THE GENERAL GEOLOGY AND GEOCHEMISTRY OF THE GRANITOID ROCKS OF THE NORTHERN GANDER LAKE BELT, NEWFOUNDLAND

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by

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ABSTRACT

The granitoid rocks of the northern Gander Lake Belt form three distinct groups, viz. quartz diorites, leucocratic granodiorites, and megacrystic biotite granites roughly in the areal proportions of 3:22:75. The study area is divisible into four distinct N-S trending units which are from west to east, 1. The Davidsville Group, 2. the metasedimentary terrain, 3. the gneissic terrain, and 4. the western Avalon Platform.

The Davidsville Group is composed of essentially non-metamorphosed Middle Ordovician shales, greywackes, and mafic volcanic rocks, which have been intruded by hornblende-biotite quartz diorites. The plutons show a zonation from hornblende quartz diorite at the margins to biotite quartz diorite in the core. The quartz diorite plutons are mineralogically similar which, along with their extensive and similar contact metamorphic aureoles, suggest that they may be connected at a shallow depth.

The metasedimentary terrain unconformably underlies the Davidsville Group, and is composed of a monotonous sequence of low greenschist facies metasediments. The metasediments have been syntectonically intruded by muscovite-biotite-garnetiferous leucocratic granodiorites which contain an abundance of pegmatites. To the southeast of Gander, the terrain has been post-tectonically intruded by the Gander Lake pluton which is similar in composition to the megacrystic biotite granites of the gneissic terrain.

The gneissic terrain is underlain by high grade gneisses, migmatites, and schists, which have been intruded by large plutons of

megacrystic biotite granite, and locally by small bodies of leucocratic granodiorite. The megacrystic biotite granite is characterised by its very coarse grain size, and large microcline megacrysts. Locally the megacrystic granites have been intensely mylonitised. The leucogranites are similar to those of the metasedimentary terrain.

The Precambrian Avalon Platform sediments and low grade schists of the study area have been intruded by megacrystic biotite granite similar to that of the gneissic terrain.

The mineralogy of the various groups of granitoid rocks is generally reflected in their chemistry. The quartz diorites are the most mafic in composition with a low content of K and Rb, a high content of Ca, Fe, and Sr, and a high K/Rb ratio. The leucocratic granodiorites are the most salic in composition with a mean silica content of almost 72%, a high content of K and Rb, and a low content of Ca, Sr, Mg, and Fe, and a low K/Rb ratio. The megacrystic biotite granites are generally intermediate in composition between the quartz diorites and the leucocratic granodiorites but have the highest content of K and F. The Deadman's Bay pluton has an initial $Sr^{87/86}$ ratio of 0.704. K shows a general increase from northwest to southeast across the study area.

The quartz diorites are similar in geological setting, petrography, and chemistry to the granitoids of island arcs and are interpreted as having a similar origin. The enrichment of the leucocratic granodiorites in lithophile elements, their syntectonic origin, lack of associated basic igneous rocks, and approximately eutectic composition suggests that they were formed by anatexis of continental crust. The origin of the megacrystic biotite granites is especially problematical in that they have a very high K content and a very low initial $Sr^{87/86}$ ratio. Neither anatexis of continental crust nor partial melting of oceanic crust can account for these two features; some combination of both processes is possible but present evidence does not allow selection of a particular mode of origin for these rocks.

The abundance of pegmatites in the Middle Ridge pluton and the known occurrence of beryl associated with these pegmatites may justify exploration for economic concentrations of Be and associated elements. The occurrence of fluorite and locally high fluorine concentrations in stream water of the North Pond area could be re-examined to ascertain the fluorite potential. With the known correlation between tin and fluorine of other mineralized areas the megacrystic biotite granites may also have potential as sources of tin.

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CHAPTER 1

INTRODUCTION

1.1. Location

The island of Newfoundland forms the northern exposed extremity of the Appalachian Mountain system. The area under discussion forms the northeastern corner of the island between Great Gull Pond (48^o 18'N 55^o 28'W) and Pitts Pond (48^o 26'N 54^o 10'W) in the south and between Beaver Hill near Frederickton (49^o 24'N 54^o 22'W) and Cape Freels (49^o 15'N 53^o 28'W) in the north (see figs. 1, 2 and 19).

Inland investigations are difficult due to forest, bogs, boulder terrains and generally poor exposure. Exposure is generally very good around the coast and in road cuts.

1.2. Purpose and Scope

There has recently been a rapid increase in geological research in the Newfoundland Appalachians (Kay, 1967; Williams, et al., 1972) but the granitoid rocks have been relatively neglected. Hence they are poorly understood, apart from general features shown on the reconnaissance maps of the Geological Survey of Canada. There is a great need for petrological, geochemical and radiometric data, as well as detailed field studies, in order to understand their importance in the overall tectonic evolution of the Appalachians, as well as their petrological and economic significance.

Mineral deposits are commonly associated with granitoid rocks, but only one economic deposit is found in Newfoundland and that to the south of the study area at St. Lawrence (Fig. 1) where fluorite-bearing veins in peralkaline alaskite are presently being mined. Because of an apparent lack of mineralization in granitoid rocks of the study area, these rocks were

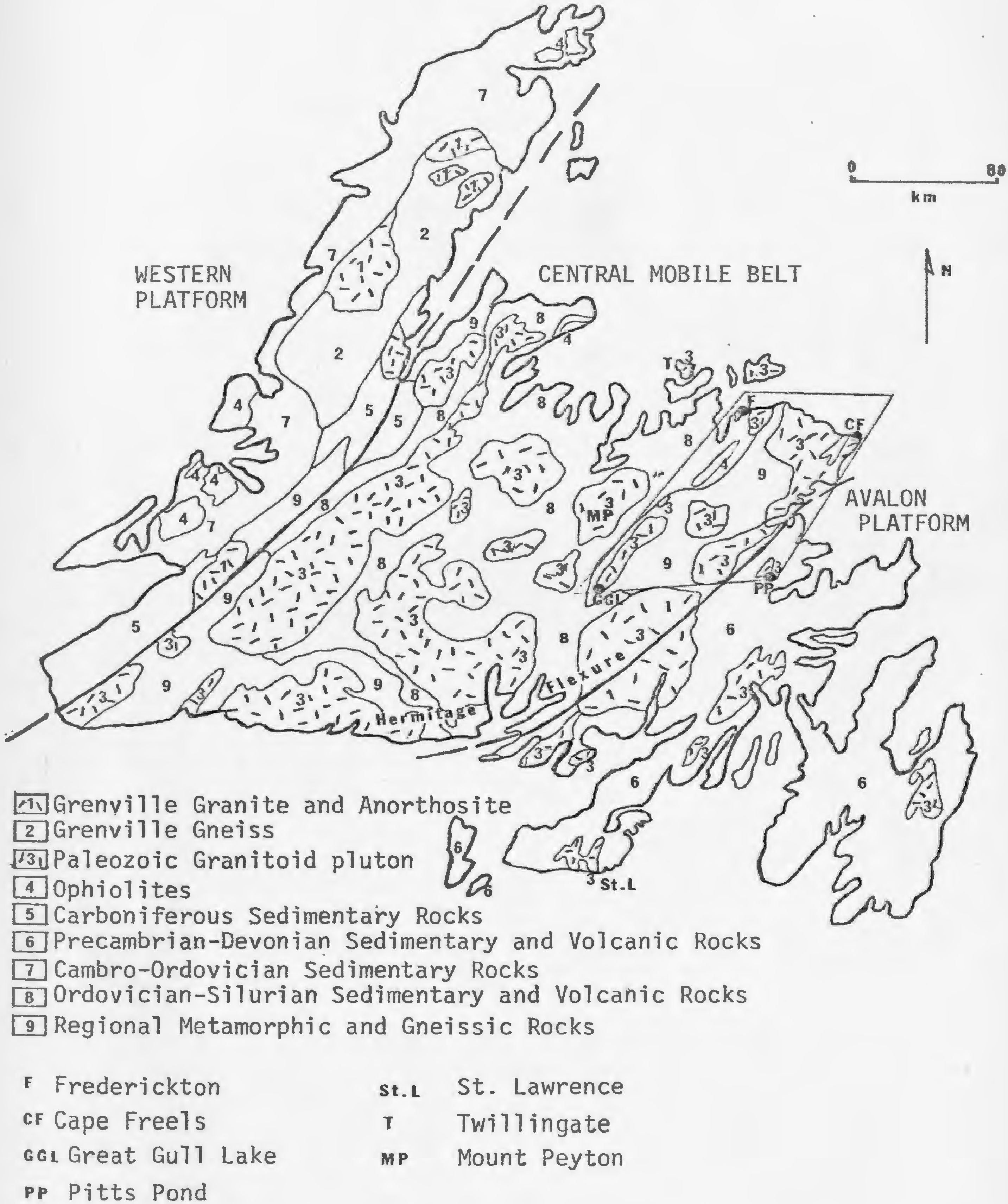

FIG. 1 - General Geology and Three Main Divisions of the Island of Newfoundland (Williams, 1964, 1967; Kay and Colbert, 1965; Kay, 1967) and location of study area.

studied to obtain geochemical and petrographical information which might help to locate potential areas of mineralization. It was also hoped that such information might contribute to the understanding of the tectonics of this part of Newfoundland and perhaps the Appalachian-Caledonian orogen in general.

Because of the wide-ranging and general nature of the study, it is necessary to carefully establish the regional setting of the plutons before discussing their geochemical characteristics. This thesis thus begins with a detailed review of previous work pertaining to eastern Newfoundland granitoid rocks in general, and the study area in particular. This review is then followed by detailed descriptions of individual plutons based on the author's own field and laboratory observations, which are then followed by geochemical descriptions, brief discussions of their petrogenesis, and their economic significance.

1.3. History of Investigation

As in most of Newfoundland, much of the early pioneering geological work in the area was carried out by J.B. Jukes (1843) and Alexander Murray and J.P. Howley (1881).

Murray and Howley (1881) compared the coarse-grained granite of Little LaPoile on the south coast with the coarse granite at "Cat Cove" (Lumsden Harbour?) near Cape Freels and suggested that the LaPoile Granite was "Lower Silurian" (Ordovician?) in age. They suggested that the granite would make an excellent building stone. The granites of the Freshwater Bay - Cape Freels area (Fig. 2) were given a Laurentian age (Archean?). In their detailed description of this series of granitoid rocks it is suggested that they have a sedimentary origin because of the alternation of the granitoid veins with "bedded gneiss and mica slate". The quartz veins (pegmatites?) were found to contain "small quantities of metallic substances....among which were grey sulpherets of iron, specular and magnetic iron, while small pink garnets were found chiefly in the micaceous parts of the rock". The gneiss was described as kaolinised and suitable for the manufacture of porcelain. Amethyst was reported in drusy cavities in the granitoid rocks. The rocks of the Gooseberry Islands area were described as "chiefly of slate with quartzites and diorites and a mass of slatey conglomerate near the base, intersected by intrusions of granite or syenite, trap, and quartz veins". These rocks were correlated with the "intermediate system" of the Avalon. Quartz-calcite veins containing copper and iron were reported, and it was suggested that they

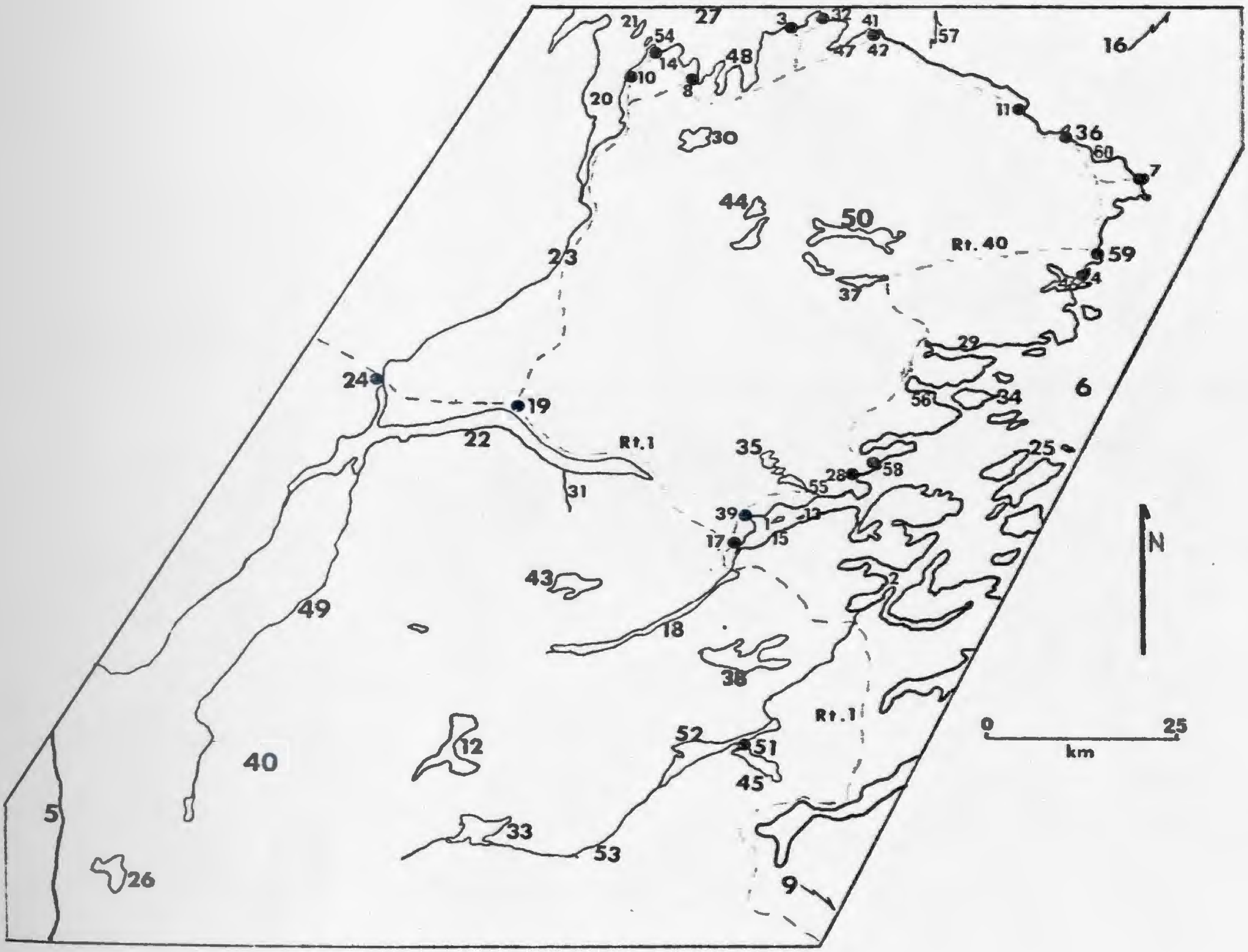

FIG. 2 - Localities Referred to in Text.

TABLE 1

Localities shown in Fig. 2

1. Air Island
2. Alexander Bay
3. Aspen Cove
4. Badger's Quay
5. Bay d'Espoir Highway
6. Bonavista Bay
7. Cape Freels
8. Carmanville
9. Clode Sound
10. Davidsville
11. Deadman's Bay
12. Deer Pond
13. Doctor Island
14. Frederickton
15. Freshwater Bay
16. Funk Island
17. Gambo
18. Gambo Pond
19. Gander
20. Gander Bay
21. Gander Island
22. Gander Lake
23. Gander River
24. Glenwood
25. Gooseberry Islands
26. Great Gull Pond
27. Hamilton Sound
28. Hare Bay
29. Indian Bay
30. Island Pond
31. Joe's Brook
32. Ladle Cove
33. Lake St. John
34. Lewis Island
35. Long Pond
36. Lumsden
37. Mocassin Pond
38. Maccles Lake
39. Middle Brook
40. Middle Ridge
41. Muddy Hole
42. Musgrave Harbour
43. North Pond
44. Ocean Pond
45. Pitts Pond
46. Pool's Harbour
47. Ragged Harbour
48. Rocky Bay
49. Southwest Gander River
50. Ten Mile Pond
51. Terra Nova
52. Terra Nova Lake
53. Terra Nova River
54. Tickle Island
55. Traverse Brook
56. Trinity Bay
57. Wadham Islands
58. Wellington
59. Wesleyville
60. Windmill Bight

might be economic. The Terra Nova granite (Fig. 3) was noted to have intruded slates and associated rocks. Numerous small veins and faults containing copper and iron were reported.

The Gander Lake granite (Fig. 3) was described as fine grained and the "corrugated and contorted gneiss" of the Joe's Brook area, Gander Lake, was correlated with the 'Laurentian' of the northern seaboard of Bonavista Bay.

Howley noted during his 1875 excursion up the Southwest Gander River that the slates, sediments, serpentine and granite have a "Laurentian aspect which coincides with the general run of that system as recognised on the northern side of Bonavista Bay, but the relation these highly metamorphosed rocks bear to the succeeding strata of gneissoid micaceous rocks and the underlying slates, or of the latter two to each other, is extremely difficult to unravel. Provisionally for present convenience, the granitic country aforesaid is assumed to be Laurentian, and the micaceous sandstones and slates are of Lower Silurian age, on or near the horizon of the Quebec Group coming in contact with the lower series by dislocation and unconformity".*

The area between Gander Lake and Freshwater Bay was noted to contain "gneiss". The area to the southwest of Gambo Pond was observed to contain mainly highly deformed 'mica slates' and sedimentary rocks 'which at some parts pass almost imperceptibly into a gneiss, the metamorphism increasing in intensity towards the interior of the country'. The rocks of this area were noted to manifest 'the effect of great disturbance', being highly folded. These rocks were tentatively given a Huronian (Aphebian?) age.

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*Note: This latter point is noteworthy in light of recent discussions on the relationships of the metamorphic rocks north of Gander Lake (Kennedy & McGonigal, 1972a, b; Jenness, 1972; Brueckner, 1972).

The first work done on the study area following the work of Jukes (1843) and Murray and Howley (1881) was that of the Newfoundland Geological Survey on the ultrabasic rocks north and south of Gander Lake. The only report published was that of Snelgrove (1934).

MacClintock and Twenhofel (1940) and Twenhofel (1947) studied the Wisconsin glaciation of the area. Twenhofel (1947) examined the rocks along Gander Lake and proposed the name 'Gander Lake Series' for the sequence of phyllites, slates and quartzites found there. Without fossil evidence he related the series to the Silurian system on the basis of lithological similarity with the Silurian strata on the islands in Hamilton Sound to the north.

Widmer in 1948 noted the presence of a third major sedimentary volcanic unit to the west of the Precambrian Musgravetown and Connecting Point Groups which he called the 'Love Cove Schist Formation' (Jenness, 1963, p. 4). No report was published on this work.

Christie (1950) mapped the granitoid rock of the Wellington area as part of his work on the Bonavista map area. He described the 'granites' as massive with a rude foliation in places, particularly at its southern contact (in the Wellington Area). He also noted 'amphibole and biotite bands in the gneiss, undoubtedly representing altered inclusions' which were 'common near the contact with the sedimentary rocks and in many places the gneiss is a finely banded migmatite'. He also noted that the muscovite-bearing granitoid dykes cut the gneiss in the south of his map area but not in the north. He suggested that the granite intrudes the sedimentary rocks and is not older as proposed by Jukes (1843) and

Murray and Howley (1881). The contacts of the pluton with the country rocks are faults, but granitoid dykes cut the sedimentary rocks and the granitoid pebbles found in the Musgravetown Group were not the same megacrystic granite.

Baird et al. (1951) discovered the first fossils in the study area, on the west shore of the Gander River, about 2 km. NNE of the railway bridge at Glenwood ($49^{o}01'$N $54^{o}51.3'$W) and at $48^{o}16'$N $57^{o}07'$W on the southwest shore of Middle Ridge Pond. They were identified by Prof. C.O. Dunbar and Dr. A.E. Wilson as various species of Middle Ordovician graptolites.

They noted the interfingering of sediment and 'granite' and the similarity between the Frederickton and Rocky Bay plutons (see Fig. 3).

They described for the first time the muscovite-biotite granites of Ragged Harbour, Ocean Pond and Middle Ridge areas (Figs. 2 and 3) and the hornfelsing to garnet grade of the country rocks was noted. The effects of granitisation were described from the west end of Gander Lake Pluton and the south side of Freshwater Bay Pluton. A 'sheared' contact between the Middle Ridge Pluton and the surrounding schists and several 'facies' of the Middle Ridge Pluton were described, as were deformation features in the pluton and the presence of garnets on the N.W. contact of the pluton.

During the 1953 field season, Jenness mapped the area between Clode Sound and Alexander Bay (1958b) and confirmed the existence of the Love Cove unit and renamed it the Love Cove Group. Grady (1953) and Jenness (1954, 1958a) mapped the Gander River Ultrabasic Belt, and Jenness found Middle Ordovician fossils at the following localities on Gander Lake:

FIG. 3 - Location of Granitoid Plutons in the Study Area, numbers of plutons in Strong et al. (1973b), and letters used in thesis.

A,2 - Frederickton
B,3 - Rocky Bay
C,4 - Aspen Cove
D,5 - Round Pond
E,6 - Ragged Harbour
F,7 - Deadman's Bay
7' - Included in description of Deadman's Bay Pluton in Strong et al. (1973a,b).
G,8 - Cape Freels
H,9 - Middle Brook
J,10 - Newport
K,11 - Gander Lake West
L,12 - Gander Lake
M,13 - Freshwater Bay
N,14 - Terra Nova
P,15 - Terra Nova River
Q,16 - Terra Nova River West
R,18 - Middle Ridge
19 - Ackley City

1. North Shore of Gander Lake 10 km. east of the outlet:

Chaetetes, Fischer in Eichwald 1829.

Brachiopod fragments, possibly Hesperorthis sp. identified by Prof. O.C. Dunbar.

2. North Shore of Gander Lake 8.8 km. east of the outlet:

Valcourea sp. Raymond 1911.

Unidentified trilobite pygidium

Horderleyella sp.(?) identified by Prof. O.C. Dunbar.

3. Trans-Canada Highway 1.6 km. north of location 1:

Brachiopod fragments, possibly Hesperorthis sp.

4. South end of quarry on east shore of Gander Lake, 1.6 km. south of Glenwood:

Climacograptus cf. rectangularis (McCoy).

Jenness (1963) mapped the southern part of the study area from 1955 to 1957 and renamed the Gander Lake Series of Twenhofel (1947) as the Gander Lake Group. He assigned an Ordovician (?) age to the whole of this Group, which included slates, volcanics, metasediments and gneisses, on the basis of the Middle Ordovician fossils found near the top of his sequence. He divided the Gander Lake Group into three Units:'Upper Unit', 'Middle Unit', and 'Lower Unit'. He assigned Devonian ages to all the granitoid plutons on the basis of K/Ar radiometric dates and suggested that the plutons in the present study area were 'large apophyses' of the Ackley City batholith to the south (see Fig. 3). He noted the intrusive nature of the Gander Lake Pluton, the hornfelsing of the country rocks to andalusite and staurolite grade and also that parts of his lower unit had been "granitised".

Williams (1964a, 1968) mapped in detail the contact relations of the various granitoids in the northern half of the study area and assigned them a Devonian age based on K/Ar dates. He also extrapolated Jenness's Gander Lake Group to the north coast.

Williams (1964b) suggested that the northeastern part of the study area had been affected by two orogenies, the Taconic and the Acadian. This conclusion was based on K/Ar isotopic ages of various granitoids in the Botwood Map Area which gave two groups of ages, viz. Ordovician and Devonian.

Williams (1969) noted the similar position of the Gander Lake Group metasediments and gneisses and the Fleur de Lys Group metasediments and gneisses on the west side of the Central Mobile Belt (see Fig. 1). He suggested that the Lower Unit of the Gander Lake Group (Jenness, 1963) was conformably overlain by Middle Ordovician slates and volcanics. Williams considered that during the Acadian orogeny the composite granitoid bodies of the Central Mobile Belt were intruded and followed by the megacrystic plutons of the Gander Lake Zone, which were followed by the leucocratic granitoids. The main phases of granitoid intrusion were Late Silurian and Devonian, based on geological evidence and radiometric dates. The Acadian orogeny was the main orogeny to affect the Central Mobile Belt, with deformation aligned along a NE-SW axis. The S-shaped structures in the southern half of the Central Mobile Belt were also related to this deformation.

Fairbairn and Berger (1969),on the basis of a Rb/Sr whole rock isochron,gave a tentative age of 600 m.y. to the Deadman's Bay pluton (on the north coast of the study area, Fig. 3) and noted that the migmatites to the southeast must be considerably older than the Ordovician age given by Jenness (1963) and Williams (1968).

Dewey (1969), Dewey and Horsborough (1969), Bird and Dewey (1970), Church and Stevens (1971), and Dewey and Bird (1971) introduced plate tectonics into tectonic interpretation of the Appalachians, with special reference to Newfoundland. Although most of this work was concerned with the west half of the island, Dewey and Bird (1971) suggested that the Gander River Ultrabasic belt was an obducted ophiolite sequence, but they did not refer to the granitoid plutons.

Williams et al. (1970) suggested that the belt of megacrystic granites and gneisses on the east half of the study area curved round from a north-south orientation to an east-west orientation along the south coast of the island, in what they called the "Hermitage Flexure". They noted that the Central Mobile Belt appeared to be cut off by the Hermitage Flexure (see Fig. 1).

McGonigal (1973) studied the metasediments, slates and plutonic rocks of the Gander Lake area and while agreeing with Jenness's (1963) divisions of the Gander Lake Group suggested that the 'Lower Unit' was basement to the 'Middle Unit' and 'Upper Unit' separated by a postulated angular unconformity, and the 'Lower Unit' was probably Precambrian.

Kennedy and McGonigal (1972a) extended McGonigal's divisions to the north coast with the 'Upper Unit' of Jenness (1963) assigned to a separate group - the Davidsville Group and the lower two units called the "gneissic terrane" and the "metasedimentary terrane", the latter being called the Gander Lake Group. The leucocratic garnetiferous granitoid plutons of the study area were assigned a Pre-Middle Ordovician age on the basis of a tectonic fabric which pre-dates that of the Davidsville Group. The megacrystic granites to the east were given a Precambrian age because their structure pre-dates that of the leucocratic bodies, and the biotite quartz diorite plutons (Frederickton and Rocky Bay) in the northwest of the area remained Devonian in age (see Fig. 5 and Table 2).

These three divisions do not correlate exactly with those of Jenness (1963). Kennedy and McGonigal (1972a) used descriptive names for the highly deformed rocks which they called the gneissic terrain and interpreted them as basement unconformably overlain by rocks of the less deformed metasedimentary terrain. These two groups are equivalent to the metamorphosed and relatively non-metamorphosed 'Lower Unit' of Jenness (1963) with the contact metamorphosed 'Middle Unit' forming part of the metasedimentary terrain. The non-metamorphosed 'Middle Unit' and 'Upper Unit' are equivalent to the Davidsville Group which, along with the Silurian Botwood Group (Williams, 1964a) form the sedimentary and volcanic terrain.

Brueckner (1972) objected to the name 'Gander Lake Group' remaining for the redefined Gander Lake Group as it violated a section of the American Commission of Stratigraphic Nomenclature (1970).

Jenness (1972) disagreed with Kennedy & McGonigal's new classification of the Gander Lake Group and suggested that the increase in metamorphic grade was due to the proximity of the granites, and he preferred the Devonian age of the granites as given by the numerous K/Ar dates.

FIG. 4 - General Geology of the Study Area based on Williams (1967) and Kennedy & McGonigal (1972).

1	Quartz Diorite	~~~~	Major Faults
2	Leucocratic Granodiorite (Leucogranite)		
3	Megacrystic Biotite Granite		
4	Gander River Ultrabasic Belt		
5	Davidsville Group		
6	Metasedimentary Terrain		
7	Gneissic Terrain		
8	Love Cove Group		
9	Musgravetown Group		
10	Connecting Point Group		

TABLE 2

Comparison and Correlation of the Stratigraphic Succession in the "Gander Lake Group" of Jenness (1963) and Williams (1964, 1968) with the Stratigraphic Succession of Kennedy and McGonigal (1972a) for the Same Rocks.

Jenness, 1963 Williams, 1964a, 1968		
Period and/or Epoch		Rock Units and Lithologies
Devonian		Leucogranites, Quartz Diorites, Ackley Batholith
MIDDLE ORDOVICIAN	GANDER LAKE GROUP	C. 'Upper Unit' Shales, greywackes, Mafic volcanic rocks
		B. 'Middle Unit' Greywacke, Black slate, calc.siltstone, basic lavas and tuffs.
		Ba. Spotted schists and amphibolite Contact mm'd. equivalents of B.
		A. 'Lower Unit' Chloritic rocks
		Aa. Contact mm'd. equiv. of A.
		Ab. Paragneiss, Mica schist.
		Ac. Granitised equiv. of Ab.

Kennedy and McGonigal, 1972a		
Rock Units and Lithologies		Period and/or Epoch
Quartz Diorites Gander Lake Pluton		Devonian
Davidsville Gp. Shales,greywackes, Conglomerate Volcanic rocks		Middle Ordovician
Metasedimentary Terrane Metamorphosed calc siltst. greywacke and mica schists with syntectonic leucogranite.	GANDER LAKE GP.	Pre-Middle Ordovician
Megacrystic Biot. Granites		Precambrian?
Gneissic Terrane Gneisses, mica schists, and migmatites.		Precambrian

In reply, Kennedy and McGonigal (1972b) reasserted their belief in the new divisions of the Gander Lake Group and cited polyphase deformation fabrics as conclusive evidence of the difference in age between the Davidsville and Gander Lake Groups.

Berger (1972) noted the syntectonic nature of the Ragged Harbour pluton and that the Deadman's Bay pluton in the Musgrave Harbour area is post-tectonic. He also noted that the Aspen Cove pluton is cataclastically deformed and cut by the Rocky Bay pluton. He also suggested that the rocks of the Gander Lake Group (Kennedy and McGonigal, 1972a) appeared to pass gradationally into the Davidsville Group.

During the summer of 1972, a reconnaissance lithogeochemical survey was carried out by the Newfoundland Department of Mines and Energy (Strong et al., 1973a, b). This involved sampling the plutons of the Gander Lake Belt and the Avalon Peninsula with analysis of the Mount Peyton and Twillingate granites also included for comparison (Fig. 1). The writer was responsible for field work in the northern half of the Gander Lake Belt, and this thesis is a more extensive analysis of the geology and geochemistry of the areas studied during that time.

CHAPTER 2

SUBDIVISIONS AND GENERAL GEOLOGY OF THE NEWFOUNDLAND APPALACHIANS

2.1. Major Subdivisions

The island has been divided into three geological provinces (Williams, 1964c) reflecting differences in tectonic and stratigraphic history (see Fig. 1). These are:

1. The Western Platform (Kay, 1967).
2. The Central Mobile Belt (Williams, 1964c).
3. The Avalon Platform (Kay and Colbert, 1965).

2.1.1. The Western Platform

The Western Platform consists of a Grenville basement of granitoid plutons and gneisses, which have been dated by the K/Ar method to give a minimum age of 900 m.y. (Lowdon, 1961) and 945 m.y. and 960 m.y. (Pringle et al., 1971). The Grenville basement is overlain by various autochthonous sedimentary and allochthonous sedimentary and ophiolite complexes. The autochthonous sedimentary rocks consist generally of platformal deposits ranging in age from Lower Cambrian to Carboniferous (Rodgers and Neale, 1963; Tuke, 1968; Williams, 1969; Stevens, 1970; Church and Stevens, 1971; Smyth, 1971). Large areas of the Western Platform are overlain by transported sedimentary rocks as well as mafic and ultramafic ophiolite complexes which have been interpreted as Lower Paleozoic oceanic crust and mantle (Stevens, 1970; Church and Stevens, 1971; Bird and Dewey, 1970; Dewey and Bird, 1971; Williams and Malpas, 1972; Comeau, 1972

2.1.2. The Central Mobile Belt

The Central Mobile Belt consists of geosynclinal and sedimentary, volcanic, metamorphic, and plutonic rocks ranging in age from Grenville (DeWitt, cited by Williams, et al., 1972) to Carboniferous. This zone is bounded to the west by the Fleur de Lys metamorphic, ultramafic and granitoid rocks and to the east and south by the Gander Lake Belt Precambrian granitoid, gneissic and metamorphic rocks (Kennedy and McGonigal, 1972a; Williams et al., 1972). The central part of the area consists mainly of sedimentary and volcanic rocks in the north, with granitoid, gneissic and metasedimentary rocks of Ordovician to Silurian age in the south (Williams, et al., 1972). Much of the Notre Dame area is composed of mafic and ultramafic rocks which are considered to be part of an ophiolite-island arc assemblage (e.g. Upadhyay, Dewey and Neale, 1971; Dewey and Bird, 1971; Upadhyay and Strong, 1973; Kean, 1973; Strong and Payne, 1973; Norman, 1973). Approximately 40% of central Newfoundland is underlain by granitoid rocks (see Fig. 1) ranging from diorite to syenite and granite. The Gander Lake Belt (see Fig. 1), with its possible westward continuation along the Hermitage Flexure towards Port aux Basques, is underlain mainly by megacrystic potassic granites. The granitoid plutons of the northern part of the Central Mobile Belt are mainly sodic quartz diorite and granodiorites related to gabbro. The Twillingate pluton is noteworthy in that it is a deformed pluton which is trondhjemitic in composition (Strong and Payne, 1973).

2.1.3. The Avalon Platform

The Avalon Platform consists of late Precambrian and Cambrian sedimentary and volcanic rocks with minor amounts of Ordovician to Devonian sediments. These have been metamorphosed in the west to low greenschist facies and in the east to prehnite-pumpellyite facies (Papezik, 1972). The Precambrian sedimentary and volcanic rocks have been intruded by a series of granitoid plutons ranging from diorite through granodiorite and alaskite to syenite and granite (Strong, et al., 1973a, b). These plutons range in age from Late Precambrian (McCartney et al., 1966) to Upper Devonian (Williams, 1971).

2.2. Structural-Metallogenic Zones

Fogwill (1970) divided the Island into seven distinctive geological environments based on varying lithological, structural and metamorphic history, radiometric and fossil dating and gravity-seismic data (Fig. 5). Each division contains its own characteristic endogenous and/or exogenous mineral deposits, but only those of the Gander Zone and eastern Hadrynian sequences display substantial granitoid mineralization.

2.3. Tectonostratigraphic Zones

Williams, et al., (1972) have divided the Canadian Appalachians into nine zones, A to I, based on the variations in tectonic and stratigraphic histories of the areas of Newfoundland, Nova Scotia and New Brunswick, (see Fig. 6) in the pre-Silurian times.

The study area forms parts of zones F, G and H. Zone F consists of Ordovician and Silurian sedimentary and volcanic rocks which have been intruded by various composite plutons, Silurian and Devonian in age, and mafic and ultramafic bodies of probable Ordovician age. Zone G consists of highly deformed gneissic and metasedimentary rocks

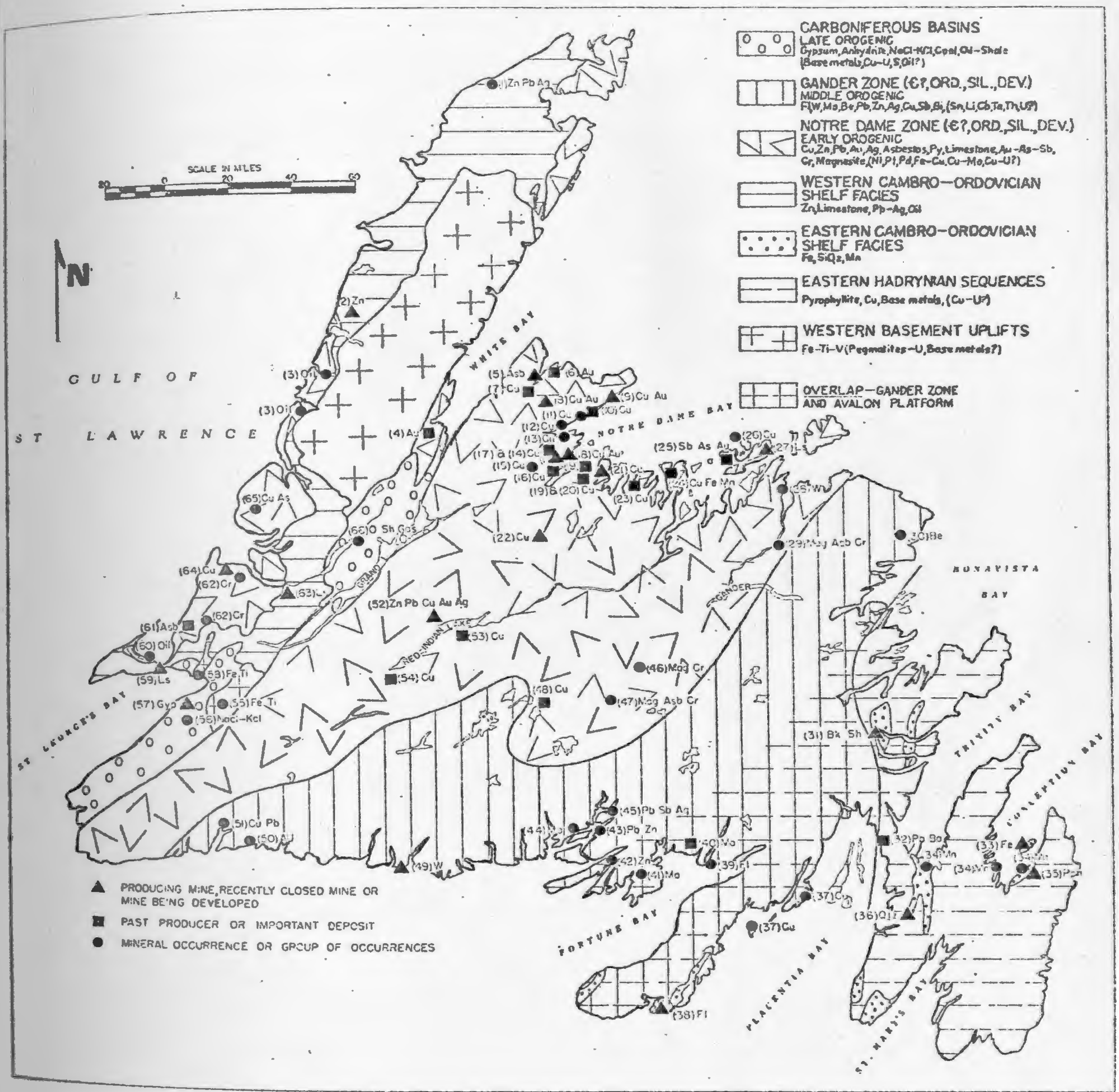

FIG. 5 - Structural-Metallogenic Zones of Newfoundland and Mineral Locations (see Table 3) (After Fogwill, 1970).

