THE RELATIONSHIP BETWEEN THE GANDER AND AVALON ZONES IN THE BONAVISTA BAY REGION, NEWFOUNDLAND

R. FRANK BLACKWOOD

THE RELATIONSHIP BETWEEN THE GANDER AND AVALON ZONES

IN THE BONAVISTA BAY REGION, NEWFOUNDLAND

by

© R. Frank Blackwood, B.Sc.

A Thesis

Submitted in Partial Fulfillment

of the Requirements for the Degree of

MASTER OF SCIENCE

Memorial University of Newfoundland

1976

ABSTRACT

The Dover Fault, characterized by a 300-500 metre wide mylonite zone, forms the boundary between the Gander and Avalon Zones in Bonavista Bay, Newfoundland. The Gander Zone, northwestwards of the fault, is underlain by a basement gneiss complex consisting of orthogneiss and paragneiss. The gneisses are intruded by a variety of granitic rocks including megacrystic granite, garnetiferous granite and gabbro. A strong, regionally developed, cataclastic foliation is superimposed upon the gneissic banding and overprints some of the granitic rocks. Metasedimentary rocks form a cover sequence to the basement gneisses in the northwestern part of the area.

The Avalon Zone, southeastwards of the Dover Fault, is underlain by Hadrynian volcanic rocks which are strongly foliated. Late Hadrynian - Early Cambrian Molasse rocks post-date the deformation of the volcanic rocks.

The Dover Fault formed in association with the regional cataclastic foliation, both are products of a tectonic event which overprints the Gander Zone and deforms the Precambrian volcanic rocks of the Avalon Zone. Thus the main movement on the fault is Precambrian. In southeastern Newfoundland, the Hermitage Bay Fault, characterized by a 50-100 metre wide breccia zone, forms the boundary between the Gander and Avalon Zones. Here, Paleozoic brecciation has destroyed most of the original (mylonitic) structure.

The Gander and Avalon Zones form two major tectonostratigraphic belts which may be traced all along the southeastern side of the

Appalachian-Caledonian system. Precambrian orogenic activity affecting these two zones is likely related to the Cadomian Orogeny.

ACKNOWLEDGEMENTS

Financial aid was provided by a Newfoundland Fellowship and a N.R.C. Grant (M.J. Kennedy) for work on this thesis.

The writer wishes to express his sincere gratitude to Professor Kennedy who supervised the project and provided the opportunity for further work in the area as a Research Assistant. He also provided financial assistance which permitted the writer to visit similar rocks within the Appalachian System. Finally, Professor Kennedy was a constant source for discussion, information, and constructive criticism.

Financial assistance was also provided by the Geology Department, M.U.N., for various excursions off the Island.

Several members of the Geology Department, M.U.N., are thanked for their useful advice on the geology discussed within this thesis; P.A. Brown, C.F. O'Driscoll, R.K. Stevens, D.F. Strong, and H. Williams.

Support in the Hermitage Bay area was provided by the Newfoundland Department of Mines and Energy.

Excellent thin sections were provided by the Lapidary staff: F. Thornhill, L. Warford and G. Ford. L. Murphy typed the manuscript. To all, many thanks.

Finally, a thank-you to M.J. West and C. Rodgers who proved able field assistants and pleasant companions.

Frontispiece: The Dover Fault underlies the town of Dover in northern Bonavista Bay. The Gander Zone is to the left of the town and the Avalon Zone to its right, looking northeast along the fault.

TABLE OF CONTENTS

Page

CHAPTER IV

METAMORPHISM

CHAPTER V

EXTENSION OF ROCKS OF THE GANDER AND AVALON ZONES TO THE WEST AND SOUTHWEST

Page

CHAPTER VI

DISCUSSION AND MAJOR CORRELATIONS

LIST OF FIGURES

LIST OF TABLES

LIST OF PLATES

Page

Page

Page

CHAPTER I

INTRODUCTION

1.1 Location and Means of Access

The map area is situated on the North-East coast of Newfoundland in Bonavista Bay. It lies between 49°00'N and 48°45'N latitude and 54°15'W and 53°40'W longitude. The area includes Deer Island, Lewis Island, Lockers Flat Island, the shores of Freshwater Bay and Lockers Reach in Northern Bonavista Bay.

The area is easily accessible by a paved highway which branches off the Trans-Canada Highway at Gambo. It crosses the area on the north side of Freshwater Bay and Lockers Reach. Coastal sections and islands can be reached by boat. Logging roads and a major forest fire in 1961 made most inland sections readily accessible.

Towns in the area include Gambo, Dark Cove, Middle Brook, Hare Bay, Dover, and Trinity.

1.2 Physiography

The area is characterized by low lying hills and valleys. Maximum elevation is 400 feet above sea level but most of the region lies between 50 and 300 feet. Numerous bogs and ponds fill the valleys.

Neither the drainage network nor the trend of the coastline reflect the strike of the country rocks. For the most part the coastline (Freshwater Bay and Lockers Reach) cuts across the strike of rock units and is in part controlled by faults. Rivers (brooks in local terminology) run across strike roughly perpendicular to the coastline, draining from the larger ponds.

Effects of Pleistocene glaciation are widespread. A veneer of till, variable in thickness (1-5 m), is developed throughout the area. Erratics are numerous and generally are composed of local rock types. The southwest end of Freshwater Bay contains numerous boulders and may represent an end moraine. In the same area, near Gambo, an extensive outwash delta reaches 100' above sea level (Jenness, 1963), indicating a rise in the coastline of at least that amount. Also, glacial striae, along with the trends of valleys and coastline, indicate that the Wisconsin ice sheet moved eastwards in this part of Bonavista Bay.

Before 1961 the area was covered with dense growths of spruce and fir trees intermixed with deciduous vegetation. This was mostly destroyed in the 1961 fire and along with it a viable pulp and paper industry. However, bedrock exposure has been greatly improved as the result of soil erosion following the fire.

1.3 Geological Setting

Newfoundland represents the northeast termination of the Appalachian Orogen and provides an excellent cross-section of Precambrian and Early Paleozoic rocks of that structural province. The island has been subdivided into three broad divisions. From west to east they are, the Western Platform (Kay, 1967), the Central Mobile Belt (Williams, 1964a), and the Avalon Platform (Kay and Colbert, 1965), (Fig. 1).

Williams et al. (1972) proposed a more detailed subdivision

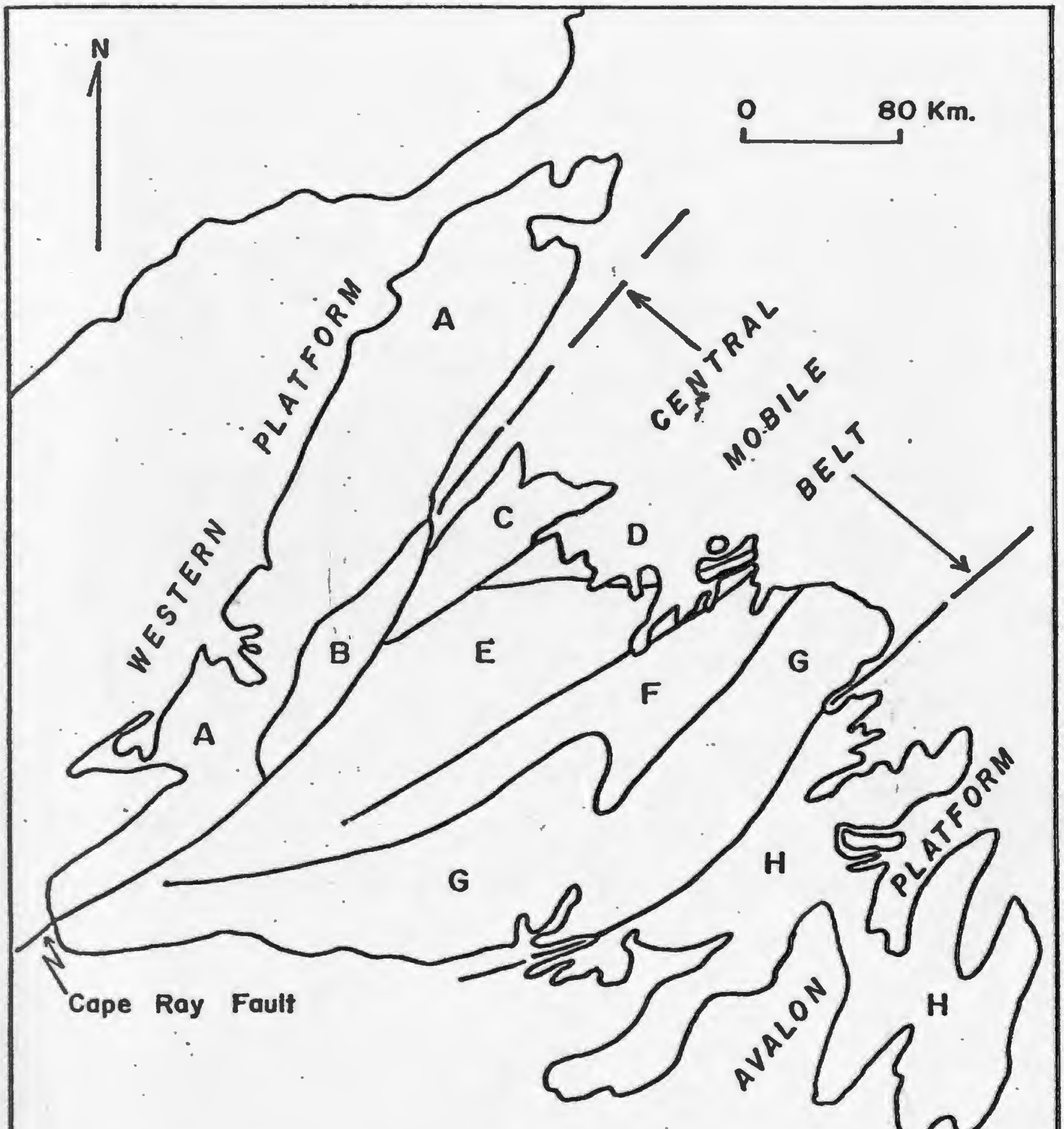


Figure 1. Tectonostratigraphic zones of Newfoundland Appalachians (after Williams et al., 1974).

of Newfoundland Appalachians into nine tectonostratigraphic zones. These zones, from west to east, are lettered A-H (Fig. 1) and are distinguished from each other by differences in Ordovician and/or earlier depositional and structural history.

A brief description of zones A-H is best facilitated by grouping those which were closely related during their development. Zones A, B and C (named the Lomond, Hampden, and Fleur de Lys respectively (Williams et al., 1974)) form the western margin of the Appalachian System. There a continental rise prism of sediment of probable Eocambrian age was deposited upon Grenvillian continental basement. Distension related to the development of the proto-Atlantic ocean is indicated by mafic dikes and volcanic rocks. This was followed by the development of a carbonate bank in the Cambrian along the newly formed continental margin.

Zones D, E, and F (named the Notre Dame, Exploits, and Botwood respectively) occur in the central part of the system. For the most part these zones represent Ordovician oceanic crust and volcanic and sedimentary rocks that were probably deposited upon oceanic crust. This interpretation is supported by the presence of Early Ordovician ophiolite suites in the Notre Dame Zone. Post-Middle Ordovician history of the central part of the system involved flysch infilling with continental volcanism and red bed deposition during the Silurian and Devonian.

Zone G (Gander Zone) and Zone H (Avalon Zone) form the eastern part of the Appalachian system. The Gander Zone consists of a continental basement complex (Bonavista Bay Gneiss Complex of Blackwood and Kennedy, 1975), overlain by a metasedimentary cover sequence with minor metavolcanic rocks. The cover rocks (Gander Group) probably represent a continental rise prism of sediment. Megacrystic microcline granites intrude the basement gneisses. Garnetiferous granites intrude both basement gneisses and the Gander Group. All rocks have been intensely deformed and together define a crystalline belt on the eastern side of the system, comparable to the Fleur de Lys Zone on the west.

The Avalon Zone consists of a series of little deformed and metamorphosed volcanic and sedimentary rocks. Its Precambrian development is related to volcanism and flysch deposition (Love Cove Group in map-area) during a period of tectonic instability. This was followed by Late Hadrynian molasse deposition (Musgravetown Group in map-area). During the Cambrian the Avalon Zone was a stable platformal area.

The Gander and Avalon Zones are separated from each other by a major fault, here termed the Dover Fault in Bonavista Bay and the Hermitage Bay Fault in Hermitage Bay (Fig. 2). The Dover Fault is marked by a mylonite zone 300-500 metres wide. The Hermitage Bay Fault is marked by a breccia zone, 50-100 metres wide, which post-dates the earlier mylonite zone (Blackwood and O'Driscoll, 1976). Relationships across the Dover Fault indicate that the Gander and Avalon Zones were juxtaposed during the Precambrian.

The Gander and Avalon Zones are intruded together by Devonian

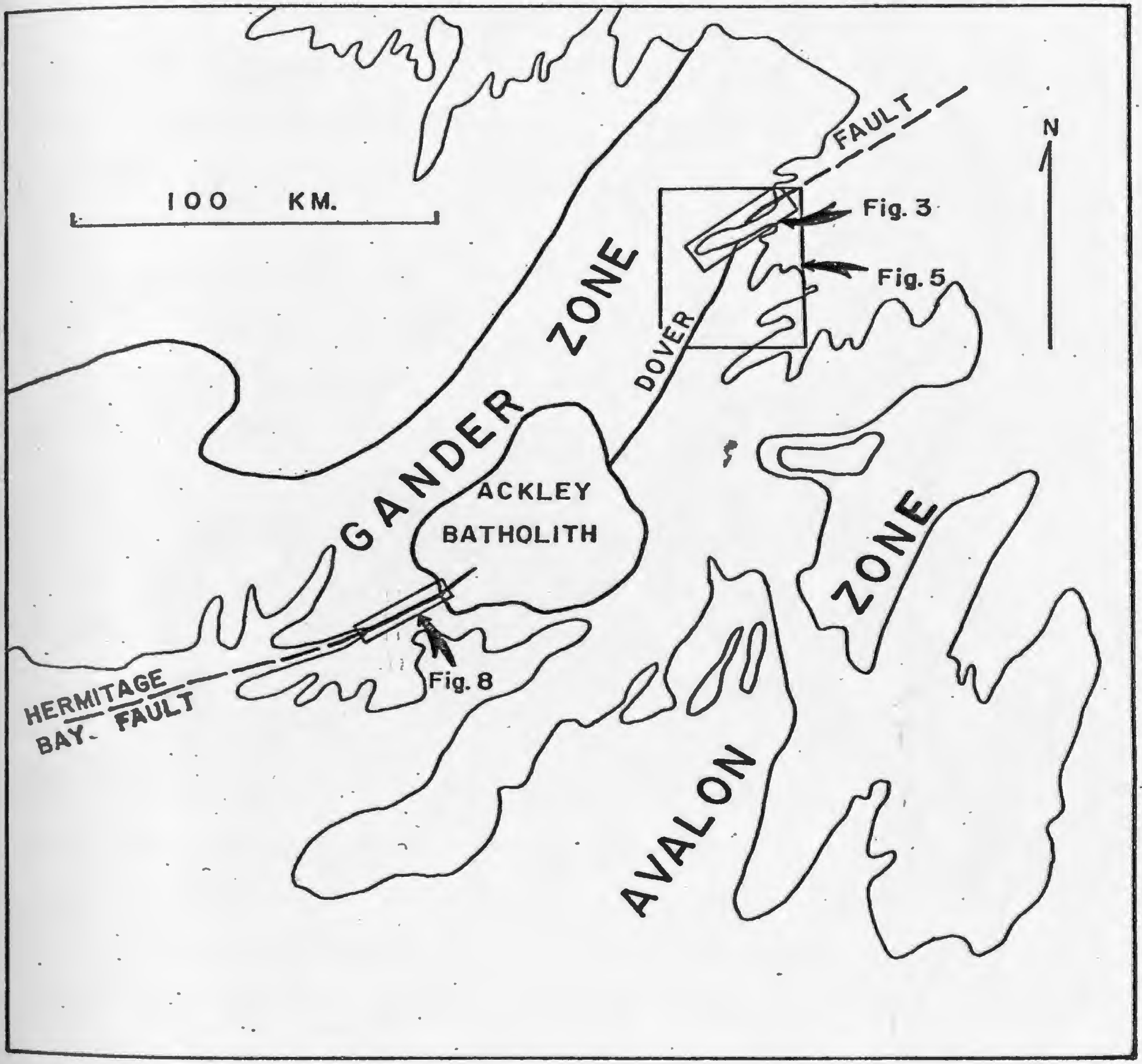


Figure 2. The Gander and Avalon Zones separated by the Dover-Hermitage Bay Fault system (showing location of Figures 3, 5, and 8).

as well as possibly Ordovician granites. Also metamorphic detritus presumably derived from the Gander Zone is found in Devonian red-beds of the Avalon Zone. These are the only Paleozoic links between the two zones.

1.4 General Geology

The map-area is composed of three major geological elements (Fig. 3). These are: (1) the gneisses and granitoid rocks of the Gander Zone; (2) the volcanic and sedimentary rocks of the Avalon Zone; and (3) the Dover Fault Zone.

The gneisses of the Gander Zone are considered part of a basement complex. They are cut by a variety of granites that have subsequently been deformed; notably megacrystic microcline granite, equigranular medium grained granite and garnetiferous granite veins. Most of these rocks are considered to be Precambrian in age. Undeformed, post-tectonic, coarse grained granites also intrude the Gander Zone and are probably of Paleozoic age.

The Avalon Zone is underlain, in part, by volcanic flows and volcanogenic sedimentary rocks that have been strongly deformed. These rocks are in fault contact with a much less deformed sequence of molasse facies. The deformed volcanic rocks pre-date the deposition of the molasse rocks of Late Hadrynian age.

The Dover Fault zone is underlain by mylonitized Gander and Avalon Zone rocks. Post-mylonite brecciation is common.

1.5 Previous Work

The earliest work done in the map-area was by A.M. Christie (1960). He made the first detailed observations on the lithology of the Musgravetown Group. He did not, however, mention the Love Cove Group whose type section was described (further south) by Widmer in 1949. Christie simply referred to the gneisses and granites of the Gander Zone in the map-area as granitic rocks.

During 1955, 1956, and 1957 the area formed part of a larger mapping project of the Geological Survey of Canada (Jenness, 1963), which clearly delineated the Musgravetown Group and showed it faulted against the Love Cove Group. Parts of the Bonavista Bay Gneiss Complex and a megacrystic granite were interpreted as being the "granitized" equivalents of the Love Cove Group. The Dover Fault was not delineated on these map sheets. Other parts of the megacrystic granite and the Bonavista Bay Gneiss Complex were placed in the Lower Unit of his Gander Lake Group. In the map area Jenness described the Lower Unit as mica-quartz paragneiss, mica schist and/or their granitized equivalents. Rocks on Lockers Flat Island were placed in the Cambrian Random Formation on account of the presence of quartzite.

From 1968-1970 the map area again formed part of a larger study (Younce, 1970). He recognized and named the Dover Fault as a narrow zone of mylonites and brecciation. He interpreted this fault as a wrench fault related to the folding and deformation of the Musgravetown Group. He pointed out that the Dover Fault separated Musgravetown and Love Cove rocks to the southeast from granite and migmatites to the northwest. Younce interpreted the Love Cove Group as simply a more intensely deformed and metamorphosed version of the Musgravetown Group. He indicated the Bonavista Bay Gneiss Complex to be the result of migmatization of Ordovician shales of the Gander Lake Group by Devonian granites.

1.6 Purpose of Present Investigation

Before this study the boundary between the Gander and Avalon Zones was considered to be a fault, although its exact location and nature was unknown. The purpose of this investigation, then, was to delineate the junction and study the relationships between the Gander and Avalon Zones in northern Bonavista Bay.

CHAPTER II

LITHOLOGICAL DESCRIPTION

The map area straddles the boundary between the Gander and Avalon Zones. Stratigraphic correlation between these two zones is not possible; the only feature common to both being a strong, steep, cataclastic northeast trending foliation. This structure is assocaited with the Dover Fault.

Due to lack of correlation across the Dover Fault and strongly contrasting geological histories of the two zones, rocks of each will be described separately in this and subsequent chapters.

2.1 Gander Zone

2.1.1 Bonavista Bay Gneiss Complex

The term Bonavista Bay Gneiss Complex (Blackwood and Kennedy, 1975) has been applied to the Precambrian? basement gneisses in the Bonavista Bay Area. Within the map area, on the basis of field relationships, this complex may be subdivided into two belts, each characterized by a different gneissic unit. The distinction between the two gneiss belts is made on lithological and structural grounds. To the northwest paragneisses occur within the Bonavista Bay Gneiss Complex (Square Pond Gneiss, see Fig. 5).

2.1.1.1 Hare Bay Gneiss

The term Hare Bay Gneiss is here proposed for that gneiss belt which forms a northeast trending, lithologically continuous map unit throughout the central part of the map area (Fig. 3). It is bounded to the northwest by the Lockers Bay Granite. Similarly, in the southeast, it is bounded by the Dover Fault granites and the Newport Granite.

The Hare Bay Gneiss has two main components: (1) a tonalitic portion which is host to (2) gneissic xenoliths of varied compositions. Most of the Hare Bay Gneiss consists of tonalite in the map area. The tonalitic gneiss has a well defined, northeast trending, gneissic foliation. This gneissosity is a metamorphically segregated banding 2-3 mm wide, and consists predominantly of alternating quartzo-feldspathic and biotite (chlorite) bands (see Plate 1). This banding must have been transposed several times and re-folding of the gneisosity is quite common in outcrop.

The composition of the tonalitic gneiss shows little variation. The light bands consist mainly of a quartz-plagioclase association, the plagioclase being oligoclase-andesine in composition. (Note: This and all other plagioclase composition determinations were done using the Michel Levy Method). The dark bands comprise lesser amounts of quartz and feldspar with a predominance of biotite (chlorite) and locally muscovite. Epidote, sphene, apatite, zircon and opaques occur in accessory proportions. Potassium feldspar is generally rare but may occur locally as microcline and orthoclase in proportions up to 30 per cent.

The xenoliths in the tonalitic portion of the Hare Bay Gneiss are varied in composition. These inclusions range in size from a few millimetres up to several metres across. Most have a well defined gneissic fabric which is variably oriented within the xenolith and

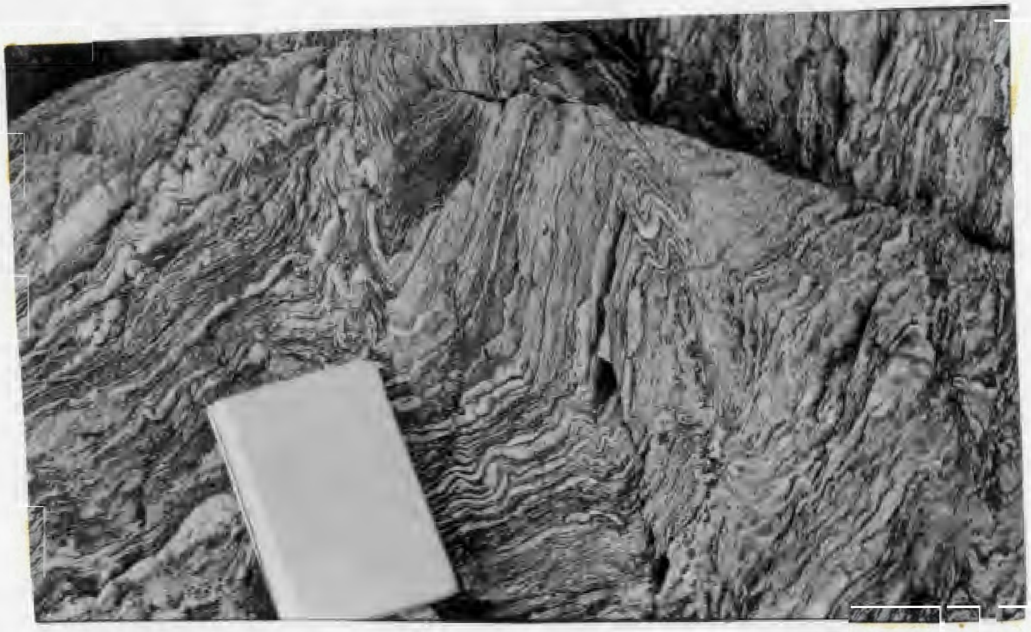


Plate 1. Well-banded Hare Bay Gneiss (Hare Bay).

Plate 2. Paragneiss xenolith in Hare Bay Gneiss (Hare Bay).

around which the external foliation in the tonalite gneiss forms augen (see Plate 2).

The bulk of these gneissic xenoliths are amphibolites. The amphibole is generally tremolite and/or actinolite. Biotite and oligoclase/andesine occur in smaller proportions with minor quartz. Chlorite commonly replaces the amphibole with sericite, carbonate and opaques occurring in accessory proportions.

Other xenoliths are psammitic to semi-pelitic in composition. Biotite, muscovite, oligoclase and quartz are the main mineral constituents with greater proportions of mica in the more pelitic xenoliths. Chlorite is after biotite but along with the opaques occur in accessory proportions.

From the above account it would appear that the xenoliths within the Hare Bay Gneiss represent an earlier gneiss sequence which was later incorporated in the tonalite. The variation in composition and type of xenoliths suggest that this early gneiss was a paragneiss sequence. It is demonstrable that the internal gneissosity of the xenoliths shows different angular relationships with the external fabric in the tonalite within one outcrop. This observation and the fact that the composition of the xenoliths is varied, refute any suggestion that the xenoliths are boudinized and rotated dikes or inclusions which suffered the same deformational history as the tonalite. Also, what may be original intrusive contacts between tonalite and amphibolite gneiss occur in the southwest and northeast corners of Hare Bay. Here a large raft of amphibolite gneiss, 50 metres across, is intruded by small granitic veins which vary in thickness from a few millimetres towards the centre of the raft to several centimetres on its margin. The veins grade in size and profusion out into clearly recognizable tonalite gneiss. Thus the Hare Bay Gneiss represents two complexes of different ages: an early, possibly paragneiss sequence which was subsequently intruded by a tonalite and then intensively tectonized to produce a gneissic foliation in the tonalite.

2.1.1.2 Traverse Brook Gneiss

The term Traverse Brook Gneiss is here proposed for that gneiss belt which runs throughout the northwestern portion of the map area (Fig. 3). Its southeast margin runs parallel to the Hare Bay Gneiss, but is separated from the latter by the Lockers Bay Granite. Its extent to the northwest has not been delineated except in the extreme west where it is intruded by the Middle Brook Granite. Other smaller granite bodies are contained within the Traverse Brook Gneiss. Their relationships with the gneiss will be discussed below.

Like the Hare Bay Gneiss, the Traverse Brook Gneiss has two main components: (1) a granitic host to (2) mainly biotite and amphibolite gneiss xenoliths. The granitic host is variable in structure and in composition. The foliation in this portion of the gneiss unit may be represented by a crude gneissic banding (see Plate 3), a composite schistosity or a single penetrative fabric. Thus, locally, an intensely schistose granitic rock, rather than true gneiss may comprise the Traverse Brook Gneiss. Whatever the manifestation, a tectonic fabric is ubiquitously developed and has a consistent northeast strike with a steep dip. Where the gneissic fabric is well

Plate 3. Crude banding in Traverse Brook Gneiss (North Shore of Lockers Bay).

Plate 4. Gneissic foliation of the Traverse Brook Gneiss forming augen around a xenolith of Hare Bay Gneiss (small island in Freshwater Bay).

developed it consists of alternating bands of predominantly quartz-feldspar rich- with biotite-muscovite rich bands. Relative proportions of these minerals vary but essentially all are represented throughout the granitic host of the Traverse Brook Gneiss. The main compositional variation is provided by the feldspars, since unlike the Hare Bay Gneiss, microcline and orthoclase are quite common in this gneiss belt. Thus the granitic host varies from tonalitic to monzonitic in composition with most potassium-feldspar-rich gneiss being granodioritic. The ubiquitous plagioclase is oligoclase-andesine in composition and where it is the only feldspar the Traverse Brook Gneiss would appear to be no different from the Hare Bay Gneiss. Chlorite may be present after biotite along with accessory sphene and apatite.

For the most part, the xenoliths in the Traverse Brook Gneiss are like the Hare Bay Gneiss (see Plate 4). They exhibit a well defined banding which is disoriented with respect to the external gneissic or composite fabric in the host. The majority of xenoliths are tonalitic in composition but generally have more biotite and muscovite than typical Hare Bay Gneiss. Quartz and chlorite is present in varying amounts. Amphibolite xenoliths are identical to rafts of same in the Hare Bay Gneiss.

The writer suggests that the Traverse Brook Gneiss is younger than, and represents a migmatized version of, the Hare Bay Gneiss. In areas where the Traverse Brook Gneiss cannot be distinguished from Hare Bay Gneiss, it is likely that these represent large rafts of preserved Hare Bay Gneiss. Tonalitic and amphibolitic xenoliths would represent the same except on a smaller scale. Sillimanite and cordierite in quartz veins cutting some Hare Bay Gneiss tonalitic xenoliths and potassic feldspar (microcline-orthoclase) in recognizable Traverse Brook Gneiss indicate temperatures capable of anatexis of a muscovite-biotite-plagioclase-quartz-gneiss (Hare Bay Gneiss) to produce a more granitic melt (Traverse Brook Gneiss). Subsequent deformation produced a tectonized host (schistose to gneissic) to xenoliths of older gneiss, now collectively referred to as the Traverse Brook Gneiss. Basic clots of hornblende and biotite also occur in the Traverse Brook Gneiss (see Plate 5). These pods are not interpreted as xenoliths but probably represent restite from the migmatization process.

A small body of granite outcrops within the Traverse Brook Gneiss on the west side of Traverse Pond (Fig. 3). This rock ranges from quartz-monzonite to granite in composition. The K-feldspar is microcline and the plagioclase has an approximate composition of An_{25}. Microcline and quartz represent 50 to 80 per cent of the rock, depending where sampled. Biotite and muscovite are always present with chlorite after the former. Structuraly this granite is identical to the host portion of the Traverse Brook Gneiss, i.e. composite to single penetrative foliations. For this reason, and also compositional similarities and the lack of clear-cut intrusive contacts with the gneiss, this body of granite is postulated as being related to the migmatitic and deformational history of the Traverse Brook Gneiss.

A much smaller body of granite, similar to that west of Traverse Pond, outcrops on the south-central shore of Hare Bay Pond. Both bodies contain clearly recognizable xenoliths of Hare Bay Gneiss

Plate 5. Basic clots (black elliptical patches) in Traverse Brook Gneiss. Also note xenoliths of earlier gneiss. (North shore of Freshwater Bay).

Plate 6. Gneissic xenolith in Lockers Bay Granite. Here the granite is finer grained close to contact with Traverse Brook Gneiss (north shore of Lockers Bay).

but no inclusions similar to the host portion of the Traverse Brook Gneiss are found. Post-gneissosity feldspar (predominantly albite-oligoclase) porphyroblasts are strongly developed in the gneissic xenoliths of the smaller body. A late, steep, penetrative foliation forms augen around these porphyroblasts. The lack of "host" Traverse Brook Gneiss as xenoliths in these granite bodies, plus no apparent intrusive contacts between granite and gneiss except where the gneiss is demonstratively Hare Bay Gneiss, and similarity in deformational style suggests that the migmatites in the Traverse Brook Gneiss and these two granite bodies are coeval.

2.1.2 Lockers Bay Granite

The term Lockers Bay Granite is here proposed for that linear intrusive body which occupies the central portion of the map area (Fig. 3). To the northwest it is in contact with the Traverse Brook Gneiss and to the southeast with the Hare Bay Gneiss. The granite is clearly intrusive as can be seen on the south side of Lockers Bay where it cuts the Hare Bay Gneiss. There a finer grained chilled margin is preserved adjacent to the contact with the gneiss. Distinct, fresh xenoliths of both Hare Bay Gneiss and Traverse Brook Gneiss also occur in the Lockers Bay Granite (see Plate 6). Elsewhere the intrusive nature of the granite is camouflaged by autometasomatism. This is best developed on Lewis Island where a gradational contact of several metres exists between the Lockers Bay Granite and the Hare Bay Gneiss. Microcline and plagioclase prophyroblasts overprint the gneissic foliation, completely obliterating the gneissic nature of the country rock close to the granite contact. Similar relationships exist between the granite and its gneissic xenoliths. The xenoliths range from being completely fresh and unaltered to nearly complete assimilation by the granite. Porphyroblast growth in the assimilated xenoliths is profuse allowing for preservation of only a "ghost" gneissic banding (see Plate 7). The development of porphyroblasts on the margins and within the granite suggests that the autometasomatism, which is local and always restricted to the Lockers Bay Granite and immediate contact rocks, is the most plausible explanation of this phenomenon (W.S. Pitcher, personal communications, 1975).

The metasomatic prophyroblasts predate a strong, penetrative, steep, northeasterly trending foliation in the Lockers Bay Granite. This foliation forms augen around the feldspar megacrysts in the granite and also those which overprint the gneissosity in the country rock. Leucocratic dikes which cut the Lockers Bay Granite locally show porphyroblastic microcline growing across the granite-dike contacts. These have been deformed by the same foliation as the Lockers Bay granite. Post-tectonic dikes which cut the granite contain no porphyroblasts.

The Lockers Bay Granite is essentially a granite, but locally may fall within the quartz-monzonite range. It is characterized by ubiquitous microcline megacrysts which range from 4-8 cm long (see Plate 8). Locally plagioclase crystals are extremely large and feldspar represents approximately 40-50 per cent of the rock. The megacrystic nature of the Lockers Bay Granite may in part reflect original

Plate 7. Profuse feldspar porphyroblast growth in a gneissic xenolith within the Lockers Bay Granite. Note "ghost" gneissic banding (Trinity Bay).

Plate 8. Strong cataclastic foliation in Lockers Bay Granite. Note "tails" developed on the microcline megacrysts. This is typical of this granite body.

coarse phenocrysts and as previously described, in part most certainly reflect porphyroblast growth.

The microcline crystals in places contain inclusions of quartz, plagioclase, and biotite. Straining is severe with development of sutured grain boundaries between the quartz and feldspar. Microperthite stringers are common. Plagioclase (oligoclase) grains are invariably sericitized with grain boundaries similar to the microcline.

The microcline megacrysts are surrounded by much finer grained quartz, plagioclase, microcline, biotite and chlorite in order of decreasing abundance. The quartz is intensely strained and occurs in elongated zones between the microcline megacrysts and also in their strain shadows. Biotite and quartz are strongly oriented and define the tectonic foliation. Commonly, chlorite is after biotite. Sphene, zircon, epidote and an opaque mineral occur as accessories.

2.1.3 The Dover Fault granites

Several bodies of granite outcrop along the trace of the Dover Fault on the Gander Zone side (Fig. 3) and are here informally referred to as the Dover Fault granites (see Plate 9). Within the map-area these linear granite bodies always intrude the Hare Bay Gneiss to the northwest and grade into mylonites of the Dover Fault to the southeast. Like the Lockers Bay Granite, the Dover Fault granites are overprinted by the steep, strong, penetrative northeast-trending foliation. With proximity to the Dover Fault, this fabric becomes an intense mylonitic foliation. Within the fault zone the igneous

Plate 9. Dover Fault granite, moderately foliated (Hare Bay).

Plate 10. Dover Fault granite showing strong cataclastic foliation (Hare Bay).

character of these granite bodies is generally destroyed and they are represented by a pink, in most places banded, mylonite (see Plate 10). The gradation between clearly recognizable granite and granite mylonite is well demonstrated by the body on the south shore of Hare Bay. Within this granite there are narrow zones (1 to 2 feet) where the mylonitic foliation becomes quite intense towards the center of these zones and the granite is replaced by a green mylonite with local feldspar porphyroblasts. The green color is due to the introduction of chlorite and epidote, a common occurrence where the granite has undergone severe cataclastic deformation.

The granite bodies at Dover and northeast of Dover show similar relationships to that of Hare Bay. However, the Dover Fault granite on the south shore of Freshwater Bay, although similar lithologically, does not show the same intense deformation as the others. Its foliation is locally developed only becoming mylonitic within the fault zone.

The Dover Fault granites are conspicuous in that they always occur on the Gander Zone side of the Dover Fault and follow the fault wherever seen. This would suggest that a zone of weakness was present before the granites were emplaced and controlled the localization of such bodies. Thus the Dover Fault granites probably post-date the initiation of the fault zone and may be of varying ages. The granite on the south shore of Freshwater Bay for example, is likely to be somewhat younger than the others and is affected by a later, less intense episode of flattening along the Dover Fault.

The Dover Fault granites are medium to coarse grained, roughly equigranular bodies and are quite rich in quartz, generally exceeding 20 per cent. Microcline and orthoclase are the main feldspars occurring in proportion up to 50 per cent. Plagioclase (An_{35}) is always present and may represent 20 per cent. Chlorite and sericite range from accessory proportions to 10 per cent with chlorite after biotite. Common accessory minerals are sphene, biotite, opaques, and epidote. Epidote also replaces allanite, a few grains of which have been found in all the Dover Fault granites. The effect of the cataclastic deformation upon the Dover Fault granites is a strong mylonitic foliation. This fabric is defined by elongated, sutured quartz grains with oriented chlorite and sericite. Feldspar becomes finely comminuted and is also preserved as porphyroclasts.

