THE STRATIGRAPHY, STRUCTURE AND PETROCHEMISTRY OF THE CLODE SOUND MAP AREA, NORTHWESTERN AVALON ZONE, NEWFOUNDLAND

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by

© Eric Maurice Hussey, B.Sc.

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Frontispiece: View of Port Blandford and Clode Sound
looking north from Southwest Hill.

ABSTRACT

The Clode Sound map area (Lat. 48°15'N, 48°30'N and Long. 54°00'W, 54°13'W) is underlain by portions of three major units of late Precambrian age which dominate the northwestern Avalon Zone. They include sedimentary, volcanic, and intrusive rocks of the Love Cove, Connecting Point and Musgravetown Groups, and the Georges Pond pluton. These rocks form a number of alternating, north trending fault-bounded belts.

The Love Cove Group has been informally redefined to include some of the sedimentary and volcanic rocks previously referred to the Musgravetown Group (Widmer, 1949; Jenness, 1963) with which it is conformable. The redefined Love Cove Group is divided into three formations. In ascending stratigraphic order these include:

1. White Point Formation - a sequence of deformed dominantly pyroclastic subaqueous (?) to subaerial volcanic rocks ranging from basalt to rhyolite in composition, which are intruded by a comagmatic pluton (Georges Pond pluton).

2. Thorburn Lake Formation - a sequence of variably deformed siltstones, greywackes and related volcanic rocks up to 1300 meters thick which overlie, and are partially equivalent to, the White Point Formation.

3. Southwest River Formation (Musgravetown Group of Jenness, 1963) - a subaerial basalt - rhyolite volcanic assemblage and an associated sequence of alluvial - fluviatile sedimentary rocks 1280 meters thick.

The Connecting Point Group, only locally examined, includes thin bedded marine siltstone and slate. It may be equivalent to portions of the Love Cove Group.

The Musgravetown Group, in its type area, unconformably overlies the Connecting Point Group. It includes in ascending order: 1. The Cannings Cove Formation (530 meters) - locally derived fanglomerates, sandstones and basalt flows, 2. Clode Sound Formation (Bull Arm Formation of Jenness, 1963) (800-2300 meters): subaerial basalt/pantellerite volcanic sequence, and 3. Charlottetown Formation: fluviatile red beds.

The Georges Pond pluton is genetically related to the White Point Formation; both appear to have a continental calcalkaline geochemistry. Volcanic rocks of the Southwest River Formation appear mildly alkaline. They may be equivalent to the Clode Sound Formation which includes peralkaline silicic volcanic rocks and alkali basalts.

The major structure of the Love Cove Group trends north and is dominated by isoclinal folding with steeply dipping axial surfaces, with development of a penetrative foliation, in the lower portions of the section. In the west, the rocks are overturned to the east and tightly folded. The upper portions of the section show more open folding with only poor fabric development. Two major faults in the area have juxtaposed contrasting structural levels or domains. The principal deformation (F_1) of the Love Cove Group was Palaeozoic, probably Acadian, in age. It is not clear how structures in the Connecting Point Group relate to those in the Love Cove Group.

Metamorphic grades in the field area vary from greenschist in the lower portions of the section, to prehnite-pumpellyite facies at higher stratigraphic levels.

The lithostratigraphic units in the map area are similar in both petrography and chemistry to, and can be correlated with equivalent units in other parts of the western Avalon Zone.

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CHAPTER 1

INTRODUCTION

1.1 Location and Access

The study area is situated in eastern Newfoundland in the Bonavista Bay area and is roughly bounded by co-ordinates Lat. 48° 15'N, 48° 30'N and Long. 54° 00'W, 54° 13'W, (fig. 1.2). The northern portions of the map area lie within Terra Nova National Park.

All-weather roads, including the Trans Canada Highway (TCH), follow closely both shores of Clode Sound. Old logging trails and more recent logging roads, now being upgraded, provide the only access to the wooded country south of Clode Sound; boats, which are available for hire from local communities, were used on Clode Sound and the larger ponds.

Port Blandford, at the head of Clode Sound, is 218 km west on the TCH from St. John's and 112 km east from Gander. Bunyan's Cove and Charlottetown, on the south and north shores of Clode Sound respectively, are the only other communities in the map area. Railway work, logging and farming are the main sources of livelihood for the local populace.

1.2 Physiography and Climate

Most of the field-area is heavily wooded with a patchy

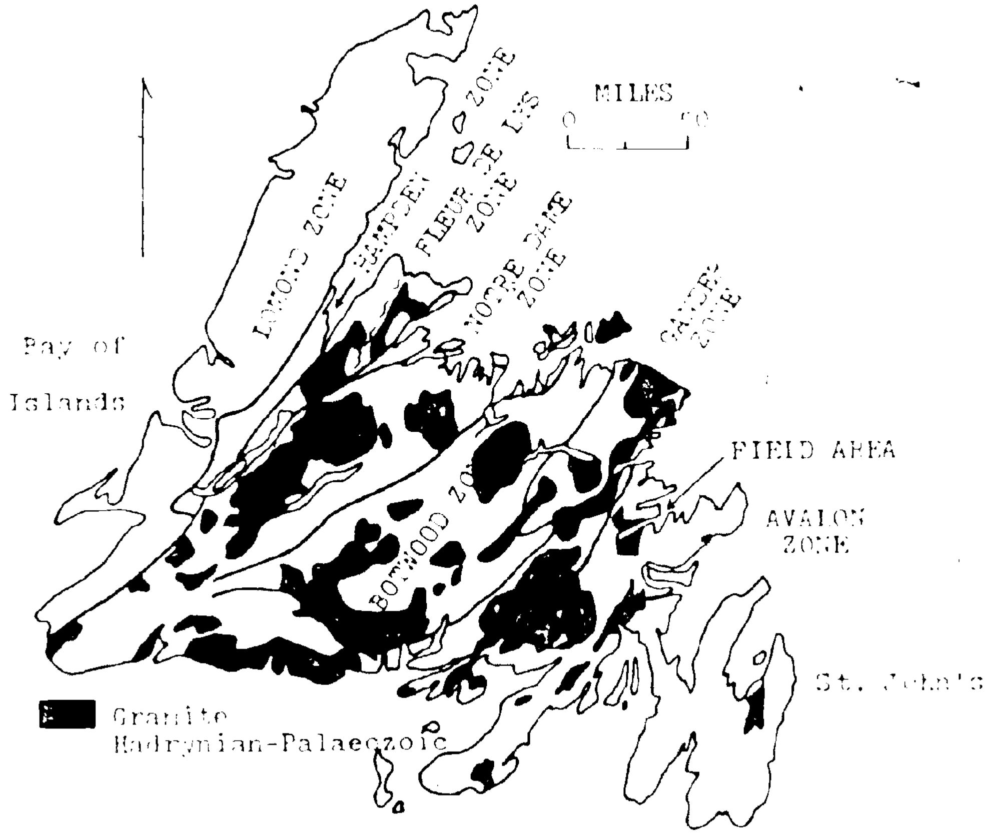


Fig. 1.2. Tectonostratigraphic subdivision of the Newfoundland Appalachians, emphasizing distribution of granitic rocks. (Williams, Kennedy and Neale, 1974)

distribution of bogs. The usually gently rolling topography rises moderately to steeply from the coast with elevations generally less than 200m (600 ft) but exceeding 335m (1000 ft) on Blandford's Ridge and the Blue Hills, barren ridges in the south. As a rough generalization steeply dipping schistose rocks and massive volcanic rocks underlie the higher, more rugged ground while more gently dipping sedimentary rocks form more subdued relief in largely drift-covered areas.

With the exception of the Port Blandford area and the shoreline to the west of Platter Cove, coastal exposure is excellent. Inland, aside from the larger ponds and brooks and high rocky ridges, exposure is in most places poor, being confined to minor brooks and ponds and scattered glacially-rounded outcrops covered with moss and lichen in the woods and on the bogs.

North of Clode Sound, only the TCH and Dunphy's Pond area were mapped to gain information on the continuity of the geology.

The summer climate varies from cool or sunny and warm to hot and humid.

1.3 Pleistocene Geology

The glacial geology of the area has been described in detail by Jenness (1963). Hence, only a brief reference to it will be made here.

Ice movement in the area was invariably in an easterly,

Plate I: Local drainage controlled by glacial scouring, east of Port Blandford.

coastward direction. Inland outcrops are usually rounded, commonly with roche moutonnee development. Roughly E-W trending striae are common and two sets intersecting at a low angle may occur on individual outcrops. Deep scouring has locally controlled drainage (Plate I).

The predominant glacial deposit is an irregularly distributed, unsorted, unstratified bouldery till. This is made obvious by the bouldery nature of most of the ponds and that of the mouth of Southwest Brook. Stratified glacial deposits are confined to the area at the head of Clode Sound, especially Northwest Arm (Jenness, 1963).

Extensive frost-heaving of joint blocks on some outcrops was pointed out to the author by the late W.D. Bruckner.

1.4 Previous Work

Much of the previous work in the general area has been of reconnaissance nature and historically, aside from Jenness (1958 , 1963), most attention has been given the Cambro-Ordovician sequences of the Random Island area.

J.B. Jukes (1843) first separated the Cambrian from the underlying Precambrian strata and noted an unconformity between them. He did not subdivide the Precambrian.

Murray and Howley (1881) subdivided and described Precambrian sedimentary rocks, classifying them as the "intermediate series" possibly Huronian in age. They correlated the sequences now termed the Musgravetown and Connecting Point Groups with those of the Signal Hill Formation (Cabot

Group) and underlying formations respectively, on the eastern Avalon Peninsula.

Buddington (1919) first studied the petrology and relationships of Precambrian volcanic and plutonic rocks of the central Avalon Peninsula.

Hayes (1948) recognized an angular unconformity at Milner's Cove, on the south shore of Clode Sound. He named the rocks above this unconformity the Musgravetown Group and those below it, the Connecting Point Group. He correlated them respectively with the Signal Hill Formation and Conception slates and the Harbour Main volcanic rocks (Howell, 1925) of the eastern Avalon Peninsula. Hayes also recognized that the Connecting Point Group is characterized by steep dips with some isoclinal folding and estimated its thickness at several thousand feet. He thought the Musgravetown Group to be approximately 10,000 ft. thick and in Trinity Bay recognized felsic lavas (the Bull Arm felsite member) in its lower and middle parts.

Rose (1948) extended those units southward to northern Placentia Bay where he also included chlorite and sericite schists in his Middle Cambrian (?) Sound Island Formation. However, Widmer (1948), in tracing this unit northward to the Terra Nova map area discerned a third major Precambrian stratigraphic unit, the

> "Love Cove schists formation; schists formed from conglomerate, sandstones, shales, basic and acid flows and dykes".

In the Northwest Arm area of Clode Sound he distinguished deformed sedimentary rocks, his Tabby Cat Cove Formation from Musgravetown Group rocks.

Christie (1950), in part, detailed the lithology of the Connecting Point and Musgravetown Groups east of Charlottetown.

Jenness (1958) confirmed the existence of Widmer's Love Cove unit and renamed it the Love Cove Group. He described distinctive features of the three major Precambrian units, and reported volcanic rocks from the Connecting Point Group.

Jenness (1963) interpreted the more deformed fault-bounded volcano-sedimentary Love Cove Group to be the oldest Precambrian unit in the region and inferred an angular unconformity with less deformed, largely fault-bounded slates and greywackes of the Connecting Point Group. He did not formally subdivide these units. Jenness considered the Musgravetown Group, which he subdivided into a number of sedimentary and volcanic formations, to be post-tectonic upon the earlier strata. He described an angular unconformity at Southward Head, Bonavista Bay, between what he described as Connecting Point Group acid volcanic and sedimentary rocks below and basal Musgravetown Group red conglomerate above. At Bread Cove, Bonavista Bay, he reported deformed detritus resembling Love Cove Group lithologies in a similar conglomerate. The Musgravetown Group was found to be conformable beneath the Cambro-Ordovician sequences of Trinity Bay.

Following earlier workers Jenness (1963) correlated the

Connecting Point and Musgravetown Groups with the Conception and the Hodgewater and Cabot Groups respectively (McCartney, 1967; Rose, 1952).

Further, Jenness did not consider the Love Cove Group to be equivalent to the Harbour Main Group but he did suggest, on the basis of structural trends that the Love Cove Group could be related to the volcano-sedimentary sequences of the northern Burin Peninsula (Bradley, 1962). Hussey (1978) on the basis of mapping in the Sound Island map sheet confirmed this correlation.
McCartney (1967), working to the south, raised the Bull Arm felsite member of Hayes (1948) to formation status, established a six fold subdivision of the Musgravetown Group and interpreted it to be conformable upon the Connecting Point Group in his field area.

Malpas (1971) mapped Bull Arm Formation volcanic rocks on the Isthmus of Avalon and produced the first petrochemical study of these rocks.

Younce (1970) mapping in northern Bonavista Bay did not accept the Love Cove Group as a stratigraphic entity. He considered the Connecting Point Group to be the oldest unit in the area and the Love Cove Group to be the deformed and metamorphosed equivalents of lower portions of the Musgravetown Group. He attributed the deformation and metamorphism to what he thought were Devonian intrusions in the Bonavista Bay area. Younce also recognized several unconformities within the Musgravetown Group and considered several of the formations within it to be facies equivalents.

Blackwood and Kennedy (1975) related movement on the Dover Fault, northwest Bonavista Bay, with juxtaposition of the Gander and Avalon Zones (Williams et.al., 1974) and Precambrian deformation of the Love Cove Group (Jenness, 1963).

O'Driscoll (1977b) reported Love Cove Group schists northwest of Placentia Bay and he included schistose volcanic and sedimentary rocks at the head of Placentia Bay in his Precambrian North Harbour Group (informal) which he inferred to be unconformably overlain by Musgravetown Group and Lower Cambrian strata.

O'Driscoll and Hussey (1977) interpreted Love Cove Group and Musgravetown relations in terms of a late Precambrian Avalonian orogeny (Lilly, 1966).

Hussey (1978a) included volcanic and sedimentary rocks northwest of Placentia Bay previously referred by Anderson (1965) to the Musgravetown Group, in the Love Cove Group which he suggested to be genetically related to the Swift Current granite.

Dal Bello (1977) mapped an area immediately north of the present field area and presented detailed petrographic and petrochemical data on the Love Cove Group, Bull Arm Formation and related rocks. He accepted Jenness' stratigraphic units but revised their boundaries.

1.5 Present Work

Field work was conducted from mid-May to mid-August and September, 1976. The base camp was situated in Port Blandford and most of the area was accessible by daily traverses from that location. One "fly camp" was necessary in the Blue Hills area. Most detailed attention was given to coastal exposures while, in general, inland exposures yielded only limited information but were useful in delineating the geographic extent and distribution of the various units. The area was mapped using 4 inches to 1 mile aerial photographs and the data were plotted on quarter mile scale forest inventory sheets.

1.6 Purpose and Scope of Study

The rethinking of geologic phenomena in the past two decades within the framework of global tectonic theory has led to a greater understanding of Appalachian geology. However, the eastern portions of the Appalachians, in particular the Avalon Zone, have remained enigmatic although in the past several years increased attention has been given the eastern margin of the system, in particular to the relationships in and between the Avalon and Gander Zones in Newfoundland (e.g.Schenk, 1971; Rast et al., 1975; Blackwood and Kennedy, 1975; Blackwood and O'Driscoll, 1976; Jayasinghe and Berger, 1976; Strong et al., 1975, 1976, 1978; O'Driscoll and Hussey, 1977).

Much has been based on the regional relationships of the Love Cove Group as described and inferred by Jenness (1963). Hence, it was decided to study the stratigraphy and relations of the Love Cove Group in its type area and adjacent units in more detail than previous workers in attempting to clarify, at least in part, the regional stratigraphic and tectonic meaning of these rocks in terms of the geology of the western Avalon Zone and that of the eastern portions of the Appalachian-Caledonides system.

CHAPTER 2

REGIONAL SETTING

2.1 Introduction

The Appalachian structural province borders the Archaean-Proterozoic Canadian Shield on the southeast. It represents principally a Palaeozoic crustal development. The first fundamental geological subdivision of the Newfoundland Appalachians was made by Williams (1964). He described it as a tripartite system comprised of a central, folded Palaeozoic volcano-sedimentary terrain, the Central Mobile Belt, bounded on the northwest and southeast by two stable platforms, the Western platform and the Avalon platform. The Western platform consists of high-grade Grenville igneous and metamorphic basement (900-1100m.y.) overlain with profound unconformity by a Cambro-Ordovician clastic-carbonate sequence. In contrast the Avalon platform is characterized by thick accumulations of late Hadrynian sedimentary and volcanic rocks and possibly related plutons. These rocks are conformably or unconformably overlain by Eocambrian-Cambrian sedimentary strata.

The Avalon Zone appears to underlie much of the Grand Banks of Newfoundland (Lilly, 1966) and thus may have a width of about 500 km, as opposed to a width of 300 km for the rest of the Newfoundland Appalachians with which it is in fault contact (Blackwood, 1976). No sialic basement to the Avalon platform is presently exposed in Newfoundland, although gneisses have been reported from Cap Miquelon (Aubert de la

Rue, 1932) immediately west of the Burin Peninsula. It should also be noted that in central Labrador, northwest of the Appalachians, Hadrynian red sandstones, conglomerates and shales unconformably overlie rocks of the Grenville structural province (Greene, 1970). More recent detailed tectonostratigraphic subdivisions of the Newfoundland Appalachians (Williams et al., 1974) have dealt largely with the central mobile belt (Fig. 1.2); the Avalon platform is now referred to as the Avalon Zone.

2.2 Stratigraphy of the Avalon Zone

The Avalon Zone is dominated by a number of distinct late Precambrian lithostratigraphic assemblages whose distribution in alternating belts defines the regional north- to northeast structural grain (Fig. 2.1). An exception to this generalization is a thick unfossiliferous Ordovician-Silurian (?) volcano-sedimentary sequence in northern Fortune Bay (Bradley, 1962; column "B", Table 1). The Palaeozoic age was based principally on correlations with rocks to the west in the Belleoram area (White, 1939). However, Williams (1971) has reinterpreted the geology of the Belleoram map sheet to produce a stratigraphy similar to that found elsewhere in the Avalon Zone (column "A", Table 1). Similar revisions in the Terrenceville and Gisbourne Lake map sheets (Bradley, 1962) appear justified on that basis.

Most of the detailed work on the Precambrian sequences has been done on the Avalon Peninsula and more recently on the Burin Peninsula (e.g. Strong et al., 1978a). In the past, the Avalon Peninsula has been the subject of controversy dealing with the geologic development of the Avalon Zone (e.g. Brückner, 1969; Papezik, 1969, 1970; Hughes and Bruckner, 1971; Anderson, 1972; Malpas, 1971; Maher, 1973; King et al., 1974; Nixon, 1975). Poole (1967) discussed the "Avalon platform" with reference to a lower largely volcanic assemblage and an upper largely sedimentary assemblage. King et al., (1974) described the Hadrynian-Ordovician stratigraphy of the Avalon Peninsula in terms of three major lithostratigraphic assemblages "which developed successively in fundamentally differing palaeogeographic settings". These assemblages are not identical to those of Poole (1967). Taylor (1977) used this approach in correlating sequences of the western Avalon Zone* with those of the Avalon Peninsula and in providing some order to discussions of regional Avalon Zone geology. A similar approach is followed here. Fig. 2.1 shows the distribution of the various lithostratigraphic assemblages throughout the Avalon Zone and the location of the stratigraphic columns shown in Table 1.

2.2.1 Lower Assemblage

On the eastern Avalon Peninsula, the lower assemblage includes the Harbour Main and Conception Groups and the Holyrood (granitoid) Plutonic Series (McCartney, 1967). The Holyrood granite is not of major stratigraphic significance in these discussions and will not be considered further. The Harbour Main

*including all portions of the Avalon Zone west of the Isthmus of Avalon

Group (>1800 meters thick) forms the base of the section; it includes terrestrial to lesser marine, mafic to silicic pyroclastics and flow rocks and minor interbedded terrestrial sedimentary rocks (McCartney, 1967). The overlying Conception Group (approx. 3000meters thick) is clearly divisible into five formations (Williams and King, 1976), is dominantly marine in nature, and is composed largely of greenish-grey, locally red, siliceous siltstones and shale with variable amounts of greywacke and chert (columns "H", "I", "J"; Table 1). These rocks consist in part of volcanic debris (McCartney, 1967; Hughes, 1977) and there are occurrences of pillowed mafic lavas, tuffs and agglomerates (McCartney, 1967; Maher, 1973; Williams and King, 1976). In the northeast, the lower portion of the sequence consists of thin-bedded arkose while thick-bedded arkose occurs at a higher stratigraphic level (King et.al., 1974). On the southern Avalon, tillites occur at an approximately middle level in a relatively complete section of the Conception Group while in the Holyrood area they occur immediately above the unconformable contact on the Harbour Main Group. Late Precambrian fossils occur in the upper portions of the Conception Group sequence at a number of localities (Misra, 1969; Williams and King, 1976).

The relations between the Harbour Main Group and the Conception Group are somewhat variable. Hughes and Bruckner (1971) suggested that they are essentially penecontemporaneous, based in part on a lateral interfingering of Conception-type sedimentary rocks (including tillite beds) and Harbour Main-type volcanic rocks east of Conception Bay (Maher, 1973). However, as described above the contact between the two groups appears unconformable elsewhere.

On the western Avalon Peninsula, King et.al. (1974) included the Connecting Point Group, and the Bull Arm Formation and the Big Head Formation of the Musgravetown Group (McCartney, 1967) in the lower assemblage. The base of the Connecting Point Group is nowhere exposed and McCartney (1967) estimated its thickness in the Trinity-Placentia Bay area at approximately 3000 meters; to the north in Bonavista Bay it may be 7700-9200 meters thick (Jenness, 1963) (columns "E" and "F", Table 1). The Connecting Point Group is considered to be the oldest unit on the western Avalon Peninsula, is dominantly marine in nature, and is so far undivided. It is composed of greenish-grey slaty shales and siltstone and greywacke beds (McCartney, 1967). Recent studies (O'Driscoll and Muggeridge, 1978; A.F. King, pers. comm., 1978) suggest that it is a shoaling-upward sequence, and intermediate to mafic volcanic rocks occur toward its top (McCartney, 1967; Jenness, 1963). The Bull Arm Formation is approximately 2400 meters thick on the Isthmus of Avalon and includes mafic and felsic flows, breccias, pyroclastic rocks, arkose, siltstone and conglomerate. It is largely subaerial in nature but does include some beds of fine-grained Connecting Point-like sedimentary rocks suggesting a marine origin for parts of the formation (McCartney, 1967).

McCartney also described conformable relations between the Connecting Point Group and the overlying (?) Bull Arm Formation at two localities. Brief studies of these localities by the present author show that the relations between the two units are not clear-cut. Indeed, McCartney (1967, p. 99) states, "satisfactory direct evidence of the contact relations is not known to be exposed in this map area". The Bull Arm Formation is conformably overlain with some intercalation by red beds of the Big Head Formation (approx. 1000 to 2200 meters thick) which is composed dominantly of "grey-green to grey siltstone, slate, green cherty argillite and arkose. These resemble [illegible] beds of the Conception Group" (McCartney, 1967, p. 51).

These rocks are separated from lower assemblage sequences of the eastern Avalon Peninsula by a belt of middle assemblage rocks and correlations are therefore somewhat tenuous. McCartney (1967) correlated the Conception Group with the Connecting Point Group. Work in progress (A.F. King, pers. comm., 1978) suggests that the Big Head Formation may be a more viable facies equivalent to the Conception Group than the Connecting Point Group. Therefore, in contrast to McCartney's view, it is possible that the Bull Arm Formation of the western Avalon Peninsula is equivalent to the Harbour Main Group. Further work is needed to clarify the relations of the Connecting Point Group.

Placentia Bay: On the Merasheen Islands of Placentia Bay, a bimodal (basalt-rhyolite) suite of volcanic rocks in the Musgravetown Group is reported to overlie conformably sedimentary rocks similar to the Connecting Point Group (O'Driscoll and Muggeridge, 1978). However, on the west side of Placentia Bay in the Paradise Sound-Bar Haven area a sequence of dominantly marine volcanic rocks (Unit 4) is conformably overlain by a thick sequence of marine sedimentary rocks (Unit 5a) which includes limestone beds and breccias and minor mafic volcanic rocks (Unit 5b) in its upper part. These rocks have been referred to the Musgravetown Group and appear conformable up into Lower Cambrian strata (O'Driscoll, 1978; column "D", Table 1). They are in steep fault contact to the west with deformed Love Cove Group volcanic rocks.

<u>Burin Peninsula</u>: On the southern Burin Peninsula, Van Alstine (1948) and Williamson (1956) correlated a broad terrain of undivided subaerial silicic pyroclastics, flows, amygdaloidal basalt, quartz-feldspar porphyries and minor related sedimentary rocks with the Harbour Main Group of the Avalon Peninsula and inferred it to be the oldest rock unit in the area. In their interpretation, the dominantly marine Rock Harbour Group (conglomerate, greywacke, siltstone, and limestone) and the overlying pillow basalt and related pyroclastics of the Burin Group (1500-2800 meters thick) are younger than the subaerial volcanic sequence with which they are in fault contact.

In contrast, in the interpretation of Strong et.al. (1976) and Taylor (1977) the Burin and Rock Harbour Groups lie unconformably beneath the terrestrial silicic terrain which they informally renamed the Marystown Group. Taylor (1977) estimated a 1900-meter thickness for the Rock Harbour Group and indicated that the Burin Group could be up to 4 km thick. Strong et.al. (1976) described eight lithostratigraphic subdivisions of the Marystown Group and indicated that lack of structural data and poor outcrop in many places prohibit reliable thickness estimates. Taylor (1977) subdivided that terrain into the dominantly silicic Marystown Group and the dominantly mafic Mortier Bay Group. Also, he took the Mortier Bay Group as late Hadrynian but suggested that it is unconformable on the Marystown Group (column "C", Table 1). O'Brien (pers. comm., 1979) is incorporating data from most of the Burin Peninsula in proposing the subdivisions shown in column "C", Table 1. These divisions correspond closely with the subdivision proposed for the present map area.

Strong et.al. (1978) inferred abundant silicic volcanic detritus in the Rock Harbour Group to be derived from the Harbour Main Group or a presently unexposed equivalent. The Marystown Group is disconformable up into Eocambrian strata (O'Brien et.al., 1977) and has therefore been taken as a correlative of the Bull Arm Formation (McCartney, 1967; Jenness, 1963). This entire terrain, including the Rock Harbour, Burin, Marystown, and Mortier Bay Groups is here, tentatively, referred to the lower assemblage of King et.al. (1974).

To the north a sequence of cross-bedded tuffaceous sandstone, greywacke, conglomerate and minor tuff intervenes between probable correlatives of the Marystown and Mortier Bay Groups (O'Brien, 1978; pers. comm., 1978). These sedimentary and tuffaceous rocks occur as a semi-continuous north-trending band extending up into the present map area. This includes the lower portions of the Southern Hills Formation (1) and the Andersons Cove Formation (Bradley, 1962), Unit 2 of Hussey (1978a), Unit 1b (in part) of Jenness (1963), and the Thorburn Lake Formation (2b) of this thesis. These rocks are here correlated, in rough terms, with lower assemblage marine or subaqueous sequences such as the Big Head Formation. On the northern Burin Peninsula, they are infolded and appear conformable upon volcanic rocks of the Deer Park Pond and Southern Hills Formations (column "B", Table 1) and the Love Cove Group (Bradley, 1962; Hussey, 1978a). The Southern Hills (3000 meters thick) and Deer Park Pond Formations (up to 1500 meters thick) are comprised dominantly of deformed silicic flows and pyroclastics, greywacke conglomerate, greywacke, slate and minor basalt. These rocks are on strike and contiguous with the Marystown Group to the south (O'Brien, 1978a, b) and the Love Cove Group to the north (Hussey, 1978a; O'Driscoll, 1978).

Descriptions of and discussions on the stratigraphy of the Bonavista Bay - Trinity Bay area (column "E", Table 1) are given in chapter 3.

Fortune Bay: In northern Fortune Bay, lower assemblage rocks of the Grand le Pierre (300 meters thick), Belle Bay

(1800 meters thick) and Andersons Cove (150-1200 meters thick) Formations are separated from the more deformed rocks described above by the Terrenceville Fault (Bradley, 1962). The Belle Bay Formation unconformably overlies the Grand le Pierre Formation; both comprise mainly silicic flows and pyroclastics, lesser mafic flow rocks and minor sedimentary rocks. The overlying Andersons Cove Formation occurs on the Burin Peninsula as well and includes greywacke conglomerate, green slate and minor pillow basalt.

Williams (1971) outlined a similar stratigraphy to the west. However, in that area the Belle Bay Formation is 3000-6000 meters thick and the Andersons Cove Formation is 300-450 meters thick. These are in turn overlain by silicic flows and agglomerates, mafic flows and sedimentary rocks of the Mooring Cove Formation (300-750 meters thick).

2.2.2 Middle Assemblage

The "Middle Assemblage" is "a thick detrital sequence dominantly composed of debris derived from rocks of the 'Lower Assemblage'" (King et.al. 1974). Rocks of this assemblage occur principally in a number of north-trending belts (Williams, 1967). On the Avalon Peninsula, these rocks are known under three different names. Rocks of the eastern zone have been named the Cabot Group (column "J", Table 1) (Rose, 1952). Those of the middle zone (Hodgewater Group) underlie most of the central Avalon Peninsula (McCartney, 1967; columns "H" and "I", Table 1). The third zone lies farther to the west and includes the middle and upper portions of the Musgravetown Group (McCartney, 1967; columns "E", "F", and "G", Table 1). The Cabot and Hodgewater Groups include rocks of similar facies. Both commence with a sequence of dark grey slates conformably and gradationally overlying the youngest Conception Group strata (i.e. St. John's and Carbonear Formations, respectively). These are transitional upwards into a sequence of grey to greenish sandstones with subordinate shale; in the Cabot Group, these rocks are overlain with a sharp diachronous contact by red sandstones and conglomerates of the Signal Hill Formation and overlying Blackhead Formation (King et.al., 1974). A few tuff horizons occur in the lower Cabot Group (King, 1972).

The lower divisions of the Musgravetown Group (Bull Arm and Big Head Formations) have been included in the lower assemblage (King et.al., 1974). However, red beds above the Big Head Formation are lithologically similar, and may be stratigraphically equivalent to, those of the Halls Town Formation in the Hodgewater Group. The upper parts of the Musgravetown Group have no equivalent in the Hodgewater Group and appear to wedge out eastward (King et.al., 1974).

To the northwest, Jenness (1963) has outlined somewhat similar lithologic assemblages in the Musgravetown Group above the Bull Arm Formation as has Fletcher (1972) on the Cape St. Mary's Peninsula (column "G", Table 1). In the present map area, most of the Southwest River Formation and possibly the Charlottetown Formation belong in this assemblage.

Rocks here referred to the "Middle Assemblage" occur throughout Placentia Bay. In northern Placentia Bay, at North Harbour, a thin sequence of variably deformed green sandstones and black slates and red conglomerates and sandstone appear to overlie conformably Love Cove Group volcanic rocks (O'Driscoll, 1977b). Deformed fault-bounded red beds occur on the west side of Placentia Bay (Unit 5d; O'Driscoll, 1978). Also, red to purple, graded and cross-bedded sandstone, shale and conglomerates (Unit 5c; O'Driscoll, 1978) occur in an apparently conformable sequence between a thick marine unit beneath referred to the Musgravetown Group (Anderson, 1965) and Eocambrian Random quartzites above; column "D", Table 1 (Unit 5c, O'Driscoll, 1978). O'Brien et.al. (1977) reports red, micaceous sandstone and mudstone (Rencontre Formation), disconformably overlying the Marystown Group on the southwestern Burin Peninsula. These rocks are, in turn, overlain by a 737 meter thick sequence of green-grey to locally red siltstone and minor limestone containing a lower Cambrian fauna in its upper parts (Chapel Island Formation). Elsewhere rocks (dominantly red-beds) placed in the "Middle Assemblage" include the Rencontre Formation in western Fortune Bay; 1500 meters, Williams (1971) (column "A", Table 1); in northeastern Fortune Bay, 1200 meters, Bradley (1962) (column "B", Table 1); and in the "knee" area of the Burin Peninsula (O'Brien, 1978b).

2.2.3 Upper Assemblage

The "Upper Assemblage" as outlined by King et.al. (1974)

is composed of two distinct divisions, the Random Formation and the overlying Cambro-Ordovician sequence. Angular unconformities separate the Random Formation from the "Middle Assemblage" beneath as well as from the overlying Cambrian rocks on the Cape St. Mary's Peninsula (Fletcher, 1972). However, Greene and Williams (1974) describe conformable relations between Random and Cambrian strata elsewhere.

The Random Formation typically includes white-weathering orthoquartzite and interbedded grey siltstone. It has a wide distribution but does not occur beneath the Cambrian of Conception Bay. It ranges from 0 to 150 meters in thickness and is Eocambrian in age on the Avalon Peninsula and northwestward. However, a thick quartzite unit correlated with the Blue Pinion Formation of the Belleoram area occurring on the southern Burin Peninsula is Early Cambrian in age (O'Brien et al., 1977), suggesting that these quartzites are markedly diachronous from east to west.

The conformable sequence of Cambro-Ordovician strata above the Random Formation is typically disposed in synclinal keels or fault blocks throughout the Avalon Zone. The Cambrian rocks include green-red shales, pink to grey limestone, manganiferous mudstones, locally pillowed mafic volcanic rocks in Trinity Bay, and black shales. The Ordovician clastic sequence includes grey and black shale, siltstone, and sandstone with oolitic hematite. It occurs in outliers in Trinity and Conception Bays and reaches 1500 meters in thickness in Conception Bay (column "I", Table 1). The Cambrian strata are up to 380 meters thick, although in

Fortune Bay the middle Cambrian Youngs Cove Formation contains grey micaceous sandstone and is approximately 600 meters thick (Williams, 1971) (see column "A", Table 1). The Nine-Mile-Hill Formation, north of Fortune Bay (column "B", Table 1) which includes hornfels, quartzite, slate, greywacke conglomerate and basalt is up to 1100 meters thick and contains an Upper Cambrian fauna (Bradley, 1962).

2.2.4 Other Stratified Rocks

Rocks which do not fall within the "assemblages" discussed occur in the western Avalon Zone (column "A", "B", and "C"; Table 1). These deposits are sub-aerial to lacustrine in nature and are Devonian to Lower Carboniferous in age (Widmer, 1950; Strong et.al., 1978b). They typically include red, brown, ~~and~~ grey conglomerate, sandstone, shale, and mudstone with minor limestone. They are contained in the Great Bay de l'Eau (300 meters), the Pools Cove (1500 meters) and the Cinq Isles (430 meters) Formations in the Fortune Bay area (Williams, 1971) and the Terrenceville (300 meters) and Spanish Room (244 meters) Formations on the Burin Peninsula (Bradley, 1962; Strong et.al., 1978b). The Cinq Isles Formation is unconformable on Upper Cambrian strata.

2.2.5 Uncertainties of Correlation across the Avalon Zone

It appears that "the environment of deposition" approach of King et.al. (1974) is a useful method of describing the geology of the Avalon Zone. As described by Taylor (1977) this approach is particularly appealing since it does not rely heavily upon absolute or relative ages. Age estimates obtained thus far are controversial (eg. Anderson, 1972; Greene and Williams, 1974; Hughes and Bruckner, 1971).

Anderson (1972) used stratigraphic means to infer an age span of 800-600 m.y. for "Lower Assemblage" rocks of the central and eastern Avalon Peninsula. A thick "Middle Assemblage" sequence intervenes between those rocks and fossiliferous Lower Cambrian strata. This limits the "Lower Assemblage" and probably much of the "Middle Assemblage" to the Hadrynian. Radiometric (Rb/Sr) age dating has given anomalously young ages for the Precambrian volcanic rocks (Fairbairn et.al., 1966). This has been attributed to the metasomatized nature of the volcanic rocks sampled (Malpas, 1971; Hughes and Malpas, 1971). Cormier (1969) working in rocks of similar age (mainly granites) on Cape Breton Island attributed such anomalies to an "updating" effect of the Acadian (Devonian) Orogeny. Such arguments probably apply to granites in the Avalon Zone (in Newfoundland) as well (see sec. 2.3).

There is at present some controversy concerning the placement of the Cambrian-Precambrian boundary (Fletcher, 1972; Greene and Williams, 1974).

A co-existence and/or sequential development of widely contrasted subaerial and submarine terrains clearly played an important role, in particular, in the "Lower Assemblage" history of the Avalon Zone. More detailed work is required to clarify these relations which will figure prominently in future modelling of these rocks. Indeed with the present understanding of these strata it is clearly impossible to draw time lines within the Precambrian section. Correlation of the various sequences and their contacts is therefore of limited if any time significance.

2.3 Intrusive Rocks of the Avalon Zone

These rocks have been described in detail by Bradley (1962), Jenness (1963), McCartney (1967, Barning (1965), Hughes (1971), O'Driscoll (1973), Teng (1974), Strong et.al. (1974a), Strong et.al. (1976), and Hussey (1978). Hence, only a brief review as it relates to the regional setting of the host rocks is given.

Major intrusions in the Avalon Zone appear divisible into two distinct suites which have apparent ages of Late Precambrian and Devonian to Carboniferous respectively and range in composition from peralkaline granite to gabbro. Alkaline or subalkaline granite is the most common phase (Strong et.al., 1974a).

The earlier suite is typified by the Holyrood granite (574 ± 11 m.y., Rb/Sr whole rock; McCartney et.al., 1966) on the Avalon Peninsula. There is some controversy as to whether it is genetically related to the Harbour Main volcanic rocks which it intrudes (i.e. McCartney, 1967; Strong and Minatidis, 1976; Hughes and Bruckner, 1971). On the western Avalon Zone, a suite of texturally and apparently compositionally related foliated composite plutons occur almost exclusively within the Love Cove volcanic terrain. One of these, the Swift Current Granite (Northern Bight granite of Jenness, 1963) has been dated at 500 ± 30 m.y. (Rb/Sr whole rock, M.S.W.D. 12.8*, Bell et.al., 1976). However, as indicated by Bell et.al. (1976), the high M.S.W.D. sheds doubt on the statistical validity of the isochron. Hussey (1978) has suggested on the basis of field evidence (see also sec. 3.3.1.3 of this thesis) that these granites are genetically and chronologically related to the Love Cove Group. Therefore, a late Precambrian age is tentatively inferred for these granites.

A number of large, discordant, post-kinematic, granitic plutons occur in the western Avalon Zone and some of these straddle the Gander-Avalon Zone boundary (see Jenness, 1963; Bradley, 1962; Williams, 1967; Hussey, 1978). These have been dated as Upper Devonian-Carboniferous (Bell et.al., 1976). They include the Ackley batholith (344 ± 8 Ma, Rb/Sr, M.S.W.D. 1.8); the Terra Nova granite (335 ± 18 Ma, Rb/Sr, M.S.W.D. 0.3), and the St. Lawrence granite (315 ± 8 Ma, Rb/Sr, M.S.W.D. 3.2). These granites show some chemical differences from the earlier suite of plutons (Strong et.al., 1974a).

2.4 Structure of the Avalon Zone

The structure of the Avalon Zone is somewhat enigmatic

*mean square of weighted deviates

and has been described in terms of two ages of deformation. These are a late Precambrian (Avalonian) and a more prominent Palaeozoic (Acadian ?) event (Lilly, 1966; Hughes, 1972; Williams et.al., 1974; Younce, 1971).

The late Precambrian "Avalonian orogeny" was originally named by Lilly (1966) on the basis of field evidence on the Avalon peninsula. Hughes (1970) considered the "Avalonian orogeny" in terms of calcalkaline volcanism, plutonism, sedimentation and vertical faulting. However, he indicated that "features indicative of compression are absent or subordinate". On the Avalon peninsula the main features of this earlier deformation include open folds with steep cleavage, high angle faulting with associated gravity sliding and transgressive-regressive events (McCartney, 1969; Papezik, 1970; King et.al., 1974). This so-called "Avalonian orogeny" is recorded in a number of unconformities which occur throughout the Avalon Zone either within the Precambrian or immediately beneath basal Cambrian rocks. These appear to range widely in age and tend to separate distinct sequences. They include the Holyrood granite - basal Cambrian nonconformity on Manuels River (Rose, 1952), the Harbour Main - Conception unconformity on Colliers Bay, the Harbour Main Group - Lower Cambrian unconformity west of Colliers Bay, and the Conception - Lower Cambrian unconformity at Bacon Cove (McCartney, 1967), the "H.D. Lilly" unconformity between the Conception and Cabot Groups (Anderson et.al., 1976), Connecting Point - Musgravetown unconformity at Milner's Cove (Hayes, 1948) and a similar contact at Southward Head (Jenness, 1963), the Grand le Pierre - Belle Bay unconformity at Grand le Pierre, Fortune Bay (Bradley, 1962), the Burin Group - Cambrian unconformity on the southern Burin peninsula (Strong et.al., 1978b) and the Musgravetown - Random unconformity on the Cape St. Mary's peninsula (Fletcher, 1972). Further, in the western Avalon Zone, Jenness (1963) used the occurrence of schistose detritus in basal Musgravetown Group conglomerates to infer a late Precambrian regional deformation of the Love Cove Group. However, Younce (1970) and Williams et.al. (1972) did not regard the schistose detritus as sufficient evidence to alter their view that the deformation was Palaeozoic (Acadian) in age since all rocks in the region, Precambrian through Ordovician, contain but a single penetrative foliation.

In general, Acadian (?) structure in the Avalon Zone is characterized by open upright north-to northeast-trending folds with a steep axial planar cleavage. This is thought to merge westward into the tight upright folds and associated schistosity of the Love Cove terrain (Williams et.al., 1974). In the southwestern Avalon Zone east-to southeast-directed overturning and associated thrusting dominate the presumed Acadian structure (O'Driscoll, 1978 ; Strong et.al., 1976). Older Precambrian faults were probably reactivated during the Acadian event (Malpas, 1971).

In summary, it appears that Avalon Zone geology is characterized by Acadian structures superimposed upon earlier Avalonian deformation. As suggested by Strong et.al. (1978b) "the evidence at present suggests that the deformational events during late Precambrian time occurred over a wide time interval, and in different parts of the Avalon Zone at different times, and perhaps the term orogeny should not be used here".

2.5 Summary

A number of models have been proposed for the late Proterozoic development of the Avalon Zone (Papezik, 1970; Hughes and Bruckner, 1971; Malpas, 1971; Strong et.al., 1978b; Strong and Minatides, 1976; Taylor, 1977). However, all of these suffer from the lack of both detailed geologic information and comprehensive petrochemical data on a regional scale and the apparent ambiguity of the relations between some major groups. This along with the lack of reliable age dates makes east-west correlation of major units difficult.

Dominantly subaerial silicic volcanism commenced in the Avalon Zone perhaps 600 m.y. ago. The type of crust upon which this occurred is not known to outcrop in the Newfoundland Avalon Zone. It is interpreted as continental crust by Papezik (1970, 1973a, 1974) and Strong et.al. (1974a, 1974b, 1978b) and as oceanic crust by Hughes and Bruckner (1971), Rodgers (1972) and Younce (1971). In the present author's view, the age relations of these volcanic rocks (eg. Harbour Main, Bull Arm, Marystown) from east to west need further clarification.

Marine sedimentation and subordinate submarine (mafic) volcanism followed or in part accompanied the subaerial silicic volcanism. There were voluminous outpourings of submarine tholeiitic mafic lava in the southwest (Strong et.al., 1976; Taylor, 1977; O'Driscoll, 1978a). The marine sedimentation and volcanism (Conception and Connecting Point Groups) occurred in deep north-trending troughs which alternated geographically with the subaerial terrains. When the subaerial volcanism ceased or waned the terrain was covered by marine sedimentation. These sedimentary rocks are relatively thin (eg. Andersons Cove Formation) or non-existent in the west as opposed to the very thick accumulations of the Connecting Point and Conception Groups in the central and eastern Avalon Zone.

The marine sedimentary rocks appear to shoal upwards suggesting an infilling of the basin and prevalence of shallow water or fluviatile environments. The detritus was derived largely from older rocks uplifted on major faults which may have been active during volcanism (McCartney, 1969; Papezik, 1970; Hughes and Bruckner, 1971). The time of transition from a marine to a subaerial environment probably varied from area to area. The fluviatile/subaerial sedimentary rocks appear to be thickest in the east and thin in the southwest (Rencontre Formation). At least in the west, there was a renewal of subaerial, but dominantly mafic, volcanism (eg. Mortier Bay Group, Mooring Cove Formation) which apparently accompanied or preceded the terrestrial sedimentation. This probably resulted, in part, from structural doming or uplift. In the east, McCartney (1967) described a mafic volcanic unit at the top of the Harbour Main Group (Colliers basalt of Papezik, 1974). It could be equivalent to the Mortier Bay Group.

Granitoid plutonism probably accompanied the silicic volcanism in the west (eg. Swift Current granite) but was apparently somewhat later in the east (Holyrood, 574 ± 11 Ma, McCartney et.al., 1966).

In latest Precambrian to middle Early Cambrian time (depending on location) a number of marine transgressions occurred, which were followed by local mafic volcanism in the Middle Cambrian and widespread marine sedimentation into the early Ordovician (McCartney, 1967; Greene and Williams, 1974).

Silurian and Devonian times were marked by compressive stresses oriented NW-SE followed by post-kinematic granitic plutonism. Lapses in this plutonism were marked in the west by alluvial fan deposition (Williams, 1971). Granites were emplaced as late as Middle Carboniferous (St. Lawrence Granite).

Except for erosion and Pleistocene glaciation the only recorded events since the Palaeozoic may be the intrusion of some Mesozoic dykes (Papezik et.al., 1975).

2.6 Regional Correlations

Apparent equivalents of the Newfoundland Avalon Zone occur to the southwest on Cape Breton Island (Fourchu Group; Wiebe, 1972; Helmstaedt and Tella, 1973), southern New Brunswick (Coldbrook Group and Ratcliffe Brook Formation; Rast et al., 1976), Massachusetts and Rhode Island (Middlesex Fells and Lynn volcanic rocks and Dedham granodiorite; Kovach et al., 1977; Skehan et al., 1978) and the extensive Carolina Slate Belt of ~~the~~ southern Appalachians (e.g. Sinha and Glover, 1976; Williams, 1978). High-grade igneous and metamorphic rocks form a basement to the late Precambrian rocks on Cape Breton Island (George River Group; Wiebe, 1972) and New Brunswick (Greenhead Group; Rast et al., 1976). Such rocks have not been observed in the Avalon Zone of Newfoundland.

CHAPTER 3

GEOLOGY AND PETROGRAPHY

3.1 INTRODUCTION

The study area is underlain by volcanic, sedimentary and intrusive rocks of late Precambrian age. The volcanic and sedimentary rocks belong to three major groups: the Love Cove Group, the Connecting Point Group, and the Musgravetown Group.

The recognition of a true stratigraphic sequence in the map area is greatly inhibited by structural complications. Hence, these rocks have been subdivided mainly on a lithostratigraphic basis, although structural and lithologic criteria can be used to infer a depositional chronology. Remapping of the area on a more detailed scale than the 1:250,000 mapping done by Jenness (1963) has thus made it possible to refine and revise his stratigraphy. The reader is referred to the accompanying 1:25,000 map (Fig. 1) when reading the descriptions of the stratigraphy of the area. The numbering on Fig. 1 should not be taken as a strictly chronologic designation because several of the units appear to be facies equivalents.

3.2 STRATIGRAPHIC REVISIONS AND NEW FORMATION NAMES

As indicated above, Jenness (1963) defined a number of alternating, north-south trending, fault-bounded belts of Love Cove Group and Musgravetown Group rocks in the Bonavista Bay area. Portions of all these belts occur in the present map-area as does the type section of the Love Cove Group.

Strata to the east of the north-south fault passing through Charlottetown and Bunyan's Cove (Charlottetown Fault of Jenness (1963)) were originally included in the Musgravetown Group (Hayes, 1948; Jenness, 1963) and their status is here maintained. However, a sequence of red-beds and volcanic rocks in the western portion of the map area previously referred to the Musgravetown Group by Jenness (1963) is here informally renamed the Southwest River Formation and included within the expanded Love Cove Group. This redefinition is based upon new structural and stratigraphic information to be discussed in a later section. Hence, the Love Cove Group is expanded both in area and stratigraphically and is divided into three major lithostratigraphic units, each of formational rank.

1. <u>White Point Formation</u> - This formation occurs in a north-south trending belt and it is defined as that sequence of rocks of largely pyroclastic origin which crops out along the shores of Clode Sound from the area of the Narrows east to the Charlottetown Fault. Rocks included in this formation also crop out in the westernmost portion of the field area on Northwest and Salmon Rivers. The type locality of the Love Cove Group (Jenness, 1963) lies within this area on the south shore of Clode Sound. The name is taken from White Point, a prominent headland on the north shore of Clode Sound.

2. <u>Thorburn Lake Formation</u> - This formation occupies a narrow north-trending belt which flanks the White Point Formation to the west. It is a sequence of variably deformed

volcanogenic sedimentary rocks and tuffs which are best exposed along the shores of Clode Sound. However, the only stratigraphically continuous section (i.e. consistently facing) occurs along the shores of Thorburn Lake in the southwestern portion of the map area (Figs. 1 and 1.1).

Together, these two formations closely approximate the Love Cove Group as outlined by Jenness (1963).

3. <u>Southwest River Formation</u> - This is the sequence of red-beds and volcanic rocks that crop out around the head of Clode Sound and which was formerly referred to the Musgravetown Group (Jenness, 1963). Good exposures occur in the Northwest Arm area of Clode Sound, but there is less structural complexity and repetition of strata (Fig. 1.1), (although not in continuous outcrop), in the Southwest River area of Thorburn Lake.

East of the Charlottetown Fault, the Musgravetown Group (Hayes, 1948) has been stratigraphically subdivided by Jenness (1963) who defined and outlined the basal Cannings Cove Formation*, the overlying Bull Arm Formation and an undivided unit. These subdivisions are here modified and refined with the introduction of new informal names for the volcanic sequence and the overlying red-beds.

The Cannings Cove Formation is here expanded to include red conglomerates and minor basaltic flows previously included in the lower portions of the overlying Bull Arm Formation. The contact between the two formations is placed

*The type localities of both the Musgravetown Group and the Cannings Cove Formation lie immediately southeast of the map area.

at the base of the overlying dominantly volcanic sequence (i.e. at the top of the highest significant occurrence of conglomerate). This is in contrast to the definition of these formations in this area by Jenness (1963) who placed the contact between them at the lowest stratigraphic occurrence of volcanic rocks. The basaltic flows, which occur in Milner's Cove on the southeast shore of Clode Sound, are volumetrically quite subordinate to the conglomerates and are not continuous along strike.

The term "Bull Arm Formation" is dropped and Clode Sound Formation tentatively suggested for the sequence of mafic and silicic volcanic rocks and minor sedimentary rocks which overlie the Cannings Cove Formation on Clode Sound where it is well exposed. This change is due in part to the uncertainties of lithostratigraphic correlations with the type area of the Bull Arm Formation as well as to significant differences in chemistry between available data on the Bull Arm Formation of the type area (Malpas, 1971) and the volcanic rocks described here (see Chap. 6). Although this is not in strict accord with the code of stratigraphic nomenclature, it appears justified at least as a temporary measure.

Jenness (1963) included sedimentary rocks lying conformably above the volcanic sequence in his undivided, unnamed unit. These rocks, which are in fault contact with the Love Cove Group on Clode Sound, are distinguished and tentatively named the Charlottetown Formation. Excellent coastal exposures occur in the Charlottetown area.

A foliated granitoid pluton, not previously mapped, occurs in the southern portion of the map area and has intruded volcanic rocks of the White Point Formation. It is well exposed in the Georges Pond area and is named the Georges Pond pluton.

STRATIGRAPHY AND PETROGRAPHY

This section is devoted to megascopic to microscopic descriptions of the rock units and their contact relationships. An attempt is made to interpret the conditions of deposition and mode of evolution of the rocks in terms of these characteristics.

3.3 LOVE COVE GROUP

3.3.1 White Point Formation (1)

3.3.1.1 General Statement

This sequence of mafic to silicic pyroclastics, flows and minor related sedimentary rocks comprises roughly the eastern two-thirds of the eastern belt of the Love Cove Group in this area as defined by Jenness (1963). It occupies a north-trending belt averaging approximately 6 km in width and widening in the south where it has been intruded by the Georges Pond pluton. Aside from Unit 1b, a minor sedimentary member in the southwest, a more detailed subdivision of this formation does not appear useful.

TABLE 2 TABLE OF FORMATIONS*

NONINTRUSIVE ROCKS						INTRUSIVE ROCKS	
ERA	PERIOD	EPOCH	GROUP	FORMATION	LITHOLOGY	INTRUSIVES	LITHOLOGY
Cenozoic		Pleistocene		Glacial Drift	Stratified to unstratified glacial till, boulder, clay, sand and gravel		
				angular unconformity			
Palaeozoic	Devonian (?)					Mafic dykes	Porphyritic diabase
Proterozoic			Musgrave-town Group 2060 to 3560	Charlottetown Formation 730	Red conglomerate, sandstone, minor grey siltstone, mafic and silic flows		
				Clode Sound Formation 800 to 2300	Basalt and pantellerite, minor ignimbrite, red sedimentary rocks, mafic dykes	Mafic dykes	Diabase
				Cannings Cove Formation 530	Red to green polymictic conglomerate, red sandstone, minor red shale and basalt		
				angular unconformity			
	Hadrynian		Connecting Point Group	undivided	Grey-black slate, siltstone, minor greywacke		
				not in contact			
Proterozoic			Love Cove Group 4000(?)	Southwest River Formation 1280	Red, fine to coarse grained sandstone, conglomerate, siltstone and red shale, basalt, rhyolite, minor tuff	Dykes	Felsite and diabase
				Thorburn Lake Formation 1300	Grey-green fine to coarse grained greywacke, conglomerate, siltstone tuff		
				White Point Formation 1300 + (?)	Silicic to mafic flows and pyroclastics, related sedimentary rocks	Georges Pond pluton	granite, diorite, gabbro, diabase, granophyre

*thickness in meters

The major part of this formation is volcaniclastic with a minor epiclastic component. Flows and possibly sills make up a lesser but significant proportion of the sequence, in particular in the Blue Hills and Blandford's Ridge where the rocks include a few possibly sub-volcanic intrusions. The formation is perhaps 75% pyroclastic in origin. Dal Bello (1977), mapping immediately to the north, found its correlatives to consist almost entirely of felsic welded tuffs, nonwelded crystal tuffs, and mafic tuffs. Flows appear to be much more abundant to the south, both in the Tug Pond area (Jenness, 1963) and in the Sound Island sheet (Hussey, 1978a).

These rocks generally display a steep penetrative fabric; due to the common lack of primary banding or bedding, only a few tight to isoclinal fold closures can be recognized. Chlorite and sericite schists are common. These features, plus a lack of reliable top indicators, make the establishment of a stratigraphic sequence and meaningful thickness estimates virtually impossible. Jenness (1963) estimated a minimum 15,000 ft. (4573 meters) thickness for the whole of the Love Cove Group. This figure cannot really be tested. However, in the case of the White Point Formation, the true stratigraphic thickness appears to be much less than the structural thickness. In the light of the above, only a lithological characterization can be attempted here.

3.3.1.2 Terminology

As used in Fig. 1, "lithic tuff" is used as a general term to describe pyroclastic rocks composed predominantly of lithic fragments regardless of size. Crystal tuff indicates a high proportion of volcanically derived crystals while a combination of the above modifiers indicates the relative proportions of either clast type (i.e. lithic-crystal tuff indicates a predominance of crystals and vice versa). In these detailed descriptions, terms used for the various size fractions are those defined by Fisher (1966) and those terms applicable to ignimbrites are used in the sense of Smith (1960) and Briggs (1976a).

3.3.1.3 Geology (1a)

Many of the primary features associated with particular types or styles of volcaniclastic or pyroclastic accumulations have largely been obliterated or masked by the tectonic flattening, lower greenschist metamorphism and matrix recrystallization. However, fragment size, size distribution, fragment composition and its relation to matrix composition are all useful in the study of these deposits. The clast population is entirely of volcanic or sub-volcanic origin.

In general terms, these rocks are characterized by an intercalation of chloritic to sericitic, relatively schistose versus relatively massive silicic tuffaceous bands which may be up to 20 meters thick (Plate II). Rhyolite and lesser mafic to intermediate flows or sills are interbedded on a similar scale; thick (up to 50 meters) mafic to intermediate dykes are common.

Plate II: Typical coastal outcrop steeply dipping sericite schists of the White Point Formation. Field of view approximately 20 meters. North shore of Clode Sound.

Purely for descriptive purposes this member is separated into four lithologic units. These are: 1. Agglomerates, lapilli tuffs and ash tuffs (of variable composition), 2. Silicic pyroclastics (many of which may be of ash flow origin), 3. Lava flows, 4. Partially reworked (in part epiclastic?) deposits.

1. <u>Agglomerates, lapilli tuffs and ash tuffs</u>: Several varieties of tuff or agglomerate with a prominent silicic component comprise a considerable portion of the section.

The fine-grained, recrystallized matrix of the tuffs and agglomerates is commonly schistose and ranges from dark green, chloritic and mafic to grey-green or cream, sericitic or siliceous and silicic in composition. Blocks or lapilli of silicic composition are present in variable proportion in all types of matrix. Mafic lapilli are more abundant in the mafic tuffs but are relatively sparse in the silicic tuffs. They may be flattened or equidimensional, dark to light green, and composed largely of chlorite and/or epidote. Also common in the mafic tuffs are purple to black, aphanitic fragments less than 1 cm long, rich in opaque minerals. White to pink sodic plagioclase crystals and crystal fragments (~2mm) and minor sutured quartz grains are common. Fine grained mafic tuffs devoid of lapilli locally show fine banding or lamination less that 2 cm thick which may be defined in part by concentrations of plagioclase crystals. These tuffs are locally interbedded with texturally similar cream-coloured felsic tuffs containing appreciable amounts of pyrite.

Bedding, with little exception, is co-planar with the steep penetrative fabric. Mafic through intermediate to silicic fragments, which may be close packed and up to 12.5 cm long, commonly occur in a sericitic-chloritic matrix. Some of these fragments have ragged, irregular terminations and are probably collapsed and/or flattened pumice lapilli (Plates III and IV).

A common rock type contains up to 25% aphanitic, pink to grey, tabular rhyolitic blocks up to 35 cm long in a chloritic matrix of mafic or intermediate composition, along with mafic lapilli and crystal fragments (Plate V). These rocks make up 20-25% of the southern shore exposures of this formation and are prominent on the north shore of Clode Sound east of Yudle Cove. They appear to be continuous along strike for at least 7.5km both north and south of Clode Sound adjacent to the Charlottetown Fault and reappear farther south, east of Georges Pond. Similar deposits have been described from the Marystown and Love Cove Groups on the Burin Peninsula (Taylor, 1977; Hussey, 1978b).

Thus a typical feature of these volcanic rocks is that they are compositionally mixed. Such deposits have been described from a number of recent volcanic terrains and their characteristics have been summarized by Walker and Skelhorn (1966). The actual mixing of the various compositional components of these tuffs could be either a primary volcanic event which has taken place in the vent or upon extrusion, or it could be secondary, involving an avalanche or debris-flow

Plate III: Deformed lapilli tuff (1a). Note ragged, probably collasped pumice lapilli beneath pencil. South of Clode Sound. Pencil 7 mm thick.

Plate IV: Deformed lapilli tuff (1a) with mainly silicic fragments. South shore of Clode Sound. Pencil 7 mm thick.

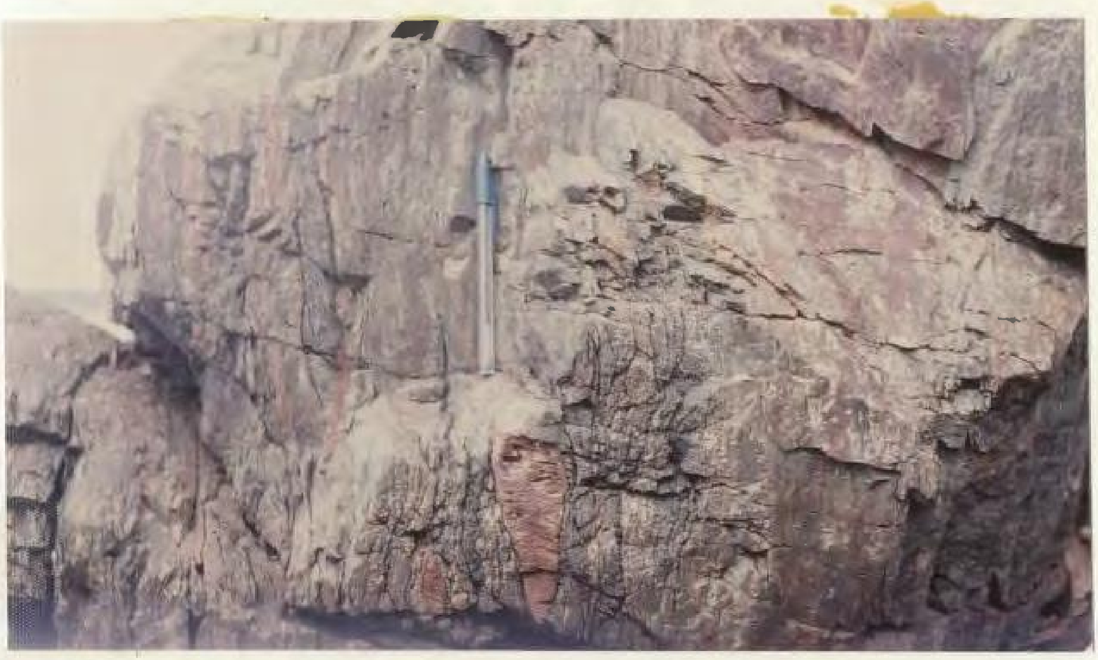


Plate V: Deformed lapilli tuff (1a) with pink rhyolite fragments in relatively mafic matrix. Bunyans Cove. Pen 15 mm long.

Plate VI: Schistose agglomerate (1a) with quartz diorite block. Loc. 51, south shore of Clode Sound. Hammer approximately 30 cm in length.

mechanism. The state of preservation of these rocks does not permit a clearer definition of their origin.

West of Loc. 51 on the south shore of Clode Sound individual units are about 3-4 meters thick and include dark grey to black silicic agglomerates which consist of aphanitic, locally plagioclase and quartz-phyric rhyolitic blocks up to 1 meter in length. These occur in a schistose, chloritic-sericitic, or more siliceous matrix. Less abundant mafic flows up to 5 meters thick are also present. Very coarse poorly sorted agglomerates and sericitized ash tuffs occur at Loc. 51. The agglomerates consist of red, white or grey to purple rhyolitic, andesitic and lesser granitic fragments, averaging 5-10 mm across but ranging, in seriate fashion, from matrix size up to blocks 60 cm across in beds less than 1 meter thick (Plate VI). The fine sericitic fabric developed in the matrix forms augen around the fragments. Similar deposits occur at the tip of the peninsula between Peter's Cove and Bunyan's Cove and west of Georges Pond. The granitoid blocks in these agglomerates petrographically appear to be derived from high level intrusive rocks, very similar to the various components of the Georges Pond granite. Hussey (1978b) reported similar relations to the south between the Swift Current granite and the Love Cove Group, and along with other field data, used this as evidence for a genetic link between the granite and the volcanic rocks. Geochemical studies in the present map area further support this contention.

East of Yudle Cove there are several units of coarse volcanic breccia up to 100 meters thick composed mainly of closely packed, angular, black to red, rhyolitic to basaltic blocks ranging up to 30cm across. The matrix is composed of variable proportions of chlorite, sericite, quartz and minor pyrite.

Locally, "banded volcanogenic cherts" are present, as well as light grey to cream, very fine-grained finely laminated cherty tuffs forming beds up to 7.5 cm thick.

2. Silicic pyroclastics: Aside from the Blue Hills - Blandford's Ridge area, these rocks (largely lithic-crystal tuffs) appear to be the most widespread in the map area. These white to light green-weathering rocks appear to have been deposited both by ash flow and by air fall processes, possibly in both subaerial and subaqueous environments although, in general, there is little evidence of reworking. Due to tight folding and metamorphism it is difficult to estimate the relative importance of either mode of emplacement.

Crystal (and vitric) tuffs (Plate VII) with numerous lithic horizons are dominant. The matrices vary from schistose with sericite and chlorite to relatively siliceous and massive. This association of crystal tuffs with coarse lithic horizons, flattened fragments and flattened, translucent, siliceous shard-like forms locally over 1 cm long (Plate VIII) support the interpretation of an ash flow origin. The tuffs contain variable proportions of white sodic plagioclase and quartz crystals up to 4 mm and white weathering, grey to pink

Plate VII: Typical felsic crystal tuff (1a). North shore of Clode Sound. Pen cover 3 cm in length.

Plate VIII: Ash flow tuff (1a). Note large block of porphyritic rhyolite. Note shard like forms in matrix. Field of view approximately 15 cm.

aphanitic silicic fragments ranging up to 8 cm, but locally reaching 30 cm in length. However, most lithic fragments are less than 2 cm across and are mainly between 1 mm and 1 cm. This is approximately the range described for many ash flows (Smith, 1960; Walker, 1972). Lithic zones are commonly 3-4 meters thick and locally contain up to 20% of medium grey collapsed and/or flattened pumice lapilli with ragged terminations (fiamme). Scattered mafic fragments are up to 5 cm long. A fine (up to 3 mm thick) banding in some tuffs could be the result of post-depositional vapor-phase crystallization (i.e. axiolitic crystallization of Enlows, 1955). This banding locally defines small scale tight folds (Plate IX).

On the TCH, 2 km southwest of Charlottetown, abundant purple to grey, flattened silicic lithic blocks (~30 cm long) occur in a light yellow schistose matrix rich in shards and crystals. Some coarse silicic breccias with fragments up to 50 cm long lie south of Clode Sound. Concentrations of coarse lithic blocks (>30 cm in diameter), such as are present in the White Point Formation, have been interpreted recently as "co-ignimbrite lag-fall deposits", proximal airfall deposits associated with ash flow eruptions (Wright and Walker, 1977).

In the Blue Hills and Blandford's Ridge, silicic breccias are locally common but may be difficult to recognize because of the similarity of fragments and matrix. The fragments are usually angular and up to several centimeters across. One "patch" of rhyolite is flanked by a tuffaceous phase of

Plate IX: Tightly folded thin compositional banding in ash flow tuff (1a). North shore of Clode Sound. Pencil approximately 15 cm in length.

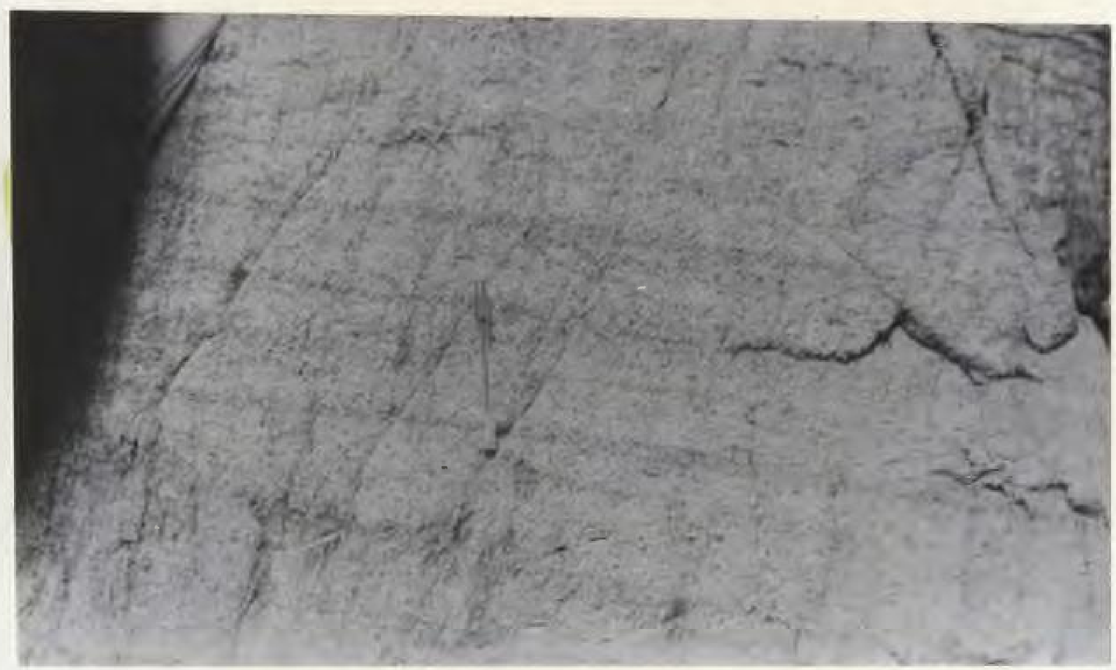


Plate X: Bedded crystal tuff (1a). North shore of Clode Sound. Pen 15 cm in length.

similar composition.

The silicic tuffs are intercalated with bands (< 1 meter thick) of fine grained laminated mafic tuff which locally define tight outcrop-scale folds.

In most instances, it is not possible to estimate the relative importance of primary (syndepositional) or tectonic flattening of the fragments in these tuffs, although locally it appears that strain has been relatively low. The amount of flattening could be controlled by the proportion of fragments to matrix and the rheological or competency contrasts between them. The achievement of accurate estimates of the total amount of tectonic flattening requires abundant reliable primary strain indicators such as accretionary lapilli (Moore and Peck, 1962) although compaction effects may still be a significant consideration. In addition, metamorphic recrystallization has largely masked the effects of welding and/or post-depositional vapor phase recrystallization.

Bedded (up to 10 cm) schistose crystal and ash (vitric?) tuffs are associated with these probable ignimbrites. They are graded from crystal and lithic fragments < 3mm in diameter at the base down to ash-sized particles (Plate X). Non bedded units show similar variations in grain size.

Immediately southwest of the Charlottetown turnoff, on the TCH, units of crystal tuff 2 meters thick are associated with green finely laminated (~0.5 mm) pyritic volcanogenic siltstones containing scattered quartz grains and thin beds of very fine-grained sericite schist (silicic ash?) intercalated with bands of chlorite schist (mafic ash?) commonly 1 cm thick. The siltstones and tuffs show some grading on a fine scale. They are very tightly folded and there is little or no evidence of reworking; however tectonically refolded slump folds are present locally, suggesting that many of these deposits are subaqueous and were probably deposited in relatively quiet water. This association may well represent the various mechanically differentiated components of a series of ash flow eruptions. Such associations have been described by a number of authors from areas of recent and ancient volcanic activity (Roobol, 1976; Potgieter and Visser, 1976). Also, the crystal enrichment and the relative depletion in the vitric component and vice versa, associated with ash flows has been well documented (Hay, 1959; Lipman, 1967; Walker, 1972; Sparks et.al., 1973; Roobol, 1976; Sparks and Walker, 1977). In view of this and other complications, all of the above authors have discounted the concept that ash flows and their resultant deposits represent a close geochemical approximation to the composition of their parent magma, a point which will be considered in chapter 6.

West of Clode Sound, rocks typical of the White Point Formation conformably underlie red-beds of the Southwest River Formation; the best exposures of the former, in that area, are found on Salmon and Northwest Rivers. Sericitic and lesser chloritic schist (lithic-crystal tuffs) are dominant.

Immature tuffaceous sedimentary rocks contain silicic detritus and sandy laminae; silicic agglomerates and "mixed" lapilli tuffs occur locally. A very poorly sorted breccia, occurring on Salmon River, may possibly be of laharic origin. The sub-rounded to angular close-packed fragments range up to 1 meter across and include rhyolite and silicic tuff in a dark green chloritic matrix. Some rhyolite flows are present, and fine-grained diabasic dykes are locally prominent.

3. Lava flows: Lava flows make up a significant portion of this formation. Although they form less than 25% of the coastal section, mafic and intermediate flows and dykes and silicic dykes, tuffs, and lesser flows are the dominant rock types in the Blue Hills and Blandford's Ridge where they are well exposed. Since the contacts are commonly obscured, it is commonly difficult to distinguish between the flows and dykes. Along the coast mafic and intermediate flows appear much less numerous than silicic flows. However it is commonly difficult, in the field, to distinguish fine grained mafic tuffs from flows due to metamorphic recrystallization. This is also the case with silicic flows and thoroughly welded recrystallized ash-flow deposits.

The Blue Hills are largely underlain by mafic to intermediate flows and dykes with minor silicic flows and dykes; on Blandfords Ridge, silicic flows and tuffs may make up to 40% of the sequence. The predominance of relatively mafic rocks in this area is reflected in their strong positive geomagnetic expression (Geophysics paper 229, G.S.C., 1968).

The rocks underlying these hills appear to represent the northernmost occurrence of significant volumes of flow rocks in the Love Cove Group, while volcaniclastic rocks are dominant farther north. This was recognized by Jenness (1963), whose lithologic unit 1a outlines the distribution of mainly flow rocks while most of the volcaniclastic rocks were included in his undivided unit.

Megascopically, the mafic and intermediate lavas are difficult to distinguish and thus estimates of the relative proportion of these lavas would be tenuous. Both types may be intercalated on outcrop scale with rhyolite or related silicic tuffs. These lava flows are mainly massive but are locally schistose; close-spaced rectangular jointing is commonly well developed. They are medium to dark grey-green, aphanitic to fine grained and locally amygdaloidal and porphyritic. None of the amygdules are flattened or elongated, and they rarely comprise more than a few per cent of these rocks. They are locally up to 5 mm across but are generally much smaller and tend to concentrate in narrow bands. They are filled with epidote and lesser quartz. The basalts are mainly aphyric but do include strikingly porphyritic phases which occur as dykes, probable flows and possibly minor shallow sub-volcanic intrusions. In such rocks, plagioclase phenocrysts are stubby, up to 8 mm long, subhedral to euhedral, and make up to 25% of some flows while others are prismatic, up to 7 mm long and comprise up to 45% of some dykes. The intermediate rocks, (andesites) are more porphyritic as a whole but the plagioclase phenocrysts, up to 3.5 mm in length, do not comprise more than 10% of these flows. Both the basalts and andesites and related dykes may contain relatively sparse mafic phenocrysts now altered to actinolite. These are up to 1 mm long, occur in clusters up to 5 mm and originally may have been green hornblende.

The rhyolite is grey to grey-green or pink, aphanitic to fine grained, aphyric to porphyritic and occurs as flows, tuffs and dykes up to 4 meters thick and is flow-banded in places. On the coast, silicic flows reach 20 meters in thickness. Phenocrysts of sodic plagioclase and/or quartz (up to 4 mm across) are common.

Grey aphanitic rhyolite forms much of the steep east-facing scarp, immediately west of the TCH bridge on Shoal Harbour River, south of the map area.

Adjacent to the margins of the Georges Pond granite the volcanic rocks have been thoroughly recrystallized and overprinted by the steep regional penetrative fabric. Meta-silicic volcanic rocks southwest of the Radio Tower on Blandford's Ridge show bands 1-3 mm thick, defined largely by contrasts in grain size and biotite-amphibole content (Plate XI). Thin aplitic veins, discordant to the banding, are foliated along with it. A similar but more diffuse and thicker banding occurs in associated mafic volcanic rocks.

4. <u>Volcanogenic sedimentary rocks</u> - This facies, which occurs largely in inland exposures, is of local occurrence and may in many cases be tuffaceous. The coarser varieties

Plate XI: Thinly banded meta-silicic volcanic rock from adjacent to margin of Georges Pond pluton. Note thin discordant granite vein. South end of Blandford's Ridge.

Plate XII: Photomicrograph of embayed quartz and plagioclase phenocrysts in deformed rhyolite (1a); sample 705B; x-nicols, x12.5.

are similar to sedimentary rocks referred to in Unit 1b. Immature poorly sorted volcanogenic greywackes contain angular to sub-angular volcanic clasts up to 7 cm long and rounded boulders of greywacke up to 35 cm across in a chloritic matrix. Also included are chlorite schists with fine to medium grained sandy laminae and thin beds up to 3 cm thick.

3.3.1.4 PETROGRAPHY* (1a)

1. Agglomerates, lapilli tuffs and ash tuffs: The mafic tuffs are composed of variable proportions of chlorite, epidote, opaque minerals, calcite, minor sericite and very fine grained quartz and/or feldspar while the silicic tuffs contain sericite, epidote, calcite, minor chlorite and opaque minerals, locally minor biotite, and very fine grained quartz and feldspar.

Laminae (<5 mm thick) are defined by contrasting grain size and by plagioclase crystals and crystal fragments up to 1.5 mm in length variably altered to epidote and calcite, ragged, strained quartz grains and angular magnetite grains. Some tuffs contain flattened black to purple aphanitic lapilli rich in opaque minerals. Calcite occurs throughout the matrix or together with quartz in scattered thin veinlets which commonly show displacements on minor fractures.

*The Michel-Levy method was used in determining plagioclase compositions and thin sections were stained for potassium feldspar using the method described by Hutchison (1974).

The aphanitic silicic blocks in the agglomerates show a pilotaxitic intergrowth of plagioclase and quartz. This texture forms augen around microphenocrysts of plagioclase and quartz and is parallel to the length or width of the tabular or elongate blocks which themselves are aligned on the steep tectonic fabric. The fine grained green mafic fragments, common in these rocks, are microvesicular with abundant chlorite, calcite and iron oxides.

The coarse agglomerates containing blocks of plutonic rocks have a schistose matrix consisting mainly of sericite with lesser chlorite and epidote. The matrix contains scattered plagioclase laths (0.1 mm) and angular partially resorbed quartz grains (< 2 mm). Silicic volcanic rock fragments are petrographically similar to rhyolites elsewhere in this formation; cream-coloured fine grained (< 1 mm) blocks consist of 65% poorly twinned sodic plagioclase laths, 25-30% interstitial epidote, hematite and 5% quartz which also occurs in thin veins. Plutonic blocks range from granite to quartz diorite. In these plutonic blocks coarse plagioclase occurs as subhedral crystals up to 8 mm in length along with quartz and microcline and lesser anti-perthite and granophyre. Opaque oxides, epidote, and minor thoroughly oxidized biotite are present in small amounts. A fine-grained siliceous aggregate occurs along some grain boundaries.

2. Silicic pyroclastics - The matrices of these rocks have almost invariably been recrystallized, commonly to sericite schist. This has masked most primary microscopic

features of the matrices which consist largely of sericite, quartz, plagioclase and minor chlorite (grains average<.025 mm). These tuffs contain up to 25% potassium feldspar. Quartz shows polygonal recrystallization within lensoid aggregates, in the pressure shadows of larger crystals, and occurs in thin veins. The only recognizable primary minerals are sodic plagioclase, quartz and minor biotite (?) (Plate XII). Their proportions vary widely but plagioclase and quartz crystals make up to 35% of some hand specimens. Plagioclase is usually the coarsest phase (up to 5 mm). Most of the grains are broken but some show euhedral forms and locally have a very thin, relatively fresh (albitic?) rim. Some of the feldspar grains show incipient sericitization and a light brown (clay?) alteration, others may be partially or completely replaced by epidote and/or calcite. K-feldspar occurs along fractures or as a thin poorly developed rim around some of these crystals. These plagioclase crystals contain small anhedral disoriented feldspar grains of similar composition. Quartz is locally the dominant crystal phase. Resorption textures and strain shadows are common and the crystals are rounded and/or broken. Locally biotite crystals up to 0.1 mm. in length have been completely altered to opaque minerals and epidote; minor amounts of brown to green metamorphic biotite are present. Opaque minerals make up less than 5% of these rocks; sphene and apatite are minor accessories.

The angular to rounded lithic clasts are generally very fine grained (< 0.2 mm) and silicic in composition. Some of them show a felsitic or pilotaxitic texture, are aphyric to microporphyritic, and include 5-10% potassium feldspar and accessory opaques. Some fragments are composed entirely of fine-grained epidote while others consist of fine-grained quartz, plagioclase and opaque minerals.

Crystal tuffs in the Blue Hills and Blandfords Ridge are typically non-foliated, and consist of angular fragments of poorly twinned plagioclase (up to 7 mm) and quartz in a finely crystalline siliceous matrix (<0.05 mm). In that area the secondary minerals include actinolite and minor biotite. The actinolite occurs as randomly oriented acicular crystals and locally appears to have replaced a primary (?) darker green amphibole.

The matrix of the tuffs is commonly banded (up to 3 mm thick). These bands which may be primary in origin, are parallel to the steep fabric and are siliceous to more sericitic and chloritic in composition.

3. Lava flows: The basalts are typically fine grained (0.1-0.5 mm). The texture is diabasic to locally fluidal, holocrystalline to intersertal. They consist of 50-60% lath-like or stubby albitized plagioclase variably replaced by epidote or calcite and 40-50% intergranular epidote, green to blue-green actinolite, lesser chlorite, and minor opaque minerals (Plate XIII). Minor interstitial quartz is present locally along with hematite, very minor green biotite and accessory sphene. No relict pyroxene was seen in these rocks.