1. Eddies Cove
2. Nfld. Zinc Mines Ltd.
3. Parsons Pond
   St. Paul's Inlet
4. Brownings Mine
   Simms Ridge
   Unknown Brook
5. Advocate Mines Ltd.
6. Goldenville Mine
7. Terra Nova Mine
8. Consolidated Rambler Mines Ltd.
9. Tilt Cove Mine
10. Betts Cove Mine
11. Mount Misery
    Betts Cove
12. Rogues Harbour
    Stocking Harbour
13. Silverdale
    Wheeler
14. Colchester Mine
    McNeily Mine
    Old English Mine
15. Randell Jackman
16. Sterling Sullivan
17. British Nfld. Explor. Ltd.
18. Atlantic Coast Copper Corp. Ltd.
19. Miles Cove Mine
20. Crescent Lake Mine
21. Pilley's Island
22. Gullbridge Mines Ltd.
23. Lockport Mine
24. Fortune Harbour
25. Moreton's Harbour
26. Sleepy Cove
    Wild Bight
27. Cobbs Arm
28. Gander Bay
29. Second Pond
    First Pond
30. Wesleyville
31. Pelly-Shaw Nfld. Ltd.
32. La Manche
33. Wabana Mines
34. Kelligrews
    Manuels
    Chapel Arm
35. Nfld. Minerals Ltd.
36. Newland Enterprises Ltd.
37. St. Annes Peninsula
    Oderin Island
38. Nfld. Fluorspar Ltd.
39. Old Baldy
40. Rencontre East
41. Salmonier Cove Pond
42. Hermitage Peninsula
43. Barasway De Cerf
44. Northwest Cove
    Pomley Cove
45. Third Basin
    Conne Basin
46. Great Bend
47. Burnt Hill
48. Great Burnt Lake
49. Grey River
50. Cinq Cerf
51. La Poile
52. Asarco Buchans Mine
53. Victoria Mine
54. Tulks Hill
55. Steel Mountain
56. Hooker - Flat Bay
57. Flintkote Co. of Canada
58. Indian Head
59. Aquathuna
60. Shoal Point
61. Lewis Brook Mine
62. Springer's Hill
    Chrome Point
    Blow-me-Down
63. North Star Cement Ltd.
64. York Harbour
65. Mount Gregory
66. Deer Lake

TABLE 3. Names of Mineral Locations on Fig. 5.

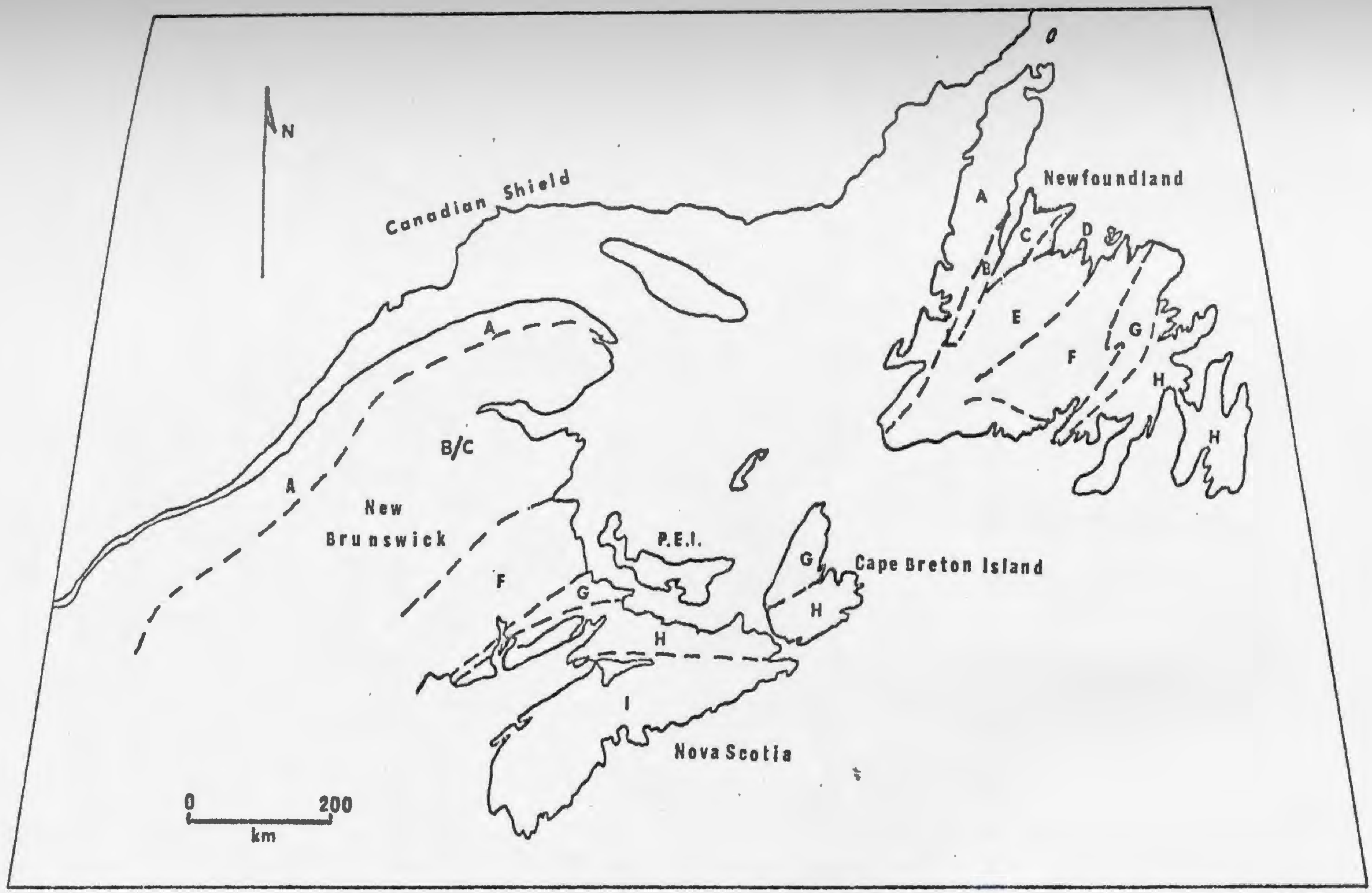

FIG. 6 - A-I: Tectonostratigraphic Zones of the Atlantic Provinces
(after Williams *et al.*, 1972).

(Kennedy and McGonigal, 1972a) and their probable extensions to Bay D'Espoir and Port aux Basques (Williams, et al., 1970). This zone has been intruded by megacrystic granites, leucogranites, and quartz monzonites ranging in age from Grenville (Williams, et al., 1972) to Devonian (Williams, 1971). Deposits and showings of tungsten, molybdenum, zinc, tin, fluorite, silver, copper, lead, and gold are associated with the plutonic rocks in the south of Zone G (see Fig. 5).

Zone H is equivalent to the Avalon Platform sediments, volcanics and granitoids. The mineral deposits and showings consist of sedimentary ores of iron and manganese, hydrothermal pyrophyllite, fluorite, copper, lead, and zinc.

2.4. Distribution of Granitoids in Newfoundland and their Relationship to the Tectonostratigraphic Zones

The granitoid rocks of Newfoundland can be divided into four major groups. These are (1) composite diorite-granite bodies, (2) muscovite-biotite granodiorite, (3) biotite-hornblende quartz diorite, and (4) megacrystic microcline-biotite granite. The latter three groups occur in the study area, with the composite diorite-granite plutons found to the west of the study area in the Central Mobile Belt.

The various types of granitoid bodies in Newfoundland are generally found within a particular zone or zones.

The potassic granites are generally restricted to the orthotectonic margins of the Central Mobile Belt, i.e. Zones A and C in the west and G in the study area. The garnetiferous leucocratic granites are apparently restricted to zone G. The composite gabbro-diorite-granodiorite plutons are dominantly found in zones E and F, the paratectonic region of the Central Mobile Belt.

The Avalon Platform (zone H) is intruded by a variety of granitoid plutons which also include a variety of alkaline and silica poor rocks such as syenites and monzonites.

Exceptions to this zonal distribution are found where granitoid plutons straddle zone boundaries or are entirely outside their expected zone. For example, the Terra Nova Pluton, which is identical to the megacrystic biotite granites of zone G, is found entirely in zone H, the Ackley City batholi straddles the G-H boundary, and the Middle Ridge Pluton cuts the F-G boundary. Leucocratic granites are generally restricted to the metasedimentary terrain (Kennedy and McGonigal, 1972a) but a large area of the gneissic terrain in the northeastern half of the study area is underlain by similarly deformed leucogranites.

The zonal subidivision of Newfoundland is generally successful in accounting for the stratigraphic distributions of the sedimentary, volcanic and metamorphic rocks, but the anomalous positions of the above mentioned plutons conflicts with the concept and remains a problem to be examined.

CHAPTER 3

GENERAL GEOLOGY OF THE STUDY AREA

3.1. Introduction

The granitoid plutons of the study area intrude a variety of rock types which include conglomerates, sandstones, metamorphic gneisses and schists, slates and basic and acidic volcanics. In the north of the study area the shales of the Davidsville Group have been intruded by a series of ultramafic rocks.

The country rocks can be separated into four main divisions (see Fig. 4).

1. The Hadrynian metavolcanics, metasediments and continental and epicontinental deposits of the Love Cove, Connecting Point and Musgravetown Groups (Jenness, 1963).
2. The "Precambrian" granitic gneisses and amphibolites of the "gneissic terrane" (Kennedy and McGonigal, 1972a).
3. The "Pre-Middle Ordovician metasedimentary terrane" (Kennedy and McGonigal, 1972a).
4. The Middle Ordovician ultramafics, sediments and volcanics of the Davidsville Group (Kennedy and McGonigal, 1972).

3.2. Hadrynian Sequence

3.2.1. The Love Cove Group

The Love Cove Group consists of two relatively narrow belts that trend just east of north across the east side of the study area. The belts are at maximum 14 km. wide and extend from Hare Bay in the north to

Swift Current in the south where they are terminated by the Ackley City and Swift Current plutons (Fig. 4). The Love Cove Group may continue to the Burin Peninsula where similar rocks occur.

Jenness (1963) described the Group as consisting of sedimentary and volcanic rocks which have been metamorphosed to a greater or lesser extent to granitised metamorphic rocks and chlorite-sericite schist. Kennedy and McGonigal (1972a) and Christie (1951) considered the granitised metamorphic rocks of the Hare Bay area to be plutonic in origin, being the highly deformed margins of the nearby plutons. (These so-called granitised rocks will be described below).

Acid lavas and pyroclastic rocks are found on the east of the eastern belt, while in the west of the belt intermediate lavas and pyroclastics are dominant with minor acidic volcanics. The volcanics have been metamorphosed to chlorite and chlorite-sericite schist, with one dominant fabric which is steeply inclined and strikes approximately north-south.

The metasediments of the Love Cove Group consist of conglomerates, feldspathic greywackes, quartzites, and shales. They are found mainly in the northern areas of the two belts and also in the south of the western belt. The arenaceous rocks are by far the most common. The conglomerates are described by Jenness (1963) as pebble and granite conglomerates composed of metasedimentary and metavolcanic material.

The shale, now a slate, is found mainly south of Terra Nova. It is composed of sericite and chlorite and found in thin bands between beds of quartzite.

The feldspathic greywackes are commonly found interbedded with volcanics. The quartzites and siltstones are thinly bedded. The siltstones are compositionally similar to the feldspathic greywackes and the quartzites appear silicified.

The sediments have the same dominant vertical schistosity as the metavolcanics. Kink bands are seen which have an orientation of 45^{o} to the dip of the main schistosity.

3.2.2. The Connecting Point Group

No contacts have been seen between the Love Cove Group and the Connecting Point Group and the two Groups are separated areally by the Musgravetown Group. The Connecting Point Group is stratigraphically above the Love Cove Group but it never occurs structurally above it. Jenness (1963) postulates an angular unconformity between the two groups on the basis of the higher degree of metamorphism and deformation in the Love Cove Group.

3.2.3. The Musgravetown Group

The Musgravetown Group underlies the area between the two parallel belts of the Love Cove Group. It also occurs to the east of the eastern belt of the Love Cove Group. Only the western belt is included in the map area. It overlies the Connecting Point Group with angular unconformity.

The Group consists of "red and green coarse grained conglomerates, subgreywackes, arkoses, and acidic to basic lavas of relatively shallow water, continental or epicontinental origin" (Jenness, 1963).

Christie (1951) noted that the conglomerate in the Hare Bay area contained granite pebbles which were finer grained than the megacrystic granites immediately to the west.

The Musgravetown Group is only slightly deformed into large scale folds with a northeasterly trend. The limbs have generally a very shallow dip.

The rocks are only slightly metamorphosed. At the southeast end of Pitts Pond, Terra Nova, near the contact with the Terra Nova Pluton, a thick sequence of greywackes has been contact metamorphosed by the granite to biotite schist and cut by pegmatite from the granite.

3.2.4. Intrusions

The rocks of the Hadrynian sequence in the map area have been intruded by the Terra Nova granite and a few basic dykes. A small stock of riebeckite granite intrudes the Love Cove and Connecting Point - Musgravetown Groups. It is apparently unrelated to the plutons farther west. (It was not studied during the project).

Dykes in the study area are rare. They are generally restricted to the region east of the study area where they are associated with the volcanics of the Bull Arm Formation.

3.3. The Gneissic Terrain

The oldest rocks of the Gander Lake Belt are the granitoid biotite gneisses, migmatites and metasediments and porphyritic granitoids which have been grouped together as the 'gneissic terrane' (Kennedy and McGonigal, 1972a).

The rocks of this terrain are found in a belt which extends from the Aspen Cove-Cape Freels area along the eastern half of the study area as far south as Bay D'Espoir (Williams, 1972).

The nature of the contact between the Love Cove Group on the east and the gneissic terrain on the west is uncertain. It is thought by Jenness (1963) and Kennedy (pers. comm. 1973) to be a fault. The lithologies are completely different across this boundary, with high grade potassic gneisses in the gneissic terrain and the low grade greenschist facies metasediments in the Love Cove Group on the east. The contact between the gneissic and metasedimentary terrains is also uncertain but is probably an angular unconformity, as there is a change from gneisses to schists over a comparatively short distance with no apparent fault.

The migmatites are composed of medium grained biotite granodiorite neosome in 10 to 50 cm. wide veins and a psammitic biotite schist palaeosome. The neosome has 3 mm. thick biotite bands orientated parallel to the main schistosity in the palaeosome and is composed of quartz, biotite, muscovite, plagioclase, and alkali feldspar. The palaeosome is usually a psammitic biotite schist composed of biotite, quartz, feldspar, muscovite, and garnet, with one dominant schistosity which in places has been complexly refolded.

The southern area of the gneissic terrain is underlain by dominantly psammitic and semi-pelitic schists, granitoid gneisses, and minor amphibolite dykes which have been highly deformed but still have the dominant N-S foliation. The gneissic terrain in the study area has been intruded by coarse grained porphyritic granitoid plutons, namely the Ragged Harbour, Deadman's Bay, Cape Freels, Newport, Middle Brook, Freshwater Bay, and Terra Nova River Plutons (see Fig. 3). The terrain has also been intruded by leucocratic garnetiferous granodiorites ("leucogranites"). Other intrusive rocks include dioritic, basaltic and granitoid dykes, pegmatites and quartz veins.

3.4. The Metasedimentary Terrain

The rocks of the metasedimentary terrain (Kennedy and McGonigal, 1972a) were formerly assigned to the 'Lower Unit' of the Gander Lake Group (Jenness, 1963). They have been redefined as a separate unit and are considered Pre-Middle Ordovician in age because of a postulated unconformable contact with the overlying Middle Ordovician Davidsville Group (McGonigal, 1973; Kennedy and McGonigal, 1972a; Uzuakpunwa, 1973).

The terrain consists of psammitic and semipelitic polyphase deformed schists, slates and metavolcanics. The metasediments and volcanics are highly deformed eugeosynclinal rocks (Jenness, 1963) which have produced large flat-lying recumbent folds in the Gander Lake area (McGonigal, 1973).

The rocks have been metamorphosed to varying degrees from chlorite and biotite schists to staurolite and andalusite schists. The staurolite and andalusite are restricted to the contact aureoles of the granitoids on the eastern margins and centre of the belt where the schists have been recrystallised. Garnet has grown between the first and second, and second and third phases of folding. Undeformed tourmaline has been found in schists from the Middle Ridge area. Andalusite and staurolite related to the Gander Lake Pluton postdate the second schistosity (Kennedy and McGonigal, 1972a).

The grade of regional metamorphism decreases from garnet grade on the east of the terrain to chlorite on the west.

The metasediments and metavolcanics have been intruded by leucocratic garnetiferous granodiorite (leucogranite) and megacrystic biotite granite.

The leucogranite is restricted to the western edge of the belt where it hornfelses the surrounding metasediments syntectonically. As in the gneissic terrain the leucogranites are garnetiferous and are highly deformed. Beryl has also been found in the Middle Ridge Pluton (Strong, et al., 1973a, b). Kennedy and McGonigal (1972a) suggest that the plutons were intruded during deformation as the fabric in the leucogranites is the same as that in the metasediments. In the north of the metasedimentary terrain, the Round Pond Pluton is highly foliated and almost indistinguishable from the surrounding metasediments. This pluton is a biotite granodiorite which is related to the nearby Ragged Harbour Pluton (Uzuakpunwa, 1973). The schistosity of the granodiorite is parallel to that in the psammitic schists and has the regional NNE-SSW trend. The common fabric in the deformed leucogranites is a vertical L-S fabric which trends NNE-SSW.

The leucogranites have associated with them pegmatites which are generally small (5-20 cm. wide) veins that intrude both the leucogranites and metasediments. In the north of the zone a large pegmatite (the Ladle Cove pegmatite (Uzuakpunwa, 1973)) contains xenoliths of deformed granodiorite and metasediment. The pegmatite is probably related to the Ragged Harbour Pluton but must be a much later intrusive phase.

Southeast of Gander Lake the metasediments are intruded by the Gander Lake Pluton which is composed of coarse grained to porphyritic granite. It does not contain any regional tectonic fabric and the staurolite and andalusite porphyroblasts in the metamorphic aureole overgrow the latest fabric in the country rocks. Near the southern contact the granite is foliated. This is probably related to local shearing and mylonitisation of the granite.

.5. The Davidsville Group

The metasedimentary terrain is overlain with apparent angular unconformity by the Davidsville Group which is the lower unit of the sedimentary and volcanic terrain (Kennedy and McGonigal, 1972a). In the Aspen Cove area the boundary is a melange zone (Kennedy and McGonigal, 1972a; Uzuakpunwa, 1973). The sedimentary and volcanic terrain consists of the Middle and Upper Ordovician Davidsville Group which is conformably overlain by the Silurian Botwood Group (Williams, 1964a). Only the Davidsville Group occurs in the study area.

The Davidsville Group consists of black slate, greywacke, mafic volcanic flows and pyroclastic rocks. The sediments have one main penetrative fabric which has been kinked and crenulated, and they are metamorphosed to low greenschist facies with the formation of chlorite schists. Around the quartz diorite intrusions in the Carmanville-Frederickton area, the sediments have been contact-metamorphosed to a brittle garnet-andalusite hornfels. The volcanic rocks do not show such contact effects.

The melange zone separating the two terrains in the north consists of black slate which contains fragments and boulders with a schistosity which predates incorporation in the melange. The metamorphic rocks in the greywackes and melange can be matched with similar rocks in the metasedimentary terrain (Kennedy and McGonigal, 1972a). This suggests that the metasedimentary terrain is much older and the junction must be a major unconformity. The volcanic rocks in the Carmanville area are tuffs, very coarse agglomerates and flows which have been altered to chlorite and magnetite. They contain abundant calcite and calcite-quartz veins. The volcanics may be related to the quartz diorites which intrude them, but this is uncertain.

The Gander River Ultrabasic Belt is a complex of serpentinised ultramafics, gabbro, pillow lavas and pyroclastics which occurs discontinuously in a linear belt from Ladle Cove to Gander Lake, with a probable continuation into the isolated ultramafic bodies west of Middle Ridge. Jenness (1963) suggested that the serpentinites and pyroxenites were emplaced as cold intrusions into pre-existing volcanics. Dewey and Bird (1971) called the belt an ophiolite complex which implied that it was tectonically emplaced.

The Davidsville Group is intruded by medium grained hornblende-biotite quartz diorites and granodiorites in the northwest of the study area. The plutons contact metamorphose the metasediments up to 3 km. from the contact (Williams, 1964a). The three plutons involved are the Frederickton, Rocky Bay and Island Pond plutons which are very similar in mineralogical and chemical composition. This and the wide areal extent of hornfelsing suggests that the exposed areas of quartz-diorite may be cupolas of the one body.

Many dykes of diorite and quartz diorite intrude the metasediments and plutons. The dykes in the country rocks strike NE-SW and in places use faults as channels to the surface.

Zoning in the Rocky Bay and Frederickton Plutons is suggested by variation in the biotite-hornblende ratio and by the chemical analyses (see chapters 4 and 5), although the western marginal facies of the Rocky Bay Pluton is very leucocratic with little mafic material (see Plate 1) and pinhead-sized garnets are found in place of biotite and hornblende in aplitic dykes (Uzuakpunwa, 1973).

The Rocky Bay Pluton cuts across the cataclastic fabric of the Aspen Cove Pluton indicating that the Rocky Bay Pluton was a later intrusion than the Pre-Middle Ordovician Aspen Cove Pluton. The Rocky Bay and Frederickton Plutons are essentially undeformed but small kink bands in the biotite and tiny faults in the plagioclase suggest that the plutons are syn- or pre-tectonic intrusions and are perhaps older than the Devonian age given by Williams (1964b) and Kennedy and McGonigal (1972a).

CHAPTER 4

PLUTON DESCRIPTIONS

4.1. Introduction

The plutons have been named and numbered in accordance with the report of Strong, Dickson, and O'Driscoll (1973). The bracketed number after the name of the pluton is the number of the pluton in that report.

4.1.1 Classification of Granitoids

The granitoids were classified in the field according to visual estimates of the proportions of alkali feldspar, quartz and plagioclase (after Bateman et al., 1963) (see Fig. 7a). This was found to be satisfactory for field classification when the feldspars were coloured, but in the finer grained leucocratic rocks when there was no difference in the colour of the feldspars, classification was more difficult and proportions of mafic minerals and quartz content were used to name the granitoid.

CIPW norms were calculated by a computer program modified from one provided by the Geological Survey of Canada, and the molecular proportions of quartz:orthoclase:albite plus anorthite were plotted on a triangular diagram for comparison with the field classification. It was found that in detail the field names for samples did not agree with the name as given by the position of the modal proportions on the field classification. Nockolds (1954)

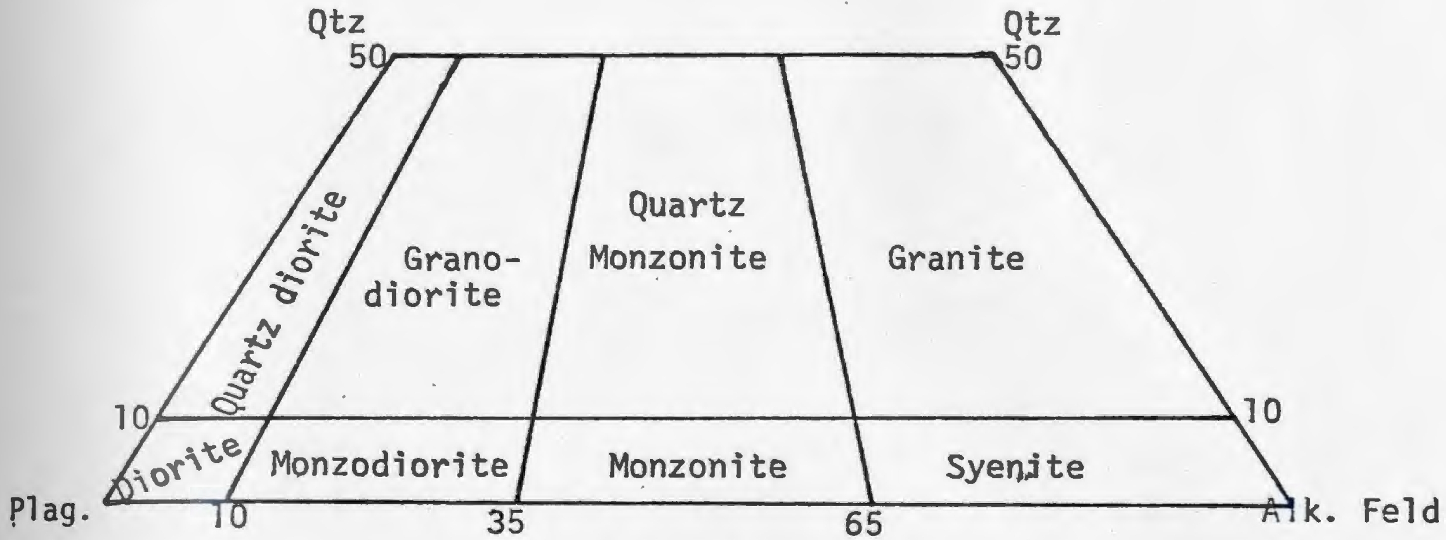

FIG. 7a

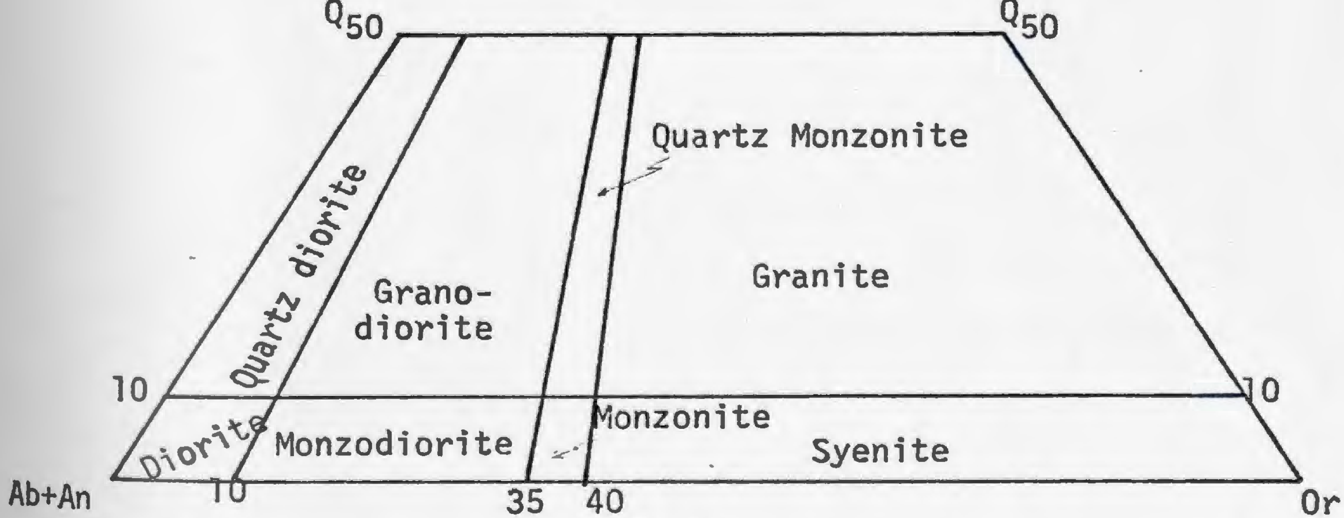

FIG. 7b

FIG. 7a - System used to classify granitoids in field; based on volumetric proportions of Qtz:Plag:Alk.Feld. (after Bateman et al. (1963).

FIG. 7b - System used to classify granitoids in thesis; based on normative proportions of Q:Ab+An:Or, based on Nockolds (1954) averages (after Strong et al., 1973b).

averages for granitoid rocks were thus plotted on the Qtz-Or-(Ab+An) diagram and arbitrary field boundaries were drawn to separate these rock types. These boundaries were then used to provide the present classification (see Fig. 7b).

4.2. The Frederickton Pluton (2)

4.2.1. Location & Contact Relations

The Frederickton pluton is located to the west of the village of Frederickton in the northwest of the study area (Fig. 3). It is an elongate pluton, 11 km. long with a 5 km. wide bulbous southern end, and extends into Gander Bay where it outcrops on Tickle Island and Gander Island. It has an exposed area of approximately 20 $km.^2$.

The pluton intrudes the Middle Ordovician Davidsville Group sediments and volcanics. The sediments have been hornfelsed with the formation of andalusite and garnet in the more pelitic beds but the volcanics are apparently unaffected by the hornfelsing.

The pluton has been given a Devonian age by Williams (1964a) and Kennedy and McGonigal (1972a).

4.2.2. Main Lithologies

The Frederickton pluton varies in composition from hornblende quartz diorite with minor biotite to biotite-hornblende granodiorite. It is generally medium grained, holocrystalline, mesocratic to leucocratic, with minor alteration of the plagioclase and ferromagnesian minerals.

The marginal areas are relatively basic, with hornblende as the dominant mafic mineral, while the central areas of the bulbous southern end and the coastal exposures to the north are more acidic, reflected in the higher proportion of biotite and the appearance of microcline.

4.2.3. Mineralogy

The mineralogy of the pluton is relatively constant, consisting of plagioclase, quartz, biotite, hornblende and with or without microcline.

Plagioclase occurs as 1 to 3 mm. subhedral crystals which in thin section show well developed polysynthetic and Carlsbad twins. Normal zoning of the plagioclase is also well shown and the crystals have a composition ranging from An_{40} in the cores to An_{25} at the rims. Variable alteration of some plagioclase crystals to sericite and epidote is restricted to irregular zones within the plagioclase. The plagioclase crystals are moderately deformed, with small faults observed in some crystals at right angles to the albite twins, and some bending of twin planes shown in other crystals. The plagioclase has inclusions of small flakes of biotite and rare apatite.

Quartz occurs as strained anhedral crystals 1 to 2 mm. long which in some sections are recrystallised and form polygonal aggregates. Biotite inclusions are common in the quartz crystals.

Hornblende forms euhedral to subhedral 1 to 3 mm. crystals and vary in abundance from 2 to 5%. They show straw-yellow to green pleochroism and slight alteration to chlorite along the edges.

Elongate inclusions of quartz have been found in some sections.

Biotite generally forms rounded 3 to 5 mm. books and small flakes. In some samples biotite accounts for about 15% of the rock. Smaller flakes of biotite are common in the hornblende-rich quartz diorites. In thin section the biotite is anhedral with dark brown to straw-yellow pleochroism. The larger flakes have inclusions of all the other minerals. Kink bands were found in several biotite crystals.

Microcline was found in one sample from the north of the pluton and forms anhedral crystals with partially developed microcline twinning.

Accessory apatite and magnetite are common.

4.2.4. Dykes

Numerous fine to medium-grained diorite and quartz diorite dykes are found west of Frederickton where they cut the Frederickton pluton as well as the sedimentary and volcanic rocks.

The dykes range in width from 50 cm. to 1.5 m. and trend NNE-SSW, dipping east or west at 40° to 80°. The more shallow dipping dykes are found along faults in the country rocks where the dip is controlled by the angle of faulting. Intermittent dyke intrusion is shown by the chilling of one dyke against another. Aligned hornblende crystals were found in one dyke and are probably related to flow of the magma.

4.3. The Rocky Bay Pluton (3)

4.3.1. Location and Contact Relations

The Rocky Bay pluton is oval in outcrop and is about 10 km. long and 6 km. wide. It underlies an area of about 45 km. around Rocky Bay, 5 km. east of Carmanville (Fig. 3).

The pluton intrudes the Davidsville Group volcanic and sedimentary rocks and truncates the Aspen Cove pluton to the east. The volcanic rocks do not show any effects of contact metamorphism. Rafts of country rocks and leucocratic dykes in the volcanics are found around the contact (see Plate 2).

Uzuakpunwa (1973) has suggested that the andalusite porphyroblasts in rocks of the metasedimentary terrain have formed as a result of intrusion of the Rocky Bay pluton.

4.3.2. Main Lithologies

The main lithology is grey medium grained biotite-rich quartz diorite. Towards the centre of the pluton, the biotite forms large 4-7 mm. circular books which give the rock a spotted appearance. The marginal rocks are darker in colour and finer grained with a higher proportion of hornblende (see Plate 3).

In the southwest of the pluton hornblende decreases, biotite increases and the rock becomes more leucocratic with white quartz, plagioclase and 5 mm. spots of biotite (see Plate 4).

4.3.3. Mineralogy

The Rocky Bay pluton is composed of essentially four minerals - quartz, plagioclase, hornblende and biotite. Quartz occurs as 1 to 3 mm. anhedral and polygonal crystals. The anhedral crystals are strained and some have sutured grain boundaries. Small inclusions of zoned plagioclase are found in some quartz crystals. Plagioclase forms subhedral laths and anhedral rounded crystals with Carlsbad and polysynthetic twins. Most of the crystals show well developed normal zoning with compositions ranging from An_{40} in the core to An_{25} at the edge of the crystals. Alteration to sericite and epidote is restricted to zones within some crystals.

Hornblende forms 1 to 2 mm. long subhedral to anhedral crystals which show straw-yellow to green pleochroism. Some crystals are fractured with veins of quartz separating fragments. Hornblende in the Rocky Bay pluton appears to be less abundant than in the Frederickton pluton, but this may be a result of the poor exposure of the former.

Biotite occurs as 3 to 5 mm. round books and smaller 1 to 3 mm. flakes which in thin section are anhedral and show dark brown to straw-yellow pleochroism. The larger biotite crystals have abundant inclusions of plagioclase and give the rock a subophitic texture.

Aspen Cove Pluton (4)

4.4.1. Location and Contact Relations

The Aspen Cove pluton is roughly triangular in outcrop and underlies an area of approximately 16 $km.^2$ around the village of Aspen Cove.

The pluton intrudes the psammitic garnet-muscovite-biotite-andalusite schists of the metasedimentary terrain to the southeast. It is faulted against the Davidsville Group to the south and is truncated by the Rocky Bay pluton to the west. A sedimentary melange to the north and northwest of the pluton is intruded by garnetiferous aplite dykes, which are similar to the Aspen Cove pluton in composition. The melange has been dated as Middle Ordovician (Kennedy & McGonigal, 1972a). If however, the dykes intruding this melange are indeed part of the Aspen Cove Pluton, the Pre-Middle Ordovician age given to the pluton is questionable.

4.4.2. Main Lithologies and Deformation

The Aspen Cove pluton is a medium grained leucocratic massive to foliated garnetiferous muscovite-biotite granodiorite. Near the northeast contact the leucogranite is highly sheared, foliated and recrystallised. This is probably related to movement along a fault separating the leucogranite and the ultramafic melange just to the east of the pluton. The foliation is strongly developed with a NNW-SSE alignment of biotite and muscovite. Much of the quartz has been flattened and granulated with sutured grain boundaries. The quartz and mica are augened around the feldspar crystals which are apparently unaffected by the deformation. The garnets are similarly resistant and maintain their roughly spherical shape. The remainder of the pluton is less deformed and contains a poorly developed foliation which has been related to the regional S_2 schistosity in the metasediment.

4.4.3. Mineralogy

The pluton is composed of equigranular interlocking quartz, plagioclase, microcline, biotite, muscovite, garnet, and with minor zircon.

Quartz occurs as 1 to 4 mm. anhedral and polygonised crystals which in the deformed samples are granulated and flattened.

Plagioclase occurs as subhedral phenocrysts from 1 to 3 mm. in length with smaller anhedral crystals in the groundmass, and ranges in composition from An_{20} to An_{25}. Carlsbad and polysynthetic twins are well developed. The plagioclase is variably altered to sericite and epidote with alteration restricted to the cores of some crystals. The oligoclase in the foliated granodiorite forms 3 to 5 mm. laths with only partially developed twinning. Kinking of the twin lamellae is the only deformation feature of the oligoclase.

Microcline forms 1 to 2 mm. subhedral to anhedral crystal with well developed microcline twinning. The microcline is much less abundant than plagioclase and occurs as an interstitial phase. Slight alteration to sericite occurs in some crystals.

Biotite forms large 2 to 5 mm. anhedral flakes which are generally orientated parallel to the foliation. The biotite shows straw-yellow to brown pleochroism with pleochroic haloes around the abundant inclusions of tiny zircons, and is variably altered to chlorite and magnetite.

Muscovite forms large 2 to 5 mm. anhedral flakes which show only poor alignment.

Garnet occurs as 1 mm. pinhead-sized red to pink crystals, which vary in abundance. They account for less than 1% of the rock. These are noteworthy because primary garnet is comparatively rare in granitoid rocks although they are common in pegmatites. Hall (1965) showed that the primary garnets in the Donegal granite and associated aplites and pegmatites contained a high proportion of spessartine and he suggested that they formed because of the 'reluctance' of manganese to enter the muscovite lattice. It is unknown whether the garnets of the Aspen Cove pluton are manganiferous, and further investigation is necessary to determine their nature and significance.

