GEOLOGY, PETROLOGY AND GEOCHEMISTRY OF THE HERMITAGE PENINSULA, SOUTHERN NEWFOUNDLAND

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by

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ABSTRACT

The Hermitage Peninsula, at the southwestern extremity of the Avalon Zone in Newfoundland is underlain by a late Precambrian conformable succession of volcanic and sedimentary rocks named the Connaigre Bay Group which is subdivided into four formations: a lowest formation of corundum-normative and garnet-bearing acidic volcanic rocks (Tickle Point Formation), a sedimentary sequence (Great Island Formation), a formation of sub-alkaline mafic volcanic rocks (Doughball Point Formation) and at the top a sequence of red sandstones, conglomerates and shales (Down's Point Formation).

Igneous rocks which intrude the Connaigre Bay Group include a hornblende-rich gabbroic-granitic intrusion (Hermitage Complex) and a granitic intrusion (Straddling Granite). These plutonic rocks are chemically similar to the volcanic rocks, which along with field and petrographic evidence suggests that they are related. The assemblage is classified as a bimodal calc-alkaline suite dominated by amphibole fractionation.

The late Precambrian Hermitage-Connaigre Bay assemblage, and the presumed correlative Simmons Brook Batholith and Long Harbour Group about 10 kilometres to the east, are intruded by Upper Devonian - Lower Carboniferous homogeneous granitic plutons, the Pass Island, Harbour Breton and Belleoram stocks. They are readily distinguished from the older calc-alkaline suite both petrographically and chemically, especially by their higher alkalies and associated trace elements.

These relatively undeformed rocks of the Avalon Zone are juxtaposed against deformed granitic rocks of the Gander Zone by the Hermitage Bay Fault. The fault is characterized by a 50-100 metre wide zone of brecciation with the main movement having a reverse southeastward component. This

movement is post-Ordovician and possibly Devonian, but the Hermitage Bay Fault does not represent the original structure which marked the boundary between the two zones.

ACKNOWLEDGEMENTS

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CHAPTER 1

GENERAL INTRODUCTION

1.1 Location, Size and Accessibility

The Hermitage Peninsula is situated on the south coast of Newfoundland between Hermitage and Connaigre Bays. It is approximately 32 kilometres long and 8 kilometres wide and extends southwesterly to Pass Island at its tip. On the peninsula, the main community is Hermitage which is linked by a network of gravel roads to other communities in the area and to the Bay d'Espoir highway which gives access to the Trans-Canada Highway. The area is serviced by Canadian National coastal boats which make regular stops at all major communities.

1.2 Physiography

The area has a rugged topography with steep cliffs rising from sea level to 377 metres. Soil is generally lacking and where bedrock is not outcropping, it is overlain by a locally derived till with bog-filled depressions. In some places the surface does not have vegetation or is covered by a sparse growth of stunted trees.

Bays are aligned with the main structural trends within the area and valleys have been modified by glacial ice movement. The highest hills are sprinkled with erratics and have been rounded, scoured, plucked and striated. Many marine terraces are evident around the coast and are approximately 16 metres above the present sea level.

1.3 Regional Geological Setting

Newfoundland straddles the Appalachian mountain system and forms the northeastern-most part of this structural province, which extends 3225 kilometres southwestward along the Atlantic seaboard to Alabama. The most complete cross-section of the system is best exposed here.

Williams (1964) subdivided the Newfoundland Appalachians into three major northeasterly-trending tectonic belts, arranged symmetrically into a two-sided system having a central Paleozoic mobile belt bounded on both sides by Precambrian and lower Paleozoic rocks forming the Western and Avalon Platforms. More recent work by Williams et al. (1972, 1974) has divided the island into eight tectono-stratigraphic zones whose boundaries are defined by major faults, structural discontinuities and mélange zones (Fig. 1.1).

The present study was conducted mainly in the Avalon Zone along the southwestern boundary and east of that boundary. Rocks of this zone are characterized predominantly by thick sequences of late Precambrian volcanic and sedimentary rocks which have not been metamorphosed to any great extent. For the most part they have been involved only in single open-folds about northeast-trending axes. In some areas the rocks show a steep penetrative foliation that is locally intense (e.g., Love Cove Group, Jenness, 1963). Lower Cambrian to Lower Ordovician sediments overlie the Precambrian rocks both unconformably and conformably and are exposed as discontinuous remnants. A number of intrusions have been emplaced in rocks of the Avalon Zone. These range in age from Precambrian to Devonian and in composition from gabbroic and ultrabasic to granitic.

No crystalline basement rocks are known in this zone in Newfoundland. However, it is believed that basement material does

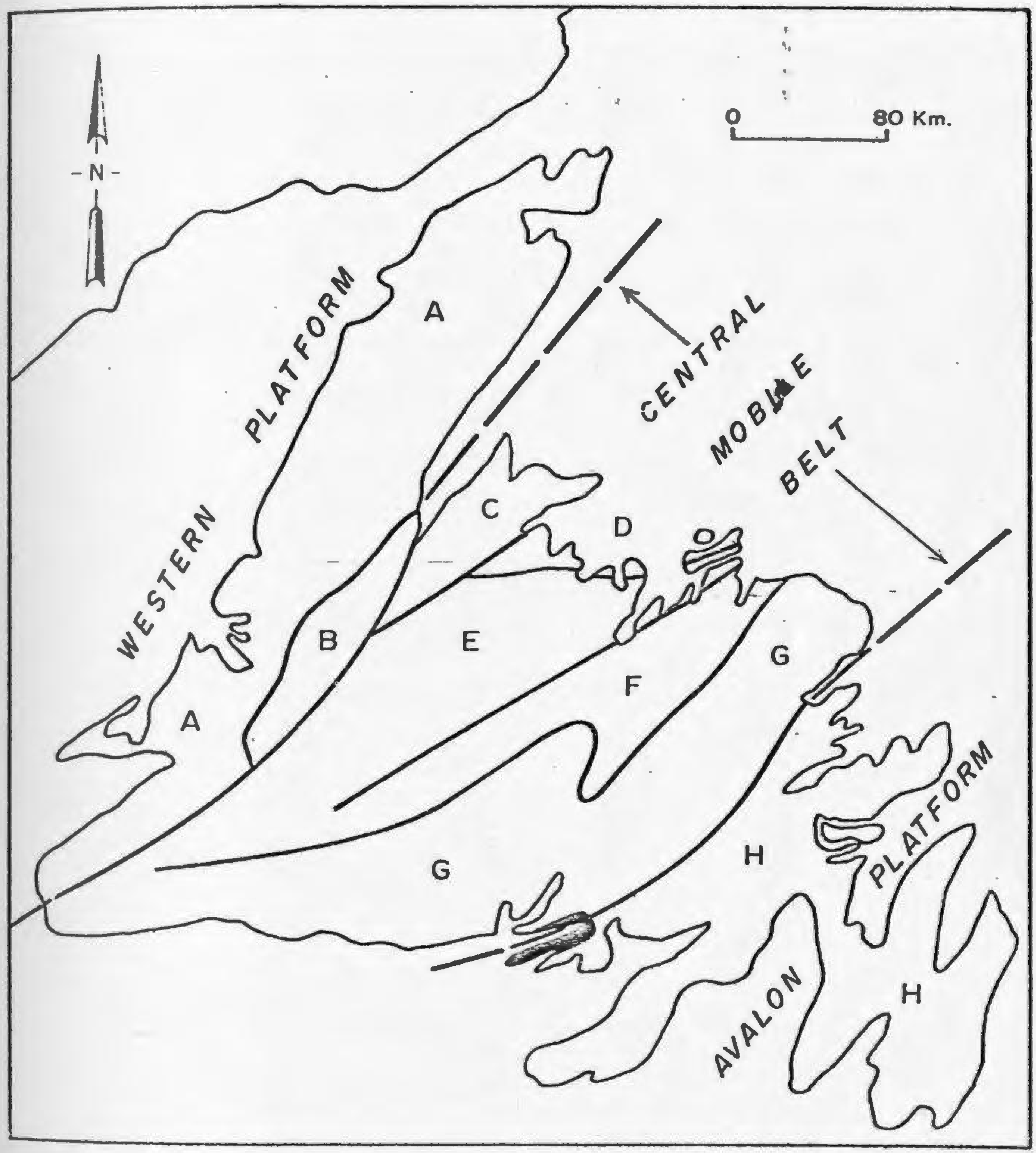


Figure 1.1 Tectonostratigraphic zones of Newfoundland Appalachians (after Williams <u>et al.</u>, 1972) (map-area in black).

occur in a correlative zone in Nova Scotia and New Brunswick. Closer still, gneisses, marbles, quartzites and amphibolites have been reported to underlie subaerial volcanics on the northern part of Miquelon (Aubert de la Rue, 1932, 1951). These may also represent basement to the Avalon Zone, and may be correlative with the Precambrian Green Head and George River Groups of New Brunswick and Nova Scotia.

The Gander Zone immediately to the west was examined briefly along its southeastern boundary. This zone is characterized by poly-deformed sedimentary rocks which overlie basement gneisses. These gneisses parallel the eastern margin of the zone and are juxtaposed against the much less deformed rocks of the Avalon Zone. In the northeast, the boundary is defined by a 300-500 metre wide mylonite zone (Blackwood and Kennedy, 1975), whereas within the map-area it is evidenced by a 50-100 metre wide zone of brecciation.

No early Paleozoic linkage has been defined previously between the Gander and Avalon Zones in Newfoundland. Williams et al. (1974) noted that both are cut by the Devonian Ackley Batholith and detritus of rocks similar to those of the Gander zone occurs in Silurian - Devonian beds of the Avalon zone, suggesting juxtaposition of the two zones by this time.

The tectonic setting of the Avalon Zone has been the subject of study, discussion and speculation during the past. Two tectonic environments are proposed and include a distensional environemnt of a Basin and Range type (Papezik, 1970) and a volcanic island or an island arc system built on oceanic or continental crust (Hughes and Brueckner, 1971; Hughes, 1970, 1972).

1.4 Previous Geological Work

The earliest work done in the Fortune Bay area of Newfoundland was by Murray (1870) and Howley (1888) and their observations are contained in the early reports of the Geological Survey of Newfoundland. Further work was done in 1927 by Dale on the Precambrian and Paleozoic geology of Fortune Bay.

In 1939 White mapped the Rencontre East area, naming and describing the various lithologies found there. His work was concerned primarily with the molybdenite deposits north of Rencontre East, and he later extended his work to the mapping of the general area. The Ackley and Simmons Brook (Bay du Nord) Batholiths and the Long Harbour Group were first described by White.

Widmer (1950) carried out field work in the Hermitage-Fortune Bay area in 1938-40 and 1946. His report and map of the area were completed in 1950 and presented as a doctoral dissertation at Princeton University. He described and mapped several granites in the area including phases of the Ackley, Simmons Brook (Bay du Nord) and Belleoram granites, and outlined the general stratigraphy including a description of the Connaigre Bay Group.

In 1948, Hayes and Rose mapped and described the geology of the area between Bonavista, Trinity and Placentia Bays. Their study included a description of the Swift Current (Northern Bight) granite which is discussed in this study.

Bradley (1962) mapped the Gisborne Lake and Terrenceville map-areas to the east and he extended the boundaries of the Ackley Batholith and also named and described the Cape Roger Mountain Batholith on the

Burin Peninsula. He correlated this batholith with the Simmons Brook (Bay du Nord) Batholith described by White (1939).

Jenness (1963) extended the boundaries of the Ackley Batholith to the northern extremity of his map-area and mentioned the possibility of it continuing around the northeastern coast of Newfoundland as far as Fogo Island. He also described the Swift Current (Northern Bight) granite to the east and correlated it with the Ackley Batholith.

The Belleoram map-area was investigated on a 1:250,000 scale as part of a geological reconnaissance study by Anderson in 1965. Similar studies were done by Anderson and Williams in the Gander Lake area in 1964 and by Williams in the Burgeo map-area in 1967. These studies outlined the general geological relationships of the areas.

Williams (1971) described the geology of the Belleoram map-area and mapped the area on a 1:50,000 scale. In this report he renamed the Bay du Nord Batholith, assigning it the new name Simmons Brook. Also contained in his report are descriptions of the Ackley Batholith and the Belleoram Stock.

The paper by Ermanovics et al. (1967) represents the only recent petrographic study of the region that has been done to date and discusses the geochemistry and petrogenesis of the Belleoram Stock.

In 1972 a reconnaissance geochemical study of eastern Newfoundland granites was conducted by Strong, Dickson, O'Driscoll and Kean under the sponsorship of the Newfoundland Department of Mines and Energy. Over 1200 granitic samples from thirty-three plutons were analysed in detail and the results of these analyses are contained in a Newfoundland Department of Mines and Energy report (Strong et al., 1974). The present study is an outgrowth of this program and interpretation of the results from selected plutons in southeastern Newfoundland is included in the present study.

1.5 Present Study

Granitic and associated rocks are widespread throughout the Appalachians and, in Canada, comprise 25 per cent of the area of exposed pre-Mississippian rocks (Williams et al., 1972, 1974). In Newfoundland, granitic rocks range in age from Precambrian to Carboniferous and occur in each of the tectono-stratigraphic zones. Despite the importance of granitic rocks in other parts of the world as the host of economic minerals, very little work was done on the Newfoundland granites until the survey by Strong et al. in 1972. Absolute ages, tectonic setting, chemistry, petrology, and associated mineralization of plutons were relatively unknown and consequently, meaningful synthesis of the regional aspects of the granitic rocks could not be made. Studies are currently in progress to establish the absolute ages of the granites (e.g., Bell and Blenkinsop, 1975; Blenkinsop et al., 1976). In many areas, detailed work has to be done to delineate granites of different ages and to outline the geology of the host rocks with the hope that by studying these critical areas, generalizations of regional importance can be made. It is with this purpose in mind that the present study was undertaken.

The map-area (Fig. 1.2) contains intrusions of different ages and composition and is well exposed so that geological relationships can be discerned. The area was mapped on a 1:50,000 scale and the stratigraphy, petrology, and geochemistry of the rocks contained in the area is presented. As a result of this work, the Connaigre Bay Group (Widmer, 1950) has been subdivided, a number of intrusions of different ages and aspect have been delineated, and the relationships of volcanic and intrusive rocks have been established. Also the intrusive rocks of the map-area are compared with other intrusions in nearby areas.

CHAPTER 2

GENERAL GEOLOGY

2.1 Introduction

The Hermitage Bay Fault separates two areas of vastly contrasting geology and marks the boundary between the Avalon and Gander Zones in Newfoundland. The Hermitage Peninsula lies along the southwestern boundary of the Avalon Zone. The oldest rocks on the peninsula are of probable late Precambrian age and consist of a thick conformable succession of silicic and mafic volcanic and sedimentary rocks which comprise the Connaigre Bay Group. This group has been separated from all other stratigraphic units by igneous intrusions or fault contacts. The group has been subdivided into four formations: a lowest formation of acidic volcanic rocks (Tickle Point Formation), a sedimentary sequence (Great Island Formation), a formation of mafic volcanic rocks (Doughball Point Formation), and at the top, a sequence of red sandstones, conglomerates, and shales (Down's Point Formation).

The sedimentary and volcanic rocks of the Connaigre Bay Group have been cut by an intrusive complex (Hermitage Complex) which occupies the southwestern half of the Hermitage Peninsula. This diorite-gabbro-granite complex is similar to intrusions farther east (Greene and O'Driscoll, 1976) and to those of the Penguin Islands, 61 kilometres to the southwest (Williams, 1967). Numerous felsic and mafic dykes and sills are associated with this intrusion which cut and feed the volcanic pile. A small associated intrusion (Straddling Granite) occupies the head of Hermitage Bay. The Hermitage Complex has been intruded by a homogeneous granite (Pass Island Granite) which is similar to the Ackley Batholith (Widmer, 1950) and believed to be the same age.

Rocks of the Gander Zone are exposed along the northwestern margin of Hermitage Bay. These are predominantly foliated, porphyritic granodiorite and granite which form that part of the Garrison Hills Gneiss Complex known as the Gaultois Granite (Widmer, 1950). Intruding the Gaultois Granite is an unnamed medium-grained foliated leucocratic granite.

The structural pattern of the Hermitage Peninsula area is dominated by faulting, with the Hermitage Bay Fault being the most prominent. Numerous faults cross-cut the area, some of which may be splays from the main Hermitage Bay Fault.

The rocks of the Hermitage Peninsula are involved in broad upright open folds with north to northeast-trending axes. Large portions of the volcanics are structureless, so more widespread folding could go unnoticed.

The geology of the area, as interpreted by the writer, is summarized in the Table of Formations (Table 1).

2.2 The Connaigre Bay Group

2.2.1 Introduction

The name Connaigre Bay was first used by Widmer (1950) to describe a sequence of silicic to mafic volcanic rocks, delineated by him to underlie most of the Hermitage and Harbour Breton Peninsulas. He considered the Connaigre Bay volcanics to be equivalent to the Long Harbour Series (White, 1939) and assigned them a similar age of

TABLE 1

Table of Formations - Avalon Zone

Era	Period	Group	Formation	Lithology
Paleozoic	Devonian		Silicic dykes	pink to orange quartz-feldspar porphyry, aphanitic pink to purple rhyolite
			Mafic dykes	porphyritic (plagioclase) medium-grained diabase
		Intrusive contact		
			Pass Island Granite	medium- to coarse-grained pink hornblende-biotite granite
	Intrusive contact with Grole Diorite			
	Ordovician or Earlier		Straddling Granite	medium-grained, pink to grey alaskite, hornblende-biotite granite and granodiorite; fine-grained pink to purple felsite
		Intrusive contact with Grole Diorite		
		Hermitage Complex	Silicic dykes	fine-grained, massive pink felsite
			Mafic dykes	medium- to fine-grained diabase
			Intrusive contact	
			Furby's Cove Granite	medium-grained pink to grey hornblende-biotite granite and granodiorite
			Intrusive contact	
			Grole Diorite	dark grey quartz diorite to diorite with hornfelsed volcanic inclusions; medium- to coarse-grained hornblende-pyroxene gabbro
Intrusive contact				
Precambrian	Hadrynian	Connaigre Bay Group	Down's Point Formation	red to purple, graded and crossbedded sandstone and pebble to cobble conglomerate; red, thinly laminated argillite; interbedded pink to purple silicic tuffs and massive rhyolite
			Conformable contact	
			Doughball Point Formation	grey to green, massive andesite and basalt; green, fine- to coarse-grained mafic tuffs and agglomerates; minor interbedded silicic flows and tuffs
			Conformable contact	
			Great Island Formation	grey and green, laminated argillite with purple conglomerate and shale at the base; rare limestone lenses; interbedded mafic tuffs and thinly bedded tuffaceous sediments
			Conformable contact	
			Tickle Point Formation	purple to pink, massive flow-banded and autobrecciated rhyolite; interbedded massive green andesite and basalt

TABLE 1 (contd.)

Table of Formations - Gander Zone

Era	Period	Group	Formation	Lithology
	Pre-Lower Ordovician		Leucocratic Granite	foliated fine-to medium-grained muscovite granite; contains undivided zones of biotite-muscovite granite
		Intrusive contact		
			Gaultois Granite	foliated porphyritic biotite-chlorite granite and granodiorite

Ordovician.

The Long Harbour Series was remapped by Williams (1971). On the basis of reinterpreted structural and stratigraphic relationships he incorporated rocks of several formations and the Long Harbour Series into a single group called the Long Harbour Group. He reassigned the age of this group to late Precambrian. Consequently, the possible equivalent Connaigre Bay Group must also be given a late Precambrian age.

2.2.2 Tickle Point Formation

Definition, Distribution, Thickness: The name Tickle Point is proposed for an assemblage of silicic volcanic rocks which comprises the lowermost formation of the Connaigre Bay Group. Within the map-area these rocks occur northeast of Friar Cove in Hermitage Bay, northeast of Salmonier Cove in Connaigre Bay, and northwest of Good Hill. Tickle Point is located at the head of Connaigre Bay north of which a section of massive rhyolite is exposed in road-cuts of the Hermitage Peninsula road.

The base of the sequence is unexposed within the map-area. The upper contact is exposed northeast of Salmonier Cove (Connaigre Bay) where pink flow-banded and autobrecciated rhyolite is overlain by the sedimentary rocks of the Great Island Formation. The true thickness of the unit cannot be estimated since the base is not exposed, however, the maximum exposed thickness is approximately 500 metres.

Lithology: The Tickle Point Formation is mainly composed of pink to purple and green silicic volcanics which have been weathered to a buff color and contain local interbeds of mafic flows. These rocks are characterized predominantly by massive rhyolite flows and more rarely by flow-banded and autobrecciated rhyolite, and silicic crystal tuff.

Massive rhyolite flows are exposed along the northeastern shores of Hermitage Bay, but individual units cannot be discerned except where massive, green to black basaltic and andesitic flows occur between the units as at Olive Cove, Round Cove, and on Frenchman's Head. Even there, contacts are obscured by shear zones and overburden. The rhyolites are porphyritic in places, with scattered phenocrysts of quartz and pink K-feldspar. Purple rhyolite with orange segregations is common.

Flow-banded units of purple rhyolite occur with massive rhyolite and rhyolite breccia high in the cliffs southeast of Frenchman's Cove, and near the top of the unit on the Hermitage Peninsula. The flow-banded units grade into massive rhyolite and are autobrecciated in places with disoriented banded rhyolite fragments in an aphanitic matrix.

East of Hardy's Cove, pink to green crystal-lithic tuff and purple flattened tuff occur with massive and flow-banded units. The tuffs are composed of quartz and feldspar crystals and angular to rounded volcanic fragments in a hard fine-grained matrix.

Petrography: Phenocrysts are generally euhedral and occur in a glassy fine-grained matrix which may be slightly sericitized. The most abundant phenocrysts are orthoclase, quartz, and rarely plagioclase. Orthoclase is generally fresh but in some samples it shows evidence of sericitization along cleavage planes and along corroded edges. Twinning of orthoclase, if present, is according to the Carlsbad law. Quartz is unstrained and in most samples is present as euhedral bipyramidal crystals typical of high temperature β -quartz. Corroded crystals are common with irregular embayments in otherwise euhedral crystals (Plate 1). Microspherulites occur and are evidenced by radiating masses of quartz and potassium feldspar which are commonly nucleated by a quartz crystal. Plagioclase crystals are rare and their composition is approximately An_{10}-An_{20}. Garnets also occur rarely as microphenocrysts in a fine-grained siliceous matrix (Plate 2).

The groundmass is usually composed of fine-intergrowths of quartz and feldspar and patches of recrystallized quartz. Chlorite and epidote occur in minor amounts. All samples contain many disseminated opaque crystals some of which have been identified as pyrite.

In the pyroclastic rocks, lithic fragments are massive to porphyritic rhyolite similar to the massive flows which occur within the formation. The mafic flows are fine-grained and commonly porphyritic. Phenocrysts of plagioclase and pyroxene occur in a fine groundmass of pyroxene and plagioclase microlites. These crystals are commonly sericitized and chlorite and epidote are abundant.

<u>Contact Relationships</u>: The base of the Tickle Point Formation is not present within the map-area. The upper contact is defined by the lowest sedimentary bed of the Great Island Formation. It is overlain conformably by the Great Island Formation in the Salmonier Cove syncline and east of Hardy's Cove. Possibly local unconformities exist, but if so they are minor ones of short duration. Elsewhere the formation is faulted against rocks of younger formations.

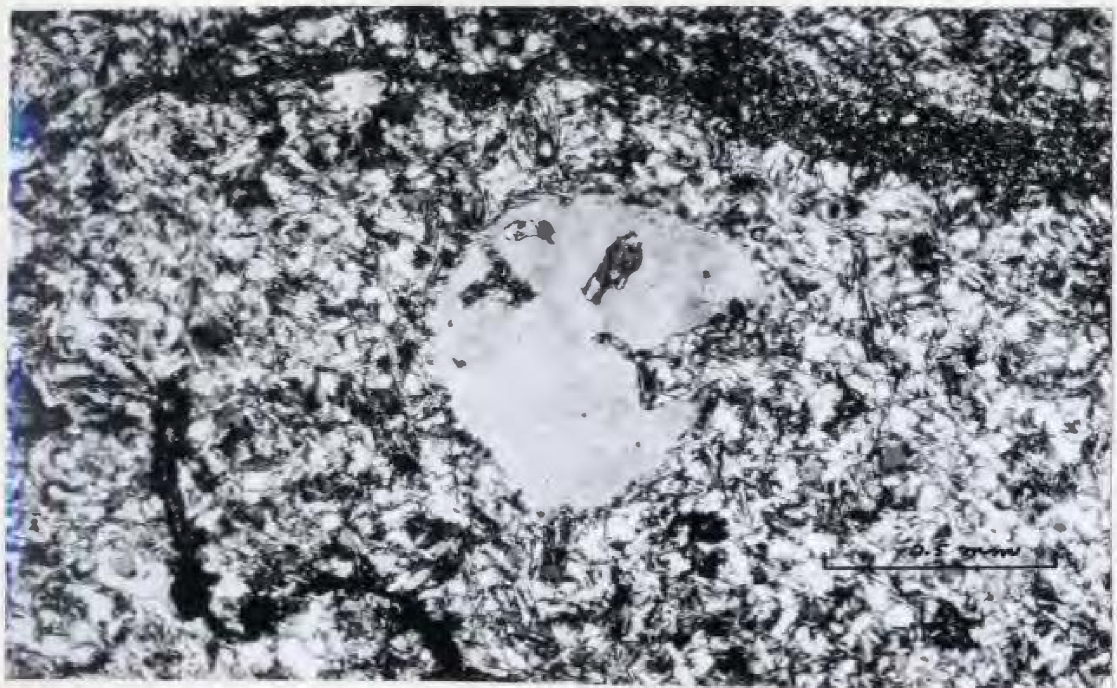


Plate 1. Corroded quartz crystal in fine-grained siliceous matrix of rhyolite in Tickle Point Formation.

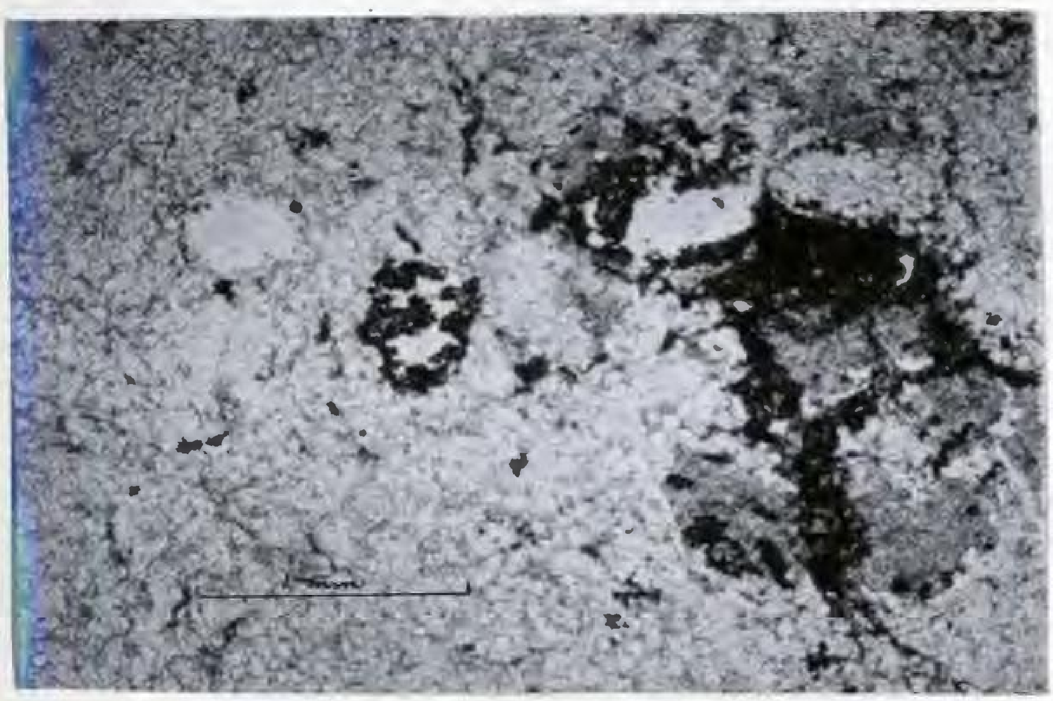


Plate 2. Garnets in fine-grained siliceous matrix of Tickle Point Formation.

The formation is intruded by numerous felsic and mafic dykes some of which are part of the Hermitage Complex. It is also intruded by dioritic and granitic rocks near Barasway Harbour which are similar to the Hermitage Complex.

2.2.3 Great Island Formation

Definition, Distribution, Thickness: The name Great Island is proposed to designate a succession of sedimentary rocks which overlie the Tickle Point Formation. Within the map-area these rocks occur at Great Island, in the Salmonier Cove syncline, and in discontinuous zones along the Harbour Breton Peninsula and northeastward to the edge of the map-area. The type area, Great Island, is located in Connaigre Bay where the upper part of the formation and the contact with the overlying formation are exposed.

The Great Island Formation is estimated at 300 metres thick in the Salmonier Cove syncline where a complete section is present. Greater thicknesses probably occur in the Good Hill area but the rocks there have been subject to much folding and faulting and some units may be repeated.

Lithology: The Great Island Formation consists of finely laminated green and grey argillite, banded mafic tuff and tuffaceous siltstone with interlayers of fine-grained grey sandstone (Plate 3). Generally these rocks weather a greenish-grey to white color.

Finely laminated argillites with local beds of fine-grained sandstone up to 30 cm thick are exposed on the Hermitage Peninsula. Here they form a sequence which is fairly homogeneous except at the

Plate 3. Finely laminated argillite with interlayers of fine-grained sandstone in Great Island Formation.

base where purple shale and conglomerate are present. In places the sandstones are finely cross-bedded and graded, with ripple marks occurring locally. Slump structures and disturbed and wavy bedding are evident throughout the sequence. Lenses of fine-grained limestone are found rarely within the argillites.

In the Good Hill area and to the northeast banded mafic tuffs predominate, with interbeds of finely laminated tuffaceous sediments. Here the rocks occur as dense dark grey hornfelses due to a number of intrusions.

The base of the sequence is exposed in the Salmonier Cove syncline and is marked by a purple to red conglomerate and sandstone and a purple shale unit. Along the Hermitage road on the eastern limb of the syncline, about 10 metres of shale and sandstone are exposed at the base, overlain by approximately 25 metres of conglomerate which is overlain by green siltstone and argillite. The conglomerate thickens and the shale is not exposed in the core of the syncline. The conglomerate consists of rounded boulders and pebbles composed of quartz and volcanic grains. The top of the formation is best exposed on Great Island where laminated argillites are overlain by mafic flows and agglomerates of the Doughball Point Formation. As the contact is approached the sediments change from green to dark grey in color. At the contact the sediments become coarser and about 30 centimetres of fine-grained grey sandstone grades into 30 centimetres of fine-grained tuff which in turn coarsens to contain volcanic lapilli and bombs.

Petrography: Thin section study reveals that the sediments are mainly a fine-grained aggregate of clay and silt. The fine-grained fractions contain abundant clay minerals such as chlorite, together with very fine grains of other minerals which cannot be determined definitely. Sericite is probably present but is indistinguishable from other clay minerals. Generally in a thin section, bands of coarse- and fine-grained material can be seen to alternate. In the coarser fractions, grains of quartz, feldspar and opaque minerals are the most abundant minerals which can be identified. Quartz occurs as clear and strained crystals; chips and rounded grains. Laths and broken crystals of plagioclase and potassium feldspar are present and may be twinned or untwinned. Generally the feldspars have been altered by sericitization. Microscopic opaque minerals were not identified definitely but megascopic disseminations of pyrite can be identified in hand specimen. Calcite is present in many samples either as a fine network of veins or as a cementing medium. In samples which do not have calcite, the cement is probably quartz or hematite. Rare lithic fragments occur which are of volcanic origin.

Contact Relationships: The Great Island Formation conformably overlies the Tickle Point Formation in the Salmonier Cove syncline. The upper contact is marked where the first mafic flow or pyroclastic unit of the Doughball Point Formation is encountered. The contact with the Doughball Point Formation is conformable. Felsic and mafic dykes which are related to the Hermitage Complex intrude the Great Island Formation. East of Good Hill the formation is intruded by the Simmons Brook and Harbour Breton plutons and is metamorphosed to hornfels. Many boundaries with other formations are fault contacts.

2.2.4 Doughball Point Formation

Definition, Distribution, Thickness: The name Doughball Point is used here to define a sequence of volcanic rocks which overlies the Great Island Formation and underlies the sedimentary rocks of the Down's Point Formation. These rocks are exposed at various localities on the Hermitage and Harbour Breton peninsulas and in the Good Hill area. The coastline of Connaigre Bay offers the clearest display of these rocks, but they are also well exposed in road cuts on the Hermitage and Harbour Breton peninsulas.

The contact between the Doughball Point Formation and underlying rocks is exposed in a number of places, with the best exposures being at Great Island and in the Good Hill and the Salmonier Cove synclines. The upper contact is exposed at the Doughball Peninsula and the peninsula between Salmonier Cove and the Tickle. The type area, Doughball Point, is located on the tip of the Doughball Peninsula in Connaigre Bay and contains exposures of the upper parts of the sequence.

A continuous section of the formation is not exposed within the map-area. The thickest exposed section is on the Hermitage Peninsula where approximately 1500 metres of mafic volcanics are exposed.

Lithology: The Doughball Point Formation consists of grey to green mafic flows and pyroclastic rocks with interbedded silicic flows and pyroclastic rocks. Mafic volcanics constitute about 85 per cent of the formation and are chiefly characterized by coarse agglomerates and tuffs associated with massive flows.

Thick massive flows occur throughout the formation and consist of fine-grained, dark grey to purplish grey and green andesite and basalt. They are locally amygdaloidal and commonly contain pyroxene phenocrysts and abundant pods and veins of epidote. Amygdules are generally composed of epidote, quartz and chlorite, with calcite occurring rarely. These units are exposed at various localities around the shores of Connaigre Bay, particularly at Kippens Harbour, Great Harbour and on Great Island. Also good exposures are found in the Good Hill syncline. At all these localities massive flows are interbedded with agglomerates and silicic tuffs.

Coarse agglomerates which underlie Doughball Point and Blow Me Down Head are the most abundant rock type of the formation (Plate 4). Agglomeratic units occur almost everywhere that the formation is exposed, around the shores of Connaigre Bay and in the Good Hill and Salmonier Cove synclines. The agglomerates are dark green to grey and contain mafic volcanic bombs and boulders which range in size from centimetres to about one metre or more in diameter. The bombs are green massive fine-grained andesite to basalt, some of which contain pyroxene phenocrysts and are very similar in composition to the massive flows. The rims of the bombs are oxidized in places to a dark purple color. The matrix is generally of the same composition as the bombs and is dark grey to green in color. In places rounded boulders of diabase are present within the agglomerate. On the east shore of Connaigre Bay a disrupted band of bright red oxidized agglomerate is present which is indicative of a flow top.

Along the western shores of Connaigre Bay, units of silicic tuff and massive rhyolite about 20 metres thick are interbedded with units of agglomerate and massive flows (Plate 5). The silicic tuffs are either

Plate 4. Coarse agglomerate of Doughball Point Formation at Doughball Point.

Plate 5a. Fine-grained, banded silicic tuff in the Doughball Point Formation (south of Kippins Harbour).