2.1.4 Middle Brook Granite

The northwest corner of the map-area around Middle Brook is underlain by an undeformed, coarse-grained, porphyritic granite called the Middle Brook Granite (Strong et al.,1974). On its northwest margin, this granite intrudes paragneisses of the Bonavista Bay Gneiss Complex (Fig. 3). This contact is excellently exposed where it crosses Middle Brook (see Plate 11), approximately 1 mile upstream from the coast. The granite is chilled against the paragneiss and the latter locally shows cordierite prophyroblasts. The intrusion of the Middle Brook Granite and its associated metamorphic aureole quite

Plate 11. Sharp contact between paragneisses and chilled Middle Brook Granite (Middle Brook).

Plate 12. Veins of Middle Brook Granite (parallel to knives) cutting deformed porphyritic granite. The veins show a weak marginal foliation (north shore of Freshwater Bay).

clearly post-dates all structures in the paragneiss.

On its southeast margin the Middle Brook Granite intrudes post-tectonically the Traverse Brook Gneiss. Numerous gneissic xenoliths occur within the granite. Near the contact with the gneisses quartz in the granite exhibits a blue tint presumably due to mild straining close to the contact. A short distance from the contact a weak foliation is developed in the Middle Brook Granite, trending approximately N20°E. On the north shore of Freshwater Bay where the contact is exposed at the coastline, the Middle Brook Granite appears to intrude post-tectonically a strongly deformed porphyritic granite body. The latter may be related to the granite bodies within the Traverse Brook Gneiss and underlies Air Island as well as immediately onshore on the south side of Freshwater Bay (Fig. 3). The fabric in this granite is the regional cataclastic foliation which trends N10°W in this area. Dikes similar to the Middle Brook Granite and presumably related to it cut the deformed granite post-tectonically (see Plate 12). Since superficially both granites look similar and since the Middle Brook does exhibit a weak fabric close to the contact it is not always easy to differentiate between these two granites along this part of the contact.. Also, on the south shore of Freshwater Bay, lack of exposure is an added problem. However, the difference in trend between the regional foliation in the deformed granite (N10°W); the conformity of the latter with the gneissic and cataclastic foliation to the east; the clearly undisturbed margins of the Middle Brook Granite elsewhere; and the presence of Middle Brook granite-like dikes cutting the deformed rock post-tectonically, strongly suggest that this granite is a completely post-tectonic intrusive body.

The Middle Brook Granite is consistently coarse grained with feldspar crystals up to 5 cm across giving it an ubiquitous porphyritic texture. Both orthoclase and plagioclase (An_{15-20}) form the feldspar and unlike that in the Lockers Bay Granite show no evidence of being prophyroblastic. Perthite intergrowths are common in the orthoclase. The plagioclase shows excellent zoning and is rarely heavily sericitized. Quartz is relatively fresh with curved or embayed grain boundaries common to all ninerals. Biotite is generally present with accessory apatite, chlorite and opaques. The rock falls in the granodiorite-granite range.

2.1.5 Garnetiferous Granite

Garnetiferous granites are quite common throughout the map-area. Although not important volumetrically this rock type may be found as veins cutting the Hare Bay and Traverse Brook Gneiss, the Lockers Bay Granite (see Plate 13) and other deformed granite bodies. These veins post-date the gneissic banding (see Plate 14) but pre-date the steep cataclastic foliation that affects all these rocks (see Plate 15). A few veins of garnetiferous granite have been found cutting the Middle Brook Granite. Both host and garnetiferous granite show no deformation in these rare occurrences (see Plate 16). Thus the garnetiferous granites are likely to be of at least two ages:

Plate 13. Garnetiferous granite vein cutting the Lockers Bay Granite pre-tectonically (south of Lockers Bay).

Plate 14. Garnetiferous granite vein cutting gneissic banding in the Traverse Brook Gneiss (Traverse Pond).

Plate 15. Garnetiferous granite vein cutting Hare Bay Gneiss. The vein shows the late cataclastic foliation which overprints the gneissic banding (Hare Bay).

Plate 16. Undeformed garnetiferous granite vein cutting Middle Brook Granite (Traverse Pond).

one pre-dating the cataclastic deformation when introduction of such granitic material was widespread; and one post-dating the Middle Brook Granite, itself a post-tectonic body. The younger veins are rare. Undeformed garnetiferous granite veins may rarely be found cutting the deformed rocks as well.

The garnetiferous granite veins are generally aplitic but may also be pegmatitic. They are generally characterized by a white color and conspicuous, rose coloured garnets. Plagioclase is ubiquitous and may represent 20 per cent of the rock. Both microcline and orthoclase occur in proportions up to 35 per cent. All veins are rich in quartz (generally 35-40 per cent) and muscovite is present in all aplite veins sampled, representing greater than 5 per cent. Large muscovite crystals occur locally in the pegmatite veins. Garnet, apatite, biotite (chlorite) and sericite occur in accessory proportions. Most of the garnets are subhedral to euhedral (see Plate 17) and the foliation forms augen around them. The foliation is generally cataclastic, being defined by elongated, sutured grains of quartz and feldspar and oriented muscovite. The veins may vary from granodiorite to quartz monzonite in composition.

2.1.6 Foliated medium grained granites

At Trinity Bay in the northeast part of the map area (Fig. 3) fine grained, roughly equigranular granites intrude the Traverse Brook Gneiss and one body intrudes the contact of the Lockers Bay Granite and the Traverse Brook Gneiss. The latter is characterized by the presence of variable amounts of biotite. Also, it has the same

Plate 17. Euhedral garnet in a garnetiferous granite vein (crossed nicols).

Plate 18. Massive, coarsely porphyritic, Newport Granite (Lewis Island).

foliation as the Lockers Bay Granite which becomes mylonitic in narrow zones within the equigranular biotite granite. The other bodies contain muscovite, are generally leucocratic, and the intensity of the fabric within them varies.

2.1.7 Newport Granite

The granite that underlies the eastern half of Lewis Island in Trinity Bay and onshore north of that island (Fig. 3) forms part of a larger pluton known as the Newport Granite (Strong et al., 1974). This granite intrudes post-tectonically the Hare Bay Gneiss and the Lockers Bay Granite.

The Newport Granite is an extremely coarse grained porphyritic pluton (see Plate 18). The feldspar crystals are predominantly orthoclase (up to 40 per cent) with local development of oligioclase (up to 20 per cent). These crystals are generally square and surrounded by smaller grains of quartz and biotite. The quartz shows little straining with only local development of undulose extinction. The biotite shows ragged grain boundaries. Sericitization is prevalent in the plagioclase.

Close to its contact with the country rocks the Newport Granite becomes weakly foliated. This makes it difficult superficially to distinguish from the Lockers Bay Granite along the contact between the two. However, it is possible to distinguish xenoliths of the Lockers Bay Granite within the Newport Granite close to the contact (see Plate 19) showing conclusively the post-tectonic intrusive

Plate 19. Lockers Bay Granite xenoliths with strong foliation (pencil) surrounded by undeformed Newport Granite. (North shore of Trinity Bay).

Plate 20. Foliated crystal tuff, Love Cove Group (peninsula south of Hare Bay).

nature of the latter.

2.2 Avalon Zone

2.2.1 Love Cove Group

The term Love Cove Group was proposed by Jenness (1963) for two narrow belts of metamorphosed and deformed volcanic and sedimentary rocks that strike in a northeast-southwest direction in Bonavista Bay and continue southwards for several kilometres. In the map area the Love Cove Group forms a narrow continuous lithological unit that runs throughout the central part of the map area (Fig. 3). It is bounded to the northwest by the Dover Fault and is in fault contact with the Musgravetown Group to the southeast. Total exposed width does not exceed 2 kilometres.

For the most part the Love Cove Group is represented as a series of acid pyroclastic rocks and flows with minor interbedded sedimentary rocks. Locally, intermediate to mafic volcanic rocks occur. Crystal tuffs are common (see Plate 20) throughout the sequence showing broken feldspar crystals in an acidic matrix. A crude primary banding is also developed along with local epidotized volcanic bombs. These tuffs are interbedded with cherty horizons and locally contain lenses of very fine, laminated, tuffaceous sedimentary rock. The latter locally shows evidence of soft sediment deformation, i.e. slump folds.

Flow banded and porphyritic rhyolites are common units and are commonly interbedded with the crystal tuffs. Locally, possible ignimbrites are present, i.e. due to severe tectonic overprinting it is difficult to determine whether or not the flattened fragments have a primary component. However, there does appear to be an eutaxitic structure developed. Coarse grained agglomerates (see Plate 21) are well exposed south of Dover along with the only occurrence of autobrecciated rhyodacite.

A small band of medium grained sandstone occurs in a tight syncline on the peninsula south of Hare Bay. Such occurrences of coarse, clastic material are rare. The southeast shore of the same peninsula is underlain by a series of fine-grained, well laminated tuffs. Presumably these were water lain and may well have been reworked.

Bedding is difficult to discern in the volcanogenic sedimentary rocks. Where developed it varies from a few millimetres thick in the fine tuffaceous bands to several centimetres in the coarse crystal tuffs. The interbedded volcanic flows are several metres thick (up to 100 metres) but generally thinner than the tuff units (up to 500 metres).

The Love Cove Group is deformed by an intense cataclastic foliation. This fabric is steep, northeast trending and passes gradationally into mylonites of the Dover Fault. Within the Love Cove Group it is axial planar to isoclinal, upright, moderately plunging (NE) folds. The cataclastic nature of the deformation makes subtle destinctions between volcanic units difficult in thin section.

Plate 21. Coarse agglomerate in the Love Cove Group. Looking on a steep foliation plane (Dover).

Plate 22. Coarse sandstone showing graded bedding in the Musgravetown Group (south shore of Content Reach).

In fact only two broad categories emerge: the acid flows and the volcanogenic sediments. In the former, phenocrysts are reduced to porphyroclasts of oligoclase and orthoclase. These crystals are broken and displaced with a severely sutured, elongated quartz-rich groundmass. The latter defines a penetrative foliation which forms augen around the broken crystals. Sericite and locally, chlorite are present and in part define the fabric. In the autobrecciated rhyodacite epidote and leucoxene occur in accessory proportions, but are restricted to the matrix. By volume the most important volcanic unit in the Love Cove Group is the crystal tuff. The original shape of the crystals have been destroyed by the cataclastic deformation and are now resolved as porphyroclasts. Generally plagiocalse (An_{30}) forms the larger porphyroclasts surrounded by a very fine matrix of chlorite, epidote, sericite, quartz and fine feldspar. The matrix may contain 80 per cent epidote, sericite and chlorite. The finely laminated sedimentary rocks show no porphyroclasts and the laminations are defined by epidote, sericite and chlorite. The classification of these rocks as tuffs, flows, sediments, etc. is based mainly upon field observations. In thin section, the effects of severe cataclastic deformation has destroyed all but the coarsest primary textures.

2.2.2 Musgravetown Group

The term Musgravetown Group was proposed by Hayes (1948) for a thick succession of red and green clastic sedimentary rocks and interbedded volcanic rocks in Bonavista and Trinity Bays. Jenness (1963) extended this group into northern Bonavista Bay. Within the field area the Musgravetown Group underlies the southern shore of Lockers Bay Reach, Lockers Flat Island and Deer Island (Fig. 3). Its northwestern margin is in fault contact with the Love Cove Group approximately 1 km west of Cat Bay Gut. Its boundary to the southeast is not exposed in the map area.

This Group has not been studied in great detail by the writer and, hence, has not been subdivided into formations in this study. However, in general, the lowest part of the Musgravetown Group exposed in the area outcrops on the south shore of Lockers Reach. There, essentially well bedded green and red sandstones outcrop (see Plate 22). The sandstone beds vary from 15 to 30 cm thick and locally contain pebbly horizons. Minor interbedded shales and siltstones also contain sandy lenses.

Overlying the greenish sandstones is a red, coarse conglomerate (see Plate 23). Poorly bedded (locally beds are 1 to 2 metres thick), this conglomerate contains pebbles of rhyolite, sandstone, acid pyroclastic rocks and volcanic flows, jasper, granite and red shale fragments. Volcanic detritus predominate and some of the pebbles look similar to deformed rocks of the Love Cove Group. (In the south the basal conglomerates of the Musgravetown Group are quite rich in detritus identical to the deformed rocks of the Love Cove Group). Locally minor red sandstone beds several centimetres thick are interbedded with the red conglomerate.

Rocks on Lockers Flat Island and in the core of a syncline

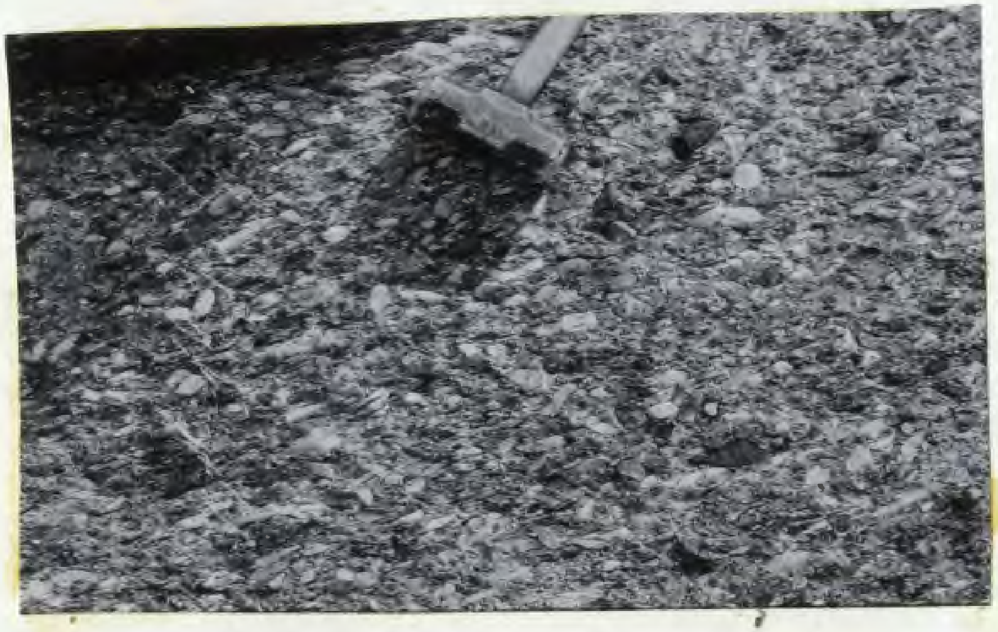


Plate 23. Conglomerate within the Musgravetown Group (south shore of Content Reach).

Plate 24. White quartzite bed interbedded with grey sandstone at its base (Musgravetown Group?, west end of Lockers Flat Island).

immediately onshore (Fig. 3) post-date the red conglomerate unit and consist of greyish-green shales and sandstones. These rocks do not differ too greatly from those underneath the red conglomerate. However, the presence of a white quartzite bed some 3-5 metres thick on the western end of Lockers Flat Island (see Plate 24) has led Jenness (1963) to conclude that these rocks belong to the Random Formation. The quartzite bed itself is interbedded at its base with grey sandy beds and shales, i.e. contact is gradational.

The rocks on Deer Island would appear to be part of the same sequence but their position is unknown. There, also, the Musgravetown Group is characterized by reddish grey sandstones and shales with red conglomerate horizons. Bedding thickness is similar to that previously described.

Primary sedimentary structures are common in the Musgravetown Group. Cross-bedding, slump-folding, ripple-marks (see Plate 25), channel structures and graded bedding are all represented. The only tectonic structure is a slaty cleavage which is preferentially developed in the fine grained beds. The coarser beds generally exhibit a weak fracture cleavage. The cleavage is axial planar to broad, open, northeast plunging folds. This deformational style and intensity, contrast sharply with the Love Cove Group which is separated from the Musgravetown Group by a fault.

2.3 Dover Fault Zone

The Dover Fault forms the southeastern limit of the Gander

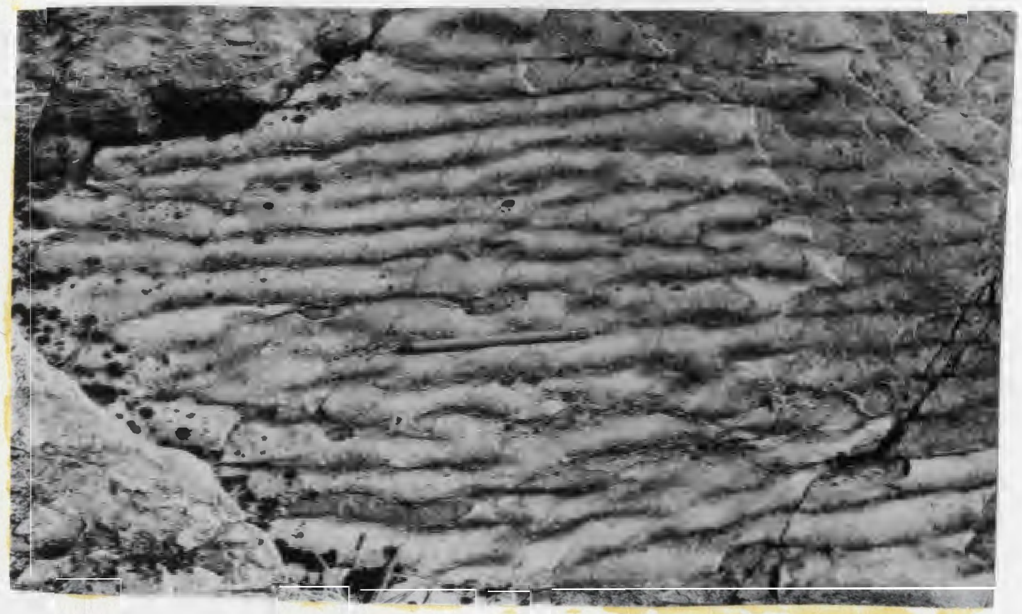


Plate 25. Ripple marks in fine sandstone of the Musgravetown Group? (Lockers Flat Island).

Plate 26. Mylonite within the Dover Fault Zone (section north of Dover).

Zone and the northwestern limit of the Avalon Zone, running in an apparent northeast curved direction throughout the central portion of the map area (Fig. 3). Its true width is not easily defined but is generally taken to include mylonitized rocks whose protoliths are difficult to determine. Fortunately continuous exposure does make it possible, except within the fault zone, to say whether the mylonite had a Gander Zone granite or a Love Cove volcanic rock as a protolith. On this basis the fault zone varies in width from 300-500 metres.

As previously described, the Dover Fault granites grade into mylonite of the Dover Fault Zone. As the grain size of the granite is cataclastically reduced the rock becomes banded, superficially resembling rhyolite (see Plate 26). Locally, the growth of epidote and chlorite may give this rock a green color. When this occurs it is very difficult to distinguish from cataclastically deformed crystal tuffs of the Love Cove Group which grades into the fault from the other side. Thus there is a portion within the central part of the Dover Fault Zone where only mylonitized rock exists and distinction between Gander and Avalon Zone rocks is impossible.

The best exposed cross-section throughout the Dover Fault is the coastal section north-east of Dover. There all gradations described above are represented. Also protoliths of a Dover Fault granite and crystal tuffs of the Love Cove Group are preserved within the fault zone. These protoliths are represented as blocks (greater than 100 metres across) surrounded on either side by mylonitized rock of uncertain origin.

The mylonitic fabric within the Dover Fault is intense, generally subvertical and trends in a northeast direction. It passes northwestwards into the late cataclastic foliation which overprints the gneisses and deforms the Lockers Bay Granite of the Gander Zone and southeastwards becomes the single, penetrative, cataclastic foliation which deforms the Love Cove Group of the Avalon Zone. Locally the mylonitic foliation is folded by upright, small-scale folds. These are related to drag folds along later faults within the zone.

The Dover Fault is conspicuous as a topographic feature within the map area. It is a zone of low relief which is controlled by the post-mylonitic brecciation that occurs along the fault zone. This brecciation may, in part, be related to fluidization processes, since the disoriented mylonite fragments are not bounded by shear surfaces but "float" in a massive chloritized matrix (see Plate 27). The formation of epidote in the most finely comminuted rocks may be related to this process.

Plate 27. Brecciated mylonite within Dover Fault Zone (section north of Dover).

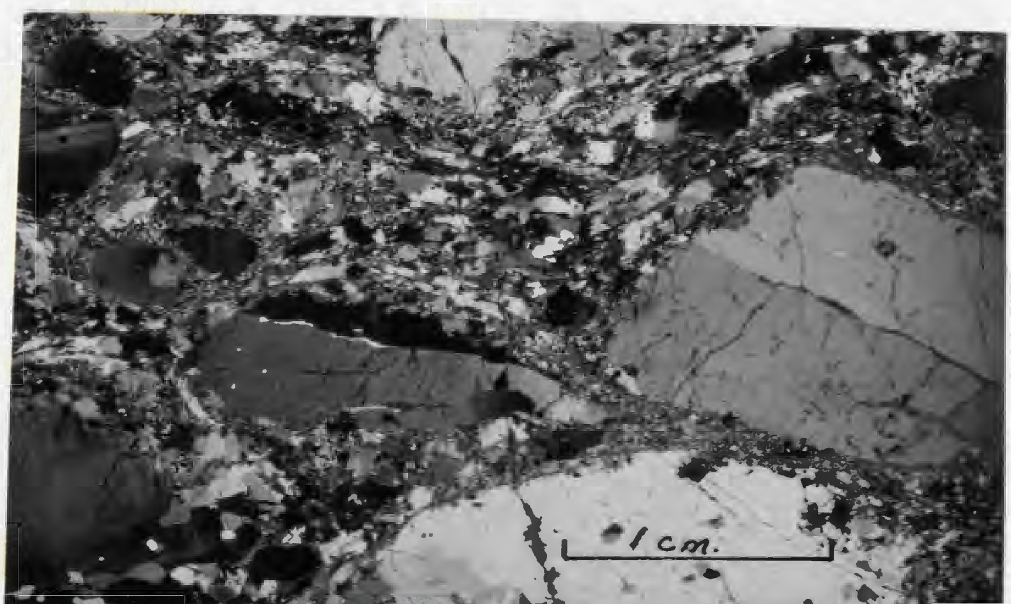


Plate 28. Cataclastic foliation (defined by elongated quartz, oriented biotite, and comminuted microcline) forming augen around the large K-feldspar megacrysts in the Lockers Bay Granite. (crossed nicols).

CHAPTER III

STRUCTURAL GEOLOGY

3.1 Introduction

The most prevasive structure in the map-area is a fine, penetrative cataclastic foliation which is common to both the Gander and Avalon Zones. Within the Gander Zone this foliation is superimposed upon the gneissic banding of the Bonavista Bay Gneiss Complex and is strongly developed in some of the granites which post-date the gneisses eg. the Lockers Bay granite and the Dover Fault granite. Within the Avalon Zone the same cataclastic foliation is axial planar to isoclinal folds of the Love Cove Group. The Dover Fault is a major mylonite zone marking the boundary between the Gander and Avalon Zones.

Structures which post-date the regional cataclastic foliation are represented by a preferentially developed slaty cleavage in the Musgravetown Group of the Avalon Zone and by a wide-spaced locally developed strain-slip cleavage in the Love Cove Group. In the Gander Zone, later structures are represented by local development of a strain-slip foliation and small shear zones. Cutting both the Gander and Avalon Zones are several high-angle faults.

The minimum age of deformation may be determined for some of the structures. This is based essentially on Love Cove-Musgravetown Group relationships. The latter is essentially Late Hadrynian in age (Jenness, 1963) and post-dates the deformation of the Love Cove Group. Therefore the regional cataclastic foliation and the associated Dover

Fault is Precambrian. The gneissic banding could be considerably older than this (Helikian?) and the post- Dover Fault strucutres are probably of Paleozoic age.

3.2 The Cataclastic Foliation

The Dover Fault separates the strongly contrasting geology of the Gander and Avalon Zones. However, the regional cataclastic foliation with which the fault is associated is common to both zones. This foliation has a north to northeast trend and steep dips generally to the west. Regionally the change in strike is reflected by a similar change in the trend of the Dover Fault (Fig. 3).

3.2.1 The Gander Zone

The cataclastic foliation is best developed in some of the granitic rocks of the Gander Zone. These include the Lockers Bay granite, the Dover Fault granites, garnetiferous granite veins and other deformed minor intrusive rocks. Within these rocks it is the only foliation developed (cataclastic terminology after Higgins, 1971).

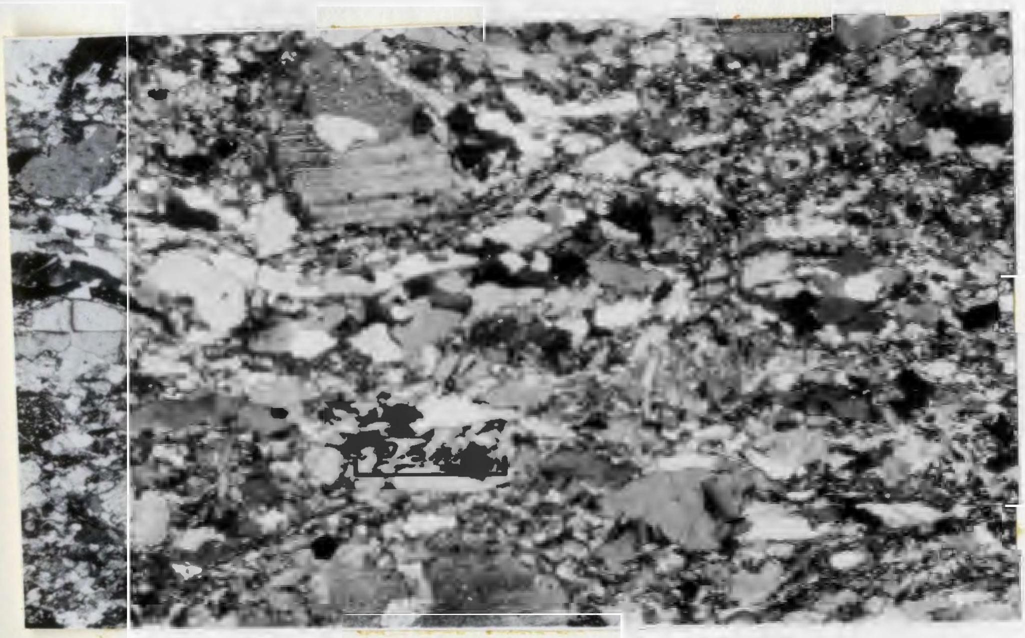
The foliation within the Lockers Bay granite and the Dover Fault granites is representative of the late deformation. In the Lockers Bay Granite it is fine, penetrative, and defined by oriented biotite, elongated quartz and crushed feldspar (see Plate 28). The cataclastically deformed minerals form augen around the large microcline megacrysts. Commonly, the feldspar megacrysts have "tails" of finely comminuted material in their lee which taper off within the planes of the foliation. Broken crystals also occur. The cataclastic foliation within the Lockers Bay Granite is ubiquitous.

Garnetiferous granite veins cut the Lockers Bay granite pre-tectonically and now exhibit the same single cataclastic foliation (see Plate 13). These veins are widespread and also cut the gneissic banding of the Bonavista Bay Gneiss Complex. Rarely, undeformed garnetiferous granite veins cut the deformed terrane as well as the undeformed Middle Brook Granite.

The cataclastic foliation is most strongly developed in the Dover Fault granites. Near the contact with the gneissis it can be recognized as a single, penetrative foliation in both rock types. As the Dover Fault is approached this deformation reduces the Dover Fault granites to a streaked-out, finely comminuted, pink mylonite (see Plate 26). This involves the gradual mechanical breakdown of the granites (see Plate 29) over a distance of 1/2 to 1 kilometre. The quartz becomes intensely elongated and feldspar crystals are reduced to mere streaks, both of which form augen around surviving feldspar porphyroclasts (see Plate 30). Chlorite (after biotite) is also present and is strongly oriented.

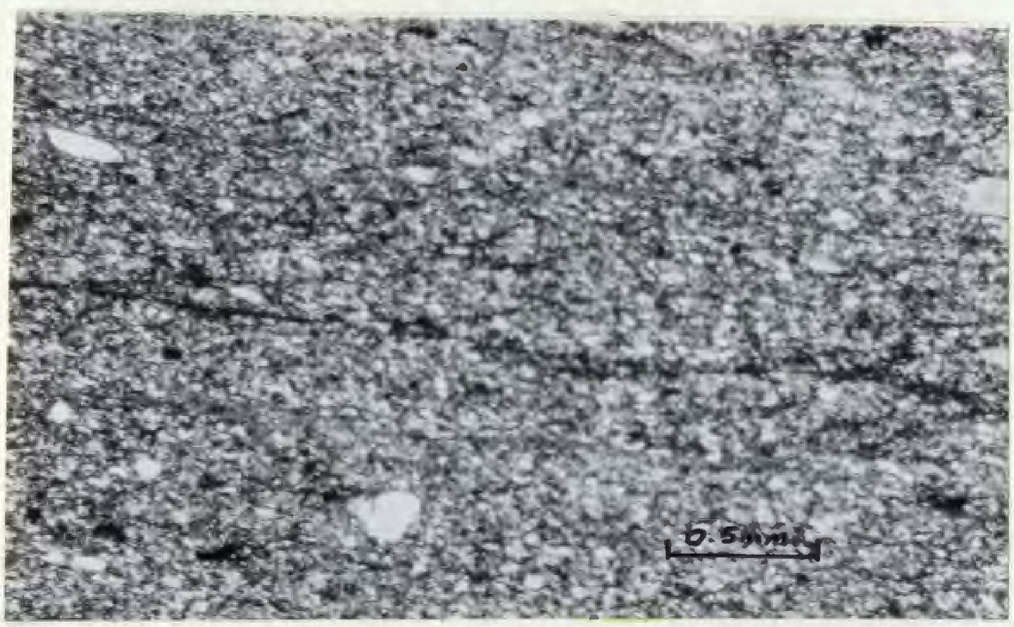
The cataclastic foliation is not always obvious in the gneissic terrane since it and the gneissic foliation are sub-parallel i.e., Locally the superimposed foliation is axial planar to tight isoclinal folds of the gneissic banding; in this fashion the gneissic banding has been transposed into parallelism with the later structure. Apart from directly observing it cutting the gneissic banding in fold

a. Coarse Protomylonite



b. Fine Protomylonite

c. Mylonite



d. ultramylonite

Plate 29 a-d show the progressive cataclastic break-down of a Dover Fault granite from protomylonite through to ultramylonite (crossed nicols) (section north of Dover).

noses, there are three criteria that may be used to detect the late foliation: (1) The Lockers Bay granite intrudes both the Hare Bay and Traverse Brook Gneisses. Along the contacts the cataclastic foliation into the Lockers Bay can be traced directly in the gneisses where it re-folds and transposes the earlier structures; (2) ubiquitous garnetiferous granite veins cut the gneissic foliation and are subsequently deformed by the late deformation; (3) feldspar porphyroblasts overprint the gneissic banding locally. The late foliation forms augen around these porphyroblasts (see Plate 31).

Narrow zones of mylonite less than 1 metre wide occur in the gneisses. These zones represent a local intensifying of the late foliation, generally with proximity to the Dover Fault (see Plate 32).

On the basis of field relationships just discussed it is possible to conclude that within the Gander Zone a regional penetrative cataclastic foliation overprints the gneisses and deforms some of the intrusive granite rocks eg., the Lockers Bay Granite and the Dover Fault granites. It is most obvious in the granitic rocks which prior to deformation were structurally isotropic; its main effect on the gneisses is to re-fold and transpose the earlier anisotropy. With proximity to the Dover Fault the regional cataclastic deformation increases and eventually merges with mylonites within the fault zone.

Several microscopic structures confirm the cataclastic nature of the regional deformation just described. Those developed in the Lockers Bay Granite are representative (except the foliation in the Dover Fault granites which is much more intense due to proximity with

Plate 30. Feldspar porphyroclasts in a Dover Fault granite. Note development of "tails" (Maccles Lake).

Plate 31a. Feldspar porphyroblasts overprinting the gneissic banding in a large raft of Hare Bay Gneiss within the Traverse Brook Gneiss (Hare Bay Pond).

Plate 31b. Feldspar porphyroblasts overprinting the gneissic foliation of the Hare Bay Gneiss and the late cataclastic foliation clearly forms augen around them. (North of Maccles Lake).

Plate 32. Narrow mylonite zone within the Hare Bay Gneiss (Lockers Bay).

the fault zone).

Quartz grains show clear evidence of intense strain: undulose extinction, development of sub-grain boundaries, severe elongation in narrow zones and sutured grain boundaries. The deformed quartz, along with strained grains of biotite/chlorite, define the foliation. Commonly, crushed or finely comminuted grains of feldspar (mainly microcline) occur with the quartz in zones between the large microcline megacrysts. These zones, along with biotite and elongated quartz, form augen around the microcline megacrysts. These feldspar megacrysts are also affected, in that simple twin planes in orthoclase are commonly irregular and diffuse due to straining of the crystal. Another feature is the rimming of the megacryst by crushed material derived from the same crystal. These pieces of crushed feldspar also become localized in the lee of the large crystals producing "tails" (see Plate 33). Thus the feldspars appear to be breaking down along their grain boundaries. Feldspar megacrysts also become broken and displaced and may be fitted, "jig saw" fashion, back into their original configuration.

3.2.2 The Avalon Zone

The oldest deformed rocks of the Avalon Zone belong to the Love Cove Group. This sequence of volcanic rocks with minor interbedded sediments has been subjected to severe cataclastic deformation. The result is a very fine, penetrative foliation which trends northeast and has steep to vertical dips. Within the Love Cove Group this

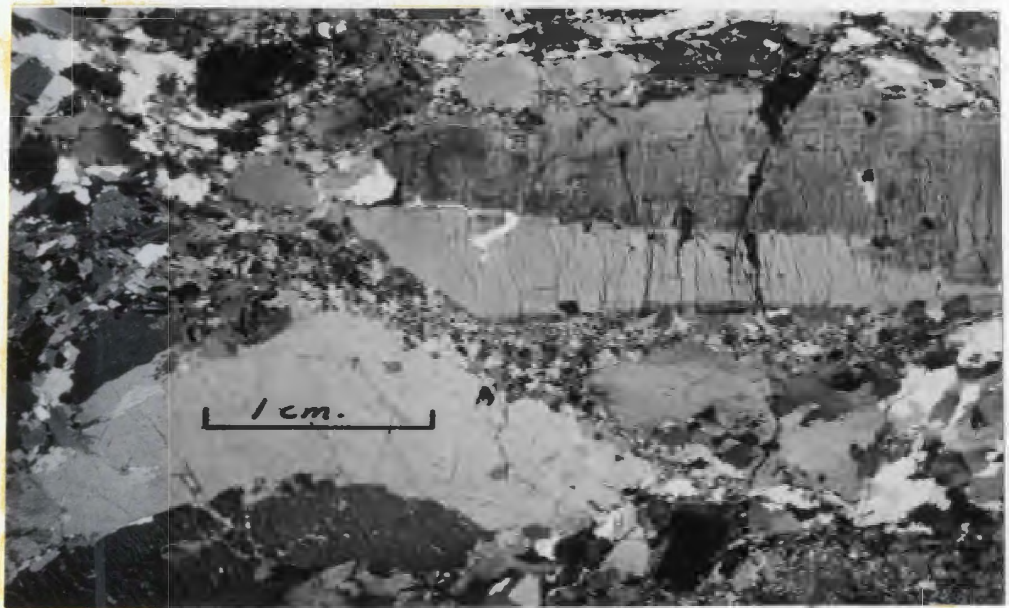


Plate 33. Microcline megacrysts in the Lockers Bay Granite showing, the development of "tails" - pieces of feldspar are broken off the parent megacryst, localized in their lee and taper off in the plane of the strong cataclastic foliation(crossed nicols).

Plate 34. Minor F_1 fold in finely laminated tuffs of the Love Cove Group (from protolith within the Dover Fault zone, north of Dover.

cataclastic foliation is axial planar to tight, upright isoclinal folds, i.e., peninsula southeast of Hare Bay. These folds plunge moderately to the northeast within the map-area. The plunge is estimated by the intersection of the main foliation and primary layering in the volcanogenic sediments in plan veiw. Seldom are first-phase, small scale structures developed. However, finely laminated cherty horizons in the crystal tuffs locally show F_1 folds (see Plate 34). These minor structures confirm the large scale structures outlined.

To some extent the effects of the cataclastic foliation depends upon the composition of the volcanic rocks. It is readily descernible in the crystal tuffs where it forms augen around the broken crystal fragments (mainly plagioclase). The matrix is generally too fine grained to observe in the field just what minerals define the foliation, which is resolved mainly by a fine parting in the rock. Phenocrysts are elongated in the planes of the foliation with "tails" commonly developed, similar to those on feldspar megacrysts in the Lockers Bay Granite (see Plate 35). The rare basic volcanic horizons in the Love Cove Group become quite strongly flattened and sheared due to differential movement between them and acid units, resulting in narrow zones of chlorite schists. The acidic flows may show little overt signs of deformation. However, where porphyritic, the small quartz and feldspar eyes are flattened.

The most important aspect of the deformation of the Love Cove Group is its direct correlation with the Dover Fault. As the fault zone is approached from the Avalon Zone the foliation in the Love Cove

Plate 35. Severe cataclastic deformation in crystal tuffs of the Love Cove Group. Some crystal fragments survive as porphyroclasts (peninsula south of Hare Bay).

