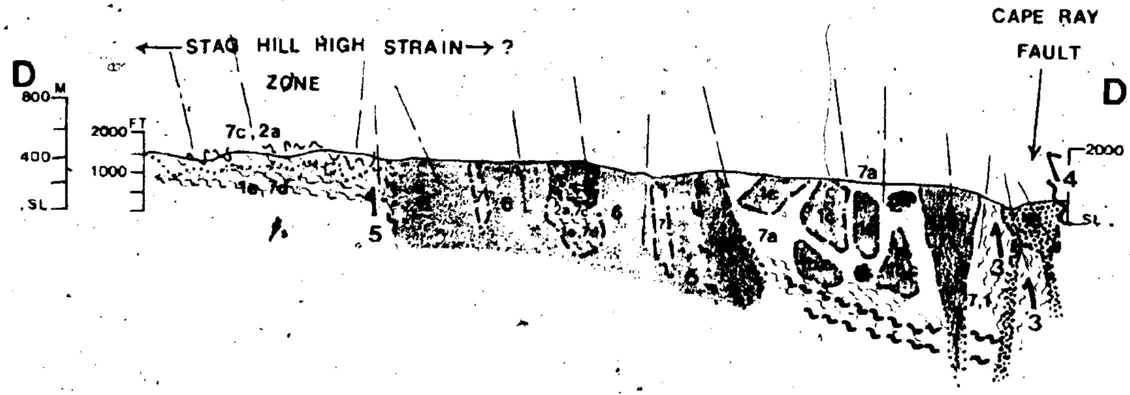
TIONS

37

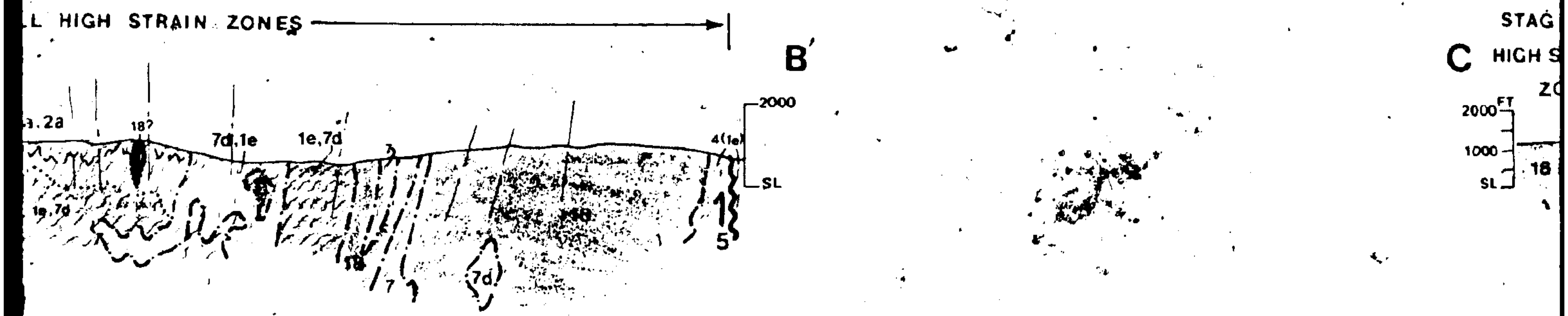

CAPE RAY
FAULT
A'
2000
SL
16
3a
3c
10c,a
10ac
10c
10a
2
3
4
17
1,7,3,10 ?

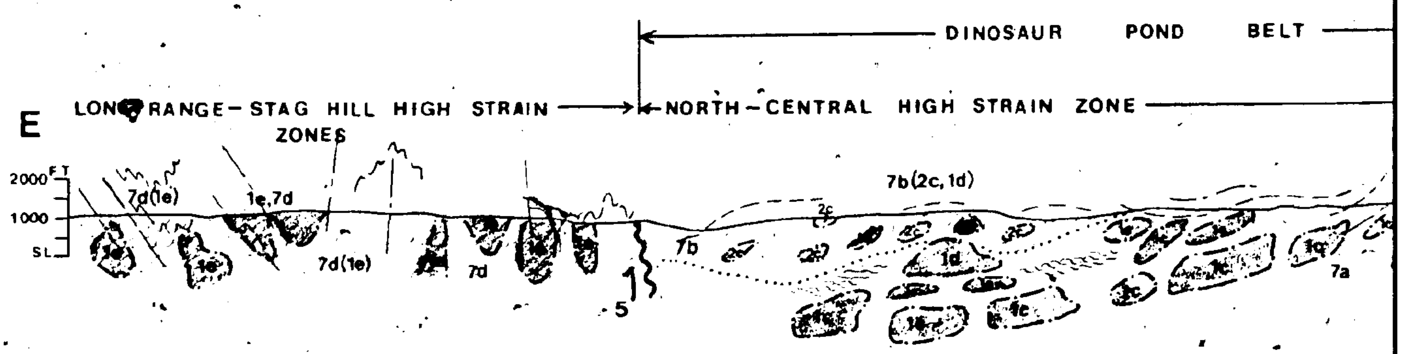

STAG HILL
HIGH STRAIN
ZONE
C
NORTH-CENTRAL HIGH STRAIN ZONE
C'
2000 FT
1000
SL
2000
SL
18
7c,1e
1e,7b
7b(1e)
7b(2c,1d,e)
7b(2c,1d)
7b(2c,1d)
7a
1c,d
1c
1d
7a
5


B
800 M
400
SL
2000 FT
1000
CODROY VALLEY
LONG RANGE
FAULT
LONG RANGE – STAG HILL
20a
19
20b
7d(1e)
2b
1e, 7d
7a, 2a
5


D
800 M
400
SL
2000 FT
1000
STAG HILL HIGH STRAIN → ?
ZONE
7c, 2a
1e, 7d
5
6
7a
CAPE RAY
FAULT
D′
2000
4
SL
3

4 of





SYMBOLS

Geological contact: approximate, assumed, gradational

Fault: approximate, assumed or minor, movement & order

Bedding

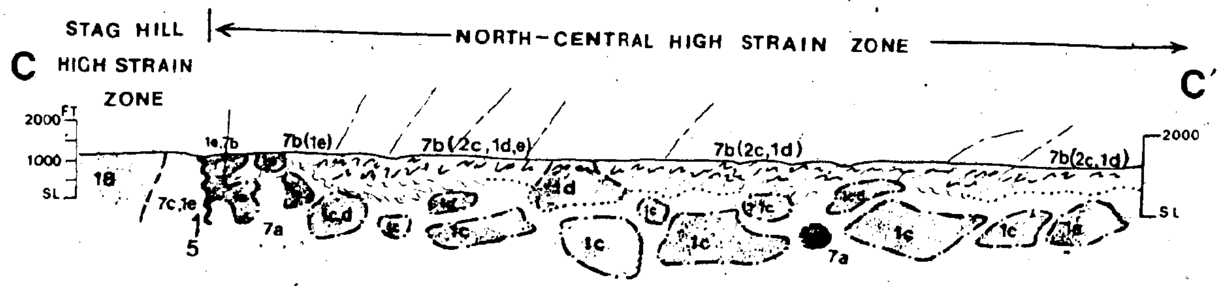
Foliations: S , or earliest schistosity recognized

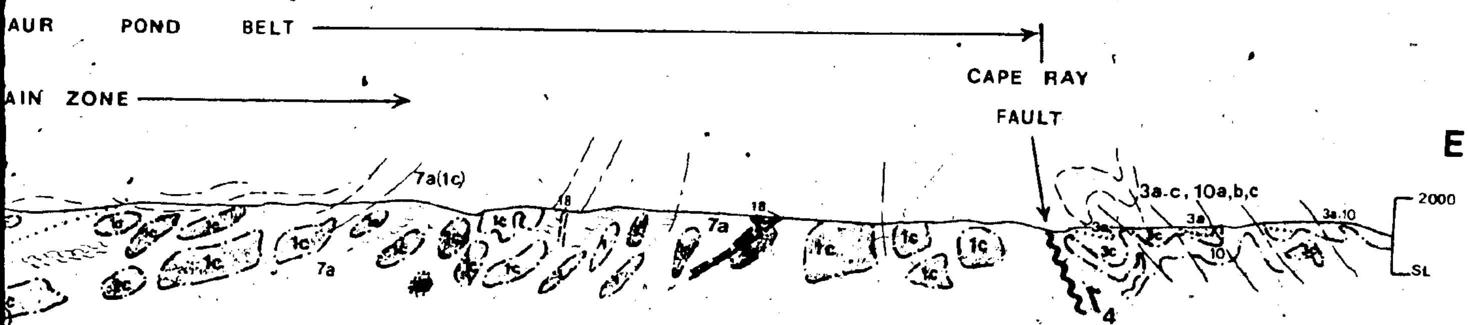
S , prominent schistosity

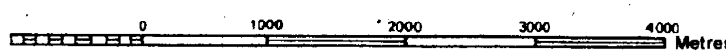
Later foliation

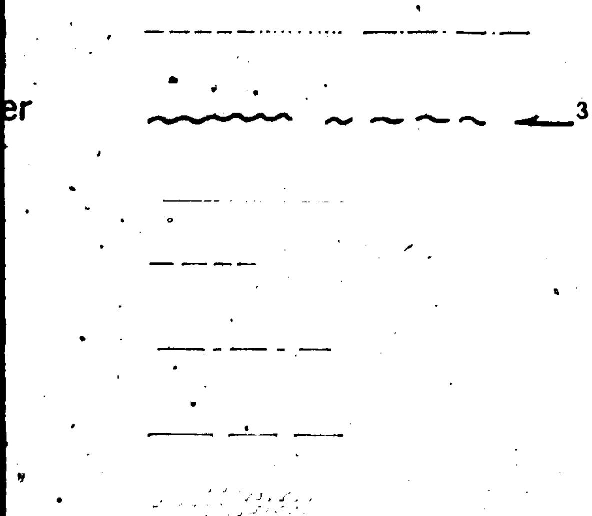
High strain zone, shear zone

5 of


STAG HILL HIGH STRAIN ZONE
NORTH-CENTRAL HIGH STRAIN ZONE
C
C′
2000 FT
1000
SL
2000
SL
18
1e,7b
7b(1e)
7b(2c,1d,e)
7b(2c,1d)
7b(2c,1d)
7c,1e
5
7a
1c,d
1d
1c
7a


AUR POND BELT
AIN ZONE
CAPE RAY FAULT
E′
7a(1c)
1c
7a
18
18
7a
3a,c, 10a,b,c
3a
3c
3a,10
10
4
2000
SL


0
1000
2000
3000
4000
Metres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3

6 of 6

SOUTHERN LONG RANGE MO

LEGEND

(for MAP 1 and CROSS-SECT

CARBONIFEROUS

21 **BARACHOIS GROUP:** Fluviatile sandstone, siltstone, shale and mudstone, rare thin coal seams, fanglomerate (Pennsylvanian; Namurian to Westphalian A).

20 **CODROY GROUP:** Siliciclastic rocks, carbonates and evaporites (Middle to Upper Visean); **20a**, Lower Codroy Group: limestone and dolomite, gypsum, sandstone and siltstone; **20b**, Upper Codroy Group: sandstone, pebbly sandstone, conglomerate, siltstone, shale and mudstone, caliche limestone, minor marine carbonate rocks.

DEVONIAN? TO CARBONIFEROUS

19 **ANGUILLE GROUP:** Lacustrine, deltaic and fluvial siliciclastic rocks; and alluvial and fluviatile sandstone, shale and mudstone, minor conglomerate, sandstone and siltstone (Famennian? to Tournaisian).