4.5. Round Pond (5), and Ragged Harbour (6) Plutons

4.5.1. Introduction

The area defined as the Round Pond and Ragged Harbour Plutons (Strong, et al., 1973a,b) include granitoid rocks of varying mineralogy, composition and deformation. Two distinct varieties can be recognized: (a) foliated coarse grained garnetiferous muscovite-biotite granite, with microcline megacrysts, and (b) highly foliated medium grained biotite quartz diorite and granodiorite. The similarity in mineralogy and deformation between the quartz diorite of the Ragged Harbour pluton and that of the Round Pond pluton suggests that they are part of the same intrusion, thus they are herein discussed together.

4.5.2. Location, Contact Relations, Lithologies and Deformation

The plutons are located in the Aspen Cove, Ladle Cove and Ragged Harbour areas (Fig. 3). The main mass of the Ragged Harbour pluton is oval in shape and has an approximate area of 180 $km.^2$. To the west, separated from the main pluton by schists of the metasedimentary terrain (Uzuakpunwa, 1973), are two small isolated bodies each of which underlies an area of 1 $km.^2$. The Ragged Harbour pluton intrudes the gneissic terrain to the east and the metasedimentary terrain to the west. Sharp contacts can be seen at Muddy Hole, just west of Musgrave Harbour, where medium grained granite cuts the gneisses, and at White Point, where aplite veins from the pluton cut the schists. The veins have been ptygmatically folded and describe the F_2 folds, suggesting a syntectonic origin for the pluton (Uzuakpunwa, 1973). The Round Pond pluton and the quartz diorite of the Ragged Harbour pluton intrude the metasediments, apparently along the dip of the beds, and have the same NW dipping foliation. The Ragged Harbour pluton is composed of several distinct rock types including medium grained quartz diorite, granodiorite, and granite, and megacrystic leucocratic granite all of which have been variably deformed. Because of the limited exposure, delineation of the areas underlain by each type was not possible and contact relations are unknown.

Biotite and muscovite in the megacrystic granite show a poorly developed orientation which trends NNE and dips at about 75°W. A muscovite granodiorite dyke cutting the granite has a well developed schistosity which dips at 15° to the north. The deformation of the granite must predate the schistosity in the dyke as the foliation in the granite is cut by the dyke and the dyke does not contain the foliation found in the granite. However the dyke displays a faint (?) foliation which appears to be absent in the granite. This may be due to the more competent nature of the coarser grained granite, and does not reflect simple refraction of a single foliation.

An area of highly foliated granite occurs towards the centre of the pluton and is similar to the megacrystic granite. The orientation of the schistosity there is completely different from the other areas of the pluton, striking 030° and dipping SE at 60°.

Towards the eastern contact near Musgrave Harbour the granite contains large microcline megacrysts. It is highly deformed with a foliation striking approximately E-W and dipping steeply to the north.

The northwest of the Ragged Harbour pluton and the two isolated masses to the west are more basic, with a high proportion of biotite, little or no muscovite, and a pronounced planar fabric. The granodiorite is intensely flattened and mica is augened around the plagioclase imparting a foliation striking 030^{o} and dipping west at 60^{o}, parallel to the regional fabric. The foliation is folded in some areas of the Round Pond pluton.

4.5.3. Mineralogy

(a) Megacrystic Granite. The main exposures of megacrystic muscovite-biotite granite are found at Ragged Harbour Bridge near the contact with the schists of the metasedimentary terrain. The main minerals are white microcline and plagioclase, quartz, biotite and muscovite (see Plate 5).

The microcline occurs as euhedral aligned megacrysts with prominent Carlsbad twins, and as anhedral crystals in the groundmass. The megacrysts and groundmass microcline show poorly developed microcline twinning and contain patch and braid perthites. Abundant inclusions of 1 mm. quartz, plagioclase, biotite and muscovite are randomly dispersed throughout the megacrysts. The microcline is variably altered to sericite.

Quartz occurs as anhedral and polygonised crystals. Sutured grain boundaries and strained crystals show that the rock has undergone deformation. Myrmekite-like quartz-feldspar intergrowths are found in some thin sections.

Plagioclase occurs as white 2 to 5 mm. subhedral to anhedral crystals and in thin section shows polysynthetic and Carlsbad twinning which give a composition of An_{15} to An_{20}. Small inclusions of biotite are found in some crystals. The plagioclase is variably altered to sericite.

Biotite is present as small .5 to 3 mm. anhedral flakes and shows brown to straw-yellow pleochroism. Pleochroic halos have formed around the numerous inclusions of zircon. Inclusions of garnet and plagioclase are common.

Muscovite is present as .5 to 2 mm. anhedral flakes. It is commonly interbanded with biotite.

Small pinhead-sized garnets are found throughout the rock. Some crystals contain small inclusions of quartz.

(b) Biotite Granodiorite. The granodiorites are composed of quartz, biotite, plagioclase, microcline, ± muscovite and garnet.

Quartz forms 1 to 3 mm. anhedral crystals, with sutured grain boundaries, uneven exinction and in some areas is granulated and flattened parallel to the foliation.

Plagioclase occurs as anhedral 1 to 3 mm. twinned and untwinned oligoclase. The Carlsbad and polysynthetically twinned oligoclase is more abundant than the untwinned oligoclase. The plagioclase in some sections has been flattened parallel to foliation and is variably altered to sericite and epidote.

Microcline is present as 1 mm. anhedral crystals with partially developed microcline twinning. It has been flattened parallel to the schistosity and is slightly altered to sericite.

Biotite occurs as abundant elongate flakes which define the schistosity. The crystals show straw-yellow to brown pleochroism with darker halos around the numerous inclusions of zircon. The biotite is variably altered to chlorite and magnetite.

Garnet occurs as 1 mm., red, subhedral and anhedral fractured crystals.

Apatite is present as small needles which are randomly distributed throughout the rock.

Muscovite is a minor constituent and occurs as elongate anhedral crystals which parallel the foliation. Uzuakpunwa (1973) has suggested that the muscovite is metamorphic in origin.

4.5.4. Pegmatites and Dykes

The Ragged Harbour pluton is cut by a variety of pegmatites and aplite dykes which vary in width from a few centimeters to several hundred meters.

The aplites are medium grained leucocratic equigranular and undeformed. They are composed of quartz, plagioclase (An_{15}), microcline, muscovite and garnet. Quartz and plagioclase account for 95% of the volume. The garnet occurs throughout the aplites and also in garnet-rich bands in some of the aplites.

Pegmatites are common throughout the Ragged Harbour pluton. They vary from 2 mm. to 1 km. in width and up to 1 km. in length. The Ladle Cove pegmatite (Uzuakpunwa, 1973) is by far the largest, underlying an area of at least 1 $km.^2$. It contains large microcline crystals up to 10 cm. in length which in places form graphic intergrowths with quartz. The microcline is white to cream in colour and forms over 50% of the pegmatite. Quartz, plagioclase and muscovite form equal proportions and form 3 to 5 mm. crystals. Garnet forms 1 to 2 mm. euhedral crystals and accounts for less than 1%.

The pegmatite contains abundant inclusions of foliated granite, quartz diorite and metasediment, and cuts across the fabric of the quartz diorite. It therefore must be post-tectonic in origin. Tourmaline-bearing coarse grained pegmatites cut the megacrystic granite. The tourmaline forms black euhedral crystals 5 to 10 mm. long.

Locally unfoliated pegmatites are cut by foliated aplites and at Muddy Hole occur together with foliated and boudinaged pegmatites, suggesting at least two phases of pegmatite intrusion.

4.5.5. Discussion

The Round Pond pluton and the quartz diorites and granodiorites of the Ragged Harbour pluton are similar structurally, petrographically and chemically (Table 4). The contrast in chemical composition (Table 4), and intensity and style of deformation between the Ragged Hr.-Round Pond quartz diorites and the leucocratic and megacrystic granites of the Ragged Harbour pluton suggest at least two phases of igneous intrusion, with the Ragged Harbour pluton being the later.

TABLE 4

Comparison of the Chemical Composition of the Round Pond & Ragged Harbour Quartz Diorite and the Ragged Harbour Granite.

Mean of Selected Oxides	Round Pond + Ragged Hr. Qtz. Diorite Granodiorite	Round Pond Qtz. Diorite	Ragged Hr. Qtz. Diorite	Ragged Hr. Granite
SiO_2	68.00	68.8	66.40	72.02
Fe_2O_3	3.32	3.37	3.20	1.21
CaO	2.60	2.09	3.66	0.84
K_2O	3.53	3.48	3.62	4.40
MgO	1.08	1.03	1.16	.82
No. of Analyses	6	4	2	7

[redacted] The Deadman's Bay Pluton (7)

4.6.1. Introduction

The Deadman's Bay pluton is a large area of megacrystic biotite granite between Musgrave Harbour and Windmill Bight in the north and Moccasin Pond in the south. In a previous report (Strong et al., 1973a), the author used the term Deadman's Bay pluton to include the leucogranite of Ocean Pond and the leucogranites and megacrystic biotite granites between Indian Bay and the southeastern boundary of the pluton as now defined (Fig. 3). This area to the southeast and the Ocean Pond pluton will be described separately.

4.6.2. Location, Contact Relations, Main Lithologies and Deformation.

The Deadman's Bay pluton is approximately square in outcrop and has an exposed area of approximately 100^0 km.^{2}. It may be considerably larger, as the southeastern Wadham Islands 15 km. NNE of Musgrave Harbour and Funk Island 55 km. NE of Lumsden are similar to the megacrystic granites of the Deadman's Bay pluton, (Williams, 1968) and would therefore give the pluton a minimum area of 3000 km.^{2}.

The Deadman's Bay pluton intrudes the high grade gneisses of the gneissic terrain and is in contact with leucocratic granodiorite 15 km. WSW of Wesleyville. At Windmill Bight the granite has intruded the migmatitic country rocks in a lit-par-lit fashion with the proportion of granite increasing within a distance of 100 m as the pluton is approached. There is only a slight decrease in grain size around the contact and the granite is very coarse grained.

WSW of Wesleyville the contact between megacrystic granite and leucocratic granodiorite is sharp. The granite shows no change in grain size and is undeformed. The granodiorite is medium grained and highly foliated suggesting that it predates the Deadmans Bay Pluton. However, it is possible that the more competent nature of the megacrystic granite prevented the development of a tectonic fabric. The foliation in the granodiorite strikes NE-SW and dips approximately 20° SE.

At Musgrave Harbour the contact appears to be a fault. Near the margin the granite contains a poorly developed fabric which may be related to shearing along the fault. The pluton consists of several varieties of orange to buff coloured, very coarse grained and megacrystic granite composed dominantly of ovoid to tabular microcline in a groundmass of quartz, plagioclase, microcline and biotite (with a notable absence of muscovite) (Plates 6 and 7). The granite is deformed only at the margins to the southeast and northwest where a rude foliation is developed, and it is fractured in the area northwest of Ten Mile Pond.

Aligned microcline megacrysts are well shown at Lumsden where they have subparallel orientation which dips at approximately 30° to the NW. This angle varies from 45° to 20° as the alignment follows a curved path. The cause of this is uncertain but is probably a primary flow structure rather than tectonic as this is the only structural feature in the outcrop.

Mantles of plagioclase on the microcline crystals are found in a few areas of the pluton. The Rapakivi feldspars occur in the coarser grained granites and mantle rounded microclines west of Deadman's Bay and the rectangular microclines at Lumsden. Mantles of microcline on plagioclase have also been observed (A.R. Berger, pers. comm.).

Local zones of epidotisation are found in the Ten Mile Pond area where much of the plagioclase is altered and veins of epidote cut the granite.

4.6.3. Mineralogy

Thin section analysis shows the granite to be holocrystalline with microcline megacrysts in an interlocking granular groundmass of microcline, plagioclase, quartz and biotite, with rarely sphene and apatite.

Microcline occurs as 1 to 10 cm. ovoid and rectangular megacrysts and as anhedral 2 to 10 mm. crystals in the groundmass. Microcline twinning shows varying degrees of development and simple Carlsbad twins are common. Inclusions of 1 to 3 mm. biotite and quartz are common and in some crystals the biotite has a zonal arrangement which suggests later over-growth of the biotite by the microcline (see Plate 8).

Plagioclase occurs as subhedral to anhedral crystals which are generally restricted to the groundmass, and as mantles around microcline. Polysynthetic and Carlsbad twins are well developed and the plagioclase has a composition of An_{15} to An_{20}. Inclusions of biotite are found in some crystals and variable alteration to sericite and epidote is common.

Quartz is found as 2 to 10 mm. anhedral crystals with rare inclusions of biotite and feldspar. Sutured grain boundaries and uneven extinction suggest deformation, and in places the quartz is found as recrystallised polygonised aggregates. Graphic quartz-alkali feldspar intergrowths have been found in some sections.

Biotite occurs as subhedral 1 mm. thick books and irregular 2 to 5 mm. diameter flakes. The crystals are pleochroic from brown to straw-yellow and rare inclusions of zircon have produced dark pleochroic halos. The biotite is variably altered to penninite and magnetite.

Sphene is rare and occurs as 1 mm. euhedral diamond-shaped crystals. Apatite forms tiny needles which are found as inclusions in the major phases.

4.6.4. Dykes and Pegmatites

The pluton is cut by aplite, granodiorite and mafic dykes, and pegmatites. A thick multiple diabase dyke cuts the pluton at Deadman's Bay (see Plate 9). It is composed of two separate intrusions of very fine grained porphyritic diabase, and fine grained diabase. The finer grained dyke is chilled against the other dyke. A thick diabase dyke found 3 km. along strike is probably a continuation of that found at Deadman's Bay.

Medium grained granodiorite dykes and sills cut the pluton with variable orientations. For example at Lumsden a thin granodiorite dyke cuts the granite dipping at an angle of 20° NW (see Plate 10).

At Deadman's Bay a small but continuous EW-striking aplite dyke cutting the granite contains patches of biotite, pyrite, and molybdenite. This molybdenite is the first reported occurrence of an economic mineral in the Deadman's Bay pluton.

4.6.5. Other Granitoid Rocks

The area between the Deadman's Bay pluton and the Newport pluton (Fig. 3) is occupied by a mixture of megacrystic foliated biotite granite, leucocratic foliated granodiorite, migmatite and metasediment. The area is very complex and has not been studied or mapped in detail. The megacrystic granite is highly deformed and in places forms an augen gneiss which has a NNE-striking steeply-dipping foliation. It is similar in many respects to the sheared and foliated granite which bounds the Cape Freels pluton (see Sect. 4.7).

The megacrystic biotite granite is mineralogically similar to the Deadman's Bay pluton, the only difference being the occurrence of hornblende in one sample.

The leucogranite is highly foliated, garnetiferous, biotite-muscovite granodiorite which has a steeply dipping foliation which strikes 030°. The foliation is overprinted in places by small kink bands. Quartz veins and garnetiferous pegmatites are common in the leucogranites, and some have been deformed.

Only one outcrop of the "Ocean Pond pluton" (Uzuakpunwa, 1973), located west of the Deadman's Bay pluton (Fig. 3), has been observed. It is medium grained, garnetiferous, muscovite-biotite granodiorite which exhibits a well developed foliation. Much of the area supposed to be underlain by the pluton is covered by boulders of leucogranite and the outcrops found were composed of high grade schists which contained abundant pegmatites.

[redacted] Cape Freels Pluton

4.7.1. Location, Contact Relations and Deformation

The Cape Freels pluton is an elongate body 20 km. long and 6 km. wide, exposed along the coast from Cape Freels to Badger's Quay. The contact between the pluton and the gneisses to the west is probably a fault with a wide mylonite zone, as shown by the intensely deformed granite along the western margin.

At Badger's Quay, the granite is intensely sheared into chlorite-microcline mylonite gneiss, while 100 m. east the next outcrop is a completely undeformed megacrystic granite. The western margin of this pluton, the most intensely deformed of all examined, is a zone of intense mylonitization which is narrowest at the fault boundary in the south and widens to about 3 km. in the north, where it is clearly shown that the deformation increases from east to west (see Plates 11-19). Although the margins of the pluton in the north of the area are generally deformed to varying degrees, with a prominent biotite foliation striking NNE-SSW, the marginal facies of the Cape Freels pluton range from a uniform megacrystic granite to a blastomylonite and mylonite schist. The variation in intensity of deformation and lithologies over a distance of 3 km. is as follows (the mylonite terminology is after Higgins, 1971).

1. Undeformed orange megacrystic biotite-microcline-plagioclase-quartz-granite (Plate 11).
2. Megacrystic granite with poorly aligned biotites and slightly granulated microcline megacrysts - protomylonite (Plate 12).
3. Orientated microcline megacrysts with biotites orientated parallel to the length of the microcline crystal - protomylonite (Plate 13).
4. Microcline megacrysts and highly granulated quartz with rounded corners and biotite aligned around the megacrysts - mylonite (Plate 14).
5. Granulated microclines, matrix increasing in proportion - porphyroclastic blastomylonite (Plate 15).
6. Completely granulated groundmass of quartz, microline, plagioclase, biotite and chlorite flowing round elongated microcline crystals. Microcline megacrysts half original size - porphyroclastic blastomylonite (Plate 16).
7. Medium grained mylonite with small 2 to 3 mm. microcline crystals in recrystallised matrix of quartz, muscovite, plagioclase and chlorite (some with small kink bands) - ultramylonite (Plates 17, 18).

8. Schistose mylonite with a microcline crystals augened by muscovite and biotite - mylonite schist or phyllonite (Plate 19).

4.7.2. Mineralogy

The pluton is essentially composed of microcline, plagioclase, quartz and biotite in the undeformed areas. As deformation of the granite increases muscovite occurs as large orientated porphyroblasts.

In thin section the granite is composed of megacrystic microcline in granular groundmass biotite, microcline, quartz and plagioclase. Bands of granulated crystals are common in the deformed areas of the pluton.

Microcline occurs as 1 to 4 cm. perthitic subhedral microline and Carlsband twinned laths, with abundant inclusions of quartz, plagioclase and biotite. As deformation becomes more intense, the microline becomes smaller and augened. Tension cracks cut some crystals and these have been veined by polygonal quartz.

Plagioclase occurs as anhedral .5 to 1 cm. crystals with polysynthetic and Carlsbad twins, has a composition of An_{15} to An_{20}, and is variably altered to sericite and epidote.

Quartz forms 2 to 10 mm. anhedral and polygonised crystals. It is often strained, with sutured grain boundaries. In the highly deformed mylonites the quartz is granulated and recrystallised.

Biotite occurs as large 2 to 10 mm. anhedral flakes which are randomly oriented in the undeformed samples and are aligned and augened around microcline in the deformed sections. The biotite is brown to straw-yellow pleochroic and is variably altered to penninite and magnetite, and contains inclusions of quartz and rarely zircon.

Apatite is found throughout the pluton as inclusions in quartz and feldspar.

Muscovite appears in the recrystallised mylonites where, with biotite, it defines the foliation. It forms 1 to 3 mm. anhedral flakes and is concentrated in the deformed and schistose bands. The muscovite is probably metamorphic in origin as no muscovite is found outside the deformed areas.

4.7.3. Dykes and Veins

The pluton is cut by several aplite and granodiorite dykes and pegmatitic quartz veins.

The aplites and granodiorites are highly deformed and show the greatest effects of deformation. They are highly granulated and banded and in places the banding is overprinted by kink bands.

The aplites are cream in colour and the only recognisable mineral in hand specimen is K-feldspar. In thin section the aplites contain quartz, orthoclase and muscovite and show a prominent alignment of muscovite. All crystals are granulated and very irregular.

The granodiorites are also deformed. They are medium grained and contain biotite and plagioclase in addition to quartz, microcline and muscovite. The granodiorite forms northerly-trending dykes with a northerly-striking foliation. Contacts with the granite are sharp but have been deformed.

Pegmatites and quartz veins are restricted to the Cape Freels and Badger's Quay areas. The pegmatites contain megacrysts of quartz, microcline and muscovite, and small red garnets.

The quartz veins are granular and highly irregular in outline. The quartz has been recrystallised to a granoblastic mosaic. Xenocrysts of microcline are found in some of the veins.

Beryl has been found in pegmatites which cut the metasediments just west of western margin of the pluton (Fogwill, 1965, 1970).

Zoned quartz crystals have been found in a 4 cm. thick vein. The quartz is smokey at the centre and clear on the outside of the crystals.

4.8. Middle Brook Pluton (9)

4.8.1. Location, Contact Relations, and Deformation

The Middle Brook pluton extends from Gambo in the south to 2.5 km. north of Indian Bay, in the north, a distance of 44 km. (Fig. 3). The lateral extent of the pluton is uncertain because of differences in interpretation between Jenness (1963) and Williams (1968) as to what is granite and what is metasediment. New road cuts in the Hare Bay area have extended the eastern boundary by at least 5 km. to include areas which were originally assigned to the lower unit of the Gander Lake Group and the Love Cove Group by Jenness (1963). The pluton varies in width from 5 km. in the Trinity area to at least 18 km. in the Hare Bay area, giving the pluton an area of 350 to 450 km.^{2}. The pluton is bounded to the south by an area of migmatites and gneisses which have been intruded by the granite along the north shore of Freshwater Bay. The country rocks may be rafts or roof pendants or faulted blocks. The Freshwater Bay pluton to the south is probably a continuation of the Middle Brook pluton but has been treated here as a separate pluton.

The pluton intrudes and hornfelses the metasediments of the gneissic terrain at Middle Brook, where at the Salmon Pool in the Provincial Park, coarse grained granite intrudes psammitic schist. The schist has been recrystallised and the foliation destroyed. There is no veining of the schist by the granite and the granite is undeformed.

On Air Island, Freshwater Bay (Fig. 2), a large mass of migmatite is found 'floating' in the granite, presumably as a roof pendant or a raft.

Towards the eastern margin of the pluton the granite becomes progressively more deformed. Undeformed megacrystic granite develops a pronounced northerly-striking steeply-dipping foliation. Bands of granulated granite with porphyroclasts of microcline cut the granite and, the granite becomes mylonite gneiss with porphyroclastic blastomylonite veins (Plate 20). Aplite dykes show a strongly developed banding giving the apparance of an ultramylonite (Plate 21). This marginal increase in deformation is similar to that of the Cape Freels pluton (see 4.7.1.).

In the undeformed state, the granite varies from coarse grained to megacrystic biotite granite. The foliated granite is megacrystic with well-developed alignment of microcline and biotite. Areas of epidotised granite occur one kilometre north of Middle Brook.

4.8.2. Mineralogy

The Middle Brook pluton is composed of essentially four minerals - microcline, plagioclase, biotite and quartz, with microcline the dominant mineral.

Microcline occurs as buff to pink subhedral 1 to 4 cm. megacrysts and anhedral 3 mm. to 1 cm. crystals in the groundmass. One to 2 mm. inclusions of biotite are common with rare pyrite. In thin section the microcline is subhedral to anhedral with variably developed microcline twinning and simple Carlsbad twins. String and patch perthites are developed in some sections. Large blebs of quartz and granophyric intergrowths occur only in samples from the contact at Middle Brook. In the deformed areas the microcline crystals are rounded and elongated parallel to the foliation, and the granite is a protomylonite.

Plagioclase forms white to yellow-green 1 to 2 cm. megacrysts and 2 to 5 mm. irregular crystals in the groundmass. In thin section the crystals are subhedral to anhedral with well developed polysynthetic and Carlsbad twins, and a composition of An_{18} to An_{22}, with variable alteration to sericite and epidote. In the deformed samples the quartz is granulated and polygonised with sutured grain boundaries in the less deformed samples.

Biotite forms rounded 2 to 4 mm. books and 1 to 3 mm. irregular flakes. It shows dark brown to straw-yellow pleochroism with halos around tiny inclusions of zircon, and is variably altered to chlorite. Biotite in the foliated granite shows a prominent alignment and augens microcline and plagioclase.

Apatite and rarely sphene also occur as accessory minerals.

4.8.3. Dykes and Pegmatites

Granodiorite and quartz diorite dykes and sills are common throughout the Middle Brook pluton and they vary in size from a few centimeters to over one kilometer in width. The granodiorite dykes and sills are generally about 30 cm. wide, fine to medium grained, and composed of quartz, muscovite, biotite, plagioclase and orthoclase. Sporadically distributed microcline crystals in the granodiorite are probably xenoliths from the megacrystic granite. The granodiorite dykes and sills commonly have a tectonic fabric with an orientation similar to the regional trend.

A large, 100 m. wide medium grained, grey diorite dyke cuts the protomylonites north of Hare Bay. It contains veins of barite, but is otherwise similar to a diorite dyke about 3 km. farther north and may be a continuation of it.

A large NW-striking quartz diorite dyke with abundant xenoliths of granite cuts the megacrystic granite in the Lond Pond - Traverse Brook area. It is about 1 km. wide and 3 km. long. The major minerals are plagioclase (An_{40}), biotite, hornblende, quartz, apatite and magnetite. The ferromagnesian minerals are partially altered to chlorite.

Small coarsely crystalline tourmaline-bearing pegmatites are common north of Middle Brook. The pegmatites contain tourmaline, quartz, microcline and rarely muscovite. The tourmaline crystals are 2 to 8 mm. long and occur as patches in the pegmatite.

[redacted] The Newport Pluton (10)

4.9.1. Location, Contact Relations, Main Lithologies and Deformation.

The Newport pluton is situated between Pool's Harbour and Lewis Island (Williams, 1968) (Fig. 3). It is approximately 25 km. long and up to 15 km. wide and has an exposed area of 160 $km.^2$.

The pluton intrudes the gneisses and migmatites of the gneissic terrain with clear contacts shown on the northern shore of

Indian Bay and the northern shore of Trinity Bay. At the Indian Bay contact the coarse grained biotite-granite and gneiss have a vertically-dipping, northerly-striking contact. Medium grained granitoid veins cut the gneiss, and these can be traced into the pluton. The gneiss has a granular texture which can be attributed to recrystallisation during intrusion of the pluton. The veins have been folded.

On the north shore of Trinity Bay, north of Lewis Island, polydeformed metasediments have been intruded by coarse grained granite. A melanocratic granitoid dyke has been intruded along parts of the contact. The granite is finer grained at the contact than in the body of the pluton. The metasediments have been hornfelsed, with the fabric partially destroyed and cut by veins of quartz and pegmatite.

The pluton appears to be cut by major east-west faults which have displaced the contact by approximately 5 km. along Indian Bay. Block faults occur along the peninsula south of Indian Bay. The blocks are about 60 to 100 m. wide and are marked by 20 to 40 m. high vertical cliffs striking WSW.

The pluton is composed of medium and coarse grained to mega-crystic biotite granite which in the south is highly deformed. On Lewis Island much of the area mapped as the lower unit of the Gander Lake Group (Jenness, 1963) is actually very coarse grained mylonite gneiss which has a NNE-striking, steeply-dipping foliation. The deformation appears to increase westwards from the centre of the island, with increasing alignment and granulation of quartz, biotite, microcline, and plagioclase, and gradual decrease in grain size. The deformation is probably related to local marginal mylonitisation, as no deformation is apparent at the contact to the north.

Xenoliths of metasediment are rare, but some large biotite-rich slabs of schist occur in massive granite on the east of Lewis Island. The schistosity of metasediment is unaffected by the deformation of the granite 500 m. to the west (see Plate 22).

4.9.2. Mineralogy

The Newport pluton consists of essentially four minerals, with microcline occurring as megacrysts in a granular groundmass of quartz, microcline, plagioclase and biotite.

Microcline forms 1 to 4 cm. long pink subhedral megacrysts and 2 to 5 mm. long euhedral crystals in the groundmass. Carlsbad twins are well developed and microcline twinning is variably developed. Mantles of plagioclase on the microcline are common near the contact on the southern shore of Indian Bay. Inclusions of the other minerals are common. String and patch perthites are common in the foliated granite on Lewis Island, and the microcline is aligned and augened by biotite and flattened quartz, and alteration to sericite is common. The size of the megacrysts decreases westwards.

Plagioclase forms 2 to 10 mm. sub-to anhedral crystals with well-developed polysynthetic and Carlsbad twins, and has a composition of An_{20} to An_{25}. Oscillatory zoned plagioclase was found in one section. Inclusions of biotite and quartz are common and the plagioclase is variably altered to sericite and epidote.

Biotite occurs as abundant 1 to 3 mm. flakes and as 1 mm. thick books. In thin section the biotite is anhedral with dark brown to straw-yellow pleochroism and in some sections pleochroic halos around inclusions of zircon. In the deformed areas the biotite is aligned in a northerly direction and occurs as much larger flakes augened around microcline. The biotite is variably altered to chlorite and magnetite.

Quartz occurs as 1 to 5 mm. anhedral and polygonised crystals with wavey extinction. Inclusions of plagioclase are common. In the deformed samples quartz occurs as elongate and granulated and polygonised aggregates with a northerly alignment.

Accessory minerals include apatite which occurs as tiny needles, and rarely sphene.

4.9.3. Dykes

Few dykes were observed in the pluton. On Lewis Island an orange, very coarse grained granite dyke cuts the pluton in a northerly direction. The granite is composed dominantly of quartz and microcline with minor plagioclase and biotite. Granophyric quartz-albite intergrowths are common. The significance of this dyke, with regard to the genesis of the megacrystic granite, is that it suggests that very coarse grained granite can be produced from a melt and does not require potassium metasomatism for the formation of microcline-megacrystic granite, only very slow cooling.

4.10. Gander Lake West Plutons (11)

4.10.1. Location and Main Lithologies and Deformation

The Gander Lake West plutons are two small bodies situated about 10 km. southwest of Gander (Fig. 3). The western pluton is elongate, trending NNE, 15 km. long and 5 km. wide, and bifurcates in the northern half to form two prongs about .5 km. wide and 5 km. long (McGonigal, 1973). The easterly pluton is roughly circular and is about 6 km. in diameter.

The plutons are composed of medium grained, granular, foliated, leucocratic muscovite-granodiorite which is locally garnetiferous. The plutons intrude the schists of the metasedimentary terrain between development of the S_1 and S_2 schistosities, and they contain the S_2 and S_3 schistosities (McGonigal, 1973; Kennedy and McGonigal, 1972a). The strike of the foliation is dominantly NNE, parallel to the schistosity of the metasediments. The plutons are therefore taken as syntectonic.

4.10.2. Mineralogy

The main minerals in the pluton are biotite, muscovite, quartz, plagioclase and K-feldspar.

Biotite occurs as 1 to 2 mm. anhedral flakes with straw-yellow to brown pleochroism. Tiny inclusions of zircon are common in the biotite and are surrounded by pleochroic halos. In places the biotite is found interleaved with muscovite.

Muscovite forms 1 to 3 mm. anhedral flakes and 1 mm. thick 'books'. The muscovite crystals are generally larger than the biotite crystals. The micas are well aligned and define the foliation.

Plagioclase forms 1 to 2 mm. anhedral crystals which have well-developed polysynthetic and Carlsbad twins, and a composition of An_{15} to An_{20}. Intergrowths of twinned and untwinned oligoclase are found in some sections. The plagioclase is variably altered to sericite and epidote. Alkali feldspar occurs as orthoclase and microcline, with various intermediate stages of development of microcline twinning. Microcline generally forms 2 to 4 mm. anhedral crystals which have inclusions of quartz and plagioclase. Orthoclase occurs as anhedral 1 to 2 mm. crystals. The alkali feldspars are slightly sericitised.

Quartz is the major mineral in the rock, and occurs as 1 to 2 mm. anhedral crystals with sutured edges and uneven extinction, and contains rare inclusions of plagioclase.

Small 1 mm. round garnets are common.

4.10.3. Pegmatites and Aplites

The plutons are cut by numerous pegmatite and aplite veins. The pegmatites are very coarse grained and composed of quartz, alkali feldspar, and muscovite, with minor ruby-coloured garnets. The pegmatites do not show any fabric. In the south of the eastern pluton the pegmatites and aplites are medium grained and granular with 1 to 2 mm. crystals of quartz, orthoclase, plagioclase (An_{15}) and muscovite, with minor euhedral garnets.

[redacted] Gander Lake Pluton (12)

4.11.1. Location, Contact Relations and Main Lithologies

The Gander Lake pluton is an approximately circular, poorly exposed pluton situated 15 km. southeast of Gander, and underlying an area of approximately 500 $km.^2$ (Fig. 3). The pluton intrudes schists of the metasedimentary terrain, and the contacts are clearly shown in three places. On the Trans Canada Highway, the western contact is intrusive with a chilled marginal facies, granitoid tourmaline-bearing veins intruding the country rocks with the production of a hard hornfels of andalusite and staurolite grade. The eastern contact on the Trans Canada Highway is a fault which brings granite against metasiltstone. The siltstone at the contact is a highly sheared talcose chloritic schist and the granite is shattered with a cubic fracture pattern. There is only a slight decrease in grain size towards the margin, with quartz becoming the main phenocryst phase. Three km. northwest of North Pond the contact between the metasediment and the granite appears to be a fault. Megacrystic granite continues right to the contact where a fine grained banded dyke intervenes between the granite and the metasediments. A granitoid dyke also intrudes along the contact. The contact is not seen on the southeast margin of the pluton but the granite near the contact is highly recrystallised and veined with microcrystalline quartz.

The numerous fault contacts and deformed marginal facies show that the pluton has suffered much post-emplacement disturbance and may be for the most part fault bounded.

The pluton contains three distinct varieties of granite, (a) coarse grained biotite-muscovite granite (Plate 23), (b) megacrystic porphyritic medium grained biotite granite (Plate 24), (c) megacrystic biotite granite (Plate 25).

4.11.2. Mineralogy

(a) The coarse grained biotite-muscovite granite occurs in the northeast corner of the pluton east and south of Gander Lake. The granite is orange to pink and composed of biotite, muscovite, quartz, plagioclase and microcline. It has a poorly developed penetrative fabric and fractured crystals towards the eastern contact which may be related to the fault. Xenoliths of biotite schist are common.

Biotite occurs as 2 to 6 mm. books which are 1 to 2 mm. thick and as .1 to .5 mm. flakes which occur in patches. In thin section the biotite is subhedral to anhedral, dark brown to straw pleochroic with dark brown halos around zircon inclusions. It is variably altered to chlorite and magnetite.

Muscovite occurs as .5 to 3 mm. flakes with some flakes intergrown with biotite.

Microcline occurs as 1 to 2 cm. phenocrysts and as anhedral 1 to 2 mm. crystals in the groundmass. The phenocrysts are well formed and in thin section have variably developed microcline twins and good

Carlsbad twins. Biotite inclusions are common in the phenocryst and groundmass microclines. Biotite crystals are found in some samples concentrated around the edges of the microcline phenocrysts. 1 to 2 mm. stringers of plagioclase are found in some of the phenocrysts.

Plagioclase forms 1 to 4 mm. anhedral to subhedral crystals with well developed polysynthetic and Carlsbad twins, and have a composition of An_{18} to An_{22}. Alteration to sericite is restricted to the edges of some crystals and the cores of others.

Quartz occurs as rounded to irregular 1 to 5 mm. crystals, and near the eastern contact, cracks cut most crystals, reflecting cataclasis of the granite. Quartz varies from colourless to grey and small inclusions of biotite are common.

(b) The porphyritic medium-grained biotite granite crops out along the southern shore of Gander Lake west of the biotite-muscovite granite. The distinctive feature of the granite here is the prominent alignment of 1 to 4 cm. microcline phenocrysts and xenoliths of biotite schist in a WSW direction.

The alignment of phenocrysts and xenoliths is probably due to flow during intrusion rather than a tectonic orientation, as the rocks show no sign of deformation and the biotite has a random orientation.

The granite varies in colour from black and white to pink and green, reflecting the variable alteration of the feldspars to sericite and epidote (see Plates 24 and 26).

Locally the plagioclase has been completely epidotised in zones where veins of epidote cut the granite, and the microcline is dull pink because of oxidation of iron. The change from fresh white granite to epidotised granite occurs over distance of a few meters.

Near the mouth of Joe's Brook, the granite is orange-pink in colour and contains abundant xenoliths of biotite-muscovite schist. The muscovite crystals found in the granite are not magmatic in origin but are derived from tiny xenoliths of schist.

The dominant mineral in the granite is microcline, which in some samples forms over 50% of the rock. The phenocrysts are subhedral to anhedral in thin section and have well developed microcline and simple Carlsbad twins. Inclusions of biotite, quartz and plagioclase are common in the phenocrysts. The groundmass microcline is anhedral and microcline-twinned and also contain inclusions of the other components.

Quartz forms rounded to irregular 1 to 3 mm. crystals. Granophyric quartz-K-feldspar intergrowths are common in some samples.

Plagioclase forms 1 to 3 mm. subhedral to anhedral crystals with well developed polysynthetic and Carlsbad twins, and has a composition of An_{18} to An_{20}. In the epidotised samples there is no trace of the original plagioclase crystals.

Biotite forms 1 to 3 mm., randomly orientated, flakes with brown to straw-yellow pleochroism,and with rare pleochroic halos around inclusions of zircon. In the epidotised samples the biotite has been completely altered to chlorite.

Accessory apatite is common.

(c) The megacrystic biotite granite is located in the south-west of the pluton in the North Pond area. It is very similar to the megacrystic granites of the gneissic terrain and is composed of microcline, quartz, biotite and plagioclase. Locally, the granite is cataclastically deformed and foliated and recrystallised. Quartz and feldspar crystals are fractured and in thin section quartz has sutured grain boundaries and uneven extinction.

Locally the granite is miarolitic with some vugs and joints coated with purple fluorite.

The dominant mineral is microcline which forms 1 to 4 cm. megacrysts and 1 to 5 mm. crystals in the groundmass. It rarely shows microcline twins and has Carlsbad twins. The microcline contains a few inclusions of quartz, biotite, and plagioclase.

Plagioclase forms 1 to 4 mm. subhedral to anhedral crystals with prominent polysynthetic and Carlsbad twinning. In some crystals the twin lamellae are bent, reflecting deformation of the granite. The plagioclase has a composition of An_{18} to An_{20} and is altered to sericite and epidote.

Biotite forms 1 to 3 mm. flakes and books which are completely altered to chlorite.

Quartz forms 2 to 10 mm. rounded and anhedral crystals. In the mylonitised samples the quartz is elongated parallel to the foliation. Polygonised and microcrystalline quartz veins cut the granite in the south of the pluton.

