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A PROVISIONAL SUBDIVISION OF THE NAIN PLUTONIC SUITE IN ITS TYPE-AREA, NAIN, LABRADOR (NTS MAP AREA 14C/12)

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ABSTRACT

The metamorphic and igneous rocks of the Nain region are subdivided into more than twenty different units, at 1:50 000 scale. These units span a time period from the (early?) Archean to the Mesoproterozoic.

The oldest rocks are quartzofeldspathic gneisses and layered ultramafic and mafic rocks assumed to be Archean, and to represent vestiges of the Nain Province preserved within a younger plutonic terrane. The mafic to ultramafic rocks are derived from a layered intrusion, some parts of which include leucogabbro and anorthosite. This layered sequence has features that set it apart from other Archean rocks in northern Labrador, but no absolute age data are available to negate the assumed age.

Several units are candidates for Paleoproterozoic magmatic activity. The Bridges Layered Intrusion, metagabbroic rocks in the vicinity of Challenger Cove and perhaps one leuconoritic intrusion on western Paul Island fall into this category.

Most of the rocks in the area are assigned to the Mesoproterozoic Nain Plutonic Suite (NPS), the region around Nain being the type-area for this batholithic assemblage of coalesced anorthositic, granitic, troctolitic, and ferrodioritic (gabbronoritic) intrusions. Over a dozen units are delineated, reflecting parts of many different conjoined plutons. The oldest of such units appears to be foliated leuconoritic and leucotroctolitic rocks exposed in the central part of the study area, and a large pegmatoidal anorthosite and leuconorite intrusion in the western part of the area. The latter of these, the Mount Lister intrusion, probably crystallized ca. 1343 Ma. The Barth Island composite intrusion, northwest of Nain, was emplaced ca. 1322 Ma, the Port Manvers Run leucotroctolite at ca. 1308 Ma, and the Satorsoakulluk ferrodiorite dyke, between Barth Island and Base Island, at ca. 1301 Ma.

Minor intrusions, in the form of gabbroic and granitic dykes, abound within the larger rock units. Several generations of such dykes are present, but relative and absolute ages of intrusion are not regionally established.

The potential for the rocks around Nain to host a large deposit of base metals seems low, the presently known prospects being limited to sulphide as a subordinate constituent associated with oxide-rich diorites, and as areally restricted concentrations within troctolitic and anorthositic rocks. Some of the massive anorthositic rocks may prove to be a source of dimension stone.

The rocks of the NPS attest to repeated episodes of magmatism of similar aspect, spanning between fifty and sixty million years. It is clear that the igneous processes that contributed to the construction of this batholith are similar to those advocated for other batholiths worldwide. The NPS intrusions collectively reflect a diversity of magma compositions and magmatic processes. The basic to silicic compositional spectrum encompassed by these rocks was considered decades ago in terms of a simple, continuous, magma fractionation trend but this notion is no longer tenable because of the multiplicity of diverse intrusions of various ages and compositions.

INTRODUCTION

The Mesoproterozoic Nain Plutonic Suite (NPS) is a batholithic mass of anorthositic, granitic, ferrodioritic (gabbronoritic) and troctolitic rocks. These rocks are a manifestation of protracted pulsing magmatism, considered presently to encompass a 60-million-year period between 1350 and 1290 Ma. The region around the community of Nain (NTS map area 14C/12) is underlain by examples of all the major compositional variants of the NPS, and it has been nominated as the type-area for the Suite (Ryan and Morse, 1985).

The 2000 field season was devoted to continuing and refining work begun in the NPS type-area in 1999 (Ryan, 2000a). The main objectives of the two-season program were, i) to produce a 1:50 000-scale map showing the general architecture of the NPS, and ii) to assess the "stratigraphic position" of some of the recently discovered mineral prospects within the overall pattern of rock units in the Nain area.

The results of the second year of geological mapping of the Nain region provide a better understanding of the distribution pattern of metamorphic and igneous rocks than was possible following the previous year's work (Ryan, 2000a). Nearly all the NTS map area 14C/12 has been surveyed – albeit by helicopter-supported widely spaced observations in some places – resulting in the recognition and the demarcation of hitherto undivided stratigraphic units. Intrusive contacts, along with a set of field criteria based especially on textural differences, has enabled the writer to subdivide the superficially similar anorthositic and leuconoritic rocks into a number of separate units. These units, in some cases, certainly represent distinctly different intrusions, but in other cases they may simply reflect variations internal to a single multiphase intrusion.

This report aims to add to the foundation laid by the 1999 survey results (Ryan, 2000a), but the 10 weeks of field work over the past two seasons has been insufficient to provide adequate answers to many of the questions raised by this short project and by the earlier work of others. The existing combination of data do, however, permit a preliminary attempt at defining the component plutons that comprise the NPS in its type-area, and this exercise is the main thrust of the body of this report. The emphasis here is on subdivision of the igneous terrane; although some features are tentatively interpreted in terms of magmatic processes, this aspect of the geology is not treated in any detail.

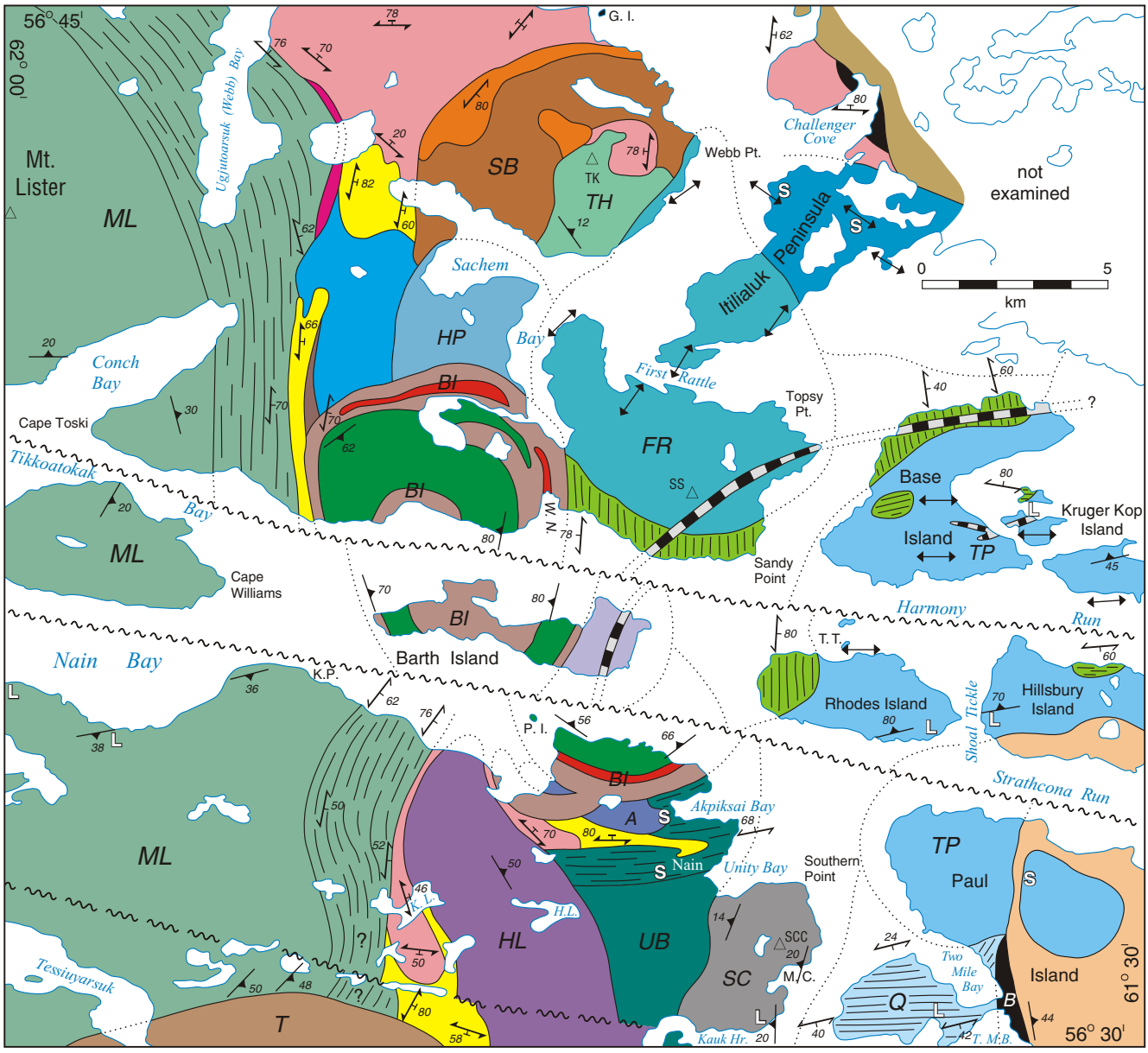
PREVIOUS WORK

The earliest work undertaken to unravel the geology of the Nain region was begun by E.P. Wheeler II in 1926, and about fifteen years later, it resulted in the first summary account of the rock types over a large part of central northern Labrador (Wheeler, 1942). Wheeler continued his work in the region until 1973 (e.g., Wheeler, 1960, 1969). Several minor projects, within the Nain Anorthosite Project, carried out between 1971 and 1981 under the leadership of S.A. Morse from the University of Massachusetts, focused on specific aspects of Nain geology, and some of these provided topics for graduate-level theses at American universities in the 1970s (see references cited below for details). Subsequently, R.A. Wiebe investigated Paul Island, and initiated one of the first attempts at deciphering the anorthositic rocks in their type-area in terms of their relative and absolute intrusive ages (*cf.* Wiebe, 1990a, Ashwal *et al.,* 1992). During the exploration boom in northern Labrador in the late 1990s, which followed the discovery of the Voisey's Bay deposit (*cf.* Kerr and Ryan, 2000), the Nain region became the site of prospecting and related investigations for nickel and copper mineralization, and much new ground- and drill-derived geological data were added to the existing information.

GENERAL GEOLOGY

The following points summarize the overall general geology of the NPS and its envelope in the Nain area (Ryan, 2000a, b; Figure 1). These points are expanded in the main

Figure 1. (opposite page) *Geological map of the Nain area, NTS map area 14C/12. The different colours demarcate most of the rock units that can be portrayed at this scale. Solid boundaries represent defined and probable unit contacts, based on several criteria mentioned in the text. The dotted lines are extrapolations of boundaries, to illustrate the interpretation that the units represent impinging and coalesced intrusions of differing age (*see *Figure 2). Closely spaced lines in some of the intrusions indicate foliated rocks; line trend mimics that of fabric.*
Geographic abbreviations:
G.I. = George's Island; W.N. = Webb Neck; K.P. = Kaiktusuak Point; P.I. = Pikaluyak Islet; M.C. = Meta Cove; T.M.B = Ten Mile Bay; K.L. = Kangilialuk Lake; H.L. = Hosenbein Lake; T.T. = The Turnpikes; TK = Tikkiraluk Hill; SCC = South Channel Cairn; SS = Sakotalik Summit
Geological abbreviations:
SB = Sachem Bay intrusion; TH = Tikkiraluk Hill intrusion; HP = Halfway Point intrusion; FR = First Rattle intrusion; BI = Barth Island intrusion; TP = Turnpikes intrusion(s); ML = Mount Lister intrusion; HL = Hosenbein Lake intrusion; A = Akpiksai Bay intrusion; UB = Unity Bay intrusion; SC = South Channel Cairn intrusion; Q = Quarry intrusion; T= Tessiuyarsuk intrusion; B = The Bridges intrusion



LEGEND

MESOPROTEROZOIC (Nain Plutonic Suite)

- BI — Granitic rocks: olivine±clinopyroxene± orthopyroxene±hornblende quartz monzonite, monzonite and granite
- Satorsoakulluk ferrodiorite dyke
- SB, BI — Ferrodioritic rocks
- BI, TH, T — Troctolitic rocks: troctolite, leucotroctolite, olivine gabbro

MESOPROTEROZOIC (Nain Plutonic Suite)

- ML, HL, UB, A, SC, TP, FR, HP — Anorthositic rocks: anorthosite, leuconorite, leucogabbro

PALEOPROTEROZOIC ?

- Massive metagabbroic and layered rocks
- Q — Foliated leuconorite

ARCHEAN

- Layered mafic gneiss
- Quartzofeldspathic gneiss

SYMBOLS

- *Trend of plagioclase megacrysts* .....
- *Igneous layering* .....
- *Foliation* .....
- *Gneissosity (inclined, vertical)*.....
- *Labradorite occurrence* .....
- *Sulphide ± oxide occurrence* .....

Figure 1. Caption on page 128.

body of this report. Mineralization of the area is placed within the context of the regional stratigraphy in another section.