DEVONIAN

18 **Perthite-rich leucogranite:** Medium to coarse grained perthite and perthite-oligoclase leucogranite, largely equigranular to alkali feldspar subporphyritic with rapikivi and quartz-feldspar porphyry phases; associated sparsely porphyritic rhyolite dykes. Forms discordant plutons which may contain screens of older granitoid rock, amphibolite, metavolcanic or metasedimentary rock: 18a, CHETWYND GRANITE; 18b, PETITES GRANITE; 18c, ISLES AUX MORTS BROOK GRANITE.

17 **Subsolvus leucogranite:** Largely medium to fine grained and equigranular, local plagioclase phenocrysts. Occurs as small lenses and larger intrusion zones, abounding with foliated granitoid and metamorphic rafts.

16 **WINDSOR POINT GROUP:** Strongly bimodal volcanic and volcaniclastic rocks, fluvial-deltaic sedimentary rocks, including black mudstone, grey siltstone and sandstone, conglomerate, calcareous siltstone, minor limestone. Contains Emsian or Eifelian palynmorphs.

15 **Subvolcanic granophyre and rhyolite porphyry:** Subvolcanic granite to rhyolite domes related to volcanic rocks of Windsor Point Group: 15a, WINDOWGLASS HILL GRANITE; 15b, NITTY GRITTY BROOK GRANITE.

14 **Syenodiorite to granite:** Contains megacrysts or phenocrysts of orthoclase/microcline and andesine and the ferromagnesian minerals biotite, amphibole, and augite (local).

13 **Megacrystic quartz monzonite:** Contains megacrysts of microcline and andesine, and the ferromagnesian minerals hornblende and biotite.

SILURIAN

12 **HAWKS NEST POND PORPHYRY:** orthoclase, plagioclase, and quartz phyric microgranite sills (U/Pb_{zircon} 410±20 Ma).

11 **Megacrystic quartz monzonite, monzogranite, granodiorite:** Contains megacrysts of microcline and andesine, and the ferromagnesian minerals biotite and hornblende: 11a, LA POILE BATHOLITH (U/Pb zircon 432±20 Ma); 11b, OTTER POINT GRANITE.

10 **Synkinematic, equigranular granodiorite/tonalite/granite:** Emplaced mainly as sheets and veins in polydeformed amphibolite facies metasedimentary and amphibolitic rocks: 10a, granodiorite and granite with mainly metasedimentary hosts; 10b, tonalite to granite with mainly amphibolitic hosts; 10c, metasomatically altered, pink to white tonalite to granite with mainly amphibolitic hosts.

UTHERN LONG RANGE MOUNTAINS

LEGEND

MAP 1 and CROSS-SECTIONS)

2 of

La Poile River Group (3-6)

6 — 6 **DOLMAN COVE FORMATION:** Dacitic crystal tuff, dacite porphyry, hackly rhyolite tuff and agglomerate horizons, siltstone and pebble conglomerate lenses: 6a, deformed and metamorphosed under greenschist facies conditions (U/Pb$_{zircon}$ 446±18 Ma); 6b, deformed and metamorphosed under amphibolite facies conditions (U/Pb$_{zircon}$ 449+20 Ma), grades locally into massive, streaky, grey 'pencil gneiss'.

5a, 5b, 5c — 5 **Subvolcanic granite stocks and rhyolite sheets:** 5a, BAGGS HILL GRANITE: porphyritic to equigranular fine grained granite and granophyre; 5b, PIGLET BROOK RHYOLITE: flesh pink, fine grained granular felsite with small, red feldspar phenocrysts; 5c, ROTI GRANITE: equigranular granodiorite/ granite to quartz and feldspar porphyritic felsite.

4 **Volcanic and volcaniclastic rocks (4a-d):**

4a — 4a **CARROT BROOK FORMATION:** Mainly felsic volcanic, pyroclastic and volcaniclastic rocks, tuffaceous greywacke, conglomerate, locally cut by mafic dykes. Deformed and metamorphosed to amphibolite facies, locally retrograded.

4b — 4b **Interlayered mafic and felsic volcanic and volcaniclastic rocks:** Includes tuffaceous greywacke and conglomerate, and is deformed and metamorphosed to amphibolite grade. (Probably laterally equivalent of Carrot Brook Formation.)

4c — 4c **GEORGES BROOK FORMATION:** Mixed mafic to felsic volcanic and volcaniclastic rocks, including rhyolite, dacite, dacite breccia, felsic ignimbrite; mafic to intermediate sills, flows, dykes, diabase, breccias; mixed mafic to felsic pyroclastic rocks; lahars; reworked volcaniclastic conglomerate, sandstone, siltstone. Deformed and metamorphosed to greenschist facies.

4d — 4d **Semipelitic schist with metaconglomerate lenses:** Metaconglomerate interbeds similar to those in neighbouring volcaniclastic rocks.

4e — 4e **Mafic intrusive rocks:** Metamorphosed diabase, fine to medium grained gabbro, diorite, quartz gabbro, and hornblende gabbro with localy (cumulate?) patches of clinopyroxenite, wehrlite, and rare dunite; coarse grained diorite.

4f — 4f **Blue Hills of Couteau metagabbro:** high level, ophiolitic metagabbro and metadiabase veined with plagiogranite; intruded by subvolcanic diorite, basalt dykes, and Baggs Hill Granite related to the island arc sequences.

3 **Metasedimentary schist and amphibolite (3a-d):**

3a — 3a **BUNKER HILL BROOK GNEISS (metasedimentary part):** Semipelitic to pelitic schist, locally with calc-silicate bands, rhyolite granule conglomerate layers, coticules, metabasalt flows or dykes. Deformed and metamorphosed to amphibolite facies; locally migmatized and/or injected with granitoid veins. Commonly contains garnet, biotite, muscovite, staurolite, kyanite and/or sillimanite.

3b — 3b **ROUND HILL BROOK PHYLLITE:** graphitic phyllite, abundant interbedded semipelitic schist and rhyolite granule conglomerate or coarse sandstone.

3c — 3c **BUNKER HILL BROOK GNEISS (amphibolitic part):** Includes coarse to fine grained amphibolite, metagabbro, metadiabase, metabasalt. Locally contains garnet and/or gedrite or anthophyllite.

13	**13 Megacrystic quartz monzonite:** Contains megacrysts of microcline and andesine, and the ferromagnesian minerals hornblende and biotite.

SILURIAN

12	**12 HAWKS NEST POND PORPHYRY:** orthoclase, plagioclase, and quartz phyric microgranite sills (U/Pb$_{zircon}$ 410$\pm$20 Ma).
11	**11 Megacrystic quartz monzonite, monzogranite, granodiorite:** Contains megacrysts of microcline and andesine, and the ferromagnesian minerals biotite and hornblende: **11a**, **LA POILE BATHOLITH** (U/Pb zircon 432$\pm$20 Ma); **11b**, OTTER POINT GRANITE.
10	**10 Synkinematic, equigranular granodiorite/tonalite/granite:** Emplaced mainly as sheets and veins in polydeformed amphibolite facies metasedimentary and amphibolitic rocks; **10a**, granodiorite and granite with mainly metasedimentary hosts; **10b**, tonalite to granite with mainly amphibolitic hosts; **10c**, metasomatically altered, pink to white tonalite to granite with mainly amphibolitic hosts.

SILURIAN?, ORDOVICIAN?

9	**9 CINQ CERF COMPLEX:** Largely foliated, equigranular granodiorite with abundant xenoliths and rafts of amphibolite, metagabbro and metapyroxenite, locally cutting metavolcanic and subvolcanic rocks.
8	**8 Mafic to felsic granitoid intrusions:** Vary from quartz diabase and gabbro to granite: 8a, CAPE RAY and RED ROCKS GRANITE; 8b, quartz diorite, porphyritic quartz monzonite, orthoclase megacrystic granite; 8c, quartz gabbro, diabase, diorite.

ORDOVICIAN

7	**7 Foliated, equigranular tonalite/granodiorite/granite:** Characterized by abundant mafic meta-plutonic, metasedimentary, and metavolcanic inclusions: 7a, tonalite/trondhjemite with largely ophiolitic gabbro and rare ultramafic inclusions; 7b, garnetiferous tonalite with abundant metasedimentary and metavolcanic inclusions; 7c, lit par lit granodiorite and garnetiferous granite associated with migmatitic metasedimentary rocks; 7d, pink weathering, foliated to gneissic tonalite to granite associated with amphibolite hosts and screens; 7e, tonalite, trondhjemite, and granodiorite hosted by the Keepings Gneiss, amphibolite, and metagabbro.

SYMBOLS

Geological boundary (approximate, assumed)	
Geological boundary (gradational)	
Fault	
Thrust fault only	
Lineament, shear joint	
Ductile shear zone, slide, mylonite, phyllonite, sericite schist zone	
Dip or plunge of minor structure (in degrees or steep, moderate, or gentle)	s ; m ; g
Schistosity, cleavage (dip indicated, vertical) ...	70
Strain-slip cleavage (dip indicated, vertical)	70
Gneissosity (dip indicated, vertical)	70
Cataclastic foliation or mylonite banding (dip indicated, vertical)	70
Igneous layering (dip indicated, vertical)	70

37

4f **Blue Hills of Couteau metagabbro:** high level, ophiolitic metagabbro and metadiabase veined with plagiogranite, intruded by subvolcanic diorite, basalt dykes, and Baggs Hill Granite related to the island arc sequences.

3 **Metasedimentary schist and amphibolite (3a-d):**

3a **BUNKER HILL BROOK GNEISS (metasedimentary part):** Semipelitic to pelitic schist, locally with calc-silicate bands, rhyolite granule conglomerate layers, coticules, metabasalt flows or dykes. Deformed and metamorphosed to amphibolite facies, locally migmatized and/or injected with granitoid veins. Commonly contains garnet, biotite, muscovite, staurolite, kyanite and/or sillimanite.

3b **ROUND HILL BROOK PHYLLITE:** graphitic phyllite, abundant interbedded semipelitic schist and rhyolite granule conglomerate or coarse sandstone.

3c **BUNKER HILL BROOK GNEISS (amphibolitic part):** Includes coarse to fine grained amphibolite, metagabbro, metadiabase, metabasalt. Locally contains garnet and/or gedrite or anthophyllite.

ORDOVICIAN OR OLDER

2 **Metasedimentary rocks (northwest of Cape Ray Fault):** 2a, largely semipelitic to pelitic schist; 2b, marble, associated calc-silicate schist; 2c, mixed metasedimentary and volcanic rocks of pelagic origin, including laminated calcareous garnet gneiss and gneissified breccia, semipelitic schist and gneiss, cummingtonite and anthophyllite bearing siliceous schist (ferrugenous metachert), microcrystalline garnet-quartz rock (ferrugenous clay), fine grained amphibolite, marble, felsic volcanic? schist, mainly occurring as hosts for granitoid rocks (?); 2d, KEEPINGS GNEISS.

1 **LONG RANGE MAFIC-ULTRAMAFIC COMPLEX:** metamorphosed ophiolitic rocks: 1a, ultramafic rocks; 1b, layered, olivine-bearing, cumulate metagabbro with ultramafic and anorthositic bands; 1c, high level, coarse to fine grained metagabbro and crosscutting metadiabase with intrusive pods of plagiogranite; 1d, mafic metavolcanic rocks and dykes; 1e, amphibolite derived from 1b, 1c, and 1d.

SYMBOLS

Bedding, tops known (inclined with dip indicated, vertical) 70

Bedding; tops unknown (inclined with dip indicated, vertical) 70

Bedding, overturned (dip indicated) 70

Axis of anticline ....

Axis of syncline ....