4.11.3. Dykes, Pegmatites and Veins

The only dyke seen in the pluton is that which is intruded along the contact of the megacrystic biotite granite with the metasediments. The dyke is granodioritic, composed of muscovite, biotite, quartz, plagioclase and orthoclase.

Aplite and quartz veins are abundant at this locality. The veins have been intruded along the joints in the granite and strike at 280^{o} and 210^{o}, and patches of fluorite also occur in these joints (see Plate 25).

In a quarry east of the margin of the pluton, foliated tourmaline-bearing pegmatites intrude the schists. Two phases of pegmatite intrusion can be recognized, but it is uncertain if these pegmatites are related to the pluton.

4.11.4. Discussion

The three distinct varieties of granite which form the Gander Lake pluton complicate the simple relationship between the schists of the metasedimentary terrain and the pluton as set out by Kennedy and McGonigal (1972a) and McGonigal (1972). The pluton was considered by them to be Devonian as it post-dated the development of the fabrics in the metasediments. It is probable that there are three distinct intrusions, and as some of the granites are deformed, they may have a pretectonic or syntectonic origin and similar age to the megacrystic granites of the gneissic terrain. The hornfelsing of the metasediments has been observed only to the north of the pluton and may be related to the intrusion of the porphyritic biotite granite which is undeformed and therefore probably younger than the medium grained biotite-muscovite granite and the megacrystic biotite granite.

[redacted] Freshwater Bay Pluton (13)

4.12.1. Location, Deformation and Main Lithologies

The Freshwater Bay pluton is an irregular shaped body which extends from Freshwater Bay to Lake St. John, a distance of 75 km. (Fig. 3). It is a maximum of 23 km. wide and has an approximate area of 700 km.^{2}. Exposure of the pluton is very limited and only on Terra Nova Lake and Freshwater Bay is there reasonably continuous exposure.

The main lithology in the pluton is a mesocratic to leucocratic coarse grained to megacrystic granite.

The pluton intrudes the gneisses and metasediments of the gneissic terrain. No contacts of the pluton have been observed, but near the eastern contact on Freshwater Bay there is a 60 m. wide zone of intense faulting, brecciation, mylonitisation, and diorite and granite dyke intrusion. The western contact is hidden by Gambo Pond, which is a narrow steep-sided elongate lake that may be a zone of faulting which has permitted preferential erosion.

Along the southern boundary of the pluton on Terra Nova Lake the megacrystic granite is foliated in a NNE direction with a well developed tectonic orientation of microcline megacrysts. The granite there is not as deformed as at the northern contact. The northeasterly direction is also followed by small pegmatites, veins and minor faults. The break in topography along the contact on Terra Nova Lake parallels the foliation in the granite and similarly suggests a tectonic boundary for granite in this area.

On Doctor Island, Freshwater Bay, the granite is deformed and forms a mylonite gneiss. The foliation is steeply dipping and openly folded around a northerly striking axis.

Various types of cataclastic rock have been formed at the eastern contact. Fault breccia composed of 5 to 20 cm. angular fragments of granite have been intruded by an anastomosing diorite dyke to produce a network of diorite with abundant granite fragments. The mylonite gneiss contains microcline porphyroclasts, with biotite and mylonitised quartz, plagioclase and microcline flowing round the porphyroclasts.

A 3 m. band of mylonitised granite shows a progressive deformation from protomylonite to mylonite gneiss to blastomylonite, with deformation increasing from east to west, giving the rock a graded appearance.

South of the mylonitised area, the granite is medium grained with a well developed foliation (Plate 27). Thin section analyses show that the foliation is not cataclastic in origin but is caused by local flattening.

4.12.2. Mineralogy

The dominant mineral of the granite is microcline, which occurs as 1 to 4 cm. megacrysts and as anhedral 1 to 5 mm. crystals in the groundmass. Carlsbad twinning is prominent in the megacrysts and microcline twinning is variably developed. String and patch perthites were found in a few megacrysts. Some of the exsolved plagioclase is Carlsbad and albite twinned and forms rectangular patches. Tension cracks cut the microcline megacrysts reflecting deformation in the Terra Nova Lake area. These have been filled by microcrystalline quartz. Alteration to sericite and kaolin is common.

Plagioclase is restricted to the matrix of the megacrystic granite and forms 1 to 6 mm. subhedral and anhedral crystals. Polysynthetic and Carlsbad twins are well developed, and the plagioclase has a composition of An_{18} to An_{25}. Some of the plagioclase shows faint normal zoning with alteration to sericite and epidote restricted to the cores.

Quartz forms rounded to irregular 1 to 5 mm. crystals in the undeformed samples and granulated .2 to 1 mm. crystals in the mylonitised samples. Recrystallisation to form polygonised .5 to 1 mm. crystals and microcrystalline patches of quartz are common.

Biotite forms 2 to 3 mm. books and 1 to 2 mm. flakes with straw-yellow to brown pleochroism, and inclusions of quartz and plagioclase are common. It is variably altered to chlorite and magnetite. In the protomylonites biotite defines the foliation and is bent and kinked.

4.12.3. Dykes and Pegmatites

The only dykes found in the pluton occur at the north-east contact where diorite and granodiorite dykes cut the brecciated and mylonitised granite.

The diorite is medium grained, dark green and composed dominantly of hornblende, biotite, and plagioclase with quartz seen only in thin section.

The granodiorite contains hornblende and biotite with quartz, plagioclase and microcline phenocrysts. It is relatively basic, containing only 60% SiO_2.

Pegmatite veins were formed near the southeast contact. They are composed of quartz, microcline, and plagioclase with minor muscovite and biotite.

[redacted] Terra Nova Pluton (14)

4.13.1. Location, Contact Relations and Main Lithologies

The Terra Nova pluton is roughly triangular in outcrop and underlies an area of approximately 80 $km.^2$ around Terra Nova village (Fig. 3). The pluton is about 20 km. long and a maximum of 10 km. wide.

The pluton intrudes the metasediments of the Love Cove Group to the west and the Musgravetown Group to the east. No contacts can be observed but at the southeast corner of Pitts Pond the Musgravetown Group greywackes have been thermally metamorphosed to biotite grade, with the production of a massive hornfels, and the rocks are cut by quartz-feldspar pegmatites.

The pluton is composed of coarse grained to megacrystic biotite granite. The eastern half of the pluton, east and southeast of Terra Nova is composed dominantly of megacrystic granite with microcline megacrysts up to 8 cm. in length in a coarse grained equigranular groundmass of quartz, microcline, plagioclase and biotite. Locally there is a well developed alignment of microcline megacrysts which are closely packed together like building bricks (see Plate 28). This is probably a primary feature formed by flowage, as the granite shows little sign of deformation.

The western half of the pluton is composed dominantly of coarse grained equigranular biotite granite with abundant 3 to 8 mm. quartz crystals.

4.13.2. Mineralogy

The microcline occurs as pink to orange, 2 to 8 cm. megacrysts and as euhedral 2 to 10 mm. anhedral crystals in the coarse grained granite and the groundmass of the megacrystic granite. Microcline twinning is variably developed and simple Carlsbad twins bisect the megacrysts. String perthites occur in some crystals. Inclusions of quartz and biotite are common and the microcline is variably altered to sericite.

Quartz forms 2 to 8 mm. rounded to anhedral crystals. They are more abundant in the coarse-grained granite than the megacrystic granite.

Plagioclase varies from 2 to 4 mm. in the coarse grained granite and up to 1 cm. crystals in the megacrystic granite. The crystals are subhedral to anhedral and have well developed polysynthetic and Carlsbad twinning and a composition of An_{16} to An_{20}. The plagioclase is variably altered to sericite and epidote.

Biotite forms 1 to 3 mm. books which are common in the megacrystic granite, and .5 to 2 mm. flakes. The crystals are anhedral with straw to brown pleochroism, and variably alteration to chlorite and magnetite. Microscopic crystals of purple fluorite are found associated with the chlorite in one sample. The fluorite may have resulted from the breakdown of biotite and feldspar which would give free F^- and Ca^{2+} ions combine to form fluorite.

4.13.3. Dykes and Veins

In the northwest of the pluton a highly altered diabase dyke cuts the pluton. On Terra Nova Lake, 30 cm. wide medium grained granodiorite dykes cut the pluton and strike east-west. Coarse grained quartz-rich granite dykes are common in the southwest of Pitts Pond. Veins of epidote are abundant throughout the pluton.

[redacted] Terra Nova River (15) and Terra Nova River West Plutons (16)

4.14.1. Location and Main Lithologies

The Terra Nova River and Terra Nova River West plutons are two small NNE striking elongate granitoid intrusions 15 km. WSW of Terra

Nova. Their areal extents are uncertain but are estimated to be 2 to 3 $km.^2$ with a maximum width of 1 km. The plutons intrude the schists and gneisses of the gneissic terrain but no contacts have been found.

The Terra Nova River pluton has only been located in two outcrops in the distributaries of the Terra Nova River and does not extend as far south of the estuary as shown by Jenness (1963). The pluton consists of a variety of granitoid rocks of varying grain size ranging from pegmatitic to medium grained pink muscovite-biotite granodiorite.

The Terra Nova River West pluton is exposed along a ridge 2 km. north of the Terra Nova River pluton, and is composed of medium grained orange-pink foliated muscovite-biotite granodiorite (see Plate 29). The pluton has a well developed NW-striking steeply dipping foliation which parallels the dominant schistosity in the schists, and the pluton is therefore pre- or syntectonic in origin. The minerals are aligned and elongated.

4.14.2. Mineralogy

Medium grained granodiorite is the main lithology and is composed of muscovite, biotite, microcline, plagioclase and quartz.

Biotite forms 1 to 3 mm. anhedral flakes which show dark brown to straw pleochroism,with brown pleochroic halos around inclusions of zircon, and is variably altered to penninite and magnetite.

Muscovite is more abundant than biotite and occurs as anhedral 1 to 3 mm. flakes, some of which are bent and broken.

Microcline forms 1 to 4 mm. anhedral crystals with partially developed microcline twinning. It is slightly altered to sericite and contains inclusions of the other components.

Plagioclase occurs as 1 to 2 mm. subhedral to anhedral crystals with well developed polysynthetic and Carlsbad twins, and an approximate composition of An_{20}. It is partially altered to sericite and epidote.

Quartz forms anhedral 1 to 2 mm. crystals, with strained extinction reflecting deformation.

4.14.3. Pegmatites and Veins

The Terra Nova River pluton is cut by NW trending 10 cm. wide muscovite-rich pegmatites. Quartz veins cut the Terra Nova River West pluton.

[redacted] Middle Ridge Pluton (18)

4.15.1. Location, Main Lithologies and Deformation

The Middle Ridge pluton is an elongate NW-striking intrusion located 25 km. southwest of Gander which extends 75 km. to the Bay d'Espoir Highway southwest of Great Gull Lake, and has an average width of 8 km. The pluton underlies an area of approximately 650 $km.^2$.

The pluton intrudes the high grade garnet-mica schists of the metasedimentary terrain but there is apparently no hornfelsing effect. The northwest contact is reported by Murray and Howley (1881) to be a thrust and/or unconformity.

The main lithology of the pluton is medium to coarse grained equigranular leucocratic foliated garnetiferous muscovite-biotite granite and granodiorite. The northeast corner of the pluton is composed of orange, very coarse grained biotite-muscovite granite.

The medium grained granite and granodiorite are highly foliated with deformation expressed throughout by a prominent alignment of mica and elongation of quartz and feldspar parallel to the north-east-striking schistosity of the country rocks and suggest a pre- or syntectonic origin for the pluton.

The orange coarse grained granite appears undeformed, but thin section analysis show that the quartz has completely recrystallised and veins of microcrystalline quartz cut through the microcline crystals.

4.15.2. Mineralogy

The pluton is composed of the six minerals characteristic of the leucogranites, viz. muscovite, biotite, microcline, plagioclase, quartz and garnet. The muscovite:biotite ratio varies from 2:1 to 1:3 in the leucocratic granite and granodiorite and is about 1:1 in the orange granite.

Muscovite varies in size from 1 to 4 mm. and forms flakes and 2 mm. thick books. The finer grained leucogranite contains 0.2 to 0.5 mm. flakes. In thin section the muscovite is anhedral with the cleavage kinked and bent.

Biotite varies in size from 1 to 3 mm. and occurs as 1 mm. thick books and single flakes. In some of the samples biotite is absent. In thin section the biotite is anhedral with brown to straw pleochroism and dark pleochroic halos around the numerous inclusions of zircon. Small inclusions of quartz are found in some flakes. The biotite is variably altered to chlorite and magnetite.

Microcline occurs as 3 to 8 mm. crystals in coarse grained granite and as 2 to 5 mm. crystals in the finer grained granitoid rocks. In thin section the microcline is subhedral to anhedral with well developed microcline and Carlsbad twins. Round and lobate inclusions of quartz are ubiquitous with rare muscovite, biotite and plagioclase. Variable alteration to sericite occurs in a few samples.

Plagioclase occurs as 1 to 3 mm. subhedral to anhedral crystals with well developed polysynthetic and Carlsbad twins, and has an approximate composition of An_{18} to An_{22}. Inclusions of biotite and muscovite are common and alteration to sericite and epidote is variable.

Quartz occurs as anhedral colourless 1 to 5 mm. crystals. In the finer grained samples quartz forms 3 to 5 mm. phenocrysts. Samples from the northeast of the pluton contain polygonised and recrystallised quartz. Myrmekitic intergrowths of quartz and feldspar are common in the more leucocratic samples.

Garnet is most common in the biotite-poor granitoid rocks where it occurs in bands and as scattered crystals. The crystals are .5 to 1.5 mm., pink to ruby coloured, euhedral, and are commonly fractured.

In one sample small 0.5 mm. euhedral crystals of anorthoclase were found. They contained inclusions of plagioclase.

4.15.3. Pegmatities, Veins and Aplites

Small quartz veins are common throughout the pluton.

The pegmatites and aplites vary from 2 cm. to 20 cm. in width and are composed of quartz, microcline, garnet, and muscovite and in places beryl. Graphic intergrowths of quartz and feldspar are common in the pegmatites. The beryl forms light green 2 to 3 mm. hexagonal crystals.

The aplite dykes are 10 to 20 cm. in width and have a granular texture. Many of the dykes are zoned with coarse grained margins and fine grained garnet-rich centres.

CHAPTER 5

GEOCHEMISTRY

5.1. Introduction

The granitoid rocks of the study area have been divided into three main petrographic types (sect. 4.2.), viz. quartz diorite, leucocratic granodiorite, and megacrystic biotite granite. The main features of each type are:

1. Quartz Diorite
   - high content of hornblende and biotite
   - plagioclase the only feldspar
   - absence of muscovite
   - moderate to high quartz content

2. Leucocratic Granodiorite (Leucogranite)
   - no hornblende, low biotite content
   - plagioclase and K-feldspar varying in proportion from 10:1 to 1:3
   - muscovite common
   - moderate to high quartz content

3. Megacrystic Biotite Granite
   - no hornblende, high content of biotite
   - microcline the dominant feldspar, especially as large megacrysts
   - absence of muscovite
   - moderate to high quartz content.

[redacted] Chemical Features of the Granitoids

5.2.1. Main Chemical Characteristics of Each Group

The petrographic differences are reflected in the chemistry, with the quartz diorite having more "basic" chemical characteristics, the leucogranites having the least "basic" characteristics, and the megacrystic biotite granite having intermediate characteristics. This is best illustrated by the silica content, with the quartz diorites having a mean of 62.72%, the leucogranites 71.94%, and the megacrystic granites containing 68.25% (Table 5).

Other elements such as Ca, K, Fe, Mg, Mn, Rb, and Sr, vary with silica content and likewise reflect the differences between the three types (Table 5). Calcium is high in the quartz diorites averaging 6.72%. In the leucogranites calcium is very low averaging only 0.99%, with the megacrystic granites averaging 1.91% (Table 5). Strontium, which is similar to Ca in ionic properties, is likewise highest in the quartz diorites with a mean of 342 ppm, lowest in the leucogranites at 65 ppm, with the megacrystic biotite granites intermediate at 201 ppm (Table 5).

K_2O is lowest in the quartz diorites at 1.26%. The leucogranites contain 4.19% K_2O and the megacrystic biotite granite 4.76% K_2O (Table 5). The leucogranites, are therefore lower in potash than the megacrystic biotite granites, the reverse of what is expected. Rubidium generally follows potassium and is low in the quartz diorites at 49 ppm, but highest in the leucogranites which contain 288 ppm, and intermediate in the megacrystic granites at 225 ppm (Table 5). K:Rb ratios decrease with increasing silica content, the quartz diorites having

TABLE 5

Major Element and Trace Element Means with Number of Analyses and One Standard Deviation for the Plutons, Groups of Plutons, and Overall Mean Analysis.

Oxide Wt.% Pluton Number	SiO_2	n	s	TiO_2	n	s	Al_2O_3	n	s	Fe_2O_{3tot}	n	s	MnO	n	s	MgO	n	s	CaO	n	s	Na_2O	n	s	K_2O	n	s	P_2O_5	n	s	L.O.I.	n	s	Total
A (2) qd	64.11	17	1.87	0.40	17	0.09	16.11	17	0.74	4.15	17	0.68	0.09	17	0.02	2.27	17	1.36	5.48	17	1.62	3.42	17	0.38	1.24	17	0.22	0.11	17	0.11	1.32	7	0.47	98.70
B (3) qd	60.57	11	2.26	0.51	11	0.07	15.34	11	0.85	5.54	11	0.78	0.11	11	0.01	2.23	11	0.36	8.63	11	1.64	3.51	11	0.11	1.28	11	0.25	0.31	11	0.07	N.D.			98.03
C (4) lg	75.43	6	0.91	0.04	6	0.04	14.08	6	0.64	1.11	6	0.35	0.08	6	0.02	0.67	6	0.28	0.49	6	0.27	4.08	6	0.18	3.92	6	0.53	0.01	6	0.02	0.90	1	0	100.81
D (5) lg	68.79	4	0.74	0.37	4	0.15	15.38	4	0.73	3.38	4	0.31	0.11	4	0.02	0.87	4	0.58	3.06	4	1.29	3.60	4	0.77	3.31	4	1.20	0.11	4	0.01	N.D.			98.98
E (6) lg	71.62	13	2.80	0.18	13	0.12	15.15	13	0.69	1.60	13	0.99	0.04	13	0.03	0.80	13	0.30	1.23	13	0.89	3.80	13	0.99	4.03	13	0.93	0.08	13	0.10	1.08	7	0.43	100.69
F (7) mg	68.34	57	3.30	0.62	57	0.28	14.35	57	0.94	3.63	57	1.33	0.09	57	0.04	1.16	57	0.56	1.65	57	0.83	3.30	57	0.47	4.77	57	0.73	0.12	57	0.08	1.35	27	0.44	99.38
G (8) mg	69.18	29	2.96	0.43	29	0.27	14.29	29	1.03	2.79	29	1.41	0.06	29	0.03	1.01	29	0.38	1.31	29	0.76	2.98	29	0.83	5.22	29	0.63	0.08	29	0.06	1.05	20	0.48	98.40
H (9) mg	64.23	36	4.92	0.81	36	0.46	14.52	36	1.37	5.09	36	2.02	0.10	36	0.03	1.88	36	0.79	3.51	36	2.37	2.98	35	0.37	4.40	36	0.97	0.23	36	0.13	1.42	18	0.63	99.17
J (10) mg	68.66	14	3.76	0.48	14	0.25	14.10	14	1.42	2.97	14	1.15	0.11	14	0.18	1.29	14	0.84	1.59	14	0.88	3.26	14	0.44	5.26	14	1.04	0.10	14	0.10	1.01	5	0.39	98.85
K (11) lg	71.59	3	0.67	0.19	3	0.11	15.47	3	1.77	1.35	3	0.24	0.06	3	0.03	0.65	3	0.57	0.48	3	0.28	3.61	3	0.48	4.27	3	1.74	0.00	3	0.00	1.90	1	0	99.57
L (12) mg	70.44	26	4.47	0.39	26	0.30	14.30	26	1.08	2.61	26	1.74	0.06	26	0.03	1.01	26	0.48	0.89	26	1.07	3.28	26	1.09	4.65	26	0.55	0.06	26	0.07	0.99	16	0.34	98.68
M (13) mg	66.98	23	6.98	0.65	23	0.47	14.78	23	1.72	3.61	23	2.63	0.09	23	0.04	1.70	23	1.23	3.08	23	2.76	3.31	23	0.42	4.26	23	0.91	0.16	23	0.18	0.37	1	0	98.99
N (14) mg	72.19	20	4.15	0.26	20	0.16	13.23	20	2.24	1.81	20	0.76	0.04	20	0.02	0.85	20	0.92	0.87	20	0.61	3.41	20	0.48	5.13	20	0.49	0.03	20	0.11	N.D.			97.82
P (15) lg	70.88	6	2.88	0.36	6	0.23	13.52	6	0.77	2.30	6	0.98	0.07	6	0.02	0.50	6	0.59	0.76	6	0.38	3.12	6	0.19	4.97	6	0.41	0.13	6	0.15	N.D.			96.61
Q (16) lg	72.54	3	0.40	0.17	3	0.05	14.90	3	1.30	1.23	3	0.07	0.05	3	0.01	0.16	3	0.27	0.71	3	0.08	3.30	3	0.11	5.05	3	0.11	0.15	3	0.06	N.D.			98.26
R (18) lg	72.04	13	3.62	0.16	13	0.09	14.43	13	0.86	1.12	13	0.52	0.07	13	0.09	0.65	13	0.40	0.64	13	0.42	4.24	13	1.03	4.18	13	1.11	0.03	13	0.04	1.02	1	0	98.58
$\bar{X}_p$	69.22	16	3.78	0.38	16	0.21	14.62	16	0.75	2.77	16	1.40	0.08	16	0.02	1.06	16	0.58	2.15	16	2.22	3.45	16	0.35	4.12	16	1.24	0.11	16	0.08	1.13	11	0.38	99.09
$\bar{X}_w$	68.33	281	5.08	0.48	281	0.35	14.50	281	1.36	3.09	281	1.88	0.08	281	0.06	1.28	281	0.88	2.23	281	2.30	3.33	280	0.81	4.32	281	1.33	0.12	281	0.12	1.20	104	0.49	98.96
$\bar{X}_w$ qd	62.72	28	2.66	0.44	28	0.10	15.81	28	0.86	4.70	28	0.99	0.10	28	0.02	2.25	28	1.07	6.72	28	2.24	3.46	28	0.30	1.26	28	0.23	0.19	28	0.14	1.32	7	0.47	98.97
$\bar{X}_w$ lg	71.94	48	3.00	0.20	48	0.15	14.64	48	1.02	1.61	48	0.94	0.06	48	0.05	0.66	48	0.42	0.99	48	0.92	3.81	48	0.81	4.19	48	1.01	0.07	48	0.09	1.14	10	0.48	99.31
$\bar{X}_w$ mg	68.25	205	4.58	0.56	205	0.37	14.29	205	1.02	3.41	205	1.91	0.08	205	0.06	1.29	205	0.81	1.91	205	1.79	3.21	204	0.63	4.76	205	0.83	0.12	205	0.12	1.20	87	0.51	99.08

TABLE 5 (Cont'd.)

Trace Elements ppm Pluton Number	Rb	n	s	Ba	n	s	Sr	n	s	Cu	n	s	Zn	n	s	Zr	n	s	F	n	s	K:Rb	Rb:Sr
A (2) qd	39	7	7.73	1243	7	125.11	355	7	49.59	0	7	0.00	11	7	7.16	86	7	9.95	337	7	62.91	284	0.11
B (3) qd	56	11	17.50	1051	11	483.26	333	11	38.46	4	11	11.11	38	11	20.06	105	11	20.06	343	10	46.92	215	0.16
C (4) lg	184	5	52.83	966	5	191.46	63	5	58.70	1	5	2.68	18	5	19.60	48	5	32.53	250	5	52.44	195	1.49
D (5) lg	163	4	45.76	1300	4	37.77	195	4	10.81	0	4	0.00	22	4	2.16	134	4	5.19	507	4	79.74	208	0.83
E (6) lg	266	13	113.22	842	13	404.07	69	13	90.58	2	13	4.58	29	13	26.43	102	13	50.03	498	13	244.40	150	10.51
F (7) mg	203	55	46.66	1132	55	399.88	294	55	134.18	1	55	3.22	53	55	26.15	279	55	73.28	988	49	378.41	224	0.70
G (8) mg	247	18	47.69	511	18	146.71	100	18	45.12	12	18	10.63	61	18	16.24	267	18	97.97	943	18	364.70	191	2.87
H (9) mg	169	32	33.87	1197	32	492.55	217	32	103.14	6	32	9.92	49	32	25.71	271	32	85.37	837	25	324.66	238	1.17
J (10) mg	194	20	29.69	617	20	409.49	194	20	96.80	1	20	2.92	54	20	13.29	249	20	64.99	608	18	267.15	286	2.59
K (11) lg	543	3	281.56	157	3	156.25	17	3	29.44	0	3	0.00	74	3	20.13	104	3	75.78	850	1	0	121	32.10
L (12) mg	335	22	138.64	508	22	427.52	108	22	110.71	4	22	4.44	46	22	22.27	176	22	127.52	817	21	429.47	146	21.80
M (13) mg	269	16	103.68	704	16	747.81	135	16	110.53	3	16	8.98	42	16	18.45	205	16	108.70	1090	6	590.46	262	2.34
N (14) mg	232	3	29.51	180	3	39.95	0	3	0.00	0	3	0.00	37	3	5.69	204	3	33.71	160	3	26.46	312	
P (15) lg	253	5	35.16	403	5	110.19	84	5	24.19	0	5	0.00	54	5	10.99	202	5	112.96	292	5	66.80	184	3.42
Q (16) lg	348	4	17.82	206	4	72.76	22	4	10.60	6	4	12.50	54	4	3.40	74	4	14.15	450	4	80.42	134	4.42
R (18) lg	350	8	74.60	199	8	131.89	23	8	42.49	1	8	2.83	54	8	14.16	113	8	52.17	612	5	319.25	113	31.62
$\bar{X}_p$	241	16	120.62	701	16	410.74	138	16	114.92	3	16	3.27	44	16	16.85	164	16	77.22	599	16	290.05	198	7.25
$\bar{X}_w$	198	226	111.98	846	226	524.80	187	226	137.05	3	226	7.22	43	226	24.30	212	226	107.79	743	194	407.47	244	6.33
$\bar{X}_w$ qd	49	18	16.09	1126	18	379.11	342	18	43.18	2	18	8.77	28	18	20.94	98	18	19.04	341	17	52.27	291	0.15
$\bar{X}_b$ lg	288	42	133.09	616	42	221.67	65	42	74.54	2	42	4.76	40	42	24.60	110	42	67.46	457	37	226.62	155	15.34
$\bar{X}_c$ mg	225	166	90.44	874	166	536.45	201	166	136.22	4	166	7.52	51	166	22.78	250	166	95.51	867	140	399.75	265	4.45

EXPLANATION OF TABLE 5

Table of Means, Number of Analyses, and standard deviations for major and trace elements for the individual plutons, main types of granitoid, average analysis, and average pluton.

A - R	-	Letters used in Harker Diagrams (Figs. 10a, 10b, 10c, 10d, 10e, 10f).
2 - 18	-	Corresponding number of pluton in Strong et al. (1973a).
$\bar{X}_p$	-	Mean composition of the plutons.
$\bar{X}_w$	-	Weighted mean composition.
$\bar{X}_w$ qd	-	Weighted mean of the Quartz Diorite.
$\bar{X}_w$ lg	-	Weighted mean of the Leucocratic Granodiorite.
$\bar{X}$ mg	-	Weighted mean of the Megacrystic Biotite Granites.
n	-	Number of analyses.
s	-	Standard deviation.
qd	-	Quartz diorite.
lg	-	Leucocratic granodiorite.
mg	-	Megacrystic biotite granite.

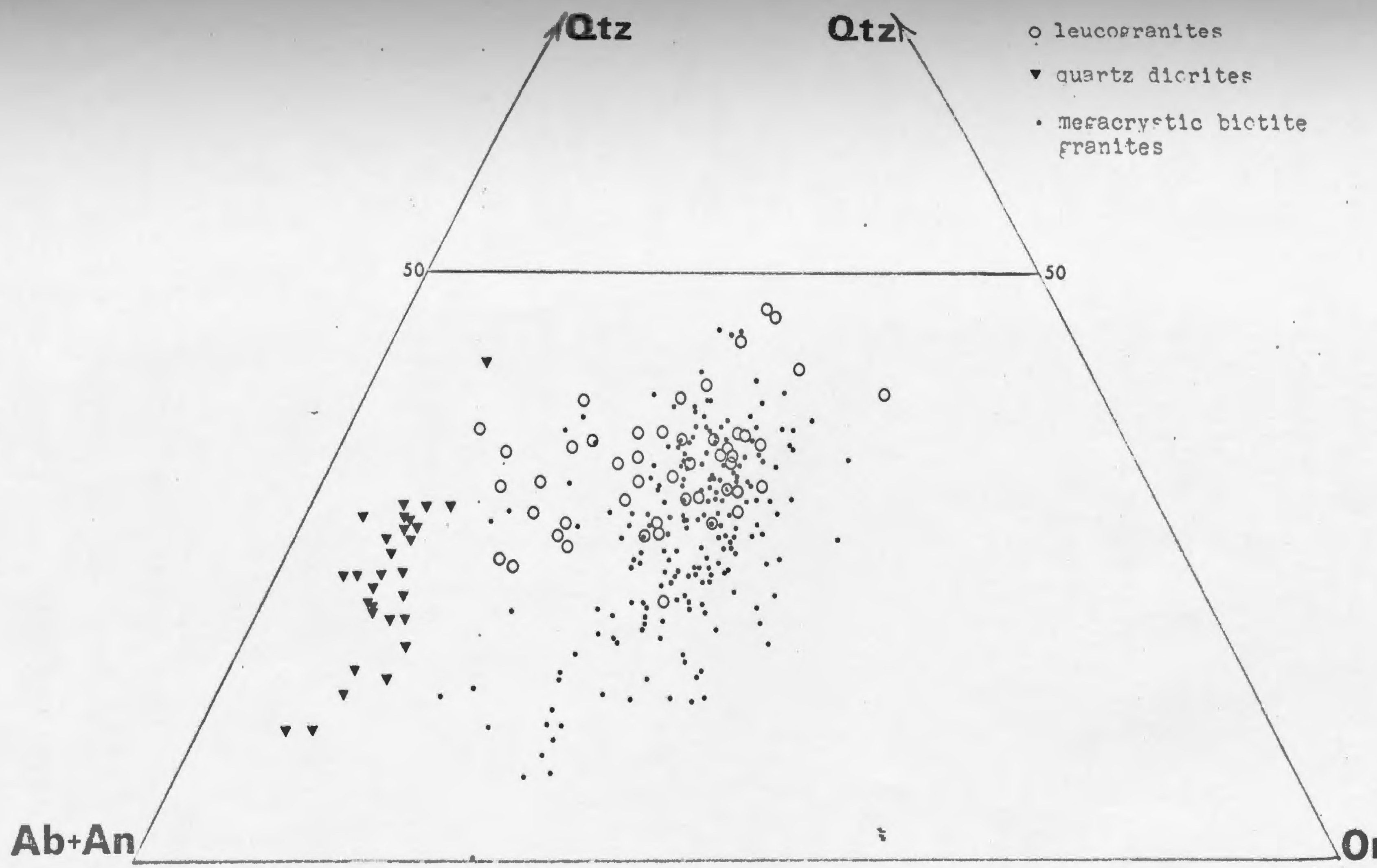

FIG. 8 - Normative proportions of Q, Ab+An, and Or normalised to 100 percent for the leucocratic granodiorites (leucogranites), quartz diorites, and megacrystic biotite granites.

the highest ratio of 291, leucogranites the lowest of 155, and the megacrystic biotite granites intermediate with a ratio of 265 (Table 5). The decrease in the K:Rb ratio in the leucogranites, a lower K_2O content emphasizes that the leucogranites have been enriched in Rb.

Iron, manganese, and magnesium, found mainly in the ferromagnesian minerals, decrease with increasing silica content. The quartz diorites, which are richest in hornblende and biotite, have the highest content of ferromagnesian elements with 4.70% Fe_2O_3 tot., 0.10% MnO, and 2.25% MgO. The leucogranites are relatively poor in ferromagnesian minerals and contain 1.61% Fe_2O_3 tot., 0.06% MnO, and 0.66% MgO. The megacrystic biotite granites which contain a high proportion of biotite contain 3.41% Fe_2O_3 tot., 0.08% MnO, and 1.29% MgO (Table 5).

Normative calculations also show that the quartz diorites are richest in normative plagioclase whereas the leucogranites are richest in normative quartz and the megacrystic biotite granites are richest in normative orthoclase (Fig. 8).

These examples show that the division of the granitoid rocks in the study area into three groups is valid on both petrographic and petrochemical evidence. Hence each group is treated on first approximation as a separate entity.

5.2.2. Chemical Variations Across the Study Area

Lateral variations in the abundance of K_2O have been described from island arc volcanic rocks (e.g. Jakeš and White, 1970), and island arc plutonic rocks (e.g. Reed and Lanphere, 1973), and across Pacific-type continental margins (e.g. Bateman and Dodge, 1970). This variation has been related to an underlying subduction zone with K_2O increasing with depth to the subduction zone (e.g. Lipman et al., 1972).

Zonation of mineral deposits has also been related to distance from the trench (depth to the subduction zone) in Southeast Asia (Mitchell and Garson, 1972) and the American Cordillera (Sillitoe, 1972). Thus both zonation of mineral deposits and lateral variation of K_2O in plutonic rocks could indicate the former presence of a subduction zone and it is interesting to speculate about such a possibility in the study area.

Selected mean analyses of the plutons were plotted in the study area from a line drawn through Frederickton, parallel to the regional NE-SW trend (Figs. 9a and 9b). The element which shows the most distinctive regular variation is potassium with a consistent increase in abundance from 1.24% to over 5% in a distance of 90 km. Although K_2O shows a general trend with increasing silica (Fig. 10c) the rate of increase of K_2O with distance is greater than the rate of increase of silica with distance, suggesting that the increase in K_2O content is not directly a function of silica concentration.

This pattern of K_2O variation supplemented by other metallogenic and geological information was interpreted by Strong et al. (1973b, c) as indicating an Appalachian subduction zone dipping away from the proto-North American continent in a present southeasterly direction.

[redacted] Quartz Diorites

5.3.1. Chemistry of the Quartz Diorites

The Frederickton and Rocky Bay plutons are the only masses of

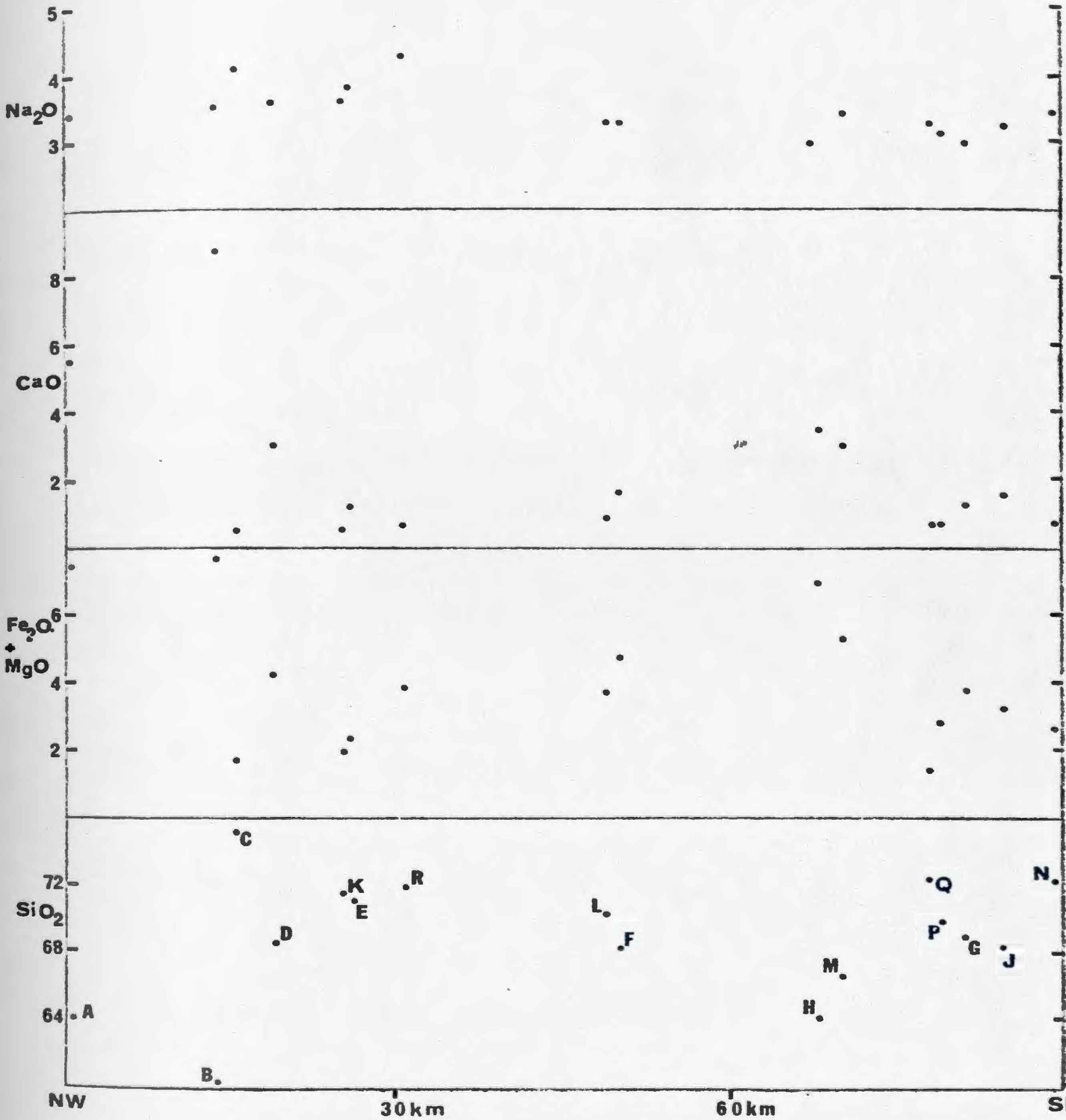

FIG. 9a

FIGS. 9a and 9b. Means of selected oxides (weight percent), trace elements (ppm), and K:Rb ratios, for each pluton plotted against distance from a NE-SW line drawn through the Fredericton pluton. Letters correspond to the pluton letters in Fig. 3.