5b. Contact between silicic tuff (right) and mafic agglomerate (left) in the Doughball Point Formation (Blow Me Down Head).

buff to green in color and weather to a buff-white color, or purple with a purple weathering color. The tuffs contain broken fragments and crystals of quartz and feldspar together with rock fragments in a fine-grained matrix. The massive units consist of hard, purple, structureless and flow-banded rhyolite.

<u>Petrography</u>: The mafic units of the formation are similar in mineralogy throughout the sequence. Agglomeratic bombs and matrix contain predominantly the same minerals as the massive flows. Although some bombs and flows are aphyric, euhedral augite phenocrysts are common, in some cases slightly zoned, and in most cases partly or wholly replaced by actinolite, chlorite and epidote, forming perfect pseudomorphs (Plate 6). Plagioclase (An_{40}-An_{50}) occurs as phenocrysts, but most commonly is restricted to the groundmass as microlites which, together with small pyroxene crystals, form an intergranular texture. In some examples, augites occur in the groundmass as skeletal crystals approximately 1 mm in length, signifying rapid crystallization (Plate 7) (Strong, 1969). Plagioclase crystals are commonly zoned and are usually altered by varying degrees to sericite and epidote. Highly altered crystals which were possibly olivine are evident in some sections. These are now masses of chlorite and serpentine which preserve a crystal form similar to olivine. Abundant epidote and chlorite crystals are present in most sections, some of which may be primary, but mostly they are the alteration products of primary minerals. Opaque minerals exist as disseminations of skeletal and cubic crystals and probably consist of magnetite and pyrite. The diabasic inclusions in the agglomerates contain brown hornblende which has grown at the expense of highly altered

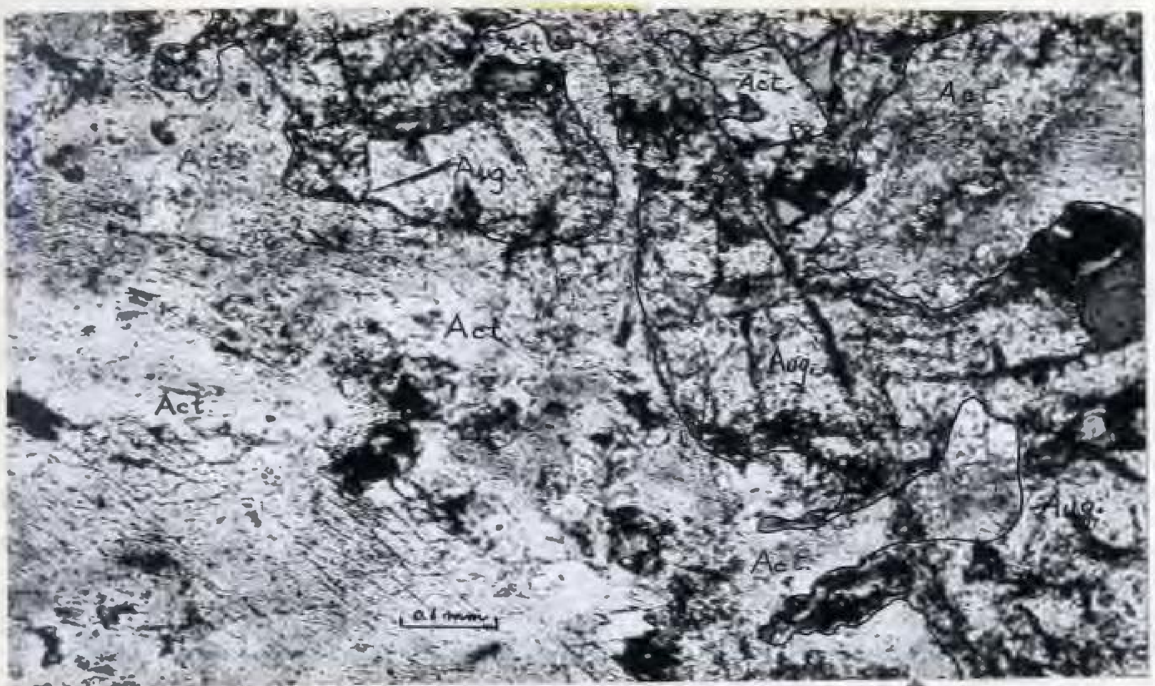


Plate 6. Actinolite (act) replacing augite (aug) in mafic flows of Doughball Point Formation.

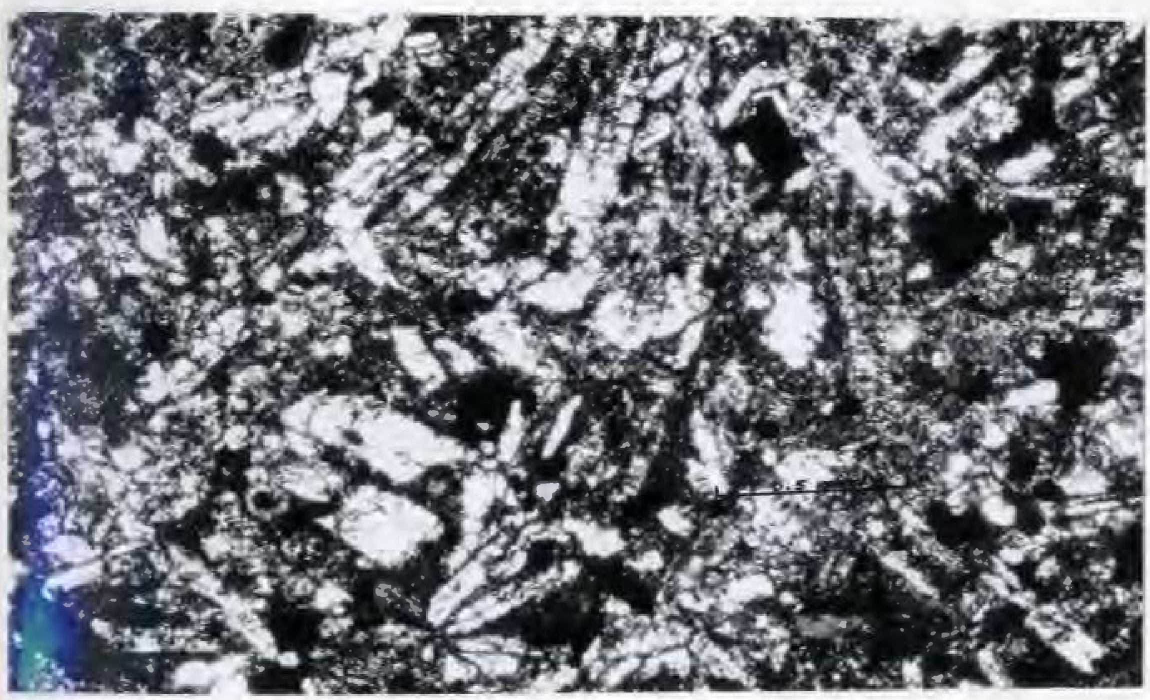


Plate 7. Skeletal crystals of augite in groundmass of mafic flows of the Doughball Point Formation.

pyroxene indicating an increase in water pressure, and in turn has been replaced by actinolite (Plate 8). This occurs with plagioclase (An_{50}) in a medium-grained rock with intergranular texture. Skeletal magnetite, sericite, chlorite, and calcite are also present. Silicic tuffs generally display a highly sericitized and chloritized fine-grained matrix. Phenocrysts occur as crystals and fragments of potassium feldspar, quartz and plagioclase (An_{30}). The feldspars are generally saussuritized and rarely dusted with hematite. Lithic fragments can be recognized and are usually represented by laths of altered feldspar in an opaque matrix. Epidote is pervasive as an alteration product.

Contact Relationships: The Doughball Point Formation conformably overlies the Great Island Formation. On Great Island and in the Salmonier Cove syncline coarse, green agglomerate overlies a coarse-grained tuff bed which overlies sedimentary units of the Great Island Formation. The top of the formation is partly transitional with sedimentary and agglomeratic to tuffaceous units alternating. The contact on the Doughball Peninsula is drawn where sedimentary beds of the Down's Point Formation become predominant. A few beds of red sandstone and shale occur below this contact. On the peninsula between Salmonier Cove and The Tickle, the contact is fairly sharp with coarse clastic rocks of the Down's Point Formation conformably overlying green agglomerate of the Doughball Point Formation.

The formation has been intruded by dykes and the main mass of the Hermitage Complex. It has been hornfelsed, agmatized and migmatized by this intrusion.

Plate 8. Actinolite (act) replacing hornblende (hb) which has grown at the expense of pyroxene in mafic rocks of the Doughball Point Formation.

2.2.5 Down's Point Formation

Definition, Distribution, Thickness: The name Down's Point is proposed for a sequence of sedimentary rocks which overlies the Doughball Point Formation and forms the youngest formation of the Connaigre Bay Group. These rocks are exposed on the Doughball Peninsula, the peninsula between Salmonier Cove and The Tickle, and in a large synclinal trough which extends from Good Hill southwestwards to the shores of Connaigre Bay. The type area, Down's Point, is situated on the east side of The Tickle in Connaigre Bay, north of which is exposed red to purple sandstones and shales which make up a major part of the formation. The base of the formation is exposed in The Tickle and on the Doughball Peninsula, but the top is not exposed in the map-area. The thickest section is present in the syncline southwest of Good Hill where approximately 1000 metres of the formation exists. However, the existence of many faults in the area may cause some units to be repeated or omitted.

Lithology: The Down's Point Formation is composed of purple to red and grey sandstone and pebble to cobble conglomerate, red finely-laminated siltstone, and interbeds of pink silicic pyroclastic rocks. Close to the basal contact agglomerates and tuffs of the Doughball Point Formation are interbedded with purple to grey sandstones of the Down's Point Formation. The agglomerates have been reworked in places with volcanic lapilli and bombs occurring in a finely laminated sandy matrix. These beds grade upwards into a series of red to purple crossbedded and graded sandstone, and conglomerate, with beds of finely laminated red shale a few feet thick. These units form a major part of the formation.

Sedimentary breccia occurs within the sandstone beds as thin layers of broken red shale disrupted by the overlying units. Boulders, pebbles and sand grains of grey and purple, rounded to angular silicic and mafic volcanic rock are the most common clasts in the coarse sediments. Quartz and feldspar grains vary in abundance, with arkosic and lithic arkosic sandstones occurring in some areas. Southwest of Good Hill beds of quartzitic sandstone are present with fine-grained black layers and lenses of magnetite.

A pink silicic tuff occurs about 5 metres above the basal contact in The Tickle. It is underlain by purple sandy conglomerate and overlain by purple sandstone. The tuff contains quartz and K-feldspar phenocrysts and silicic volcanic fragments in a hard aphanitic matrix. A similar unit about 100 metres thick occurs farther up in the sequence and is exposed in the syncline southwest of Good Hill.

Petrography: Thin sections of fine-grained samples show that the rock is made up predominantly of a fine aggregate of clay minerals and sericite with quartz, potassium feldspar and plagioclase occurring as angular and rounded grains and rarely as euhedral crystals. Generally, feldspars have been sericitized. Abundant rounded and subangular rock fragments are present and are commonly altered to an opaque aggregate. Muscovite occurs rarely in some sections. Epidote is present and is in part an alteration product of detrital minerals. Opaque minerals are disseminated throughout the samples. The silicic tuffs contain phenocrysts of euhedral quartz, potassium feldspar and rarely plagioclase in a fine-grained to glassy sericitized matrix.

2.2.6 Age and Correlation

As denoted in section 2.2.1 the age of the Connaigre Bay Group is probably late Precambrian. The only direct evidence which suggests this in the area is a whole-rock Rb/Sr age on the Straddling Granite of 490 ± 10 million years (Blenkinsop et al., 1976). This granite intrudes the Connaigre Bay Group thus putting an upper limit on the age of the group. The Connaigre Bay Group is lithologically similar to the Long Harbour Group (Williams, 1971) and the Musgravetown Group (Jenness, 1963). Both these groups are overlain conformably by Eocambrian to Cambrian sedimentary rocks (Greene, 1975; Williams, 1971; Jenness, 1963) and have been assigned a late Precambrian age. The four-fold division of the Connaigre Bay Group is similar to that of the Long Harbour Group (Williams, 1971).

2.3 Intrusive Rocks

2.3.1 Hermitage Complex

2.3.1.1 Introduction

The Hermitage Complex is a name proposed for an intrusion of variable composition which is located along the southwestern half of the Hermitage Peninsula. The rocks included in this complex were interpreted by Widmer (1950) as a zone of complex migmatites and agmatites related to intrusion of the Ackley type granite at the southwestern tip of the Hermitage Peninsula (Pass Island Granite). This interpretation is not supported by the present study, since most rocks of the Hermitage Complex show clear intrusive relationships with the Connaigre Bay Group. It is believed that the migmatite and agmatite zones are related to the intrusive sequence represented by the gabbro, diorite, and granite of the Hermitage Complex and that the Pass Island Granite was not reactive enough to melt and remobilize the mafic volcanics to produce diorite and gabbro.

A tentative age of 450 million years has been obtained by $^{40}Ar/^{39}Ar$ method on hornblende from a gabbro of the Hermitage Complex (P.H. Reynolds, pers. comm. 1975), further demonstrating its difference from the Ackley type granite which has given an age of late Devonian on samples taken east of the map area (Bell, pers. comm., 1975). The hornblende from which the $^{40}Ar/^{39}Ar$ date was obtained appears to have been "disturbed", so it is probable that these rocks might in fact be older than 450 million years (V. Stukas, pers. comm., 1975).

The Hermitage Complex is subdivided into two units: a mafic phase (Grole Diorite) and a silicic phase (Furby's Cove Granite). With more detailed mapping the mafic rocks could possibly be subdivided further into various phases from gabbroic to quartz dioritic. Numerous dykes related to the Hermitage Complex cut both the intrusive complex and the volcanic-sedimentary pile which makes up the Connaigre Bay Group, and these are discussed separately.

2.3.1.2 Grole Diorite

Definition and Extent: The Grole Diorite constitutes a major portion of the Hermitage Complex with approximately 85 per cent of the rocks falling into this subdivision. Quartz diorite, diorite, and gabbro are exposed along the northwestern coast of the Hermitage Peninsula from Pass Island to about 2 kilometres northeast of Furby's Cove and along the southeastern coast between Dog Cove Head and Partridge Cove. The eastern contact extends from Partridge Cove across the peninsula to Hermitage Bay northeast of Furby's Cove, while the southern contact runs between Dog Cove and the Pass Island Tickle. Grole, the type locality, is a deserted community situated on the northwestern coast of the Hermitage Peninsula about 5 kilometres northeast of Pass Island.

Lithology: The Grole Diorite consists of a variety of black and dark green to grey, medium- to coarse-grained gabbro, diorite, quartz diorite, and granodiorite. Bodies of coarse-grained black gabbro (Plate 9) outcrop on the west side of Hermitage Cove and southwestwards along the Hermitage Peninsula coast, and along the road between Dawson's Cove and Dog Cove. The gabbro is composed of large crystals of hornblende, pyroxene, and plagioclase. For the most part the gabbro is equigranular, but in some areas, pockets of porphyritic gabbro occur with phenocrysts of hornblende up to 2 centimetres long in a finer plagioclase-hornblende-pyroxene matrix. Locally, the gabbro is enriched in mafic minerals to be almost entirely composed of black interlocking crystals of hornblende and pyroxene.

Intruding the gabbro is a medium-grained grey to green diorite which forms the major part of the Grole Diorite (Plate 10). It is mainly composed of plagioclase and mafic minerals including hornblende, pyroxene and rarely biotite. Much of the diorite is massive but in many places a foliation is portrayed by aligned mafic minerals. In various places the diorite contains abundant massive fine-grained volcanic inclusions which have been partly assimilated. Mafic minerals are aligned and partially melted inclusions are stretched and aligned so that in some places the rock has a crude banding consisting of

Plate 9. Coarse-grained black gabbro of the Grole Diorite.

Plate 10. Inclusion of gabbro in medium-grained diorite which forms the major part of the Grole Diorite.

Plate 11. Fine-grained volcanic inclusions in the Grole Diorite which have been partially melted and aligned.

discontinuous dark volcanic bands with intervening light dioritic bands (Plate 11). The best examples of this can be seen at Grole and Landing Cove. Migmitazation of the volcanics is clearly demonstrated in a roadside quarry near Partridge Cove. Here, the inclusions range from angular to partially melted and aligned fragments, to almost completely resorbed fragments which are evidenced as dark bands in a dioritic matrix (Plate 12). In a roadcut east of Hermitage, xenoliths of foliated sedimentary and volcanic rocks are included in the Grole Diorite. These appear to have been foliated prior to inclusion and in places plagioclase porphyroblasts, possibly related to the diorite, overprint the foliation.

Quartz diorite and granodiorite occur locally. Along the northeastern shore of Hermitage Cove is medium-grained quartz diorite containing hornblende, plagioclase and quartz. The amount of quartz varies in abundance up to about 15 per cent and the quartz diorite grades into diorite with the gradual loss of quartz. Granodiorite occurs rarely as dykes and local segregations close to the margins of the pluton.

A small intrusion occurs at Barasway Harbour, marginal to the Straddling Granite. This consists of medium-grained diorite and quartz diorite similar to the main mass of the Grole Diorite. Locally, it exhibits a weak foliation and contains many volcanic inclusions which are partially melted. Because of its similarity to the Grole Diorite it has been included with it.

Petrography: Petrographic studies show that the gabbro is composed mainly of amphibole, pyroxene and plagioclase, with minor

Plate 12. Volcanic inclusions of the Doughball Point Formation (upper centre) in the Grole Diorite which range from angular to partially melted and aligned, to almost completely resorbed fragments.

Plate 13. Core of hypersthene (hy) showing schiller structure which has been partly replaced by hornblende (hb).

amounts of sphene, epidote, apatite, zircon, zoisite and prehnite.

Hornblende is the most abundant mineral making up 40 to 70 per cent of the gabbro. It is characterized by yellow-brown to green euhedral to subhedral crystals, which vary in grain size from 1 millimetre to 2 centimetres. Minor amounts of green actinolite replace the hornblende. Anhedral to euhedral crystals of hypersthene are common, with augite rare. Hypersthene generally portrays schiller structure and is commonly partly replaced by the hornblende and in some sections occurs only as cores within brown to green hornblende (Plate 13). Sphene, apatite, zircon, and some epidote occur as primary accessory minerals, but zoisite, prehnite and some epidote are the results of alteration. Plagioclase varies in abundance from 5 per cent to 40 per cent. It is usually interstitial with the mafic minerals but may be also intergranular, and ranges in composition from An_{30} to An_{45} with generally saussurtized cores and clear albitic rims.

The diorite is of similar mineralogy to the gabbro with different proportions of minerals, and it is finer grained and hypidiomorphic. Plagioclase (An_{22}-An_{30}) is more abundant than in the gabbro, with hornblende and pyroxene present in lesser amounts. Biotite, where present, is commonly sagenitic with rutile (Plate 14). Apatite, sphene, zircon and epidote are important accessory minerals. Prehnite and epidote are alteration products of the primary minerals. One modal analysis of a typical diorite gives the following results: plagioclase - 35 per cent, hornblende - 30 per cent, pyroxene - 20 per cent, biotite - 10 per cent, and accessory minerals - 5 per cent. The quartz diorite contains up to 15 per cent interstitial quartz coexisting with similar minerals to the diorite.

2.3.1.3 Furby's Cove Granite

Definition and Extent: The Furby's Cove Granite intrudes the Grole Diorite and is intimately associated with it. It occurs as a number of separate bodies of granite within the Hermitage Complex around Furby's Cove and Hermitage Cove. Smaller bodies of granite occur west of Grole, but these may be related to the Pass Island Granite. The body around Furby's Cove was partially delineated by Widmer (1950) but was found to be more extensive by the writer.

Lithology: The Furby's Cove Granite is composed of homogeneous pink, equigranular, medium-grained granite consisting mainly of potash feldspar, quartz, plagioclase and chlorite. Quartz is almost always milky white to pale blue in color. Potash feldspar and plagioclase are both pink in color which makes it difficult to distinguish between the two in hand specimen. Mafic minerals are commonly altered to chlorite. The main variation in composition between different areas within the granite is an increase or decrease in quartz and feldspar.

Much of the granite is massive, as at Hermitage Cove and Big Black Head, but locally a faint foliation is present, as at Furby's Cove. The granite contains inclusions of diorite and mafic volcanic rocks. Pink aphanitic dykes are common close to the granitic masses and nearer the granite these dykes are larger, coarser-grained, and more numerous.

Petrography: Thin section studies reveal an equigranular rock consisting mainly of quartz, plagioclase, potash feldspar, and chloritized mafic minerals. Variation in composition is evident, with plagioclase increasing in amount from 25 per cent in some samples to 50 per cent in others and potash feldspar ranging from 10 to 35 per cent, with quartz being always present at about 35 to 40 per cent. The Furby's Cove Granite ranges in composition from granitic to granodioritic on the basis of feldspar ratios. Mafic minerals are ubiquitous but minor, making up about 5 per cent of the total rock.

Quartz generally has the typical undulose extinction of strained crystals and sutured or granulated grain boundaries, although in some areas it has been partially recrystallized to form polygonal aggregates. Plagioclase is generally turbid and sericitized. Many crystals have been bent and broken and have granulated edges. Potash feldspar is commonly represented by microcline perthite which has been slightly altered by sericitization. Chlorite is mainly an alteration product of mafic minerals. It occurs interspersed among the feldspar and quartz and commonly contains inclusions of zircon with pleochroic halos. The chlorite therefore, is probably after biotite. Sphene, and apatite are present as minute crystals, and epidote is a common alteration product of mafic minerals and feldspars.

2.3.1.4 Dykes

Associated with the Hermitage Complex are numerous dykes which intrude one another, the plutonic rocks, and the volcanic rocks of the Connaigre Bay Group. They are common in most parts of the map area and are well exposed along the coastlines (Plate 15). They range in width from one

Plate 14. Sagenitic texture shown by rutile in flakes of biotite.

Plate 15. Silicic and mafic dykes of the Hermitage Complex intruding one another and the Grole Diorite (Hermitage Cove).

metre to a few tens of metres and in composition from diabasic to granitic.

Acidic dykes are commonly pink to light grey, aphanitic to fine-grained, massive to porphyritic felsite. Quartz and potash feldspar are the most common phenocrysts in porphyritic varieties and occur sparsely in a very fine-grained siliceous matrix. Most dykes are aphanitic and massive and in places coarsen to a fine-grained granite. Flow-banding is present along the margins of many dykes.

In thin section it can be seen that phenocrysts are generally euhedral crystals of quartz, potash feldspar, and rarely plagioclase. Feldspars are commonly saussuritized and the quartz is corroded. As in the volcanics, quartz occurs as bipyramidal crystals typical of the high-temperature form of β-quartz. Devitrification microspherulites are evident in some sections. Muscovite and biotite are present in some samples, with epidote, chlorite, apatite and zircon occurring as accessory and secondary minerals. Garnets occur rarely in the groundmass (Plate 16). The matrix may be glassy or a fine-grained intergrowth of quartz, potash feldspar, plagioclase and opaque minerals.

Diabase dykes are dark green to dark grey, fine-grained, aphanitic to porphyritic. Pyroxene phenocrysts are common, with scattered plagioclase phenocrysts, and these dykes are similar in appearance to the mafic volcanic rocks of the Doughball Point Formation.

Petrographic studies show that the mafic dykes are made up predominantly of hypersthene, augite, plagioclase and hornblende. The pyroxenes are abundant in the groundmass and common as euhedral phenocrysts. In many samples they are partly replaced by actinolite, chlorite, and epidote. Plagioclase forms a major part of the groundmass, is commonly zoned, and with pyroxene, produces intersertial to sub-ophitic textures. Plagioclase phenocrysts are present rarely. Generally plagioclase crystals have been altered by sericitization. Hornblende, where present, occurs in the groundmass as euhedral to subhedral pleochroic, yellow to brown crystals. In some cases it is partly replaced by actinolite.

2.3.1.5 Structural Relationships

The Hermitage Complex intrudes, agmatizes and migmatizes the volcanic rocks of the Connaigre Bay Group. Contact migmatites are well exposed along the Hermitage Peninsula road and west of Partridge Cove along the coast. As described above, the volcanic rocks have been partially melted and remobilized close to the contact. A metamorphic aureole about 1 kilometre wide has been produced, with the volcanics coarsened and baked to a dense black hornfels.

The contact northeast of Furby's Cove between the granite and the volcanics is intrusive, although a fault which affects the granite and the volcanics is located close to the contact. A mylonite zone is developed in both the granite and the volcanics, and the granite grades from massive to protomylonitic to mylonitic. Protomylonitic granite is evidenced by elongated quartz and broken and granulated feldspar in a fine-grained matrix of quartz, feldspar and sericite which forms bands wrapped around the porphyroclasts (Plate 17). The granite becomes mylonitic within the fault zone with small porphyroclasts of feldspar in a fine grained to microcrystalline banded matrix of recrystallized

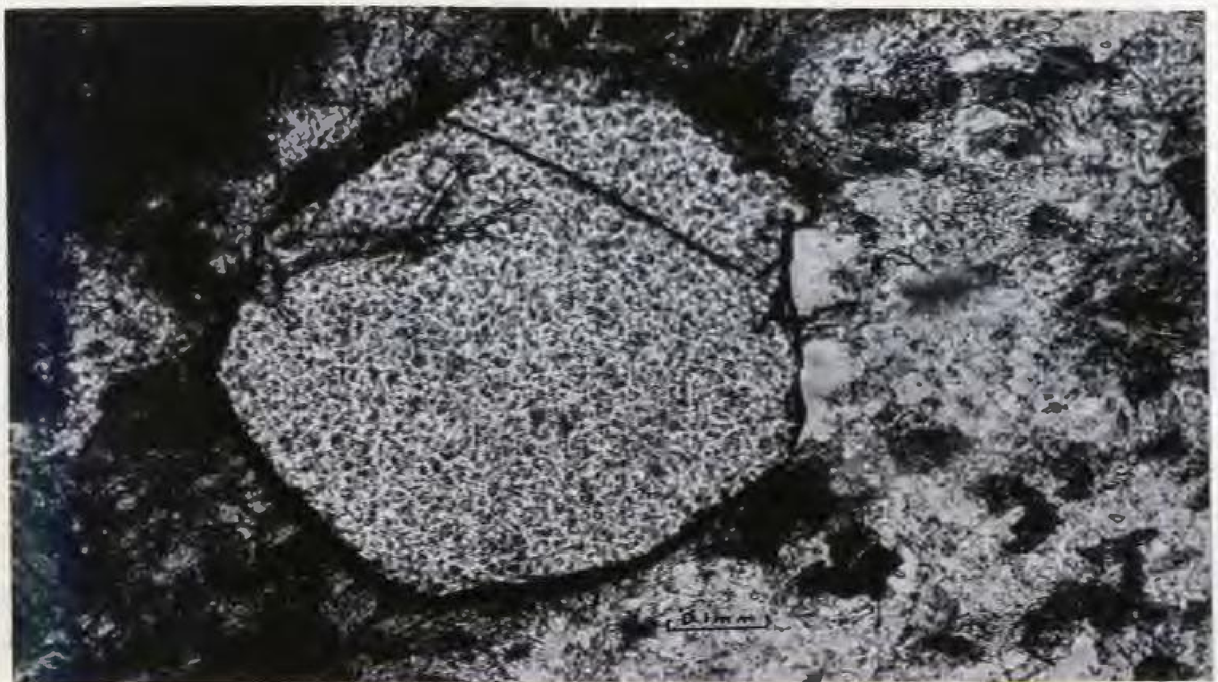


Plate 16. Garnet in silicic dyke of the Hermitage Complex.

Plate 17. Protomylonitic granite with elongated quartz and broken and granulated feldspar in a fine-grained matrix of quartz, feldspar and sericite.

quartz and granulated feldspar (Plate 18).

The fabric in the diorite is believed to be a result of semi-solid flow close to the margins of the pluton as described for numerous other plutons (eg. Pitcher and Berger, 1972). The orientation of the fabric is inconsistent over small areas and is best displayed in areas containing abundant inclusions. Although the contact is not exposed along the coast of the peninsula southwest of Hermitage, it is believed to be close-by because of the abundant inclusions contained in the diorite there. The most conclusive evidence for the fabric being a result of flow is contained in dioritic dykes cutting the gabbro. These dykes contain a foliation similar to the main mass of diorite which parallels the margin of the dyke as it changes direction (Plate 19). In thin section, the foliated diorite does not show any evidence of excessive straining or recrystallization, although plagioclase laths and biotite are crudely aligned, again suggesting flow foliation (Plate 20). Locally a fabric is developed which is due to folding, e.g., in the cove immediately northeast of Hermitage Cove. Here mafic dykes intruding granodiorite have been folded with an axial planar fabric developed in the granodiorite, defined by the alignment of biotite. In thin section the quartz has been partially recrystallized but shows undulose extinction with sutured grain boundaries and the feldspars are bent and granulated.

The Pass Island Granite intrudes the Grole Diorite of the Hermitage Complex, with the contact well exposed near Pass Island Tickle where an intrusive breccia is developed. A foliation is developed in the granite and the diorite within a few metres of the contact and

Plate 18. Mylonitic granite with small porphyroclasts of feldspar in a fine-grained to microcrystalline matrix of recrystallized quartz and feldspar.

Plate 19. Foliated dioritic dyke intruding massive gabbro of the Hermitage Complex with foliation parallel to margin of dyke.

Plate 20. Crudely aligned unstrained plagioclase and biotite in foliated diorite of the Hermitage Complex.

is probably a result of marginal shearing after crystallization of the granite.

Silicic and mafic dykes most commonly intrude the lowest three formations of the Connaigre Bay Group and the plutonic rocks of the Hermitage Complex. Northeast of Hermitage Cove, alternating mafic and silicic dykes form almost continuous outcrop and intrude one another in no set pattern. Dykes up to 20 metres wide can be found intruding most rocks in the map-area, except the Down's Point Formation. Very few outcrops of this formation contain dykes similar to the dykes of the Hermitage Complex.

2.3.1.6 Age and Correlation

As stated above, a tentative isotopic age of 450 million years or older has been obtained by $^{40}Ar/^{39}Ar$ method from gabbro of the Hermitage Complex. This age, if correct, separates the Hermitage Complex in time from the Devonian intrusions which are common in the Gander and Avalon Zones of Newfoundland. A pre-Devonian age has also been established for the Simmons Brook Batholith which outcrops to the east of the map-area. It is overlain unconformably by the Devonian or earlier Pools Cove Formation which is intruded by late Devonian Ackley-type granite (Williams, 1971; Greene and O'Driscoll, 1976). The Swift Current Granite on the Burin Peninsula has been dated by a Rb/Sr whole rock isochron (λ $^{87}Rb = 1.47 \times 10^{-11} yr^{-1}$) at 510 $\pm$ 20 million years (Bell and Blenkinsop, 1975) and has been correlated with the Cape Roger Mountain Batholith also on the Burin Peninsula (O'Driscoll, 1973). The Hermitage Complex is similar mineralogically to the Simmons Brook Batholith (Greene and

O'Driscoll, 1975) and although more mafic, is correlative in time to the Swift Current and Cape Roger Mountain Batholiths.

2.3.2 Straddling Granite

Definition and Extent: The name Straddling Granite is proposed for a small intrusion located at the head of Hermitage Bay, sitting astride the boundary of the Avalon and Gander Zones. The granite occupies an area of approximately 25 square kilometres and was first described by Widmer (1950). His work contains the only description of the granite to date. He represented this body as a minor intrusion associated with the Ackley Batholith to the east. Anderson (1965) also indicated that the Straddling Granite was Ackley type.

Lithology: The Straddling Granite is composed of equigranular, medium-grained, orange-pink to grey granite to granodiorite (Plate 21). The main constituents of the granite are potash feldspar, quartz and plagioclase, with minor mafic minerals. A major part of the granite appears alaskitic with mafic minerals sparse and the rock consisting almost wholly of quartz and feldspar. Because of orange-pink plagioclase the granite looks similar in places to the more potash rich Harbour Breton Granite which outcrops a few miles to the east. Possibly some of the rocks mapped as Straddling Granite are actually Harbour Breton Granite. Marginal to the Straddling Granite is diorite similar to that of the Hermitage Complex and included with it. Buff to grey coloured granodiorite occurs in places within the granite and consists of quartz, plagioclase, potash feldspar and chloritized biotite.

Plate 21. Equigranular, medium-grained granite typical of the Straddling Granite (Hermitage Bay Brook).

The Straddling Granite has been cataclastically deformed and brecciated with a 50-100 metre wide breccia zone developed along the Hermitage Bay Fault. A fine network of quartz veins cement brecciated fragments close to this zone with development of cockade structures and partially filled fractures.

Petrography: Thin sections show that the granite is composed of quartz, plagioclase, potash feldspar, biotite, muscovite, chlorite and epidote. Generally, the biotite has been altered to chlorite and epidote. Potash feldspar is commonly represented by broken and granulated crystals of microcline perthite. Quartz crystals have been strained and generally have irregular boundaries. Plagioclase crystals (An_{33}-An_{38}) are commonly bent and broken and have been sericitized to varying degrees. A modal analyses of a typical specimen of Straddling Granite is as follows: quartz - 30 per cent, potash feldspar - 20 per cent, plagioclase - 35 per cent, biotite - 5 per cent, muscovite - 3 per cent, chlorite - 5 per cent, epidote - 2 per cent.

Relationships and Age: The Straddling Granite intrudes rocks of the Connaigre Bay Group in the Avalon Zone producing a thin metamorphic aureole. Locally acidic volcanics have been pyrophyllitized close to the contact. Within the Gander Zone the contact is obscured by faulting and vegetation. The Straddling Granite is presumed to intrude the rocks of the Gander Zone since there is an abrupt change from non-foliated granite to foliated granite. A whole-rock Rb/Sr isochron age determination has yielded an age of 490 $\pm$ 10 million years (λ $^{87}Rb = 1.47 \times 10^{-11} yr^{-1}$) for the Straddling Granite (Blenkinsop et al., 1976). This places the

Straddling Granite in the group of intrusions older than the Ackley Granite which include the Swift Current Granite, the Simmons Brook Batholith, and the Hermitage Complex. Possibly the Straddling Granite is a granitic phase of the Simmons Brook Batholith or the Hermitage Complex. The possibility will be discussed further in the chapter on chemistry.

2.3.3 Pass Island Granite

Definition and Extent: The name Pass Island Granite was used by Strong *et al* (1974) for the granitic intrusion situated at the south-western tip of the Hermitage Peninsula. Widmer (1950) described the intrusion and included it in his Ackley-type granites. The Shag Rocks of Connaigre Bay are composed of this granite and Widmer (1950) states that the unusually shallow bottom of Connaigre Bay between the Shag Rocks and the Hermitage Peninsula is probably underlain by the Ackley-type granite.

The granite has an area on land of approximately 45 square kilometres, with the contact extending westward from Dog Cove to the Pass Island Tickle. The granite intrudes the Hermitage Complex along its northern contact and contains volcanic and dioritic inclusions.

Lithology: The Pass Island Granite is composed of homogeneous orange to pink, medium- to coarse-grained granite. It consists essentially of pink potash feldspar, milky white to grey quartz, buff to green plagioclase, hornblende and biotite. It appears fresh and is porphyritic in places, with phenocrysts of pink potash feldspar. Many potash feldspar crystals have rims of white plagioclase (Plate 22).

Outcrops on the tip of the Hermitage Peninsula show the clearest

Plate 22. Pass Island Granite showing potash feldspar with rims of plagioclase (rapakivi texture).