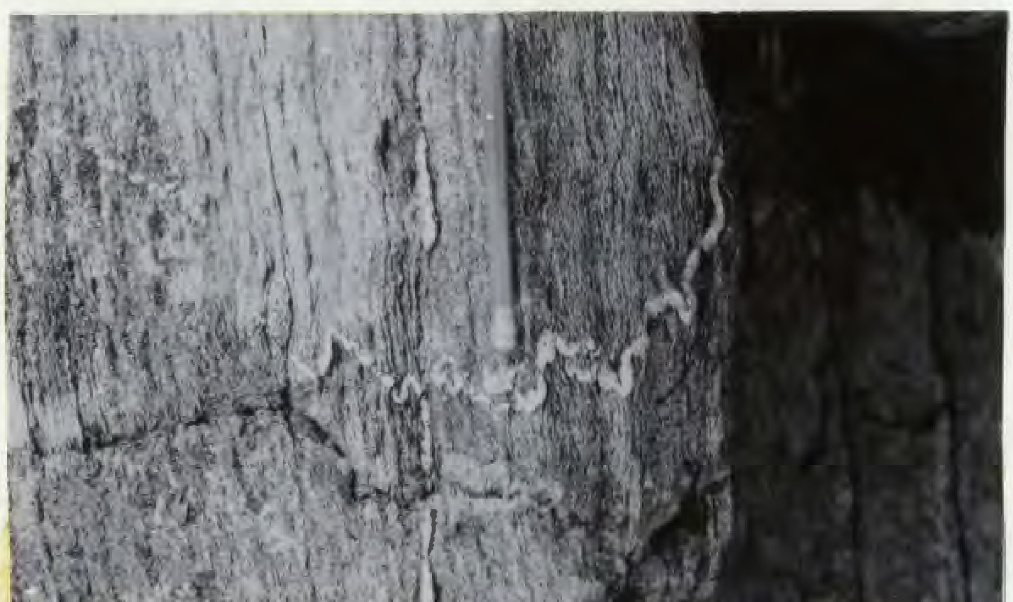


Plate 36. Mylonitized crystal tuffs of the Love Cove Group close to the Dover Fault (Dover).

Group becomes more intense. Eventually it passes gradually into mylonites of the Dover Fault Zone. On the margins and within the Dover Fault, Love Cove Group volcanic rocks are reduced to a green finely banded mylonite (see Plate 36).

It is very difficult to recognize primary volcanic features in thin sections of the Love Cove volcanic rocks. This is because the regional cataclastic foliation has for the most part destroyed these small-scale features. In the crystal tuffs fine bands of severly crushed material alternate with bands containing porphyroclasts that are larger and more prominent (see Plate 37). The fine bands are probably fluxion lines but may also represent an original variation within the crystal tuff. In all the rocks the matrix quartz and feldspar show strongly sutured grain boundaries with the elongated quartz generally defining the foliation. Fine grains of sericite and larger grains of chlorite are also oriented and along with elongated quartz form augen around the surviving porphyroclasts. In some specimens the foliation is undoubtedly defined by finely crushed zones (fluxion lines) (see Plate 38). Commonly the porphyroclasts are fractured with actual displacement occurring between two pieces of the same crystal (see Plate 39). These fracture planes intersect the main external fabric at a moderate angle, a common feature in rocks deformed by a simple shear mechanism (Fig. 4).

The main foliation which deforms the Love Cove Group is demonstratably cataclastic like that which overprints the Gander Zone. From both sides this foliation can be demonstrated to merge into the

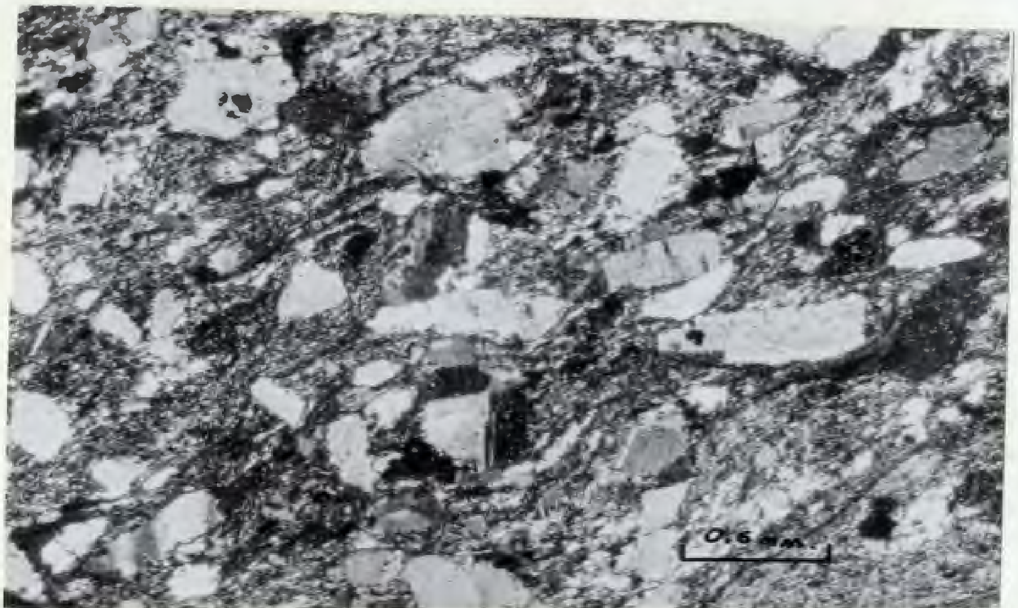


Plate 37. A strong, cataclastic foliation forming augen around feldspar porphyroclasts in crystal tuffs of the Love Cove Group (crossed nicols).

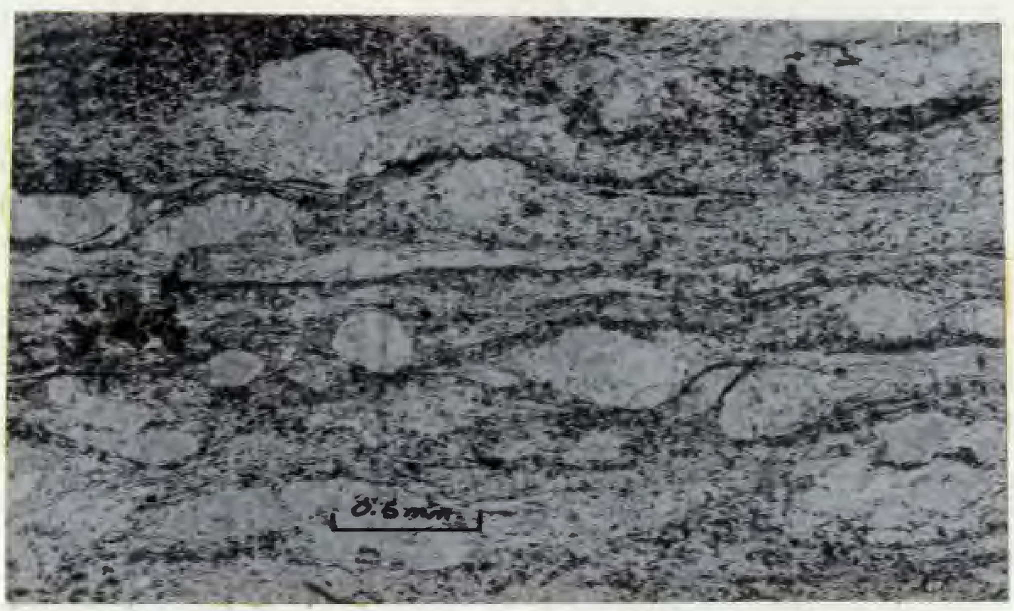


Plate 38. Fluxion lines in mylonitized volcanic rocks of the Love Cove Group (Plane light).

Plate 39. An oligioclase crystal broken and displaced along a micro-shear zone which intersects the main cataclastic foliation (NE-SW in picture) at approximately 45°. Love Cove Group crystal tuffs (crossed nicols).

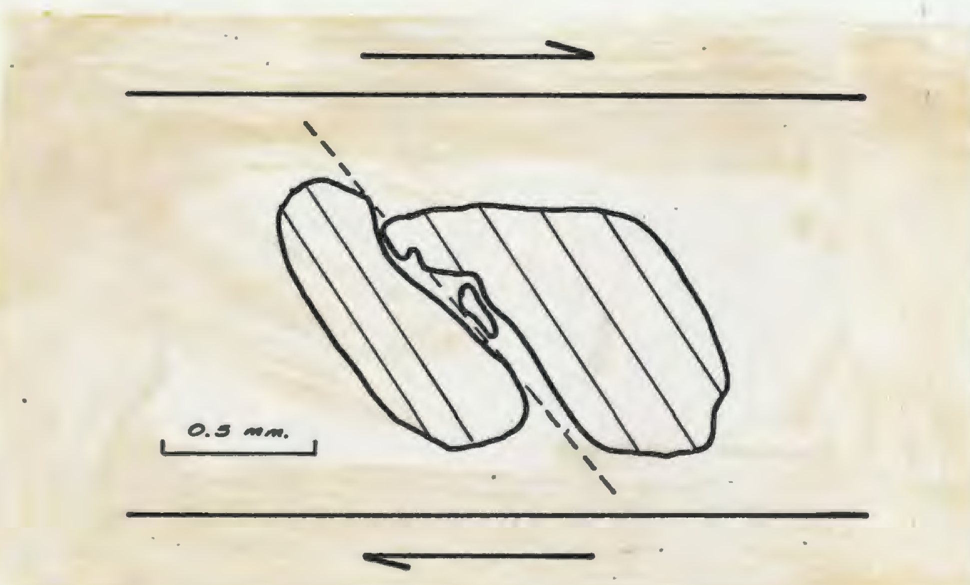


Fig. 4. Individual feldspar crystal is displaced along micro-shear surfaces. (Sketch based upon Plate 39). This implies a simple shear mechanism with sense of shear movement as indicated above. Note: Careful, detailed oriented sampling across the Dover Fault may provide some clue to the fault's latest movement history.

Dover Fault mylonites and are part of the same regional deformational event. It is also clear that the Dover Fault formed in association with that event. (It should be noted that recrystallization or constructive as well as destructive mineral development occurred in association with this cataclastic foliation. Where possible the constructive growths will be outlined in the chapter on metamorphism.)

3.2.3 The Dover Fault Zone

The Dover Fault runs throughout the central portion of the map-area, defined by a mylonite zone some 300-500 metres wide. It has for the most part, a general northeast trend which is slightly curved within the map area. Some of this variation in a general northeast trend may be due to later cross-faults, however, it appears to reflect also the original geometry of the fault zone. The zone is consistently steep (except where modified by later faults, eg. west of Dover).

The major lithologic units of the Gander Zone and the Love Cove Group of the Avalon Zone are disposed in roughly linear belts, parallel to the trace of the Dover Fault. The cataclastic, penetrative foliation which overprints these units is also parallel regionally with the mylonites which define the Dover Fault. As we have seen this foliation merges and becomes one with the mylonites of the fault zone. Hence, the Dover Fault involves both Gander and Avalon Zone rocks, clearly recognizable on its margins. The central portion of the fault zone represents a more intense version of the cataclastic foliation seen in the protoliths.

The Dover Fault Zone exhibits many microstructures typical of mylonitization. Acid volcanic rocks of the Avalon Zone and granites of the Gander Zone lose all original textures. Fluxion lines of finely crushed and comminuted quartz and feldspar along with sericite and chlorite are common. Feldspar porphyroclasts are shattered with segments of the same crystal showing displaced twin lamellae (see Plate 40). Obvious granulation of porphyroclasts occurs with deformation taking place from the margin inwards. In this fashion the porphyroclasts (mainly feldspar with local knots of sutured quartz grains) become rounded i.e., grinding due to differential movement between fluxion lines. Generally a complete range of angular to round crystal fragments may be found.

Locally zones of ultramylonite occur with a very fine banding defined by fluxion lines (see Plate 41). Porphyroclasts rarely occur and the groundmass is extremely fine grained. Generally the introduction of chlorite and epidote in these zones gives the rock a green color.

3.3 Earlier Structures

The complex gneissic banding of the Bonavista Bay Gneiss Complex is the only structure which predate the regional cataclastic foliation in the map area. It is almost impossible to correlate successive deformations in gneisses which exhibit a complex internal structural history. However, some distinctions may be made particularly

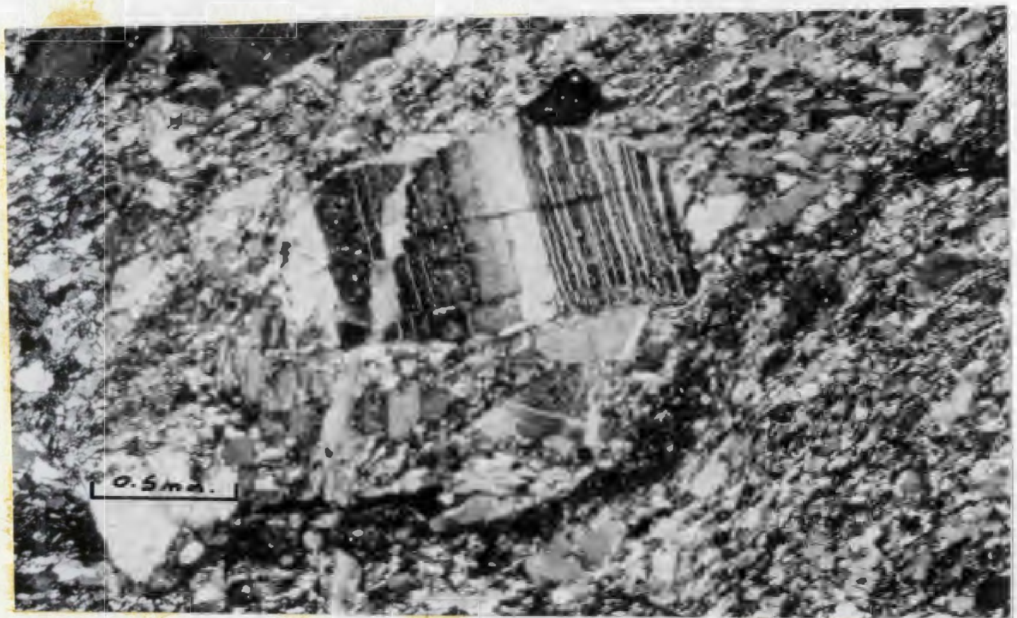


Plate 40. Oligoclase porphyroclast in Dover Fault zone showing micro-displacement of twin lamellae. Note granulation along the bottom edge (crossed nicols).

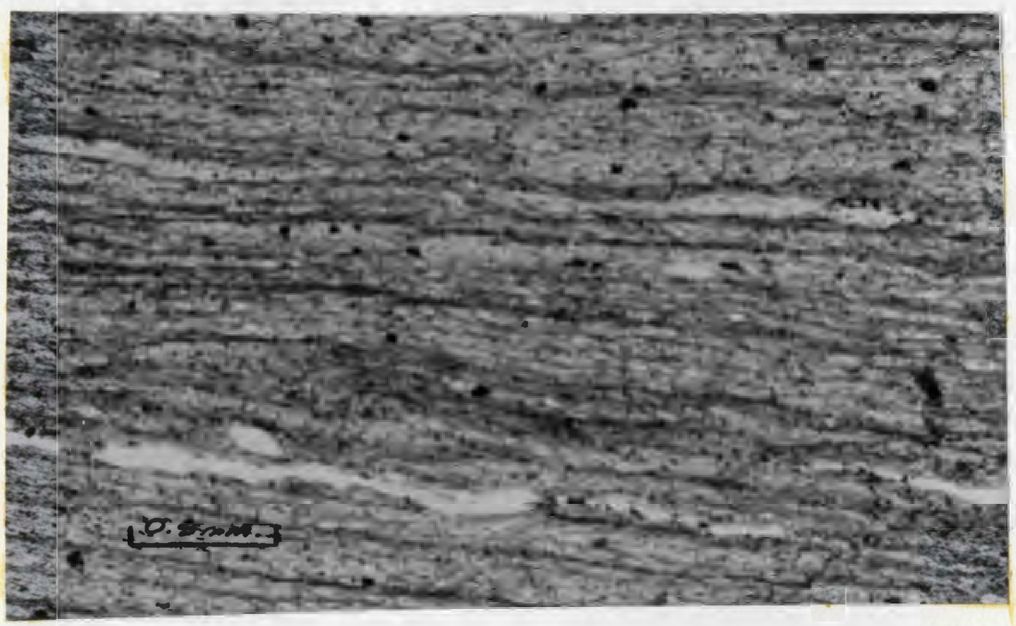


Plate 41. Ultramylonite in Dover Fault zone. Note fluxion lines. (plane light).

between the Hare Bay Gneiss and the Traverse Brook Gneiss.

3.3.1 Hare Bay Gneiss

The gneissic foliation in the tonalitic portion of the Hare Bay Gneiss is a metamorphically segregated banding 2-3 mm wide. For the most part it is regularly developed and has a consistant northeast trend with steep dips. Locally it can become quite complexly folded with Type 1 and 3 interference patterns (Ramsay, 1967) well developed (see Plate 42). These small scale folds, although fairly consistent in trending northeast, have extremely variable plunges demonstrable in any one outcrop. Locally, where refolds are discernable, the first apparent fold of the gneissic banding is an extremely tight isocline whose limbs eventually merge parallel to the trend of the gneissic foliation or are sharply attenuated. The number of deformational events which precede those interfolial folds is difficult to determine. However, the coarse, consistent, metamorphic character of the gneissic banding would suggest an earlier involved history of metamorphic segregation and structural transposition. On this basis the interfolial folds would at the very minimum, be third phase folds, i.e., gneissic banding is composite, making the refolds of a fourth generation. These phases represent the latest structural events now recognizable in the Hare Bay Gneiss and it is likely that a complex tectonic history, as suggested by the very nature of these rocks, pre-date that which is now discernable.

No systematic grouping of small scale structures is possible

Plate 42. Type 1 interference pattern produces an "eye" fold in Hare Bay Gneiss (Dover).

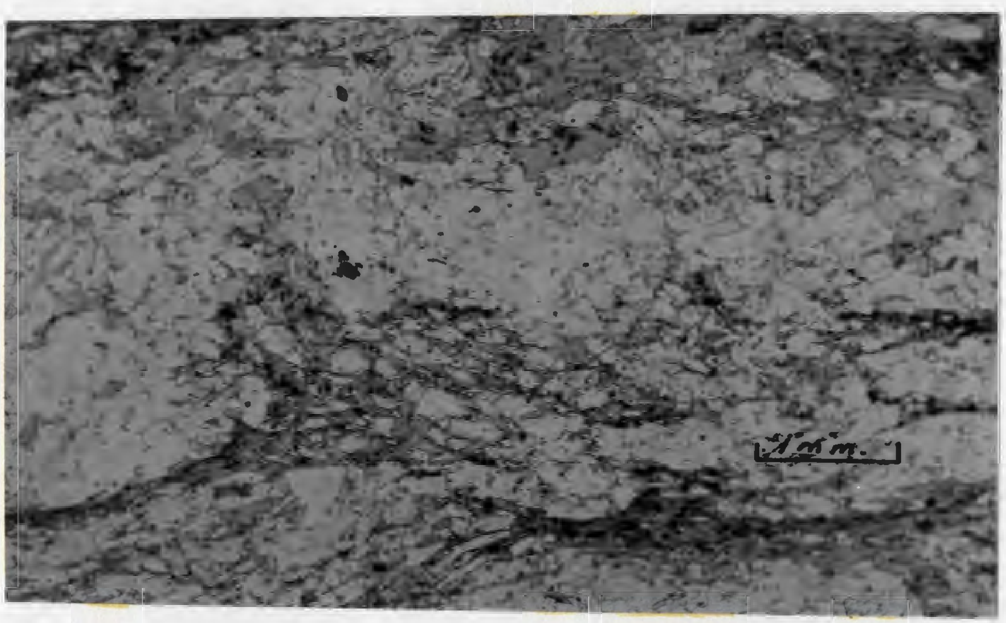


Plate 43. Interfolial fold, defined by early biotite between foliation planes marked by younger biotite, in the Hare Bay Gneiss (plane light).

except for the gneissic banding and the latest re-folds. The latter trend in a general northwest direction, are moderate to tight with vertical axial planes and variable plunges. The trend of these re-folds and the gneissic banding is largely controlled by the super-imposed cataclastic foliation.

The tonalite portion of the Hare Bay Gneiss forms augen around paragneiss xenoliths (see Plate 2). These xenoliths have a clearly defined gneissic foliation which is generally finer and more regular than that in the tonalite host. This foliation in the paragneisses is commonly folded with the axial trace of these folds being at all angles with the external foliation in the tonalitic gneiss.

In thin section the gneisses do not reveal much concerning their structural history. In fact, the gneissic banding, so prominent in outcrop, is generally indistinguishable. Where discernable it consists of alternating bands of quartzo-feldspathic material containing few other minerals, and bands where biotite, muscovite, and chlorite are concentrated. This alternation, not generally well shown in thin section, gives the gneisses their well banded appearance on the out-crop scale. In some sections evidence of transposition is preserved with remanants of an earlier composite (gneissic) foliation contained between the foliation planes of the main gneissic banding. The earlier composite foliation may be preserved as microscopic inter-folial folds (see Plate 43) and as knots of material with an internal composite foliation at an angle to the external main gneissic banding which forms augen around them. It is difficult to determine whether the transposition seen in various sections are all the same age and possibly related to the latest deformation of the gneisses by the cataclastic foliation or represent earlier stages in the structural development of the gneisses. The first case is likely since similar relationships between gneisses and the superimposed foliation are observable in the field.

The grain boundaries of the individual minerals are fairly consistent for all sections studied. Both quartz and feldspar show varying degrees of suturing along grain boundaries. Locally, embayed to curved boundaries are present. Where sutured boundaries are prominent the quartz generally has been elongated, contains many sub-grain boundaries, and exhibits good undulose extinction. The micas (mainly biotite) are oriented and are coarser where defining an earlier foliation than the main gneissosity.

3.3.2 Traverse Brook Gneiss

The Traverse Brook Gneiss is structurally more inhomogeneous than the Hare Bay Gneiss. The gneissic banding is locally and crudely developed, is much coarser than that of the Hare Bay Gneiss and is marked by diffuse bands of segregated material (see Plate 3). The result is that this gneissic foliation is discontinuous and irregular i.e., in the vicinity of Traverse Pond and Western end of Hare Bay Pond.

It has been suggested that the Traverse Brook Gneiss represents a migmatized version of the Hare Bay Gneiss. Numerous xenoliths and large rafts of typical Hare Bay Gneiss occur within the younger gneiss terrane whose foliation forms augen around them (see Plate 4).

The irregular, diffuse, coarse, gneissic foliation typical of the Traverse Brook Gneiss grades into rocks where no clear cut gneissosity is evident in many places. Instead, a strong, penetrative composite foliation replaces the crude gneissic banding and the rock is identical to an intensely deformed granite. An earlier foliation is generally quite visible as a preserved orientation of minerals (mainly biotite and/or muscovite) between the foliation planes of the main fabric. Locally only one penetrative foliation is evident in this gneiss terrane. These changes in the tectonic foliation apparently affect rocks of the same age. They grade into one another with no orderly distribution and represent a common phenomenon in migmatite terranes. It should be noted that the crude gneissic banding is the most common of the three styles.

The Traverse Brook Gneisses exhibits a fairly simple pattern of small-scale folding of the gneissic banding (except for those more complex areas containing rafts of Hare Bay Gneiss). Generally these moderate to tight, variably plunging northeast trending folds are related to the superimposed late foliation (contact between Lockers Bay Granite and Traverse Brook Gneiss, north of Hare Bay Pond; see Plate 44). This differs from the Hare Bay Gneiss where the late foliation folds already isoclinally folded gneissic banding (contact between Lockers Bay Granite and Hare Bay Gneiss, south shore of Lockers Bay; see Plate 45).

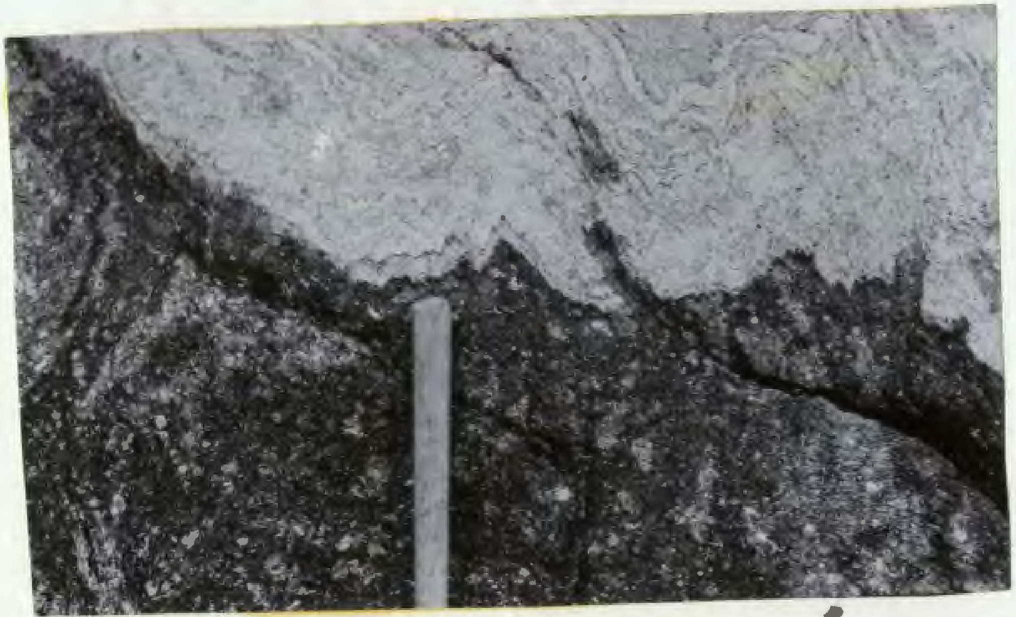


Plate 44. Contact between Lockers Bay Granite (dark area) and Traverse Brook Gneiss. The cataclastic foliation in the granite is axial planar to folds of the gneissic banding (north of Hare Bay Pond).

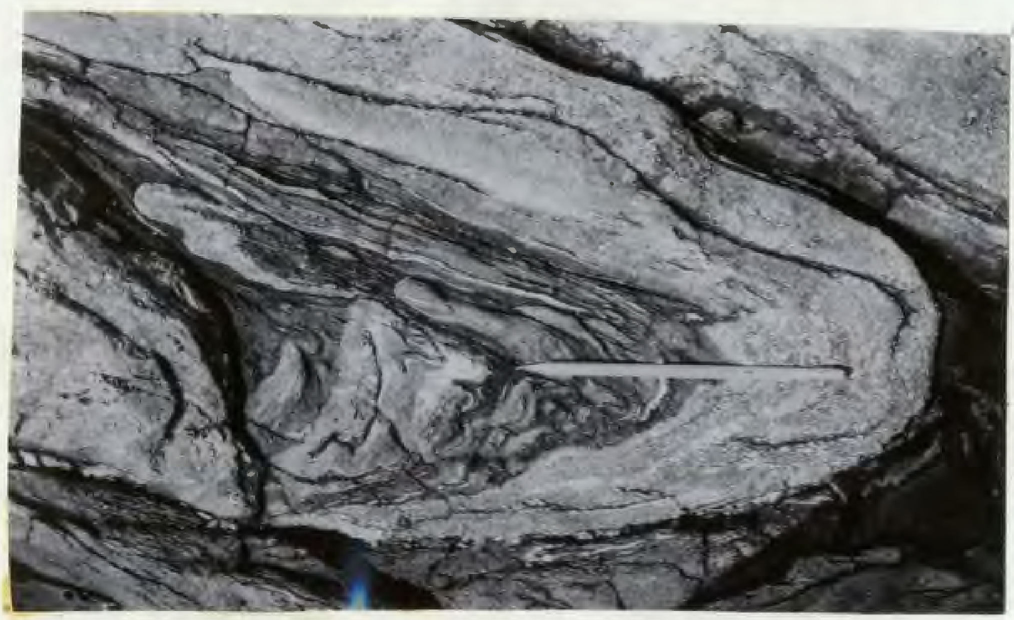


Plate 45. A folded vein of fine-grained Lockers Bay Granite in the Hare Bay Gneiss along contact with same. The axial planar foliation to the folded vein re-folds earlier structures in the gneiss producing a type 3 interference pattern (south shore of Lockers Bay).

The body of granite south of Traverse Pond has similar structural features to the Traverse Brook Gneiss. The foliation within it varies from gneissic (see Plate 46) to a single penetrative one.

The gneissic banding of the Traverse Brook Gneiss is most difficult to outline in thin section. For the most part, a strong alignment of biotite/chlorite and muscovite is all that is evident. Locally, elongated, sutured quartz grains may define the foliation. Where developed, the gneissic foliation is defined by diffuse bands of muscovite, orthoclase, some plagioclase (An_{30}), quartz and rare biotite plus muscovite alternating with bands containing higher proportions of biotite/chlorite and muscovite. Rarely do sharp lines separate these bands and generally no clearly defined boundaries exist. Commonly, evidence of transposition is preserved as microscopic interfolial folds (defined by micas) between the coarsely developed composite foliation planes of the main foliation. Most mineral grains show evidence of being overprinted by the cataclastic fabric. Severely strained and "crushed" feldspars are common along with intensely sutured quartz grains. The feldspars are the coarsest grains, around which the micas form augen.

3.4 Later Structures

Structures which post date the regional cataclastic foliation are developed in both the Gander and Avalon Zones. Except for the cleavage in the Musgravetown Group these structures are small-scale and locally developed.

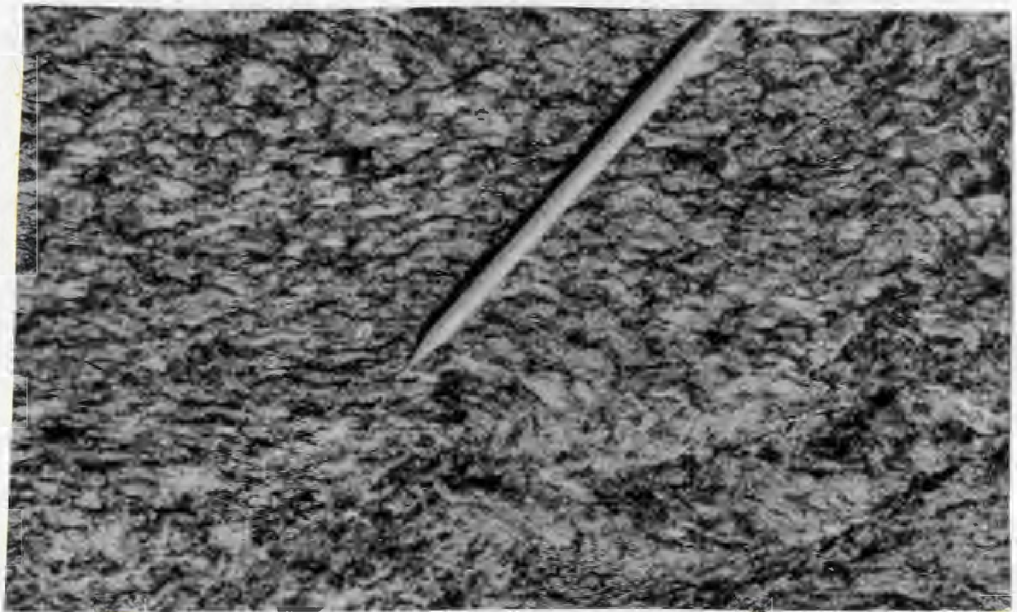


Plate 46. Gneissic foliation in granitic body within the Traverse Brook Gneiss (north shore of Freshwater Bay).

Plate 47. A shear zone which cuts the Lockers Bay Granite after the regional cataclastic deformation (Hare Bay Pond).

3.4.1 Shear Zones

Small shear zones less than 1 metre wide locally cut the deformed granites of the Gander Zone and the Love Cove Group of the Avalon Zone. Within the Lockers Bay Granite and the Dover Fault granites, these zones deform the pre-existing cataclastic foliation (see Plate 47) (east of Hare Bay Pond and south side of Hare Bay respectively). The angle between the shear zone boundaries and the earlier foliation is always shallow (less than 45°) with no apparent rotation of the latter into them. Commonly these shear zones are parallel to the regional foliation in plan but cross-cut it in sections. No evidence of the earlier foliation is preserved within the zones and the granites are progressively mylonitized from their margins in towards the center of the zones. Similar zones cut the cataclastic foliation of the Love Cove Group (east of Dover Fault, south side of Freshwater Bay). These zones exhibit no systematic distribution and are possibly related to later movement along the Dover Fault.

3.4.2 Strain-Slip Foliation

A locally developed, widely spaced, strain-slip foliation transposes the main foliation in the Love Cove Group (see Plate 48). It generally has a north-northeast trend and with steep easterly dips (coastal exposure west of Cat Bay Gut). Locally the transposition is less complete and this later deformation is resolved as small-scale, moderately tight, folds or kinks of the cataclastic foliation. This structure also overprints mylonites of the Dover Fault Zone (north-

Plate 48. Widely spaced locally developed, strain-slip foliation in fine tuffaceous rocks of the Love Cove Group. S_1, barely seen in this photograph, is parallel to pencil (peninsula south of Hare Bay).

east of Dover) and some of the deformed granite rocks of the Gander Zone (garnetiferous granite, south shore of Freshwater Bay). It may be associated with either later movement along the Dover Fault or the deformation of the Musgravetown Group (see below).

3.4.3 Slaty Cleavage in Musgravetown Group

The deformational style affecting the Musgravetown Group contrasts sharply with that of the Love Cove Group. These contrasts occur abruptly across a high-angle fault which separates the two groups west of Cat Bay Gut. A preferentially developed, northeast trending, moderately west and east dipping cleavage deforms the siltstones, sandstones and conglomerates of the Musgravetown Group (see Plate 49). It is much more prominent in the fine grained silty horizons than in the massive sandstone units. It is also more widely spaced than the fine foliation in the Love Cove Group. Individual clasts (lithic and mineral) are not flattened or elongated on the cleavage planes. Conglomerate horizons and other coarse grained units exhibit a coarse fracture cleavage. The cleavage is axial planar to large scale open-folds which plunge gently or moderately to the northeast. These folds have wavelengths of greater than 2 km, three of which are mappable in the area (Fig. 3). In the fold hinges, small scale bulking of the bedding surfaces related to the main folds occur. No later tectonic structures are evident.

3.4.4 Faults

Post-mylonite brecciation is an important feature of the Dover

Plate 49. Preferentially developed slaty cleavage in shales and sandstone of the Musgravetown Group (south of Lockers Reach).

Fault Zone and is responsible for its limited topographic expression (low relief along the south of Hare Bay, Dover, and north of Dover sections). Clearly recognizable disoriented fragments of mylonite, one cm to several cm across, occur along this segment of the fault (see Plate 27). These fragments are not bounded by shear planes but "float" in a chlorite/epidote rich, fine-grained matrix (see Plate 50). This brecciation may in part be related to some fluidization process such as tuffisite intrusion, localized along the fault, i.e. locally green chlorite/epidote rich matrix invades the mylonite fragments (section south of Hare Bay). Carbonate is also common, filling post-mylonite transverse fractures. This brecciation is also interpreted to be related to differential movements, along the pre-existing zone of weakness. Locally, minor upright drag folds (see Plate 51) associated with high angle faults occur (Dover section), also a fault with apparent dextral displacement runs into the Dover Fault Zone (see below).

A presumed high-angle fault with an approximate N45°E trend runs along Freshwater Bay, through the trace of the Dover Fault on the north shore of Lockers Reach and cuts a small island south of Lewis Island (Fig. 3). Its presence is suggested in Freshwater Bay by narrow mylonite and breccia zones which cut the deformed granite south of Air Island (see Plate 52) and by brecciation of the Hare Bay Gneiss in a narrow headland, on the north shore of the bay. The small island south of Lewis Island is cut by the extension of this fault. The Newport Granite underlies this island, the southern half

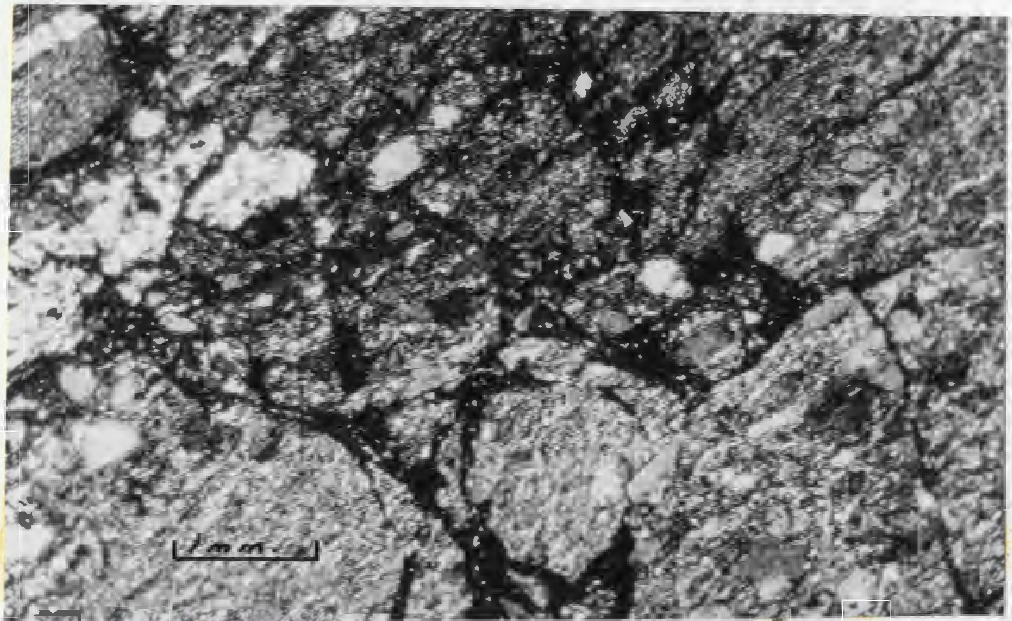


Plate 50. Brecciated mylonite from Dover Fault zone (plane light).