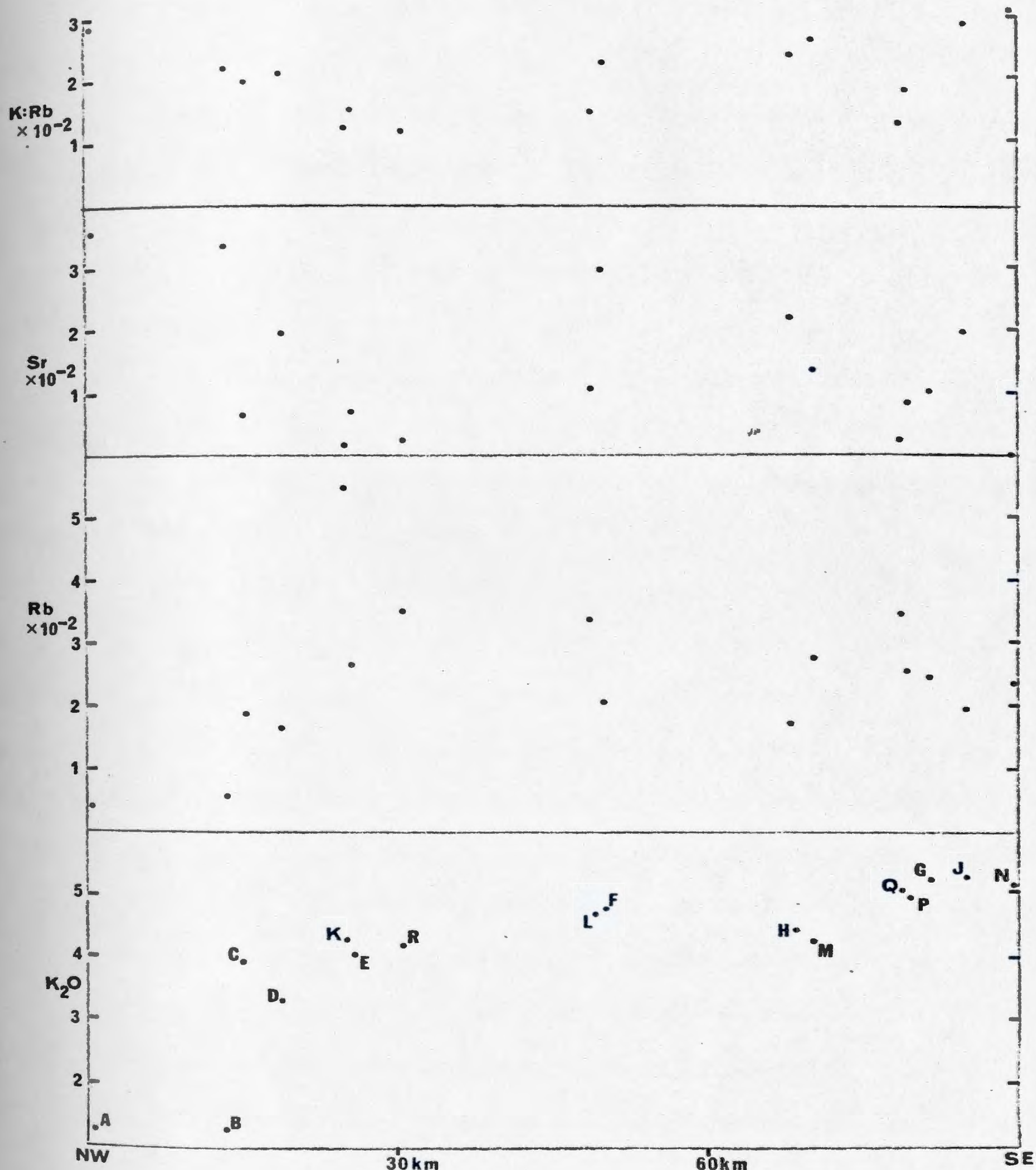

FIG. 9b

quartz diorite in the study area. They are very similar chemically and intra-pluton variation is greater than the differences between the plutons.

The plutons appear to have a zonal arrangement of rock types. At the margins, hornblende-rich quartz diorite is found, which generally changes with decrease in the hornblende:biotite ratio to biotite quartz diorite in the core. This change is also reflected in the chemistry, and is best shown by the Rocky Bay pluton where the surface of the pluton is essentially horizontal. Chemical analyses show that the margins are considerably more basic than the core (see Fig. 11) reflecting the change in colour from grey to black and white, and the change in the ratio of hornblende to biotite (see Plates 3 and 4).

From Table 5, and Figs. 10a, b, c, d, e, f, it can be seen that the Rocky Bay pluton is more basic than the Frederickton pluton. This difference is caused partly by the dominance of samples from the basic margins of the Rocky Bay pluton, but the most acid sample from the core of the Rocky Bay pluton is only slightly more acid than the mean composition of the Frederickton pluton (Fig. 11). This difference in composition is also shown by the Fe_2O_3 and CaO contents which are much higher in the Rocky Bay pluton. The other elements show similar variations.

In the Rocky Bay pluton, however, Rb is higher and the K:Rb ratio is much lower (284 Frederickton v. 215 Rocky Bay). This conflicts with the expected trend of a decrease in the K:Rb ratio with increasing silica content.

Rb enters micas in preference to feldspars (Taylor, 1965) and the high proportion of biotite-rich quartz diorite in the Rocky Bay pluton compared to the Frederickton pluton, and the concentration of Rb in the

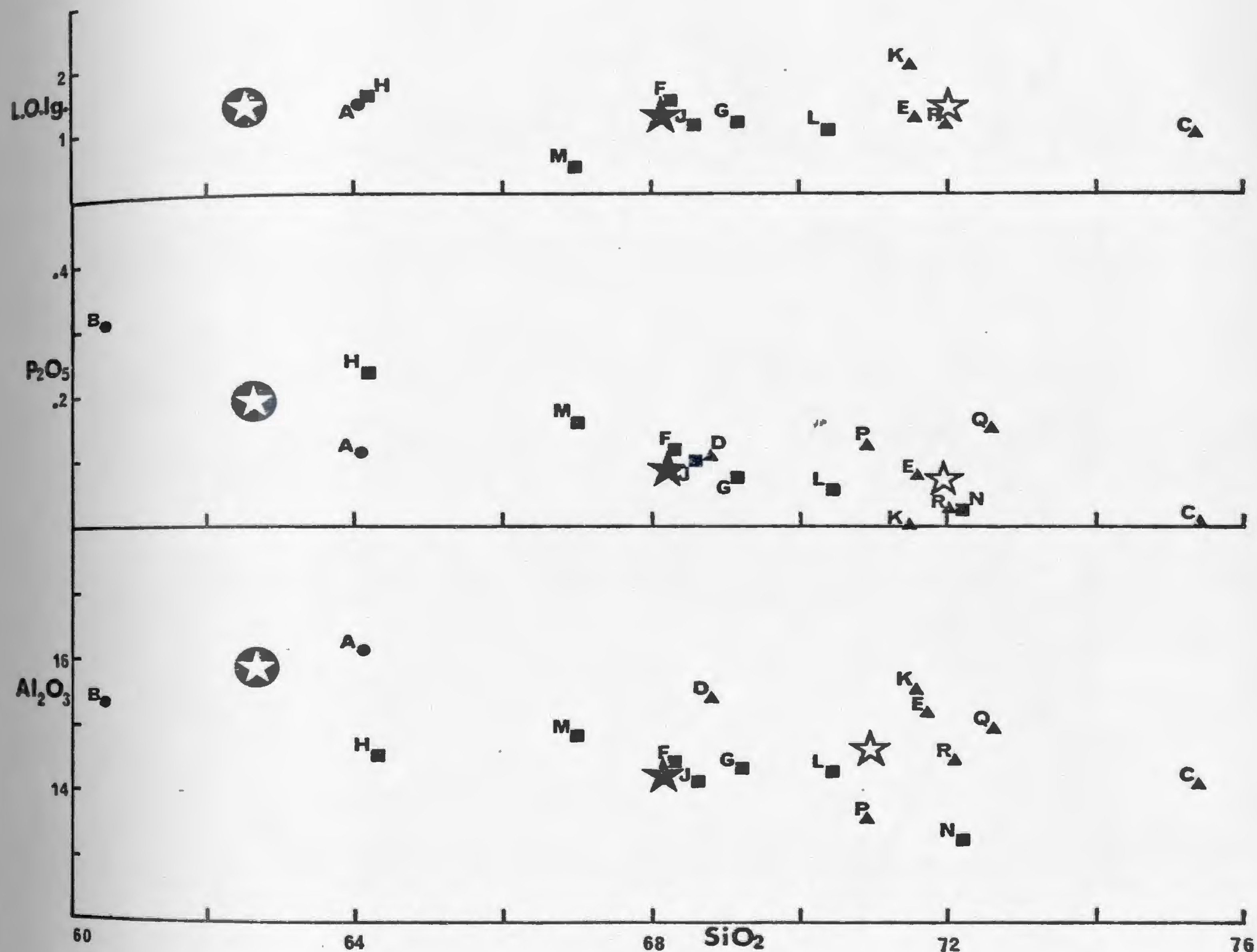

FIG. 10a

FIGS. 10a, 10b, 10c, 10d, 10e, 10f. Plots of mean oxides and Loss on Ignition (L.O.Ig.) (weight percent) and trace elements (ppm) against SiO_2 weight percent for each pluton. Letters correspond to pluton letters in Fig. 3.

- ● Quartz Diorite plutons
- ▲ Leucogranite plutons
- ■ Megacrystic Biotite Granite plutons
- Weighted mean of each element in the quartz diorites
- ☆ Weighted mean of each element in the leucogranites
- ★ Weighted mean of each element in the megacrystic biotite granites

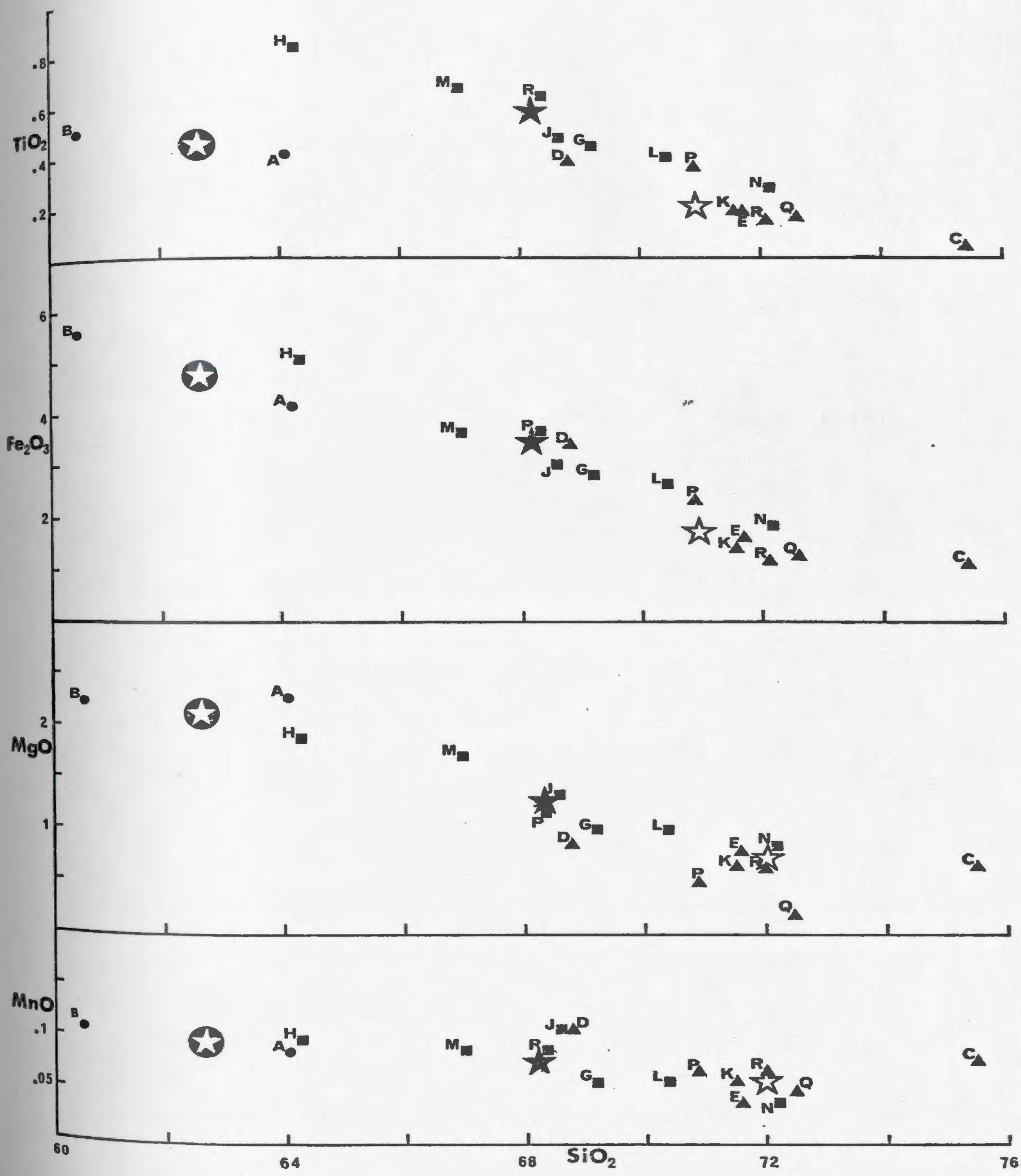

Fig. 10b

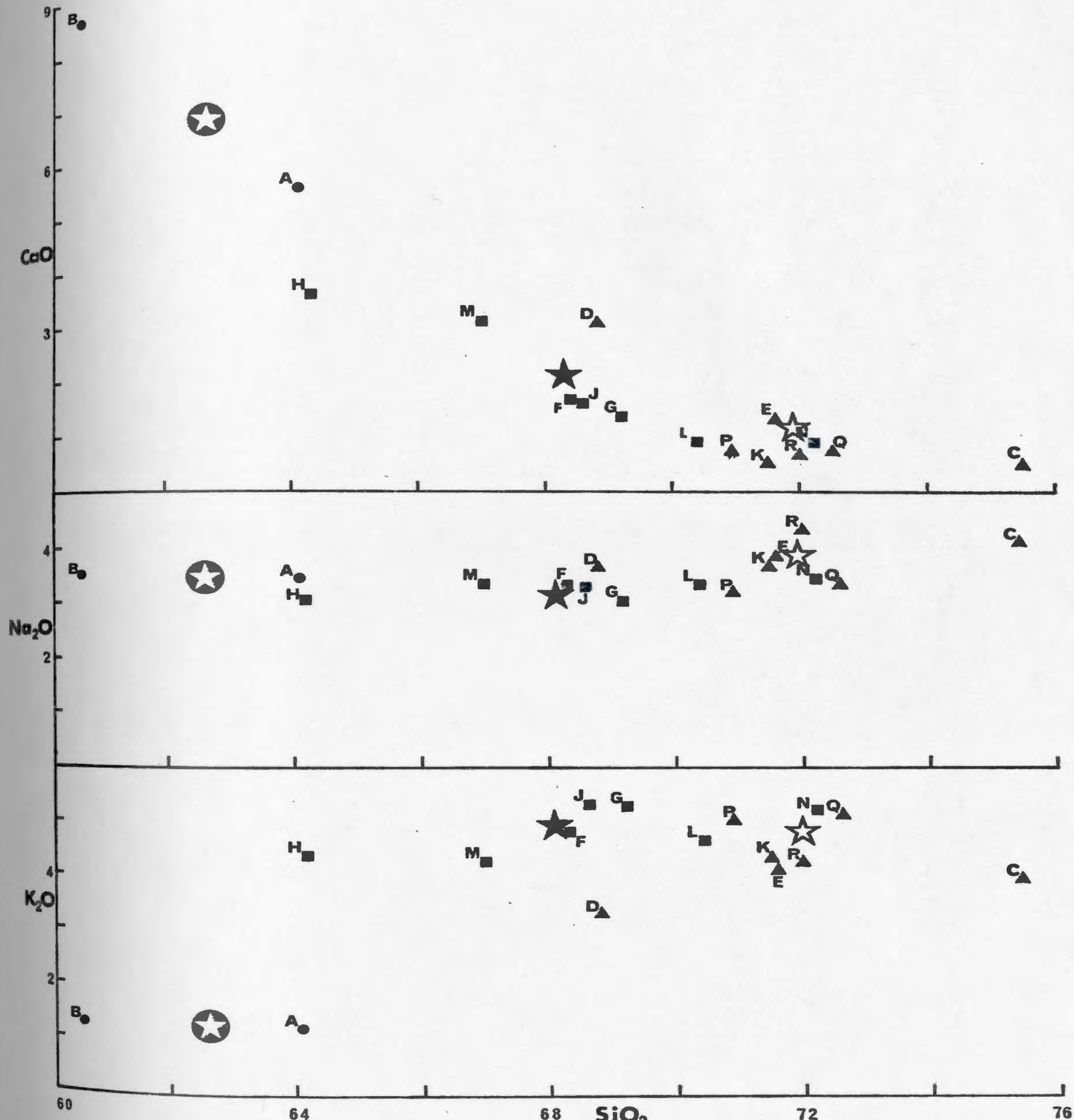

Fig. 10c

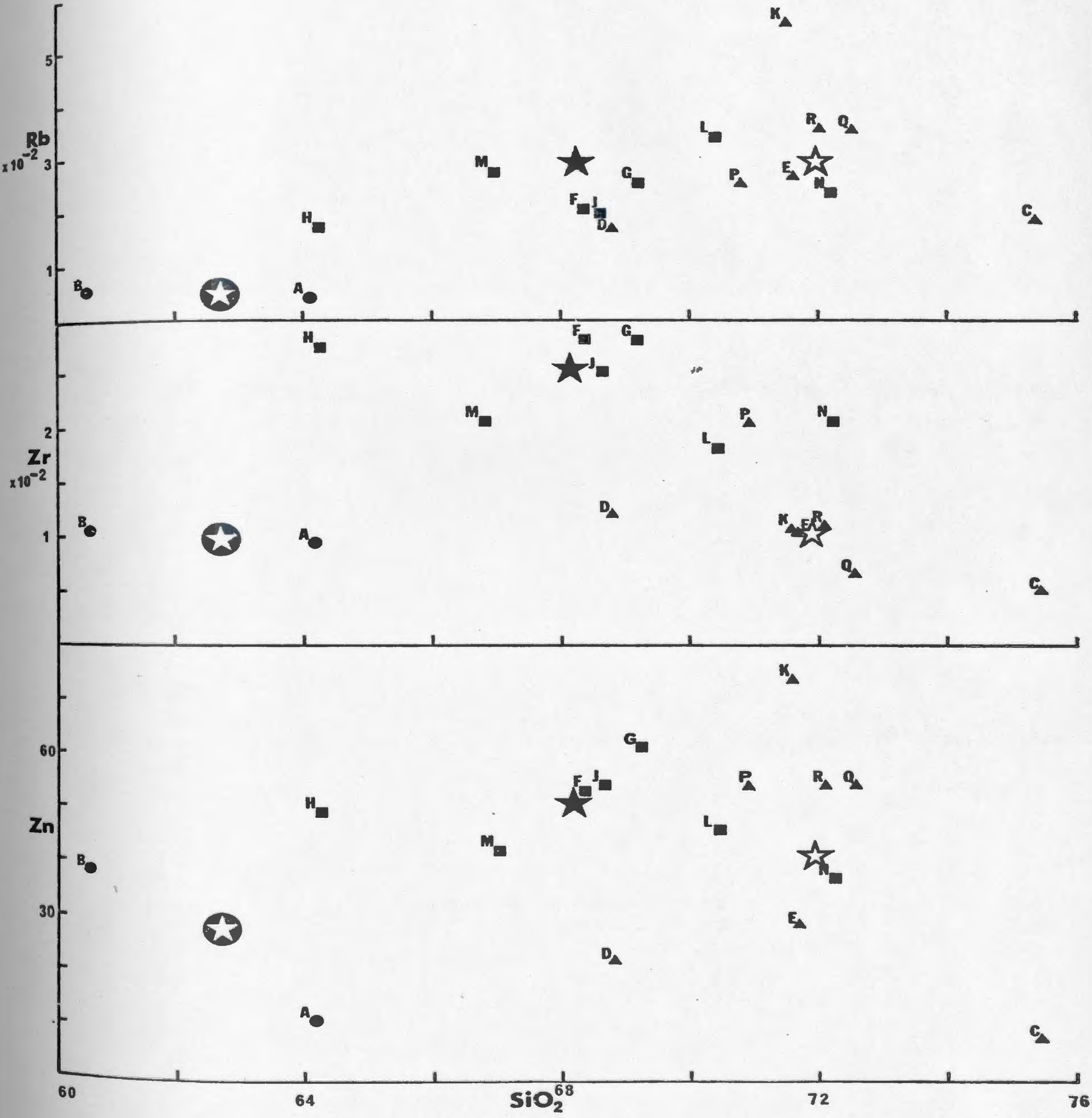
Rb
x10^-2
5
3
1
Zr
x10^-2
2
1
Zn
60
30
60
64
68
72
76
SiO2
K
R
Q
L
M
G
P
E
N
F
J
D
H
C
B
A

Fig. 10d

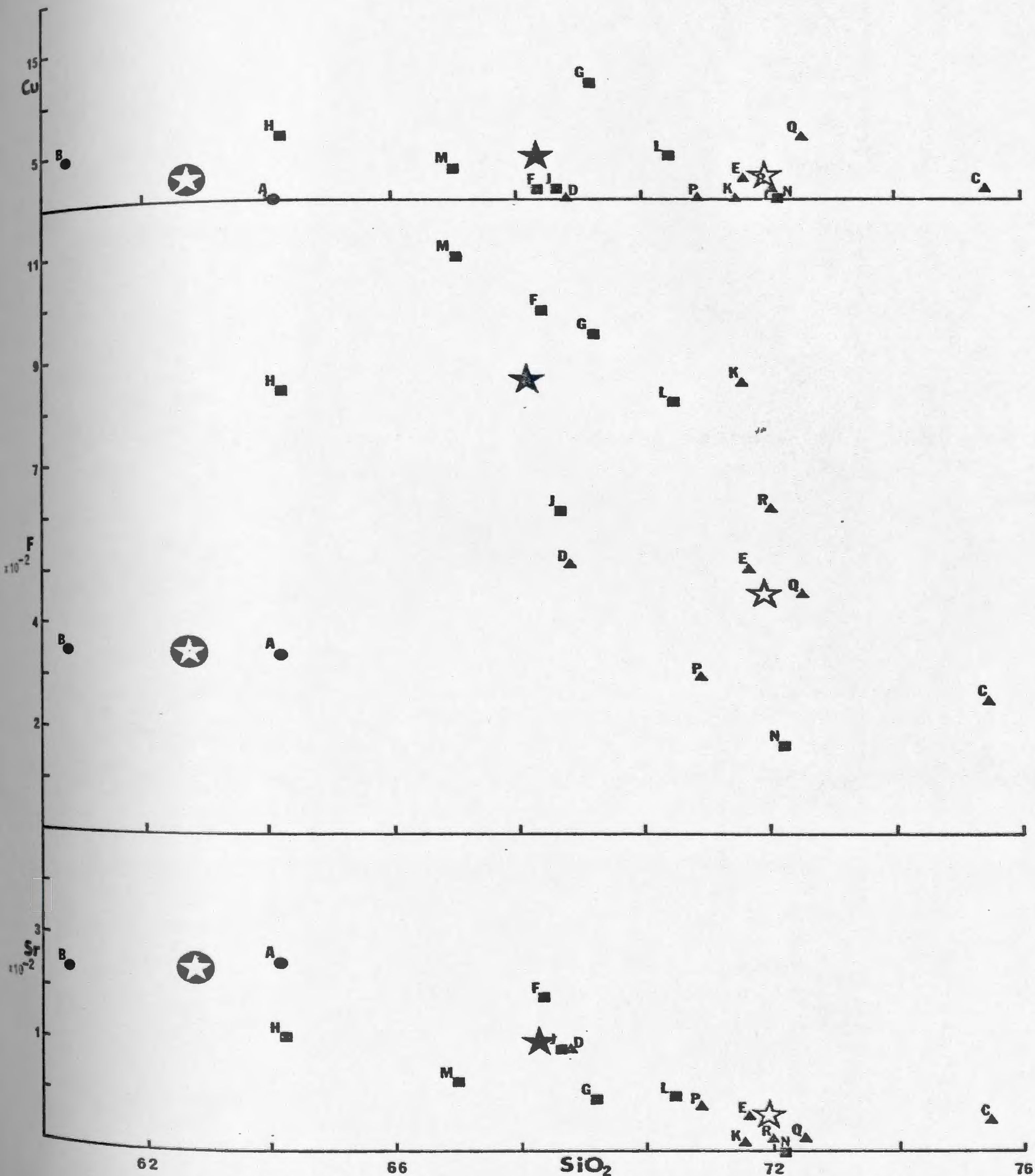

Fig. 10e

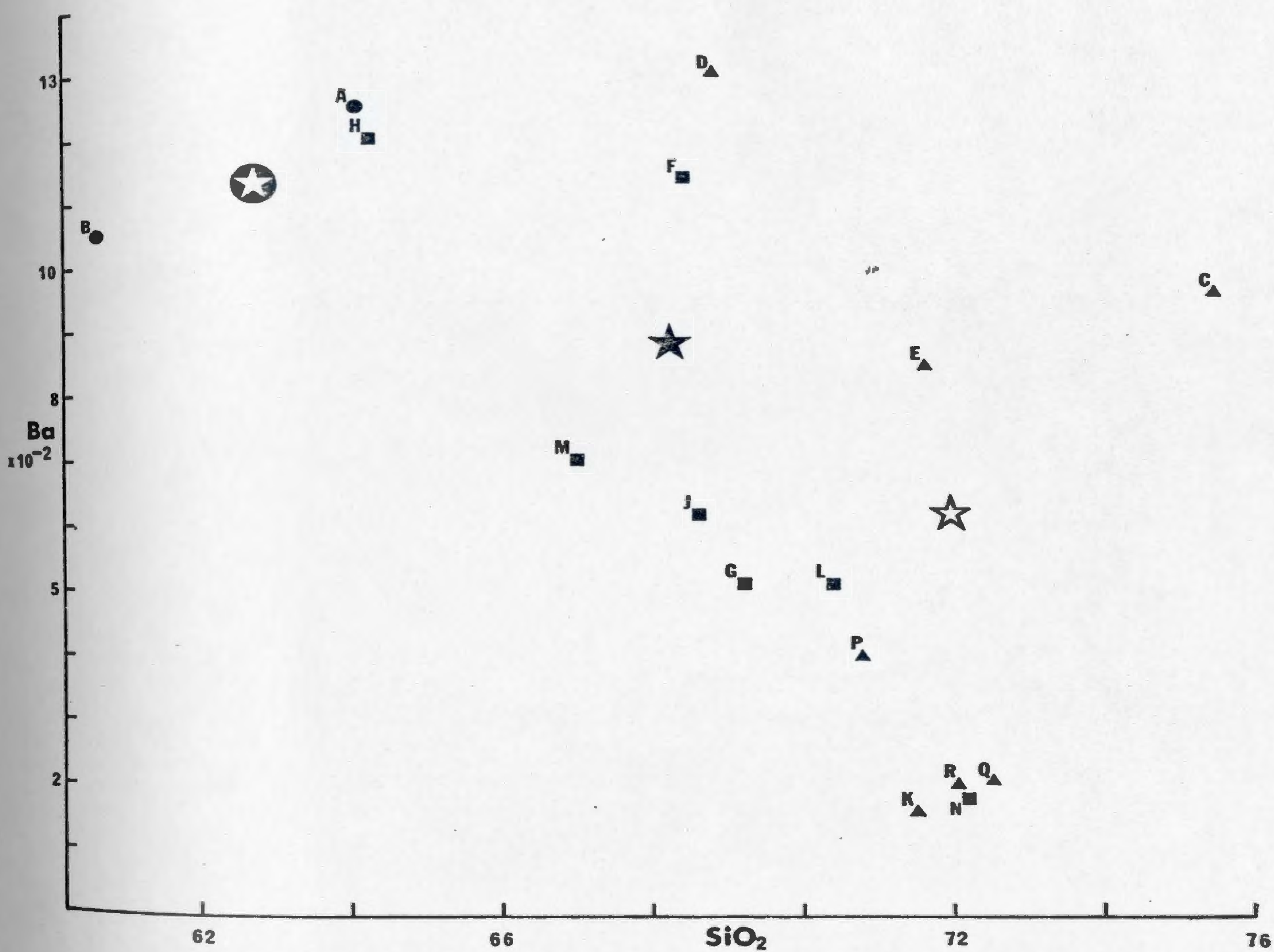

Fig. 10f

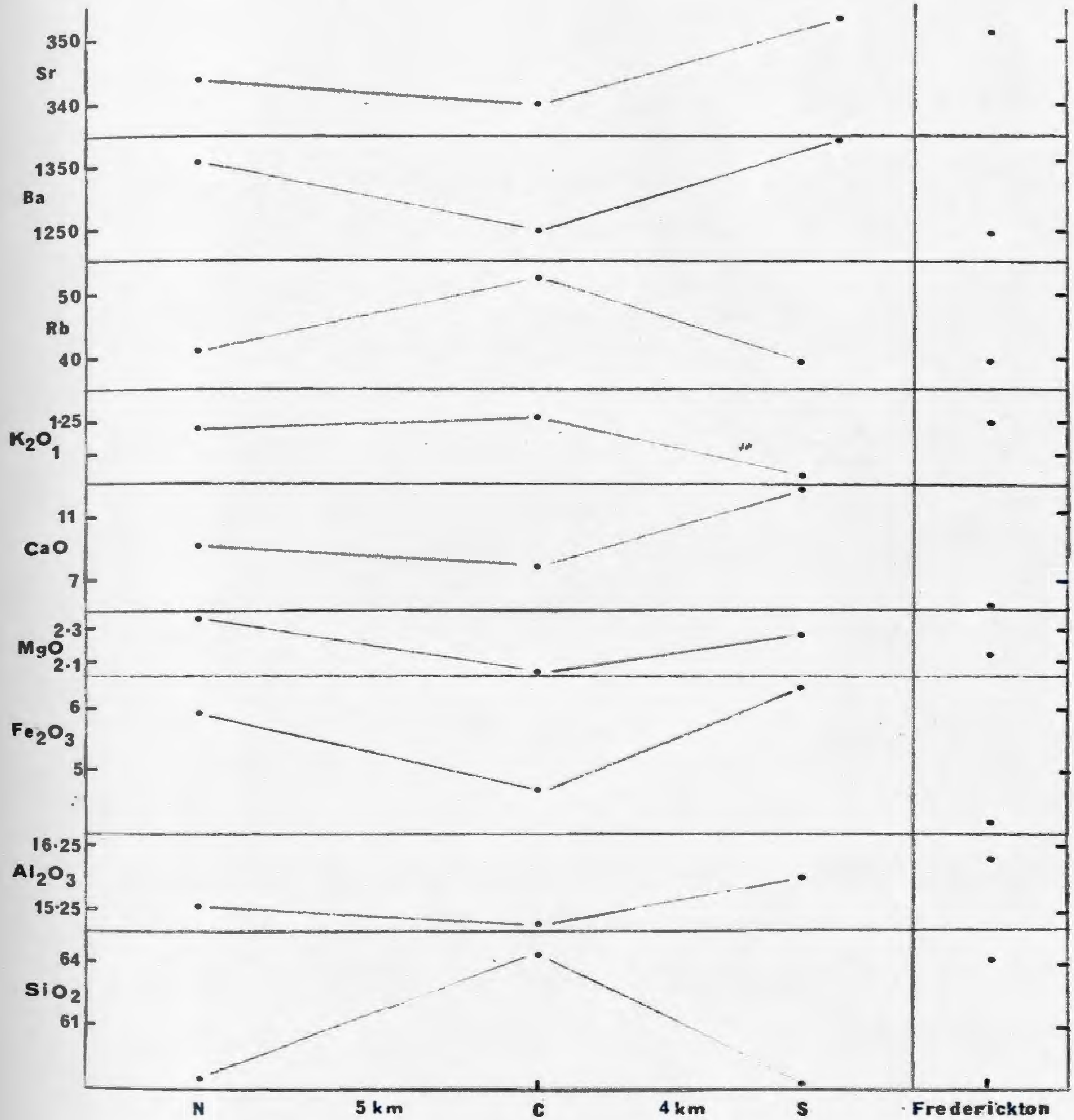

FIG. 11 - Plots of selected oxides (weight percent) and trace elements (ppm) from the Rocky Bay pluton to show the variation from the northern margin (N) and the southern margin (S) towards the core (C), and the mean analyses of the Frederickton pluton for the same elements.

biotite has reduced the K:Rb ratio. The slightly higher proportion of K_2O in the Rocky Bay pluton is a reflection of the higher proportion of K_2O in biotite compared to hornblende.

5.3.2. Petrogenesis

Calculations of Q:Ab + An:Or for the Rocky Bay and Frederickton plutons (Fig. 8) plot near the Or:Ab + An join and trend away from Ab+An with the analyses for the Rocky Bay pluton forming the lower half of the plots being richer in normative plagioclase. The continuity of trend suggests a comagmatic origin, with the Rocky Bay pluton forming earlier in the cooling history of the magma than the Frederickton pluton.

The trend away from Ab+An coincides with the trend for the Late Cretaceous and Early Tertiary plutonic rocks in the Alaska-Aleutian area (Fig. 12) which have an island arc origin (Reed and Lanphere, 1973). Other similarities between the two areas are:

1. The plutons are K-poor hornblende and biotite quartz diorites.
2. The plutons intrude deep-water shales and greywackes.
3. Some of the plutons of the Notre Dame Bay area have been assigned an Ordovician age (Williams <u>et al.</u>, 1972) and the petrographic similarity between these plutons and the Rocky Bay and Frederickton plutons suggests that they may also be Ordovician in age. The Rocky Bay and Frederickton plutons intrude volcanic agglomerates which are dated as Middle Ordovician (Kennedy and McGonigal, 1972a). It is therefore possible that the volcanic rocks are genetically related to the plutons. This is also found in the Aleutian arc and further supports an island arc origin for the Rocky Bay and Frederickton plutons, by partial melting of oceanic

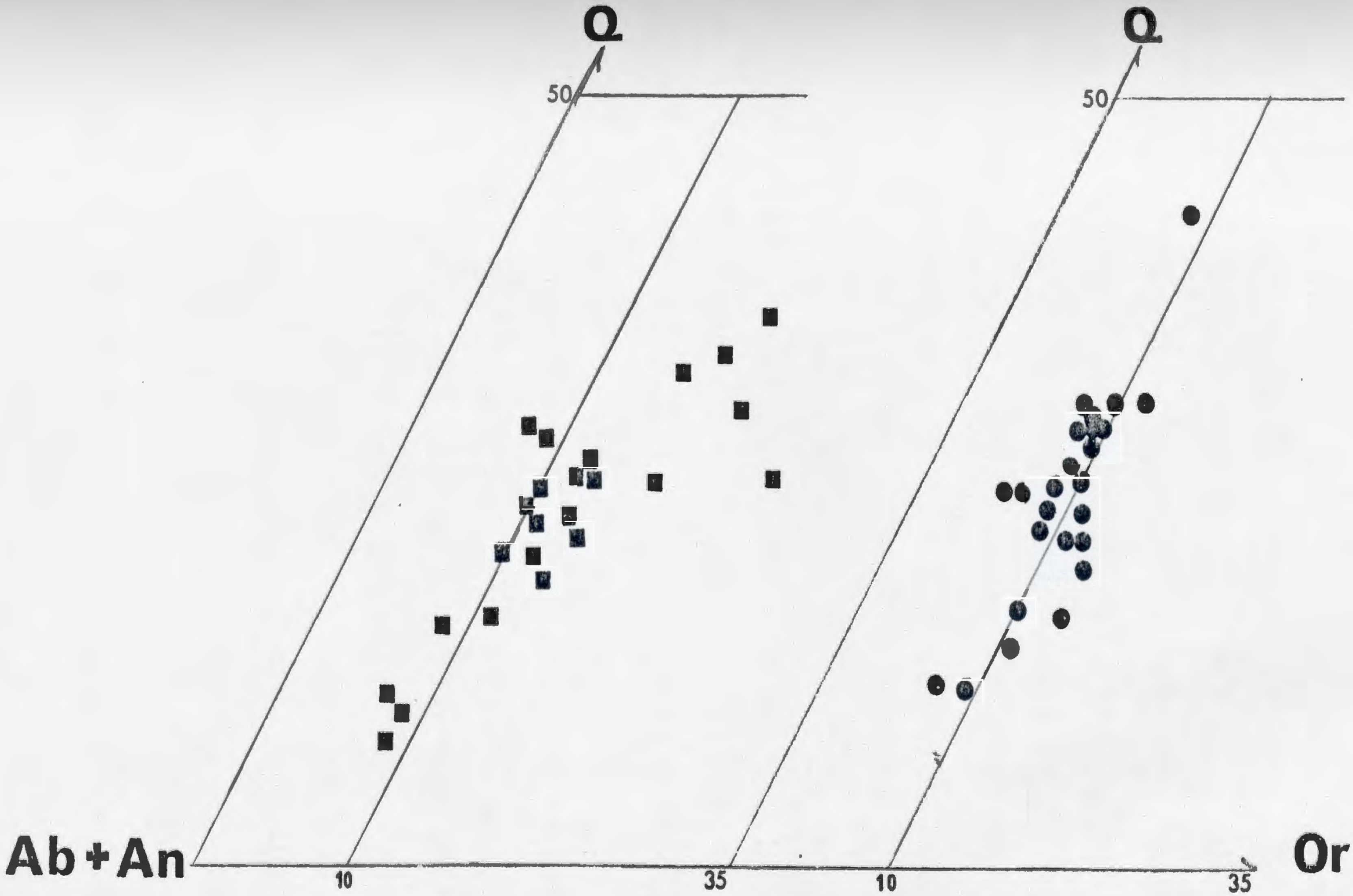

FIG. 12 - Normative proportions of Q, Ab+An, and Or normalised to 100 percent for the Rocky Bay and Frederickton plutons and the Late Cretaceous - Early Tertiary plutonic rocks of the Alaska-Aleutian area (after Reed and Lanphere, 1973).