1. The country-rock septa between the NPS plutons include units assumed to be both Archean and Paleoproterozoic. Those assumed to be Archean preserve an extensive, metamorphosed, layered intrusion varying from peridotite to anorthosite. This layered intrusion has been traced from Sachem Bay to the southern border of the study area. Fragments of peridotite, mafic rocks and rare anorthosite locally abound in the abutting quartzofeldspathic (enderbitic) granulites, the latter derived from a tonalitic pluton that had been emplaced into the layered body. Rocks of probable Paleoproterozoic age include metagabbro in the Challenger Cove area, well-layered rocks of The Bridges intrusion east of Two Mile Bay, and foliated leuconorite between Two Mile Bay and Ten Mile Bay.

2. NPS anorthositic rocks, although very similar in appearance throughout the area, can be subdivided into as many as ten different units; orthopyroxene or olivine is the sole mafic mineral in some units, but in others both minerals are present. There is very little geochronological control on the ages of these intrusions, and some could, in fact, be Paleoproterozoic. Some of the anorthositic rocks display well-developed foliations, interpreted to be formed both by compaction of cumulus and intercumulus minerals shortly after consolidation in a magma chamber and by solid-state deformation and recrystallization well after solidification (*cf.* Ryan, 2000a). Fairly continuous foliated units are represented by olivine-bearing leuconoritic rocks along the northern part of Base Island (Satorsoakulluk), anorthositic to leuconoritic rocks in the vicinity of Akpiksai Bay, and anorthositic to leuconoritic rocks stretching across Nain Bay from Ugjutoarsuk (Webb) Bay. Rafts of the foliated rocks occur in younger abutting plutons in all these areas. Such inclusive relations, as well as primary textural differences, modal mineral variations, and layering orientations, have been used to define the boundaries to the anorthositic intrusions.

3. Multiple injections of contrasting magmas – ferrodioritic, granitic, and troctolitic – have contributed to the construction of the ca. 1322 Ma Barth Island intrusion, leading to internally complex rocks and debatable contact relations. A similar assemblage of uniform and hybridized ferrodioritic and monzonitic rocks on the north side of Sachem Bay points to the presence of another chamber that was similarly open to pulsing and contrasting magma influxes. Here, too, troctolite sits atop ferrodiorite and quartz monzonite, the latter two forming a curving map pattern analogous to that of the border rocks of the Barth Island intrusion.

UNIT DESCRIPTIONS AND STRATIGRAPHIC RELATIONSHIPS

This section of the report is devoted to a summary description of some of the salient features of each of the main rock units shown on the sketch map of Figure 1. Some units too small to portray at the scale of Figure 1 are also mentioned. The reader is referred to a recently released *Open File* preliminary map and accompanying descriptive notes (Ryan, 2001) for the data used to arrive at the pattern shown in the sketch, as well as for more details of the subdivisions and for more complete documentation of observed and assumed relationships between many of the units described below.

ROCKS OF ASSUMED ARCHEAN AGE

This subdivision includes gneissic rocks assumed to belong to the Archean Nain Province. These rocks are a direct southward continuation of Archean gneisses that occur in the Okak Bay–Webb Bay area (*cf.* Ryan, 1990), but some of them have characteristics that set them apart from Nain Province rocks observed in the aforementioned areas or elsewhere in northern Labrador. These "unique" rocks are provisionally considered Archean, but their overall aspect accords them an uncertain relative place in the regional stratigraphy, and they could be, in fact, Paleoproterozoic.

Migmatitic Granulite-Facies Quartzofeldspathic Gneisses

These rocks occur primarily along the northern periphery of the map area (Ugjutoarsuk (Webb) Bay–Sachem Bay–Challenger Cove), on an islet (not shown on Figure 1) west of Barth Island, and on the south side of Nain Bay. They are mostly quartzofeldspathic granulites that characteristically contain centimetre- to metre-scale inclusions of mafic and ultramafic rock; meta-anorthositic and leucogabbroic inclusions are locally present on the island west of Barth Island and south of Nain Bay. Mildly deformed enderbitic rocks, having abundant angular inclusions of mafic and ultramafic rock, as well as irregular mafic enclaves, are present on the islet west of Barth Island and south of Nain Bay, and may be well preserved examples of the granitoid protolith to the regional gneisses. Some of the quartzofeldspathic granulites on the western side of the peninsula at the entrance to Challenger Cove and just north of the map area at Webb Bay contain disrupted massive and non-migmatized mafic lenses that have plagioclase megacrysts. These feldsparphyric mafic units are reminscent of Saglek dykes, which, by comparison with northern Labrador, would imply

an early Archean age for the granulites (Ryan, 2000a, page 256).

Layered Ultramafic, Mafic and Anorthositic Rocks

This group of non-migmatized mafic, ultramafic, mesocratic and pale-weathering leucogabbronoritic to anorthositic rocks is derived from a layered intrusion. The unit as shown in Figure 1 constitutes several separate belts of slightly overall differing aspect. Assigned to this subdivision are layered rocks in the Webb Point area, west of Sachem Bay, south of Nain Bay, and south of Akpiksai Bay. Quartzofeldspathic rocks are locally present within this layered unit, but are subordinate to the layered melanocratic components. As a unit, these rocks are unusual within the Archean of northern Labrador by their continuity and coherency; elsewhere, similar rocks in the Nain Province are generally extensively migmatized, complexly polydeformed, and of much less areal extent. Another feature distinguishing them from "normal" mafic units within the Nain Province of northern Labrador is the abundance of olivine in the more melanocratic mafic members. Parts of this unit were previously recognized by C.C. Rubins during mapping in the region in 1967, 1968 and 1971 (*cf.* Rubins, 1973). Rubins was unsure of the setting of these rocks, interpreting them initially as part of the country-rock to the NPS (Rubins, 1971, p. 38; Rubins and de Waard, 1971) but later (Rubins, 1973) as being "layered, medium-grained anorthositic rocks" belonging to the NPS. The unit exhibits mineral assemblages consistent with granulite-facies metamorphism (clinopyroxene, orthopyroxene, brown hornblende), but the original mafic rocks may have been gabbronoritic. A belt of layered mafic, ultramafic and anorthositic rocks within the Archean gneiss complex along the southern border to the Hettasch intrusion, north of Webb Bay (Ryan, 1993), may be correlative with the layered group in the present study area.

The mesocratic rocks are generally greenish-grey- to purplish-grey-green-weathering, whereas the mafic rocks are dark-grey- to nearly black-weathering. Both rock types vary in their field textures from homogeneous granular ("salt-and-pepper") to diffusely layered on the centimetre to metre scale. Locally, the mafic rocks have oval to irregular, pale-grey blotches composed of fine-grained orthopyroxene, plagioclase and opaque oxide (Plate 1) that are interpreted to be decompression products of former garnets. No relict garnet could be found in outcrops where such blotches were seen, so the pale-grey granular areas were given the informal field name "garnet ghosts".

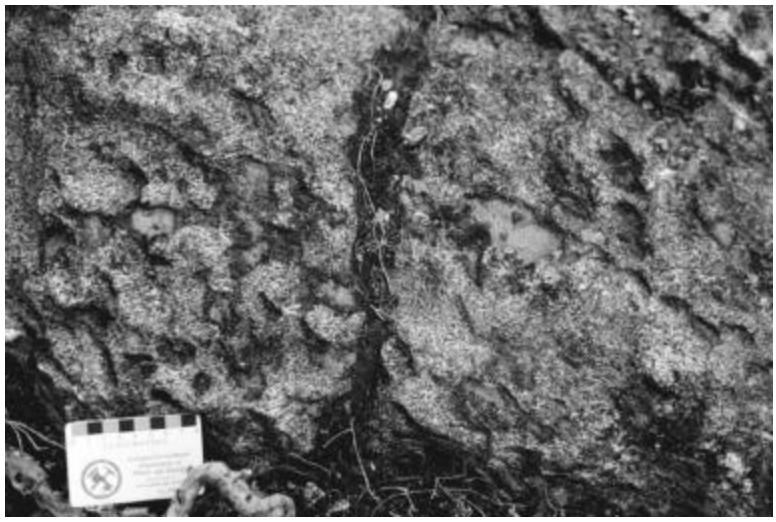


Plate 1. *Granular gabbronoritic rock within the layered sequence north of Sachem Bay, showing fine-grained pale-grey blotches considered to be "garnet ghosts".*

Ultramafic rocks are less abundant than the mesocratic and mafic rocks. They are normally dark-brown- to reddish-brown-weathering, and constitute podiform layers that are generally tens of centimetres thick within mafic and mesocratic rocks; units on the scale of tens of metres in size are present west of Webb Point and west of Sachem Bay (Plate 2). Most, if not all, of the ultramafic rocks are olivine-bearing, and in some dunitic outcrops the abundance and oval aspect of the olivine implies a cumulus origin.

Leucogabbroic and anorthositic rocks are the regionally least abundant component of this sequence. They are most widespread south of Kangilialuk Lake (south of Nain Bay) but they also occur on the ridge west of Nain and west of Sachem Bay. Generally, these are streaky-textured granular rocks, but original feldspar morphology is preserved in some places (e.g., oval shapes on Nain ridge). Meandering darker layers within some of the leucocratic rocks seem to be derived from contemporaneous(?) mafic dykes (e.g., south of Kangilialuk Lake, east of Conch Bay); other darker layers are most certainly later dykes that postdate a foliation in their hosts but are also deformed. There is a greenish-blue labradorite schiller to some of the plagioclase in these deformed leucocratic rocks, and in some cases, the granular anorthositic rocks of this unit superficially resemble adjacent foliated younger leuconoritic rocks. The older rocks differ, however, from the younger ones in having a polyphase structural history (e.g., exhibit folded layering and foliations).

Both the ultramafic and mafic rocks of this layered unit locally have distinct centimetre-scale layers and veins, as

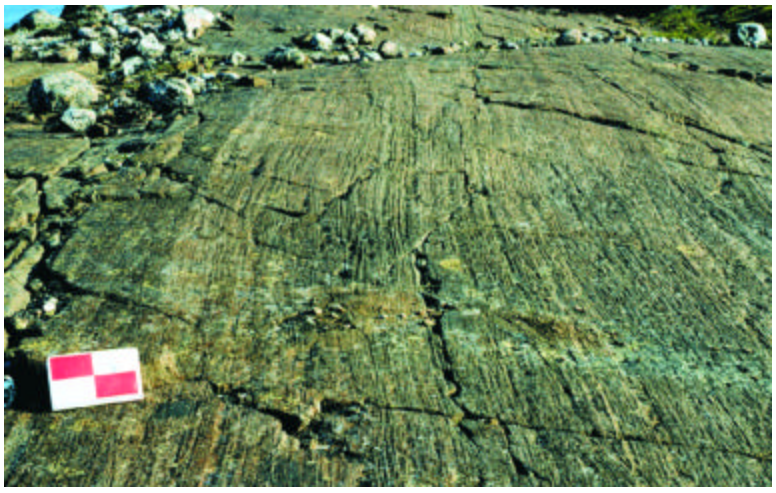


Plate 2. *Finely layered ultramafic rock from the sequence west of Webb Point; the layering here probably being a relict of primary magmatic origin rather than being totally tectonic.*

well as discordant granular dykes, of white anorthosite (e.g., southwest of Akpiksai Bay and west of Webb Point). The parallel array gives such rocks a diffuse migmatitic appearance. These anorthositic components are locally folded and foliated and cannot be temporally divorced from the layered unit itself, i.e., cannot be reliably correlated with proximal younger anorthositic intrusions.

The layered unit is broken up by the adjacent quartzofeldspathic granulite gneisses north of Sachem Bay and south of Nain Bay, and it seems to have been the source for the numerous mafic and ultramafic rafts that occur regionally within the quartzofeldspathic gneisses. It is intruded by sheets of (Archean?) pale-grey to brownish-grey, orthopyroxene-bearing granitoid rock in the Nain Hill–Akpiksai Bay area; elsewhere a migmatitic aspect is locally imparted by an abundance of quartzofeldspatic veins.

Leuconoritic and Anorthositic Rocks
(not shown on Figure 1)

This layered unit of olivine-bearing mafic rocks and olivine-free, mesocratic, leuconoritic and anorthositic rocks occurs within leucocratic gneisses at the west end of an islet west of Barth Island (Ryan, 2001). Foliated leuconorite, similar to the "stratigraphically highest" parts of this unit on the islet, was also observed west of the Barth Island composite intrusion north of Nain Bay. Assigning an Archean age to this unit is debatable. It could be allied with the layered mafic rocks described in the foregoing section, but might be Paleoproterozoic. It may even be Mesoproterozoic and thus part of the NPS!