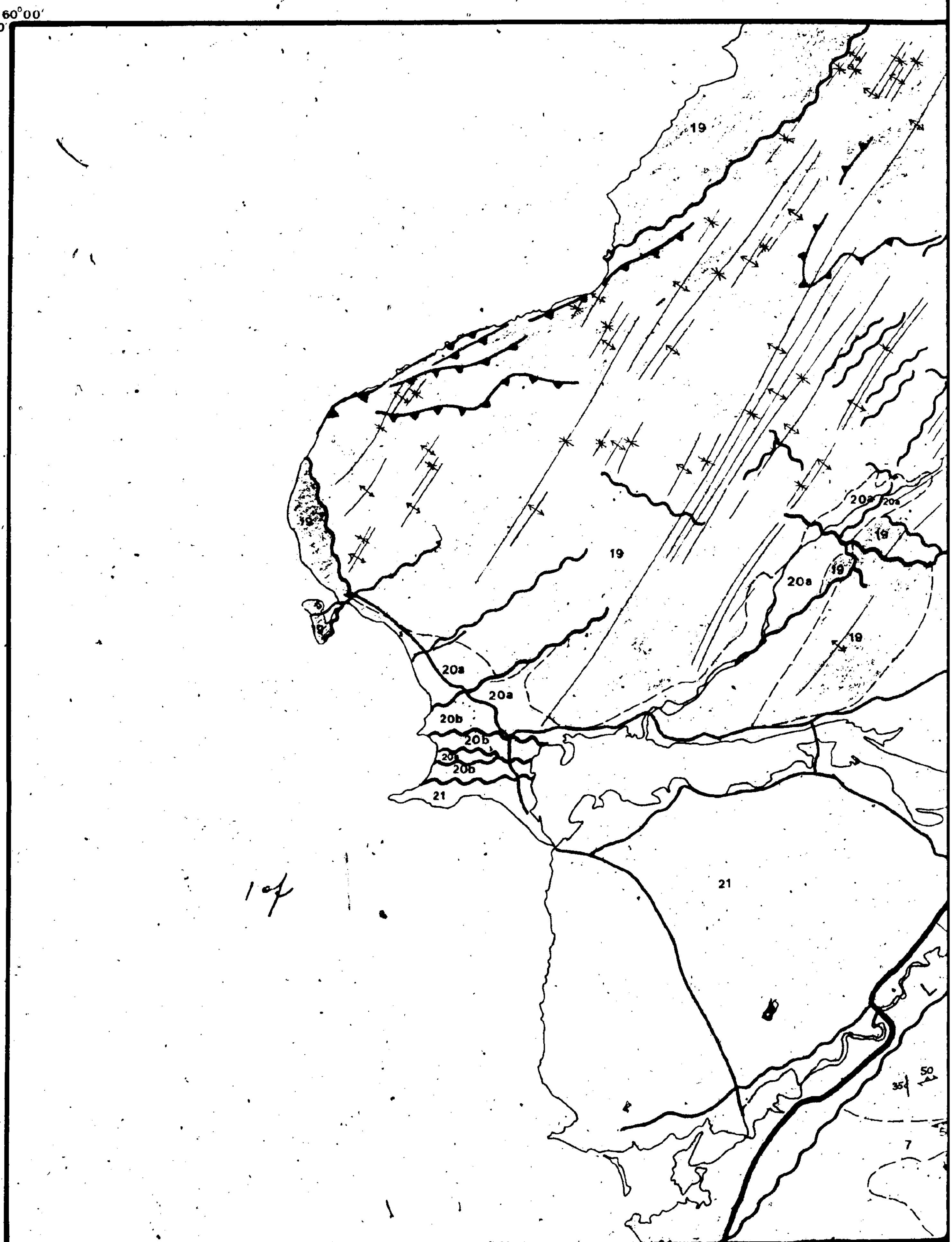
Hinge of minor fold (plunge indicated) 70

Lineations (plunge indicated) 70

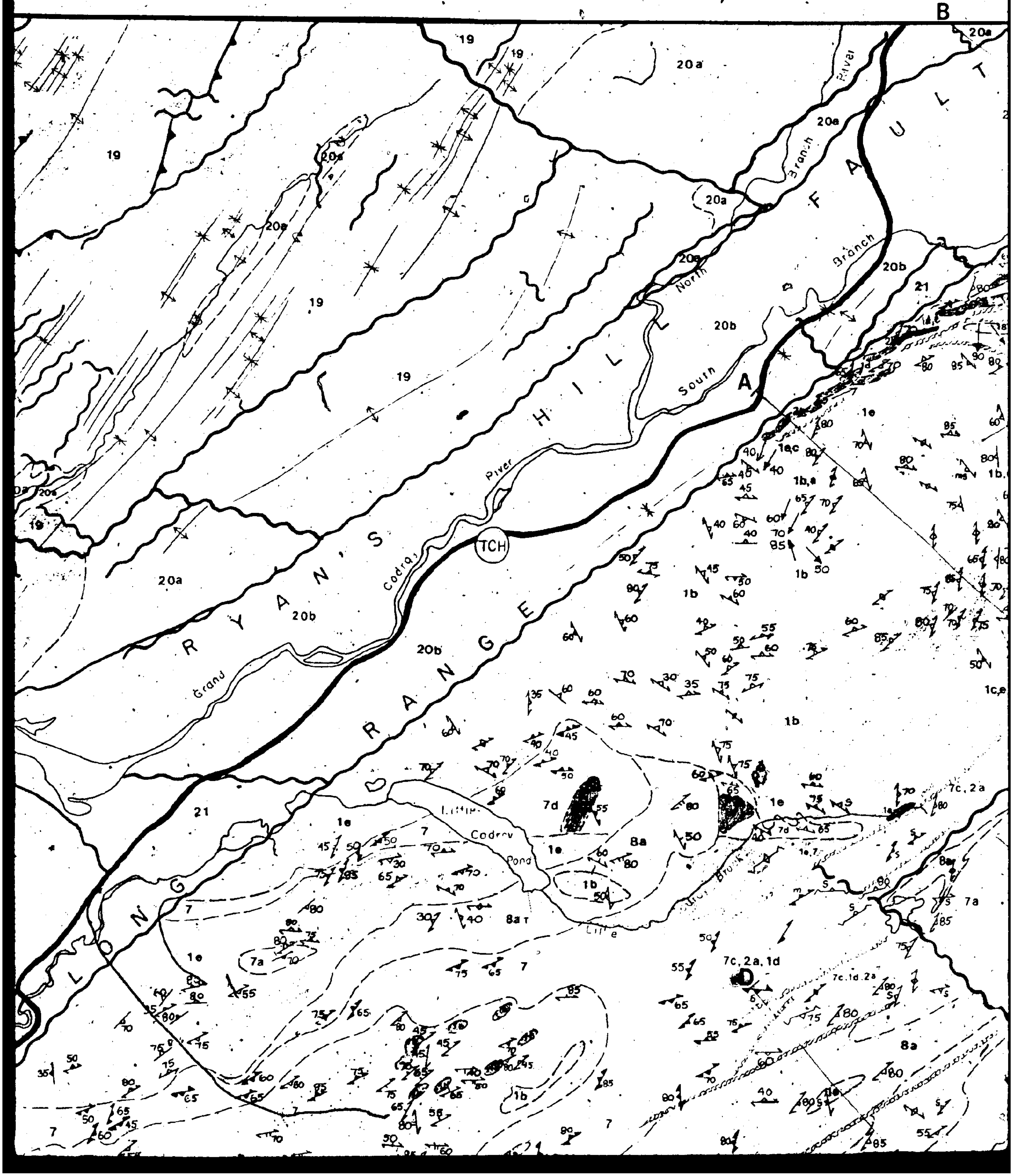
- M mineral alignment — M 70
- A mineral aggregate alignment — A 70
- R rodding — R 70

Dyke (defined, approximate, assumed) ....

4 of 4

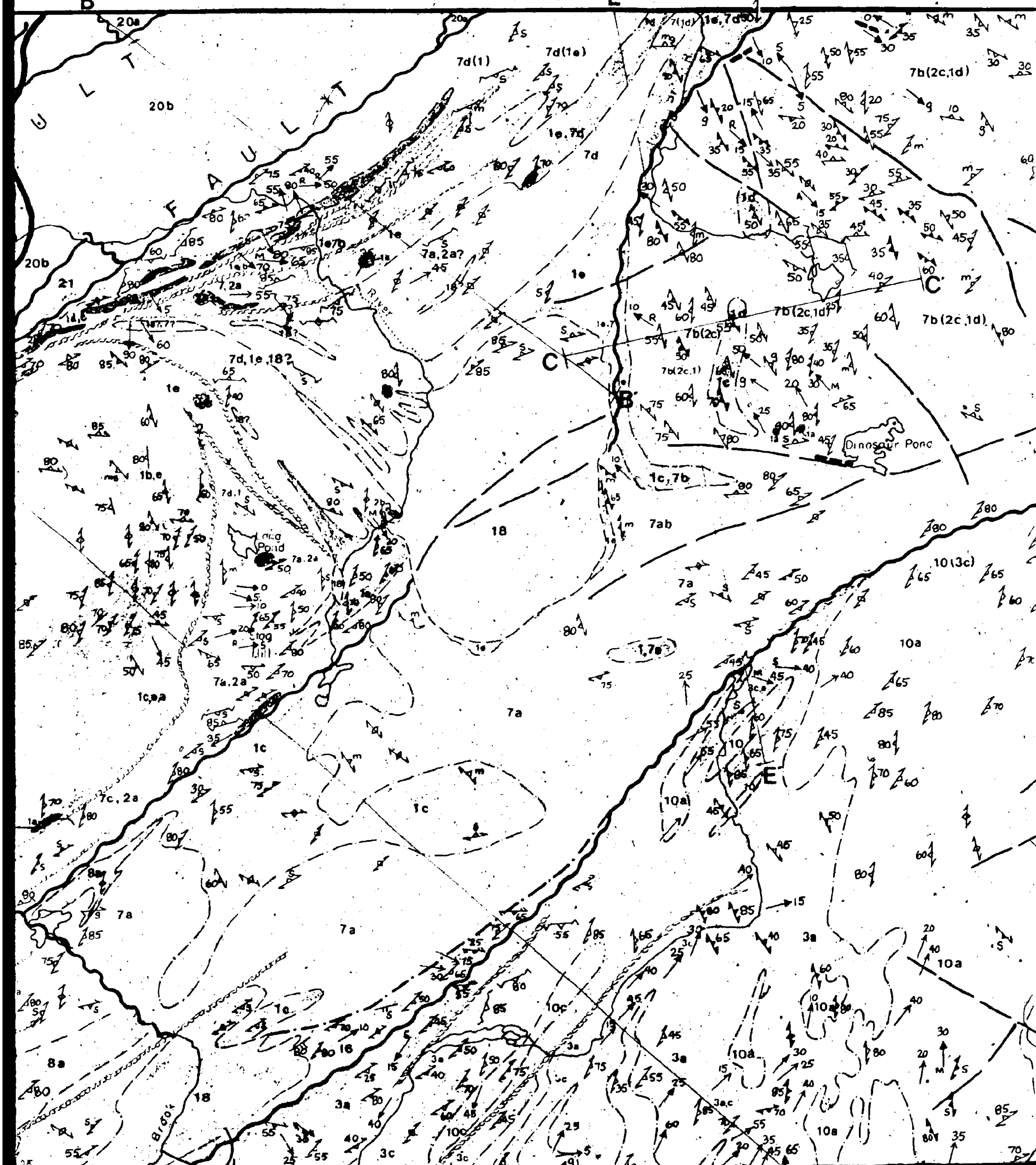

60°00′
48°00′
19
19
19
19
19
19
20a
20a
20a
20a
20a
20b
20b
20b
20b
21
21
1 of
7
35
50
L