Plate 23. Pass Island Granite showing coarse-grained and fine-grained phases.

exposures of the granite. Here can be seen pockets of coarse-grained granite in a finer phase with diffuse boundaries (Plate 23) as well as hornblende-rich schlieren (Plate 24). These phenomena are probably the result of local variations in volatiles in the magma with increased volatiles giving rise to the coarse-grained phases and hornblende schlieren.

Inclusions in the granite generally appear unaltered, although a few have undergone potassium metasomatism, as evidenced by the growth of potash feldspar porphyroblasts in, and across boundaries of, dark fine-grained inclusions (Plate 25).

The granite contact is well-exposed northwest of Pass Island Tickle as described in section 2.3.1.5. The granite becomes finer-grained as the contact is approached and contains a faint fabric in the contact zone. The intrusive breccia is composed of aligned lenticular inclusions of diorite in fine-grained granite (Plate 26).

Petrography: Thin sections show that the granite is composed mainly of quartz, potash feldspar, plagioclase, biotite and hornblende, with minor zircon, and apatite. Quartz makes up about 35 per cent of the rock and forms slightly strained anhedral crystals with irregular boundaries. In some samples quartz forms irregular branching intergrowths with plagioclase, where the plagioclase abuts potash feldspar a myrmekitic texture is formed (Plate 27). The granite contains about 30 per cent potash feldspar which is usually represented by large crystals of microcline perthite. These crystals have not been altered to any great extent and because of this are easily distinguished from untwinned

Plate 24. Pass Island Granite showing hornblende-rich schlieren.

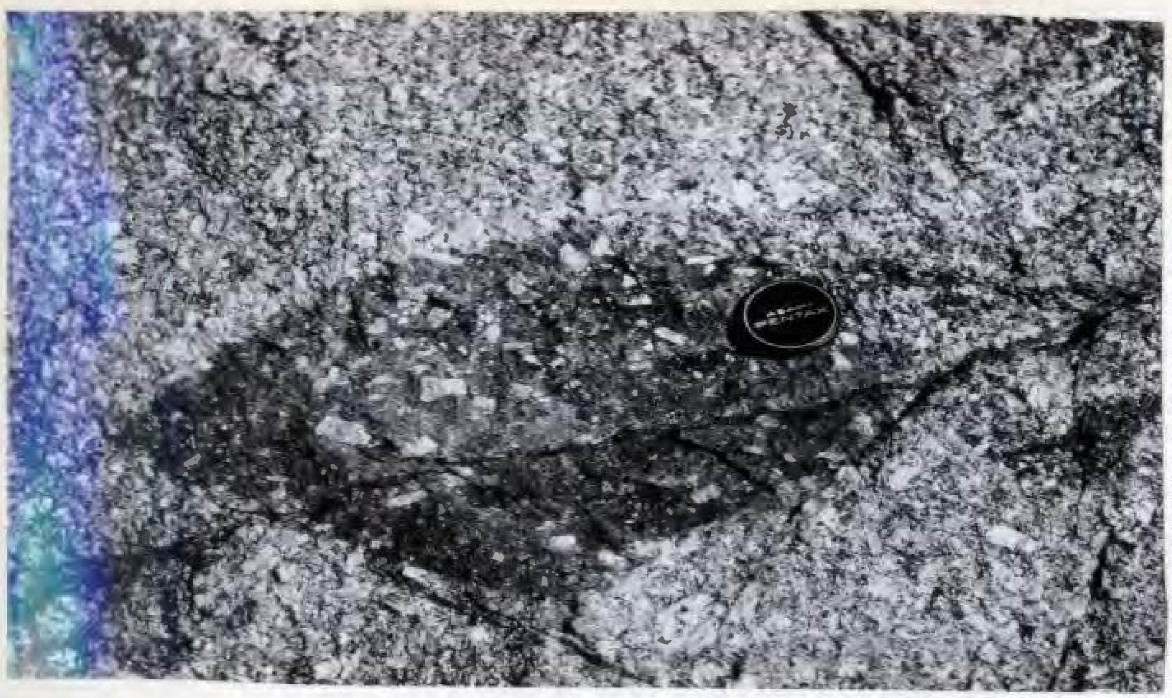


Plate 25. Fine-grained inclusion in the Pass Island Granite overprinted by potash feldspar porphyroblasts.

Plate 26. Intrusive breccia at the contact between the Pass Island Granite and the Grole Diorite (northeast of Pass Island Tickle).

Plate 27. Myrmekitic texture in Pass Island Granite.

plagioclase which has been sericitized and is a light brown color in plane light. Plagioclase is also twinned in some cases, with the total plagioclase content being approximately 25 per cent. As evidenced by the myrmekitic texture, potash feldspar has been replaced marginally by plagioclase and quartz, possibly a deuteric alteration phenomenon. Euhedral to anhedral crystals of hornblende and biotite are present in roughly equal amounts making up about 10 per cent of the rock. The hornblende is pleochroic in colors from brown to green. Zircon is an abundant accessory mineral occurring in the hornblende and biotite producing pleochroic halos. Apatite is present as tiny crystals in all the essential minerals

<u>Age and Correlation</u>: There is no direct evidence which can be used to establish the age of the Pass Island Granite, since no geochronological work has been carried out on the body. The granite intrudes the Hermitage Complex and is therefore younger than it. It is mineralogically and chemically similar to the Harbour Breton Granite which has given a whole rock Rb/Sr age of 340 ± 20 million years (K. Bell, pers. comm., 1975). This age is compatible with the age of the Ackley Batholith with which the Pass Island and Harbour Breton Granites have been correlated (Widmer, 1950).

2.3.4 Late Dykes

Silicic and mafic dykes of unknown affinity represent the latest intrusions within the map-area. These dykes cut the Pass Island Granite indicating a Devonian or later age. Similar dykes cut fossiliferous Devonian rocks to the east (Greene, 1975). Possibly some dykes included in the Hermitage Complex belong to this late group but they cannot be definitely separated.

Silicic dykes are composed of orange to purple, aphanitic to porphyritic rhyolite. Phenocrysts of K-feldspar and quartz up to 1 centimetre across are set in a fine-grained matrix in the porphyritic varieties.

Diabase dykes are commonly porphyritic in the central zones with fine-grained chilled margins. Phenocrysts are composed of green plagioclase laths up to 2 centimetres in length set in an equigranular matrix of plagioclase and amphibole. In places these dykes are also amygdaloidal indicating high-level emplacement. Quartz commonly fills the amygdules.

2.4 Gander Zone

2.4.1 Introduction

Rocks of the Gander Zone were studied briefly in the field in the area close to the Straddling Granite. These consist of two types of granitoid rocks, one a porphyritic granite to granodiorite named the Gaultois Granite and the other an unnamed medium-grained granite called the "leucocratic granite" in this report. These rocks exhibit a regional penetrative fabric.

2.4.2 Gaultois Granite

Widmer (1950) used the name Gaultois Porphyry for intrusive rocks along the northwestern side of Hermitage Bay. These rocks had previously been mentioned by Jewell (1939) and by White (1939).

Colman-Sadd (1974) mapped part of the granite in the area around Gaultois and to the west and used the name Gaultois Granite.

The intrusion is an elongate body and extends approximately 30 kilometres southwestward from the map-area along the northwestern shore of Hermitage Bay. Similar rocks are also found north and northeast of the map-area (Colman-Sadd, 1976; Greene and O'Driscoll, 1976)

The Gaultois Granite is a pink, porphyritic granite to granodiorite composed of microcline phenocrysts set in a coarse-grained matrix of quartz, plagioclase, and chloritized biotite. The biotite, defines the fabric for the most part and forms augen around the phenocrysts. Quartz crystals have been strained and elongated and in places help define the fabric (Plate 28). The feldspars are commonly broken and crushed.

2.4.3 Leucocratic Granite

The leucocratic granite is located in the northeast corner of the map-area and is part of an intrusion which extends at least 8 kilometres to the north (Greene and O'Driscoll, 1976; Colman-Sadd, 1976). However, the true extent of this body is not known since only a small part of it has been mapped.

The leucocratic granite is composed of fine- to medium-grained, equigranular granite. Its main constituents are potash feldspar, plagioclase, quartz, muscovite, biotite and chlorite. Muscovite occurs as the only mica mineral in places but also occurs with biotite. It becomes non-existant in local zones of biotite granite. Contacts between muscovite granite and biotite granite are both gradational and abrupt.

Plate 28. Gaultois Granite showing strong foliation defined by elongated quartz, granulated feldspar and aligned biotite.

Plate 29. Strongly foliated biotite phase in contact with weakly foliated muscovite phase of the leucocratic granite.

The granite is overprinted by a foliation that is generally well-defined by quartz flattening as well as mica alignment. However, the intensity of this fabric varies considerably and without apparent pattern. Locally, where there is an abrupt change between the two phases of granite, the biotite phase exhibits a strong fabric and the muscovite phase exhibits a weak fabric (Plate 29) This may indicate that the muscovite granite is the later phase and that the pluton was intruded syn-tectonically.

Abundant garnetiferous leucocratic dykes and veins intrude the granite and both portray the same foliation (Plate 30). It has been suggested by Colman-Sadd (1976) that these are a garnetiferous phase of the leucocratic granite and only occur close to the margins of the intrusion. These dykes also intrude the Gaultois Granite within the map-area.

2.4.4 Relationships and Age

Large rafts of porphyritic quartz diorite, granodiorite, and granite are included within the leucocratic granite and are considered to be phases of the Gaultois Granite (Greene and O'Driscoll, 1976; Colman-Sadd, 1976). The leucocratic granite is presumed to be intruded by the Straddling Granite (section 2.3.2). This places an upper limit of lowermost Ordovician on the age of intrusion and deformation of rocks of the Gander Zone within the map-area. Possibly the age of these rocks is Precambrian as suggested by Widmer (1950).

Plate 30. Garnetiferous foliated leucocratic dyke intruding the Gaultois Granite.

2.5 Aeromagnetic Patterns

Aeromagnetic measurements made over the map-area (Fig. 2.1) reflect the varying compositions of the underlying rock-types. The silicic volcanic rocks of the Tickle Point Formation, the granitic rocks of the Pass Island, Furby's Cove and Straddling Granites and the sedimentary rocks of the Great Island Formation are reflected by widely spaced contours representing broad anomalies of relatively low intensity. The mafic volcanic and intrusive rocks of the Doughball Point Formation and the Grole Diorite are indicated by a number of closely spaced contours defining elliptical shaped anomalies of relatively high intensity. These magnetic highs possibly indicate areas of feeder roots in the diorite and volcanic rocks.

On the Doughball Peninsula a magnetic high extends northwards along the peninsula over rocks of the Down's Point Formation reflecting the mafic volcanic rocks of the underlying Doughball Point Formation. Magnetic highs in the Good Hill area could be caused by the mafic tuffs of the Great Island Formation and by the abundance of magnetite which occurs in veins in the Doughball Point Formation and as lenses in the sandstones of the Down's Point Formation.

Within the Grole Diorite north of the contact with the Pass Island Granite the magnetic pattern is of low intensity. This probably indicates that the contact of the Pass Island Granite is dipping northwards beneath the Grole Diorite. This is supported by the orientation of the marginal foliation in the granite which dips gently to the north.

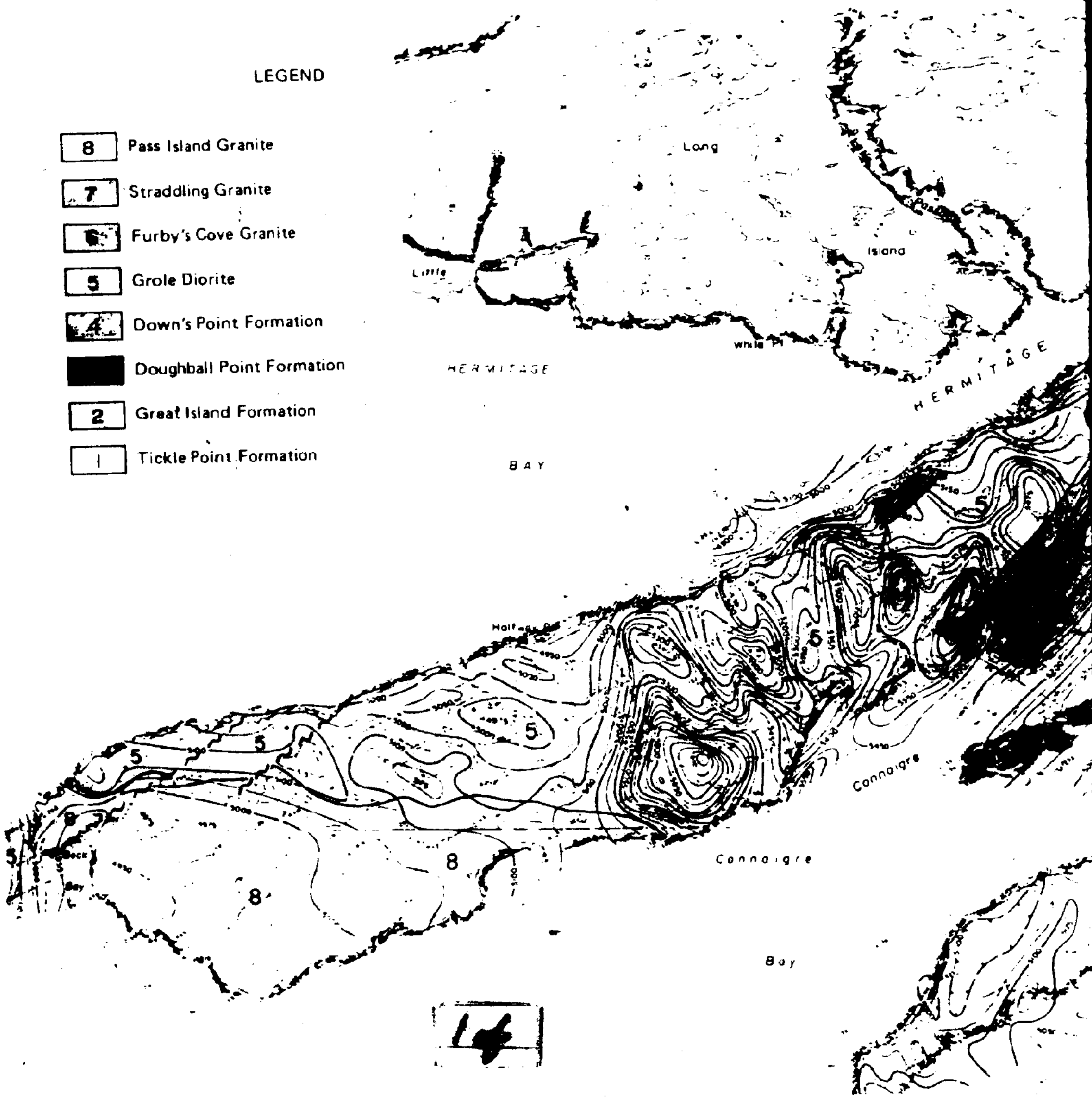
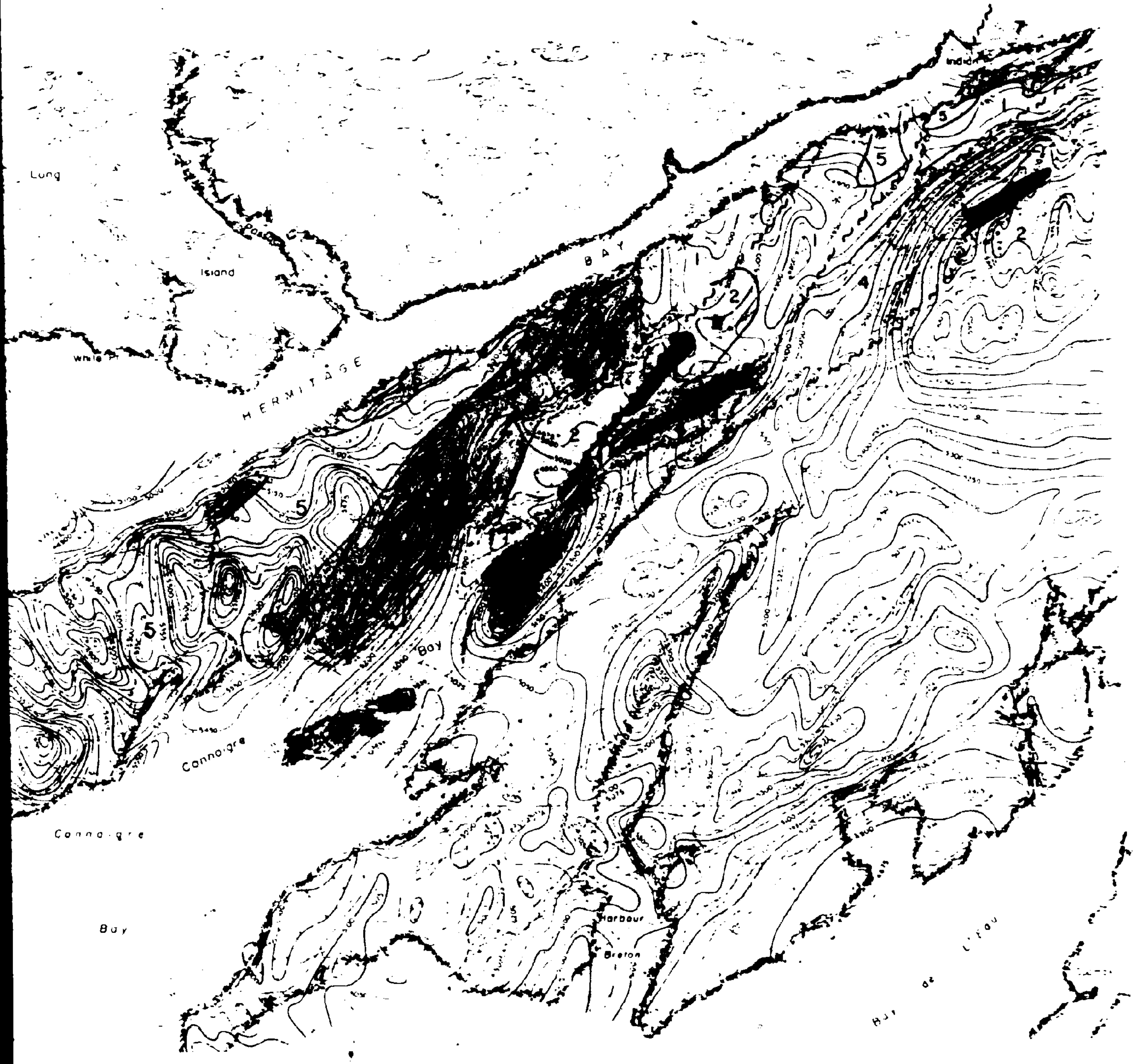


Figure 2.1 Aeromagnetic map of the Hermitage Peninsula area with generalized geology superimposed. Magnetic contour interval is 25 gammas, scale: 1 inch = 2 miles (NALCO Aeromagnetic Survey Results, 1962; used with permission).



insula area with
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= 2 miles (NALCO
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CHAPTER 3

STRUCTURE

3.1 Introduction

The map-area is divided into two areas of contrasting structural style by the northeast-trending Hermitage Bay Fault which marks the boundary between rocks of the Avalon and Gander Zones (Williams et al., 1974). To the northwest of this fault, in the Gander Zone, are deformed granitic rocks within the map-area, and structurally complex gneisses and other crystalline rocks northwest of the map-area (Colman-Sadd, 1976). These contrast sharply with the relatively undeformed volcanics, sedimentary and intrusive rocks of the Avalon Zone to the southeast.

3.2 Avalon Zone

Within the map-area, the structural pattern of the Avalon Zone is dominated by the development of numerous fault zones and by broad open folds. The faults generally trend in a north to northeasterly direction. Although fault planes cannot always be seen, shear zones dipping moderately to steeply to the northwest are evident in many areas. Examples of these faults can be seen on the southwestern part of the Hermitage Peninsula, in The Tickle, in Salmonier Cove and on Great Island. Many of these faults have the older rocks to the northwest indicating a high angle reverse compoment of movement. In The Tickle and Salmonier Cove, rocks of the Tickle Point Formation have moved upward and southeastward over rocks of younger formations.

Similarly rocks of the Great Island Formation have moved upward over those of the Doughball Point Formation on Great Island. Normal faults with steep to moderate dips occur at Good Hill and displace the axis of the Good Hill Syncline. The nature of movement along many faults is unknown. Some have a left-lateral strike separation such as the one on Great Island and the ones which displace the axis of the Good Hill Syncline.

Most of the rocks within the Avalon Zone are involved in upright open folds with northeast-trending, gently plunging axes. These axes generally plunge to the southwest, e.g. Salmonier Cove and Good Hill Synclines, but a northeast plunging fold is evident on the Doughball Peninsula. The rocks are not penetratively cleaved although a steep slaty axial planar cleavage is developed in the fine-grained sedimentary rocks.

3.3 Gander Zone

In contrast to the rocks of the Avalon Zone, most of those of the Gander Zone are overprinted by a pervasive northeast-trending, northwest-dipping tectonic fabric. The intensity of this fabric varies erratically, but is generally well-defined by flattened and elongated quartz as well as mica alignment. Porphyritic quartz diorite and granite of the Gaultois Granite occur as rafts within, and exhibit a fabric similar in orientation to that of the leucocratic granite, suggesting that both rocks are overprinted by the same fabric. However, to the southwest, similar foliated leucocratic granite contains xenoliths of the Gaultois Granite which were foliated prior to intrusion (Colman-Sadd, 1974).

Within the map-area, the Straddling Granite does not exhibit the pervasive fabric common to other Gander Zone rocks and is presumed to intrude the leucocratic granite. At Russell Head, the Gaultois Granite is in fault contact with the Straddling Granite. The fault zone dips steeply to the west with the Gaultois Granite thrust over the Straddling Granite. A strong topographic depression is evident along the line of the fault. Within the fault zone, the Straddling Granite is intensely mylonitized with the fabric gradually decreasing in intensity to become non-existant about 1.5 kilometres away from the fault.

3.4 Hermitage Bay Fault

The Hermitage Bay Fault is the major fault line of the area and possibly of the southeastern part of Newfoundland. It was first described by White (1939) and later by Widmer (1950). White was unable to determine whether it was a normal or reverse fault, but Widmer concluded that its nature is high-angle reverse. The fault is a relatively straight feature extending northeastward from the head of Hermitage Bay. It is marked by a 50-100 metre wide zone of brecciation which contains subangular to rounded fragments of disoriented foliated Gander Zone rocks and unfoliated Avalon Zone rocks in a fine-grained matrix of crushed granitic and volcanic rocks (Plate 31).

The fault separates strongly metamorphosed rocks of the Gander Zone from the less metamorphosed rocks of the Avalon Zone. Northeast of the map-area (Fig. 3.1) rocks of the Simmons Brook Batholith and

Plate 31. Breccia within the Hermitage Bay Fault Zone.

the Connaigre Bay Group are truncated by the Hermitage Bay Fault and juxtaposed against the deformed and foliated leucocratic and Gaultois Granites (Greene and O'Driscoll, 1976; Williams, 1971).

Within the map-area, the Straddling Granite has been cataclastically deformed and brecciated by the Hermitage Bay Fault. At the head of Hermitage Bay, zones of green to grey, sheared and finely granulated granite are present with shear zones dipping steeply to the west. This suggests a movement having a reverse component and bringing Gander Zone rocks upward and eastward over Avalon Zone rocks.

The Dover Fault in northeastern Newfoundland forms the boundary between the Gander and Avalon Zones (Blackwood and Kennedy, 1975; Blackwood, 1976) and is characterized by a 300-500 metre wide zone of intense mylonitization. However, unlike the Dover Fault, there is no evidence of mylonitization along the Hermitage Bay Fault within the map-area.

3.5 Discussion

In the Avalon Zone, only one period of folding is indicated by the simple fold patterns. This resulted in a regional northwest-southeast shortening with the compression probably being relieved finally by the development of high angle northwestward dipping thrust faults. This type of deformation is evident in rocks of the Connaigre Bay Group and the Hermitage Complex and is probably synchronous with the emplacement of the Devonian intrusions in the area. Although the Upper Devonian Great Bay de l'Eau Formation is relatively unfolded (Williams, 1971) there is evidence that thrusting continued after its deposition.

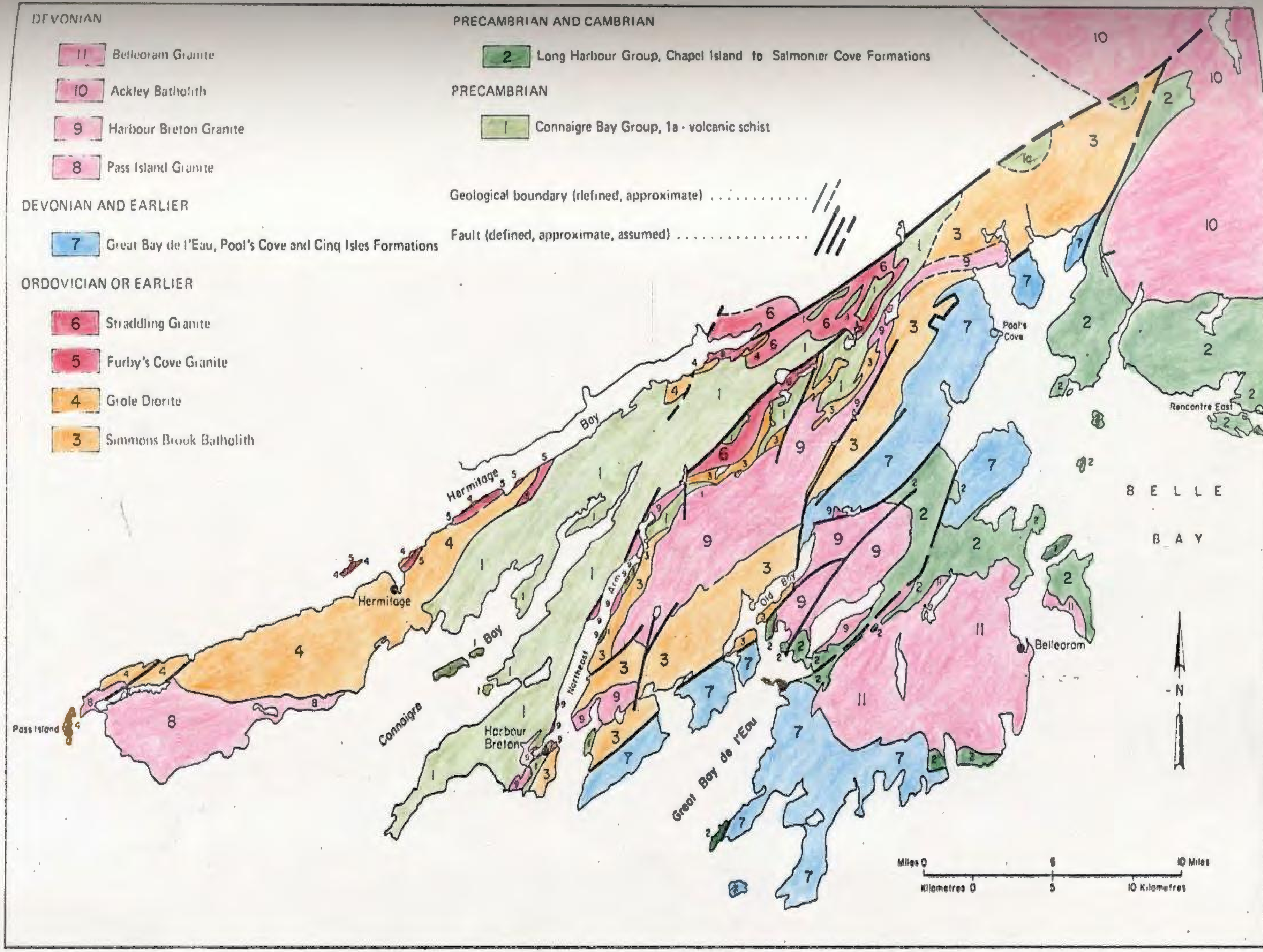


Figure 3.1 Generalized geological map of the Hermitage - Fortune Bay area (in part after Greene and O'Driscoll, 1976; Greene, 1975; Williams, 1971).

To the east the Great Bay de l'Eau conglomerate is overthrust by volcanics of the Long Harbour Group (Greene, 1975). Possibly the conglomerate formed as a result of the final adjustments to the thrust movements (Widmer, 1950).

At least two periods of intrusion are evident within the map-area. The Hermitage Complex, the Straddling Granite, and the Simmons Brook Batholith which occurs just outside the map-area, are probably of similar ages. All these bodies intrude the Connaigre Bay Group, but neither intrudes rocks of younger ages. As stated earlier, the Simmons Brook Batholith is overlain unconformably by the probable Devonian Pools Cove Formation to the southeast (Williams, 1971; Greene and O'Driscoll, 1975). The Pass Island Granite is correlated with the Harbour Breton Granite which outcrops to the east and intrudes the Pools Cove Formation. The Harbour Breton Granite is an Ackley-type intrusion which has been dated at 340 ± 20 million years (Bell, pers. comm. 1975). This represents the latest intrusion in the map-area although later intrusive activity is evident in the eastern Gaultois and the Belleoram map-areas (Greene and O'Driscoll, 1975; Williams, 1971).

Rocks of the Gander Zone were deformed prior to the intrusion of the Straddling Granite since that granite intrudes the foliated terrane post-tectonically. Within the map-area only one pervasive fabric is evident in the rocks of the Gander Zone. However to the northwest, gneissic banding has been overprinted by later regionally penetrative fabrics (Colman -Sadd, 1974). Presumably the Gander Zone rocks of the map-area contain one of these fabrics which pre-dates the Straddling

Granite and this is, therefore, early Cambrian or Precambrian in age and suggests a complex structural history in Precambrian times.

The leucocratic granites to the southwest which contain xenoliths of pre-deformed Gaultois Granite are considered to be Middle Ordovician or younger in age. They have been correlated on lithological similarity with the North Bay Granite which intrudes the fossiliferous Middle Ordovician Baie d'Espoir Group (Colman-Sadd, 1976). However, the leucocratic granite within the map-area, which is also lithologically similar to the North Bay Granite (Colman-Sadd, 1976), is older than the Straddling Granite and is therefore pre-Ordovician in age and cannot be correlated with the North Bay Granite.

As presently defined, the Hermitage Bay Fault and its presumed projection, the Dover Fault (Fig. 3.2) are not of the same aspect although both mark the boundary between the Gander and Avalon Zones. The Dover Fault is a zone of intense mylonitization with the main phase of movement postulated to be contemporaneous with deformation of rocks in the Avalon and Gander Zones which took place during the juxtaposing of the two zones. The deformation and consequently, the Dover Fault are believed to be Precambrian in age (Blackwood and Kennedy, 1975; Blackwood, 1976). This conflicts with recent geochronological evidence which indicates that significant movement took place in Devonian times (Blenkinsop et al., 1976).

The Hermitage Bay Fault, on the other hand, is a breccia zone with no indication of mylonitization. It is a post-Cambrian feature since it brecciates the Straddling Granite. Possibly this brecciation is related to movements which extended into the Devonian as has been

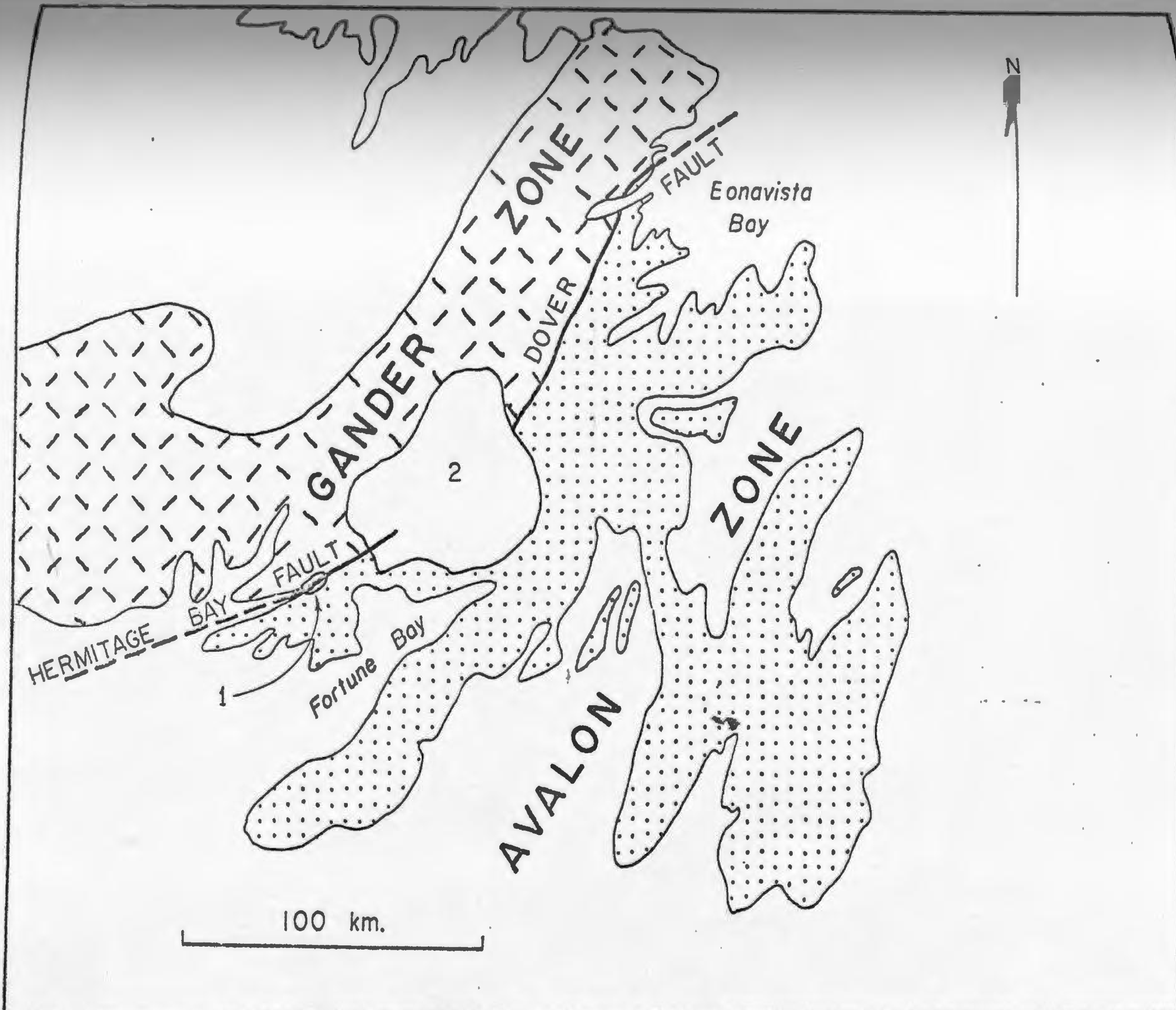


Figure 3.2 The Gander and Avalon Zones showing the Hermitage Bay Fault, the Dover Fault, the Straddling Granite (1), and the Ackley Batholith (2) (after Blackwood and O'Driscoll, 1976).

described.