The main unit at the western tip of islet is bounded to the east and west by a leucocratic, anorthositic-looking, enderbitic to opdalitic rock, having mafic, ultramafic and anorthositic enclaves. The eastern contact with the older quartzofeldspathic rocks is sheared, but appears to have originally been intrusive, with the leuconoritic rock from this unit being younger. The structurally lowest unit on the islet is a locally rusty-weathering and friable rock, containing abundant disseminated opaque oxide. It is layered and foliated, varying compositionally from leuconoritic to ultramafic, but dominated by grey-brown gabbronorite that is locally characterized by subhedral to lozenge-shaped dark-grey to black plagioclase crystals up to 5 cm long. Some less intensely foliated gabbronoritic parts of the unit retain subophitic texture and well-preserved plagioclase crystals. The layered rocks are overlain by streaky-foliated leucogabbronoritic to anorthositic rocks; the leucogabbronoritic rocks have isolated dark-grey plagioclase crystals in a pale-grey matrix and also contain variably recrystallized dark-brown to black orthopyroxene megacrysts. Foliated leucogabbronorite, having dark plagioclase megacrysts, that occurs west of the Barth Island composite intrusion north of Nain Bay is similar to the one associated with the more melanocratic rocks on the islet; both these occurrences resemble, but are not considered to be related to, megacryst-poor parts of the NPS seriate leuconorite west of Sachem Bay (see subsequent section).

Paragneiss
(not shown on Figure 1)

Metasedimentary units are rare within the gneiss terrane. The only ones noted during the course of the survey are forsterite-biotite calc-silicate rocks and corundum(?)-bearing metasediments as metre-scale rafts within the quartzofeldspathic gneisses east of Ugjutoarsuk (Webb) Bay. A thin quartzite unit occurs within a gneiss screen enclosed by the monzonitic body on the highland east of the bay.

ROCKS OF ASSUMED PALEOPROTEROZOIC AGE

There are several rock units that prior to the past decade were considered to be part of the NPS. At least one of these, The Bridges layered sequence, has yielded isotopic indications of being pre-NPS. Other candidates for a pre-NPS niche are included in this section, but apart from their field aspects and possible relation to some abutting units there is no control on their ages.

Metagabbro

Two bodies of amphibolitized and deformed gabbroic and gabbronoritic rocks of possible Paleoproterozoic age occur in the northern part of the study area. The westernmost body is exposed on George's Island and the other body stretches north–south across Challenger Cove. The latter was referred to by Woodward (1973) as "gneisses of uncertain origin". Primary textures are well-preserved in both intrusions, despite secondary hydration (Plate 3). They are medium- to coarse- grained rocks, having shiny, black, amphibolitized pyroxenes and variably recrystallized dark-grey plagioclase. A pitted weathering aspect to parts of the unit on George's Island suggests that olivine may be locally present. In both bodies, the massive to mildly foliated igneous rock is locally transformed into strongly foliated amphibolite (or mafic granulite) in "hot shear zones"; this feature is especially evident in the Challenger Cove body along its eastern side near the Port Manvers Run leucotroctolite.

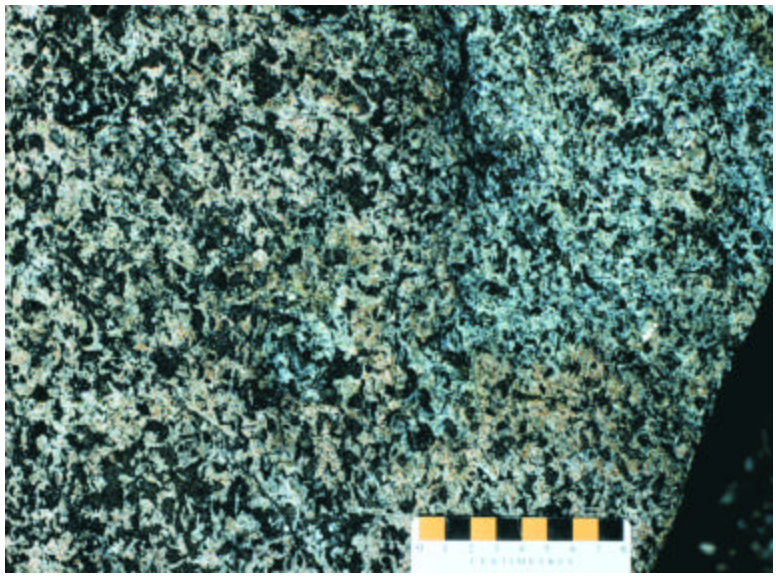


Plate 3. *Igneous texture within amphibolitized Paleoproterozoic(?) gabbronorite, Challenger Cove.*

These metagabbroic rocks are intruded into Archean gneisses; the exposed interface on George's Island is locally sheared and indistinct. The western body is intruded by amphibolitized and foliated metadiabase dykes on an islet north of George's Island, a feature also exhibited by some of the Paleoproterozoic intrusions farther north in the Okak Bay region (Ryan *et al.*, 1998) and one of the field aspects of the metagabbroic rocks in the present study area that imply a Paleoproterozoic age.

The Bridges Intrusion

A discrete unit of well layered leucocratic to ultramafic rocks on western Paul Island, varying internally from anorthosite through to peridotite but dominantly olivine-bearing gabbro, was named The Bridges Layered Group by Planansky (1971). Subsequently it was named The Bridges Layered Intrusion (Wiebe, 1990a). The Bridges is bounded by anorthositic rocks, but the exact nature of the contact between The Bridges and some of these leucocratic rocks is not altogether clear (*cf.* Planansky, 1971, 1973; Wiebe, 1990a). A Nd–Sm whole-rock age determination of 1667 ± 75 Ma (Ashwal *et al.*, 1992) provides an indication that The Bridges is a Paleoproterozoic layered sequence, one that has been fortuitously preserved within a terrane of largely Mesoproterozoic igneous rocks (Ryan and Emslie, 1994).

In the present study area, The Bridges forms part of the highland immediately east of Two Mile Bay, where it is the northern termination of a southward-widening, east- to southeast-facing, monoclinal unit that continues across Ten Mile Bay for over 5 km. East of Two Mile Bay it has a south-plunging synclinal form, truncated by younger troctolitic to leuconoritic rocks on its eastern side (*see* section “Troctolitic Rocks on Paul Island”), but it may rest in modified depositional contact against the foliated leuconorite to the west (*see* “Quarry Intrusion” below). Very little of The Bridges is present in the study area, the best exposed part being a knoll near the shore on the north side of Ten Mile Bay. Some of the primary traits described by previous workers (e.g., Planansky, 1971; Ashwal *et al.*, 1992) can be seen in the small part of The Bridges within the present area, but recrystallization and deformation obscure them locally. Primary features include the compositionally contrasting cumulus layering on the order of centimetres to metres, modally graded layering, current-related trough layering, annealed syn-depositional faults that displace the layering, and "slump folds" and "slides" within the layering. Poikilitic orthopyroxene and olivine can be seen in some of the anorthositic layers, and a plagioclase lamination fabric parallel to layering trend is also visible in some of the gabbroic layers.

Quarry Intrusion

This unit of foliated, grey to brownish-grey leuconorite and anorthosite is exposed on the peninsula between Two Mile Bay and Ten Mile Bay. Rocks directly west of The Bridges Layered Intrusion east of Two Mile Bay may also be part of this unit, but the leuconorite here is texturally different from that exposed on the peninsula. The name for this unit is derived from a dimension-stone quarry that has been

opened in this unit on the north side of Ten Mile Bay, and the quarry on the south side of the bay (outside the study-area) is also considered to be within it (Ryan, 2000a).

The rationale for suggesting that the Quarry leuconorite is possibly Paleoproterozoic was outlined following the 1999 survey (Ryan, 2000a). The regional attitude of the foliation in the Quarry leuconorite and the orientation of The Bridges layered rocks implies that the latter "unconformably overlies" the foliated leuconorite; if The Bridges is ca. 1670 Ma, then the leuconorite must be older. This relationship would also verify the view expressed by Wiebe (1990a, p. 6) that the layered sequence has an "abrupt lower depositional contact" with the leuconorite.

The Quarry leuconorite is a dark-grey to pale-grey to purplish-grey rock comprising leuconorite and anorthosite having variable grain size (2 to 10 cm typically). Recrystallized orthopyroxene megacrysts occur locally; the association of fine granular plagioclase and pyroxene in such recrystallized megacrysts suggests these orthopyroxenes are the high-alumina type. The foliation in the Ten Mile Bay area is mainly defined by elongate streaks of granular orthopyroxene (± clinopyroxene, green hornblende), most, if not all, of which seems to be derived from the elongation (compaction?) of an original clotty (poikilitic) texture. However, in some rocks the foliation is formed by trains of variably recrystallized coarse orthopyroxene. The foliated rock proximal to The Bridges layered sequence east of Two Mile Bay is different from that around Ten Mile Bay, in as much as the fabric is defined by fine continuous folia of granular pyroxene (crystal-scale layering?), is more continuous, and is of L>S type in places. In spite of these differences, and the possibility that these foliated rocks could be part of the Bridges itself, all rocks are included with the Quarry leuconorite at this time; the mesoscopic contrasts may simply reflect differing response to deformation.

ROCKS OF MESOPROTEROZOIC AGE (NAIN PLUTONIC SUITE)

Most of the igneous rocks exposed in the Nain area belong to the NPS, subdivided in this report within the framework of field criteria and time devoted to their examination. Previously used stratigraphic identifiers are employed for some of the units, and provisional names are introduced for newly defined ones. There is little difference between the NPS here and elsewhere – it is a polyphase suite of rocks reflecting episodic emplacement of similar plutons over a protracted time.

ANORTHOSITIC INTRUSIONS (including olivine-bearing types)

This regionally monotonous group of leucocratic rocks includes a broad range of textural and compositional types. They are subdivided into separate map units where aggregated criteria justify it (Figure 1), in some cases clearly representing separate intrusions. Inclusions of texturally and mineralogically different rocks can be definitely delineated in some outcrops (e.g., sharp-edged blocks surrounded by a different rock type) and are exotic with respect to their host. However, in many cases texturally different parts of outcrops (e.g., pegmatitic bodies of leuconorite in finer leuconorite or anorthosite) have diffuse contacts with the more abundant host. These textural variants could attest variable nucleation rates within the same body, mushy cognate rafts, or small contemporaneous intrusions, rather than older solid blocks. Units for which provisional names are suggested are dealt with first. The order of presentation does not imply relative age, but some indications of observed and inferred relationships are given.

Mount Lister Intrusion

This large intrusion of pegmatoidal anorthosite and leuconorite underlies the western part of the map area, stretching from Ugjutoarsuk (Webb) Bay southward across Nain Bay. The unit is named for Mount Lister, an imposing bare, grey mountain to the northwest of Conch Bay. The intrusion is a white- to pale-grey-weathering, generally coarse-grained to pegmatoidal rock; significant fracturing and recrystallization of the feldspar is evident. The best preserved dark-grey igneous feldspars have blue-green to deep royal blue labradorite schiller, some crystals of which are in excess of a metre on a side. Orthopyroxene is usually less recrystallized than plagioclase. Coarse orthopyroxene, reaching over a metre in size locally, is widespread. Most, if not all, pyroxene has intercumulus habit in the pegmatitic parts (where it partly encloses plagioclase and is accompanied by masses of ilmenite and lesser apatite), but the megacrystic type is of less certain indigenous origin in the overall finer phases. Kinked cleavage planes are a regionally developed attribute, and in some outcrops the pyroxene clearly displays a halo of amphibole + biotite.

The Mount Lister intrusion is diffusely layered on a large scale. The layering comprises alternating pale-grey to white anorthosite to grey leuconorite, best visible on the steep cliffs of Nain Bay, Tikkokatokak Bay and Conch Bay; this feature of the Mount Lister intrusion can be better appreciated from afar (*see also* Morse and Wheeler, 1974). At Conch Bay, the layering strikes east and dips north, on the shore northwest of Cape Williams it strikes northeast and dips southeast, and on the south side of Nain Bay it strikes easterly and has a gentle dip to the south. These variations indicate a gentle domal attitude for the main part of the unit here.