Actinolite appears to have replaced darker green to brownish green amphibole phenocrysts. Most plagioclase

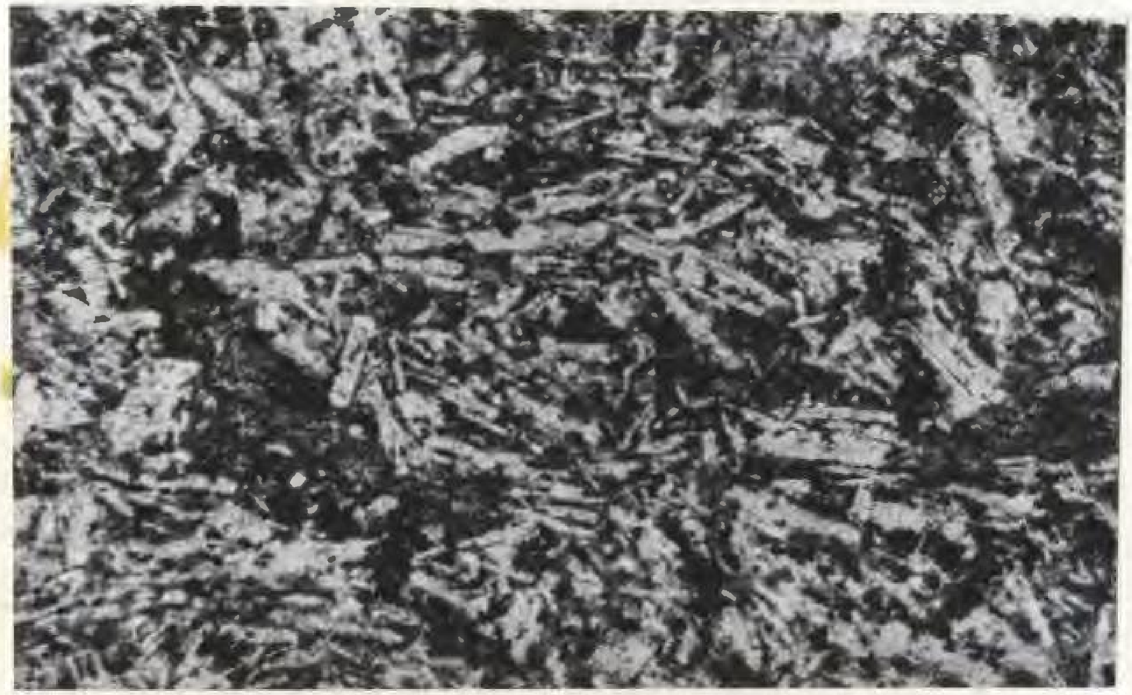


Plate XIII: Photomicrograph of typical basalt (1a) with fluidal intersertal texture; x-nicols, x12.5.

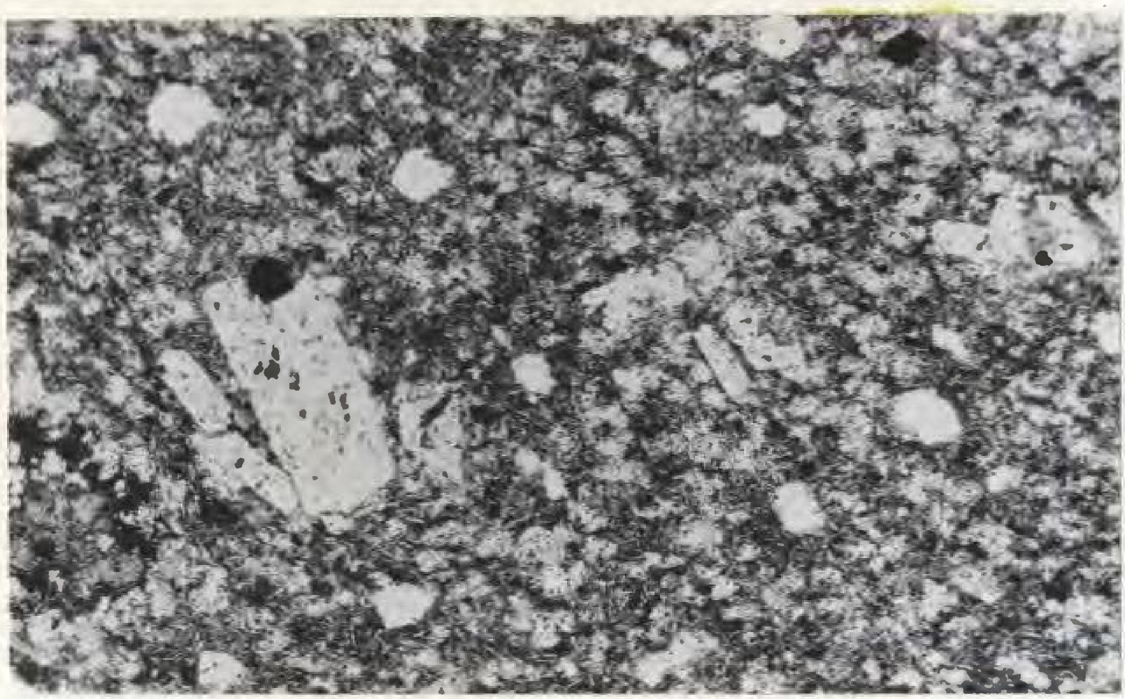


Plate XIV: Photomicrograph of porphyritic andesite (1a); p.p.1., x12.5.

phenocrysts have been albitized, some are completely replaced by epidote and sericite. They occur in a diabasic to slightly ophitic intergrowth of pleochroic blue green to green actinolite and altered plagioclase.

The andesites are fine grained (0.1 mm) and are composed of 55-70% sodic plagioclase, 15-40% fine grained actinolite, chlorite, epidote and opaque minerals, 7-15% interstitial quartz and locally minor interstitial feldspar (Plate XIV). Phenocrysts show similar alteration patterns as those in the basalts and the largest plagioclase phenocrysts show well developed normal to oscillatory zoning.

Epidote, chlorite and lesser quartz occur in the amygdules and in thin veins.

The rhyolites are aphanitic to fine grained (0.05-0.5 mm). The matrices are largely microcrystalline but locally show poorly developed spherulites. A fine grained trachytic texture is parallel to the locally developed flow banding which is defined by concentrations of disseminated hematite. Granophyric intergrowths are developed in places.

Poorly-to well-twinned sodic plagioclase, partially resorbed quartz and rare altered biotite are the only phenocryst phases. They locally make up to 25% of some rocks. The plagioclase phenocrysts are dominant and may show faint zoning; biotite phenocrysts have been replaced by opaque minerals, chlorite and lesser epidote.

In some rocks, potassium feldspar occurs as small inclusions in plagioclase phenocrysts, in others it may make up to 50% of the groundmass. It appears to be microcline.

Accessories include sphene, opaque minerals and apatite.

Opaque minerals occur as rare subhedral microphenocrysts, as disseminations or locally as tiny (<0.3 mm) rosettes of acicular crystals.

Secondary minerals include quartz, epidote, sericite, calcite, minor chlorite, piedmontite and biotite. Epidote comprises up to 20% of some rhyolites, and thin quartz veins are common.

3.3.1.5 Geology and Petrography (Unit 1b of Love Cove Group)

This subdivision underlies two barren hills to the southwest of the Radio Tower on Blandfords Ridge; it is separated in part because of its apparently reworked nature but mainly due to peculiarities in its polymictic clast composition.

Most of the outcrop consists of green foliated, non-bedded diamictite. This contains angular to rounded clasts of sedimentary rocks and silicic to mafic volcanic and lesser sub-volcanic rocks, ranging up to 35 cm across. In the southern outcrop, the coarsest clasts appear to be concentrated in the eastern portion while there is little or no coarse detritus in the western portion of the outcrop. The boulder- and cobble-size detritus appears to be the most rounded and consists almost invariably of orthoquartzite, vein quartz, and recrystallized quartz exotic to the area. Some well or sub-rounded fragments show a few rather angular faces indicating perhaps fracturing of originally wholly rounded clasts or glacial facets. Smaller fragments are sub-rounded to angular.

Plate XV: Orthoquartzite clast in deformed diamictite (1b). South of Radio Tower. Hand lens 4 cm in length.

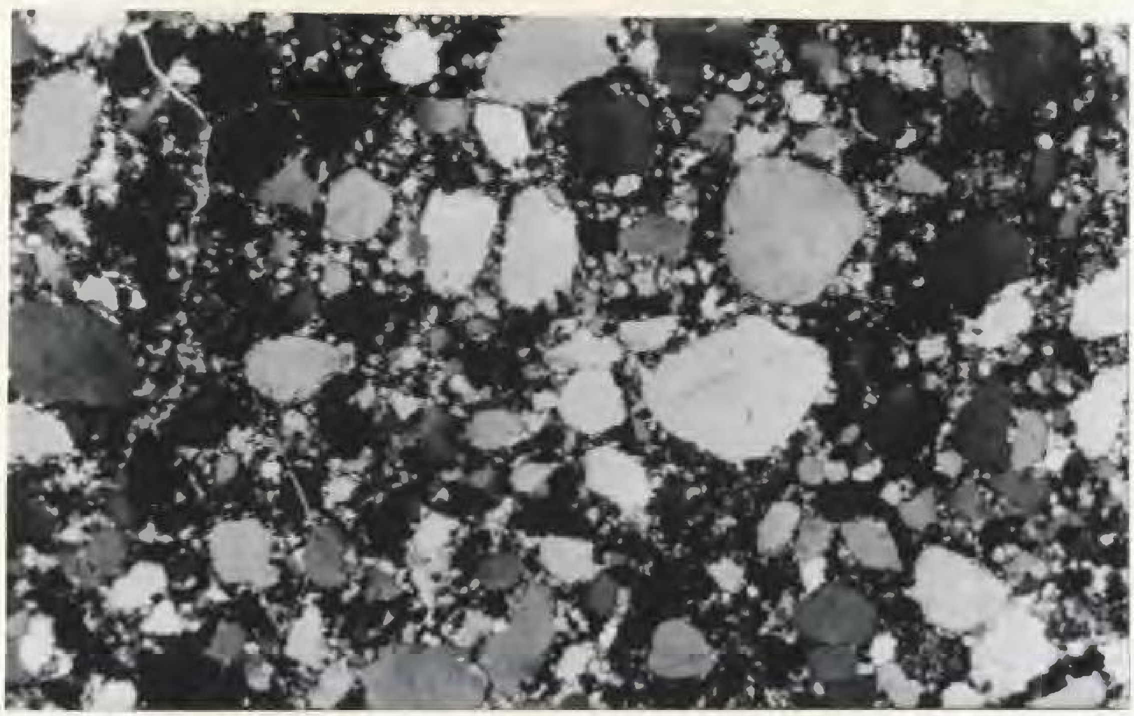


Plate XVI: Photomicrograph of orthoquartzite block in diamictite (1b). Note grain rounding and bimodal grain size distribution; x-nicols, x12.5.

Volcanic detritus, which is common in the pebble-to sand-size range, includes abundant variably altered aphanitic light grey rhyolite and basalt.

Mineral fragments are largely angular and are dominated by quartz and lesser plagioclase. The matrix exhibits 3-4 mm thick anastomosing psammitic and pelitic bands. There is pronounced recrystallization on the steep fabric which forms augen around the clasts. Minor pyrite and very minor chalcopyrite are found locally. Minor mafic pyroclastics are associated with these rocks.

The pebbles and cobbles of light grey mature orthoquartzite (Plate XV) provide a marked compositional and textural contrast to the deposit in which they occur and to any other sedimentary rock within the map area. The clasts are composed of 85% quartz, minor plagioclase and 15% largely interstitial epidote. The quartz occurs as well rounded to sub-rounded grains up to 1 mm across (avg. 0.4 mm) in a very fine grained siliceous matrix which has been recrystallized along with the margins of the larger grains. There is a distinct bimodality in grain distribution (Plate XVI). It is not clear whether this orthoquartzite has a proximal or distal origin although petrographically similar clasts occur in diamictites elsewhere in the Avalon Zone of Newfoundland (W.D. Bruckner, pers. comm. 1978).

"Tongues" of white fine-grained (<0.1 mm) plagioclase-phyric rhyolite similar to unit 1a rhyolites have intruded these sedimentary rocks, together with a few thin aphanitic mafic and minor porphyritic dykes (?) of intermediate composition.

3.3.1.6 Contact Relationships

The White Point Formation is bounded on the east by the prominent, steeply dipping, north-south trending Charlottetown Fault which juxtaposes schists of that formation against gently to moderately dipping, non-foliated, unmetamorphosed red sandstones and conglomerates of the Charlottetown Formation (Musgravetown Group). To the west, pyroclastics of the White Point Formation appear to grade into tuffaceous sedimentary rocks and tuffs of the Thorburn Lake Formation. Relationships of correlative sequences to the south in the Sound Island map area suggest that the Thorburn Lake Formation in part overlies the volcanic rocks and in part is a facies equivalent of at least the pyroclastic portion of the White Point Formation (Hussey, 1978a).

However, on Northwest River, Unit 3a (Southwest River Formation) appears to lie conformably upon the White Point Formation, suggesting that it is, at least in its lower portions, equivalent to the Thorburn Lake Formation and/or that it has cut down into and in places completely stripped away lithologies typical of the Thorburn Lake Formation.

3.3.1.7 Correlations

Correlatives of the White Point Formation extend both to the north and to the south. Jenness (1963) and Anderson (1965) defined the limits of these volcanic rocks in rough terms and Jenness (1963) originally suggested a correlation between the Love Cove Group and volcanic and sedimentary rocks in the Terrenceville map area (Bradley, 1962). Dal Bello (1977), working to the north, mapped a fault-bounded belt of deformed pyroclastic rocks and dykes and restricted the term Love Cove Group to it. These rocks are directly on strike and practically contiguous with the White Point Formation. Volcanic rocks in the Sound Island area (Unit 1 of Hussey, 1978a) also bear many compositional and textural similarities to rocks of the

White Point Formation. These are on strike with and comparable to the dominantly silicic volcanic rocks of the Deer Park Pond and Southern Hills Formations of the Terrenceville and Gisbourne Lake map-areas (Bradley, 1962) and to variably deformed volcanic rocks in the Baine Harbour and Point Enragee map sheets (O'Brien, 1978a, 1978b).

3.3.1.8 Interpretation

A number of specific features of the White Point Formation indicate that these rocks are the product of explosive, possibly calcalkaline volcanism. These are:

1. the high proportion and textural variety of volcaniclastic and/or pyroclastic material and the associated, partially equivalent thick sequence of pyroclastic rocks and tuffaceous sedimentary rocks. The dominantly explosive nature of the volcanism is further illustrated by the local occurrence (Plate VI) of numerous high-level granitoid plutonic blocks.

2. the petrographic (and chemical) range in composition from basalt (47% SiO_2) through andesite to rhyolite.

3. various aspects of the chemistry, to be discussed later, strongly suggest a calcalkaline affinity (chap. 6).

4. a number of foliated granitoid plutons have been intruded into and are localized within this belt of volcanic rocks extending from the Bonavista Bay area (Georges Pond granite) to at least the Baine Harbour and Point Enragee map sheets on the Burin Peninsula (O'Brien, 1978a, 1978b). Evidence has been cited (see sec. 3.3.1.3 and Hussey, 1978a) for a genetic link between these granites and the volcanic

rocks. The Georges Pond granite appears to have calcalkaline affinities and O'Driscoll (1973) has suggested that the Swift Current granite is calcalkaline.

Most workers appear to agree that the Avalon Zone is underlain by sialic crust (eg. Williams et.al., 1972; Strong et.al., 1978a) and there are reports of possible basement gneisses on Cap Miquelon (Aubert de la Rue, 1932) approximately 30 km west of the Burin Peninsula. Papezik (1973) has reported garnets of uncertain provenance from late Precambrian molasse of the Avalon Peninsula. However, Miller (1977) indicates that aside from the areas underlain by the Ackley batholith and the Swift Current granite, major portions of the crust of the western Avalon Zone are relatively mafic in nature. This appears to be at variance with most of the descriptions and interpretations of the surface geology (eg. Jenness, 1963; F. Anderson, 1965; Strong et.al., 1976; Hussey, 1978a); only Younce (1970) considered the Love Cove Group (and the Bull Arm Formation) to have been deposited on a basic crust overlain by sedimentary rocks of the Connecting Point Group. These differing points of view may be evaluated by referring to recent work dealing with Cenozoic to Recent island arc and continental margin magmatism.

Many workers (eg. McBirney, 1969; Pichler and Zeil, 1969; Jakeš and White, 1972) have noted that although gradations in composition exist, andesites developed in continental margin settings tend to be less mafic than those developed in island arcs. Differences have been noted in K_2O levels (Dickinson, 1968), Fe_2O_3 (total) and CaO (Forbes et.al., 1969), MgO/FeO + Fe_2O_3 (Yoder, 1969), various trace elements (Zeil and Pichler, 1967), and Na_2O_3, K_2O, Rb, Ba and Zr (Cole, 1978). As most of these elements are susceptible to mobilization during metamorphism any comparisons made with the White Point Formation must be considered suspect. However, a significant feature of the White Point Formation is the high proportion (at least 50%) of silicic volcanic rocks; the proportion of silicic material is even higher if one includes the probably related granites. Numerous authors (Dickinson, 1968; McBirney and Weill, 1966; Ewart and Stipp, 1968; Brothers, 1970; Jakes and White, 1972; and Carmichael et.al., 1974) have noted the paucity of dacites and the rarity of rhyolites in island arcs and their dominance in ensialic arcs. The reasons for the distinction between the composition and proportions of the volcanic products of these contrasted environments are various and some of these are still in dispute, but the observed difference between ensialic and island arcs is well established. Hence, it is thought that the Love Cove Group was deposited on continental crust.

The state of preservation of these rocks makes it difficult to interpret the surficial environment of deposition. However, a number of points should be noted:

1. the sparsely vesicular nature of the volcanic rocks could indicate sub-aqueous eruption.

2. the occurrence of banded volcanogenic chert and very fine, graded and slumped, green sandstone and siltstone probably indicate at least local basins of deposition with

only limited if any reworking.

3. the bedded nature of some of the tuffs may result from hydraulic reworking.

It is not possible at this point to judge the relative importance of sub-aerial or sub-aqueous deposition for the ash flows, but in view of the above, it is possible that sub-aerial and/or sub-aqueous conditions existed at various times and places throughout this terrain.

Interpretations of these rocks must consider the occurrence of the diamictites of Unit 1b and its numerous clasts of mature orthoquartzite. The evidence discussed indicates that these deposits were incorporated into this terrain while it was volcanically active and presumably tectonically unstable as well. Two possible origins for these rocks are those involving glacial (tillite) or mudflow mechanisms. They do resemble tillites occurring to the east on the Avalon Peninsula (W.D. Bruckner, pers. comm., 1978). However, due to their deformed state it is not possible to distinguish a glaciomarine from a mudflow mode of emplacement.

3.3.2 Thorburn Lake Formation (2)

3.3.2.1 General Statement

This formation is a dominantly clastic assemblage divisible, lithostratigraphically, into three units, only two of which (2a and 2b) are of significant areal extent. These rocks occur in a north-trending, 2.5 km. wide belt cut obliquely by a fault separating the above two units which show some lithological similarities. Unit 2a has a larger epiclastic content than 2b, and there appear to be significant differences in their style of structural development. It is possible that the deposition of these two members did not overlap in time. The Thorburn Lake Formation largely coincides with Unit 1b of Jenness (1963) in the western portion of the east belt of the Love Cove Group.

3.3.2.2 Geology (2a)

This sedimentary member is confined to a narrow wedge-shaped belt extending north from Watershoot Steadies. It is dominated by cross-stratified siltstone and greywacke cut by numerous thick north-trending mafic dykes (Plate XVII). As no continuous significant thickness is available for study, only a lithologic characterization can be attempted.

Most of this member consists of white-weathering grey to grey-green, thin bedded (<10 cm) finely laminated and cross-laminated siltstone and cherty or pebbly siltstone (Plate XVIII). The rest is comprised of very fine to coarse grained sandstone and variable amounts of greywacke and pebble conglomerate, which occur in beds up to 60 cm thick. There appears to be a positive correlation between grain size and bed thickness. The siltstones are locally graded and slump-folded, commonly with minor dislocation and/or brecciation.

Clasts are angular to sub-rounded; sub-rounded to well rounded clasts up to 5 cm across occur in the coarser horizons. In general, these rocks are not well sorted.

On Dunphy's Pond, the dominant rock type is grey-green medium grained greywacke with some finer and coarser grained

Plate XVII: North trending mafic dyke (3 meters thick) cutting siltstones (2a). North shore of Clode Sound.

Plate XVIII: Laminated siltstone (2a). Note low angle cross laminae. North shore of Clode Sound. Pencil approximately 15 cm in length.

varieties. In the west, adjacent to red sedimentary rocks of the Southwest River Formation, they contain scattered fragments of red siltstone. These commonly laminated to cross-laminated rocks are medium-bedded in the west. In the east, they are thin bedded with planar lamination, have a tuffaceous aspect, and have been intruded by fine grained silicic dykes. Hematite and hydrous iron oxides are commonly developed on joint surfaces. Minor green mafic tuffs with a carbonate-rich or siliceous matrix occur locally on Clode Sound.

These rocks are disposed in large scale open to tight folds with variable fabric development on the steep axial surfaces (Figs. 1 and 1.1). In the south, a fine sericitic-chloritic fabric is locally developed, parallels bedding and intersects cross-laminae at a low angle.

3.3.2.3 Petrography (2a)

The detritus in these sedimentary rocks is largely volcanic in origin, silicic detritus being dominant. In detail this detritus includes:

1. angular to sub-rounded plagioclase and lesser quartz
2. various textural varieties of rhyolite or dacite
3. fragments of mafic to intermediate flows and tuffs with an altered aphanitic matrix consisting of epidote, chlorite, and iron oxides and albitized plagioclase microphenocrysts.

The matrix is fine grained, siliceous and recrystallized and commonly includes chlorite, sericite and epidote. Some of the epidote may be detrital.

3.3.2.4 Geology (2b)

These rocks extend south from The Narrows (Clode Sound) and include the type section of the formation at Thorburn Lake. In the type section data are restricted to isolated shoreline outcrops; however, good structural control (i.e. numerous and consistent facing determinations) has made it possible to estimate a probable maximum stratigraphic thickness of 1311 meters (4300 feet) on this east-dipping, east-facing sequence. Elsewhere, lack of or obliteration of facing criteria and outcrop and larger-scale very tight folds make reasonable thickness estimates impossible.

The Thorburn Lake section also includes several outcrops along the TCH immediately east of the lake. Bedding/schistosity intersections indicate that these rocks are in the eastern portion of the nose of a tight anticline plunging steeply to the south which appears to be faulted to the west against fractured massive volcanic rocks of Unit 3b. In addition, there is local tight parasitic asymmetric folding of bedding.

This section is a rather monotonous sequence of grey to grey-green, dominantly medium-grained tuffaceous greywacke and granule to pebble greywacke conglomerate. These rocks are commonly evenly laminated to medium-bedded* with some thick bedding (up to 40 cm) in the upper half of the section. Extensive cross-lamination is developed throughout in beds of all thicknesses (Plate XIX) but grading is generally not well developed. Since most of the outcrops consist only of

*classification of bed thicknesses after Ingram (1954).

Plate XIX: Cross-laminated medium grained greywacke (2b). East shore of Thorburn Lake. Pencil approximately 15 cm in length.

Plate XX: Folded, (F_1) siltstone and very fine grained sandstone (2b). North shore of Clode Sound. Pencil approximately 12 cm in length.

a roughly horizontal surface with little vertical relief, the exact geometry and orientation of the cross-laminae could not be determined.

Average grain size is variable but appears to decrease higher in the section, being commonly up to 3 cm in the lower portions and less than 1 cm in the higher portions of the sequence. One rhyolite block on Thorburn Lake is approximately 1 meter in length. Rounded quartz grains (up to 7 mm) are commonly abundant and pink to grey or purple silicic volcanic detritus is dominant; mafic clasts are less common. The grains are commonly flattened or realigned on the fabric.

The occurrence of coarse detritus and in places large volcanic blocks may be indicative of explosive extrusion of pyroclastic debris and/or movement of similar material off volcanic highlands by debris (mud) flow or avalanching mechanisms. Later reworking could produce the observed sedimentologic features.

North of Thorburn Lake, the rocks are typically laminated to thin bedded although medium bedded (>15 cm) and more massive units are not uncommon. Bedding is generally parallel to the fabric. Cross-laminae are present locally and at one locality indicate slight overturning to the west. It is possible that this outcrop lies on the east limb of a tight syncline, the opposite limb of which is exposed in part in the type section. Fine grained tuffaceous greywacke and commonly siliceous grey siltstones are more abundant in the north; finely banded mafic tuffs and very fine grained sedimentary rocks have been recrystallized to chlorite schist.

Along the shore (at The Narrows) and immediately south of Clode Sound, there is a significant proportion of crystal and lithic-crystal tuffs. The eastern limit of this unit is graditional with the adjacent tuffaceous sequence (Unit 1a) and consequently is somewhat arbitrarily drawn where non-bedded unreworked tuffs become the dominant rock type. Relatively massive, green, coarse-grained crystal tuff, weathering light green and showing traces of banding with lesser beds (up to 4 cm thick) of finer grained material, is common, along with scattered rhyolitic, possibly pumiceous, fragments in a soft chloritic matrix. However, even at the shore localities, grey to green, laminated to medium bedded pyritic volcanogenic siltstones (Plate XX) and fine grained graded sandstone remain the dominant rock types. These beds are locally reworked and may contain tabular fragments of green siltstone up to 8 cm long. Similar rocks occur in Unit 1a. Alternating relatively siliceous versus schistose chloritic beds (up to 1 meter) are common.

Diabase dykes appear in variable abundance. Quartz veins, which are commonly joint-controlled locally contain calcite, chlorite, and very minor chalcocite partly altered to malachite.

3.3.2.5 Petrography (2b)

Altered plagioclase and lesser partially resorbed quartz grains are common, along with other silicic detritus and locally up to 5% subhedral magnetite grains. The finest layers are recrystallized and are composed largely of varying proportions of sericite and chlorite and (in the south) minor green biotite. The fabric forms augen around clusters of epidote crystals.

3.3.2.6 Geology and Petrography (2c)

This lithologic subdivision comprises a number of isolated lenses of volcanic rocks. Along the coast this includes lithic-crystal and crystal-lithic tuffs and minor bedded tuffaceous sedimentary rocks faulted in the west against siltstones of Unit 2a and gradational in the east with tuffaceous and sedimentary rocks of Unit 2b. On the south shore, fractured grey rhyolite occurs in a minor fault block (Plate XXI). Also included are fine grained laminated silicic to mafic tuffs. Massive flattened lithic tuffs contain lapilli commonly averaging 1 cm but locally up to 8 cm long. Fragments are variable in colors and silicic through andesitic in composition. More than 50% of the fragments are composed of anhedral plagioclase and <5% to 40% intergranular iron oxides (grain size <0.5 mm). In silicic fragments, similar proportions of opaque oxides define a thin banding. These rocks include abundant altered green plagioclase and quartz crystals (up to 2.5 mm). Secondary mineralogy includes epidote, chlorite and sericite.

Inland, lenses of volcanic rocks appear to be intercalated with greywackes and tuffaceous sedimentary rocks of Unit 2b. The western lens includes fine-grained, pink to grey rhyolite and minor silicic lithic tuffs with lapilli up to 5 cm in diameter. These rocks are strongly jointed and extensively altered to epidote. A strong cleavage is developed in narrow zones.

Thin section shows that the silicic flows are partially recrystallized and consist of roughly equal proportions of quartz and K-feldspar, with minor sericite, opaque oxides, chlorite, epidote ahd accessory sphene.

The eastern lens is composed solely of steeply dipping, finely colour banded (2-3 mm) very fine grained chlorite schist (meta mafic waterlain tuff?). The banding is parallel to the foliation.

3.3.2.7 Contact Relationships

Units 2a and 2b of this formation are in fault contact along the coast; inland they are assumed to be faulted against one another and against adjacent formations. A fault contact is probable in the Thorburn Lake area between fractured volcanic rocks of Unit 3b and chloritic, fractured, steeply dipping greywackes of Unit 2b. This fault is, in part, a portion of the NNE-trending Platter Cove Fault of Jenness (1963). However, its northward extension from the north shore of Clode Sound does not coincide with Jenness' fault. It is exposed in shoreline outcrops where it brings together extensively fractured, moderately dipping siltstone (2a) against fractured to schistose volcanic rocks of Unit 2c. In contrast, it appears that the area of the contact between Units 2a and 1a on Dunphy's Pond represents an eastward lithological and structural/metamorphic gradation from cleaved

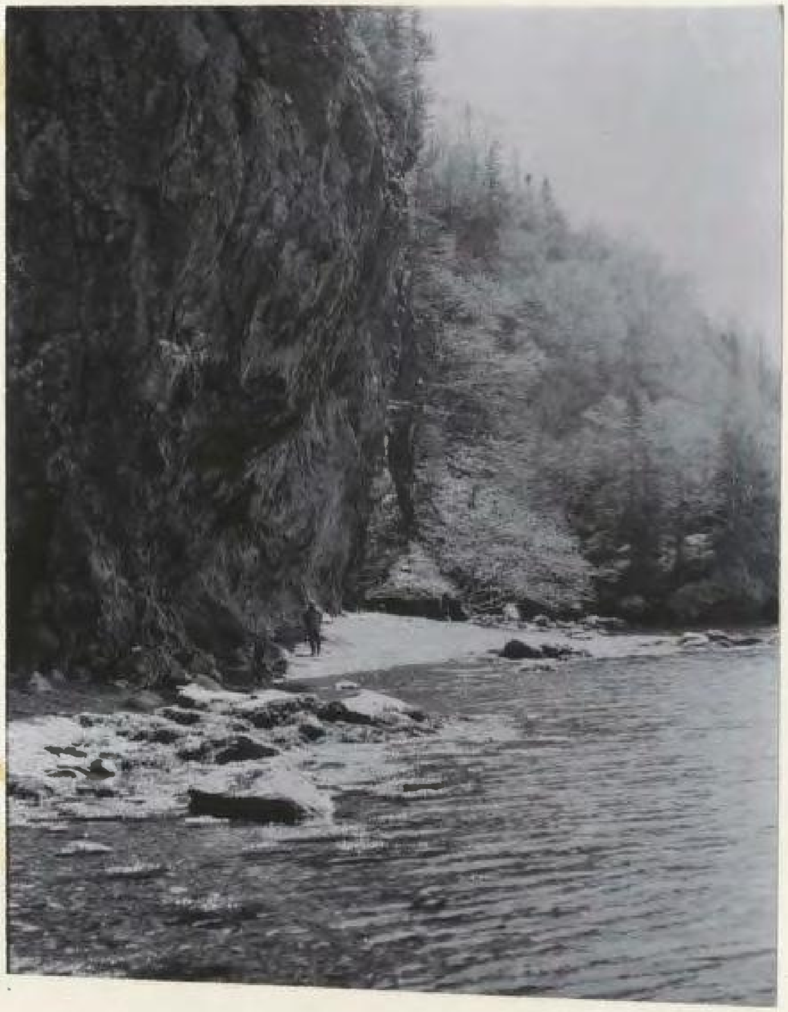


Plate XXI: Fault scarp on south shore of Clode Sound Between Units 2a and 2c.

greywackes and tuffaceous sedimentary rocks of the Thorburn Lake Formation into steeply dipping commonly schistose volcanic rocks of the White Point Formation.

The relationships between the Southwest River and Thorburn Lake Formations suggest that these sequences are at least in part, coeval and are probably facies equivalents. Jenness (1963) included the southern portion of Unit 2a in the Musgravetown Group and the northern portion in the Love Cove Group. Hence from Platter Cove north he assumed a fault between the Love Cove and Musgravetown Groups here referred to as the Thorburn Lake (2a) and Southwest River Formations (3a) respectively. However, both north and south of Clode Sound there is no strong evidence for a major dislocation between these units, although fracturing in outcrops about 1 km northeast of Middle Point may indicate possibly minor displacement at the contact. This contact follows a north-plunging anticlinal axis which extends from Dunphy's Pond to the Port Blandford area. Immediately east of Port Blandford, volcanic rocks of Unit 3b appear to underlie both units and form the core of the fold. Bedding orientations close to the contact 1 km northeast of Middle Point indicate that green pebbly siltstones of Unit 2a conformably overlie red sandstones and conglomerate of Unit 3a. A fine-grained green mafic tuff several meters thick occurs close to the contact. However, north of the present map area in the Glovertown area, where possibly correlative sequences occur, red pebble conglomerates and sandstones clearly overlie conformably green crossbedded sandstones and siltstones (Dal Bello, 1977).

3.3.2.8 Correlations

Unit 2a of the Thorburn Lake Formation is on strike with and possibly equivalent to a sequence of greywackes mapped by Dal Bello (1977) to the north in the Glovertown area and referred by him to the Rocky Harbour Formation of Jenness (1963)*. In the Sound Island map area to the south, and also on strike, a sequence of greywackes, greywacke conglomerates and tuffaceous sedimentary rocks conformably overlie variably deformed volcanic rocks very similar to and correlated with the White Point Formation (Hussey, 1978a). Also, these rocks are on strike with the Anderson's Cove and Southern Hills Formations of Bradley (1962) and with tuffaceous sedimentary rocks overlying volcanic rocks in the "Knee" area of the Burin Peninsula (O'Brien, 1978a, 1978b). Hence, the Thorburn Lake Formation appears to be a segment of a semi-continuous belt of sedimentary and tuffaceous sedimentary rocks, associated with volcanic rocks with a width of 2-3 km and extending from Bonavista Bay to the Burin Peninsula (Fig. 2.1).

3.3.2.9 Interpretation

The apparent continuity of this belt of volcanogenic sedimentary rocks and tuffs, described above, must be accounted for in any interpretation of these rocks. Also, the abundance of volcanic detritus and intercalation of tuffs suggest that these rocks not only overlie the volcanic rocks (Hussey, 1978a) but are also in part their facies equivalent.

* The only difference implied here with respect to Dal Bello's work is strictly one of definition, and of interpretation of the relationships between these greywackes and volcanic rocks of the Love Cove Group.

The occurrence of cross-lamination on varying scales has been interpreted as an indication of shallow agitated water (eg. Turner and Walker, 1973). Mitchell (1970) described medium-to coarse-grained pebbly volcanic sandstones disposed in "large-scale tabular sets of tangential unidirectional fore-set beds, separated by thin apparently structureless beds of sandstone". He thought these to be shallow marine or fluviatile sedimentary rocks deposited by traction currents. This description and interpretation appears compatible with at least the type section of the Thorburn Lake Formation. However, lithologies along the coast include fine-grained volcanogenic sandstones and siltstones which are graded and slumped. These may have been formed by deposition in less turbulent water, possibly a lacustrine or submarine environment. Dal Bello (1977) has suggested on the basis of their sedimentology and trace element studies that correlatives of Unit 2a are lacustrine deposits and facies equivalents of fluviatile red beds lying to the northwest.

Facies relations as outlined above have been described from regions of Tertiary to Recent volcanism. Donnelly (1966) described submarine deposition on the flanks of a subaerial cone and Lipman et.al. (1978) outlined comparable relations in a terrestrial environment. Such associations of fluviatile and lacustrine sedimentation are typical of basin development within the Basin and Range province of the western United States (Gilbert and Reynolds, 1973; Robinson et.al., 1968). Hence, all aspects of the Thorburn Lake Formation, in particular Unit 2b, indicate that these rocks represent a thick, in part subaqueous, detrital apron developed on the flanks of an elongate, predominantly volcaniclastic volcanic pile. Deposition of portions of Unit 2a may have been more closely related in time, to volcanism associated with Unit 3a.

3.3.3 Southwest River Formation (3)

3.3.3.1 General Statement

This formation occupies a roughly 6 km-wide belt striking north and south of the head of Clode Sound. It is divisible into two members, one predominantly sedimentary, the other mainly volcanic. Both of these are intruded by a variety of mafic and silicic dykes. The sedimentary member is composed largely of red sedimentary rocks which include lenses of massive volcanic rocks; it appears that volcanism was in large part coeval with sedimentation. Jenness (1963) referred these rocks to his undifferentiated middle formation within the Musgravetown Group

In the Northwest River area, red sedimentary rocks conformably overlie deformed pyroclastic and flow rocks referred to the Love Cove Group by Jenness (1963) and to the White Point Formation in this thesis. Jenness (1963) described the contact as a fault. The sedimentary rocks contain a penetrative fabric related to overturning of the strata (Refer to Figs. 1 and 1.1). Open more upright folds dominate the structure to the east. On the basis of their structural state, Widmer (1949) thought the sedimentary rocks in the Northwest River - Northwest Arm area to be distinct from what he described as relatively undeformed Musgravetown Group strata nearby. He named the deformed sedimentary rocks the Tabby Cat Cove Formation. However, no significant break could be found between those "units", and the contrast in structure within these sedimentary rocks is clearly the result of their respective disposition within the asymmetric synform into which these rocks are folded in this area. West of Thorburn Lake in the Southwest River area, the type section of these rocks lies on the eastern upright limb of this structure in a west dipping, west facing section.

3.3.3.2 Geology (3a)

The basal portion of the type section of these sedimentary rocks crops out along Thorburn Lake and along the railway track east of the lake. Higher levels of the section are poorly exposed between the lake and Southwest River where these rocks are moderately well exposed.

A thickness of 1280 meters was estimated using an average dip for the whole section of 25°. Similar approximations have been used to prepare a stratigraphic section (Table 3). This does not represent a single straight line traverse but is a composite of all available information in the immediate Thorburn Lake area. Hence, it may not be entirely accurate in detail, but it does show the general sequence reasonably well.

The following observations are based on the composite section:

1. The basal (~100 meters) portion of the section consists of grey, relatively massive conglomerate and coarse-grained sandstone. These are transitional upward into the

Table 3

Composite Section through the Southwest River Formation (3a) (see text).

1280 meters	Red, medium bedded (15-20 cm) cross laminated medium grained sandstone with minor intraformational conglomerate. Red shaley beds (up to 1 meter) common.
	Thick to very thick (average 1 meter) red sandstone, conglomerate and siltstone. Sandstones cross-laminated and scoured.
	Red and green fissile sandstone.
	Interlaminated and interbedded red-whitish sandstone and red shale overlying coarse grained sandstone with large scale cross bedding. Minor soft green siltstone.
	Medium to coarse grained light grey sandstone.
	Red to whitish sandstone with fine grained sandy and silty laminae.
	Red, pebbly, thin to thick bedded (1 meter) sandstone with intraformational conglomerate, commonly fissile. On strike with red fissile sandstone and shale.
	Grey massive to poorly laminated sandstone and granule to pebble conglomerate
640 meters	Massive amygdaloidal basalt.
	Dark green, poorly laminated, thick bedded sandstone. Scattered oblong fragments of fine grained red sandstone up to 40 cm long.
	No outcrop.
320 meters	Red, pebbly, laminated to massive, thick bedded sandstone.
	Red, poorly sorted, cross laminated to cross bedded sandstone.
	Red, medium to coarse grained laminated to massive, thick to very thickly bedded sandstone.
	Grey to minor red massive, coarse grained to very coarse grained (>1 mm) sandstone, pebbly sandstone, pebble conglomerate. Poorly sorted with clasts up to 12 cm across. Cross laminated to cross bedded sandstone.
0 meters	Fractured mafic to lesser silicic volcanic rocks, porphyritic diabase.
	-------------Fault contact with Thorburn Lake Formation-----------

2. The sandstones, especially in the lower half of the section, are mainly coarse-grained and are characterized by thick bedding and cross stratification, commonly in sets >30 cm in thickness.

3. From the middle portion of the section upward, finer-grained red sedimentary rocks including red shales are relatively common, along with associated intraformational conglomerates. Beds also tend to be thinner in the upper portion of the section (Plate XXII).

4. The sedimentary rocks are commonly micaceous. Rocks typical of the upper half of the section are predominant west and north of Port Blandford.

Bedding/fabric relations and primary facing criteria were used in determining the structure (Sec. A-A'; Fig. 1.1). On Northwest River, a basal red pebble conglomerate of the Southwest River Formation is foliated (Plate XXIII) and contains the same fabric relations as the flows, volcaniclastics and dykes of Unit la beneath. The lower contact is undulating and appears to have some relief on the volcanic rocks. This may be an erosional feature. The conglomerate is up to 3 meters thick and is overlain by black to green slate and red to grey, laminated to massive, cross-bedded sandstones. Bedding is overturned in a number of places (Plate XXIV) but is openly warped to the east (Plate XXV). Sedimentary structures are well preserved on the north shore of Clode Sound. Cross-laminae are well developed on a centimeter scale in beds up to 2 meters thick. Also evident are symmetrical ripple marks, mudcracks and load casts (Plates XXVI and XXVII).

Plate XXII: Thin to medium bedding in intercalated red sandstones and shales in upper portions of Unit 3a. Southwest River. Hammer is 30 cm in length.

Plate XXIII: Foliated basal pebble conglomerate of Unit 3a on Northwest River. Pencil approximately 11 cm in length.

Plate XXIV: Slightly overturned red beds (younging to right) of Unit 3a near mouth of Northwest River on Clode Sound. Hammer approximately 30 cm in length.

Plate XXV: Open folding in very thick bedded red sandstone. North shore of Clode Sound. This outcrop is on the east limb of the fold depicted in section A-A', Fig. 1.1.

Plate XXVI: Cross-bedding in Southwest River Formation. North shore of Clode Sound. Pencil approximately 12 cm in length.

Plate XXVII: Symmetrical ripple marks in Southwest River Formation. North shore of Clode Sound. Hammer approximately 30 cm in length.

Plate XXVIII: Cross bedded pebbly sandstone and conglomerate in Southwest River Formation. Southeast shore of Clode Sound. Hammer head approximately 18 cm in length.

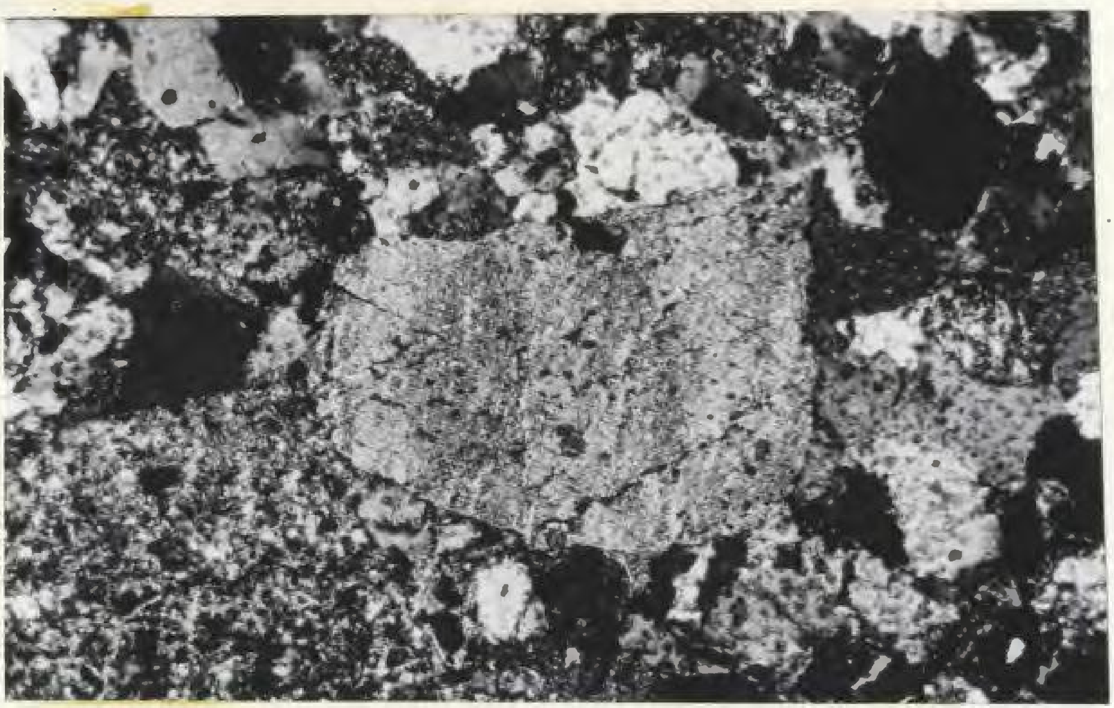


Plate XXIX: Photomicrograph of clast of sericite schist in red sandstone (3a); x-nicols, x12.5.

Northeast of Port Blandford fine to medium grained sandstone and siltstone are common; they are interbedded with lenses of pebble conglomerate (Plate XXVIII). These rocks are probably in the lower half of the sedimentary section and appear "transitional" into sedimentary rocks of Unit 2a. At Middle Point, conglomerate and pebbly sandstone beds up to 2 meters thick with cobbles up to 20 cm across are associated with poorly sorted non-bedded lapilli tuff.

It is not uncommon for beds to change from a green to red colour both laterally and vertically. This observation is in accordance with recent ideas and suggestions that the red colour of red beds may in large part be a diagenetic or at least a post-depositional effect (Walker, 1967; Walker and Honea, 1969; Turner and Archer, 1977).

Irregular veins containing quartz and lesser epidote and calcite are generally conformable with bedding.

3.3.3.3 Petrography (3a)

On the basis of their mineral composition these rocks range from arkose to lithic arkose and minor sub-arkose (Folk, 1974). Texturally they are mainly submature and are not well sorted; grain morphology varies from sub-angular to lesser sub-rounded. The grains are generally closely packed with a seriate grain-size distribution, although a very fine-grained matrix, commonly altered to sericite and minor calcite, comprises up to 50% of some sandstones.

Volcanic fragments, dominated by silicic compositions, are the dominant clast type. The following is a list, roughly in order of decreasing abundance, of clast compositions occurring in these rocks;

1. Sodic plagioclase
2. Quartz, commonly showing embayment textures.
3. Aphanitic rhyolite and dacite, most commonly red in color
4. epidote
5. muscovite flakes, commonly partially replaced by chlorite; especially common in silty beds
6. aphanitic, amygdaloidal mafic to intermediate volcanic rocks, commonly thoroughly oxidized
7. grey argillite and diorite
8. fine grained microcline granite
9. very minor microcline
10. rare sub-rounded clasts of fine grained kinked sericite schist (Plate XXIX).

3.3.3.4 Geology (3b)

To the east and south of Port Blandford, volcanic rocks of this member comprise a lensoid unit. They form the core of an antiform flanked by Units 3a and 2a and crop out on the east limb of the complementary synformal structure described in the previous section but do not reappear on its west limb. Hence, these volcanics are probably equivalent to much of the lower section of Unit 3a exposed on the west limb of the syncline. In fact, portions of Units 3a, 3b, and 2a may be facies equivalents. Gravity data (Weir, 1970) suggest that Unit 3b is much more extensive in the subsurface (H. Miller, pers. comm., 1978).

A relatively planar stratigraphic contact between rhyolite of Unit 3b and overlying sedimentary rocks (3a) is exposed on Watershoot Steady Brook about 250 meters east of the Trans-Canada Highway (TCH). The flow banding in the rhyolites, although locally flow-folded, is generally even and gently dipping to flat lying and conforms to the attitude of the overlying strata.

The greatest outcrop width of this member is along Watershoot Steadies. It is dominated by at least 70% red to grey rhyolite which is fine-grained to aphanitic and locally flow-banded. These rocks commonly show conchoidal fracture and are porphyritic with pink to green altered plagioclase phenocrysts up to 2 mm long. Massive rhyolites are interbedded with finely comminuted to coarse grained rhyolitic breccias or autobrecciated rhyolite with angular blocks up to 15 cm long in a red siliceous matrix.

Basalts are intercalated with the rhyolites. They appear to be more abundant in the north and south and together with diabase dykes make up about 20% of this unit. The basalts are medium grey to reddish (hematite-stained), fine grained and amygdaloidal; they locally contain olivine phenocrysts altered to iddingsite. One flow contains an angular block of rhyolite approximately 65 cm in length. Amygdules vary from rounded to amoeboid in shape; they are up to 6 cm long and make up less than 10% of most flows, though locally they are much more abundant and tend to concentrate in vague patches. Epidote, chlorite, hematite, calcite, quartz and locally albite (?), prehnite and pumpellyite fill the amygdules in varying proportions.

A few massive beds of red sandstone are intercalated with the volcanic rocks. One coastal outcrop of massive, unsorted conglomerate contains well rounded clasts (up to 30 cm across) of amygdaloidal basalt, red sandstone, red rhyolite and minor grey-green siliceous siltstone. Quartz is abundant in the matrix.

These rocks are predominantly unfoliated. However, rhyolites in the east portion of the member have a very fine grained anastomosing strain-slip fabric which masks primary textures. The fabric elements have been disoriented in places by later fracturing. Light yellow-green sericite schist with a foliation dipping gently east-southeast is locally developed.

3.3.3.5 Petrography (3b)

Both petrographically and chemically, these volcanic rocks constitute a markedly bimodal suite.

Flow-banding in the rhyolites is up to 7 mm thick and is defined mainly by differences in grain size, varying concentrations of disseminated hematite and preferential development of epidote (Plate XXX). Most bands have a felsitic texture (in the sense of Hatch et.al., 1972) composed largely of quartz and potash feldspar. Some bands are dominated by microspherulitic crystallization of quartz or pectinate (axiolitic) crystallization in the thinnest bands. Trachytic intergrowths of quartz and potash feldspar occur in some sections; grain boundaries are outlined by a fine hematite dust.

Scattered microphenocrysts of sodic plagioclase (<2 mm) are common and may include diffuse zones of potash feldspar. A pink microcrystalline plug (?) of rhyolite (Loc. 427) cutting Unit 2b contains <5% anhedral to subhedral alkali-feldspar phenocrysts which exhibit a patch-or flame-like

Plate XXX: Photomicrograph of typical flow banded rhyolite (3b); x-nicols, x16.

perthitic to anti-perthitic intergrowth of potash feldspar and albite. These locally include small disoriented blebs of quartz. The present composition and textures of these phenocrysts may well reflect alkali metasomatism.

Hematite occurs as a fine dust, anhedral grains, and as thin spindles up to 1 mm in length, in amounts ranging from less than 2% to about 5%.

Very fine grained (<.01 mm) tuffs occurring along Watershoot Steadies include angular quartz, K-feldspar and plagioclase grains up to 0.15 mm in an altered brown silicic groundmass.

Secondary minerals in the rhyolites include minor sericite, epidote (<5%) and very minor chlorite. Accessory piemontite partly replacing plagioclase phenocrysts occurs locally.

The mafic volcanic rocks are fine-grained (<0.5 mm) and variably altered; they include basalt and olivine basalt. Secondary mineral assemblages indicate a sub-greenschist (prehnite-pumpellyite) metamorphic grade, in contrast to the lower greenschist mineral assemblages developed in White Point Formation flows and dykes.

The basalts are characterized by intergranular to ophitic textures. They are composed of 50-60% plagioclase, 15-25% augite, 0-10% olivine, 5-10% hematite, 10-20% chlorite, epidote, sericite, and calcite. The plagioclase is albitized and partially replaced by epidote, chlorite, and lesser sericite; the olivine is altered to serpentine, iddingsite, and opaque minerals. Minor subhedral plagioclase microphenocrysts are up to 2 mm across and anhedral to subhedral olivine phenocrysts are up to 3 mm in length. The matrix adjacent to the margins of some vesicles has been thoroughly epidotized and carbonatized and minor quartz occurs locally in the matrix.

3.3.3.6 Correlations

The Southwest River Formation lies within an extensive belt of red sedimentary rocks and volcanic rocks which is approximately 130 km in length and extends from the northwest portion of the Sound Island map sheet, Placentia Bay, where volcanic rocks predominate (Anderson, 1965; Hussey, 1978a) to northern Bonavista Bay (Jenness, 1963). Both Jenness (1963) and Anderson (1965) referred these rocks to the Musgravetown Group. The contact relationships of the Southwest River Formation are described in secs. 3.3.2.7 and 3.3.3.1. It was largely undivided but Jenness did delineate certain areas underlain by specific formations. In the Glovertown area, Dal Bello (1977) expanded the belt to include portions of Jenness' Love Cove Group and distinguished four formations modelled after those of Jenness (1963).

Jenness (1963) and Younce (1970) considered gently dipping sedimentary rocks (sandstone, quartzite, siltstone, and shale) on Locker's Flat Island in northern Bonavista Bay to be Eocambrian (Random) in age. Recently, suggestions have been made that these strata, which appear conformable with red sedimentary rocks possibly equivalent to the Southwest River Formation, are lithologically similar to some Eocambrian deposits (eg. Chapel Island Formation) of Fortune

Bay and the southern Burin Peninsula (B. Greene, S. O'Brien, C.F. O'Driscoll; pers. comm., 1978). In the same area of Bonavista Bay, the unfoliated, gently dipping red beds are in fault contact with Love Cove Group schists (Jenness, 1963; Blackwood, 1976).

3.3.3.7 Interpretation

The terrestrial-fluviatile nature of these deposits appears certain in view of:

1. the dominant red, oxidized state of much of the sequence

2. the abundance of conglomerate and coarse sandstone

3. the commonly well developed large scale (>30 cm sets) cross-stratification. According to Turner and Walker (1973), the presence of cross-stratification in sets more than 10 cm thick strongly suggests shallow agitated water.

4. red siltstone containing mud-cracks

5. coarse intraformational conglomerate (tabular red shale and siltstone fragments up to 40 cm long in sandstone beds)

6. the association with highly oxidized amygdaloidal basalt and rhyolite flows.

Constraints placed on a palaeoenvironmental interpretation of these rocks are necessarily limited by the lack of detailed stratigraphic information, both in a lateral and a vertical sense. However, the large volume of data in recent years concerning a number of different types of fluviatile settings makes possible the formation of generalized models (eg. Allen, 1970; Smith, 1970; Miall, 1970; Costello and Walker, 1972; Steel, 1974; Hayes and Kana, 1976; and Walker, 1976). The apparent trend, up section, towards generally thinner bedding and finer grain sizes including red shales (overbank fines or vertical accretion deposits) may indicate the gradual maturing of a river system or systems with the development of a lower-energy hydraulic regime. This may have resulted from an erosional retreat of the source area and/or a lowering of the river gradient. Contemporaneous or semi-contemporaneous volcanism or active syn-volcanic faulting may initially have provided a high relief and subsequent dissection could have produced the observed temporal variation in the style of sedimentation. Coarse grained thick bedded sandstones and intraformational conglomerates in the upper half of the sequence may reflect (sudden?) increases in river gradient via continued faulting within or at the margins of the basin or could be due to purely environmental controls.

As indicated, lack of detailed stratigraphic information makes it impossible to model these rocks specifically after either of the two best known fluvial systems (i.e. braided river, or meandering system) although it is obvious that development of a braided or meandering system will, in part, be controlled by the kind of gradients encountered and the grain size of the sediment load. In that light, the sedimentary section could represent a composite palaeoenvironmental scheme. However, current theory would suggest that soil binding by plants is an important factor in stabilizing river banks or levees in meandering rivers, although accumulations of clays and other fine material may be of equal utility in that regard (Schumm, 1968; McGowen and Gerner, 1970; Smith, 1976). Therefore, it is generally accepted that meandering systems are largely restricted to post-Silurian times. Hence, an alluvial fan and/or braided river model (McGowen and Gerner, 1970) is suggested for these rocks, especially in view of the coarse-grained nature of many of these sedimentary rocks. An alluvial fan environment, developed on fault scarps (?), probably dominated the earlier stages of development of the sequence.

The close association between bimodal basalt-rhyolite suites and tensional tectonic environments, either in continental or oceanic settings, is well documented (eg. Gibson and Walker, 1964; Cox, 1971; Rao, 1971; Martin and Piwinski, 1972; Lipman et.al., 1972, 1978; Wachendorf, 1973; and Rankin, 1976). The similarly bimodal, alkaline (Chapter 6) nature of volcanic rocks in the Southwest River Formation appears to indicate a comparable tectonic regime and in fact, the fault which presently bounds Unit 3b (Thorburn Lake fault) may have been active, along with others, during such times. Gravity profiles (Weir, 1970) across that fault indicate a west dip with a significant amount of normal movement (H. Miller, pers. comm., 1978). This faulting may have been more widespread than it now appears and may well have been contemporaneous with and spanned the duration of volcanism and sedimentation represented by the Southwest River Formation. The chemical and petrographic signature of Unit 3b discussed above, along with the gross stratigraphic development of the sedimentary rocks of Unit 3a, strongly suggest graben development associated with an extensional tectonic regime.

3.4 CONNECTING POINT GROUP (4)

3.4.1 General Statement

Rocks assigned to the Connecting Point Group (Hayes, 1948) crop out along the shore of Clode Sound in the north-eastern portion of the map-area. Aside from exposures north-east of Bread and Milner's Coves on the north and south shores of Clode Sound, rocks referred to this group underlie Platter Island and a strip of coast line less than 1 km in width on the south shore of Clode Sound due east of the Charlottetown peninsula (Fig. 1). The latter occurrence has not been previously reported.

Hayes (1948) originally recognized the angular unconformity immediately east of Milner's Cove on Clode Sound. He named the sequence of sedimentary rocks below the unconformity the Connecting Point Group and the volcanic and sedimentary rocks above, the Musgravetown Group. The type locality is situated at the head of Clode Sound, approximately 5 km northeast of Milner's Cove.

An independent thickness estimate of this group can certainly not be made here; however it is instructive to review previous estimates. Jenness (1963) in the Bonavista Bay area did not recognize a top or bottom to the group but estimated a thickness of between 25,000 feet (7700 meters) and 30,000 feet (9200 meters). McCartney (1967), working to the south, could not define the base but included approximately 9000 feet (2750 meters) of strata in the Connecting Point Group.

Detailed studies of this group are beyond the scope of this work and hence only a lithological characterization of coastal outcrops in the Bread Cove - Milner's Cove area will be given.

3.4.2 Geology

Regionally this group is dominated by argillite, lesser greywacke, cherty quartzite and minor conglomerate and mafic lava flows (Jenness, 1963). In the present field area it consists predominantly of white-weathering, dark grey, thin to medium bedded and finely laminated siltstone and siliceous siltstone or slate (see Plate XXXII). These are locally graded. Beds of greywacke 10-20 cm thick occur in the north-east and contain angular intraformational clasts up to 1 cm across. At one locality immediately northeast of Milner's Cove, a siltstone bed contains scattered yellow rounded pebbles of felsite (?). Jenness (1963) reported abundant, relatively fresh sedimentary and volcanic detritus in these rocks.

The beds are steeply to moderately dipping and are asymmetrically folded on variably plunging axes or drag folded on steep fractures. The cleavage is heterogeneously developed and is commonly parallel to bedding. Boudinage and brecciation of less competent beds has occurred although brecciation is in places confined to the hinge region of folds.

Plate XXXI: Mafic dyke which post-dates foliation (S_1) in the Connecting Point Group. West side of Bread Cove. Hammer is approximately 30 cm in length.

Plate XXXII: Angular unconformity between the Connecting Point Group and overlying green conglomerates of the Cannings Cove Formation. East of Milner's Cove.

These rocks are slaty in appearance with incipient development of very fine grained sericite. On the west side of Bread Cove they may be described as phyllites; a fine grained penetrative sericitic fabric has been folded on a small scale and kinked in the westernmost outcrop, about 100 meters east of the nearest outcrops of the overlying Cannings Cove conglomerates. The fabric is brecciated in steep, narrow zones up to 10 cm wide. This is probably related to faulting of the contact between the Connecting Point and Musgravetown Groups.

One distinctive feature of the Connecting Point Group in the field area is the presence of ubiquitous diabase dykes and sills. These make up at least 5% of the whole but locally are much more abundant. They are less than 4 meters thick and show well developed chilled margins. These dykes are brown-weathering, light to medium grey, fine grained and may locally have vesicular interiors. They are generally massive with local fracturing and minor displacement of the contacts. The diabase dykes appear to post-date the phyllitic or slaty cleavage in the sedimentary rocks (Plate XXXI). Chemically they resemble the overlying mafic lavas of the Clode Sound Formation.

3.4.3 Contact Relationships

In contrast to Hayes (1948), Jenness (1963) thought the contact at Milner's Cove to be a fault of sinistral displacement, although he did recognize an angular unconformity between these groups at Southward Head, eastern Bonavista Bay.

Younce (1970) and the present author concur with Hayes' (1948) original description. The contact is not a plane surface and appears to be of a relatively irregular erosional nature with steeply dipping thin-bedded sedimentary rocks beneath and massive, non-bedded green conglomerate above (Plate XXXII). The rock face by which the unconformity is exposed is, in fact, a steeply dipping slickensided fault surface, but there is no evidence for movement along the trace of the contact itself. Along the north shore of Clode Sound the contact is not exposed. Red conglomerates of the Cannings Cove Formation form a conspicuous, steep, east-facing, north-trending scarp. Adjacent outcrops of Connecting Point Group rocks show evidence of brittle fracturing and brecciation in steep narrow zones. Hence, the contact north of Clode Sound is thought to be faulted.

Younce (1970) recognized the unconformity at Milner's Cove, but reported that to the north, in the Newman Sound area, the Bull Arm Formation overlies the Connecting Point Group without angular unconformity. McCartney (1967) described a conformable relationship between those same two units in the Isthmus of Avalon area although he admitted that the contact relations were not entirely clear in that area. Despite this, in the Merasheen Islands of Placentia Bay, several hundred feet of sedimentary rocks similar to those of the Connecting Point Group have recently been reported to underlie conformably a bimodal volcanic sequence presumably correlative with the Bull Arm Formation (O'Driscoll & Muggeridge, 1978).

Such ambiguities in regional contact relationships may either shed light on the inhomogeneous nature of pre-Musgravetown Group tectonics or conversely may shed doubt on the present understanding of the age and correlation of the various bimodal volcanic sequences overlying the Connecting Point Group in the western Avalon Zone.

3.4.4 Correlations and Interpretation

Jenness (1963), McCartney (1967), Anderson (1965) O'Driscoll (1977b), and O'Driscoll and Muggeridge (1978) have outlined the regional distribution of this geographically extensive, undivided, largely fault-bounded group. It is restricted to a north-south trending belt approximately 150 km long, extending from central Bonavista Bay to the islands of central Placentia Bay. It lies to the east of, and in the north adjacent to, the Love Cove Group and its correlatives. Unfortunately, the contacts are invariably faulted or covered (Jenness, 1963; Younce, 1971; Dal Bello, 1977).

Jenness (1963) thought the Connecting Point Group to be younger than the Love Cove Group and inferred an unconformity between them because of the more deformed nature of the latter. Younce (1971) rejected this interpretation, considered the Connecting Point Group to be the oldest unit in the region, and thought the Love Cove Group to be a deformed equivalent of the Bull Arm Formation. O'Driscoll and Hussey (1977) suggested that the two groups are temporally equivalent and proposed that the Connecting Point Group could represent a marine basinal facies of the Love Cove Group volcaniclastic pile which is also flanked on the west by a partially subaqueous detrital apron (i.e. Thorburn Lake Formation).

However, little or no detailed sedimentological and stratigraphic work has been done on these rocks although reconnaissance work by the present author and A.F. King indicate that significant portions (in the upper half?) of the Connecting Point Group are of a relatively shallow-water facies. Further, probable correlatives of the Connecting Point Group in western Placentia Bay grade conformably into overlying white quartzites very similar to those of the Random Formation (C.F. O'Driscoll, 1978a; pers. comm.,1978). Detailed mapping may yield results similar to those obtained by Williams and King (1976) on the possibly correlative Conception Group of the southeastern Avalon Peninsula. A truly meaningful integration of this sequence into a regional synthesis of the Avalon Zone must await such work.

3.5 MUSGRAVETOWN GROUP

3.5.1 Introduction

Jenness (1963) outlined the distribution of the Musgravetown Group throughout the Bonavista Bay map-area; he established a five-fold subdivision of the group, based in part upon formations established to the south by McCartney (1967) (Table I). However, Younce (1970) considered these subdivisions to have no chronologic significance and to be in large part facies equivalents. Jenness (1963) found no one complete section for the Musgravetown Group in Bonavista Bay and estimated its thickness at 10,000 feet (3060 meters), while McCartney (1967) estimated an approximate 13,000 feet (3900 meters) thickness for the group.

In this study, mapping of rocks assigned to the Musgravetown Group was carried out only along Clode Sound and along a strip of ground adjacent to the Charlottetown Fault. Outcrop is very poor to the east of the field area and all contacts with the very poorly exposed western Cambro-Ordovician basin of Jenness (1963) are covered by glacial drift. Good coastal exposures allow definition of three constituent formations of this incomplete section of the Musgravetown Group. These are the Cannings Cove Formation (Jenness, 1963), the Clode Sound Formation (Bull Arm Formation of Jenness, 1963) and the Charlottetown Formation. However, there are significant differences in the proportion of sedimentary to volcanic rocks and mafic to silicic volcanic rocks between the north and south shores of Clode Sound, suggesting that the various lithologies within the Clode Sound Formation are in large part facies equivalents. The simple, unbroken, homoclinally dipping sequence on the north shore yields reliable thickness estimates for the Clode Sound and Charlottetown Formations. A complete section for the Cannings Cove Formation is exposed on the south shore at Milner's Cove. From these two sections a total thickness of between 2060 and 3560 meters is estimated for the whole section. The uncertainty in the estimate is due to the lack of stratification in the volcanic rocks.

It may be significant that the constituent rock types of this group are in many respects quite similar to those of the Southwest River Formation. The implications of this will be discussed in a later section.

3.5.2 Cannings Cove Formation (5)

3.5.2.1 General Statement

Jenness (1963) found the Cannings Cove Formation to be highly variable in thickness, ranging from a complete 100 ft. (33 meters) section at Southward Head, southeastern Bonavista Bay, to an incomplete 2400 ft. (735 meters) section at the type locality, approximately 5 km east of Milner's Cove. He subdivided that section into a lower 1700 ft. (520 meters) sequence of green conglomerates and an upper 700 ft. (214 meters) section of red conglomerate and lesser sandstone. He thought the lower contact with sedimentary rocks of the Connecting Point Group east of Milner's Cove to be a fault, and therefore considered the 340 ft. (113 meters) of sedimentary rocks below the stratigraphically lowest occurrence of volcanic rocks to be incomplete. In this study red conglomerates and minor basaltic flows previously included by Jenness (1963) in the lower portions of the Bull Arm Formation are placed within the Cannings Cove Formation. A thickness of 530 meters is estimated for this redefined unit.

Younce (1970) interpreted the abundance of fresh volcanic detritus in the Cannings Cove Formation, along with the apparent local absence of conglomerates intervening between the Bull Arm Formation and the Connecting Point Group, as evidence that it is either equivalent in age to or younger than the Bull Arm Formation. Dal Bello (1977) concurred with that view. The sections on Clode Sound however clearly indicate that the Cannings Cove Formation underlies and is older than or contemporaneous with a major portion of the Bull Arm Formation.

3.5.2.2 Geology and Petrography

The formation is dominated by red, poorly sorted, paraconglomerates. In the Clode Sound area it is composed of three lithologic subdivisions. These subunits are: 1. Basal green conglomerate and sandstone (40 meters); 2. red conglomerate and sandstone and minor basalt (455 meters); 3. grey to red, fine to very coarse grained sandstone (35 meters). The colour of these rocks reflects the fine hematitic coating on individual grains. The basal green conglomerates include more sedimentary detritus than the red sequence. This detritus was derived mainly from the underlying Connecting Point Group. Otherwise, the red and green conglomerates are similar.

Members 1 and 2 are composed dominantly of gently-to steeply-dipping polymictic conglomerate and subordinate medium-to coarse-grained sandstone. These sedimentary rocks are thin-to thick-bedded; the sandstone, locally laminated, occurs in beds up to 15 cm thick or may occur as cross-beds in channel deposits occupying scours up to 40 cm deep, (Plate XXXIII). Bedding is defined by contrasts in grain size and in the conglomerates it is accentuated by an alignment or imbrication of clasts (Plate XXXIV). The conglomerates are poorly sorted; clasts range from a coarse sand-size to rounded boulders 35 cm in diameter and vary in shape from angular to well rounded (Plates XXXIII and XXXV). Red shale occurs locally.

There is a wide variety of detritus. Different rock types, variable in abundance, include:

1. green siltstone, greywacke, and black chert (Connecting Point Group),

2. red to green sandstone,

3. red aphanitic rhyolite

4. massive to amygdaloidal basalt, which may be highly oxidized

5. fine grained tuffs and felsic clasts

6. pink, medium grained, in part porphyritic, perthitic to granophyric granite; very minor foliated white leucogranite (see Plate XXXV).

7. quartz and lesser feldspar fragments

8. various altered siliceous rocks including fractured grey altered rhyolite (?)

9. locally up to 5-10% white to light green sericite schist or sericitic tuffaceous rocks. These are most prominent west of Bread Cove (Plates XXXVI and XXXVII).

10. medium-grained garnet-biotite-muscovite-quartz schist

Plate XXXIII: Scour in Cannings Cove conglomerate filled with sandstone. Note imbrication in conglomerate above scour. West of Bread Cove. Hammer is approximately 30 cm in length.

Plate XXXIV: Typical outcrop of red conglomerate and sandstone of the Cannings Cove Formation, west of Bread Cove. Field of view approximately 10 meters.

Plate XXXV: Closeup of typical Cannings Cove conglomerate. Note the pebble of foliated leucogranite.

Plate XXXVI: Similar to Plate XXXV but with abundant clasts of sericite schist.

Plate XXXVII: Slabbed section of Cannings Cove conglomerate, note abundance of clasts of sericite schist.

Plate XXXVIII Inverse graded green sandstone bed with black shale chips at base. Near top of Cannings Cove Formation west of Milner's Cove.

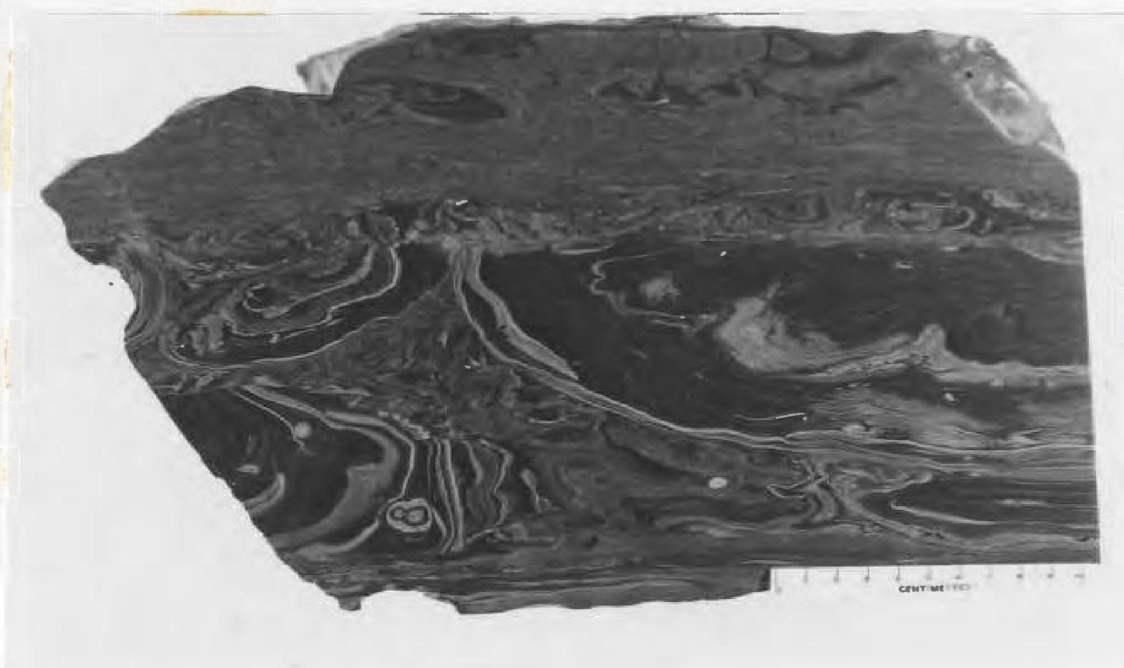


Plate XXXIX Load cast and pseudonodule development in green laminated sandstone and siltstone. Cannings Cove Formation west of Milner's Cove.

11. rare foliated garnetiferous leucogranite (R.F. Blackwood, pers. comm.)

12. in the Cannings Cove area, grey diorite and quartz-plagioclase-hornblende gneiss (Younce, 1970).

Subordinate fine-grained amygdaloidal flows in this formation are up to 25 meters thick. They locally have oxidized, scoriaceous flow tops and amygdules are commonly streaked out in the plane of flow. Mafic dykes with chilled margins cut both the flows and sedimentary rocks.

Member 3 occupies the uppermost 35 meters of the Cannings Cove Formation. It consists of grey to red, medium-bedded to very thinly laminated sandstone of variable grain size. A few inversely graded beds about 10-15 cm thick vary from finely laminated silty bases up to coarse grained sandstone (Plate XXXVIII). Black shale chips occur in the lower half of some of these beds. One green sandstone bed about 30-50 cm thick shows well developed load casts up to 20 cm across and smaller pseudonodules (Plate XXXIX).

3.5.3 Clode Sound Formation (6)

3.5.3.1 General Statement

McCartney (1967) named the predominantly volcanic assemblage, comprising the lower portions of the Musgravetown Group in Trinity Bay, the Bull Arm Formation, and Jenness (1963) correlated the volcanic sequence on Clode Sound with that unit. However, the chemistry of the silicic rocks in that sequence in the map area appears quite distinct from the chemistry of rhyolites close to the type area of the Bull Arm Formation (Malpas, 1971). These distinctions will be discussed in detail in chapter 6. Hence, it is possible that these sequences are not correlative and therefore the sequence on Clode Sound is tentatively renamed Clode Sound Formation pending further work.

The Clode Sound Formation is defined as that sequence of volcanic and minor sedimentary rocks resting conformably upon the Cannings Cove Formation on Clode Sound, Jenness (1963) described basalts, andesites, trachytes and rhyolites from this section. However, petrographic and chemical studies indicate that the volcanic rocks are composed solely of basalts and pantellerites (peralkaline rhyolites enriched in Fe and depleted in Al_2O_3). The identification of the rhyolites as peralkaline is based solely on major and trace element data (see chapter 6).

Jenness (1958 , 1963) estimated the thickness of this section at somewhat over 2500 feet (765 meters) but included sedimentary rocks here referred to the Cannings Cove Formation. The present estimate is between 800 and 2300 meters, assuming minimum and maximum average dips of 20° and 60°.

The formation is divided somewhat arbitrarily into four lithologic subdivisions which have only limited stratigraphic significance. However, several generalizations can be made about the volcanic rocks. Unit 6a is composed dominantly of basalt. Along the south shore of Clode Sound it consists exclusively of basalt with a sharp transition in the Old House Cove area (Loc. 119) up into Unit 6b pantellerites (the term rhyolite is used in Fig. 1 as a field designation) which underlie all the hills in the area (incl. the Branch Hills southeast of Bunyan's Cove; Loc. 355). However, on the north shore of Clode Sound, the lower one-third of the Unit 6a section is basalt while higher portions contain increasing proportions of silicic rocks; mafic and silicic rocks are also intercalated south of Clode Sound. Both the basalts and the pantellerites have a strong aeromagnetic expression.

It is difficult to make an accurate estimate of the proportion of mafic to silicic rocks on the basis of available data. However, on the whole, basalts may make up 60-70% and the pantellerites 30-40% of the formation by volume, excluding the sedimentary rocks.

Unit 6c includes a variety of terrestrial sedimentary rocks associated with volcanic rocks of the Clode Sound Formation. Unit 6d includes minor mafic stocks probably associated with the volcanic rocks which they intrude.

3.5.3.2 Geology (6a and 6b)

The basalts occur almost invariably as flows, indicative of "quiet" fissure (?)-style eruptions. Inland, a minor mafic breccia contains fragments of porphyritic diabase (up to 3 cm) in a sparse matrix. Their contacts are not clearly defined but the flows are probably in the order of 20 meters thick.

Bedding plane "jointing" is prominent in some flows and locally very thin even flow-lines are defined by fine concentrations of opaque oxides.

These rocks are dark grey or green or locally red. They are dominantly aphanitic to fine-grained and are aphyric or sparsely porphyritic with olivine (up to 3.5 mm) or plagioclase (up to 6 mm) phenocrysts. Augite phenocrysts are uncommon but were seen in one inland outcrop (Loc. 845) which also contains up to 30% plagioclase phenocrysts and minor olivine microphenocrysts. Olivine basalts (including the rocks containing the highest amounts of Mg) are most abundant stratigraphically below the first appearance of silicic lavas but do occur, more sparingly, higher in the section.

Without exception, these rocks are amygdaloidal. The amygdules, up to 5 mm across, are sparse in some flows and comprise up to 20% of others. They are variable in shape (Plate XL) and may be evenly distributed throughout the flows, or occur in vague patches or in intensely vesicular zones up to 1-3 meters apart. These bands are gently dipping, the amygdules being elongated in the plane of flow. This suggests rather fluid laminar flow of relatively hot lavas (MacDonald, 1967).

In roughly decreasing order of abundance, calcite, chlorite, hematite, epidote, sericite, minor quartz and locally K-feldspar and albite occur in the amygdules, in thin irregular veinlets, and on joint surfaces. Hematite staining is widespread and thin red "Liesegang colour-banding" is developed in places. This either parallels joint surfaces or occurs as concentric bands which have at their core amygdules containing calcite and radially patterned or botryoidal hematite (Plate XLI). Diffusion rings developed in weathered basalts (Singer and Navrot, 1970) and granite (Augustithus and Otteman, 1966) are somewhat similar to these.

The pantellerites are pink, red or purple, and locally grey. They are aphanitic with conchoidal fracture. In places, they are pervasively jointed in rectangular fashion. A dark manganese stain or hydrous iron oxide is developed on the joint surfaces. These flows are sparsely porphyritic with pink to white euhedral feldspar phenocrysts up to 5 mm long. Vugs occur locally and are filled with polygonal quartz, chlorite, calcite or siderite. A light grey, fine-grained massive rhyolite dyke 6 meters thick contains minor pyrite and pyrrhotite.

These rocks are evenly flow-banded on a millimeter to centimeter scale. The bands are defined most clearly by varying concentrations of hematite, and a hematitic mottling may accompany the banding. Especially along the south shore flow folding of the banding is well developed (Plate XLII) and is gradational into flow breccias (Plate XLIII) which contain angular, disoriented fragments averaging 0.5 to 1 cm but locally reaching 1 meter in maximum dimension. The flow banding is probably the result of laminar flow in a viscous medium reflected by differential crystallization and

Plate XL: Amygdaloidal basalt (6a). South shore of Clode Sound. Hammer approximately 30 cm in length.

Plate XLI: Photomicrograph of botryoidal texture of hematite and calcite in amygdule (basalt of Unit 6a). This texture apparently related to Liesegang banding; p.p.l., x12.5.

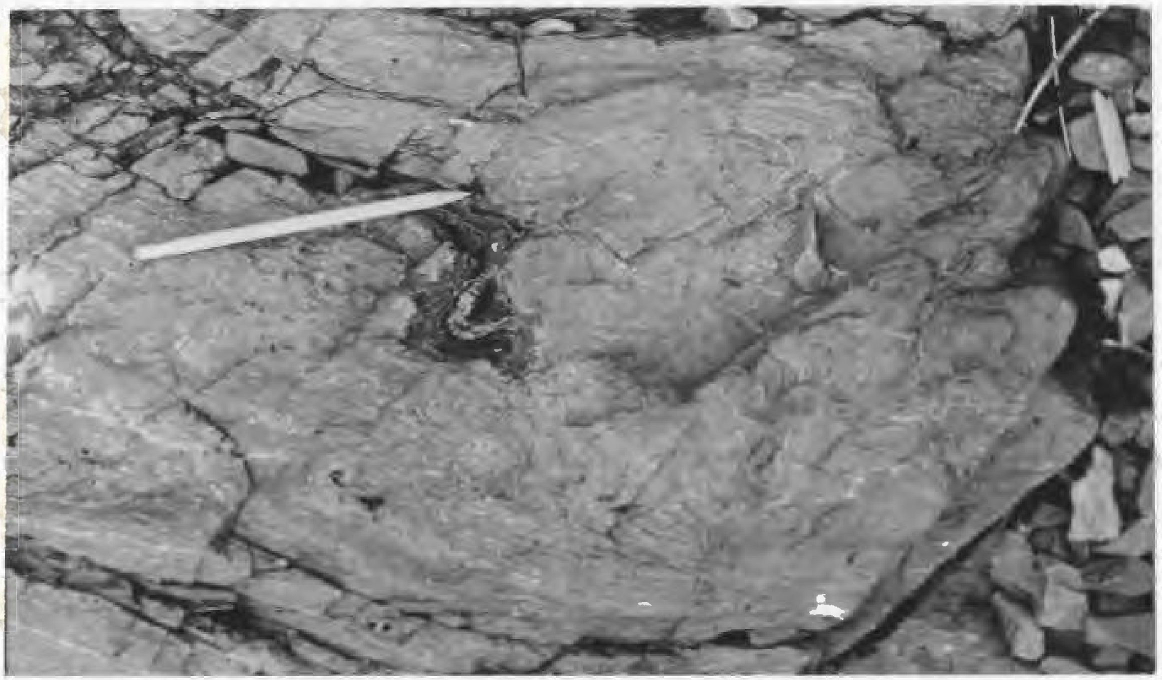


Plate XLII: Flow folding in flow banded pantellerite (6b). South shore of Clode Sound. Pencil approximately 15 cm in length.