2 of



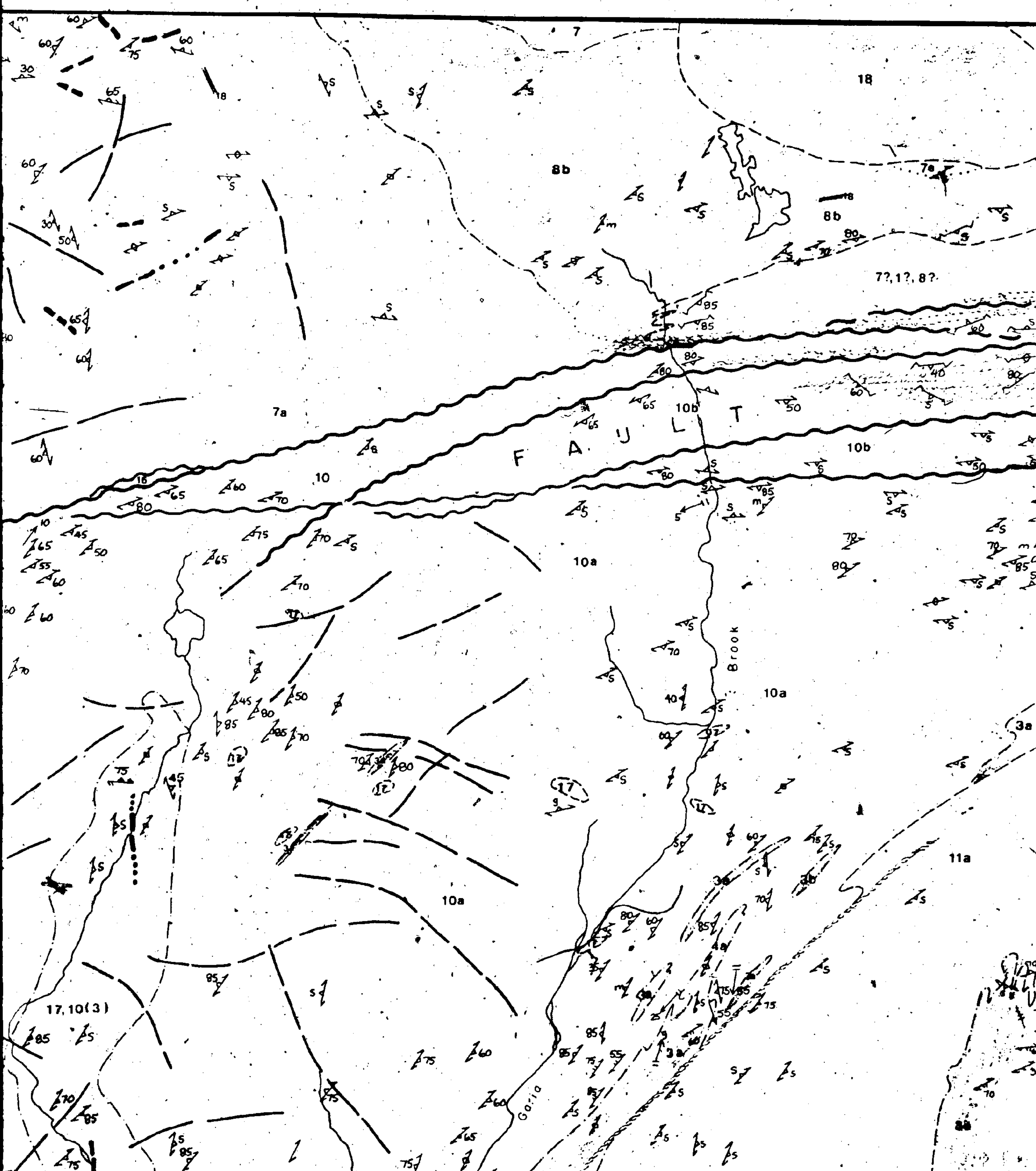
B
A
D
RYAN'S HILL FAULT
LONG RANGE
Grand Codroy River
North Branch
South Branch
River
TCH
Little Codroy Pond
19
20a
20b
21
1b
1e
1b,a
1e,c
1c,e
7
7a
7d
8a
7c, 2a, 1d
7c, 2a
7c,1d,2a

37

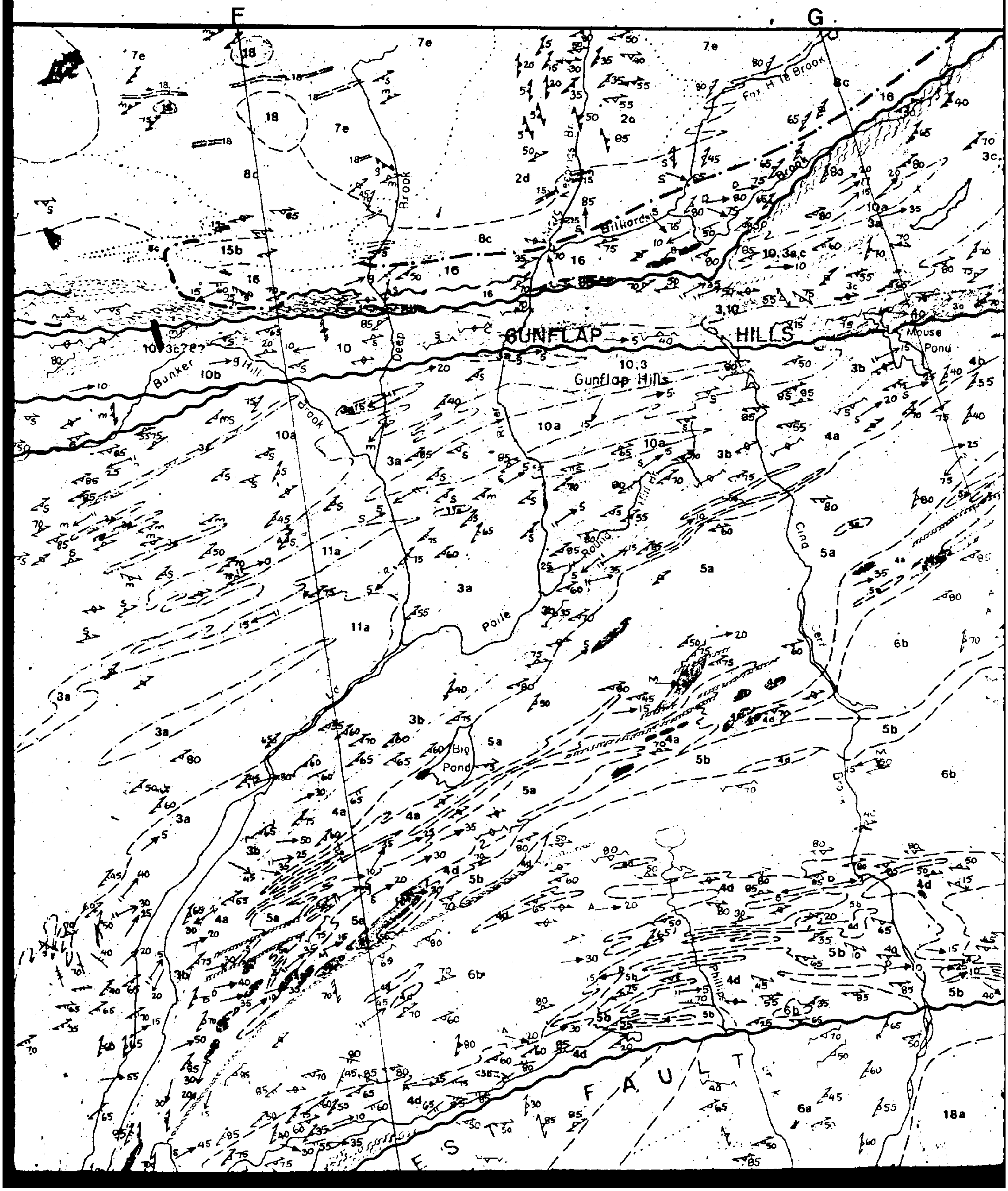


B
E
FAULT
20a
20b
21
7d(1)
7d(1e)
1e,7d
7d
7a,2a?
1e
7b(2c,1d)
7b(2c)
1d
C
B
Dinosaur Pond
1c,7b
18
7ab
7a
10(3c)
10a
1,7e
1c
7c,2a
8a
10c
3a
3c
E
River

4 of

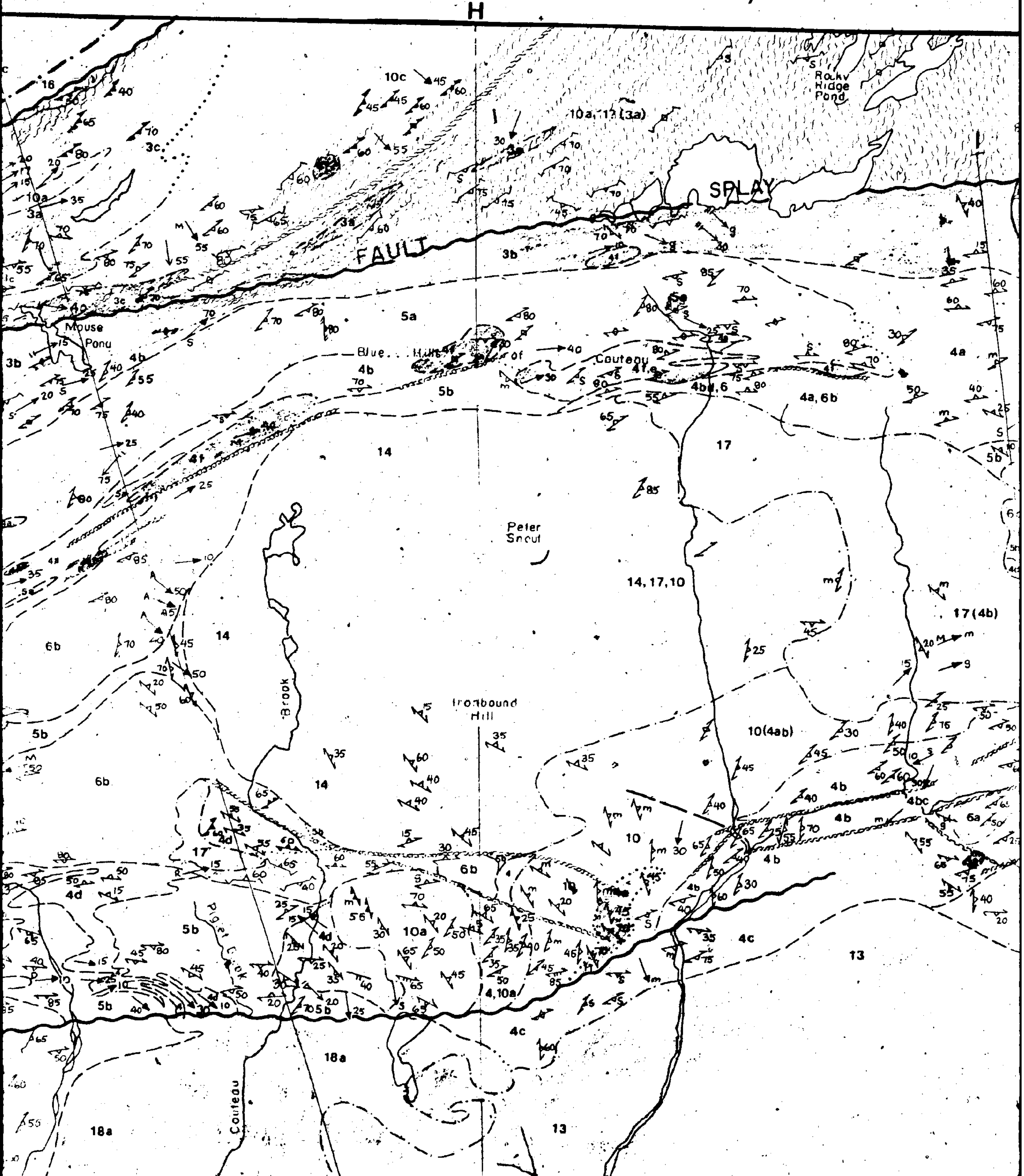

7
18
8b
8b
7a
7?, 1?, 8?
7a
F A U L T
10b
10b
10
10a
10a
10a
Brook
3a
11a
17, 10(3)
Garia