The outer part of the Mount Lister intrusion north and directly south of Nain Bay comprises foliated and recrystal-

lized rocks derived principally from layered leuconorite and anorthosite and subophitic-textured leuconorite. This deformed border zone is 3 km or more wide in the Ugjutoarsuk (Webb) Bay–Conch Bay area and on the south shore of Nain Bay, but seems to be narrower or completely absent in the vicinity of Kangilialuk Lake (few observations have been made in the latter area). The foliated zone is steeply east-dipping east of Conch Bay, and moderately dipping to the east, south of Nain Bay. The foliation attitude conforms to the trace of the contact between the intrusion and its envelope, except for east of Ugjutoarsuk (Webb) Bay where a few measurements indicate that it trends oblique to the trace of contact between the pluton and the gneisses; the significance of this latter geometric relation is unclear. The border zone comprises granular, recrystallized, and foliated rocks having local preservation of primary textures and features. The fabric in leuconoritic compositions is defined by aggregates of ortho- and clinopyroxene, locally having a halo of hornblende and biotite. Many anorthositic rocks have no foliation because of their granular and annealed character, but oriented lozenges of remnant igneous plagioclase are present within less recrystallized examples (Plate 4).

Plate 4. *Dark-grey, fractured, oriented, igneous plagioclase remnants in a granular recrystallized matrix, within anorthosite of the marginal zone of the Mount Lister intrusion, shore of Conch Bay.*

The contact between the Mount Lister intrusion and the abutting gneisses has not been observed. In several places, the two are separated by a sheath of foliated monzonite (*see* later section). Gneisses proximal to the intrusion, north of Kangilialuk Lake, are laminated and mylonitic, but whether this structural attribute was caused by strain associated with pluton emplacement is not certain because it is not present everywhere.

Unity Bay Intrusion

This medium- to coarse-grained leuconorite and anorthosite intrusion comprises foliated and massive anorthositic, leuconoritic and lesser leucogabbroic rocks exposed in the vicinity of Nain, extending from Akpiksai Bay to Kauk Harbour. It is named after the bay on which the town of Nain is situated. It seems to be one of the early or diapiric intrusions of the NPS, like the Mount Lister intrusion and the Pearly Gates intrusion (Ryan, 1993) to the west. It is composed of coarse-grained leuconorite and anorthosite, but high-temperature recrystallization and deformation have modified many original features locally, especially in the north. The pre-recrystallization grain size is of 0.5 to 5 cm, but coarser parts of rock have plagioclase in excess of 20 cm. Plagioclase in the least recrystallized rocks is generally steel grey, but there is a mauve cast locally evident. Primary textures vary from seriate (1 to 10 cm equant to tabular plagioclase) to "clotted" (poikilitic orthopyroxene forming irregular clots within a more plagioclase-rich groundmass). Magnetite is widespread and usually present in most outcrops, but volumes are quite variable. The orthopyroxene is generally less recrystallized than the feldspar. Orthopyroxene, both as isolated megacrysts and as coarse intercumulus components, widely display kinked cleavages. Locally, the orthopyroxene occurs in lenses and segregations where it is accompanied by opaque oxide. Elongate aggregates of both the coarse- and fine-grained (recrystallized) pyroxene may reach in excess of 1 m in maximum dimension.

The northern part of the Unity Bay intrusion in the vicinity of Akpiksai Bay comprises rocks that are very strongly recrystallized and deformed, similar to those of the margin of the Mount Lister intrusion. A pervasive fabric defined by lenses of granular orthopyroxene and grey plagioclase lozenges in a white to pale-grey feldspar matrix trends east–west to slightly north of east, and dips steeply to the north. Deformed orthopyroxene megacrysts seem to be mostly subophitic remnants, and perhaps indigenous rather than xenocrystic. If this foliated zone does represent a "marginal facies" to the Unity Bay intrusion then the actual contact with older rocks has been excised by the fine-grained ferrodioritic rock of the outer Barth Island intrusion and by the Akpiksai Bay leuconorite that abut it to the north (*see* relevant sections below).

The Unity Bay intrusion is characterized by numerous, but widely distributed, sinuous, grey to black to brown, gabbronoritic dykes. These dykes are granular to slightly

feldsparphyric, locally have pinch-and-swell structures, and may be foliated parallel to their strike. Their bifurcating aspect implies emplacement along irregular fractures that were sites of subsequent "jostling"; they clearly crosscut the deformational fabric of the foliated zone.

The only rocks in the immediate vicinity that are older than the Unity Bay intrusion are the quartzofeldspathic gneisses and the layered mafic and ultramafic rocks forming the east–west belt, west of Unity Bay. These seem to have been originally completely enclosed by the Unity Bay anorthositic rocks, implying a roof pendant keel rather than having been peripheral to the outer margin of the pluton. The contact with the layered rocks is exposed at several places west of Akpiksai Bay and on the ridge west of Nain. The interface is sharp and only slightly transgressive to layering on the outcrop scale, but limbs and hinges of isoclinal folds within the older rock are truncated. Narrow sills of leuconorite permeate along the layering and fabric of the layered rocks, and the younger rock is foliated and recrystallized.

South Channel Cairn Intrusion

This layered to massive leucogabbro, leuconorite and anorthosite unit was previously included with the Unity Bay pluton (Ryan, 2000a). The map pattern, some textural considerations, and the geophysical signature of this unit (Ryan, 2000a, Figure 2a) are compatible with the proposal that this unit represents a different intrusion from the Unity Bay one, but firm field evidence for this is lacking. It is disposed as a gently inclined layered unit that occupies the area south of Unity Bay between Mount Sophie (south-southeast of Nain harbour) and the coast, and is named for South Channel Cairn, a prominent knoll north of Meta Cove. The predominant rock in this intrusion is a pale-grey leuconorite, locally having irregular orthopyroxene megacrysts. Abundant blue labradorite, akin to that of the Quarry leuconorite, is present in coastal exposures between Southern Point and Kauk Harbour. The South Channel Cairn intrusion displays well-developed layering (0.5 to 2 m) in its type locality, as well as near Mt. Sophie and along the coast between Southern Point and Kauk Harbour. In all cases the layering, best seen on large cliffs, is gently inclined toward the west or northwest. Generally, the layering has diffuse contacts, and in some leuconoritic layers "compacted" orthopyroxene oikocrysts locally define a crude layer-parallel foliation. On the coast near Meta Cove the unit exhibits an east–west foliation, clearly highly discordant to the primary layering orientation.

The South Channel Cairn intrusion is assumed to be younger than both the Quarry leuconorite and the Unity Bay intrusion, having the form of a mildly undulating sheet that rests on the former and dips underneath the latter. No contacts were seen to substantiate this, but several rafts of white anorthosite akin to those of the Unity Bay intrusion are present near the South Channel Cairn.

Akpiksai Bay Intrusion

This unit of massive to weakly foliated leuconorite to anorthosite, having a fairly uniform distribution to the orthopyroxene, is an elongate body west of Akpiksai Bay, from which the name is derived. It is separated from the Unity Bay intrusion on the basis of mesoscopic aspects such as texture and degree of deformation. It intrudes layered mafic, ultramafic, and leuconoritic rocks west of Akpiksai Bay.

The Apiksai Bay intrusion is mainly a medium-grained, grey, leuconoritic rock. The overall even distribution and the higher volume of pyroxene compared to the Unity Bay intrusion are two criteria used to separate the two units; in the Unity Bay intrusion, orthopyroxene is usually present as separate spongy areas producing a "clotted" texture. The Akpiksai Bay intrusion is massive to mildly foliated, and this textural contrast with the strongly deformed rocks of the Unity Bay intrusion on the coast of Akpiksai Bay is another criterion for designation of this leuconorite as a separate intrusion. Finally, rafts of white granular anorthosite like those of the Unity Bay intrusion occur within the Akpiksai Bay intrusion, adding another criterion to conclude that the Akpiksi Bay intrusion is a separate body.

Hosenbein Lake Intrusion

This intrusion of brownish-weathering leuconorite, massive olivine gabbro, and grey-weathering clotty- to seriate-textured leuconorite is an elongate pluton extending from Nain Bay south-southeast across Hosenbein Lake (from which the stratigraphic modifier is derived). It exhibits north to south and west to east variations in composition and texture. The northern part (wall?) is dominantly a brownish-weathering oxide-rich leuconorite containing dark-grey plagioclase crysts (mesoscopically similar to some ferrodioritic rocks; *see* later section). The western margin (floor) at Kangilialuk Lake is locally characterized by a medium-grained, leucocratic, biotite-bearing, olivine–gabbro or clinopyroxene–troctolite, which grades into a rather uniform clotty-textured leuconorite internally. The massive clotty-textured rock grades eastward (upward) into layered (northeast-dipping) clotty-textured rocks having rafts of foliated leuconorite and recrystallized anorthosite. The layered rocks are overlain by a seriate-textured leuconorite in which the plagioclase is white to pale grey to steel-blue-grey. Centimetre- to tens-of-metre-scale inclu-

conorite (with orthopyroxene as undeformed masses and as a foliation-forming mineral) probably derived from the Mount Lister intrusion (in the west) and from the Unity Bay intrusion (in the east) are widespread in the Hosenbein Lake intrusion (Plate 5). Such inclusions are especially abundant near the contact with the Unity Bay intrusion, so much so that the contact between the two in Figure 1 is really a "best fit" for that junction (*cf.* Ryan, 2000a, page 258).

The Hosenbein Lake intrusion appears to have the form of an easterly inclined laccolith, with its floor consisting of gneisses, and its roof dominated by the anorthositic and leuconoritic rocks of the Unity Bay intrusion. An abundance of large inclusions in its southern part may indicate that it plunges southeast underneath the Unity Bay intrusion or that roof collapse of the older rock was more extensive there than to the north.

Plate 5. *Raft of coarse-grained foliated leuconorite (in front of person), derived from the Unity Bay intrusion, supported by massive and undeformed seriate leuconorite of the Hosenbein Lake intrusion (behind person), west of Kauk Harbour.*

The Turnpikes Intrusion(s)

This massive, grey-weathering, locally olivine-bearing, leuconorite and anorthosite unit includes all the massive leuconoritic and anorthositic rocks stretching from Base Island, through Kruger Kop Island, Rhodes Island, Hillsbury Island, to Paul Island. It may encompass more than one intrusion, but no firm criteria for coherent subdivision at the 1:50 000 scale could be established. The rocks on the western part of Paul Island, especially, are doubtful candidates for inclusion in this unit. The name for this unit is derived from The Turnpikes, a couple of islets in Harmony Run, just north of Rhodes Island (Figure 1).

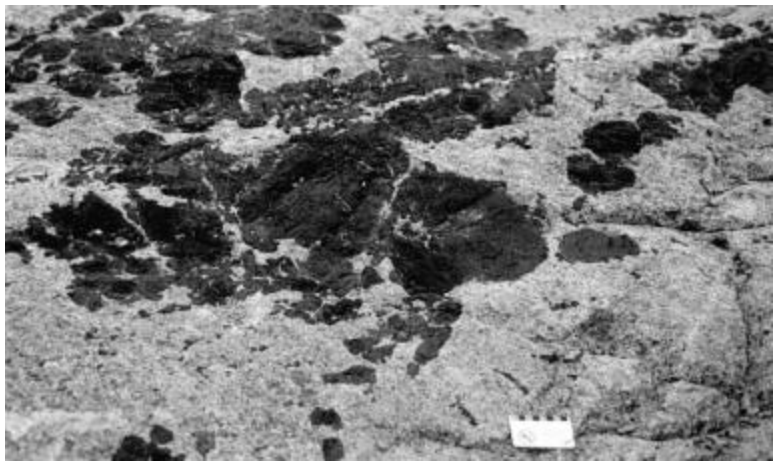


Plate 6. *An aggregate of "exotic" orthopyroxene megacrysts within anorthosite of The Turnpikes intrusion(s), north shore of Rhodes Island.*

The Turnpikes intrusion comprises mostly white, pale-grey, brownish-grey to mauve-grey anorthosite and leuconorite. There are lesser leucocratic rocks in which olivine seems to be the dominant mafic silicate (e.g., northeast point of Base Island). The grain size varies from medium grained to very coarse grained (feldspars up to 30 cm) and it is recrystallized locally. There is a seriate aspect to the plagioclase tablets in the most pyroxene-rich of the leuconorite members. Megacrysts of orthopyroxene, both as isolated individuals and as trains of many anhedral crystals, are locally present (Plate 6). Some of the "exotic" orthopyroxene megacrysts, as well as those that are subophitic and indigenous to the leuconorite, have olivine cores. Dark-grey plagioclase megacrysts, as noted above, are widely distributed, and there are local indications that disaggregated dark-grey anorthosite (slightly older cumulate?) contributed to the crystal population. A common, although not universal, texture is a north-of-east preferred orientation to the feldspar; rare layering has the same trend, and dips moderately (30 to 60°) to the north. Within this unit some of the rocks have a distinctive yellowish-green labradorite schiller to the feldspars, especially evident on both sides of Shoal Tickle and on one of the islands east of Base Island.