Plate 51. Drag folds of mylonitic foliation within the Dover Fault zone (Hare Bay).

Plate 52. Strong cataclastic foliation developed in a narrow zone within a porphyritic granite (south side of Freshwater Bay).

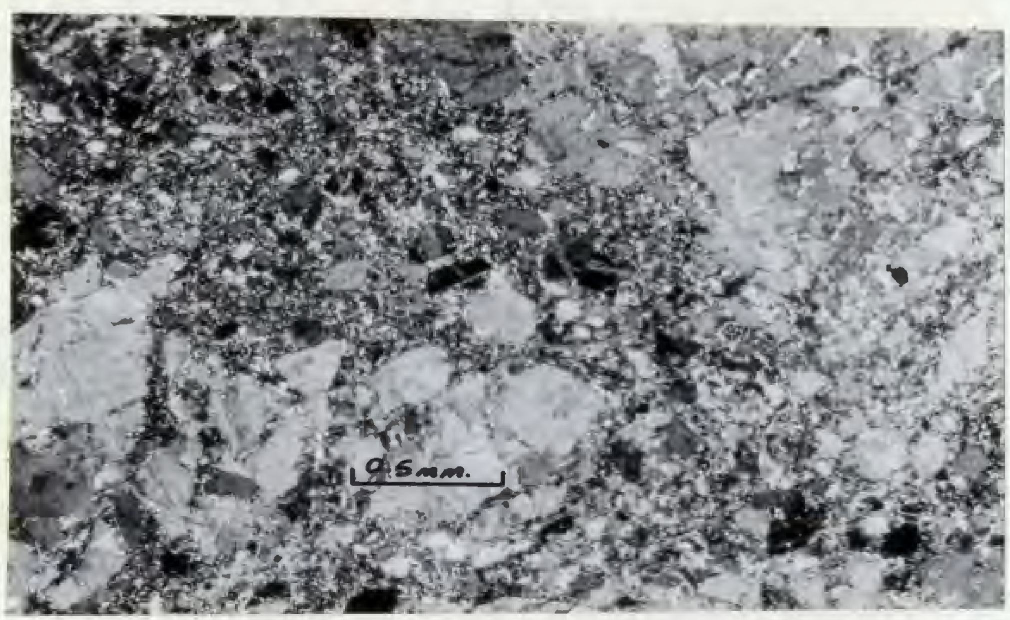


Plate 53. Brecciated Newport Granite (crossed nicols)

of which is severely brecciated. Quartz and feldspar clasts are surrounded by a fine-grained chlorite rich matrix in the brecciated area (see Plate 53). The sense of displacement along this fault has not been determined. It may form part of a larger fault system which runs southeast of Freshwater Bay along Gambo Pond (Fig. 5).

An east-west fault with apparent dextral displacement runs along Lockers Bay. The Lockers Bay Granite, the Hare Bay Gneiss and possibly the Dover Fault are displaced by this structure. Local brecciation occurs on headlands underlain by the Lockers Bay Granite on the north shore of the Bay. Inland from Lockers Bay the fault is marked by a long valley filled with glacial debris. To the east it may run into the N45°E fault previously described.

A similar east-west trending fault, but with smaller displacement cuts a Dover Fault granite and the Hare Bay Gneiss at Hare Bay.

Several east-west trending lineaments on Lockers Flat Island and Deer Island may also mark high angle faults.

On the south shore of Lewis Island, a north-south trending fault cuts and locally brecciates the Hare Bay Gneiss. On the north shore it separates the Lockers Bay Granite from the Hare Bay Gneiss.

The fault which separates the Musgravetown Group from the Love Cove Group has an approximate N15°E trend and would appear not to be a large disruptive zone. The fault zone is marked by a small gravel filled depression a few metres wide. The exposures of Musgravetown Group adjacent to the fault are gently to moderately dipping red siltstones which exhibit some fracturing. The penetratively deformed Love Cove volcanic rocks show no brecciation close to the fault. The sense of movement is not known but it is presumably high-angle, dip-slip with down-throw to the east.

3.5 Summary

The regional cataclastic foliation is common to both the Gander and Avalon Zones. The Dover Fault formed in association with this deformation during the juxtaposing of the Gander and Avalon Zones in the Precambrian. Earlier structures in the area include the gneissic foliations of the Bonavista Bay Gneiss Complex. Small-scale later structures are locally developed in both zones. The relationships between these structures and the deformation of the Musgravetown Group is not known. High angle faults cut the area and may in part contribute to later movement along the Dover Fault.

CHAPTER IV

METAMORPHISM

4.1 Introduction

The strongly deformed rocks in the map-area have undergone varying degrees of metamorphism. Low to middle greenschist conditions existed during the regional cataclastic deformation of the Love Cove Group (Avalon Zone) and there is some evidence that similar conditions prevailed during the regional cataclastic deformation of the Gander Zone. Due to retrogression it is very difficult to determine what metamorphic conditions affected the gneisses prior to the formation of the late foliation. The metamorphic grade now evident in the Hare Bay Gneiss is generally low. There is one suggestion of anatectic conditions having affected the Traverse Brook Gneiss. The Musgravetown Group is essentially non-metamorphic.

4.2 Metamorphism during the regional cataclastic deformation

New mineral growth (neomineralization) and re-crystallization are associated with the regional cataclastic deformation (the dominant texture is, however, cataclastic). Within the Lockers Bay Granite, biotite is ubiquitous and generally strongly oriented, forming augen around the large feldspar megacrysts. This biotite is probably primary and was flattened and rotated during the cataclastic deformation of the rock (i.e., locally small patches of biotite oriented at a high angle to the cataclastic foliation, occur in the foliated granite suggesting these grains had an original orientation which resisted rotation during deformation). Primary biotite is also common in undeformed megacrystic granites outside the map-area eg., the eastern margin of the Deadman's Bay Granite (Fairbairn and Berger, 1969). In thin section it is clear that biotite is partly replaced by chlorite but locally replacement is complete. The chlorite is strongly oriented and forms augen around porphyroclasts. Thus it is interpreted to be syn-tectonic although some static mimetic growth cannot be discounted. The general scarcity of chlorite in the Lockers Bay Granite may reflect a lack of water in the deforming body. Quartz is strongly re-crystallized in the Lockers Bay Granite producing stringers of sutured, elongated quartz grains.

Minor biotite is retrogressed to chlorite in the garnetiferous granites. Both help define the foliation. Muscovite and sericite with irregular to straight grain boundaries are syn-tectonic and overprint rare primary biotite (see Plate 54). Quartz is severely re-crystallized like that in the Lockers Bay Granite.

Commonly in the mylonites of the Dover Fault Zone, chlorite and sericite are developed syn-tectonically. These minerals clearly define the fabric and mark the fluxion lines. Quartz is intensely sutured and aligned in narrow zones. Locally distinct subhedral grains of epidote and massive interstitial epidote occur in the matrix. It is difficult to know whether this epidote is pre- or syn- tectonic. However, clearly post-tectonic epidote does occur in post-mylonitic fractures. In the Dover Fault granites, syn-tectonic chlorite is after biotite.

Plate 54. Coarse grained muscovite overprints minor biotite (dark grey to black areas) in garnetiferous granite (Plane light).

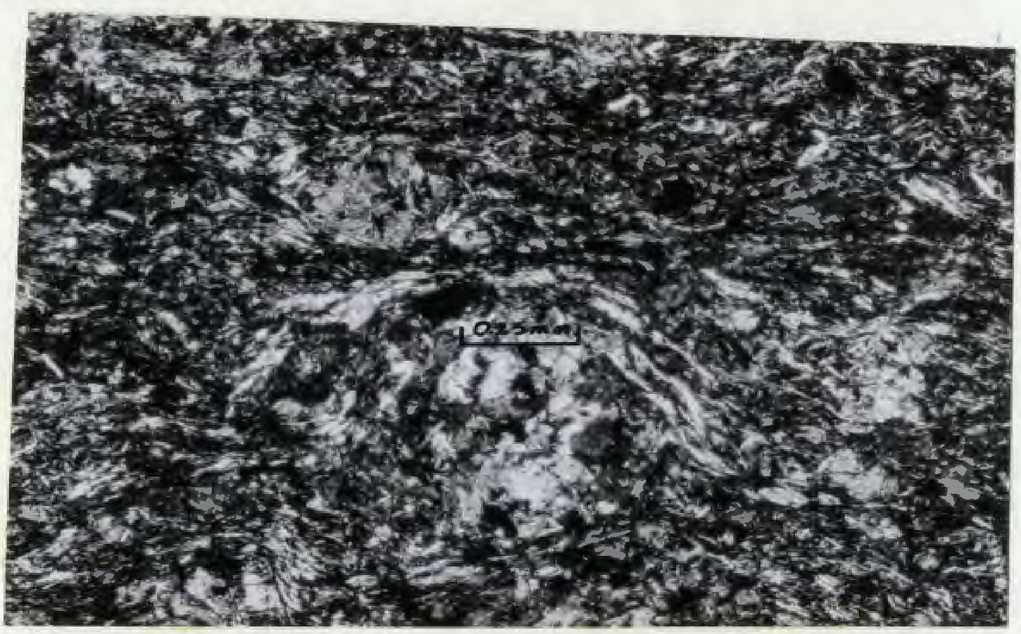


Plate 55. Syn-tectonic sericite forming augen around epidote clots (lower middle picture) in Love Cove volcanic rocks (crossed nicols).

In the Love Cove Group chlorite and sericite have grown syntectonically. The re-crystallization of quartz is ubiquitous with typical elongation and suturing of grains. These minerals define the pervasive foliation. Pre-tectonic and possibly syn-tectonic epidote occur. Syn-tectonic sericite forms augen around the older epidote grains (see Plate 55), the latter define narrow fluxion lines.

Thus, a syn-tectonic mineral assemblage characterizes the regional cataclastic foliation. This assemblage is apparently developed in deformed granitic rocks and possibly had a retrogressive effect upon the gneisses (see below) of the Gander Zone; in Love Cove Group volcanic rocks of the Avalon Zone; and in mylonites of the Dover Fault Zone. A low to middle greenschist facies of metamorphism is suggested by the neomineralized and recrystallized chlorite, sericite, muscovite, epidote and quartz.

4.3 Metamorphism affecting the gneisses

4.3.1 The Hare Bay Gneiss

The paragneiss xenoliths in the Hare Bay Gneiss fall into two main catagories: psammitic/semi-pelitic and amphibolitic. The main foliation in the former is generally defined by a biotite/chlorite alignment. The chlorite is after biotite and the matrix quartz is recrystallized and elongated. The superimposed cataclastic foliation forms augen around subhedral garnet porphyroblasts (see Plate 56) and oligoclase porphyroblasts. Coarser grains of earlier biotite occur

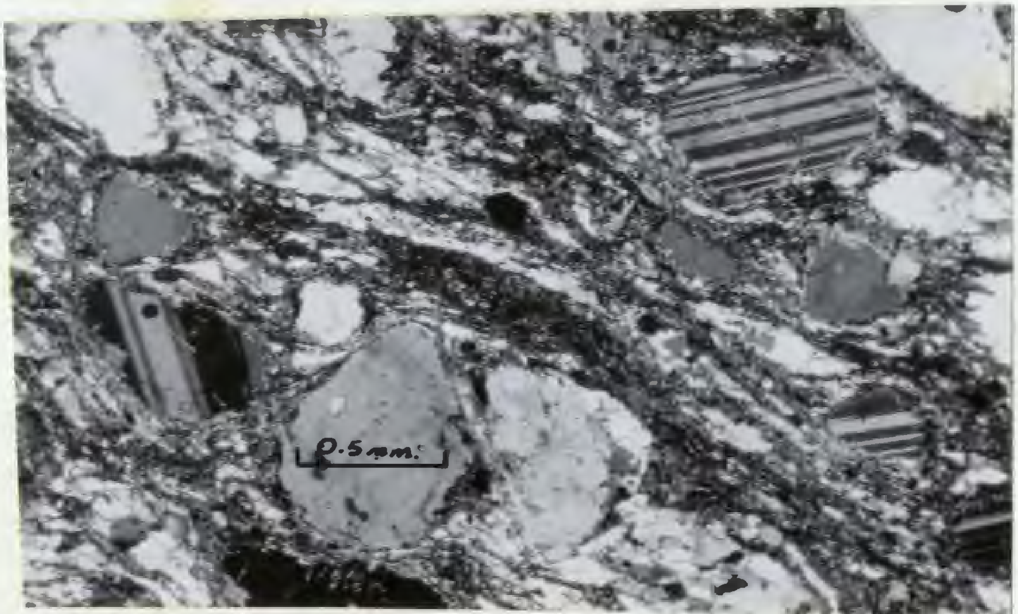


Plate 56 A garnet porphyroblast (upper centre of picture) in a paragneiss raft within the Hare Bay Gneiss. Note the strong overprinting by the cataclastic foliation which in detail forms augen around the garnet (crossed nicols).

Plate 57. The main foliation defined by an amphibole growth which forms augen around a clot of hornblende defining an earlier fabric. From an amphibolite gneiss xenolith within the Hare Bay Gneiss (crossed nicols).

as inclusions in the feldspar porphyroblasts. Thus, a garnet-biotite-plagioclase-quartz assemblage pre-dates the later biotite-chlorite-quartz alignment. In the amphibolite xenoliths, amphibole (hornblende as well as tremolite/actinolite) define the main foliation. The amphibole generally comprises greater than 50 per cent of the rock with the remaining being plagioclase and biotite. Two periods of hornblende growth are evident: an early one occurs as oriented crystals with relatively straight grain boundaries between the main foliation planes; this main foliation is defined by a subsequent amphibole growth (see Plate 57). Also basal sections of early hornblende with embayed grain boundaries have later amphibole of the main foliation forming augen around them.

The latest recrystallization of minerals in the paragneiss xenoliths may be of any age. Locally it may be related to the late cataclastic foliation or any of the transpositions which affected the host rock, a tonalitic gneiss. Whatever, the early metamorphic history of these xenoliths might suggest at least amphibolite facies conditions.

No high grade metamorphic minerals were observed in the tonalitic portion of the Hare Bay Gneiss. Two periods of biotite growth are evident with the earlier defining interfolial folds between the main foliation planes- also defined by biotite (see Plate 43). Muscovite growths are of at least two ages - small flakes in the matrix form augen around plagioclase porphyroblasts containing inclusion trails of an earlier muscovite orientation. Muscovite may also be observed as late porphyroblasts with random orientations (see Plate 58). Chlorite is also common and is generally associated with the main foliation. Quartz is recrystallized and elongated, helping define the main foliation which forms augen around oligoclase/andesine porphyroblasts. Higher grades can be suggested for the early metamorphic history for these rocks. However, low to medium greenschist facies would appear to mark the latest event.

4.3.2 The Traverse Brook Gneiss

The Traverse Brook Gneiss shows two ages of muscovite and biotite growth. The first defines an earlier foliation as inclusion trails in feldspar porphyroblasts and as interfolial folds. The second defines the main foliation. Muscovite also occurs as large porphyroblasts around which the later muscovite forms augen (see Plate 59). Biotite is replaced by chlorite. Other minerals are microcline/orthoclase and oligoclase/andesine; relative ages unknown. Quartz is generally recrystallized along the planes of the main foliation. Cordierite and sillimanite (see Plate 60) are developed in a quartz vein cutting a xenolith of Hare Bay Gneiss within the Traverse Brook Gneiss (north shore of Lockers Bay). This vein is likely related to the Traverse Brook Gneiss. Although this evidence is not conclusive, such metamorphic minerals could indicate anatectic conditions affecting the development of the Traverse Brook Gneiss. Presumably the later event, as indicated by the most common mineral assemblage, is of a much lower grade.

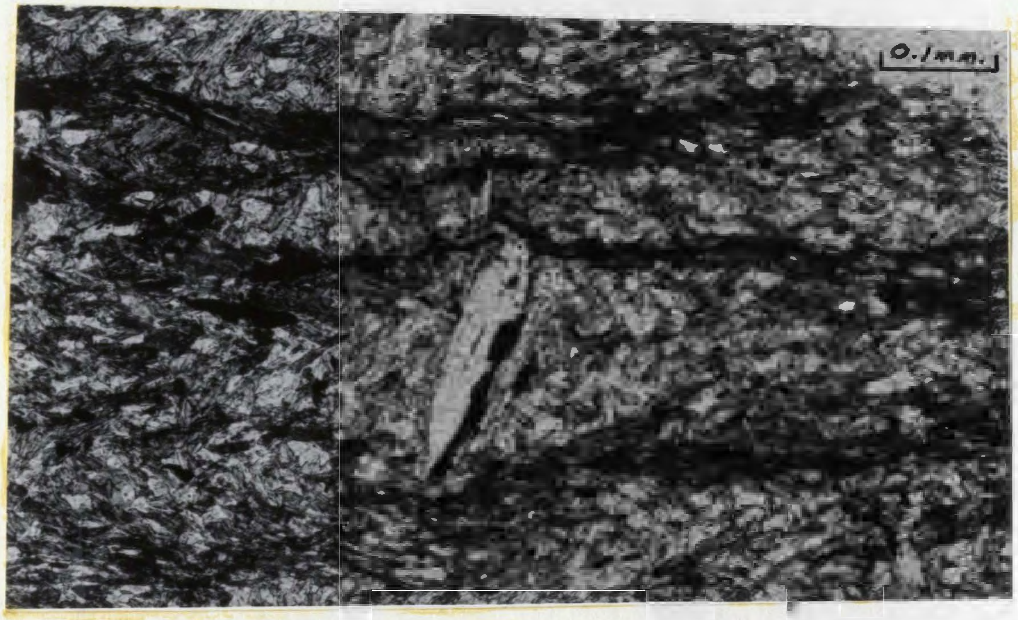


Plate 58. Lenticular muscovite porphyroblast overprinting crenulated biotite in the Hare Bay Gneiss (crossed nicols).

Plate 59. Large muscovite porphyroblast (lower right corner of plate) around which fine grained muscovite and sericite form augen in the Traverse Brook Gneiss (crossed nicols).

Plate 60a. Cordierite within the Traverse Brook Gneiss showing pleochroic halos around minute zircon inclusions. (crossed nicols).

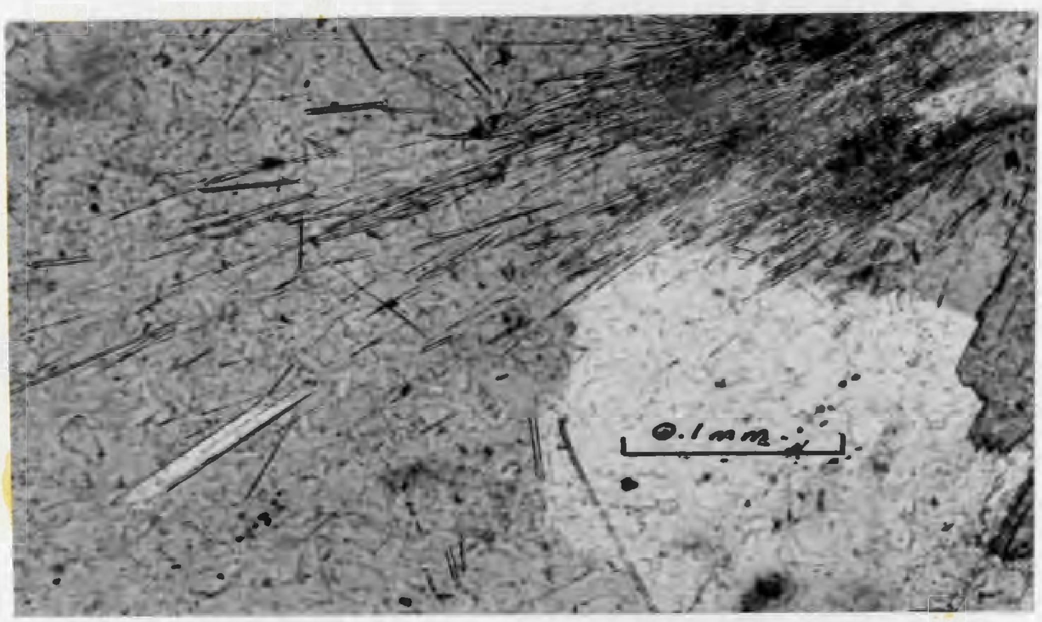


Plate 60b. Radiating needles of Sillimanite in the Traverse Brook Gneiss (crossed nicols).

There is no consistent development of metamorphic minerals in the Bonavista Bay Gneiss Complex. Where the same mineral is represented there is poor control on its relative age. These facts, combined with the obvious retrogression of the gneisses (presumably related to the regional cataclastic deformation and metamorphism) makes a systematic deciphering of their metamorphic history extremely difficult.

CHAPTER V

EXTENSION OF ROCKS OF THE GANDER AND AVALON ZONES TO THE WEST AND SOUTHWEST

5.1 Introduction

As a result of further work by the writer, many of the map units shown in Fig. 3 may be extended (Fig. 5). Also the paragneiss component of the Bonavista Bay Gneiss Complex may be better defined and the gneisses can be shown to be part of a basement terrane. The overlying cover rocks of the Gander Group are separated from the basement gneisses by a zone of reconstitution. The large post-tectonic granite plutons are further delineated and contact relationships are consistent with those previously described.

5.2 The Dover Fault

The Dover Fault has been traced as a continuous structure from Bonavista Bay to the south shore of Terra Nova Lake, an approximate distance of 60 kilometres. The fault continues to mark the boundary between the Gander and Avalon Zones, relationships across it are consistently the same and well-developed mylonites remain the main characteristic. The sections at Maccles Lake and Terra Nova Lake demonstrate this quite clearly.

5.3 Avalon Zone

5.3.1 Love Cove Group

The narrow belt of Love Cove Group rocks shown in Fig. 3, extends to cross the Trans-Canada Highway near Glovertown and widens to nearly twice its northern width south of the Glovertown Junction from where it then continues to Terra Nova Lake (Fig. 5). Typically, it consists of mainly acid volcanic rocks, flows and very fine tuffs. The penetrative cataclastic foliation with its north-northeast trend is ubiquitous, and consistently merges with mylonites along the Dover Fault.

5.3.2 Musgravetown Group

The Musgravetown Group, lithologically and structurally, is essentially the same to the south. It continues to be in fault contact with the Love Cove Group.

5.4 Gander Zone

5.4.1 The Dover Fault Granites

The Dover Fault granites are conspicuously regular in their continuation adjacent to the Dover Fault (see Fig. 5). Like the Love Cove Group of the Avalon Zone, they become severely mylonitized towards the Dover Fault and lose all their igneous textures. On the Trans-Canada Highway, just west of the Glovertown Junction and again approximately one kilometre south of there, the Dover Fault granites show possible evidence of repeated flattening along the Dover Fault. Early feldspars have been reduced to mere streaks in the rock; subsequent feldspar porphyroblasts are flattened slightly with earlier deformed ones forming augen around them (see Plate 61). This may also be explained by late syn-tectonic feldspar porphyroblastic growth. Both suggest a long involved history for the Dover Fault mylonites.

Severely mylonitized gabbro is associated with the Dover Fault granites at those sections around Maccles Lake. Locally it appears that the granite intrudes the gabbro pre-tectonically, i.e. both have been overprinted by the same cataclastic foliation. Plagioclase feldspar in the gabbro is resolved as white streaks in the rock.

Locally the Dover Fault granites and associated gabbro are intruded post-tectonically by relatively fresh granitic material (see Plate 62); occurring generally as veins or stringers cutting the mylonitized country rock. Within the Dover Fault zone some of this late granitic material may become brecciated by later movements (Maccles Lake, northern-most section).

5.4.2 The Lockers Bay Granite

The Lockers Bay Granite outcrops on the Trans Canada Highway between Glovertown and Gambo Pond and continues south of there where it is apparently cut off by the relatively undeformed Maccles Lake Granite (north of Maccles Lake - Fig. 5). The Lockers Bay Granite is typically megacrystic and deformed by the cataclastic foliation. It is also shown to clearly intrude the gneiss of the Bonavista Bay Gneiss Complex (see Plate 63).

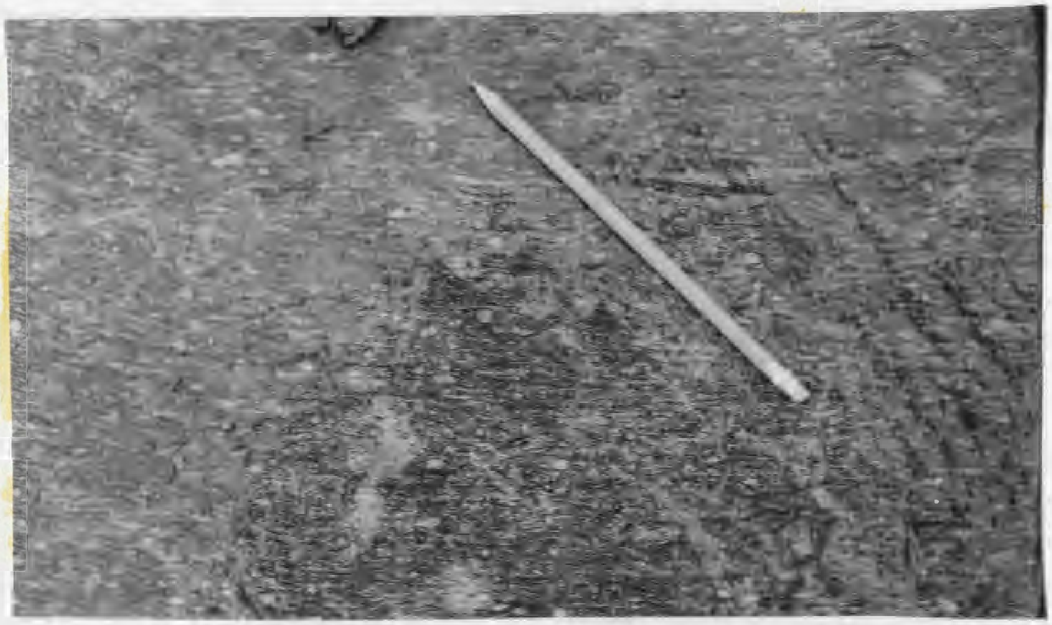


Plate 61. Streaked out feldspars defining a strong cataclastic foliation which forms augen around much less deformed feldspar porphyroclasts in a Dover Fault granite (north of Maccles Lake).

Plate 62. A xenolith of mylonitized gabbro (left side of plate) in late granite within the Dover Fault Zone. The granite shows local brecciation (Maccles Lake).

Plate 63. Contact between Lockers Bay Granite and Hare Bay Gneiss. Note the difficulty in seeing the late foliation in the gneisses (north of Maccles Lake).

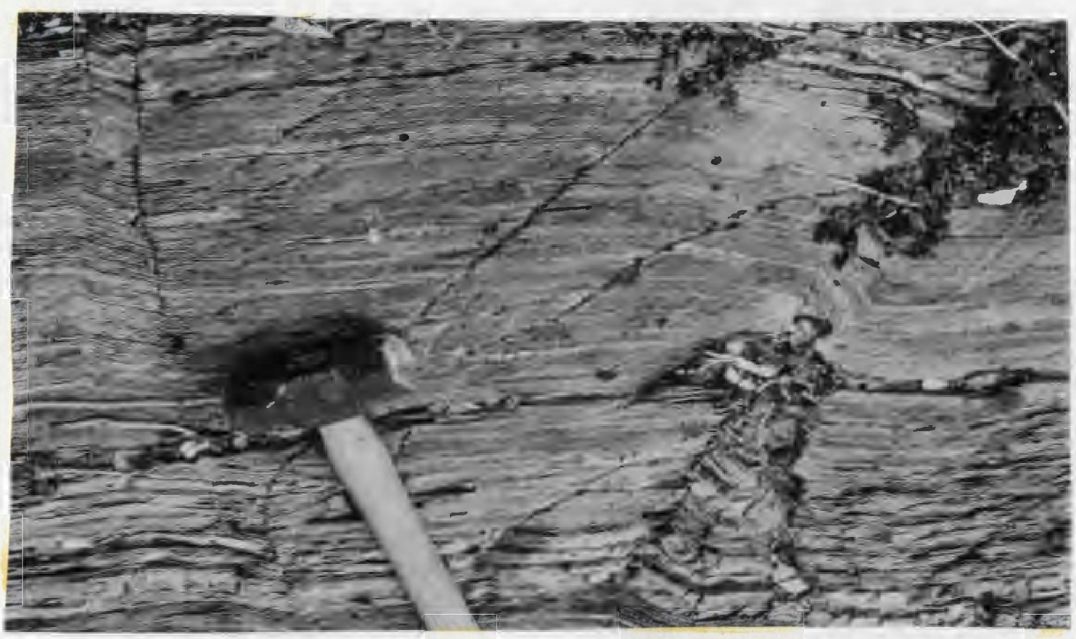


Plate 64. Well-banded psammitic paragneiss of the Square Pond Gneiss (west of Gull Pond).

5.4.3 The Bonavista Bay Gneiss Complex

The Bonavista Bay Gneiss Complex has an involved history of migmitization and deformation. The suggestion of an earlier gneissic unit, likely paragneiss, resulted from the study of the Hare Bay Gneiss. This work has shown that such a suggestion is valid with the Bonavista Bay Gneiss Complex consisting of an older paragneiss terrain and a subsequent granite (tonalite) gneiss terrane. The latter would appear to have originated by migmitization of the older rocks. The writer now concludes that the Traverse Brook Gneiss, although providing an easily mappable unit in Figure 3 is, in fact, a local phenomenon of limited importance on a regional scale. It is, then, the Hare Bay Gneiss and the paragneisses which represent the fundamental units of the Bonavista Bay Gneiss Complex.

The Bonavista Bay Gneiss Complex is roughly disposed into two belts, trending approximately north-northeast. They are separated by two large areas of granitic rock, the Middle Brook and Maccles Lake Granites (Fig. 5). As a generalization the western belt is predominantly paragneisses and the eastern belt is mainly granite gneiss. The two granites are clearly post-tectonic.

5.4.3.1 The Square Pond Gneiss

The paragneisses, here termed the Square Pond Gneiss, are the older of the two gneissic units. An excellent section displaying both lithological and structural features is provided by the Trans Canada Highway from Gambo Junction to the northwest corner of Square Pond. A road metal quarry at the northeast corner of Square Pond exposes rocks typical of the paragneiss terrain: a well-banded, light grey psammitic gneiss (see Plate 64). The gneissosity is extremely regular with sharp boundaries marking both sides of an individual band. The average width of the banding is 2-3 mm, but it may be finer or coarser. The gneissosity is defined by dark bands richer in biotite and chlorite (semi-pelitic) alternating with slightly wider bands of light grey, more psammitic material. Locally, the main banding contains interfolial folds and is quite strongly transposed to produce a new gneissosity (see Plate 65). Subsequent to the development of the complex gneissic banding, the paragneiss is overprinted by a late, single penetrative foliation. This is best shown by garnetiferous granite veins which cut all phases of the gneissic banding and are also deformed by the late foliation. In the road metal quarry in question the late foliation is axial planar to a large scale fold (hinge zone approximately 30 metres wide) which folds the complex gneiss banding producing types 1 and 3 interference patterns in the hinge.

Another aspect of the Square Pond Gneiss is exposed at the Gambo Junction and successive outcrops between there and the road

Plate 65. Transposition in the Square Pond Gneiss (north of Gambo Pond).

Plate 66. Garnetiferous xenolith of Square Pond Gneiss in Hare Bay Gneiss (Maccles Lake).

metal quarry on the Trans Canada Highway. Superficially these paragneisses are structurally simpler and more pelitic than those at Square Pond. A gneissic banding is no longer evident, the foliation is phyllitic, the rocks are dark grey to greenish in color and fine-grained. Close observation shows, however, that the foliation is composite and rarely is disposed in small scale, tight, isoclinal folds of extremely variable plunge. Also, zones of more psammitic gneiss showing the regular gneissic banding and structural complexities exhibited in the road metal quarry, occur interlayered with this apparent "phyllite" sequence (roadside outcrop at Gambo, approximately 1 km from Trans Canada Highway turnoff and along railroad track near Butt's Pond). It is concluded that these rocks are part of the same paragneiss sequence but due to the lithological differences, do not show a successive development of gneissic structures, i.e. being more pelitic, subsequent deformation completely transposed earlier structures. This regional change in lithology possibly reflects original variation within a sedimentary sequence. In this regard it should be noted that on weathered surfaces the paragneiss is identical to a metasedimentary terrane but no clastic textures or primary structures are preserved.

The metamorphic grade of the Square Pond Gneiss is consistently low (except in local migmatite zones). Chlorite and biotite, with the latter predominating, is quite common.

The Square Pond Gneiss is also well developed around Gull Pond, due north of Square Pond. To the east of Gull Pond the paragneiss shows an extremely regular, consistent, narrow gneissic banding.

It is possible to trace this remarkable "pin-stripe" banding several kilometres along strike. Also the strike of the banding changes from a north-northeast trend to a north-northwesterly one.

Several gabbro bodies intrude the Square Pond gneiss, i.e. at Gull Pond (Fig. 5). The gabbros post-date the gneissic banding but have subsequently been deformed. Ubiquitous garnetiferous granite veins cut the gabbro pre-tectonically.

5.4.3.2 The Hare Bay Gneiss

The eastern belt of gneisses, the granitic gneisses, is essentially a continuation of those shown on Fig. 3 and are similar to the Hare Bay Gneiss - the name which is applied to this eastern belt of the Bonavista Bay Gneiss Complex. The Hare Bay Gneiss contains xenoliths of paragneiss; the Square Pond Gneiss would appear to be the source for these xenoliths. Although the eastern belt is predominantly "granite" gneiss, it does contain large rafts of paragneiss, one such zone occurs on the northeast shore of Maccles Lake adjacent to the Dover Fault granite. The zone is approximately 1/2 km wide and is mainly psammitic gneiss. To the west it forms an apparently gradational contact with the granite gneiss. The contact zone is several metres wide and shows profuse plagioclase porphyroblast growth. The paragneiss grades into recognizable granite gneiss which also contains xenoliths of the former (see Plate 66). The banding in the granite gneiss is less regular than that in the paragneiss but still quite distinct; it resembles a typical orthogneiss.

The development of garnet porphyroblasts overprinting the paragneiss banding is another important feature. The garnets occur in both the paragneiss zone and locally in paragneiss xenoliths within the granite gneiss. Garnets also occur locally in the granite gneiss at this locality. Although detailed thin section work needs to be done, there is a strong suggestion that the Hare Bay Gneiss and its southward extension represent post-paragneiss migmatites which have subsequently been regionally deformed. The same is suggested by zones of granite gneiss developed within the Square Pond Gneiss, i.e. Mint Brook and southwest of Gull Pond. There, also, garnet porphyroblasts overprint the paragneiss banding close to the migmatite zones.

The belt of Hare Bay Gneiss continues to the south shore of Terra Nova Lake. The Square Pond Gneiss has been mapped only as far south as Gambo Pond.

5.4.4 Relationships between the Bonavista Bay Gneiss Complex and the Gander Group.

The Bonavista Bay Gneiss Complex has been interpreted as a basement gneiss terrain. The Gander Group metasedimentary sequence has been interpreted as the cover terrain (Kennedy and McGonigal, 1972). The section provided by Home Pond and Gull Pond (Fig. 5) strongly supports the above, with the contact between the two being a zone of structural reconstitution. First, the lithology and structures of the Gander Group will be outlined and secondly, the effect of these structures on the Square Pond Gneiss will be described.

5.4.4.1 The Gander Group

The contact between the gneisses and metasedimentary rocks of the Gander Group occurs where Home Pond and Gull Pond meet and continues to the northeast near the southwest end of Wing Pond. It continues to the southwest, south of Soulis Pond. Northwest of this contact the area is underlain by the Gander Group. Along Home Pond the Gander Group looks superficially much like the psammitic paragneiss to the southeast. That is, the bulk of the metasedimentary rocks are light grey psammites. However, several important differences do exist: the psammites of the Gander Group clearly show a clastic texture i.e., individual sand grains are quite distinguishable; bedding is evident especially where the psammites are interbedded with black pelites (see Plate 67); laminations are distinguishable within the pelite horizons and primary structures such as slumping are evident. Thus, although polydeformed, there is no doubt as to the sedimentary aspects of the Gander Group in this area.

Compared to the Square Pond Gneiss, the Gander Group is structurally simple. However, in this area at least three phases of deformation are recognizable. The first foliation, S_1, is a very fine penetrative fabric consistently parallel to bedding. Both bedding and S_1 have shallow dips to the west-northwest and strike north-northeast. The second foliation, S_2, is the most conspicious in outcrop (see Plate 68). S_2 is a widely spaced strain-slip foliation which has a consistent northeast trend and for the most part has a very shallow northwestward dip, everywhere gentler than bedding.

Plate 67. Interbedded black pelites and psammites of the Gander Group (Home Pond).

Plate 68. Widely developed S_2 (parallel to pencil) cuts bedding and S_1 (parallel to bedding) in fine-grained psammites of the Gander Group (Wing Pond).

Thus, the section of Gander Group along Home Pond would appear to be on the lower limb of a large recumbent F_2 antiform overturned towards the southeast. (This is in accord with Kennedy and McGonigal's work on the Gander Group to the southwest). The wide spacing of the ubiquitous S_2 fabric also adds to the false impression that the rocks are similar to the paragneiss of the Square Pond Gneiss.