The juxtaposing of the Gander and Avalon Zones took place prior to the emplacement of the Straddling Granite since that granite intrudes both zones. If the nature of the juxtaposing is similar to that postulated in northeastern Newfoundland (Blackwood and Kennedy, 1975), then an earlier movement along the site of the Hermitage Bay Fault is necessary. The age of this movement must pre-date deposition of the Connaigre Bay Group since these rocks show no evidence of being affected by the movement. Mylonites and an older deformed terrane could have been in part removed by late movements along the Hermitage Bay Fault and in part covered by rocks of the Connaigre Bay Group. To the immediate northeast of the map-area (Fig. 3.1) there are indications of acidic volcanics with an intense penetrative fabric on the Avalon Zone side of the Hermitage Bay Fault which may be equivalents of the Love Cove Group (Blackwood and O'Driscoll, 1976). However, more work is necessary to map out the exact relationships between these deformed volcanics and the undeformed Connaigre Bay Group volcanics which outcrop close-by. Another indication of an earlier deformed terrane is contained in the inclusions in the Hermitage Complex which contain a fabric which has been overgrown by porphyroblasts related to the intrusion.

CHAPTER 4

CHEMISTRY

4.1 Introduction

Rock specimens were collected from each formation and intrusion in the area. Sample locations are shown in Figure 4.1. Those samples showing signs of contamination such as veins and amygdules of secondary minerals were discarded and only the relatively unaltered specimens were retained for analyses. The samples were crushed to 1 centimetre chips in a steel jaw crusher and pulverized to -100 mesh powder in a Seibtechnik tungsten-carbide swing mill.

Chemical analyses for major and trace elements were carried out on 55 samples. Major elements, except ferrous iron, were determined using a Perkin Elmer 303 Atomic Absorption Spectrometer. Ferrous iron was determined according to the procedure outlined by Maxwell (1968, p. 49). Trace element analyses were carried out by X-ray fluorescence using a Phillips 1220C computerized spectrometer. Complete analytical procedures are described in Appendix 1.

Prior to computation of C.I.P.W. norms and plotting of diagrams, adjustments were made for oxidation and hydration with totals recalculated to 100 per cent, following the procedure outlined by Irvine and Baragar (1971). The results and C.I.P.W. norms are presented in Tables 2 to 4 (Appendix 2).

A number of plutons within or near the thesis area were sampled by the author and analysed during an earlier study (Strong et al., 1974) and these results are also discussed in this chapter. The analysed rocks fall into two chemically distinct groups. One group consists of

Figure 4.1 Locations of analysed samples within map-area.

a number of intrusive and volcanic rocks believed to be of similar ages, including the Hermitage Complex, Straddling Granite, Simmons Brook Batholith, and the Connaigre Bay volcanic rocks (Fig.3.1). Isotopic ages on the Straddling Granite and the Hermitage Complex indicate a late Cambrian- early Ordovician age on these rocks. The second group consists of Middle to Upper Devonian granitic intrusions, the Belleoram, Harbour Breton and Pass Island plutons (Fig. 3.1).

4.2 Hermitage - Connaigre Bay Assemblage

The name Hermitage - Connaigre Bay Assemblage is used here informally to facilitate description and refers to intrusive rocks of the Hermitage Complex and the Straddling Granite, and volcanic rocks of the Connaigre Bay Group. Frequency distribution diagrams are given for SiO_2 in each subdivision of the assemblage in Figures 4.2a to 4.2c with a combined frequency diagram given in Figure 4.2d. These diagrams show that the assemblage is strongly bimodal with a distinct silica gap in the 60-70 per cent SiO_2 range. The bimodality is most clearly demonstrated in the volcanic rocks of the Connaigre Bay Group (Fig. 4.2c).

4.2.1 Variation Diagrams

Major element oxides and trace elements are plotted against silica in Figures 4.3 and 4.5 for all analysed samples of the Hermitage-Connaigre Bay Assemblage. Silica was chosen as the independent variable because of its abundance and because magmatic differentiation generally produces rocks of steadily increasing silica content (Krauskopf, 1967).

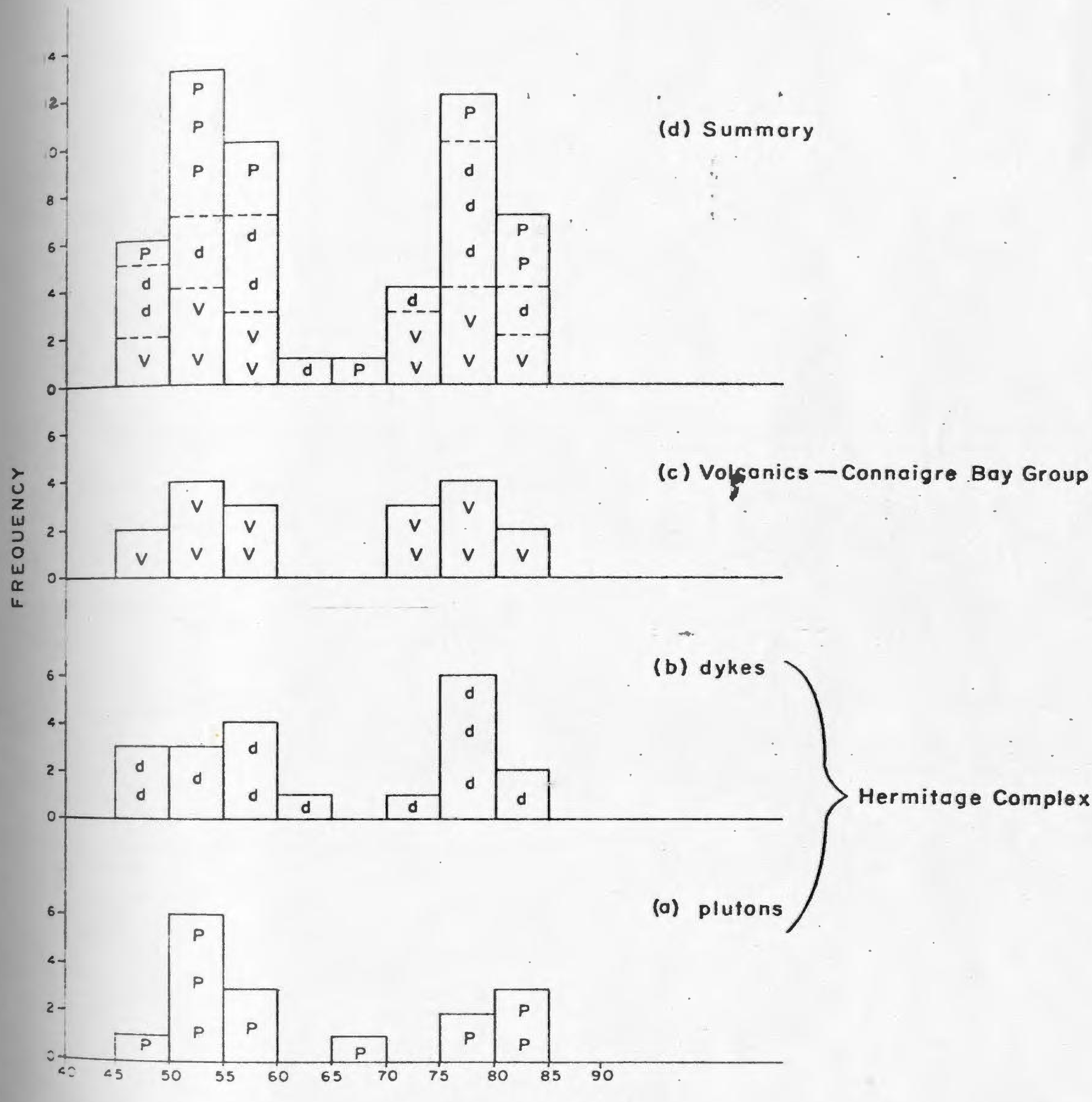


Figure 4.2 Frequency distribution of SiO_2 for the analysed samples of the Hermitage - Connaigre Bay Assemblage.

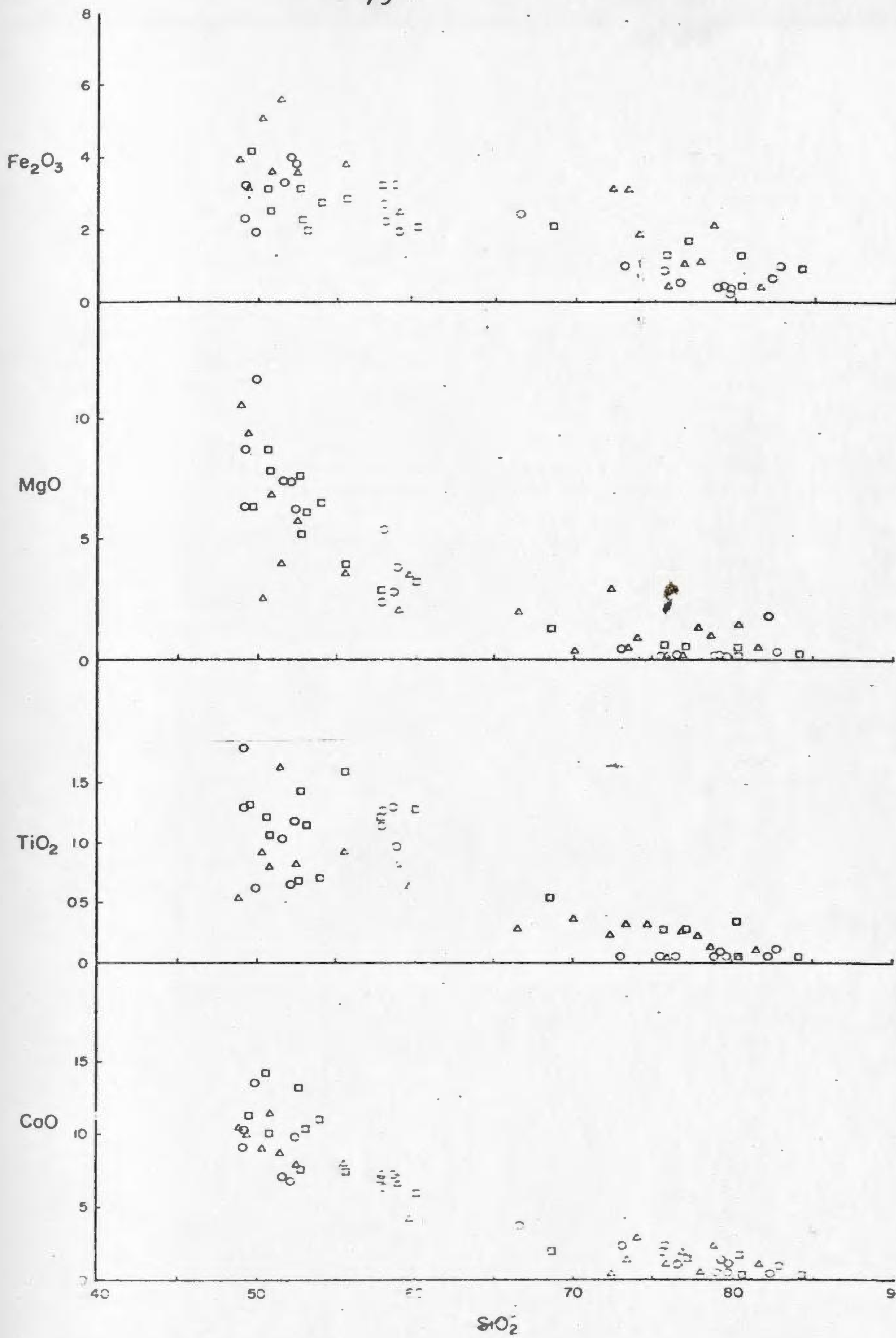


Figure 4.3 Major element oxides (wt. %) vs. SiO_2 (wt. %) variation diagrams for the Hermitage - Connaigre Bay Assemblage. Δ = Connaigre Bay Group volcanic rocks, o = Hermitage Complex dykes, □ = Hermitage Complex and Straddling Granite.

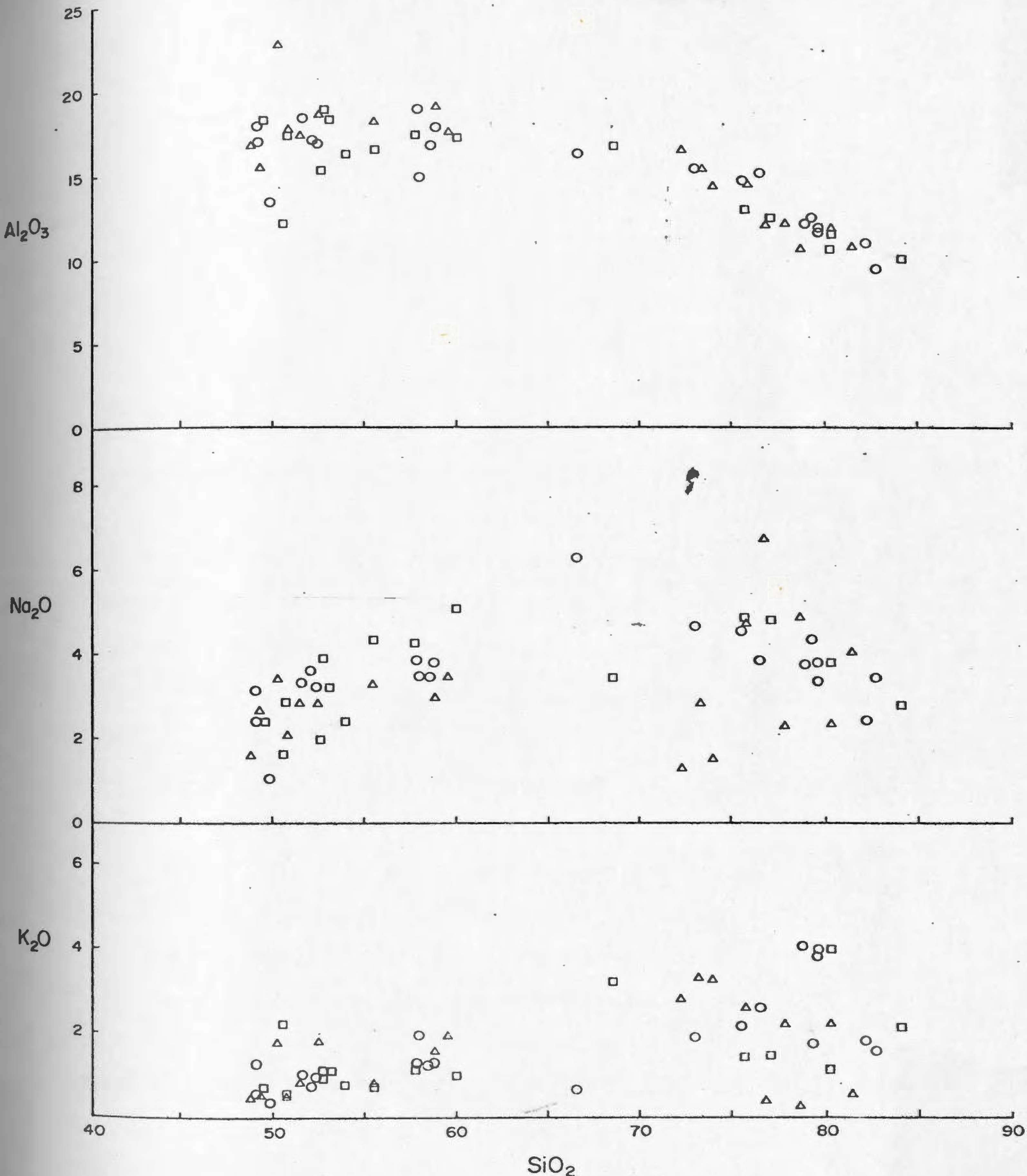


Figure 4.3 (contd.)

It can be seen from the diagrams that silica varies from 48 to 84 per cent. Because of the constant sum effect this increase in silica will be accompanied by the sum of the other oxides decreasing from 52 to 16 per cent. Therefore, from the method of plotting, each oxide will appear to decrease to about 30 per cent of its initial concentration regardless of differentiation.

The diagrams show relatively smooth trends from mafic to acidic rocks, consistent with the hypothesis that rocks of the Connaigre Bay Group, the Hermitage Complex and the Straddling Granite are genetically related, presumably by magmatic differentiation.

Inspection of the diagrams shows that CaO, MgO, Fe_2O_3 and TiO_2 have negative correlations with SiO_2 and decrease to much less than 30 per cent of their initial values, as would be expected from differentation, since these oxides are concentrated in the low silica minerals such as pyroxene, hornblende, and calcic plagioclase. The apparent decrease in Al_2O_3 is a result of the method of plotting and actually Al_2O_3 remains fairly constant or perhaps increases slightly as differentiation proceeds. The alkali metals increase across the variation diagram reflecting the concentration of these elements in alkali feldspars and micas of the later stages of differentiation. There is a wide scatter of points in the Na_2O and K_2O diagrams, especially in the acidic rocks, probably due to a mobilization and redistribution of alkalis during metamorphism. When Na_2O is plotted versus K_2O for the acidic rocks (Fig. 4.4) a rough negative correlation is outlined between the two elements. This may reflect a metasomatic exchange of alkalis possibly due to a hydrothermal process during late stages of

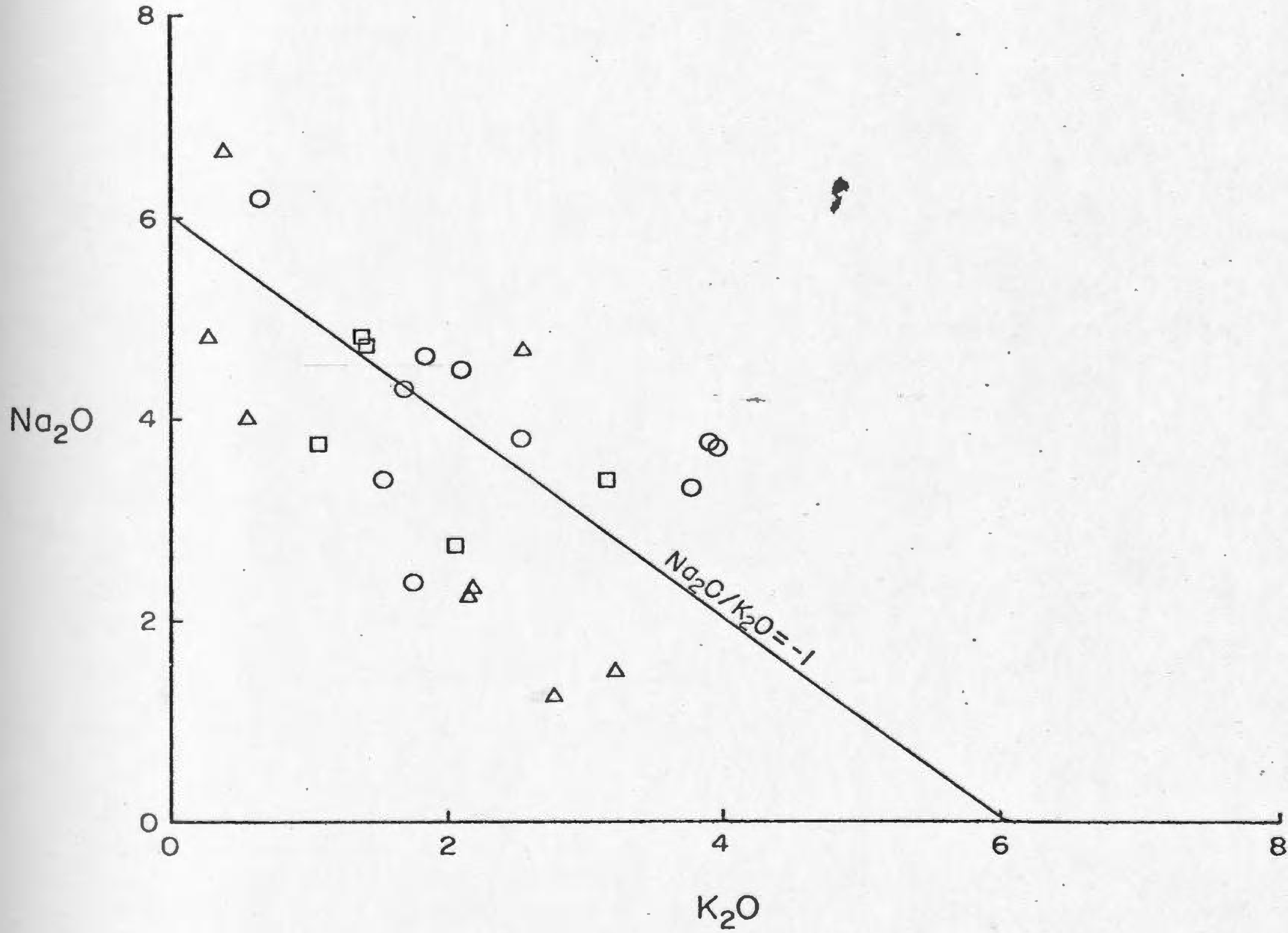


Figure 4.4 Na_2O vs. K_2O (wt. %) variation diagram for rocks of the Hermitage - Connaigre Bay Assemblage. Symbols as for Figure 4.3.

volcanism, as outlined by Brown and Ellis (1970). Smith (1968) reports that Na and K vary concordantly during low-grade regional metamorphism which would cause the points to move toward a positive slope on a Na_2O - K_2O plot. The superposition of such positive and negative slopes would result in a random scatter of points such as seen in Figure 4.4. A plot of K_2O + Na_2O vs. SiO_2 (Fig. 4.6) shows that the total alkali content remains fairly constant, indicating only local readjustment of total alkalis (Strong, 1973; Kean, 1973; Thurlow, 1973; DeGrace et al., 1976).

Although plots of trace elements (Fig. 4.5) show a wide scatter of points, some general trends are demonstrated. Rubidium and barium follow the trend of potassium as predicted from their geochemical similarities (Taylor, 1965) with rubidium following potassium more closely than barium, since divalent ions are favoured in early-formed potassium minerals. The wide scatter of rubidium and barium is similar to that of potassium, and presumably reflect the same processes.

Strontium shows a positive correlation with calcium for which it commonly substitutes in the plagioclases. Zirconium cannot fit easily into common silicate structures and forms zircon, a stable mineral of its own. Petrographic studies show that zircon is present as an accessory mineral in both mafic and acidic phases, occurring mainly as inclusions in hornblende and biotite.

Chromium and nickel become depleted early during the differentiation sequence and closely follow the trend of magnesia. Although chromium substitutes for magnesium and iron in pyroxenes, it also forms

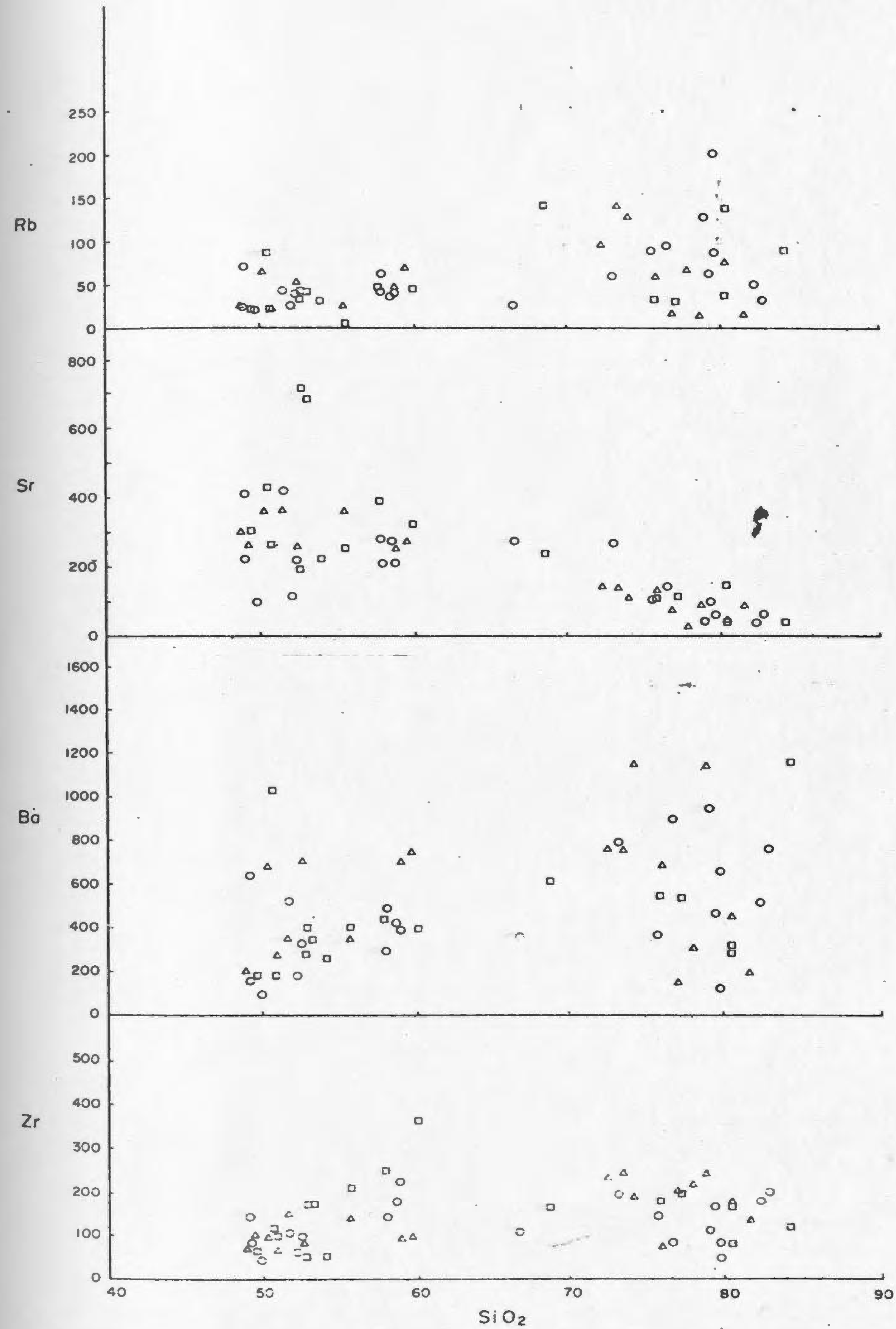


Figure 4.5 Trace elements (ppm) vs. SiO_2 (wt. %) variation diagrams for the Hermitage - Connaigre Bay Assemblage. Symbols as for Figure 4.3.

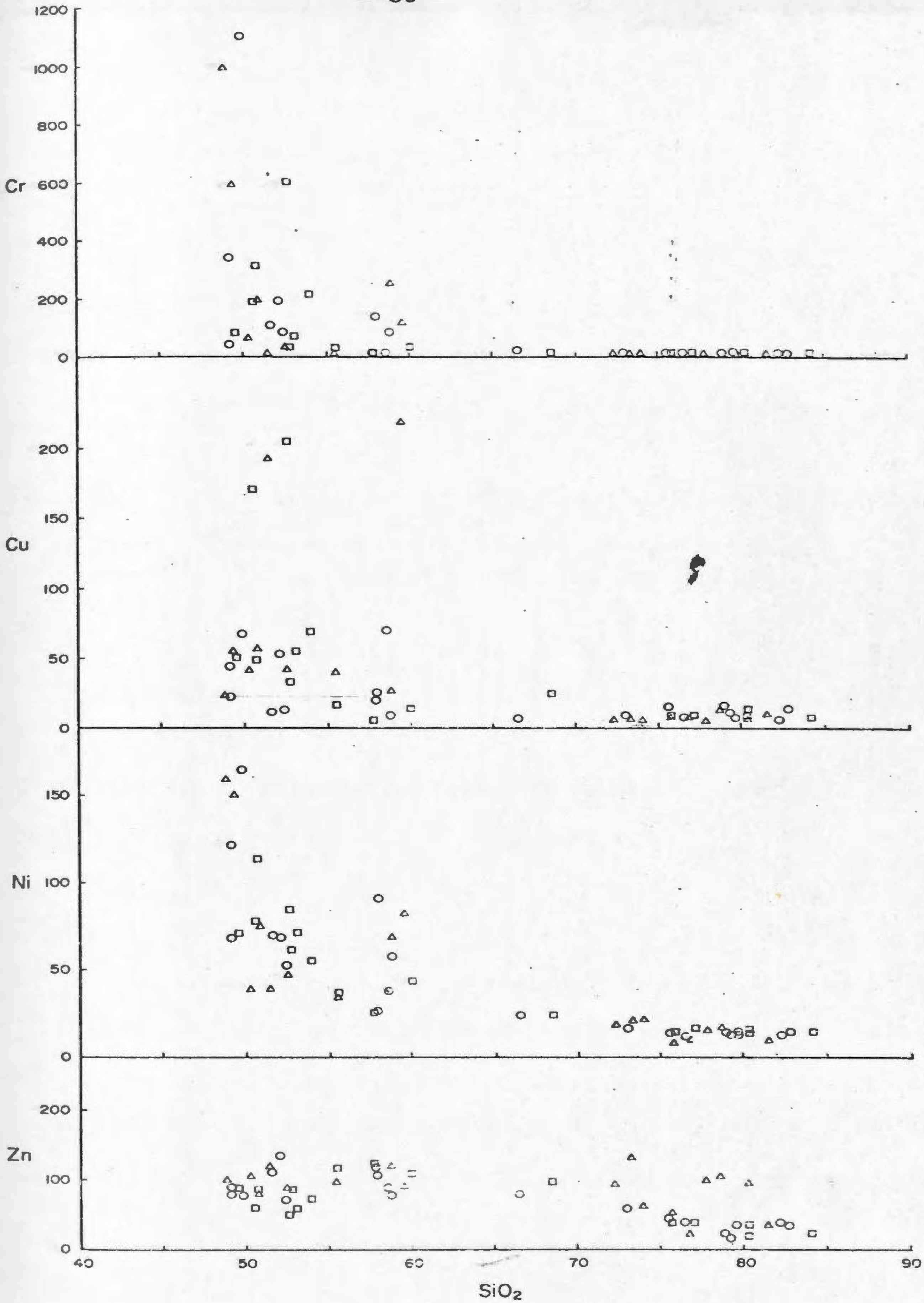


Figure 4.5 (contd.)

the stable mineral chromite. Petrographic studies did not include identification of opaque minerals so it is not known if chromite is present.

Copper is also enriched in mafic rocks, with anomalous values in two samples of volcanic rocks and in two samples of intrusive rocks. Copper mineralization was noted in an area close to the sample locations of the volcanic rocks but none was noticed in the intrusive rocks. Disseminated pyrite, however, is common in mafic rocks, and possibly contains some copper as a trace element. Zinc substitutes for iron (Taylor, 1965) and decreases as differentiation proceeds.

4.2.2 Classification

In an attempt to classify the volcanic and intrusive rocks of the Hermitage - Connaigre Bay Assemblage, diagrams commonly used in the current literature are used. It has been seen in Figure 4.2 that the assemblage is strongly bimodal and in Figures 4.3 and 4.5 that intrusive and extrusive rocks of the assemblage are of comparable chemical composition.

Total alkalis vs. silica diagrams have been used by MacDonald (1968), MacDonald and Katsura (1964), Kuno (1968) and others as a means of distinguishing alkalic from tholeiitic rocks. This diagram was tested further by Irvine and Baragar (1971) who redefined the curve separating alkaline and subalkaline compositions. A plot of alkalis vs. silica (Fig. 4.6) shows that the rocks of the Hermitage - Connaigre Bay Assemblage fall within the subalkaline field of Irvine and Baragar (1971).

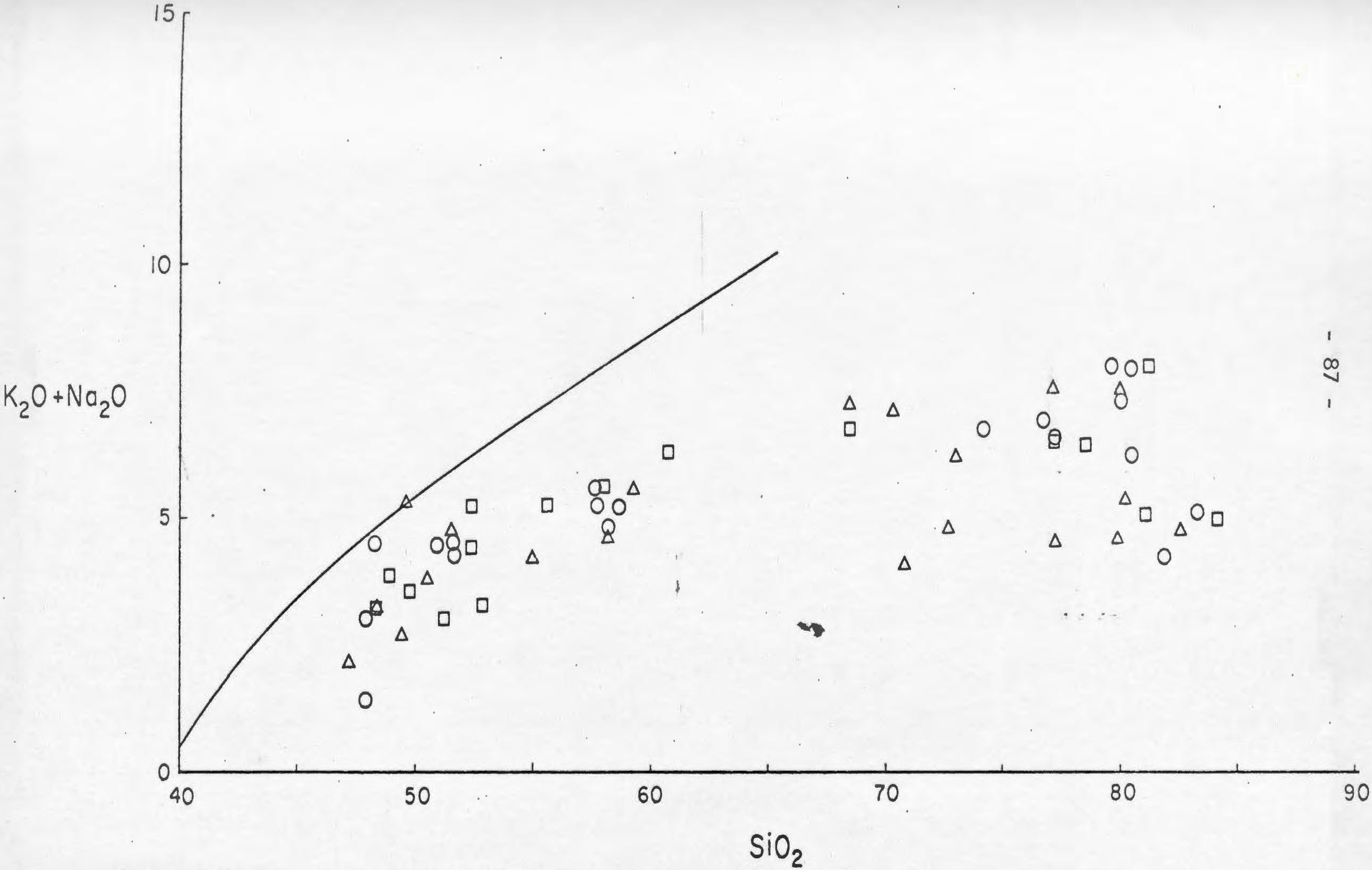


Figure 4.6 Total alkalis (wt. %) vs. SiO_2 (wt. %) for the Hermitage - Connaigre Bay Assemblage. Symbols as for Figure 4.3. Line after Irvine and Baragar (1971) separating alkaline field (above) and subalkaline field (below).

An AFM plot (Fig. 4.7), introduced by Wager and Deer (1939) to demonstrate the extreme iron enrichment of the Skaergaard intrusion, is commonly used to distinguish between calc-alkaline and tholeiitic rocks. Figure 4.7 reveals that the plotted analyses have a moderate degree of iron enrichment typical of alkaline and calc-alkaline rocks. A comparison with calc-alkaline suites given by Irvine and Baragar (1971) shows that the trend of the Hermitage - Connaigre Bay Assemblage is comparable to those of the Cascades and the Aleutians.