An abundance of foliated leuconoritic inclusions characterizes the unit through eastern Rhodes Island and northeast of Two Mile Bay (Plate 7), probably derived from proximal foliated rocks. Foliated rocks through central Base Island seem to be a large raft of older material within the massive rocks of this unit, and foliated inclusions are also present on the islands in the bay east of Base Island. Inclusions of foliated olivine-bearing leuconoritic rocks are also

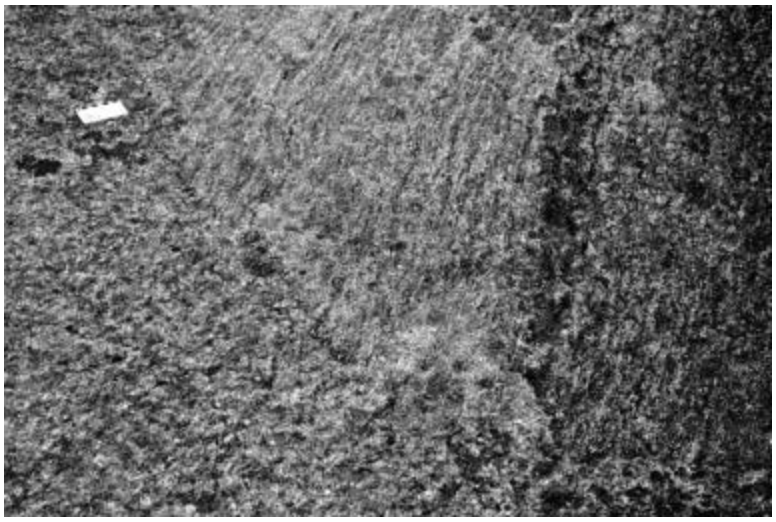


Plate 7. *Contact, running diagonally (upper left to lower right) across photo, between a raft of foliated leuconorite and enclosing massive leuconorite, Paul Island. Host is assigned to The Turnpikes intrusion(s) whereas the foliated inclusion is considered to be derived from foliated rocks assigned to the Quarry leuconorite.*

present on southeastern Base Island and form a lenticular belt along the northern shoreline of Hillsbury Island. One raft of massive leucotroctolite is present on the larger of The Turnpikes, and one large raft of layered rocks from The Bridges sequence was observed east of Two Mile Bay.

Halfway Point Intrusion

This mottled to clotty textured leuconorite unit occurs south of Sachem Bay, and its stratigraphic designation comes from the local name for a point in the bay. The outline of this unit is based mainly on one particular field attribute, namely, the presence of irregular patches of oikocrystic orthopyroxene ("clotted texture") that give most outcrops a mottled aspect. It is generally pale-grey- to brownish-grey-weathering in shoreline outcrop, but white inland; it takes on a greenish hue where chloritized. Grain size of the feldspar tablets is generally 1 to 2 cm, and the oikocrystic pyroxene exceeds 10 cm. There is some hint of a subhorizontal orientation to elongate oikocrysts, but nowhere could a consistent and reliable orientation for this feature be measured.

First Rattle Intrusion

Rocks assigned to this massive grey-weathering anorthosite and leuconorite unit seem to outline a pear-shaped pluton that underlies the coastline of First Rattle (for which the unit is named) and extends north through Itilialuk Peninsula and south through Sakotalik Summit.

The First Rattle pluton comprises massive pale-grey to dark-grey anorthosite and leuconorite, having varying volumes of dark-grey to black plagioclase crystals (Plate 8) that locally show a preferred northeast orientation (Figure 1). The anorthosite within this pluton commonly has a hairline fracture array on weathered surface that resembles cracked glazing on pottery. Darker grey leuconorite, locally crumbly and having olivine within the core of the orthopyroxene, occurs along the eastern part of the pluton between Itilialuk Peninsula and Sandy Point. The First Rattle pluton contains numerous inclusions of foliated leucotroctolite and olivine-bearing leuconorite between Topsy Point and Sandy Point, presumably derived from the nearby foliated rocks (*see* below); there is a correlation between the presence of olivine-bearing inclusions and the presence of olivine in the host, but the significance is unclear.

This pluton may the youngest anorthositic pluton in the immediate area because the map pattern implies that it crosscuts the abutting anorthositic units and is transected only by the eastern edge of the composite Barth Island intrusion and the Satorsoakulluk ferrodiorite dyke.

Foliated Leuconorite, Leucotroctolite and Anorthosite

This subdivision encompasses all the streaky-foliated to massive rocks – leuconorite, olivine-bearing leuconorite, leucotroctolite and anorthosite – exposed in the Base Island–Rhodes Island–Sandy Point area. It includes rocks in which olivine (mm to 1 by 0.5 m scale) occurs either alone (leucotroctolite) or as cores to orthopyroxene (olivine leuconorite); even in the most olivine-rich rocks orthopyroxene may be present as an atoll that separates some olivine from plagioclase. Olivine seems to be completely absent from some of the leuconoritic and anorthositic rocks assigned to this unit, but may be too sparse to be readily identified in the field. It is possible that several different intrusions are represented by this subdivision. There is no implication that all such foliated rocks are coeval, and the unit may, encompass some Paleoproterozoic rocks. The westward extrapolation of this unit between Sandy Point and the lower part of Sachem Bay (Webb Neck) is conjectural because of limited data from this area.

Nearly all the northern part of Base Island is underlain by foliated olivine leuconoritic to leucotroctolitic rocks having a northerly trend and moderate east dip (Plate 9). Large (xenocrystic?) olivine crystals (on the order of 50 cm) hav-

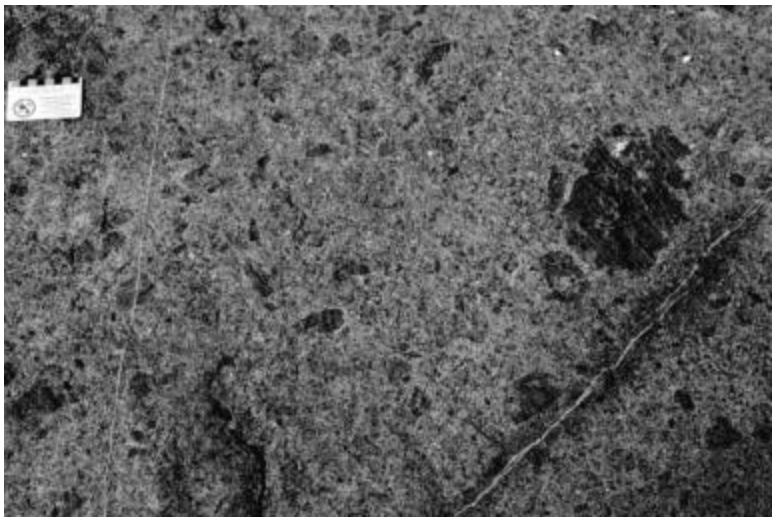


Plate 8. *Dark-grey plagioclase megacrysts within lighter grey anorthosite of the First Rattle intrusion, shoreline of First Rattle.*

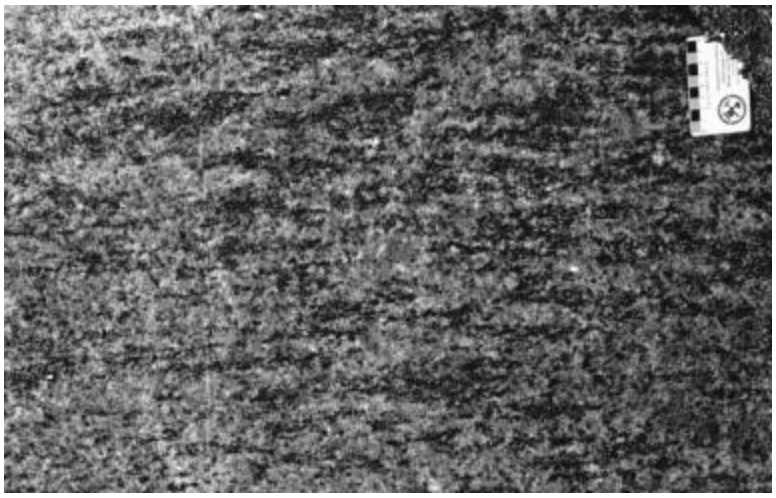


Plate 9. *Streaky foliation within (olivine bearing??) leuconorite, north shoreline of Base Island.*

ing an orthopyroxene halo, are locally present in some of these rocks. These rocks are white-weathering on the coast, but have a reddish streaky nature inland. Biotite and hornblende are intergrown with, and form replacement rims on, pyroxene in most of these rocks. Foliated rocks in the poorly exposed centre of Base Island, as well as similar foliated rocks on the southeast peninsula of the island and on islands in the bay to the east, are assumed to be large inclusions or inclusion-rich regions comprising rocks equivalent to those on the north shore of the island, but suspended within The Turnpikes intrusion(s).

Foliated rocks at the western end of Rhodes Island are anorthosite and leuconorite, layered on centimetre- to metre-scale, having remnants of coarse orthopyroxene and displaying a fabric defined by lozenges and streaks of orthopyroxene. Anorthositic rocks are granular and recrystallized but lack a pervasive foliation. No olivine was seen here.

The rocks addressed above are intruded by The Turnpikes intrusion(s), as demonstrated by the truncation of foliations and the presence of inclusions at outcrop scale and at map scale. The unit is also intruded by, and rafts of it occur in, the First Rattle anorthosite and leuconorite. Also, it is assumed to be intruded by the eastern, ferrodioritic, margin of the Barth Island composite intrusion, but the contact was not directly observed and the mapped interface between the two units is concordant with the foliation in the anorthositic rocks.

Layered, Locally Foliated Anorthosite and Leuconorite

(not shown on Figure 1)

A massive to weakly layered, locally foliated, white (recrystallized) and mauve-grey (nonrecrystallized) anorthosite and leuconorite unit of unknown age and full extent is well exposed on the southeastern, eastern and northern flanks of the northeastern part of the ridge west of Nain. It lies to the north of the east–west-trending Archean-layered mafic and ultramafic rocks on Figure 1. Leuconoritic rocks of this unit are intrusive into the layered sequence. This unit varies from crystalline and granular–granoblastic to igneous textured. It includes massive grey-mauve anorthosite, and coarser leucocratic rocks having subophitic orthopyroxene over 10 cm in diameter. Diffusely layered and weakly foliated brownish granulitic to leucogranulitic (gabbronoritic) varieties, as well as massive, black, salt-and-pepper mafic "granulites" having plagioclase megacrysts, are also present. The diffusely layered rocks are the "stratigraphically lowest" ones exposed, and they are apparently transitional upward into pale-grey to white granular to igneous-textured leuconoritic rocks having granular pyroxene streaks, orthopyroxene megacrysts, local pale-blue labradorite plagioclase, and inclusions of pegmatoidal leuconorite and white anorthosite.

Seriate-Textured Leuconorite

Seriate leuconorite was partly outlined and briefly described following reconnaissance work on the highland west of Sachem Bay in 1992 (Ryan, 1993). It is fairly uniform throughout the area, being an overall grey leuconorite, locally having a rusty patina, and characterized by large

blocky dark-grey plagioclase (including 10 to 15 cm megacrystic xenocrysts) surrounded by a white, somewhat granular (recrystallized) matrix having subophitic texture (Plate 10).

It has intruded the layered ultramafic to anorthositic Archean(?) rocks on its northern side, and the eastern margin of the Mount Lister intrusion (including a foliated monzonite) on its western side. Rafts of foliated and recrystallized anorthosite and leuconorite are common locally at the contact with the Mount Lister intrusion (Plate 11). The topographic distribution of older rocks indicates the layered rocks on the western side of the leuconorite lie above the intrusion, and the monzonite and recrystallized anorthosite and leuconorite abutting it to the west are similarly part of the western roof to the intrusion.