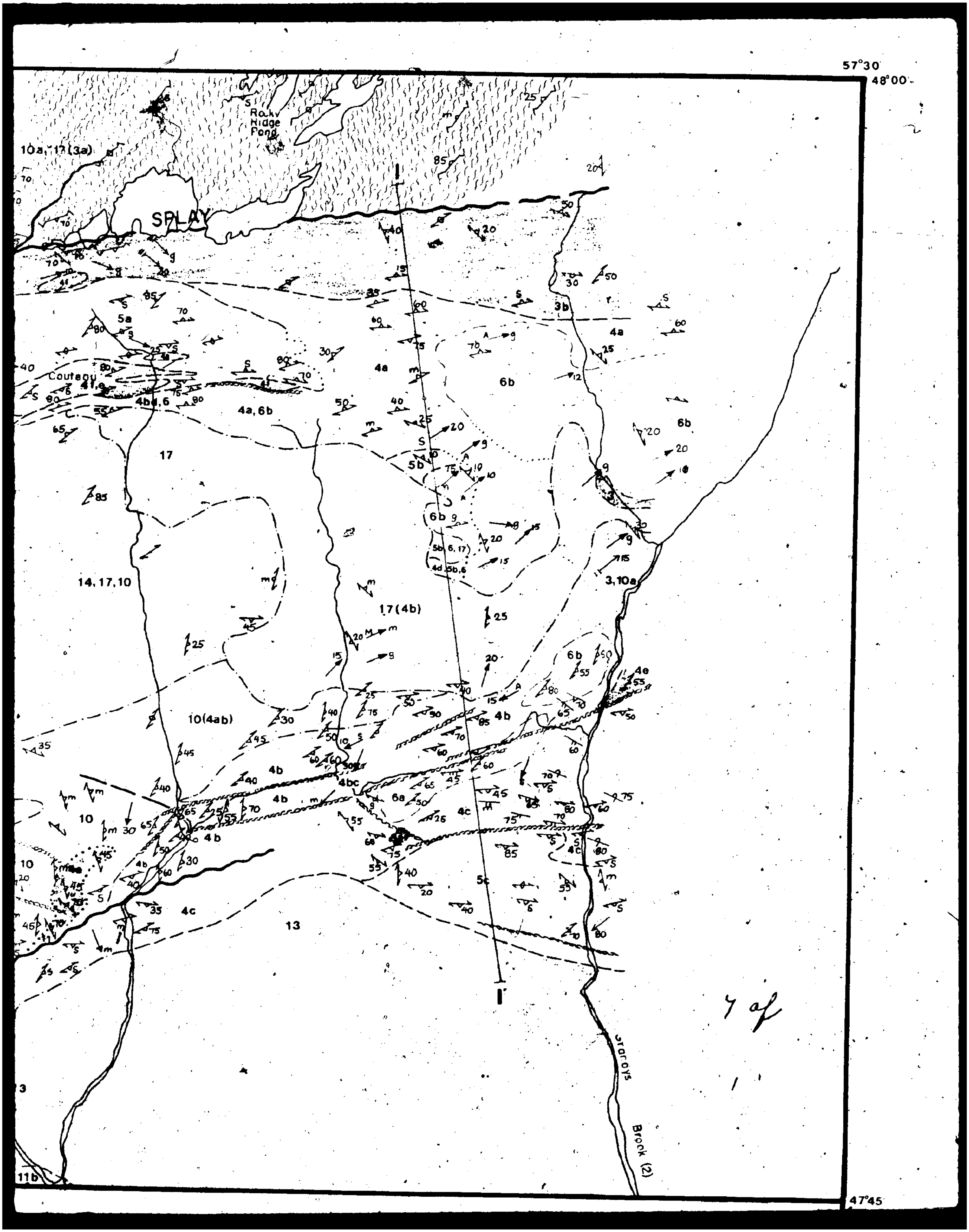
5 of

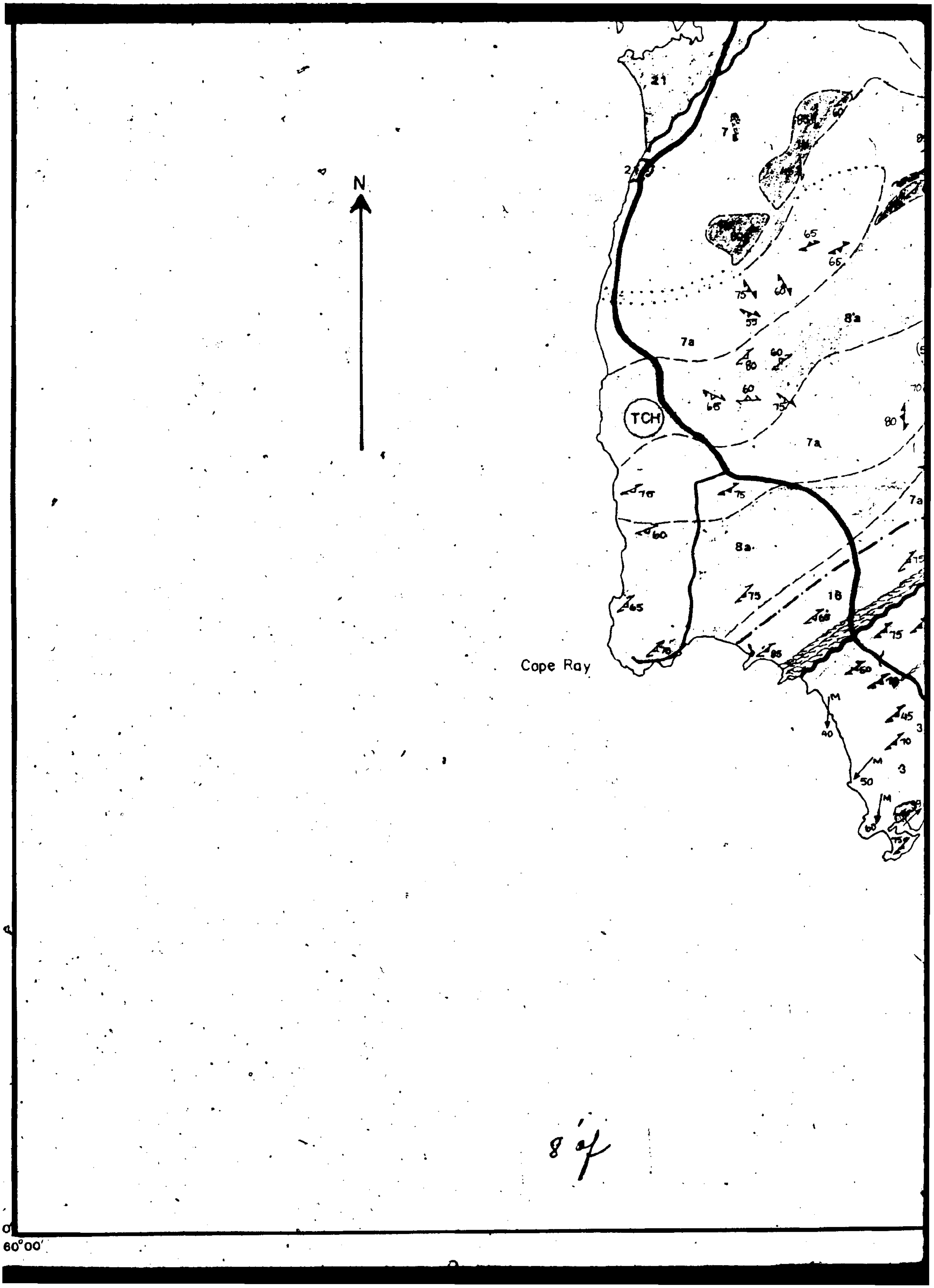


F
G
GUNFLAP HILLS
Gunflap Hills
Mouse Pond
Big Pond
Deep Brook
River
Poile
Bunker Hill
Brook
Billiards Brook
Cinq Cerf
Philips
FAULT

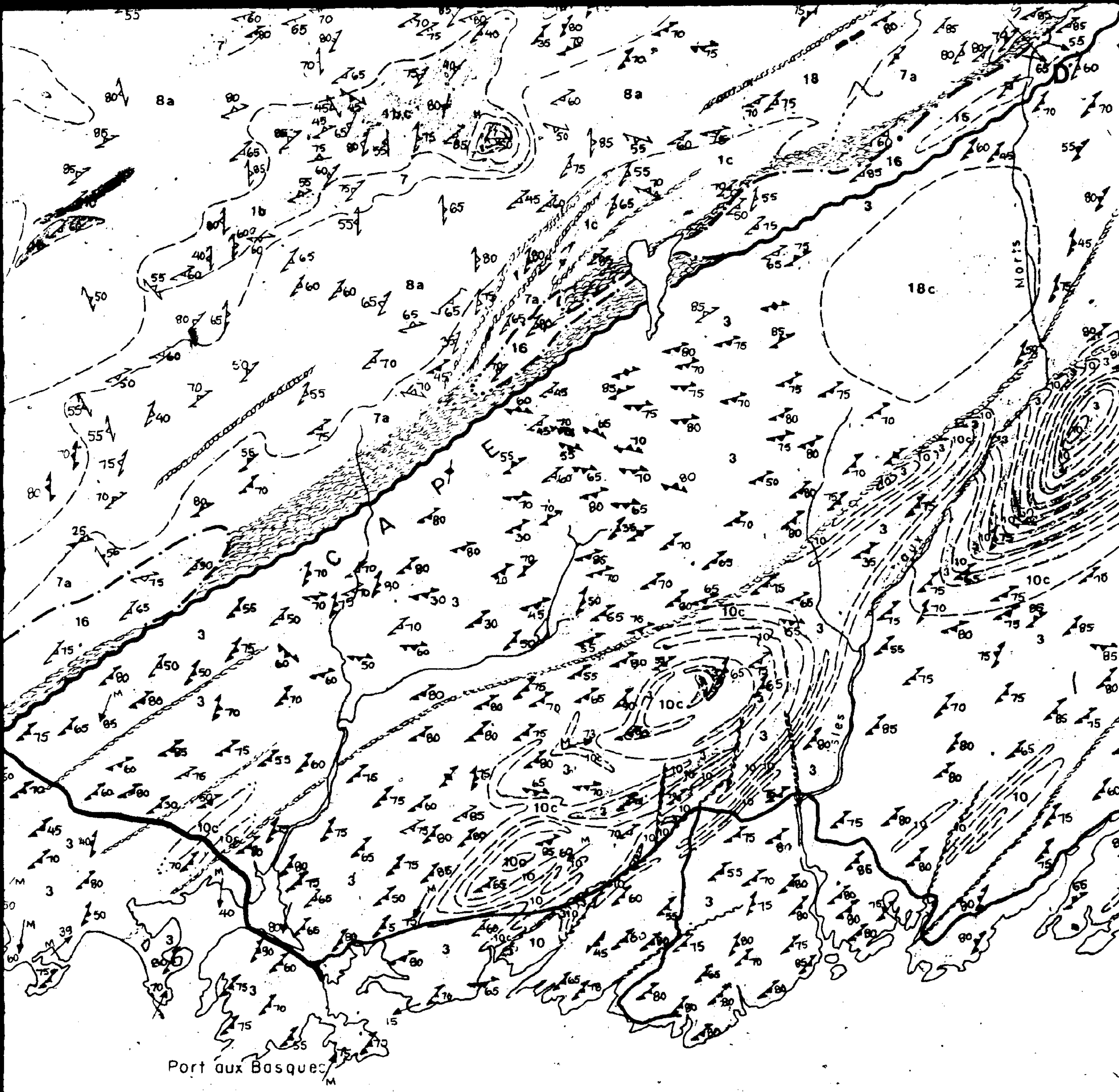
6 of


H
Rocky Ridge Pond
SPLAY
FAULT
Mouse Pond
Blue Hill of Couteau
Peter Snout
Ironbound Hill
Brook
Piget Brook
Couteau
10a, 13 (3a)
14, 17, 10
17 (4b)
10(4ab)
4a, 6b
4bd, 6
4, 10a
18a
13