Peacock's (1931) alkali-lime index is given by the weight percentage of SiO_2 at which the weight percentages of CaO and total alkalis are equal. Four chemical classes of igneous rocks were distinguished by Peacock on the basis of this index. These are indicated in Figure 4.8 which shows the "Peacock Index" for the assemblage to be within the calc-alkalic field.

On the basis of these diagrams it appears that the Hermitage - Connaigre Bay Assemblage can be classified as a bimodal calc-alkaline suite.

4.2.3 Petrogenesis

The presence of very coarse agglomerates and related pyroclastic deposits, indicating a closeness of vents; small circular magnetic highs in extrusive and intrusives, indicating feeder "roots"; numerous felsic and mafic dykes and petrographic similarities between units; indicate that the Hermitage Complex acted as the source for the volcanic material in the Connaigre Bay Group. This indication from field, magnetic, and petrographic evidence is supported by the chemical similarities discussed in the previous section.

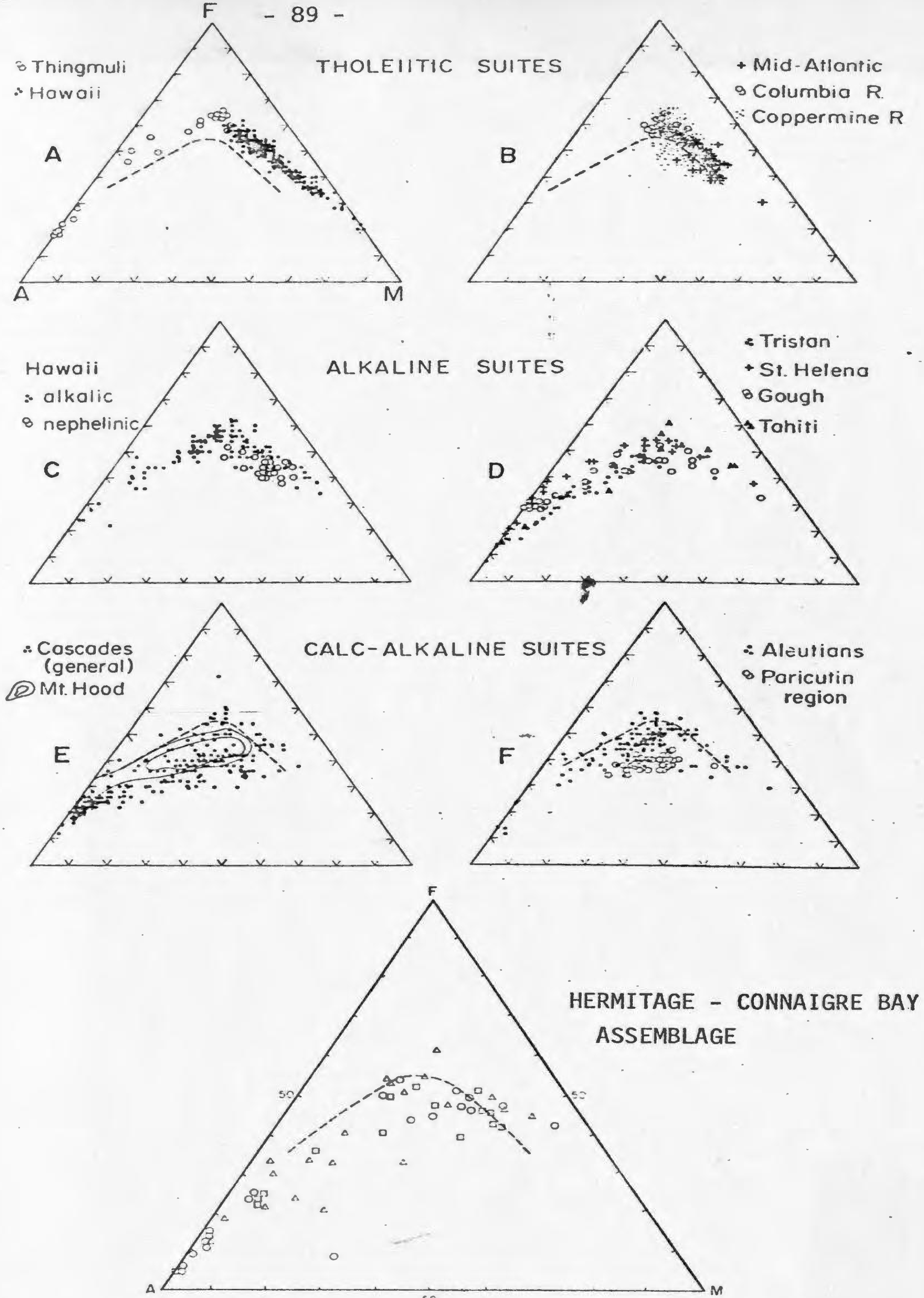


Figure 4.7 $A(Na_2O + K_2O)$: F(total iron as FeO): M(MgO) diagram for the Hermitage - Connaigre Bay Assemblage compared to suites given by Irvine and Baragar (1971). Symbols as for Figure 4.3.

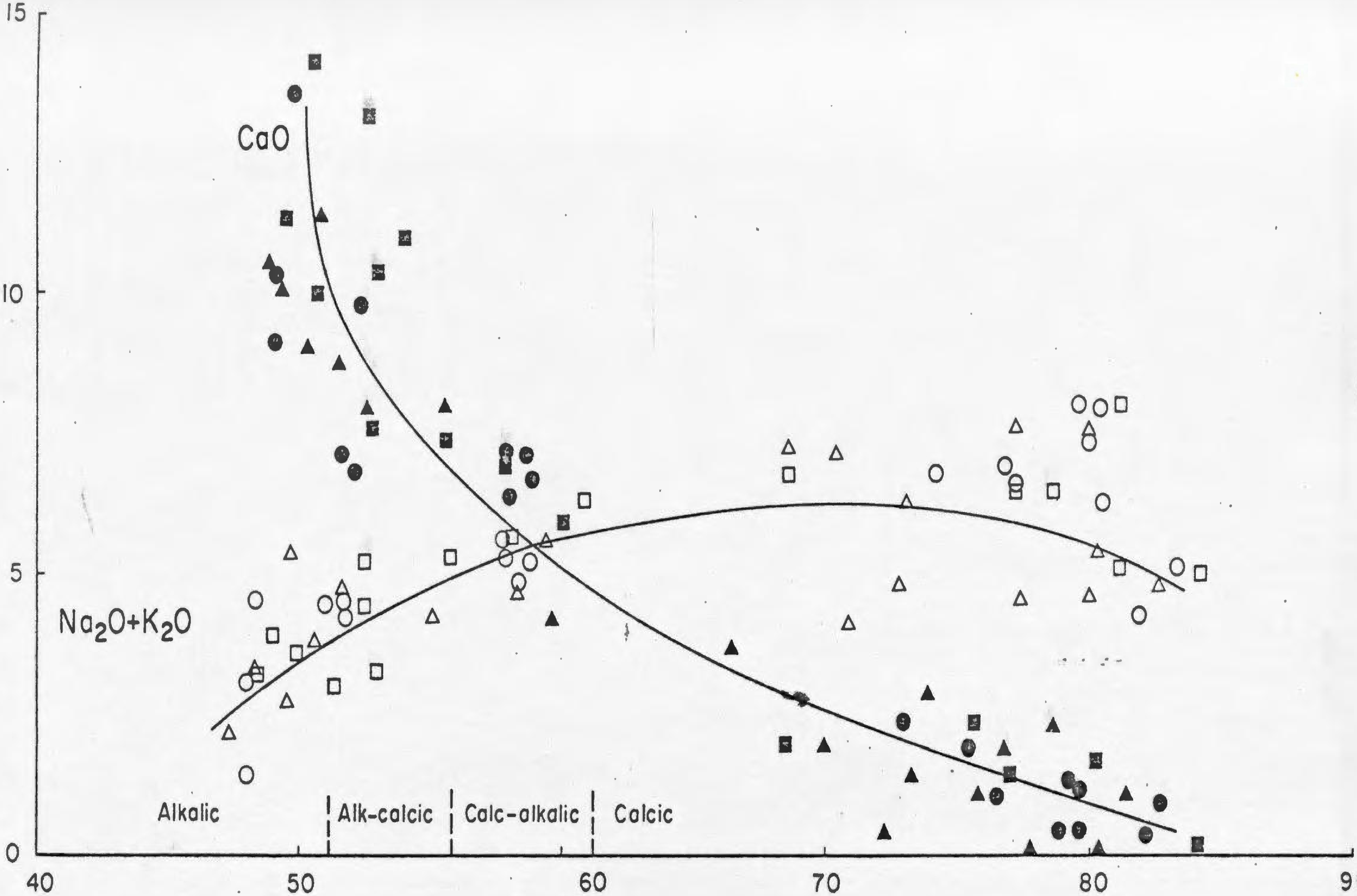


Figure 4.8 Peacock (1931) diagram for the Hermitage - Connaigre Bay Assemblage. Symbols as for Figure 4.3.

Martin and Piwinskii (1972) demonstrated that bimodal suites are characteristic of non-orogenic magmatism. However their tested bimodal suites consisted predominantly of tholeiitic or alkalic rocks which are not present in the Hermitage - Connaigre Bay Assemblage. Yoder (1973) advanced a tentative hypothesis to explain how liquids of contrasting composition, which are necessary to produce contemporaneous rhyolitic and basaltic magmas, originate. These liquids may be generated from the same parental material by fractional melting. He attributes the "Daly gap" (Daly, 1925) to the fractional melting process without regard to the time interval between contrasting magmas.

In the western United States early Cenozoic volcanism consisted largely of calc-alkaline igneous suites that became more alkalic toward the continental interior (Christiansen et al., 1972; Lipman et al., 1972). Lithological associations locally deviate significantly from the general intermediate compositional character in conjunction with lateral variations in alkali content. Bimodal calc-alkaline fields are reported as part of a compositional spectrum that regionally is predominantly intermediate in composition. This volcanism is transitional between orogenic (Cascades) and nonorogenic (Basin and Range) environments.

The Connaigre Bay Group has been correlated with the Long Harbour Group to the east (Widmer, 1950) which has been correlated with the Bull Arm Formation (Williams, 1971) one of the lower formations in the Musgravetown Group. A comparison of the chemistry of these rocks of apparently equivalent ages shows a progressive change in composition from calc-alkalic near the margin of the Avalon zone to more alkalic eastwards

(Strong, 1976). These changes are similar to those which take place across subduction zones in the rocks of island and continental margin arcs.

K/Rb ratios for the Hermitage -Connaigre Bay Assemblage are plotted in Figure 4.9. They range from approximately 150 to 400 with a majority around 230. Calc-alkaline rocks of island arcs generally have higher ratios than those plotted in Figure 4.9 with mean values between 400 and 500 (Jakeš and White, 1970). However, in Andean-type volcanic rocks K/Rb ratios are generally lower with mean values around 230 (Jakeš and White, 1972). This is similar to average values for the Hermitage - Connaigre Bay Assemblage.

As with many intrusive and extrusive calc-alkaline suites, the Hermitage -Connaigre Bay Assemblage shows a continuous trend from diopside-normative mafic magma to corundum-normative acidic magma (Fig. 4.10). A number of models have been proposed for the production of corundum-normative magmas. These are summarized by Cawthorn and Brown (1976c) and Cawthorn et al. (1976b) and include: (1) Secondary alteration (Heming and Carmichael, 1973); (2) vapour phase transfer (Luth et al., 1964); (3) assimilation (Ewart and Stipp, 1968); (4) crustal remelting (Presnall and Bateman, 1973); (5) partial melting of hydrous peridotite (Kushiro and Yoder, 1972), and (6) fractional crystallization (Osborn, 1959; Kuno, 1968; Green and Ringwood, 1968; Kushiro and Yoder, 1972; Cawthorn and O'Hara, 1976a). While most of these models can be used to explain the production of corundum-normative magmas, they are of limited applicability and cannot be accepted as a general mechanism.

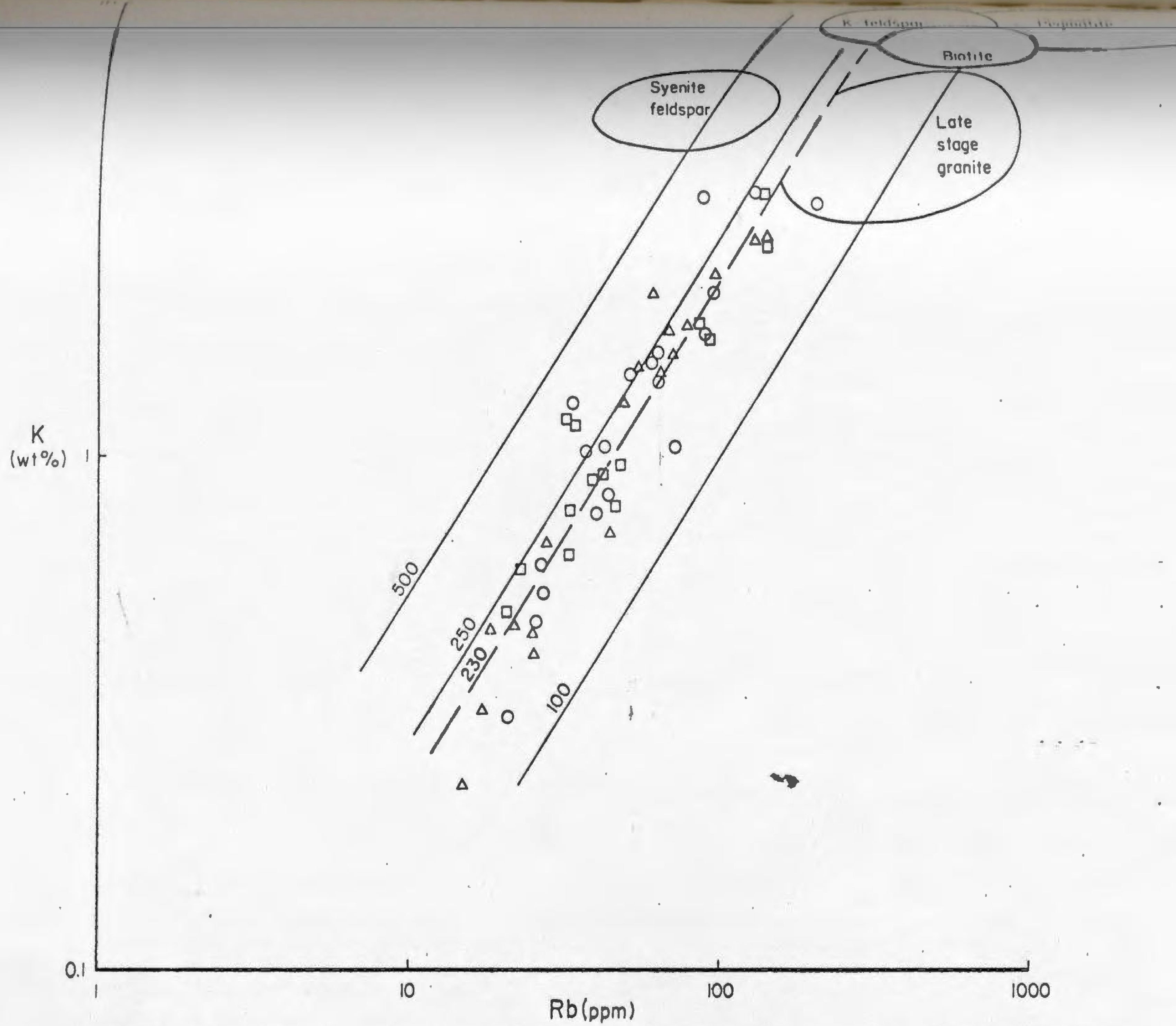


Figure 4.9 K vs. Rb variation diagram for the Hermitage - Connaigre Bay Assemblage compared to other materials outlined by Taylor (1965). Symbols as for Figure 4.3.

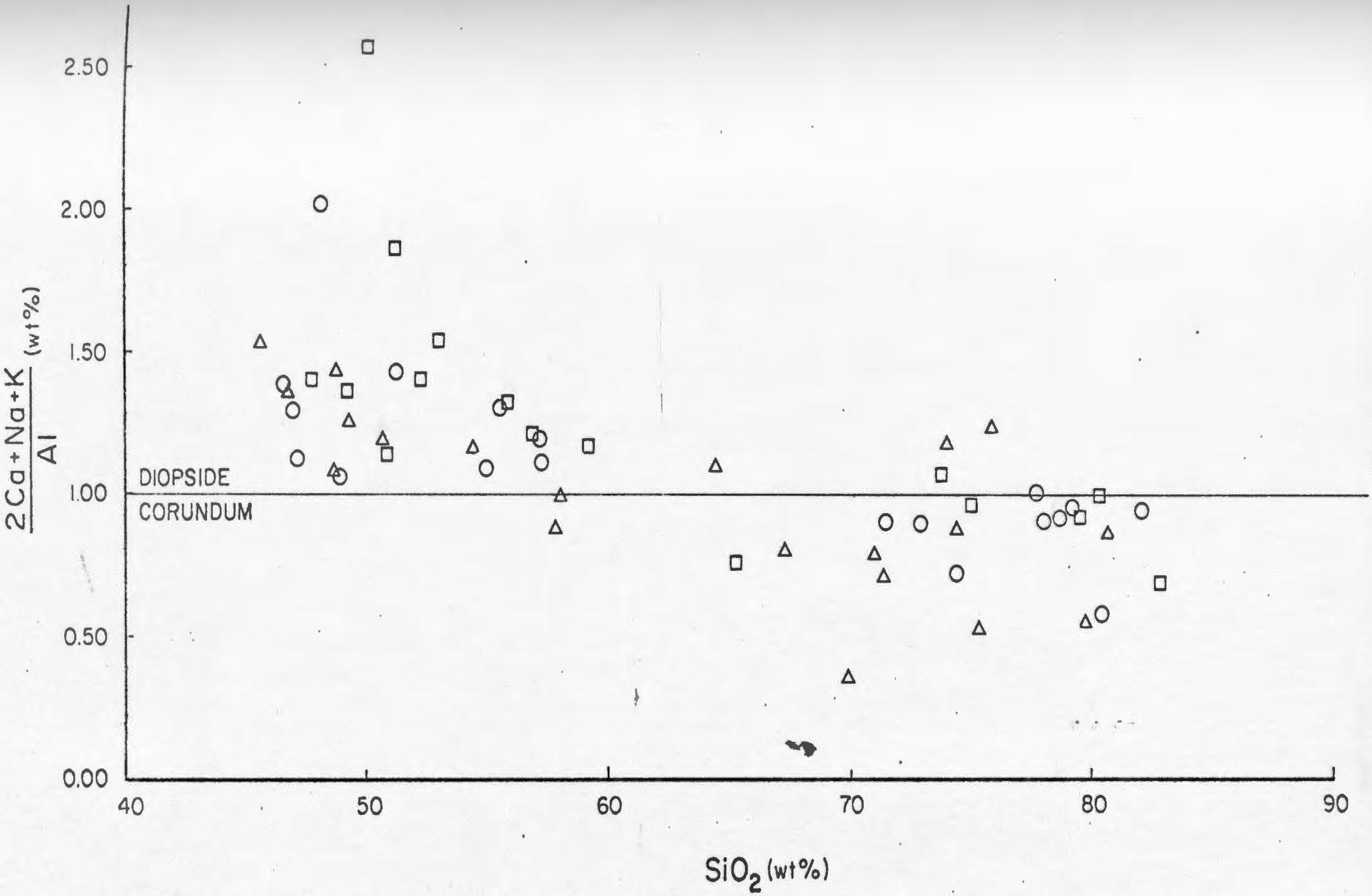


Figure 4.10 Plot of (2Ca + Na + K)/Al against SiO_2 (P_2O_5 and CO_2 removed as apatite and calcite prior to calculation of ratio) for the Hermitage - Connaigre Bay Assemblage. Symbols as for Figure 4.3.

The most favourable mechanism for producing a calc-alkaline trend to high-silica, corundum-normative liquids appears to be fractional crystallization of amphibole as has been suggested by Cawthorn and O'Hara (1976a) and supported by more evidence of Cawthorn et al. (1976b, 1976c).

Petrographic and field evidence indicate abundant amphibole in the Hermitage Complex. In the most mafic phases, hornblende forms up to 70 per cent of the total rock (see section 2.3.1.2). Because of this abundance of hornblende in rocks interpreted to be the source of corundum-normative, garnet-bearing volcanic rocks, they have been examined in terms of the work of Cawthorn et al. (1976a, 1976b, 1976c).

Figure 4.11 is a phase diagram with mineral compositions in the system (2 Ca + Na + K) - Al - (Fe^{3+} + Fe^{2+} + Mn + Mg). According to Cawthorn and Brown (1976c), corundum-normative liquids may crystallize biotite or amphibole, depending on the Na/(Na + K) ratio of the liquid. They suggest that the difference between the phase diagrams in Figures 4.11a and 4.11b is due primarily to the ratio Na/(Na + K). Compositions with a high ratio (>0.6) will tend to show a large primary phase field of amphibole and produce phase relationships akin to Figure 4.11a. For those with a lower ratio the stability field of mica will expand to produce Figure 4.11b. The crystallization of calc-alkaline magmas may be controlled by phases similar to those in Figure 4.11a. Figure 4.12 is the one presented by Cawthorn and Brown (1976c) to explain the occurrence of garnet in granitic compositions. With increasing pressure, partial water pressure, or decreasing oxygen fugacity, a garnet stability field is developed in the end-stages of

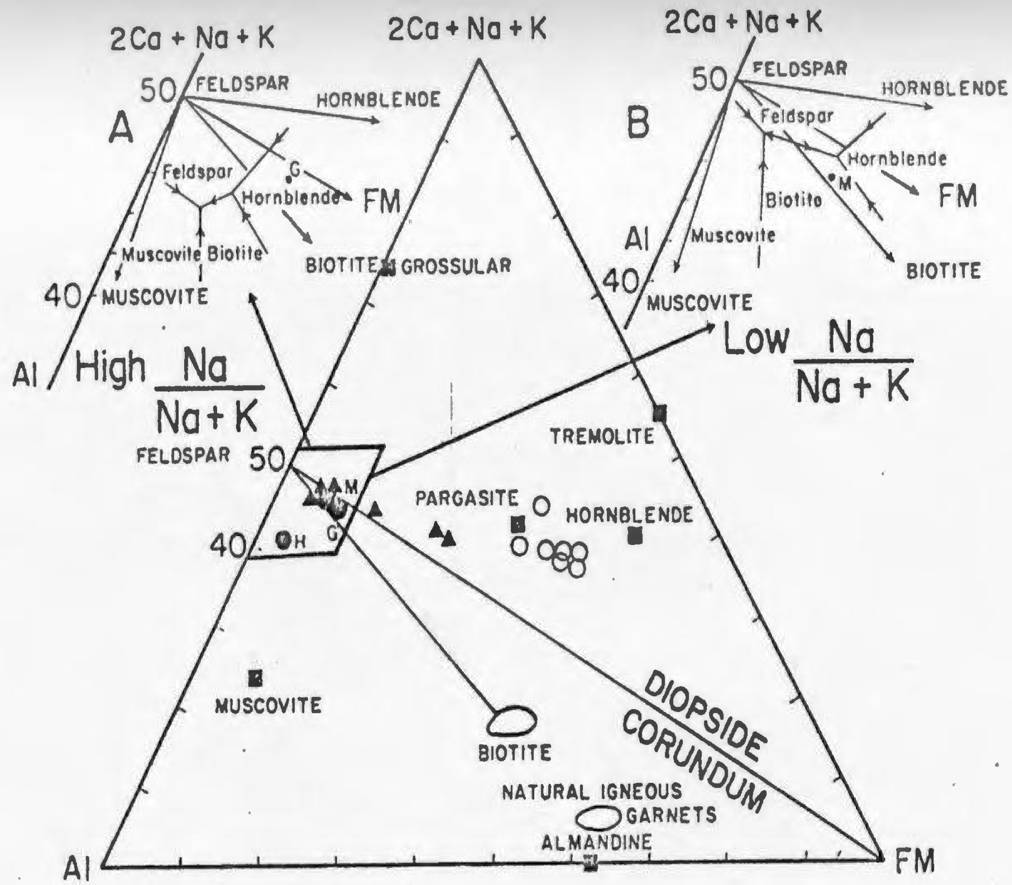


Figure 4.11 Hypothetical phase diagram and mineral compositions in the system (2Ca + Na + K) - Al - (Fe^{3+} + Fe^{2+} + Mn + Mg) in cation proportions projected from Si (after Cawthorn and Brown, 1976c). Open circles - synthetic amphibole compositions; triangles - analyses from Baker (1968) for St. Kitts volcanics. Hornblende from Dodge et al. (1968, BCC-12); muscovite from Best et al. (1974); range of natural biotites and garnets in granites shown schematically. G and M - granodiorite and monzonite from Piwinskii and Wyllie (1970); H - muscovite granite from Huang and Wyllie (1973). Mineral compositions in capital letters, mineral phase fields in small letters. Inset A-phase relationships for part of the system with high Na/(Na + K) ratio, B-phase relationships with low Na/(Na + K) ratio.

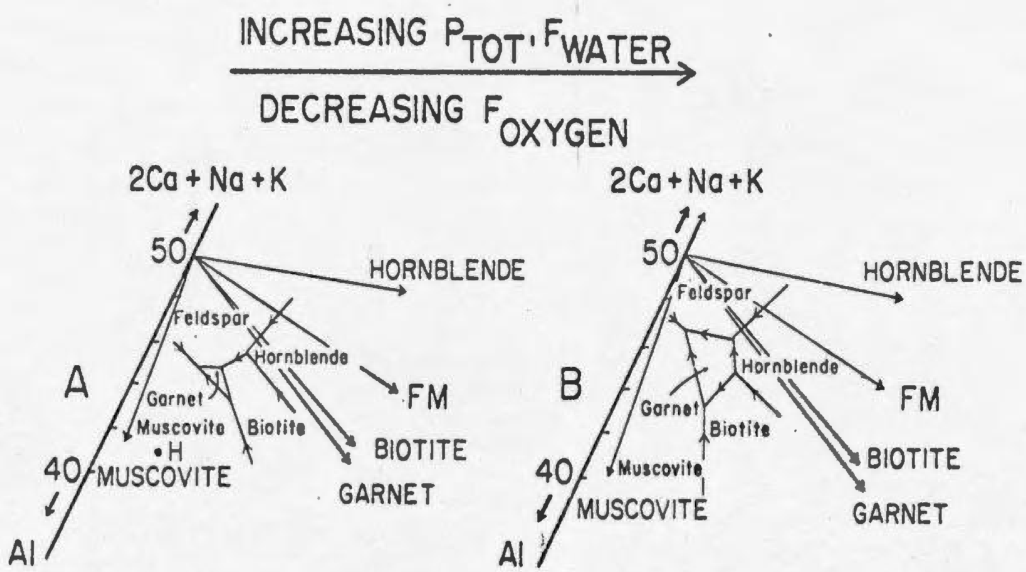


Figure 4.12 Hypothetical phase relationships in part of the system (2Ca + Na + K) - Al - (Fe^{3+} + Fe^{2+} + Mn + Mg) projected from Si, under slightly different conditions from Figure 4.11.

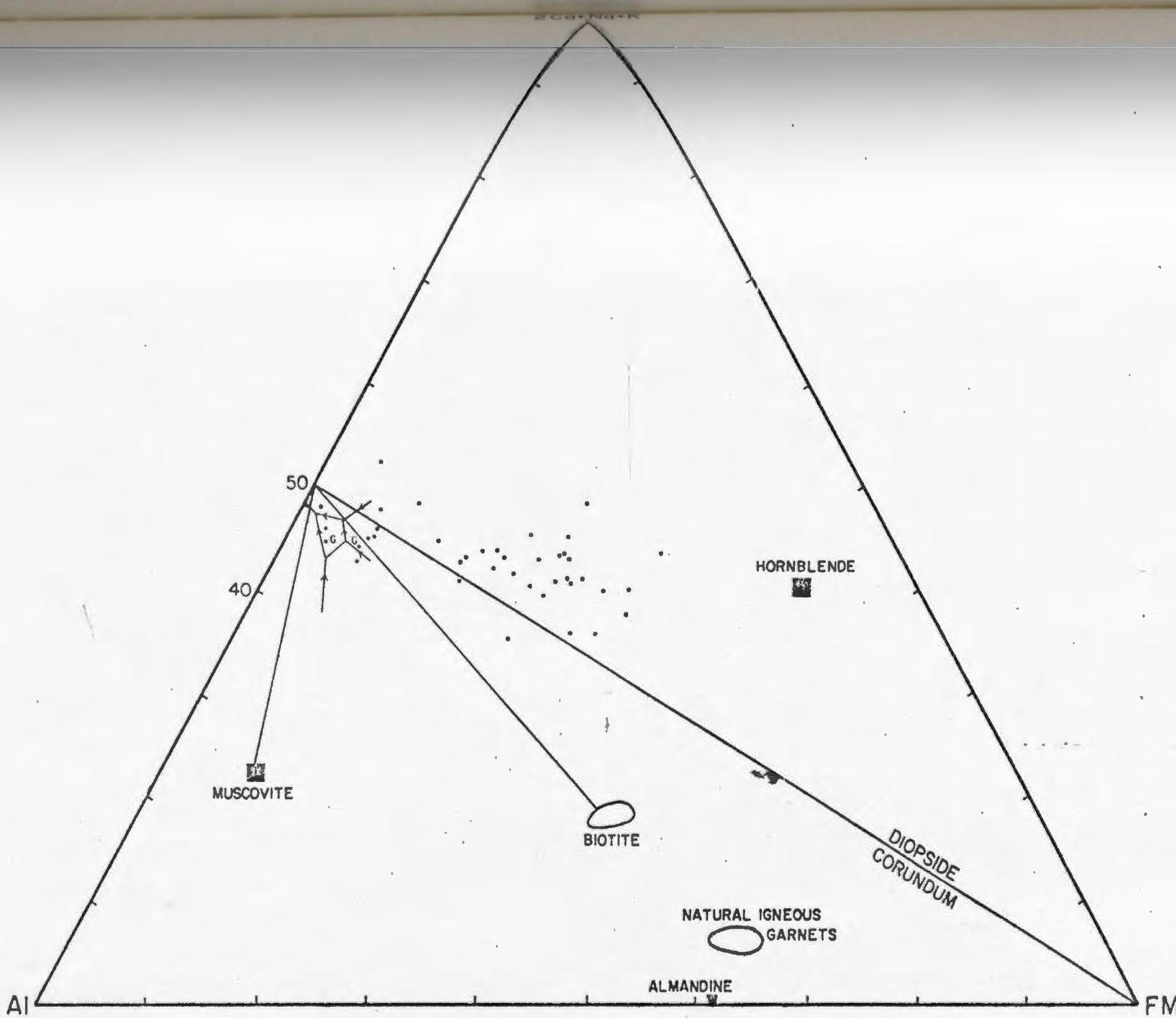


Figure 4.13 Plot of Hermitage - Connaigre Bay Assemblage compositions in the system $(2Ca + Na + K) - Al - (Fe^{3+} + Fe^{2+} + Mn + Mg)$ in cation proportions projected from Si.

crystallization and garnet precipitates together with muscovite, feldspars, and quartz.

Compositions of rocks of the Hermitage - Connaigre Bay Assemblage are plotted in the Cawthorn and Brown (1976) phase diagram in Figure 4.13. Only those compositions with Na/Na + K greater than 0.70 are plotted. It can be seen that the samples plot on a trend projecting away from hornblende, suggesting hornblende fractionation. Two samples contain garnet in the groundmass and are marked "G". One plots within the garnet stability field suggested by Cawthorn and Brown (1976) while the other plots just outside it. This suggests that conditions existing during the crystallization of the Hermitage - Connaigre Bay Assemblage were such that the garnet stability field was slightly larger than that presented by Cawthorn and Brown (1976). Since the size of the garnet field increases with increasing pressure, it is assumed that the rocks crystallized at moderately high pressure.

4.3 Pass Island Granite

Fifteen rock samples of the Pass Island Granite were analyzed for major and trace elements and are presented in Table 5 (Appendix 2). Examination of the results shows that the silica content of the rocks fall within the range 65-80 per cent.

4.3.1 Variation Diagrams

The various major element oxides and trace elements are plotted against silica and are presented in Figures 4.14 and 4.15. The constant sum effects of the increase in silica were discussed in section 4.2.1

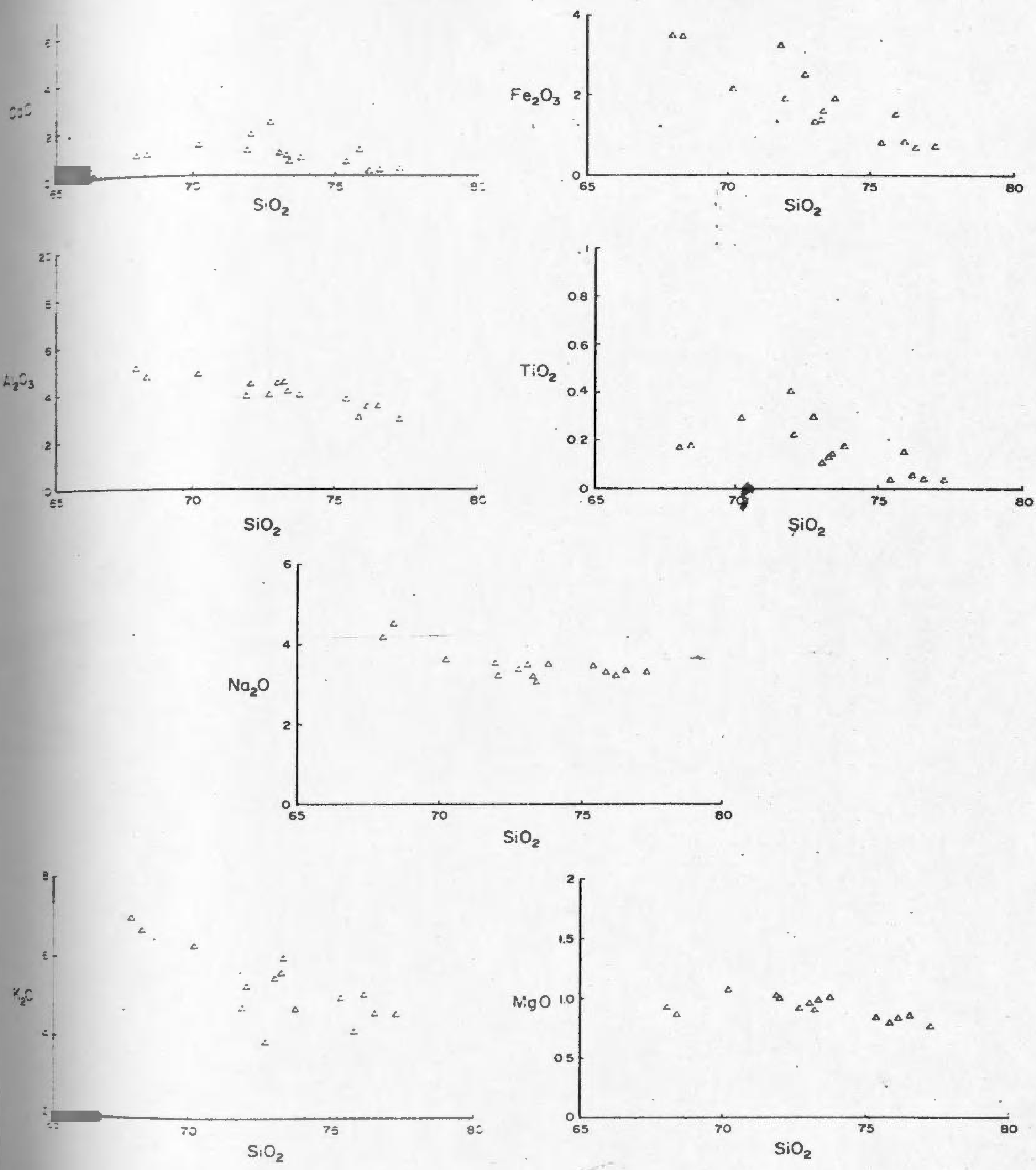


Figure 4.14 Major element oxides (wt. %) vs. SiO_2 (wt. %) variation diagrams for the Pass Island Granite.