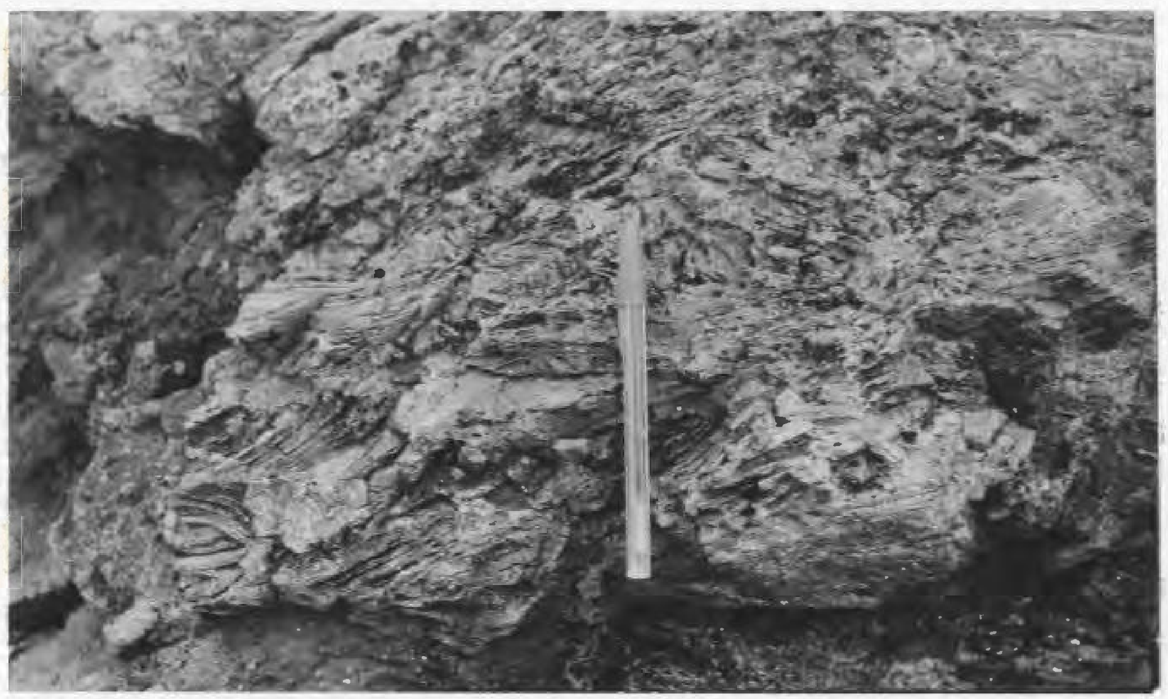


Plate XLIII: Autobrecciated pantellerite (6b). South shore of Clode Sound. Pen approximately 15 cm in length.

devitrification during cooling (Malpas, 1971). Curtis (1954) interpreted such autobrecciation in terms of the escape of small amounts of volatiles from the flow and the resulting marked increase in viscosity.

Most of the above-described characteristics, with the possible exception of the autobrecciation, could be interpreted in terms of rheoignimbrites (eg. Lock, 1972) or primary laminar viscous flowage structures described from dominantly alkalic or peralkalic ash flows (eg. Schmincke and Swanson, 1967; Schmincke, 1974). These particular silicic flows lack most features typical of ash flows (i.e. vitroclastic or eutaxitic texture etc.) and are quite homogeneous. However such a characteristic is not necessarily a conclusive evidence against an ash flow origin. Schmincke (1974) states "Volatiles released during devitrification may form gas vesicles or miarolitic cavities in the densely welded rock, tending to obliterate pyroclastic or eutaxitic texture and structure. Indeed, densely welded, and particularly coarsely crystallized peralkaline welded tuffs may resemble lava flows much more than calcalkaline ash-flow tuffs of comparable thickness". It should be noted that some of these rocks show a peculiar "spherulitic" groundmass texture consisting of rounded quartz-feldspar aggregates surrounded by dark rims of hematite or light green chlorite. Schmincke (1974) described similar textures from ash flows on Gran Canaria involving quartz, feldspar and aegirine or alkali amphibole. Hence, the mode of eruption and emplacement of many of these pantellerites may have included both lava flow and ash-flow mechanisms. A clearly recognizable red ignimbrite approximately 7 meters thick occurs at Old House Cove, intercalated with basalts. It shows a pronounced eutaxitic texture with flattened devitrified light pink pumice lapilli up to 15 cm long and smaller angular lithic fragments. The unit appears to be strongly welded throughout most of its thickness. This is atypical of calcalkaline rhyolite (Smith, 1960; Smith and Bailey, 1966) but has been described from rather thin pantelleritic ash-flows from a number of localities (eg. Gibson, 1970; Schmincke, 1974).

If some of these rocks are of an ash-flow origin, the value of whole-rock chemical analyses of these volcanic rocks should be considered. Arguments put forward in sec. 3.3.1.3 suggest that the composition of calcalkaline ash flows are not representative of their parent magma.

Although eruptions of peralkaline ash flows have not been observed and described, Schmincke and Swanson (1967) and Schmincke (1974) use volcanological, mineralogic and chemical data to draw distinctions between peralkaline and calcalkaline ash-flows. They demonstrate the peralkaline varieties to have consistently much smaller individual volume and infer them to be of significantly higher temperature and lower viscosity than their calcalkaline equivalents. Hence, the mode of eruption is thought to be significantly different from that of calcalkaline ash-flows. Schmincke (1974) states that calcalkaline ash-flows are believed to travel as dilute-phase fluidized beds while peralkaline ash flows may be less inflated and closer to dense-phase fluidized beds. Therefore, these tuffs may not be as susceptible to mechanical differentiation of the various size fractions of particulate matter during emplacement as their calcalkaline counterparts. In that regard, the compositions of the peralkaline tuffs may be relatively close geochemical approximations to their parent magma.

Mafic dykes which intrude the Clode Sound Formation and the Connecting Point Group are similar to the basalts of Unit 6a. They are green to grey, non-vesicular and fine to medium grained (up to 3 mm) with chilled margins and diabasic texture. These dykes are up to 3 meters thick, steeply dipping and of variable orientation. No mafic dykes were seen to cut pantellerites of Unit 6b which appear to be the uppermost portion of the volcanic pile; hence most of these dykes are thought to be feeders for basalts of Unit 6a. Their petrography is described with the volcanic rocks.

3.5.3.3 Petrography (6a and 6b)

Groundmass textures of the basalts are dominantly intergranular to intersertal (0.1 - 0.6 mm). Grain size is locally up to 2 mm and ophitic texture is rarely developed. Intergranular augite is commonly the least altered phase. It also occurs, in places as euhedral phenocrysts or in glomeroporphyritic clusters up to 2.5 mm across (Plate XLIV).

Olivine is completely altered (hematite, serpentine, iddingsite); it occurs either as an intergranular phase or as subhedral phenocrysts (Plate XLV). Plagioclase is commonly extensively sericitized or replaced by carbonate and locally chlorite. It generally has ragged margins suggestive of overgrowths and/or replacement (albitization?). It is not common as a phenocryst phase. Accessory K-feldspar occurs in some basalts as an intergranular phase or as minor inclusions in plagioclase laths. However, in some flows it makes up to 5% and is concentrated around amygdules, suggesting at least local potash metasomatism. Hematite generally occurs as anhedral grains of a secondary origin, produced by oxidation, upon extrusion, of the primary mafic phases and/or interstitial glasses.

Secondary alteration products make up to 35% of some samples and are developed both in the groundmass and in amygdules. However, mineral assemblages diagnostic of a particular metamorphic grade were not recognized, aside from prehnite in a hematite-quartz vein along a brook northeast of the Blue Hills. Chlorite and calcite are most common, and various zoning patterns of amygdules indicate the crystallization sequence chlorite, epidote, calcite (Plate XLVI). Hematite and calcite appear to have crystallized simultaneously. Quartz is of only minor local occurrence in vesicles and the groundmass.

The apparently very low grade of metamorphism may be attributed to burial effects produced through an elevated temperature and active groundwater circulation as described by Wood et.al. (1976) from Iceland.

The diabase dykes are generally similar petrographically to the basalts. They consist of fine-to medium-grained intergranular-diabasic intergrowths of fresh to altered plagioclase (An_{50}) and augite. There is minor deuteric alteration of augite and opaque oxides to minor, partially chloritized, brown biotite.

The pantellerites are aphanitic (0.05-0.2 mm), appear to have been originally glassy, and are composed predominantly of felsitic (in the sense of Hatch et.al. 1972) to lesser spherulitic intergrowths (Plates XLVII and XLVIII) of plagioclase, K-feldspar and quartz. Aplitic texture is locally developed. The anhedral intergrowths which comprise the felsitic groundmass have a concentric aspect, in their outer portions, defined by hematite. In some flows, they have overgrown a fine banding and are commonly outlined by interstitial hematite. Several flows contain abundant crystallites, commonly aligned and altered; trachytic texture is developed in some flow bands which are commonly defined by textural contrasts in adjacent bands.

Hematite is ubiquitous in these rocks and has a number of habits. It makes up to 15% of some samples but is as low as 2-3% in others. It occurs as thin bands, as spindle shapes, or most commonly as anhedral interstitial disseminated grains. Rare skeletal opaque microphenocrysts up to 0.6 mm in length are present in some rocks. Brecciated pantellerite (Loc. 100) adjacent to the Charlottetown Fault is cemented by up to

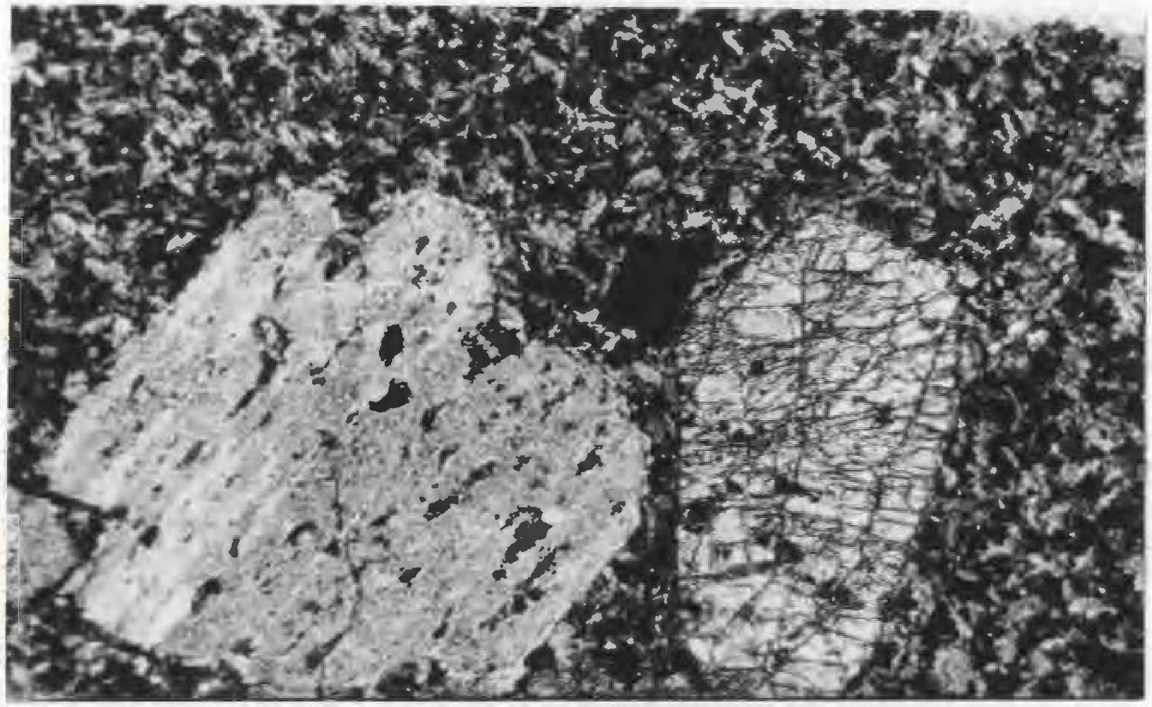


Plate XLIV: Photomicrograph of porphyritic basalt (6a) with subhedral saussuritized plagioclase and unaltered augite phenocrysts (Sample 845); x-nicols, x12.5.

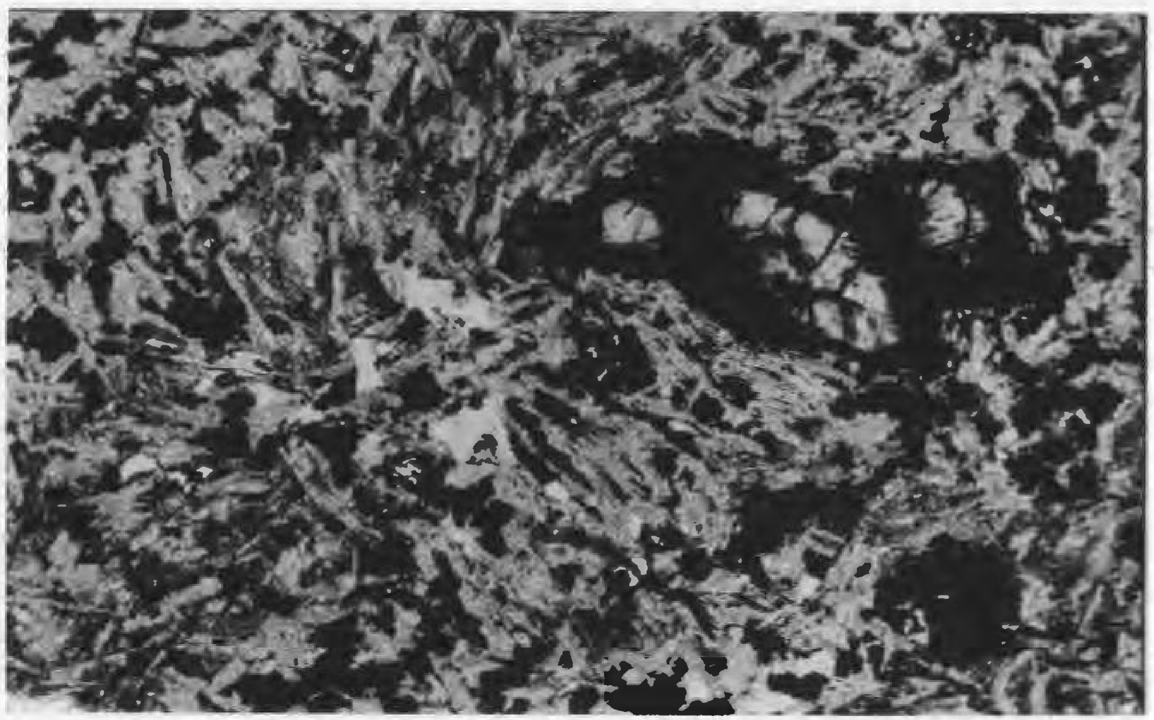


Plate XLV: Photomicrograph of olivine basalt (6a). Altered olivine occurs as phenocrysts and as an intergranular phase with hematite. The plagioclase is saussuritized; p.p.1., x12.5.

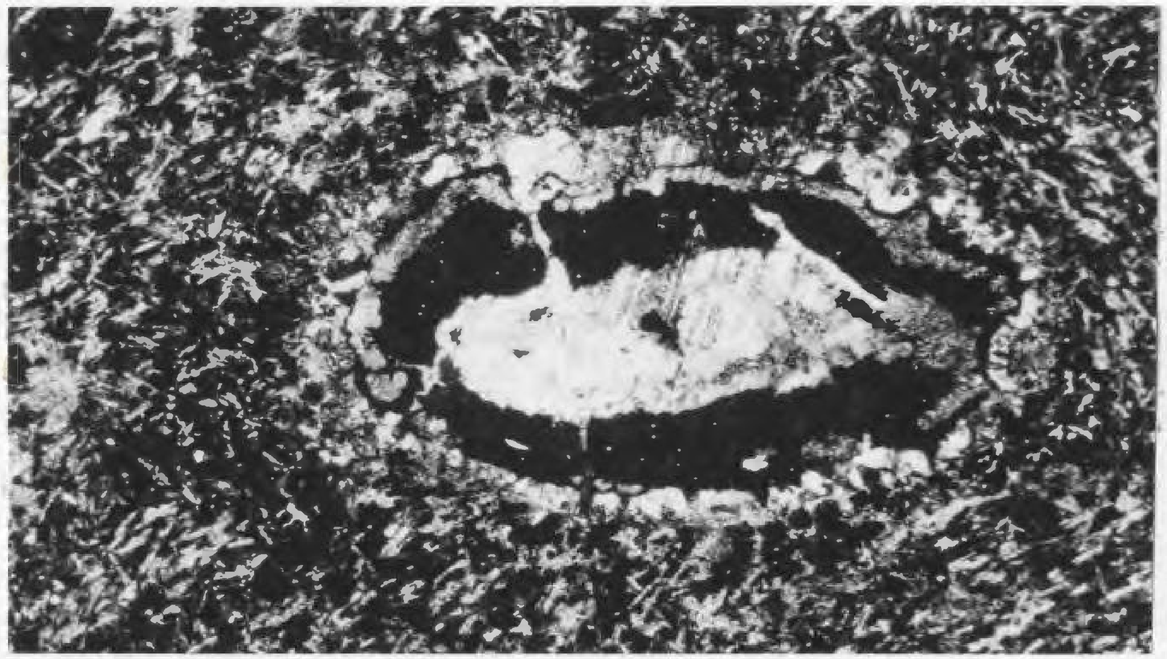


Plate XLVI: Photomicrograph of zoned amygdule in basalt (6a). Chlorite intervenes between epidote at the margin and calcite at the core; x-nicols, x12.5.

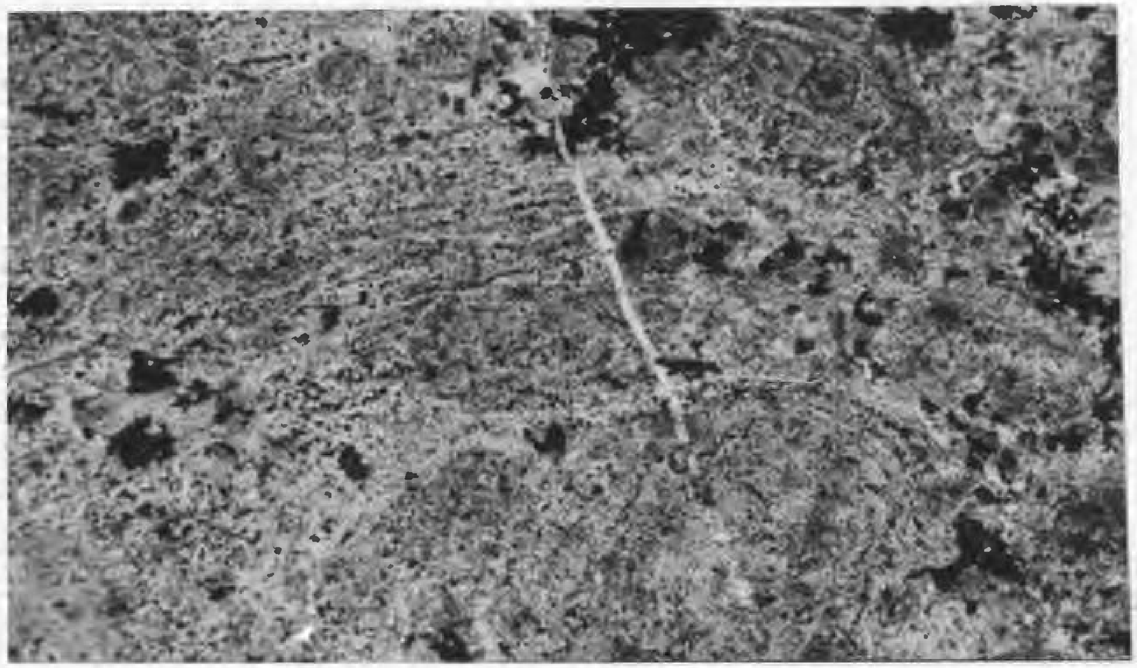


Plate XLVII: Photomicrograph of thin primary (flow?) banding in pantellerite (6b); p.p.1., x12.5.

Plate XLVIII: Same as Plate XLVII; x-nicols. Note spherulitic (or felsitic) texture which has been superimposed on the thin banding shown above; x12.5.

Plate XLIX: Photomicrograph of chequer-board texture in albite phenocryst in pantellerite (6b); x-nicols, x50.

Plate L: Photomicrograph of vitroclastic texture in welded ash flow tuff (6b); x-nicols, x12.5.

20-30% hematite.

Potassium feldspar in the groundmass varies from less than 25% up to approximately 70%; where abundant it is concentrated as bladed or platy crystals in spherulitic or spherulitic-like intergrowths. Plagioclase (untwinned) is not abundant; chemical data indicate some of the pantellerites to contain little or no plagioclase. These rocks are aphyric to sparsely porphyritic. Aside from minor resorbed quartz phenocrysts in some rhyolite dykes, secondary albite is the only phenocryst phase. It typically shows diffuse albite twinning, simple Carlsbad twinning or a "chequer board"-like texture (Plate XLIX) suggestive of replacement of K-feldspar (Battey, 1955; Hughes and Malpas, 1971). It is replaced by carbonate and/or lesser sericite. Some accessory pyrite is present locally.

The one clearly recognizable ash-flow tuff is welded and fiamme have pectinate borders (Briggs, 1976a) and siliceous anhedrally recrystallized or spherulitic interiors. The tuff is composed largely of quartz and lesser sodic plagioclase. The potash feldspar (less than 5%) is concentrated in the fiamme. Flattened shards are outlined by a fine hematite dust and they have characteristic axiolitic (pectinate) devitrification (Plate L). Crystals or crystal fragments are rare.

The secondary minerals of these rocks include minor light green to bright green-yellow chlorite, carbonate (calcite + siderite), sericite and very minor epidote.

However, chlorite makes up ~20% and carbonate approximately 5% of one dark grey porphyritic pantellerite (Loc. 119). Carbonate (in part siderite) comprises up to 5% of other flows, occurring as irregular patches and as a replacement of phenocrysts. Abundant sericite and thin irregular quartz veins occur in fault-brecciated pantellerite at Bunyan's Cove. As stated earlier, the classification of this rock is based on chemical composition alone; typical alkaline minerals of pantellerites are lacking.

3.5.3.4 Geology (6c)

Most sedimentary rocks within the Clode Sound Formation are included in this member. These rocks probably represent localized sedimentary deposition within the volcanic terrain. Along the coast, a maximum of 200 meters of siltstone and sandstone occurs within the basaltic sequence. These are red to green and are intruded by numerous mafic dykes. South of Clode Sound, light-grey well-laminated siltstones and sandstones with intraformational conglomerates are overlain by massive non-bedded red sandstone, pebbly sandstone and conglomerate. This section probably represents the filling in of a local (lacustrine?) basin of deposition.

3.5.3.5 Geology (6d)

This includes two minor steep-sided medium-grained (2-3 mm) diorite to gabbroic stocks (<100 meters in diameter) intruded by diabase. They are probably genetically related to the volcanic rocks.

3.5.4 Charlottetown Formation (7)

3.5.4.1 General Statement

Rocks of this formation were mapped along Clode Sound and along the Bunyan's Cove road. The well-exposed red sedimentary and minor volcanic rocks on the south shore are openly folded and no appreciable section is exposed. However, a minimum thickness of 730meters (using assumed average dip of 15°) has been obtained for the poorly-exposed partial section on the north shore. Jenness (1963) referred these rocks to his undifferentiated middle formation(s) within the Musgravetown Group. They appear to overlie conformably the Clode Sound Formation and are faulted in the west against schists of the White Point Formation.

3.5.4.2 Geology

Near the base of the section lie red, laminated, fine to medium grained sandstone and siltstone, interbedded with pebbly sandstone containing abundant clasts of red siltstone. Above these are grey, massive to thinly bedded siltstone, sandstone and pebble conglomerate. The highest preserved portions of the section at Charlottetown include red, massive to medium bedded pebble conglomerate and cross-bedded coarse grained sandstone. Individual conglomerate beds are of variable thickness. Red to dark grey, finely laminated, locally slumped siltstones are interbedded with conglomerate and sandstone.

These rocks are generally poorly sorted, and the clast population includes green to red sandstone, siltstone, red to grey chert, red rhyolite, altered crystal tuff, minor oxidized basalt, quartz and feldspar, and epidote. Schistose detritus similar to that in the Cannings Cove Formation occurs at several places on the north shore and comprises 1-2% of some outcrops at the northeast end of the Charlottetown peninsula.

Sedimentary rocks with minor included flows of basalt and pantellerite are fractured adjacent to the Charlottetown Fault in Bunyan's Cove. They are brecciated in zones up to 30 cm wide parallel to bedding. Zones or fine networks of quartz veins are common and dark green chlorite or iron oxide is developed on joint surfaces.

Locally a cleavage is poorly developed, and minor aligned sericite occurs along the margins of some clasts in the sedimentary rocks.

3.5.5 Contact Relationships and Correlations

The Musgravetown Group is faulted on the west against schists of the Love Cove Group and in the east is faulted or unconformable upon the Connecting Point Group. The western Cambro-Ordovician basin (Jenness, 1963) has been interpreted by Jenness to overlie the Musgravetown Group. However, there is little or no outcrop in the area of the assumed contact.

These rocks occur in the central belt of the Musgravetown Group (Jenness, 1963). To the north, the peralkaline Traytown

Granite has intruded this belt; it has been dated radiometrically as Carboniferous (D.F. Strong, pers. comm., 1977). Dal Bello (1977) mapped rocks of this same belt to the north and the volcanic rocks there appear chemically similar to those in the present map area. The silicic lavas of this area are distinct chemically from any Precambrian lavas yet studied in the Avalon Zone and appear to show some chemical affinities with peralkaline Carboniferous intrusions and volcanic rocks described from the Burin Peninsula (Strong et. al., 1974, 1976, 1978a).

3.5.6 Interpretation

Following discussions on red-bed fluviatile systems in sec. 3.3.3.7, this sequence can be interpreted as largely subaerial in nature and the sedimentary rocks in terms of a fluviatile model. Literature cited in that section indicates that in a terrestrial environment only alluvial fan or gravelly-braided stream systems include the kind of high proportions of conglomeratic material comprising the lower two members of the Cannings Cove Formation. Sufficient detailed sedimentologic information on various ancient alluvial fan sequences and recent alluvial fans and their respective facies is now available to allow a meaningful comparison with the Cannings Cove Formation (eg. Miall, 1970a, b; Bull, 1972; Boothroyd, 1972, 1976, 1977; Steel, 1974). A number of characteristics of the Cannings Cove Formation, taken together, appear indicative of alluvial fan sedimentation. These are:

1. abundance of clast-supported conglomerates with sandy matrices and lesser sandstones

2. very poor sorting

3. generally poor rounding

4. imbrication and alignment of pebbles

5. local scouring with development of large scale cross-bedding

6. only very minor shales or siltstone.

It is well established that in alluvial fans there is a decrease in average grain size in a down-fan direction and a concomittant increase in the proportion of sand (Boothroyd, 1972, 1976, 1977). The apparent high average grain size of the Cannings Cove Formation sedimentary rocks suggests that they are comprised largely of proximal to mid-alluvial fan sedimentary rocks (Boothroyd, 1977). Further work is needed to refine this interpretation. These data further illustrate the probably local derivation of the detritus in these sedimentary rocks.

Limited information on the Charlottetown Formation suggests that it also was laid down in a fluvial system.

Sedimentary rocks of the Cannings Cove Formation were probably shed off fault scarps. The 495 meter thickness of conglomeratic deposits and basaltic flows suggests that such faults would have been active during the sedimentation, probably with the development of significant relief. They may possibly be represented, in part, by faults now juxtaposing the Musgravetown Group and the Connecting Point and Love Cove Groups. The abundance of relatively fresh volcanic detritus and the intercalated volcanic rocks indicates active volcanism during sedimentation and faulting (?).

The development and nature of this sequence clearly resembles that of the Southwest River Formation. This comparison is further strengthened by the marked bimodality of the volcanic rocks of the Clode Sound Formation. Such bimodal magmatism is widely thought to be diagnostic of rift or extensional tectonics and commonly horst-and-graben development (see sec. 3.3.3.7). Such an interpretation is supported by the peralkaline nature of the associated silicic flows. The occurrence of voluminous peralkaline lavas is most commonly associated with areas of epeirogenic uplift and rift formation on the continents (MacDonald, 1974); their occurrence has been used in areas of calcalkaline volcanicity or compressional tectonics as evidence for the onset of an extensional tectonic regime (MacDonald, 1974; Smith, 1976; Smith et.al., 1977).

The reasons for the distinction between the Southwest River Formation and the Musgravetown Group include: 1. chemical differences between the silicic rocks of either sequence and 2. the occurrence of abundant deformed detritus in the Cannings Cove Formation conglomerates. These points will be discussed in later sections.

9

3.6 INTRUSIVE ROCKS

3.6.1 Dykes

3.6.1.1 General Statement

Dykes in the Love Cove Group are oriented into at least two distinct swarms. The most widespread and abundant dykes trend north-south and consist of green to grey, fine-to medium-grained diabase and diorite. These are concentrated in the White Point Formation (1a) and Unit 2a of the Thorburn Lake Formation (Plate XVII). The other set of dykes has a west-northwest to west-southwest trend. It is largely confined to the Southwest River Formation but mafic dykes of this orientation occur locally in the Blandfords Ridge area in Unit 1a. These dykes are texturally variable and include both mafic and silicic compositions. The relation between the two sets of dykes (N-S versus E-W) is unknown. The pattern of dykes shown in Fig. 1 does not illustrate abundance but merely indicates distribution and orientation.

3.6.1.2 Geology and Petrography

N-S dyke swarm: The north-south dyke swarm within the White Point Formation is about 2.5 km wide and on the north shore of Clode Sound extends from the east side of White Point to the Yudle Cove Peninsula. It retains this width both to the north and to the south of Clode Sound. The dykes are invariably steeply dipping, in general conform to the orientation of the fabric and rarely vary more than 30^{o} in strike form true north. A few of these dykes post-date the steep regional foliation. However most dykes display the fabric, although relatively poorly. They occur throughout the volcanic sequence, and locally cut the northern portions of the Georges Pond granite. Along the coast, rare granite dykes have been intruded by diabase.

These dykes range from less than 1 meter to 50 meters in thickness and locally they constitute 25% of the section. Minor apophyses or offshoots are common and many of the dykes bifurcate, surrounding elongate rafts of the host rock. Such features are indicative of permissive emplacement. The dykes are relatively massive and show rectangular jointing; some are cleaved or schistose in narrow zones. Significantly perhaps, none of these dykes appear to have been folded or affected by boudinage. The apparent lack of folding may indicate that the dykes have undergone only minimal tectonic rotation and had originally steep dips. The lack of boudinage may merely indicate the relative competence of these rocks. However, dykes which have intruded the Georges Pond granite have a penetrative fabric parallel to the margins, while the adjacent granite is massive. Similar relations have been described from the Swift Current granite (O'Driscoll, 1973). Semi-concordant to concordant diabase sills occur locally in Unit 2a and diabase dykes also intrude meta-volcanic rocks of Unit 2c and a small granite plug intruding that unit.

The dykes are green to grey, medium grained (0.3 to 1 mm), and have a brown weathered surface. Some are aphyric, others contain plagioclase phenocrysts which average 3 mm but may reach 1 cm in length. Locally they have chilled margins exceptionally up to 6 cm thick; amygdules up to 1 cm across, containing epidote and quartz, occur adjacent to the chilled margins. In the Blue Hills and Blandfords Ridge, these dykes contain much less veins of epidote and quartz than host rocks of similar composition. Pyrite is a common accessory.

Textures are dominantly diabasic, or ophitic to sub-ophitic in dykes of the Blandfords Ridge area. The primary texture is commonly obscured by secondary minerals including ragged colourless to light green actinolitic (?) amphiboles. The present mineral assemblage consists of varying proportions of sodic plagioclase, actinolite, relics of primary amphibole, <1% to 10% opaque minerals, epidote, chlorite, sericite, minor calcite, locally very minor biotite, potassium feldspar and accessory sphene and apatite. Very minor interstitial quartz occurs locally but may form up to 5-10% of intermediate dykes.

Plagioclase is albitized and partially replaced by sericite and epidote. Some plagioclase phenocrysts contain sparse small inclusions of potassium feldspar.

Actinolite (?) appears to have largely replaced a brown to brownish-green amphibole, minor relics of which are preserved. The actinolite in rocks of Blandford's Ridge has much deeper pleochroic colours (i.e. medium blue green → green → straw yellow) than in dykes along the coast. Very minor brown or green biotite has overgrown the actinolite in both mafic and silicic rocks. All amphiboles and biotite show at least incipient chloritization. Skeletal opaque grains are common; in some dykes they are altered to a hydrous iron oxide. One dyke in Unit 2a contains up to 10% K-feldspar both as interstitial grains and as inclusions in altered plagioclase phenocrysts.

WNW - WSW dyke swarm: All of the dykes in the WNW to WSW swarm may be genetically related. However, as a group they are texturally and compositionally distinct from the dykes above.

Essentially, three distinct kinds of dykes are included here:

1. largely aphyric or sparsely porphyritic diabase
2. mafic dykes with abundant coarse plagioclase phenocrysts
3. felsic and compositionally mixed dykes

1. The diabase dykes are dark grey and aphanitic to fine grained; they are up to 4 meters thick with chilled margins up to 2 cm wide. They intrude rocks of the Southwest River Formation on Watershoot Steady brook, Southwest River and Middle Brook. These dykes have up to 5% white relatively fresh plagioclase phenocrysts up to 1 cm long. The intergranular diabasic textures include feldspar laths ranging in seriate fashion up to microphenocrysts 2 mm long. Intergranular opaque minerals, abundant calcite, minor chlorite and accessory brown biotite complete the mineral assemblage. The biotite appears deuteric and occurs as halos around opaque grains. Small spherical vesicles are filled with chlorite.

2. Dark grey mafic dykes with large feldspar phenocrysts

occur adjacent to the TCH bridge on Southwest River and along the shore of Northwest Arm. They have chilled margins and contain up to 30% phenocrysts of white calcic andesine to labradorite, which range in seriate fashion up to 4 cm and in places up to 10 cm in length. These phenocrysts show a flow alignment parallel to the margins of the dykes. The groundmass consists of an intergranular intergrowth of 70% unaltered normally-zoned plagioclase, 5-10% anhedral opaque oxides, and 10-15% reddish brown slightly pleochroic augite. The augite is locally sub-ophitic but also occurs as acicular crystals intergrown with plagioclase of similar form. The phenocrysts exhibit normal to oscillatory zoning. Ten to fifteen per cent of the rock is formed by chlorite and calcite occurring largely in amygdules up to 2.5 mm across.

3. Pink fine-grained felsic dykes cut Unit 3a. They crop out on the TCH northwest of Thorburn Lake (Loc. 605) and on Southwest River. These dykes have steep dips and are up to 10 meters thick. On the TCH calcite with accessory fluorite occurs in an irregular network of veins in the host rocks. The dykes have an equigranular texture (<0.3 mm), and consist of 45% quartz, 35% partially saussuritized or epidotized sodic plagioclase, 20% potassium feldspar, and in one dyke several per cent partially chloritized green to brown biotite. Accessory minerals are sericite and calcite. The cores of some plagioclase grains have been replaced by K-feldspar and quartz and fine myrmekitic intergrowths are common. The dyke on Southwest River contains numerous

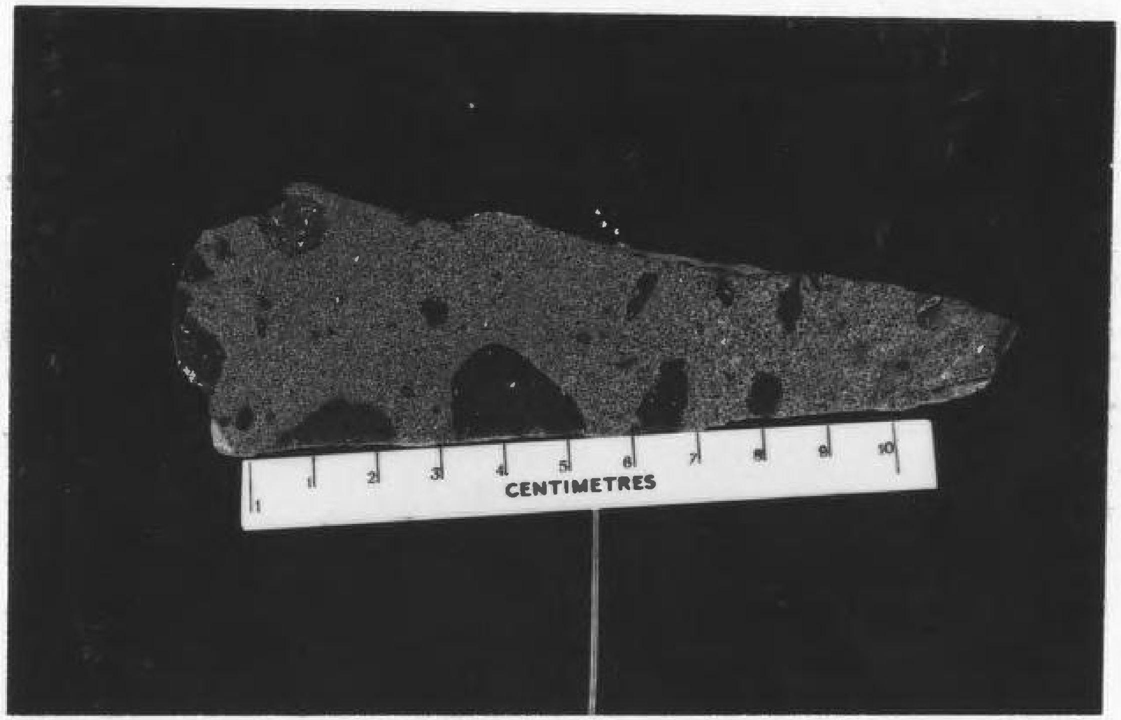


Plate LI: Rounded mafic inclusions in felsite dyke which cuts rocks of Unit 3a.

irregularly shaped, green, fine grained (<0.2 mm) mafic inclusions up to 15 cm long (Plate LI). These inclusions are amygdaloidal, contain sparse plagioclase phenocrysts less than 2 mm long and have very thin chilled margins. The best examples of such associations between acid and basic rocks occur in regions of bimodal magmatism and are thought to result from the mixing of two liquids of contrasted composition (eg. Blake et.al., 1965; Walker and Skelhorn, 1966).

A texturally unique dyke approximately 8 meters thick, striking east-west, crops out at the west end of the causeway in Port Blandford. Its northern margin is composed of fine-grained diabase. The fine-grained equigranular matrix consists of 45-50% altered plagioclase, 25% K-feldspar, 25% interstitial quartz and minor altered biotite microphenocrysts. It also contains quartz-filled amygdules and dark grey chloritic mafic inclusions. Plagioclase and potassium feldspar phenocrysts or aggregates of phenocrysts are up to 4.5 cm long; they are abundant and locally make up to 50% of the rock. Both the plagioclase and potassium feldspar are zoned; mantles of one phase up to 2 mm thick occur around and inclusions up to 3 mm long occur within phenocrysts of the other. The phenocrysts show Carlsbad twinning; their outer portions are commonly altered to epidote and sericite.

3.6.1.3 Age Relationships

N-S dyke swarm: The dykes predate the steep foliation in the Love Cove Group. It is not known how they relate to the numerous diabase dykes in the Connecting Point Group which were only briefly examined. The abundance, concentration and apparently permissive style of emplacement of these dykes suggest a significant amount of crustal dilation. It is difficult to distinguish these dykes chemically from any of the volcanic rocks in the map area.

The volcanic suites and nature of sedimentation in the Southwest River Formation (Unit 3) and the Musgravetown Group are indicative of crustal doming, resultant extension, and horst-and-graben development. The large volume of dykes in portions of the Love Cove Group suggests at least locally significant crustal dilation. Therefore, the bulk of the dyke swarms possibly post-dates volcanism associated with the construction of the White Point Formation volcanic pile, and may be indicative of its disruption and possibly an alteration in the regional tectonic pattern.

<u>WNW - WSW dyke swarm</u>: Alkalic dykes which are mineralogically and texturally identical to the dykes with large plagioclase phenocrysts described above occur in the northeastern Gander Zone and are demonstrably Devonian in age (Jayasinghe, 1978). They clearly post-date a steep foliation which has been correlated with the steep fabric in the Love Cove Group (Blackwood, 1976; Blackwood and Kennedy, 1976). Their relationship to the regional fabric in the present map area is not clear, but by inference the dykes in question are also post-tectonic and possibly of Devonian age. Whether other dykes in this swarm should be correlated in similar fashion is not clear. The felsic and mixed dykes could be related to Unit 3b.

3.6.2 Georges Pond Pluton (8)

3.6.2.1 General Statement

The Georges Pond pluton is a massive to foliated, elongate, dominantly granitoid body which has not been previously reported. It underlies approximately 24 km^2 in the map area and extends southward into the Tug Pond map sheet. It is directly on strike, and could be contiguous, with the northernmost lobe of the Swift Current granite (Jenness, 1963; O'Driscoll, 1973). This body was intruded into the White Point Formation and has been deformed together with it. Rocks typical of the pluton crop out on the north shore of Georges Pond and are well exposed in the barren reaches of Blandford's Ridge and the Blue Hills. In areas of low relief the granite appears as huge frost-heaved boulders.

This pluton has been given a tentative "Cambrian or earlier" age in Fig. 1. This is based on a Rb/Sr date 500 ± 30 Ma (Bell et.al., 1977) for the probably correlative Swift Current granite to the south.

A number of small stocks of diverse composition have been grouped in Unit 8a. These may or may not be genetically related to each other or to the Georges Pond pluton. They are commonly altered and intrude Units 3a, 2a, and 2c.

3.6.2.2 Geology (8)

In the following description, the rock classification used is that proposed by Streckiesen (1967).

This intrusion varies from granite to gabbro in composition. The dominant phase is biotite granite, followed by granodiorite, diorite, quartz diorite, monzonite, granophyre, gabbro, and minor diabase. Aside from xenoliths and dykes no sharp contacts were seen between the various compositional phases of the pluton. Gradational compositional boundaries exist between such phases as granite-granodiorite and diorite. There does not appear to be any regular pattern of distribution of the various phases of this intrusion; only the granophyre appears to be largely confined to the east-central portions of the pluton due east of the Radio Tower. Gabbro, which has a strong geomagnetic expression, is concentrated south of Georges Pond; it is also probably responsible for a similar geophysical high which covers the central portions of Georges Pond.

These rocks are dominantly medium-grained (1-3 mm). Relatively fresh biotite-olivine gabbro and diorite underlie a high hill (Loc. 629) south of Georges Pond. The proportion of mafic minerals varies somewhat throughout the outcrop. At that locality, a minor intrusion breccia contained in the gabbro consists of mafic fragments up to 40 cm across in a leucocratic matrix. Granite dykes cut the outcrop. Diorite or quartz monzodiorite occurs at the north end of Louse Lake (a small NNW-trending lake between Blandford's Ridge and the Blue Hills). The diorites consist dominantly of amphibole or actinolitized pyroxene and altered plagioclase. Pink granite usually carries up to 5% green or brown biotite and is locally porphyritic with microcline phenocrysts 5-10 mm across. Hornblende is a minor accessory, which is more abundant in the granodiorites and diorites. The granophyre is pink with white euhedral to subhedral plagioclase phenocrysts up to 4 mm long.

In the northeast portion of the pluton, there are a few thin very irregular pods of pegmatite and quartz veins (some of them joint controlled) and local epidote alteration. Granite dykes or veins cut various phases of the pluton and its host rocks, including quartz-epidote veinlets in White Point Formation volcanic rocks. Straight, pink, fine grained aplitic dykes which intrude all other phases of the pluton are up to 15 cm thick; on Blandford's Ridge, they trend east-west.

Xenoliths occur in all except the most mafic phases of the intrusion. They tend to be more mafic than their host and are rare in the granite but more abundant in the granodiorite. The granites commonly contain biotite-rich clots. In places the xenoliths are up to 30 cm across and may have rather indistinct margins indicative of at least incipient assimilation. They are generally grey-green, fine grained, mafic to intermediate in composition and locally comprise up to 50% of some outcrops.

Diabase, porphyritic diorite and hornblende gabbro dykes up to 10 meters thick locally cut the granite. Grey rhyolite occurs within the intrusion but its relation to the granite is uncertain.

The contact of the pluton with host rocks was not seen.

However volcanic rocks adjacent to the granite have been thoroughly recrystallized and the resulting hornfels has been overprinted by the steep regional foliation. On Blandford's Ridge, fine-grained mafic to intermediate fragments occur in a fine-grained pink aplitic matrix.

The intrusive rocks range from massive to cleaved with an alignment of chloritized mafic minerals or they are locally schistose and sericitized in zones up to 2 meters wide. Rectangular jointing is common, and may grade into close-spaced jointing with cleavage development. A foliation is most consistently developed in the eastern portion of the pluton. Quartz grains are partially granulated or locally stretched out into elongate wispy shapes.

3.6.2.3 Petrography (8)

Granite is the most abundant rock type in this pluton. It has the following ranges in mineral content: 40-60% quartz, 15-25% microcline, 30-35% altered plagioclase, up to 5% green to brown biotite, and accessory green hornblende, opaque minerals, sphene and apatite. Plagioclase is commonly the coarsest mineral phase, showing complex or simple twinning in anhedral to subhedral grains up to 4 mm long. These are set in a finer matrix of quartz and microcline, which may occur as a granophyric intergrowth. The plagioclase generally has altered cores (sericitized or epidotized) with fresh rims. Anhedral microcline phenocrysts are slightly perthitic and up to 1 cm long. They appear to have grown across primary grain boundaries and include subhedral plagioclase grains. Fresh or chloritized biotite occurs as grains up to 2 mm long or as fine aggregates along grain boundaries or in inclusions. Sphene is typically anhedral or may occur in irregular intergrowths with quartz. Apatite needles are concentrated in biotite and the hornblende is anhedral and pleochroic (green to straw yellow). Granodiorite is gradational with the granite and contains at least 50% quartz, approximately 40% sericitized plagioclase, 5-10% microcline and granophyric intergrowths, and minor fine-grained green biotite.

Quartz monozodiorite in the northern portion of the pluton is composed of 70-75% partially sericitized plagioclase, 10-15% potassium feldspar, 10% quartz, 5% green-yellow biotite, minor epidote, opaque minerals and accessory apatite. The quartz and potassium feldspar are interstitial between larger anhedral plagioclase grains which contain abundant tiny inclusions of potassium feldspar.

The diorites have a typical xenomorphic-granular texture. They are composed of 50-60% clinopyroxene and amphibole. The plagioclase is commonly altered to epidote, sericite and chlorite and the augite is extensively replaced around crystal margins, along cleavage planes and in irregular intracrystalline patches by green-brown hornblende. Both are partly altered to a light green to colourless actinolite, epidote, and chlorite. Opaque oxides form small skeletal grains.

The gabbro occurring south of Georges Pond (Loc. 629) is medium grained (~1.5 mm) and composed of 60% augite, 25%

well-twinned fresh labradorite (An_{55}), 5-10% olivine, 5% brown hornblende with very minor blue green actinolitic amphibole, 5% anhedral opaque grains, minor reddish brown biotite, and chlorite. The augite is subhedral and shows simple twinning. It is partly replaced or rimmed by intergranular brown hornblende which also occurs along cleavage traces and as irregular intragranular patches. The hornblende also forms halos around opaque grains and locally olivine grains (Plate LII). Biotite bears a similar relation to the opaque oxides; locally it is also rimmed by hornblende. The hornblende shows incipient alteration to an actinolitic amphibole and later minor chloritization. The olivine which may include small rounded grains of plagioclase is fresh or altered to opaques, carbonate and iddingsite. Both the augite and hornblende are altered to bright green amphibole in aplitic intrusion breccias.

Granophyre occurs both within the Georges Pond granite and at the east end of Dunphy's Pond where it forms fine to medium grained, steeply dipping granophyric sheets or dykes (?) up to 14 meters thick. These are probably related to the Georges Pond granite and comprise up to 20-30% of the section of the White Point Formation in that area. The granophyres contain up to 15-20% euhedral to subhedral sericitic plagioclase or rounded microcline phenocrysts up to 2 mm across in a largely granophyric groundmass (Plate LIII). Quartz phenocrysts have been largely resorbed. There is dark brown and bright green-yellow biotite, accessory anhedral opaque oxides, sphene, epidote, apatite,

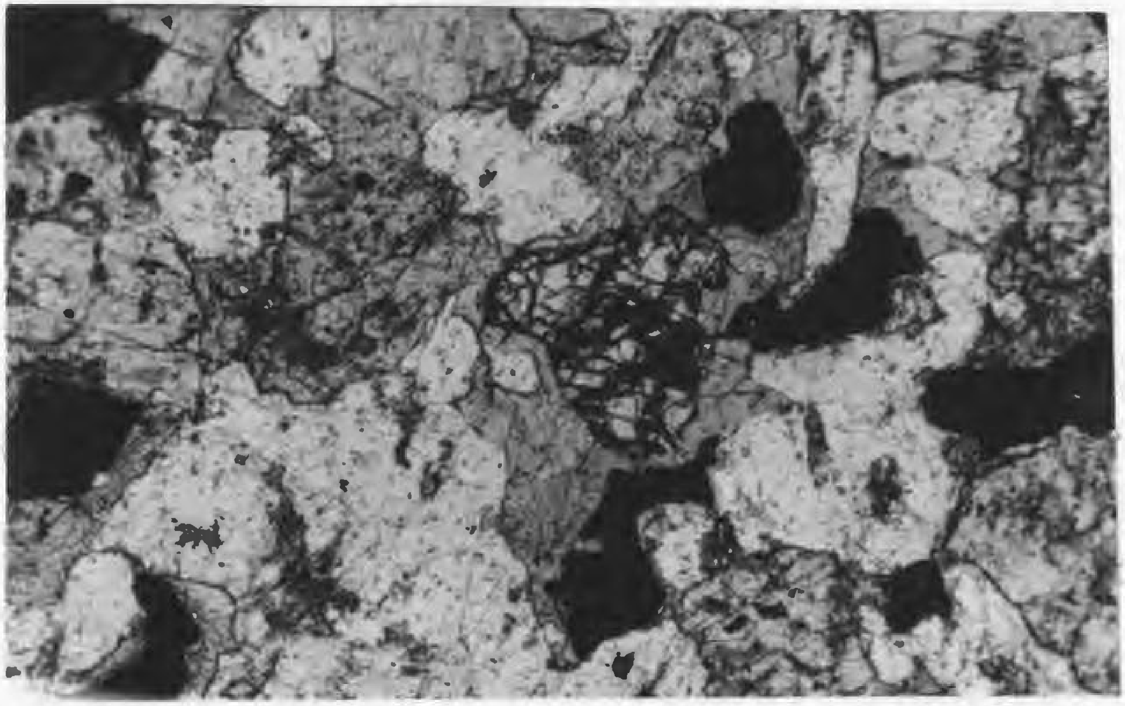


Plate LII: Photomicrograph of olivine gabbro (sample 629C). Note halo of hornblende around olivine grain; p.p.l., x12.5.

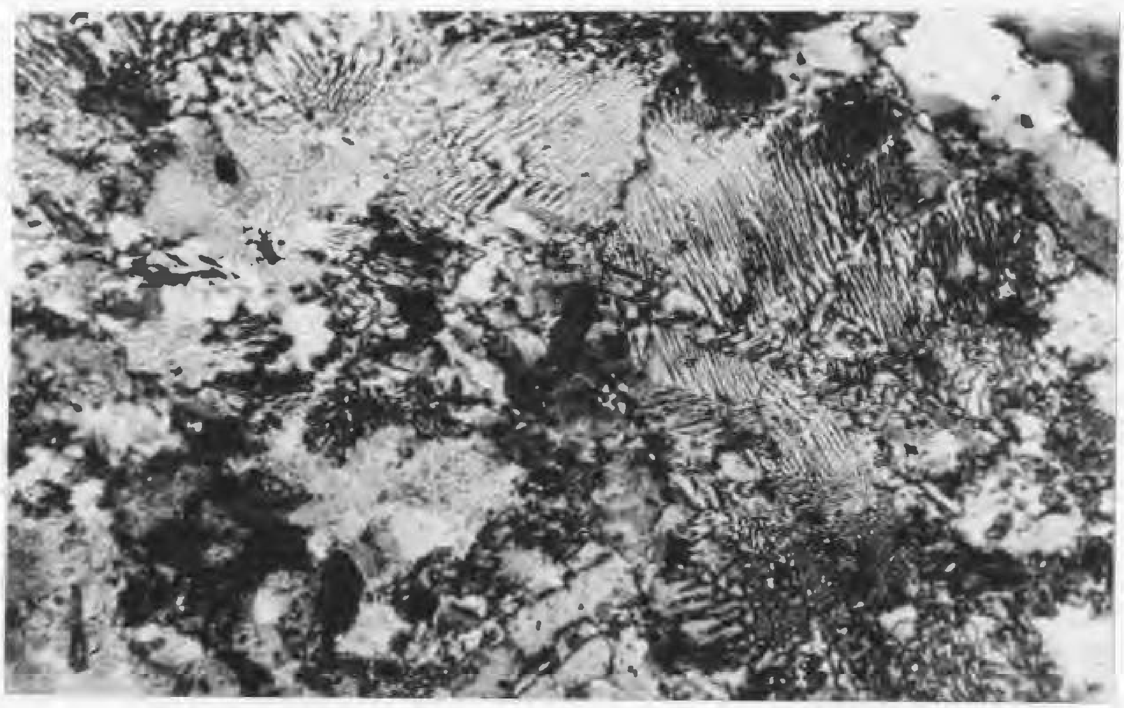


Plate LIII: Photomicrograph of granophyre from the Georges Pond pluton; x-nicols, x50.

Aplites in the Georges Pond granite are composed of 50% quartz, 30% in part perthitic microcline, 15% sericitized albite, 5% bright green-yellow biotite, accessory sphene, epidote, and opaque minerals.

3.6.2.4 Geology and Petrography (8a)

Three separate intrusions are included under this heading. An altered pink, medium-grained (up to 4 mm) syenitic stock occurs in a small steep-sided fault block at the west end of The Narrows. It is composed of altered antiperthitic plagioclase, epidote and 5-10% quartz. The stock has intruded massive volcanic rocks of Unit 2c and both are severely fractured.

A gabbro stock underlies the north side of Middle Point and aeromagnetic data indicate that it is much more extensive to the north. It has steep contacts and has enclosed lenses of sedimentary rock.

A very poorly exposed intrusion occurs in the Watershoot Steadies area. Outcrops range from pervasively altered fine- to medium-grained gabbro to porphyritic diabase.

3.6.2.5 Contact and Age Relationships and Correlations

The contact relationships have been described in previous sections. However, the orientation of the contacts of this pluton in section cannot be surmised from geologic data. Gravity profiles (Weir, 1970) across the southwest contact suggest that it is probably steep and that the granite has a significant extension at depth (H. Miller, pers. comm., 1978).

All aspects of the Georges Pond granite including field relationships, relation to the Love Cove Group, mineralogy, texture and composition appear similar to those of the Swift Current granite to the south. Such a correlation, by inference, includes all the other foliated plutons to the south including the Cape Roger Mountain batholith and the Jacques Fontaine sill (Bradley, 1962) and a number of unnamed granite bodies in the Baine Harbour and Point Enragée map-sheets (O'Brien, 1978a, 1978b). The Anchor Drogue pluton in the Marystown map-area (Taylor, 1977) may also be included here. In this group may also be included silicic volcanic and/or sub-volcanic porphyries in parts of the western belt of the Love Cove Group (Jenness, 1963; R.F. Blackwood, pers. comm., 1978). It is clear from the above that an extensive, voluminous, suite of foliated granitoid plutons is distributed along much of the western Avalon Zone. These intrusions, without exception, are confined to rocks of the Love Cove Group or volcanic sequences which are demonstrably correlative and on strike with the Love Cove Group.

The age of these granites may be estimated from a number of observations:

1. the 500 ± 30 Ma Rb/Sr age determination on the Swift Current granite (Bell et.al., 1977). This date was accepted tentatively for the purposes of Fig. 1. However, the rather high M.S.W.D. (mean square of weighted deviates, 12.8) sheds doubt on the statistical ~~validity~~ of the isochron. In view of

the general agreement (Jenness, 1963; Younce, 1970) as to the late Precambrian depositional age of the Love Cove Group, either the interpretation of consanguinity suggested above is unjustified, or the Lower Paleozoic age of the Swift Current granite could be interpreted as the result of Paleozoic (?) isotopic remobilization. This possibility is in accordance with Lower Paleozoic Rb-Sr age determinations on demonstrably Precambrian volcanic rocks elsewhere in the Avalon Zone (e.g. Fairbairn et al., 1966).

2. relations described earlier (sec. 3.3.1.3 and Hussey, 1978a) suggest a genetic link between the volcanic rocks and the granites.

3. these granites are either pre-or syntectonic with respect to the regional fabric of the Love Cove Group. Therefore, the age of the fabric places an upper limit on the age of the granites. Jenness (1963) inferred a Precambrian age for the foliation, although he thought the Northern Bight granite* to be Devonian in age. Younce (1970) considered the principal age of deformation to be Acadian (Devonian).

4. early correlations of the Swift Current granite and the post-tectonic Ackley batholith (Jenness, 1963) have been discounted on the basis of structural, geochemical, and radiometric age determinations (Bradley, 1962; O'Driscoll, 1973; Strong et al., 1974; Bell and Blenkinsop, 1975; Bell et al., 1977; Hussey, 1978a).

In the light of the above, a late Precambrian age for the Georges Pond granite and its presumed correlatives appears probable.

*renamed Swift Gurrent granite by O'Driscoll (1973)

3.6.2.6. Interpretation

The commonly established sequence in batholiths elsewhere (eg. Hamilton and Myers, 1967; Holz, 1971; Kistler et.al., 1971; Klepper et. al., 1971) shows that progressively younger intrusive phases of the plutons commonly become less mafic, and the bulk of these intrusions is composed of granodiorite and granite (Streckeisen, 1967). An average composition of granite or granodiorite for the Georges Pond granite and other similar granites to the south (Jenness, 1963; Bradley, 1962; Strong et.al., 1974) is comparable to that of the central and eastern Sierra Nevada which is underlain by continental crust (Holz, 1971; Kistler et.al., 1971) as opposed to the Mesozoic dominantly quartz dioritic plutons of the Klamath Mountains and western Sierra Nevada which were emplaced into relatively mafic crust (Holz, 1971) and plutonism of the Carribean island arcs (eg. Kesler et.al., 1977). This suggests that the western Avalon Zone, at least, is underlain by sialic crust.

In the granite and granodiorite, plagioclase consistently appears to have been the initial liquidus phase followed by microcline and quartz. It is difficult to interpret the relations of the mafic mineral phases. Microcline "phenocrysts" occur locally but are anhedral in detail and appear to have overgrown relatively intact plagioclase grains. Hence, potash feldspar appears to consistently have been a late magmatic phase. Also, the granite is subsolvus (Tuttle and Bowen, 1958) in nature. The local abundance of granophyre (plagioclase phyric) is suggestive of epizonal or high level intrusion and crystallization (Hughes, 1960, 1971). This supports suggestions for a genetic link between this granite and the enclosing volcanic rocks. Furthermore, aphanitic quartz and feldspar porphyries are of common occurrence at the margins of the Swift Current granite which also contains granophyres (Hussey, 1978a, 1978b). Similar interpretations of granitic plutons and batholiths have been made in more recent terrains (eg. Hamilton and Myers, 1967; Tabor and Crowder, 1969; Lipman et.al., 1978).

CHAPTER 4

STRUCTURE

4.1 Introduction

The map area is characterized by a roughly north-trending structural grain which is defined by the attitude of both major fold and fault structures. The area can be subdivided conveniently into three major belts on the basis of structural style criteria: 1. the Western belt, 2. the Central fault block, 3. the Eastern belt. The three belts are in fault contact. The Central fault block is bounded by steeply dipping, north trending faults, which may have a significant dip slip displacement component and across which there are sharp structural and metamorphic contrasts.

There appears to be a large variation in the orientation of F_1 fold structures from the Western belt to the Central fault block. The Western belt is dominated by a moderately west dipping structure defined by a major (F_1) asymmetric syncline with an overturned western limb. An associated foliation (S_1) appears to form a convergent cleavage fan within that fold. Fold structures in the eastern portion of the belt are relatively symmetric with steeply dipping axial surfaces.

The Central fault block is characterized by a steeply dipping to vertical structure defined by small scale tight to isoclinal folds (F_1) and an axial-plane cleavage or schistosity (S_1). Bedding is most commonly parallel to S_1. Bedding/foliation intersections and younging criteria indicate the presence of a major syncline (F_1) in rocks of Unit 2b. Later folding and fabric development is of only local occurrence.

The Eastern belt is occupied by gently to moderately west dipping non-cleaved rocks of the Musgravetown Group which unconformably overlie the steeply dipping, tightly folded (F_1) and cleaved strata of the Connecting Point Group.

In this chapter, the structural characteristics (eg. morphology and orientation of folds, foliations, lineations and faults) are described for each of the three belts outlined above (sections 4.2, 4.3, 4.4, and 4.5). A synthesis of the regional structure of the area is given in section 4.6. This includes discussions of the history and nature of the deformation in the area. The structure of the study area is compared with that developed elsewhere in the western Avalon Zone. Figs. 1 and 1.1 present plan and section views, respectively, of the geology and structure of the field area.

4.2 Western Belt

The Western belt occupies the western portion of the field area and is in steep fault contact on its eastern flank with rocks of the Central fault block. To the west it extends beyond the limits of the study area. It is underlain by the western segment of the White Point Formation, the whole of the Southwest River Formation and Unit 2a (Thorburn Lake Formation). This belt is divided into two subareas (X and Y) in Fig. 4.1 (D, E, and F) on the basis of fabric-orientation data.

Folds: Well preserved bedding and abundant younging criteria have made it possible to outline several major folds which dominate the structure of this zone. The folds have maximum wavelengths in the order of 6 km; they plunge shallowly to the north and south, and axial planes dip moderately west in the western portion of this area and steeply east and west to vertically in the east. The main structure (F_1) is a tight asymmetric syncline comprising most of the Southwest River Formation. Its western limb is overturned and here bedding is locally obscured by an intense development of an axial plane foliation (S_1) at a low angle or parallel to bedding (S_0). There are parasitic asymmetric folds with moderately west-dipping axial surfaces ranging from mesoscopic up to 750 meters in wavelength (see Fig. 1.1) within this structure. In the core region, these are tight to isoclinal but they are open to the east (Plate XXV). There is a series of more open folds with steep to vertical axial surfaces, to the east of the major syncline and the axial trace of an open anticline complementary to the major structure is parallel to and locally coincides with a lithologic contact between Units 3a and 2a. Volcanic rocks occupy the core of the anticline in the south. In the north on Dunphy's Pond, a series of large scale F_1 folds with vertical axial surfaces and moderately north-plunging axes tighten up eastward toward the outcrop of the White Point Formation of the Central fault block.

On Northwest River open folds (F_2) of bedding and S_1 occur. These folds have steep or vertical axial surfaces and horizontal axes. There is no associated fabric development (Fig. 1.1; Plate LIV).

Kink bands are commonly developed in schists of Unit 1a, and locally they are associated with a crenulation cleavage. Their relationship to the F_2 structure is unknown.

<u>Axial plane foliations and lineations</u>: The main fabric (S_1) occurs as an axial plane foliation to F_1 folds. Its relation to the folding has been deduced largely from bedding/cleavage intersections and younging criteria. The S_1 foliation appears to form a broad convergent fan in the major syncline described above (Fig 1.1). It is commonly much shallower than bedding (angle of obliquity $\sim 40^o$) on the steep limbs of parasitic folds (Plate XXV). The S_1 fabric is moderately west dipping on the west limb in the core region of the syncline and steep to vertical on the east limb (see Fig. 4.1) where it forms an angle of up to 80^o with relatively gently dipping bedding. In the west (as in the Central fault block) in tuffs and lavas of Unit 1a the foliation (S_1) is variable in grain size from a fine-grained schistosity to a slaty cleavage and from homogeneous to anastomosing in morphology (see sec. 4.3; Plates LX, LXI,

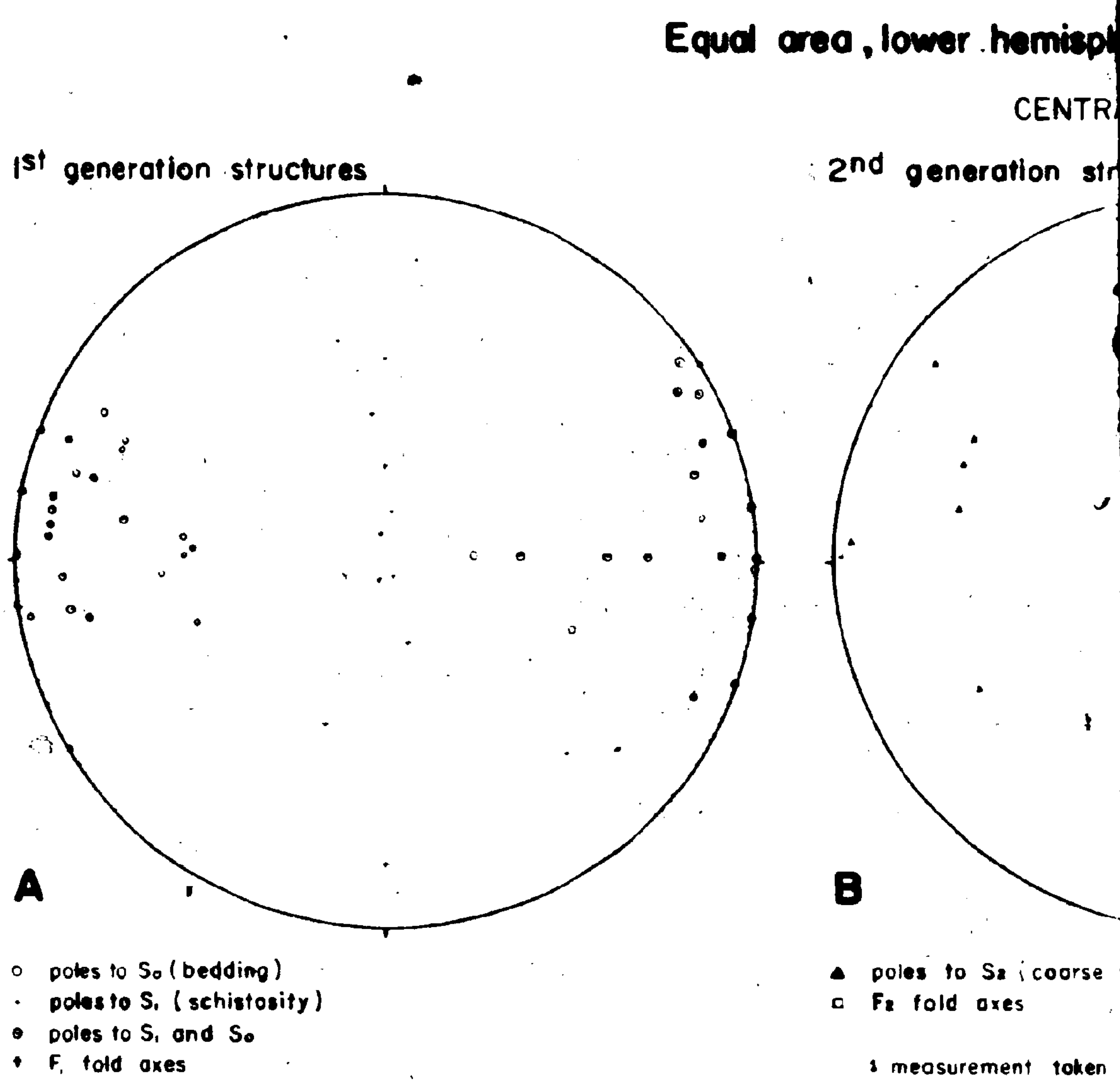

Equal area, lower hemisp
CENTR
1st generation structures
2nd generation str
A
B
o poles to So (bedding)
· poles to S1 (schistosity)
⊙ poles to S1 and So
♦ F1 fold axes
▲ poles to S2 (coarse
□ F2 fold axes
1 measurement taken

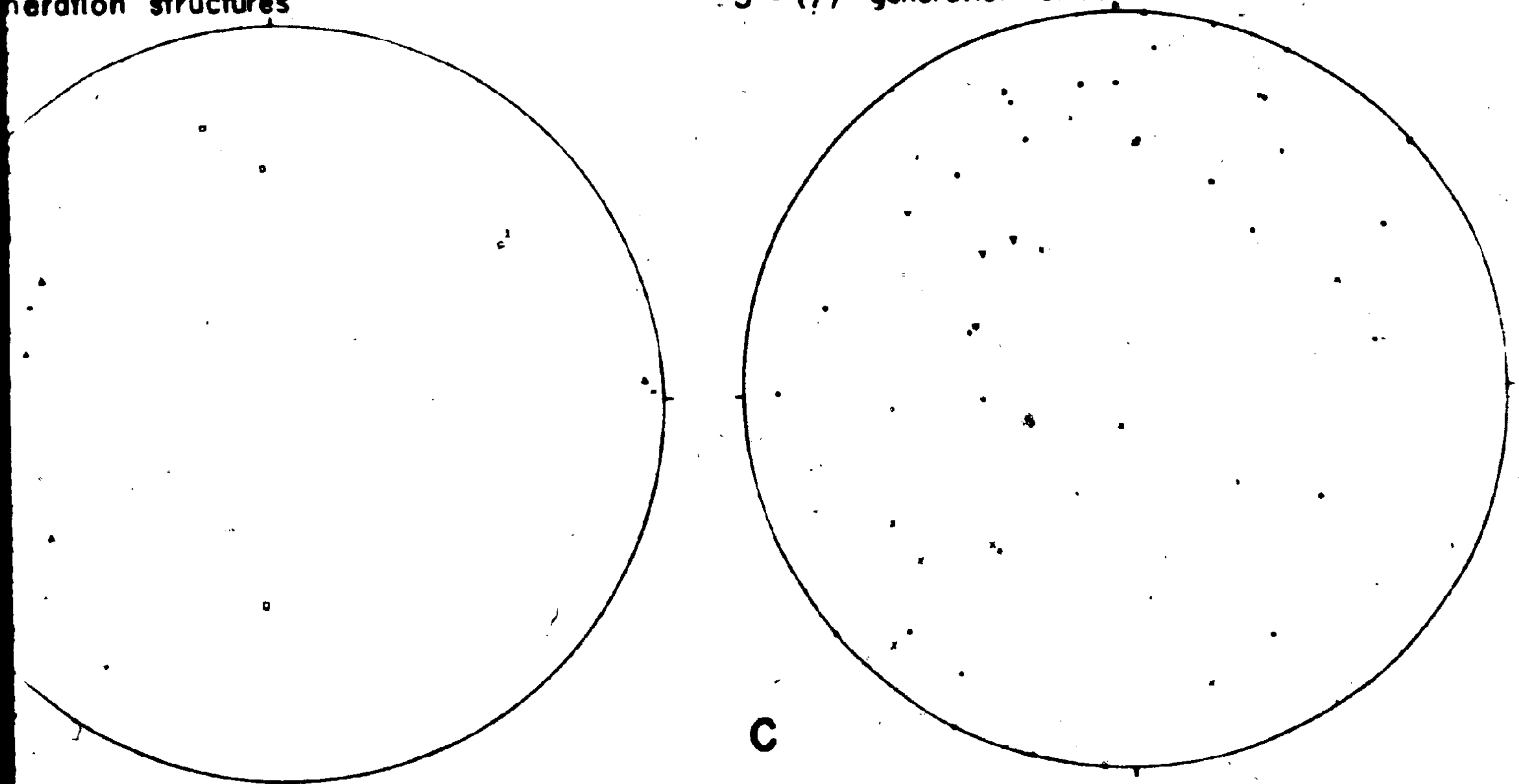
Figure 4·1

r hemisphere projections of structural data

CENTRAL FAULT BLOCK

eration structures

3rd (?) generation structures



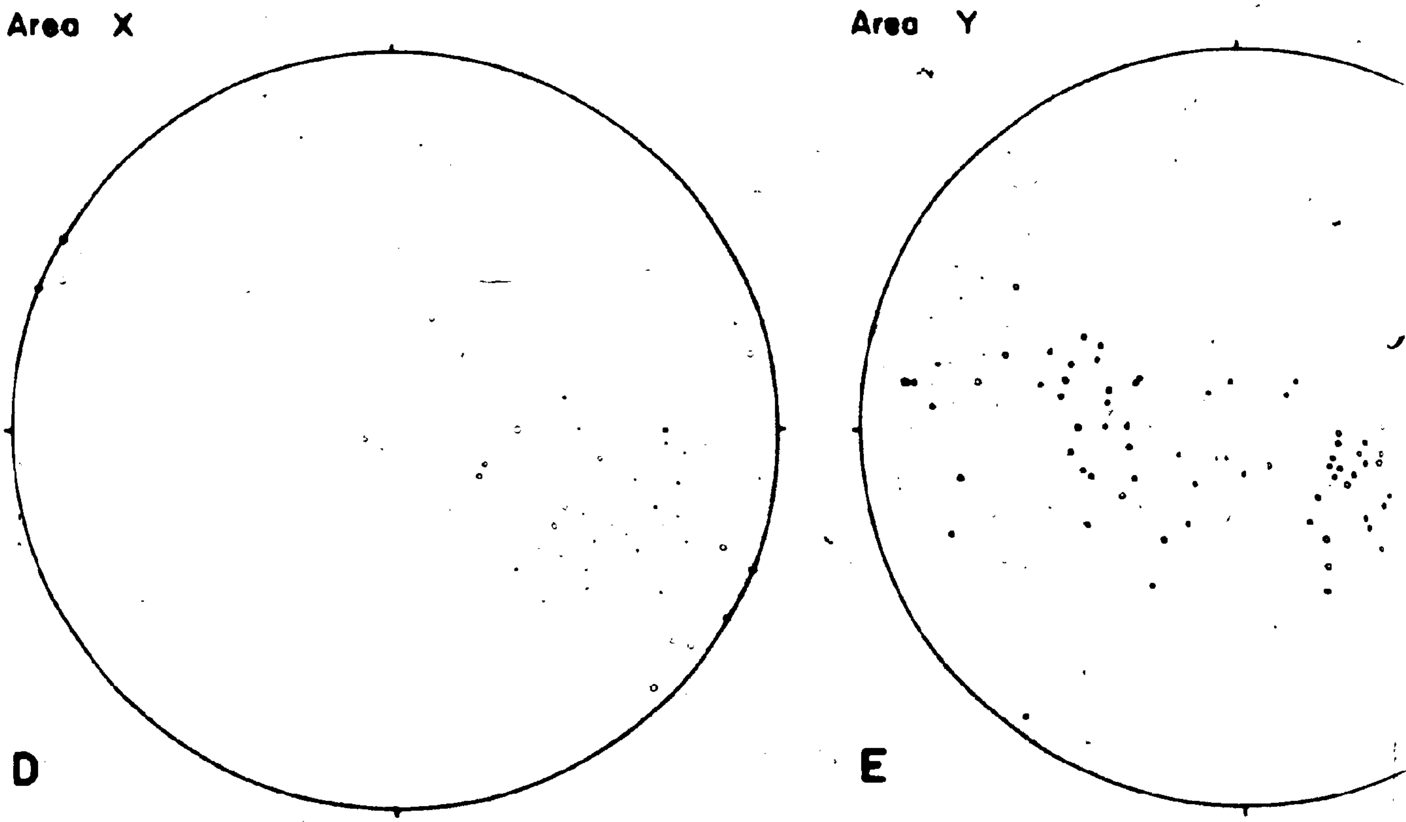
o S₂ (coarse fracture cleavage)
d axes

urement taken adjacent to fault plane

× poles to axial plane foliations related to kinking
● poles to axial planes of kink bands
▼ axes of chevron folds and kink bands

Equal area, lowe

WESTERN ZONE



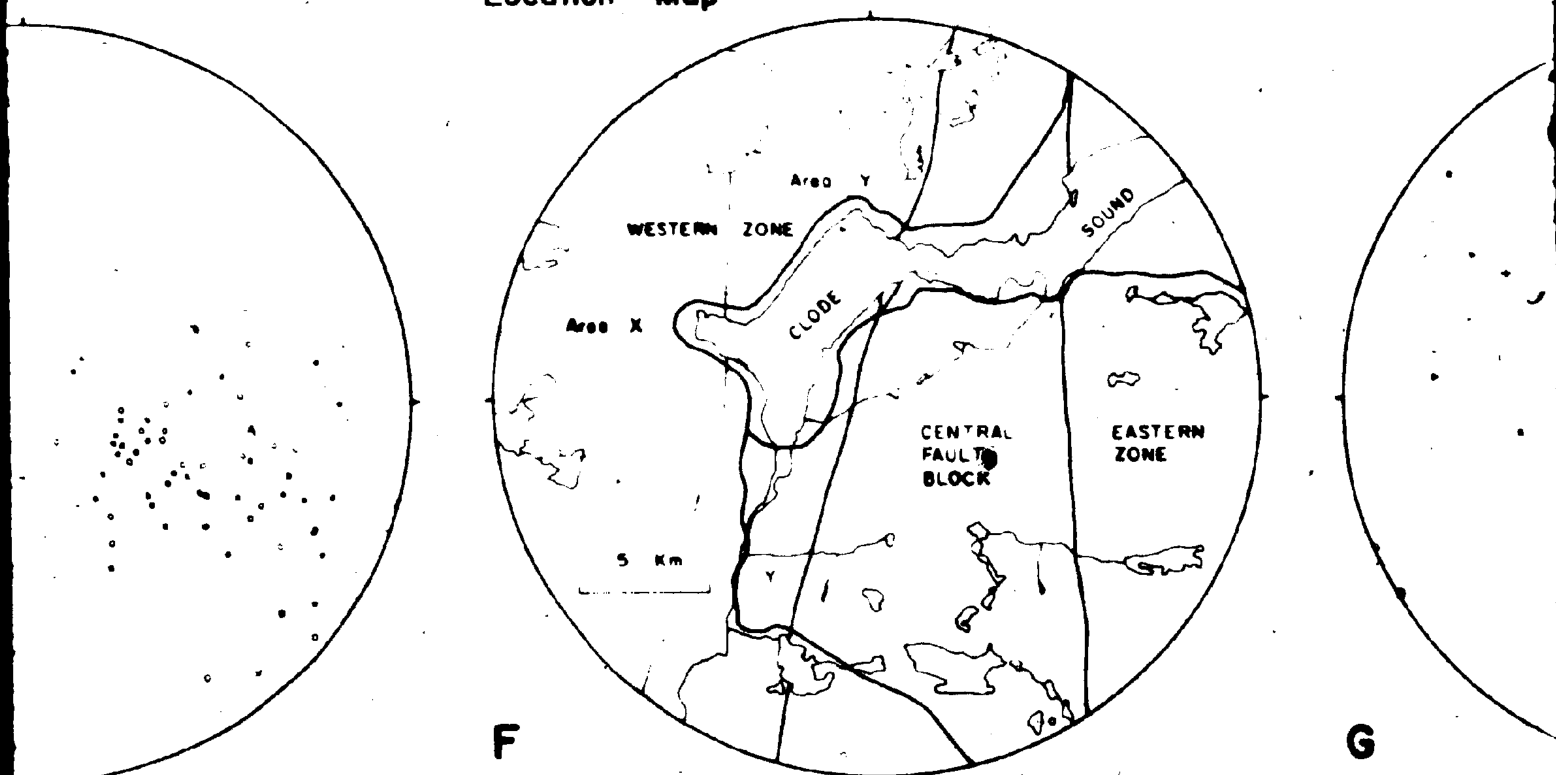
o poles to bedding
· poles to foliation

Figure 4·1

area, lower hemisphere projections of structural data

RN ZONE

Location Map



Connecting Poin

poles to bed

poles to folia

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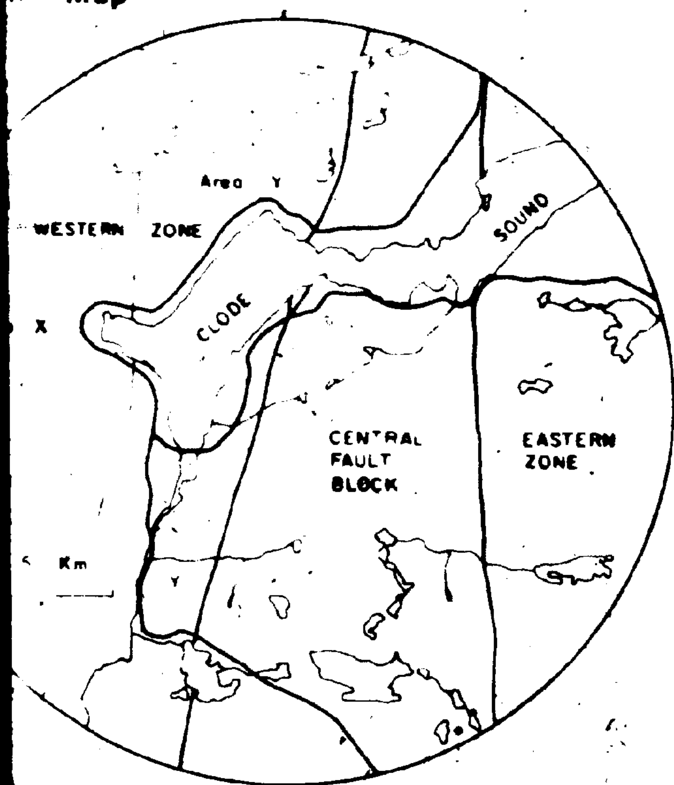
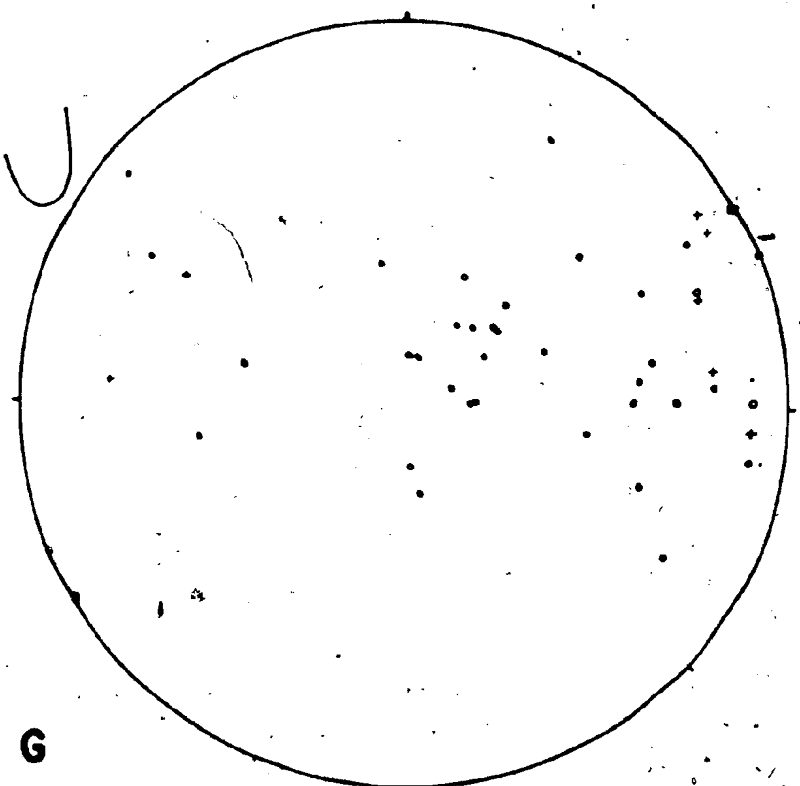
n Map



EASTERN ZONE



G

Connecting Point Group
+ poles to bedding
▫ poles to foliation

Musgravetown Group
◦ poles to bedding
· poles to foliation

Plate LIV: Open F_2 fold of bedding and S_1 foliation on Northwest River. Note hammer and folder in foreground for scale.