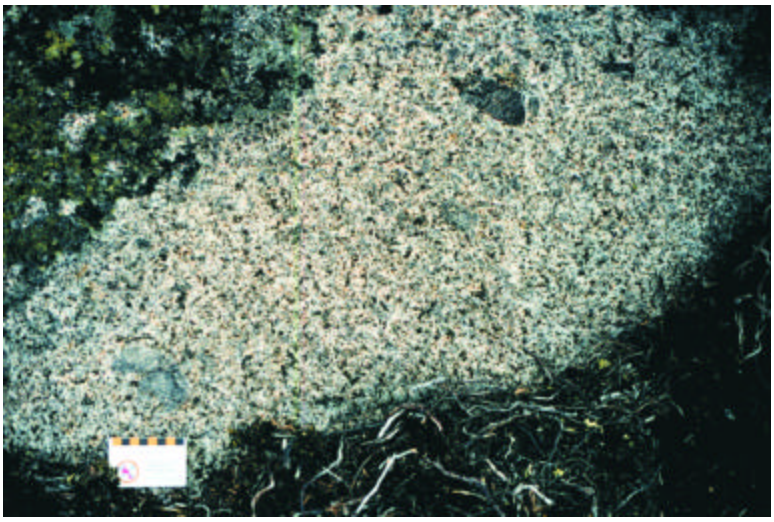


Plate 10. *Dark-grey subhedral plagioclase megacrysts enclosed by a seriate leuconorite matrix, west of Sachem Bay.*

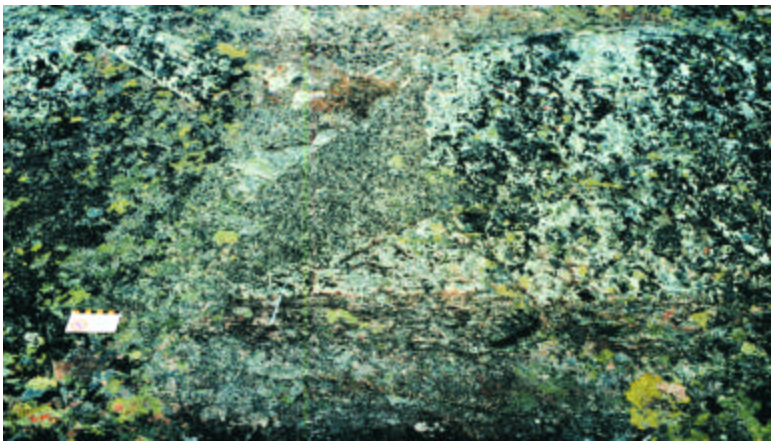


Plate 11. *Angular blocks of recrystallized anorthosite and foliated leuconorite (lower part of block at right) suspended within massive undeformed seriate leuconorite, west of Sachem Bay. The blocks are interpreted to be spalled from the deformed and annealed margin of the Mount Lister intrusion and are common along the contact between the two units.*

Massive, White to Pale Grey-Weathering Anorthosite and Leuconorite

Medium-grained to pegmatoidal (20 cm plagioclase), white-weathering, generally uniformly subophitic-textured, variably recrystallized anorthosite and leuconorite underlies the central part of the Itilialuk Peninsula. Zones of darker feldspar megacrysts in this unit have a consistent southeast trend (Figure 1). Intercumulus combinations of olivine, orthopyroxene, and opaque oxides occur in some parts of the pegmatoidal members of this unit. Rafts of older foliated leuconorite occur along the central southeast shoreline of the peninsula. Seemingly peculiar to this unit are several sulphide gossans (tens of square metres in size) developed over interstitial pyrrhotite (Plate 12).

This unit is assumed to be intruded by massive dark grey anorthosite of the First Rattle intrusion to the west, but a 2 km-wide, gravel-covered saddle obscures the actual contact; the interpretation is reasonable based on the recrystallized state of this intrusion and the non-recrystallized First Rattle intrusion. It is also reasonable to conclude that this unit is older than the fresh troctolitic rocks of the Port Manvers Run intrusion (see below), but these two were not seen in contact either.

Massive Anorthosite, Leuconorite and Leucogabbro

Massive, white- to pale-grey-weathering anorthosite, leuconorite and leucogabbro occur on the eastern end of Barth Island, but their designation as a remnant of an intrusion separate from others in the area is ambiguous. The unit comprises variably recrystallized anorthosite, leuconorite and leucogabbro. Grain size is typically 1 cm, but plagioclase megacrysts reach up to 40 cm. Unlike similar rock at Itilialuk Peninsula, there is no preferred alignment to feldspar megacrysts. Orthopyroxene is poikilitic, and magnetite is common in the leuconoritic parts of unit. Olivine is rare or absent, appearing to be present only in irregular pegmatitic parts of one outcrop examined, where it is associated with orthopyroxene and magnetite.

This unit forms the floor to west-dipping ferrodiorite of the eastern margin of the Barth Island composite intrusion (*see* section "Barth Island ferrodiorite"). The junction between the two is exposed; significant thermal metamor-

Plate 12. *One of several sulphide gossans within leuconorite of the central Itilialuk Peninsula. Note the sharp contact between mineralized and unmineralized rock.*

phic effects – if there are any – from the overlying younger intrusion are not obvious in the older rock.

TROCTOLITIC INTRUSIONS

This subdivision includes the Barth Island troctolite (part of the Barth Island composite intrusion) as well as all other rocks in which olivine is a modally important mineral over a wide area. These intrusions comprise a texturally diverse group of generally unfoliated rocks in which the grain size varies between fine grained and pegmatitic. They are separated from the olivine-bearing anorthositic and leuconoritic rocks described in the foregoing section because olivine is the most abundant, and in many cases the only, mafic mineral recognized in field exposures encapsulated by the unit boundaries. Orthopyroxene is also present in these rocks, but rarely is it the major mineral. Each of the outlined units is a product of a discrete magma batch, and together they seem to record (protracted?) episodic emplacement of magmas capable of crystallizing olivine. Troctolites on Barth Island and north of Sachem Bay seem to be intimately associated with abutting ferrodioritic and granitic rocks. In both these areas, all three major rock types may collectively form composite intrusions, but without sufficient data the troctolite north of Sachem Bay is designated with a separate stratigraphic identifier than the abutting ferrodioritic and granitic units.

Barth Island Troctolite

This unit has been subjected to several detailed field, petrographic, and geochemical studies over the last three decades, most notably by D. de Waard and his students at Syracuse University during the Nain Anorthosite Project (*cf.* de Waard and Mulhern, 1973; de Waard, 1976; Rubins, 1973; Levendosky, 1975; Mulhern, 1974). The distribution of the Barth Island troctolite outlined north of Nain Bay is based mainly on these earlier surveys.

The Barth Island troctolite forms a fault-offset, ring-shaped body, extending from the south shore of Nain Bay across the eastern and western parts of Barth Island to the north shore of Nain Bay. It is a pale greyish-green- to brown-weathering, fine- to medium-grained rock, generally displaying ophitic to subophitic texture, and varying compositionally from leucotroctolite to troctolite to olivine gabbro. Olivine locally has a narrow halo of orthopyroxene; biotite and brown hornblende are also widely distributed, but seeming to be most prominent adjacent to granitoid rocks. The troctolite is generally devoid of sharply developed layering, but has diffuse and discontinuous compositional variations in places (e.g., south shore of Nain Bay, east end of Barth Island), allowing determination of the inclination of the ring.

Contacts between the troctolite and the surrounding rocks are ambiguous and conflicting, probably reflecting the close temporal relationship between all the rocks in the Barth Island intrusion:

i) The interface between the troctolite and the underlying monzonite south of Nain Bay is sharp, and the attitude of the contact, as well as the weak layering in the troctolite, are parallel to a primary foliation in the monzonite (*see* section "Granitoid Rocks of the Barth Island Intrusion"). A thin veneer of fine-grained ferrodioritic(?) rock above the monzonite marks the actual contact, and may be gradational into the troctolite. Troctolite above the monzonite has numerous irregular and anastomosing aplitic charnockitic (orthopyroxene-bearing granite) dykes (not equivalent to the late biotite-bearing aplitic granitic dykes so widespread in the region).

ii) The contact between monzonite (too small to illustrate at the scale of Figure 1) and troctolite at the west end of Barth Island is characterized by angular rafts of amphibolitized, biotite-bearing troctolite enclosed by the granitoid rock, and straight-walled granitoid dykes transect the troctolite.

iii) Along the northwest margin of the Barth Island intrusion north of Nain Bay the troctolite is in sharp contact with ferrodioritic and hybrid rocks. Foliation in the fer-

rodiorite and hybrid group is truncated in map-view by the nonfoliated troctolite.

iv) Troctolite is assumed to be intruded by, and overlain by, the ferrodiorite through the centre of Barth Island but extensive Quaternary cover on the island obscures the contact.

Tikkiraluk Hill Troctolite

Troctolite north of Sachem Bay is assigned the name of the prominent peak, Tikkiraluk Hill, at its northwest edge. The Tikkiraluk Hill troctolite is a fine- to medium-grained rock, similar to that within the Barth Island intrusion. It is generally massive, but has a diffuse, shallowly inclined, northeasterly dipping, centimetre-scale layering along its southwestern margin. Poikilitic orthopyroxene is recognizable locally, and biotite is prominent adjacent to granite west of Tikkiraluk Hill itself.

The troctolite intrudes and overlies gneisses on its northern side and is transgressive to the mapped outline of granitoid rocks on its northwestern and western sides (latter too small to show on Figure 1; *see* Ryan, 2001). One exposed contact with the granitoid rocks is similar to that described above within the Barth Island intrusion – a narrow zone of fine-grained, hybridized rock (mafic host having quartz and feldspar xenocrysts; perhaps ferrodioritic), sits atop the granitoid, and this hybridized rock passes transitionally upward into the troctolite. A transgressive and intrusive contact with the abutting ferrodiorite to the west also seems reasonable, based on the map pattern and on the contact with granitic rocks associated with the ferrodiorite. The Tikkiraluk Hill troctolite is, however, older than the First Rattle pluton, the contact between the two being exposed at the north entrance to Sachem Bay.

Port Manvers Run Intrusion

This unit of dark-grey to black leucotroctolite is present in the northeast part of the study area, and was examined in reconnaissance manner only. It comprises medium- to coarse-grained, dark-grey to black troctolite, and is assumed to be part of the Port Manvers Run intrusion that forms a more extensive unit to the east and north (Wiebe, 1983, p. 66, 1992; Xue and Morse, 1993). No contacts with abutting rocks were directly observed, but the map pattern indicates that it is intrusive into granulite-facies gneisses, Paleoproterozoic(?) metagabbro, and Mesoproterozoic recrystallized anorthositic rocks in the Challenger Cove – Itilialuk Peninsula area. Isotopic data derived from zircons extracted from hornblende–biotite–quartz-bearing pockets within troctolite along the shoreline north of Challenger Cove are interpreted to signify crystallization at 1308 ± 2 Ma (M.A. Hamilton, written communication, 2000).

Troctolitic Rocks on Paul Island

This unit of leucotroctolite, troctolite, and orthopyroxene-bearing troctolitic rocks occurs east of Two Mile Bay on Paul Island, and was originally demarcated by Wiebe (1990a). It is here considered to be of slightly greater areal extent than depicted by Wiebe (*op. cit.*), encompassing massive and diffusely layered olivine-bearing rocks along the lower cliff levels on the north shore of the island. The revised map pattern may be interpreted as indicating that the leuconorite occupying the higher elevations of the island, and assigned to The Turnpikes intrusion, is actually a roof to the troctolite here. Grey leucotroctolite, leuconorite and anorthosite occupying the southern part of Hillsbury Island (*cf.* Emslie, *in* Berg *et al.*, 1994, pages 53-54) are assumed to be a continuation of this unit. This correlation across Strathcona Run is not firm because the Hillsbury Island rocks are generally more leucocratic than the norm for similar rocks on Paul Island; the northern part may, however, represent a different "facies" of the intrusion.

The western central part of this unit on Paul Island has the form of an east-dipping dyke comprising a slightly chaotic array of irregular to lenticular reddish-weathering troctolite, blotchy-red leucotroctolite and grey to black anorthosite (*cf.* Wiebe, 1990a; Miller *et al.*, 1996). Both Wiebe (*op. cit.*) and Miller and co-workers (*op. cit.*) indicated that this dyke transects leuconorite in this area, but the actual contact between the two is in many places generally very difficult to perceive. Red-weathering troctolite similar to that in the dyke, and having diffuse lenticles of grey anorthosite, also occurs on the shoreline of Ten Mile Bay and the north shore of Paul Island, where pegmatitic zones contain olivine in excess of 30 cm. The western contact of the unit thus seems to reflect relations at different levels in the intrusion - the sea-level contact being a wall, and that at the higher elevations being the roof where the overlying leuconorite fractured and allowed magma to ascend through it. The latter relations are at variance with those advocated by Wiebe (1990a, p. 6) who considered the contact between The Turnpikes leuconorite (his unit NLN) and the leucotroctolite (his unit LTR) to be gradational. The younger age, and thus separate intrusion, for the troctolitic unit is also suggested by the apparent difference in mechanical effect that each had on older rocks – the leuconoritic rocks are regionally choked with foliated inclusions whereas the "younger" olivine-bearing rocks seem to be entirely lacking them.