Subsequent to D_2, a phase of vertical, open folding with sub-horizontal axes overprints the Gander Group. The F_3 folds are only locally developed and are generally small-scale i.e., wavelengths of a few centimetres. Locally, however, the general strike and dip of S_2 and bedding is changed by larger F_3 folds i.e., S_2 may be steep and dip to the east where folded by F_3 folds.

Thus, the Gander Group represents a polydeformed, clearly metasedimentary terrain in the vicinity of Home Pond. The metamorphic grade however is quite low, apparently of low greenschist facies.

5.4.4.2 The effect of structures in the Gander Group on the Square Pond Gneiss.

The contact between the Square Pond Gneiss and the Gander Group is not exposed. However, at the southwest corner of Wing Pond, Gander Group and Square Pond Gneiss are separated by only 250 metres. In that area S_1, as usual, is parallel to bedding in the Gander Group. The nearest outcrop of paragneiss shows that the gneissic banding also strikes parallel to S_1 of the Gander Group, and here the gneissic banding is apparently mylonitized in that same direction. Although not conclusive, this suggests that the effect of the Gander Group D_1, is to mylonitize the basement gneisses parallel to the pre-existing banding. Also, close to the contact, the gneissosity of the Square Pond Gneiss and S_1 (and bedding of the Gander Group) strike parallel i.e., even where there are abrupt changes in strike, the changes are consistent for both terranes. Thus it appears that S_1 of the Gander Group controls the attitude, locally, of the Square Pond Gneiss.

The second deformation of the Gander Group, represented by the widely developed S_2 foliation, has a more obvious effect on the basement gneisses. In the Gander Group, S_2 has a consistent northeast trend and generally strikes sub-parallel to bedding. It can however, intersect bedding and S_1 at a considerable angle (southwest corner of Wing Pond). The same is true for its effect upon the Square Pond Gneiss, quite clearly displayed along the south and west shores of Gull Pond. The gneissic banding is generally vertical and the Gander Group S_2 cuts it with shallow dips to the northwest (see Plate 69). Locally the paragneisses strike northwest, have sub-vertical dips, and are cut by the S_2 foliation. The gneissic banding is also disposed in minor recumbent folds to which the shallow northwestward dipping foliation is axial planar (see Plate 70). These effects of the Gander Group S_2 are also developed in local patches of granite gneiss found in the same vicinity i.e., S_2 only deforms S_1 and S_0 of Gander Group but re-works complex gneissic foliations in Square

Plate 69. Gently inclined S_2 of the Gander Group (parallel to pencil)cutting across sub-vertical gneissic banding of the Square Pond Gneiss (Gull Pond).

Plate 70. Recumbent folds of the gneissic banding within the Square Pond Gneiss (Gull Pond). S_2 of the Gander Group forms the axial plane foliation.

Pond Gneiss.

Structural re-working of the Square Pond Gneiss during the deformation of the Gander Group is also demonstrated by that body of gabbro on the west shore of Gull Pond (Fig. 5). The gabbro intrudes the paragneisses, post-dating the gneissic banding. The southern portion of this body is virtually undeformed (Plate 71). Its northeast extension, however, has been quite strongly deformed by a strong penetrative foliation which locally is composite (see Plate 72) i.e., result of transposition of an earlier foliation. This foliation trends northeast and has variable dips i.e., both gentle and steep to the northwest and southeast. Locally this variation in dip may be attributed to a late phase of folding similar to the F_3 folds of the Gander Group. The gabbro is therefore interpreted to intrude the basement terrain prior to the deformation of the overlying Gander Group. It is essentially massive along its southern margin but is overprinted by the Gander Group deformations along its northern margin, closest to the basement/cover contact. The main foliation is probably S_2, explaining its local composite nature. The later re-folds would be F_3 folds of the Gander Group.

Continuous exposure between the postulated basement terrain and cover rocks do not occur in the Gull Pond-Home Pond area. However, the contrasts between the paragneisses and the metasedimentary rocks, the sharp contact between the different terranes, and the re-working of the older gneissic foliation by the Gander Group deformations clearly demonstrate that a basement/cover relationship does exist.

Plate 71. Gabbro cutting Square Pond Gneiss west of Gull Pond. Gabbro is relatively undeformed here, in the southern part of the body.

Plate 72. Gabbro at Gull Pond showing the composite, gently dipping S_2 foliation of the Gander Group. Here, the gabbro is deformed since it is close to the zone of reconstitution.

5.5 Aeromagnetic Patterns

The contact between the Gander Group and the Bonavista Bay Gneiss Complex is also evident from aeromagnetic maps (Fig. 6). The Gander Group (Home Pond) is reflected by evenly and widely spaced magnetic contours representing broad anomalies of relatively low intensity. The low metamorphic grade and lack of detrital magnetite in the Gander Group could account for this. The magnetic pattern over the Square Pond Gneiss (Gull Pond and Wing Pond) consists of closely spaced contours defining numerous ellipical shaped anomalies of relatively high intensity. The involved metamorphic and structural history of the gneisses, small gabbro plugs, the possible presence of amphibolites, explains this strong contrast with the Gander Group terrane. The abrupt change in the aeromagnetic pattern defines a line which coincides with the mapped basement/cover contact.

Diffuse anomalies of lower intensity than that over the paragneiss terrane reflects the Middle Brook Granite. The granite-Paragneiss contact east of Gull Pond marks the change in aeromagnetic patterns.

5.6 Post-tectonic Intrusive Rocks

5.6.1 The Middle Brook Granite

The Middle Brook Granite (Fig. 5) is less extensive than shown by Jenness (1963). Everywhere the granite is relatively fresh and undeformed and post-dates all structures in the country rocks, i.e.,

Figure 6 Aeromagnetic pattern of the Home Pond-Gull Pond area showing the Gander Group, the Square Pond Gneiss, and the Middle Brook Granite. Magnetic Contour Interval is 20 gammas. (Geological Survey of Canada Aeromagnetic Map #190G, 1954).

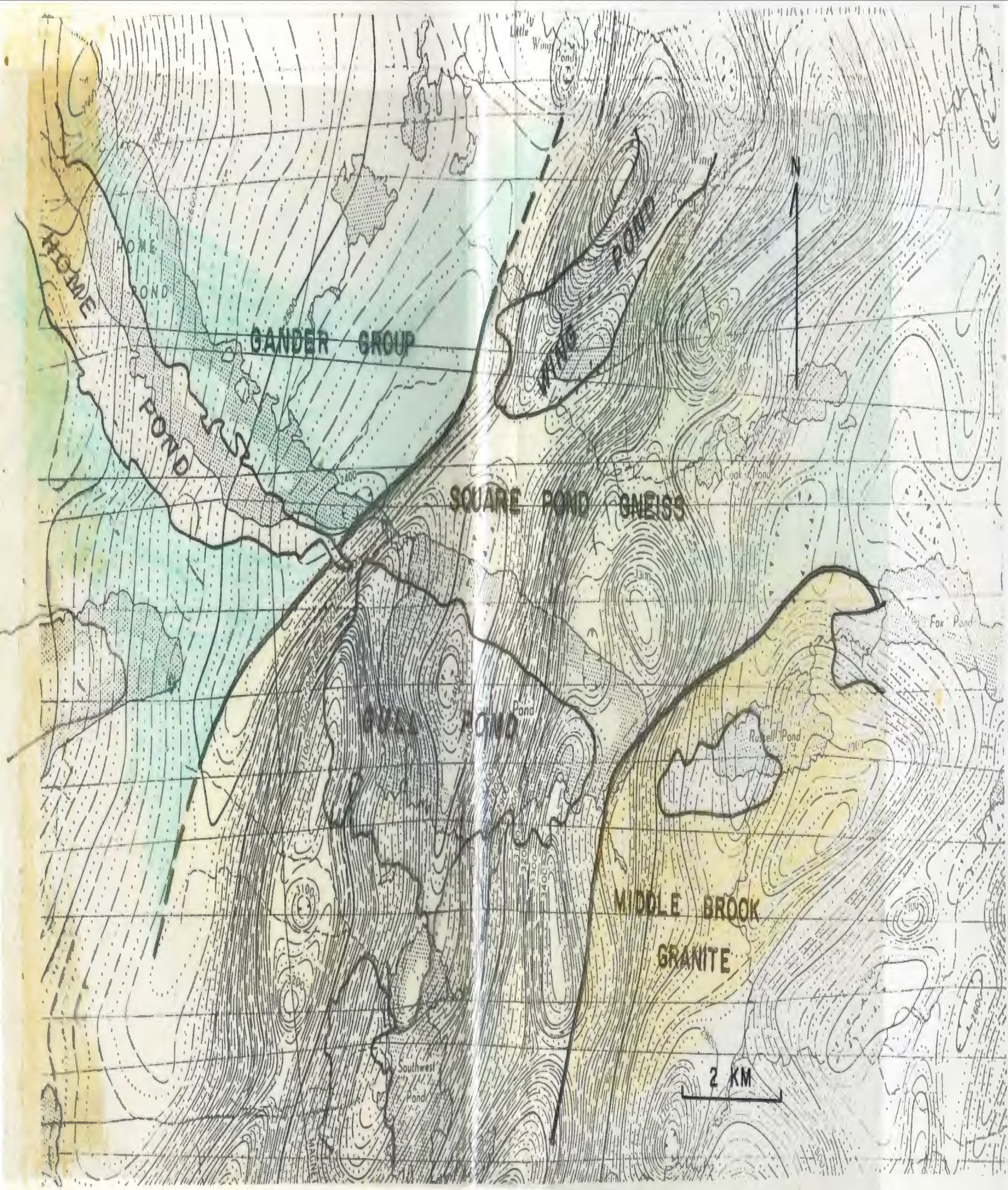


Figure 6 Aeromagnetic pattern of the Home Pond-Gull Pond area showing the Gander Group, the Square Pond Gneiss, and the Middle Brook Granite. Magnetic Contour Interval is 20 gammas. (Geological Survey of Canada Aeromagnetic Map #190G, 1954).

cordierite and andalusite porphyroblasts overprint the foliation of the Square Pond Gneiss in a narrow contact aureole (Gambo Junction and east of Gull Pond). In the northern portion of the body, widely spaced feldspar phenocrysts give the granite a "spottingly" porphyritic texture.

5.6.2 The Maccles Lake Granite

A large body of granite very similar to the Middle Brook Granite underlies an area to the south of the latter. A particularly good section of this granite is exposed along the western half of Maccles Lake and is here referred to as the Maccles Lake Granite (previously referred to as the Freshwater Bay Granite by Strong et al. (1974) and Bell et al. (1974)). However, this granite does not extend to Freshwater Bay, which was an interpretation based on the earlier work of Jenness (1963). There is no evidence to suggest that it links up with the Middle Brook Granite. (There is no outcrop around northeast end of Gambo Pond and bottom of Freshwater Bay, and continuity is not suggested on aeromagnetic map of area.)

The Maccles Lake Granite is a coarse grained, porphyritic body rich in biotite (see Plate 73). For the most part it is massive but locally may have a weak foliation which is defined by a poor alignment of biotite. There is no quartz alignment, feldspars are without "tails" and no augen structures are developed. On the granite's eastern margin, north shore of Maccles Lake, there is a more intense foliation, confined to the contact area of the granite and interpreted

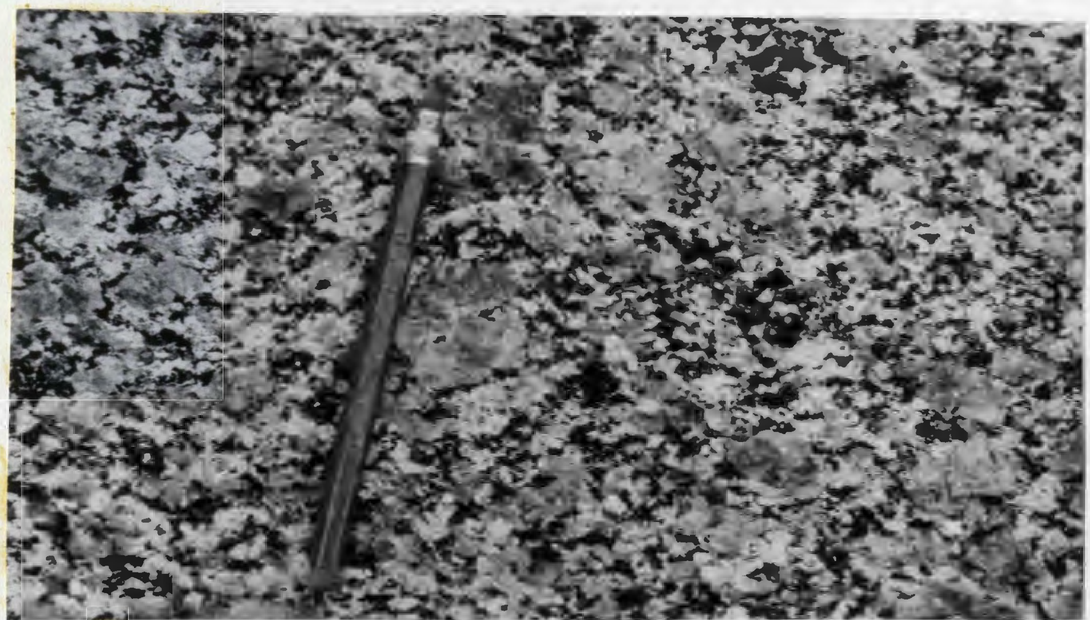


Plate 73. Massive, porphyritic, Maccles Lake Granite (Maccles Lake).

Plate 74. Massive Terra Nova Granite containing a xenolith of mylonite (Terra Nova Lake).

to be induced by the intrusion of the granite into the country rocks).

The Maccles Lake Granite appears to intrude the Lockers Bay Granite. Unfortunately the contact area is not exposed but the map pattern and contrasts between the two granites support this interpretation (Fig. 5). This granite also intrudes the Hare Bay Gneiss post-tectonically. Locally, contact migmatites are developed (south shore of Maccles Lake). This local migmatization of the granite gneiss results in an agmatite. No penetrative deformation is evident in the granitic matrix.

5.6.3 The Terra Nova Granite

The Terra Nova Granite is a smaller body which is centered around the eastern end of Terra Nova Lake. It is a fresh undeformed granite very similar to the Newport Granite and contains large microcline megacrysts surrounded by small grains of quartz and biotite. On its western margin it intrudes and is chilled against the Love Cove Group and mylonites of the Dover Fault. The latter may be seen on the north shore of Terra Nova Lake where feldspathic mylonites are cut by the granite. The granite also contains xenoliths of granitic mylonite related to the Dover Fault granites (see Plate 74). On its eastern margin the Terra Nova Granite intrudes the Musgravetown Group producing a contact metamorphic aureole.

5.7 Conclusions

The Dover Fault forms the Gander/Avalon Zone boundary for some 60 km in northeastern Newfoundland. Structural relationships and most adjacent rock units are consistent along its mapped length. The Bonavista Bay Gneiss Complex represents two gneissic units; a para-gneiss terrane and a younger orthogneiss terrane. This complex is basement to cover rocks of the Gander Group. Large post-tectonic granite intrusions cut the deformed rocks of the Gander and Avalon Zones.

CHAPTER VI

DISCUSSION AND MAJOR CORRELATIONS

6.1 Age of Rocks and Deformation

The Dover Fault is considered to be Precambrian in age i.e., the juxtaposing of the Gander and Avalon Zones is Precambrian. Since the regional cataclastic foliation with which the Dover Fault is associated overprints the gneisses and some of the granites of the Gander Zone and deforms the Love Cove Group of the Avalon Zone, then controls on the deformational age of the Love Cove Group will apply to all rocks affected by the same event. In this regard the Musgravetown Group is extremely important.

Relatively undeformed clastic sedimentary rocks of the Musgravetown Group are in fault contact with the Love Cove Group within the map-area (Fig. 5) as well as elsewhere in the Avalon Zone (Jenness, 1963). The strong contrast in metamorphism and deformational intensity across these faults would suggest that the Love Cove Group (see Plate 75) was deposited and deformed prior to the Musgravetown Group (see Plate 76). Jenness (1963) reported the presence of greenschist volcanic fragments of the Love Cove Group in basal conglomerates of the Musgravetown Group. This locality at Bread Cove southwestern part of Bonavista Bay, was visited by the writer. Abundant greenschist fragments were found identical to units within the Love Cove Group. Other metamorphic fragments such as deformed garnetiferous granite and schistose granite were also found (strongly supporting a molasse

Plate 75. General view of strongly deformed Love Cove Group. (north shore of Content Reach).

Plate 76. General view of gently dipping Musgravetown Group (south shore of Content Reach).

type facies for the Musgravetown Group). Since then, other localities around southern Bonavista Bay have been seen with schistose Love Cove fragments being a common occurrence in Musgravetown Group conglomerates. Thus, it is reasonably clear that the Love Cove Group was deformed prior to the deposition of the Musgravetown Group. The Musgravetown Group is conformably or unconformably overlain by fossiliferous Lower Cambrian strata elsewhere within the Avalon Zone (Jenness, 1963). Therefore this molasse facies sequence is late Hadrynian or possibly Early Cambrian in age and the Love Cove Group must be Precambrian.

The Bonavista Bay Gneiss Complex is overprinted by the Precambrian cataclastic foliation. Before this it had a complex structural history. Although impossible to state absolutely, these gneisses are interpreted to represent a basement terrane of possible Helikian (or older) age.

The Lockers Bay Granite, by the same argument, is considered Precambrian. The Dover Fault granites may be younger since they appear to be localized along the fault, suggesting an already present zone of weakness.

Kennedy and McGonigal (1972) and Kennedy (1975) have shown that the deformation of the Gander Group must pre-date the Middle Ordovician Davidsville Group farther to the west. They based their conclusions upon the nature of the contact between the two groups: unconformity in the south and mélange in the north; the presence of metamorphic detritus of likely Gander Group derivation within the

Davidsville Group greywackes; and the abrupt change and contrasts between the simply deformed Davidsville Group and the polydeformed Gander Group. Since the Davidsville Group contains Middle Ordovician brachiopods (Jenness, 1963), the Gander Group must have been deformed in pre-Middle Ordovician time.

S_1 of the Gander Group appears to locally mylonitize the Square Pond Gneiss parallel to the gneissic banding. It could also be the same late foliation which is ubiquitously developed in the Square Pond Gneiss. Within the Hare Bay Gneiss the overprinting of the gneissic banding by the late cataclastic foliation is analogous. Thus, it is probable that S_1 of the Gander Group and the regional cataclastic foliation with which the Dover Fault is associated were formed by the same deformational event, which would thus be of Precambrian age.

Subsequent deformation of the Gander Group may be considerably younger than D_1. D_2 for example, is restricted to the cover rocks except for minor re-working along the contact with the basement gneisses; the polarization of D_2 structures indicate that structural mobilization was initiated west of the basement/cover contact; D_2 reflects comparatively high level deformation (thrusting in cover rocks) which has a limited eastward influence. This contrasts sharply with the earlier regional steep foliation which deforms the western margin of the Avalon Zone, overprints the Bonavista Bay Gneiss Complex, and may also be S_1 of the Gander Group.

Kennedy (1975) referred to possible Precambrian deformation of the Gander Group as the Ganderian Orogeny, and considered all the structures to be related to that orogenic episode. Although this is quite possible, the structural contrasts outlined above permit a poly-orogenic model to be applied in explaining the deformational history of the Gander Group.

Post-tectonic granites, i.e. the Terra Nova, Maccles Lake, Middle Brook and Newport, may be of any age younger than the regional cataclastic foliation, probably Middle Paleozoic.

6.1.1 Radiometric ages on some granitic rocks

Bell and Blenkinsop (1974) and Bell (pers. comm., 1975) have produced several radiometric ages using the Rb-Sr whole-rock method on granitic plutons of both the Gander and Avalon Zones. These data (see Table 1) both concur and conflict with the geological field data and the interpretations already outlined in this and preceeding chapters. Only those granitic rocks directly related to the writer's work will be discussed (Fig. 7).

TABLE I

Rb-Sr whole-rock ages on some granitic rocks from Southeastern Newfoundland.

Straddling Granite	490 ± 10 m.y.
Ackley Batholith	344 ± 8 m.y.
Terra Nova Granite	335 ± 18 m.y.
Maccles Lake (Freshwater Bay Granite of Bell *et al.*, 1974)	360 ± 17 m.y.
Middle Brook Granite	440 ± 30 m.y.
Lockers Bay Granite	300 ± 18 m.y.
Dover Fault Granite (South of Hare Bay)	400 ± 30 m.y.

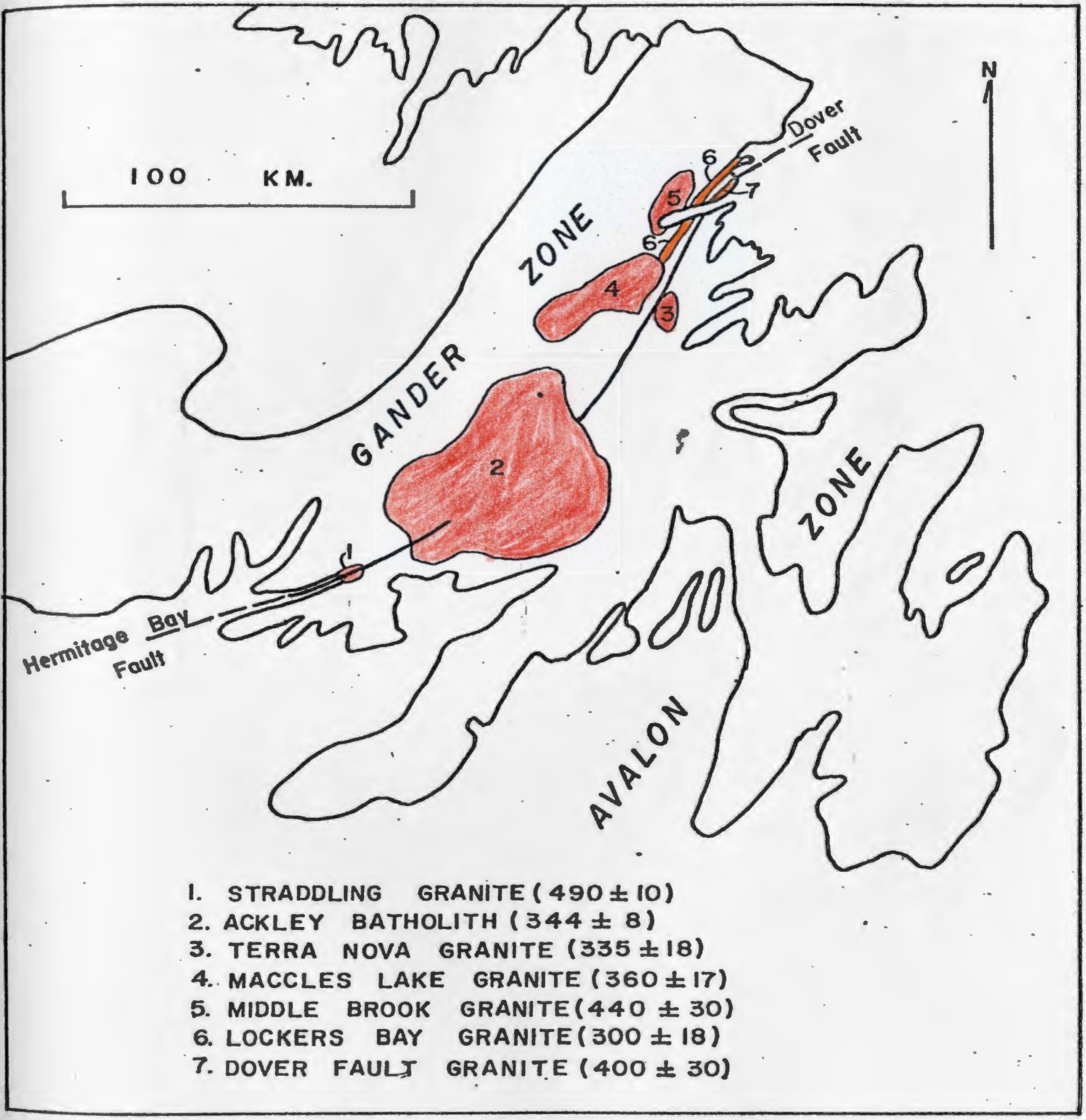


Figure 7. Some granitic rocks of eastern Newfoundland showing their Rb-Sr Whole rock ages.

<u>The Straddling Granite</u> - This granite is common to both the Gander and Avalon Zones in southeastern Newfoundland and therefore post-dates the postulated Precambrian juxtaposing of the two zones (Blackwood and O'Driscoll, 1976). The Rb-Sr age of 490 ± 10 m.y. supports this interpretation.

<u>Ackley Batholith</u> - This large batholith intrudes both the Gander and Avalon Zones, virtually welding them together, and post-dates the Cambrian rocks of the Avalon Zone (Williams, 1971). Its Rb-Sr age of 344 ± 8 m.y. does not conflict with any of the interpretations proposed.

<u>Terra Nova Granite</u> - This granite post-dates the Dover Fault and rocks deformed in association with it. Its age of 335 ± 18 m.y. does not conflict with this.

<u>Maccles Lake Granite</u> (Freshwater Bay Granite of Bell, 1974). This body intrudes the Hare Bay Gneiss post-tectonically and appears to cut off the Lockers Bay Granite. Its Rb-Sr age of 360 ± 17 m.y. is in agreement with this.

<u>Middle Brook Granite</u> - Intrudes the Traverse Brook and Square Pond Gneiss post-tectonically and post-dates the cataclastic foliation associated with the Dover Fault. The age of 440 ± 30 m.y. for this post-tectonic, undeformed pluton is supportive of geology already described.

Lockers Bay Granite - Interpreted to be Precambrian by writer based on field evidence. The Rb-Sr age of 300 ± 18 m.y. for this highly deformed body poses a serious problem. The writer cannot justify a Carboniferous age for this pluton when considering the regional geology. Also, the age of 440 ± 30 m.y., on the nearby, obviously post-tectonic, Middle Brook Granite is incongruous with a 300 ± 18 m.y. age for the regionally deformed Lockers Bay (Fig. 3). The age must be significant but the writer doubts that it represents the intrusion or deformational age of the granite.

Dover Fault Granites (South of Hare Bay) - These granites probably post-date the initiation of the Dover Fault since they appear to be localized along it. Also, the deformational inhomogeneity exhibited by these granites suggest different times of intrusion are represented with respect to movement along the Dover Fault. Thus, the age of 400 ± 30 m.y. on that granite body south of Hare Bay may not be in conflict with the data already presented, i.e., the deformation of that body would represent re-flattening along the Dover Fault at this time. However, that re-flattening would have to be quite marginal to the Dover Fault and parallel to the existing foliation i.e., since that foliation overprints the gneisses, deforms the Lockers Bay Granite and is Precambrian in age (even the radiometric data would suggest that the pre-existing foliation is pre- 440 ± 30 m.y., the age of the Middle Brook Granite).

The radiometric ages fall into two categories: those of undeformed post-tectonic granites which support or certainly do not contradict the field evidence or the writer's interpretation; and those of highly deformed cataclastic granites which strongly conflict with the field evidence, the writer's interpretations and to some extent other radiometric dates. Thus, in a qualitive fashion there seems to be some relationship between anomalously young Rb-Sr ages and the granites' cataclastic history of deformation. Odom and Fullagar (1973) reached a similar conclusion on Rb-Sr dates of the Henderson Gneiss, a major lithological unit of the Inner Piedmont, where it becomes mylonitized adjacent to the Brevard Zone in North and South Carolina. They also suggest that the young ages reflect some post-cataclasis, low temperature event which only affected the already severely mylonitized rocks. Perhaps this may explain the problems presented by the Rb-Sr ages in this area. Finally, if the Rb-Sr ages are significant they indicate that a major Variscan regional event (including the Dover Fault) must have affected the westernmost Avalon Zone and most of the Gander Zone. Although some age dates themselves refute this event, the structural and stratigraphic history of the western Avalon Zone makes this most unlikely.

6.2 The Gander/Avalon Zone Boundary in Southern Newfoundland (after Blackwood and O'Driscoll, 1976).

6.2.1 Introduction

The Hermitage Bay Fault (Widmer, 1950) forms the boundary between the Gander and Avalon Zones in southeastern Newfoundland. It separates deformed granitic rocks of the Gander Zone from undeformed sedimentary, volcanic, and granitic rocks of the Avalon Zone. The fault was interpreted by Widmer (1950) to be a northwest dipping, high angle reverse fault. In fact it is a breccia zone which does not represent the original structure which marked the boundary. In this regard it contrasts sharply with the Dover Fault. Also, the Hermitage Bay Fault is probably a Paleozoic feature since it involves Late Hadrynian - Early Cambrian molasse facies rocks.

The Gander and Avalon Zones are cut by two granite bodies which straddle the boundary between the two zones. One is the Ackley Batholith (White, 1939) that cuts the southern portion of the boundary; the other is a small pluton that cuts the boundary in the extreme south. Northeast of Ackley Batholith, the Dover Fault marks the contact between the two zones; to the southwest the contact is the Hermitage Bay Fault (Fig. 2).

6.2.2 Geology of the Gander Zone adjacent to the Hermitage Bay Fault.

A variety of granitic rocks underlie the Gander Zone in this region (Fig. 8). Along the Hermitage Bay Fault discontinuous lenticular bodies of megacrystic granite are exposed. This rock is characterized by large microcline megacrysts 2-4 cm long. Overprinting the granite is a strong, northeast-trending, steeply-dipping, tectonic foliation. This penetrative foliation is defined by a biotite/chlorite

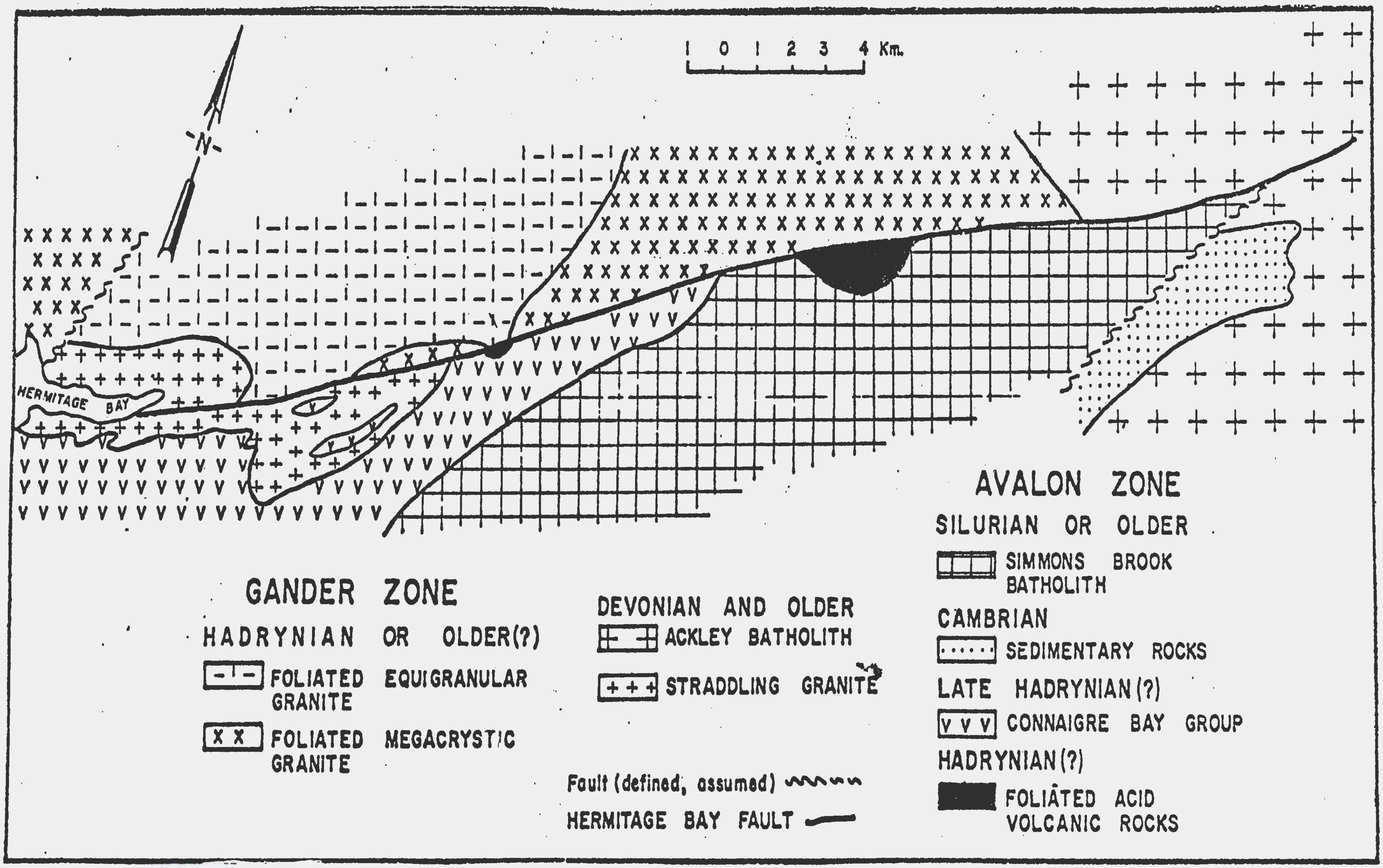


Figure 8. Geology adjacent to the Hermitage Bay Fault in south-eastern Newfoundland (after Blackwood and O'Driscoll, 1976).

alignment (locally by the elongation of quartz) and forms augen around the microcline megacrysts. These rocks are cut locally by a widely spaced strain-slip cleavage.

To the northwest the megacrystic granite is intruded by a fine to medium grained, equigranular granite (Fig. 8). Muscovite is generally characteristic of this granite but may not occur in local zones of biotite granite. No clear cut intrusive contacts occur between the muscovite granite and the biotite (muscovite) granite. These granitic rocks are considered part of a composite pluton. Overprinting the equigranular granite is a pervasive, northeast trending, northwest dipping foliation. This foliation varies in intensity and where strongly developed, mica alignment and quartz elongation are common. Locally the equigranular granite is intruded pretectonically by garnetiferous granite veins.

Farther to the northwest, these granites and similar bodies intrude basement gneisses of the Gander Zone (Coleman-Sadd, 1976).

6.2.3 Geology of the Avalon Zone adjacent to the Hermitage Bay Fault

Acidic to mafic volcanic and associated pyroclastic rocks comprise the Connaigre Bay Group (Widmer, 1950) close to the Hermitage Bay Fault (Fig. 8). These include rhyolitic and basaltic flows, fine laminated tuffs, and agglomerates. Farther south, the Connaigre Bay Group also contains red clastic rocks including sandstones and coarse conglomerates (O'Driscoll, 1976). These sedimentary and volcanic rocks are involved in northeast-trending, gently plunging folds with a preferentially developed axial planar cleavage. However, no regional penetrative foliation affects the Connaigre Bay Group and it is relatively undeformed adjacent to the Hermitage Bay Fault. The Connaigre Bay Group is undated, but it is correlated with the Late Hadrynian Long Harbour Group to the east (Widmer, 1950; Williams, 1971). These rocks are also correlated in general with the molasse facies rocks of the Avalon Zone.

Intrusive rocks, mainly dioritic to granodioritic in composition, cut the Connaigre Bay Group in this region and form part of a much larger intrusion to the southeast, the Simmons Brook Batholith (Williams, 1971). The northwest limit of this batholith is marked by the Hermitage Bay Fault. Adjacent to the fault, minor zones of shearing and brecciation occur. For the most part, however, these intrusive rocks are undeformed and show no evidence of a penetrative foliation. In the south, the Simmons Brook Batholith is unconformably overlain by the Cinq Isles and Pools Cove Formations of probable Devonian age (Williams, 1971). Minor intrusive rocks also cut the Connaigre Bay Group and include pink-purple felsites, medium-grained diorite, medium-grained gabbro and leucogranite.

Intensely deformed acid volcanic rocks outcrop in two isolated localities along the Hermitage Bay Fault (Fig. 8). The southern occurrence is small, but the northern occurrence occupies an area at least three km long by more than one km wide. These volcanic rocks contrast sharply with the surrounding Connaigre Bay Group and Simmons

Brook Batholith since they are deformed by a fine penetrative foliation (see Plate 77). This foliation has a cataclastic component discernable in the northern locality. There the volcanic rocks are intruded pre-tectonically by a granodiorite body. In the coarser-grained rock the plagioclase crystals are strongly flattened and mechanically broken down to produce "tails". Elongate quartz and strongly oriented biotite form augen around these pyroclasts. The foliation consistently trends northeast with steep dips.

6.2.4 Granitic rocks common to both Gander and Avalon Zones

An equigranular, medium-grained granite with pink feldspar cuts both the Gander and Avalon Zones at the northeast end of Hermitage Bay (Fig. 8). It is here referred to as the Straddling Granite. This granite is generally leucocratic with quartz, potash feldspar and plagioclase predominating. Locally, muscovite and minor biotite occur. In the Gander Zone the Straddling Granite cuts the deformed equigranular granite post-tectonically. In the Avalon Zone it intrudes volcanic rocks of the Connaigre Bay Group. This granite has no penetrative foliation and is undeformed except for local shear zones.

In the northeast the Ackley Batholith cuts both the Gander and Avalon Zones. This huge undeformed batholith has several phases of granite with a corase-grained, porphyritic phase predominating. It intrudes Cambrian sedimentary rocks, and correlatives of this granite intrude probable Devonian sediments of the Cinq Isles and Pools Cove Formations to the southeast (Williams, 1971).