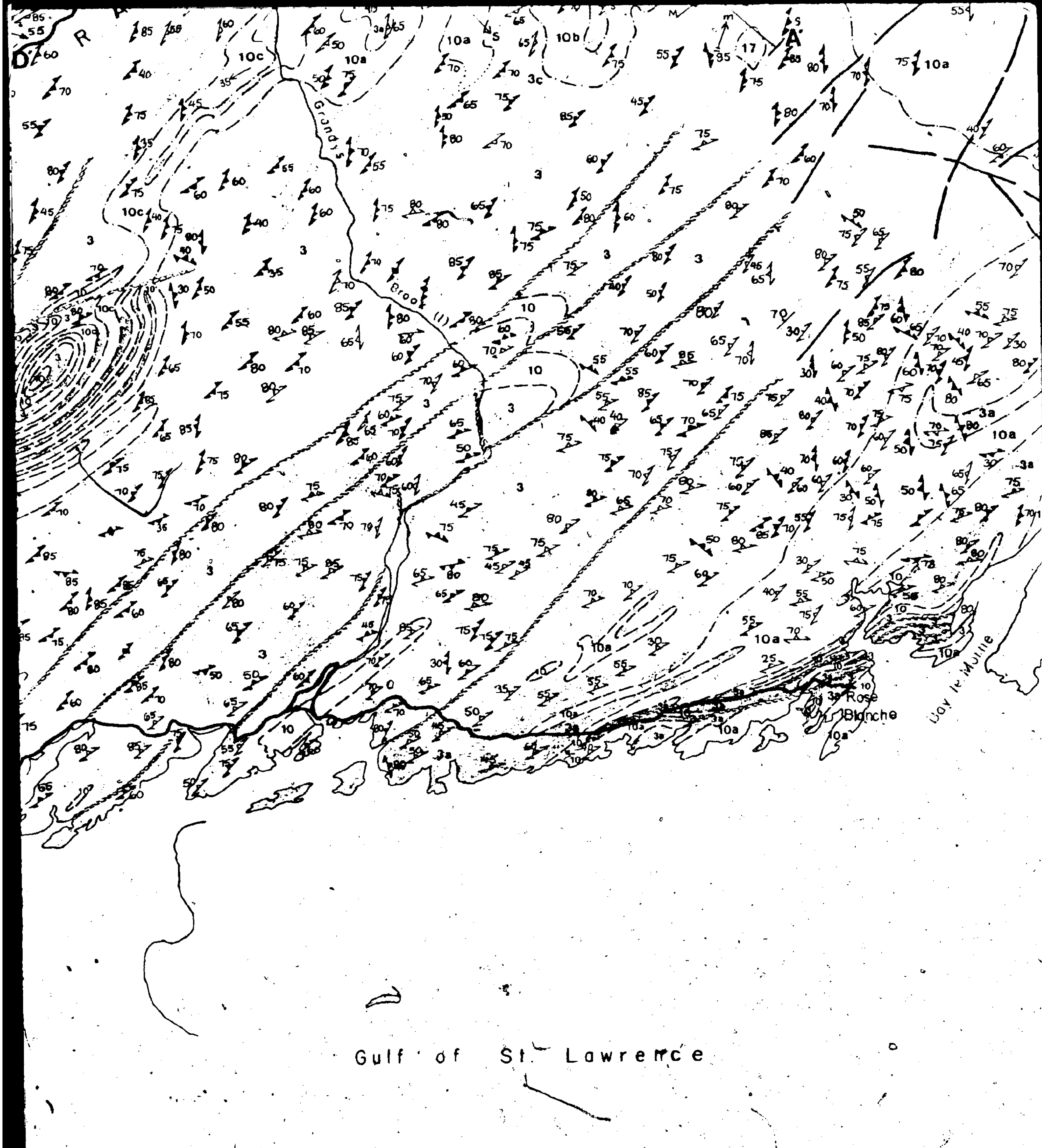

57°30
48°00
47°45
Rocky Ridge Pond
SPLAY
10a, 17(3a)
Coteau
4a, 6b
4bd, 6
5a
4a
6b
3b
5b
17
14, 17, 10
17(4b)
3, 10a
10(4ab)
4b
4bc
6a
4c
4e
5c
10
13
3
11b
Brock (2)

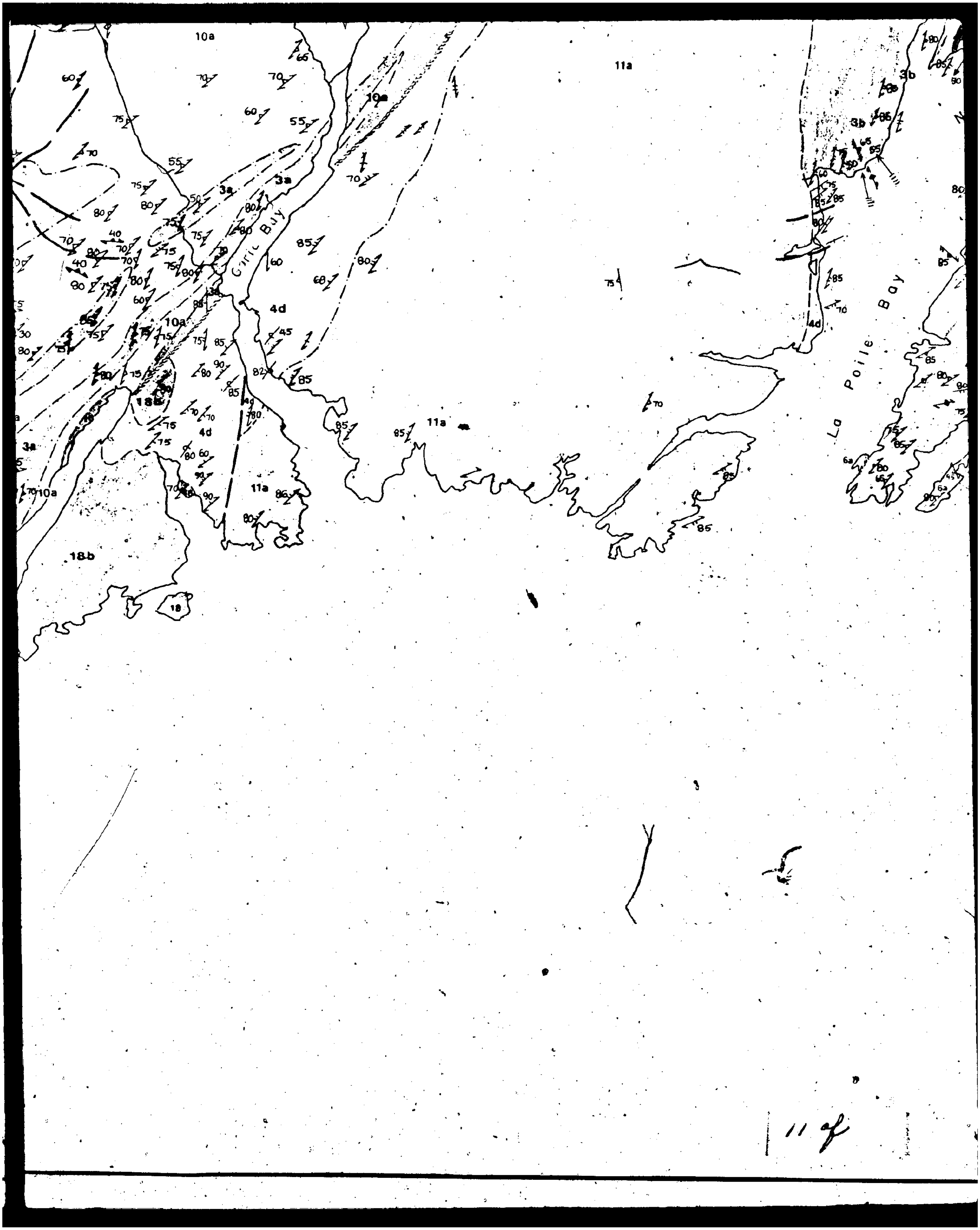


8 of



9 of


Grandys Brook
Rose Blanche
Bay le Moine
Gulf of St. Lawrence



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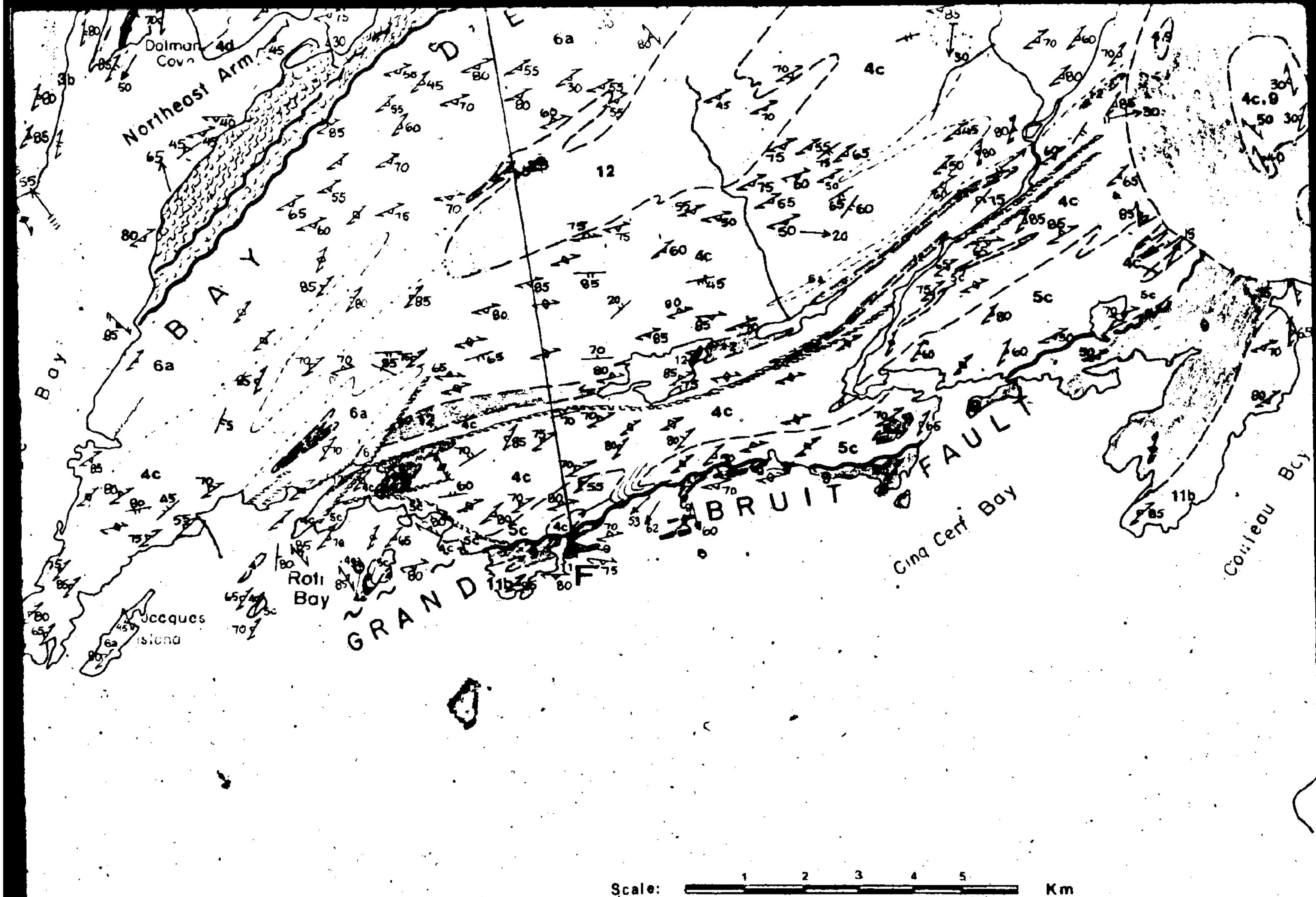
Dalman Cove
Northeast Arm
BAY D
Roti Bay
Jacques Island
GRAND BRUIT FAULT
Cinq Cerf Bay
Couteau Bay
Scale: 1 2 3 4 5 Km