■ Alaska - Aleutian area plutonic rocks

● Rocky Bay and Frederickton plutons.

crust in a Benioff Zone (Stern and Wyllie, 1973).

[redacted] Leucocratic Granodiorite (Leucogranites)

5.4.1. Introduction

The leucogranite plutons are composed of foliated muscovite-biotite granodiorite and granite and are restricted to the metamorphic and gneissic terrains. Only the plutons in the metamorphic terrain will be discussed in this section as very few samples were obtained from the leucogranites in the gneissic terrain and the areas of leucogranite in the gneissic terrain are not well defined.

5.4.2. Chemistry of the Leucogranites

The plutons have a relatively uniform composition with only the Round Pond and Aspen Cove plutons showing any significant variation in composition (Table 5, Figs. 10a to f).

Variation in composition within a pluton is generally greatest in the larger ones e.g. Ragged Harbour and Middle Ridge, where there is a rough zonation of less acid to more acid from the margins to the core, without any appreciable change in mineralogy (Fig. 13). Fig. 13 shows that the only consistent variant is silica. CaO shows a decrease in the Ragged Harbour pluton but the Middle Ridge pluton is so low in CaO that the small variations are within experimental error. K:Rb ratios show a general decrease towards the core but there is no consistent trend. Sample #193 shows a relatively high K:Rb ratio and as suggested above (Sect. 4.5.5) is probably part of an earlier intrusion.

The inconsistencies in chemical trends within the Ragged Harbour

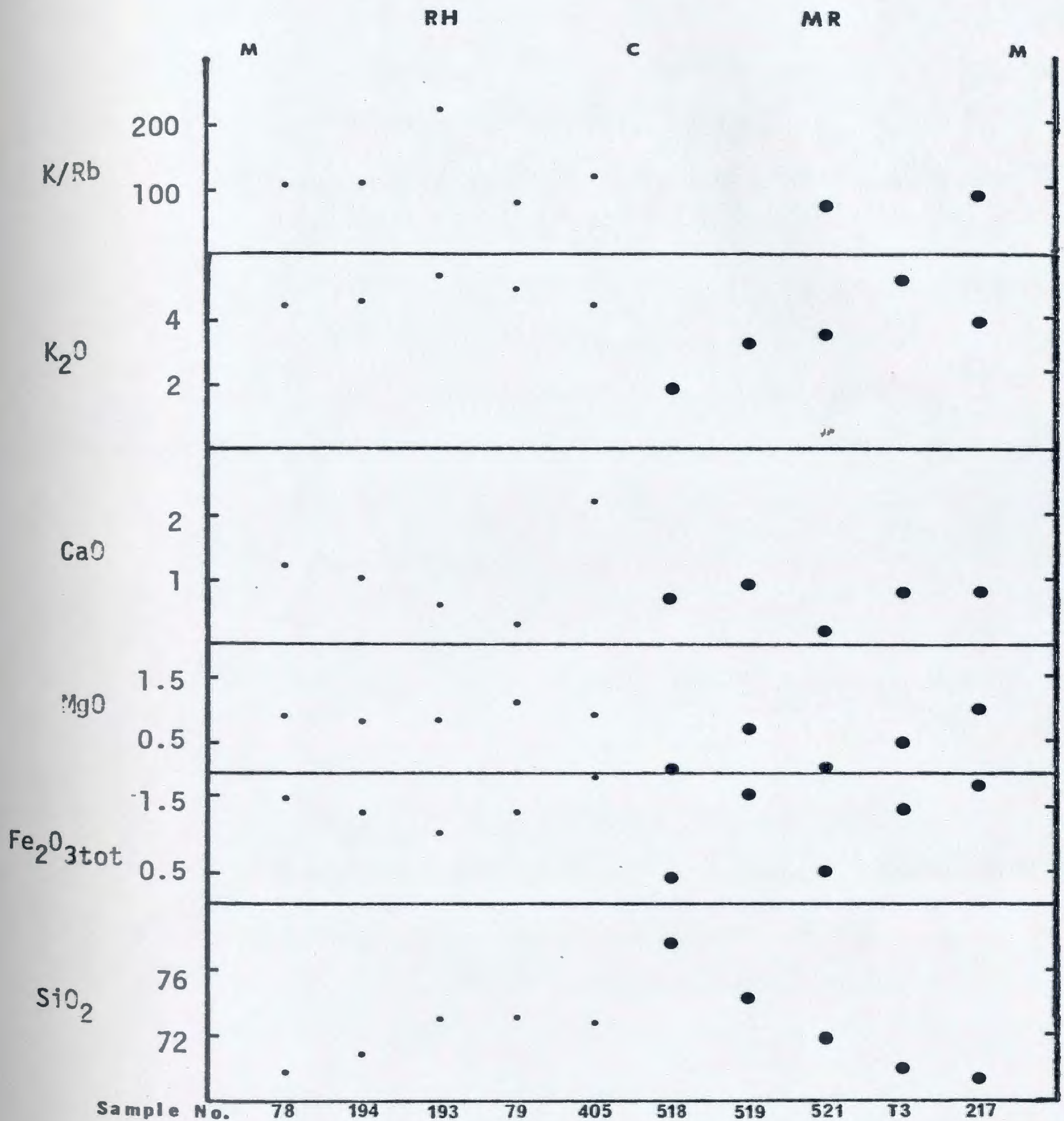

FIG. 13 - Variation, from the margin to the core, of selected oxides in weight percent and K/Rb ratio in the Ragged Harbour and Middle Ridge plutons.

M - Margin

C - Core

RH - Ragged Harbour Pluton •

MR - Middle Ridge Pluton ●

and Middle Ridge plutons suggests that the plutons are inhomogeneous and may represent local fluctuations in the crystallisation of the magma.

The Round Pond and Aspen Cove plutons are the only leucogranites which differ significantly from the mean composition. The Round Pond pluton is less acid as indicated by the higher CaO, Fe_2O_3, Ba, and Sr (Figs. 10a to f). In these respects it is similar to the quartz diorites but the much higher K_2O, and Rb, and lower Rb:Sr ratio satisfactorily differentiates the pluton from the quartz diorites.

The Aspen Cove pluton is the most acid of all the plutons studied and with 75.43% SiO_2 is 3.5% higher than the mean for the leucogranites. Elements associated with lower silica granitoids are depleted, especially Ca and Fe, with the other elements having the same average abundances as the leucogranites (Figs. 10a to f).

5.4.3. Petrogenesis

The enrichment of the leucogranites in the large cation and lithophile elements such as K and Rb, and the low K:Rb ratios and high Rb:Sr ratios, suggest two possibilities for their origin: a) late stage fractionation products of a more basic magma, or b) anatexis of crustal rocks.

The leucogranites were emplaced during the deformation and metamorphism of the metasedimentary terrain (McGonigal, 1973; Kennedy and McGonigal, 1972a; Uzuakpunwa, 1973) i.e. during a period when the region had a high geothermal gradient. Pegmatites are abundant in the leucogranites and this suggests that the leucogranite magma was wet, a condition which would have promoted anatexis of continental crust.

The lack of basic igneous rocks suggests that the leucogranites were not formed from a basic magma. Also large negative gravity anomalies are found in the area underlain by the leucogranites whereas a positive anomaly would be found over a differentiated basic magma.

Analyses for the small Terra Nova River and Terra Nova River West plutons plot near the eutectic in the Q:Ab+An:Or diagram (Fig. 14) for 2 to 5% normative An (James and Hamilton, 1969) at low (1 kb) water pressures. The scatter of points for the larger plutons approximates on the Qtz.-Plag. cotectic and may represent the fractionation trend of a crystallising anatectic melt, or just partial melting involving plagioclase and quartz.

An anatectic origin for the leucogranites appears therefore to be consistent with the data presented above rather than the leucogranites being the products of a fractionated basic magma. Such an origin at such shallow depths (low P_{H_2O}) would indicate a very high geothernal gradient during their formation.

5.5. Megacrystic Biotite Granites

5.5.1. Introduction

The megacrystic biotite granite plutons in the study area are composed of essentially four minerals, viz. quartz, plagioclase, biotite, and microcline, with the greatest variation in the plutons being an increase in the proportion of plagioclase to microcline and a general decrease in grain size towards the margins.

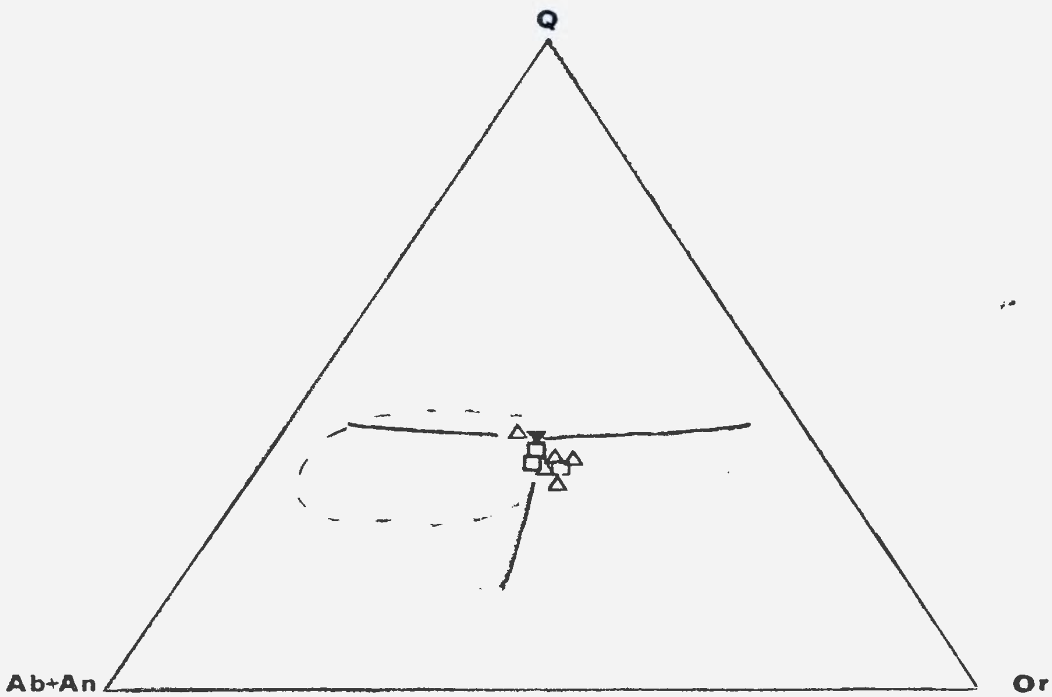

FIG. 14 - Normative proportions of Q, Ab+ An, and Or normalised to 100 percent, for the Terra Nova River and Terra Nova River West Plutons.

△ Terra Nova River West pluton

□ Terra Nova River pluton

▼ 'Eutectic' composition at 1 kb P_{H_2O} and An_2 in the system $KAlSi_3O_8$-$NaAlSi_3O_8$-$CaAl_2Si_2O_8$-SiO_2-H_2O (after James and Hamilton, 1969).

/ Other leucocratic granodiorites

The megacrystic granites are generally restricted to the gneissic terrain of Zone G, but the Terra Nova pluton intrudes the Avalon Platform sediments (Zone H), and the Gander Lake pluton which shows a wide petrographic variations is entirely within the metasedimentary terrain of Zone G.

5.5.2. Chemistry of the Megacrystic Biotite Granites

The consistent mineralogy and the small variations in proportions of minerals shown within the plutons are reflected to a great extent in the chemistry with the most acid and most basic plutons within one standard deviation of the mean (Table 5).

The plutons vary systematically in chemistry, with Ti, Fe, Mg, Mn, Ca, Al, Sr, Ba, and F decreasing, and K, Na, and Rb, increasing with increasing silica (Figs. 10a to f).

The eastern megacrystic biotite granite plutons, viz. Cape Freels, Newport, and Terra Nova, are more acid than the plutons to the west (Figs. 10a to f) and even the marginal facies are more acid than the margins of the western plutons, which suggests that the eastern plutons were intruded in a more evolved state Tables 6 and 7). The more acid nature of the eastern plutons is also shown by the lower Al, Ca, Mg, Fe, Ti, Sr, and Ba, and higher K and generally higher Rb.

The variation from less acid at the margins to more acid in the core is particularly well shown in the Deadman's Bay pluton where there is a complete cross-section (Table 7). The table shows that from the margins to the core there is a regular decrease in Ti, Fe, Mg, P, Ba, Sr,

TABLE 6

Compositions of the Marginal Facies of the Eastern Megacrystic Biotite Granite Plutons

	Cape Freels Pluton		Newport Pluton		Terra Nova Pluton	
[redacted]e No.	174	177	334	345	462	473
SiO_2	66.4	67.0	61.9	69.6	72.2	72.7
TiO_2	0.6	0.6	0.8	0.6	0.3	0.5
Al_2O_3	14.2	14.1	16.7	13.9	13.3	12.4
Fe_2O_3 tot	3.8	3.8	4.3	3.4	1.9	2.5
MnO	0.06	0.13	0.04	0.07	0.03	0.05
MgO	1.2	1.1	2.1	0.8	2.7	0.0
CaO	1.8	1.8	2.9	2.2	0.4	0.6
Na_2O	3.3	3.3	2.2	3.6	3.5	3.3
K_2O	5.5	5.0	8.0	3.7	5.7	4.9
P_2O_5	0.1	0.1	0.3	0.0	0.5	0.0
K:Rb	139	-	388	201	-	-

TABLE 7

Variation in Composition Across the Deadman's Bay Pluton from West to East.

WEST MARGIN				CENTRE				EAST MARGIN
Sample No.	81	87	88	95	98	131	137	136
SiO_2%	62.8	64.2	71.2	72.2	71.1	68.9	66.4	69.7
TiO_2	1.1	0.7	0.5	0.3	0.3	0.5	0.6	0.6
Al_2O_3	14.8	15.8	13.9	15.5	15.6	16.4	15.3	14.1
Fe_2O_3 tot.	6.0	4.0	2.9	1.8	1.9	3.0	3.8	3.4
MnO	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1
MgO	2.2	1.7	1.2	1.0	1.0	1.4	0.9	1.1
CaO	3.3	1.1	0.6	1.1	1.0	1.3	1.0	2.2
Na_2O	3.2	3.9	3.6	3.5	3.6	4.2	3.4	3.4
K_2O	4.5	5.6	5.0	5.3	5.2	4.9	5.4	2.7
P_2O_5	0.2	0.1	0.1	0.0	0.1	0.0	0.1	0.2
Rb ppm	142	185	197	238	253	203	212	204
Ba	1741	1593	1326	1146	1156	1393	1595	745
Sr	499	489	248	249	164	490	443	284
Zn	72	88	49	28	21	32	30	69
Zr	357	406	266	189	219	245	300	284
F	1340	840	580	630	620	540	870	1130

X------------------------ 40 km ----------------------------X

Zn, Zr, and F, and a regular increase in Si, Al, Na, K, and Rb. These changes in chemistry are generally reflected in a higher proportion of plagioclase and biotite at the margins. This difference in composition between the marginal areas and the central areas is found in all the megacrystic plutons of the gneissic terrain but is less well shown in the Terra Nova and Gander Lake plutons.

The Middle Brook pluton has a mean composition which is 4% lower in silica than the mean for all the megacrystic biotite granites. This is a reflection of the high proportion of samples from the marginal areas of the pluton in the Freshwater Bay area. Inside of the contact areas the pluton is as acid as the central areas of the other megacrystic biotite granites.

The Terra Nova pluton which is the most acid of all the megacrystic biotite granite plutons does not show any consistent decrease in acidity towards the margins and only locally does it contain less than 70% SiO_2. The high silica content is reflected in the high proportion of megacrystic quartz and a decrease in the proportion of biotite.

Many pluton-country rock contacts show a marked enrichment in fluorine (Fig. 15). The mean fluorine concentration in the megacrystic biotite granites is 867 ppm, but at the margins the fluorine concentration in places exceeds 1200 ppm. The mean fluorine concentrations in the quartz diorites and leucogranites are considerably lower at 341 ppm and 457 ppm respectively (Table 5). The Gander Lake pluton, at 1090 ppm F, has the highest mean fluorine concentration. This is mainly due to the high number

FIG. 15 - Distribution of whole-rock fluorine concentrations in the granitoid rocks of the northern Gander Lake Belt. Numbers of plutons equivalent to those in Fig.3.

- 0 to 499 ppm
- 500 to 999 ppm
- 1000 to 1499 ppm
- 1500 ppm and over

of samples from near the northern contact, but samples from near the western contact north-west of North Pond are low in fluorine even though fluorite is found in the specimens from this area.

Fluorine is one of the most mobile elements in a magma and tends to concentrate in the apical regions of a pluton (Tauson and Kozlov, 1972). Fluorine, therefore, would concentrate at the margins of the plutons where the contact was near the roof of the pluton or the contact dipped away from the pluton.

On the south shore of Gander Lake a large fragment of country rock is almost surrounded by granite and is probably a cap to the granite. If so the northern area of the Gander Lake pluton is very near the roof of the pluton.

The concentration of fluorine at the contacts is also well shown in the Deadman's Bay pluton where concentrations exceeding 1500 ppm are found at the north-east and north-west margins. There is also a high concentration of fluorine in the south-central area of the pluton in the Ten Mile Pond area and for over 15 km. west of the north-eastern contact. These other areas of high fluorine suggest that the present granite surface was near the undulating roof of the pluton. The lateral extent of the high fluorine concentration at the eastern contact compared to the west suggests that the western contact was further below the roof, and possibly that the roof of the eastern contact zone dipped at a shallower angle.

5.5.3. Petrogenesis

Normative plots of Q:Ab+An:Or (Fig. 8) of the megacrystic biotite granites have a trend which shows an increase in normative quartz and orthoclase and a corresponding decrease in normative plagioclase. This continuity of trend of the plutons suggests that the plutons formed under similar conditions although there may have been several phases of intrusion.

Major problems concerning the megacrystic biotite granites are 1) the large area of the whole Gander Lake Belt which is underlain by them. A minimum total area of 10,000 $km.^2$ is estimated for the megacrystic biotite granites with approximately 3,000 $km.^2$ within the study area. 2) A second problem is the high average K_2O content of these plutons. It is essential to understand the source of the potassium in order to explain the origin of the megacrystic biotite granites.

There are six theoretically possible solutions to the origin of such large areas of potassium-rich granite.

1. Granitisation in situ of the country rocks by migration of potassium ions has been often cited for the origin of granite. There is some evidence for such a process in the study area. Megacrysts of microcline feldspar are found in mafic dykes which contain less than 60% SiO_2 and a zonal arrangement of biotite inclusions in microcline crystals is common (Plate 8). Pitcher and Berger (1972) have shown microcline crystals which have grown across small dykes in granite. These examples show that microcline crystals can grow through solid state processes and that microcline growth is periodic. However, the contacts of many of the plutons with the country rocks are sharp and there is little sign of growth

of K-feldspar in the country rocks. Dykes of megacrystic biotite granite can be traced from the country rocks back into the pluton. Inclusions of non-granitised schistose inclusions are common in the megacrystic biotite granite (Plate 30). Thus granitisation is not envisaged as the sole process involved in the formation of these plutons.

2. It is theoretically possible to produce granitic material by the fractional crystallisation of basic magma. The average K_2O content of a basic magma such as the Skaergaard intrusion (Wager, 1960) is only 0.2% and therefore to produce a granite containing 4.76% K_2O would require a volume of basic magma at least 25 times as great as the volume of granite. Such a large mass of basic magma would produce a large positive gravity anomaly, but in the areas underlain by the granite there is a negative gravity anomaly. This process is therefore not considered to have been involved in the formation of the megacrystic biotite granites.

3. Extraction of a granitic melt from the mantle is also theoretically possible. To obtain such a large volume of granitic material by fractional melting would require about 250 volumes of mantle material, assuming the K_2O content of the mantle is 0.02% (White, 1967), with complete extraction of potassium. It would also require a very long time for extraction and collection. Furthermore it does not explain the restriction of the megacrystic biotite granites to a relatively narrow belt. If granite could be produced in the mantle and intruded then granite should not be restricted to areas of continental crust as it apparently is. The initial Sr^{87}/Sr^{86} ratios of the magmas produced in oceanic environments are in the order of

0.703 (Subbarao, et al., 1973). The initial ratios found in the Deadman's Bay pluton are similar. Fairbairn and Berger (1969) show an initial ratio of 0.704, and Cormier (written communication, 1973) has found an initial ratio of 0.704 ± 3, which suggests that the granites may be related to the mantle in some way.

4. Partial fusion of continental crust in water-saturated and undersaturated conditions has been cited by many workers as a probable mechanism for the origin of large amounts of granitic magma. This method solves many of the problems concerning granite batholiths, such as the source of the potassium. In such a process, an increase in K_2O by a factor of 1.64 over that in average continental crust (Harris, 1971) would provide sufficient potassium to form the megacrystic biotite granite of the study area. The lack of pegmatites in these megacrystic biotite granites suggests that the magma was undersaturated in water and could therefore travel upwards farther than a wet magma as outlined by Brown and Fyfe, (1970). Some recent models (e.g. Presnall and Bateman 1973; Brown, 1973) suggest that heat for the production of the melt would be provided by the latent heat of crystallisation of a crystallising magma produced from partially melted oceanic crust in a subduction zone. Possible evidence against such a process for the formation of the megacrystic biotite granites would be the low Sr^{87}/Sr^{86} ratio found in the Deadman's Bay pluton. A ratio greater than 0.71 would be expected from partial melting of older basement gneisses such as are found in the Gander Lake Belt, whereas the initial ratio is 0.704.

5. Melting of wet oceanic crust in a subduction zone has been postulated for the formation of acid volcanic and plutonic rocks (Oxburgh and Turcotte, 1970; Dickinson, 1970; Gilluly, 1971). Stern and Wyllie (1973) have shown experimentally that granitic and rhyolitic magma could not be produced from the destruction of oceanic crust at depths greater than 35 km. Magmas produced by the melting of oceanic crust have low initial ratios in the order of 0.703 (Culbert, 1972) which is comparable to that found in the megacrystic granites. However, the K:Rb ratios in the rocks described by Culbert are much higher, in the order of 300 to 400 compared to 265 for the megacrystic biotite granites. Thus the production of the megacrystic granites by the destruction of oceanic crust does not account for the geochemical features of the megacrystic biotite granites, but may be one of a number of factors involved.

6. Presnall and Bateman (1973) have suggested that the Sierra Nevada Batholith has been produced by the mixing of magma produced by melting of the lower crust and andesitic and basaltic magmas extracted from a downgoing slab of oceanic crust. They suggest that the high temperature of the rising andesitic magma would provide sufficient heat to melt even dry continental crust. This process allows for the formation of large volumes of granitic magma with intermediate Sr^{87}/Sr^{86} ratios, by a combination of the high ratios of the crustal melts and the low ratios of the andesitic magmas. However, the relatively homogeneous nature of the megacrystic biotite granites conflicts with the composite nature of the batholiths of the Pacific coast of North and South America. The compositional trend of the megacrystic biotite granites is distinctly

different from the Sierra Nevada batholith (Fig. 16).

The methods of formation of granitic magmas outlined above show that it is possible to obtain megacrystic biotite granites by methods 4, 5, and 6, but none of the methods satisfactorily explain all the variations found.

The megacrystic biotite granites have not been mapped in detail and it is possible that more detailed geochemical and petrographic data will allow for the recognition of different phases of intrusion. If, however, similar processes as envisaged for the Sierra Nevada batholith (Presnall and Bateman, 1973), produced the Newfoundland megacrystic biotite granites they must have been generated under entirely different conditions or from entirely different source rocks than those of the Pacific batholiths.

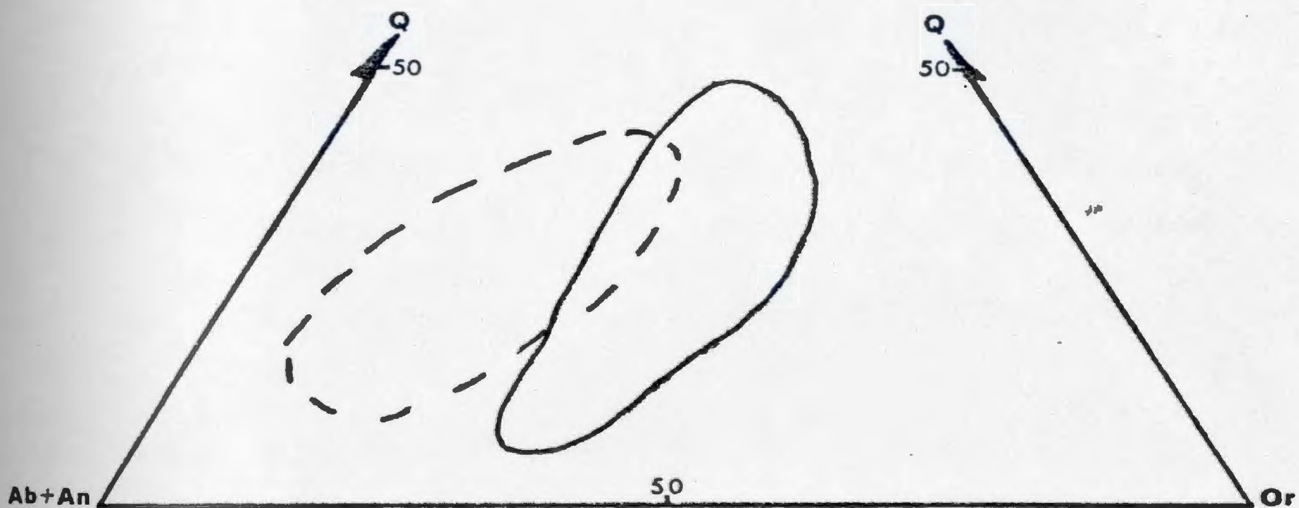

FIG. 16 - Normative proportions of Q, Ab+An, and Or normalised to 100 percent, for the Sierra Nevada Batholith (Presnall and Bateman, 1973) and the megacrystic biotite granites.

Sierra Nevada Batholith

Megacrystic Biotite Granites

CHAPTER 6

ECONOMIC POTENTIAL

6.1. Introduction

Numerous showings are associated with the granitoid rocks of the Gander Lake belt, including wolframite, scheelite, molybdenite, chalcopyrite, beryl, fluorite, and galena (Williams, 1968; Fogwill, 1970). New showings discovered in the present investigation include fluorite in the Gander Lake and Terra Nova plutons, molybdenite in the Deadman's Bay pluton, and beryl in the Middle Ridge pluton (Strong et al., 1973a, b).

One aim of the project was to compare the chemistry of the unmineralised and mineralised plutons, and especially those of the study area with the fluorite-bearing alaskite pluton in St. Lawrence.

The St. Lawrence alaskite is characterised by high SiO_2, K_2O, Rb, Zr, and F and very low Al_2O_3, MgO, CaO, P_2O_5, Ba, and Sr (Table 8) and by a simple mineralogy, viz. quartz and two feldspars and a low content of mafic minerals. It is peralkaline and riebeckite-bearing.

No pluton in the study area compares chemically or petrographically with the St. Lawrence pluton, and the chances of finding similar fluorite deposits are therefore thought to be low.

TABLE 8

Mean composition of the St. Lawrence Pluton (From Teng, 1974)

SiO_2	76.77%	Rb	295 ppm
TiO_2	0.15	Ba	70
Al_2O_3	10.91	Sr	0
Fe_2O_3	1.75	Cu	0
MnO	0.02	Zn	50
MgO	0.23	Zr	516
CaO	0.36	F	1308
Na_2O	3.57		
K_2O	4.73		
P_2O_5	0.00		

6.2. Beryl

Beryl is found in the metamorphic rocks 8 km. west of Wesleyville, in pegmatites associated with the leucogranites, and in coarse grained quartz-feldspar-muscovite pegmatites associated with the leucogranites of the Middle Ridge pluton west of Dead Wolf Pond.

Beryllium is a very mobile element in magmas and tends to concentrate in the apical regions of plutons (Tauson and Kozlov, 1972). Pegmatites also tend to concentrate towards the upper surface of a pluton. The exposed areas of the Middle Ridge pluton are dominantly near the roof as indicated by a large roof pendant found in the northeast of the pluton (Jenness, 1963) and also by the abundance of pegmatites.

Thus the presence of beryl makes this pluton especially interesting and justifies further exploration.

6.3. Molybdenite

Sizable showings of molybdenite are found associated with megacrystic biotite granite, particularly with the Ackley City pluton where molybdenite is found in the marginal aplites in the Rencontre East area (White, 1940).

The molybdenite of the Deadman's Bay pluton is found as flakes associated with patches of chlorite and pyrite in a small aplite vein cutting the granite, the only aplite noticed by the writer in the area.

6.4. Fluorite

Microscopic specks of fluorite in the Terra Nova pluton are associated with altered megacrystic granite. This is taken to be related to the breakdown of biotite. The fluorine content of the pluton is below average and the potential for fluorite appears to be low.

The Gander Lake pluton contains two showings of fluorite.
1) Near the contact northwest of North Pond, small patches of purple fluorite were found in cavities and along joint planes in the megacrystic biotite granite. The granite at this locality is variably altered to sericite and chlorite and is veined by a multitude of quartz and aplite veins. Analyses of the granite at this locality show a low content of fluorine but stream water analyses showed over 1.5 ppm fluorine, which is

the highest obtained from stream water analyses in the Gander Lake Belt (H.C. Teng, pers. comm.). The anomalously high fluorine content of the water and the presence of fluorite in the granite suggest that this area should be re-examined to ascertain the fluorite potential. 2) In the northern contact area of the Gander Lake pluton a number of fluorine-bearing quartz-feldspar pegmatite boulders form a narrow belt which strikes north across the Trans-Canada Highway. The boulders are not considered to be glacial in origin because of their angularity and restricted rock type, but appear to have been dumped in this area, e.g. during highway construction. However, as the boulders are covered with lichen and rotten broken trees and as no road works were carried out in this area before 1955 it is probable that these boulders are locally derived and may be the result of frost shattering of a vein. Analyses showed that these boulders contained 2000 ppm fluorine which along with the presence of fluorite in the boulders and the high fluorine content of the surrounding granite justify further investigation.

Stream water analyses in the Hare Bay-Trinity area give locally high fluorine concentrations with the highest reading being 0.58 ppm. The stream drainage areas are underlain by granitoid gneisses and migmatites, and fluorite is reported by local residents. However, Blackwood who is doing his M.Sc. thesis in the area (pers. comm. 1973) suggests that the reported fluorite is amethyst which is common in the Trinity area of Bonavista Bay.

6.5. Whole Rock Fluorine Analyses and Tin

Whole rock analyses of the granitoid rocks of the study area showed that the megacrystic biotite granites were by far the richest in fluorine. This could be a function of the high proportion of biotite in the granite as mica contains most of the fluorite in a granitoid rock. Odikadze (1971) however, has shown that the amount of fluorine in a granitoid rock may be independent of the proportion of mica, presumably when it is concentrated in fluorite or apatite.

Barakso and Gower (1973) showed a 0.857 correlation coefficient between the tin and fluorine contents of a granitoid rock. Tin, like fluorine tends to be trapped in biotite (Levashev *et al.*, 1971) and with the high correlation between tin and fluorine suggests that the biotites of the megacrystic granites may have a high tin content. Thus the tin content of the megacrystic granites and/or their biotites should be ascertained.

6.6. Tungsten

Scheelite has been reported in quartz veins cutting the Horwood granodiorite, to the west of Gander Bay (Fogwill, 1965; 1970). Although not geochemically analysed during the survey, this pluton is petrographically similar to the Rocky Bay and Frederickton plutons. Other similarities include the presence of quartz veins in the Frederickton pluton and a small quartz vein containing (?) wolframite. This suggests that there is some possibility of further showings of scheelite or wolframite in the Frederickton pluton.

6.7. Copper

Porphyry copper deposits are commonly associated with quartz diorites and quartz monzonites of both island arc and cordilleran type continental margins (Bryner, 1969; Mitchell and Garson, 1970) and occur near the apical regions of the plutons. An island arc nature of the Rocky Bay and Frederickton plutons has been suggested (5.3.2.) and the undulating contact relations of the Rocky Bay, Frederickton, and Island Pond plutons and their possible connection at depth suggest that the volcanic and sedimentary cover could be a suitable environment for disseminated copper.

Chalcopyrite occurs in the black shale melange east of the Rocky Bay pluton (Uzuakpunwa, pers. comm.) and veins of calcite and pyrite are common in small fault breccias in the melange. This suggests that there could be copper in the vicinity of the plutons.

6.8. Lead

Disseminated galena is reported in psammitic gneisses in the Musgrave Harbour area, near the contact with the Deadman's Bay pluton (Williams, 1968). This prospect was not observed during the present study.

6.9. Semi-Precious Minerals

Veins of crystalline quartz occur in the megacrystic biotite granite near the Valleyfield turn-off 8 km. west of Valleyfield. A continuous vein of prismatic quartz 2 - 5 cm. wide contains zoned crystals which are smokey in the central half and grade into clear quartz.

Similar veins occur in the Trinity area and these contain well-formed quartz crystals which are zoned from smokey through colourless to amethyst.

Excavation of the veins could be difficult as they cut massive granite. The extent of the veins has not been ascertained but might be sufficient to support a small home based jewellery industry.

6.10. Conclusions and Discussion

The quartz diorites, because of their geological environment, may have some potential for copper, but require much more detailed analyses including analysis of the volcanic rocks. The leucogranites have a high potential for minerals associated with pegmatites. The megacrystic granites may locally have a potential for fluorite and may have a potential for tin.

Chemical analyses have shown that within the study area there are no plutons similar to the St. Lawrence pluton.

Trace element analyses and a few major elements have been useful in characterising the granitoids and suggesting their ore-bearing potential. Direct analyses for economic elements such as Be, Mo, W, Ti, Hg, Sn and Ta, would be most useful and with the other pathfinder elements such as F, Cl, and Li, the full potential of the granitoid rocks could be ascertained.

CHAPTER 7

DISCUSSION AND SUMMARY

7.1. Discussion

7.1.1. West-East Variation in K_2O Content

The increase in K_2O from west to east in the granitoid rocks of the Gander Lake Belt has been convincingly illustrated by Strong et al. (1973b, c).

Brown and Fyfe (1972) and Allen et al. (1972) have suggested that such increases in potassium are related to the higher thermal stability of phlogopite relative to hornblende, so that with increasing depth of fusion along a subduction zone there is a higher K_2O content in magmas produced by partial fusion of phlogopite-bearing oceanic sedimentary and volcanic rocks. This assumes, however, that all granitoid plutons are directly related to such melts and is a plausible explanation for the regular potassium variation only if the assumption is valid.

Bateman and Eaton (1967) have suggested that the variation in K_2O of the Sierra Nevada batholith is related to an increase in the proportion of more potassic rocks in a geosyncline towards the continent, so that during deformation and metamorphism of the geosyncline there will be an increase in the K_2O content of the melts produced by anatexis of the geosynclinal sediments. This assumes among other things that in an orogen there is no major disruption of the lateral distribution of the various geosynclinal facies during deformation.

The leucogranites of the Gander Lake Belt are almost certainly formed by anatexis of continental crust (see sect. 5.4.3) and contain no material derived from any descending lithospheric plate. The only relationship with a subduction zone might possibly be the transfer of heat from andesitic melts produced from the downgoing plate and trapped lower in the crust (c.f. Presnall and Bateman, 1973). As the leucogranites are not involved with the relative stabilities of hornblende and phlogopite the overall variation in K_2O content in the Gander Lake Belt cannot be accounted for by this hypothesis.

The concept of an initial K_2O distribution is left as the only known alternative to explain the K_2O variation in the leucogranites. If one accepts the overall tectonic model of Strong, et al. (1973c) involving eastward subduction of an oceanic plate, then this must somehow work in conjunction with the melts produced from the downgoing slab of oceanic crust to produce a systematic K_2O variation over an orogen.*

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*Note: Since completion of this thesis Kistler and Peterman (1973) have suggested that the chemical and isotopic variations of the Mesozoic granitoids of Central California could be best explained if the parent magmas of the majority of granitoids were derived in a region that was laterally variable in composition and in a zone of melting that intersected both upper mantle and lower crust. This is similar to the ideas expressed by the author but Kistler and Peterman (1973) do not suggest that some of their magmas were derived entirely within continental crust.

7.1.2. Significance of the Rocky Bay and Aspen Cove Plutons

An island arc origin of the quartz diorites (see Sect. 5.3.2.) and an anatectic origin within continental crust of the Aspen Cove leucogranite (see Sect. 5.4.3.) have been postulated.

Stevens et al. (1973) suggest that the "Central Newfoundland island arc" was separated from the continent to the east by a "marginal ocean basin" underlain by oceanic crust and fed by diapirs of ultrabasic magma, now represented by the Gander River Ultrabasic Belt (Jenness, 1954).

The truncation of the Aspen Cove leucogranite by the Rocky Bay quartz diorite suggests that the island arc (to which the latter was related) was against the continent and therefore the marginal ocean basin had closed completely in this area. The Aspen Cove pluton is located at the very edge of the metasedimentary terrain and therefore represents the present edge of the original continental crust, which suggests that there must have been destruction of continental crust before intrusion of the Rocky Bay pluton.