Plate 77. Deformed acid volcanic rocks along Hermitage Bay Fault.

Plate 78. Breccia within the Hermitage Bay Fault Zone. Note fragments of foliated Gander Zone granite.

6.2.5 The Hermitage Bay Fault

The Hermitage Bay Fault is a relatively straight feature extending from Hermitage Bay northeastward to the Ackley Batholith (Fig. 8). It is marked by a deep, steep-walled valley. The deformed granitic rocks of the Gander Zone occur to the northwest of the fault; to the southeast the relatively undeformed volcanic and intrusive rocks of the Avalon Zone are exposed.

The fault is a 50-100 metre wide breccia zone. The breccia contains both Gander and Avalon Zone rocks represented as small (less than 1 cm) to large (greater than 7 cm) fragments (see Plate 78). Some fragments may be angular but most are sub-angular to rounded. Gander Zone fragments may be distinguished by their pre-brecciation foliation which is disoriented within the fault zone. Avalon Zone fragments are represented by brecciated, previously undeformed rock. Generally there is a fairly sharp contact between the two types of breccia within the fault zone. The development of chlorite is common. Along parts of the fault-controlled valley, exposure is poor and the composition of the breccia is unknown.

The Hermitage Bay Fault cuts the Straddling Granite which becomes severely brecciated within the fault zone. It also extends for several metres into the Ackley Batholith.

6.2.6 Discussion

The Dover Fault is cut off southwards by the Ackley Batholith. It is probable that a continuation of this fault once marked the

Gander/Avalon Zone boundary south of the Ackley Batholith as well. The Hermitage Bay Fault, however, now occupies that site.

In southeastern Newfoundland the Straddling Granite is common to both the Gander and Avalon Zones and post-dates the juxtaposing of the two zones. The Hermitage Bay Fault post-dates the Straddling Granite and therefore is not the original structure which marked the boundary. The deformed acid volcanic rocks along the Hermitage Bay Fault are quite similar to those of the Love Cove Group in the northeast. It is suggested that these strongly foliated rocks are remnants of an older deformed terrane that once marked the northwestern margin of the Avalon Zone and were deformed as a result of the juxtaposing of the Gander and Avalon Zones. The strong foliation in the megacrystic granite of the Gander Zone is the result of the same deformation.

The Simmons Brook Batholith, a Silurian or older intrusion, is undeformed (except for local brecciation) adjacent to the Hermitage Bay Fault. Likewise, the Late Hadrynian Connaigre Bay Group is not penetratively foliated along the fault. Therefore, the juxtaposing of the Gander and Avalon Zones with the associated regional cataclastic foliation predated these rocks and is Precambrian in age. The volcanic and red clastic rocks of the Connaigre Bay Group have a similar spatial relationship with the Gander/Avalon Zone boundary as the Musgravetown Group in northeastern Newfoundland. O'Driscoll (1976) reported xenoliths of foliated sedimentary and volcanic rocks in a diorite which cuts the Connaigre Bay Group. The xenoliths are interpreted to represent the older deformed terrane upon which the molasse facies and associated volcanic rocks were deposited.

Thus it appears that a continuation of the Dover Fault once marked the Gander/Avalon Zone boundary in southeastern Newfoundland. Subsequent movement modified this contact, producing the Hermitage Bay Fault along the older zone of weakness. In this area, the Connaigre Bay Group covers the Hadrynian deformed terrane of the Avalon Zone. The movement which produced the Hermitage Bay Fault post-dates the Straddling Granite and Ackley Batholith. This would make it of probable Devonian age possibly related to the Acadian Orogeny in Newfoundland.

6.3 General Conclusions regarding the Gander and Avalon Zones in Newfoundland

The Gander and Avalon Zones mark the southeastern side of the Appalachian system in Newfoundland. The Dover Fault forms the boundary between the zones in northeastern Newfoundland, initiated during the juxtaposing of the two zones in the Precambrian. Subsequent movement probably in the Devonian, modified this fault in southeastern Newfoundland producing the Hermitage Bay Fault.

The Gander Zone underlies an area to the northwest of the Dover-Hermitage Bay Fault system. It forms a belt of crystalline rocks running northeast-southwest in eastern Newfoundland; along the south coast of the island it swings around into an approximate east-west trend, eventually ending at the Cape Ray Fault (Brown, 1973) in western Newfoundland (Fig. 1). The Gander Zone is underlain by a basement gneiss terrane called the Bonavista Bay Gneiss Complex in northeastern Newfoundland. The Gander Group forms a cover sequence to these basement rocks. In southeastern Newfoundland, S.P. Coleman-Sadd (1974) described a reconstitution zone between gneiss and overlying polydeformed metasedimentary rocks of the Baie d'Espoir Group. The latter has been correlated with rocks in the Gander region (Jenness, 1963) and the south coast gneisses are likely an extension of the Bonavista Bay Gneiss Complex.

The age of deformation of the Gander Group is pre-Middle Ordovician and the first structures (D_1) may be Precambrian. Subsequent structures (D_2) may be much younger (Lower Paleozoic?). The Bonavista Bay Gneiss Complex is Precambrian and may be as old as Helikian. During the Late Precambrian the gneisses were overprinted by a regional foliation (Ganderian Orogeny).

The Avalon Zone underlies that area to the southeast of the Dover-Hermitage Bay Fault system and includes the eastern portion of Newfoundland. It also extends to the continental margin (Grant, 1972) and is the largest of the tectonostratigraphic zones, being twice the width of the remaining Appalachian Belt.

The oldest rocks in the Avalon Zone are Precambrian volcanic and flyschoid sequences. These are represented by the deformed Love Cove and Connecting Point Groups on the zone's western margin. The equivalents of these rocks are less deformed towards the center of the zone, i.e. the Harbour Main and Conception Groups (Rose, 1952). The rocks were deformed in the Precambrian (Avalonian Orogeny of Lilly, 1966).

Late Hadrian-Early Cambrian molasse facies and volcanic rocks of the Musgravetown Group unconformably overlie the Love Cove Group and Connecting Point Group (Hayes, 1948) at the western margin of the Avalon Zone. In the east, towards the center of the zone, equivalents of the Musgravetown Group, i.e. Hodgewater Group (Hutchinson, 1953) and Cabot Group (Rose, 1952) lie with slight, disconformity or conformably upon the Conception Group. This change from west to east reflects a decrease in the intensity of the Avalonian Orogeny away from the margin of the Avalon Zone.

6.4 Gander and Avalon Zone Correlations in the Canadian and Southern Appalachians.

The zonal subdivision of the Newfoundland Appalachians has been applied with some success to the rest of the Canadian Appalachians (Williams, Kennedy and Neale, 1972). Since then the southwestward extension of the Gander and Avalon Zones have been refined (Rast, Kennedy and Blackwood, 1976). This is best done in New Brunswick where crystalline rocks of the Miramichi Highlands, including megacrystic and garnetiferous granitic rocks, are comparable to the Gander Zone of Newfoundland (Fig. 9). The Avalon Zone is underlain by gneisses and metasedimentary rocks of the Green Head Group (Alcock, 1938) which forms a basement terrane to the volcanic and minor flyschoid rocks of the Coldbrook Group (Alcock, 1938). The latter is unconformably overlain by the Late Hadrynian-Early Cambrian molasse facies of the Ratcliffe Brook Formation (Patel, 1973, 1975). In New Brunswick, the

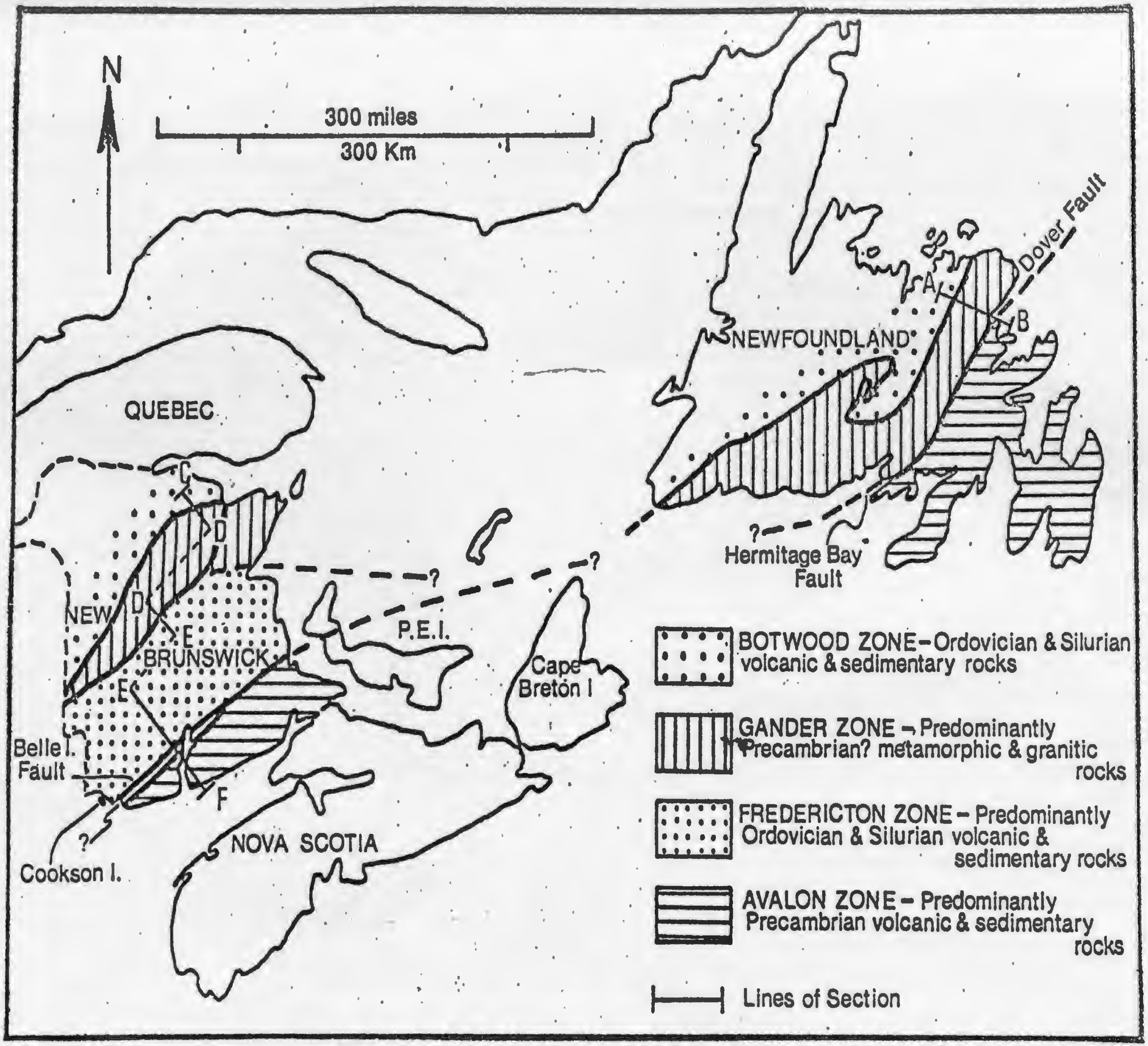


Figure 9. Distribution of Gander, Avalon and Fredericton Zones in Newfoundland and New Brunswick (after Rast, Kennedy and Blackwood, 1976).

Gander and Avalon Zones are separated by 65 km of Ordovician and Silurian rocks. This Early Paleozoic basin unconformably overlaps the Gander Zone and is in fault contact with the Avalon Zone. Called the Fredericton Zone by Rast, Kennedy and Blackwood (1976), it apparently has developed upon the old Precambrian fault (Dover Fault of Newfoundland) that separates the Gander and Avalon Zones.

In Nova Scotia, distinction into Gander-Avalon Zone rocks is more difficult. However, the southern portion of the George River Group (Weeks, 1954) is probably equivalent to the Greenhead Group of New Brunswick. The George River is overlain with inferred unconformity by Precambrian volcanic and flyschoid rocks (Weeks, 1954) similar to those found elsewhere in the Avalon Zone. The northern portion of the George River Group (on Cape Breton Island) contains polydeformed volcanic and sedimentary rocks which may represent Gander Zone equivalents (Neale and Kennedy, 1975).

In Maine, at least two occurrences of crystalline rocks may be correlated with the Gander Zone (Fig. 10). One includes parts of the Grand Pitch Formation (Neuman, 1967) in northeastern Maine, which is similar to metasedimentary rocks of the Miramichi Highlands, and by extension to the Gander Group of Newfoundland. These rocks, however, are considered by Neuman (1967) to be Early Cambrian in age. In southeastern Maine, the Casco Bay Group consists of metasedimentary and metavolcanic rocks, including amphibolites and lime-silicate gneisses (Hussey, 1971). Garnetiferous granite veins post-date the gneissic banding and have been subsequently deformed. These rocks

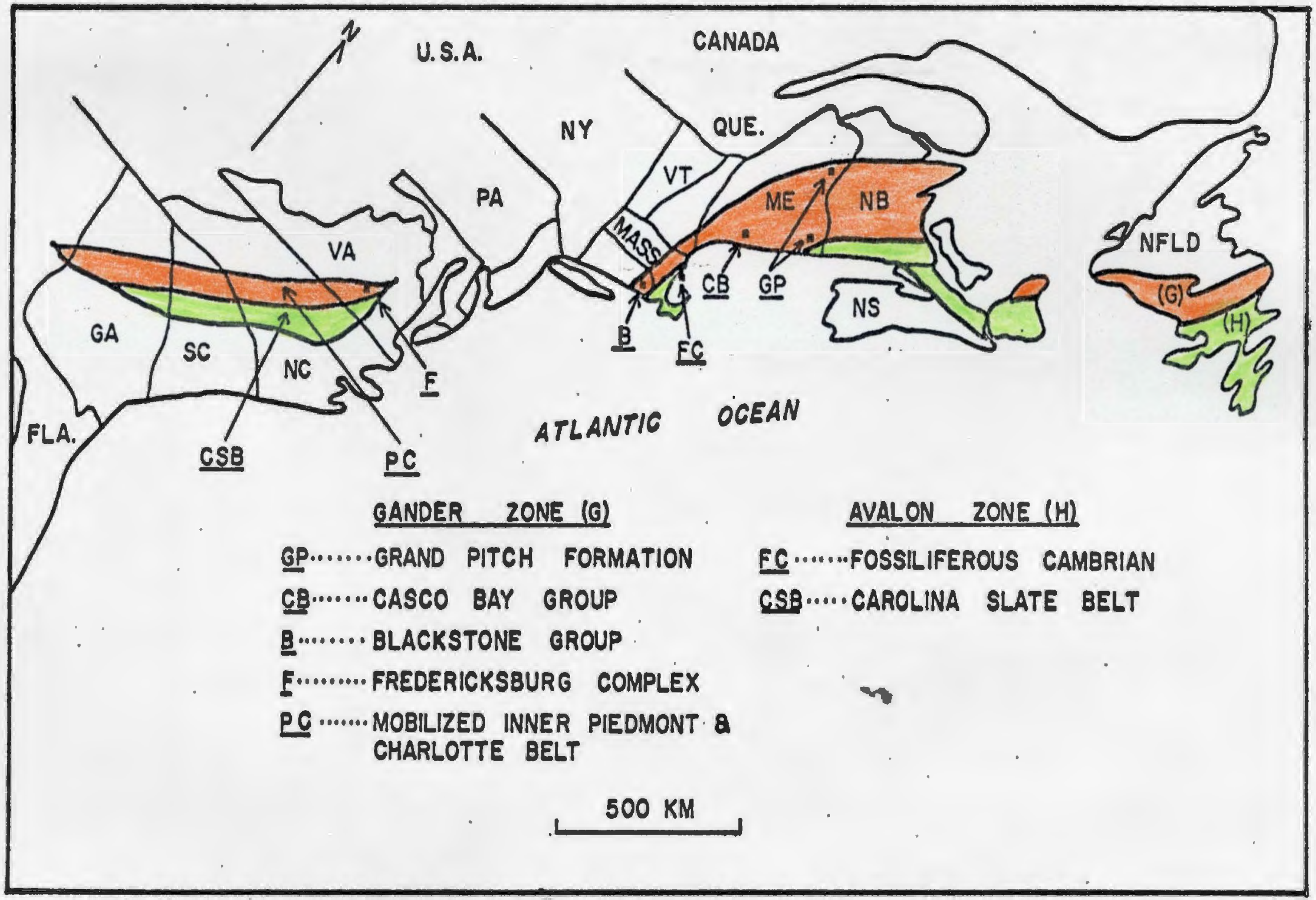


Figure 10. Possible correlatives of the Gander and Avalon Zones in the Canadian and Southern Appalachians.

are analogous to the Bonavista Bay Gneiss Complex and in part to the Gander Group, although the metamorphic grade is generally higher. However, the Casco Bay Group may actually be a continuation of the basement to the Avalon Zone, i.e. Green Head Group in New Brunswick, George River Group in Nova Scotia (not exposed in Newfoundland but presumably similar to the Bonavista Bay Gneiss Complex).

Fossiliferous Cambrian rocks of eastern Massachusetts unconformably overlie a granodiorite body (Rodgers, 1972). In Newfoundland, the Avalonian Orogeny as originally defined by Lilly (1966), is marked by a similar unconformity between Cambrian strata and the Holyrood Granite. Thus the Boston area may represent an extension of the Avalon Zone.

In Rhode Island, the Blackstone Group is considered to be Precambrian (Quinn, 1971) and appears to resemble the Gander Group (Kennedy, 1975). If this area (Fig. 10) represents a continuation of the Gander Zone, then the Gander-Avalon boundary may lie just east of Cape Cod.

The Fredericksburg Complex in northeast Virginia consists of granodiorite gneiss, microcline gneissic granite and schists (Pavlides et al., 1974). The gneissic rocks are similar to the Bonavista Bay Gneiss Complex and the schists may represent Gander Group. Ages of Late Precambrian to Lower Paleozoic are uncertain but these rocks in Virginia are good correlatives with the Gander Zone.

Farther south, much of the area underlain by the Mobilized Inner Piedmont and the Charlotte Belt (Hatcher, 1972) may be Gander

Zone correlatives. The Carolina Slate Belt comprising Late Precambrian-Cambrian volcanic and volcaniclastic rocks is probably a continuation of the Avalon Zone (Rodgers, 1972).

6.5 Gander and Avalon Zone Correlations in the Caledonian System

The most obvious European correlatives of the Gander and Avalon Zones are found in Wales and southeast Ireland. Possible Gander Zone equivalents are exposed on the island of Anglesey, northern Wales (Fig. 11). Anglesey is underlain by the Mona Complex which may be divided into two broad units: a bedded series of metasedimentary rocks including quartzites, schists and greywackes with metavolcanic rocks; and a series of banded gneisses. Greenly (1919) contended that the gneisses were basement to the bedded series but Shackleton (1956) maintains that the metasediemntary rocks are gradational into the gneisses with the latter representing a migmatized version of the former in areas of syntectonic migmatitic activity. However, Brian Sturt (pers comm., 1975) has observed gneissic xenoliths within the Coedana granite, a body responsible for much of the migmitization of the bedded series according to Shackleton. The xenoliths must represent a tectonized terrane older than the granite and are likely part of a basement complex to the bedded series. Shackleton (1975) allows that both explanations are now plausible. The Mona Complex is dated as Precambrian radiometrically (Moorbath and Shackleton, 1966) and by stratigraphic means, i.e. unconformably overlain by the Late Hadrynian Arvonian volcanic rocks in southeast

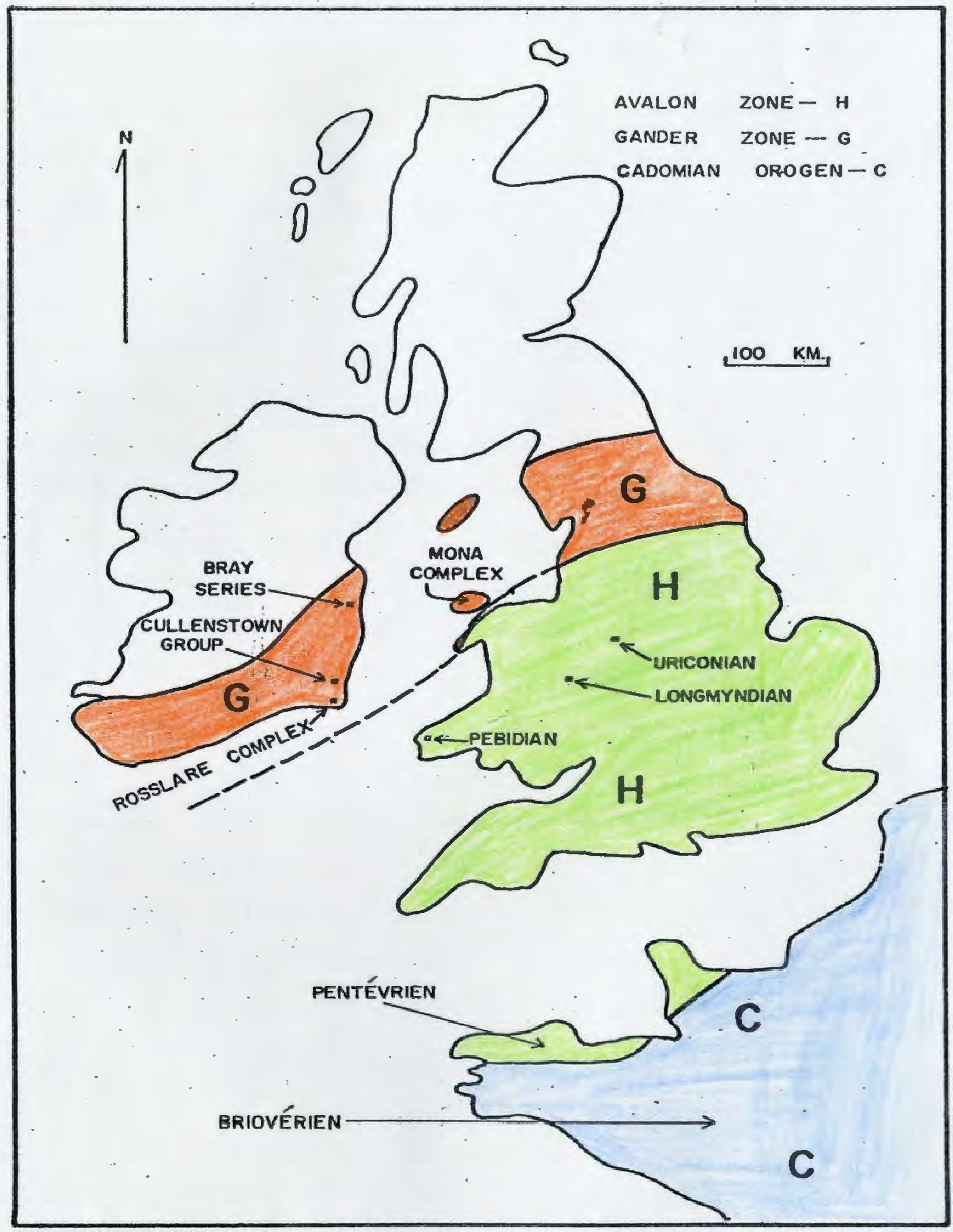


Figure 11. Possible correlatives of the Gander and Avalon Zones in the Caledonian System showing the Cadomian Orogen.

Anglesey (Greenly, 1919). Thus, it may be possible to equate the Bonavista Bay Gneiss Complex with the probably basement gneisses of the Mona Complex and the Gander Group with the bedded series of the Mona Complex.

In southeast Ireland the Rosslare Complex consists of banded and nebulitic orthogneiss and paragneiss (Thorpe, 1974) with a complex history of deformation, metamorphism and mobilization. It is much more complex than the adjacent Cullenstown Group, a clearly younger sequence of metasedimentary rocks. Both the Rosslare Complex and the Cullenstown Group are considered Precambrian (Rast and Crimes, 1969). The Cullenstown Group is similar to parts of the bedded series of the Mona Complex (Max, 1975) on Anglesey and by extension with the Gander Group. The Rosslare Complex would be correlated with the basement? gneisses of the Mona Complex and is a good correlative lithologically and structurally with the Bonavista Bay Gneiss Complex, i.e. Precambrian orthogneiss and paragneiss.

Excellent correlations exist between the Avalon Zone and rocks in South Wales and the Welsh borderlands (Fig. 11). In north Pembrokeshire, South Wales, Precambrian volcanic rocks called the Pebidian are intruded by granitic and granophyric rocks called the Dimetian (Green, 1908). The Dimetian is overlain by the Caerfai Basal Conglomerate of Lower Cambrian age (Rast and Crimes, 1969). In Newfoundland, the Precambrian Harbour Main Group consists of mainly volcanic rocks which are intruded by the Holyrood Granite. The Holyrood Granite is disconformably overlain by a Cambrian basal conglomerate; thus the similarity between Newfoundland and that part of Wales is pronounced.

In the Welsh borderlands a more complete correlation of Avalon Zone stratigraphy is represented by the Precambrian Uriconian and Longmyndian successions. The former consists of acid volcanic rocks and is similar to the Harbour Main Group. The Longmyndian is subdivided into two broad units; Grey Longmyndian and Red Longmyndian (Rast and Crimes, 1969). The former consists of grey and purple laminated siltstones, shales, sandstones and tuffs. The Conception Group with its laminated sandstones and local volcanic horizons is readily correlated with the Grey Longmyndian. However, the upper part of the Grey Longmyndian consists mainly of purple and green shales which sit unconformably upon the lower part of the sequence. These shales may be correlated with those found at the base of the Cabot Group which sits upon the Conception Group in Newfoundland. The Red Longmyndian sits unconformably upon the Grey, and consists mostly of sandstones and conglomerates with some shales and tuffs. These rocks are analogous to the red conglomerates and sandstones at the top of the Cabot Group in Newfoundland. Like the Cabot and its Newfoundland equivalents of Hodgewater and Musgravetown Groups, the Red Longmyndian is probably a molasse sequence.

The boundary between the Gander and Avalon Zones is less easily defined in Wales. However, it is suggested here that it runs through the Menai Strait which separates Anglesey from North Wales. The following reasons are used for doing so: (1) the bedded series of the

Mona Complex may be restricted to the northwest of the proposed boundary as the Gander Group is of the Dover Fault. The occurrence of crystalline inliers such as the Dutch Gin Schists, Rushton Schists, Primrose Hill Gneiss and the Malvern Gneiss (Rast and Grimes, 1968) in Wales does not refute this. These metamorphic rocks are probably basement to the Precambrian Avalonian rocks just described. As such they may better be correlated with the basement? gneiss of Anglesey and the Bonavista Bay Gneiss Complex; (2) rocks of Avalon Zone affinity do not cross the Menai Strait; except for the acid volcanic rocks of the Arvonian (Greenly, 1919) which unconformely overlie mica schists of the Mona Complex in southeast Anglesey. The Arvonian of North Wales is overlain conformably by the basal Cambrian conglomerate (Wood, 1969). It is thus Eocambrian in age and likely correlative with the volcanic and sedimentary rocks of similar age and appearance in Newfoundland, e.g. Musgravetown Group. Therefore the Arvonian would post-date a Dover Fault equivalent through the Menai Strait; (3) The Menai Strait is the locality of persistent deep-seated fault movements from the Precambrian onward (Wood, 1974) although no zone similar to the Dover Fault is preserved.

6.6 Relationships between Gander-Avalon Zones and the Precambrian Cadomian Orogeny; a proposed plate tectonic model.

In northwest France, Cogné (1962, 1974) sub-divided the Precambrian rocks into the Pentévrien, a migmatized basement gneiss complex, and the Briovérien, a much less metamorphosed Late Precambrian sequence. The Briovérien contains blue schists, ophiolites, syntectonic intrusive rocks, and sedimentary and volcanic rocks of "geosynclinal" aspect. These rocks represent a polyphase orogen, the Cadomian Orogen (Fig. 11), whose tectonic activity ceased in the Eocambrian and was generally sealed by late intrusion at 550 million years (Cogné, 1962). Similar belts of Precambrian orogenic activity occur in Spain, Western Africa, and eastern South America.

It is here suggested that: (1) The Pentévrien basement gneisses are continuous with the basement rocks of the Welsh borderlands, Anglesey, and southeast Ireland; thus by inference with the Bonavista Bay Gneiss Complex; (2) The Briovérien represents the time equivalent of the cover rocks to the basement terrane of the Gander and Avalon Zones i.e., Gander Group, Cullenstown Group, and bedded succession of Mona Complex in the Gander Zone; pre-molasse volcanic and flyschoid rocks of the Avalon Zone; (3) the Cadomian Orogeny is responsible for the Precambrian tectonic development of the Gander (Ganderian Orogeny) and Avalon (Avalonian Orogeny) Zones.

Traditionally the Avalon and Gander Zones are considered as part of the Appalachian system (a reasonable prospect since they mark the southeast side of that orogenic belt). However, in attributing the Precambrian development of these zones to the Cadomian Orogeny, the following points might be considered:

1) The Gander and Avalon Zones have been subjected to Precambrian orogenic activity; the Cadomian Orogeny is a major orogenic belt with a considerable Precambrian depositional and tectonic history.

2) There is no hard evidence that the western margin of the Appalachian System was an established feature before Eocambrian time, with earliest tectonism being a Cambro-Ordovician event. In order for the Avalon and Gander Zones to be depositionally and tectonically related to the Proto-Atlantic Ocean to the northwest, the western margin of that ocean would have to have been in existence well back into the Precambrian.

Note: The thick sequences of young Moine and Torridonian Precambrian clastic rocks on the northwestern margin of the Caledonian Belt in Scotland do not necessarily imply oceanic crust of the same age to the southeast. The younger Dalradian rocks (Late Precambrian-Ordovician) do however, imply a Proto-Atlantic Ocean active by Cambro-Ordovician time.

3) Explanation of the Precambrian development of the Gander and Avalon Zones in relation to the Appalachian System involves the supposition that the Proto-Atlantic was the site of considerable plate activity (i.e. subduction) in the Late Proterozoic. The Cadomian Orogeny, on the other hand, is demonstratably of the right age and suitably situated to explain both the occurrence and distribution of the Gander and Avalon Zones.

4) The Avalon Zone is the largest of the tectonostratigraphic zones in the Newfoundland Appalachians, being twice as wide as the rest of the orogen. This is probably due to rigid continental crust forming the basement of that zone, which might be considered as a micro-plate. Also, the style of deformation of the western margin of

the Avalon Zone, and the overprinting of the Gander Zone by the same event is special and perhaps unique. It is a widespread event which differs considerably from subsequent deformation of the Gander Zone; these later structures have a westward (Appalachian) generation and are of limited eastward influence. The early low grade regional deformation of the Gander and Avalon Zones is thus viewed as non-Appalachian; the Cadomian Orogeny is a positive alternative in explaning this orogenic event that produced the juxtaposing of the Gander and Avalon Zones.

5) The Gander and Avalon Zones have been affected by Paleozoic processes related to the Proto-Atlantic Ocean, i.e., the Avalon Zone became a stable platform, the Gander Zone is redeformed (D_2 of Gander Group) and the Dover Fault is reactivated.

The following model (Fig. 12) is proposed for the plate-tectonic development of the Gander and Avalon Zones (with particular reference to Newfoundland):

A/ At 800 m.y., the Cadomian Ocean is well developed. Continental crust (Pentévrien) is overlain by continental margin deposits (Briovérien). Subduction underneath Paleo-North America produces the earliest volcanic rocks now seen on the Avalon Zone.

B/ Between 700-800 m.y., continued subduction of Cadomian oceanic crust occurs. This results in a small back-arc basin, possibly situated upon an older zone of weakness in the continental crust. In this way a micro-plate (Avalon) is isolated from Paleo-North America.

The Gander Group with a westward provenance, is deposited in the graben- like back-arc basin (which need not be floored by a great expanse of oceanic crust). Volcanicity and associated sedimentation continues on the Avalon plate resulting in deposition of Love Cove, Harbour Main, Connecting Point and Conception Groups.

Within the Paleo-North American Craton, already developed graben over zones of weakness in the crust have received sedimentation (Torridonian and Young Moines).

C/ Near the end of the 600-700 m.y. period, the Cadomian Ocean is closed out, producing the Cadomian Orogen. This forces the Avalon micro-plate back against Paleo-North America producing the Ganderian/Avalonian Orogeny. The Dover Fault marks the juxtaposing of what is now the Avalon Zone with the main craton.

During the Ganderian/Avalonian Orogeny, deformation is concentrated along the margin of the Avalon plate and Paleo-North America. In this way the Love Cove and Connecting Point Groups are much more deformed than their lateral equivalents toward the centre of the plate i.e., Harbour Main and Conception Groups. Likewise, the Gander Group is deformed by the same regional compression.

During the Late Precambrian - Early Cambrian time the molasse rocks, i.e. Musgravetown Group and equivalents, are deposited in large fault controlled basins. They sit with marked unconformity on the western margin of the Avalon Zone, but much less so towards the centre of the zone. Coeval with these deposits are centres of volcanicity.

Around 600 m.y. distension back within the Paleo-North

America Craton marks the initiation of Iapetus (the Proto-Atlantic Ocean). Dikes intrude the developing margin and earliest sedimentation occurs.

Note: Iapetus may have originated along the earlier graben structures which received the Young Moines and Torridonian sedimentation. This would explain the position of these rocks underneath the Dalradian on the northwestern margin of the Caledonian system.

D/ The Iapetus ocean is well established between 500-600 m.y.. The western margin of the ocean is marked by the Fleur de Lys Supergroup (Dalradian) and platformal sediments. The eastern margin is developed upon the Gander Zone which is now completely separated from Paleo-North America. Sedimentation at this time upon the eastern margin is marked by the Bray Series (Lamplugh, 1903) in southeast Ireland.

The Gander and Avalon Zones are part of a stable craton covered with platformal sediments. However, eastward subduction of Iapetus oceanic crust causes vertical movement along the Dover Fault and locally, distension i.e., Fredericton Zone of New Brunswick developes.

E/ Before 450 m.y. ophiolite (the Gander Zone ultramafic belt) is obducted, possibly from a small back-arc basin developed along the eastern margin. This overiding slab imparts the high level recumbent structures to the Gander Group. The eastward influence of the deformation is controlled by the limited advance of the ophiolite slab in that direction.

Post 450 m.y., the Caradocian Davidsville Group is unconformably deposited upon the tectonized margin. However, the margin is still somewhat unstable and this results in a melange developing locally at the base of the Davidsville Group.

Renewed vertical movement along the Dover Fault produces major uplifting of Gander Zone relative to Avalon Zone. In this way the Cambrian and younger platformal sediments and a large part of the Gander Group are stripped off. The timing of this event need not be rigid.

Conclusion

The Cadomian Orogeny is responsible for the Precambrian development of the Gander and Avalon Zones. Subsequent modification occurs during the development of the Paleozoic Iapetus Ocean.

REFERENCES

Aeromagnetic Map #190G, 1954. Geol. Surv. Can.

Alcock, F.J., 1938. Geology of Saint John Region, New Brunswick. Geol. Surv. Can. Mem. 216.

Bell, K. and Blenkinsop, J., 1975. The Geochronology of Eastern Newfoundland. Nature, 254, pp. 410-411.

Blackwood, R.F. and Kennedy, M.J., 1975. The Dover Fault: Western Boundary of the Avalon Zone in Northeastern Newfoundland. Can. J. Earth Sci., 12, pp. 320-325.

Blackwood, R.F. and O'Driscoll, C.F., 1976. The Gander-Avalon Zone Boundary in Southeastern Newfoundland. Can. J. Earth Sci., 13, in press.

Brown, P.A., 1973. Possible Cryptic Suture in South-west Newfoundland. Nature, Phys. Sci., 246, pp. 9-10.

Christie, A.M., 1950. Geology of Bonavista Map-Area. Geol. Surv. Can. Paper 50-7.

Cogné, J., 1962. Le briovérien. Esquisse des caractères stratigraphiques, métamorphique structuraux et paléogeographiques, de l'Antecambrien récent dans le Massif Armoricain. Bull. Soc. Géol. France, 4, pp. 413-430.

Cogné, J., 1974. Les grands traits structuraux du Massif Armoricain. In: La chaine Varisque d'Europe moyenne et occoidentale Colloque International du CNRS, Rennes. Programmes des séances et résumés des publications.

Colman-Sadd, S.P., 1974. The Geologic Development of the Bay d'Espoir Area, Southeastern Newfoundland. Unpubl. Ph.D. thesis, Memorial University of Newfoundland, St. John's, Nfld.

Colman-Sadd, S.P., 1976. Geological mapping - Bay d'Espoir Area. In: Report of Activities for 1975, Nfld. Dept. of Mines and Energy, Min. Dev. Div., Report 76-1, pp. 38-46.

Dunning, F.W., and Max, M.D., 1975. The Exposed and Correlated Precambrian Basement of the British Isles. In: A Correlation of the Precambrian rocks in the British Isles (Harris, A.L., Sharkleton, R.M., Watson, J., Downie, C., Harland, W.B., and Moorbath, S.; Eds.). Spec. Rept. No. 6: Precambrian, Geol. Soc. London, p. 12.

Fairbairn, H.W. and Berger, A.R., 1969. Preliminary geochronological Studies in northeast Newfoundland. 17th. Ann. Progr. Rept. Mass Inst. Technol., A.E.C. 1381-17, pp. 19-20.

Grant, A.L., 1972. The Continental Margin off Labrador and Eastern Newfoundland - morphology and geology. Can. J. of Earth Sci., 9, pp. 1394-1440.