Most of the inland part of the unit examined east of Two Mile Bay is a dark-grey, friable, orthopyroxene-bearing leucotroctolite, olivine-bearing leuconorite and olivine anorthosite, having plagioclase a few centimetres to a few tens of centimetres long; plagioclase megacrysts are locally present. Olivine in this unit has an orthopyroxene rind, and

the interstitial orthopyroxene has olivine cores. Local textural considerations imply olivine was a cumulus mineral, subsequently overgrown and replaced by the intercumulus orthopyroxene. The unit is devoid of significant structure that could be used to indicate geometric and stratigraphic relations within the intrusion. One outcrop having northeast-striking and moderately northwest-dipping layering was observed on the north shore of Paul Island.

The troctolitic rocks of this unit intrude the eastern side of The Bridges layered sequence. One outcrop east of Two Mile Bay exposes a transgressive contact between foliated leuconorite (assigned to the Quarry intrusion) and the western side of the troctolite.

Tessiuyarsuk Intrusion

Troctolitic rocks – including leucotroctolite, troctolite and olivine-bearing leuconorite – in the lowland at the entrance to, and east of, Tessiuyarsuk (Saltwater Pond) are assumed to be the northern margin of a larger intrusion, the youngest in the immediate area. It was identified as a separate anorthositic subdivision by Wheeler (1969) and Rubins (1971, 1973), both of who termed it a "dark facies" to distinguish it from "pale facies" rocks to the north of it. This intrusion comprises medium- to coarse-grained, friable rocks, generally dark grey, having interstitial olivine and orthopyroxene from 1 to 20 cm in size. It intrudes layered mafic to mesocratic Archean gneisses and the Mount Lister intrusion within the study area. Extrapolation of contacts, based on the work of Wheeler (1969), implies that the Tessiuyarsuk intrusion also crosscuts the Hosenbein Lake pluton south of the study area.

DIORITIC INTRUSIONS

This is a texturally diverse group of rocks that includes the Barth Island and Sachem Bay ferrodioritic rocks as well as several large dykes in the area. These rocks are generally of gabbronoritic composition (i.e., having two or more pyroxenes), and generally without the subophitic texture that characterizes the anorthositic plutons. The names of the rocks that fall within this category of intrusions have been a matter of debate (for historical overview *see* Appendix *in* Ryan, 1993). They were referred to as "jotunitic" by de Waard (1976) because of the widespread presence of minor modal volumes of potassium feldspar and quartz, but the term "ferrodiorite" is used here to maintain continuity with recently proposed nomenclature (*cf.* Wiebe, 1990b; Emslie *et al.*, 1994). These intrusions are overall finer grained than the anorthositic plutons, but locally there are coarser variants. They are enriched in opaque oxide minerals (magnetite and ilmenite); orthopyroxene (inverted pigeonite) oikocrysts are widely distributed, and locally postdate the development of igneous fabrics in these rocks. Mingling with contemporaneous granitoid magmas is indicated on outcrop scale by the nature of the contacts between mafic and silicic rocks.

Barth Island Ferrodiorite

This all encompassing unit includes the rocks extending from the south shore of Nain Bay across Barth Island and north of Nain Bay, both below and above the troctolite unit. It is an overall texturally diverse group of rocks varying from homogeneous granular types to "porphyritic" types in which phenocrysts and/or xenocrysts of feldspar may be present either as single and/or multigrain components having oval or lenticular form. Olivine is present in some, and inverted pigeonite is widespread. The lower unit locally exhibits a mingled and hybridized relation to monzonitic rocks abutting it, but such mingled rocks are apparently absent from the central (upper) unit on the island. The ferrodioritic rocks within the Barth Island composite intrusion have been studied by de Waard (1976), Mulhern (1974) and Levendosky (1975). The ferrodiorite on the western end of Barth Island has a zircon crystallization age of 1322 ± 2 Ma (Hamilton *et al.*, 1994; M. Hamilton, personal communication, 2000). It should be noted that a southwest-projecting "appendage" of ferrodioritic rocks south of Pilaluyak Islet is shown on Figure 1 as being an offshoot of the southern Barth margin, but this is a very liberal interpretation. This projection includes a layered oxide-rich rock mapped by Rubins (1971, 1973), coarse-grained and oxide-rich rocks cutting anorthosite on the shore to the east, and fine-grained rocks abutting gneisses inland from the cove. None of these may be genetically part of the Barth Island composite intrusion, but could be an older group that has been truncated by the Barth ferrodioritic rocks.

East-dipping, layered rocks, clearly derived from a composite and mingled group of magmas (Ryan, 2000a), is exposed at the western tip of Barth Island. Compositional variations here indicate pulses of single-component and hybrid magmas. Present are orthopyroxene-poikilitic (inverted pigeonite), fine-grained, ferrodiorite having load-casts into monzonitic rocks underlying it (Ryan, 2000a, Plate 11), and streaky-textured "porphyritic" rocks comprising variable concentrations of perthite and/or quartz-cemented blocky plagioclase crystals in a ferrodioritic matrix (Ryan, 2000a, Plate 20). Trough structures imply current/erosional activity. Ferrodioritic rocks here also have irregular pegmatoidal quartz–feldspar–hornblende–biotite patches (captured silicic magma?), adjacent to which poikilitic black hornblende is developed within the enclosing finer grained rock. The relation of the western Barth Island layered sequence to the overlying granitoid suggests that the latter has a cumulate fayalite-bearing base that grades upward into a paler, more quartz-rich granitoid rock;

granite above the layered sequence is intruded into the overlying troctolite in this area.

The easternmost ferrodioritic unit at the type-area for the Barth Island intrusion is a granular variety that exhibits abrupt grain size and compositional changes, is locally enriched in streaks of feldspar xenocrysts, and has a weak compositional layering. Here, too, poikilitic orthopyroxene (inverted pigeonite) is locally present.

Granular gabbronoritic rocks ("granulites") below monzonite on the south shore of Nain Bay, referred to as a "zone of noritic rocks" by Rubins (1973), are texturally different from most of the ferrodioritic rocks at the same relative stratigraphic level on western Barth Island. Those on the mainland are uniform granular, lack the sharply defined and composite layering, have isolated crystals and trains of dark-grey plagioclase and associated leuconorite (possibly representing a disaggregate earlier cumulate), are diffusely foliated/banded, and have "seams" of pyroxene. These also have abundant disseminated opaque oxide.

Ferrodiorite along the northwest margin of the Barth Island body was examined in a cursory manner only and its distribution there, as well as all the northern part of the intrusion, is taken from the work of Mulhern (1974). The ferrodiorite comprises fine-grained homogeneous and hybrid rocks locally having abundant streaky trains of feldspar crystals. The northern and eastern parts of the unit near Sachem Bay have more coarser grained gabbroic textured rocks than elsewhere. The aeromagnetic signatures of rocks within the northern part of the Barth Island composite intrusion (*cf*. Ryan, 2000a, Figure 2b) indicate that the distribution of ferrodiorite shown on Mulhern's map may not be correct. The whole area is now part of a graduate study by Mr. Owen Gaskill at Memorial University.

The ferrodiorite above the troctolite on the north shore of Barth Island is an olivine-rich gabbroic rock that is texturally diverse: coarser (pyroxene and olivine up to 7 cm) and finer phases (equigranular rock with grains <0.5 cm) are interspersed in abrupt to apparent gradational contact (differing nucleation rates in a single magma or juxtaposition of two partially crystalline magmas having differing crystal development?). Poikilitic orthopyroxene (inverted pigeonite?) occurs in the finer grained rocks along the north shore in places; pegmatoidal granitoid patches having poikilitic hornblende are also locally present. Central Barth Island has few exposures of the uppermost unit, but those examined there indicate that the rock is granular and the grain size is on the order of 0.5 to 1 cm. Poikilitic orthopyroxene and poikilitic black hornblende are both present locally, and there are scattered crystals of intergrown potassium feldspar and plagioclase. Some rocks of this stratigraphically highest unit seem to be monzodioritic and monzonitic in composition, and some contain quartz. Locally, there is an abundance of irregular to globular, fine-grained, basaltic enclaves. Some of the globules are elongate when viewed on vertical surfaces, and some contain xenocrysts of Carlsbad-twinned potassium feldspar.

Several sharp contacts indicate that the lower ferrodiorite unit is intrusive into, and dips inward from, the enveloping rocks. The most definitive contacts are the sharp interfaces with leuconorite on eastern Barth Island and with gneisses at the eastern tip of a small islet (not shown on Figure 1) west of Barth Island. Contacts between generally coarse-grained gabbroic rocks and the adjacent leuconorite and anorthosite plutons on the north side of Nain Bay are less well defined. The nature of the contact between the external ferrodiorite halo and the leuconoritic rocks west of Akpiksai Bay is not fully documented apart from a 500 foot (165 metre) hill directly east of Pikaluyak Cove where ferrodiorite abuts leuconorite and includes rafts of massive to foliated anorthositic rock as well as coarser grained (older?) ferrodiorite like that on the hillside to the south. The contact between the "upper" ferrodiorite and the abutting troctolite has not been observed.

Sachem Bay Ferrodiorite

This ferrodiorite intrusion was initially identified during reconnaissance work near Sachem Bay (Ryan, 1993, 2000a). It underlies a large area north of Sachem Bay and a smaller triangular area south of the Bay. The components of the Sachem Bay unit are overall similar to those in the Barth Island intrusion, in being brown-weathering, granular to somewhat gabbroic-textured, friable, rocks having local abrupt grain-size variations. The Sachem Bay ferrodiorite is locally a hybrid rock, having patchy, but seemingly regional, distribution of potassium (?) feldspar crystals; interstitial quartz is widespread in this unit. Irregular, greenish-brown oikocrystic orthopyroxene (inverted pigeonite) is locally obvious, and the white to grey plagioclase generally lacks well-defined crystal outlines; rare dark-grey feldspar crystals are assumed to be xenocrystic. Olivine is locally present and poikilitic hornblende and/or biotite can be seen in some outcrops. Ilmenite, magnetite, or both, can be abundant; the oxide generally lacks the clear intercumulus habit of that in the anorthositic rocks, forming instead irregular globules and lenticular concentrations.

Mingled contacts with adjacent "rapakivi" quartz monzonite, which locally forms diffuse-bordered lenses within it, can be seen in many places. The geometry of this intrusion is uncertain. Its outer border conforms to the curving outline of the granitic rock to the north, and seems to be steeply dipping to the east and south. Internally, however,

the topographic distribution between interlayered lenses of granitic rocks and the diorite implies a subhorizontal attitude. Field criteria to ascertain geometry are sparse, but several examples of gently north-dipping layering have been observed near Sachem Bay.

The Sachem Bay ferrodiorite intrudes quartzofeldspathic and mafic gneisses north of the Bay and contains rafts of layered mafic granulitic rocks on the north shoreline of the Bay. It is assumed to intrude seriate leuconorite south of Sachem Bay; the contact was not observed, but the relation is implied by the map pattern and from one raft of seriate-type leuconorite within ferrodiorite near the shore of western Sachem Bay. It may be older than, and intruded by, Halfway Point mottled leuconorite on the west side of Sachem Bay, by Tikkiraluk Hill troctolite north of the Bay, and by First Rattle leuconorite near Webb Point; no direct contact was observed in either case, but map pattern implies the relative age.

Granular Brownish Ferrodiorite

A ferrodiorite of unknown stratigraphic context stretches northward from the Barth ferrodiorite east of Conch Bay. It is very similar to the Barth ferrodiorite and could merge into the Barth rocks in a sandy valley to the south, but is considered herein to be a separate and unrelated unit because of its setting. It defines a narrow sheath separating the western border of the seriate leuconorite from Archean gneisses, and is clearly intrusive into the latter. The unit has not been mapped out completely, and may not be continuous; in places, it seems to be just a metre thick. It is, like the other ferrodioritic rocks in the region, a brown, granular rock that is predominantly massive but does locally display a streaky layered character. A hybrid variety, having schlieren of coarse monzonite, is also present, and it contains dark-grey plagioclase crystals like those of the adjacent leuconorite. At its southern end, it dips gently eastward underneath the leuconorite, but the contact between the two is diffuse.

Satorsoakulluk Ferrodiorite Dyke

This large, gently curving, dyke of granular, brownish, ferrodiorite can be traced from Barth Island to Base Island. It was shown on the earliest map of the region by Wheeler (1942) and was studied in more detail by de Waard and Hancock (1974). On Barth Island and northwest of Sandy Point it is a fine- to medium-grained, brown-weathering, single, planar intrusion, but on Base Island it comprises several narrower parallel intrusions. A smaller birfurcating dyke, assumed to be part of the same episode of magmatism, occurs on one of the islands in the bay east of Base Island (Figure 1), extends westward through the shoreline of Base Island and disappears inland under gravel. The Satorsoakulluk dyke crosscuts all other major map units in the Nain area, but is itself transected by numerous veins and dykes of grey "granodiorite" and pink granite and by a couple of diabase dykes of the easterly trending swarm (*see* later section). Zircons in this rock give a U–Pb crystallization age of 1315 ± 2, whereas the badelleyite crystallization age is 1301 ± 2; zircons are considered to be inherited, whereas the badelleyite age reflects the time of crystallization of the dyke magma (Hamilton *et al.,* 1994).