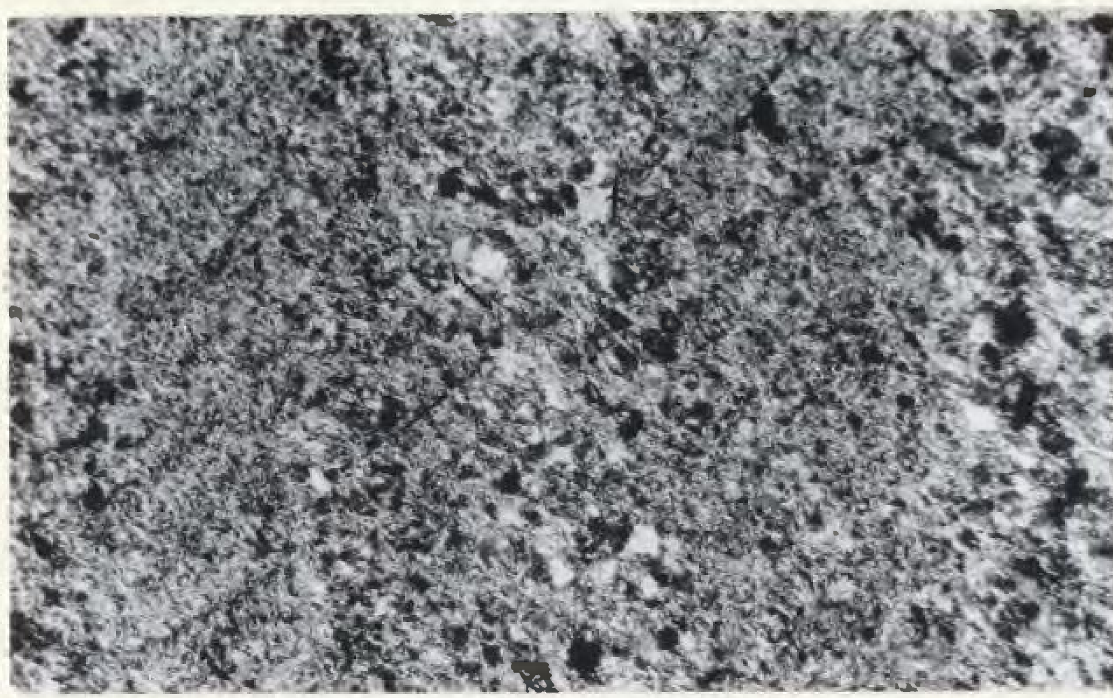


Plate LV: Photomicrograph of cleaved siltstone immediately above the basal conglomerate (3a) on Northwest River (see Plate XXIII). Bedding is vertical, S_1 dips to right and a later crenulation cleavage (S_2?) dips to the left; x-nicols, x20.

and LXII) while siltstone and sandstone of Unit 3a contain a homogeneous planar slaty cleavage defined by sericite (Plate LV). Quartz grains show only minor recrystallization, with lobate to serrated grain boundaries. The foliation occurs as a homogeneous cleavage in local zones to the east and in the Dunphy's Pond area. Locally, clasts in greywackes of Unit 2a are severely flattened in the plane of the foliation. However, in general (in area Y, Fig. 4.1F) S_1 is not developed or occurs as a spaced fracture cleavage as in sandstone beds of Unit 3a (Plate XXIV).

In the eastern portion of the belt, in Unit 2a, a very fine sericitic foliation parallels the gently-to moderately-dipping bedding in some mudstone or siltstone beds and is at an angle to cross-laminae. This could be a metamorphic overprint of the original sediment fabric. Its relation to S_1 is unknown.

Locally a crenulation (S_2?) has overprinted S_1 in pelitic layers of Unit 3a (Plate LV) and in sericite schist of Unit 1a.

In the west, a lineation (L_1) is defined by the intersection of bedding and S_1. It is parallel to F_1 fold axes. An L_2 crenulation lineation is locally developed and is defined in part by the fold axes of kink bands. No stretching or elongation of clasts or any other marker, was observed in association with either lineation.

4.3 Central Fault Block

The Central fault block occupies the central portion of the field area and is bounded by two steep or vertical north-trending faults. It is underlain by the White Point Formation, the Georges Pond pluton and the Thorburn Lake Formation (2b and 2c).

Folds: This belt can be described in terms of a simple fold system with steep to vertical axial surfaces and steep to moderately north and south plunging axes, with the exception of areas occupied by massive to locally schistose volcanic rocks and granite (i.e. Blue Hills and Blandfords Ridge). However, only in the rocks of Unit 2b is it possible to define fold closures in a given section on the basis of younging criteria and bedding/cleavage relationships. In the Thorburn Lake area these criteria were used in outlining an east-dipping, upright, 1300 meter-thick section of greywackes (see sec. 3.3.2.4). The common lack of bedding and absence of younging criteria in the adjacent White Point Formation limits further analysis of the major structure (F_1) in this zone, although evidence presented previously (sec. 3.3.2.4) indicates that the Thorburn Lake Formation (2b) in part overlies the White Point Formation, suggesting that Unit 2b occurs in a tight (F_1) north-striking syncline.

Aside from the inferred large-scale fold, the structure in this zone is defined mainly by relatively small-scale folds. At least two generations of such folds have been recognized in this belt. F_1 folds are seen to fold the primary compositional layering or bedding. The main S_1 fabric, axial planar to F_1 folds, has been folded on F_2

structures. Only the first generation of folds (F_1) is of regional development.

Apparently symmetric isoclinal folds (F_1) with wavelengths up to 25 meters occur in siltstones of Unit 2b and locally in intercalated mafic and silicic tuffs of Unit 1a (Plate XX). Otherwise F_1 folds tend to have wavelengths of less than 2 meters and are asymmetric (S and Z style) in nature. These mesoscopic folds are most commonly very tight to isoclinal. However, there appears to be a lithologic control on fold style. Similar folds are the dominant form in siltstones (Plate XX) and tuffs although chevron-type folds occur in some minor occurrences of banded chert. The axes of these folds trend N-S with only minor deviation and plunge gently to steeply to the north and/or south (Fig. 4.1A). The axial surfaces defined by S_1, are steep to vertical and bedding is parallel or subparallel to S_1 (Fig. 4.1A).

F_2 folds have wavelengths less than 1 meter. They are of chevron style and fold S_1 (Plate LVI). Their axial surfaces and fold axes are similar in attitude to first-generation structures (Fig. 4.1B) and in some cases folds of either generation may be confused. S_1 is kinked and/or chevron-folded on a centimeter scale (Plates LVII and LVIII) throughout the Central fault block. The relationship of S_2 (a spaced fracture cleavage) to this small scale folding is not clear. The kink bands have a wide range of orientations and may occur in conjugate sets. The dominant

Plate LVI: Tight chevron folding (F_2) of S_1 (Central fault block, Unit 1a). South shore of Clode Sound. Hammer is 30 cm in length.

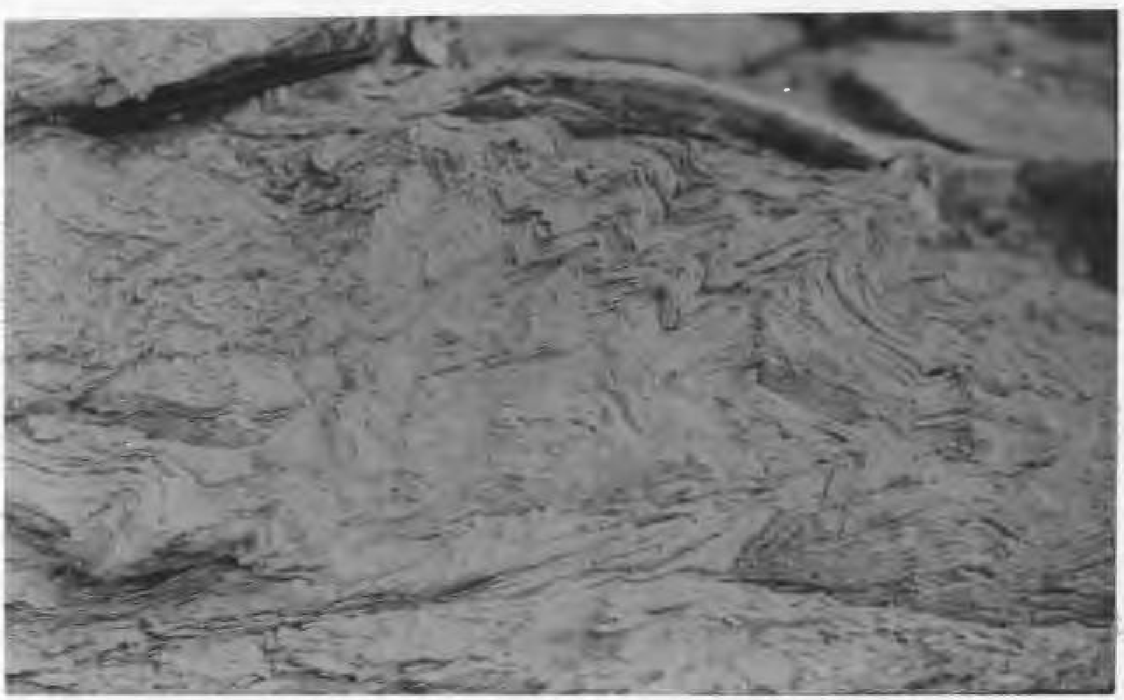


Plate LVII: F_3 (?) kink bands folding S_1 in sericite schist (1a) with development of crenulation cleavage. North shore of Clode Sound. Pen is approximately 14 cm in length.

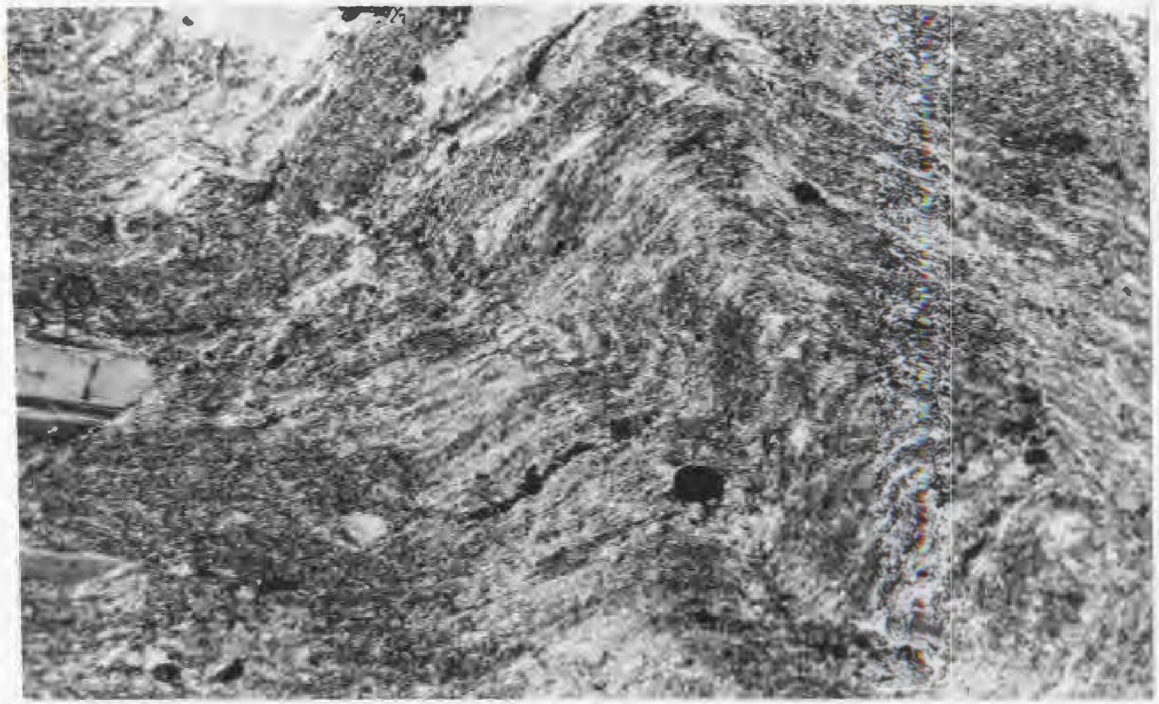


Plate LVIII: Photomicrograph of kink band on S_1 in meta-felsic tuff (1a); x-nicols, x12.5.

Plate LIX: S_1 (?) boudinage of quartz vein. North shore of Clode Sound. Boudin approximately 40 cm in length.

orientation, along with the axial surfaces of the chevron folds is WNW-ESE. The fold axes plunge gently to moderately to the east and/or west (Fig. 4.1C) in contrast to the northern trends of the earlier (?) structures.

Boudinage: Quartz veins oblique to S_1 are asymmetrically folded (F_1) on varying scales; veins at a low angle to or conformable to S_1 commonly show boudinage with prominent pinch and swell structures (Plate LIX).

Axial plane foliations and lineations: S_1 is axial planar to F_1 folds and is most commonly defined by a parallel alignment of sericite and/or chlorite. Grain size in both the chlorite and sericite schists ranges up to 0.3 mm. This fabric is commonly accentuated in the tuffs by flattened fragments or lapilli. The degree of development of S_1 appears to be dependent both on the degree of strain and grain size or texture of the various rock types. For example relatively micaceous rocks, such as sedimentary rocks or tuff tend to exhibit a pervasive schistosity and are commonly essentially chlorite and sericite schists while more silicic rocks such as rhyolite flows or relatively coarse grained mafic dykes or flows are comparatively massive and may show fabric development only on their margins. Hence S_1 varies from a relatively anastomosing slaty cleavage to a more pervasive planar alignment of sericite, chlorite and recrystallized quartz. In siliceous rocks, the quartz occurs as equant grains with curved to sutured grain boundaries while its shape in micaceous rocks is controlled by the growth of micas. Plates LX, LXI, and LXII illustrate three typical fabric morphologies occurring in the Central fault block. S_1 wraps around phenocrysts in porphyritic rocks; in the most recrystallized silicic tuffs, a fine metamorphic layering up to 1 mm thick is composed of alternating quartz-rich and sericite-rich domains. The volcanic rocks and the granite in the south are relatively massive but in places do show a schistosity or fracture cleavage (S_1?; Plate LXIII). In the granite, the fabric most commonly occurs as an alignment of chloritized mafic minerals. S_2 is only locally developed and is a spaced fracture cleavage commonly sub-parallel or at a low angle to the more homogeneous S_1 schistosity or slaty cleavage (Plate LXIV). S_2 strikes north-south and is dominantly steeply east dipping (Fig. 4.1B).

A variably dipping crenulation cleavage, associated with asymmetric kink-band development, is locally well developed and has overprinted S_1, preferentially in micaceous layers (Plates LXV and LXVI). Its relation to S_2 is not clear. The dominant trend is WNW-ESE with mainly steep northeast dips and moderate axial plunges to the northwest (Fig. 4.1C). A similar, probably related foliation on the south shore of The Narrows has a very shallow dip and roughly horizontal axis.

Intersection lineations are common on F_1 folds of well bedded rocks in the Central fault block. There does not appear to be any L_1 elongation of fragments and no mineral lineation was noted. A fine crenulation lineation is locally

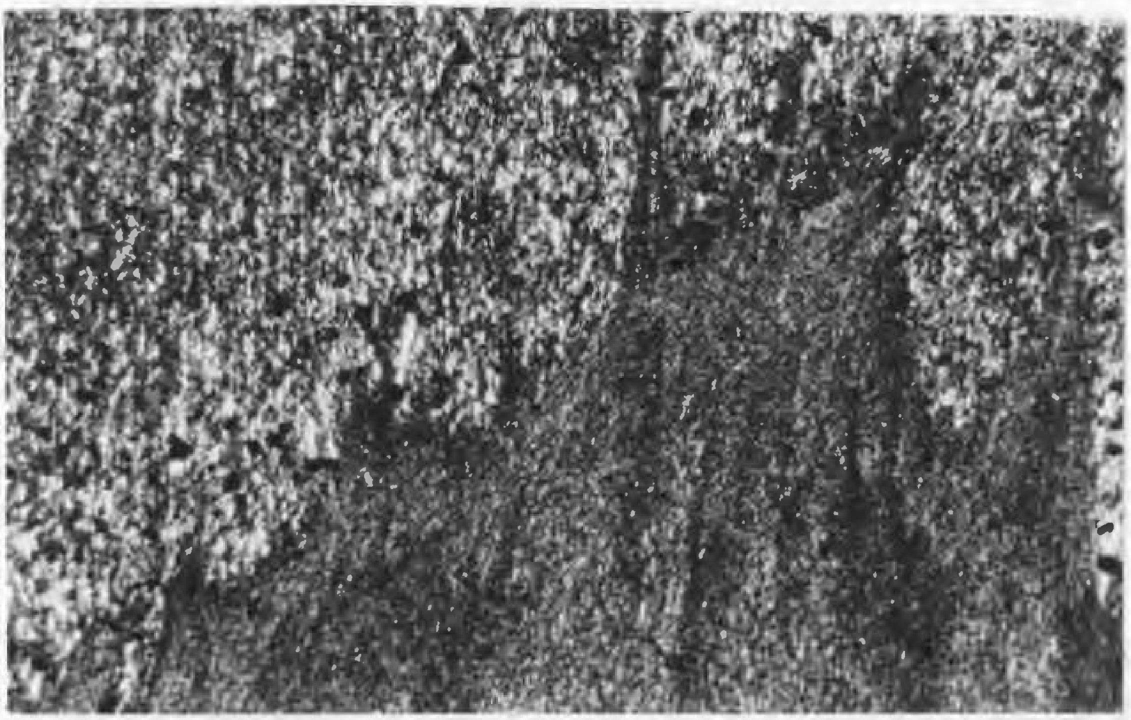


Plate LX: Photomicrograph of F_1 fold in siltstone (2b) with well developed axial planar cleavage. Note intrusion of fine grained bed along cleavage; x-nicols, x12.5.

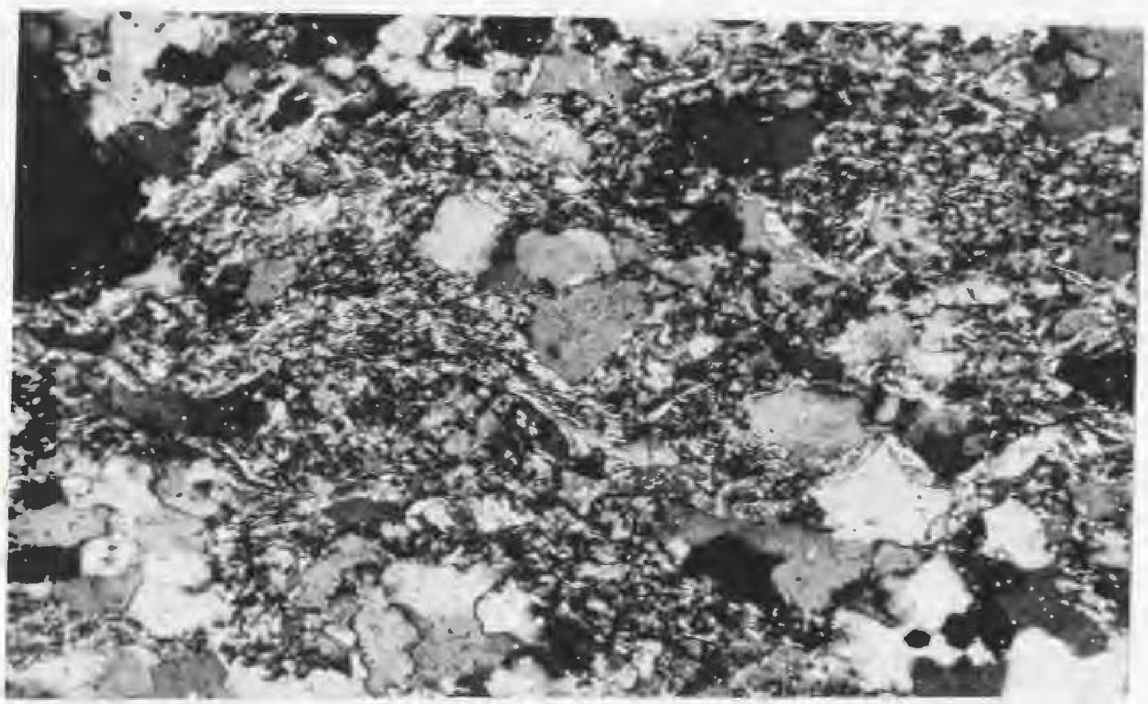


Plate LXI: Photomicrograph of anastomosing S_1 foliation defined by sericite in recrystallized siliceous tuff (1a); x-nicols, x12.5.

Plate LXII: Photomicrograph of S_1 foliation defined by sericite in a porphyritic rhyolite (1a); x-nicols, x12.5.

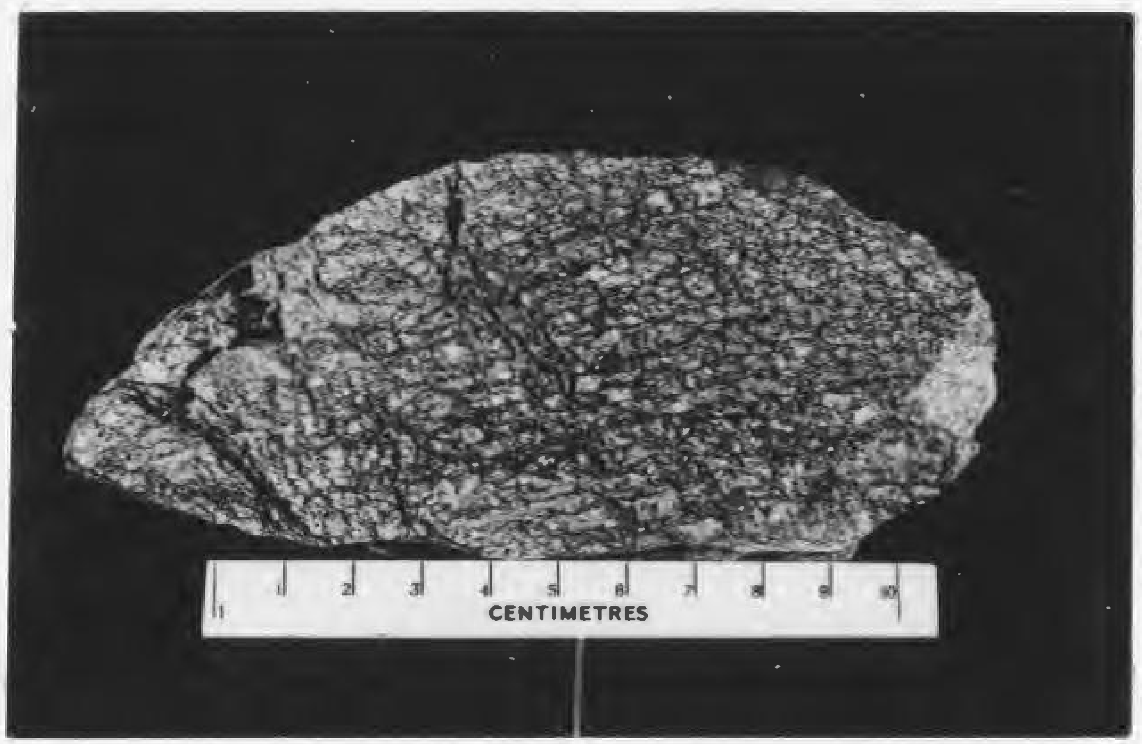


Plate LXIII: Foliated (S_1) Georges Pond granite. Note cross-fracture approximately at right angles to S_1.

Plate LXIV: Fracture cleavage (S_2) at low angle to S_1. South shore of Clode Sound. Pencil is approximately 11 cm in length and is parallel to S_1.

Plate LXV: Crenulation cleavage (S_3?) related to kinking, overprinting S_1. Exposed portion of pencil is approximately 8 cm in length and is parallel to S_1.

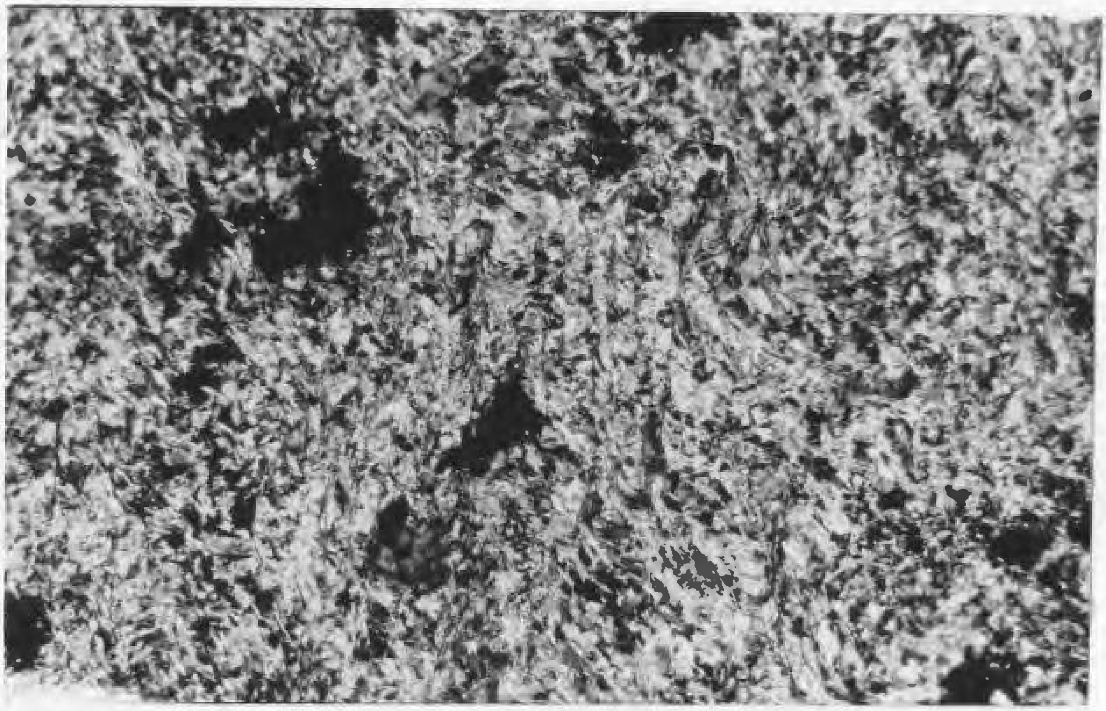


Plate LXVI: Photomicrograph of crenulation cleavage (S_3?) related to kink bands; x-nicols, x12.5.

developed on F_2 folds of the S_1 foliation.

4.4 Eastern Belt

The Eastern belt occupies the easternmost portion of the field area. It is underlain by the Connecting Point and Musgravetown Groups. The Connecting Point Group is never seen in contact with the Love Cove Group (which is in steep fault contact with the Musgravetown Group).

The structure in the Connecting Point Group is similar in style to F_1 structures in the Central fault block. Thin bedded sedimentary rocks of the Connecting Point Group are tightly, asymmetrically folded (F_1) on steeply dipping to vertical north-trending axial surfaces. The fold axes plunge moderately to the north and/or south. The associated axial plane foliation (S_1) usually is a slaty cleavage. The S_1 fabric is locally gently warped.

The Musgravetown Group overlies the Connecting Point Group with angular unconformity (angle of obliquity up to 90^{o}; see sec. 3.4.3; Plate XXXII). The structure of the Musgravetown Group contrasts with that in the Connecting Point Group and in most of the Love Cove Group. Basal green conglomerates of the Cannings Cove Formation are poorly cleaved adjacent to minor faults which have modified the contact with the Connecting Point Group. F_1 structures so typical of the Love Cove and Connecting Point Groups appear to be absent in the Musgravetown Group which is disposed in a west-dipping monoclinal structure. This monocline has a roughly horizontal axis. Bedding dips as much as 73° in the east and is practically horizontal or gently dipping in the west. Some open concentric folding occurs immediately east of Bunyans Cove. A vertical or steeply dipping, poorly developed spaced fracture cleavage has developed locally. There is no discernible mineral growth on it.

In the west, gently to moderately dipping, non-cleaved sandstones and conglomerates of the Musgravetown Group are faulted against steeply dipping to vertical sericite and chlorite schists and penetratively cleaved metavolcanic rocks of the White Point Formation.

4.5 Faults

Three steeply dipping or vertical north-striking faults occur in the map area. Two of these bound the Central fault block, while the third has modified the contact between the Connecting Point Group and the Musgravetown Group west of Bread Cove in the Eastern belt. Contrasts in structure and metamorphism (see chapter 5), in particular across the faults bounding the Central fault block, indicate that these faults have juxtaposed different structural domains.

Gravity data (Weir, 1970) suggest significant normal movement (west side down) on the Western fault (H. Miller, pers. comm., 1978). Its dip is vertical at The Narrows but becomes shallower (west-dipping) in the Thorburn Lake area (H. Miller, pers. comm., 1978). Pink felsites intruded along the fault have been fractured along with sedimentary and volcanic rocks on the downthrown side. Schists in the footwall appear less affected. Structural contrasts across this fault are clearly shown in Fig. 1.1. However, the attitude of the fault appears to conform with F_1 structures in the rocks on either side although the map pattern suggests that S_1 of the Central fault block may be truncated locally by the fault. In the Thorburn Lake area, the metamorphic grade in Unit 3b basalts west of the fault is of the prehnite-pumpellyite facies, while tuffaceous greywackes east of the fault appear affected by greenschist metamorphism. These contrasts can be explained in terms of post-metamorphic juxtaposition of different structural levels. However, further north in the Glovertown area equivalent metamorphic grades and structures prevail on either side of the fault (Dal Bello, 1977). This may imply that the fault has a considerable rotational component.

The steeply-dipping or vertical Charlottetown fault has a marked topographic expression and has produced considerable alteration (incl. silicification), fracturing and folding in schists of the White Point Formation and fracturing, brecciation and possibly folding in volcanic and sedimentary rocks of the Charlottetown Formation. Younce (1970) thought this to be a major wrench fault with variable senses and amounts of net slip displacement along it. Interpretation of the stratigraphy suggests that, at least in this area, there is a significant component of dip-slip movement on this fault.

In the Central fault block, there are numerous fractures parallel to S_1 on which there was probably limited movement. These may be related to the development of the fabric as has been shown for slates of the Welsh Basin (cf., Hobbs et.al., 1976).

4.6 Interpretation

In a regional context and in terms of the original definition of the Love Cove Group, the lithologic sequence and the structural style of the western "band"* of the Love Cove Group appears quite similar to that of the eastern "band" of the group (Jenness, 1963; Blackwood, 1976; Blackwood, pers. comm., 1977). Therefore, the major structures (F_1) developed in the western portion of the present map area, although of somewhat different orientation than elsewhere in the Love Cove Group (as defined here) are thought to represent the same generation as the F_1 structures in the Central fault block.

The contrast in style of folding may be due to regional heterogeneity of strain. Wood (1973) demonstrated the variability in the amount of flattening of reduction spots in steeply dipping Cambrian slates of the Welsh Basin and

*in terms of Jenness' (1963) definition of the Love Cove Group, the Central fault block and the White Point Formation occurring in the Western belt of this thesis, comprise portions of the eastern and western "bands", respectively, of the Love Cove Group (Jenness, 1963) (i.e. compare Map 1129A of Jenness (1963) with Fig. 1 of this thesis).

concomittant changes in the degree of vertical extension. He also found a spatial correlation between large vertical extensions and plunge culminations, and small vertical extensions and plunge depressions, thereby indicating that, at least in the Welsh Basin, variation in fold plunge is largely due to heterogeneity of strain. Such a mechanism may also have been at least partially responsible for the large variation in fold plunges in the Central fault block and elsewhere in the field area.

Moderate westerly dips are not typical of the bulk of the Love Cove Group. However, Jenness (1963) found such dips of the foliation on the east flank of the western "band" of the Love Cove Group and west-dipping bedding in the adjacent Musgravetown Group, from the Clode Sound area (western belt of this thesis) to the southern limits of the belt. Hence, the major asymmetric synclinal structure defined in the present map area may extend southward, approximately 45 km, to the Whitehead Pond area where it is cut off by the Ackley batholith.

The style of structure outlined for the Western belt of the present map area is dominated elsewhere in the western Avalon Zone by thrusting or high angle faulting (Strong et.al., 1978a; O'Driscoll, 1978 ; Younce, 1970). It is probable that the structure depicted in Fig. 1.1 (section A-A′) is associated with thrust or reverse faults to the north where gently dipping cleaved upright sedimentary rocks correlative with Unit 3a are in steep fault contact with sericite schists correlative with Unit 1a. Much of the western limb and core region of the northern extension of the syncline shown in Fig. 1.1 may have been removed on such faults, producing the observed structural contrasts seen in northern Bonavista Bay. (Unit 3a had previously been referred to the Musgravetown Group and Unit 1a to the Love Cove Group of Jenness (1963)). The structural contrasts across faults juxtaposing the Love Cove and Musgravetown Groups (Jenness, 1963) described above, had been used, along with other evidence to be evaluated later, to suggest that the deposition of the Musgravetown Group post-dated the regional deformation of the Love Cove Group. That argument appears to be refuted by the relationships described from the Western belt of the present map area where the western band of the Musgravetown Group (Jenness, 1963) conformably or perhaps disconformably overlies the Love Cove Group (Jenness, 1963). The status of the central band of Musgravetown Group rocks (Jenness, 1963) which underlies much of the eastern structural belt of the present map area is less clear. It is unconformable on the Connecting Point Group but it is in fault contact with the Love Cove Group. Clasts of sericite schist occurring in Musgravetown Group conglomerates are similar to rock types within the Love Cove Group. Discussions of this deformed detritus are deferred to a later chapter.

On the basis of the contrast in the apparent intensity of deformation, Jenness (1963) interpreted the Connecting Point Group to unconformably overlie the Love Cove Group.

However, these two sequences are never seen in contact and the Connecting Point Group consistently lies to the east of the Love Cove Group. Younce (1970) described an eastward decrease in the amplitude of folds within the Connecting Point Group. This may be due to a purely lithologic control on the style of deformation or it could indicate a westward increase in the overall intensity of deformation. It is possible that the principal structures (F_1) in these rocks are of the same age and that contrasts between the two groups are largely a function of their relative structural positions at the time of deformation.

The style of structures described from the Central fault block appears to be characteristic of the Love Cove Group throughout the western Avalon Zone (Jenness, 1963; Dal Bello, 1977; Hussey, 1978). Other sequences tend to be dominated by a simple, open structure, locally with cleavage development although Cambrian and Musgravetown strata on the west side of Placentia Bay have been thrust, overturned and in places tightly folded (Strong et.al., 1976; O'Driscoll, 1978). In the south, on the Burin Peninsula the Love Cove terrain appears to strike into the volcanic terrain of the Musgravetown Group without any discernible break (O'Brien, 1978a, b). The Marystown Group is conformable or disconformable up into Cambrian strata (eg. O'Brien et.al., 1977). The southern portion of the belt of rocks referred to the Love Cove Group (O'Driscoll, 1978 ; O'Brien, 1978a, b) is characterized by an inhomogeneously developed regional foliation (S_1) in which the fabric occurs in discrete zones interspersed with more massive lithologies (O'Brien, 1978a, b). The proportion of schistose rocks decreases southward and the structure in the Marystown Group farther south is dominated by west dipping thrusts or shear zones (e.g. Strong et al., 1976).

In northwestern Bonavista Bay, the steep S_1 foliation of the Love Cove Group is gradational into mylonites of the Dover Fault which juxtaposes the Gander and Avalon Zones (Blackwood, 1976). The mylonitic fabric overprints the gneisses and some of the granites in the Gander Zone (Blackwood, 1976). The age of the fabric is therefore relevant to the timing of significant movements on the Dover Fault and places an upper age limit on metamorphic and igneous rocks in the northeastern Gander Zone overprinted by the fabric. Various lines of evidence to be summarized and discussed fully in the concluding chapter suggest that the regional foliation of the Love Cove Group is Palaeozoic (Acadian?) in age.

However, the unconformity described between the cleaved Connecting Point Group and the Musgravetown Group on Clode Sound can be taken as evidence for Precambrian (Avalonian) deformation assuming that the Musgravetown Group at that locality is in fact, late Precambrian in age. Younce (1970) correlated portions of the Musgravetown Group with the Love Cove Group and therefore considered the Connecting Point Group to be the oldest unit in the area. The unconformity just east of Milner's Cove can therefore be considered the only good evidence for an Avalonian event on the western Avalon Zone. It is not clear what the relationship is between structures in the Connecting Point Group and those in the Love Cove Group as these rock groups are never seen in contact and are generally spatially separated.

CHAPTER 5

METAMORPHISM

5.1 Introduction

A number of distinct metamorphic mineral assemblages occur in the map area. Their distribution and associations are outlined below. It appears possible to relate, in part, the timing of these various associations of mineral growths to specific structural events. However, it should be noted that information on the metamorphic petrology of some units, such as the Connecting Point Group, is incomplete and the following synthesis of the patterns of the metamorphism in the field area may be subject to future revision.

Mafic volcanic rocks and/or pelitic sedimentary rocks occur in all groups in the map area and studies of their metamorphic petrology are useful in outlining the distribution of the various metamorphic facies.

Albite, chlorite, epidote, calcite, iron oxide and minor quartz, in various combinations and proportions, occur in mafic igneous rocks throughout the map area. However, some phases of the Georges Pond pluton and some diabase dykes in the Southwest River Formation are relatively unaltered. Sericite and/or chlorite and epidote are developed in most sedimentary rocks in the study area. These metamorphic assemblages are in association with more diagnostic minerals in specific portions of the area. In basalts of Unit 3b (Southwest River Formation), these minerals are accompanied by prehnite and pumpellyite. In addition, prehnite has been identified in the field in Unit 6a (Musgravetown Group). Actinolite occurs in mafic dykes cutting Unit 2a, but otherwise appears to be restricted to volcanic rocks of the Central fault block. It is best developed in mafic to silicic rocks in the vicinity of the Georges Pond pluton. Stilpnomelane is restricted to the White Point and Thorburn Lake Formations of the Central fault block. To the north in the Glovertown area, biotite occurs in correlatives of Unit 2a to the west of the northern extension of the Central fault block (Dal Bello, 1977).

The prehnite-pumpellyite isograd is difficult to define since sample data are limited (2 localities in Unit 3b) and mafic compositions are sparse elsewhere in the Southwest River Formation. Sedimentary rocks of Unit 3a typically contain sericite and minor calcite and chlorite. However, it is clear that the prehnite-pumpellyite isograd falls no farther east than the fault bounding Unit 3b. It may be restricted to the south side of Clode Sound since mafic dykes intruding Unit 2a on the north shore contain secondary actinolite. Limited data on the Musgravetown and Connecting Point Groups suggest that mineral assemblages in these units indicate low metamorphic grades but do not specify any particular facies. The location of the biotite isograd in the field area is difficult to place on the basis of the data available, but appears to fall within the faults bounding the Central fault block although this is not strictly the case to the north (Dal Bello, 1977).

In general, there is a rough correlation between metamorphic grade and the intensity of deformation and therefore a correspondance between the structural and metamorphic zones. The Central fault block is exclusively the site of the highest metamorphic grades in the study area. The prehnite-pumpellyite zone encompasses the least deformed strata in the area, in the southeast portion of the Western belt and possibly in the Musgravetown Group of the Eastern belt; these rocks occur in the uppermost portions of the stratigraphic column. Lower greenschist mineral assemblages appear to dominate much of the Western belt (in the Northwest River area) and the Connecting Point Group of the Eastern belt.

In the following sections, the metamorphic mineral assemblages in the area are described both in terms of rock composition (i.e. mafic, silicic, and sedimentary rocks) and their relation to the structural development of the area.

5.2 Mineral Assemblages

Mafic compositions: All mafic volcanic and hypabyssal rocks of the Central fault block are composed largely of chlorite, epidote, albite, calcite, iron oxide and minor quartz and sericite in varying proportions. Quartz and calcite commonly occur in thin veins. In addition, colorless to pale green actinolite (up to 2 mm) occurs as a replacement

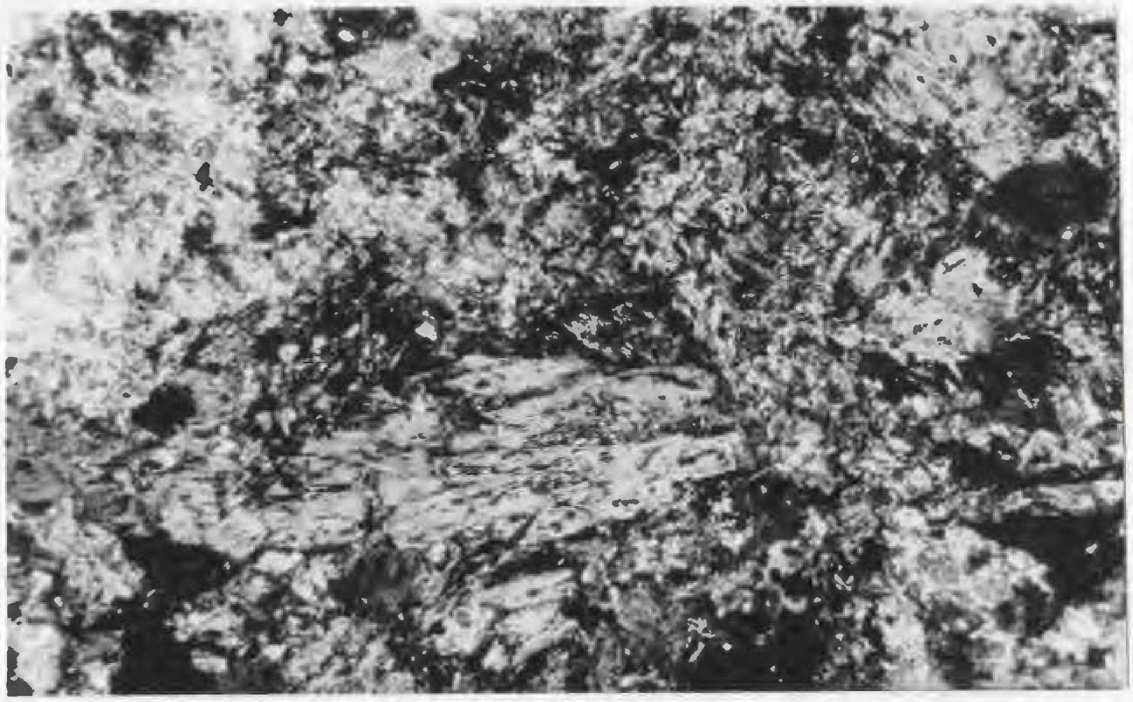


Plate LXVII: Photomicrograph of actinolite developed in mafic dyke (N-S swarm) in Unit 2a. North shore of Clode Sound; x-nicols, x12.5.

Plate LXVIII: Photomicrograph of post-kinematic (post S_1) stilpnomelane rosette in deformed rhyolite; x-nicols, x50.

of pyroxene in dykes within Unit 1a and in mafic to intermediate flows in the Blue Hills and Blandfords Ridge. It commonly occurs as ragged randomly oriented grains which have grown across grain boundaries of primary pyroxenes (Plate LXVII). In places it is partially chloritized. The dykes and massive volcanic rocks also contain accessory green to brown biotite and minor K-feldspar. Primary feldspar has been replaced by epidote, calcite, and albite.

Mafic flows of Units 3b and 6a typically contain albite, chlorite, epidote, calcite, iron oxide (largely hematite) and hydrous iron oxide. The chlorite, epidote, calcite and hematite occur both in amygdules and in the groundmass. Prehnite and pumpellyite were not seen in thin sections in basalts of Unit 6a but in basalts of Unit 3b they occur both in amygdules and the groundmass.

Silicic compositions: Silicic tuffs and flows of Unit 1a contain variable proportions of albite, quartz, sericite, minor chlorite, locally abundant epidote, minor stilpnomelane and locally actinolite (with minor green biotite) in silicic breccias in Blandfords Ridge. Primary plagioclase has invariably been replaced by epidote or sericite and albite.

Secondary mineralogy in silicic rocks of the Southwest River Formation (3b) and the Musgravetown Group (6a, 6b) is sparse. Unit 3b rhyolites contain minor sericite, piedmontite, minor epidote, and hematite while rhyolites (pantellerites) of Units 6a and 6b contain minor sericite, chlorite, calcite and locally minor siderite.

Mafic minerals in the various phases of the Georges Pond pluton are partially to wholly chloritized, and locally the feldspars are extensively saussuritized.

Sedimentary rocks: Tuffaceous greywackes and siltstone of the Thorburn Lake Formation typically contain abundant chlorite, epidote and lesser sericite. Accessory green biotite occurs in the southern portions of Unit 2b The matrix of red sedimentary rocks of Unit 3a commonly includes abundant sericite and smaller amounts of calcite. Minor secondary sericite occurs in sedimentary rocks of the Musgravetown Group.

Abundant sericite, minor chlorite and epidote were seen in phyllite of the Connecting Point Group.

5.3 Relationship of Mineral Growth to Fabric Development

The S_1 foliation of the Love Cove Group (and of the Connecting Point Group) is invariably defined by sericite and/or chlorite. However, sericite and chlorite may be disoriented in the strain shadows of phenocrysts. In the Love Cove Group, a pronounced S_1 shape fabric of quartz in metatuffs and sedimentary rocks (Plate LX) has apparently been controlled by a preexisting mica alignment. At other localities, quartz has recrystallized to form a polygonal texture in some meta-silicic tuffs. The chlorite and/or sericite which define S_1 are buckled and locally realigned on later crenulation cleavages.

The relation of actinolite growth to fabric development is not clear since it tends to occur in massive, non-foliated rock types. A large proportion of the actinolite, in particular in the Blue Hills and Blandford's Ridge could be associated with a contact metamorphism (pre or syntectonic?) adjacent to the margins of the Georges Pond pluton.

Stilpnomelane is most common in silicic volcanic rocks of the White Point Formation. Brown to reddish-brown stilpnomelane occurs as tiny post-kinematic rosettes (<0.3 mm) which have grown across S_1 (Plate LXVIII), or mimetically in S_1 or along fractures subparallel to S_1. It has also crystallized on biotite microphenocrysts previously pseudomorphed by epidote and opaque minerals. The relation of the stilpnomelane to the S_2 fracture or crenulation cleavages is not known.

The relationship of prehnite-pumpellyite facies metamorphism of Unit 3b and low grade metamorphism of the Musgravetown Group to fabric development in the map area is unknown since these rocks are non-foliated.

The major faults bounding the Central fault block now juxtapose rocks of widely contrasted metamorphic grade, implying that there may have been a significant movement on those faults. The occurrence of biotite-grade metamorphic assemblages to the north on either side of the western fault suggests a component of rotational movement on that structure. However, it appears that after regional metamorphism affected this area, the Central fault block acted as a horst with substantial uplift, relative to adjacent structural belts.

5.4 Interpretation

The grade of metamorphism in the redefined Love Cove Group is, in part, a function of depth in the stratigraphic section, the ~~lowest~~ grades (prehnite-pumpellyite facies) prevailing in the Southwest River Formation.

Post-F_1 stilpnomelane growths, similar to that described above, have been reported to the south in the northern Placentia Bay area (Hussey, 1978b) from correlatives of Units 2b and 1a. Dal Bello (1977) reported green biotite to the north from correlatives of Unit 2a. It is clear that the main deformation (F_1) of the Love Cove Group was accompanied by metamorphism of lower greenschist-facies grade, and that lower-most greenschist facies temperatures were maintained for a time post-kinematically.

CHAPTER 6

CHEMISTRY

6.1 Introduction

It is clear that geochemical studies concerning a number of geological environments can be truly meaningful only if there is a concomittant understanding of the stratigraphy and field relations. In this case, the chemistry is used only as a supplement to field and petrographic studies; considering the number of analyses per unit, the chemical data are of a preliminary nature only, and conclusions drawn from them should therefore be regarded as tentative. However, even with these reservations, a number of relatively clear distinctions, trends and affinities can be recognized.

For this study, sixty-seven (67) complete major element and trace-element analyses have been done including data for Zr, Sr, Rb, Zn, Cu, Ba, Nb, Ga, Pb, Ni, Cr, V, and Y (see Appendix 4). Sample locations are given on Fig. 1. Analyses are given for the three major volcanic units, associated dykes and the Georges Pond pluton.

This study along with that of Malpas (1971) and Dal Bello (1977) represents the only geochemical work on volcanic rocks in the northwestern Avalon Zone. The granitic rocks in that area were included in the regional geochemical study of eastern Newfoundland granitoid rocks by Strong et.al.

(1974).

Many authors agree that ash flows represent mechanically fractionated derivatives of their parent magma and that therefore their chemical composition, either in whole or in part, is not representative of the parent magma (eg. Hay, 1959; Lipman, 1967; Sparks et.al., 1973; Sparks and Walker, 1977). On this basis, ash flow tuffs and other pyroclastic and related sedimentary rocks were largely avoided in selecting samples for geochemical studies in the present work. Thus, chemical analyses presented here include mainly flows and intrusive rocks, and are intended principally as an aid in deciphering the magmatic lineage, especially where field or petrographic evidence is not sufficiently specific. The patterns of distribution of major and trace elements for each igneous suite are compared and contrasted on a number of binary plots.

The rest of this chapter is divided into a number of sections dealing with alteration in the rocks in general and with the geochemistry of each of the distinct rock units in particular. A number of conclusions are drawn concerning the geochemical affinity and relations of the various suites using those elements that are believed to be least affected by metasomatic changes.

Analytical methods, along with precision and accuracy data for both major and trace element determinations are presented in Appendix 2. The raw major and trace element analyses and recalculated anhydrous analyses (with adjusted Fe_2O_3/FeO) and derived C.I.P.W. normative compositions of these rocks are presented in Appendix 4.

6.2 Alteration

All igneous rocks in the map area have suffered some alteration, and in the volcanic rocks it is commonly severe. The intrusive rocks and some of the Musgravetown Group basalts appear to be least altered; some gabbros contain relatively unaltered olivine, pyroxene and plagioclase. Secondary processes affecting the igneous chemistry of the altered rocks include: (a) chemical changes contemporaneous or associated with eruption and various surficial processes; i.e. fumarolic alteration, glass-crystal alkali exchange and ground-water leaching (with devitrification?), oxidation, late magmatic or deuteric alteration in intrusive rocks; (b) ionic transfer and oxidation during low-grade metamorphic recrystallization; (c) weathering.(This has largely been avoided in sampling and is of no significance here.). It is difficult to distinguish between the effect of either of the two former processes and hence they will be treated together.

Indications of the degree of alteration suffered by these rocks include the nature of the secondary mineralogy, the Fe_2O_3/FeO oxidation ratios (Fig. 6.1), Loss on Ignition (LOI) levels (Fig. 6.2), and variations in alkali content

(Fig. 6.3).

Secondary mineralogy: Elemental mobility, in particular of the alkalies, and addition of H_2O and CO_2 is suggested by the filling of amygdules with chlorite, epidote, and calcite and by the replacement of plagioclase by sericite or by albite and calcite or epidote. In some basalts (Unit 3b, 6a) the cores of some plagioclase laths have been replaced by chlorite indicating leaching of CaO* and Na_2O. In addition, albite phenocrysts in silicic rocks of Unit 6 and locally Unit 3b commonly show a "chequer-board" texture (Plate XLIX) suggesting replacement of potash feldspar by albite (Battey, 1955). Veins composed of quartz, epidote, and locally chlorite are also evidence for at least local metasomatism. Silicification is of only local importance and was largely avoided in sampling.

Oxidation: Fig. 6.1 shows the wide range in Fe_2O_3/FeO values in rocks of the study area, particularly in basalts of Units 3b and 6a where a hematite stain is commonly developed. The occurrence of Liesegang bands may indicate limited mobility of iron associated with weathering or groundwater percolation (Singer and Navrot, 1970). The degree of saturation or undersaturation of the normative composition of mafic igneous rocks is strongly influenced by the level of oxidation of their iron content. Hughes and Hussey (1976) and Brooks (1976) reviewed the corrections for the Fe_2O_3/FeO ratio used by various authors for a range

*these basalts are corundum-normative

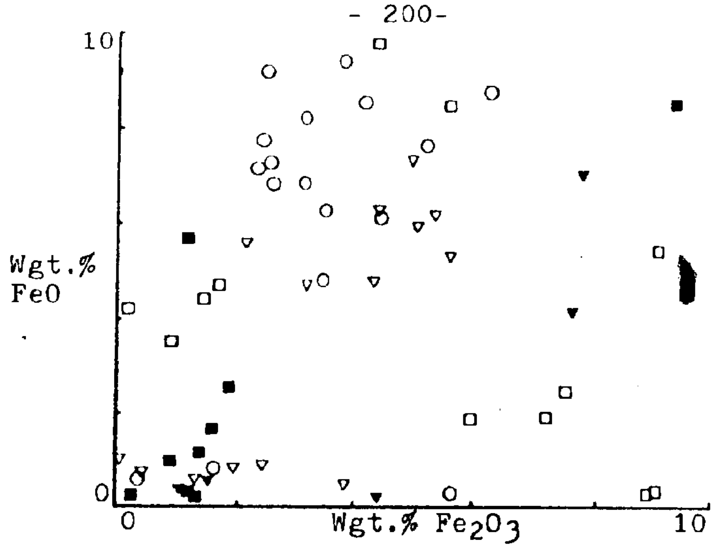


Fig. 6.1 - Variation in oxidation state of Fe in rocks of map area.

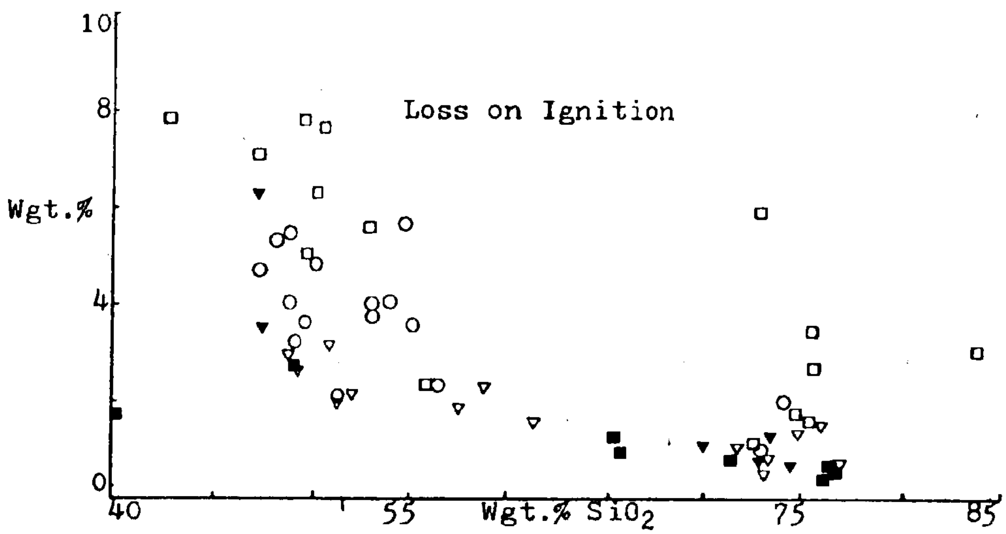


Fig. 6.2 - Relation of Loss on Ignition to SiO_2 in rocks of map area

White Pt. Fm. - ▽
Georges Pd. pluton - ■
SW River Fm. - ▼
Clode Sd. Fm. - □
Dykes - O

of basaltic rocks from a number of environments and both made appeals for a standardized procedure. Hughes and Hussey (1976) suggested a ratio of $Fe_2O_3/FeO + Fe_2O_3 = 0.20$ ($Fe_2O_3/FeO = 0.25$) while Brooks (1976), working largely with tholeiites, suggested $Fe_2O_3/FeO = 0.15$ for mafic volcanic rocks. Hughes and Hussey (in press) indicate that a reconciliation of these two viewpoints and adoption of the mean of the two ratios yields a more useful value ($Fe_2O_3/FeO = 0.20$). This is somewhat high for tholeiites and low for alkali basalts but in sequences of uncertain affinity the adoption of such a standard value may prove useful. Hence, the recalculated analyses have been adjusted to $Fe_2O_3/FeO = 0.20$. Adjustments for other rock types are given in Appendix 3.

<u>Loss on Ignition</u>: Fig. 6.2 shows the generally inverse relationship between SiO_2 and Loss on Ignition. LOI is highest in volcanic rocks and some mafic dykes affected by the lowest grade of metamorphism. It averages 5.9% in basalts of Units 3b and 6 and 2.7% in silicic rocks of Unit 6. Loss on Ignition is not as significant a factor in Unit 1a; it averages 2.6% in the basalts and 0.9% in the rhyolites.

<u>Alkali contents</u>: The alkali contents of rocks in the study area appear to have been severely affected by secondary processes, as indicated by a wide variation in total alkalies and in the K_2O/Na_2O ratio. Although all units show a broad scatter, both these parameters show greatest variability in mafic and silicic rocks of Unit 3b and particularly

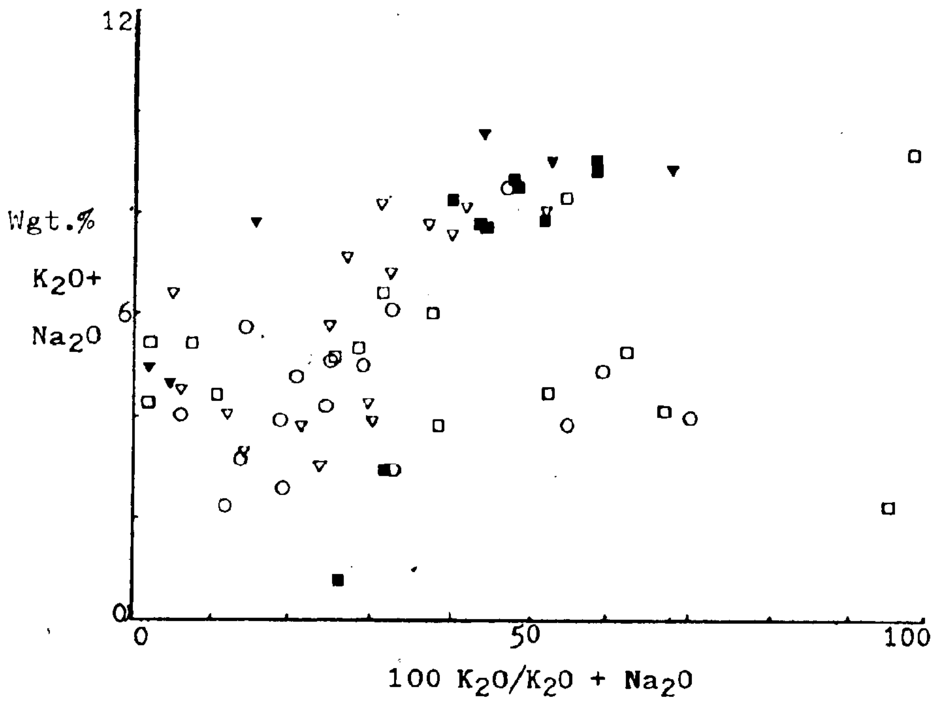


Fig. 6.3 - Variation of alkalies in all rock units in map area.

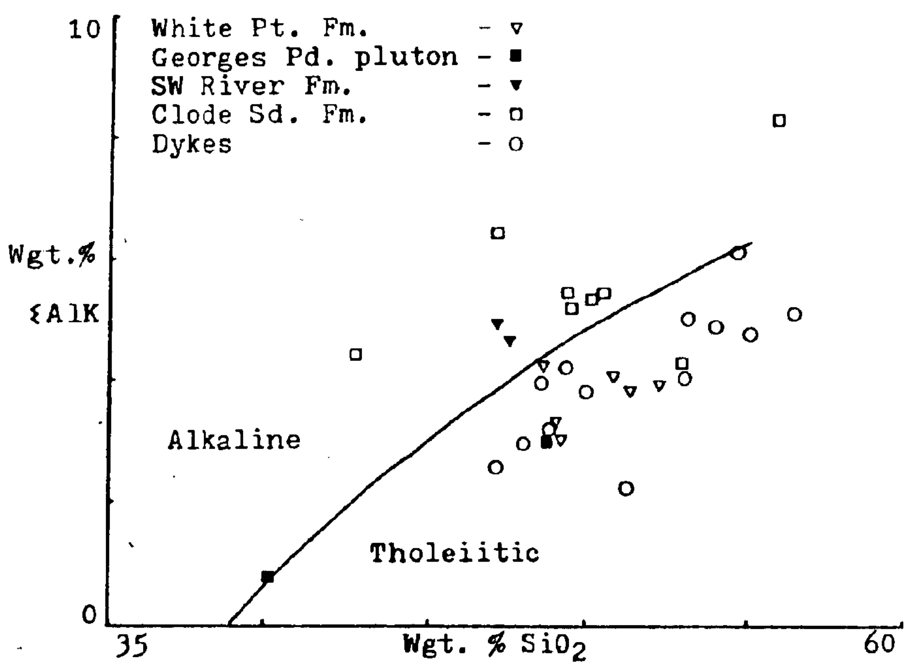


Fig. 6.4 - Alkalies - SiO_2 diagram (Irvine and Baragar, 1971).

Unit 6 (see Table 4; Fig. 6.3). The rocks of relatively higher metamorphic grade (eg. Unit 1a) tend to show less scatter on Fig. 6.3 although this does not necessarily imply limited alkali mobility.

Table 4 - Range in alkali levels in the volcanic rocks

	Basalts	Rhyolites
Unit 1a		
Na_2O	2.28-3.40	3.88-5.60
K_2O	0.45-1.18	1.88-4.18
ΣAlk	2.97-4.08	7.08-8.11
Unit 3b		
Na_2O	4.27-4.55	2.86-6.55
K_2O	0.19-0.08	1.20-5.86
ΣAlk	4.46-4.63	7.75-9.41
Unit 6		
Na_2O	3.63-4.88	0.11-3.73
K_2O	0.06-1.74	1.37-8.84
ΣAlk	3.79-5.89	2.15-9.02

There is some doubt as to the correct interpretation of the alkalies-silica plot (Fig. 6.4) for the basaltic rocks (Macdonald and Katsura, 1964; Irvine and Baragar, 1971). Rocks of the White Point Formation and most mafic dykes in the map area are confined to the tholeiitic or subalkaline while basalts of Units 3b and 6a occur largely in the alkaline field. However, the distribution of these points may also reflect the fact that rocks in the tholeiitic field contain greenschist grade mineral assemblages while those in the alkaline field are of lower metamorphic grade. It is possible that the metamorphism has enhanced primary chemical differences between these rocks. However, it is not entirely clear what the contrast in alkali levels between these rock units reflects. This diagram will therefore not be used to support an interpretation of a primary magmatic distinction between these rocks.

Many authors (Hopgood, 1962; Vallance, 1969, 1974; Smith, 1968; Smitheringale, 1972; Hart et al., 1974; Cann, 1970; Wood et al., 1976; Kerrich et al., 1977) agree that low-grade metamorphic processes in a number of environments produce variable metasomatic effects in mafic volcanic rocks for most major and trace elements, and in some cases more than a 50% change in the concentrations of some elements (i.e. especially Na, K, Ca, Ba, Rb, and Sr). Also, aside from some workers (eg. Donnelly, 1963) it is generally believed that keratophyric or poenitic compositions in silicic volcanic rocks are the result of secondary metasomatic processes (eg. Battey, 1955; Hughes, 1973). Malpas (1971) and Hughes and Malpas (1972) associated K and Ba metasomatism in silicic rocks of the Bull Arm Formation with Acadian folding while Levi (1969) ascribed the composition of some keratophyric ash flows to burial metamorphism of prehnite-pumpellyite to greenschist-grade. Such compositions however, may reflect the cumulative effects of a number of processes, not the least of which could be surficial or near-surface alkali mobilization. Lipman et al. (1969) suggest that there is essentially no alkali mobility, while Kochhar (1977) indicates that there can be quite significant sodium loss associated with primary crystallization and cooling of calcalkali rhyolites. Lofgren (1970) demonstrated increased devitrification rates in the presence of alkali-rich solutions and along with Scott (1970) showed significant alkali exchange between silicic glass and an aqueous phase. However, it is the silicic peralkaline lavas which appear to be most susceptible to elemental mobility upon hydration and/or devitrification (Noble, 1965a,b; 1970a). The severity of these effects appears to be related to the degree of peralkalinity, being most pronounced in pantellerites. This may be due to a lack of sufficient alumina to combine with the alkalies (Noble, 1970a). Loss of Na_2O (up to 25% from some obsidians; up to 50% from ash fall tuffs) is the most consistent change with addition or depletion of K_2O (Noble 1965a,b, 1967, 1970a; Ewart et.al., 1968; Baker and Henage, 1978). This is accompanied by loss of halogens and a lesser mobility of Mg, Sr, Ca, and possibly by a local depletion in SiO_2; Fe is relatively immobile, but is invariably oxidized (Noble, 1970a). U is commonly lost (Rosholt and Noble, 1969).

It appears then that most major elements and geochemically associated trace elements are affected by secondary metasomatic processes and therefore may not be reliable in distinguishing volcanic units, (especially where these have undergone variable degrees of alteration) or in determining magmatic affinity. Unfortunately, the most widely used graphical illustrations of geochemical trends in magmatic evolution typically involve the alkalies. These include the AFM diagram (Wager and Deer, 1939), the alkali-lime index (Peacock, 1931), alkali-silica plot (Macdonald and Katsura, 1964; Kuno, 1966; Irvine and Barager, 1971) and the alkalinity index-silica plot (Wright, 1969). The petrogenetic value of any such plots is clearly limited or nullified by the alteration described above. However, in recent years, it has been shown that some elements are relatively resistant to metasomatism under a variety of conditions. These include Al, Ti, Zr, Y, Nb, and in many cases P (Pearce and Cann, 1971, 1973; Vallance, 1974; Carmicheal, 1969; Cann, 1970; Hart et.al., 1974; Wood et.al., 1976; Baker and Henage, 1978). Consequently, a number of authors using these elements have devised binary and ternary plots designed to distinguish magmatic affinity and tectonic environment (Cann, 1970; Pearce and Cann, 1973; Floyd and Winchester, 1975; Winchester and Floyd, 1976, 1977; Pearce and Gale, 1978). Obviously, the reliability of these plots depends largely on the extent of sampling of the various magmatic suites included in their construction. For example, Pearce and Cann (1973) do not appear to have included continental margin and intracontinental calcalkaline basalts in the preparation of their diagrams. Indeed, several authors have found some of these plots to be erroneous in delineating tectonic environment (eg. Morrison, 1978). Thus, these immobile element plots are valuable, when used with discretion, in suggesting a magmatic affinity for altered rock units although they should not be taken as an independent indication of tectonic environment. With these reservations in mind, a number of such binary plots are used to describe the magmatic affinity of igneous rocks in the map area. Plots involving SiO_2 were used in this study since in general there is little or no petrographic or chemical evidence for significant addition or depletion in silica in the samples analysed.

Harker (1909) plots are given for each unit purely for descriptive purposes to clearly outline elemental distributions in these rocks.

6.3 White Point Formation

The composition of volcanic rocks in this formation range from basalt through andesite to rhyolite. Field relations (sec. 3.3.1.3) and chemical data presented below suggest a genetic link between the White Point Formation and the Georges Pond pluton. When both these units are included on a frequency versus silica histogram (Fig. 6.5), there is a continuum of compositions from basic to acidic. This is in contrast to the marked bimodality of Units 3b and 6 (see Fig 6.12).

<u>Major elements</u>: The average compositions for volcanic rocks of the White Point Formation compare closely with rocks from ensialic orogenic terrains (Table 5). Basalts of Unit 1a are quite similar to high-alumina types from calcalkaline terrains (eg. Cascade Range, western United States).

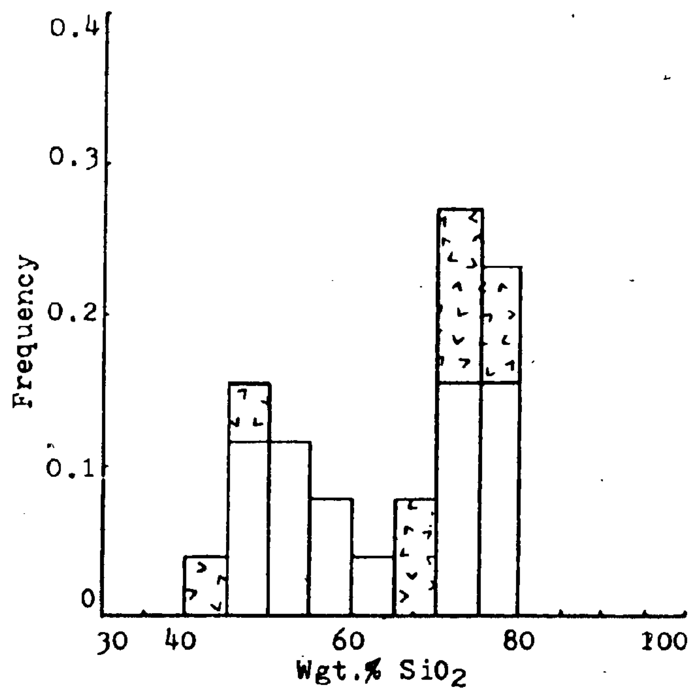


Fig. 6.5 - Histogram of frequency vs SiO_2 for White Pt. Fm. and Georges Pd. pluton.

White Pt. Fm. -

Georges Pd. pluton -

Table 5 Comparison of average analyses from units in stu

	1	2	3	4	5	6	7	8	9	10
SiO_2	48.63	58.80	74.61	73.25	49.16	53.8	49.15	60.00	69.68	73.23
TiO_2	1.15	1.01	0.32	0.07	2.29	2.0	1.52	1.04	0.36	0.24
Al_2O_3	17.20	15.45	13.20	12.30	13.33	13.9	17.73	16.00	15.21	14.03
FeO	5.78	5.05	0.69	-	9.71	9.3	7.20	6.20	1.90	1.70
Fe_2O_3	4.76	2.53	0.99	1.81	1.31	2.6	2.76	1.89	1.08	0.60
MnO	0.19	0.18	0.06	0.03	0.16	0.2	0.14	0.16	0.04	0.02
MgO	5.92	3.61	0.36	0.23	10.41	4.1	6.91	3.90	0.91	0.35
CaO	9.35	4.68	1.15	0.44	10.93	7.9	9.91	5.87	2.70	1.32
Na_2O	2.83	4.42	4.81	2.66	2.15	3.0	2.88	3.85	4.47	3.94
K_2O	0.78	1.75	2.94	5.75	0.15	1.5	0.72	0.87	3.01	4.08
P_2O_5	0.20	0.31	0.06	0.04	0.16	0.4	0.26	0.23	0.10	0.05
LOI	2.59	1.93	0.93	2.64	-	-	-	-	-	-
Rb	20	33	56	186						
Sr	541	415	140	75						
Ba	211	644	795	1526						
Cu	58	46	7							
Pb	5	11	9							
Zn	106	170	96							
Cr	167	25	5							
Ni	87	10	3							
V	255	156	20							
Ga	21	18	16							
Zr	108	188	231	284						
Y	16	29	33							
Nb	6	9	13							

1. Unit 1a basalt (Avg. of 6)
2. Unit 1a andesite (Avg. of 2)
3. Unit 1a rhyolite (Avg. of 6)
4. Bull Arm Fm. (avg. of 7), Malpas, 1971.
5. Ol. tholeiite (Irvine & Baragar, 1971)
6. Tholeiite (" " " ")
7. Hi-Al basalt (" " " ")
8. Andesite (" " " ")
9. Dacite (" " " ")
10. Rhyolite (" " " ")
11. Unit 3b basalt (Avg. of 2)
12. Unit 3b rhyolite (Avg. of 4)
13. Unit 6 basalt (Avg. of 7)
14. Unit 6 porphyritic basalt (1)
15. Unit 6 pantellerite (Avg. of
16. Avg. cont. alk. basalt (Manso
17. "K-poor" alk. ol. basalt (Irv
18. Tristanite (Irvine & Baragar,
19. Pantellerite (Pantelleria; Bo

es from units in study area with compositions of more recent igneous rocks of known magma

8	9	10	11	12	13	14	15	16	17	18	19	20
50.00	69.68	73.23	44.85	71.83	44.81	53.41	73.28	47.1	45.4	55.85	69.81	75.31
1.04	0.36	0.24	1.76	0.35	2.18	0.82	0.35	2.2	3.0	1.80	0.45	0.21
16.00	15.21	14.03	15.95	13.94	15.49	17.67	9.20	15.7	14.7	18.98	8.59	10.43
6.20	1.90	1.70	5.32	0.50	5.99	1.82	2.42	7.8	9.2	3.11	5.76	0.80
1.89	1.08	0.60	7.26	2.10	5.93	5.68	4.85	3.4	4.1	2.59	2.28	3.22
0.16	0.04	0.02	0.20	0.04	0.33	0.14	0.14	0.16	0.2	0.12	0.28	0.09
3.90	0.91	0.35	9.94	0.42	5.02	3.13	0.20	7.1	7.8	2.04	0.10	0.10
5.87	2.70	1.32	4.69	0.88	6.43	4.69	1.38	10.1	10.5	4.51	0.42	0.13
3.85	4.47	3.94	4.41	4.75	4.06	3.71	1.68	3.3	3.0	5.16	6.46	3.99
0.87	3.01	4.08	0.14	3.95	0.73	4.24	3.19	1.5	1.0	4.08	4.49	4.65
0.23	0.10	0.05	0.28	0.07	0.61	0.24	0.03	0.47	0.4	0.39	0.13	0.03
-	-	-	4.88	0.94	6.73	2.33	2.79	1.1	-	-	0.19	0.89
			4	82	26	101	109	23			n.d.	n.d.
			244	77	467	633	59	566			7	6
			84	723	294	1350	142				50	10
			59	8	43	37	10				5	8
			8	9	4	1	24				30	70
			100	39	109	81	230				n.d.	n.d.
			227	4	170	24	2				1	1
			97	2	68	13	14				3	2
			316	21	278	182	19				5	5
			17	17	21	19	34				45	28
			119	298	183	167	1538				2500	1800
			18	39	27	31	120				220	140
			11	20	15	6	158				450	150

basalt (Avg. of 2)
hyolite (Avg. of 4)
salt (Avg. of 7)
rphyritic basalt (1)
ntellerite (Avg. of 7)
. alk. basalt (Manson, 1967)
alk. ol. basalt (Irvine & Baragar, 1971)
e (Irvine & Baragar, 1971)
ite (Pantelleria; Bowden, 1972)

20. Comendite (Sardinia; Bowden, 1972)
21. Sub-alkaline rhyolite (Taupo, New Zealand; Ewart et.
22. Georges Pond pluton - Diorite (sample 555).
23. Georges Pond pluton - Granite (sample 641; dominant
24. Cordillera Central (Avg. composition) - Dominican Re
25. Sierra Nevada (" ") - Western U.S.

s of more recent igneous rocks of known magmatic and tectonic affinity.

	15	16	17	18	19	20	21	22	23	24	25	
1	73.28	47.1	45.4	55.85	69.81	75.31	74.22	64.71	71.47	62.4	68.4	SiO_2
2	0.35	2.2	3.0	1.80	0.45	0.21	0.28	0.70	0.24	0.5	0.4	TiO_2
7	9.20	15.7	14.7	18.98	8.59	10.43	13.27	15.82	14.52	15.1	15.3	Al_2O_3
2	2.42	7.8	9.2	3.11	5.76	0.80	0.92	2.53	0.94	-	-	FeO
3	4.85	3.4	4.1	2.59	2.28	3.22	0.88	1.83	0.85	5.6(T)	3.0(T)	Fe_2O_3
4	0.14	0.16	0.2	0.12	0.28	0.09	0.05	0.14	0.09	0.1	0.1	MnO
3	0.20	7.1	7.8	2.04	0.10	0.10	0.28	1.41	0.50	2.7	1.2	MgO
9	1.38	10.1	10.5	4.51	0.42	0.13	1.59	2.98	1.62	6.5	3.2	CaO
1	1.68	3.3	3.0	5.16	6.46	3.99	4.24	4.44	4.28	3.5	3.4	Na_2O
4	3.19	1.5	1.0	4.08	4.49	4.65	3.18	3.98	3.28	1.2	3.6	K_2O
4	0.03	0.47	0.4	0.39	0.13	0.03	0.05	0.14	-	n.d.	n.d.	P_2O_5
3	2.79	1.1	-	-	0.19	0.89	1.03	0.97	0.82	-	-	LOI
1	109	23			n.d.	n.d.	108	122	88			Rb
3	59	566			7	6	125	326	154			Sr
0	142				50	10	870	825	646			Ba
7	10				5	8	6	8	3	67	20	Cu
1	24				30	70	18	10	5	6	20	Pb
1	230				n.d.	n.d.	n.d.	64	46	46	-	Zn
4	2				1	1	2	7	5	30	30	Cr
3	14				3	2	n.d.	5	3	17	10	Ni
2	19				5	5	9	53	18	133	100	V
9	34				45	28	16	13	15			Ga
7	1538				2500	1800	160	212	163			Zr
1	120				220	140	28	40	28			Y
6	158				450	150	6	10	9			Nb

te (Sardinia; Bowden, 1972)
aline rhyolite (Taupo, New Zealand; Ewart et.al., 1968b)
Pond pluton - Diorite (sample 555).
Pond pluton - Granite (sample 641; dominant phase)
era Central (Avg. composition) - Dominican Republic (Kesler et.al. 1977)
Nevada (" ") - Western U.S.A. (Kesler et.al., 1977)

Harker (1909) plots (Fig. 6.6) include analyses for Unit 1a and the Georges Pond pluton and for most elements there are relatively narrow well defined trends. The scatter on a number of plots is thought to be due largely to secondary alteration although Loss on Ignition is not conspicuously high in these rocks. Predictably, there is an inverse relationship between the concentrations of SiO_2 and all other major element oxides (especially $FeO_{(T)}$, MgO and CaO) except the alkalies which show a positive correlation. Compared to other volcanic sequences in the area, the alkalies show relatively little scatter and the rhyolites are relatively sodic. The basalts are marked by relatively high Al_2O_3 and SiO_2 and they are invariably hypersthene and/or quartz normative.

Trace elements: As with major element oxides, trace element concentrations (eg. Ba, Rb, Sr, and Zr) in these volcanic rocks are similar to those in sub-alkaline volcanic rocks extruded upon continental crust (Table 5).