Green, J.F.N., 1908. The geological structure of the St. David's Area (Pembrokenshire). Quat. J. Geol. Soc. London, 64, pp. 363-383.

Greenly, E., 1919. The geology of Anglesey. Geol. Surv. Gt. Brit., Mem. Geol. Surv. Gt. Brit., Engl. Wales, 1, 388 p.

Hatcher, R.D., Jr., 1972. Developmental model for the Southern Appalachians. Geol. Soc. America Bull., 83, pp. 2735-2760.

Hayes, A.O., 1948. Geology of the Area between Bonavista and Trinity Bays, Eastern Newfoundland. Geol. Surv. Newfoundland Bull. 32, pt. 1.

Higgins, M.W., 1971. Cataclastic Rocks. U.S. Geol. Surv. Prof. Pap. 687, 97 p.

Hussey, A.M., II, 1971. Geological Map and Cross Section of the Orrs Island 7 1/2' Quadrangle and Adjacent Area, Maine GM-2, Maine Geological Survey, Augusta, Maine.

Hutchinson, R.D., 1953. Geology of Harbour Grace Map Area, Newfoundland. Geol. Surv. Can. Mem. 275.

Jenness, S.E., 1963. Terra Nova and Bonavista Map-areas, Newfoundland. Geol. Surv. Can. Me. 327.

Kay, M., 1967. Stratigraphy and structure of northeastern Newfoundland bearing on drift in North Atlantic. Am. Assoc. Petroleum Geologists Bull., 51, pp. 579-600.

Kay, M. and Colbert, E.H., 1965. Stratigraphy and life history. New York, John Wiley, 736 p.

Kennedy, M.J., 1975. Repetitive Orogeny in the Northeastern Appalachians - New Plate Models Based upon Newfoundland Examples. Tectonophysics, 28, pp. 39-87.

Kennedy, M.J. and McGonigal, M.H., 1972. The Gander Lake and Davidsville Groups of Northeastern Newfoundland: New Data and Geotectonic Implications. Can. J. Earth Sci., 9, pp. 452-459.

Lilly, H.B., 1966. Late Precambrian and Appalachian tectonics in the light of submarine exploration on the Great Bank of Newfoundland and in the Gulf of St. Lawrence, Preliminary view. Am. J. Sci., 264, pp. 569-574.

Max, M.D., 1975. Precambrian rocks of southeast Ireland. In: a correlation of the Precambrian Rocks in the British Isles (Harris, A.L., Shackleton, R.M., Watson, J., Downie, C., Harland, W.B., and Moorbath, S.; Eds.). Spec. Rept. No. 6, Precambrian, Geol. Soc. London, pp. 97-101.

Moorbath, S. and Shackleton, R.M., 1966. Isotopic ages from the Precambrian Mona Complex of Anglesey, North Wales (Great Britain). Earth Planet. Sci. Lett, 1, pp. 113-117.

Neale, E.R.W. and Kennedy, M.J., 1975. Basement and cover rocks at Cape North, Cape Breton Island, Nova Scotia. Maritime Sediments, 11, pp. 1-4.

Neuman, R.B., 1967. Bedrock geology of the Shin Pond and Staceyville quadrangles, Penobscot County, Maine. U.S. Geol. Surv. Prof. Pap., 524-1.

Odom, A.L. and Fullagar, P.D., 1973. Geochronologic and Tectonic Relationships between the Inner Piedmont, Brevard Zone, and Blue Ridge Belts, North Carolina. Am. J. Sci., 273-A, pp. 133-149.

O'Driscoll, C.F., 1976. Geology of the Hermitage Peninsula, southern Newfoundland - including a petrochemical comparison of granitoid intrusions. Unpubl. M.Sc. thesis (in prep.), Mem. Univ. of Nfld., St. John's, Nfld.

Patel, I., 1973. Sedimentology of the Ratcliff Brook Formation (Lower Cambrian?) in southeastern New Brunswick. Geol. Soc. Am. Northeast Sect. Ann. Mtg. Abst. with Prog. 5, pp. 206-207.

Patel, I., 1975. The Precambrian-Cambrian boundary in southern New Brunswick. Geol. Soc. Am. Northeast Sect. Ann. Mtg. Abst. with Prog. 7, p. 104.

Pawlides, L., Sylvester, K.A., Daniels, D.L. and Bates, R.G., 1974. Correlation Between Geophysical Data and Rock Types in the Piedmont and Coastal Plain of Northeast Virginia and Related Areas. J. Research U.S. Geol. Surv., 2, pp. 569-580.

Quinn, A.~~W.~~, 1971. Bedrock geology of Rhode Island. U.S. Geol. Surv. Bull., 1295.

Ramsay, J.G., 1967. The Folding and Fracturing of Rocks. McGraw-Hill, New York, 568 p.

Rast, N. and Crimes, T.P., 1969. Caledonian orogenic episodes in the British Isles and northwestern France and their tectonic and chronological interpretation. Tectonophysics, 7, pp. 277-307.

Rast. N., Kennedy, M.J. and Blackwood, R.F., 1976. Comparison of some Tectonostratigraphic Zones in the Appalachians of Newfoundland and New Brunswick. Can. J. Earth Sci., 13, in press.

Rodgers, J., 1972. Late Precambrian (post-Grenville) rocks of the Appalachian Region. Am. J. Sci., 272, pp. 507-520.

Rose, E.R., 1952. Torbay Map-Area, Newfoundland. Geol. Surv. Can. Mem. 265.

Shackleton, R.M., 1956. Notes on the structure and relations of the Precambrian and Ordovician rocks of southwestern Lleyn, Caernarvonshire. Liverpool Manchester Geol. J., 1, pp. 400-409.

Shackleton, R.M., 1975. Precambrian rocks of Wales. In: a correlation of the Precambrian rocks in the British Isles (Harris, A.L., Shackleton, R.M., Watson, J., Downie, C., Harland, W.B., and Moorbath, S.; Eds.). Spec. Rept. No. 6: Precambrian, Geol. Soc. London, pp. 76-82.

Strong, D.F., Dickson, W.L., O'Driscoll, C.F., and Kean, B.F., 1974. Geochemistry of Eastern Newfoundland Granitoid rocks. Nfld. Dept. of Mines and Energy, Min. Dev. Div., Rept. 74-3.

Thorpe, R.S., 1974. Geochemical evidence for the original nature of the Rosslare Complex, S.E. Eire. Proc. R. Dubl. Soc. 5A, pp. 199-206.

Weeks, L.J., 1954. Southeast Cape Breton Island, Nova Scotia. Geol. Surv. Can. Mem. 277.

Widmer, K., 1949. Glovertown-Clode sound area, Newfoundland. Unpubl. geol. map, Geol. Surv. Can.

Widmer, K., 1950. Geology of the Hermitage Bay Area, Newfoundland. Unpubl. Ph.D. thesis, Princeton Univ., Princeton, New Jersey.

Williams, H., 1964a. The Appalachians in northeastern Newfoundland - A two-sided symmetrical system. Am. J. Sci., 262, pp. 1137-1158.

Williams, H., 1971. Geology of Belleoram map-area, Newfoundland (1M/11). Geol. Surv. Can., Pap 70-65.

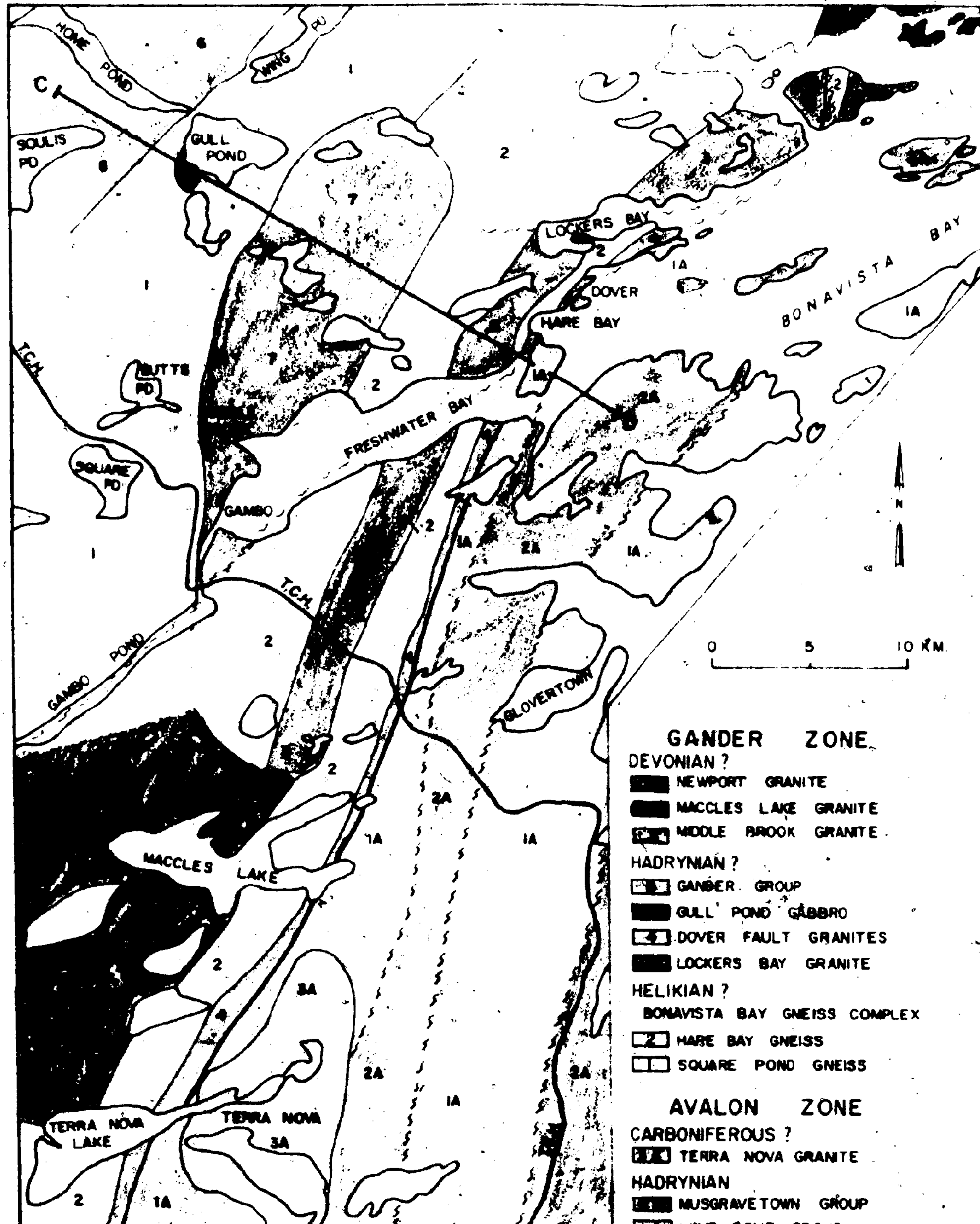
Williams, H., Kennedy, M.J., Neale, E.R.W., 1974. The northeastward termination of the Appalcahian Orogen. In: The Ocean Basins and Margins, 2, (Nairn, A.E.M. and Stehli, F.G.; Eds.) Plenum Press, New York, pp. 79-123.

White, D.E., 1939. Geology and molybdenite deposits of the Rencontre East Area, Fortune Bay, Newfoundland. Unpubl. Ph.D. thesis, Princeton Univ., Princeton, New Jersey.

Wood, D.S., 1969. The base and correlation of the Cambrian rocks of North Wales. In: The Precambrian and Lower Paleozoic of Wales (Wood, A.; Ed.). Univ. of Wales Press, Cardiff, pp. 47-66.

Wood, D.S., 1974. Ophiolites, melanges, blueschists, and ignimbrites; Early Caledonian subduction in Wales? In: Modern and Ancient Geosynclinal Sedimentation (Dott, R.H., Jr. and Shaver, R.H.; Eds.). Soc. Econ. Paleontal. Mineral. Spec. Publ. 19, pp. 334-344.

Younce, G.B., 1970. Structural Geology and Stratigraphy of the Bonavista Bay Region, Newfoundland. Unpubl. Ph.D. thesis, Cornell Univ., Ithaiu, New York.



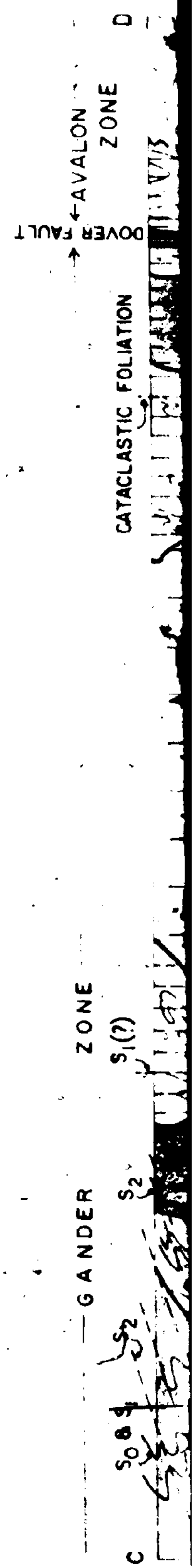
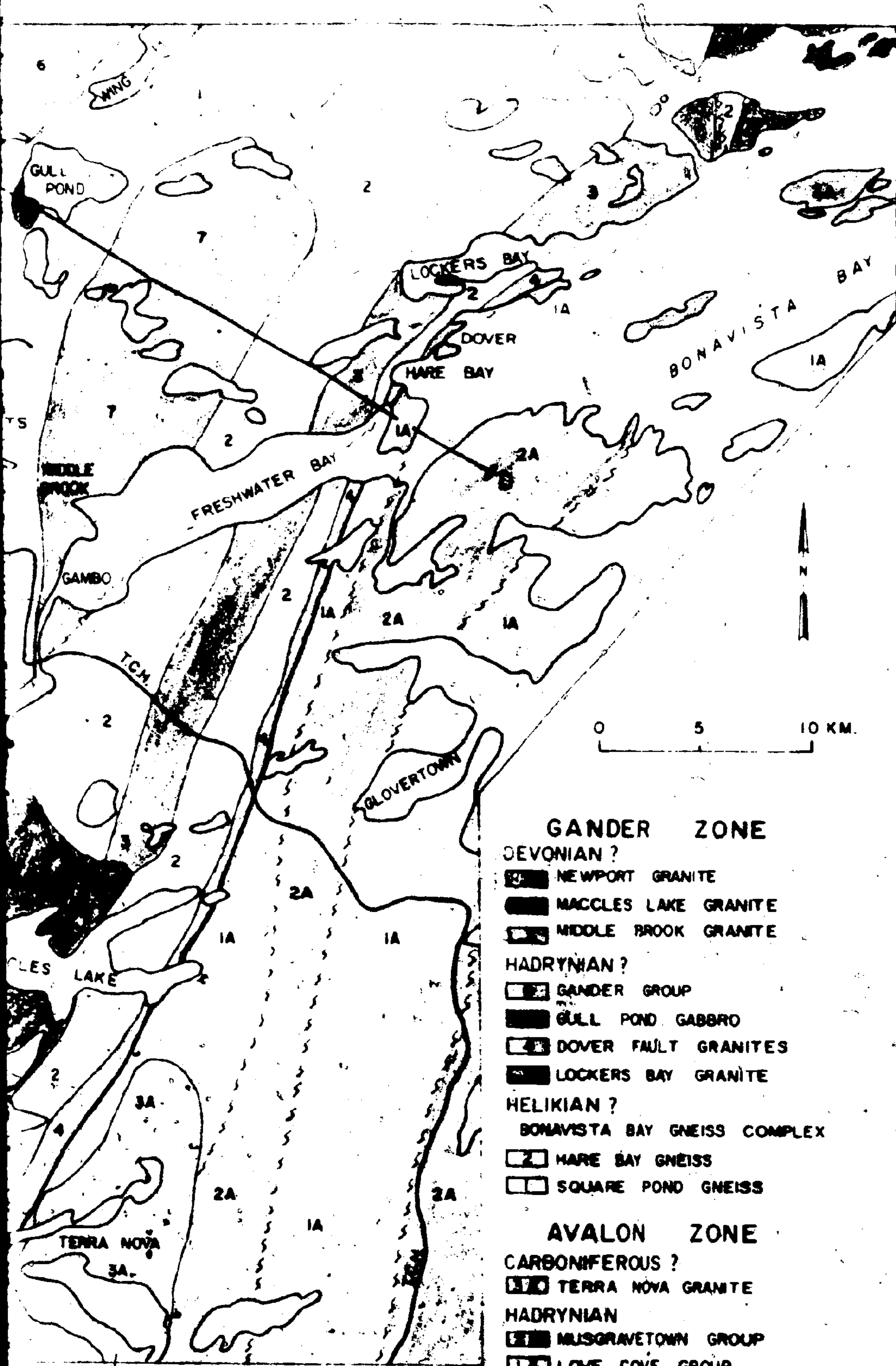
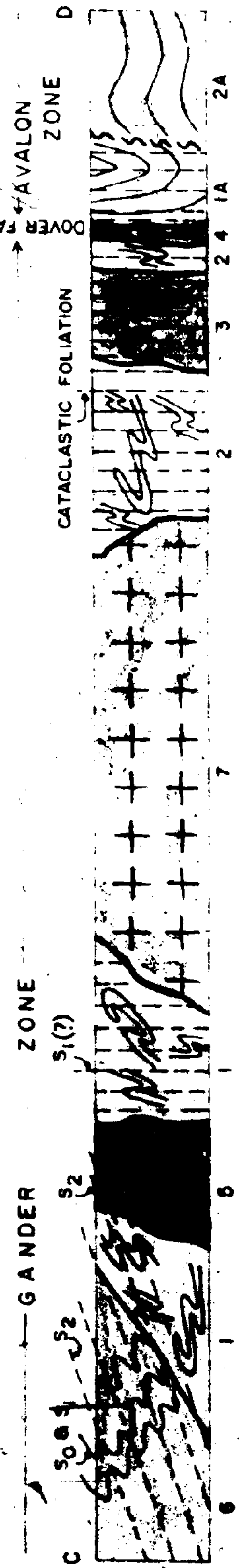


Fig. 5 Generalized geological map of eastern Bonavista Bay (In part after Jenness, 1963)

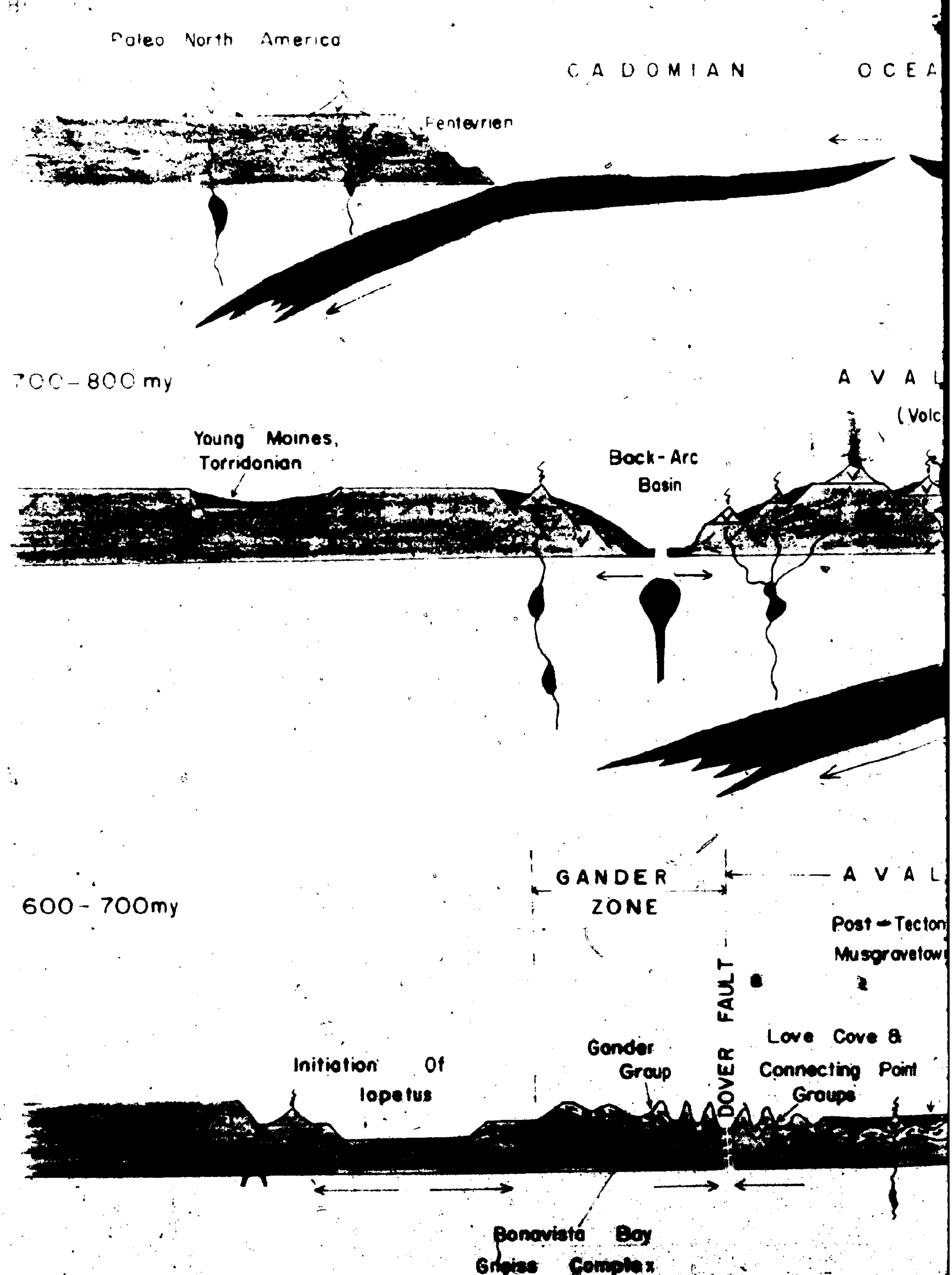
10F



Generalized geological map of eastern Bonavista Bay (in part after Jenness, 1963)

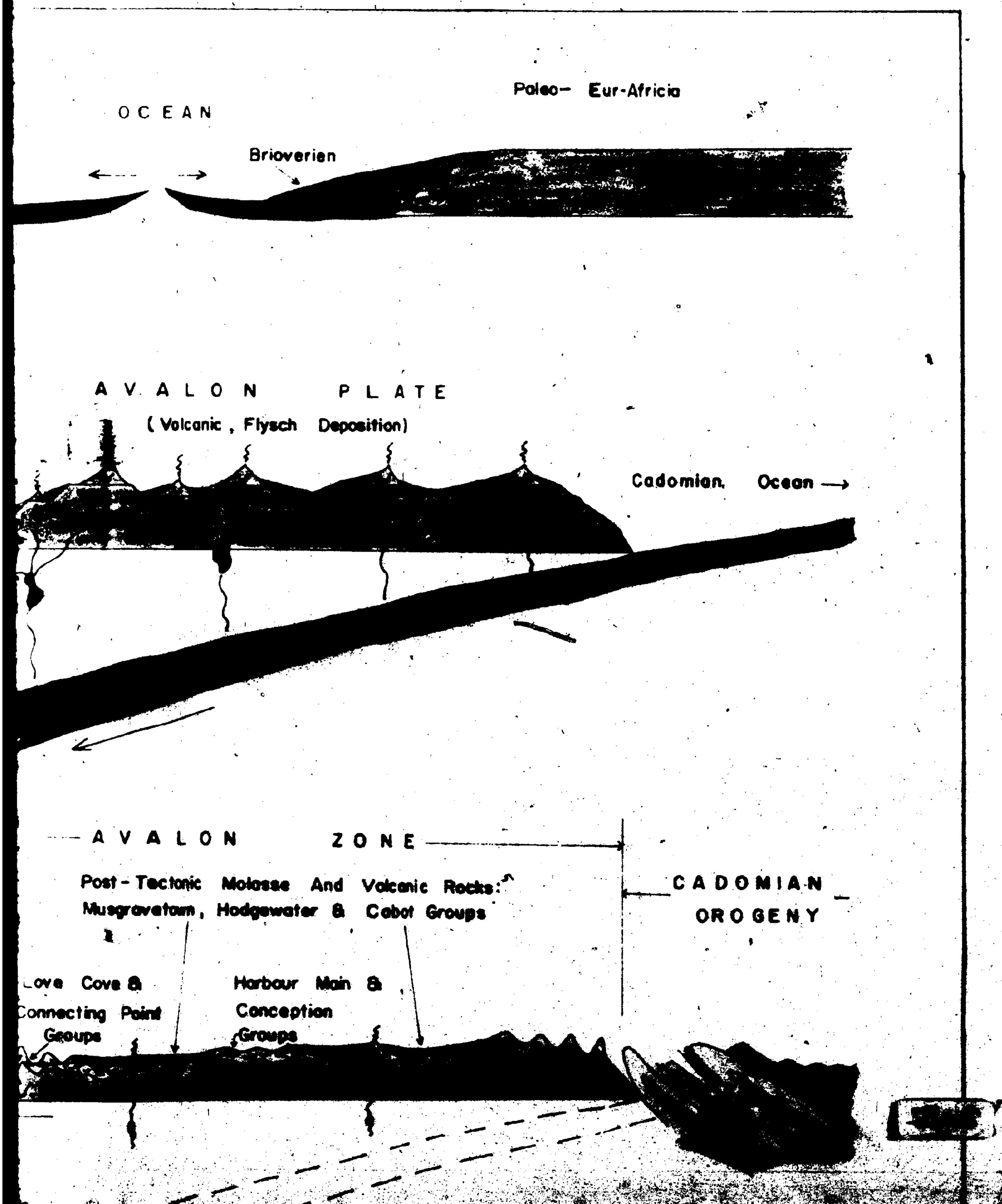


Schematic cross-section through C-D (2x)



Paleo North America
CADOMIAN
OCEA
Pentevrien
700-800 my
AVAL
(Volc
Young Moines, Torridonian
Back-Arc Basin
GANDER ZONE
AVAL
600-700my
Post-Tecton
Musgravetow
DOVER FAULT
Love Cove &
Connecting Point Groups
Gander Group
Initiation Of Iapetus
Bonavista Bay Gneiss Complex

1oF


Paleo- Eur-Africia
OCEAN
Brioverien
AVALON PLATE
(Volcanic , Flysch Deposition)
Cadomian Ocean
AVALON ZONE
Post-Tectonic Molasse And Volcanic Rocks:
Musgravetown, Hodgewater & Cabot Groups
CADOMIAN
OROGENY
Love Cove &
Connecting Point
Groups
Harbour Main &
Conception
Groups

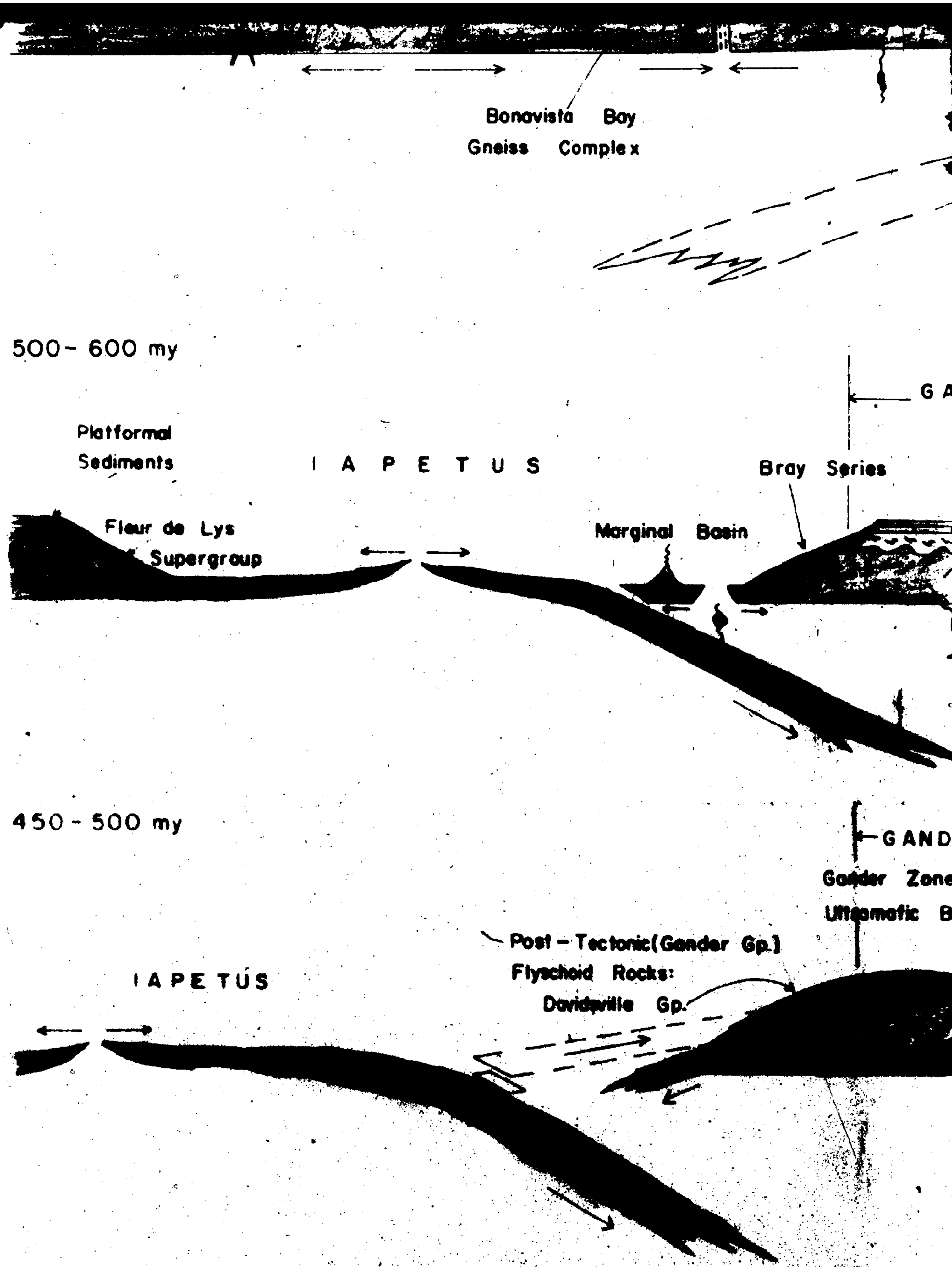
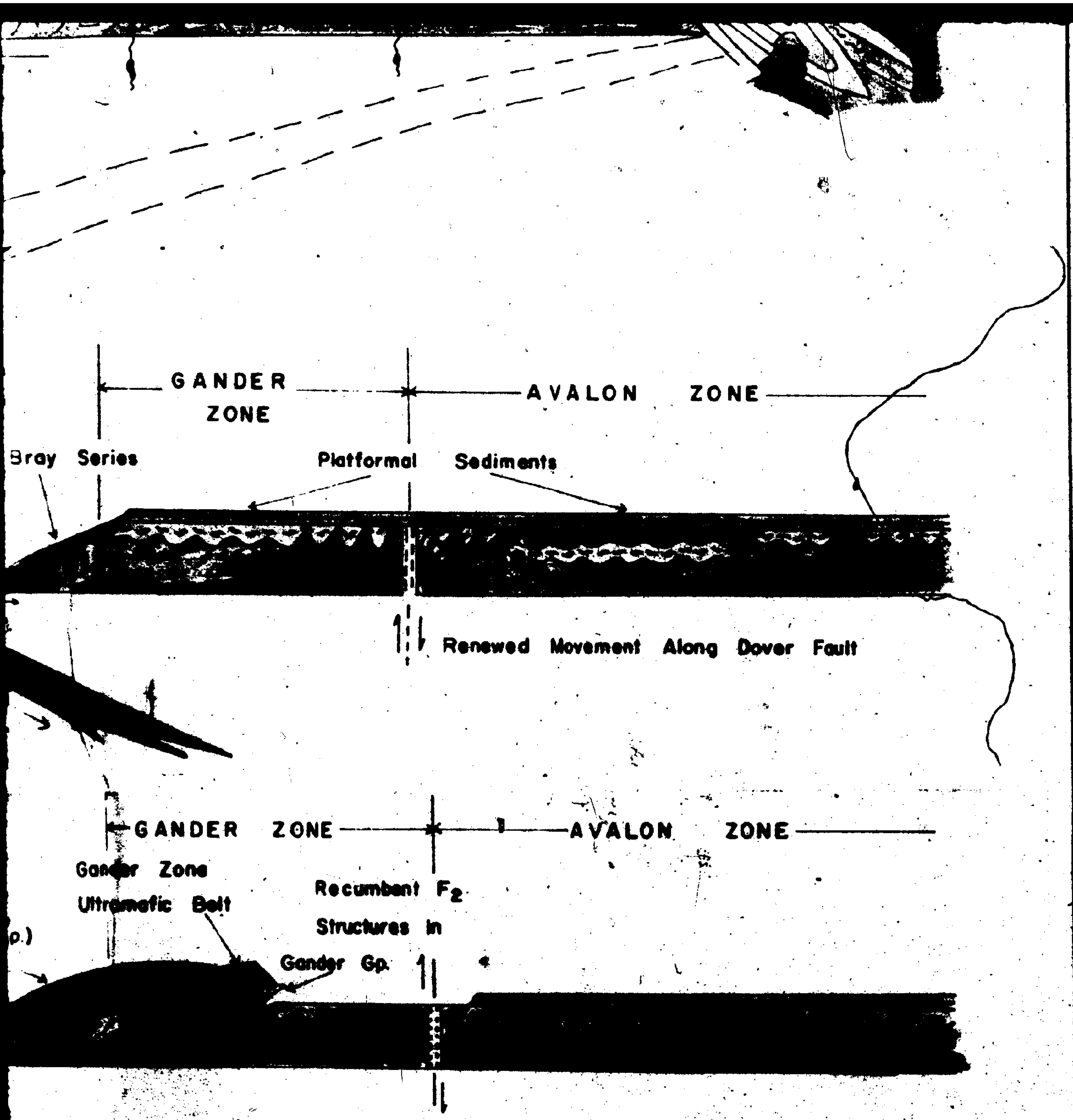
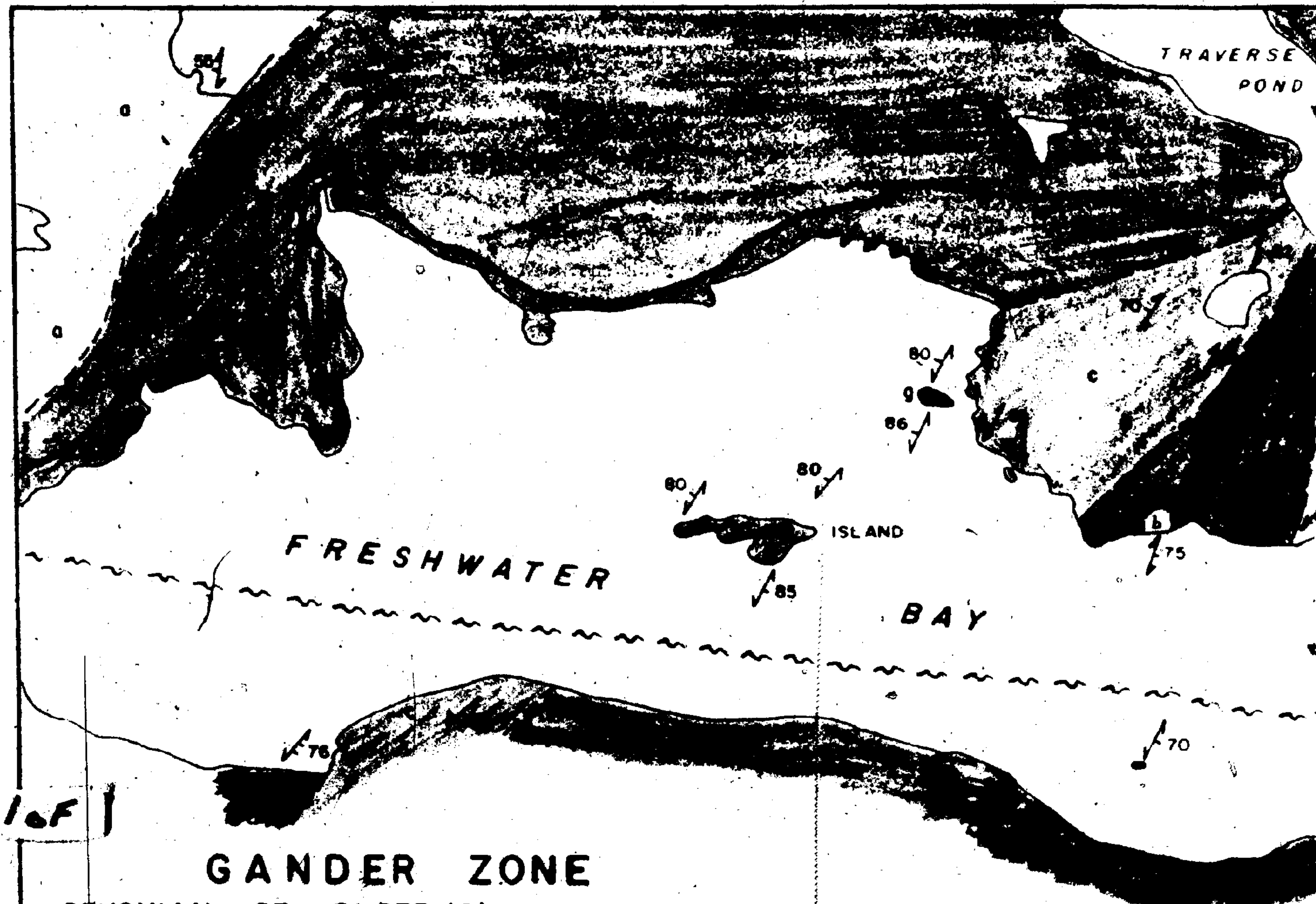


FIG. 12 PLATE TECTONIC MODEL FOR GANDER AND AVALON ZONES



MODEL FOR DEVELOPMENT OF THE ZONES



GANDER ZONE

DEVONIAN OR OLDER (?)