7.1.3. Ages of the Granitoids

Geological evidence for the ages of the granitoids is limited and only locally is it possible to postulate the order of intrusion. The quartz diorites have intruded the Davidsville Group shales and greywackes which extend to Glenwood, west of Gander, where the sediments contain Middle Ordovician fossils. It is therefore possible to give a maximum age of Middle Ordovician to the quartz diorites.

Petrographic similarities between Ordovician quartz diorites in the Notre Dame Bay area and the quartz diorites of the study area also suggest that they may be Ordovician in age. The leucogranites have intruded the metasedimentary terrain syntectonically (McGonigal, 1973; Kennedy and McGonigal, 1972a; Uzuakpunwa, 1973). The metasedimentary terrain is unconformably overlain by the Davidsville Group as it does not contain the polyphase fabrics of the metasedimentary terrain (Kennedy and McGonigal, 1972a; McGonigal, 1973; Uzuakpunwa, 1973). It is therefore possible to say that the leucogranites are Pre-Middle Ordovician in age but there is no geological evidence as to their true age. The megacrystic biotite granites have intruded the Precambrian gneissic terrain (Kennedy and McGonigal, 1972a) and the late Precambrian Love Cove and Musgravetown Groups (Jenness, 1963). The Gander Lake pluton, which is locally composed of megacrystic biotite granite, has intruded the metasedimentary terrain post-tectonically (McGonigal, 1973; Kennedy and McGonigal, 1972a) and is therefore younger than the leucogranites.

Williams _et al._ (1972) have suggested that the megacrystic biotite granites are older than the leucogranites as garnetiferous pegmatites, which they considered to be related to the leucogranites, cut the megacrystic biotite granites.

A.R. Berger (Pers. Comm., 1972) has noted that the main tectonic fabric in the Ragged Harbour pluton (leucogranite), which is also found in the metasediments intruded by the leucogranite, is truncated by the Deadman's Bay pluton (megacrystic biotite granite). This suggests that the Ragged Harbour pluton is older than the Deadman's Bay pluton. P.J. Brown (Pers. Comm., 1973) has noted that there are at least two periods of intrusion of megacrystic biotite granite in the south-western extension of the Gander Lake Belt (Williams et al. 1972) in the La Poile area, Port aux Basques where the older granite is deformed and the younger granite has intruded fossiliferous Devonian sediments and is also deformed.

Deformation in the megacrystic biotite granites is mainly cataclastic and of uncertain age, but Blackwood (Pers. Comm., 1973) working in the Hare Bay area has noted that tectonically deformed mega-crystic biotite granite is intruded by undeformed megacrystic biotite granite suggesting that there have been at least two phases of intrusion of megacrystic biotite granite, apparently analagous to the Port aux Basques - La Poile area.

Thus the relative ages of the megacrystic biotite granite and the leucogranite are uncertain, although apart from the presence of garnetiferous pegmatites in the megacrystic biotite granites the most likely possibility is that at least some of the megacrystic biotite granites are younger than the leucogranites. The relative ages of quartz diorite and the megacrystic biotite granites are uncertain.

K-Ar age determinations have been made on the Ragged Harbour and Deadman's Bay plutons (Williams, 1964b) and the Gander Lake and Fresh-water Bay plutons (Jenness, 1963). Muscovite from the Ragged Harbour pluton gave an isotopic age of 360 m.y., biotite from the Deadman's Bay pluton gave an age of 335 m.y., muscovite and biotite from the Gander Lake pluton gave isotopic ages of 244 m.y. and 350 m.y. respectively, and biotite from the Freshwater Bay pluton gave an age of 317 m.y. The ages range from Middle Devonian to Upper Permian but are probably too young as 1) there is little geological evidence of plutonic activity after the Devonian, and 2) the discrepancy in ages given by the minerals from the Gander Lake pluton suggest that there may have been argon loss, and 3) fossil evidence indicates that the Ragged Harbour pluton is Pre-Middle Ordovician in age and not Devonian as suggested by the isotopic age.

Whole-rock Rb-Sr isotopic ages have been attempted on the Deadman's Bay pluton by Fairbairn and Berger (1969) and Cormier (written communication, 1973). Fairbairn and Berger give a preliminary age of 600 m.y. ± 100 m.y., and Cormier has calculated an age of 565 m.y. ± 85 m.y. These ages suggest a Late Precambrian to Earliest Cambrian age for the Deadman's Bay pluton. The wide range of error in the ages may be due to the large area of the pluton from which specimens were obtained as it is possible that specimens were collected from several, as yet unrecognised, phases of intrusion. The ages, however, suggest that the pluton is much older than the K-Ar isotopic age of 335 m.y. (Williams, 1964b).

Williams _et al._ (1972) have suggested that the northern half of Cape Breton Island, Nova Scotia, is a correlative of the Gander Lake Belt (Zone G) and therefore that the granitoid rocks in each area are equivalent. Cormier (1972) has shown that the granitoid rocks of Cape

Breton Island range in age from Late Precambrian to Devonian, with the majority of ages near the Precambrian-Cambrian boundary at 570 m.y.

The ages of Fairbairn and Berger (1969) and Cormier (written communication, 1973) are therefore in agreement with the majority of ages from northern Cape Breton Island, and it is probable from this and the geological evidence from the Gander Lake Belt that the granitoid rocks of the Gander Lake Belt range in age from Late Precambrian to Devonian. However, this can only be ascertained by careful mapping and extensive isotopic dating of the granitoids.

7.1.4. Mylonitisation at the Margins of the Megacrystic Biotite Granite Plutons.

Extensive mylonitisation near the contacts of the megacrystic biotite granites is common throughout the gneissic terrain. In the study area intense mylonitisation has occurred in several areas towards the east of the gneissic terrain. Outside the study area, areas of extensive mylonitisation are found in the northwest of the Ackley City pluton, and in the Bay D'Espoir area (S.P. Colman-Sadd, pers. comm., 1973).

The linear arrangement of these areas suggests that they may be part of an extensive mylonite zone over 350 km. in length which stretches from the Cape Freels area to Bay D'Espoir. Such areas of mylonitisation occur in the vicinity of major structures such as the San Andreas Fault (Higgins, 1971) and it is interesting to speculate that such a fault system may be present along the eastern margin of the

Gander Lake Belt. A major fault occurs between the Love Cove Group and the gneissic terrain where high-grade gneisses are faulted against low grade schists. The mylonitisation in the gneissic terrain may therefore be related to this fault.

7.2. Summary

The granitoid rocks of the study area have been divided into three main groups viz. quartz diorites, leucogranites, and megacrystic biotite granites, with each group mainly found in one of the three main divisions of the study area, i.e. the sedimentary terrain (Davidsville Group), the metasedimentary terrain, and the gneissic terrain respectively (Kennedy and McGonigal, 1972a).

The quartz diorites occur in the northwest of the study area and intrude the fossiliferous lower units of the Davidsville Group. The quartz diorites are characterised by a high content of biotite and/or hornblende, plagioclase, and quartz, and show a zonation from less acid margins to more acid cores. The chemistry reflects the mineralogy with a high Ca, Fe, Mg, and Sr content and a low K, Rb, and silica content. A comparison of their geological setting to the quartz diorites of the Aleutian Arc (Reed and Lanphere, 1973) suggests that the quartz diorites may have an island arc origin, i.e. they presumably represent the most easterly part of the "Central Newfoundland island arc" of Stevens et al. (1973).

The leucocratic granodiorites (leucogranites) occur mainly in a discontinuous NE-SW trending belt in the metasedimentary terrain which is composed of low to medium grade metasediments (Kennedy and McGonigal, 1972a) although small leucogranite plutons occur in the gneissic terrain. The leucogranites have intruded the metasedimentary terrain syntectonically (Kennedy and McGonigal, 1972a; McGonigal, 1973; Uzuakpunwa, 1973) and are characterised by a high content of quartz, muscovite, and feldspar, and a low biotite content. Small pin-head sized garnets are also characteristic. The leucogranites are characterised chemically by a high silica, K, and Rb content and Rb:Sr ratios and a low Ca, Fe, Mg, and Sr content and K:Rb ratios. The enrichment of the leucogranites in the lithophile elements, along with other evidence such as the lack of basic plutonic rocks, the syntectonic origin of the leucogranites, the abundance of pegmatites suggesting a wet magma, and the apparently "eutectic" composition at 1 kb P_{H_2O} and 2 to 5% An (in the system $KAlSi_3O_8$-$NaAlSi_3O_8$-$CaAl_2Si_2O_8$-SiO_2-H_2O, James and Hamilton, 1969) suggests that the leucogranites formed by anatexis of continental crust.

The megacrystic biotite granites are generally restricted to the gneissic terrain which is composed of high grade gneisses and migmatites (Kennedy and McGonigal, 1972a). The megacrystic biotite granites are very coarse grained, composed essentially of microcline, quartz, biotite, and plagioclase, and are generally chemically intermediate between the quartz diorites and leucogranites, with high K_2O and Rb, and relatively low Ca, Fe, Mg, and Sr. Rb:Sr ratios are near unity and K:Rb ratios are in the high normal range (Taylor, 1965). Initial $Sr^{87/86}$ isotope ratios of the Deadman's Bay pluton are low, in the order of 0.704 (Fairbairn and Berger, 1969; Cormier, written comm.). The low initial $Sr^{87/86}$ ratio discounts a pure anatectic origin within continental crust. Magmas produced by partial melting of oceanic crust would produce plutonic rocks less acid than the megacrystic biotite granites (Stern and Wyllie, 1973), but would produce a low initial Sr ratio. Some combination of both processes for the production of granitic melts as envisaged by Presnall and Bateman (1973) is possible, but present evidence does not allow the selection of a particular mode of origin.

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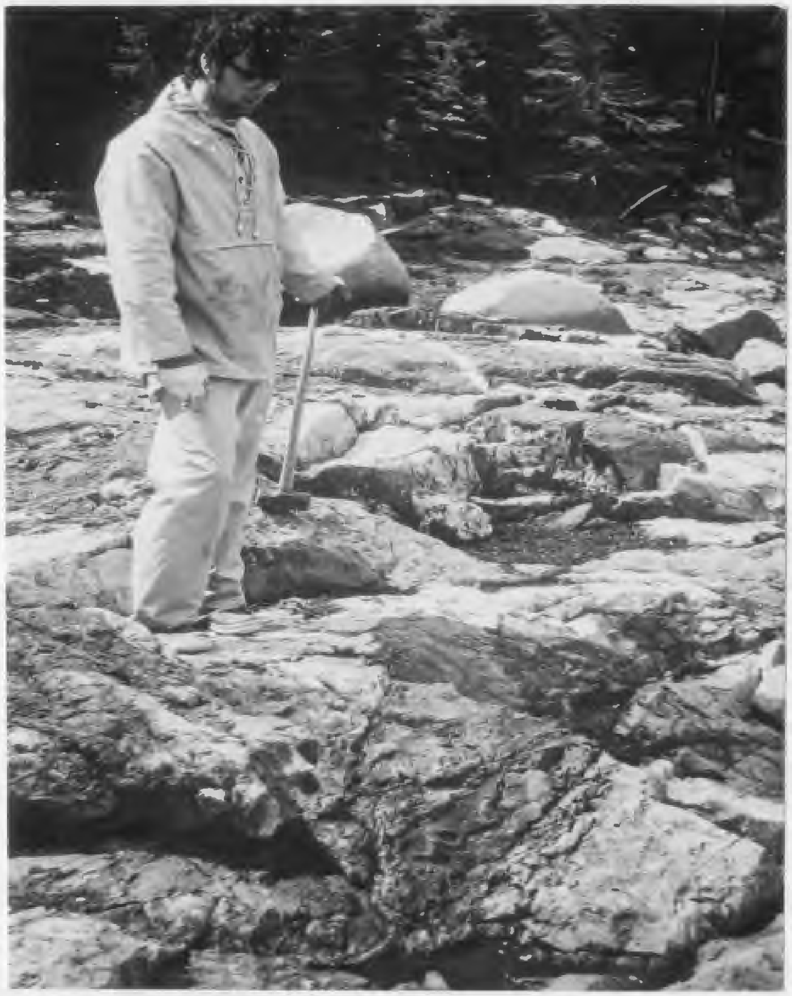


PLATE 1: Leucocratic quartz diorite dykes cutting volcanic agglomerates near the N.W. contact of the Rocky Bay Pluton, Rocky Bay.

PLATE 2: Slivers of volcanic rocks in quartz diorite near the N.W. contact of the Rocky Bay pluton.

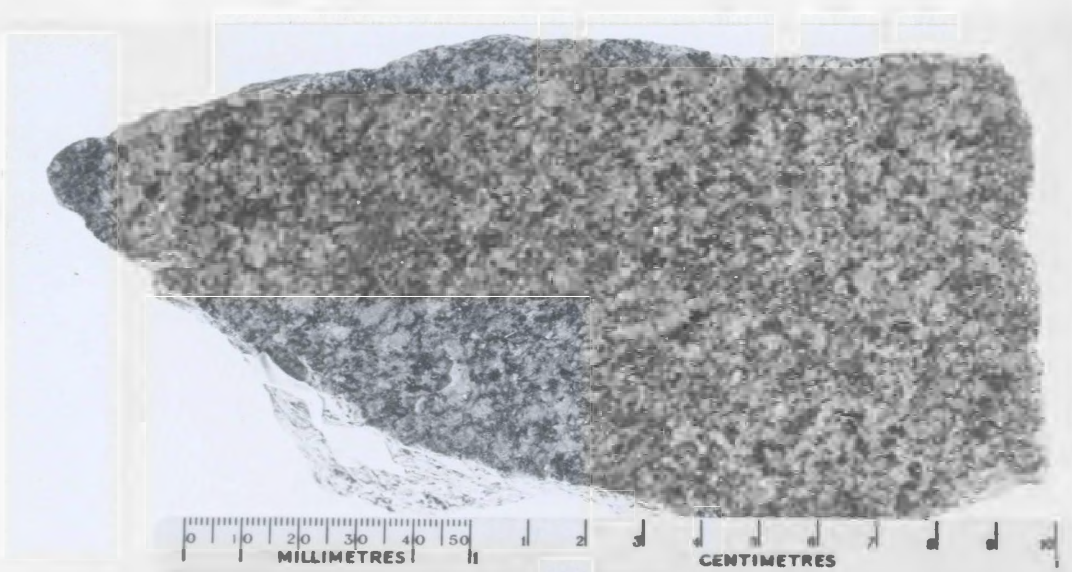


PLATE 3: Hornblende-biotite quartz diorite from the N.W. margin of the Rocky Bay pluton, Rocky Bay.

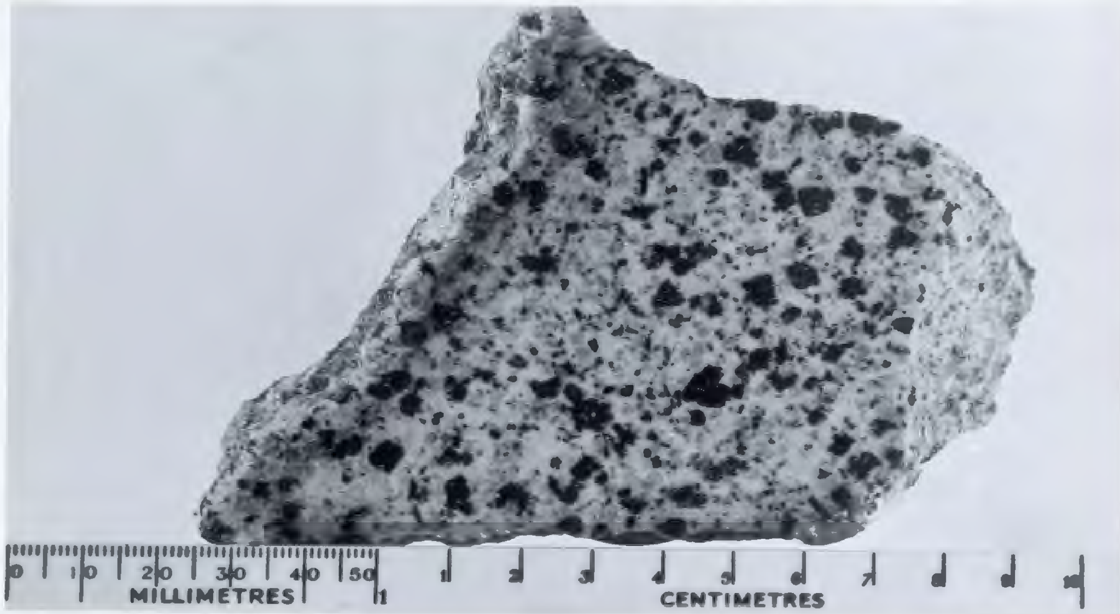


PLATE 4: Biotite quartz diorite from the centre of the Rocky Bay pluton.

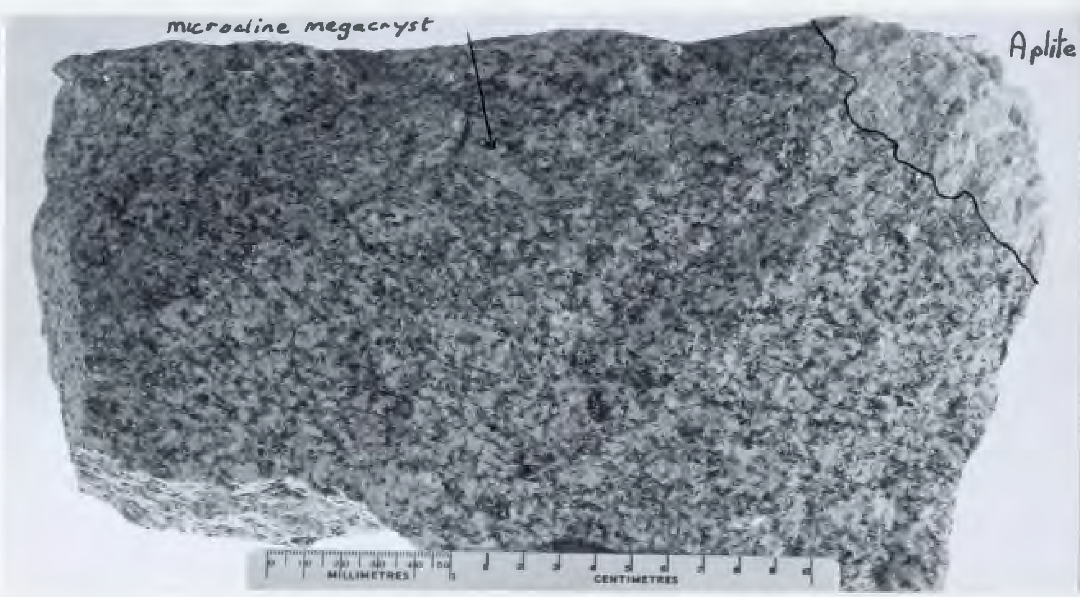


PLATE 5: Muscovite-biotite leucocratic granodiorite containing microcline megacrysts and cut by a small garnetiferous aplite dyke (top right), from the west margin of the Ragged Harbour pluton.

PLATE 6: Megacrystic biotite granite from the Deadman's Bay pluton, 5 km. west of Deadman's Bay, containing large megacrysts of microcline with rims of plagioclase.

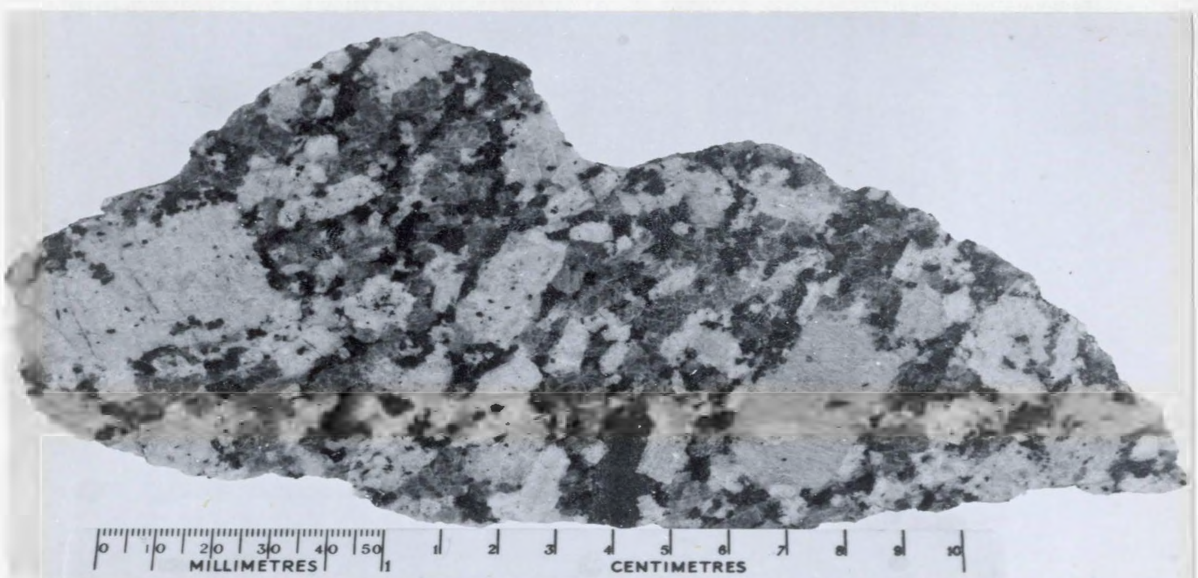


PLATE 7: Megacrystic biotite granite from the Deadman's Bay pluton, near Lumsden, with inclusions of biotite and plagioclase in the microcline megacrysts. The megacrysts are rimmed with plagioclase.

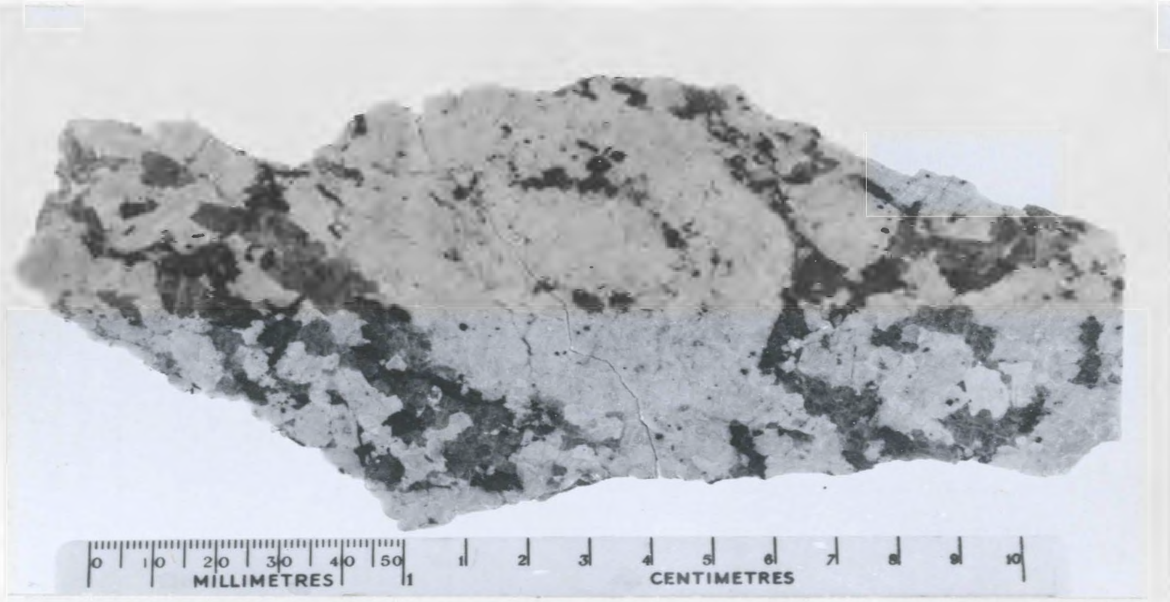


PLATE 8: Megacrystic biotite granite from the Deadman's Bay pluton, near Lumsden, with a circular arrangement of biotite inclusions in the large microcline megacryst.

PLATE 9: Composite diabase dyke cutting the Deadman's Bay pluton at Deadman's Bay.

PLATE 10: Medium grained granodiorite dyke cutting the Deadman's Bay pluton, east of Lumsden.

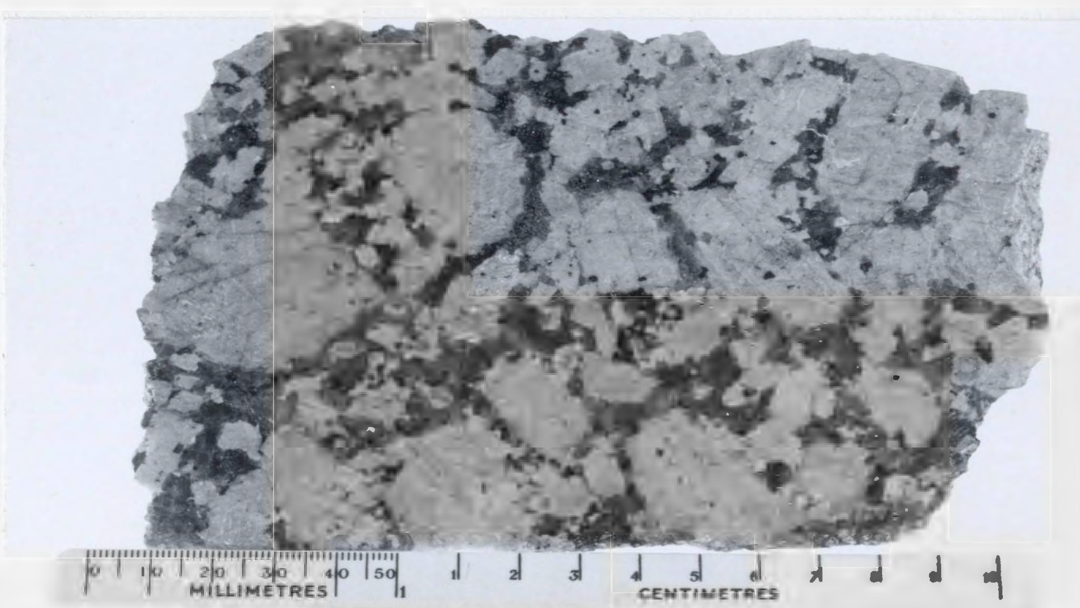


PLATE 11: Massive megacrystic biotite granite from the Cape Freels pluton, near Cape Freels: (= 1 in sect. 4.7.1.).

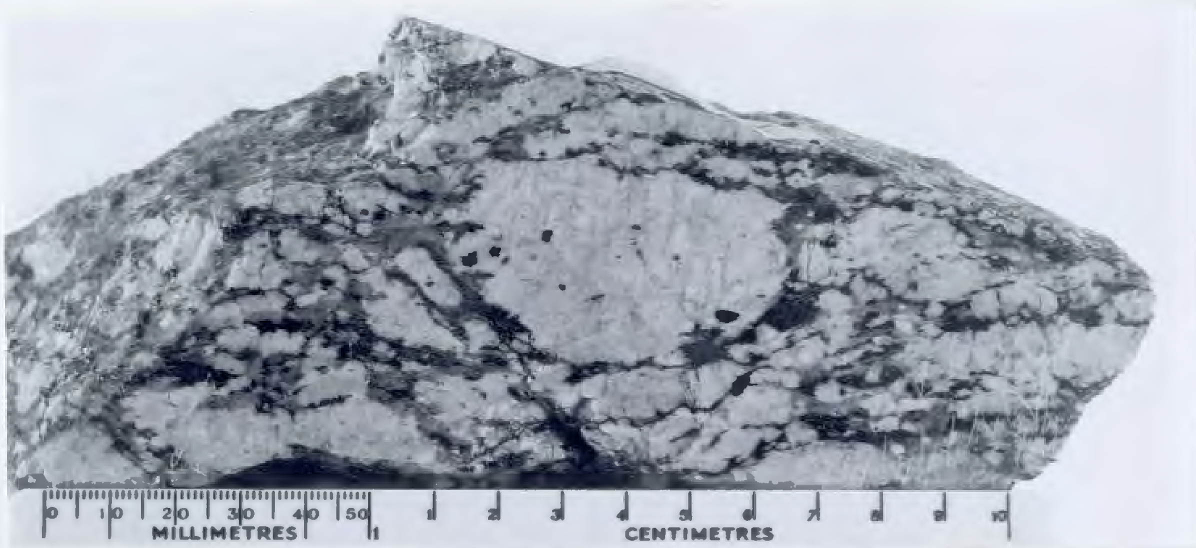


PLATE 12: Megacrystic biotite granite with poorly aligned microcline megacrysts - protomylonite: (= 2 in sect. 4.7.1.).

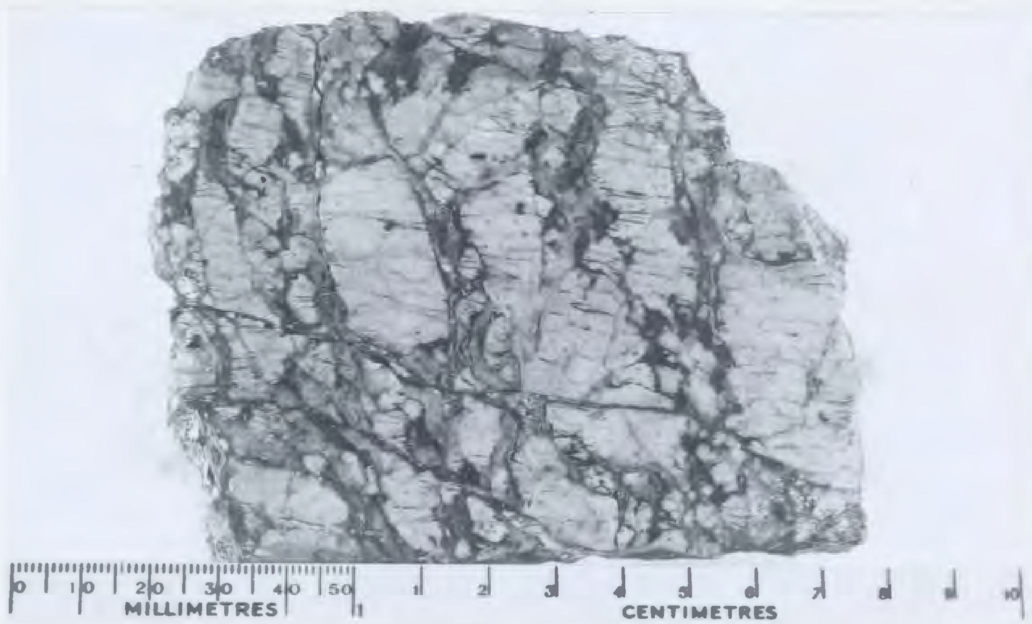


PLATE 13: Megacrystic biotite granite with orientated microcline megacrysts - protomylonite: (= 3 in sect. 4.7.1.).

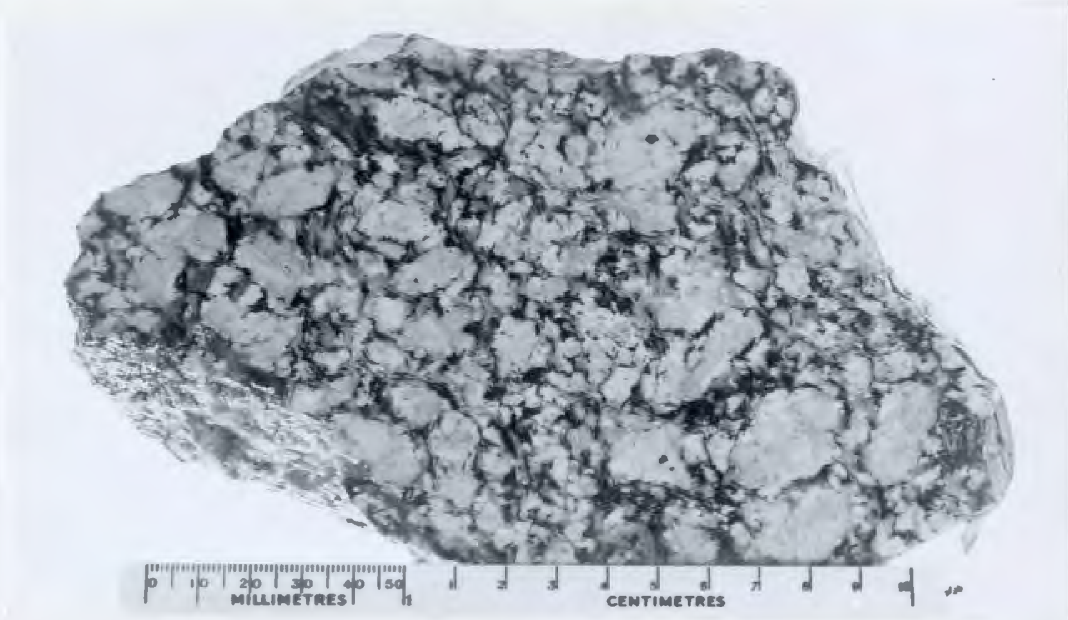


PLATE 14: Highly deformed megacrystic biotite granite containing rounded microcline crystals with granulated quartz and biotite 'flowing' round the microcline crystals - mylonite: (= 4 in sect. 4.7.1.).

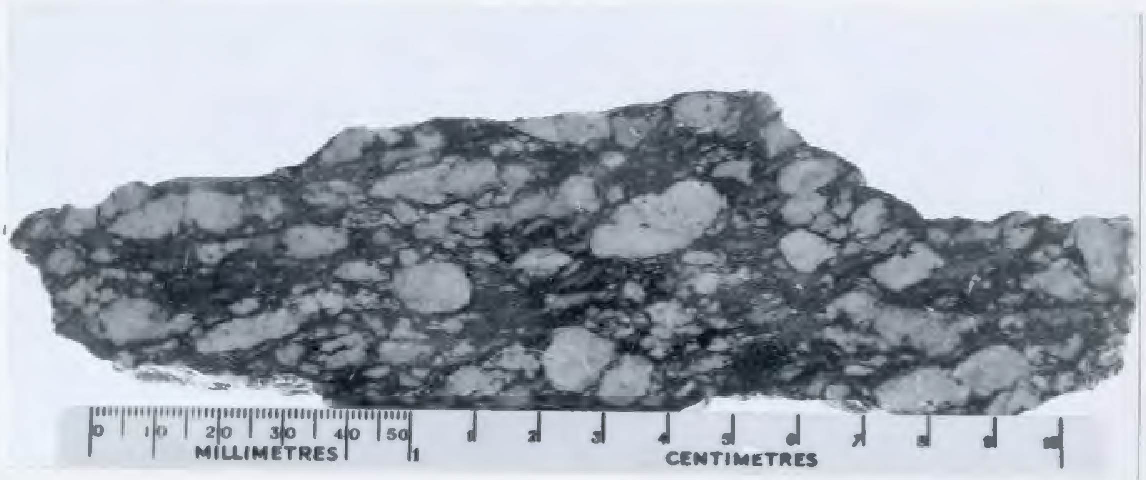


PLATE 15: Highly deformed biotite granite with granulated microcline crystals in fine grained matrix - porphyroclastic blastomylonite: (= 5 in sect. 4.7.1.)

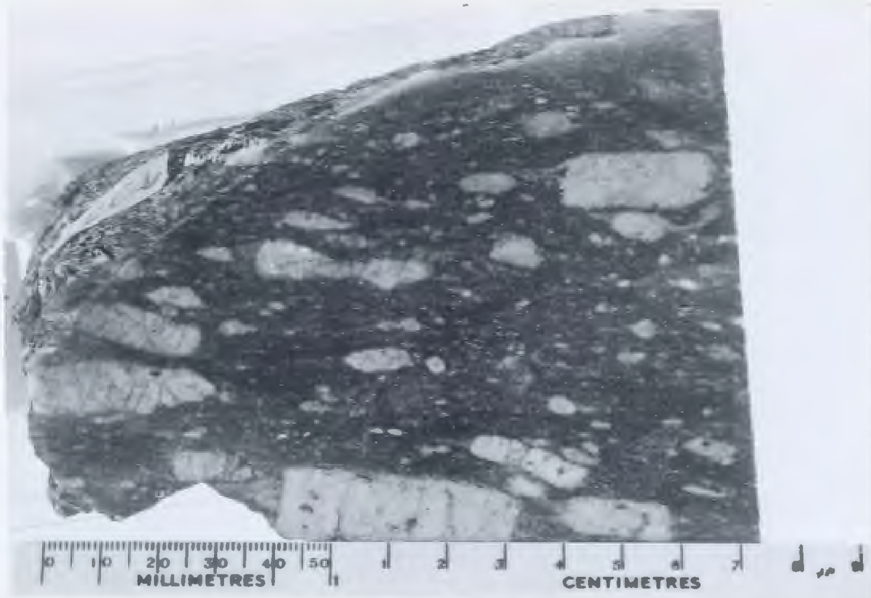


PLATE 16: Highly deformed biotite granite with microcline crystals cut by tension cracks in fine grained matrix. Proportion of porphyroclasts to matrix has decreased compared to Plate 15 - porphyroclastic blastomylonite: (= 6 in sect. 4.7.1.).