Harker (1909) variation diagrams (Fig. 6.7) show negative correlations between SiO_2 and Cr, Ni, V, Sr, Cu, Zn, and Ga and positive correlations with Zr, Y, Nb, Rb, Ba, and Pb. Chromium, nickel, and vanadium appear to behave similarly and correlate with Mg and Fe (Taylor, 1965). Even in the most basic rocks, chromium and nickel concentrations only locally exceed 200 and 125 ppm respectively. There is considerable scatter for strontium and barium and to a lesser degree for lead and rubidium in the rhyolites. This

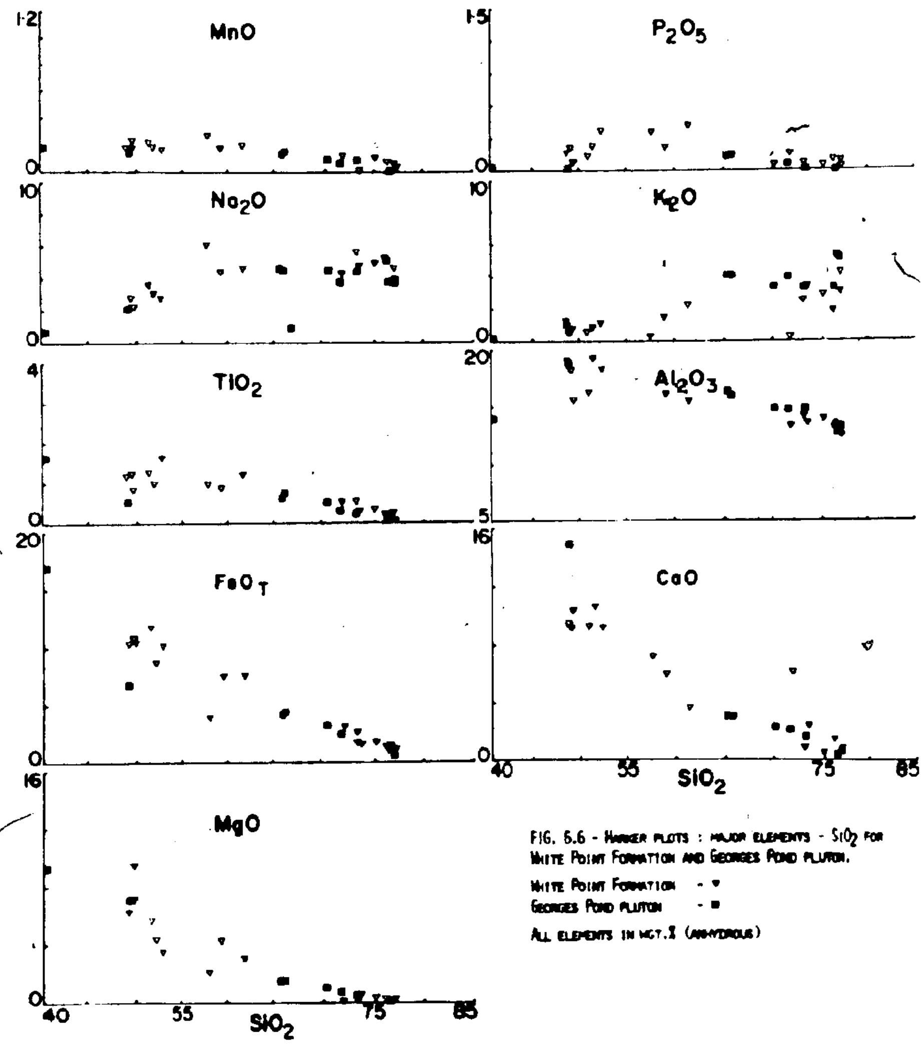


FIG. 6.6 - HARKER PLOTS : MAJOR ELEMENTS - SiO_2 FOR WHITE POINT FORMATION AND GEORGES POND PLUTON.

WHITE POINT FORMATION - ▼

GEORGES POND PLUTON - ■

ALL ELEMENTS IN WGT.% (ANHYDROUS)

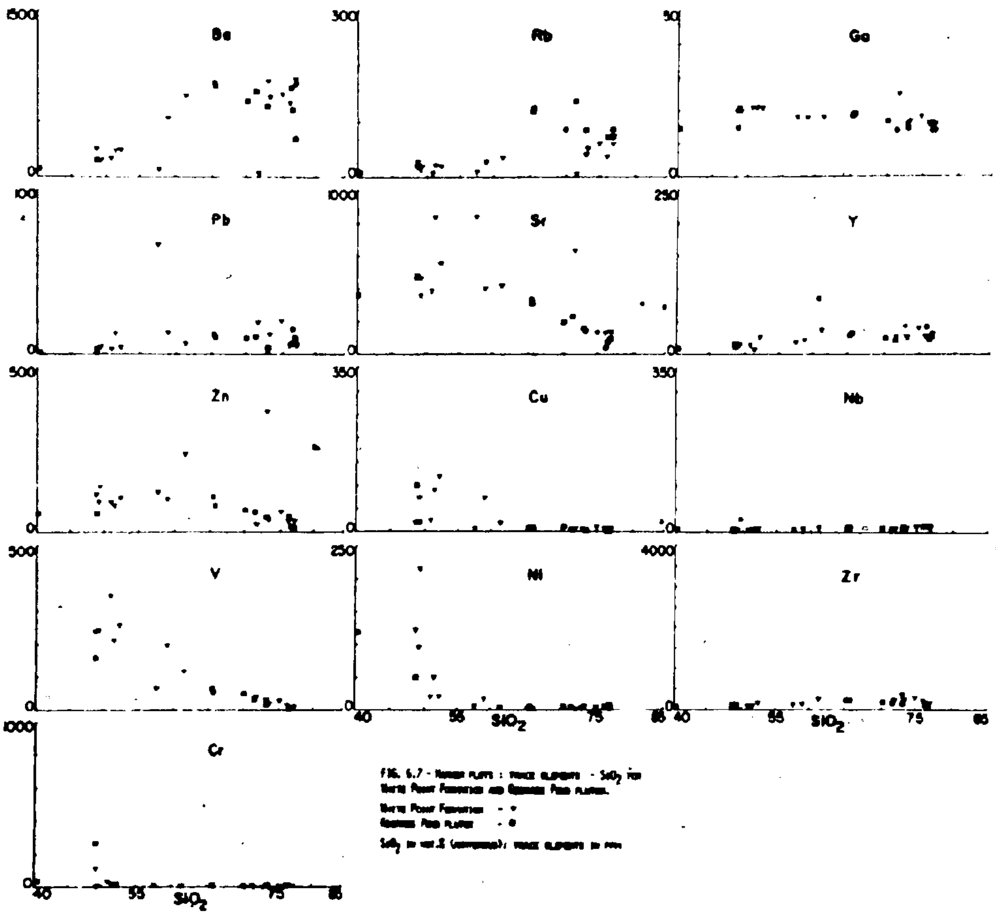


FIG. 6.7 - [illegible] : [illegible] - SiO_2 [illegible]
[illegible]

[illegible] - ▼
[illegible] - ●

SiO_2 [illegible]

is probably related to the known geochemical affinity of these elements to calcium and the alkalies (Taylor, 1965) which appear to have been somewhat mobile. Zinc and copper show only limited scatter while gallium, zirconium, yttrium, and niobium all show narrow very well defined trends, supporting the idea that these elements are not affected by secondary alteration.

Discriminant diagrams: Under a variety of conditions MgO, $FeO_{(T)}$ and Al_2O_3 are relatively resistant to metasomatism (Carmicheal, 1969; Winchester and Floyd, 1976). Pearce, Gorman and Birkett (1977), using these three oxides, prepared a ternary plot for rocks ranging from 50 to 60% silica in which the fields for a number of tectonic environments were defined by a large number of data points. Most rocks of Units 6 and 3b do not have suitable silica contents and form a broad scatter. However, mafic and intermediate rocks of Unit 1a are suitable and concentrate in the orogenic field suggesting calcalkaline affinities (Fig. 6.8).

Recently, a number of plots employing relatively "immobile" elements (eg. Zr, Y, Nb, Ti, and P) have been used to differentiate alkaline from tholeiitic or subalkaline basalts (Floyd and Winchester, 1975; Winchester and Floyd, 1976). Two of these, P_2O_5 versus Zr (Fig. 6.9) and TiO_2 versus Zr/P_2O_5 (Fig. 6.10), illustrate the clearly subalkaline nature of the basalts of Unit 1a. Winchester and Floyd (1977) produced a suite of binary plots which

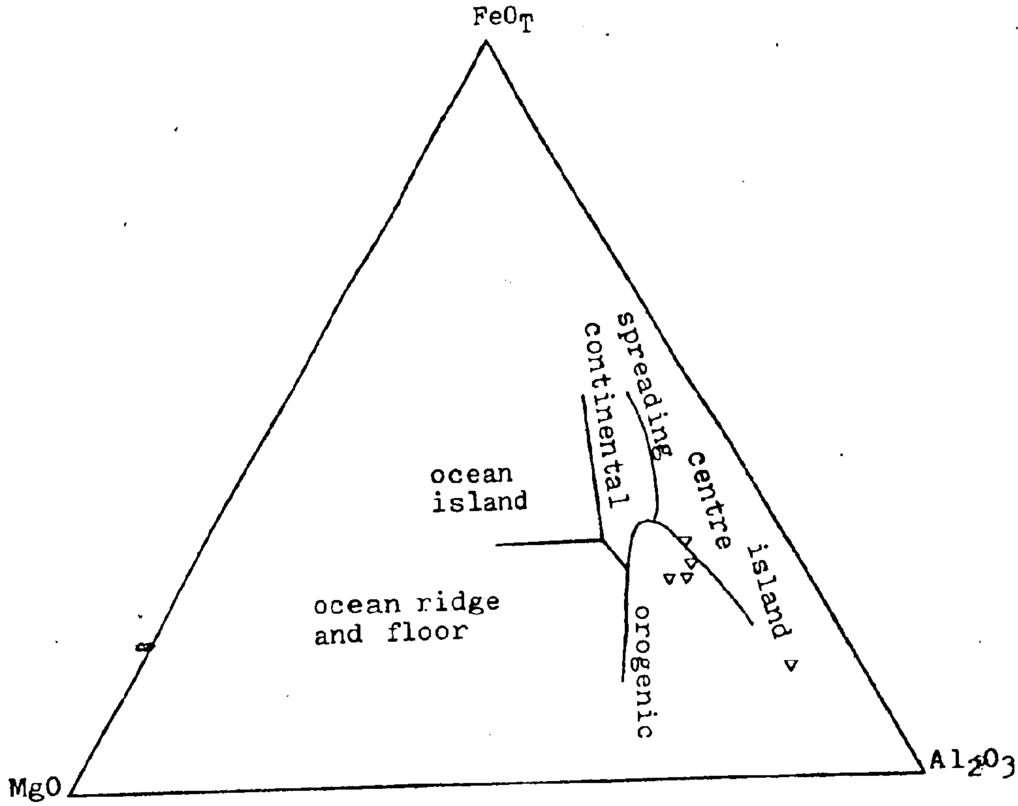


Fig. 6.8 - FeO_T - MgO - Al_2O_3 plot for mafic volcanic rocks with 50-60% SiO_2; after Pearce et.al. (1977). White Pt. Fm.

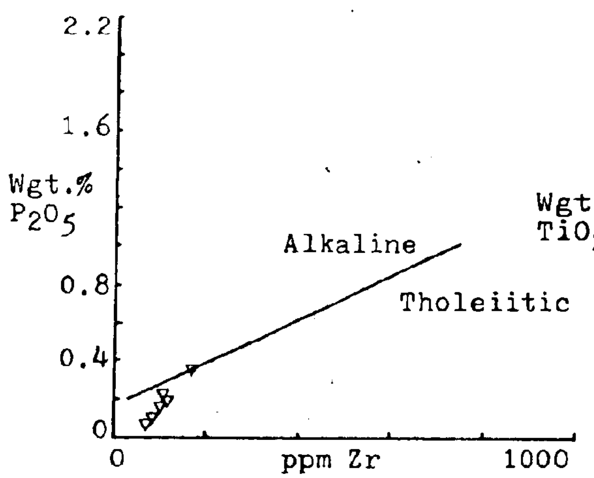


Fig. 6.9 - P_2O_5-Zr diagram for basalts of White Pt. Fm.; after Winchester and Floyd (1976).

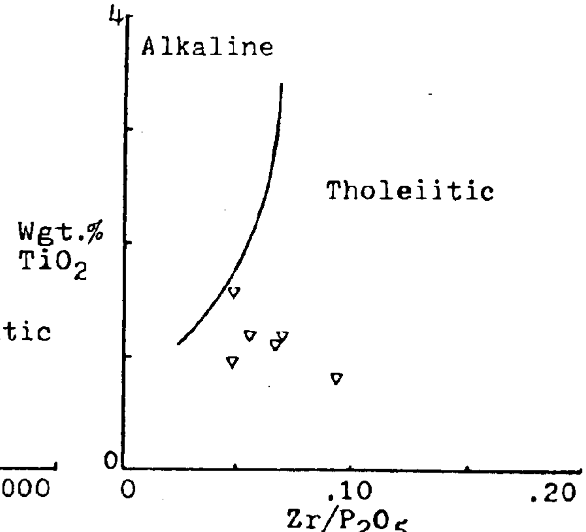


Fig. 6.10 - TiO_2-Zr/P_2O_5 plot for basalts of White Pt. Fm.; after Winchester & Floyd (1976).

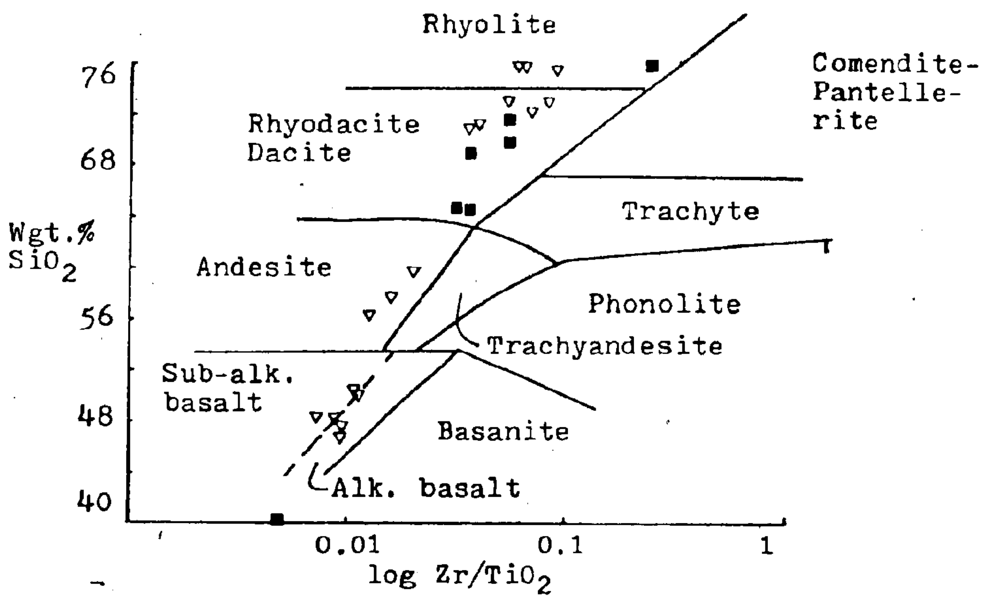


Fig. 6.11 - SiO_2 - log Zr/TiO_2 diagram for White Pt. Fm. and Georges Pd. pluton. Various fields after Winchester & Floyd (1977).

White Pt. Fm. - ▽
Georges Pd. pluton - ■

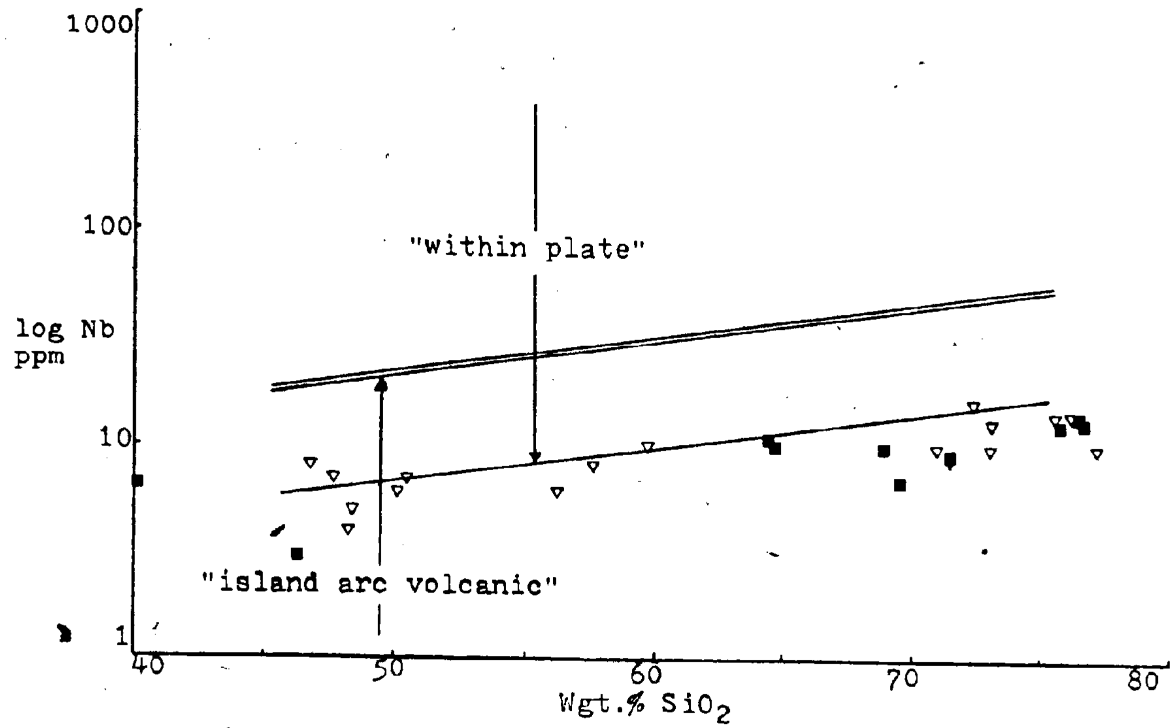


Fig. 6.12 - log Nb - SiO_2 diagram for White Pt. Fm. and Georges Pd. pluton. Fields after Pearce and Gale (1978).

White Pt. Fm. - ▽
Georges Pd. pluton - ■

use SiO_2 and "immobile" element ratios to distinguish rock types in altered terrains. In their SiO_2 - Zr/TiO_2 (Fig. 6.11) plot, basalts of Unit 1a straddle the boundary between subalkaline and alkaline basalts and the intermediate and acid rocks plot in the andesite and dacite-rhyolite fields respectively. Lastly, Pearce and Gale (1978) defined overlapping orogenic and non-orogenic fields on a Nb/SiO_2 plot (Fig. 6.12). Most analyses of Unit 1a and of the Georges Pond pluton lie within the "island arc volcanic" field. Hence, both the major and trace element geochemical data appear to indicate a calcalkaline affinity for the White Point Formation.

6.4 Musgravetown Group

Analyses for volcanic rocks from the Cannings Cove and Charlottetown Formations are included with those from the Clode Sound Formation (Unit 6) in this section.

There are a number of similarities between the chemistry and petrography of Unit 6 and Unit 3b and therefore they are included on the histogram (Fig. 6.13). Rocks of Unit 6 are distinctly bimodal (Fig. 6.13) with a silica gap from 52.90 to 72.68% (anhydrous); one highly porphyritic basalt contains 56.01% SiO_2. In Unit 6 basic and acid rocks are commonly intercalated and the silica or Daly gap appears real and is not a function of sampling bias.

Major elements: The average composition of the basalts compares roughly with that of mildly alkaline basalts in

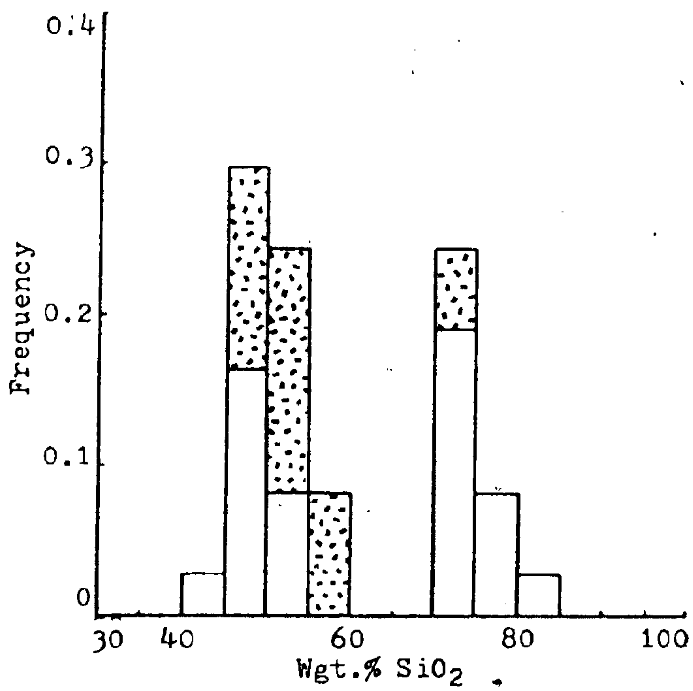


Fig. 6.13 - Histogram of frequency vs SiO_2 for Clode Sound Fm., SW River Fm (3b) and dykes in map area.

Clode Sd. Fm. and SW River Fm. -

Dykes -

other regions while the silicic rocks do not resemble "normal" or subalkaline rhyolite (Table 5). They have high iron, low alumina and anomalous trace element concentrations similar to pantellerites (highly peralkaline rhyolite).

Harker plots (6.14) of SiO_2 versus the major elements tend to show more scatter than for the White Point Formation, and this probably reflects the sub-greenschist alteration. However, the scatter in the case of some relatively "immobile" elements (eg. TiO_2) could be due to primary variations or a lack of geochemical coherence with SiO_2. Also, Loss on Ignition is relatively high for both the mafic and the silicic rocks. Elemental trends (versus SiO_2) are somewhat similar to those of the White Point Formation. However, the levels of concentrations for many elements are significantly different. For example, compared to Unit 1a, Musgravetown basalts tend to have lower SiO_2, Al_2O_3, CaO, and aside from the olivine basalts lower MgO. The basalts also have slightly higher $FeO_{(T)}$, higher P_2O_5, MnO, TiO_2, variable but higher K_2O and Na_2O, and they range from hypersthene-to nepheline-normative. The "pantellerites" of the Musgravetown Group have significantly lower Al_2O_3 (7.37 to 11.02%) and higher $FeO_{(T)}$(4.25 to 9.60%) than any other silicic rocks in the map area. They also have variable CaO, higher MnO and lower P_2O_5 and Na_2O than the other silicic rocks.

The identification of "pantellerites" is based on comparisons with rocks in other regions (Table 5), "immobile"

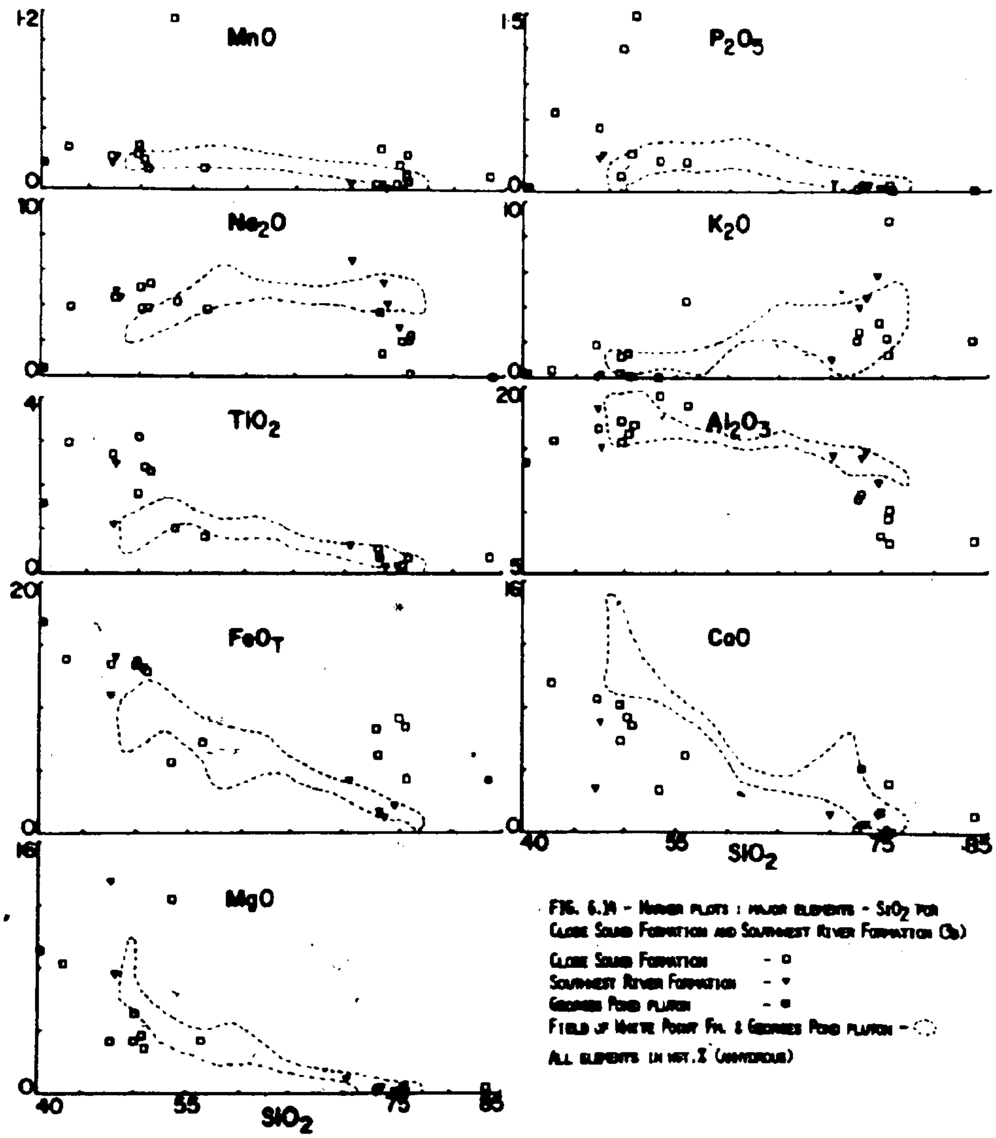


FIG. 6.14 - Harker plots : major elements - SiO_2 for Clode Sound Formation and Southwest River Formation (Sb)

Clode Sound Formation - □
Southwest River Formation - ▼
Georges Pond pluton - ●
Field of White Point Fm. & Georges Pond pluton - ⋯

All elements in wt.% (anhydrous)

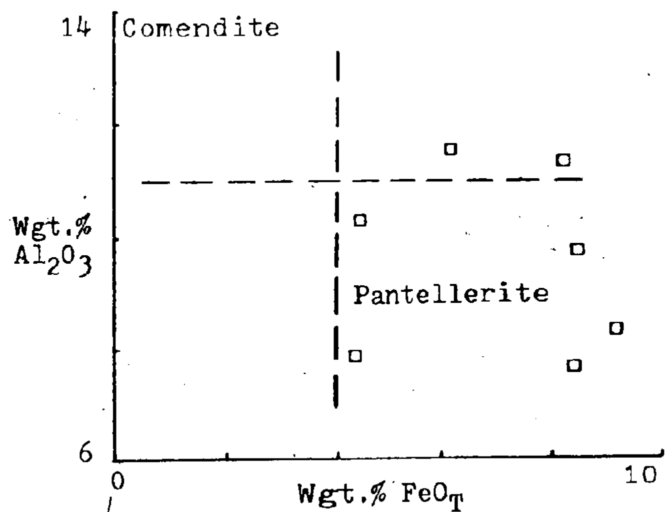


Fig. 6.15 - Al_2O_3-FeO_T diagram for "pantellerites" of Clode Sd. Fm.; after Macdonald (1974). (see Fig. 6.21)

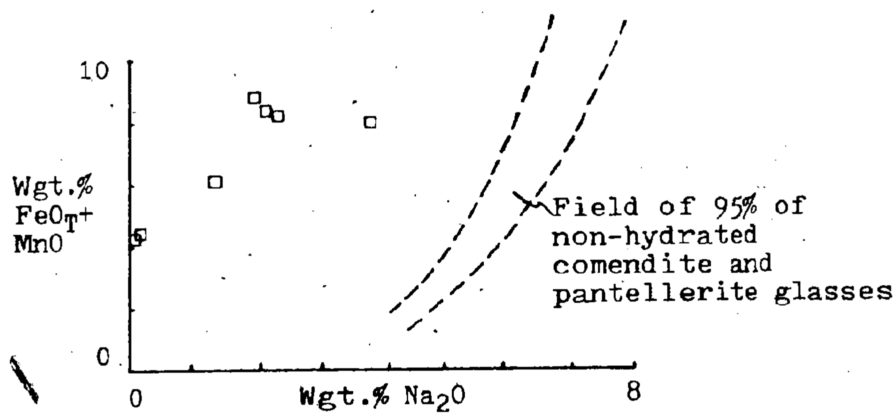


Fig. 6.16 - FeO_T + MnO - Na_2O diagram for "pantellerites" of Clode Sd. Fm., showing soda loss; after Noble (1970a).

element plots to be presented later, and on the basis of the Al_2O_3 versus $FeO_{(T)}$ diagram (Fig. 6.15) of Macdonald (1974) which distinguishes comendites and pantellerites. Noble (1970a) considered iron to be, in general, relatively immobile in peralkaline rocks and he defined the field of peralkaline (comendite-pantellerite) oversaturated, non-hydrated obsidians on a Na_2O-$FeO_{(T)}$ plot (Fig. 6.16). This diagram indicates that the pantellerites in question were affected by secondary loss of at least 2.5 to 6% Na_2O or up to 95% of the soda content in some samples (eg. 355). This appears to explain the fact that these "pantellerites" are not peralkaline according to their agpaitic indices (i.e. molecular $Na_2O + K_2O/Al_2O_3$) and the relatively low soda levels compared with other silicic rocks in the study area.

Trace elements: Trace element patterns for these rocks are quite distinctive, and separate them from all other rocks in the map area. There is a negative correlation between SiO_2 and Cr, V, Cu, Ni and Sr and a positive correlation with Rb (Fig. 6.17). Sr, Ba and Rb show considerable scatter probably related to Ca and alkali mobilization. Nb, Y, and Zr to a smaller degree are enriched in basalts of Unit 6 relative to Unit 1a. However, the most striking pattern is the Ni concentration (up to 65 ppm), the variable but commonly extreme enrichment in Ga, Zr, Y, Nb and the depletion in Ba (as low as 4 ppm) in the pantellerites. Aside from the nickel enrichment,

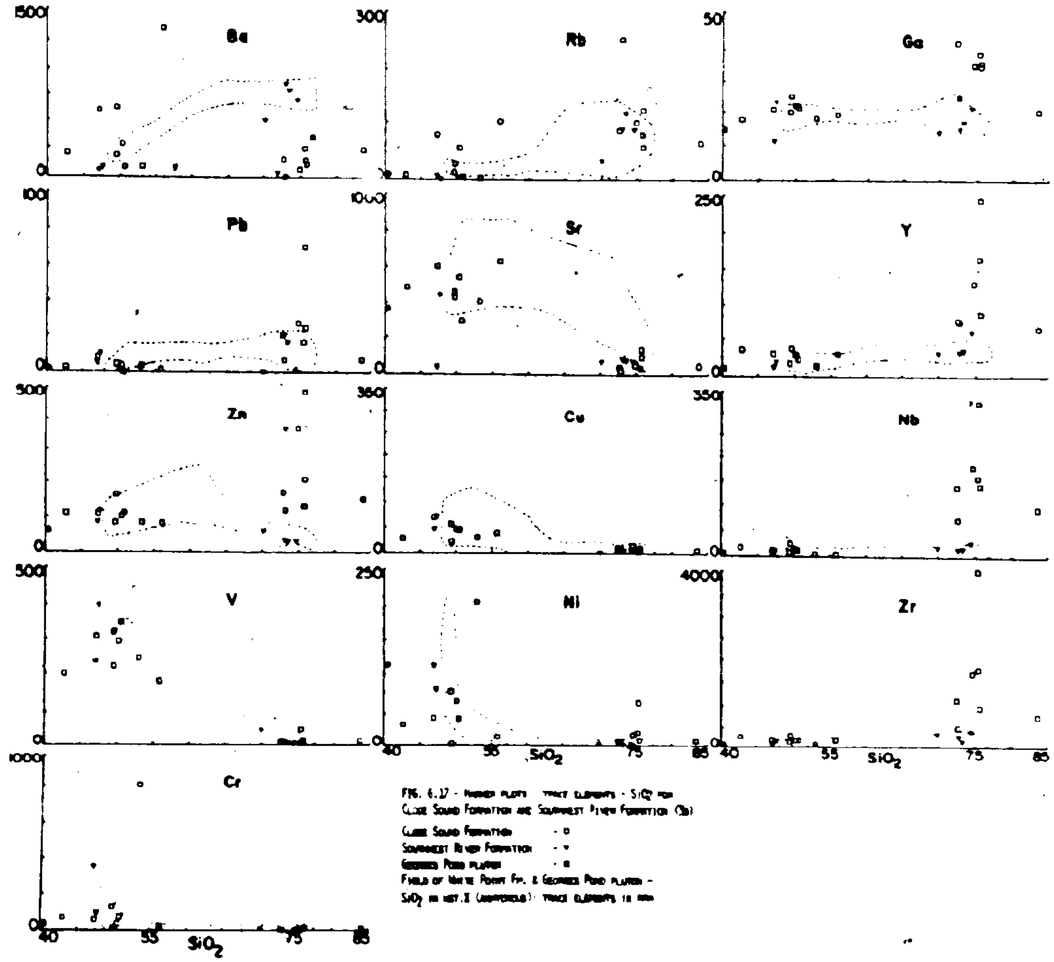


FIG. 6.17 - Harker plots: trace elements - SiO_2 for Clode Sound Formation and Southwest River Formation (Sb)

Clode Sound Formation - □
Southwest River Formation - ▾
Georges Pond pluton - ■
Field of White Point Fm. & Georges Pond pluton -
SiO_2 in wt.% (anhydrous): trace elements in ppm

these trace element patterns are typical of peralkaline volcanic rocks (especially pantellerites) throughout the world (eg. Noble, 1965a; Ewart et.al., 1968; Gibson, 1970; Weaver et.al., 1972; Baker and Henage, 1977).

Discriminant Diagrams: Basalts of the Musgravetown Group appear to straddle the boundary between the alkaline and subalkaline or tholeiitic fields on the P_2O_5 versus Zr (Fig. 6.18) and TiO_2 versus Zr/P_2O_5 (Fig. 6.19) plots of Winchester and Floyd (1976). On Winchester and Floyd's (1977) diagram of SiO_2 versus Zr/TiO_2 (Fig. 6.20), the basic rocks lie exclusively in the alkali basalt field and the silicic lavas occur, predictably, within the comendite-pantellerite field. Further, the common occurrence of modal iddingsitized olivine both in the groundmass and as phenocrysts in these basalts suggests alkaline affinities. Indeed, alkalic to transitional basaltic rocks are typically associated with peralkaline silicic volcanic rocks (eg. Gass and Mallick, 1968; Barberi et.al., 1975). Barberi et.al. (1975) also note that basalts associated with the more peralkaline pantellerites are more alkalic than those associated in other areas with the less peralkaline comendites. This association (i.e. alkalic to transitional basalts and peralkaline rhyolite) may be equated with the Coombs trend of Miyashiro (1978).

On the Nb-SiO_2 plot of Pearce and Gale (1978) (Fig. 6.21) the basalts cluster in the field of overlap between the orogenic and non-orogenic zones. However, the pantellerites

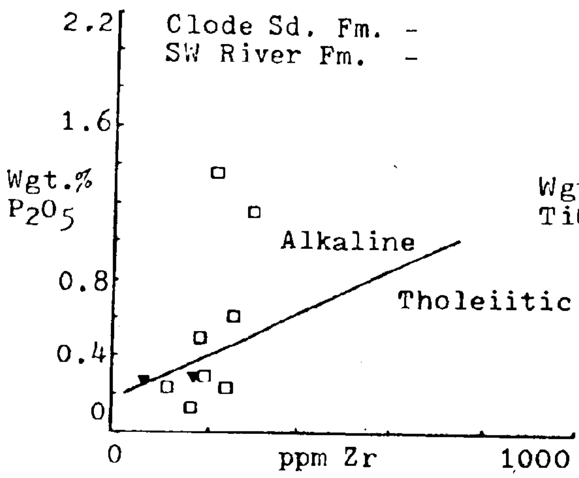


Fig. 6.18 - P_2O_5 - Zr plot for basalts of Clode Sd. Fm. & SW River Fm.;(after Winchester & Floyd (1976)

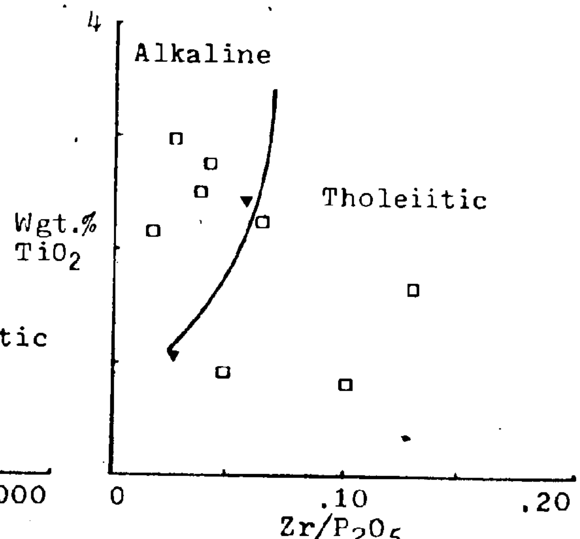


Fig. 6.19 - TiO_2-Zr/P_2O_5 plot for basalts of Clode Sd. Fm. & SW River Fm.; after Winchester & Floyd (1976).

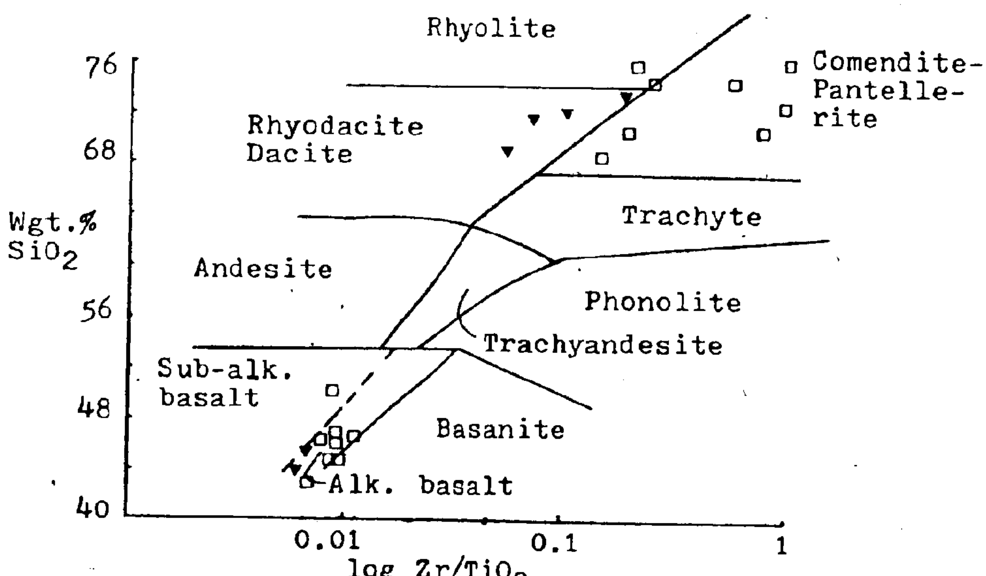


Fig. 6.20 - SiO_2-log Zr/TiO_2 diagram for Clode Sd. Fm. and SW River Fm. (3b). Various fields after Winchester & Floyd (1977).

Clode Sd. Fm. - □
SW River Fm. - ▼

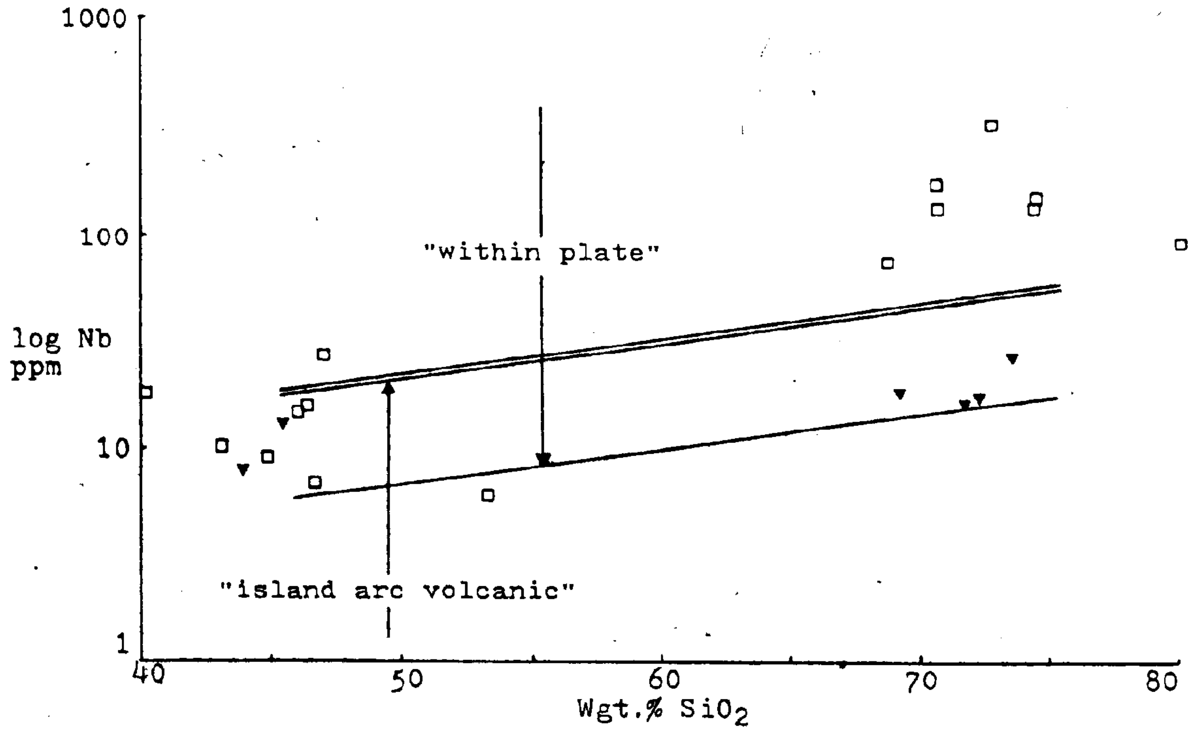


Fig. 6.21 - log Nb - SiO_2 diagram for Clode Sd. Fm. and SW River Fm. (3b). Fields after Pearce and Gale (1978).

Clode Sd. Fm. - □
SW River Fm. (3b) - ▼

fall well within the non-orogenic or within-plate field. This contrasts sharply with the apparently "island arc" nature of the White Point Formation.

From the above, it appears that volcanism within the Musgravetown Group was of a highly alkalic nature in contrast to the subalkaline geochemistry of the White Point Formation.

6.5 Southwest River Formation (3b)

Geochemical data are limited to six samples (2 basalts and 4 rhyolites) from this unit and the discussion will therefore be brief.

This unit is bimodal in the same sense as Unit 6 (Fig. 6.13) and many of the patterns of distribution of the elements are similar to those in Unit 6. Both petrographically and chemically, basalts of Unit 3b are similar to those of the Musgravetown Group (see Figs. 6.4, 6.14, 6.17 to 6.21) showing similar contrasts with basalts of Unit 1a. However, the rhyolites do not show any peralkaline tendencies (eg. enrichment in "residual" elements Zr, Y, Ga) and in that sense are similar to silicic rocks of Unit 1a. The rhyolites of Unit 3b have Rb and K_2O levels somewhat similar to the pantellerites; they are less sodic, in general, than rhyolites of Unit 1a but more sodic than the pantellerites. In Fig. 6.21 it is clear that Nb levels are consistently higher in Unit 3b than in Unit 1a and the former suite of analyses lies in the area of overlap of the "island arc" and "within plate" fields. The similarity of the basalts to mafic volcanic rocks in Unit 6 suggest that Unit 3b may be at least mildly alkaline in nature although on the basis of present data its petrogenetic relation to other igneous units in the map area is difficult to establish with any certainty. Noble (1968) described the continuum of compositions from pantellerite to comendite to "normal" or subalkaline rhyolite and it is possible that such a genetic link exists between Unit 3b and the Musgravetown Group.

6.6 Georges Pond pluton

This intrusion is composite in nature; it ranges from gabbro to granophyre but is composed largely of granitic and lesser dioritic rocks (Fig. 6.5). Relatively fresh biotite-olivine gabbro (eg. 629C) occurring locally may not be related to this intrusion but is included here for completeness.

The sampling of this pluton was not weighted in favour of the dominant phase, granite (Streckiesen, 1967). Only representative samples of each distinct phase were analyzed. Selected representative analyses of this pluton are compared with the average composition of calcalkaline batholiths elsewhere (Table 5); the Georges Pond pluton appears most similar to plutons emplaced in continental crust.

The alkalies may have undergone only limited alteration since they show only minimal scatter on Fig. 6.3 (ΣAlk versus 100 K_2O/ΣAlk). The proportion of K_2O to Na_2O vary somewhat, but overall their concentrations are roughly equal. Loss on Ignition is less than 2% in all rock types.

In general, the relation of both major and trace elements to SiO_2 (Figs. 6.6 and 6.7) is very similar to that for the White Point Formation, and for most elements the trends are narrow and well defined. The pluton tends to have slightly lower P_2O_5 and TiO_2 than Unit 1a. Both Rb and Ba show some scatter, and higher Rb levels in the granite are probably related to its higher potash content compared to the White Point Formation. The intrusion plots in the dacite-rhyolite fields on the SiO_2 versus Zr/TiO_2 diagram (Fig. 6.11) of Winchester and Floyd (1977) and all phases occur solely in the "island arc" field with Unit 1a on the Nb-SiO_2 plot of Pearce and Gale (1978). These data suggest to the author that the Georges Pond granite is calcalkaline in nature and related magmatically to the White Point Formation. The Georges Pond pluton is texturally and compositionally similar to the Swift Current granite which O'Driscoll (1973) has interpreted to be calcalkaline on the basis of major element chemistry.

6.7 Dykes

A total of 16 dykes were analyzed, 14 mafic and 2 silicic. All but two of these occur in the Love Cove Group. Sample 616 was taken from a dyke in the Connecting Point Group east of Bread Cove and sample 625 is from a minor fault block of Connecting Point like rock on the south shore of Clode Sound (Fig. 1). No samples of the highly porphyritic (Devonian?) dykes of the WNW-ESE swarm (sec. 3.6.1.2) were analysed. Sample 616 from the dyke swarm east of Bread Cove appears somewhat similar to basalts of the Musgravetown Group with low SiO_2 and high MgO (Fig. 6.22), high Cr and Ni (Fig. 6.23) and high Nb (Figs. 6.23 and 6.26). However, more geochemical and petrographic work is required to confirm a genetic relation between those dykes and the Musgravetown Group.

In general, the composition of most dykes sampled in the map area does not appear indicative of their location or orientation (i.e. WNW-ESE versus N-S swarm). All mafic dykes analysed are hypersthene-normative (with corrected Fe_2O_3/FeO) and all lie in the subalkaline field in the ΣAlk-SiO_2 plot (Fig. 6.4). Their SiO_2 content ranges from 47.14 to 56.47% (anhydrous). The silicic dykes are rhyolitic in composition (Fig. 6.13).

<u>Major elements</u>: Compared to the various volcanic units in the study area the mafic dykes appear to have variable chemical tendencies. Harker major and trace element plots (Figs. 6.22 and 6.23) show that aside from plagioclase-phyric samples, the dykes have similar Al_2O_3 contents as basalts of Unit 6. The major element chemistry of the two silicic dykes which were collected from the western portion of the field area is similar to that of Unit 3b or 1a.

<u>Discriminant diagrams</u>: The mafic dykes lie largely in the subalkaline field on the P_2O_5-Zr and TiO_2-Zr/P_2O_5 plots

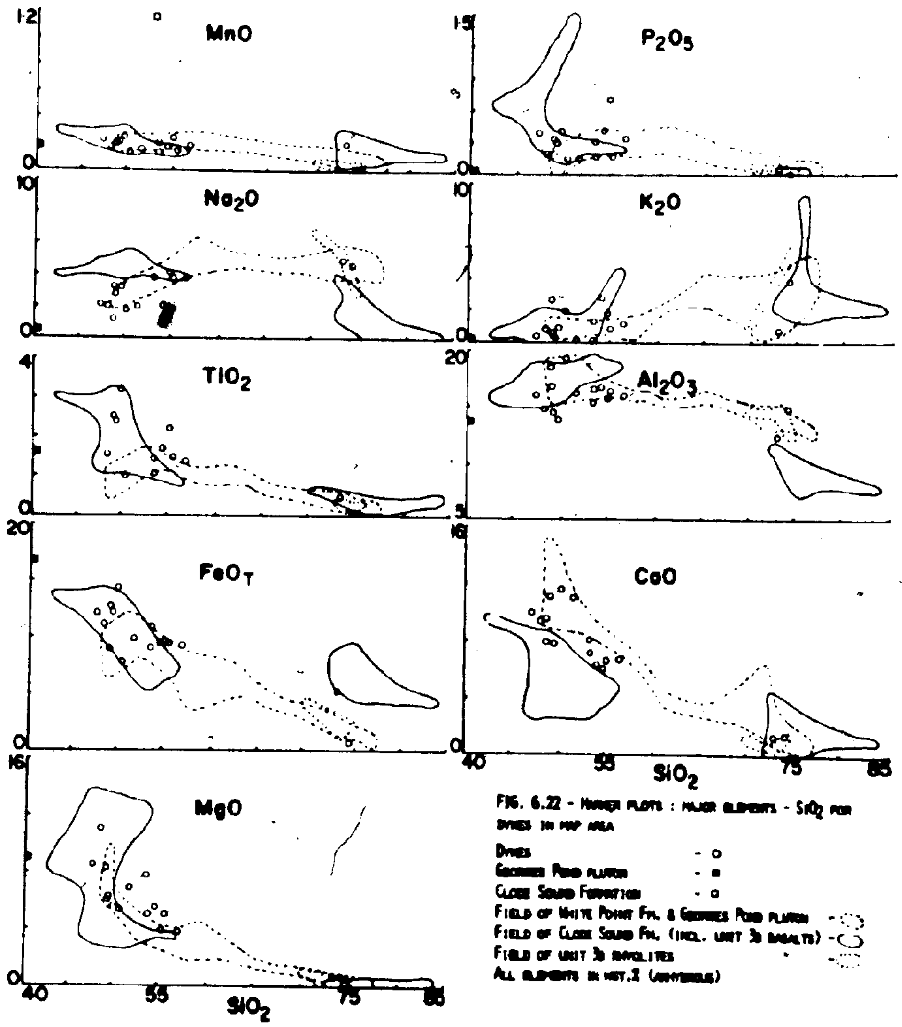


FIG. 6.22 - Harker plots : major elements - SiO_2 for dykes in map area

Dykes - o
Georges Pond pluton - ■
Cloe Sound Formation - o
Field of White Point Fm. & Georges Pond pluton -
Field of Cloe Sound Fm. (incl. unit 3b basalts) -
Field of unit 3b rhyolites -
All elements in wt.% (anhydrous)

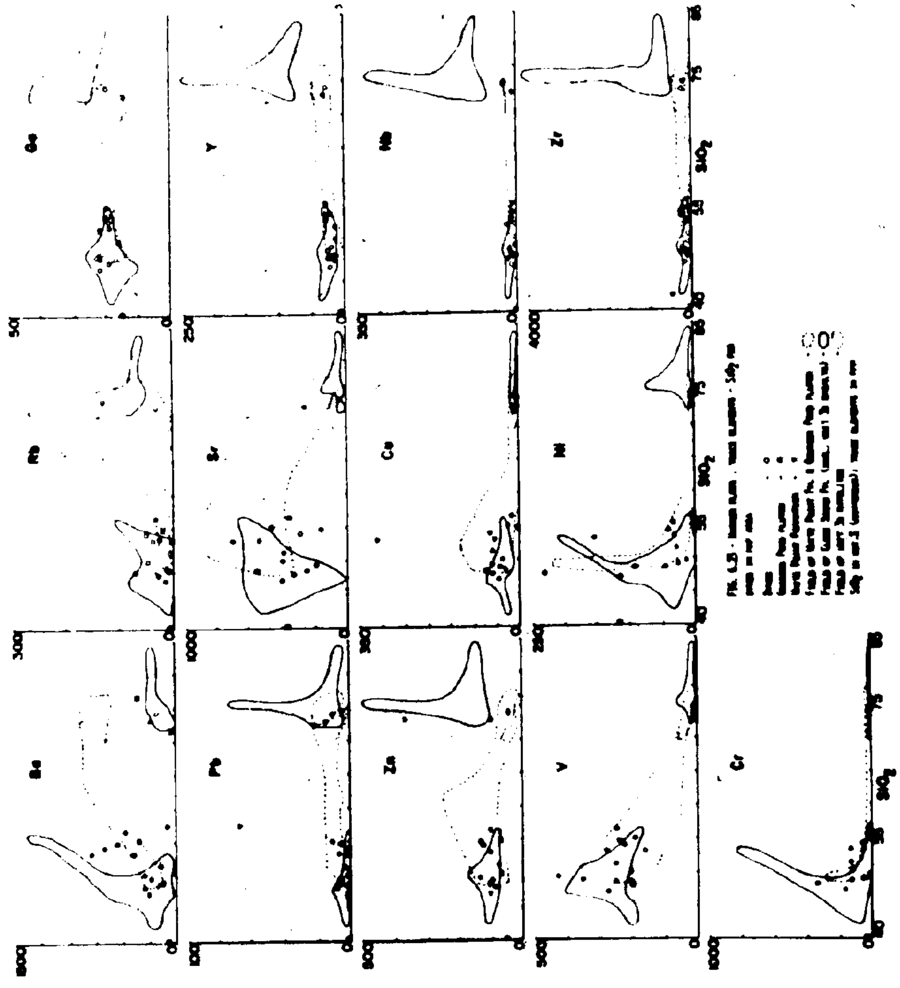

Ba
Rb
Ge
Pb
Sr
Y
Zn
Cu
Nb
V
Ni
Zr
Cr
1000
300
50
100
1000
250
800
300
300
500
250
4000
1000
0
40
55
75
85
SiO_2

FIG. 6.25 -

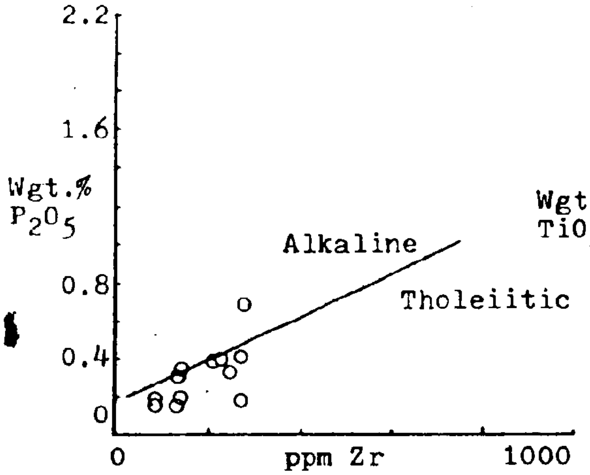


Fig. 6.24 - P_2O_5-Zr plot for mafic dykes in map area; after Winchester & Floyd (1976).

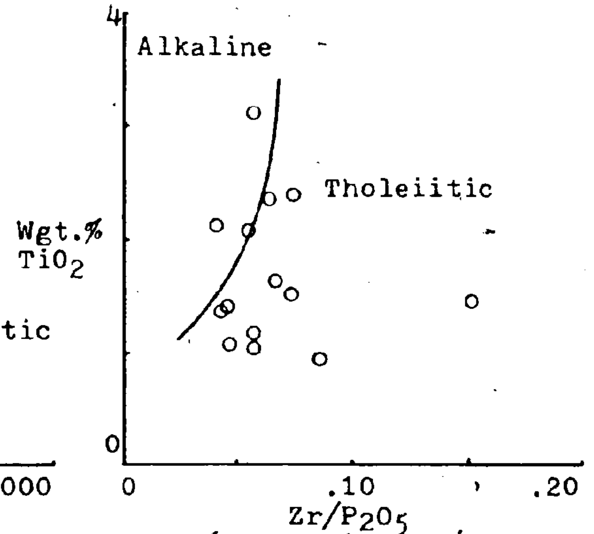


Fig. 6.25 - TiO_2-Zr/P_2O_5 plot for mafic dykes in map area; after Winchester & Floyd (1976).

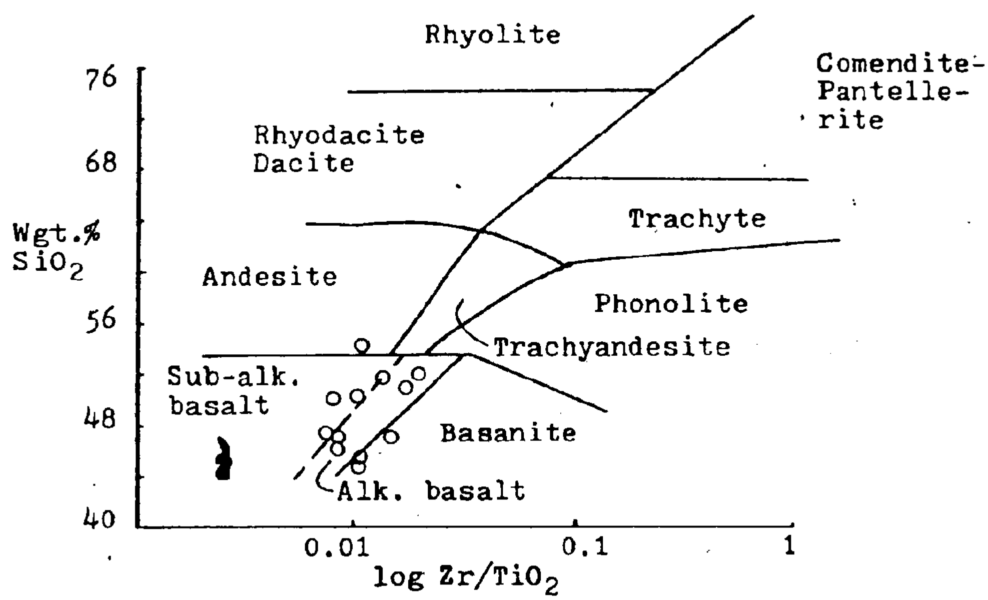


Fig. 6.26 - SiO_2 - log Zr/TiO_2 diagram for dykes in map area. Various fields after Winchester and Floyd (1977).

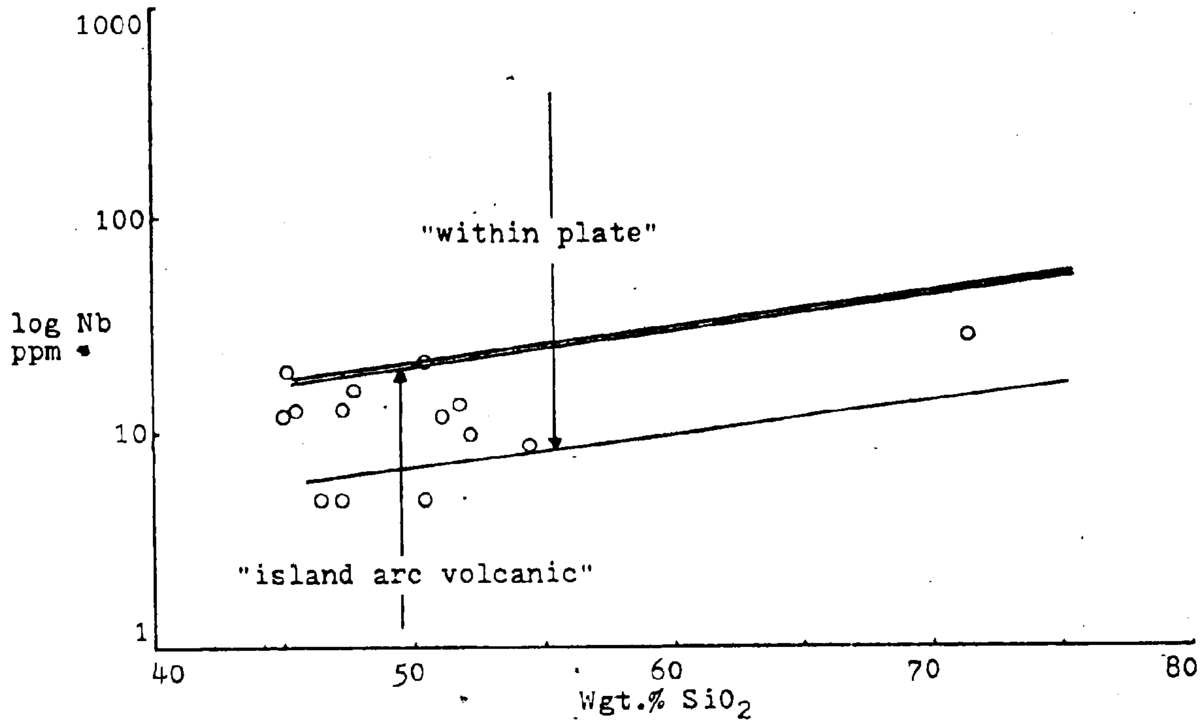


Fig. 6.27 - log Nb - SiO_2 diagram for dykes in map area. Fields after Pearce and Gale (1978).

(Figs. 6.24 and 6.25) of Winchester and Floyd (1976) and they straddle both the subalkaline and alkaline fields on the SiO_2-Zr/TiO_2 diagram (Fig. 6.26) (Winchester and Floyd, 1977). However, both the mafic and silicic dykes tend to occur, along with basalts of Units 3b and 6, in the area of overlap between the "island arc" and "within plate" fields on the Nb-SiO_2 diagram (Fig. 6.27) (Pearce and Gale, 1978).

The dykes intruding the Love Cove Group appear subalkaline in nature although their relation to the volcanic units in the area is generally not clear.

6.8 Conclusions

1. The effects of the alteration are most obvious in the lower-grade rocks in the map area and much of the major element chemistry, in particular the alkalies, is of limited use in comparing and contrasting the various volcanic sequences. However, the relatively immobile major and trace elements can be used to distinguish between rocks of apparently differing magmatic affinities.

2. At least 2 (White Point Formation and Georges Pond pluton and the Musgravetown Group) and possibly 3 distinct suites of igneous rocks occur in the map area. This is supported by the separation on the log Nb-log Zr plot (Fig. 6.28).

3. The Georges Pond pluton appears to be genetically related to the White Point Formation volcanic rocks and it is

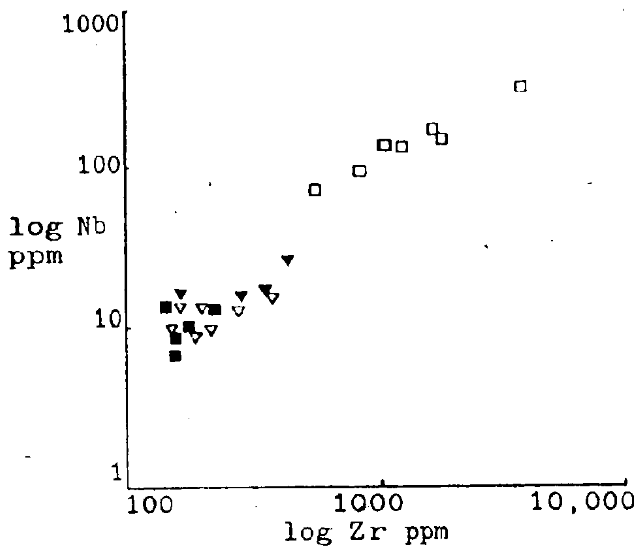


Fig. 6.28 - log Nb - log Zr plot for silicic rocks in map area.

White Pt. Fm. - ▽
Georges Pd. pluton - ■
SW River Fm. (3b) - ▼
Clode Sd. Fm. - □

suggested that both are calcalkaline in nature. Certainly it appears clear that they are subalkaline in character. The high proportion of silicic rocks suggests these rocks were emplaced within and upon continental crust.

4. The petrochemical affinity of the Southwest River Formation (3b) volcanic rocks and their relation to other igneous units in the study area is not clear. Comparisons with the Musgravetown Group rocks suggest that Unit 3b may be mildly alkaline.

5. Volcanic rocks of the Musgravetown Group are markedly bimodal with respect to SiO_2 content and clearly distinct from the White Point Formation. The acidic rocks are strongly peralkaline in nature, and their original alkali contents (especially Na_2O) have been strongly leached. The associated basalts are transitional and/or alkalic in nature. This appears to be the first report of peralkaline igneous activity of Late Precambrian age in the Avalon Zone.

6. In general, the younger volcanic sequence(s) (e.g. Musgravetown Group) are more alkalic in nature than the older rocks (e.g. White Point Formation) in the map area. This trend appears similar to that observed on the Burin Peninsula (S.J. O'Brien, pers. comm., 1979).

7. The chemistry of Unit 1a (Love Cove Group), and Unit 6 (Musgravetown Group) corresponds closely to that found for those units to the north (Dal Bello, 1977).

CHAPTER 7

DISCUSSION

This chapter is divided into three sections which include discussions of the clasts of sericite schists in the Cannings Cove Formation, regional correlations, and the significance of petrochemistry to the interpretation of the geology.

7.1 Clasts of sericite schist in the Cannings Cove Formation

In the past, one of the major problems in the area has been the stratigraphic and structural relationship between the Love Cove and Connecting Point Groups and the Love Cove and Musgravetown Groups. As mentioned in sec. 3.5.6, the interpretation of the relationship between the Love Cove and Musgravetown Groups is based in part on the occurrence of pebbles of sericite schist in conglomerates of the Cannings Cove Formation.

Jenness (1963) first described the clasts of sericite schist at a locality west of Bread Cove and used that detritus along with other data to infer that the Musgravetown Group was post-tectonic (and unconformable) upon the Love Cove Group. Dal Bello (1977) concurred with this interpretation. However, Younce (1970, p. 133) interpreted the schistose detritus in the Cannings Cove Formation to be "eroded contact metamorphic deposits of earlier Bull Arm acidic volcanics".

The occurrence of these pebbles and their interpretation have attained regional significance in recent years (eg. Blackwood, 1976, 1977, 1978; Blackwood and Kennedy, 1976). Therefore, a number of points and questions require consideration in order to evaluate these contrasted opinions. These are:

1. the foliated clasts comprise up to 5% of some outcrops of the Cannings Cove Formation, and were seen both west of Bread Cove and in the Milner's Cove area and in much diminished proportion in conglomerates of the Charlottetown Formation. Hence, either these clasts have been partially reworked or their source was exposed and available to supply such detritus throughout the depositional history of the Musgravetown Group (as defined here).

2. the proximal nature of the Cannings Cove Formation conglomerates suggests local derivation of the detritus.

3. immediately west of Bread Cove, adjacent to outcrops of the Cannings Cove Formation, an outcrop of Connecting Point Group metasediment shows a fine-grained penetrative sericitic fabric. Such a foliation is not commonly seen in the Connecting Point Group and could be related to faulting. A portion of the deformed detritus can be attributed to this source. It should also be noted that mafic dykes apparently related to overlying volcanic rocks post-date the foliation in the Connecting Point Group

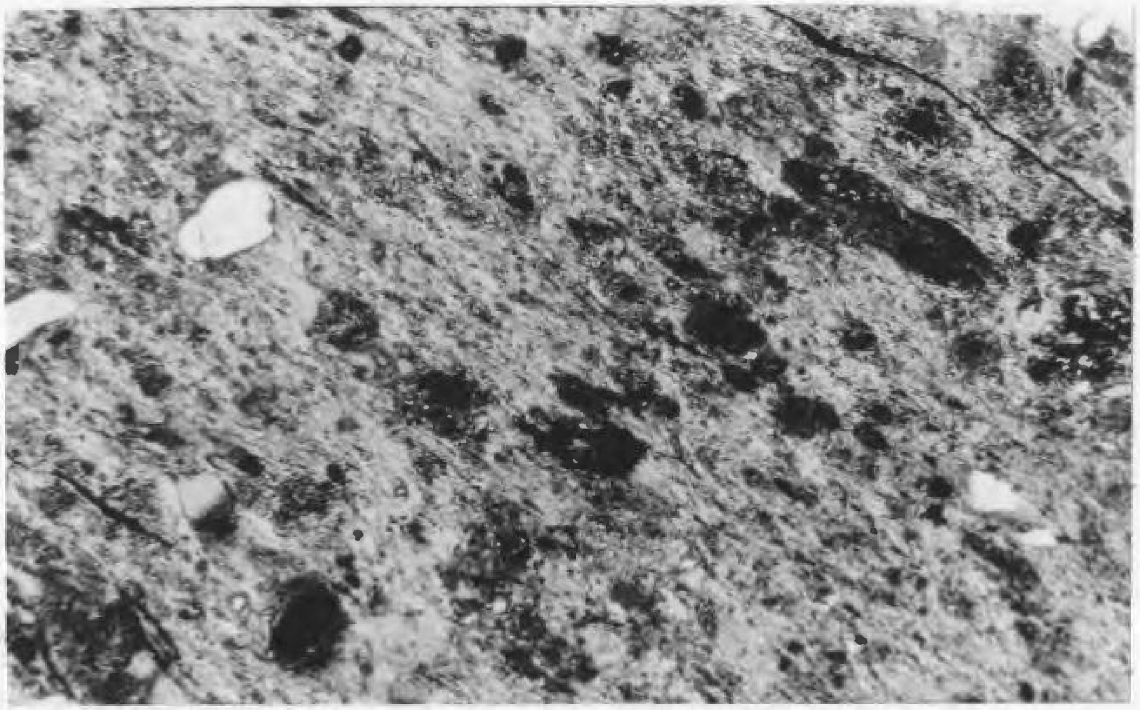


Plate LXIX: Photomicrograph of clast of sericite schist (meta-silicic tuff) in Cannings Cove Formation. Note penetrative foliation; x-nicols, x12.5.

(Plate XXXI).

4. much of the foliated detritus does however closely resemble rocks typical of the Love Cove Group, i.e. fine grained deformed silicic crystal tuffs (compare Plates LXI, LXII and LXIX).

5. one small grain of sericite schist was found in red-beds of the Southwest River Formation which are conformable or disconformable upon schistose volcanic rocks of the White Point Formation.

6. Blackwood (1976) reported not only greenschist fragments but also deformed garnetiferous granite and schistose granite from the Bread Cove locality. Foliated leucogranite and garnet-bearing schist are reported here (see sec. 3.5.2.2). The only presently outcropping source for this detritus lies to the west and northwest in the Gander Zone (Williams et.al., 1974). In that area, locally garnetiferous leucogranites have been overprinted by a steep foliation which has been correlated with mylonite development on the Dover Fault and the steep fabric of the Love Cove Group (Blackwood, 1976; Blackwood and Kennedy, 1976).

7. finally, field evidence cited in secs. 3.3.3.2 and 3.3.3.6 clearly suggests that the redefined Love Cove Group is essentially conformable up into Eocambrian or Cambrian strata exposed on Locker's Flat and adjacent islands in northern Bonavista Bay. This assumes that there are no significant breaks as indicated by Jenness (1963), in the

belt of red sedimentary rocks extending from the head of Clode Sound to Locker's Flat Island. Further, the Ackley batholith, dated at 345 ± 5 Ma (Bell et.al., 1977) post-dates the regional foliation of the Love Cove Group (Hussey, 1978a). Therefore the present author suggests that the regional deformation of the Love Cove Group was a post-Cambrian, pre-Ackley batholith (Acadian?) event (see Appendix 5).

The Musgravetown Group on Clode Sound and in its type area is thought to be late Precambrian on the basis of close lithostratigraphic similarities to sequences to the south which are demonstrably conformable or disconformable up into Cambrian strata (Hayes, 1948; Christie, 1950; Jenness, 1963; Younce, 1970). Therefore Jenness (1963) interpreted the deformed detritus in the basal Musgravetown conglomerates as indicating Precambrian deformation of the Love Cove Group. However, the evidence cited above suggests a Palaeozoic age for the regional deformation (F_1) of the Love Cove Group. On the assumption that the clasts of sericite schist in the Cannings Cove Formation were derived from the Love Cove Group (it is the only presently outcropping lithologically similar source), this conflict is difficult to resolve without questioning the depositional age of the Musgravetown Group on Clode Sound and in its type area. The volcanic rocks of the Clode Sound Formation are distinct from sub-alkaline volcanic rocks in the Southwest River Formation and in the Bull Arm Formation (Malpas, 1971) in that they appear to be peralkaline. However, in regional stratigraphic arguments it may not be valid to base such a distinction solely on chemical grounds, since associations of subalkaline or alkaline and peralkaline rhyolites have been reported from a number of regions (Macdonald, 1974).

Assuming the Musgravetown Group east of Charlottetown is late Precambrian in age, then the unconformity at its base and the steep cleavage in the Connecting Point Group beneath it do record an "Avalonian" event in the sense of Hughes (1970). It is not clear how this relates to the apparently Palaeozoic deformation (F_1) of the Love Cove Group. Either, as Younce (1970) suggested, the Connecting Point Group is the oldest unit in the region and was deformed prior to deposition of other rocks in the map area, or it is possible that an early foliation in the Love Cove Group has been masked by Palaeozoic structures. Also the clasts of sericite schist in the Cannings Cove Formation could be derived from a source not presently exposed. At present there is no evidence for either explanation. Detailed mapping of the Connecting Point Group and its contacts may help to solve this problem.

7.2 Regional Correlations

In regional stratigraphic terms (see Chapter 2), the Love Cove Group is on strike, contiguous with and apparently equivalent to volcanic and sedimentary rocks on the Burin Peninsula which are disconformably overlain by Eocambrian-

Cambrian strata. In detail (see Table 1), this would equate the White Point Formation and the Marystown Group of Taylor (1977), (Taylors Bay Formation of O'Brien, pers. comm., 1979), the Thorburn Lake Formation and the Garnish Formation (O'Brien, pers. comm., 1979), the Southwest River Formation (3b) and the Mortier Bay Group of Taylor (1977) or Calmer Formation of O'Brien (pers. comm., 1979) and Unit 3a and the Rencontre Formation (O'Brien et.al., 1977). The Musgravetown Group of the present map area could be equivalent to the Hare Hills Formation, the Grand Beach Complex, the Barasway Complex and the Mt. St. Anne Formation of the southern Burin Peninsula (O'Brien, pers. comm., 1979). This dominantly subaerial terrain is faulted on the east against thick marine sequences included in the Burin, Rock Harbour, Musgravetown and Connecting Point Groups (Jenness, 1963; Anderson, 1965; Strong et.al., 1976; O'Driscoll, 1978). These marine strata include deep marine sedimentary and pillowed mafic volcanic rocks (eg. Strong et.al., 1976). O'Driscoll (1978) described mafic volcanic rocks underlying a thick marine sequence apparently conformably overlain by red fluviatile sedimentary rocks and Eocambrian-Cambrian strata in western Placentia Bay and by a basalt-rhyolite sequence (equivalent to Southwest River Formation (3b) or Mortier Bay Group?) in central Placentia Bay (O'Driscoll and Muggeridge, 1978). These relationships suggest to the present author that subaerial dominantly silicic volcanism, of possibly variable petrochemical affinity, was accompanied by deep marine sedimentation and tholeiitic (Taylor, 1977) mafic volcanism in an adjoining elongate basin (see Fig. 2.1). On this basis, the White Point Formation and at least Unit 2b of the Thorburn Lake Formation are thought to be equivalent to the Connecting Point Group in the present map area. These rocks are overlain with variable contact relationships by fluviatile sedimentary and subaerial volcanic rocks of different (more alkaline) chemistry (eg. Southwest River Formation and Musgravetown Group) than the earlier volcanic rocks.

A major fault system has juxtaposed the subaerial volcanic terrain and the thick marine sequences. This system includes the Cottels Island - Charlottetown Fault in Bonavista Bay (Jenness, 1963; Younce, 1970). Younce (1970) thought this fault to have a significant strike-slip component. Numerous late Precambrian and Cambrian grabens or basins are localized along this fault system throughout its length (Anderson, 1965; Williams, 1967). These faults have apparently been reactivated in post-Cambrian times.

Lastly, it should be noted that the redefinition of the Love Cove and Musgravetown Groups in this thesis is tentative and subject to revision pending further detailed work in the Bonavista Bay area.

7.3 Significance of Petrochemistry

The condition of the crust throughout late Precambrian times in the Avalon Zone is debatable. Most volcanic units yet studied in the Avalon Zone, aside from the White Point Formation (and the Taylors Bay Formation; O'Brien, pers. comm., 1979), appear distinctly bimodal in nature. However, on the basis of major and/or trace element studies these rocks have been interpreted to be either calcalkaline (eg. Malpas, 1971; O'Driscoll, 1977) or mildly alkaline (Papezik, 1970; Nixon, 1975; Strong et.al., 1978a). Also, some of the Precambrian granites have been interpreted to be calcalkaline (eg. Strong and Minatidis, 1975). The White Point Formation is here interpreted to be calcalkaline although Strong et.al. (1978a) described its apparent correlative, the Marystown Group, as bimodal and mildly alkaline. Noble et.al. (1965) described a close association in space and time of alkalic, calcalkalic and calcic volcanism in the Basin and Range province of the southwestern United States. This suggests perhaps that in such terrains, variations in the chemistry of volcanic rocks cannot be taken as a diagnostic indicator of significant alterations of the prevailing tectonic patterns. Indeed, it is questionable whether the concepts of igneous petrochemistry developed in areas of well-defined tectonic patterns can be meaningfully (or at least rigidly) applied to such broad, relatively non-linear, dominantly silicic volcanic terrains as the Avalon Zone or the Tertiary of the American southwest.

Despite these arguments, it does appear that crustal extension, rupturing, and associated oceanic magmatism

(Burin Group) and sedimentation occurred in the southwestern Avalon Zone (Taylor, 1977; Strong et.al., 1978a). The belt of marine sedimentary and volcanic rocks in the southwestern Avalon Zone extends to the north and includes the Connecting Point Group (see Fig 2.1). However, in contrast to the "sequential interpretation" of Strong et.al. (1978a) the development of this elongate north trending oceanic domain which completely traverses the Avalon Zone, may have been, at least in part, contemporaneous with the subaerial silicic volcanism and associated plutonism. The late history of this terrain was marked by significant uplift of the basin or oceanic domain and possibly also of the subaerial terrain. This uplift is shown by the deposition of red fluviatile sedimentary rocks and in places bimodal (locally peralkaline?) volcanic sequences (eg. Mortier Bay Group, Mooring Cove Formation, Southwest River Formation, Rencontre Formation, Musgravetown Group of the present map area?) which disconformably or unconformably overlie the older rocks. Prior to this uplift marine (?) sedimentation (Thorburn Lake Formation, Andersons Cove Formation) overlapped the subaerial terrain. The whole region was eventually the site of shallow water marine Eocambrian-Cambrian sedimentation and minor mafic volcanism.

CHAPTER 8

CONCLUDING STATEMENTS

1. The map area is underlain by late Precambrian rocks disposed in three fault-bounded, north-trending structural zones. The redefined Love Cove Group occupies the central and western zones which comprise most of the field area. The Connecting Point Group and Musgravetown Group occur in the east.

2. The lithostratigraphy in the field area is complicated by facies variations typical of much of the Avalon Zone stratigraphy.

3. The Love Cove Group is composed of three formations; the White Point Formation, the Thorburn Lake Formation, and the Southwest River Formation. Portions of some of these formations are facies equivalents of others.

The White Point Formation is a dominantly pyroclastic silicic volcanic pile intruded by a comagmatic pluton (the Georges Pond pluton) (see Appendix 5). Diamictites are locally developed.

The Thorburn Lake Formation includes tuffaceous greywackes, sandstone, siltstone, tuff, and some lava. These rocks were deposited in subaerial and in part subaqueous environments. Unit 2b of this formation is in part equivalent to the White Point Formation while Unit 2a is a partial facies equivalent of portions of the Southwest River Formation.

The Southwest River Formation is comprised of a subaerial bimodal volcanic sequence (3b) associated with fluviatile sedimentary rocks (3a).

4. The Connecting Point Group is undivided. It is a thick marine sequence which could be equivalent to the White Point Formation and the Thorburn Lake Formation (2b) (see Appendix 5). It is overlain unconformably by the Musgravetown Group.

5. The Musgravetown Group consists of fluviatile sedimentary rocks (in part alluvial fan deposits) and a thick subaerial basalt-rhyolite volcanic sequence similar lithologically to the Southwest River Formation. Both sequences represent graben fill.

6. The Charlottetown Formation (7) and the Southwest River Formation (3a) are similar to "Middle Assemblage" rocks while all other rocks in the map area are lithologically similar to "Lower Assemblage" strata found elsewhere in the Avalon Zone.

7. The Georges Pond pluton is magmatically related to the volcanic rocks it intrudes and therefore is considered late Precambrian in age. It is equivalent to similar plutons (eg. Swift Current granite, Cape Roger Mountain granite) to the south (see Appendix 5).

8. Geochemically there are three suites of volcanic rocks in the map area. These represent two and possibly three distinct volcanic episodes.

The White Point Formation differs petrographically from other volcanic rocks in the map area. It appears, along with the Georges Pond pluton, to have calcalkaline chemistry.

Both the Southwest River Formation (3b) and the Clode Sound Formation are distinctly bimodal. Basalts of either unit have alkaline affinities. However, rhyolites (pantellerites?) of the Clode Sound Formation appear peralkaline in character as opposed to the subalkaline nature of Unit 3b rhyolites. These rocks are typical of terrains dominated by epeirogenic uplift or doming.

9. The rocks of the field area developed upon continental crust.

10. The "Avalonian Orogeny" on the western Avalon Zone affected both the Love Cove and Connecting Point Groups. It consisted mainly of block faulting and open folding with local low-grade fabric development. There was significant uplift and subaerial erosion. The unconformity at Milner's Cove may be the only good evidence for this event on the western Avalon Zone.

11. The two major faults in the map area probably originated as wrench or normal faults associated with extension and horst and graben development related to bimodal volcanism and fluvial sedimentation. These faults may also reflect reactivation of older underlying structures.

12. The principal penetrative deformation (F_1) of the Love Cove Group was Palaeozoic, probably Acadian in age (see Appendix 5). It involved tight to isoclinal folding at depth.