NEWPORT GRANITE

MASSIVE COARSE - GRAINED PORPHYRITIC GRANITE

MIDDLE BROOK GRANITE

MASSIVE COARSE - GRAINED PORPHYRITIC GRANITE / GRANODIORITE

HADRYNIAN (?)

DOVER FAULT GRANITES

FOLIATED (LOCALLY MYLONITIZED) EQUIGRANULAR MEDIUM - GRAINED GRANITES

MINOR INTRUSIVE ROCKS

FOLIATED COARSE - GRAINED PORPHYRITIC GRANITE

FOLIATED MEDIUM - GRAINED GRANITE

FOLIATED MEDIUM - GRAINED GARNETIFEROUS MONZONITE

HADRYNIAN OR OLDER

LOCKERS BAY GRANITE

FOLIATED MEGACRYSTIC MICROCLINE GRANITE

HELIKIAN (?)

BONAVISTA BAY GNEISS COMPLEX

TRAVERSE BROOK GNEISS

GRANITIC ORTHOGNEISS WITH RAFTS OF TONALITIC ORTHOGNEISS

RELATED GRANITES(?)

FOLIATED (LOCALLY GNEISSIC) MEDIUM GRAINED GRANITE

HARE BAY GNEISS

AVALON

LATE HADRYNIAN (-E

MUSGRAVETOWN GRO

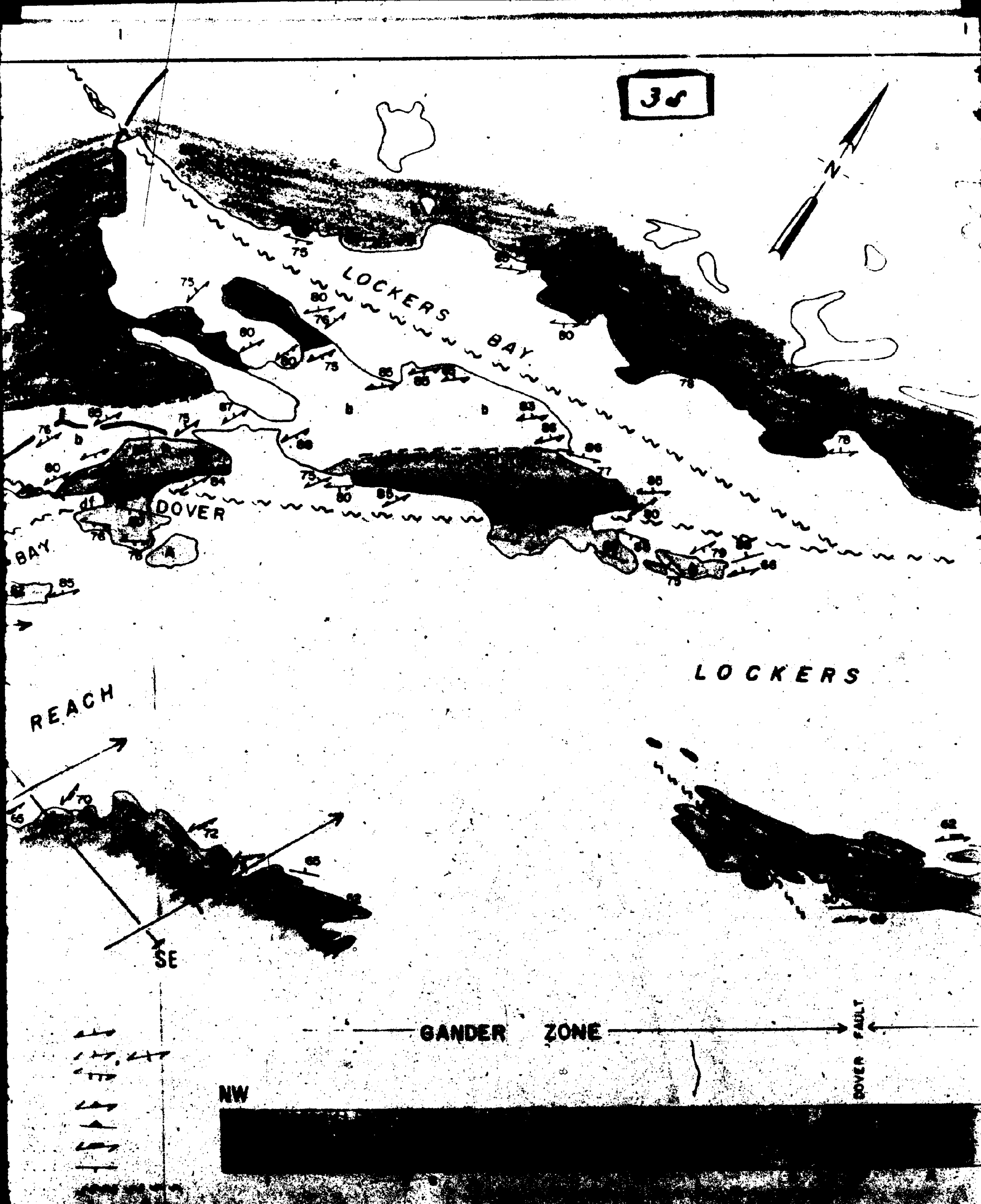
RED (LOCALLY GREEN COARSE CONGLOMERAT MINOR SHALE) SLATY

HADRYNIAN

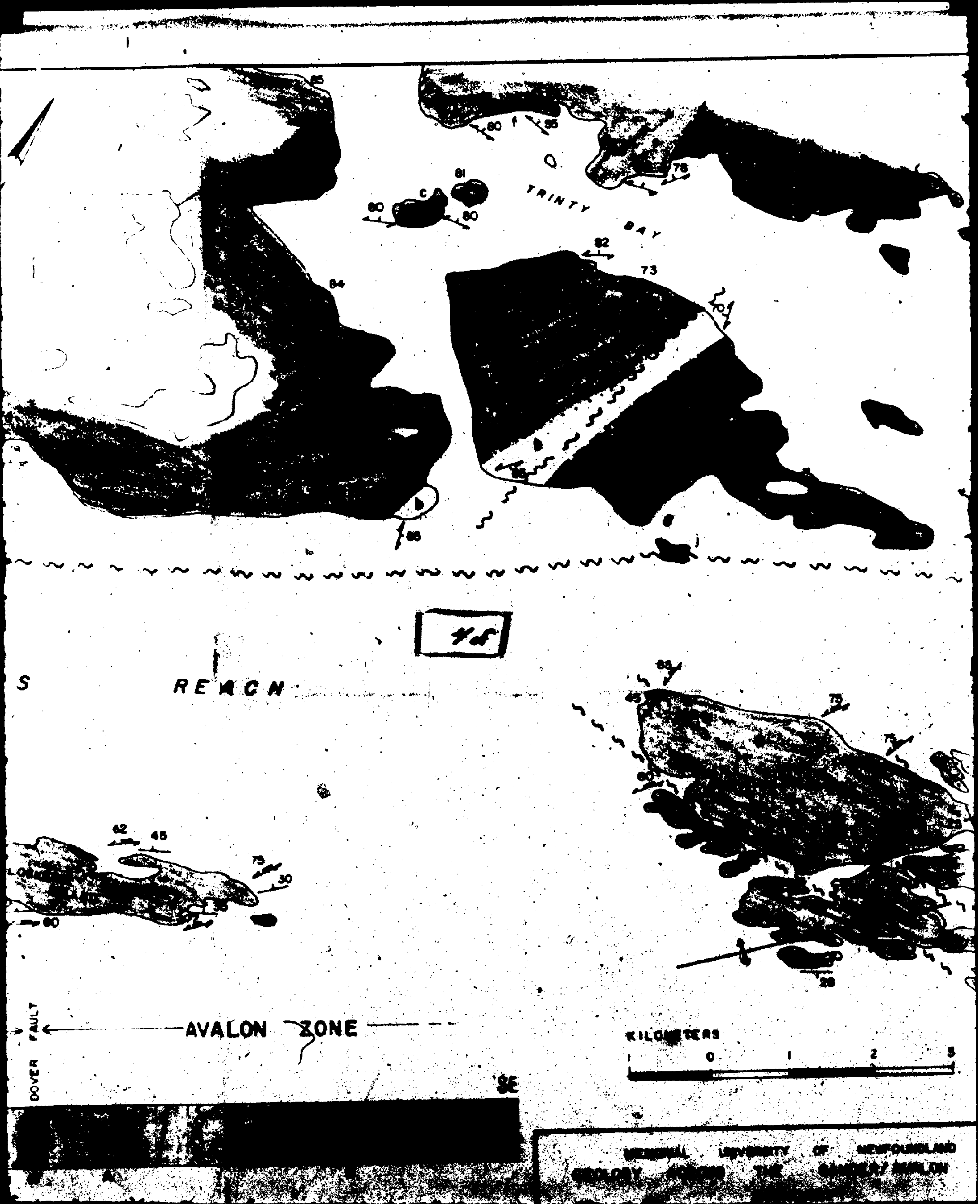
LOVE COVE GROU

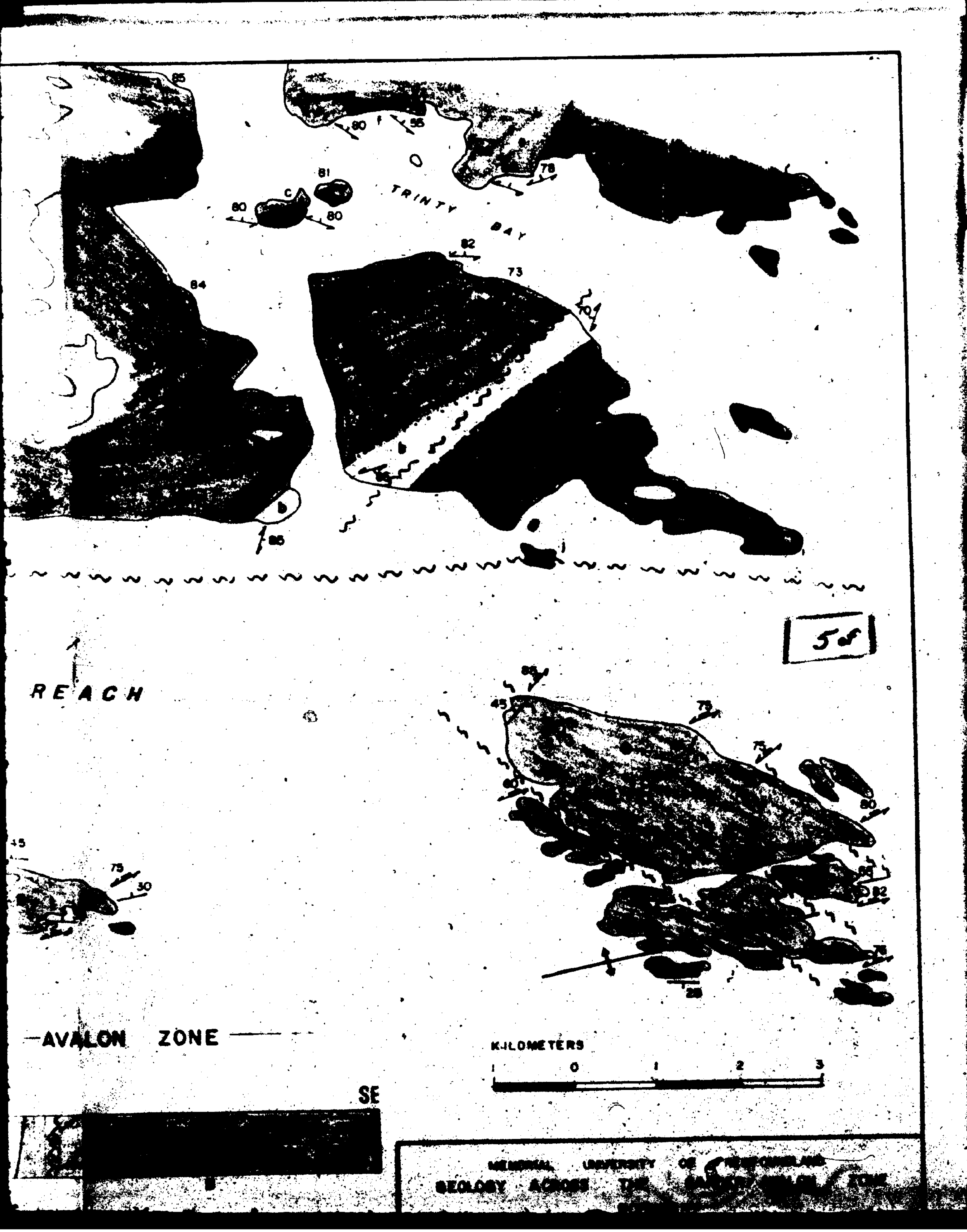
FOLIATED (LOCALLY M AND VOLCANOGENIC SE CRYSTAL TUFFS)

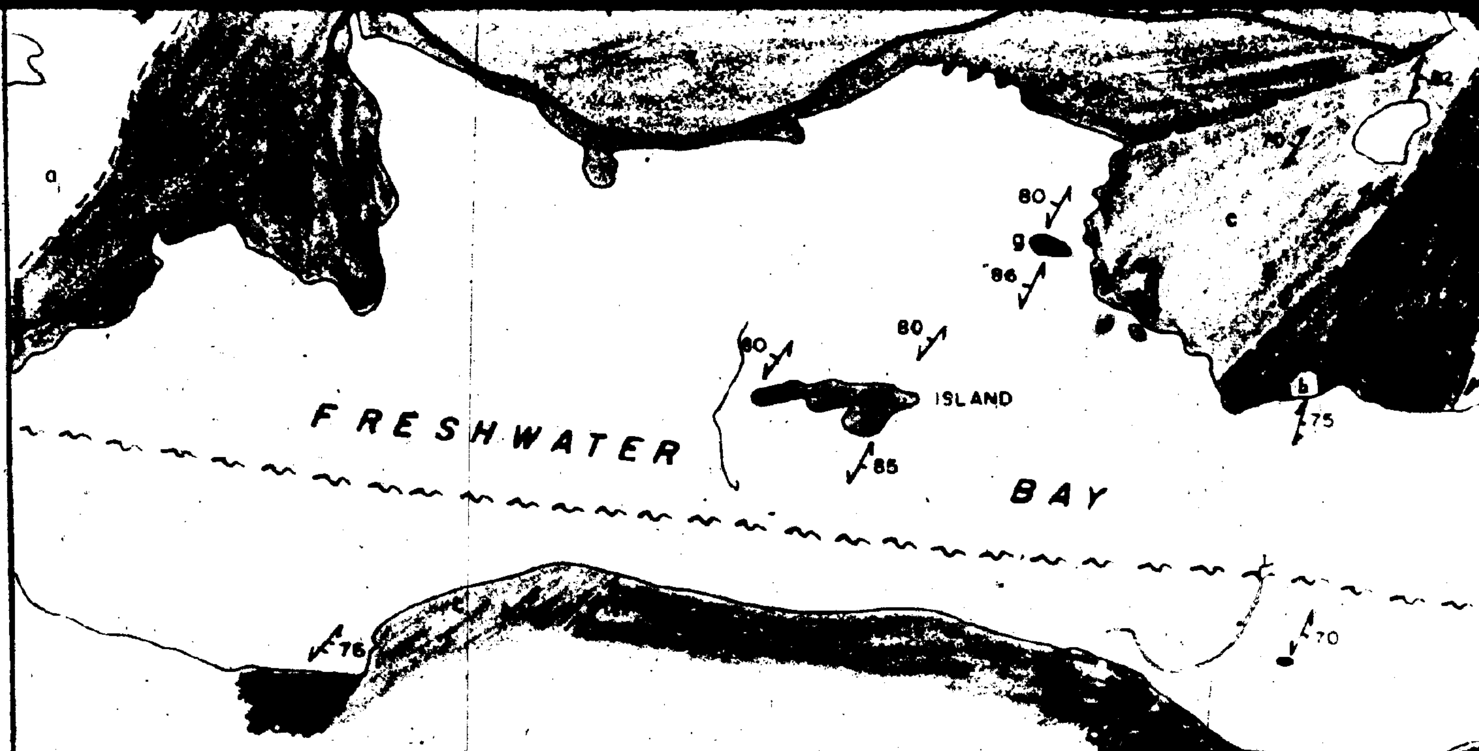
TRAVERSE POND
HARE BAY POND
HARE BAY
CONTENT REACH
CAT BAY
AVALON ZONE*
HADRYNIAN (-EARLY CAMBRIAN ?)
GRAVETOWN GROUP
ED (LOCALLY GREEN) MEDIUM - GRAINED SANDSTONE AND
OARSE CONGLOMERATE (INCLUDES SILTSTONE AND
NOR SHALE) SLATY CLEAVAGE
NIAN
E COVE GROUP
OLIATED (LOCALLY MYLONITIZED) ACID VOLCANIC (FLOWS
ND VOLCANOGENIC SEDIMENTARY ROCKS ; MAINLY
RYSTAL TUFFS)
SYMBOLS
GNEISSIC FOLIATION (INCLINED)
CATACLASTIC FOLIATION (INCLINED, VERTICAL)
STRAIN-SLIP FOLIATION (INCLINED)
MYLONITIC FOLIATION (RELATED TO FAULTS OTHER THAN
DOVER FAULT — INCLINED)
WEAK FOLIATION IN INTRUSIVE ROCKS (INCLINED)
SLATY CLEAVAGE (INCLINED)
BEDDING (INCLINED)



3S
N
LOCKERS BAY
DOVER
BAY
REACH
LOCKERS
SE
GANDER ZONE
DOVER FAULT
NW


TRINITY BAY
REACH
AVALON ZONE
DOVER FAULT
KILOMETERS
0 1 2 3
SE
MEMORIAL UNIVERSITY OF NEWFOUNDLAND


TRINITY BAY
REACH
AVALON ZONE
KILOMETERS
1 0 1 2 3
SE
5 of
MEMORIAL UNIVERSITY OF NEWFOUNDLAND
GEOLOGY ACROSS THE ZONE



GANDER ZONE

DEVONIAN OR OLDER (?)

NEWPORT GRANITE

MASSIVE COARSE - GRAINED PORPHYRITIC GRANITE

MIDDLE BROOK GRANITE

MASSIVE COARSE - GRAINED PORPHYRITIC GRANITE / GRANODIORITE

HADRYNIAN (?)

DOVER FAULT GRANITES

FOLIATED (LOCALLY MYLONITIZED) EQUIGRANULAR MEDIUM - GRAINED GRANITES

MINOR INTRUSIVE ROCKS

FOLIATED COARSE - GRAINED PORPHYRITIC GRANITE

FOLIATED MEDIUM - GRAINED GRANITE

FOLIATED MEDIUM - GRAINED GARNETIFEROUS MONZONITE

HADRYNIAN OR OLDER

LOCKERS BAY GRANITE

FOLIATED MEGACRYSTIC MICROCLINE GRANITE

HELIKIAN (?)

BONAVISTA BAY GNEISS COMPLEX

TRAVERSE BROOK GNEISS

GRANITIC ORTHOGNEISS, WITH RAFTS OF TONALITIC ORTHOGNEISS

RELATED GRANITES (?)

FOLIATED (LOCALLY GNEISSIC) MEDIUM GRAINED GRANITE

HARE BAY GNEISS

b TONALITIC ORTHOGNEISS WITH RAFTS OF PARAGNEISS

SQUARE POND GNEISS

PSAMMATIC AND SEMI - PELITIC GNEISS

AVALON

LATE HADRYNIAN (-E

MUSGRAVETOWN GR

RED (LOCALLY GREEN COARSE CONGLOMERA MINOR SHALE) SLATY

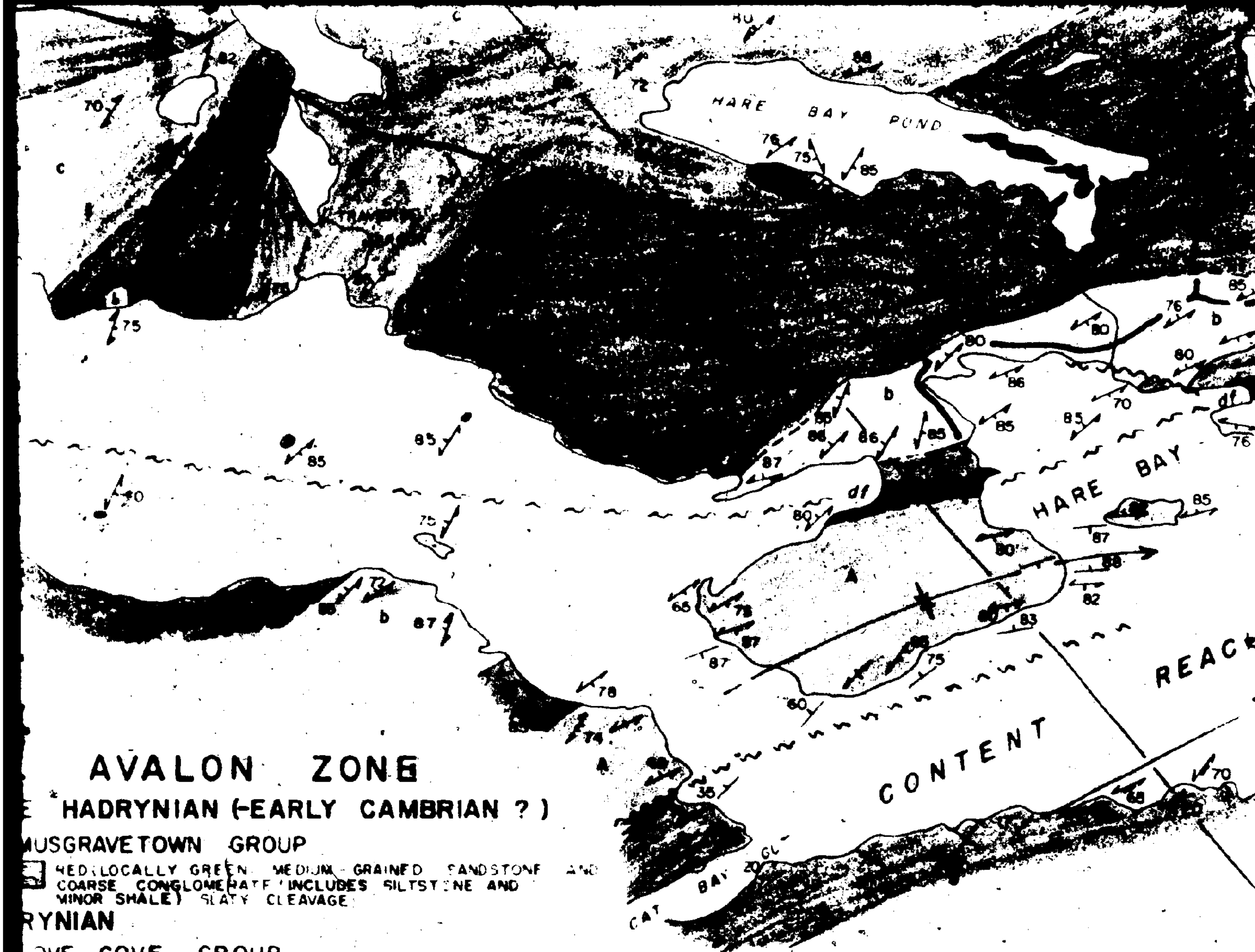
HADRYNIAN

LOVE COVE GROU

FOLIATED (LOCALLY M AND VOLCANOGENIC S CRYSTAL TUFFS)

DOVER FAULT

MYLONITIZED ROCKS OF THE GANDER AND AVALON ZONES (h,



AVALON ZONE

E HADRYNIAN (-EARLY CAMBRIAN ?)

MUSGRAVETOWN GROUP

RED (LOCALLY GREEN) MEDIUM-GRAINED SANDSTONE AND COARSE CONGLOMERATE (INCLUDES SILTSTONE AND MINOR SHALE) SLATY CLEAVAGE

RYNIAN

LOVE COVE GROUP

FOLIATED (LOCALLY MYLONITIZED) ACID VOLCANIC FLOWS AND VOLCANOGENIC SEDIMENTARY ROCKS (MAINLY CRYSTAL TUFFS)

SYMBOLS

GNEISSIC FOLIATION (INCLINED)

CATACLASTIC FOLIATION (INCLINED, VERTICAL)

STRAIN-SLIP FOLIATION (INCLINED)

MYLONITIC FOLIATION (RELATED TO FAULTS OTHER THAN DOVER FAULT - INCLINED)

WEAK FOLIATION IN INTRUSIVE ROCKS (INCLINED)

SLATY CLEAVAGE (INCLINED)

BEDDING (INCLINED)

FAULT (DEFINED, APPROXIMATE, ASSUMED)

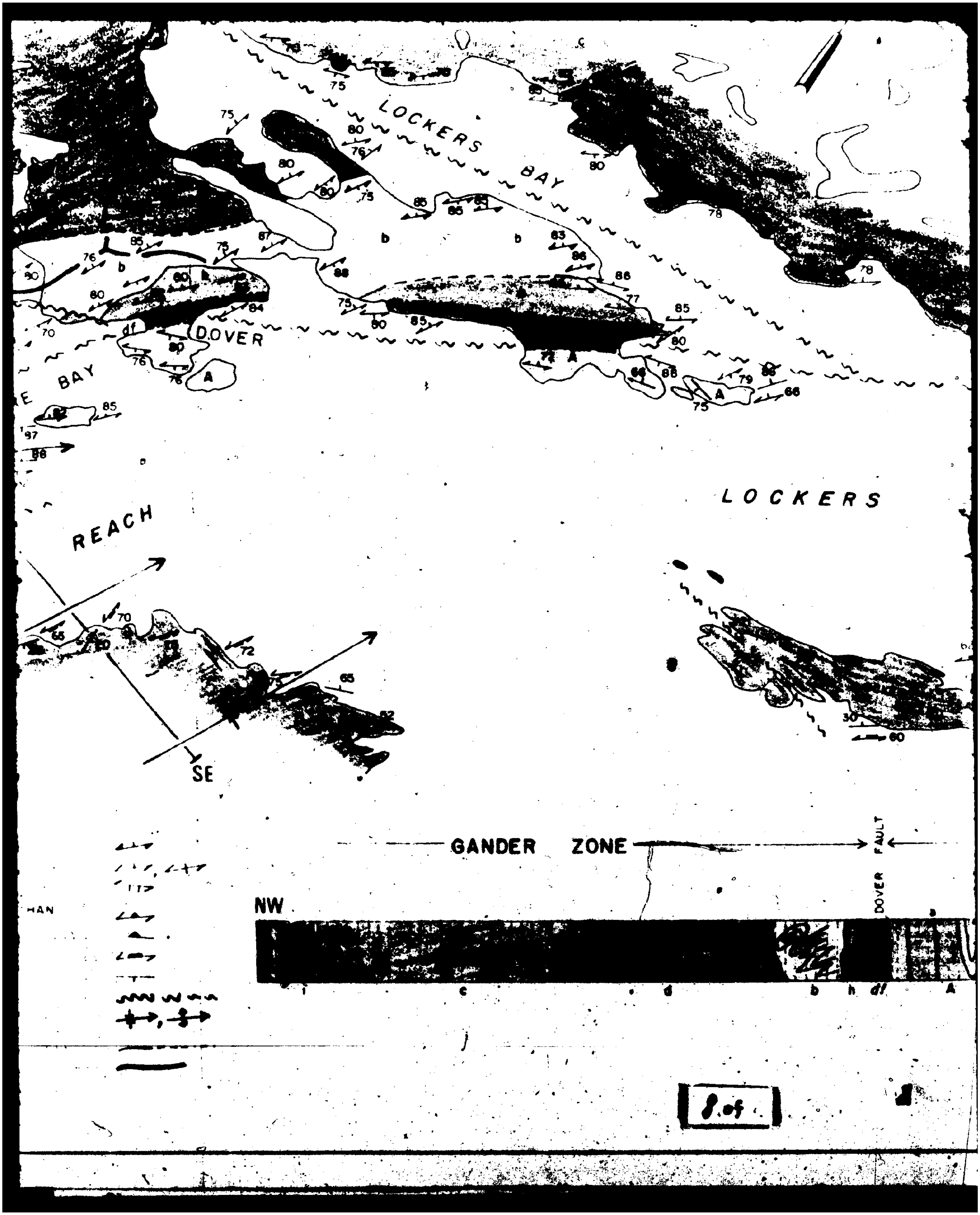
PLUNGING FOLD AXIS (SYNCLINE, ANTICLINE)

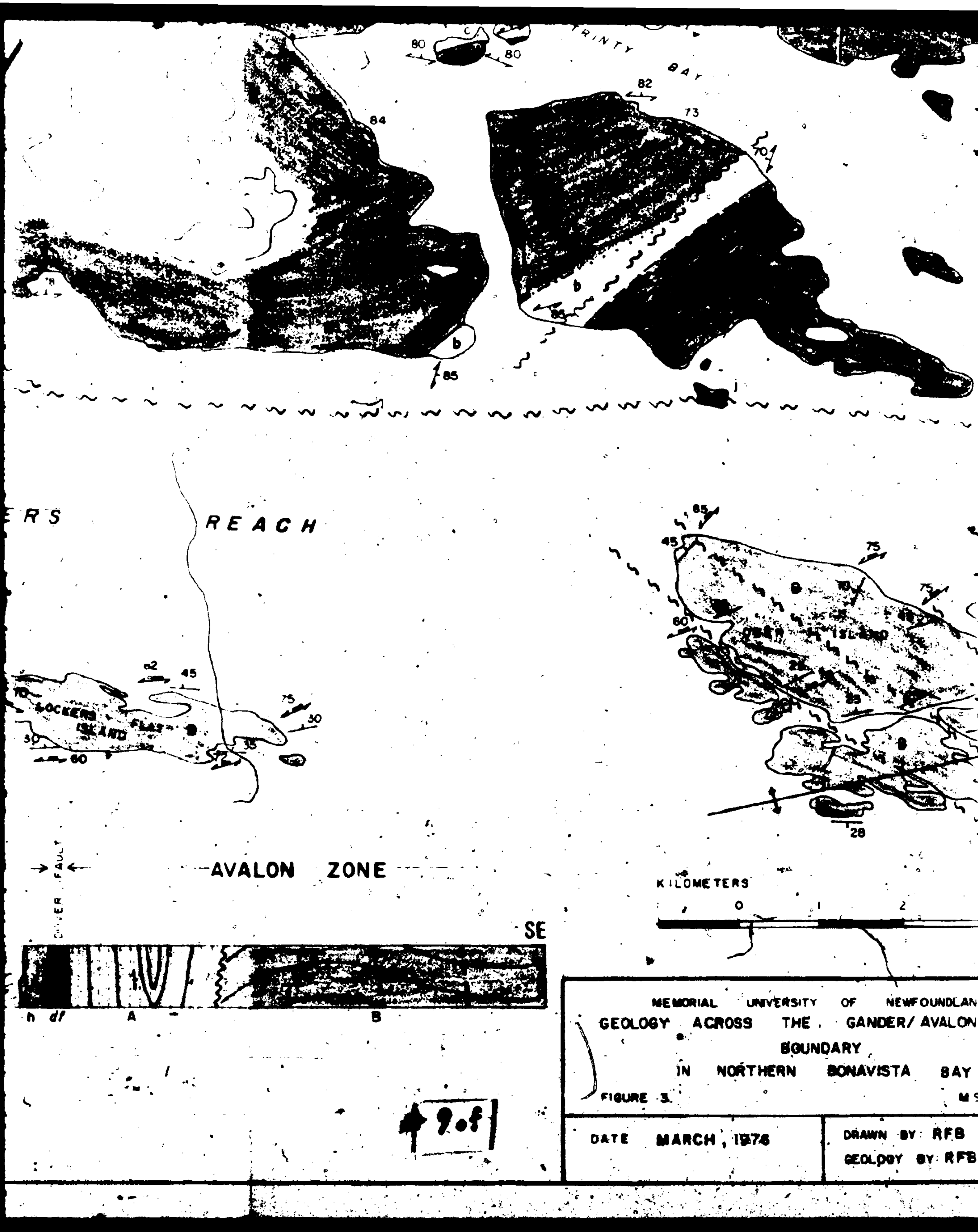
GEOLOGICAL CONTACT (DEFINED, APPROXIMATE, GRADATIONAL)

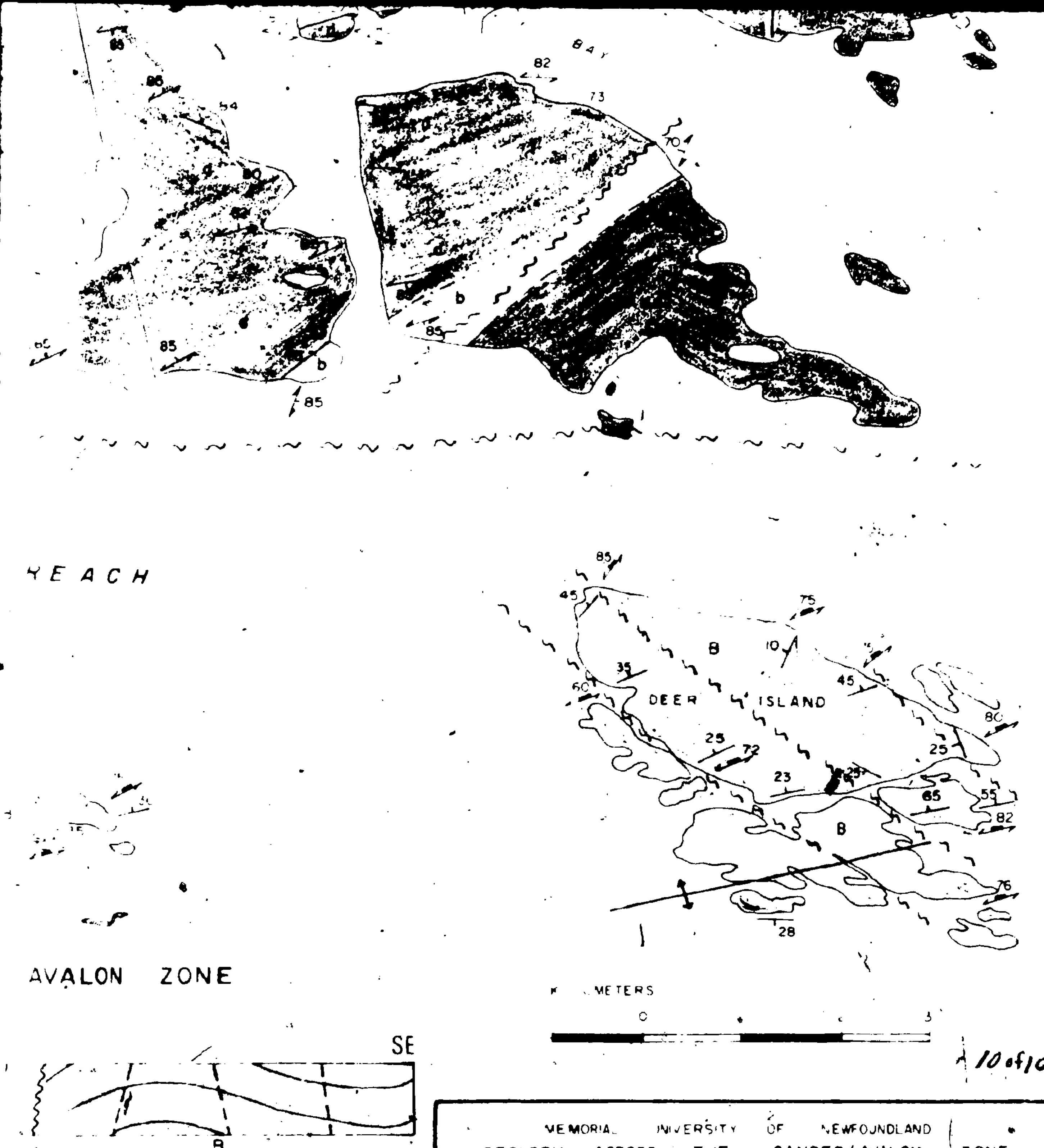
ROAD (PAVED)

FAULT

ZED ROCKS OF THE
AND AVALON ZONES (h,A)


LOCKERS BAY
DOVER
BAY
REACH
LOCKERS
SE
GANDER ZONE
DOVER FAULT
NW
8.of


TRINITY BAY
RS REACH
LOCKERS ISLAND FLAT
AVALON ZONE
DOVER FAULT
SE
h df A B
KILOMETERS
0 1 2
MEMORIAL UNIVERSITY OF NEWFOUNDLAND
GEOLOGY ACROSS THE GANDER/AVALON BOUNDARY IN NORTHERN BONAVISTA BAY
FIGURE 3.
DATE MARCH, 1976
DRAWN BY: RFB
GEOLOGY BY: RFB



10 of 10

MEMORIAL UNIVERSITY OF NEWFOUNDLAND

GEOLOGY ACROSS THE GANDER/AVALON ZONE BOUNDARY IN NORTHERN BONAVISTA BAY

FIGURE 3 — M.SC. THESIS

DATE: MARCH, 1976	DRAWN BY RFB GEOLOGY BY RFB