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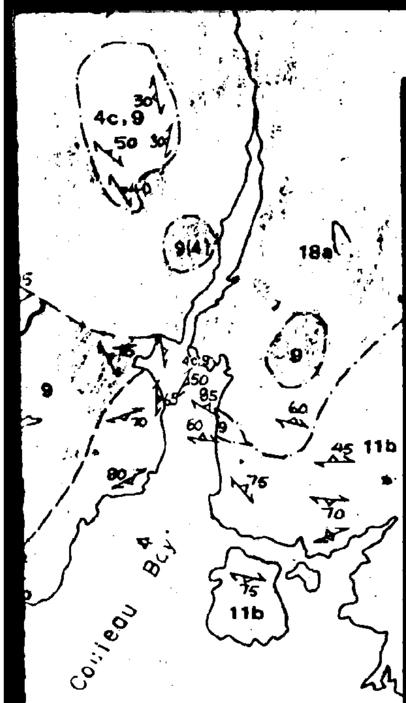

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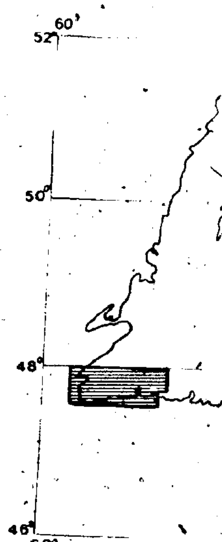

MAP I

to be accompanied
by cross-sections:

SHEET 1: AA' to EE'

SHEET 2: FF' to II'

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ology of the southern Long Range
ountains, southwest Newfoundland

Compiled and drawn by
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1982

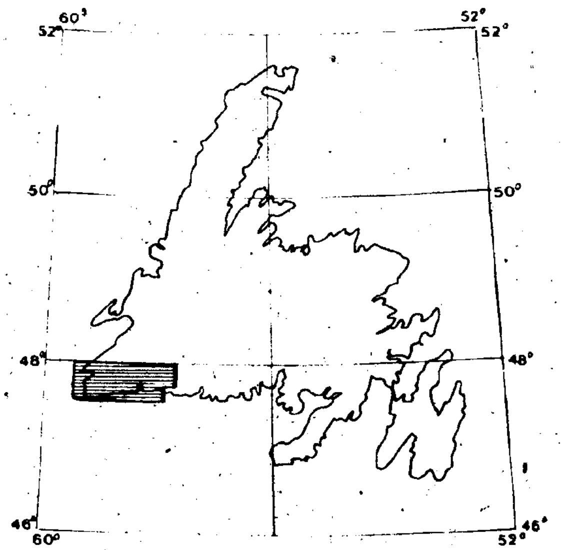
14 of 14.

MAP I

to be accompanied
by cross-sections:

SHEET 1: AA' to EE'

SHEET 2: FF' to II'



MUN DEPARTMENT OF EARTH SCIENCES

Structural trends and settings of late-orogenic granites and sedimentary sequences, southern Long Range Mts.

Compiled by
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1982

INDEX MAP

MAP 2

1 of 1

ARTH

late-
entary
Mts.

LEGEND

Measured structural trends:

- Main foliation with dip 0°-30°, 30°-60°, 60°-90°
- Extension lineations with plunges 60°-90°, 30°-60°, 0-30°
- Fold hinges with plunges 60°-90°, 30°-60°, 0°-30°
- Fold axial traces
- Fault, continuous or major; discontinuous or minor
- Thrust fault, high angle thrust fault
- Shear zone, slide
- Unconformity

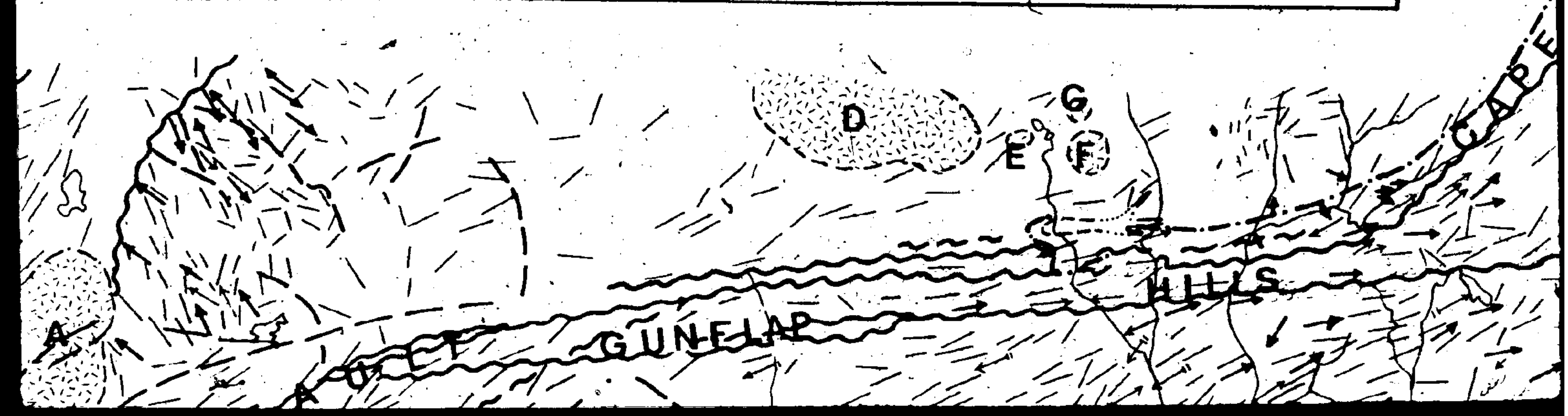
Perthite-rich leucograntie

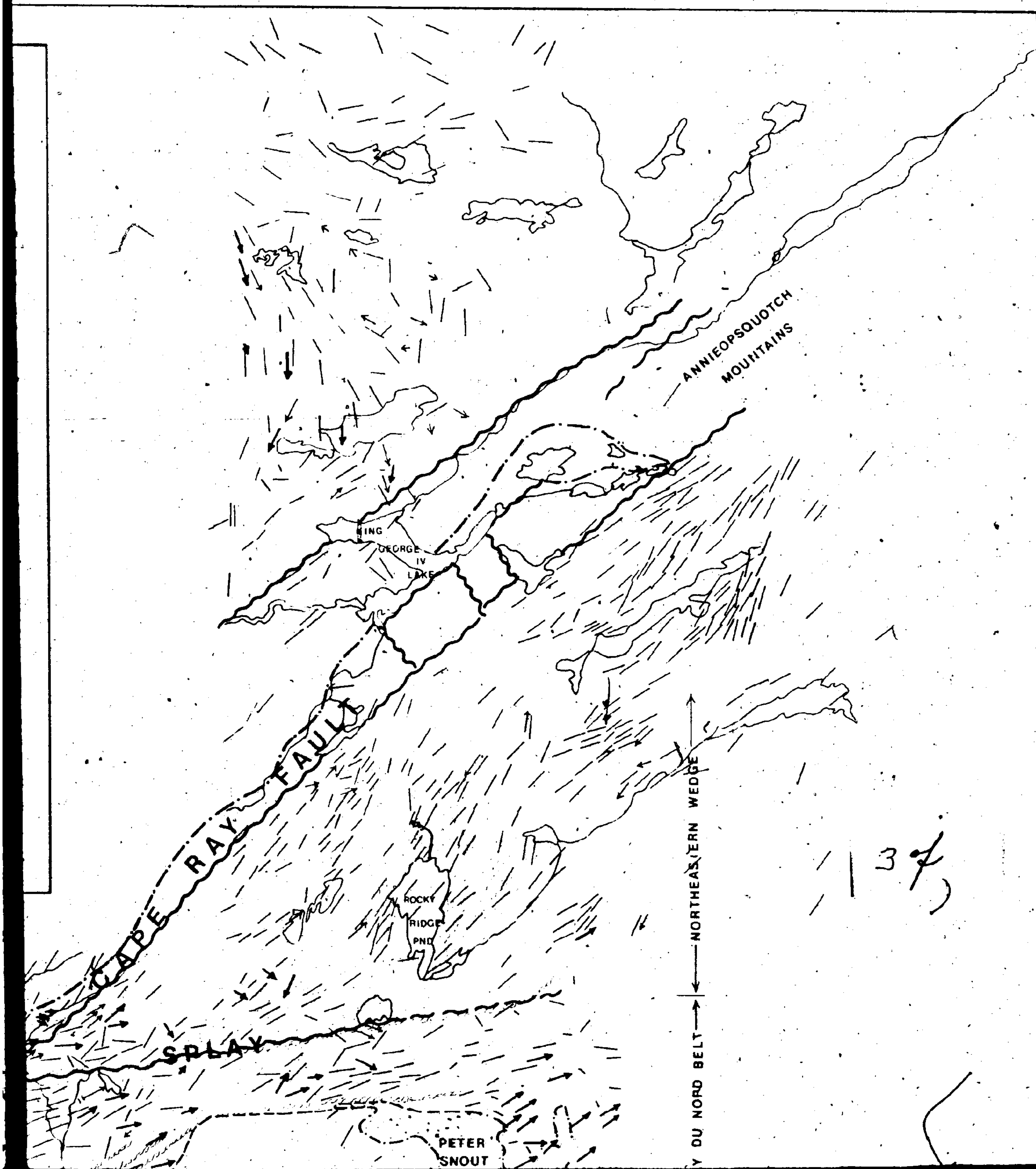
Subsolvus leucogranite

Marble

Windsor Point Group

Anguille, Codroy and Barachois Groups




ANNIEOPSQUOTCH
MOUNTAINS
KING
GEORGE
IV
LAKE
CAPE RAY FAULT
SPLAY
ROCKY
RIDGE
PND
PETER
SNOUT
Y DU NORD BELT
NORTHEASTERN WEDGE