This may have acted to "tighten up" or thoroughly overprint "Avalonian" structures. Major overturned structures developed in the west and the upper portions of the section were openly folded with locally pronounced flattening.

13. Jenness' (1963) original interpretation that the structure in the Love Cove Group was Precambrian in age was used by Blackwood (1976) and Blackwood and Kennedy (1976) to infer Precambrian juxtaposition of the Gander and Avalon Zones along the Dover Fault. On this basis they developed a plate tectonic model involving late Precambrian orogenesis of the Gander and Avalon Zones. It is the present author's view that at least the time sequence of this model is erroneous and appropriate revisions are required.

14. A metamorphism of lower-greenschist grade accompanied the major deformation of the Love Cove Group. This apparently syntectonic growth was overprinted by a static crystallization of stilpnomelane which could have been related to the emplacement of late post-kinematic plutons such as the Devonian Ackley batholith. However, prehnite-pumpellyite facies metamorphism prevailed in the upper portions of the section.

15. An integrated geological, geochemical, and radiometric age-dating,(eg. U/Pb) program is the key to resolving outstanding problems of Avalon Zone geology.

BIBLIOGRAPHY

Abbey, S. 1968. Analysis of rocks and minerals by atomic absortion spectrophotometry; Pt. 2: Determinations of total iron, magnesium, calcium, sodium and potassium. Geol. Surv. Can., Pap. 68-20, 21p.

Abbott, M.J. 1969. Petrology of the Nandewar Volcano, N.S.W. Australia. Contrib. Mineral and Petrol., v. 20, p. 115-134.

Allen, J.R.L. 1970. Studies in fluviatile sedimentation: a comparison of fining-upward cyclothems, with special reference to coarse-member composition and interpretation. J. Sed. Petrol., v. 40, p.298-323.

American Geological Institute 1972. Glossary of Geology, 1st ed., Washington, D.C., 857p.

Anderson, F.D. 1965. Belleoram, Newfoundland: Geological Survey of Canada, Map 8 - 1965.

Anderson, M.M. 1972. A possible time span for the Late Precambrian of the Avalon Peninsula, southeastern Newfoundland in the light of worldwide correlation of fossils, tillites, and rock units within the succession. Can. J. Earth Sci., v.9, p. 1710-1726.

Anderson, M.M. and Misra, S.B. 1968. Fossils found in the Precambrian Conception Group of south-eastern Newfoundland. Nature, v. 220, no. 5168, p. 680-681.

Anderson, M.M., Bruckner, W.D., King, A.F., and Maher, J.B. 1975. The Late Proterozoic "H.D. Lilly Unconformity" at Red Head, northeastern Avalon Peninsula, Newfoundland, Amer. J. Sci., v. 275, p. 1012-1027.

Arculus, R.J. and Johnson, R.W. 1978. Criticism of generalized models for the magmatic evolution of arc-trench systems Earth and Planet. Sci. Letters, v. 39, p. 118-126.

Aubert de la Rue, E. 1932. 1932. Premiers resultats d'une mission geologique aux les Saint Pierre et Miquelon; Revue de Geog. Phys. et de Geol Dynam., V. 5, p. 417-535.

Augustithus, S.S., and Otteman, J. 1966. On diffusion rings and spheroidal weathering; Chem. Geol., V. 1, p. 201-209.

BIBLIOGRAPHY (Cont'd)

Bailey, D.K., and MacDonald, R. 1970. Petrochemical variations among mildly peralkaline (comendite) obsidians from the oceans and continents; Contrib. Mineral. & Petrol., v.28, p.340-351.

Baker, B.H., and Henage, L.F. 1977. Compositional changes during crystallization of some peralkaline silicic lavas of the Kenya rift valley, J. Volcanol. Geotherm. Res., v.2, p.17-28.

Barberi, F., Ferrara, G., Santacroce, R., Treuil, M., and Varet, J. 1975. A transitional basalt-pantellerite sequence of fractional crystallization, the Boina Centre (Afar Rift, Ethiopia). J. Petrology, v.16, p.22-56.

Barning, K. 1965. Petrology of the north-western part of the Holyrood granite batholith. unpubl. M. Sc. thesis, Memorial Univ., St. John's, Newfoundland, 88p.

Battey, M.H. 1955. Alkali metasomatism and the petrology of some keratophyres. Geol. Mag., v.92, no.2, p.104-126.

Bell, K., and Blenkinsop, J. 1975. Geochronology of eastern Newfoundland. Nature, v.254, p.410-411.

Bell, K., Blenkinsop, J., and Strong, D.F. 1977. The geochronology of some granitic bodies from eastern Newfoundland and its bearing on Appalachian evolution. Can. J. Earth Sci., v.14, p.456-476.

Benioff, H. 1954. Orogenesis and deep crustal structure-additional evidence from seismology. Geol. Soc. Amer. Bull., v.65, p.385-400.

Best, M.G., and Brimhall, W.H. 1974. Late Cenozoic alkalic basaltic magmas in the western Colorado plateau and the Basin and Range transition zone, U.S.A., and their bearing on mantle dynamics. Geol. Soc. Am. Bull., v.85, p.1677-1690.

Blackwood, R.F. 1976. The relationship between the Gander and Avalon Zones in the Bonavista Bay region, Newfoundland. unpubl. M. Sc. thesis, Memorial Univ., St. John's, Newfoundland, 156p.

Blackwood, R.F. 1977. Geology of the Hare Bay area, northwestern Bonavista Bay, Newfoundland; In Report of Activities for 1976, R.V. Gibbons (Ed.): Nfld. Dept. Mines and Energy, Min. Development Division, Report 77.5.

BIBLIOGRAPHY (Cont'd)

Blackwood, R.F. 1977. Geology of the east half of the Gambo (2D/16) map-area and the northwest portion of the St. Brendans (2C/13) map-area, Newfoundland. Nfld. Dept. Mines and Energy, Min. Development Division, Report 77-5, 20p.

Blackwood, R.F. 1978. Northeastern Gander Zone, Newfoundland; In Report of Activities for 1976, R.V. Gibbons (Ed.); Nfld. Dept. Mines and Energy, Min. Development Division, Report 78-1, p. 72-79.

Blackwood, F., and Kennedy, M.J. 1975. The Dover Fault: western boundary of the Avalon Zone in northeastern Newfoundland. Can. J. Earth Sci., v.12, p.320-325.

Blackwood, R.F., and O'Driscoll, C.F. 1976. The Gander-Avalon Zone boundary in southeastern Newfoundland. Can. J. Earth Sci., v.13, p.1155-1159.

Blake, D.H., Elwell, R.W.D., Gibson, I.L., Skelhorn, R.R., and Walker, G.P.L. 1965. Some relationships resulting from the intimate association of acid and basic magmas. Quart. J. Geol. Soc. London, v.121, p.31-49.

Blenkinsop, J., Cucman, P.F., and Bell, K. 1976. Age relationships along the Hermitage Bay-Dover Fault system, Newfoundland. Nature, v.262, p.377-378.

Boothroyd, J.C. 1972. Coarse-grained sedimentation on a braided-outwash fan, northeast Gulf of Alaska. Technical Rep. No. 6-CRD, Coastal Research Division, Univ. of South Carolina, Columbia, S.C., 127p.

Boothroyd, J.C. 1976. Sandur Plains, northeast Gulf of Alaska: A model for alluvial fan - fan delta sedimentation in cold-temperature environments In Recent and Ancient Sedimentary Environments in Alaska. Editor, Miller, T.P.; Alaska Geol. Soc., Anchorage, p. N1-N6.

Boothroyd, J.C. 1977. Braided streams and alluvial fans. In Terrigenous Clastic Depositional Environments: some modern examples. Editors, Hayes, M.O., and Kana, T.W.; Amer. Assoc. Petrol. Geol. Field Course; Tech. Rept. 11-CRD. Univ. of South Carolina, S.C., p.I17-I26.

Bowden, P. 1974. Oversaturated alkaline rocks; granites, pantellerites and comendites. In The Alkaline Rocks, Editor, Sorenson, H., John Wiley & Sons, New York, p.109-123.

BIBLIOGRAPHY (Cont'd)

Bradley, D.A. 1962. Geology of the Gisbourne Lake - Terrenceville map-area, Newfoundland. Geol. Surv. Can., Mem. 321, 56p.

Briggs, N.D. 1975. Determination of cause of thickness variation in ignimbrites (NOTE). N.Z. Jour. Geol. and Geophys., v.18, p.501-506.

Briggs, N.D. 1976a. Welding and crystallization zonation in Whakamaru ignimbrite, Central North Island, New Zealand. N.Z. Jour. Geol. and Geophys., v.19, p.189-212.

Briggs, N.D. 1976b. Recognition and correlation of subdivisions within the Whakamaru ignimbrite, Central North Island, New Zealand. N.Z. Jour. Geol. and Geophys., v.19, p.463-501.

Brooks, C.K. 1976. The Fe_2O_3/FeO ratio of basalt analyses: an appeal for a standardized procedure. Bull. Geol. Soc. Denmark, v.25, p.117-120.

Brothers, R.N. 1970. Petrological affinities of volcanic rocks from the Tonga-Kermadec Island Arc, southwest Pacific, Bull Volcanol., v.34, p.308-329.

Bruckner, W.D. 1969. Geology of eastern part of Avalon Peninsula, Newfoundland - a summary. Amer. Assoc. Petrol. Geol., Mem. 12, p.130-138.

Bruckner, W.D. 1977. Significance of new tillite finds for east-west correlations of Proterozoic Avalon-Zone formations in southeastern Newfoundland (Canada). Estudios Geol., v.33, p.357-364.

Bruckner, W.D., and Anderson, M.M. 1971. Late Precambrian glacial deposits in southeastern Newfoundland - a preliminary note. Geol. Assoc. Can., Proc., v.24, p.95-102.

Buddington, A.F. 1919. Precambrian rocks of southeast Newfoundland. J. Geol., v.27, p.449-479.

Bull, W.B. 1972. Recognition of alluvial fan deposits in the stratigraphic record. In Recognition of Ancient Sedimentary Environments. Editors, Rigby, J.K., and Hamblin, W.K., Soc. Econ. Palaeon. and Mineral. Spec. Pub. 16, 340p.

Cann, J.R. 1970. Rb, Sr, Y, Zr, and Nb in some ocean-floor basaltic rocks. Earth Planet. Sci. Letters, v.10, p.7-11.

BIBLIOGRAPHY (Cont'd)

Carmichael, D.M. 1969. On the mechanisms of prograde metamorphic reactions in quartz-bearing pelitic rocks. Contrib. Mineral. and Petrol., v.20, p.244-267.

Carmichael, I.S.E., Turner, F.J., and Verhoogen, J. 1974. Igneous Petrology. McGraw-Hill, New York., 739p.

Chapman, C.A. 1962. Diabase-granite composite dykes, with pillow-like structure, Mount Desert Island, Maine. J. Geol., v.70, p.539-564.

Chayes, F. 1969. The chemical composition of Cenozoic andesite. In Proceedings of the Andesite Conference. Editor, McBirney, A.R., Oregon Dept. Geol. Min. Ind. Bull. 65, p.1-11.

Christie, A.M. 1950. Geology of Bonavista map area, Newfoundland. Geol. Surv. Can., Paper 50-7.

Coats, R.R. 1962. Magma type and crustal structure in the Aleutian arc, In The Crust of the Pacific Basin. Geophys. Monograph 6. Editors, Macdonald, G.A., and Kuno, H. Am. Geophys. Union, Washington, D.C., p.92-109.

Cole, J.W. 1978. Andesites of the Tongariro volcanic centre, North Island, New Zealand. J. Volcanol. Geotherm. Res., v.3, p.121-153.

Cook, K.L. 1966. Rift system in the Basin and Range province. In The World Rift System. Editor, Irvine, T.N., Geol. Surv. Can. Pap. 66-14, p. 246-277.

Cormier, R.F. 1969. Radiometric dating of the Coldbrook Group of southern New Brunswick, Canada. Can. J. Earth Sci., v.6, p. 393-395.

Costello, W.R. and Walker, R.G. 1972. Pleistocene sedimentology, Credit River, southern Ontario: a new component of the braided river model. J. Sed. Petrol., v.42, p. 389-400.

Cox, K.G. 1971. Karroo lavas and associated igneous rocks of Southern Africa. Bull. Volcanol., v.35, p.867-886.

Curtis, G.N. 1954. Mode of origin of pyroclastic debris in the Mehrten Formation of the Sierra Nevada. Univ. Calif. Publ. Bull., Dept. Geol. Sci., v.29, p.453-502.

Dal Bello, A.E. 1977. Stratigraphic position and petrochemistry of the Love Cove Group, Glovertown-Traytown map area, Bonavista Bay, Newfoundland, Canada. unpubl. M. Sc. thesis, Memorial Univ., St. John's, Newfoundland, 159p.

Deer, W.A., Howie, R.A., and Zussman, J. An Introduction to the Rock-Forming Minerals. Longman Group Ltd., London, 528p.

BIBLIOGRAPHY (Cont'd)

Dickinson, W.R. 1968. Circum-Pacific andesite types. J. Geophys. Res., v.73, p. 2261-2269.

Donnelly, T.W. 1963. Genesis of albite in early orogenic volcanic rocks. Amer. J. Sci., v.261, p.957-972.

Donnelly, T.W. 1966. Geology of St. Thomas and St. John, U.S. Virgin Islands. Geol. Soc. Am. Mem. 98, p.85-176.

El-Hinnawi, E.E., Pichler, H., and Zeil, W. 1969. Trace element distribution in Chilean ignimbrites. Contrib. Mineral. and Petrol., v.24, p.50-62.

Enlows, H.E. 1955. Welded tuffs of Chiricahua National Monument, Arizona. Geol. Soc. Am. Bull., v.66, p.1215-1246.

Ewart, A., and Stipp, J.J. 1968. Petrogenesis of the volcanic rocks of the Central North Island, New Zealand, as indicated by a study of Sr^{87}/Sr^{86} ratios, and Sr, Rb, K, U, and Th abundances. Geochim. Cosmochim. Acta, v.32, p.699-735.

Ewart, A., Taylor, S.R., and Capp, A.C. 1968. Geochemistry of the pantellerites of Mayor Island, New Zealand. Contrib. Mineral. and Petrol., v. 17, p.116-140.

Fairbairn, H.W., Bottino, M.L., Pinson Jr., W.H., and Hurley, P.M. 1966. Whole rock age and initial Sr^{87}/Sr^{86} of volcanics underlying fossiliferous Lower Cambrian in the Atlantic provinces of Canada. Can. J. Earth Sci., v.3, p.509-521.

Ferrara, G., and Treuil, M. 1974. Petrological implications of trace element and Sr isotope distributions in basalt-pantellerite series. Bull. Volcanol. (Spec. Issue), v.38, p.548-574.

Fisher, R.V. 1960. Classification of volcanic breccias. Geol. Soc. Am. Bull., v.71, p.973-982.

Fisher, R.V. 1966. Rocks composed of volcanic fragments and their classification. Earth Sci. Rev., v.1, p.287-298.

Fiske, R.S. 1963. Subaqueous pyroclastic flows in the Ohanapecosh Formation, Washington. Geol. Soc. Am. Bull., v.74, p.391-406.

Fletcher, T.P. 1972. Geology and Lower to Middle Cambrian Trilobite Faunas of the southwest Avalon, Newfoundland. Unpubl. Ph. D. thesis, Christ's College, Cambridge.

BIBLIOGRAPHY (Cont'd)

Floyd, P.A. 1977. Rare earth element mobility and geochemical characterization of spilitic rocks. Nature, v.269, p.134-137.

Floyd, P.A., and Winchester, J.A. 1975. Magma type and tectonic setting discrimination using immobile elements. Earth Plan. Sci. Letters, v.27, p.211-218.

Floyd, P.A., and Winchester, J.A. 1976. Petrochemical affinities of Dalradian metabasaltic rocks: a reply to C.M. Graham. Earth Plan. Sci. Letters, v.32, p.213-214.

Folk, R.L. 1974. Petrology of Sedimentary Rocks. Austin, Texas, Hemphill's, 170p.

Forbes, R.B., Ray, D.K., Katsura, T., Matsumoto, T., Haramura, H., and Furst, M.J. 1969. The comparative chemical composition of continental vs. island arc andesites in Alaska. In Proceedings of the Andesite Conference. Editor, McBirney, A.R., Oregon Dept. Geol. Min. Ind. Bull. 65, p.111-120.

Gass, I.G., and Mallick, D.I.J. 1968. Jebel Khariz: an Upper Miocene strato-volcano of comenditic affinity on the South Arabian coast. Bull. volcanol., v.32, p33-88.

Geophysics Paper 229, 1968. Geological Survey of Canada.

Gibson, I.L. 1970. A pantellerite welded ash-flow tuff from the Ethiopian Rift Valley. Contrib. Mineral. and Petrol., v.28, p.89-111.

Gibson, I.L., and Walker, G.P.L. 1964. Some composite rhyolite-basalt lavas and related composite dykes in eastern Iceland. Proc. Geologists Assoc. (Engl.), v.74, p.301-318.

Gibson, I.L., and Tazieff, H. 1967. Additional theory of origin of fiamme in ignimbrites. Nature, v.215, p. 1473-1474.

Gilbert, C.M., and Reynolds, M.W. 1973. Character and chronology of basin development, western margin of the Basin and Range Province. Geol. Soc. Am. Bull., v.84, p.2489-2510.

Gilluly, J. 1971. Plate tectonics and magmatic evolution. Geol. Soc. Am. Bull., v.82, p.2383-2396.

BIBLIOGRAPHY (Cont'd)

Glover, L., III, and Sinha, A.K. 1973. The Virgilina deformation, a late Precambrian to early Cambrian (?) orogenic event in the central Piedmont of Virginia and North Carolina. Amer. J. Sci., v.273-A, p. 234-251.

Graham, C.M. 1976. Petrochemical affinities of Dalradian meta-basaltic rocks: discussion of paper by J.A. Winchester and P.A. Floyd. Earth Plan. Sci. Letters, v.32, p.210-212.

Greene, B.A. 1972. Geological map of Labrador, scale 1:1,000,000. Nfld. Dept. Mines and Energy, Min. Dev. Division, St. John's, Newfoundland.

Greene, B.A., and Williams, H. 1974. New fossil localities and the base of the Cambrian in southeastern Newfoundland. Can. J. Earth Sci., v.11, p. 319-323.

Hamilton, W., and Myers, W.B. 1967. The nature of batholiths. U.S. Geol. Surv. Prof. Paper, 554-C, 30p.

Harker, A. 1909. Natural History of Igneous Rocks.

Hart, S.R., Erlank, A.J., and Kable, E.J.D. 1974. Sea-floor basalt alteration: some chemical and Sr isotope effects. Contrib. Mineral. and Petrol., v.44, p.219-230.

Hatch, F.H., Wells, A.K., and Wells, M.K. 1972. Petrology of the Igneous Rocks. Murby and Co., London, 551p.

Hay, R.L. 1959. Formation of the crystal-rich glowing avalanche deposits of St. Vincent, British West Indies, J. Geology, v.67, p.540-562.

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

Hayes, M.O., and Kana, T.W. (eds.) 1976. Terrigenous Clastic Depositional Environments: some modern examples. Amer. Assoc. Petrol. Geol. Field Course; Tech. Rept. 11-CRD; Univ. of S. Carolina, 316p.

Helmstaedt, H., and Tella, S. 1973. Pre-Carboniferous structural history of S.E. Cape Breton Island, Nova Scotia. Maritime Sediments, v.9, p.88-99.

Hobbs, B.E., Means, W.D., and Williams, P.F. 1976. An Outline of Structural Geology. John Wiley & Sons, New York, 571p.

BIBLIOGRAPHY (Cont'd)

Holmes, A. 1921. Petrographic Methods and Calculation with Some Examples of Results Achieved. Murby, 1921, 515p.

Hopgood, A.M. 1962. Radial distribution of soda in a pillow of spilitic lava from the Franciscan, California. Amer. Jour. Sci., v.260, p.383-396.

Hotz, P.E. 1971. Petrography, chemical composition, and age of plutons of the Klamath Mountains and a comparison with plutons of the east-central and western Sierra Nevada. U.S. Geol. Surv. Prof. Paper, 684p.

Howell, B.F. 1925. The faunas of the Cambrian Paradoxides beds at Manuels, Newfoundland. Bull. Am. Palaeo., v.11, no.43, p.1-140.

Hughes, C.J. 1960. The Southern Mountains Igneous Complex, Isle of Rhum. Geol. Soc. Lond., Quart. J., v.116, p.111-138.

Hughes, C.J. 1970. The Late Precambrian Avalonian orogeny in Avalon, southeast Newfoundland. Amer. J. Sci., v.269, p. 183-190.

Hughes, C.J. 1971. Anatomy of a granophyre intrusion. Lithos, v.4, p.403-415.

Hughes, C.J. 1972. Geology of the Avalon Peninsula, Newfoundland and its possible correspondance with Morocco. Notes et Memoires du Service Geologique de Maroc, no. 236, p. 265-275.

Hughes, C.J. 1973. Spilites, keratophyres, and the igneous spectrum. Geol. Mag., v.109, p.513-527.

Hughes, C.J. 1976. Volcanogenic cherts in the late Precambrian Conception Group, Avalon Peninsula, Newfoundland. Can. J. Earth Sci., v.13, p.512-519.

Hughes, C.J., and Malpas, J.G. 1971. Metasomatism in the late Precambrian Bull Arm Formation in southeastern Newfoundland: recognition and implications. Geol. Assoc. Can., Proc., v.24, p.85-93.

Hughes, C.J., and Bruckner, W.D. 1971. Late Precambrian rocks of eastern Avalon Peninsula, Newfoundland - a volcanic island complex. Can. J. Earth Sci., v.8, p. 899-915.

Hughes, C.J., and Bruckner, W.D. 1972. Late Precambrian rocks of eastern Avalon Peninsula, Newfoundland - a volcanic island complex: reply. Can. J. Earth Sci., v.9, p.1059-1060.

BIBLIOGRAPHY (Cont'd)

Hughes, C.J., and Hussey, E.M. 1976. M and Mg values in igneous rocks: proposed usage and a comment on currently employed Fe_2O_3 corrections. Geochim. et. Cosmochim. Acta., v.40, p.485-486.

Hughes, C.J., and Hussey, E.M. (in press). Standardized procedure for presenting corrected Fe_2O_3/FeO ratios in analyses of fine grained mafic rocks.

Hussey, E.M. 1978a. Geology of the Sound Island map-area west half (IM/16); Report of Activities for 1977, R.V. Gibbons (Ed.); Nfld. Dept. Mines and Energy, Min. Development Division, Report 78-1, pp. 110-115.

Hussey, E.M. 1978b. Geology of the Sound Island map-area west half (IM/16); Nfld. Dept. Mines and Energy, Min. Development Division, unpubl. detailed internal report, 39p.

Hutchison, C.S. 1974. Laboratory Handbook of Petrographic Techniques. John Wiley and Sons, New York, 527p.

Ingram, R.L. 1954. Terminology for the thickness of stratification and parting units in sedimentary rocks (a brief statement on terminology). Geol. Soc. Am., Bull., v.65, p.937-938.

Irvine, T.N., and Barager, W.R.A. 1971. A guide to the chemical classification of the common volcanic rocks. Can. J. Earth Sci., v.8, p.523-548.

Jakes, P., and White, A.J.R. 1972. Major and trace element abundances in volcanic rocks of orogenic areas. Geol. Soc. Am. Bull., v.83, p.29-40.

Jayasinghe, N.R. 1978. Devonian alkalic basalt dykes of northeastern Newfoundland: evidence of a tensional environment. Can. J. Earth Sci., v.15, p.848-853.

Jayasinghe, N.R., and Berger, A.R. 1976. On the plutonic evolution of the Wesleyville area, Bonavista Bay, Newfoundland. Can. J. Earth Sci., v.13, p.1560-1570.

Jenness, S,E. 1958. Geology of Newman-Sound Map-Area, Northeastern Newfoundland. Geol. Surv. of Nfld., Report no. 12A.

Jenness, S.E. 1960. Late Pleistocene glaciation of eastern Newfoundland. Geol. Soc. Amer. Bull., v.71, p.161-179.

BIBLIOGRAPHY (Cont'd)

Jenness, S.E. 1963. Terra Nova and Bonavista Map Areas, Newfoundland. Geol. Surv. Can., Mem. 327, 184p.

Johnson, R.W., MacKenzie, D.E., and Smith, I.E.M. 1978. Volcanic rock associations at convergent plate boundaries: Reappraisal of the concept using case histories from Papua New Guinea. Geol. Soc. Am. Bull., v.89, p.96-106.

Jones, E.J.W., Mitchell, J.G., Shido, F., and Phillips, J.D. 1972. Igneous rocks dredged from the Rockall Plateau. Nature, v.237, p.118-120.

Jukes, J.B. 1843. General Report of the Geological Survey of Newfoundland during the years 1839-1840. Vols. I and II, John Murray, London, England, 180p.

Kennedy, M.J. 1975. Repetitive orogeny in the northeastern Appalachians-new plate models based upon Newfoundland examples. Tectonophysics, v.28, p.39-87.

Kerrich, R., Fyfe, W.S., Gorman, B.E., and Allison, I. 1977. Local modification of rock chemistry by deformation. Contrib. Mineral. and Petrol., v.65, p.183-190.

Kesler, S.E., Lewis, J.F., Jones, L.M., and Walker, R.L. 1977. Early island-arc intrusive activity, Codillera Central, Dominican Republic. Contrib. Mineral. and Petrol. v.65, p.91-99.

Keyes, D.A. 1948. A petrogenetic study of the Come-By-Chance-Swift Current area of southern Newfoundland. unpubl. B. Sc. thesis, Queen's University, Kingston, Ontario, 41p.

King, A.F. 1972. Late Precambrian molasse of the Avalon Platform, Newfoundland. Geol. Soc. Am., Abstr. with Programs, v.4, no.1, p.26.

King, A.F. 1974. Late Precambrian (Hadrynian) and early Palaeozoic rocks of eastern Newfoundland. Geol. Assoc. Can. and Mineral. Assoc. Can., Program with Abstr., p.49.

King, A.F. 1977. Subdivision and palaeogeography of late Precambrian and early Palaeozoic rocks of the Avalon Peninsula, Newfoundland. Geol. Soc. Am., Abstr. with Programs, p.284.

King, A.F., Bruckner, W.D., Anderson, M.M., and Fletcher, T.P. 1974. Late Precambrian and Cambrian Sedimentary Sequences of Eastern Newfoundland. Geol. Assoc. Can., Field Trip Manual, B6.

BIBLIOGRAPHY (Cont'd)

Kistler, R.W., Evernden, J.F., and Shaw, H.R. 1971. Sierra Nevada plutonic cycle: Part I, Origin of composite granitic batholiths. Geol. Soc. Am. Bull., v.82, p.853-868.

Klepper, M.R., Robinson, G.D., and Smedes, H.W. 1971. On the nature of the Boulder Batholith in Montana. Geol. Soc. Am. Bull., v.82, p.1563-1580.

Kochhar, N. 1977. Post-emplacement alkali modifications in rapidly cooled acid volcanic rocks. Am. Mineral., v.62, p.333-335.

Kovach, A., Hurley, P.M., and Fairbairn, H.W. 1977. Rb-Sr whole rock age determinations of the Dedham Granodiorite, eastern Massachussetts. Amer. J. Sci., v.277, p.905-912.

Krynine, P.D. 1949. The origin of red beds. N.Y. Acad. Sci., Ser. II, v.2, p.60-68.

Kuno, H. 1960. High-alumina basalt. J. Petrology, v.1, p.121-145.

Kuno, H. 1966. Lateral variation of basalt magma across continental margins and island arcs. Bull. volcanol., v.29, p.195-222.

Lahee, F.H. 1961. Field Geology. McGraw-Hill Book Co., New York, 926p.

Levi, B. 1969. Burial metamorphism of a Cretaceous volcanic sequence west from Santiago, Chile. Contrib. Mineral. and Petrol., v.24, p.30-49.

Lilljequist, R. and Svenson, S. 1974. Exceptionally well preserved Precambrian ignimbrites and basic lavas in N. Sweden. Geologiska Foreningens i Stockholm Forhandlinger, v.96, p.221-229.

Lilly, H.D. 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. Amer. J. Sci., v.264, p.569-574.

Lipman, P.W. 1965. Chemical comparison of glass and crystalline volcanic rocks. U.S. Geol. Surv. Bull. 1201-D, D1-D24.

Lipman, P.W. 1967. Mineral and chemical variations within an ash-flow sheet from Aso Caldera, southwestern Japan. Contrib. Mineral. and Petrol., v.16, p.300-327.

BIBLIOGRAPHY (Con't'd)

Lipman, P.W. 1969. Alkali and tholeiitic basaltic volcanism related to the Rio Grande depression, southern Colorado and northern New Mexico. Geol. Soc. Am. Bull., v.80, p.1343-1354.

Lipman, P.W., Christiansen, R.L., and Alstine, R.F. 1969. Retention of alkalies by calc-alkaline rhyolites during crystallization and hydration. Am. Mineral., v.54, p.286-291.

Lipman, P.W., Prostka, H.J., and Christiansen, R.L. 1972. Cenozoic volcanism and plate-tectonic evolution of the western United States. Phil. Trans. Royal Soc. London, series A, v.271, p.217-284.

Lipman, P.W., Doe, B.R., Hedge, C.E., and Steven, T.A. 1978. Petrologic evolution of the San Juan volcanic field, southwestern Colorado: Pb and Sr isotope evidence. Geol. Soc. Am. Bull., v.89, p.59-82.

Lock, B.E. 1972. A lower Palaeozoic rheo-ignimbrite from White Bay, Newfoundland. Can. J. Earth Sci., v.9, p.1495-1503.

Macdonald, G.A. 1967. Forms and structures of extrusive basaltic rocks. In Basalts: The Poldervaart Treatise on Rocks of Basaltic Composition. Editors, Hess, H., and Poldervaart, A., Interscience Publishers, New York, N.Y., 495p.

Macdonald, G.A., and Katsura, T. 1964. Chemical composition of Hawaiian lavas. J. Petrology, v.5, p.82-133.

Macdonald, R. 1974. Tectonic settings and magma associations. Bull. Volcanol. (Spec. Issue), v.38, p.575-593.

Macdonald, R., and Gibson, I.L. 1969. Pantellerite obsidians from the Volcano Chabbi (Ethiopia). Contrib. Mineral. and Petrol., v.24, p.239-244.

Macdonald, R., and Bailey, D.K. 1973. The chemistry of the peralkaline oversaturated obsidians. U.S. Geol. Surv. Prof. Paper 440, p. N1-N37.

Maher, J.B. 1971. Stratigraphy and Petrology of the Pouch Cove, Cape St. Francis Area, Newfoundland. unpubl. M. Sc. thesis, Memorial Univ., St. John's, Newfoundland.

Malpas, J. 1971. The Petrochemistry of the Bull Arm Formation near Rantem Station, southeast Newfoundland. unpubl. M. Sc. thesis, Memorial Univ., St. John's Newfoundland, 95p.

BIBLIOGRAPHY (Cont'd)

Manson, V. 1967. Geochemistry of basaltic rocks: major elements In Basalts: The Poldervaart Treatise on Rocks of Basaltic Composition. Editors, Hess, H., and Poldervaart, A., Interscience Publishers, New York, N.Y., 495p.

Martin, R.F. and Piwinski, A.J. 1972. Magmatism and tectonic setting. J. Geophys. Res., v.77, p.4966-4975.

Maxwell, J.A. 1968. Rock and Mineral Analyses. Interscience Publishers, New York, 584p.

McBirney, A.R. 1968. Second additional theory of origin of fiamme in ignimbrites. Nature, v.217, p.938.

McBirney, A.R. 1969. Andesitic and rhyolitic volcanism of orogenic basalts. In The Earth's Crust and Upper Mantle. Editor, Hart, P.J., Amer. Geophys. Union Monograph 13, p.501-507.

McBirney, A.R. 1969. Compositional variations in Cenozoic calc-alkaline suites of Central America. Oreg. Dept. Geol. Miner. Ind., Bull. 65 (Proc. of the Andesite Conference; ed. A.R. McBirney) p.185-189.

McBirney, A.R., and Weill, D.F. 1966. Rhyolite magmas of Central America. Bull. Volcanol., v.29, p.435-448.

McCartney, W.D. 1958. Sunnyside, Newfoundland. Geol. Surv. Can. Paper, 58-8.

McCartney, W.D. 1967. Whitbourne map-area, Newfoundland. Geol. Surv. Can., Mem. 341, 135p.

McCartney, W.D. 1969. Geology of the Avalon Peninsula, southeast Newfoundland. Amer. Assoc. Petrol. Geol., Mem. 12, p.115-129.

McCartney, W.D., Poole, W.H., Wanless, R.K., Williams, H., and Loveridge, W.D. 1966. Rb/Sr age and geological setting of the Holyrood Granite, southeast Newfoundland. Can. J. Earth Sci., v.3, p.947-957.

McCurry, P., and Wright, J.B. 1977. Geochemistry of calc-alkaline volcanics in northwestern Nigeria, and a possible Pan-African suture zone. Earth and Planet. Sci. Letters, v.37, p.90-96.

McGowen, J.H., and Garner, L.E. 1970. Physiographic features and stratification types of coarse grained point bars: modern and ancient examples. Sedimentology, v.14, p.77-111.

BIBLIOGRAPHY (Cont'd)

Miall, A.D. 1970. Devonian alluvial fans, Prince of Wales Island, Arctic Canada. J. Sediment. Petrol., v.40, p.556-571.

Miller, H. 1977. Gravity zoning in Newfoundland. Tectonophysics, v.38, p.317-326.

Misra, S.B. 1971. Stratigraphy and depositional history of late Precambrian Coelenterate-bearing rocks, southeastern Newfoundland. Geol. Soc. Am. Bull., v.82, p.979-988.

Mitchell, A.H.G. 1970. Facies of an early Miocene volcanic arc, Malekula Island, New Hebrides. Sedimentology, v.14, p.201-243.

Miyashiro, A. 1978. Nature of alkalic volcanic rock series. Contrib. Mineral. and Petrol., v.66, p.91-104.

Mohr, P.A. 1970. Volcanic composition in relation to tectonics in the Ethiopian rift system: a preliminary investigation. Bull. volcanol., v.34, p.141-157.

Moore, J.G., and Peck, D.L. 1962. Accretionary lapilli in volcanic rocks of western continental United States. J. Geology, v.70, p.182-193.

Morrison, M.A. 1978. The use of "immobile" trace elements to distinguish the palaeotectonic affinities of metabasalts: applications to the Paleocene basalts of Mull and Skye, northwest Scotland. Earth and Planet. Sci. Letters, v.39, p.407-416.

Murray, A., and Howley, J.P. 1881. Geol. Surv., Newfoundland, 1864-1880, Edward Stanford, London.

Naylor, R.S. 1971. Acadian Orogeny: an abrupt and brief event. Science, v.172, p.558-560.

Nixon, G.T. 1975. Late Precambrian (Hadrynian) ash-flow tuffs and associated rocks of the Harbour Main Group near Colliers, Avalon Peninsula, southeast Newfoundland. unpubl. M. Sc. thesis, Memorial Univ., St. John's, Nfld.

Nixon, G.T., and Papezik, V.S. 1979. Late Precambrian ash-flow tuffs and associated rocks of the Harbour Main Group near Colliers, eastern Newfoundland: chemistry and magmatic affinities. Can. J. Earth Sci., v.16, p. 167-181.

BIBLIOGRAPHY (Cont'd)

Noble, D.C. 1965a. Gold Flat member of the Thirsty Canyon Tuff - a pantellerite ash-flow sheet in southern Nevada. U.S. Geol. Surv. Prof. Paper, 525B, p.B85-B90.

Noble, D.C. 1965b. Ground-water leaching of sodium from quickly cooled volcanic rocks. (Abstr.). Am. Mineral., v.50, p.289.

Noble, D.C. 1967. Sodium, potassium, and ferrous iron contents of some secondarily hydrated natural silicic glasses. Am. Mineral., v.52, p.280-286.

Noble, D.C. 1968a. Systematic variations of major elements in comendite and pantellerite glasses. Earth and Planet. Sci. Letters, v.4, p.167-172.

Noble, D.C. 1968b. Kane Springs Wash Volcanic Center, Lincoln County, Nevada. Geol. Soc. Am. Mem., 110, p.109-116.

Noble, D.C. 1970a. Loss of sodium from crystallized comendite welded tuff of the Miocene Grouse Canyon member of the Belted Range Tuff, Nevada. Geol. Soc. Am. Bull., v.81, p.2677-2688.

Noble, D.C. 1970b. Pantellerite in the Paleozoic volcanics of the Georgetown Inlier, Queensland, and the close association of peralkaline and subalkaline silicic magmas in post-orogenic igneous activity. J. Geol. Soc. Australia, v.16, p.765-766.

Noble, D.C. 1972. Some observations on the Cenozoic volcano-tectonic evolution of the Great Basin, western United States. Earth and Planet. Sci. Letters, v.17, p.142-150.

Noble, D.C., and Billings, M.P. 1967. Pyroclastic rocks of the White Mountain Magma Series, New Hampshire. Nature, v.216, p.906-907.

Noble, D.C., Chipman, D.W., and Giles, D.L. 1968. Peralkaline silicic volcanic rocks in northwestern Nevada. Science, v.160, p.1337-1338.

Noble, D.C. and Haffty, J. 1968. Minor element and revised major element contents of some Mediterranean pantellerites and comendites. J. Petrology, v.10, p.502-509.

Noble, D.C., Haffty, J., and Hedge, C.E. 1969. Strontium and magnesium contents of some natural peralkaline silicic glasses and their petrogenetic significance. Amer. J. Sci., v.267, p.598-608.

BIBLIOGRAPHY (Cont'd)

Noble, D.C., Kistler, R.W., Christiansen, R.L., Lipman, P.W., and Poole, F.G. 1965. Close association in space and time of alkalic, calc-alkalic, and calcic volcanism in southern Nevada (abstr.). Geol. Soc. Am. Spec. Paper, v.82, p.143-144.

Noble, D.C., Smith, V.C., and Peck, L.C. 1967. Loss of halogens from crystallized and glassy silicic volcanic rocks. Geochim. Cosmochim. Acta., v.31, p.215-223.

O'Brien, S.J. 1978a. Geology of the Baine Harbour map area, west half (1M/7); Report of Activities for 1977, R.V. Gibbons (Ed.); Nfld. Dept. Mines and Energy, Min. Development Division, Report. 78-1, p.156-161.

O'Brien, S.J. 1978b. Baine Harbour (1M/7) and Point Enragée (1M/6) areas In Preliminary Project Reports for 1978, Nfld. Dept. Mines and Energy, Min. Development Division, Report 78-10, p.58-60.

O'Brien, S.J., Strong, P.G., and Evans, J.L. 1977. Geology of the Grand Bank (1M/4) and Lamaline (1L/13) map areas, Newfoundland; Nfld. Dept. Mines and Energy, Min. Development, Division, Report 77-7, 16p.

O'Driscoll, C.F. 1973, Geology and petrochemistry of the Swift Current granite, Newfoundland. unpubl. B. Sc. thesis, Memorial Univ., St. John's, Newfoundland, 84p.

O'Driscoll, C.F. 1977a. Geology, Petrology and Geochemistry of the Hermitage Peninsula, Southern Newfoundland. unpubl. M. Sc. thesis, Memorial Univ., St. John's, Newfoundland, 150p.

O'Driscoll, C.F. 1977b. Geology of the Sound Island map-area, east half (1M/16); In Report of Activities for 1976, R.V. Gibbons (Ed.); Nfld. Dept. Mines and Energy, Min. Development Division, Report 77-1, p.43-48.

O'Driscoll, C.F. 1978. Geology of the Harbour Buffett map-area, west half (1M/9); In Report of Activities for 1977, R.V. Gibbons (Ed.); Nfld. Dept. Mines and Energy, Min. Development Division, Report 78-1, p.162-166.

O'Driscoll, C.F., and Hussey, E.M. 1977. The Avalonian orogeny of the western Avalon Zone, Newfoundland. Geol. Soc. Am., Abstr. with Programs, p.306.

O'Driscoll, C.F., and Muggeridge, W.W. 1978. Merasheen Project In Preliminary Project Reports for 1978, Nfld. Dept. Mines and Energy, Min. Development Division, Report 78-10, p.61-63.

BIBLIOGRAPHY (Cont'd)

Papezik, V.S. 1969. Late Precambrian ignimbrites of the Avalon Peninsula, Newfoundland. Can. J. Earth Sci., v.6, p.1405-1414.

Papezik, V.S. 1970. Petrochemistry of volcanic rocks of the Harbour Main Group, Avalon Peninsula, Newfoundland. Can. J. Earth Sci., v.7, p.1485-1498.

Papezik, V.S. 1973. Detrital garnet and muscovite in Late Precambrian sandstone near St. John's, Newfoundland, and their significance. Can. J. Earth Sci., v.10, p.430-432.

Papezik, V.S. 1974a. Igneous rocks of the Avalon Platform. Geol. Assoc. Can., Field trip Manual B-5, 22p.

Papezik, V.S. 1974b. Prehnite-pumpellyite facies metamorphism of Late Precambrian rocks of the Avalon Peninsula, Newfoundland. Can. Mineral., v.12, p.463-468.

Papezik, V.S., Hodych, J.P., and Goodacre, A.K. 1975. The Avalon magnetic lineament: a possible continuation of the Triassic dyke system of New Brunswick and Nova Scotia. Can. J. Earth Sci., v.12, p.332.

Parsons, W.H. 1969. Criteria for the recognition of volcanic breccias: review. Geol. Soc. Am. Mem. 115, p.263-304.

Peacock, M.A. 1931. Classification of igneous rocks. J. Geology, v.39, p.54-67.

Pearce, J.A., and Cann, J.R. 1971. Ophiolite origin investigated by discriminant analysis using Ti, Zr, and Y. Earth and Planet. Sci. Letters, v.12, p.339-349.

Pearce, J.A., and Cann, J.R. 1973. Tectonic setting of basic volcanic rocks determined using trace element analyses. Earth and Planet. Sci. Letters, v.19, p.290-300.

Pearce, J.A., and Gale, N.H. 1978. Identification of ore-deposition environments from trace-element geochemistry. In Volcanic Processes in ore genesis, Spec. Publ. 7, Geol. Soc. London, p.14-24.

Pearce, T.H. 1968. A contribution to the theory of variation diagrams. Contrib. Mineral. and Petrol., v.19, p.142-157.

Pearce, T.H., Gorman, B.E., and Birkett, T.C. 1975. The TiO_2-K_2O - P_2O_5 diagram: a method of discriminating between oceanic and non-oceanic basalts. Earth and Planet. Sci. Letters, v.24, p.419-426.

BIBLIOGRAPHY (Cont'd)

Pearce, T.H., Gorman, B.E., and Birkett, T.C. 1977. The relationship between major element chemistry and tectonic environment of basic and intermediate volcanic rocks. Earth and Planet. Sci. Letters, v.36, p.121-132.

Poole, W.H. 1967. Tectonic evolution of Appalachian region of Canada. Geol. Surv. Can., Spec. Paper 4 (H. Lilly Mem.), p.9-51.

Poole, W.H. 1976. Plate tectonic evolution of the Canadian Appalachian region. Geol. Surv. Can., Paper 76-1B, p.113-126.

Potgieter, C.D., and Visser, J.N.J. 1976. Precambrian ignimbrites and associated volcaniclastics from the Herbert District, Northern Cape Province. Trans. Geol. Soc. S. Afr., v.79, p.27-30.

Pichler, H., and Zeil, W. 1969. Andesites of the Chilean Andes. Oreg. Dept. Geol. Miner. Ind., Bull. 65 (Proc. of the Andesite Conference; ed. A.R. McBirney), p.165-174.

Rankin, D.W. 1976. Appalachian salients and recesses: late Precambrian continental breakup and the opening of the Iapetus Ocean. J. Geophys. Res., v.81, p.5605-5619.

Rao, S.S. 1971. Petrogenesis of acid rocks of the Deccan Traps. Bull. Volcanol., v.35, p.983-997.

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., v.13, p.868-875.

Rast, N., O'Brien. B.H., and Wardle, R.J. 1976. Relationships between Precambrian and Lower Palaeozoic rocks of the "Avalon Platform" in New Brunswick, the northeast Appalachians and the British Isles. Tectonophysics, v.30, p.315-338.

Robinson, P.T., McKee, E.H., and Moiola, R.J. 1968. Cenozoic volcanism and sedimentation, Silver Peak region, western Nevada and adjacent California. Geol. Soc. Am. Mem. 116, p.577-612.

Rodgers, J. 1972. Latest Precambrian (post-Grenville) rocks of the Appalachian region. Amer. J. Sci., v.272, p.507-520.

BIBLIOGRAPHY (Cont'd)

Roobol, M.J. 1976. Post-eruptive mechanical sorting of pyroclastic material - an example from Jamaica. Geol. Mag., v.113, p.429-440.

Rose, E.R. 1948. Geology of the Area between Bonavista, Trinity and Placentia Bays, Eastern Newfoundland. Geol. Surv. Nfld., Bull. 32, pt.2, p.39-49.

Rose, E.R. 1952. Torbay Map-Area, Newfoundland. Geol. Surv. Can., Mem. 265, 64p.

Rosholt, J.N., and Noble, D.C. 1969. Loss of uranium from crystallized silicic volcanic rocks. Earth and Planet. Sci. Letters, v.6, p.268-270.

Schenk, P.E. 1971. Southeastern Atlantic Canada, northeastern Africa, and continental drift. Can. J. Earth Sci., v.8, p.1218-1251.

Schmincke, H. -U. 1974. Volcanological aspects of peralkaline silicic welded ash-flow tuffs. Bull. Volcanol. (Spec. Issue), v.38, p.594-636.

Schmincke, H. -U., and Swanson, D.A. 1967. Laminar viscous flowage structures in ash flow tuffs from Gran Canaria, Canary Islands. J. Geology, v.75, p.641-664.

Schumm, S.A. 1968. Speculations concerning paleohydrologic controls of terrestrial sedimentation. Geol. Soc. Am. Bull., v.79, p.1573-1588.

Singer, A., and Navrot, J. 1970. Diffusion rings in altered basalt. Chem. Geol., v.6, p.31-41.

Skehan, J.W., Murray, D.P., Palmer, A.R., Smith, A.T., and Belt, E.S. 1978. Significance of fossiliferous Middle Cambrian rocks of Rhode Island to the history of the Avalon microcontinent. Geology, v.6, p.694-698.

Smith, D.G. 1976. Effect of vegetation on lateral migration of anastomosed channels of a glacier meltwater river. Geol. Soc. Am. Bull., v.87, p.857-860.

Smith, I.E.M. 1976. Peralkaline rhyolites from the D'Entrecasteaux Islands, Papua New Guinea. In Volcanism in Australia. Editor, R.W. Johnson, Elsevier, Amsterdam, p.275-285.

Smith, I.E.M., Chappell, B.W., Ward, G.K., and Freeman, R.S. 1977. Peralkaline rhyolites associated with andesitic arcs of the southwest Pacific. Earth and Planet. Sci. Letters, v.37, p.230-236.

BIBLIOGRAPHY (Cont'd)

Smith, N.D. 1970. The braided stream depositional environment: comparison of the Platte River with some Silurian clastic rocks, north-central Appalachians. Geol. Soc. Am. Bull., v.81, p.2993-3014.

Smith, R.E. 1968. Redistribution of major elements in the alteration of some basic lavas during burial metamorphism. J. Petrology, v.9, p.191-219.

Smith, R.E., and Smith, S.E. 1976. Comments on the use of Ti, Zr Y, Sr, K, P, and Nb in classification of basaltic magmas. Earth and Planet. Sci. Letters, v.32, p.114-120.

Smith, R.L. 1960. Zones and zonal variations in welded ash flows. U.S. Geol. Surv. Prof. Paper 354-F, p.149-159.

Smith, R.L. and Bailey, R.A. 1966. The Bandelier tuff: a study of ash-flow eruption cycles from zoned magma chambers. Bull. Volcanol., v.29, p.83-104.

Smitheringale, W.G. 1972. Low potash Lush's Bight tholeiites: ancient oceanic crust in Newfoundland. Can. J. Earth Sci., v.9, p.574-588.

Sparks, R.S.J., Self, S., and Walker, G.P.L. 1973. Products of ignimbrite eruptions. Geology, v.1, p.115-118.

Sparks, R.S.J., and Wilson, L. 1976. A model for the formation of ignimbrite by gravitional column collapse. J. Geol. Soc., v.132, p.441-452.

Sparks, R.S.J., and Walker, G.P.L. 1977, The significance of vitric-enriched air fall ashes associated with crystal-enriched ignimbrites. J. Volcanol. Geotherm. Res., v.2, p.329-342.

Spry, A. 1969. Metamorphic Textures, Pergamon Press, New York, 350p.

Steel, R.J. 1974. New Red Sandstone floodplain and piedmont sedimentation in the Hebridean Province, Scotland. J. Sediment. Petrol., v.44, p.336-357.

Stewart, J.H. 1971. Basin and Range structure: A system of horsts and grabens produced by deep-seated extension. Geol. Soc. Am. Bull., v.82, p.1019-1044.

Streckeisen, A. 1967. Classification and nomenclature of igneous rocks. Neues Jahrb. Mineral., v.107, p.144-240.

BIBLIOGRAPHY (Cont'd)

Strong, D.F., Dickson, W.L., O'Driscoll, C.F., and Kean, B.F. 1974. Geochemistry of Eastern Newfoundland Granitoid Rocks. Nfld. Dept. Mines and Energy, Min. Development Division, Report 74-3, 140p.

Strong, D.F., Dickson, W.L., O'Driscoll, C.F., Kean, B.F., and Stevens, R.K. 1974. Geochemical evidence for eastward Appalachian subduction in Newfoundland. Nature, v.248, p.37-39.

Strong, D.F., and Minatidis, D.G. 1975. Geochemistry and tectonic setting of the late Precambrian Holyrood plutonic series of eastern Newfoundland. Lithos, v.8, p.283-295.

Strong, D.F., O'Brien, S.J., Strong, P.G., Taylor, S.W., and Wilton, D.H. 1976. Geology of the St. Lawrence (1L/14) and Marystown (1M/3) map sheets, Newfoundland; Nfld. Dept. Mines and Energy, Min. Development Division, Prelim. Report 895, 38p.

Strong, D.F., O'Brien, S.J., Taylor, S.W., Strong, P.G., and Wilton, D.H. 1978a. Aborted Proterozoic rifting in eastern Newfoundland. Can. J. Earth Sci., v.15, p.117-131.

Strong, D.F., O'Brien, S.J., Taylor, S.W., Strong, P.G., and Wilton, D.H. 1978b. Marystown (1M/3) and St. Lawrence (1L/14) map areas, Newfoundland. Nfld. Dept. Mines and Energy, Min. Development Division, Report 77-8, 46p.

Tabor, R.W., and Crowder, D.F. 1969. On batholiths and volcanoes - Intrusion and eruption of late Cenozoic magmas in the Glacier Peak area, North Cascades, Washington. U.S. Geol. Surv. Prof. Paper 604, 67p.

Taylor, S.R. 1965. The application of trace element data to problems in petrology In Physics and Chemistry of the Earth. Editors, Ahrens, L.H., Press, F., Runcorn, S.K., and Urey, H.C., v.6, p.133-213.

Taylor, S.W. 1977. Geology of the Marystown map sheet (east half). Burin Peninsula, southeast Newfoundland; unpubl. M. Sc. thesis, Memorial Univ., St. John's, Newfoundland, 165p.

Teng, H. 1974. Lithochemical Study of the St. Lawrence Granite, St. Lawrence, Nfld. unpubl. M. Sc. thesis, Memorial Univ., St. John's, Newfoundland.

Turner, C.C., and Walker, R.G. 1973. Sedimentology, stratigraphy, and crustal evolution of the Archean greenstone belt near Sioux Lookout, Ontario. Can. J. Earth Sci., v.10, p.817-845.

BIBLIOGRAPHY (Cont'd)

Turner, P., and Archer, R. 1977. The role of biotite in the diagenesis of red beds from the Devonian of northern Scotland. Sediment. Geol., v.19, p.241-251.

Tuttle, O.F., and Bowen, N.L. 1958. Origin of granite in the light of experimental studies in the system $NaAlSi_3O_8$ - $KAlSi_3O_8$ - SiO_2 - H_2O. Geol. Soc. Am. Mem. 74, 153p.

Vallance, T.G. 1969. Spilites again: some consequences of the dehydration of basalts. Linn. Soc. N.S.W., Proc., v.94, p.8-51.

Vallance, T.G. 1974. Spilitic degradation of a tholeiitic basalt, J. Petrology, v.15, p.79.

Van Alstine, R.E. 1948. Geology and Mineral Deposits of the St. Lawrence Area, Burin Peninsula, Nfld. Geol. Surv. Nfld., Bull., no23.

Wachendorf, H. 1973. The rhyolitic lava flows of the Lebombos (SE - Africa). Bull. Volcanol., v.37, p.515-529.

Wager, L.R., and Deer, W.A. 1939. The petrology of the Skaergaard intrusion, Kangerdluk-Iugssuag, East Greenland. Meddl. om Gronland, v.105, no.4, p1-352.

Walker, G.P.L., and Skelhorn, R.R. 1966. Some associations of acid and basic igneous rocks. Earth Sci. Rev., v.2, p.93-109.

Walker, G.P.L. 1972. Crystal concentration in ignimbrites. Contrib. Mineral. and Petrol., v.36, p.135-146.

Walker, R.G. 1976. Facies Models: 1, General Introduction. Geoscience Canada, v.3, p.21-24.

Walker, R.G. 1976. Facies Models: 2. Turbidites and associated coarse clastic deposits. Geoscience Canada, v.3, p.25-36.

Walker, T.R. 1967. Formation of red beds in modern and ancient deserts. Geol. Soc. Am. Bull., v.78, p.353-368.

Walker, T.R., and Honea, R.M. 1969. Iron content of modern deposits in the Sonoran Desert: a contribution to the origin of red beds. Geol. Soc. Am. Bull., v.80, p.535-544.

Weaver, S.D., Sceal, J.S.C., and Gibson, I.L. 1972. Trace-element data relevant to the origin of trachytic and pantelleritic lavas in the East African Rift system. Contrib. Mineral. and Petrol., v.36, p.181-194.

BIBLIOGRAPHY (Cont'd)

Weeks, L.J. 1954. Southeast Cape Breton Island, Nova Scotia. Geol. Surv. Can., Mem. 277, 112p.

Weir, H.C. 1970. A Gravity Profile Across Newfoundland. unpubl. M. Sc. thesis, Memorial Univ., St. John's, Newfoundland, 164p.

White, D.E. 1939. Geology and molybdenite deposits of the Rencontre East area, Fortune Bay, Newfoundland. unpubl. Ph. D. dissertation, Princeton University, Princeton, N.J.

Widmer, K. 1949. Glovertown - Clode Sound area, Newfoundland. Geol. Surv. Nfld., St. John's, Nfld., unpubl. geological map.

Widmer, K. 1950. Geology of the Hermitage Bay area, Fortune Bay, Newfoundland. unpubl. Ph. D. dissertation, Princeton University, Princeton, N.J.

Wiebe, R.A. 1972. Igneous and tectonic events in north-eastern Cape Breton Island, Nova Scotia. Can. J. Earth Sci., v.9, p.1262-1277.

Wiebe, R.A. 1973. Precambrian rocks of Cape Breton Island. Marit. Sediments, v.9, p.100-103.

Williams, H. 1964. The Appalachians in northwestern Newfoundland - a two sided symmetrical system. Amer. J. Sci., v.262, p.1137-1158.

Williams, H. 1967. Geology, Island of Newfoundland. Geol. Surv. Can., Map 1231A.

Williams, H. 1971. Geology of Belleoram map-area. Geol. Surv. Can., Paper 70-65, 39p.

Williams, H. 1978. Tectonic Lithofacies Map of the Appalachian Orogen. map no. 1, Memorial Univ. of Nfld. International Geological Correlation Project no.27.

Williams, H., Kennedy, M.J., and Neale, E.R.W. 1972. The Appalachian structural province <u>In</u> Structural Styles in Canada. Editors, Price, R.A., and Douglas, R.J.W., Geol. Assoc. Can., Spec. Paper 11, p.181-262.

Williams, H., Kennedy, M.J., and Neale, E.R.W. 1974. The northeastward termination of the Appalachian orogen. <u>In</u> The Ocean Basins and Margins. Editors, Nairn, A.E.M., and Stehli, F.G., v.2,

BIBLIOGRAPHY (Cont'd)

Williams, H., and King, A.F. 1976. Southern Avalon Peninsula, Newfoundland: Trepassey map-area (1K). Geol. Surv. Can. Report of Activities, Part A, Paper 76-1A, p.179-182.

Williamson, D.H. 1956. The Geology of the fluorspar district of St. Lawrence, Burin Peninsula, Nfld. Nfld. Dept. Mines, Agric. and Res., Min. Res. Div., unpubl. report.

Winchester, J.A., and Floyd, P.A. 1976. Geochemical magma type discriminatior: application to altered and metamorphosed basic igneous rocks. Earth and Planet. Sci. Letters, v.28, p.459-469.

Winchester, J.A., and Floyd, P.A. 1977. Geochemical discrimination of different magma series and their differentiation products using immobile elements. Chem. Geology, v.20, p.325-343.

Wood, D.A., Gibson, I.L., and Thompson, R.N. 1976. Elemental mobility during zeolite facies metamorphism of the Tertiary basalts of eastern Iceland. Contrib. Mineral. and Petrol., v.55, p.241-254.

Wood, D.S. 1973. Patterns and magnitudes of natural strain in rocks. Roy. Soc. London, Phil. Trans., v.274A, p.373-382.

Wood, D.S. 1974. Current views of the development of slaty cleavage. Earth and Planet. Sci., Ann. Rev., v.2, p.369-401.

Wright, A.E., and Bowes, D.R. 1968. Formation of explosion breccias. Bull. Volcanol., v.32, p.15-32.

Wright, J.B. 1969. A simple alkalinity ratio and its application to questions of non-orogenic granite genesis. Geol. Mag., v.106, p.370-384.

Wright, J.V., and Walker, G.P.L. 1977. The ignimbrite source problem: significance of a co-ignimbrite lag-fall deposit. Geology, v.5, p.729-732.

Yoder, H.S. 1969. Calcalkaline andesites: experimental data bearing on the origin of their assumed characteristics. In Proceedings of the Andesite Conference. Editor, McBirney, A.R., Oregon Dept. Geol. Min. Ind. Bull. 65, p.77-89.

Yoder, Jr., H.S. 1973. Contemporaneous basaltic and rhyolitic magmas. Am. Mineral., v.58, p.153-171.

BIBLIOGRAPHY (Cont'd)

Yoder, H.S., and Tilley, C.E. 1962. Origin of basalt magmas: An experimental study of natural and synthetic rock systems. J. Petrology, v.3, p.342-532.

Younce, G.B. 1970. Structural geology and stratigraphy of the Bonavista Bay region, Newfoundland. unpubl. Ph. D. dissertation, Cornell University, Ithaca, New York, 188p.

Zeil, W., and Pichler, H. 1967. Die Kanozoische Rhyolith-Formation in mittleren Abschnitt der Anden. Geol. Rundschau, v.57, p.48-81.

APPENDIX 1

Individual descriptions of representative, analysed samples

Formation	Sample No.	Groundmass	Phenocrysts	Alteration	Comments
White Point Formation	674B Basalt	Altered; fine grained; actinolite, chlorite, epidote, albite, minor quartz, green biotite	<5% actinolite phenos after hornblende (?)	pyroxene to actinolite, epidote and chlorite; plagioclase to albite	non-foliated
	778A Basalt	diabasic texture; plagioclase, actinolite, epidote, chlorite	20% plagioclase phenos <7 mm	pyroxene and/or hornblende to actinolite; plagioclase to sericite and epidote	non-foliated; minor quartz in matrix
	778C Andesite	diabasic texture; actinolite, plagioclase 10-15% quartz, chlorite, epidote	5% poorly twinned plagioclase phenos 1 mm	pyroxene to actinolite, chlorite, epidote	non-foliated; amygdules up to 3.5 mm with epidote, chlorite minor quartz
	705B Rhyolite	microcrystalline; quartz, K-feldspar, lesser plagioclase, minor biotite, opaques	10% quartz and oligoclase phenos up to 3.5 mm, biotite	K-feldspar and plagioclase to sericite; biotite to epidote and chlorite	groundmass foliated, fabric defined by sericite, lesser chlorite
Southwest River Formation (3b)	607 Basalt	ophitic texture; augite, plagioclase, opaques	microphenos of plagioclase	augite and opaques partially chloritised; epidote, minor sericite, hematite	minor amygdules filled with hematite, chlorite
	446 Rhyolite	felsitic to spherulitic; quartz, untwinned plagioclase, lesser K-feldspar, <2% hematite, epidote	None	plagioclase and K-feldspar to minor sericite; plagioclase to epidote	thinly flow banded
Musgravetown Group	852 Basalt	intergranular; plagioclase, olivine, opaques	altered olivine phenos 1 mm	olivine to iddingsite, serpentine, opaques; opaques to chlorite; plagioclase to albite and chlorite	amygdules contain chlorite, epidote calcite and albite (?)
	845 Basalt	very fine grained, intergranular; plagioclase and hematite, 20% K-feldspar	30% altered plagioclase phenos, up to 5 mm; minor augite and altered olivine phenos	plagioclase to sericite; augite partially to chlorite; olivine to iddingsite, opaques and chlorite	plagioclase phenos are light green and the groundmass is red
	621 Pantellerite	coarse felsitic texture; quartz, plagioclase, K-feldspar, 10% hematite, 5% siderite	None		fine banding overgrown by felsitic texture
Georges Pond pluton	629C Gabbro	medium grained	60% augite, 25% labradorite, 5-10% olivine, 5% amphibole, 5% opaques, minor biotite, apatite	augite to hornblende and to actinolite; opaques to hornblende; olivine to iddingsite and opaque minerals.	olivine only partially altered; non-foliated
	800 Diorite	medium grained	75% plagioclase, 10% K-feldspar, 10% quartz, 5% biotite and opaques	plagioclase to sericite; minor epidote	poor foliation defined by sericite
	555 Granite	medium grained	40% quartz, 30% microcline, 25% plagioclase, 5% biotite, minor hornblende, sphene, apatite	plagioclase cores to sericite; very minor epidote	plagioclase poorly zoned; non-foliated
Dykes	616 Diabase	intergranular; plagioclase, titanaugite, opaques, minor biotite	None	biotite forms halo around opaque grains; minor chlorite, sericite	occurs in Connecting Point Group
	226A Diabase	diabasic (0.5 mm); actinolite, altered plagioclase, skeletal opaques	None	plagioclase to epidote and albite actinolite to chlorite	occurs in White Point Formation

Appendix 2

Preparation of Samples, Methods of Analysis and Precision and Accuracy Data

Attempts were made to obtain the freshest samples from any given outcrop. Alteration veins and amygdules were avoided where possible. Samples of volcanic rocks were at least 1.5 kg in weight while samples of intrusive rocks were at least 3 kg. Any weathered surface on the samples was either chipped off in the field or sawed off later and the resulting surfaces ground to remove saw marks. The samples were then thoroughly scrubbed with a stiff brush, broken into ½ inch chips with a hammer and a steel plate and pulverized in a tungsten-carbide TEMA swing mill to -200 mesh. Before crushing, the chips were quartered and alternate quarters mixed and split and alternate quarters of that split were taken for crushing. One swing mill load was used for volcanic rock samples and three loads for the coarse grained intrusive rock samples. Splits of these powders were taken for analysis.

The major element oxides excluding P_2O_5 and FeO were analyzed for, using a Perkin Elmer 303 Atomic Absorption spectrophotometer. .1 grams of sample were dissolved in 5 c.c. of conc. H.F. This was heated (in a closed container) for 30 min. on a steam bath to effect solution and then diluted with 50 c.c. of saturated boric acid and made up to 200 c.c. with distilled water. These rock solutions were compared with various dilutions of standard blends of both artificial and U.S.G.S. standards. For CaO and MgO, 10 c.c. of La_2O_3 solution and 5 c.c. of HCl were added per 50 c.c. of rock solution to act as a releasing agent to suppress the interference of aluminum and phosphorus with these determinations. Precision and accuracy data for the Atomic Absorption analyses are given in Table 6.

Ferrous iron was determined by the titrametric method described by Maxwell (1968). 5 ml of ammonium vanadate solution was added to approximately 1.2 grams of sample and the resulting solution was mixed in an automatic shaker overnight. 10 ml. of sulphuric-phosphatic mixed acid was then added to the sample and the resulting solution mixed with 200 ml. of saturated boric acid solution. 10 ml. of ferrous ammonium sulfate solution and 1 ml. of barium diphenylamine sulphonate indicator was then added and the sample titrated with standard potassium dichromate solution to a grey end point.

P_2O_5 was determined colorimetrically by the method described by Maxwell (1968, p.394).

Loss on Ignition (LOI) was calculated by measuring a known amount of powder (approx. 0.5 g) into a porcelain crucible, heating at 1050°C for two hours, cooling in a dessicator and reweighing and expressing the difference in weight per cent.

Trace elements were determined using a Phillips PW 1450 computerized spectrometer. A standard program to analyze for 13 trace elements was used. The rock powders were pressed at 25 tons for 1 minute with 12% phenolformaldehyde as a binding agent. The resulting discs were baked for 10 minutes at 200°C. A silver X-ray tube and LiF (200,220) analyzer crystals were used. Excitation was 50 kV and 40 mA. The results were matrix corrected using the Compton peak of the X-ray tube. Accuracy and precision data for the analyses are given in Table 7.

TABLE 6

Precision and Accuracy Data

Major element oxide determination by Atomic Absorption Spectrophotometry for U.S.G.S. standard rocks.

p - published values (Abbey, 1968)

m - mean value

s - standard deviation

n - number of determinations

		SiO_2	TiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O	MnO
GSP-1 (Grano-diorite)	p	67.27	0.65	15.18	4.26	2.06	0.98	2.77	5.50	0.04
	m	68.65	0.60	14.77	4.22	1.94	0.96	2.74	5.44	0.04
	n	7	7	7	8	8	7	8	6	8
	s	0.60	0.08	0.22	0.07	0.07	0.03	0.06	0.12	0.01
AGV-1 (Ande-site)	p	58.97	1.06	17.01	6.73	4.94	1.53	4.26	2.86	0.10
	m	59.63	1.08	17.13	6.70	4.78	1.47	4.06	2.88	0.10
	n	3	3	4	4	4	4	4	3	4
	s	0.90	0.11	0.23	0.33	0.16	0.07	0.12	0.10	0.00

Table 7

Precision and Accuracy data

Trace element determinations by XRF for U.S.G.S. and University of Toronto standard rocks. Memorial University, March 10-20, 1978.

Note: all determinations in ppm

s = standard deviation, n = number of determinations.

p = published values, m = mean value

		V	Cr	Ni	Cu	Zn	Ga	Rb	Sr	Y	Zr	Nb	Ba	Pb
W-1	m	240	92	70	117	85	20	22	189	24	98	8	171	7
	s	5	6	3	4	2	2	2	6	2	2	1	12	3
	n	13	13	13	13	13	13	13	13	11	13	13	13	13
	p	240	120	78	110	86	16	21	190	25	105	10	160	8
G-2	m	43	13	2	17	85	24	166	477	11	292	10	1865	27
	s	3	3	2	1	2	1	2	7	2	3	1	30	2
	n	10	10	10	10	10	10	10	10	11	10	10	10	10
	p	34	9	6	11	85	23	170	480	12	300	14	1850	29
GSP-1	m	60	13	8	38	102	24	252	237	25	471	21	1288	56
	s	5	2	4	2	2	2	3	5	2	2	2	13	4
	n	6	6	6	6	6	6	6	6	11	6	6	6	6
	p	44	13	9	35	98	21	250	230	32	500	29	1300	53
BCR-1	m	402	25	11	28	121	22	49	338	36	188	12	740	18
	s	4	6	3	1	2	1	2	8	1	1	3	10	4
	n	6	6	6	6	6	6	6	6	11	6	6	6	6
	p	410	16	13	19	120	23	47	330	37	185	14	680	15
AGV-1	m	129	12	13	64	87	23	70	687	22	233	12	1218	37
	s	5	3	3	2	2	2	3	11	1	3	1	27	5
	n	10	10	10	10	10	10	10	10	11	10	10	10	10
	p	125	12	17	63	84	20	67	660	26	220	15	1200	36
UTA-1	m	102	22	10	29	57	22	47	507	19	165	9	446	6
	s	4	3	1	1	3	2	3	9	1	2	1	17	3
	n	5	5	5	5	5	5	5	5	10	5	5	5	5
UTB-1	m	433	32	22	44	136	23	32	316	43	194	15	599	5
	s	7	4	1	4	2	2	2	5	1	2	2	27	4
	n	5	5	5	5	5	5	5	5	10	5	5	5	4
UTB-2	m	353	12	4	26	111	23	55	312	36	190	13	755	14
	s	6	2	5	2	2	2	4	6	1	3	1	22	5
	n	5	5	5	5	5	5	5	5	10	5	5	5	4

Appendix 3

Values employed for the correction of oxidation ratios used in this study.

Basalt	$Fe_2O_3/FeO = 0.20$	(Hughes and Hussey, 1976; Brooks, 1976; Hughes and Hussey, in press).
Andesite	$Fe_2O_3/FeO = 0.736$	(Chayes, 1969)
Rhyolite	$Fe_2O_3/FeO = 0.631$	(MacDonald, 1974)
Pantellerite	$Fe_2O_3/FeO = 0.527$	(MacDonald, 1974)

Appendix 4

Raw major and trace element analyses (A) and recalculated anhydrous analyses with corrected Fe_2O_3/FeO (see Appendix 3) and derived C.I.P.W. normative compositions (B) for all samples analyzed in this study.

(- = not detected)

Analyzed sample numbers correspond to localities shown on Fig. 1

The samples were analyzed by the author at Memorial University, Geology Dept. in 1976 and 1977.

Clode Sound area, Newfoundland

A. Original analyses

	778A	778B	674B	687A	689A	691
SiO_2	50.50	50.10	48.40	48.30	46.80	47.70
TiO_2	1.58	0.97	1.20	0.83	1.12	1.20
Al_2O_3	17.70	18.70	15.40	15.40	18.30	17.70
FeO	6.04	4.70	6.97	5.87	5.12	5.98
Fe_2O_3	4.24	4.20	4.69	4.92	5.37	5.15
MnO	0.16	0.18	0.21	0.23	0.18	0.17
MgO	3.39	4.24	5.44	9.39	6.06	6.97
CaO	8.86	10.36	8.81	10.13	9.02	8.93
Na_2O	2.68	2.95	3.40	2.28	2.90	2.76
K_2O	1.11	0.78	0.45	0.69	1.18	0.45
P_2O_5	0.36	0.23	0.13	0.08	0.16	0.21
LOI	2.15	1.95	3.18	2.69	3.01	2.58
	98.77	99.35	98.27	99.91	99.23	99.80
Rb	21	23	9	21	29	15
Sr	579	841	393	362	491	485
Ba	254	250	181	162	269	150
Cu	119	90	25	22	20	73
Pb	5	13	4	5	1	-
Zn	105	82	92	141	118	95
Cr	17	19	39	683	133	113
Ni	21	50	20	214	122	96
V	256	211	346	242	240	237
Ga	21	21	21	20	20	21
Zr	167	89	80	68	93	104
Y	26	8	14	15	17	17
Nb	7	6	5	4	8	7

White Point Formation - Basalts and related shallow intrusions, 778A - plagioclase phenocrysts; 691 recrystallized.

Clode Sound area, Newfoundland

B1

B. Analyses recalculated to 100% anhydrous with corrected Fe_2O_3/FeO.

	778A	778B	674B	687A	689A	691
SiO_2	52.34	51.50	50.99	49.28	48.76	49.17
TiO_2	1.64	1.00	1.26	0.85	1.17	1.24
Al_2O_3	18.35	19.22	16.22	15.71	19.07	18.25
FeO	8.65	7.39	10.00	8.91	8.79	9.28
Fe_2O_3	1.73	1.48	2.00	1.79	1.76	1.86
MnO	0.17	0.19	0.22	0.23	0.19	0.18
MgO	3.51	4.36	5.73	9.58	6.31	7.19
CaO	9.18	10.65	9.28	10.34	9.40	9.20
Na_2O	2.78	3.03	3.58	2.33	3.02	2.85
K_2O	1.15	0.80	0.47	0.70	1.23	0.46
P_2O_5	0.37	0.24	0.14	0.08	0.17	0.22
BaO	0.03	0.03	0.02	0.02	0.03	0.02
SrO	0.07	0.10	0.05	0.04	0.06	0.06
Cr_2O_3	-	-	0.01	0.10	0.02	0.02
ZrO_2	0.02	0.02	0.01	0.01	0.01	0.02
NiO	-	0.01	-	0.03	0.02	0.01
CIPW norms						
Q	4.30	0.24	-	-	-	-
Or	6.80	4.74	2.80	4.16	7.27	2.74
Ab	23.52	25.68	30.32	19.70	25.58	24.09
An	34.22	36.50	26.81	30.37	34.86	35.67
Ne	-	-	-	-	-	-
Lc	-	-	-	-	-	-
Cor	-	-	-	-	-	-
Di	7.69	12.55	15.37	16.72	8.99	7.23
Hy	16.98	15.69	11.70	10.99	0.77	15.32
Wol	-	-	-	-	-	-
Ol	-	-	7.36	13.52	17.34	9.38
Mt	2.51	2.15	2.90	2.59	2.55	2.69
Il	3.11	1.90	2.40	1.61	2.22	2.35
Hm	-	-	-	-	-	-
Chr	-	-	0.01	0.15	0.03	0.03
Ap	0.87	0.55	0.32	0.19	0.39	0.50

Clode Sound area, Newfoundland

A. Original analyses

	51	777	778C	P118	79
SiO_2	56.40	57.80	59.80	73.09	73.14
TiO_2	0.96	0.85	1.17	0.30	0.34
Al_2O_3	20.30	15.80	15.10	13.50	13.60
FeO	0.48	5.49	4.60	0.59	0.57
Fe_2O_3	3.75	2.03	3.02	1.15	1.24
MnO	0.26	0.17	0.19	0.05	0.10
MgO	2.12	4.18	3.03	0.56	0.36
CaO	7.03	5.83	3.53	2.37	0.53
Na_2O	6.00	4.29	4.54	4.75	4.85
K_2O	0.30	1.37	2.12	3.36	2.75
P_2O_5	0.35	0.21	0.41	-	0.04
LOI	1.84	2.27	1.58	0.79	1.32
	99.80	100.29	99.08	100.51	98.84
Rb	11	29	37	54	63
Sr	852	415	426	139	140
Ba	78	539	749	731	752
Cu	7	72	19	1	12
Pb	67	14	7	13	21
Zn	124	102	238	40	63
Cr	10	46	3	5	5
Ni	6	16	3	5	4
V	67	194	117	22	28
Ga	18	18	18	17	18
Zr	103	124	239	222	283
Y	19	22	36	26	40
Nb	6	8	10	10	13

White Point Formation - Andesites, 51, 777, 778C; Rhyolites, P118, 79. 51 - mainly altered to quartz, albite, epidote assemblage.

Clode Sound area, Newfoundland

B. Analyses recalculated to 100% anhydrous with corrected Fe_2O_3/FeO.

	51	777	778C	P118	79
SiO_2	57.62	58.81	61.21	73.27	74.93
TiO_2	0.98	0.86	1.20	0.30	0.35
Al_2O_3	20.74	16.08	15.46	13.53	13.93
FeO	2.37	4.48	4.50	1.04	1.11
Fe_2O_3	1.75	3.30	3.32	0.65	0.70
MnO	0.27	0.17	0.19	-	0.10
MgO	2.17	4.25	3.10	0.56	0.37
CaO	7.18	5.93	3.61	2.38	0.54
Na_2O	6.13	4.37	4.65	4.76	4.97
K_2O	0.31	1.39	2.17	3.37	2.82
P_2O_5	0.36	0.21	0.42	-	0.04
BaO	0.01	0.06	0.09	0.08	0.09
SrO	0.10	0.05	0.05	0.02	0.02
Cr_2O_3	-	0.01	-	-	-
ZrO_2	0.02	0.02	0.03	0.03	0.04
NiO	-	-	-	-	-
CIPW norms					
Q	3.41	9.29	12.91	27.67	33.11
Or	1.81	8.24	12.84	19.92	16.67
Ab	51.90	36.97	39.36	40.33	42.09
An	28.19	20.17	14.92	5.61	2.63
Ne	-	-	-	-	-
Lc	-	-	-	-	-
Cor	-	-	-	-	-
Di	4.36	6.56	0.48	4.67	-
Hy	5.09	11.83	11.42	-	1.99
Wol	-	-	-	0.27	-
Ol	-	-	-	-	-
Mt	2.53	4.78	4.81	0.95	1.01
Il	1.86	1.64	2.28	0.57	0.66
Hm	-	-	-	-	-
Chr	-	0.01	-	-	-
Ap	0.83	0.50	0.98	-	0.10

Clode Sound area, Newfoundland

A. Original analyses

	700	78	123B	797	705B
SiO_2	71.40	75.60	76.20	72.40	77.20
TiO_2	0.52	0.23	0.28	0.54	0.24
Al_2O_3	13.30	13.00	12.60	14.00	12.50
FeO	0.92	0.33	1.03	0.85	0.75
Fe_2O_3	2.36	1.15	0.09	1.89	0.42
MnO	0.12	0.07	0.06	0.08	0.04
MgO	0.15	0.33	0.34	0.29	0.28
CaO	6.09	1.48	0.86	0.88	0.76
Na_2O	4.24	5.20	4.56	5.60	3.88
K_2O	0.27	1.88	2.97	2.51	4.18
P_2O_5	0.16	0.10	0.09	0.07	0.04
LOI	1.01	1.50	0.70	0.53	0.75
	100.54	100.87	99.78	99.65	101.05
Rb	7	39	61	43	75
Sr	643	132	134	167	143
Ba	44	674	894	873	848
Cu	7	8	6	7	6
Pb	20	6	7	3	6
Zn	26	36	35	367	35
Cr	7	2	5	7	4
Ni	-	-	-	5	2
V	40	16	11	28	12
Ga	25	16	16	16	14
Zr	193	205	169	379	154
Y	26	29	30	42	32
Nb	9	14	14	16	10

White Point Formation rhyolites - 78, 705B - quartz and plagioclase phenocrysts.

Clode Sound area, Newfoundland

B. Analyses recalculated to 100% anhydrous with corrected Fe_2O_3/FeO.

	700	78	123B	797	705B
SiO_2	71.74	76.03	76.77	72.99	76.88
TiO_2	0.52	0.23	0.28	0.54	0.24
Al_2O_3	13.36	13.07	12.69	14.11	12.45
FeO	1.95	0.88	0.72	1.64	0.72
Fe_2O_3	1.24	0.55	0.45	1.04	0.45
MnO	0.12	0.07	0.06	0.08	0.04
MgO	0.15	0.33	0.34	0.29	0.28
CaO	6.12	1.49	0.87	0.89	0.76
Na_2O	4.26	5.23	4.59	5.65	3.86
K_2O	0.27	1.89	2.99	2.53	4.16
P_2O_5	0.16	0.10	0.09	0.07	0.04
BaO	-	0.08	0.10	0.10	0.09
SrO	-	0.02	0.02	0.02	0.02
Cr_2O_3	-	-	-	-	-
ZrO_2	0.03	0.03	0.02	0.05	0.02
NiO	-	-	-	-	-
CIPW norms					
Q	34.89	34.58	36.15	27.62	36.20
Or	1.60	11.18	17.70	14.97	24.62
Ab	36.07	44.29	38.91	47.83	32.72
An	16.55	6.62	3.94	4.18	3.72
Ne	-	-	-	-	-
Lc	-	-	-	-	-
Cor	-	-	0.46	0.56	0.23
Di	4.42	0.25	-	-	-
Hy	-	1.60	1.44	2.14	1.32
Wol	3.30	-	-	-	-
Ol	-	-	-	-	-
Mt	1.79	0.80	0.66	1.51	0.65
Il	0.99	0.44	0.54	1.04	0.45
Hm	-	-	-	-	-
Chr	-	-	-	-	-
Ap	0.37	0.23	0.21	0.16	0.09

Clode Sound area, Newfoundland

A. Original analyses

	852	870B	856	621B	875A
SiO_2	46.78	44.97	39.07	43.20	46.45
TiO_2	0.94	1.66	2.76	2.50	2.26
Al_2O_3	17.06	15.79	14.48	15.40	15.22
FeO	3.91	7.70	1.72	4.98	4.24
Fe_2O_3	1.22	5.06	12.14	8.27	8.84
MnO	1.02	0.23	0.27	0.20	0.19
MgO	10.91	3.02	7.57	2.94	3.33
CaO	2.40	7.43	8.73	7.85	6.79
Na_2O	3.73	4.63	3.65	4.15	3.63
K_2O	0.06	0.33	0.40	1.74	1.32
P_2O_5	0.23	0.13	0.61	0.49	0.30
LOI	5.56	7.76	7.79	7.06	6.26
	99.01	98.70	99.19	98.78	98.83
Rb ppm	2	13	8	77	53
Sr	410	471	498	607	545
Ba	90	186	206	589	284
Cu	28	57	28	70	47
Pb	3	5	3	8	4
Zn	84	86	111	108	102
Cr	812	130	75	58	37
Ni	204	78	35	44	66
V	245	322	201	310	296
Ga	18	20	18	21	22
Zr	75	125	253	169	177
Y	15	18	35	30	29
Nb	7	9	19	12	15

Clode Sound Formation basalts; 852 olivine phenocrysts.