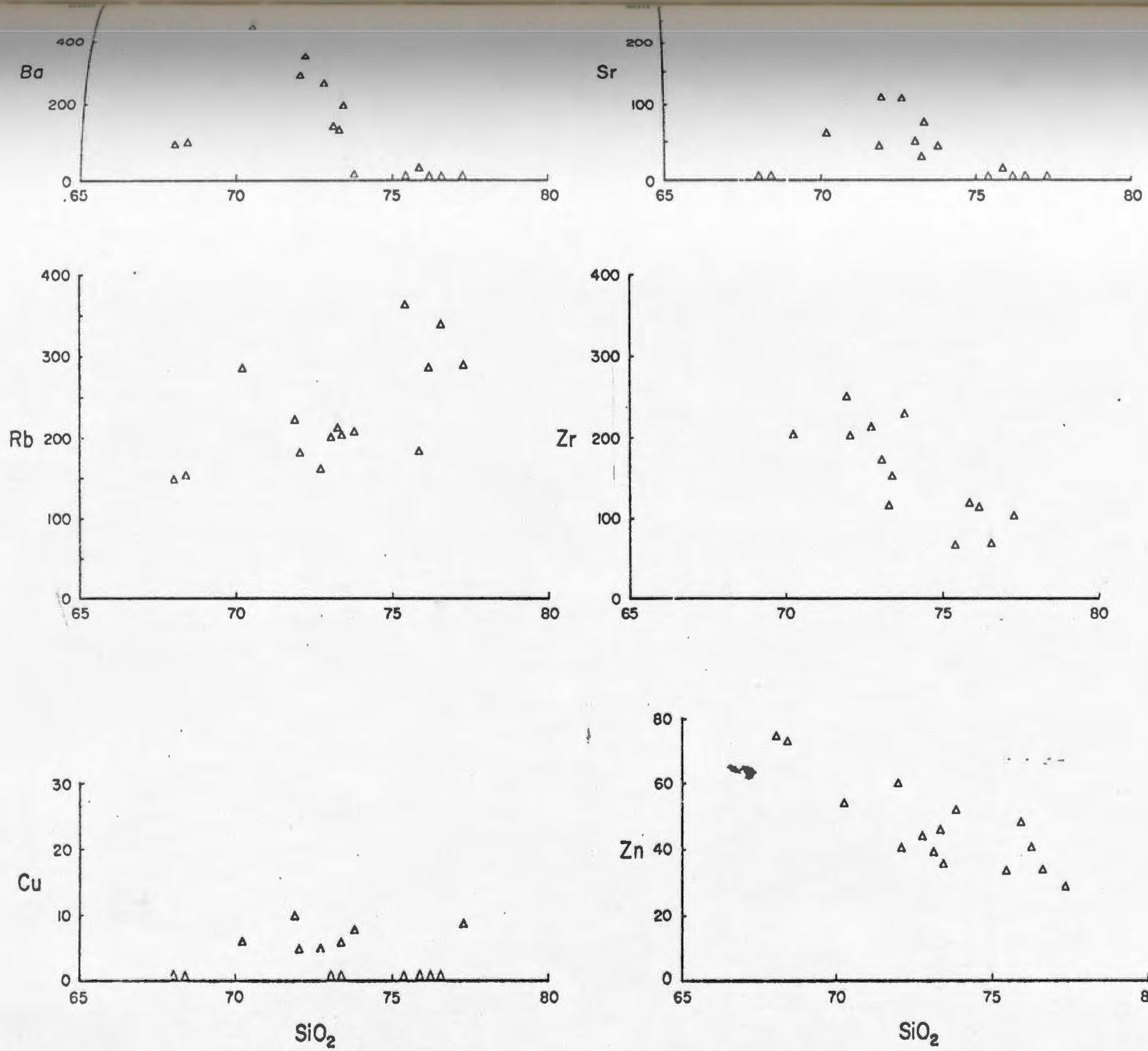


Figure 4.15 Trace elements (ppm) vs. SiO_2 (wt. %) variation diagrams for the Pass Island Granite.

and will not be repeated here.

The variation diagrams for the major oxides show relatively smooth trends with CaO, TiO_2, Fe_2O_3, MgO, Na_2O and Al_2O_3 having negative correlations with silica. K_2O shows more scatter than the other oxides but still shows a poor negative correlation. The scatter is possibly due to autometasomatism during the late stages of crystallization resulting in a redistribution of K_2O. The trends of the major oxides are consistent with trends expected from a differentiating magma.

Trace elements generally show a wide scatter, but some trends are demonstrated. Barium shows a negative correlation with silica as expected since it follows potassium (Taylor, 1965). However, rubidium, which is also predicted to follow potassium (Taylor, 1965) actually has a negative correlation with it and increases rapidly with increasing silica. This is possibly due to the tendency for rubidium to be favoured in late-forming potassium minerals (Krauskopf, 1967) resulting in a concentration in late fractions.

Zirconium decreases rapidly across the diagram, indicating an early crystallization of zircon. Petrographic studies show abundant zircon concentrated in the mafic minerals. Strontium and zinc decrease with differentiation and show a negative correlation with silica; copper shows a positive correlation with silica.

4.3.2 Classification

The Pass Island Granite is classified using the geochemical classification of Strong et al. (1974) (Fig. 4.16). The classification is based on molecular proportions of the CIPW normative quartz:

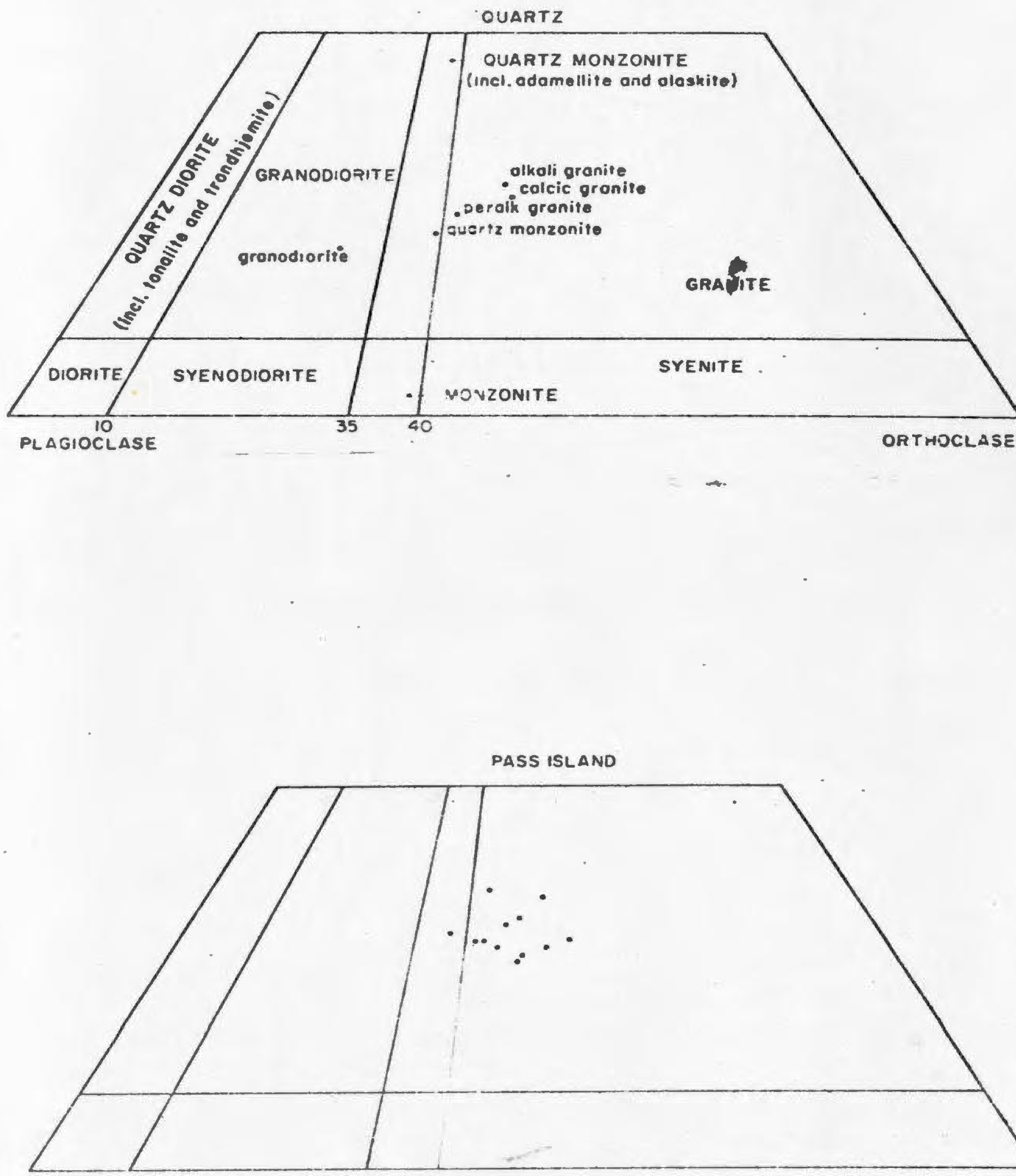


Figure 4.16 Classification of rocks from the Pass Island Granite by molecular proportions of CIPW normative quartz: plagioclase (Ab + An): orthoclase, based on Nockold's (1954) average compositions plotted in upper diagram (after Strong et al., 1974).

orthoclase: plagioclase (Ab + An) and boundaries were drawn with reference to the average rock compositions of Nockolds (1954). Modal classifications have been used by Streckeisen (1967), Hotz (1971) and the IUGS Subcommission (1973), but the modal mineralogy does not duplicate the normative mineralogy because of solid solution effects (Strong et al., 1974). Consequently with the normative classification the granitic field had to be expanded and the quartz monzonite field reduced relative to the modal classification.

The Pass Island Granite is classified as mainly granite with one composition falling in the quartz monzonite range.

4.3.3 K/Rb and Rb/Sr ratios

The plot of K versus Rb is shown in Figure 4.17, in comparison with the generalized geochemical relationships of potassium - rubidium in common crustal rocks (Taylor, 1965). The compositions show a trend toward the zone of rubidium enrichment in the field of late stage granites.

Rubidium - strontium ratios are plotted in Figure 4.18 and compared to Californian granitic rocks (after Kistler et al., 1971). The rocks plot on a trend toward Sr depletion and Rb enrichment and approximate a theoretical path for the composition of a differentiating liquid.

4.4 Intrusive Rocks of the Fortune - Hermitage Bay Area

Intrusions of the Fortune - Hermitage Bay area include those described within the map-area and the Simmons Brook, Harbour Breton

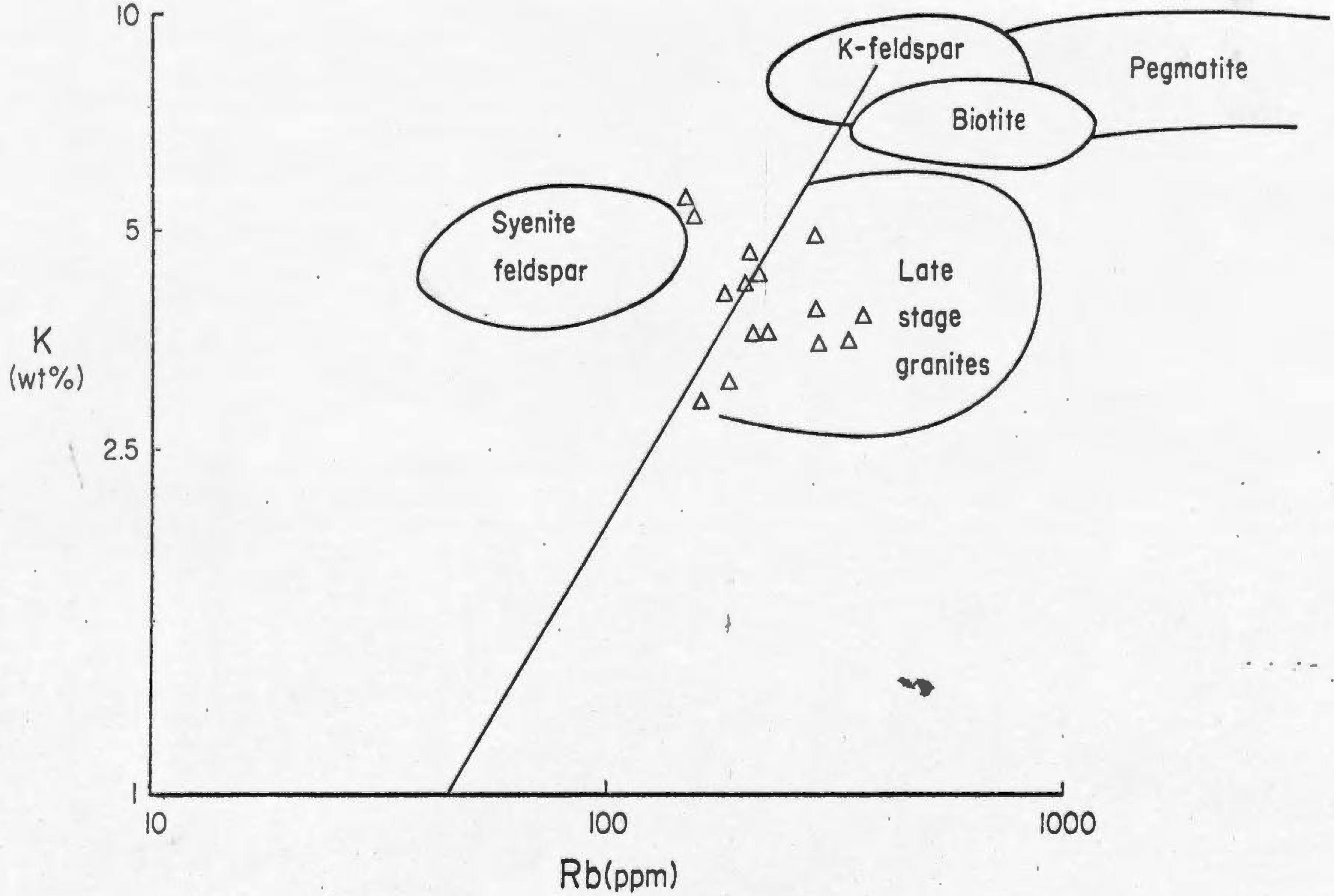


Figure 4.17 K vs. Rb variation diagram for the Pass Island Granite compared to other materials outlined by Taylor (1965).

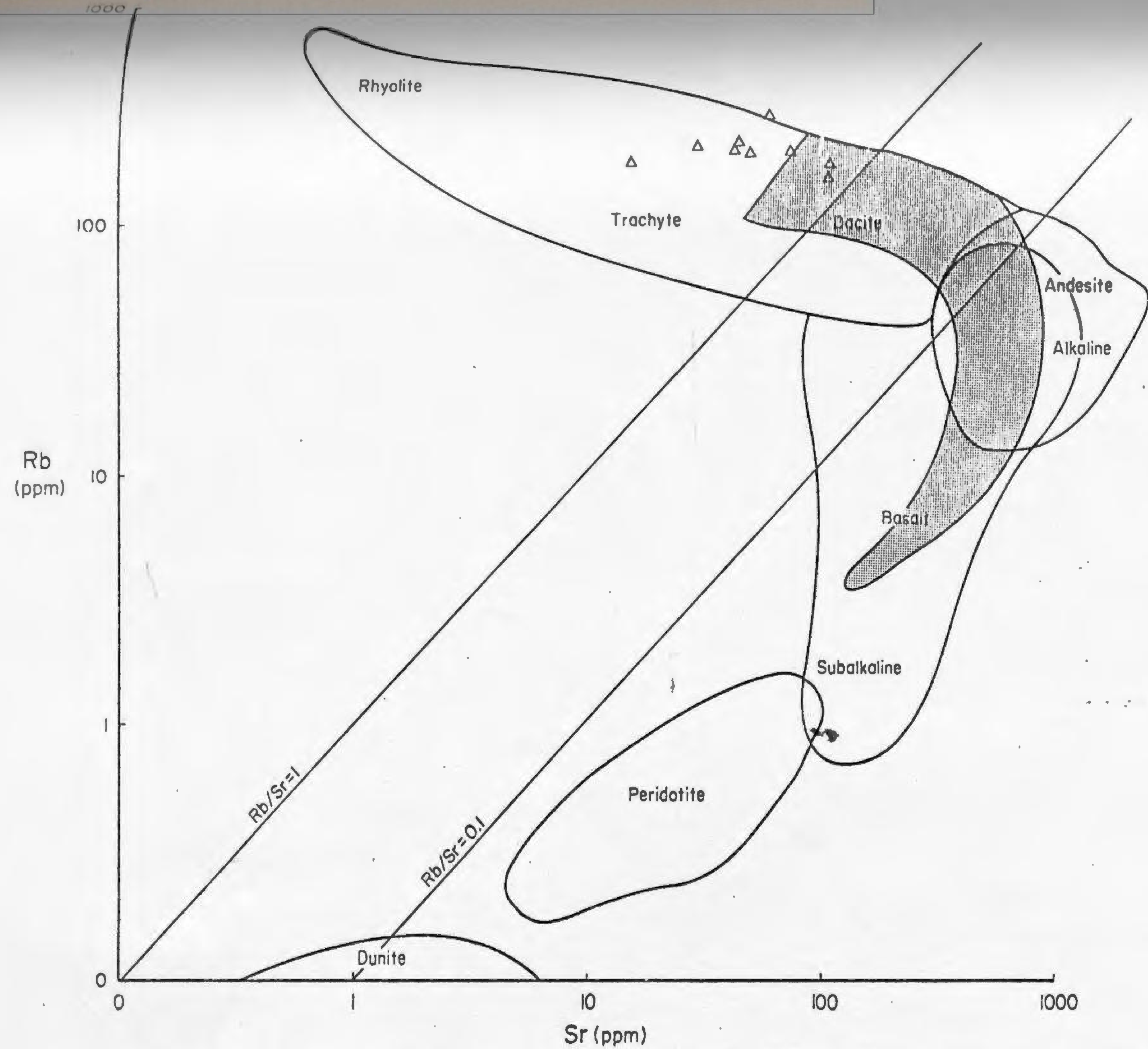


Figure 4.18 Rb vs. Sr variation diagram for the Pass Island Granite compared to that of the Sierra Nevada (shaded area) (after Kistler et al., 1971).

and Belleoram intrusions outside the map-area (Fig. 3.1). They can be subdivided into two groups based on geochronological (Bell and Blenkinsop, 1975; Blenkinsop et al., 1976) and stratigraphic (Williams, 1971; Greene and O'Driscoll, 1976) evidence. One group consists of the Hermitage - Connaigre Bay Assemblage and the Simmons Brook Batholith which are pre-Devonian in age, while the other group consists of the Pass Island, Harbour Breton and Belleoram intrusions and are Devonian and later in age. In this section an attempt is made to compare the geochemistry of these various plutons to investigate whether there is any apparent relationship among them.

Figures 4.19 and 4.20 are plots of some major oxides and trace elements against silica for all the plutons with trend lines of the Hermitage - Connaigre Bay Assemblage superimposed on them. Inspection of the diagrams shows that values for Al_2O_3, Na_2O and MgO are similar for all plutons. CaO is slightly higher in the Hermitage -Connaigre Bay Assemblage and Simmons Brook Batholith (Group I) than in the Pass Island, Belleoram and Harbour Breton plutons (Group II). TiO_2 is lower at low silica values and higher at high silica values for Group I than for Group II. K_2O also separates the two groups with values for Group I being much lower than those for Group II. Ba shows a wide scatter and there is no separation of plots for the two groups. Rb values generally follow potassium with Group I plotting much lower than Group II especially in late differentiates where Rb increases in Group II. Sr values are much higher for the Simmons Brook Batholith than any of the others except for two samples of the Hermitage Complex (see Fig. 4.5). Zr is generally similar for all intrusions except the Belleoram Pluton and

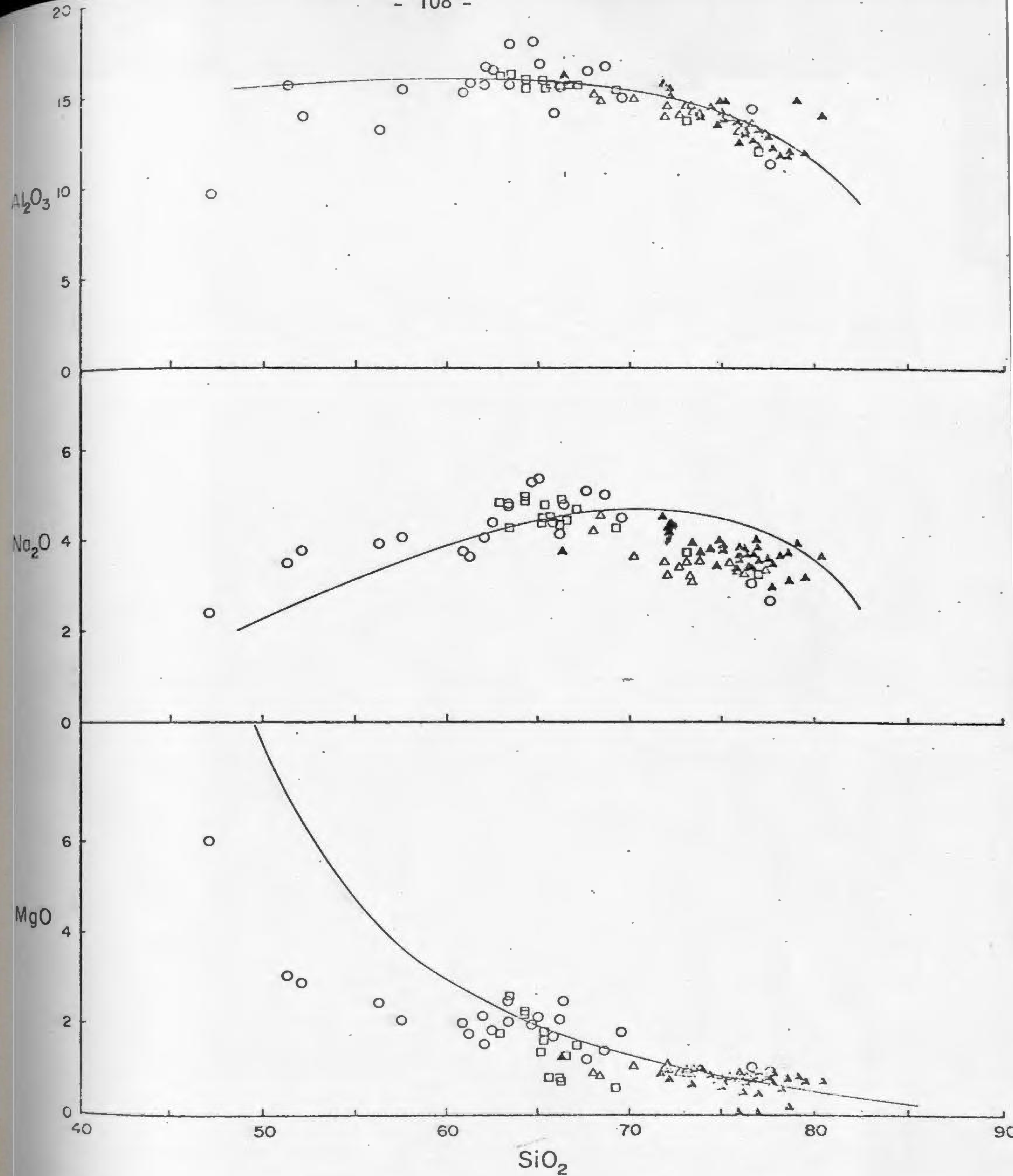


Figure 4.19 Major element oxides (wt. %) vs. SiO_2 (wt. %) variation diagrams for intrusive rocks of the Fortune - Hermitage Bay area. Δ = Pass Island Granite, ▲ = Harbour Breton Granite, □ = Belleoram Granite, o = Simmons Brook Batholith. Solid line is trend of Hermitage - Connaigre Bay Assemblage.

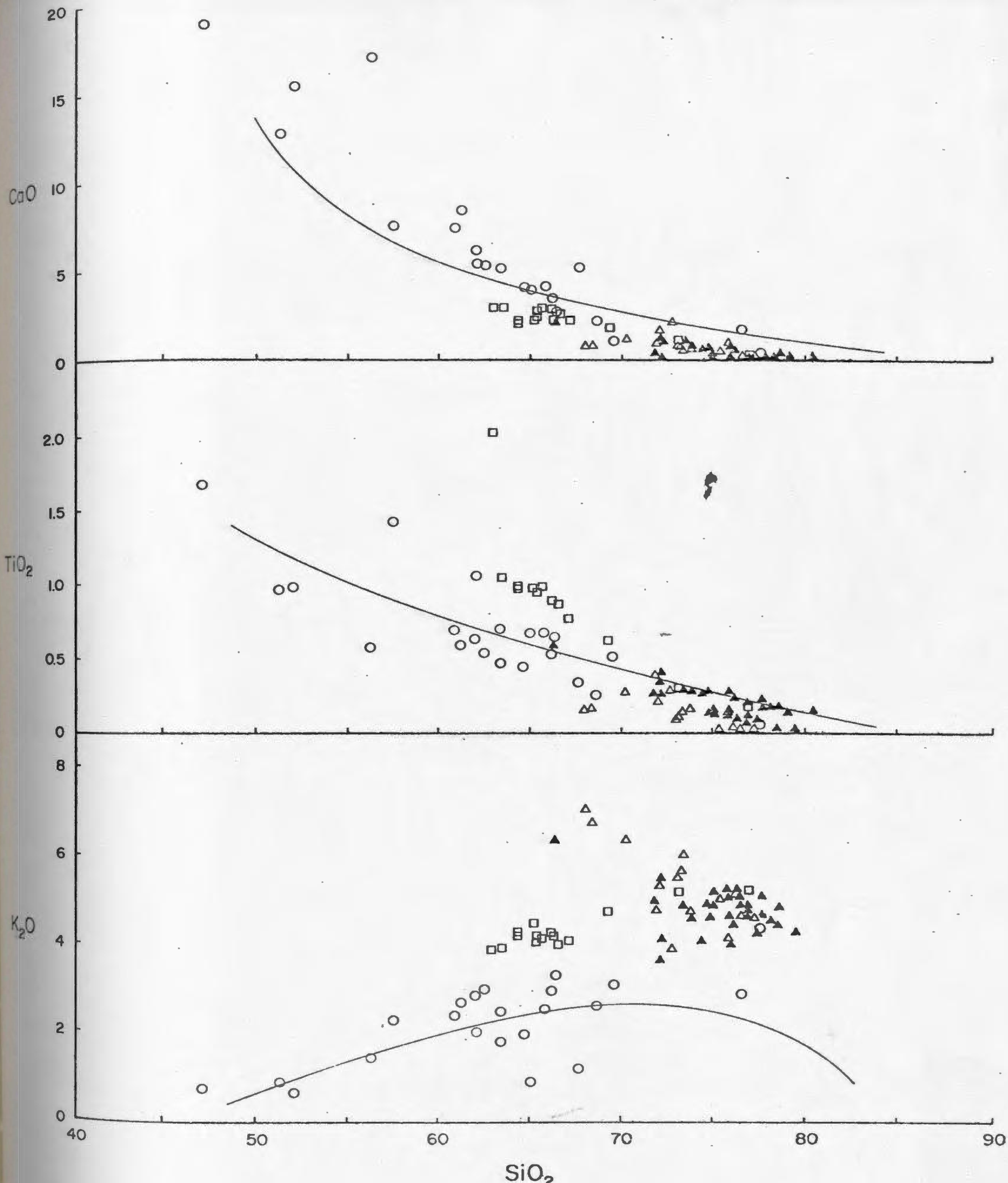


Figure 4.19 (contd.)

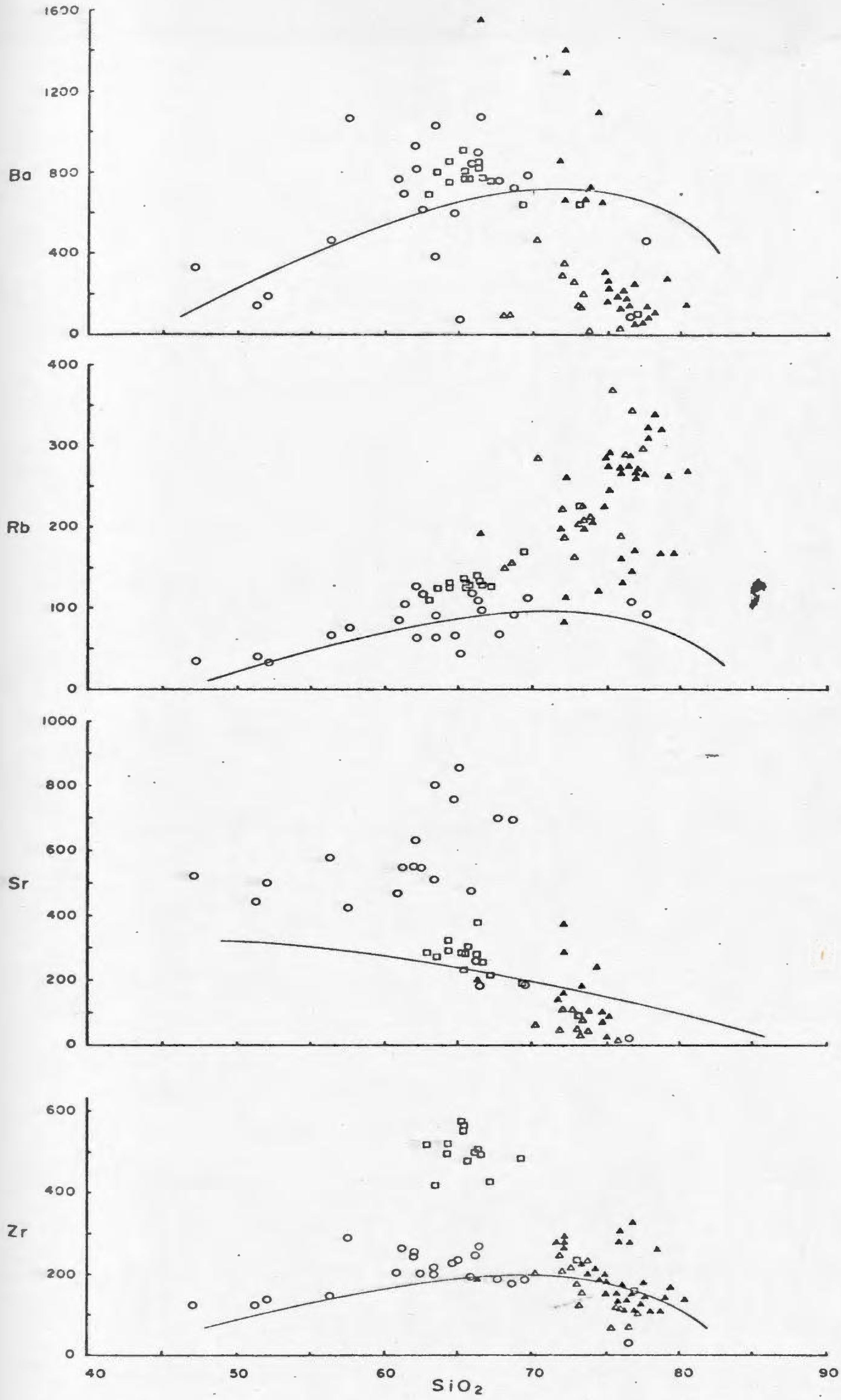


Figure 4.20 Trace elements (ppm) vs. SiO_2 (wt. %) variation diagrams for intrusive rocks of the Fortune - Hermitage Bay area. Symbols as for Figure 4.19.

two samples from the Pass Island Pluton which plot much higher than the others.

A plot of alkalis against silica (Fig. 4.21) clearly separates rocks of the two groups. Each group plots along different trends, each of which is fairly smooth. Group I contains much lower alkalis than Group II. Potassium - rubidium ratios of the plutons excluding the Hermitage - Connaigre Bay Assemblage are plotted in Figure 4.22 . Rocks of the Simmons Brook Batholith plot along a similar trend to that of the Hermitage - Connaigre Bay Assemblage (see Fig. 4.9) with an approximate average of 230. The Belleoram, Pass Island and Harbour Breton plutons show a trend toward rubidium enrichment in the field of late stage granites (from Taylor, 1965). The Belleoram rocks have an average ratio of 250 while those of Pass Island and Harbour Breton have an average of 150.

From the data presented above it can be concluded that the Hermitage - Connaigre Bay Assemblage and the Simmons Brook Batholith are geochemically similar. Since the geochronology and stratigraphy support a similar age for these rocks, then it is possible that they are genetically related. The Pass Island, Belleoram, and Harbour Breton Plutons are geochemically similar and differ from the Hermitage - Connaigre Bay - Simmons Brook compositions. The Pass Island and Harbour Breton Plutons have been correlated by lithological similarities (section 2.3.3) and the Belleoram and Harbour Breton Plutons are of a similar age (340 $\pm$ 20 million years for Harbour Breton (Bell, pers. comm., 1975) and 342 $\pm$ 20 million years for Belleoram (Wanless <u>et al.</u>, 1967). These relationships, along with the geochemical evidence, suggest that this group of plutons are also genetically related.