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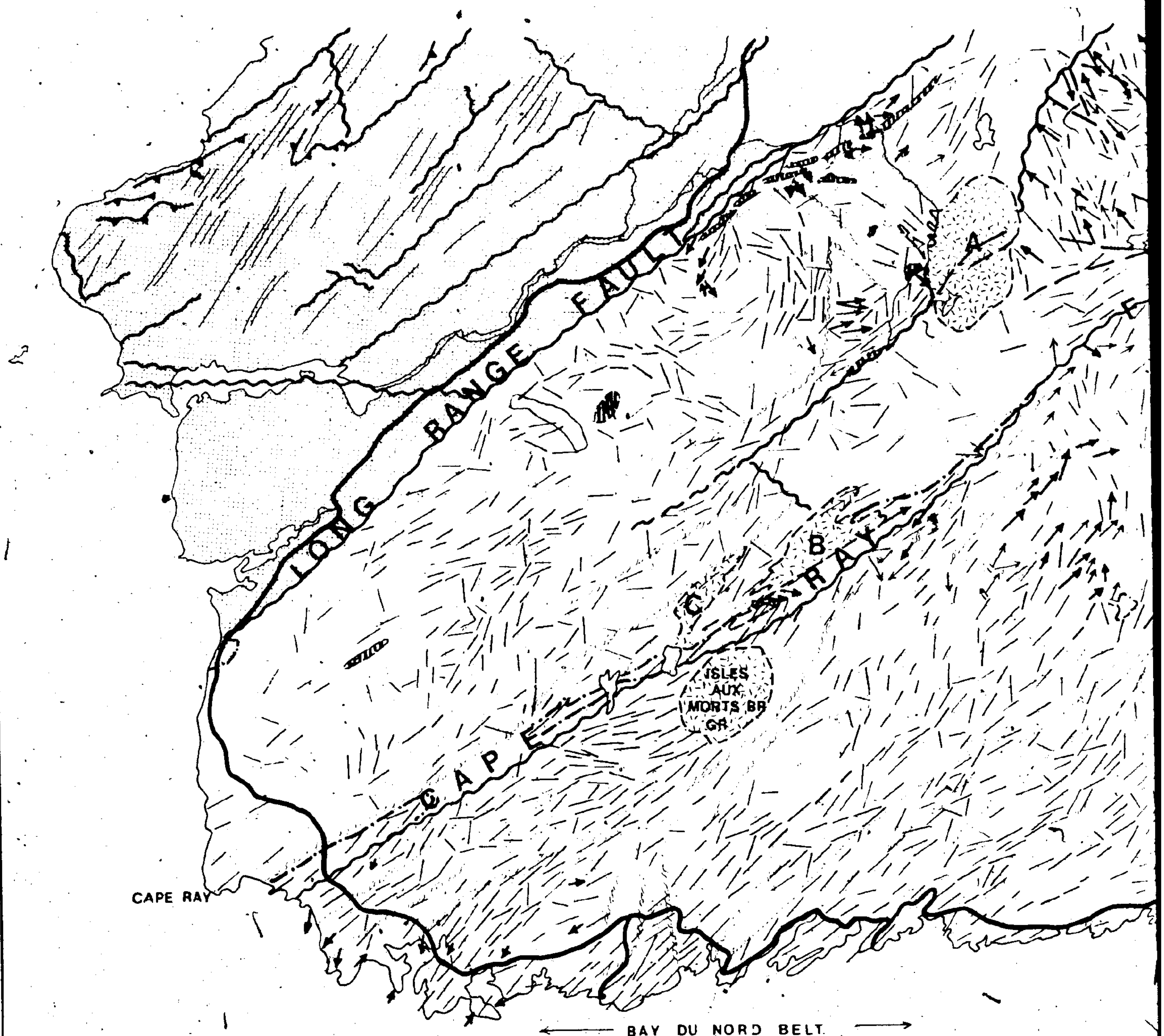
INDEX MAP



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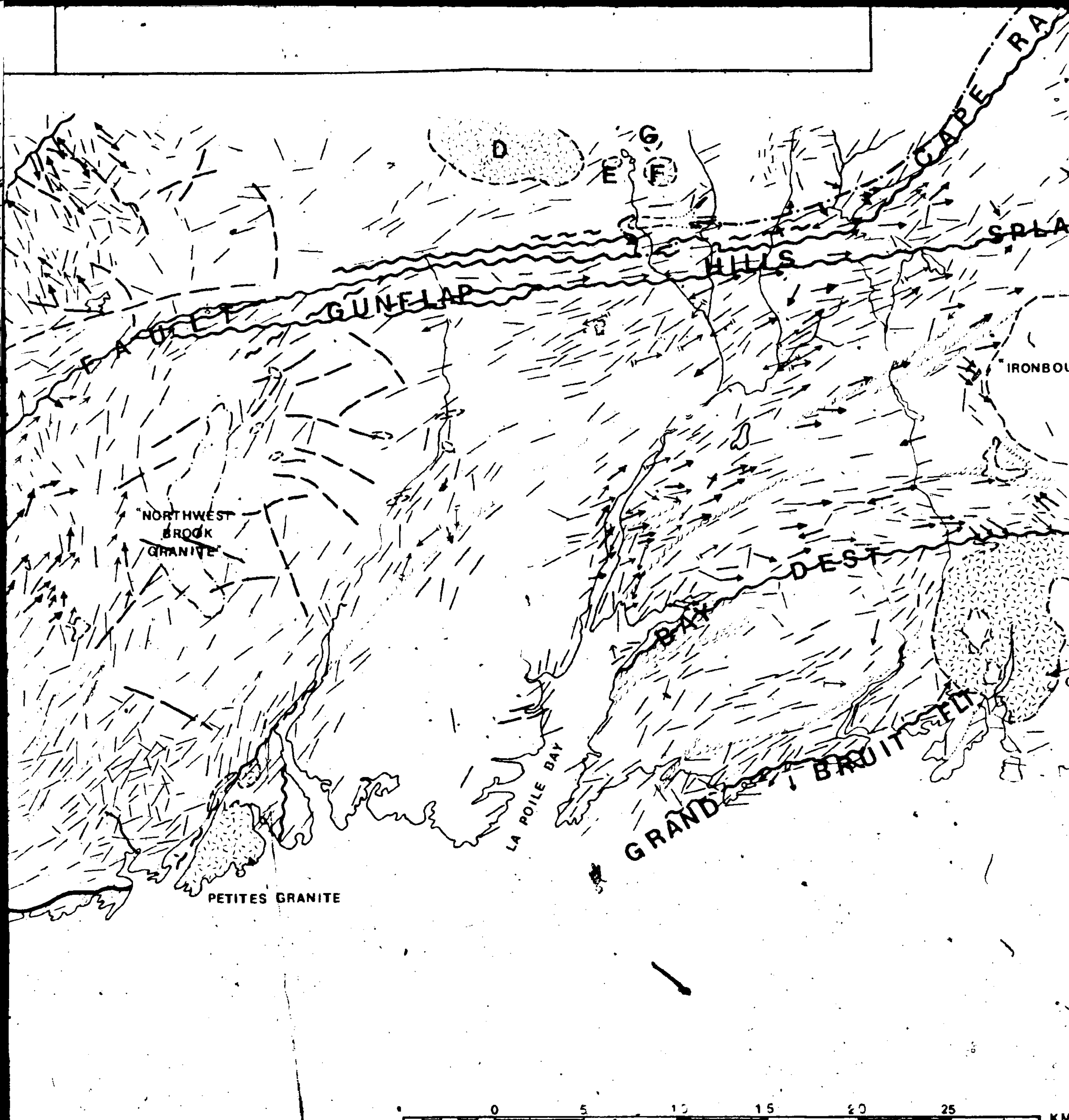
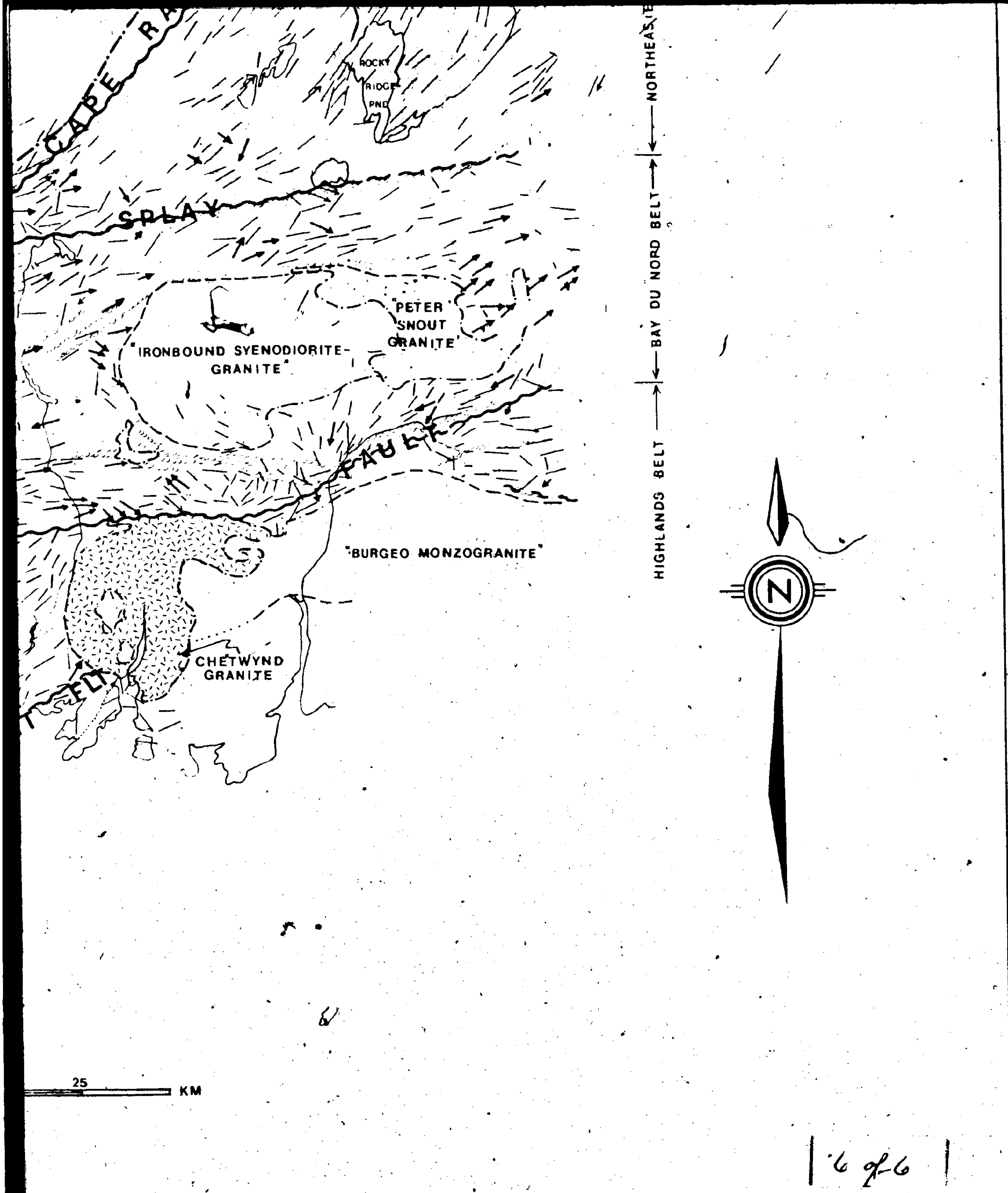

CAPE RA
D
G
E
F
SPLA
HILLS
FAULT
GUNFLAP
"IRONBOU
"NORTHWEST BROOK GRANITE"
DEST
BAY
LA POILE BAY
GRAND BRUIT FLT
PETITES GRANITE
0 5 10 15 20 25 KM

5 of


CAPE RA
SPLAY
FAULT
ROCKY RIDGE PND
"IRONBOUND SYENODIORITE-GRANITE"
"PETER SNOUT GRANITE"
"BURGEO MONZOGRANITE"
CHETWYND GRANITE
NORTHEAST
BAY DU NORD BELT
HIGHLANDS BELT
N
25
KM

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