Clode Sound area, Newfoundland

B. Analyses recalculated to 100% anhydrous with corrected Fe_2O_3/FeO.

	852	870B	856	621B	875A
SiO_2	52.90	49.54	43.16	47.32	50.47
TiO_2	1.06	1.83	3.05	2.74	2.46
Al_2O_3	19.29	17.39	15.99	16.87	16.54
FeO	4.79	11.44	11.84	11.54	11.23
Fe_2O_3	0.96	2.29	2.36	2.31	2.25
MnO	1.15	0.25	0.30	0.22	0.21
MgO	12.34	3.33	8.36	3.22	3.62
CaO	2.71	8.18	9.64	8.60	7.38
Na_2O	4.22	5.10	4.03	4.55	3.94
K_2O	0.07	0.36	0.44	1.91	1.43
P_2O_5	0.26	0.14	0.67	0.54	0.33
BaO	0.01	0.02	0.03	0.07	0.03
SrO	0.05	0.06	0.07	0.08	0.07
Cr_2O_3	0.13	0.02	0.01	0.01	0.01
ZrO_2	0.01	0.02	0.04	0.03	0.03
NiO	0.03	0.01	-	0.01	0.01
CIPW norms					
Q	0.78	-	-	-	-
Or	0.40	2.15	2.61	11.28	8.48
Ab	35.71	36.13	15.63	22.72	33.40
An	11.96	23.51	24.26	20.02	23.20
Ne	-	3.82	10.03	8.55	-
Lc	-	-	-	-	-
Cor	7.90	-	-	-	-
Di	-	13.89	15.95	16.52	9.74
Hy	39.03	-	-	-	8.43
Wol	-	-	-	-	-
Ol	-	13.34	20.71	11.09	8.04
Mt	1.39	3.32	3.43	3.35	3.26
Il	2.02	3.48	5.79	5.21	4.67
Hm	-	-	-	-	-
Chr	0.20	0.03	0.02	0.01	0.01
Ap	0.60	0.33	1.57	1.25	0.76

Clode Sound area, Newfoundland

A. Original analyses

	875B	692	845	100	114
SiO_2	46.11	47.10	53.41	74.59	70.76
TiO_2	2.16	2.98	0.82	0.30	0.56
Al_2O_3	15.58	14.90	17.67	9.59	11.02
FeO	10.10	9.28	1.82	0.37	0.28
Fe_2O_3	1.89	4.10	5.68	8.90	8.61
MnO	0.13	0.29	0.14	0.10	0.05
MgO	2.63	4.73	3.13	0.38	0.09
CaO	6.26	5.57	4.69	0.20	0.25
Na_2O	4.88	3.73	3.71	2.12	3.73
K_2O	0.09	1.20	4.24	2.29	2.16
P_2O_5	0.44	1.15	0.24	0.06	0.04
LOI	7.55	5.03	2.33	1.02	1.15
	97.82	100.06	97.88	100.53	98.70
Rb	5	26	101	78	86
Sr	300	435	633	35	42
Ba	86	614	1350	252	152
Cu	46	23	37	7	10
Pb	1	5	1	16	20
Zn	108	163	81	124	168
Cr	74	3	24	2	1
Ni	43	3	13	21	8
V	351	223	182	54	16
Ga	21	25	19	39	42
Zr	189	284	167	1848	1216
Y	23	36	31	163	78
Nb	14	26	6	155	138

Clode Sound Formation - 875B, 692 - basalts; 845 - basalt with plagioclase, clinopyroxene and olivine phenocrysts; 100, 114, pantellerites; 100 brecciated.

Clode Sound area, Newfoundland

B. Analyses recalculated to 100% anhydrous with corrected Fe_2O_3/FeO.

	875B	692	845	100	114
SiO_2	50.51	49.58	56.01	75.65	72.83
TiO_2	2.37	3.14	0.86	0.30	0.58
Al_2O_3	17.07	15.68	18.53	9.73	11.34
FeO	10.95	11.57	6.17	5.[illegible]	5.61
Fe_2O_3	2.19	2.32	1.24	3.04	2.95
MnO	0.14	0.31	0.15	0.10	0.05
MgO	2.88	4.98	3.28	0.39	0.09
CaO	6.86	5.86	4.92	0.20	0.26
Na_2O	5.35	3.93	3.89	2.15	3.84
K_2O	0.10	1.26	4.45	2.32	2.22
P_2O_5	1.49	1.21	0.25	0.06	0.04
BaO	0.01	0.07	0.16	0.03	0.02
SrO	0.04	0.05	0.08	-	-
Cr_2O_3	0.01	-	-	-	-
ZrO_2	0.03	0.04	0.02	0.24	0.16
NiO	0.01	-	-	-	-
CIPW norms					
Q	-	-	-	49.98	38.27
Or	0.58	7.47	26.32	13.76	13.16
Ab	45.25	33.25	32.97	18.24	32.54
An	22.29	21.46	20.00	0.68	1.06
Ne	-	-	-	-	-
Lc	-	-	-	-	-
Cor	-	-	-	3.44	2.24
Di	1.89	0.08	2.75	-	-
Hy	12.77	21.34	8.18	8.75	7.25
Wol	-	-	-	-	-
Ol	6.07	4.26	5.76	-	-
Mt	3.18	3.36	1.80	4.42	4.29
Il	4.50	5.96	1.64	0.58	1.10
Hm	-	-	-	-	-
Chr	0.02	-	0.01	-	-
Ap	3.46	2.82	0.59	0.14	0.10

Clode Sound area, Newfoundland

A. Original analyses

	119	355	621	873	878
SiO_2	68.80	74.50	72.89	70.29	80.63
TiO_2	0.35	0.38	0.32	0.20	0.36
Al_2O_3	10.90	10.10	7.37	7.87	7.58
FeO	4.50	4.17	1.87	2.33	3.40
Fe_2O_3	1.53	0.17	6.89	7.06	0.82
MnO	0.27	0.06	0.23	0.17	0.10
MgO	0.28	-	0.19	0.10	0.36
CaO	3.96	0.06	2.99	1.20	1.02
Na_2O	1.33	0.18	2.31	1.92	0.11
K_2O	2.55	8.84	1.37	3.05	2.04
P_2O_5	0.05	0.04	-	-	-
LOI	5.92	2.68	3.44	1.74	3.00
	100.44	101.18	99.87	99.96	99.43
Rb	258	122	56	100	63
Sr	26	89	135	50	42
Ba	4	115	146	69	236
Cu	10	10	10	13	6
Pb	7	25	70	27	7
Zn	116	202	485	365	147
Cr	2	2	-	2	2
Ni	7	7	65	16	8
V	16	17	10	5	17
Ga	25	36	35	35	20
Zr	564	1033	4041	1681	831
Y	76	86	245	128	65
Nb	73	140	325	177	95

Clode Sound Formation pantellerites; 119 with abundant altered K - feldspar phenocrysts.

Clode Sound area, Newfoundland

B. Analyses recalculated to 100% anhydrous with corrected Fe_2O_3/FeO.

	119	355	621	873	878
SiO_2	72.68	75.41	75.46	74.85	83.44
TiO_2	0.37	0.38	0.33	0.21	0.37
Al_2O_3	11.52	10.22	7.63	8.32	7.84
FeO	4.22	2.97	5.67	6.23	2.91
Fe_2O_3	2.22	1.56	2.99	3.29	1.53
MnO	0.29	0.06	0.24	0.18	0.10
MgO	0.30	-	0.20	0.11	0.37
CaO	4.18	0.06	3.10	1.27	1.06
Na_2O	1.41	0.18	2.39	2.06	0.11
K_2O	2.69	8.95	1.42	3.23	2.11
P_2O_5	0.05	0.04	-	-	-
BaO	-	0.01	0.02	0.01	0.03
SrO	-	0.01	0.02	0.01	0.01
Cr_2O_3	-	-	-	-	-
ZrO_2	0.08	0.14	0.54	0.24	0.11
NiO	-	-	-	-	-
CIPW norms					
Q	43.02	38.47	47.92	44.29	70.28
Or	15.93	52.96	8.43	19.11	12.49
Ab	11.90	1.54	20.35	17.49	0.96
An	17.17	0.09	5.93	3.94	5.31
Ne	-	-	-	-	-
Lc	-	-	-	-	-
Cor	-	0.21	-	-	3.43
Di	2.86	-	8.47	2.13	-
Hy	5.07	3.64	3.91	7.86	4.59
Wol	-	-	-	-	-
Ol	-	-	-	-	-
Mt	3.22	2.26	4.36	4.78	2.22
Il	0.70	0.73	0.63	0.40	0.71
Hm	-	-	-	-	-
Chr	-	-	-	-	-
Ap	0.12	0.09	-	-	-

Clode Sound area, Newfoundland

A. Original analyses

	136	607	446	448	752	427
SiO_2	44.10	45.60	72.40	71.90	69.33	73.70
TiO_2	1.08	2.43	0.16	0.38	0.62	0.22
Al_2O_3	17.20	14.70	14.70	14.30	14.46	12.30
FeO	3.89	6.75	0.42	0.56	0.22	0.81
Fe_2O_3	7.09	7.43	1.02	1.47	4.35	1.55
MnO	0.17	0.23	0.01	0.04	0.06	0.04
MgO	12.54	7.33	0.37	0.12	0.95	0.24
CaO	2.63	6.75	0.61	0.44	1.20	1.28
Na_2O	4.55	4.27	4.27	5.32	6.55	2.86
K_2O	0.08	0.19	4.65	4.09	1.20	5.86
P_2O_5	0.26	0.30	0.07	0.07	0.09	0.04
LOI	6.24	3.51	1.26	0.75	1.10	0.65
	99.82	99.49	99.94	99.44	100.13	99.55
Rb	3	-	116	89	34	87
Sr	44	452	76	97	79	75
Ba	82	99	798	876	507	709
Cu	39	71	7	5	9	9
Pb	6	10	16	20	-	1
Zn	86	116	32	34	59	31
Cr	494	99	3	1	10	3
Ni	106	81	2	1	2	3
V	250	396	12	8	51	11
Ga	13	23	17	15	14	21
Zr	76	166	169	288	355	438
Y	15	21	33	32	31	59
Nb	6	13	17	16	18	27

Southwest River Formation (3b) - 136, 607 basalts; 446, 448 752, 427 rhyolites.

Clode Sound area, Newfoundland

B. Analyses recalculated to 100% anhydrous with corrected

Fe_2O_3/FeO.

	136	607	446	448	752	427
SiO_2	47.34	47.71	73.32	72.80	70.11	74.46
TiO_2	1.16	2.54	0.16	0.38	0.63	0.22
Al_2O_3	18.47	15.38	14.89	14.48	14.62	12.43
FeO	9.35	11.92	0.86	1.22	2.67	1.42
Fe_2O_3	1.87	2.39	0.55	0.77	1.69	0.90
MnO	0.18	0.24	0.01	0.04	0.06	0.04
MgO	13.46	7.67	0.37	0.12	0.96	0.24
CaO	2.82	7.06	0.62	0.45	1.21	1.29
Na_2O	4.88	4.47	4.32	5.39	6.62	2.89
K_2O	0.09	0.20	4.71	4.14	1.21	5.92
P_2O_5	0.28	0.31	0.07	0.07	0.09	0.04
BaO	0.01	0.01	0.09	0.10	0.06	0.08
SrO	0.01	0.05	0.01	0.01	0.01	0.01
Cr_2O_3	0.06	0.02	-	-	-	-
ZrO_2	0.01	0.02	0.02	0.04	0.05	0.06
NiO	0.02	0.01	-	-	-	-

CIPW norms

	136	607	446	448	752	427
Q	-	-	28.00	24.14	21.95	31.83
Or	0.51	1.18	27.85	24.50	7.18	35.03
Ab	41.34	34.59	36.62	45.63	56.10	24.48
An	12.24	21.34	2.80	1.96	5.56	3.46
Ne	-	1.75	-	-	-	-
Lc	-	-	-	-	-	-
Cor	5.86	-	1.65	0.42	0.38	-
Di	-	9.75	-	-	-	2.45
Hy	0.35	-	1.81	1.34	4.98	0.93
Wol	-	-	-	-	-	-
Ol	34.07	22.35	-	-	-	-
Mt	2.71	3.46	0.79	1.12	2.45	1.31
Il	2.20	4.83	0.31	0.73	1.19	0.42
Hm	-	-	-	-	-	-
Chr	0.08	0.02	-	-	-	-
Ap	0.65	0.73	0.16	0.16	0.21	0.09

Clode Sound area, Newfoundland

A. Original analyses

	629C	629B	555	800	591
SiO_2	39.47	46.32	64.71	64.47	68.88
TiO_2	1.58	0.50	0.70	0.62	0.52
Al_2O_3	13.76	17.83	15.82	16.00	14.48
FeO	8.36	4.10	2.53	2.49	1.65
Fe_2O_3	9.18	2.50	1.83	1.79	1.53
MnO	0.17	0.14	0.14	0.13	0.09
MgO	9.05	6.72	1.41	1.44	1.04
CaO	15.92	14.11	2.98	2.98	2.29
Na_2O	0.58	1.96	4.44	4.53	4.38
K_2O	0.20	0.87	3.98	4.02	3.29
P_2O_5	-	-	0.14	0.14	0.06
LOI	1.72	2.88	0.97	1.32	1.10
	99.99	97.94	99.65	99.94	99.32
Rb	8	22	122	120	85
Sr	367	471	326	333	204
Ba	84	170	825	859	699
Cu	687	100	8	7	12
Pb	-	4	10	15	1
Zn	60	58	64	89	46
Cr	38	269	7	1	11
Ni	116	51	5	10	7
V	689	159	53	64	48
Ga	15	15	13	17	19
Zr	39	51	212	219	208
Y	10	13	40	39	34
Nb	7	3	10	11	10

Georges Pond pluton - 629C, 629B gabbro; 555, 800 diorite; 591 granite.

Clode Sound area, Newfoundland

B. Analyses recalculated to 100% anhydrous with corrected Fe_2O_3/FeO.

	629C	629B	555	800	591
SiO_2	40.39	48.73	65.47	65.27	70.04
TiO_2	1.62	0.53	0.71	0.63	0.53
Al_2O_3	14.08	18.76	16.01	16.20	14.72
FeO	14.42	5.68	2.56	2.52	1.68
Fe_2O_3	2.89	1.14	1.85	1.81	1.56
MnO	0.17	0.15	0.14	0.13	0.09
MgO	9.26	7.07	1.43	1.46	1.06
CaO	16.29	14.84	3.01	3.02	2.33
Na_2O	0.59	2.06	4.49	4.59	4.45
K_2O	0.20	0.92	4.03	4.07	3.35
P_2O_5	-	-	0.14	0.14	0.06
BaO	0.01	0.02	0.09	0.10	0.08
SrO	0.04	0.06	0.04	0.04	0.02
Cr_2O_3	-	0.04	-	-	-
ZrO_2	0.01	0.01	0.03	0.03	0.03
NiO	0.02	0.01	-	-	-
CIPW norms					
Q	-	-	15.19	14.19	24.60
Or	-	5.41	23.82	24.08	19.79
Ab	-	12.63	38.05	38.85	37.72
An	35.99	39.24	11.63	11.61	10.31
Ne	2.79	2.61	-	-	-
Lc	0.97	-	-	-	-
Cor	-	-	-	-	-
Di	26.36	28.04	2.20	2.24	0.86
Hy	-	-	4.75	4.88	3.32
Wol	-	-	-	-	-
Ol	26.47	9.35	-	-	-
Mt	4.28	1.65	2.69	2.63	2.26
Il	3.14	1.00	1.35	1.19	1.01
Hm	-	-	-	-	-
Chr	0.01	0.06	-	-	-
Ap	-	-	0.33	0.33	0.14

Clode Sound area, Newfoundland

A. Original analyses

	515	641	601	564	743
SiO_2	69.57	71.47	76.59	75.73	76.40
TiO_2	0.30	0.24	0.06	0.02	0.15
Al_2O_3	14.39	14.52	13.42	12.90	12.80
FeO	1.17	0.94	0.26	0.28	1.03
Fe_2O_3	1.31	0.85	1.27	0.25	-
MnO	0.07	0.09	0.08	-	0.01
MgO	0.79	0.50	0.13	0.11	0.13
CaO	2.04	1.62	0.35	0.55	0.32
Na_2O	3.77	4.28	5.00	3.68	3.79
K_2O	3.88	3.28	3.31	5.04	5.27
P_2O_5	0.06	-	-	-	0.01
LOI	0.80	0.82	0.41	0.54	0.68
	98.15	98.62	100.88	99.10	100.46
Rb	124	88	75	88	75
Sr	235	154	42	94	78
Ba	786	646	807	354	619
Cu	2	3	2	1	4
Pb	10	5	7	11	16
Zn	43	46	48	17	22
Cr	15	5	1	4	3
Ni	6	3	6	7	-
V	35	18	2	2	11
Ga	16	15	16	14	16
Zr	165	163	227	70	154
Y	32	28	42	27	25
Nb	7	9	13	13	14

Georges Pond pluton - 515, 641, granite; 601, 743 granophyre; 564, aplite.

Clode Sound area, Newfoundland

B. Analyses recalculated to 100% anhydrous with corrected Fe_2O_3/FeO.

	515	641	601	564	743
SiO_2	71.36	73.00	76.14	76.79	76.39
TiO_2	0.31	0.25	0.06	0.02	0.15
Al_2O_3	14.76	14.83	13.34	13.08	12.80
FeO	1.20	0.96	0.26	0.28	1.03
Fe_2O_3	1.34	0.87	1.26	0.25	-
MnO	0.07	0.09	0.08	-	0.01
MgO	0.81	0.51	0.13	0.11	0.13
CaO	2.09	1.65	0.35	0.56	0.32
Na_2O	3.87	4.37	4.97	3.73	3.79
K_2O	3.98	3.35	3.29	5.11	5.27
P_2O_5	0.06	-	-	-	0.01
BaO	0.09	0.07	0.09	0.04	0.07
SrO	0.03	0.02	-	0.01	0.01
Cr_2O_3	-	-	-	-	-
ZrO_2	0.02	0.02	0.02	0.01	0.02
NiO	-	-	-	-	-

CIPW norms

	515	641	601	564	743
Q	27.71	30.02	33.65	34.01	32.53
Or	23.54	19.81	19.46	30.21	31.16
Ab	32.75	37.02	42.10	31.59	32.09
An	10.23	8.40	1.90	2.87	1.68
Ne	-	-	-	-	-
Lc	-	-	-	-	-
Cor	0.35	0.94	0.91	0.36	0.25
Di	-	-	-	-	-
Hy	2.74	2.08	0.32	0.56	1.99
Wol	-	-	-	--	-
Ol	-	-	-	-	-
Mt	1.95	1.26	0.92	0.37	-
Il	0.58	0.47	0.11	0.04	0.29
Hm	-	-	0.63	-	-
Chr	-	-	-	-	-
Ap	0.14	-	-	-	0.02

Clode Sound area, Newfoundland

A. Original analyses

	625	616	605	573B	834
SiO_2	50.40	45.10	71.38	71.05	52.19
TiO_2	1.05	1.50	-	0.50	1.44
Al_2O_3	15.70	13.98	14.26	12.06	15.62
FeO	7.82	8.65	0.61	0.31	6.52
Fe_2O_3	2.90	2.24	0.33	5.48	2.89
MnO	0.20	0.17	0.03	0.20	0.15
MgO	4.88	10.45	0.08	0.73	4.83
CaO	6.88	8.92	1.46	1.42	6.41
Na_2O	3.44	1.91	4.46	4.84	3.64
K_2O	1.33	0.88	3.74	0.79	0.90
P_2O_5	0.17	0.19	-	0.07	0.18
LOI	3.79	5.33	2.04	1.03	3.63
	98.56	99.32	98.38	98.48	98.40
Rb	31	29	131	32	21
Sr	543	330	47	262	458
Ba	752	313	191	247	359
Cu	310	64	1	–	29
Pb	2	9	12	16	12
Zn	97	90	44	100	74
Cr	77	337	4	–	16
Ni	50	232	4	3	36
V	307	203	5	14	194
Ga	20	19	20	15	19
Zr	84	111	166	224	231
Y	21	17	30	34	22
Nb	4	20	29	10	10

Dykes - 625, 616, mafic dykes in Connecting Point Group; 605, 573B, silicic; 834, mafic, all in Southwest River Formation.

Clode Sound area, Newfoundland

B. Analyses recalculated to 100% anhydrous with corrected Fe_2O_3/FeO.

	625	616	605	573B	834
SiO_2	53.14	47.92	74.04	73.09	55.07
TiO_2	1.11	1.59	-	0.51	1.52
Al_2O_3	16.55	14.85	14.79	12.41	16.48
FeO	9.32	9.60	0.60	3.45	8.16
Fe_2O_3	1.87	1.92	0.38	2.17	1.64
MnO	0.21	0.18	0.03	0.21	0.16
MgO	5.15	11.10	0.08	0.75	5.10
CaO	7.25	9.48	1.51	1.46	6.76
Na_2O	3.63	2.03	4.63	4.98	3.84
K_2O	1.40	0.93	3.88	0.81	0.95
P_2O_5	0.18	0.20	-	0.07	0.19
BaO	0.09	0.04	0.02	0.03	0.04
SrO	0.07	0.04	0.01	0.03	0.06
Cr_2O_3	0.01	0.05	-	-	-
ZrO_2	0.01	0.02	0.02	0.03	0.03
NiO	-	0.03	-	-	-
CIPW norms					
Q	-	-	28.51	35.08	3.89
Or	8.30	5.53	22.93	4.81	5.62
Ab	30.72	17.19	39.16	42.16	32.53
An	24.77	28.68	7.57	6.92	24.95
Ne	-	-	-	-	-
Lc	-	-	-	-	-
Cor	-	-	0.21	0.80	-
Di	8.67	13.96	-	-	6.29
Hy	21.24	11.54	1.05	5.94	21.02
Wol	-	-	-	-	-
Ol	1.05	16.73	-	-	-
Mt	2.71	2.79	0.56	3.15	2.37
Il	2.10	3.03	-	0.98	2.89
Hm	-	-	-	-	-
Chr	0.01	0.08	-	-	-
Ap	0.42	0.47	-	0.17	0.44

Clode Sound area, Newfoundland

A. Original analyses

	448B	P116	24E	193B	196
SiO_2	45.46	51.76	47.23	51.19	46.40
TiO_2	2.38	2.12	0.96	1.64	1.08
Al_2O_3	15.76	14.97	18.22	15.90	17.70
FeO	8.82	7.36	4.60	6.91	6.51
Fe_2O_3	3.54	2.19	3.23	2.31	2.38
MnO	0.20	0.24	0.14	0.18	0.19
MgO	5.68	3.72	5.09	5.33	7.97
CaO	7.57	5.82	11.11	6.14	9.27
Na_2O	3.06	3.97	1.69	1.95	1.18
K_2O	0.66	1.82	1.93	2.69	2.65
P_2O_5	0.33	0.68	0.16	0.41	0.19
LOI	5.49	5.68	4.87	4.11	4.06
	99.95	100.33	99.22	98.67	99.57
Rb	10	20	48	53	72
Sr	548	167	395	301	262
Ba	150	554	309	665	194
Cu	37	13	41	70	79
Pb	-	3	3	1	3
Zn	101	131	71	128	102
Cr	5	11	123	64	128
Ni	50	7	41	44	95
V	252	243	208	228	207
Ga	18	22	19	19	17
Zr	194	279	100	274	86
Y	18	39	22	31	28
Nb	13	14	5	12	5

Mafic dykes - 448B in Southwest River Formation; P116, 24E, 193B, 196 in Thorburn Lake Formation (2a).

Clode Sound area, Newfoundland

B. Analyses recalculated to 100% anhydrous with corrected Fe_2O_3/FeO.

	448B	P116	24E	193B	196
SiO_2	48.65	54.65	50.10	53.99	48.57
TiO_2	2.55	2.24	1.02	1.73	1.13
Al_2O_3	16.87	15.81	19.33	16.80	18.53
FeO	10.89	8.35	6.75	8.05	7.67
Fe_2O_3	2.18	1.67	1.35	1.61	1.54
MnO	0.21	0.25	0.15	0.19	0.20
MgO	6.08	3.93	5.40	5.63	8.34
CaO	8.10	6.15	11.78	6.49	9.70
Na_2O	3.27	4.19	1.79	2.06	1.24
K_2O	0.71	1.92	2.05	2.84	2.77
P_2O_5	0.35	0.72	0.17	0.43	0.20
BaO	0.02	0.07	0.04	0.08	0.02
SrO	0.07	0.02	0.05	0.04	0.03
Cr_2O_3	-	-	0.02	0.01	0.02
ZrO_2	0.04	0.04	0.01	0.04	0.01
NiO	0.01	-	0.01	0.01	0.01
CIPW norms					
Q	-	2.53	-	5.27	-
Or	4.18	11.36	12.11	16.81	16.40
Ab	27.73	35.50	15.18	17.45	10.46
An	29.26	18.65	38.67	28.23	36.84
Ne	-	-	-	-	-
Lc	-	-	-	-	-
Cor	-	-	-	-	-
Di	7.35	6.13	15.51	1.17	8.25
Hy	13.56	17.48	10.21	24.42	10.16
Wol	-	-	-	-	-
Ol	9.09	-	4.02	-	13.02
Mt	3.17	2.42	1.95	2.33	2.23
Il	4.84	4.25	1.94	3.29	2.15
Hm	-	-	-	-	-
Chr	-	-	0.03	0.01	0.03
Ap	0.82	1.67	0.39	1.01	0.46

Clode Sound area, Newfoundland

A. Original analyses

	86	688	69B	76B	228A	567
SiO_2	50.50	50.20	47.67	45.00	47.30	54.50
TiO_2	1.41	1.17	3.12	2.08	2.34	1.37
Al_2O_3	14.70	15.90	13.42	15.34	14.10	15.50
FeO	6.82	5.99	8.47	8.17	7.43	6.10
Fe_2O_3	2.13	4.31	6.02	3.94	5.00	3.31
MnO	0.14	0.16	0.25	0.22	0.21	0.19
MgO	7.40	6.91	5.41	8.24	6.13	3.75
CaO	7.82	10.88	7.67	9.64	10.82	6.55
Na_2O	3.63	1.97	3.11	2.03	2.70	3.75
K_2O	0.21	0.26	0.96	0.46	0.42	1.20
P_2O_5	0.31	0.16	0.40	0.39	0.30	0.34
LOI	4.04	2.06	3.67	4.71	3.25	2.35
	99.11	99.97	100.18	100.22	100.00	98.91
Rb	3	7	14	15	11	35
Sr	703	390	210	396	575	373
Ba	403	149	246	276	130	478
Cu	59	65	76	51	47	21
Pb	2	4	-	3	7	1
Zn	105	80	143	108	102	106
Cr	137	140	27	176	69	21
Ni	155	31	31	118	33	7
V	166	253	430	276	354	249
Ga	22	16	23	22	23	20
Zr	124	82	227	174	176	135
Y	16	16	31	24	25	30
Nb	22	6	16	12	13	9

Mafic dykes in White Point Formation.

Clode Sound area, Newfoundland

B. Analyses recalculated to 100% anhydrous with corrected Fe_2O_3/FeO.

	86	688	69B	76B	228A	567
SiO_2	53.02	51.36	49.54	47.14	48.98	56.47
TiO_2	1.48	1.20	3.24	2.18	2.42	1.42
Al_2O_3	15.43	16.27	13.95	16.07	14.60	16.06
FeO	7.77	8.56	12.23	10.40	10.47	7.98
Fe_2O_3	1.55	1.71	2.44	2.08	2.09	1.60
MnO	0.15	0.16	0.26	0.23	0.22	0.20
MgO	7.83	7.07	5.62	8.63	6.35	3.89
CaO	8.21	11.13	7.97	10.10	11.20	6.79
Na_2O	3.81	2.02	3.23	2.13	2.80	3.89
K_2O	0.22	0.27	1.00	0.48	0.43	1.24
P_2O_5	0.33	0.16	0.42	0.41	0.31	0.35
BaO	0.05	0.02	0.03	0.03	0.02	0.06
SrO	0.09	0.05	0.02	0.05	0.07	0.04
Cr_2O_3	0.02	0.02	-	0.03	0.01	-
ZrO_2	0.02	0.01	0.03	0.02	0.03	0.02
NiO	0.02	-	-	0.02	-	-

CIPW norms

	86	688	69B	76B	228A	567
Q	-	3.14	-	-	-	6.42
Or	1.30	1.57	5.90	2.85	2.57	7.35
Ab	32.28	17.06	27.37	18.01	23.67	32.90
An	24.38	34.57	20.61	32.90	26.02	22.73
Ne	-	-	-	-	-	-
Lc	-	-	-	-	-	-
Cor	-	-	-	-	-	-
Di	11.86	16.18	13.60	12.06	22.90	7.41
Hy	23.65	22.31	19.06	15.80	11.02	17.35
Wol	-	-	-	-	-	-
Ol	0.67	-	2.78	10.22	5.44	-
Mt	2.26	2.48	3.54	3.02	3.03	2.32
Il	2.81	2.27	6.16	4.14	4.61	2.70
Hm	-	-	-	-	-	-
Chr	0.03	0.03	0.01	0.04	0.02	-
Ap	0.76	0.38	0.97	0.95	0.72	0.82

APPENDIX 5

First Results of Radiometric Age Dating Program

A radiometric age-dating program (U/Pb, Rb/Sr, $Ar_{40/39}$) is being conducted by D. Dallmeyer, University of Georgia, under the auspices of the Newfoundland Dept. of Mines and Energy. Samples were collected by S.J. O'Brien, C.F. O'Driscoll, and the present author at various sites throughout the western Avalon Zone including several in the present map area. A number of age dates have recently become available (D. Dallmeyer, pers. comm., 1979). They include:

Love Cove volcanics (Swift Current area) These volcanics are on strike and correlative with the White Point Formation of the present map area.	$^{206}Pb/^{238}U$	- 590 ± 30 m.y.
Swift Current granite (correlative of Georges Pond pluton)	$^{206}Pb/^{238}U$	- 580 ± 20 m.y.
	Rb/Sr	- 548 ± 11 m.y.
	$^{87}Sr/^{86}Sr$	- 0.70326 ± 0.00037
Swift Current granite (hornblende separates)	$Ar_{40/39}$	- 561 ± 15 m.y.
		- 528 ± 15 m.y.
Ackley batholith (biotite separates)	$Ar_{40/39}$	- 352 ± 10 m.y.
		- 356 ± 10 m.y.
Sericite schists from Love Cove Group collected from Clode Sound area south to the Burin Peninsula	$Ar_{40/39}$ (whole rock)	A - 385 ± 10 m.y.
		B - 386 ± 10 "
		C - 391 ± 10 "
		D - 388 ± 10 "
		E - 388 ± 10 "
		F - 382 ± 5 "

The $Ar_{40/39}$ release spectra on hornblende separates from the Swift Current granite suggest that it has undergone a post-crystallization thermal event which has apparently "updated" the Rb/Sr age data. Otherwise the ages reported above appear to be reliable indications of the age of formation of the rocks or in the case of the sericite schists the age of metamorphism. Clearly, these dates are of considerable significance to interpretations put forward in this thesis.

Jenness (1963) and Dal Bello (1977) suggested that the Love Cove Group forms the base or lower portions of a section occupied by the Connecting Point and Musgravetown Groups and the Eocambrian-Cambrian succession in ascending order. However, the 590 $\pm$ 30m.y. U/Pb date suggests that the Love Cove Group does not underlie the Connecting Point Group and its position is somewhat comparable with that of the volcanic rocks elsewhere on the western Avalon Zone (eg. Marystown Group, column "C'", Table 1).

The 580 $\pm$ 30 m.y. U/Pb date on the Swift Current granite appears to support the case for a genetic link between the early granites (eg. Swift Current, Cape Roger Mountain, and Georges Pond plutons) and the Love Cove volcanic terrain.

Coherent and consistent $Ar_{40/39}$ release spectra on sericite schist from correlatives of the White Point Formation to the south strongly support the interpretation that the principal (S_1) deformation of the Love Cove Group was Acadian in age.

The $Ar_{40/39}$ ages on biotite separates from the Ackley batholith are consistent with its post-kinematic relation to the S_1 fabric of the Love Cove Group.

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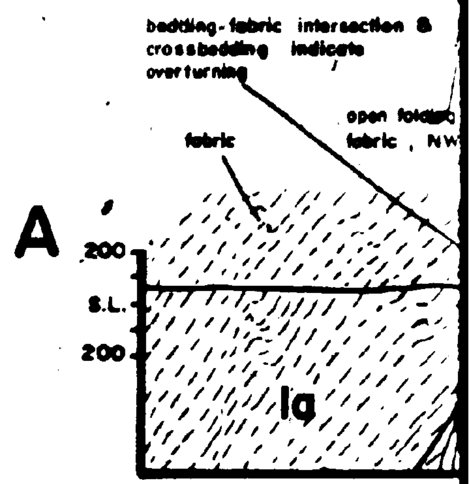
STRUC
CLOD



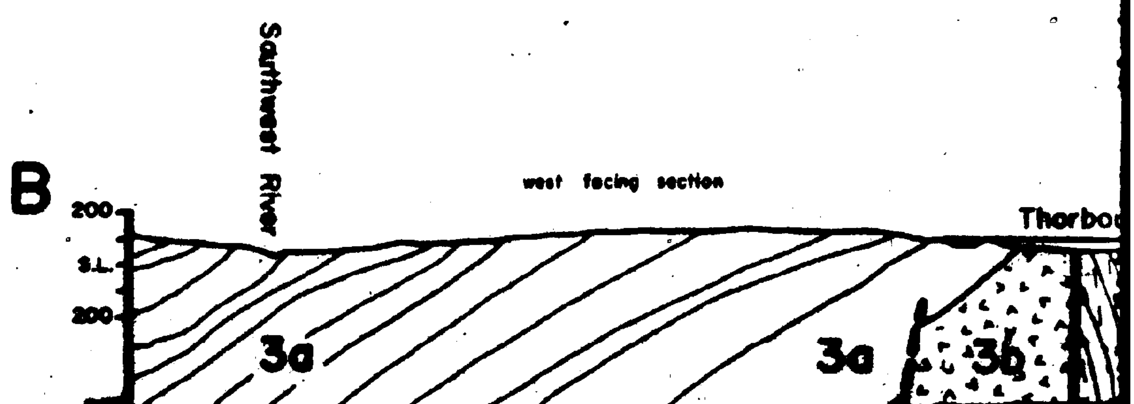
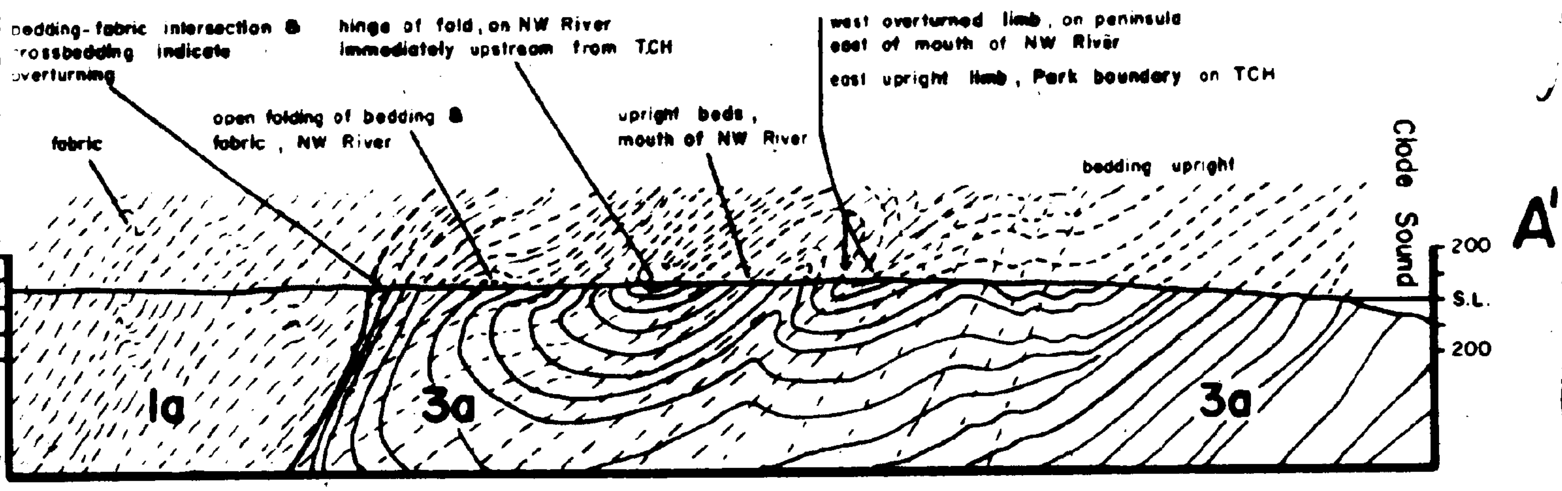


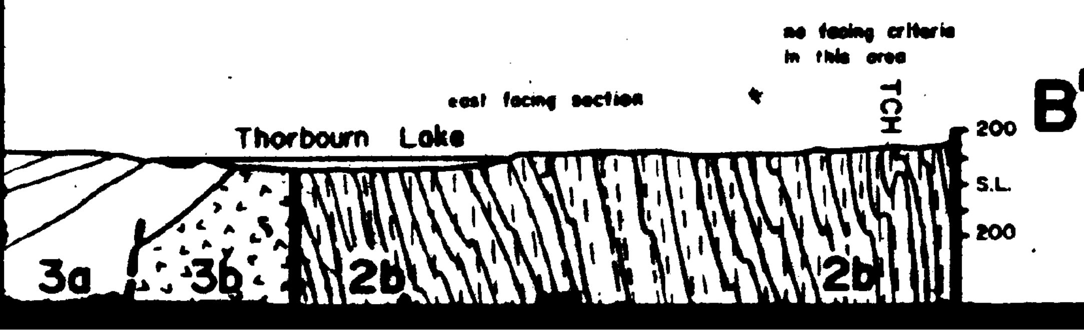
Figure 1·1

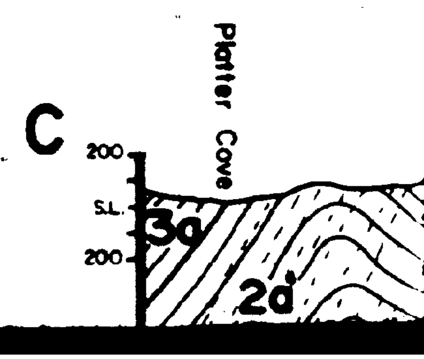
(to accompany Figure 1)

STRUCTURAL CROSS-SECTIONS CLODE SOUND MAP AREA

all views looking north





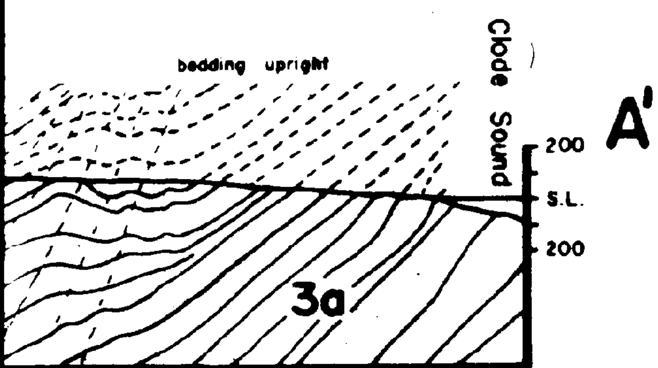


[34]

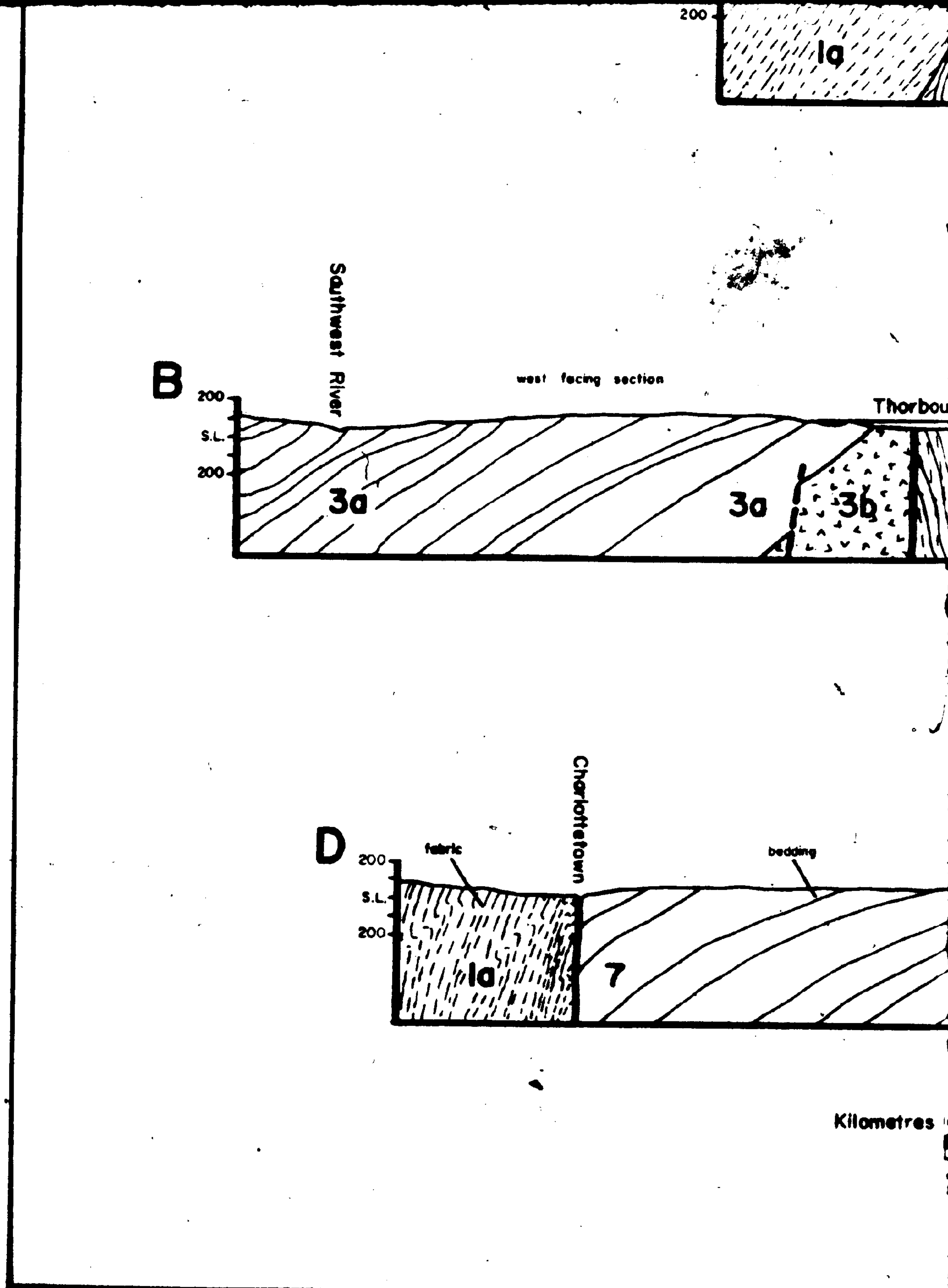
1)

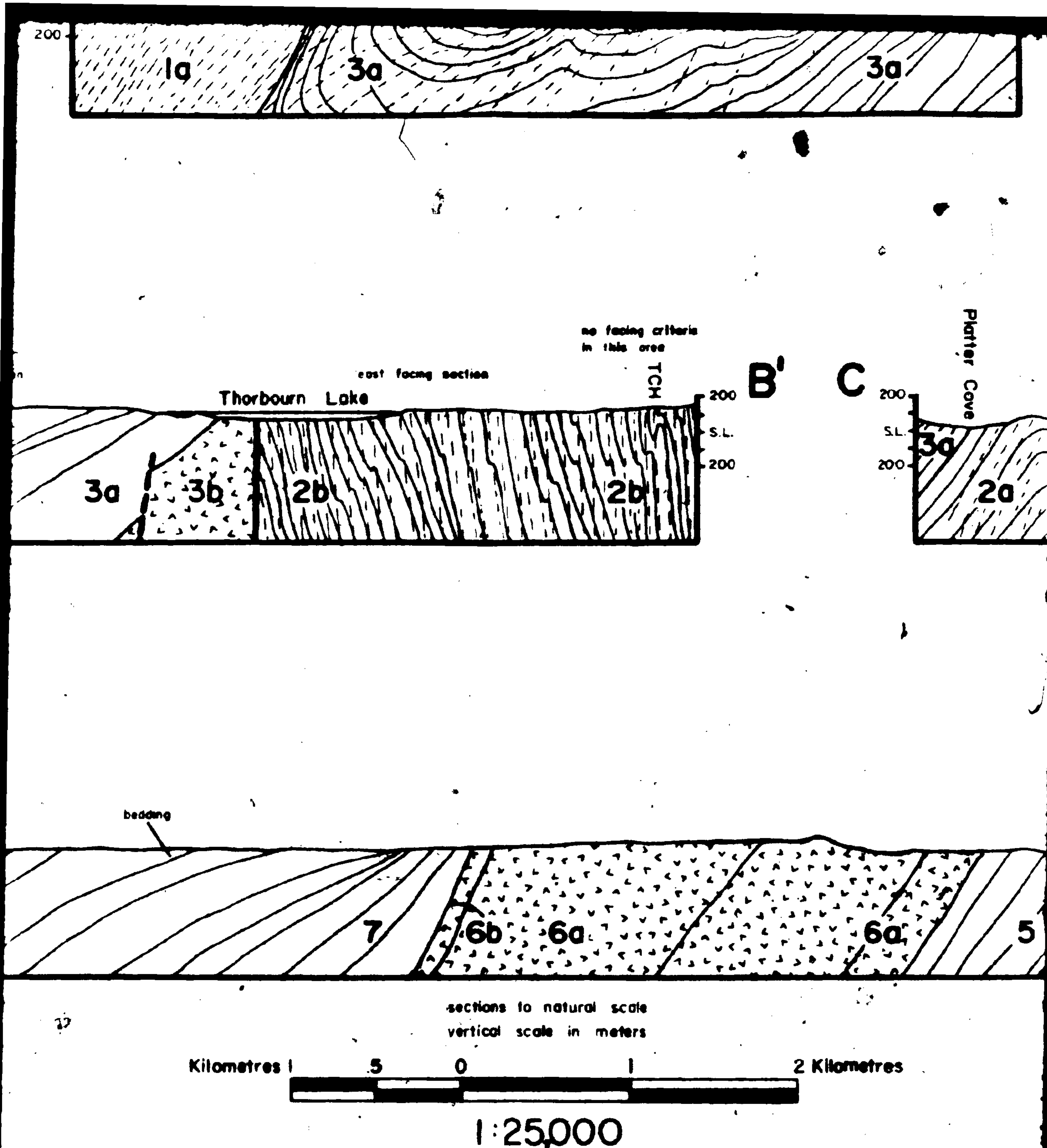
S-SECTIONS
AP AREA

rturned limb, on peninsula
mouth of NW River
ight limb, Park boundary on TCH



eris


200
Ia
B
Southwest River
west facing section
Thorbou
200
S.L.
200
3a
3a
3b
D
fabric
Charlottetown
bedding
200
S.L.
200
Ia
7
Kilometres


200
1a
3a
3a
no facing criteria
in this area
east facing section
Thorbourn Lake
TCH
200
S.L.
200
B'
C
200
S.L.
200
Platter Cove
3a
3b
2b
2b
3a
2a
bedding
7
6b
6a
6a
5
sections to natural scale
vertical scale in meters
Kilometres 1 .5 0 1 2 Kilometres
1:25,000

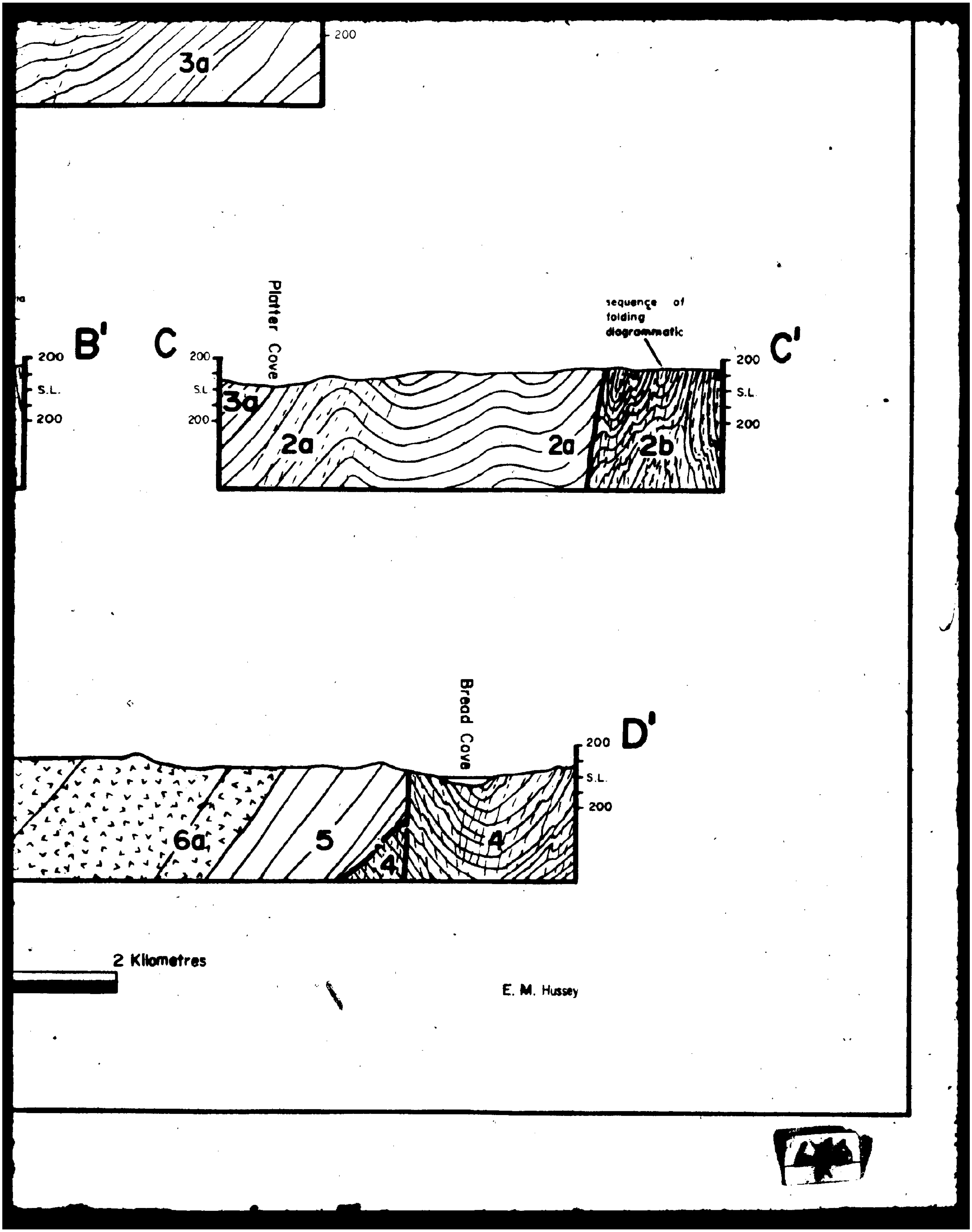

200
3a
B'
200
S.L.
200
C
C'
200
S.L.
200
Platter Cove
3a
2a
2a
2b
sequence of folding diagrammatic
200
S.L.
200
Bread Cove
D'
200
S.L.
200
6a
5
4
4
2 Kilometres
E. M. Hussey

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Table 1 Various Interpretations of Stratigraphic Relatio[ns]

	A	B	C	C'	D	
	FORTUNE BAY	NORTHERN BURIN PEN.	SOUTHERN BURIN PEN.	SOUTHERN BURIN PEN.	WESTERN PLACENTIA BAY	WESTERN T[...]
Carboni-ferous			Presumed Carboniferous Grand Beach Complex Rocky Ridge Complex Clanceys Pond Complex Alk. to peralk. silicic breccias & flows			
Devonian	Late Great Bay de l'Eau Form. 300+ rd. gy. & pk. cgl. ū rd. & pu. sn., ls. & granitic rocks as pebbles (?) or earlier Pools Cove Form. 1500 rd. granite cobble cgl., pk. to buff arkosic cgl., buff, coarse boulder cgl. (?) or earlier Cinq Isle Form. 450 rd. micaceous sn., qts. pebble cgl., rd. sh. & micritic ls.	Late Terrenceville Form 300+ bn. & gy. cgl. & sn., gy-gn. sh. & rd. ms.	Late Spanish Room Form. 244 rd. st. & cgl., ls., sh., ms.			
Silurian		(?) Rencontre Form. 60-1200 basal rd. & pu. volc. cgl., rd. st., sn., & minor rd. sh. 1 felsite flow				
Ordovician		Middle and/or Late (?) Andersons Cove Form. 150-1200 gw. cgl. ū silicic pebbles, gn. tuff, varved slates, mets-cgl., minor bl. ū pillows. Middle and/or Late (?) Belle Bay Form. 1800 felsite, rhy. porph., andesite porph. flows, minor bl. flows, rd. agglom. & tuff, minor felsite, rd., gn. & pu. sn. Early (?) Grand Le Pierre Form. 300 dense bn., x-lithic tuff minor felsite, gw., chert & basalt				Early Clarenvil[le] (?) gy. sh., [...]
Cambrian	Middle Youngs Cove Form. 600 gy. sn. micaceous st., sh., minor rd. & pu. sh. Middle to Lower Blue Pinion Form. wh. qtzite & gy. sh. & sn. & st. Lower Cambrian to Latest Precambrian Chapel Island Form.	Upper Nine Mile Hill Form. 1100 hornfelse, qtzite, bl., & gw. cgl.	Lower Blue Pinion Form. rd.-bn. st., gh. qtzite. Lower Cambrian to Latest Precambrian Chapel Island Form. Inlet Group 1190: Middle Pleasant View Form. 100 gn. rd. ms & sh., ls. & gy. sh. Lower Salt Pond Form. 450 rd. sh. & pk. ls., gy. & pu. sh. Eocambrian Bay View Form.	Paleozoic stratigraphy as in column C	Lower Bonavista Form. rd.-gn. sl. & pk. ls. Eocambrian Random Form.	Upper Elliott C[ove] gy. & bk. [...] Middle Manuels Ri[ver] bk. & gy. [...] Middle Chamberlai[n] rd. & gn. [...] Lower Brigus For[m.] rd. & gn. [...] Lower Smith Pt. [...] Lower Bonavista [...] rd. & gn. [...]
Precambrian	(?) gy-gn. sn. & st., minor rd. st. Latest Precambrian Rencontre Form. 600-900 pu. x-bedded sn., rd. micaceous st., pu. & rd. cgl., gy. st. & argillite Latest Precambrian Mooring Cove Form. 550-750 silicic agglom., mafic flows, rd. & gy. sed. rocks Late Precambrian Andersons Cove Form. 300-450 gy. argillite, sn., st., minor pu. tuff, st. & tuff. sed. rocks Late Precambrian Belle Bay Form. 3000-4000 silicic & mafic volc. rocks, minor pu. to gy. st.	Deer Park Pond Form. 0-1500 schistose porph. yellow & gn. felsite & tuff; meta. bl. & minor meta. gw. Southern Hills Form. 3000 gw. cgl.; rd. & pu. felsite in mid. part; meta. bl. in upper part	737 gy-gn. sn., rd. sn., ls. Latest Precambrian Rencontre Form. rd. st. and ms. (Bay View Form.) 600 gy. & gn. sn., rd. st., minor qtzite. & ls. Late Precambrian Burtler Bay Group 1000 Includes two formations Dom. mafic flows and pyrocl., silicic pyrocl., rd. st., sn. & cgl. Marystown Group 10,000 Includes 6 formations Dom. silicic to int. tuff, rhy. & locally pillowed bl. near base; felsic and mafic flows & pyrocl., plag. phyric bl., por. sed., rhy., related sed., local vent agglom. Beaver Pond Form. 900+ chl. schist, pillow bl., minor ls.	Latest Precambrian Rencontre Form. Grand Beach Complex Mt. St. Anne Form. Bare Hills Form. Garnaway Complex 1000 Calmer Form. 1000 Garnish Form. 900 x-bedded tuff. sn. Taylors Bay Form. 3000-6000 (Marystown Group)	orthoqtzite, sn. & sh. Latest Precambrian Units 5c & 5d rd. & pu. st. & cgl. Marystown Group: Unit 5b bl. flows & agglom., tuff, minor ls. Unit 5a gn. sn., st, bk. sh., pebbly st., cgl., ls. beds & breccias Unit 4 basalt, agglom. & tuff Love Cove Group: Unit 2 gn. gw. & st., cgl. (equiv. to 5a?) Unit 1 silicic to mafic flows & pyrocl. (equiv. to 4?)	Latest Random For[m.] wh. gn.gy. [...] x-bedded [...] Crown Hill [...] 800+ rd. pebble [...] [...] rd. [...] Rocky Harb[our] 300+ yellowish [...] sn. Undifferen[tiated] 300+ gy., gn., [...] sn., gy-br[...] Bull Arm F[orm.] 1000 silicic & [...] rd. & gy. [...] minor pyro[cl.] [...]ian C[...]

Table modified after Taylor (1977)

[illegible] Stratigraphic Relations across the Avalon Zone, Newfoundland

D	E	F	G	H	I	J
...NTIA BAY	WESTERN TRINITY BAY	WESTERN AVALON PEN	CAPE ST. MARY'S	EASTERN TRINITY BAY	CONCEPTION BAY	EASTERN AVALON
	Early Clarenville Group (?) gy. sh., bk. sh. & sn.				Early Bell Island & Wabana Groups 1500 shale, sandstone & oolitic hematite	
...rm. ... pk. ls. sn. & sh. ...mbrian ...d ... & cgl.	Upper Elliott Cove Group gy. & bk. sh. & sn. Middle 30 Manuels River Form. bk. & gy. sh. Middle 90 Chamberlains Brook Form. rd. & gn. manganiferous ms. Lower 110 Brigus Form. rd. & gn. sn. w pk. ls. Lower 10 Smith Pt. Form. - pk. ls. Lower 140 Bonavista Form. rd. & gn. sh. w pk. ls.	Middle Chamberlains Brook manganiferous beds Lower 20-130 Brigus Form. rd. & gn. sl. w pk. ls. Lower 16 Smith Point Form. pk. algal ls., rd. limy argillite lam. Lower 0-30 Bonavista Form. rd. & gn. sl. w ls. & cgl.	Upper 81 Gull Cove Form., sn. & sh. Beckford Head Form. gy., gn. sn. w minor volc. Middle Manuels River Form. bk. & gy. sh. Middle 150 Chamberlains Brook Form. rd. & gn. ms. w mafic flows Lower 125 Brigus Form. rd. & gn. sh. w pk. ls. Lower 10 Smith Pt. Form., pk. ls. Lower 60 Bonavista Form. rd. & gn. sh. w pk. ls.	Elliot Cove Form., 90+, sh. & st. Manuels River Form. 130 dk. gy. & bk. sh. & sl. w ls. & minor pillow bl. Chamberlains Brook Form. 110+ gy. gn. sl. & sh., w ls. & manganese at base Brigus Form. 23-130+ rd. & gn. sl. w ls. nodules Smith Pt. Form. pk. algal ls., 15 Bonavista Form. 0-30 rd. & gn. sl., thin ls. & basal cgl.		
	Latest ?-110 Random Form. wh. gn.gy. & pk. qtzite., x-bedded sn. & st.	Latest 0-180 Random Form. wh. qtzite., qtz-pebble cgl., arkosic interbeds	Random Form. 125+ wh., gn., gy. & pk. qtzite., x-bedded sn. & st.	Random Form. 0-180 wh. qtzite., cgl.		[illegible] Form. [illegible] rd. & gn. gy. arkosic sn., minor sl., cgl. & sn.
...agglom., ... ls. ... bk. sh., ...cgl., ls. ...ies ...om. & tuff ..., cgl. ...a?) ...afic flows ...quiv. to b?)	Crown Hill Form. 800+ rd. pebble cgl. & st., some rd. sn., gn. sn. Rocky Harbour Form. 300+ yellowish gn. x-bedded sn. Undifferentiated 300+ gy., gn., & rd. st. & sn., gy-bn. pebble cgl. Bull Arm Form. 600 silicic & mafic lavas, rd. & gy. st. & cgl., minor pyrocl.	Crown Hill Form. 0-300 rd. pebble cgl., minor gn. cgl. & rd. st. Undivided Units 350+ rd. cgl. & arkose, gn. sn., gy. sn., slate, argillite Trinny Cove Form. 600 gn. & rd. arkose, grit, sn., gy. sn. Maturin Ponds Form. 300-600 massive & bedded rd. arkose & st.	Cross Point Form. 80 dk. rd. x-bedded grits & thin cgl. Northern Head Form. 500 dk. rd. st., sn. & sl. w gn. sn. & gn. qtz. cgl. Lears Cove Form. 220 rd. sn., st. & grits w some gy. gn. sn. & sh. Brierly Cove Form. 330 rd. qtz. cgl. w dk. rd. x-bedded sn., st. & grits w some shale, gn. st., sn. & bn. sl.	Snows Pond Form. 900-2100 rd. st. & sn., gy. gn. st. & sn. Whiteway Form. 100 rd. sn. & st. w minor gn. beds Hells Town Form. 830-1500 massive gy. st. & sn. Carbonear Form. 1000-1200 gy. sl. & sn.	Conception Group 1800-2500 gy. gn. sn., sl. & gr. & cgl. & minor rd. sn. & mafic flows	Signal Hill Form. 2300+ rd. cgl., rd., gn. & gn. gy. arkosic sn., minor sl., sn. St. John's Form. 300+ dk. gy. to bk. sl. grit w cgl. lenses & st. at top Torbay Slate 900+ flinty gn. st., gn., rd., & bn. sl., qtz. sn. & cgl. Conception Slate 3000+ flinty gn. & gy. sn., fine gn. & gy. st.,

450
rd. micaceous sn., qtz. pebble cgl., rd. sh. & micritic ls.

Silurian

(?)
Rencontre Form.
60-1200
basal rd. & pu. volc. cgl., rd. st., sn., & minor rd. sh. 1 felsite flow

Ordovician

Middle and/or Late (?)
Andersons Cove Form.
150-1200
gy. cgl. w silicic pebbles, gn. tuff, varved slates, meta-cgl., minor bl. w pillows.

Middle and/or Late (?)
Belle Bay Form.
1800
felsite, rhy. porph., andesite porph. flows, minor bl. flows, rd. agglom. & tuff, minor felsite, rd., gn. & pu. sn.

Early (?)
Grand Le Pierre Form.
300
dense bn., x-lithic tuff minor felsite, gw., chert & basalt

Early
Clarenville ...
(?)
gy. sh., bk. ...

Cambrian

Middle
Youngs Cove Form.
600
gy. sn. micaceous st., sh., minor rd. & pu. sh.

Middle to Lower
Blue Pinion Form.
wh. qtzite & gy. sh. & sn. & st.

Lower Cambrian to Latest Precambrian
Chapel Island Form.
(?)
gy-gn. sn. & st., minor rd. st.

Upper
Nine Mile Hill Form.
1100
hornfelses, qtzite. bl., & gw. cgl.

Lower
Blue Pinion Form.
rd.-bk. st., wh. qtzite.

Lower Cambrian to Latest Precambrian
Chapel Island Form.
737
gy-gn. bn., rd. sn., ls.

Inlet Group 1150

Middle
Pleasant View Form.
100
gn. rd. ms & sh., ls. & gy. sh.

Lower
Salt Pond Form.
450
rd. sh. & pk. ls., gy. & pu. sh.

Eocambrian
Bay View Form.
600
gy. & gn. sn., rd. st., minor qtzite. & ls.

Paleozoic stratigraphy as in column C

Lower
Bonavista Form.
rd.-gn. sl. & pk. ls.

Eocambrian
Random Form.
orthoqtzite, sn. & sh.

Upper
Elliott Cove ...
gy. & bk. sh...

Middle 30...
Manuels River ...
bk. & gy. sh...

Middle 90...
Chamberlains ...
rd. & gn. ...

Lower 1...
Brigus Form ...
rd. & gn. ...

Lower 1...
Smith Pt. Fo...

Lower 1...
Bonavista Fo...
rd. & gn. ...

Precambrian

Latest Precambrian
Rencontre Form.
600-900
pu. x-bedded sn., rd. micaceous st., pu. & rd. cgl., gy. st. & argillite

Latest Precambrian
Mooring Cove Form.
350-750
silicic agglom., mafic flows, rd. & gy. sed. rocks

Late Precambrian
Andersons Cove Form.
300-450
gy. argillite, sn., st., minor pu. tuff, st. & tuff. sed. rocks

Late Precambrian
Belle Bay Form.
3000-6000
silicic & mafic volc. rocks, minor pu. to gy. st.

Deer Park Pond Form.
0-1500
schistose porph. yellow & gn. felsite & tuff; meta. bl. & minor meta. gw.

Southern Hills Form.
3000
gw. cgl.; rd. & pu. felsite in mid. part; meta. bl. in upper part

Latest Precambrian
Rencontre Form.
rd. st. and ms.

Late Precambrian
Mortier Bay Group
1000
Includes two formations
Dom. mafic flows and pyrocl., silicic pyrocl., rd. st., sn. & cgl.

Marystown Group
10,000
Includes 6 formations
Dom. silicic to int. tuff, rhy. & locally pillowed bl. near base; felsic and mafic flows & pyrocl., plag. phyric bl., por. and., rhy., related sed., local vent agglom.

Beaver Pond Form.
900+
chl. schist, pillow bl., minor ls.

Burin Group 4000+

Wandsworth Gabbro
1500
gabbro, granodiorite, diabase

Path End Form.
1200
pillowed and. & mafic tuff & agglom.

Port Au Bras Form.
900
gy. massive tuff, sn., st., ms., minor gw., argillite, ls.

Pardy Island Form.
1800
bk. to rd. pillowed bl., minor rd. to gy. st., rd. ls.

Wild Cove Form.
900
gy-gn. cgl. & minor x-bedded sn.

Ridge Cove Form.
1400
gy-gn. lam.st., sn. & gw. & minor cgl., ls.

Latest Precambrian
Rencontre Form.

Grand Beach Complex
Mt. St. Anne Form.
Hare Hills Form.
Baraseway Complex
1000

Calmer Form.
1000

Garnish Form.
500
x-bedded tuff. sn.

Taylors Bay Form.
3000-4000

Marystown Group

Latest Precambrian
Units 5c & 5d
rd. & pu. st. & cgl.

Musgravetown Group

Unit 5b
bl. flows & agglom., tuff, minor ls.

Unit 5a
gn. sn., st, bk. sh., pebbly st., agl., ls. beds & breccias

Unit 4
basalt, agglom. & tuff

Love Cove Group

Unit 2
gn. gy. & st., agl. (equiv. to 5a?)

Unit 1
silicic to mafic flows & pyrocl. (equiv. to 4?)

Latest ...
Random Form. ...
wh. gn.gy. ...
x-bedded sn ...

Crown Hill ...
800+
rd. pebbly ...
some rd. ...

Rocky Harbo...
300+
yellowish ...
sn.

Undifferent...
300+
gy., gn., ...
sn., gy-bn. ...

Bull Arm Fo...
8000
silicic & ...
rd. & gy. ...
minor pyroc...

Cannings C...
130
rd. & gn. ...
sn. & st.

Connecting ...
5000
gn. to bk. ...
qtzite., ...
mafic volc...

Love Cove ...
5000
silicic to ...
pyrocl., ...
commonly ...
schists

Table modified after Taylor (1977)

Sources of Information
Column A - Williams (1971)
Column B - Bradley (1962)
Column C - Strong et.al. (1978b), O'Brien et.al. (1977),
Column C' - S. J. O'Brien (pers. comm., 1979) TAYLOR '77
Column D - O'Driscoll (1978a)
Column E - Jenness (1963)
Column F - McCartney (1967)
Column G - Fletcher (1972)
Column H - McCartney (1967)
Column I - McCartney (1967)
Column J - Rose (1952)

Abbreviations

cgl. - conglomerate	gn. - green
sn. - sandstone	gy. - grey
st. - siltstone	rd. - red
sl. - slate	bk. - black
gw. - greywacke	bn. - brown
and. - andesite	wh. - white
bl. - basalt	pk. - pink
rhy. - rhyolite	pu. - purple
pyrocl. - pyroclastics	
agglom. - agglomerate	
ls. - limestone	
chl. - chlorite	
porph. - porphyry	
tuff. - tuffaceous	

Early
Clarenville Group
(?)
gy. sh., bk. sh. & sn.

Early
Bell Island & Wabana Groups
1500
shale, sandstone & oolitic hematite

Upper
Elliott Cove Group
gy. & bk. sh. & sn.

Middle 30
Manuels River Form.
bk. & gy. sh.

Middle 90
Chamberlains Brook Form.
rd. & gn. manganiferous ms.

Lower 110
Brigus Form.
rd. & gn. sn. w̄ pk. ls.

Lower 10
Smith Pt. Form. - pk. ls.

Lower 140
Bonavista Form.
rd. & gn. sh. w̄ pk. ls.

Latest 80-110
Random Form.
wh. gn.gy. & pk. qtzite., x-bedded sn. & st.

Crown Hill Form.
800+
rd. pebble cgl. & st., some rd. sn., gn. sn.

Rocky Harbour Form.
300+
yellowish gn. x-bedded sn.

Undifferentiated
300+
gy., gn., & rd. st. & sn., gy-bn. pebble cgl.

Bull Arm Form.
5800
silicic & mafic lavas, rd. & gy. st. & cgl., minor pyrocl.

Cannings Cove Form.
30
rd. & gn. cgl., w̄ rd. sn. & st.

Connecting Point Group
8500
gn. to bk. st., cherty qtzite., sn. & cgl., mafic volc.

Love Cove Group
4500
silicic to mafic flows & pyrocl., st., sn. & cgl. commonly altered to schists

Middle
Chamberlains Brook
manganiferous beds

Lower 20-130
Brigus Form.
rd. & gn. sl. w̄ pk. ls.

Lower 16
Smith Point Form.
pk. algal. ls., rd. limy argillite lam.

Lower 0-30
Bonavista Form.
rd. & gn. sl. w̄ ls. & cgl.

Latest 0-180
Random Form.
wh. qtzite., qtz-pebble cgl., arkosic interbeds

Crown Hill Form.
0-300
rd. pebble cgl., minor gn. cgl. & rd. st.

Undivided Units
350+
rd. cgl. & arkose, gn. sn., gy. sn., slate, argillite

Trinny Cove Form.
600
gn. & rd. arkose, grit, sn., gy. sn.

Maturin Ponds Form.
300-600
massive & bedded rd. arkose & st.

Big Head Form.
1000-2200
massive pk. st., gn. & gy. sn. & st., rd. st., sn. & cgl.

Bull Arm Form.
2900
silicic & mafic flows & pyrocl., minor sed.

Connecting Point Group
2800
gn. & gy. sn., sl., gw., bk. cherty argillite, minor rd. tuff.

Upper 81
Gull Cove Form., sn. & sh.

Beckford Head Form.
gy., gn. sn. w̄ minor volc.

Middle
Manuels River Form.
bk. & gy. sh.

Middle 150
Chamberlains Brook Form.
rd. & gn. ms. w̄ mafic flows

Lower 125
Brigus Form.
rd. & gn. sh. w̄ pk. ls.

Lower 10
Smith Pt. Form., pk. ls.

Lower 60
Bonavista Form.
rd. & gn. sh. w̄ pk. ls.

Random Form. 125+
wh., gn., gy. & pk. qtzite., x-bedded sn. & st.

Crown Point Form.
80
dk. rd. x-bedded grits & thin cgl.

Northern Head Form.
500
dk. rd. st., sn. & sl. w̄ gn. sn. & gn. qtz. cgl.

Lears Cove Form.
220
rd. sn., st. & grits w̄ some gy. gn. sn. & sh.

Briarly Cove Form.
230
rd. qtz. cgl. w̄ dk. rd. x-bedded sn., st. & grits w̄ some shale, gn. st., sn. & bn. sl.

Bull Arm Form.
60-2500
silicic lavas, breccias, & tuffs, & interbedded gy. gn. st., sn. & sl.

Smith Pt. Form.
pk. algal ls., 15

Bonavista Form.
0-30
rd. & gn. sl., thin ls. & basal cgl.

Random Form. 0-180
wh. qtzite., cgl.

Snows Pond Form.
900-2100
rd. st. & sn., gy. gn. st. & sn.

Whiteway Form.
100
rd. sn. & st. w̄ minor gn. beds

Halls Town Form.
830-1500
massive gy. st. & sn.

Carbonear Form.
1000-1200
gy. sl. & sn.

Conception Group
1800-2500
gy. gn. sn., sl. & gw. & cgl. w̄ minor rd. sn. & mafic flows

Harbour Main Group
1800+
andesite, basalts, rhyolite, & related pyrocl. some rd. sed. & minor gy. gn. sed.

Elliot Cove Form., 90+, sh. & st.

Manuels River Form. 130
dk. gy. & bk. sh. & sl. w̄ ls. & minor pillow bl.

Chamberlains Brook Form. 110+
gy. gn. sl. & sh., w̄ ls. & manganese at base

Brigus Form. 23-130+
rd. & gn. sl. w̄ ls. nodules

[illegible] Form. 1650+
rd. & gn. gy. arkosic sn., minor sl., cgl. & sn.

Signal Hill Form.
2300+
rd. cgl., rd., gn. & gn. gy. arkosic sn., minor sl., sn.

St. John's Form.
300+
dk. gy. to bk. sl. & grit w̄ cgl. lenses & st. at top

Torbay Slate
900+
flinty gn. st., gn., rd., & bn. sl., qtz. sn. & cgl.

Conception Slate
900+
flinty gn. & gy. sn., fine gn. & gy. st., gn. to gy. sl. w̄ some rd. sl., minor tuff & agglom.

Harbour Main Group
1000
chl. schists, amyg. and., rhy., felsite & bl. w̄ volc. breccias agglom., tuff & interbedded gn. & rd. sn., sl. & coarse cgl.