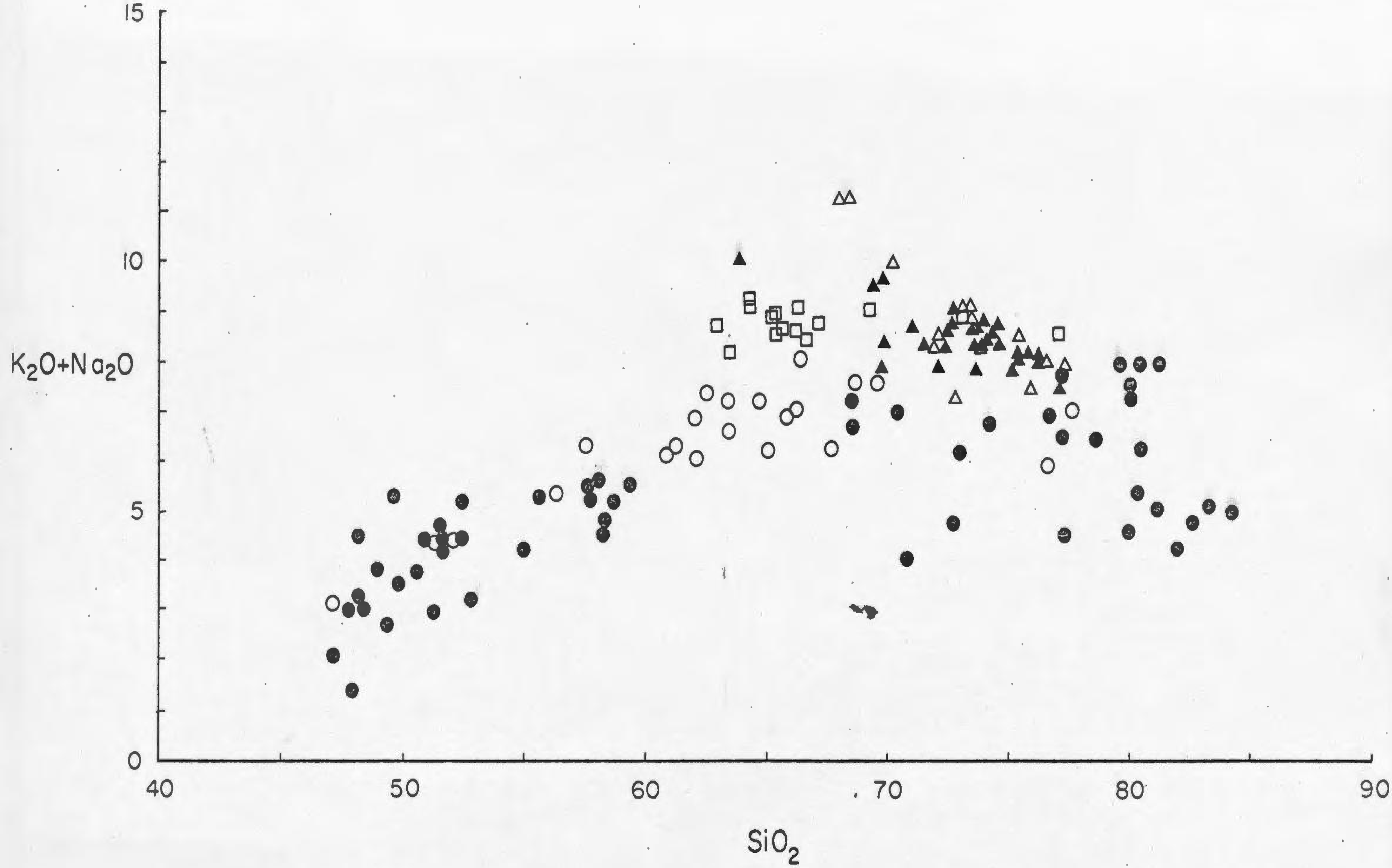


Figure 4.21 Total alkalis (wt. %) vs. SiO_2 (wt. %) for intrusive rocks of the Fortune - Hermitage Bay area. Symbols as for Figure 4.19 except ● = compositions of Hermitage - Connaigre Bay Assemblage.

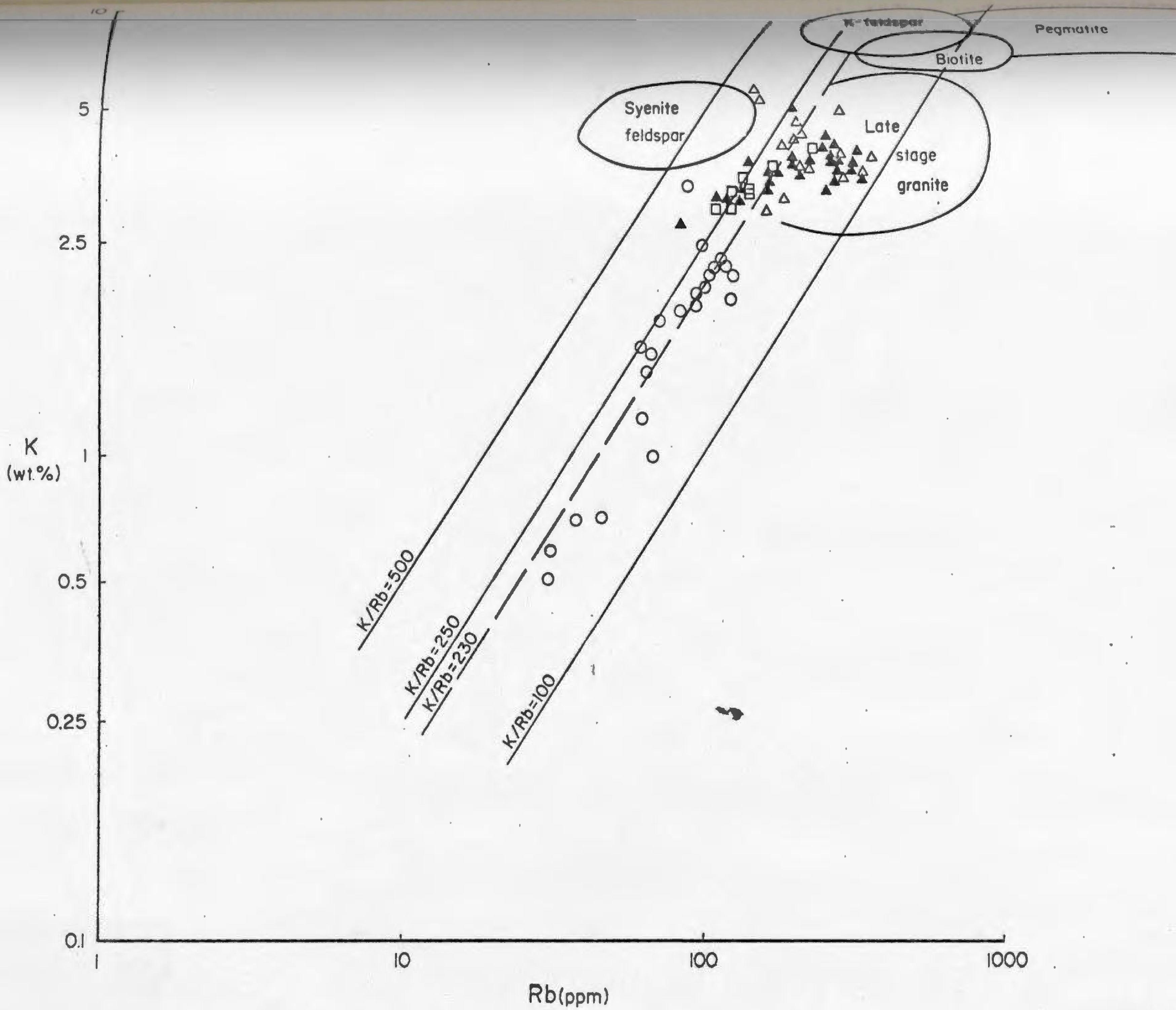


Figure 4.22 K vs. Rb variation diagram for intrusive rocks of the Fortune - Hermitage Bay area. Symbols as for Figure 4.19.

CHAPTER 5

ECONOMIC GEOLOGY

The map-area contains a number of minor mineral showings, most of which were discovered during the present study. One showing, which was investigated by NALCO in 1964-65 occurs at Frenchman's Head within the Tickle Point Formation where galena, sphalerite, chalcopyrite and pyrite occur as disseminations in rhyolite and andesite. This showing is close to the top of the formation where it is in contact with the sediments of the Great Island Formation.

Massive pyrite was found in a road-cut at Shoal Brook associated with acidic volcanics of the Tickle Point Formation. This showing is close to the upper contact of the formation but may be localized to some extent by fault movements. A cap of gossan overlies the pyrite, with the glacial till being cemented by limonite. Similar showings are found on the Harbour Breton Peninsula within the same formation (Greene and O'Driscoll, 1976).

Minor showings of copper sulphides are found within the Doughball Point Formation east of Blow-Me-Down. These are generally associated with calcite and epidote in thin veins, along shear planes, and disseminated in the matrix of agglomerates. Similar showings have also been reported by Greene and O'Driscoll (1976) within the Doughball Point Formation on the Harbour Breton Peninsula. At Good Hill, magnetite is found associated with quartz and epidote as veins and disseminations in mafic flows of the Doughball Point Formation. Close-by, magnetite is also found as laminae and lenses in grey sandstone of the Down's Point

Formation and has probably been derived from the underlying mafic flows.

None of these showings are of more than academic interest at present.

CHAPTER 6

SUMMARY

The following is a brief summary of the findings of this study:

1. The Connaigre Bay Group forms a conformable succession which is subdivided into four formations: a lowest formation of acidic volcanic rocks (Tickle Point Formation), a sedimentary sequence (Great Island Formation), a formation of mafic volcanic rocks (Doughball Point Formation) and at the top a sequence of red sandstones, conglomerates and shales (Down's Point Formation).

2. The stratigraphy and lithology of the Connaigre Bay Group is similar to that of the Precambrian Long Harbour Group (Williams, 1971) to the east.

3. The Connaigre Bay Group has been intruded by an igneous complex (Hermitage Complex) which outcrops along the southwestern part of the Hermitage Peninsula.

4. The Hermitage Complex can be divided into two units: a diorite-gabbro unit (Grole Diorite) and a granitic unit (Furby's Cove Granite).

5. The Straddling Granite intrudes rocks of the Connaigre Bay Group and the Hermitage Complex and is probably a granitic phase of the Hermitage Complex similar to the Furby's Cove Granite.

6. Rocks of the Hermitage Complex, Straddling Granite and the Connaigre Bay Group are chemically similar and are believed to be genetically related by magmatic differentiation. The name Hermitage-Connaigre Bay Assemblage is used informally to describe these rocks.

7. On the basis of field, magnetic, petrographic and chemical evidence it is believed that the Hermitage Complex acted as the source for the volcanic material in the Connaigre Bay Group.

8. The Hermitage - Connaigre Bay Assemblage is classified as a bimodal calc-alkaline suite.

9. K/Rb ratios of the Hermitage - Connaigre Bay Assemblage are similar to those of Andean-type volcanic rocks.

10. Silicic intrusive rocks of the Hermitage Complex and silicic volcanic rocks of the Connaigre Bay Group contain garnet in the groundmass.

11. Mafic phases of the Hermitage Complex contain abundant amphibole and are interpreted to be the source of corundum-normative, garnet-bearing volcanic rocks of the Connaigre Bay Group. When compositions are plotted on Cawthorn and Brown (1976c) diagrams this interpretation is supported.

12. The Hermitage Complex has been intruded by a probable Devonian granite (Pass Island Granite) along its southwestern extremity.

13. Intrusive and volcanic rocks of the Fortune - Hermitage Bay area can be subdivided into two groups based on geochronological, stratigraphic and geochemical evidence. One group consists of the Connaigre Bay Group, the Straddling Granite, the Hermitage Complex and the Simmons Brook Batholith which are chemically similar and pre-Devonian in age. The other group consists of the Pass Island, Harbour Breton and Belleoram Granites which are chemically similar and Devonian or later in age.

14. An early Paleozoic or late Precambrian linkage is defined between the Gander and Avalon Zones since the Straddling Granite intrudes both zones and yields a Rb/Sr age of 490 ± 10 million years (Blenkinsop et al., 1976).

15. Rocks of the Gander Zone were deformed prior to the intrusion of the Straddling Granite, suggesting a complex structural history in Precambrian times.

16. The Hermitage Bay Fault forms the boundary between the Gander and Avalon Zones in southern Newfoundland and is characterized by a 50-100 metre wide breccia zone.

17. The main movement along the Hermitage Bay Fault affects the Straddling Granite, is post-Ordovician and probably Devonian in age.

18. The Hermitage Bay Fault as presently defined does not represent the original structure which marked the boundary between the Gander and Avalon Zones.

19. The Hermitage Bay Fault and the Dover Fault are not of the same aspect although both form the boundary between the Gander and Avalon Zones.

20. The geology of the Avalon Zone in the Fortune - Hermitage Bay area preserves four developmental stages:

1) a succession of late Precambrian volcanic and sedimentary rocks which in the east pass conformably up into fossiliferous Lower Cambrian rocks (Williams, 1971; Greene, 1975).

2) an intrusive suite which is Ordovician or earlier in age ranging from gabbroic to granitic in composition and possibly genetically related to the Late Precambrian volcanic rocks.

3) an Upper Devonian sequence of sandstone, shale, limestone and coarse conglomerate which unconformably overlies late Precambrian and Cambrian volcanic and sedimentary rocks and the related intrusive complex.

4) a suite of Devonian and later granitic rocks which intrude the Upper Devonian succession and all other rocks in the area.

REFERENCES

Anderson, F.D., 1965. Belleoram, Newfoundland: Geol. Surv. Can. Map. 8-1965.

Anderson. F.D. and Williams, H., 1964. Gander Lake (west half), Newfoundland: Geol. Surv. Can. Map 1195A.

Aubert de la Rue, E., 1932. Premiers résultats d'une mission géologique aux îles Saint-Pierre et Miquelon: Revue de Géographie physique et de Géologie dynamique, Paris, 5, pp. 417-456.

Aubert de la Rue, E., 1951. Recherches Géologiques et Minières aux Iles Saint-Pierre et Miquelon: Ministère de la France d'Outre-Mer, Paris.

Baker, P.E., 1968. Petrology of Mt. Misery volcano, St. Kitts, West Indies: Lithos, 1, pp. 124-150.

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

Best, M.G., Armstrong, R.L., Graustein, W.C., Embree, G.L. and Ahlborn, R.C., 1974. Mica granites of the Kern Mountains pluton, eastern White Pine County, Nevada: remobilized basement of the Cordilleran miogeosyncline: Geol. Soc. Am. Bull., 85, pp. 1277-1286.

Blackwood, R.F., 1976. The relationships between the Gander and Avalon Zones in the Bonavista Bay region, Newfoundland: Unpubl. M.Sc. thesis, Memorial University of Newfoundland, St. John's, Nfld., 156 p.

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

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

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

Bradley, D.A., 1962. Gisborne Lake and Terrenceville map-areas, Newfoundland: Geol. Surv. Can. Mem. 321, 56 p.

Browne, P.R.L. and Ellis, A.J., 1970. The Ohaki - Broadlands hydrothermal area, New Zealand: mineralogy and related geochemistry: Am. J. Sci., 269, pp. 97-131.

Cawthorn, R.G. and O'Hara, M.J., 1976a. Amphibole fractionation and calc-alkaline magma genesis: Am. J. Sci., 276, pp. 309-329.

Cawthorn, R.G., Strong, D.F. and Brown, P.A., 1976b. Origin of corundum-normative intrusive and extrusive calc-alkaline magmas: Nature, 259, pp. 102-104.

Cawthorn, R.G. and Brown, P.A., 1976c. A model for the formation and crystallization of corundum-normative calc-alkaline magmas through amphibole fractionation: J. Geol., 84, pp. 467-476.

Christiansen, R.L. and Lipman, P.W., 1972. Cenozoic volcanism and plate-tectonic evolution of the western United States, II; Late Cenozoic: Phil. Trans. R. Soc. London, 271, pp. 249-284.

Colman-Sadd, S.P., 1974. The geological development of the Bay d'Espoir area, southeastern Newfoundland: Unpubl. Ph.D. thesis, Memorial University of Newfoundland, St. John's, Nfld., 271 p.

Colman-Sadd, S.P., 1976. Geology of the St. Alban's map-area, Newfoundland (1M/13): Nfld. Dept. of Mines and Energy, Min. Dev. Div., Rept. 76-4, 19 p.

Dale, N.C., 1927. Precambrian and Paleozoic geology of Fortune Bay, Newfoundland: Geol. Soc. Am. Bull., 38, pp. 411-430.

Daly, R.A., 1925. The geology of Ascension Island: Proc. Amer. Acad. Arts Sci., 60, pp. 1-80.

DeGrace, J.R., Kean, B.F., Hsu, E. and Green, T., 1976. Geology of the Nippers Harbour map-area (2E/13) Newfoundland: Nfld. Dept. of Mines and Energy, Min. Dev. Div. Rep. 76-3, 73 p.

Dodge, F.C.W., Papike, J.J. and Mays, R.E., 1968. Hornblendes from granitic rocks of the central Sierra Nevada batholith, California: J. Petrol., 9, pp. 378-410.

Ermanovics, I.F., Edgar, A.D. and Currie, K.L., 1967. Evidence bearing on the origin of the Belleoram Stock, southern Newfoundland: Can. J. Earth Sci., 4, pp. 413-431.

Ewart, A. and Stipp, J.J., 1968. Petrogenesis of the volcanic rocks of the central North Island, New Zealand, as indicated by a study of Sr^{87}/Sr^{86} ratios, and Sr, Rb, K, U and Th abundances: Geochim. Cosmochim. Acta, 32, pp. 699-736.

Green, T.H. and Ringwood, A.E., 1968. Genesis of the calc-alkaline igneous rock suite: Contr. Min. Petrol., 18, pp. 105-162.

Greene, B.A., 1975. Harbour Breton map-area. In: Report of Activities for 1974, (Fleming, J.M., Ed.) Nfld. Dept. of Mines and Energy, Min. Dev. Div. Rep. 75-1, pp. 3-9.

Greene, B.A. and O'Driscoll, C.F., 1975. Gaultois, Newfoundland (1M/12): Nfld. Dept. of Mines and Energy, Min. Dev. Div. Open file Nfld. 139.

Greene, B.A. and O'Driscoll, C.F., 1976. Gaultois map area. In: Report of Activities for 1975 (Greene, B.A., Ed.) Nfld. Dept. of Mines and Energy, Min. Dev. Div. Rep. 76-1, pp. 56-63.

Hayes, A.O., 1948. Geology of the area between Bonavista and Trinity Bays, eastern Newfoundland: Geol. Surv. Nfld. Bull. 32, pt. 1, 34 p.

Heming, R.F. and Carmichael, I.S.E., 1973. High-temperature pumice flows from the Rabaul caldera, Papua, New Guinea: Contr. Min. Petrol., 38, pp. 1-20.

Hotz, P.E., 1971. Plutonic rocks of the Klamath Mountains, California and Oregon: U.S.G.S. Prof. Pap. 684-B, 50 p.

Howley, J.P., 1888. Geological Survey of Newfoundland - Report for 1887.

Huang, W.L. and Wyllie, P.J., 1973. Melting relations of muscovite-granite to 35 kbar as a model for fusion of metamorphosed subducted oceanic sediments: Contr. Min. Petrol., 42, pp. 1-14.

Hughes, C.J., 1970. The late Precambrian Avalonian Orogeny in Avalon, southeast Newfoundland: Am. J. Sci., 269, pp. 183-190.

Hughes, C.J., 1972. Geology of the Avalon Peninsula and its possible correspondence with Morocco: Notes M. Serv. géol. Maroc, 236, pp. 265-275.

Hughes, C.J. and Brueckner, W.D., 1971. Late Precambrian Rocks of Eastern Avalon Peninsula, Newfoundland - a volcanic island complex: Can. J. Earth Sci., 8, pp. 899-915.

Irvine, T.N. and Baragar, W.R.A., 1971. A guide to the chemical classification of the common volcanic rocks: Can. J. Earth Sci., 8, pp. 523-548.

IUGS Subcommission on the Systematics of Igneous Rocks, 1973. Plutonic rocks - classification and nomenclature: Geotimes, 18, pp. 26-30.

Jakeš, P. and White, A.J.R., 1970. K/Rb ratios of rocks from island arcs: Geochim. et Cosmochim. Acta, 34, pp. 849-856.

Jakeš, P. and White, A.J.R., 1972. Major and trace element abundances in volcanic rocks of orogenic areas: Geol. Soc. Am. Bull., 83, pp. 29-40.

Jenness, S.E., 1963. Terra Nova and Bonavista map-areas, Newfoundland: Geol. Surv. Can. Mem. 327, 184 p.

Jewell, W.B., 1939. Geology and mineral deposits of the Baie d'Espoir area: Geol. Surv. Nfld. Bull 17, 29 p.

Kean. B.F., 1973. Stratigraphy, petrology and geochemistry of volcanic rocks of Long Island, Newfoundland: Unpubl. M.Sc. thesis, Memorial University of Newfoundland, St. John's, Nfld., 155 p.

Kistler, R.W., Evernden, J.F. and Shaw, H.R., 1971. Sierra Nevada plutonic cycle: Part I, origin of composite granitic batholiths: Geol. Soc. Am. Bull., 82, pp. 853-868.

Krauskopf, K.B., 1967. Introduction to Geochemistry: McGraw-Hill, New York, 721 p.

Kuno. H., 1968. Differentiation of basalt magmas. In: Basalts: the Poldervaart treatise on rocks of basaltic composition (Hees and Poldervaart, Eds.) 2. Wiley, New York.

Kushiro, I. and Yoder, H.S., 1972. Origin of the calc-alkaline peraluminous andesites and dacites: Carnegie Inst. Wash. Yearb., 71, pp. 411-413.

Lipman, P.W., Prostka, H.J. and Christiansen, R.L., 1972. Cenozoic volcanism and plate-tectonic evolution of the western United States, I; early and middle Cenozoic: Phil. Trans. R. Soc. London, 271, pp. 217-248.

Luth, W.C., Johns, R.H. and Tuttle, O.F., 1964. The granite system at pressures of 4 to 10 kb: J. Geophys. Res., 69, pp. 759-773.

MacDonald, G.A., 1968. Composition and origin of Hawaiian lavas: Geol. Soc. Am. Mem. 116, pp. 477-522.

MacDonald, G.A. and Katsura, T., 1964. Chemical composition of Hawaiian Lavas: J. Petrol., 5, pp. 82-133.

Martin, R.F. and Piwinskii, A.J., 1972. Magmatism and tectonic settings: J. Geophys. Res., 77, pp. 4966-4975.

Murray, A., 1870. Geological Survey of Newfoundland - Report for 1870.

NALCO, 1962. Aeromagnetic Survey Results, (used with permission).

Nockolds, S.R., 1954. Average chemical composition of some igneous rocks: Geol. Soc. Am. Bull., 65, pp. 1007-1032.

O'Driscoll, C.F., 1973. Geology and petrochemistry of the Swift Current Granite, Newfoundland: Unpubl. B.Sc. (Hons.) thesis, Memorial University of Newfoundland, St. John's, Nfld., 84 p.

Osborn, E.F., 1959. Role of oxygen pressure in the crystallization and differentiation of basaltic magma: Am. J. Sci., 257, pp. 609-647.

Papezik, V.S., 1970. Petrochemistry of volcanic rocks of the Harbour Main Group, Avalon Peninsula, Newfoundland: Can. J. Earth Sci., 7, pp. 1485-1498.

Peacock, M.A., 1931. Classification of igneous rocks series. J. Geol., 39, pp. 54-57.

Pitcher, W.S. and Berger, A.R., 1972. The Geology of Donegal: A study of granite emplacement and unroofing. John Wiley and Sons,Inc., Toronto, 435 p.

Piwinskii, A.J. and Wyllie, P.J., 1970. Experimental studies of igneous rock series: felsic body suite from the Needle Point pluton, Wallawa batholith, Oregon: J. Geol., 78, pp. 52-76.

Presnall, D.C. and Bateman, P.C., 1973. Fusion relations in the system $NaAlSi_3O_8$ - $CaAl_2Si_2O_8$ - $KAlSi_3O_8$ - SiO_2 - H_2O and generation of granitic magmas in the Sierra Nevada batholith. Geol. Soc. Am. Bull., 84, pp. 3181-3202.

Rose, E.R., 1948. Geology of the area between Bonavista, Trinity and Placentia Bays, eastern Newfoundland: Geol. Surv. Nfld. Bull. 32, pt. 2, pp. 41-49.

Smith, R.E., 1968. Redistribution of major elements in the alteration of some basic lavas during burial metamorphism: J. Petrol., 9, pp. 191-219.

Streckeisen, A.L., 1967. Classification and nomenclature of igneous rocks: N. Jb. Miner. Abh., 107, pp. 144-214.

Strong, D.F., 1973. Lush's Bight and Roberts Arm Groups of central Newfoundland: possible juxtaposed oceanic and island-arc volcanic suites: Geol. Soc. Am. Bull., 84, pp. 3917-3928.

Strong, D.F. (in press). Volcanic regimes of Newfoundland. _In_: Volcanic Regimes of Canada (Baragar, W.R.A., Ed.). Geol. Assoc. Canada, spec. paper.

Strong, D.F., Dickson, W.L., O'Driscoll, C.F. and Kean, B.F., 1974. Geochemistry of eastern Newfoundland granitoid rocks: Dept. of Mines and Energy, Min. Dev. Div. Rep. 74-3, 140 p.

Taylor, S.R., 1965. The application of trace element dates to problems in petrology. _In_: Physics and Chemistry of the Earth, 6, pp. 133-212.

Thurlow, J.G., 1973. Lithogeochemical studies in the vicinity of the Buchans massive sulphide deposits, central Newfoundland: Unpubl. M.Sc. thesis, Memorial University of Newfoundland, St. John's, Nfld., 171 p.

Wager, L.R. and Deer, W.A., 1939. The petrology of the Skaergaard intrusion, Kangerdlugssuag, East Greenland: Medd. Groenland, 105, pp. 1-352.

Wanless, R.K., Stevens, R.D., Lachance, G.R. and Edmonds, C.M., 1967. Age determinations and geological studies: Geol. Surv. Can. Pap. 66-17.

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

Widmer, K., 1950. Geology of the Hermitage Bay area, Newfoundland: Unpubl. Ph.D. thesis, Princeton University, Princeton, New Jersey.

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

Williams, H., 1967. Burgeo, Newfoundland: Geol. Surv. Can. Map 1280A.

Williams, H., 1971. Geology of Belleoram map-area, Newfoundland (1M/11). Geol. Surv. Can. Pap 70-65, 39 p.

Williams, H., Kennedy, M.J. and Neale, E.R.W., 1972. The Appalachian structural province. <u>In</u>: Variations in Tectonic Styles in Canada (Price, R.A. and Douglas, R.J.W., Eds.). Geol. Assoc. Canada, spec. paper 11, pp. 181-261.

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

Yoder, H.S. Jr., 1973. Contemporaneous basaltic and rhyolitic magmas: Am. Min., 58, pp. 153-171.

APPENDIX 1

Analytical Procedures

Samples were prepared for analyses by Atomic Absorption Spectrometry according to the following procedures: 0.1000 g of rock powder were digested in 5 ml hydrofluoric acid and diluted with 50 ml saturated boric acid solution and 145 ml distilled water. Further dilutions were made for comparison with standard blends using artifical and United States Geological Survey rock standards. Solutions were further diluted for analyses of CaO and MgO. 5 ml HCl and 10 ml La_2O_3 solution were added to 5 ml sample solution and made up to 50 ml with distilled water. This dilution acts as a releasing agent to suppress the interference of aluminum and phosphorus with these determinations.

For FeO determinations, 0.200 g of sample were decomposed in 10 ml concentrated hydrofluoric acid and 5 ml ammonium metavanadate solution (0.1N). 10 ml sulfuric - phosphoric and mixture ($H_3PO_4 : H_2SO_4 : H_2O = 1:2:2$), 200 ml boric acid solution (100 g in 2ℓ H_2O), and 10 ml ferrous ammonium sulfate solution (0.025 N) were added to the sample solution. This was titrated to a grey end point with standard potassium dichromate solution (0.05 N) using 1 ml barium diphenylamine sulfonate solution (0.2 per cent) as an indicator. Sample solutions were compared with blank solutions and FeO was calculated according to the equation:

% FeO =

$$\frac{\text{titration for sample - titration for blank}}{1000} \times N \times \frac{71.85}{1} \times \frac{100}{\text{sample wt.}} \text{ (g)}$$

N = 0.05

X-ray fluorescence analyses were determined for samples prepared in the following manner: Unfused rock powders were mixed with a binding agent and pressed into discs with boric acid backings for one minute at 15 tons per square inch each. A tungsten X-ray tube and LiF crystal analyser were used with excitation at 80 KV and 20 mA.

Estimated precision and accuracy for analyses of the granitoid rocks are shown in the following tables (Strong et al., 1974):

PRECISION OF ANALYTICAL METHODS

(a) for major elements

Element	40 Fused Samples of CD-371			13 Unfused Samples of LD-75		
	Range (%)	Mean	S.dev.	Range (%)	Mean	S.dev.
SiO_2	10.70	76.58	1.94	6.90	76.21	1.91
TiO_2	0.10	0.17	0.03	0.02	0.03	0.01
Al_2O_3	1.40	12.28	0.36	1.37	14.13	0.35
Fe_2O_3	0.34	1.15	0.08	0.57	1.45	0.20
MgO	5.80	0.30	0.94	1.66	0.91	0.45
CaO	0.76	0.87	0.10	0.24	1.11	0.08
K_2O	0.17	1.73	0.03	0.58	2.43	0.23
P_2O_5	0.01	0.005	0.002	0.10	0.04	0.09

(b) for trace elements (from 9 independent discs of LD-75)

Element	Range (ppm)	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

S.dev.: Standard deviation
Range : $Obs._{max.} - Obs._{min.}$

ACCURACY OF ANALYTICAL METHODS

(a) 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) as determined by comparison of 24 samples analyzed 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

(c) as determined by fit of standards to calibration curve

Element	Range (ppm)	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

S.dev.: Standard deviation
Range : $Obs._{max.} - Obs._{min.}$

APPENDIX 2

CHEMICAL ANALYSES

(Tables 2-5)

TABLE 2
CONNAIGRE BAY VOLCANICS

SAMPLE PERCENT	CD-73-37	CD-73-40	CD-73-56	CD-73 57	CD-73 94	CD-73156
SIO2	58.00	57.80	48.79	45.65	54.40	71.40
TIO2	0.81	0.62	0.78	1.21	0.91	0.31
AL2O3	18.67	16.93	16.81	14.20	17.65	14.85
FE2O3	2.44	0.0	3.46	2.93	3.72	3.00
FEO	5.45	8.87	5.92	7.37	5.74	0.02
MNO	0.12	0.11	0.16	0.18	0.17	0.04
MGO	2.05	3.41	6.60	8.68	3.54	0.52
CAO	6.59	4.08	10.96	9.37	7.85	1.40
NA2O	2.91	3.36	2.00	2.43	3.22	2.73
K2O	1.54	1.86	0.55	0.51	0.81	3.18
H2O	2.05	2.55	3.21	7.27	1.37	2.17
TOTAL	100.63	99.59	99.24	99.80	99.38	99.62
PPM						
ZR	95	97	67	97	137	239
SR	249	266	255	242	353	138
RB	48	68	21	23	27	136
ZN	118	87	78	85	96	127
CU	27	213	55	51	40	7
BA	701	729	268	162	343	739
NB	12	13	10	9	12	20
NI	68	80	72	139	34	20
CR	253	118	190	548	18	12

TABLE 2 (continued)
CONNAIGRE BAY VOLCANICS

SAMPLE PERCENT	CD-73 70	CD-73 78	CD-73 92	CD-73117	CD-73127	CD-73161	CD-73167
SIO2	74.06	75.36	74.40	80.63	75.88	71.03	69.86
TIO2	0.13	0.22	0.05	0.11	0.26	0.31	0.23
AL2O3	9.97	11.68	14.13	10.62	11.87	13.67	15.82
FE2O3	1.95	1.05	0.42	0.37	1.01	1.75	3.00
FEO	0.0	2.76	0.68	1.04	0.72	1.09	0.56
MNO	0.13	0.08	0.11	0.04	0.02	0.06	0.05
MGO	0.97	1.29	0.22	0.53	0.22	0.86	2.84
CAO	2.16	0.16	1.08	1.10	1.87	2.76	0.44
NA2O	4.55	2.20	4.61	3.98	6.58	1.45	1.23
K2O	0.26	2.09	2.50	0.55	0.38	3.09	2.68
H2O	3.25	2.37	1.19	0.79	1.70	3.21	2.98
TOTAL	97.43	99.26	99.39	99.76	100.51	99.28	99.69
PPM							
ZR	228	212	75	135	200	182	225
SR	88	33	132	90	78	110	140
RB	14	66	59	18	17	123	93
ZN	97	95	52	34	21	59	89
CU	13	6	8	11	8	6	6
BA	1077	300	677	199	152	1104	741
NB	14	15	13	13	13	16	23
NI	16	15	8	10	10	21	18
CR	10	9	9	12	11	18	10

TABLE 2 (continued)
CONNAIGRE BAY VOLCANICS

SAMPLE PERCENT	CD-73166	CD-73170	CE-73203	CD-73206	CE-73 32
SIO2	49.30	48.55	50.67	46.73	79.73
TIO2	1.56	0.89	0.80	0.52	0.05
AL2O3	16.49	21.76	17.78	15.87	11.68
FE2O3	5.36	4.90	3.50	3.78	1.20
FEO	7.06	4.05	5.88	6.32	0.46
MNO	0.20	0.15	0.17	0.17	0.06
MGO	3.87	2.49	5.57	10.13	1.46
CAO	8.40	8.76	7.71	10.11	0.16
NA2O	2.71	3.29	2.72	1.55	2.31
K2O	0.83	1.71	1.74	0.48	2.17
H2O	3.31	3.27	3.48	4.06	1.61
TOTAL	99.09	99.82	100.02	99.72	100.89
PPM					
ZR	143	95	82	68	173
SR	347	347	253	289	48
RB	42	62	52	24	77
ZN	114	102	86	96	91
CU	185	41	41	23	7
BA	341	662	688	199	452
NB	12	9	8	12	17
NI	38	38	46	152	14
CR	16	65	38	950	13

TABLE 3
HERMITAGE COMPLEX

SAMPLE PERCENT	CD-73 8	CD-73 14	CD-73 45	CD-73 59	CD-73 71	CD-73 76	CD-73 89
SIO2	48.18	51.24	57.22	48.93	47.18	46.53	46.98
TIO2	0.60	1.15	0.94	0.98	0.59	1.22	1.71
AL2O3	12.78	16.32	17.19	17.25	15.24	15.84	16.93
FE2O3	1.84	3.71	1.86	3.11	3.58	3.04	2.18
FEO	7.46	5.56	4.88	6.60	6.99	7.06	8.68
MNO	0.17	0.15	0.14	0.17	0.26	0.20	0.21
MGO	11.23	6.10	3.70	7.03	6.70	8.25	6.07
CAO	13.06	9.57	6.54	6.73	6.16	9.77	8.72
NA2O	1.00	3.12	3.66	3.12	3.24	2.26	2.98
K2O	0.36	0.91	1.22	0.96	0.67	0.54	1.20
H2O	2.32	1.99	2.15	4.15	9.11	4.36	3.39
TOTAL	99.00	99.82	99.50	99.03	99.72	99.07	99.05
PPM							
ZR	44	95	220	102	57	79	138
SR	97	213	204	395	105	209	390
RB	20	39	41	41	24	24	68
ZN	74	69	75	105	120	82	75
CU	65	13	9	11	48	42	22
BA	94	320	383	496	167	149	613
NB	8	9	12	10	8	8	15
NI	159	51	56	66	62	115	65
CR	1063	85	86	104	174	321	43

TABLE 3 (continued)
HERMITAGE COMPLEX

SAMPLE PERCENT	CD-73 18	CD-7343B	CD-73 48	CD-73103	CD-73121	CD-73124	CD-73140	CD-73158
SIO2	78.00	71.48	72.87	80.36	79.16	78.65	77.68	74.39
TIO2	0.09	0.05	0.05	0.05	0.05	0.05	0.05	0.05
AL2O3	12.14	14.93	14.01	10.63	11.60	11.96	11.21	14.57
FE2O3	0.37	0.94	0.79	0.59	0.20	0.36	0.33	0.48
FEO	0.50	1.36	0.44	0.0	0.32	0.47	0.07	0.36
MNO	0.03	0.17	0.06	0.03	0.01	0.02	0.14	0.04
MGO	0.16	0.43	0.11	1.75	0.09	0.12	0.11	0.21
CAO	1.26	2.29	1.84	0.36	0.44	0.44	1.13	1.03
NA2O	4.22	4.52	4.33	2.32	3.73	3.69	3.23	3.69
K2O	1.67	1.81	2.03	1.71	3.86	3.96	3.68	2.46
H2O	1.89	1.08	2.76	0.93	0.30	0.25	1.61	1.82
TOTAL	100.33	99.06	99.29	98.73	99.76	99.97	99.24	99.10
PPM								
ZR	163	190	141	175	83	112	48	82
SR	98	259	101	39	62	43	59	138
RB	62	59	86	50	87	128	197	92
ZN	14	56	41	35	31	21	33	36
CU	11	9	15	6	8	16	7	8
BA	459	774	354	505	654	943	121	872
NB	17	14	16	15	16	19	33	18
NI	12	16	13	12	12	14	12	11
CR	13	14	13	14	15	12	19	13