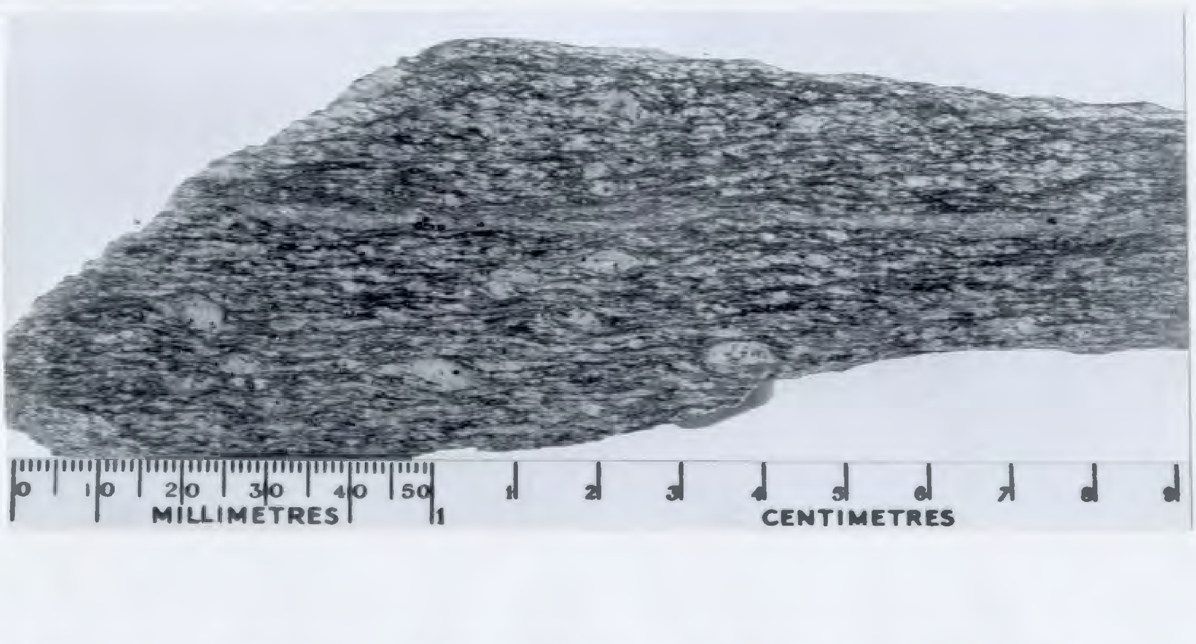


PLATE 17: Medium grained highly foliated granite with re-crystallised groundmass containing muscovite and biotite - ultramylonite: (= 7 in sect. 4.7.1.).

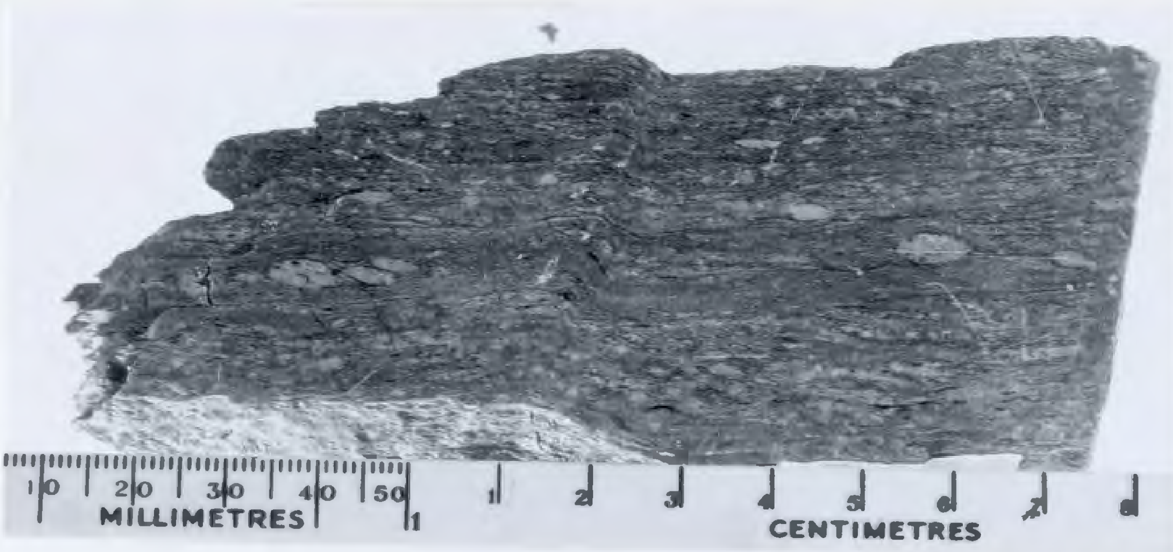


PLATE 18: Medium grained highly foliated granite in which the groundmass has recrystallised to muscovite, biotite, quartz, and plagioclase - ultramylonite: (= 7 in sect. 4.7.1.).

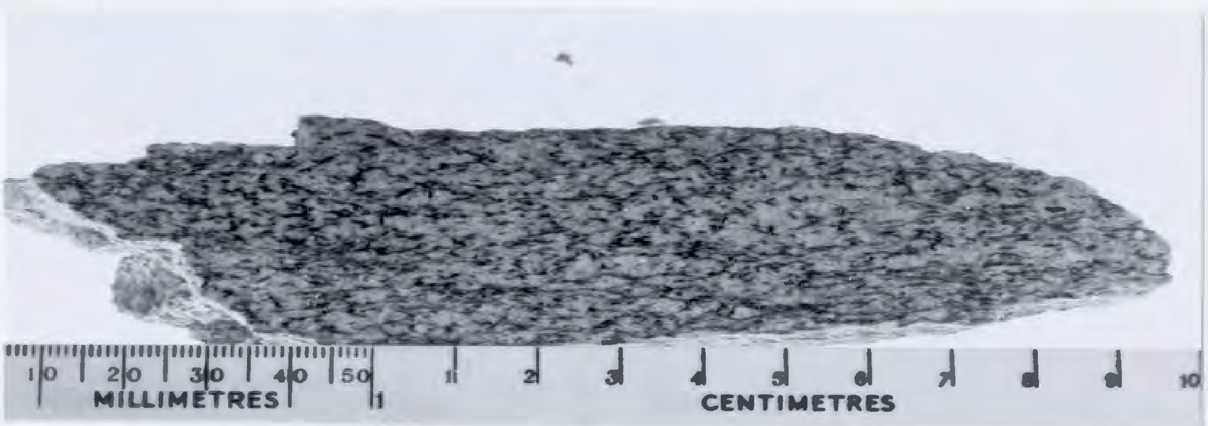


PLATE 19: Schistose medium grained granite with small microcline porphyroclasts augened by muscovite and biotite - mylonite schist: (= 8 in sect. 4.7.1.).

PLATE 20: Mylonitised granite from the Middle Brook pluton 2 km. south of Hare Bay.

PLATE 21: Mylonitised aplite dyke (centre) cutting deformed megacrystic granite near Hare Bay.

PLATE 22: Xenoliths of biotite schist in the Newport pluton megacrystic biotite granite, Lewis Island.

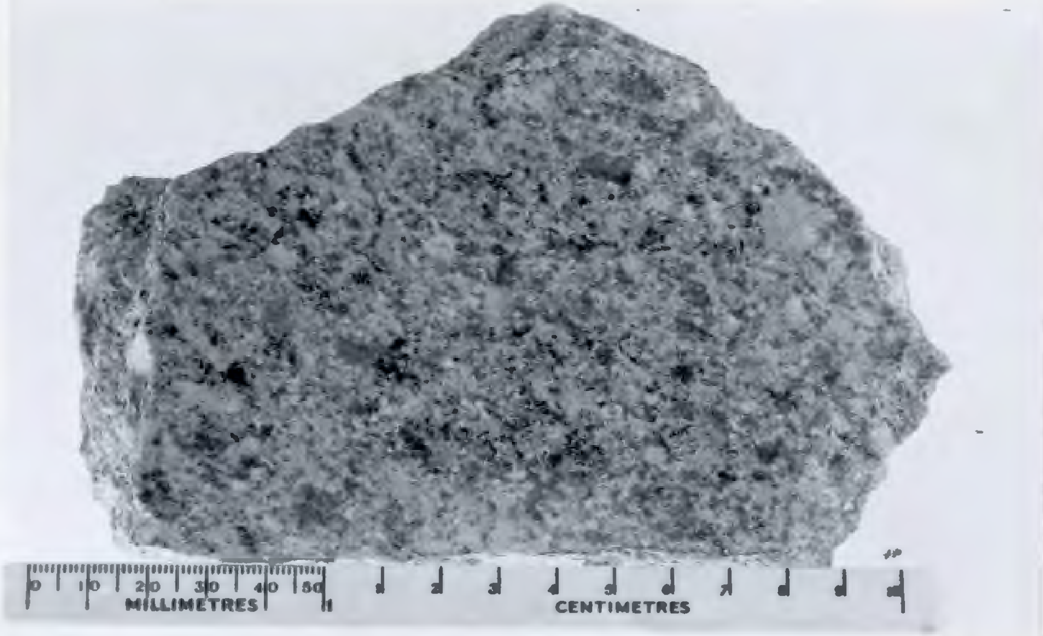


PLATE 23: Coarse grained biotite muscovite granite from the northeast part of the Gander Lake pluton.

PLATE 24: Porphyritic biotite granite from the northwest part of the Gander Lake pluton, showing aligned microcline phenocrysts.

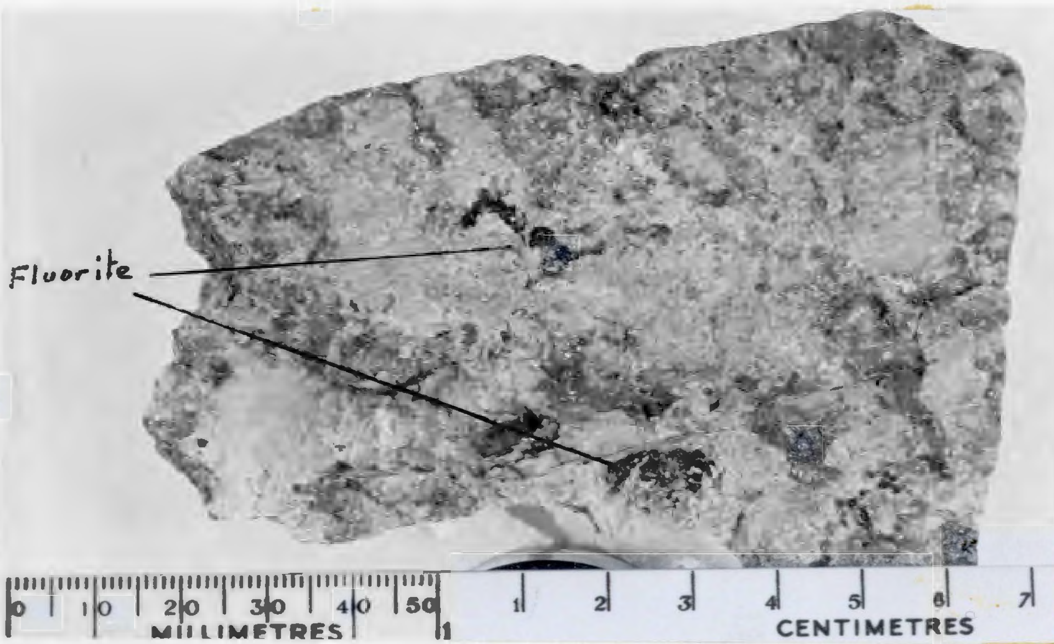


PLATE 25: Megacrystic biotite granite from the Gander Lake pluton, with patches of fluorite (dark grey).

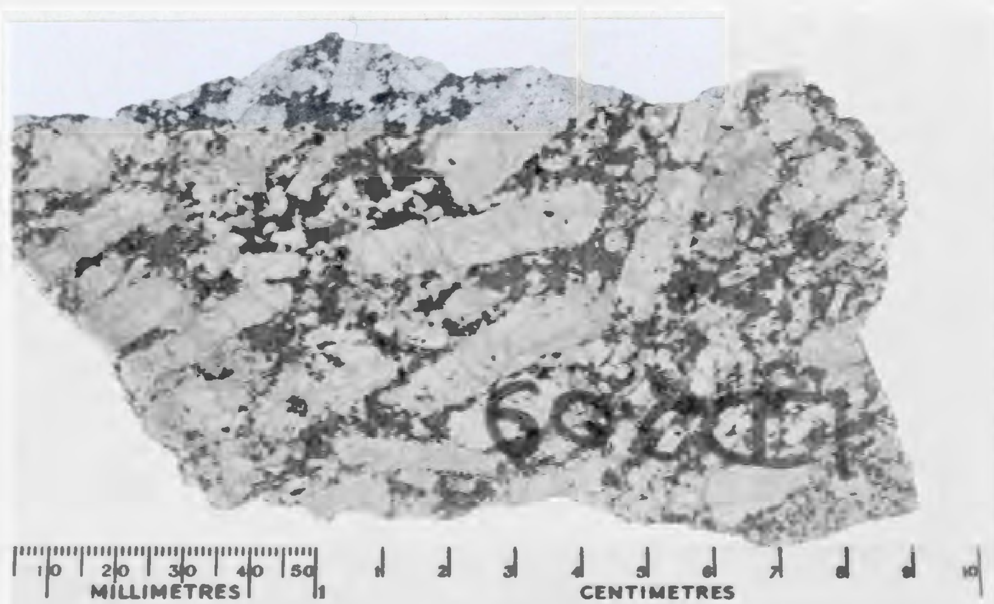


PLATE 26: Epidotised porphyritic granite from same locality as Plate 24. Light coloured crystals - pink altered microcline, light grey - epidote, black - cavities in the epidote.

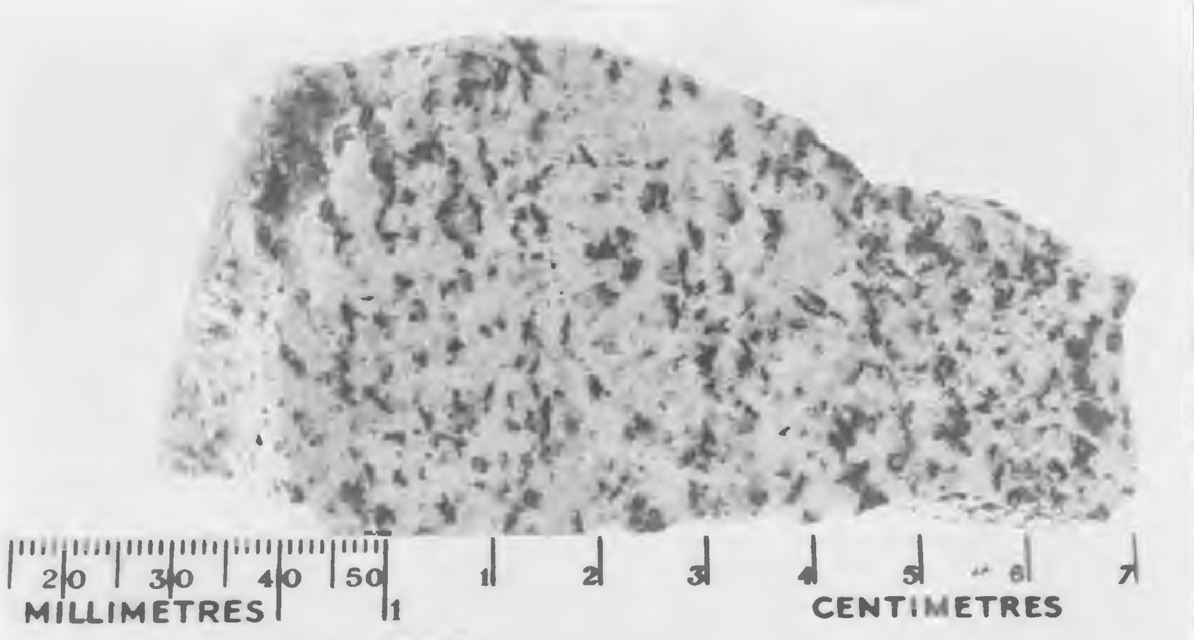


PLATE 27: Tectonically foliated biotite granodiorite from the north part of the Freshwater Bay pluton, southeast shore of Freshwater Bay.

PLATE 28: Aligned microcline megacrysts in the undeformed megacrystic biotite granite of the Terra Nova pluton, east shore of Pitts Pond.

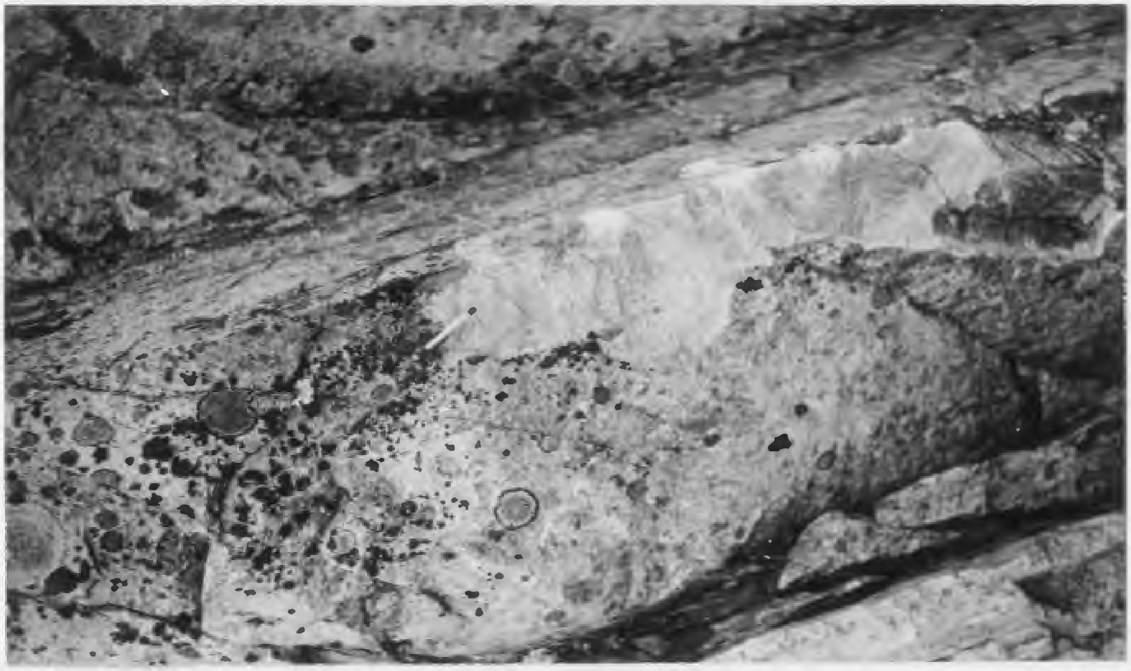


PLATE 29: Medium grained foliated granodiorite from the Terra Nova River West pluton.

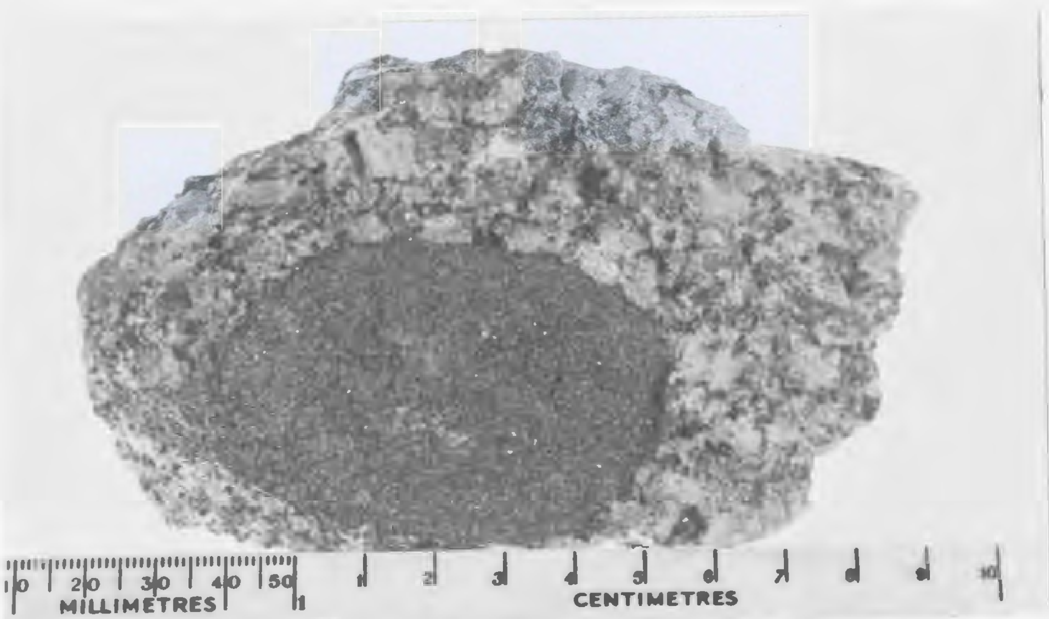


PLATE 30: Rounded xenolith of psammitic biotite schist in megacrystic biotite granite, from the Deadman's Bay pluton, near Lumsden.

APPENDIX I

1.1. Sampling Methods

The sampling programme was planned to permit assessment of the geochemical variability at and around outcrops, the overall variability within plutons, the variability between plutons and the variability within and outside of the Gander Lake Belt. An attempt was made at obtaining about one sample per square mile, but in many cases this was not possible because of poor exposure and inaccessibility (See Fig. 17a, 17b).

Eight-pound sledge hammers were used to collect single and duplicate rock samples of 5 to 10 kg, depending on grain-size (cf. Wager and Brown, 1960). The specimens were described according to a format adapted from R.G. Garrett, Geological Survey of Canada, with the intention of using his computer programmes developed for a similar study of Yukon granitoids (Garrett, 1973). This format is shown in Fig. 18.

1.2. Laboratory Methods

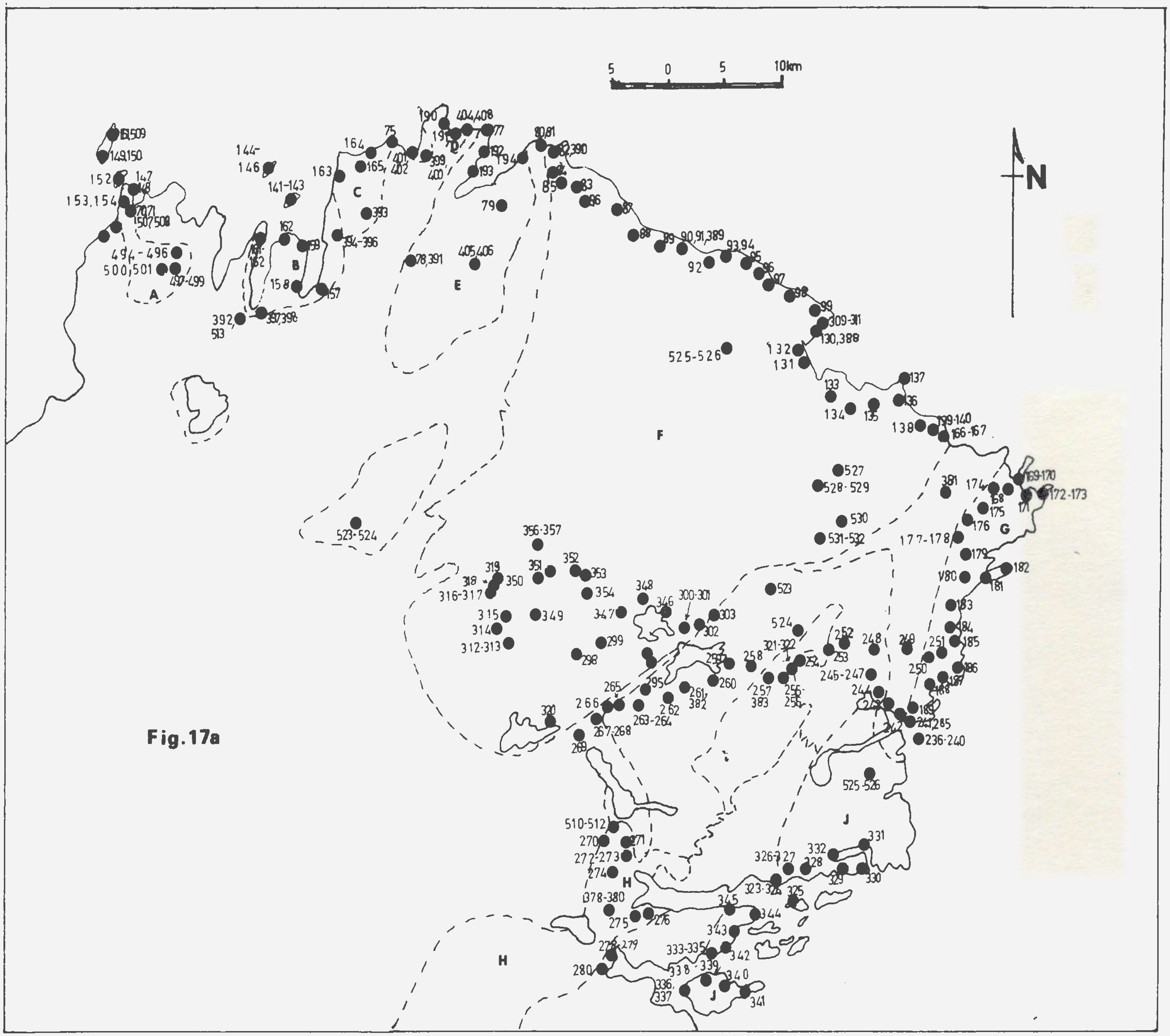
1.2.1. Sample Preparation

All the samples were crushed according to the following procedure:

1) Each sample was broken into chips using a small sledge hammer on a thick plywood board. A slab was saved for sectioning.

2) A clean, representative sample of chips was crushed to 1-2 cm. or smaller pieces in a steel jaw crusher.

3) A representative sample of these pieces was crushed in a tungsten-carbide Seibtechnik swing mill for three to four minutes producing a rock powder of -100 mesh, as determined by random sieving checks.



FIGS. 17a and 17b: Location of Samples in the northern and southern halves of the study area respectively.

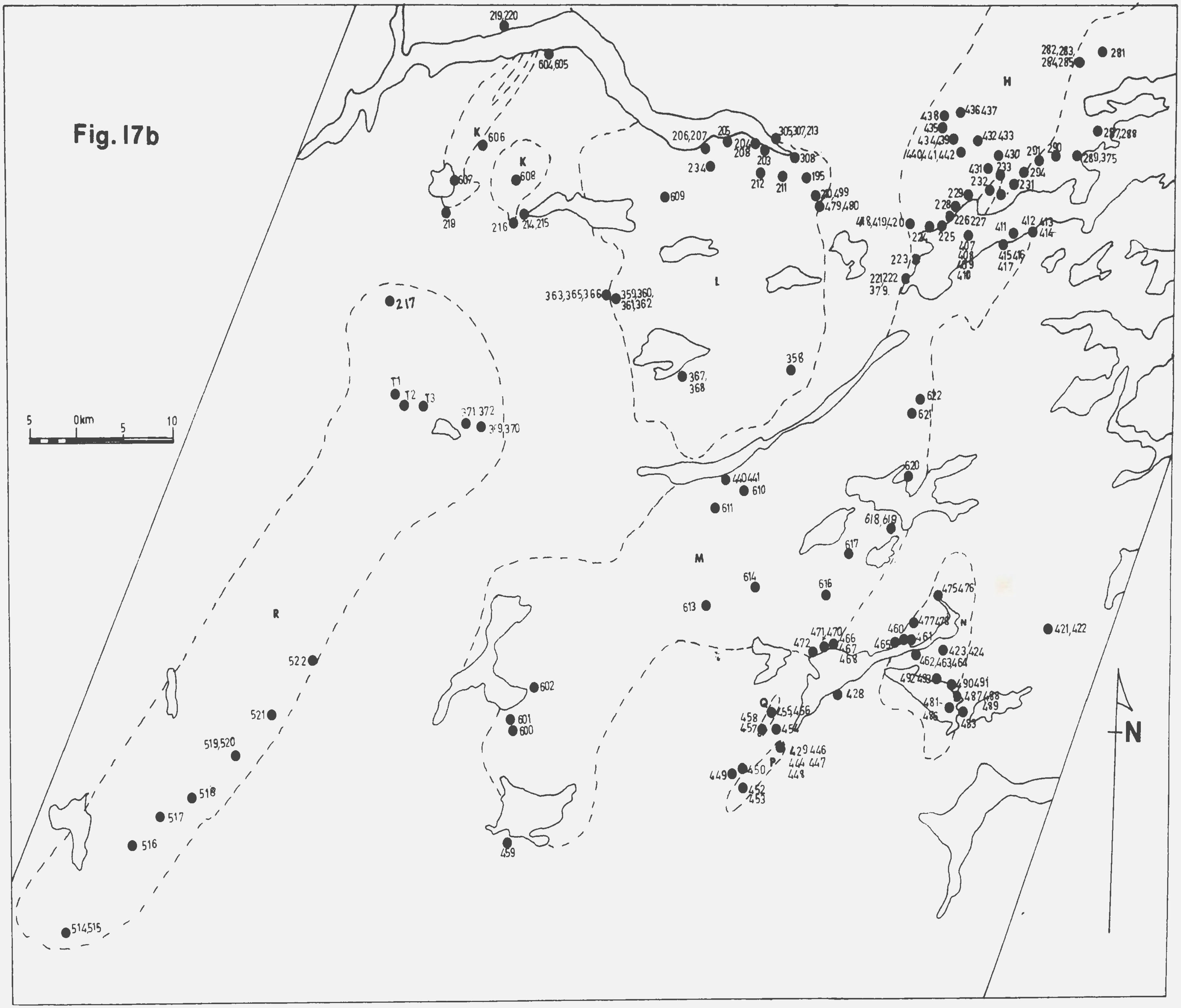

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Fig. 17b

Col. 23-31

DLMT Dolomite
LMSN Limestone
BKSH Black Shale
SHLE Shale
SLSN Siltstone
SNDS Sandstone
ARKS Arkose
CGLM Conglomerate
QRTZ Quartzite
CHRT Chert
GRCK Greywacke
SLTE Slate
SPDS Spotted Slate
HRFL Hornfels
SKRN Skarn
GRSN Greisen
QRZD Qtz. Diorite
GRDR Granodiorite
QZMZ Qtz. Monzonite
ALSK Alaskite
GRNT Granite
SDCG Sodic Granite
DORT Diorite
MNZN Monzonite
SENT Syenite
ALKS Alkali Syenite
QZPP Qtz. Porphyry
FPPP Feld. Porphyry
QZFP Qtz. - Feld. Porphyry
DCIT Dacite
RDCT Rhyodacite
RYLT Rhyolite
ANDS Andesite
TRCD Trachyandesite
TRCT Trachyte
TUFF Tuff
BSLT Basalt
DIBS Diabase
GBBR Gabbro
SRPN Serpentinite
VEIN Vein Material

Col. 32-33

04 Proterozoic
10 Paleozoic
12 Cambrian
14 Ordovician
16 Silurian
18 Devonian
20 Carboniferous
24 Permian
30 Mesozoic
32 Triassic
34 Jurassic
36 Cretaceous
42 Tertiary

Col. 34

1 Single grab sample
2 Channel sample
3 Composite sample
4 Drill core
5 Other

Col. 35

0 White < 20%
1 White & Black 20-40%
2 White = Black 40-60%
3 Black & White 60-80%
4 Black > 80%
5 Grey
6 Green
7 Buff
8 Orange or Yellow
9 Red or Purple

Col. 36

0	<.004 clay	glassy
1	.004-.025 silt	aphanitic
2	.025-.052 v.f. sand	aphanitic
3	.062-.250 f. sand	v.f. grained
4	0.25-0.50 m.c. sand	v.f. grained
5	0.50-1.00 c. sand	fine grained
6	1.00-2.00 v.c. sand	med. grained
7	2.00-5.00 granules	med. grained
8	5.00-20.0 pebbles	coarse grained
9	>20.0 boulders	v.c. grained

Col. 37

0 Uniform
1 Variable
2 Aplitic
3 Poikilitic
4 Miarolitic
5 Myrmekitic
6 Megacrystic
7 Pegmatitic
8 Cataclastic
9 Other

Col. 38

0 Massive
1 Bedded
2 Crossbedded
3 Slump structured
4 Oriented megacrysts
5 Trachytic

Col. 39

0 Fresh
1 Weathered
2 Gossanous
3 Hydrothermal, white
4 Hydrothermal, rusty

Col. 40

0 Feldspars clear
1 Feldspars cloudy

Col. 41

0 No megacrysts
1 Feld. megacrysts
2 Qtz. megacrysts
3 Qtz. & Feld. megacrysts
4 Metamorphic porphyroblasts
5 Other

Col. 42-43

Hb. & Biot. content of total dark minerals, on scales of 0-9

Col. 44

0 Sulphides absent
1 Sulphides present

Col. 45-49

Approx. outcrop area in sq. miles

Col. 50-54

Altitude above sea level

PROJECT NO. AREA: PHOTO: COLLECTOR: DATE:

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
	SAMPLE						NUMBER					ZONE			X (EAST)						Y (NORTH)							ROCK TYPE			AGE		SAMP TYPE	COLOR	GR SIZE	TEXTURE	[illegible]	ALTER.	
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GEOCHEMICAL ROCK SAMPLE CARD

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
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REMARKS:

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
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REMARKS:

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
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REMARKS:

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
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41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80

REMARKS:

Fig. 18 - Format used to describe the granitoid rocks.

4) The powder was put into 4 oz. jars and dried overnight in an oven at 110^{o}C.

1.2.2. Major and Trace Element Analysis

Eight major and six trace elements were determined by X-ray fluorescence analysis of discs pressed from the rock powder using a Phillips 1220-C computerised spectrometer. Approximately 1/3 of the samples were analysed by a method modified from that of Rose et al. (1962). The sample discs were prepared in the following manner.

1) 1.5 g of rock powder was thoroughly mixed with two to three drops of N-30-88 Mowiol binding agent until the colour was uniform.

2) Using a boric acid backing, this powder was pressed into a disc for one minute at 15 tons per square inch.

The eight major elements determined using fused powders were prepared by the following method:

1) 0.7500 g of rock powder + 0.7500 g of La_2O_3 + 6.00 g of $Li_2B_4O_7$ were carefully weighed out, mixed together, and put in a graphite crucible.

2) A dozen crucibles at a time were put in a muffle furnace pre-heated to 1,000^{o}C and left to fuse for 30-35 minutes.

3) After fusion the resulting glass beads were allowed to cool for 1 minute and put in clean glass jars.

4) The weight of each bead was readjusted to exactly 7.5000 g with dried $Li_2B_4O_7$, compensating for weight lost during fusion and thus giving an exact dilution.

5) Each bead plus the $Li_2B_4O_7$ was placed in a tungsten-carbide ball mill vial, cracked with a steel cylinder, and then crushed in the ball mill to -100 mesh.

6) The powder was then put in bottles and dried overnight at 110°C.

7) The sample discs were then prepared as outlined above.

Na and Mn were analysed using a Perkin Elmer 303 Atomic Absorbtion Spectrometer using a method similar to Langmhyr and Paus (1968). The solutions were prepared by the following method:

1) 0.2000 g of powder was mixed with 5 ml of concentrated HF and heated on a steam bath for 20 minutes until completely dissolved.

2) Each sample was diluted with 50 ml of saturated boric acid and made up to 200 ml with distilled water.

3) Analyses were done by comparison with international rock standards.

1.2.3. Loss on Ignition

Loss on ignition was calculated by measuring a known amount of powder into a porcelain crucible, heating at 1050°C for two hours, weighing again and expressing the difference in percent. It is assumed that the loss on ignition represents predominantly H_2O and CO_2.

1.3. Precision and Accuracy

The precision and accuracy of major and trace element analyses are shown in Tables 8 and 9. It will be readily seen that analytical errors are significantly less than the chemical variation discussed in the text.

TABLE 9

(a) Precision of analytical methods for Major Elements

ELEMENT	FUSED SAMPLE (CD-371)				UNFUSED SAMPLE (LD-75)			
	Range (%)	Mean	S. Dev.	N	Range (%)	Mean	S. Dev.	N
SiO_2	10.70	76.58	1.94	41	6.90	76.21	1.91	13
TiO_2	0.10	0.17	0.03	41	0.02	0.03	0.01	13
Al_2O_3	1.40	12.28	0.36	41	1.37	14.13	0.35	13
Fe_2O_3	0.34	1.15	0.08	41	0.57	1.45	0.20	13
MgO	5.80	0.30	0.94	41	1.66	0.91	0.45	13
CaO	0.76	0.87	0.10	41	0.24	1.11	0.08	13
K_2O	0.17	1.73	0.03	41	0.58	2.43	0.23	13
P_2O_5	0.01	0.005	0.002	41	0.10	0.04	0.09	13

(b) Precision of analytical methods for Trace Elements (from 9 independent discs of LD-75).

ELEMENT	RANGE	MEAN	S. DEV.
Zr	33	68	10
Sr	21	138	9
Rb	8	106	3
Zn	9	37	3
Cu	16	4	6
Ba	197	755	74

TABLE 10

(a) Accuracy of Major Element Analysis as determined by fit of standards to calibration curve.

ELEMENT	FUSED SAMPLES			UNFUSED SAMPLES		
	Range(%)	S. Dev.	No. Stds.	Range(%)	S. Dev.	No. Stds.
SiO_2	38.5	0.67	21	23.3	1.63	10
TiO_2	4.59	0.03	23	1.08	0.06	9
Al_2O_3	23.35	0.37	23	4.20	0.67	11
Fe_2O_3	27.83	0.16	20	7.50	0.20	9
MgO	49.70	0.89	18	3.33	0.27	7
CaO	13.63	0.10	21	7.70	0.55	8
K_2O	11.78	0.07	21	4.52	0.14	9
P_2O_5	1.90	0.09	18	-	-	-

(b) Accuracy of Major Element Analysis as determined by comparison of 24 samples analysed by X-ray fluorescence and atomic absorption.

ELEMENT	RANGE (%)	S. DEV.
SiO_2	7.74	0.99
TiO_2	0.71	0.02
Al_2O_3	7.40	0.30
Fe_2O_3	5.06	0.10
MgO	0.34	0.05
CaO	0.55	0.05
K_2O	5.00	0.04
P_2O_5	0.23	0.04

TABLE 10(cont'd.)

(c) Accuracy of Trace Elements analysis by fit of standards to calibration curve.

TRACE ELEMENTS			
ELEMENT	Range (p.p.m.)	S. Dev.	No. Stds.
Zr	490	13	16
Sr	784	18	19
Rb	245	6	23
Zn	161	12	24
Cu	105	5	23
Ba	1,803	33	18