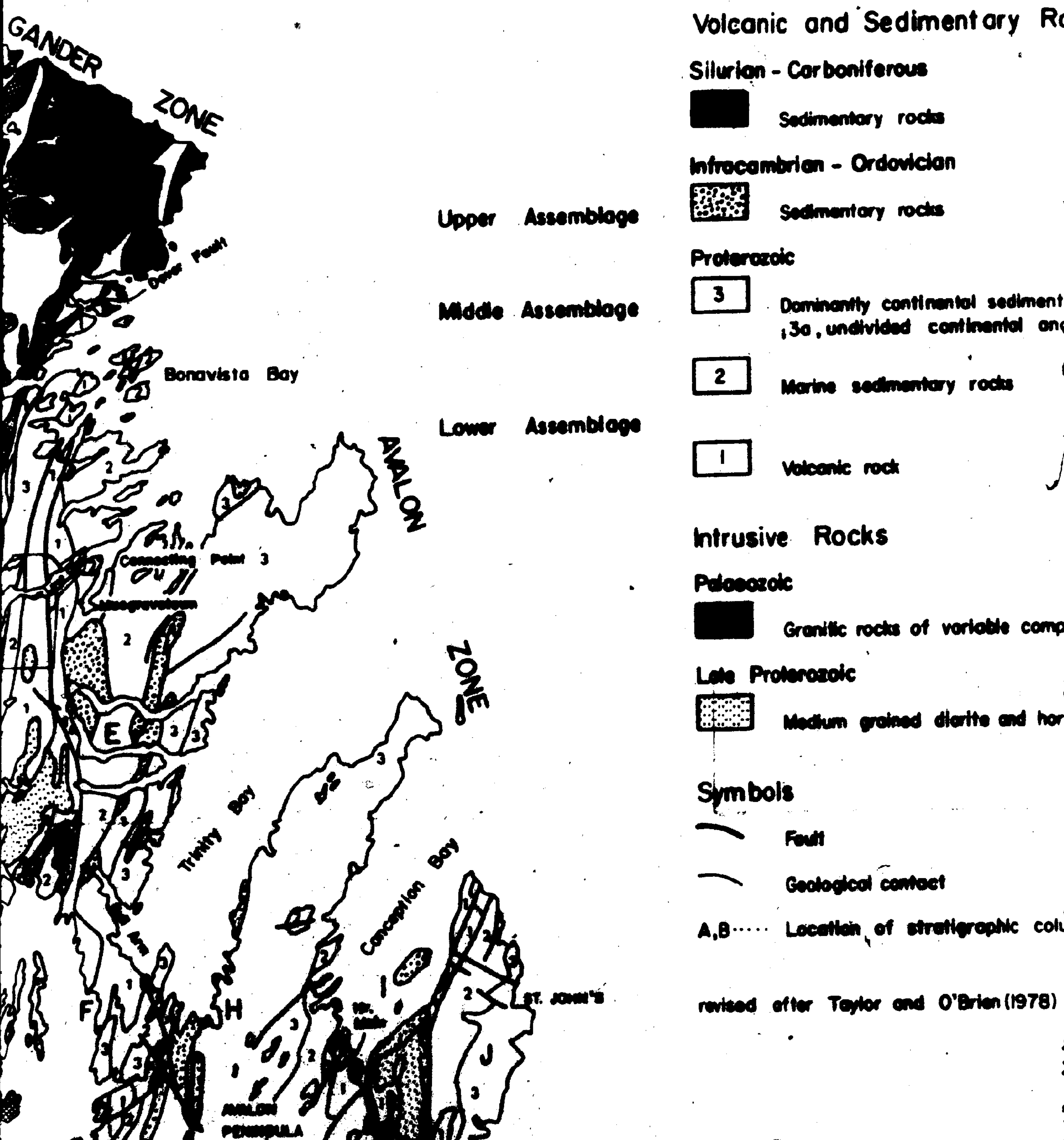
14

Figure

Lithostratigraphic Subdivision of

Figure 2·1

Subdivision of the Avalon Zone, Newfoundland



Zone , Newfoundland

Volcanic and Sedimentary Rocks

Silurian - Carboniferous

Sedimentary rocks

Infracambrian - Ordovician

Upper Assemblage — Sedimentary rocks

Proterozoic

Middle Assemblage — 3 Dominantly continental sedimentary rocks ;3a, undivided continental and marine rocks

2 Marine sedimentary rocks

Lower Assemblage — 1 Volcanic rock

Intrusive Rocks

Paleozoic

Granitic rocks of variable composition and texture

Late Proterozoic

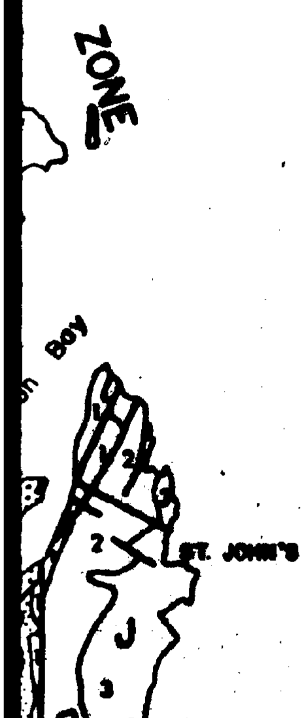
Medium grained diorite and hornblende, biotite granite

Symbols

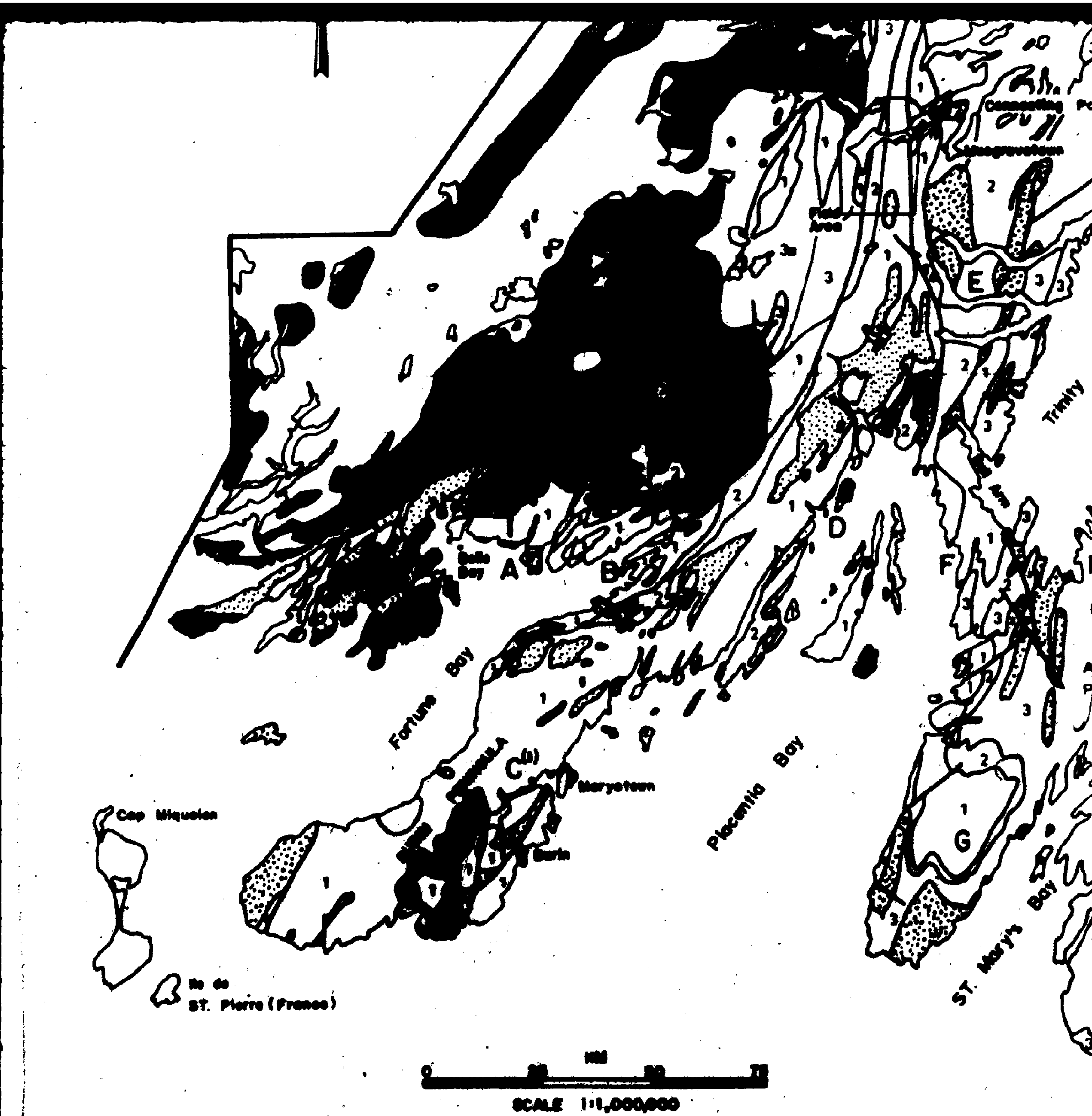
Fault

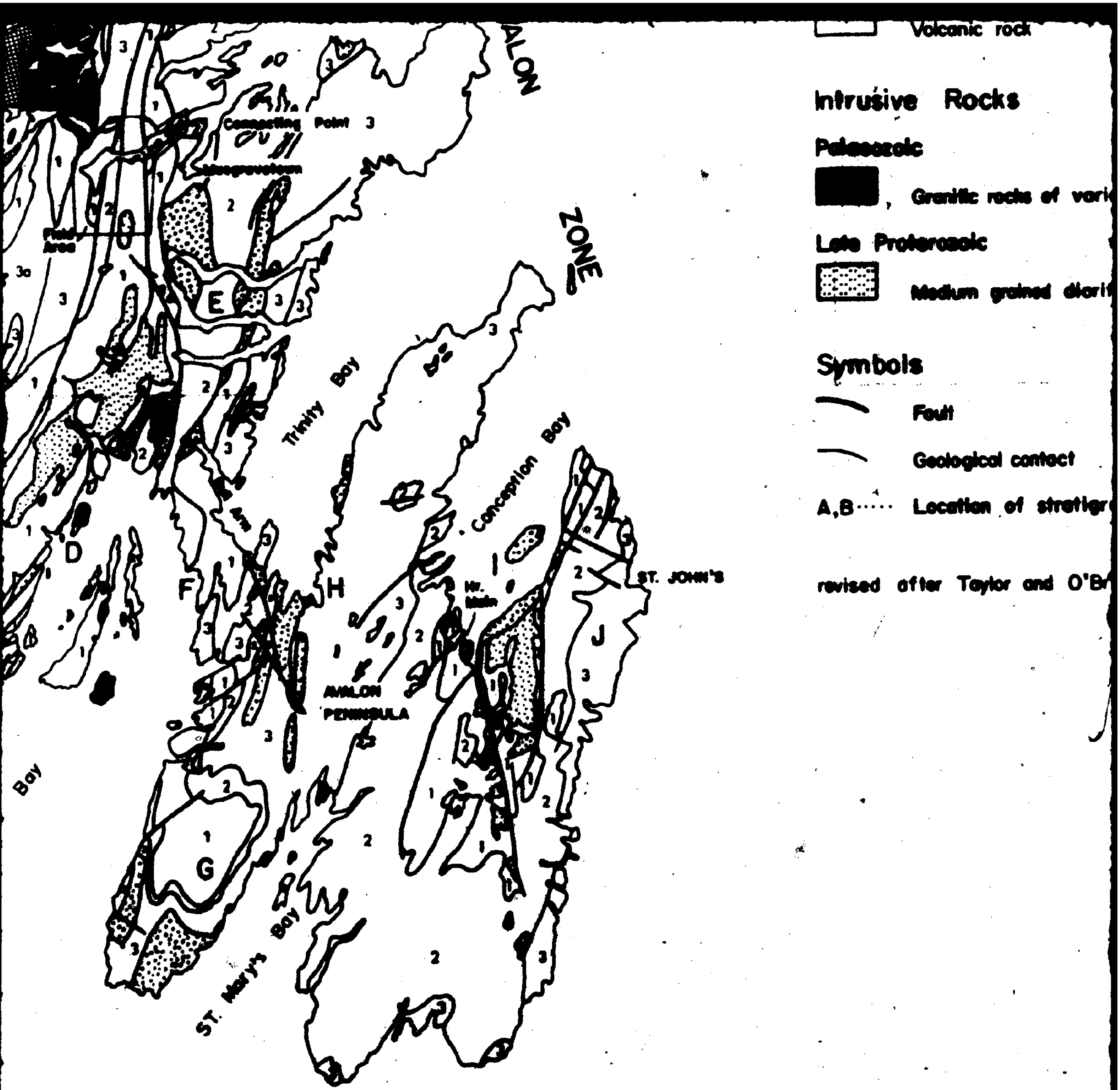
Geological contact

A,B····· Location of stratigraphic columns (Table 1)

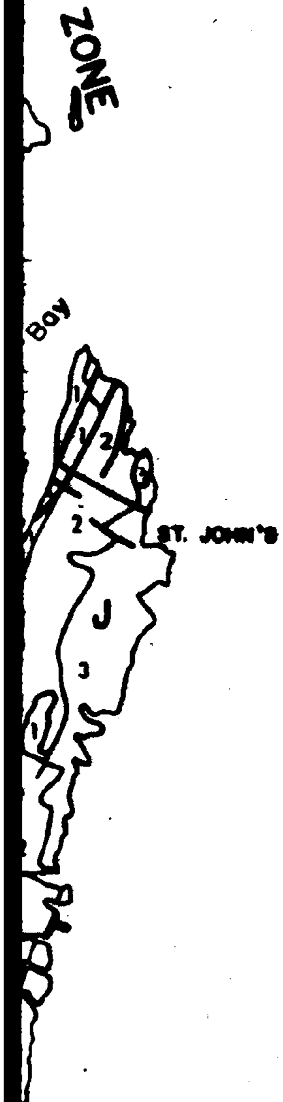


revised after Taylor and O'Brien (1978)


Belle Bay
A
B
C(ii)
D
E
F
G
Fortune Bay
Placentia Bay
ST. Mary's Bay
Trinity
Marystown
Burin
Cap Miquelon
Ile de
ST. Pierre (France)
KM
0 25 50 75
SCALE 1:1,000,000



Volcanic rock
Intrusive Rocks
Palaeozoic
, Granitic rocks of vari
Late Proterozoic
Medium grained diori
Symbols
Fault
Geological contact
A,B····· Location of stratigr
revised after Taylor and O'Br
ALON
ZONE
Connecting Point
Musgravetown
Field Area
Trinity Bay
Conception Bay
ST. JOHN'S
Hr. Main
AVALON PENINSULA
ST. Mary's Bay
Bay
D
E
F
G
H
I
J



Volcanic rock

Intrusive Rocks

Paleozoic

Granitic rocks of variable composition and texture

Late Proterozoic

Medium grained diorite and hornblende, biotite granite

Symbols

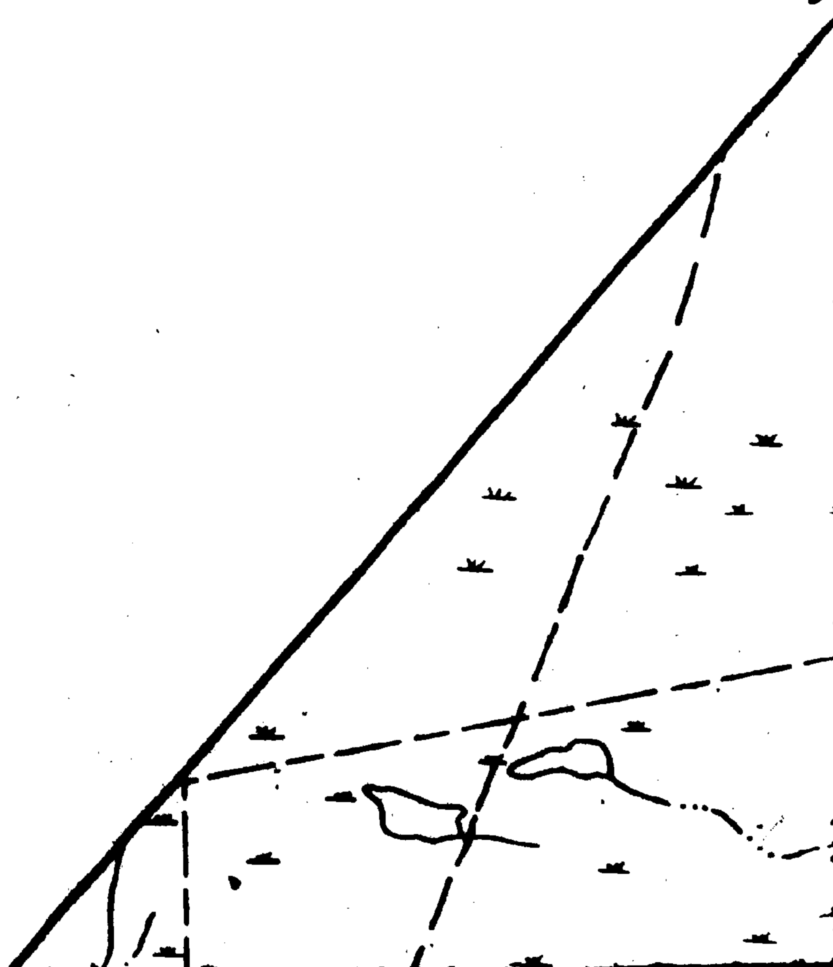
Fault

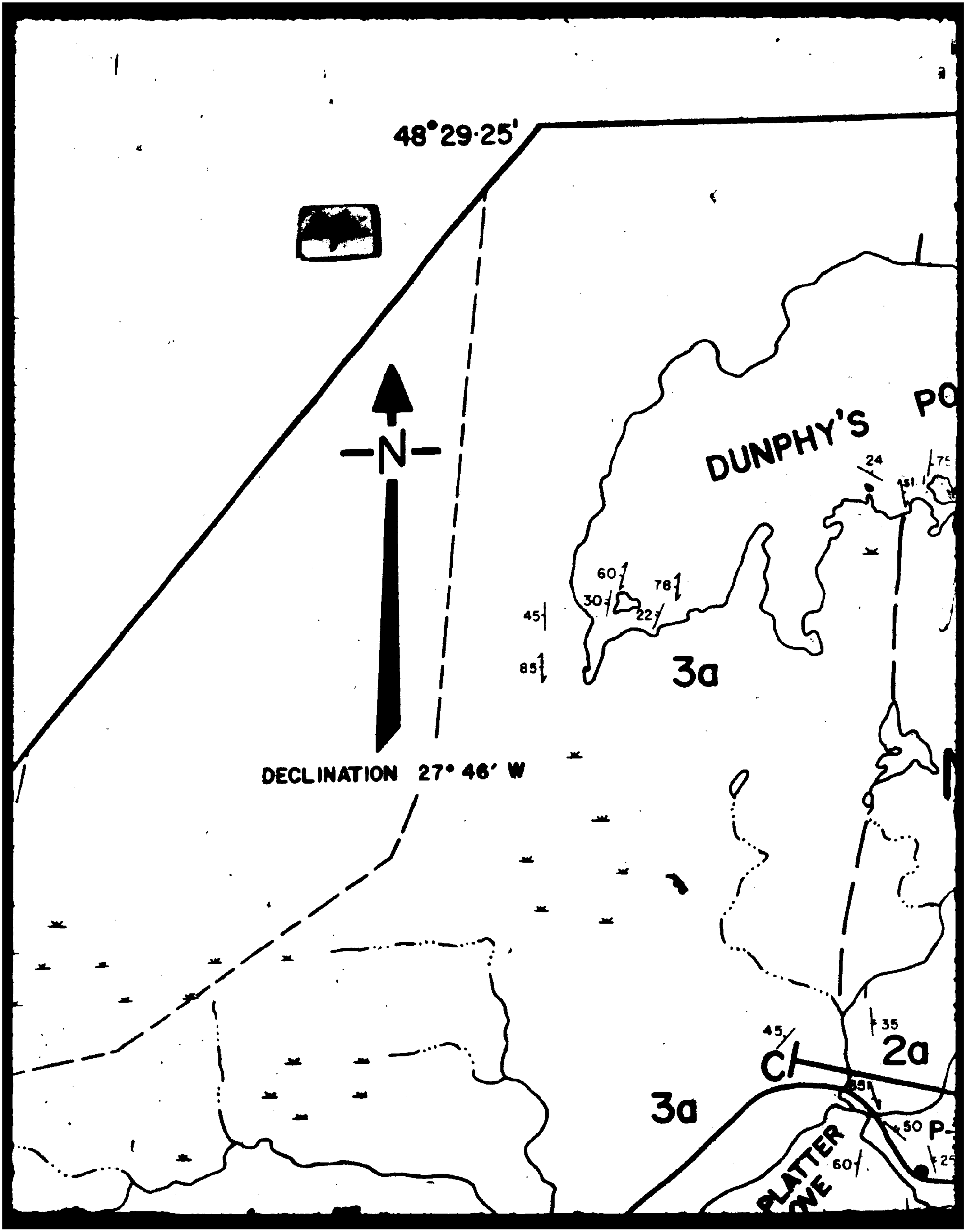
Geological contact

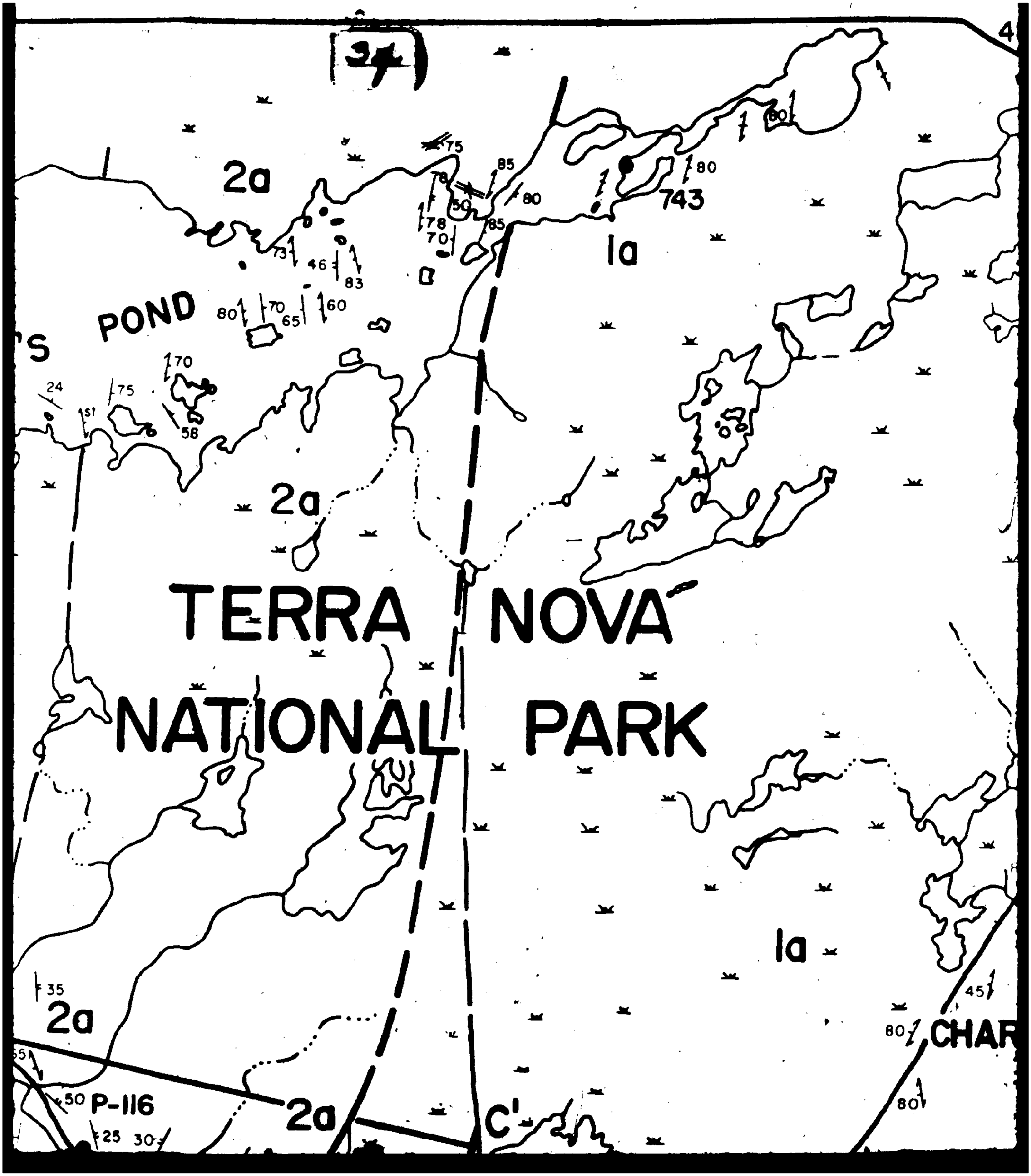
A,B ····· Location of stratigraphic columns (Table I)

revised after Taylor and O'Brien (1978)

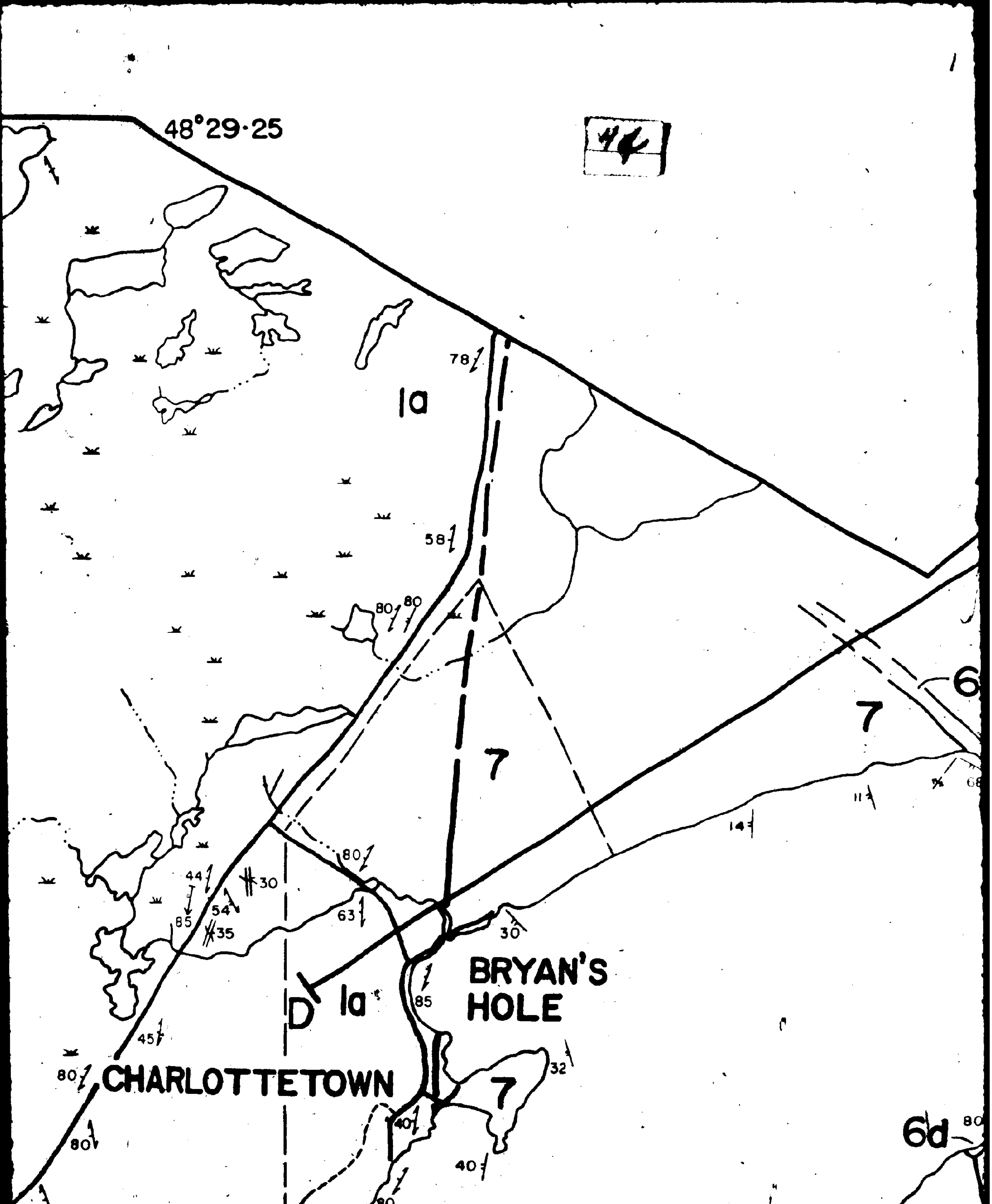
E. Hussey, 1978



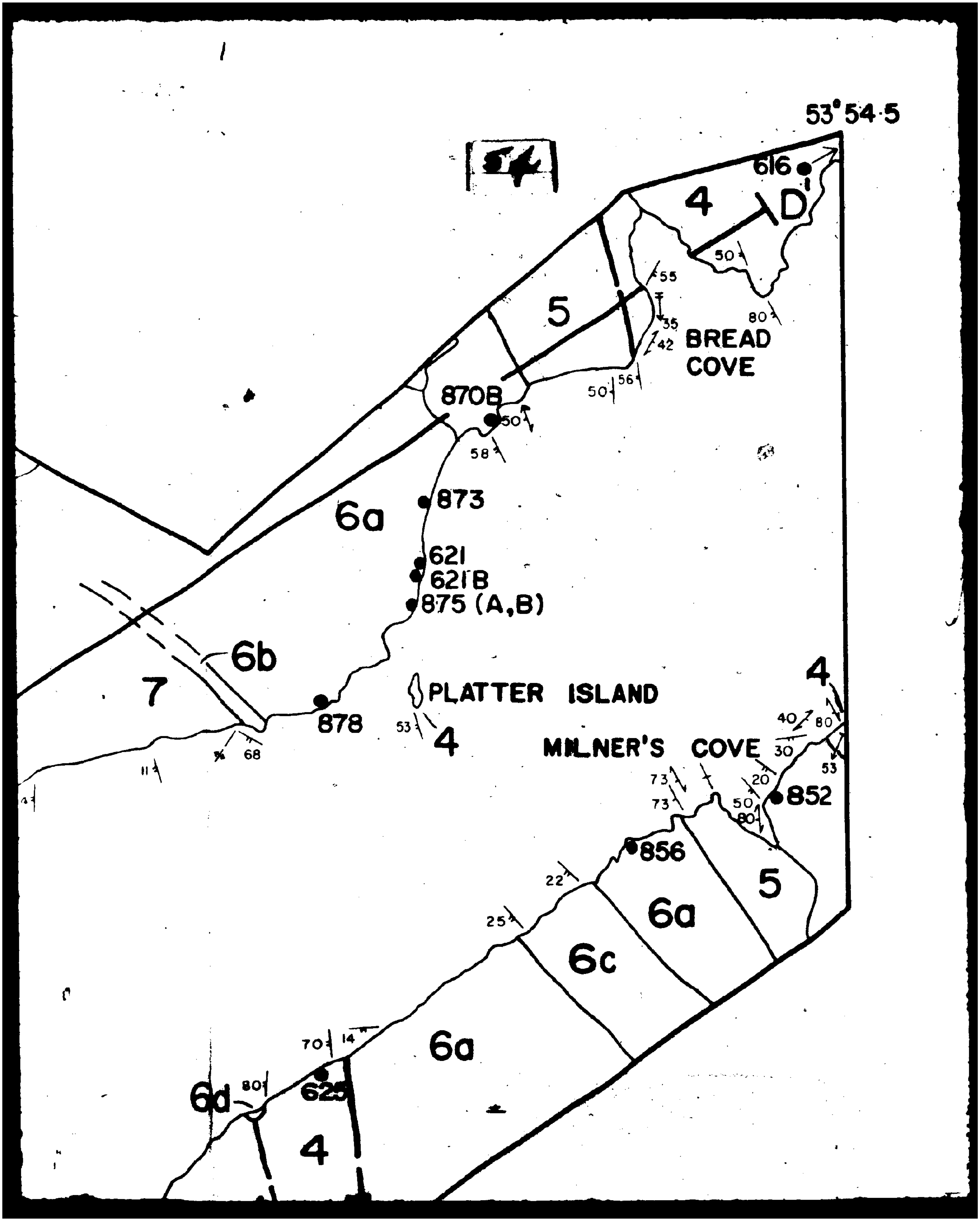

48°29·25'
N
DECLINATION 27° 46' W
DUNPHY'S PO
3a
3a
2a
C
P
PLATTER
OVE
24
75
60
78
30
22
45
85
45
35
85
50
60
25



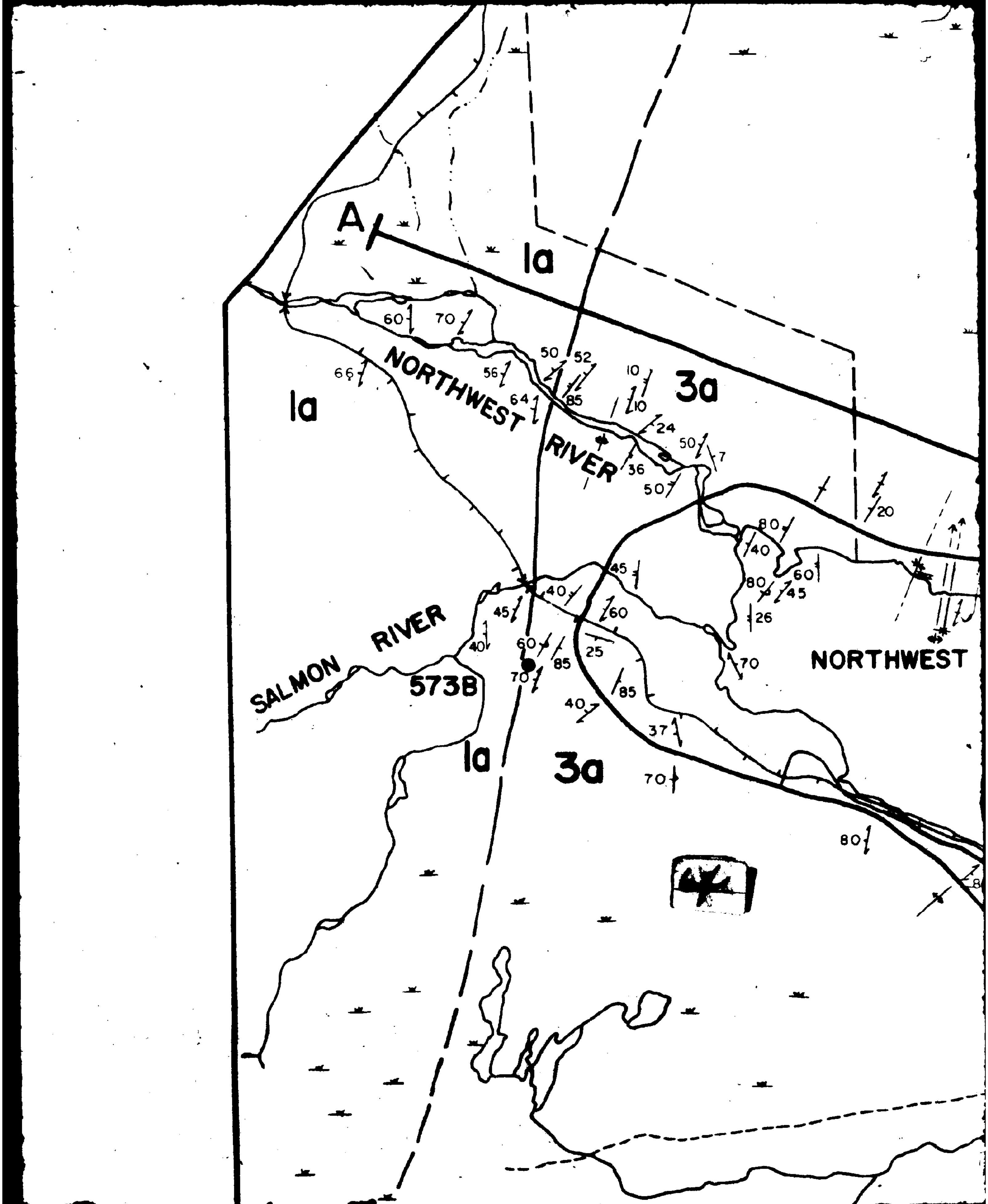
34
2a
1a
743
POND
S
2a
TERRA NOVA
NATIONAL PARK
1a
2a
CHAR
P-116
2a
C'



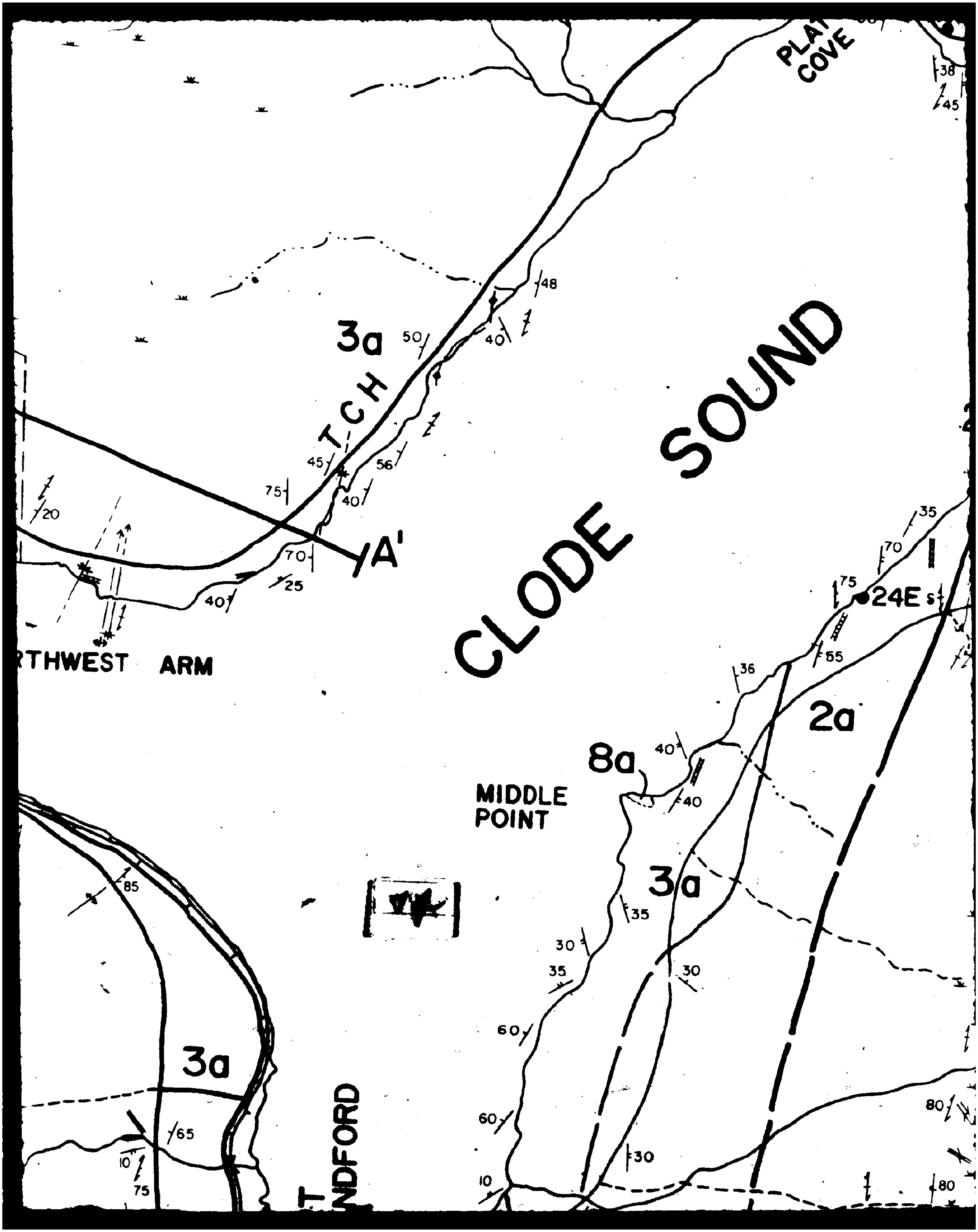
48°29·25
44
1a
7
7
6
BRYAN'S
HOLE
D
1a
CHARLOTTETOWN
7
6d
78
58
80
80
80
44
30
54
85
35
63
30
14
11
68
85
45
80
32
40
80
40
80
80

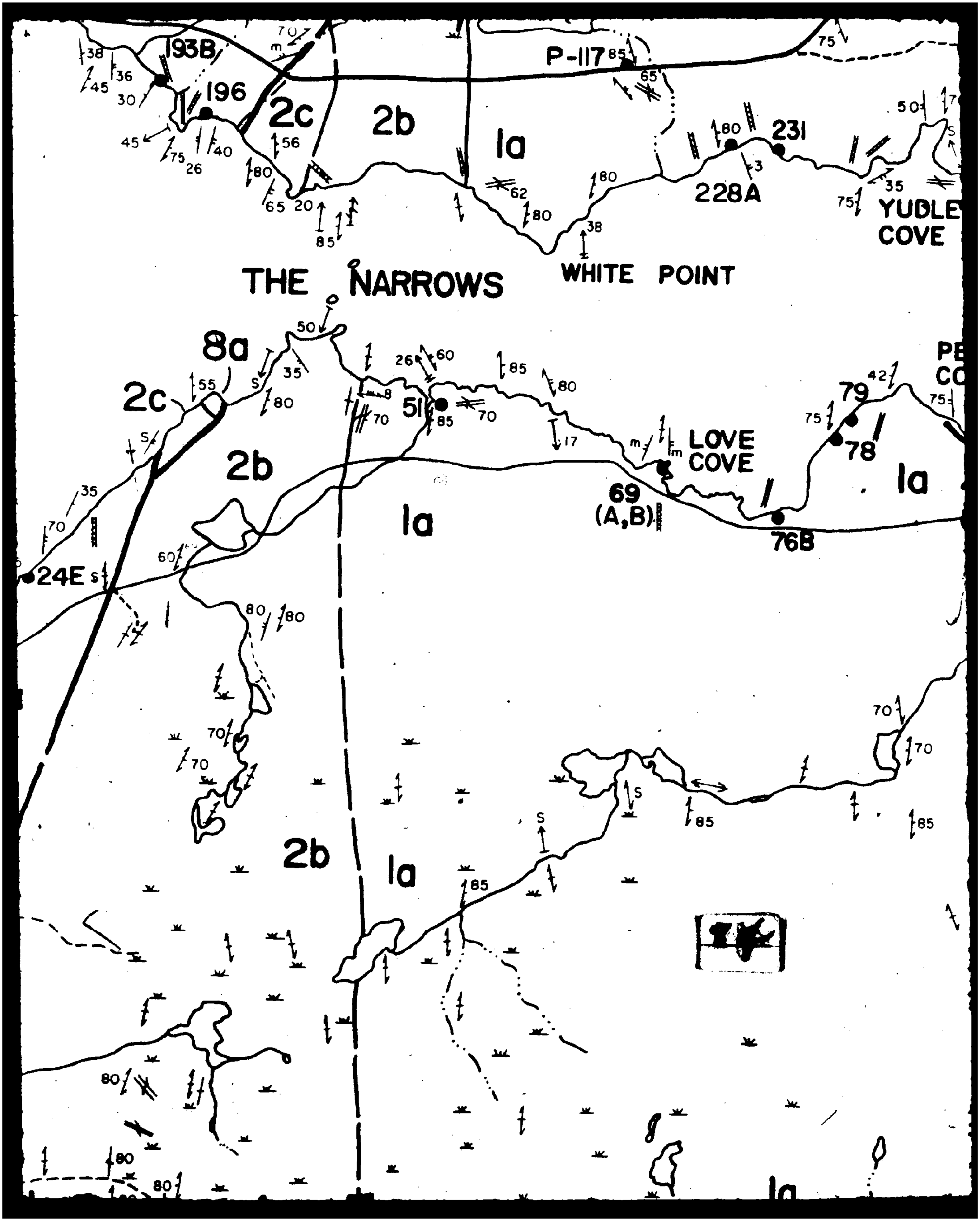


53° 54·5
616
4
D'
5
BREAD
COVE
870B
6a
873
621
621B
875 (A,B)
6b
7
878
PLATTER ISLAND
4
MILNER'S COVE
852
856
5
6a
6c
6a
625
6d
4

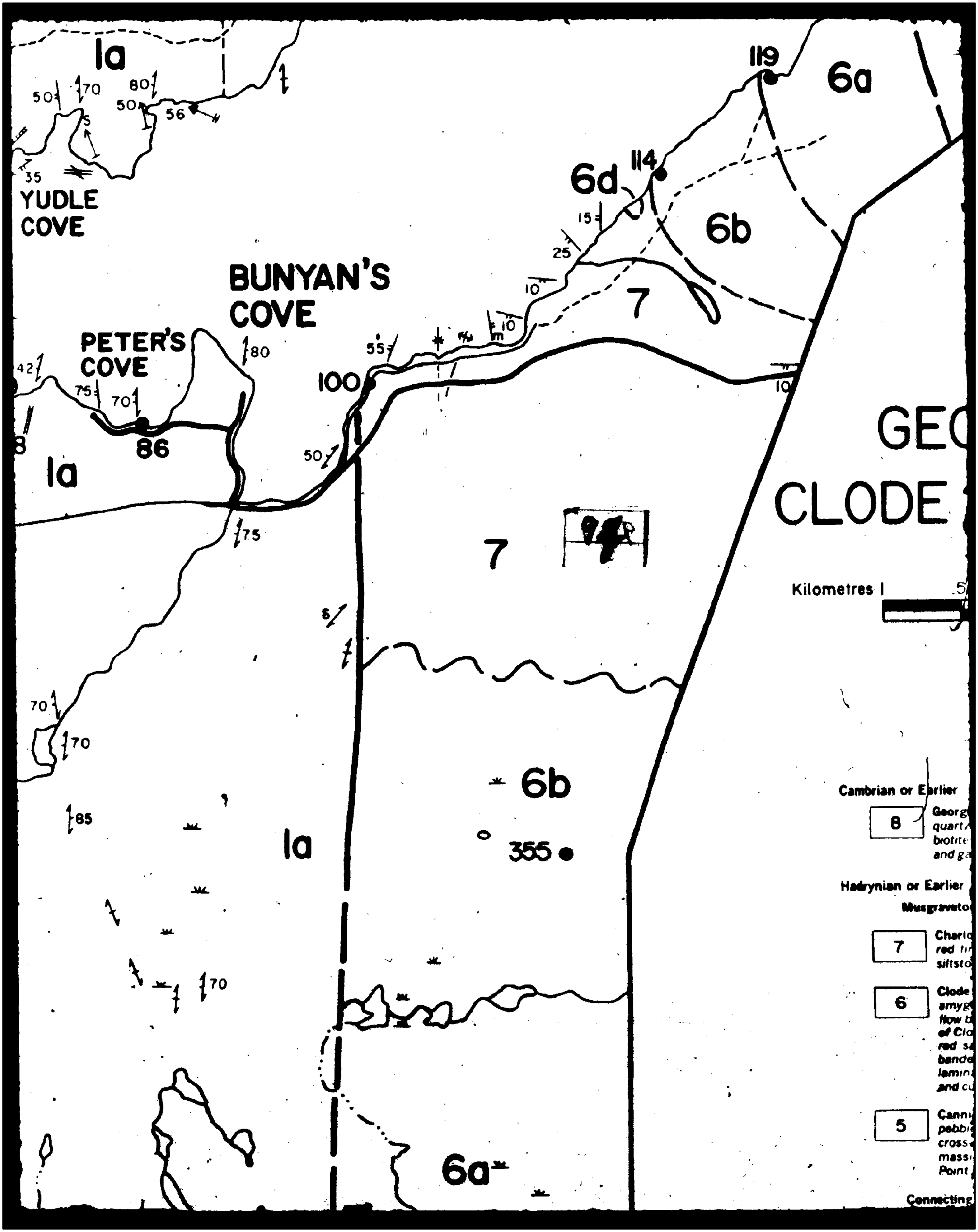


A
la
3a
NORTHWEST RIVER
la
SALMON RIVER
573B
la
3a
NORTHWEST


CLODE SOUND
PLAT COVE
TCH
3a
A'
RTHWEST ARM
24E
2a
8a
MIDDLE POINT
3a
3a
NDFORD



193B
196
2c
2b
la
P-117
231
228A
YUDLE
COVE
THE NARROWS
WHITE POINT
8a
2c
2b
51
LOVE
COVE
79
78
la
69
(A,B)
76B
24E
la
2b
la
la



1a
YUDLE
COVE
BUNYAN'S
COVE
PETER'S
COVE
86
100
114
119
6a
6d
6b
7
1a
7
6b
355
1a
6a
GEO
CLODE
Kilometres 1
Cambrian or Earlier
8
Hadrynian or Earlier
7
6
5
Connecting

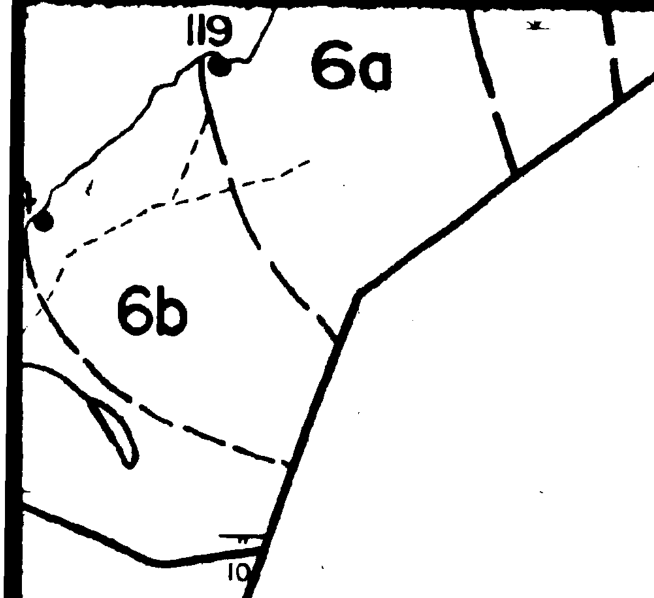


Figure I

GEOLOGY OF THE CLODE SOUND MAP AREA

Kilometres 1 .5 0 1 2 Kilometres

1:25,000

LEGEND

Cambrian or Earlier

8	**Georges Pond Granite:** *Medium grained biotite-hornblende granite, monzonite, quartz diorite, diorite; minor aplite, diabase and intrusion breccia; diorite with fresh biotite olivine gabbro in southeast (Location 629C); 8a, isolated, altered granitic and gabbroic plugs*

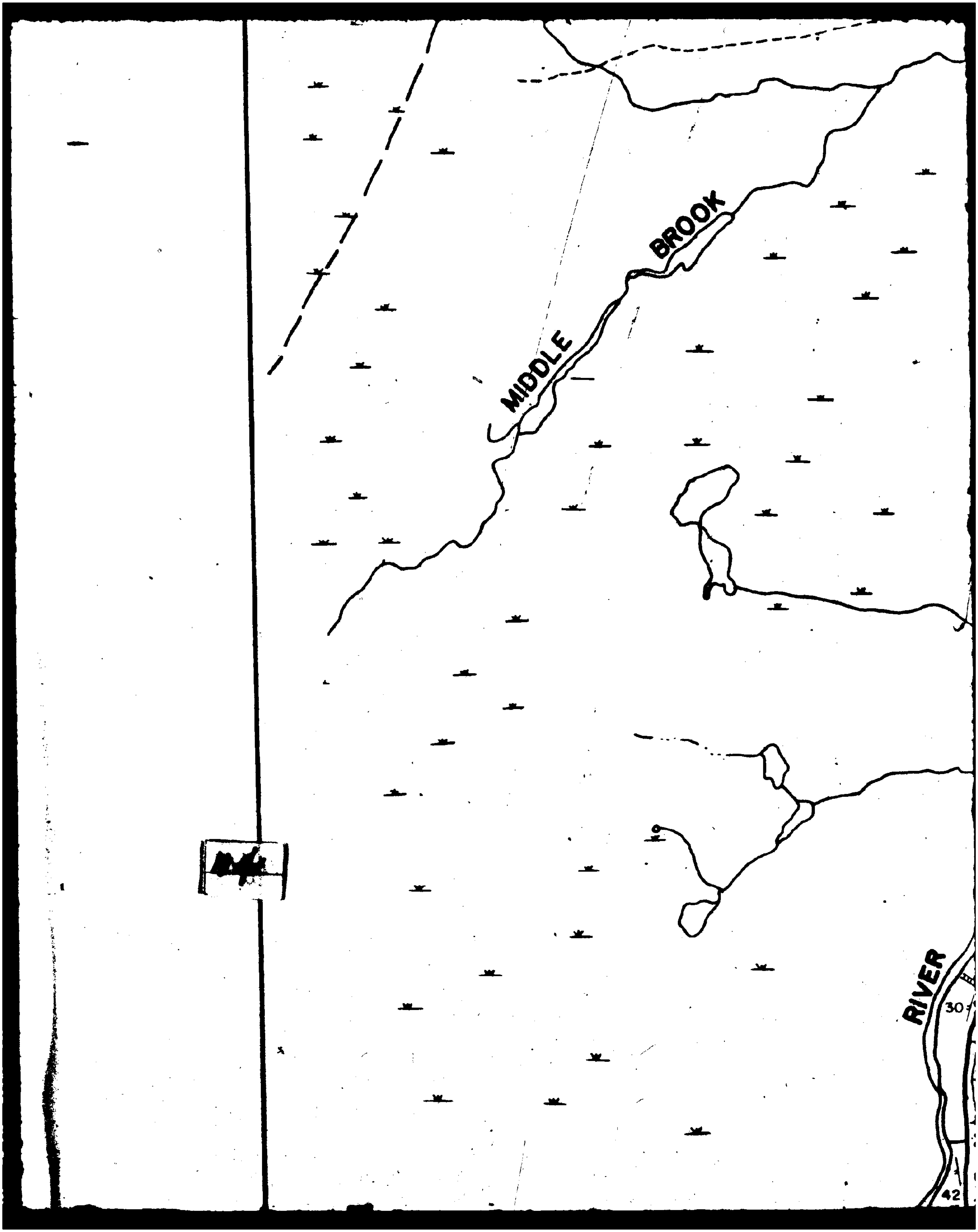
Hadrynian or Earlier

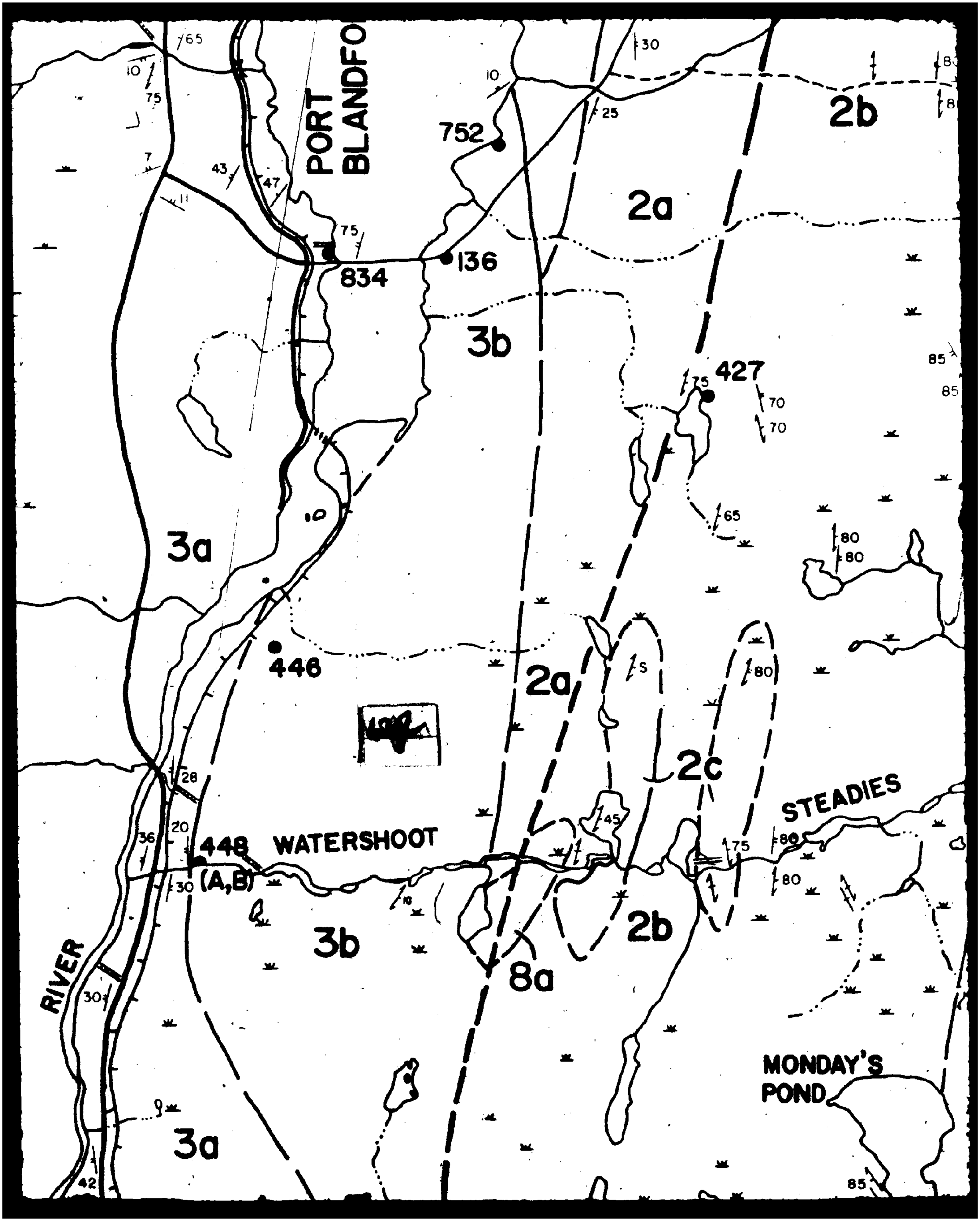
Musgravetown Group (5-7)

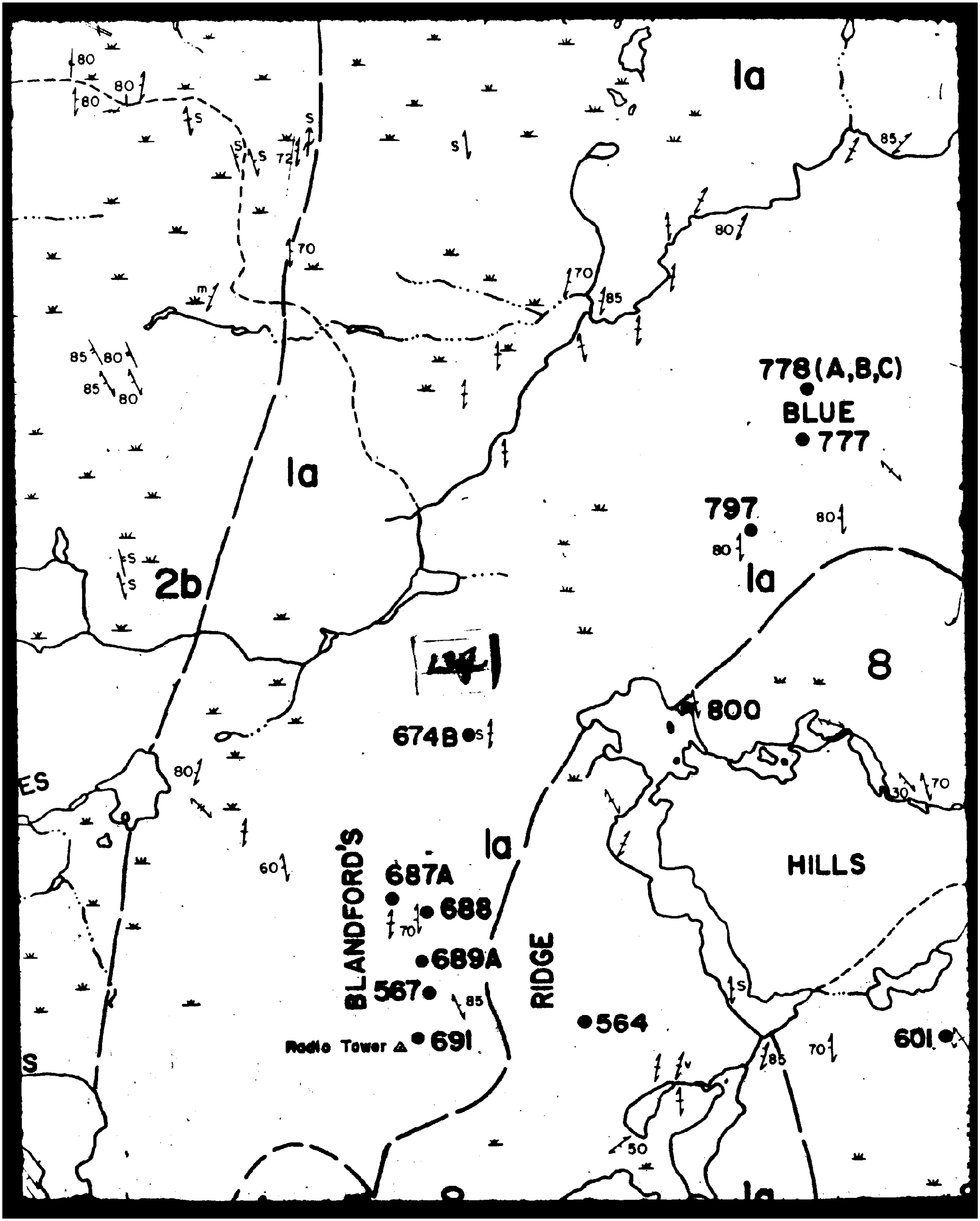
7	**Charlottetown Formation:** *Red to minor gray conglomerate and pebbly sandstone; red fine to medium grained, massive to laminated, cross-bedded sandstone and siltstone; minor dark gray finely laminated siltstone; minor silicic and mafic flows.*
6	**Clode Sound Formation:** *6a, Medium to dark gray, fine grained, massive to amygdaloidal aphyric olivine basalt to feldspar phyric basalt; includes massive to flow banded rhyolite south of location 873 and intercalated rhyolite and basalt south of Clode Sound, diabasic to minor silicic dikes, minor gray sandstone, very minor red sandstone and ignimbrite; 6b, red to purple, fine grained, massive to flow banded to autobrecciated, locally feldsparphyric, rhyolite; 6c, red, green and gray laminated to thin bedded siltstone with numerous mafic dikes; pebbly sandstone and conglomerate in south; 6d, isolated gabbroic to dioritic plugs.*
5	**Cannings Cove Formation:** *Green basal pebble conglomerate; red, often imbricated, pebble to boulder polymictic conglomerate; fine to coarse grained, laminated, cross-bedded sandstone beds and lenses; very minor red shale; intercalated massive to amygdaloidal aphyric olivine basalt flows; unconformable on Connecting Point Group.*

Connecting Point Group

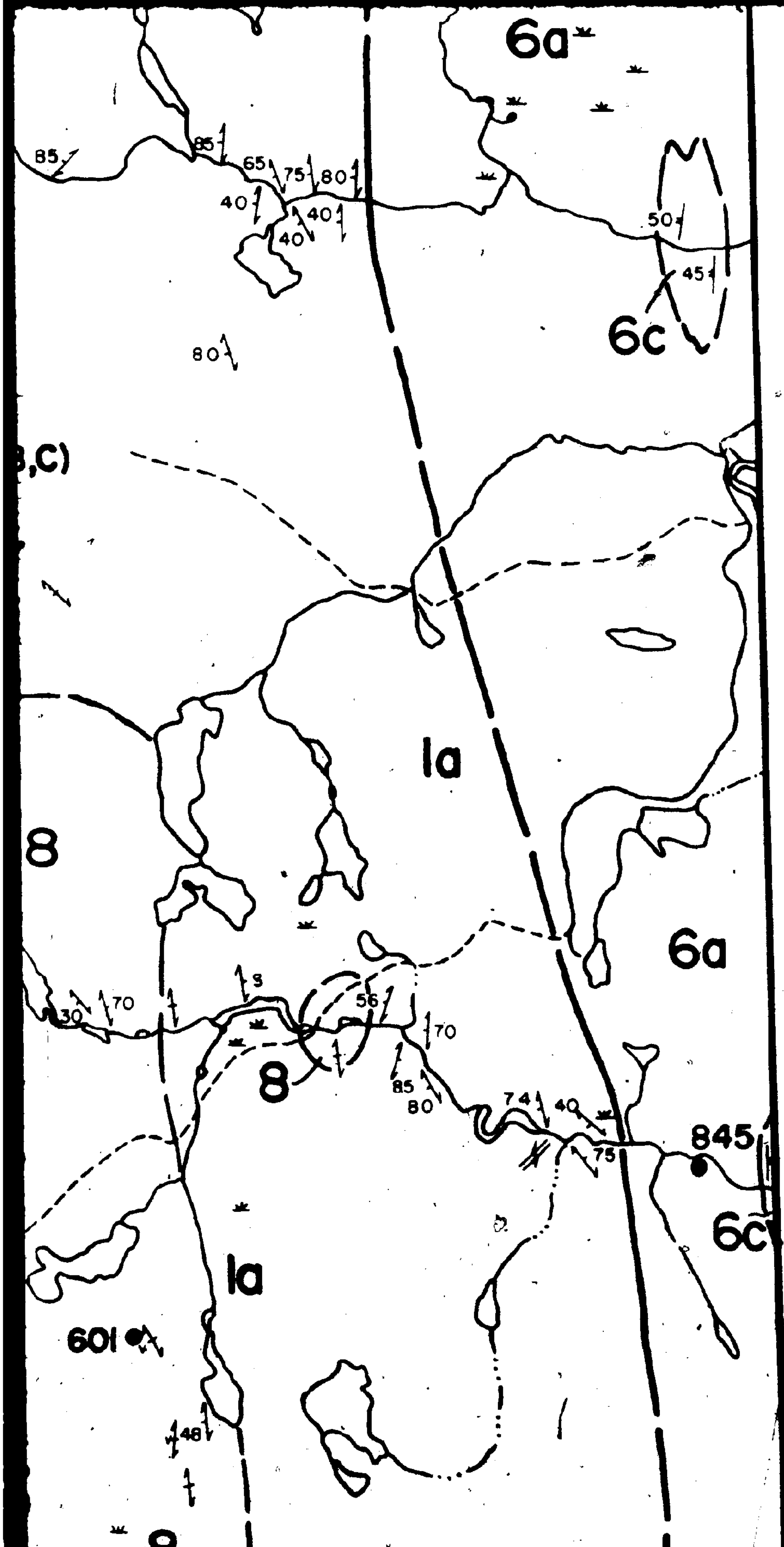
Da[illegible] to black, thin bedded to laminated siltstone and lesser slate; light green


MIDDLE
BROOK
RIVER
30
42


PORT BLANDFO
752
834
136
2b
2a
3b
427
3a
446
2a
2c
STEADIES
WATERSHOOT
448
(A,B)
3b
2b
8a
RIVER
MONDAY'S POND
3a



la
la
2b
la
8
778(A,B,C)
BLUE
777
797
800
674B
ES
HILLS
BLANDFORD'S
RIDGE
687A
688
689A
567
564
691
Radio Tower
601
S



massive to
Point Group

Connecting Point (

4 Dark gray to
siltstone and
schist on wes

Love Cove Group (1

3 Southwest Ri
lesser massiv
pebble conglo
coarsely porp
amygdaloidal
rhyolite; very
mafic dikes

2 Thorburn La
fine to coar
conglomerat
minor tuff, a
coast, abund
tuffaceous g
coarse lithic
and volcano

1 White Point
coarse, lithic
minor relate
numerous
Blue Hills a
are domina
1b, green,

Geological boundary (define

Fault (defined, approximate

Unconformity

Bedding, tops known (inclin

Bedding, tops unknown (inc

Syncline

Anticline

Cleavage, schistosity (incline
S-steep, V-variable, M-mode

1st phase, 2nd phase

Kink band (inclined, vertica

Axis of minor fold (1st phas
S, Z sense of vergence look

Dike

Geochemical sample localit

Bog

Rail line

Road (paved, unpaved)

Trail or poor road

Park boundary

Geology by E M Hussey,

cross bedded sandstone beds and lenses; very minor red shale, intercalated massive to amygdaloidal aphyric olivine basalt flows; unconformable on Connecting Point Group

Connecting Point Group

4 Dark gray to black, thin bedded to laminated siltstone and lesser slate; light green siltstone and cherty siltstone and minor thick bedded graywacke; minor sericite schist on west side of Bread Cove; numerous diabase dikes and sills

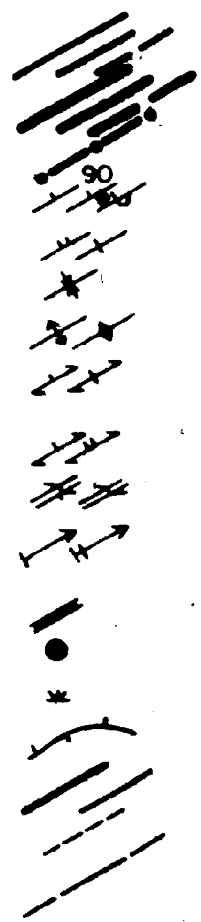
Love Cove Group (1-3)

3 **Southwest River Formation**: 3a, Red to lesser gray green, thick to thin bedded to lesser massive, cross-bedded fine to coarse grained pebbly sandstone, granule to pebble conglomerate, siltstone, and red shale; minor volcanic breccia and tuff and coarsely porphyritic to aphyric mafic and silicic dikes; 3b, dark gray, fine grained amygdaloidal basalt and red, flow banded to autobrecciated, massive fine grained rhyolite; very minor boulder conglomerate and finer grained sedimentary rocks, mafic dikes.

2 **Thorburn Lake Formation**: 2a, Gray green, thin to thick bedded, cross-laminated, fine to coarse grained graywacke, and lesser granule to pebble graywacke conglomerate, planar laminated, cross-laminated siltstone and cherty siltstone, minor tuff, abundant mafic dikes; 2b, similar to 2a, includes, especially along the coast, abundant laminated siliceous to chloritic sericitic volcanogenic siltstone, tuffaceous graywacke and primary tuff, mafic and silicic dikes and plugs; 2c, fine to coarse lithic tuff, crystal-lithic tuff, fine grained gray silicic to mafic waterlain tuff and volcanogenic sediment; pink to gray, fine grained massive rhyolite.

1 **White Point Formation**: 1a, Silicic to mafic, white through black, fine grained to very coarse, lithic, crystal-lithic, crystal tuff, welded tuff, and related more massive flows, minor related sediments, equivalent chlorite and/or sericite schists; banded cherts; numerous mafic and minor granitic dikes; rare quartz-feldspar porphyry; in the Blue Hills and Blandford's Ridge, mafic to silicic flow rocks and related intrusives are dominant with minor pyroclastics; possible laharic breccia west of Clode Sound; 1b, green, poorly sorted quartzite pebble graywacke intruded by rhyolite domes

SYMBOLS



Geological boundary (defined, approximate, assumed)

Fault (defined, approximate, assumed)

Unconformity

Bedding, tops known (inclined, vertical, overturned)

Bedding, tops unknown (inclined, vertical)

Syncline

Anticline

Cleavage, schistosity (inclined, vertical)
S steep, V variable, M moderate

1st phase, 2nd phase

Kink band (inclined, vertical)

Axis of minor fold (1st phase, 2nd phase)
S, Z sense of vergence looking along arrow

Dike

Geochemical sample locality (with sample No.)

Bog

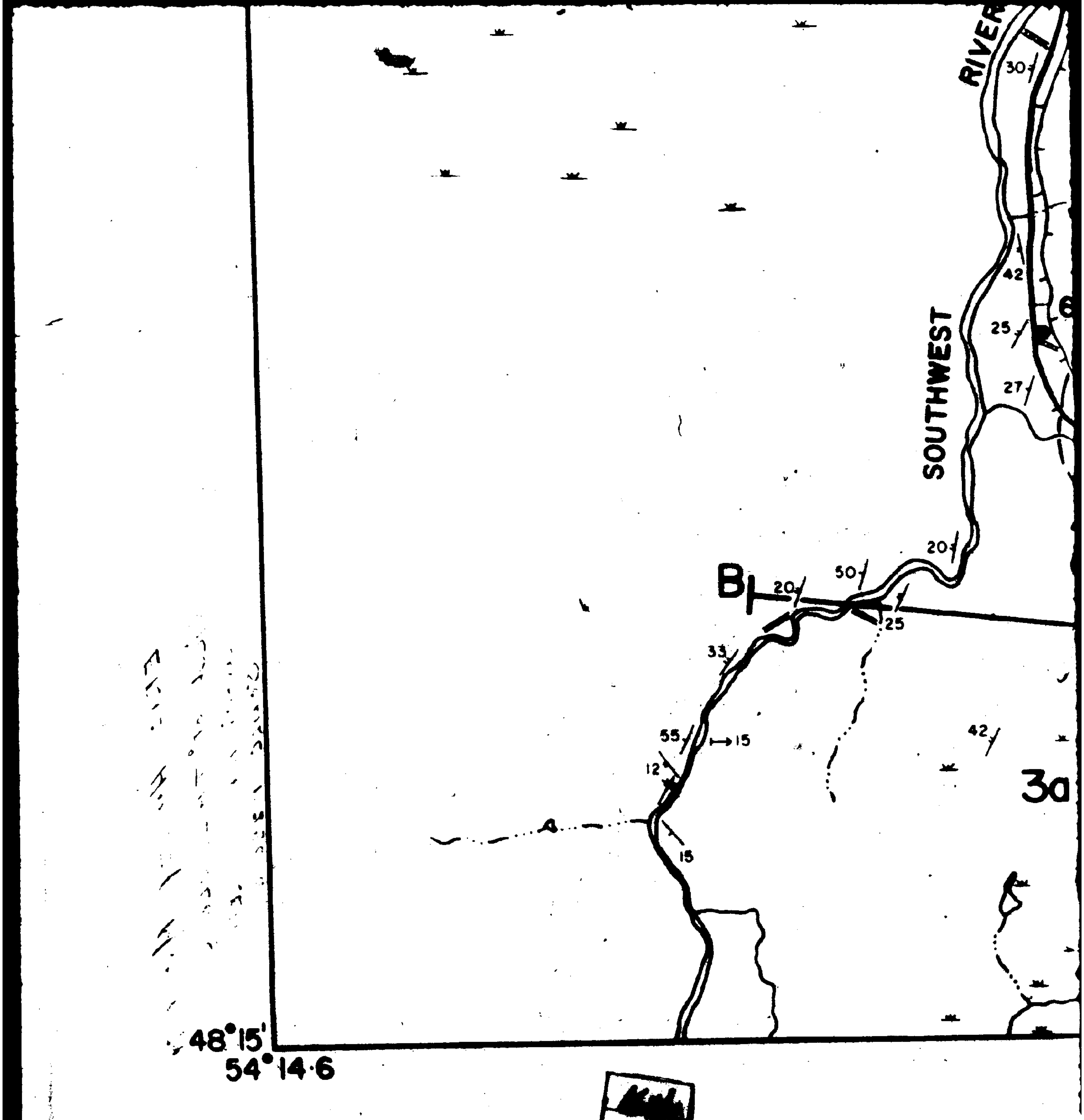
Rail line

Road (paved, unpaved)

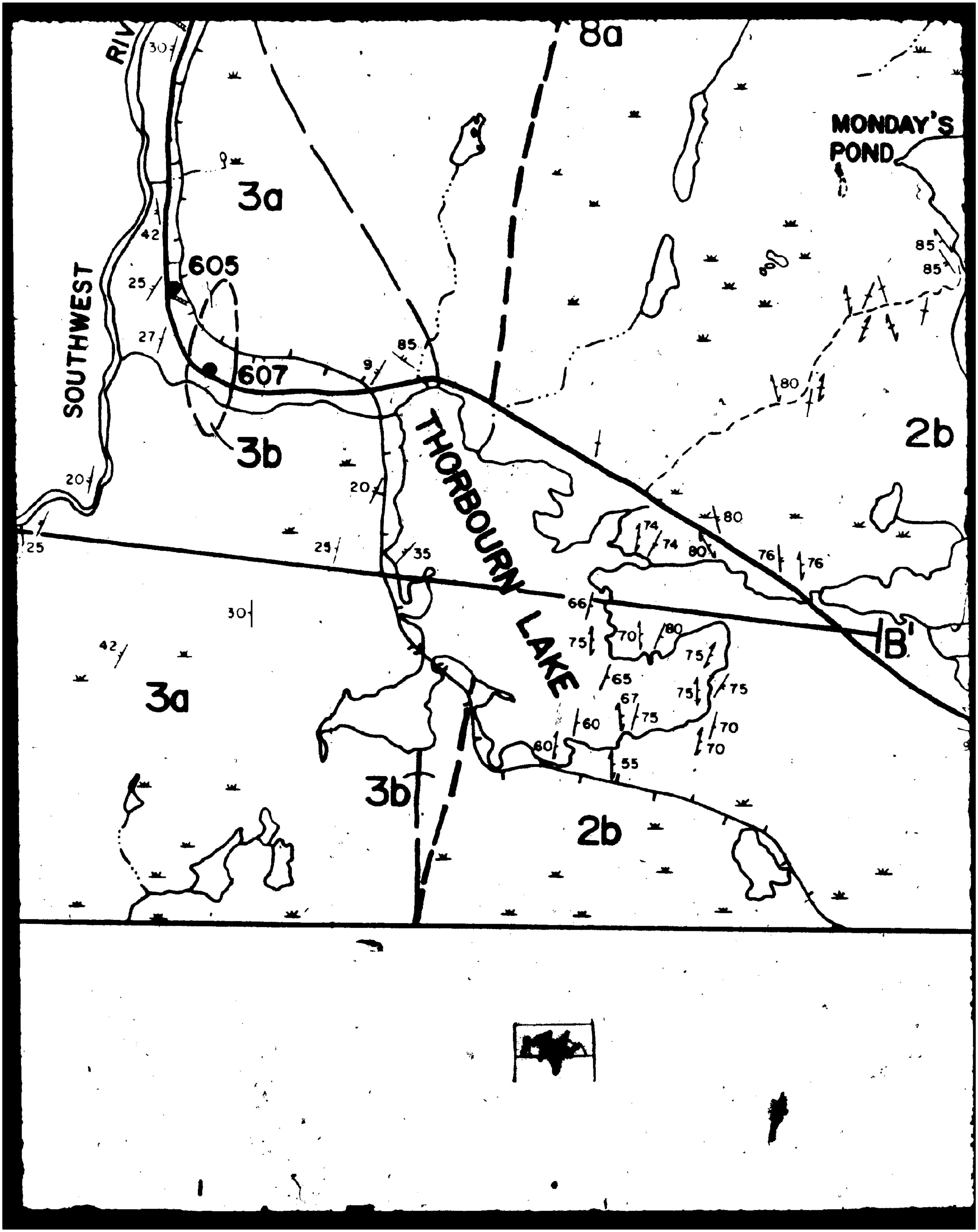
Trail or poor road

Park boundary

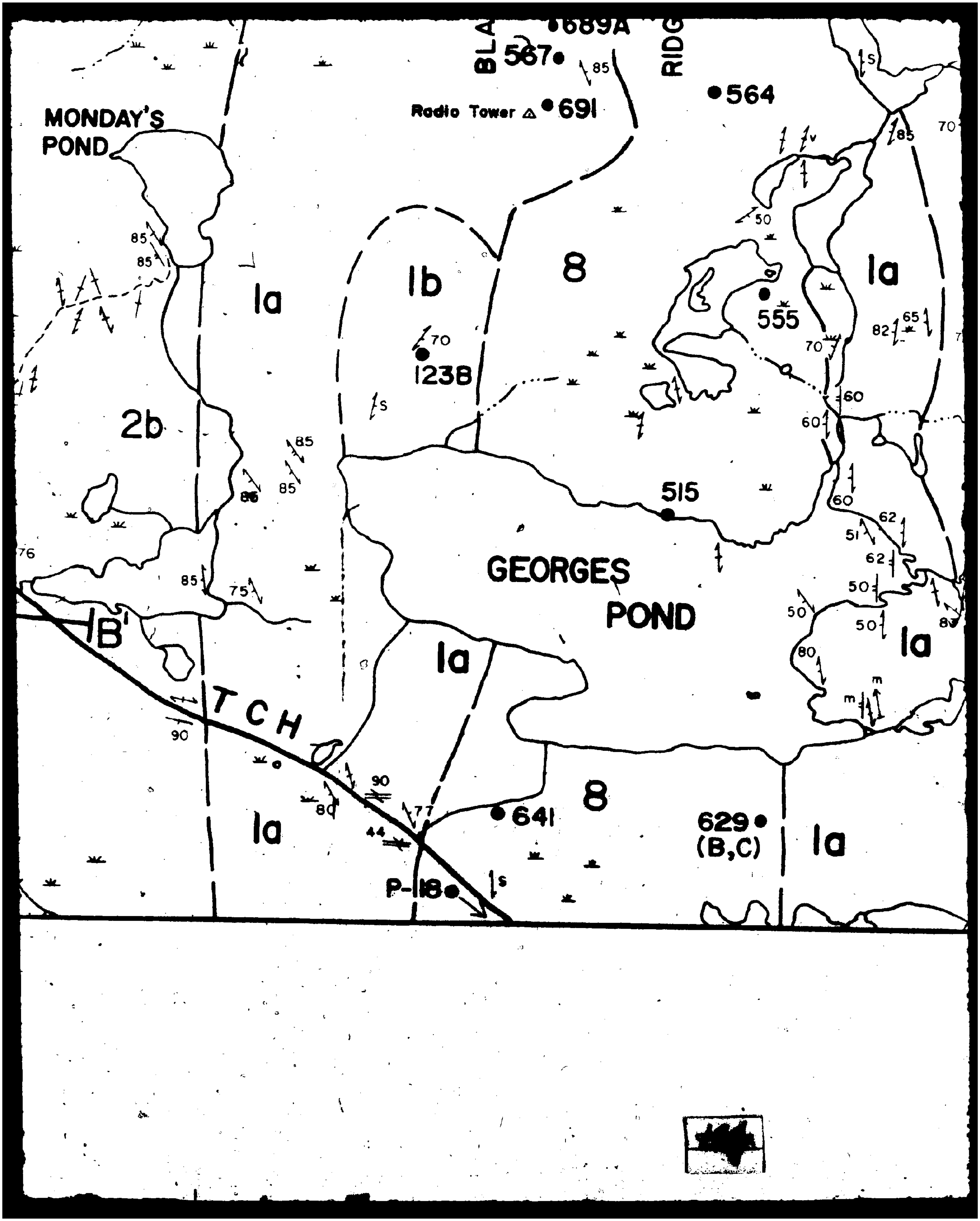
Geology by E. M. Hussey, 1977



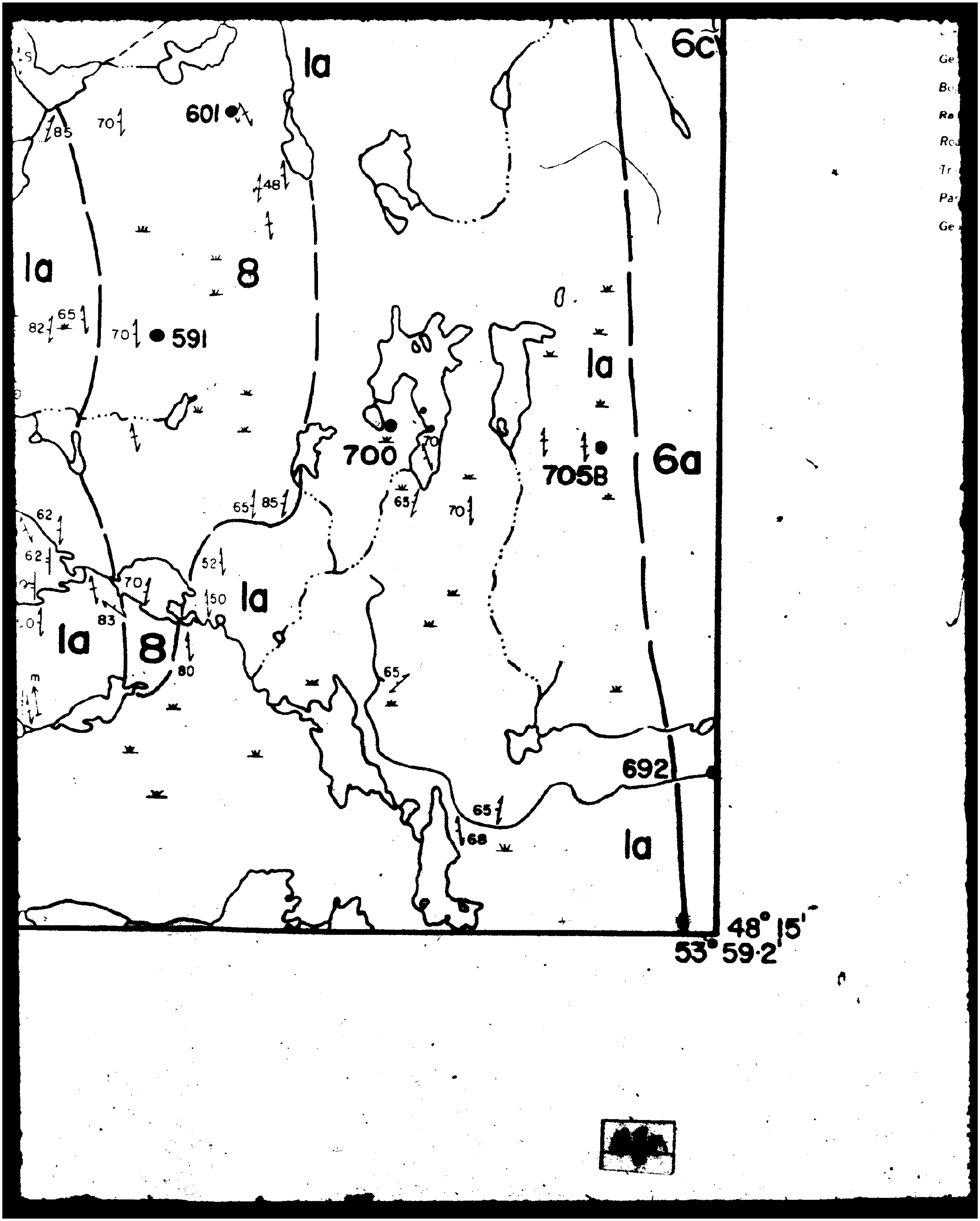
RIVER
SOUTHWEST
30
42
25
27
20
50
20
25
B
33
55
15
12
15
42
3a
48°15'
54°14·6



8a
MONDAY'S POND
3a
605
607
3b
SOUTHWEST
RIV
THORBOURN LAKE
2b
B'
3a
3b
2b



MONDAY'S
POND
GEORGES
POND
Radio Tower
TCH
BLA
RIDG
1a
1b
2b
8
1B'
689A
567
691
564
555
1238
515
641
629
(B,C)
P-118


6c
Ge
Bo
Ra
Ro
Tr
Pa
Ge
1a
601
85
70
48
1a
8
82
65
70
591
1a
700
70
6a
705B
62
65
85
65
70
62
52
70
1a
50
1a
83
8
80
65
692
65
68
1a
48° 15'
53° 59·2'

Geochemical sample locality (with sample No.)

Bog

Rail line

Road (paved, unpaved)

Trail or poor road

Park boundary

Geology by E.M. Hussey, 1977

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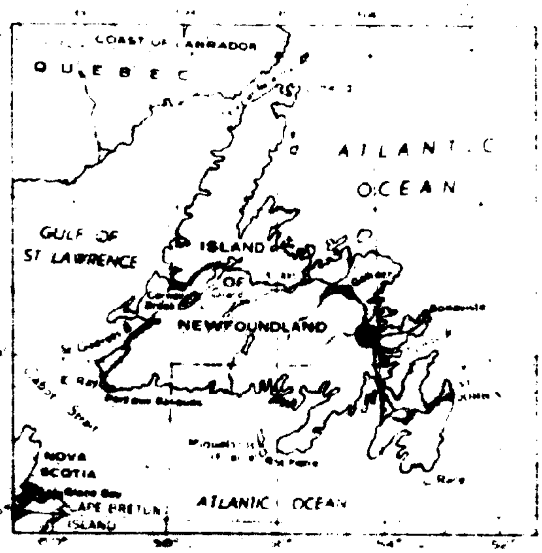
OF NEWFOUNDLAND



INDEX MAP

2°15'


A'
200
S.L.
- 200