TABLE 3 (continued)
HERMITAGE COMPLEX

SAMPLE PERCENT	CD-73 13	CD-73 46	CD-73 82	CE-73 84	CD-73 90	CD-73109	CD-73141	CD-73150
SIO2	55.86	51.20	55.76	49.24	50.73	52.27	50.00	59.20
TIO2	1.19	0.66	1.59	1.03	1.37	1.13	1.20	1.26
AL2O3	16.94	14.71	16.37	16.69	17.89	17.81	11.81	16.87
FE2O3	3.16	3.01	2.85	2.42	2.16	1.94	3.08	2.00
FEO	5.03	4.55	7.10	6.78	6.76	4.76	6.26	4.25
MNO	0.28	0.14	0.22	0.17	0.15	0.12	0.16	0.17
MGO	2.82	7.41	3.96	7.62	5.00	6.00	8.60	3.17
CAO	6.83	12.78	7.44	9.72	7.30	10.21	13.98	5.81
NA2O	4.16	1.91	4.31	2.77	3.73	3.14	1.60	4.95
K2O	1.14	0.92	0.74	0.58	1.07	1.09	2.16	0.96
H2O	0.94	2.08	1.61	1.73	2.45	2.26	2.01	2.33
TOTAL	99.35	99.37	101.95	98.75	98.61	100.73	100.86	100.97
PPM								
ZR	247	52	211	99	164	170	115	360
SR	381	188	254	260	683	668	422	317
RB	47	32	3	20	41	41	85	45
ZN	119	48	116	83	82	57	59	106
CU	6	199	17	47	32	54	169	14
BA	434	274	405	179	388	340	1018	393
NB	15	9	15	10	20	17	11	19
NI	25	82	37	110	59	70	77	43
CR	16	585	33	302	32	71	184	36

TABLE 3 (continued)
HERMITAGE COMPLEX

SAMPLE PERCENT	CD-73 98	CD-73176	CD-73199	CD-73 10	CD-73168	CD-73 6	CD-73 12
SIO2	55.50	54.91	57.11	82.00	64.41	47.76	52.97
TIO2	1.21	1.08	1.26	0.11	0.28	1.27	0.69
AL2O3	14.09	17.76	16.18	9.27	15.63	17.38	15.78
FE2O3	2.07	2.53	3.12	0.93	2.31	4.01	2.68
FEO	6.35	4.66	5.52	0.72	2.02	5.83	5.56
MNO	0.15	0.16	0.16	0.03	0.11	0.13	0.16
MGO	5.16	2.25	2.70	0.31	1.93	6.14	6.40
CAO	6.08	6.76	6.91	0.91	3.57	10.94	10.80
NA2O	3.30	3.61	3.34	3.36	5.98	2.28	2.34
K2O	1.84	1.20	1.20	1.52	0.63	0.70	0.76
H2O	3.27	4.76	2.43	0.85	3.13	2.57	2.09
TOTAL	99.02	99.68	99.93	100.01	100.00	99.01	100.23
PPM							
ZR	138	135	173	198	106	65	53
SR	200	264	265	63	264	293	221
RB	60	40	36	33	26	22	32
ZN	101	110	85	32	75	84	70
CU	24	19	68	14	7	49	68
BA	471	282	410	756	348	181	255
NB	13	11	13	22	13	10	9
NI	87	25	37	14	23	68	54
CR	134	15	15	12	25	81	211

TABLE 4
STRADDLING GRANITE

SAMPLE PERCENT	SG- 001	SG- 002	SG- 003	SG- 004	SG- 005	SG- 006
SIO2	65.26	79.48	82.79	73.80	75.00	80.29
TIO2	0.51	0.05	0.05	0.27	0.27	0.34
AL2O3	15.76	11.26	9.79	12.51	11.99	10.50
FE2O3	1.96	0.40	0.86	1.23	1.58	1.23
FEO	2.33	0.0	0.04	0.74	0.56	0.60
MNO	0.07	0.0	0.02	0.04	0.04	0.04
MGO	1.24	0.05	0.10	0.59	0.52	0.47
CAO	1.87	0.08	0.08	2.29	1.40	1.71
NA2O	3.23	3.73	2.70	4.69	4.60	3.76
K2O	3.01	3.87	2.04	1.35	1.38	1.08
H2O	4.37	0.50	0.44	1.50	0.92	1.25
TOTAL	99.61	99.42	98.91	99.01	98.26	101.27
PPM						
ZR	156	80	118	177	189	165
SR	225	40	41	107	112	146
RB	134	136	89	33	31	39
ZN	91	17	21	37	36	33
CU	24	14	8	8	9	10
BA	586	289	1139	535	523	319
NB	17	16	10	14	15	10
NI	23	13	14	14	16	15
CR	13	17	13	14	17	17

TABLE 5
PASS ISLAND

SAMPLE PERCENT	CD000317	CD000318	CD000319	CD000320	CD000314	CD000315	CD000316
SIO2	77.07	77.24	77.24	77.29	73.63	78.44	76.90
TIO2	0.04	0.04	0.14	0.16	0.11	0.04	0.06
AL2O3	14.07	13.60	15.29	13.27	14.65	13.11	13.58
FE2O3	0.81	0.71	1.46	1.54	1.33	0.73	0.85
MNO	0.06	0.06	0.05	0.05	0.07	0.04	0.07
MGO	0.86	0.87	0.96	0.81	0.97	0.78	0.85
CAO	0.59	0.25	0.90	1.10	0.95	0.29	0.17
NA2O	3.57	3.40	3.39	3.39	3.53	3.38	3.28
K2O	5.14	4.70	5.97	4.24	5.57	4.68	5.17
P2O5	0.02	0.02	0.04	0.03	0.08	0.0	0.0
TOTAL	102.23	100.88	105.44	101.88	100.79	102.49	100.93
PPM							
ZR	69	71	123	123	176	107	117
SR	0	0	32	16	51	0	0
RB	372	342	225	188	203	295	289
ZN	35	35	49	50	40	30	42
CU	0	0	0	0	0	9	0
BA	0	0	138	34	141	0	0
SN	116	110	950	984	1062	1046	999
MO	161	159	144	149	155	153	146
NB	156	153	136	141	149	146	140
BI	808	774	677	687	726	729	710
PB	769	751	635	656	706	697	687
F	530	150	260	250	220	170	170

TABLE 5 (continued)
PASS ISLAND

SAMPLE PERCENT	CD000306	CD000307	CD000308	CD000309	CD000310	CD000311	CD000312	CD000313
SIO2	67.87	67.89	71.17	69.61	74.28	73.28	73.58	74.49
TIO2	0.17	0.18	0.40	0.29	0.15	0.30	0.23	0.18
AL2O3	15.06	14.62	13.74	14.70	14.29	14.06	14.70	14.11
FE2O3	3.49	3.45	3.22	2.14	1.60	2.51	1.94	1.94
MNO	0.11	0.11	0.07	0.06	0.04	0.05	0.04	0.07
MGO	0.93	0.86	1.02	1.07	1.00	0.93	1.03	1.02
CAO	0.88	0.92	1.06	1.28	0.60	2.20	1.78	0.74
NA2O	4.20	4.50	3.49	3.61	3.13	3.42	3.30	3.56
K2O	7.03	6.70	4.74	6.29	6.09	3.95	5.44	4.80
P2O5	0.06	0.05	0.07	0.10	0.05	0.09	0.09	0.05
TOTAL	99.80	99.28	98.98	99.15	101.23	100.79	102.13	100.96
PPM								
ZR	705	712	249	202	156	216	208	232
SR	0	0	45	61	77	110	113	44
RB	149	154	221	283	207	163	186	211
ZN	75	73	60	54	37	45	42	53
CU	0	1	10	6	6	5	5	8
BA	93	98	282	458	201	263	354	18
SN	1022	970	1037	1008	1042	1039	1021	1009
MO	147	141	150	147	150	151	148	147
NB	144	137	144	141	142	144	141	141
BI	714	675	702	699	716	710	701	699
PB	679	646	684	671	689	677	673	679
F	0	200	480	350	210	320	290	290

1f

LEGEND

AVALON ZONE

DEVONIAN

Pink to orange porphyritic and aphanitic silicic dykes

Porphyritic diabase dykes

PASS ISLAND GRANITE: medium to coarse grained, pink, biotite granite

ORDOVICIAN OR EARLIER

STRADDLING GRANITE: 9a - medium grained, pink to orange, alaskitic granite; 9b - orange-pink hornblende-biotite granite, may include some Harbour Breton Granite; 9c - buff to grey granodiorite; 9d - fine grained, massive pink to purple felsite

HERMITAGE COMPLEX

Fine grained pink silicic dykes

Medium to fine grained diabase dykes

FURBYS COVE GRANITE: medium grained, pink, hornblende-biotite granite

GROLE DIORITE: dark grey quartz diorite to diorite with hornfelsed volcanic inclusions; medium to coarse grained black, hornblende-pyroxene gabbro; numerous basic and silicic dykes

PRECAMBRIAN

CONNAIGRE BAY GROUP

DOWNS POINT FORMATION: red to purple, graded and cross-bedded sandstone and pebble to cobble conglomerate; red, thinly laminated argillite; 4a - pink to purple, massive rhyolite and silicic tuffs

DOUGHBALL POINT FORMATION: grey to green, massive andesite and basalt; green, fine to coarse, basic tuffs and agglomerates; minor interbedded silicic flows and tuffs

GREAT ISLAND FORMATION: laminated, grey and green argillite, with purple conglomerate and shale at the base; rare limestone lenses; 2a - interbedded basic tuffs and thinly bedded tuffaceous sediments

SYMBOLS

Geological boundary (defined, approximate, assumed)

Bedding, tops known (horizontal, inclined, overturned)

Bedding, tops unknown (inclined, vertical)

Fault (defined, approximate, assumed)

Anticlinal axis (arrow indicates plunge)

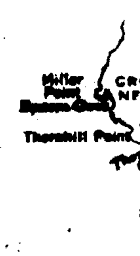
Synclinal axis (arrow indicates plunge)

Limit of geological mapping

Schistosity, cleavage, foliation (inclined, vertical)

Mineral Occurrence

Copper	Cu
Lead	Pb
Zinc	Zn
Pyrite	py



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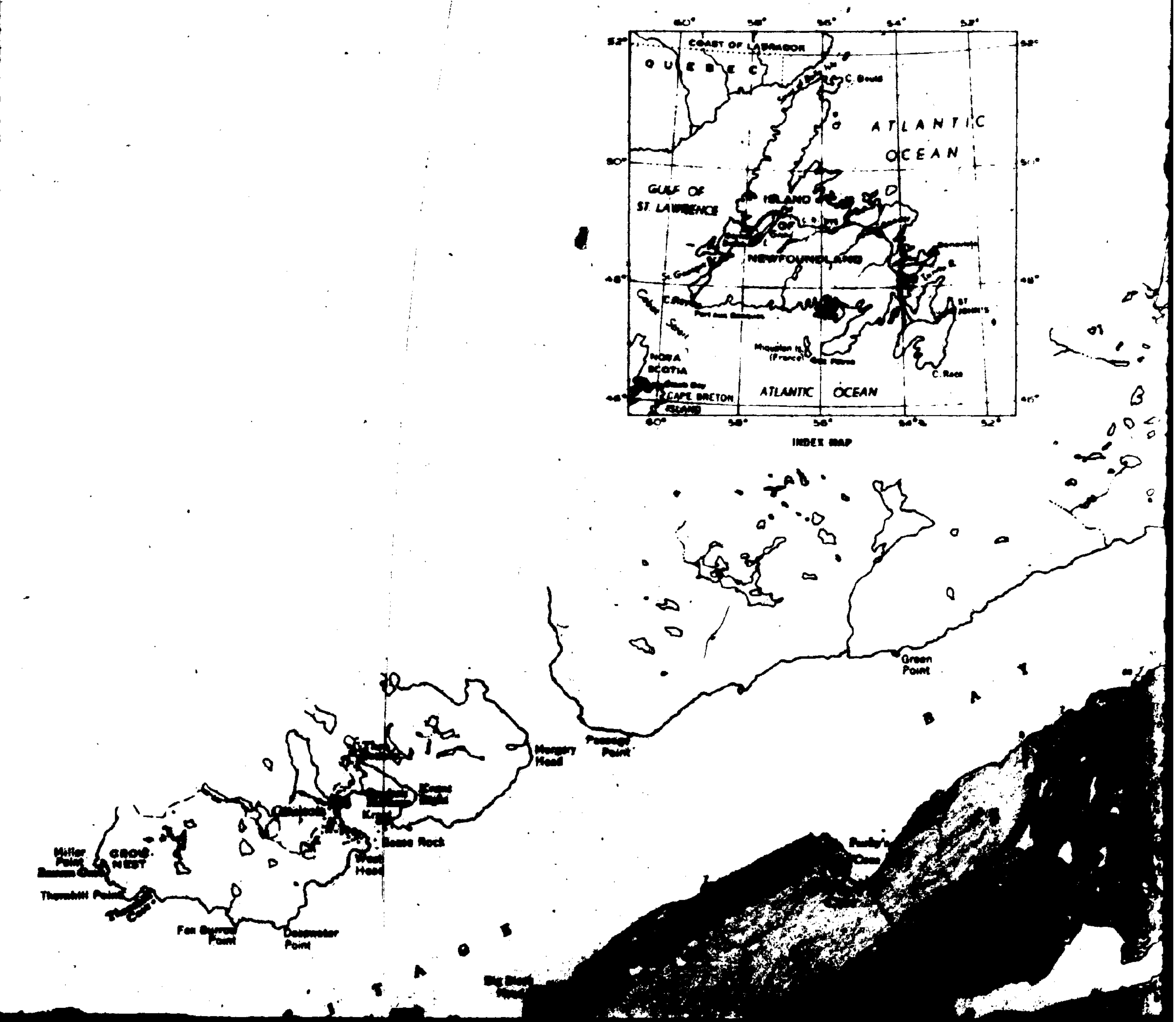

COAST OF LABRADOR
QUEBEC
ATLANTIC OCEAN
GULF OF ST. LAWRENCE
ISLAND OF NEWFOUNDLAND
NOVA SCOTIA
CAPE BRETON ISLAND
ATLANTIC OCEAN
C. Race
INDEX MAP
Green Point
Hungry Head
Passage Point
Goose Rock
B A Y

44

N
Big Head
Round Cove Head
White Point
Twaney Head
Frenchman Cove
Frenchman Head
Pb, Zn
Cu, Py
Cu, Py
5
1


54
Indian Point
WINTER HILL
FORTUNE BAY DISTRICT
HERMITAGE DISTRICT
Cu,py
5
4
1235

interbedded basic tuffs and thinly banded tuffaceous sediments

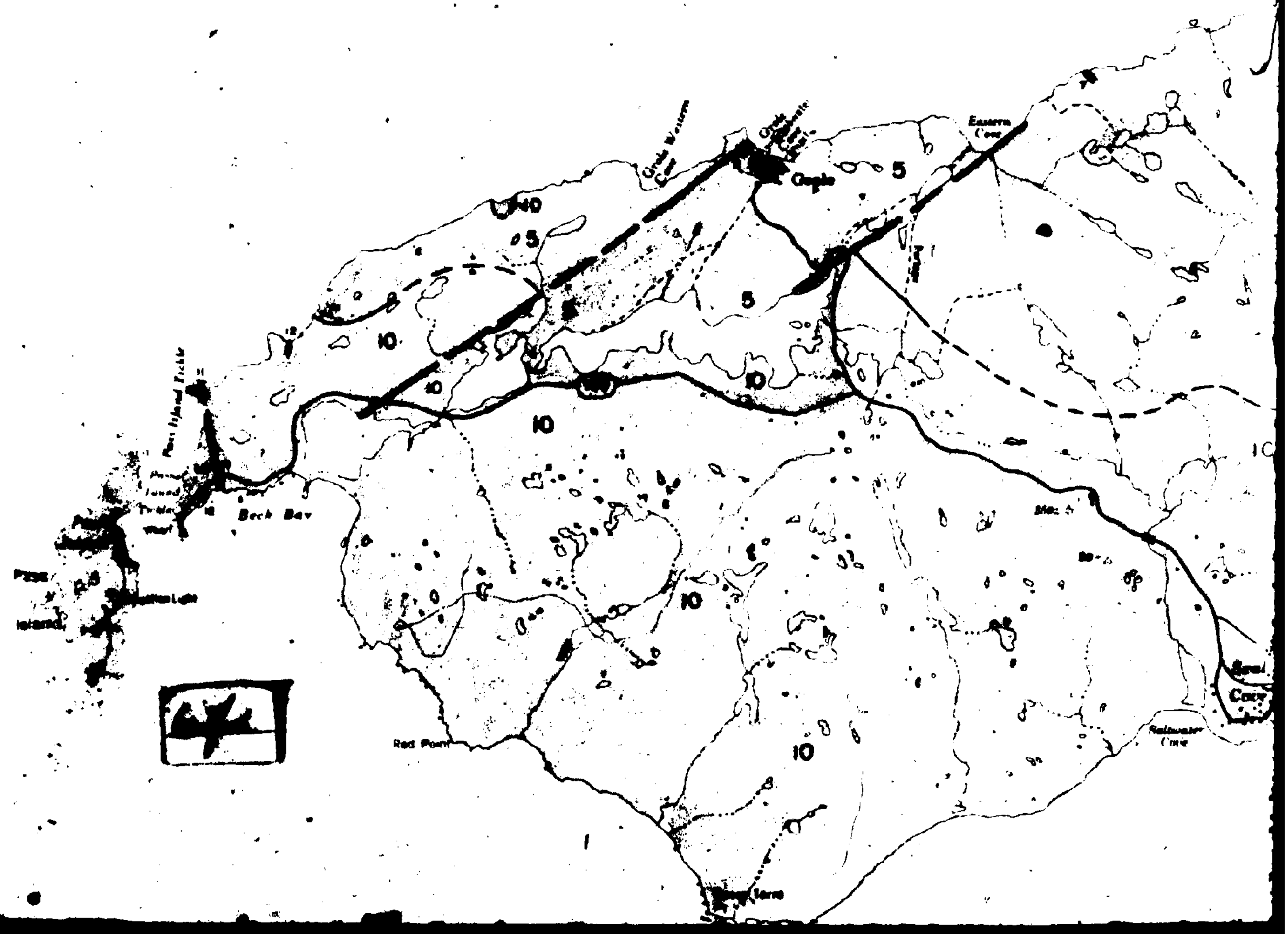
1 TICKLE POINT FORMATION: purple to pink, massive, flow banded and autobrecciated rhyolite; interbedded massive green andesite and basalt

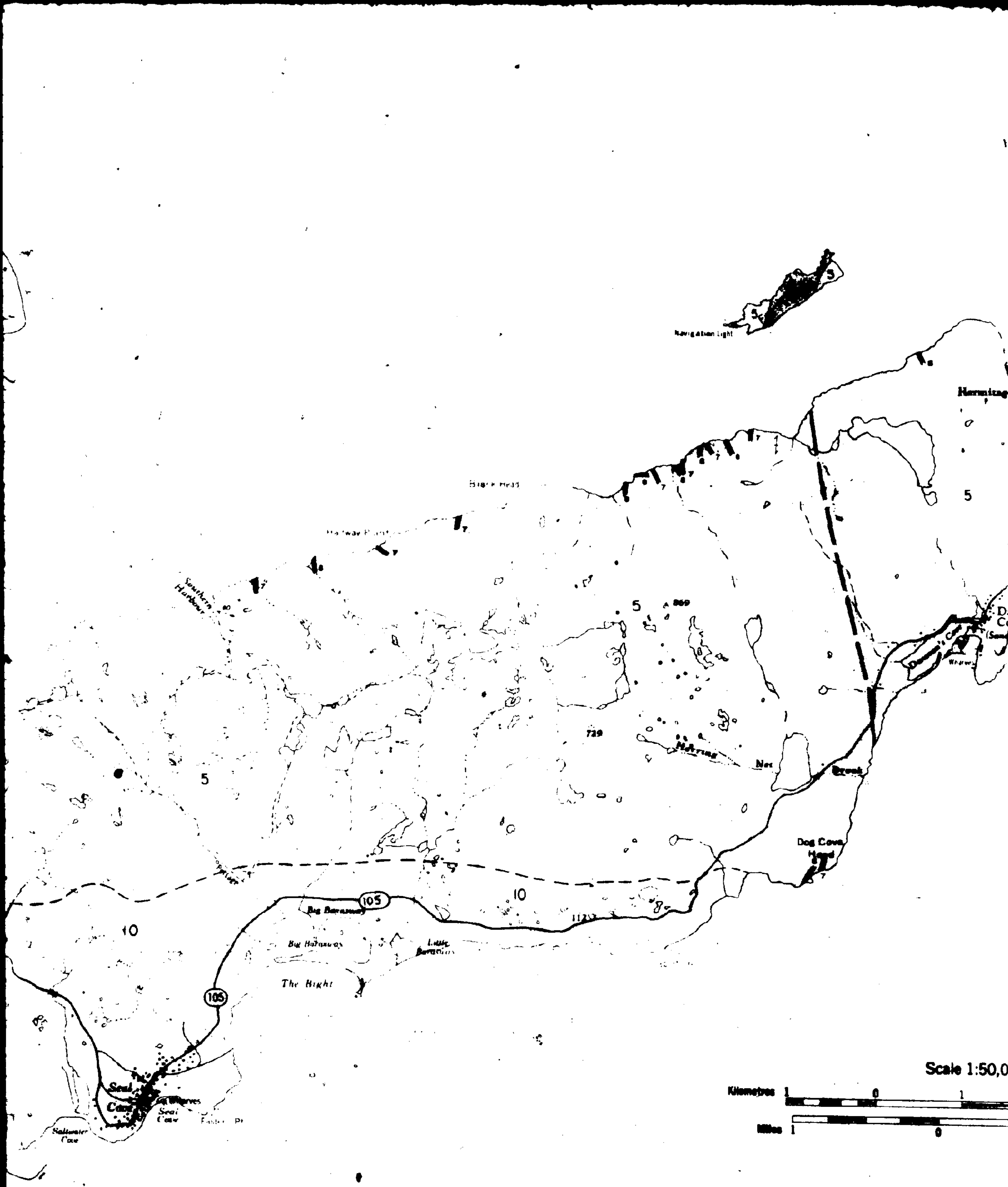
GANDER ZONE

PRE-LOWER ORDOVICIAN

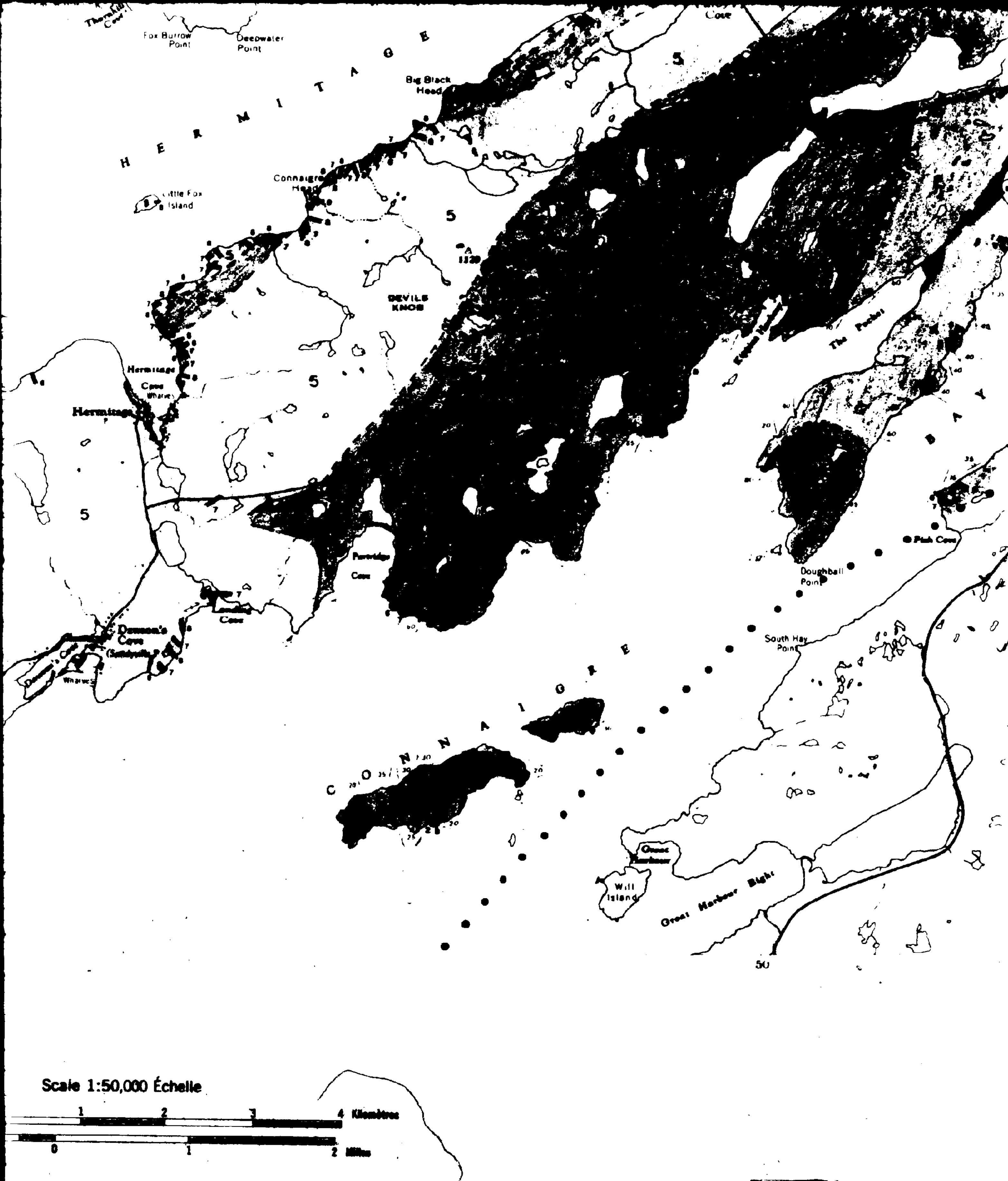
Foliated fine to medium grained muscovite granite; contains undivided zones of biotite-muscovite granite

A GAULTOIS GRANITE: foliated, porphyritic granite and granodiorite

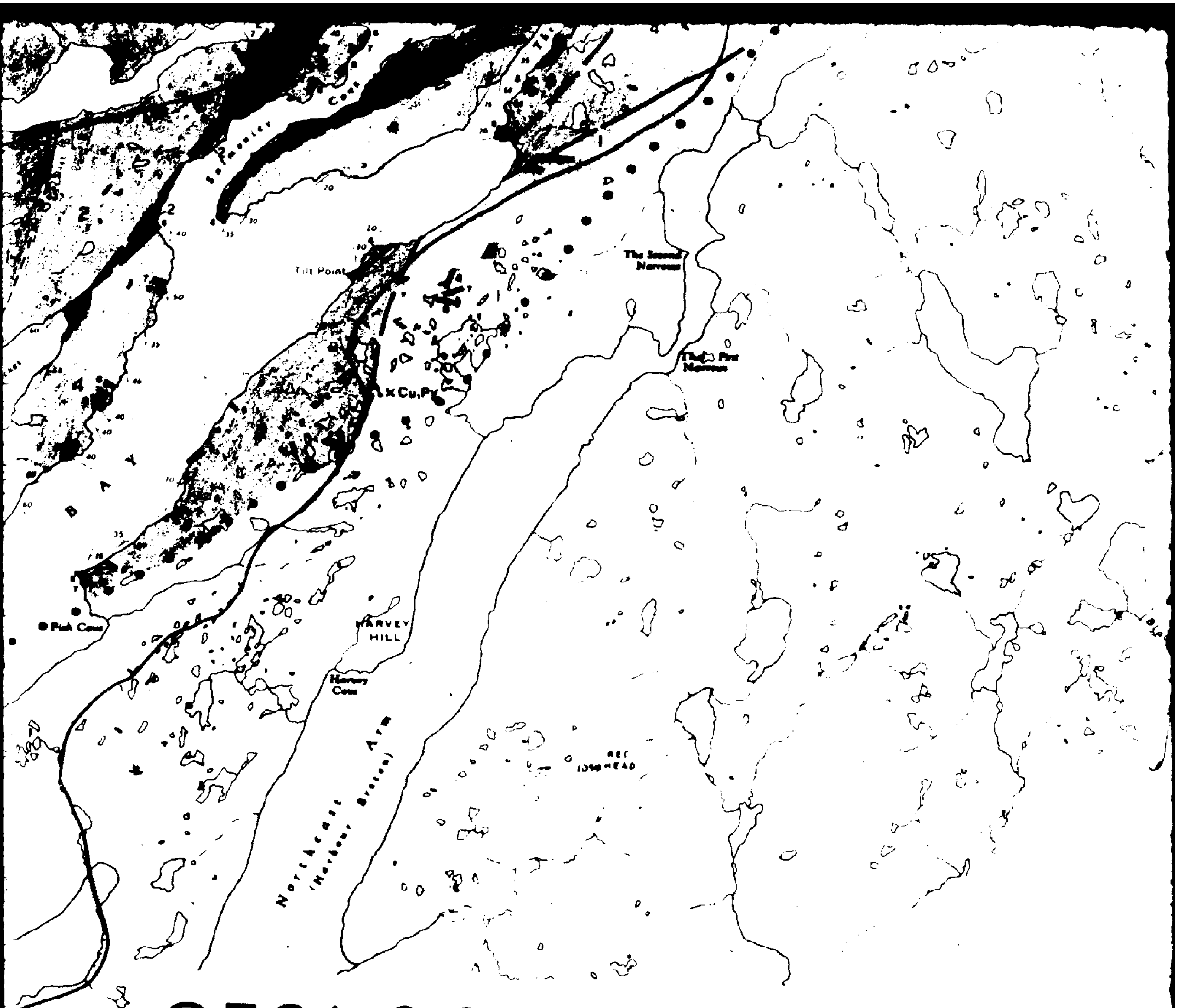




Navigation Light
Hermitage
Southern Harbour
5
10
105
Big Barasway
The Bight
Seal Cove
Saltwater Cove
Dog Cove Head
Brook
Scale 1:50,00
Kilometres
Miles


Fox Burrow Point
Deepwater Point
H E R M I T A G E
Big Black Head
Connaigre Head
Little Fox Island
DEVILS KNOB
Hermitage Cove
Wharves
Hermitage
Partridge Cove
Landing Cove
Dawson's Cove
Wharves
The Pocket
Doughball Point
Fish Cove
South Hay Point
C O N N A I G R E
B A Y
Great Harbour
Will Island
Great Harbour Bight
Scale 1:50,000 Échelle
0 1 2 3 4 Kilomètres
0 1 2 Miles

84

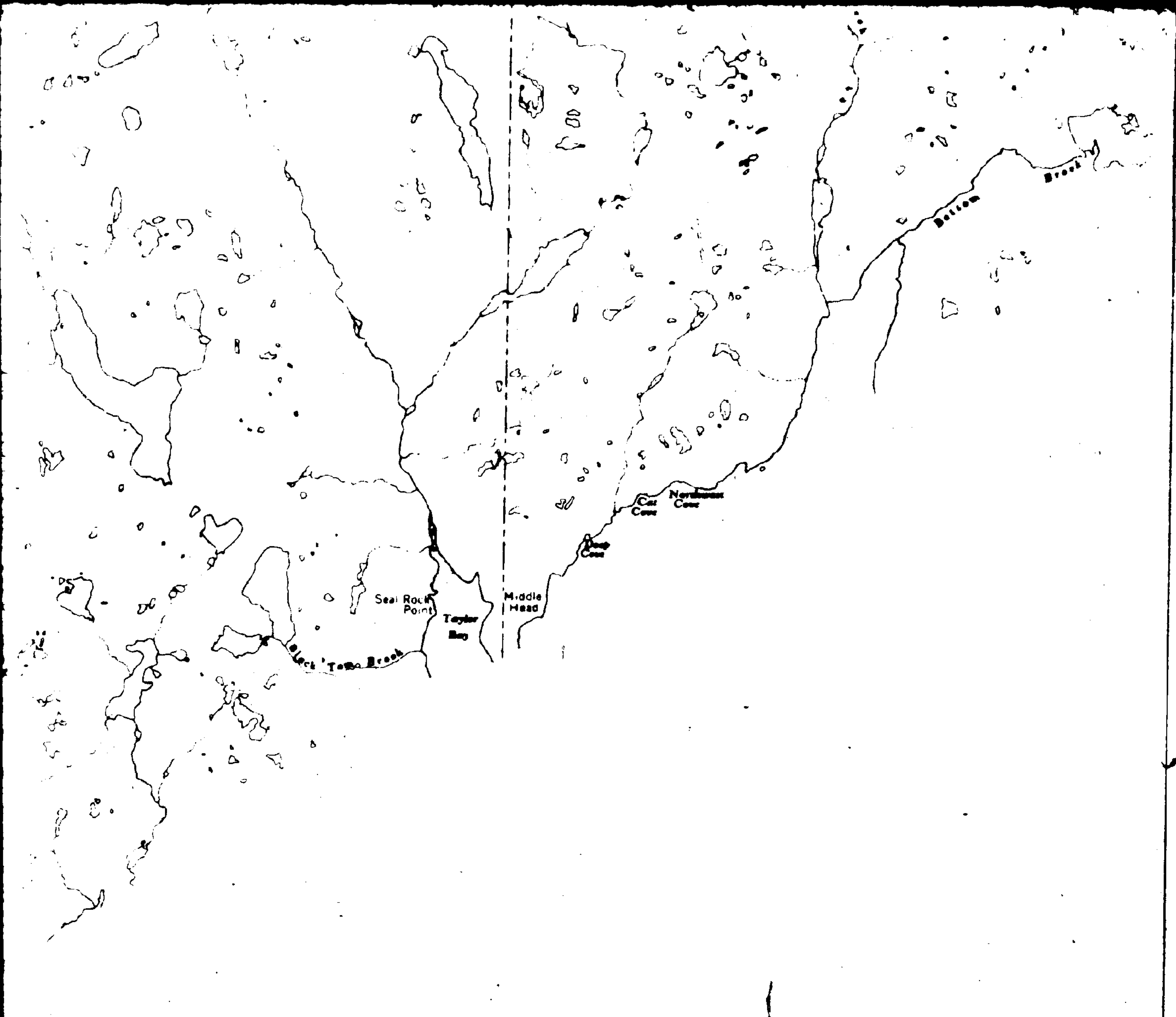


GEOLOGY OF THE HERMI

SOUTHERN NEWF

DATE: MARCH, 1977

FIG. 1.2



HERMITAGE PENINSULA

NEWFOUNDLAND

GEOLOGY BY: C.F. O'D.

FIG. 12