The Satorsoakulluk dyke is a composite body on the south shore of Barth Island (Ryan, 2000a), having an abundance of angular xenoliths, many of which are exotic with respect to its walls. Fragments noted in the dyke here include anorthosite, gneisses, ultramafic rocks, layered oxide-bearing ferrodiorite, hybrid diorite having granitic veins, and a diatremic breccia having a diversity of rounded clasts including granitic, ultramafic and calc-silicate rocks and milky quartz. These xenolithic fragments are suspended within a composite matrix, comprising a slightly porphyritic medium-grained ferrodiorite and a pillowed fine-grained phase. The finer grained rock exhibits dumb-bell and diapiric structures consistent with syn-magmatic deformation, due to viscosity contrasts between the differing phases of the composite magma when it engulfed the fragments (Plate 13). Exotic fragments within the dyke also occur on Base Island where the dyke crosscuts foliated, olivine-bearing rocks; the fragments within it are nearly all nonfoliate seriate-textured leuconorite, clearly not derived from the immediate walls.

Oxide-Rich Sulphide-Bearing Ferrodiorite
(not shown on Figure 1)

Rusty, locally oxide(magnetite)-rich ferrodioritic rocks were the primary target of exploration by NDT Ventures during their investigation of mineralized rocks in the Nain area between 1996 and 1998 (*cf.* Hinchey *et al.,* 1999; Hinchey, 1999). The unit includes those rocks that comprise the series of interconnecting sheets and dykes – a stockwork – west of Akpiksai Bay as well as smaller dykes on the ridge west of Nain perhaps encompassing more than one generation of intrusions. They are all dark-brown to rusty, granular, gabbronoritic (?) rocks having abundant magnetite and subordinate sulphide; in some cases the silicate crystals are supported by an oxide matrix, indicating the latter was probably a liquid during dyke emplacement. There is a local diffuse layering west of Akpiksai Bay, and many of the smaller dykes are layered parallel to their trend. The rocks are locally porphyritic, but also contain dark-grey plagioclase crystals that may be xenocrysts. The main mass west of Akpiksai Bay appears to have exploited the intrusive contact between foliated leuconoritic rocks of the Unity Bay pluton

Plate 13. *Indications of the physical interaction between a xenolith and the engulfing composite magma within the Satorsoakalluk ferrodiorite dyke on the south shore of Barth Island. The magma in this part of the dyke was a two component system: a slush of crystals, within which was suspended mushy mafic pillows. The pillows were torn apart and compressed against (underneath??) a rigid angular piece of layered oxide-rich dioritic rock that was suspended in, or fell into, the magma.*

and massive leuconoritic to anorthositic rocks of the Akpiksai Bay pluton. There are field indications that these ferrodiorite rocks are older than the Hosenbein Lake intrusion – such dykes are found in inclusions of Unity Bay pluton within the Hosenbein Lake leuconorite, but are apparently absent from the enclosing leuconorite itself. The relationship to the Barth Island ferrodiorite has not been established.

GRANITIC INTRUSIONS

The largest masses of granitic rocks in the area are mostly coarse grained, encompassing those interpreted to be of cumulus as well as intrusive origin with respect to some of the rocks they abut. They run the gamut from massive to strongly foliated, the latter having fabrics attributed to igneous as well as post-crystallization processes; many contain olivine. In addition to these, granitic dykes are widespread, and quite probably represent several episodes of such magmatism (*see* "Minor Intrusions" section).

Foliated Monzonite and Quartz Monzonite

This semi-continuous massive to strongly foliated, augite + fayalite-bearing, porphyritic monzonite and quartz monzonite unit is traceable from east of Ugjutoarsuk (Webb) Bay as far south as Kangilialuk Lake (the narrow southern extent is not shown on Figure 1). It is disposed as a sheath between the foliated border of the Mount Lister intrusion and the enveloping gneisses. The presence of deformed granitoid rocks adjacent to the Mount Lister intrusion west and northwest of Ugjutoarsuk (Webb) Bay was indicated by Ryan (1993). Geochronological investigation of zircon from one such unit exposed northwest of Ugjutoarsuk (Webb) Bay indicated a crystallization age of 1343 ± 3 Ma (Connelly and Ryan, 1994) The monzonitic rock is, in most cases, deformed like the Mount Lister border, but east of Ugjutoarsuk (Webb) Bay, where it is widest, it is much less foliated than south of Nain Bay. The less deformed and wider unit of the present study area was identified during the earlier reconnaissance work as well, but at that time was thought to be a younger intrusion (Ryan, 1993, p. 69).

The rocks assigned to this unit normally weather pale pink or white, but are distinctly green on fresh surface where olivine has not been altered; fresh samples give a "tinny" sound when struck with a sledge. East of Ugjutoarsuk (Webb) Bay the monzonite is a diffusely layered, fine-grained, brown to pink, massive rock having a few scattered potassium feldspar crystals. Elsewhere the rock was coarser grained; for example, south of Nain Bay it displays an augen texture in which mesoperthitic feldspar lozenges and lenticles of quartz are preserved within an anastomosing recrystallized matrix.

The contacts between the monzonitic sheath and its enclosing rocks, where directly observed, are "tectonic". The granitoid rock displays the same style of foliation as the abutting deformed leuconorite of the Mount Lister margin (Plate 14), implying simultaneous deformation, and the foliation is parallel to the layering of the bounding gneisses. The unit east of Ugjutoarsuk (Webb) Bay is assumed to be intruded by, and form part of the roof to, the seriate leuconorite to the east; the surmised relation is based on map pattern between the two units because no direct contact has been observed.

Granitoid Rocks of the Barth Island Intrusion

This massive to foliated, augite + fayalite-bearing granitoid unit, which could be broadly characterized compositionally as charnockitic, encompasses all the granitoid rocks within the Barth Island composite intrusion north and west of Akpiksai Bay, at the west end of Barth Island (too small to show on Figure 1) and north of Nain Bay. These rocks may be products of more than one pulse of silicic magmatism. They occupy different stratigraphic levels within the intrusion, and are absent from the eastern side of the intrusion on Barth Island itself. They were termed "adamellite" by de Waard and his students (de Waard, 1976; Rubins, 1973; Mulhern, 1974).

These rocks weather pale grey to slightly rusty to pale buff; a bluish-green cast characterizes rocks in which olivine and clinopyroxene are abundant. They vary from even grained to porphyritic, locally having perthitic feldspar phenocrysts a few centimetres long. Oval grains of quartz ("drop quartz") are quite conspicuous in most rocks of this unit, and hornblende and biotite are present. Many outcrops display a foliation that seems to have been formed prior to full consolidation of the crystal mass. Elongate mafic enclaves, having feldspar xenocrysts from the enclosing granitoid, are widely distributed, and exhibit cuspate and embayed contacts against their host; these enclaves were probably derived from basic dykes intruded into and disrupted within the silicic crystal mush.

Plate 14. *Foliated monzonitic rocks (dark), part of the deformed sheath marginal to the Mount Lister intrusion, in contact with foliated leuconorite (light-coloured rocks), south shore of Nain Bay. The deformed monzonite separates the foliated leuconorite of the Mount Lister margin here from Archean gneisses, the latter off the photo to the right.*

The granitoid parts of the Barth Island intrusion have ambiguous contacts with their surroundings. The contact with the overlying troctolite on Pikaluyak Islet and the south side of Nain Bay, for example, is sharp, but there is a very thin veneer of fine-grained ferrodioritic(?) rock separating coarse quartz monzonite from troctolite (Plate 15). The finer grained rock and the monzonite are mingled along this contact; the interface is locally lobate, and irregular streamers of monzonite interfinger with the fine-grained rock. Along this contact, too, irregular buff-weathering aplitic charnockitic dykes penetrate the troctolite above the contact; it is possible that the troctolite was emplaced across a substrate of unconsolidated monzonite cumulate, and the dykes represent filter-pressed silicic magma expelled upward.

Plate 15. *Lobate contact between fine-grained gabbronorite (ferrodiorite), which is overlain by troctolite here, and coarse-grained fayalite quartz monzonite (cumulate?), within the Barth Island composite intrusion at the southwest edge of Pikaluyak Islet.*

The contact of the monzonitic rock with the underlying fine-grained rock (ferrodiorite) south of Nain Bay is abrupt, but this interface, too, seems to be a mingled one. The monzonite becomes white-weathering within 10 m or so of the contact with the finer mafic rock and is locally foliated along this junction. The interpretation of the original nature of the contact is equivocal; it may either represent one where the dense ferrodiorite magma was emplaced as a sill along a contact between solid leuconorite and a slushy monzonite cumulate, lifting the latter from its "basement", or one where the monzonite was emplaced across a floor of rusty ferrodiorite.

The contact between ferrodiorite and quartz monzonite is also exposed at the west end of Barth Island. Here the monzonitic rocks grades from a coarse-grained feldspar-enriched base of cumulus character (sitting against fine-grained ferrodiorite) to higher levels of finer grained (<1 cm) monzonitic to quartz–monzonitic rock in which some potassium feldspar crystals have plagioclase mantles (rapakivi texture). The latter rock type contains angular biotite-porphyroblastic troctolite inclusions near the contact with the troctolite.

The unit to the north of Nain Bay has a different stratigraphic position than to the south, totally encased by massive ferrodiorite, hybrid rocks, and coarser gabbroic rocks. The relationships between the units remain uncertain.

Granitoid Rocks North of Sachem Bay

Fayalite-bearing granitoid rocks form arcuate bodies and also irregular masses (the latter too small to show on Figure 1) associated with the ferrodiorite in the highland region north of Sachem Bay. It is quite likely that the ferrodioritic and granitic rocks here are part of a single composite intrusion. These granitoid rocks are generally coarse grained, slightly brown to white-weathering, and pyroxene- and olivine-bearing, within which some variants are particularly quartz-rich. Rapakivi characteristics – oval feldspars and aggregates of "drop quartz" – are apparent in some outcrops. Poikilitic black hornblende is locally prominent, especially in the white-weathering variants. Like the Barth Island granitoids, mafic enclaves are widely distributed, and a pre-full-consolidation foliation is locally developed. Some of the examples of this granitoid rock, internal to the ferrodiorite and associated hybrid rocks and too small to portray on Figure 1, seem to be cumulates.

This granitoid rock has intruded the gneisses west of Webb Point; blocks of gneiss occur in the granitoid, and granitic dykes cut the gneiss. It is interpreted to be intruded by the Tikkiraluk Hill troctolite. The interface between the troctolite and the granite just north of Sachem Bay is sharp, but features imply that the granitic rocks may not have been totally solid at the time of contact with the troctolite. For example, the troctolite is fine grained (could be a ferrodiorite) at the contact and contains sparse feldspar and quartz xenocrysts from the underlying rock; the fine-grained massive rock passes into coarser troctolite within 5 m of the contact, a relation analagous to the contact between monzonite and troctolite south of Nain Bay.

MINOR INTRUSIONS

These rocks are subordinate with respect to the other igneous rocks of the area, and may embrace a wide age range. They include, particularly, the regionally widespread outcrop-scale mafic and silicic dykes, as well as other more continuous dykes. None of these units is portrayed on Figure 1, but many are displayed on the 1:50 000 map (Ryan, 2001).

Kaiktusuak Dykes

Northwest-trending massive, slightly porphyritic, fayalite–augite monzonite dykes, up to 25 m in width, seemingly almost exclusively within the Mount Lister pluton, are named Kaiktusuak dykes for the steep face of pale anorthositic rock atop which they are well displayed. The only known occurrence of such rock outside the Mount Lister intrusion is a dyke of overall coarser grained granitoid rock in the gneisses south of Kangilialuk Lake that is interpreted to be an extension of a monzonite crosscutting the Mount Lister body. These dykes exhibit sharp, straight-walled contacts with older rocks, and are interpreted to have been emplaced well after the deformation of the Mount Lister margin. It cannot be fervently argued that the Kaiktusuak dykes predate the other plutons, but this may well be the case. They are generally fine grained, yellowish-brown- to white-weathering rocks, having abundant mesoperthite. Rare feldspar phenocrysts are present. Like all the fayalite-bearing granitoid rocks in the area they are distinctly bluish-green on fresh surface.

Gabbronoritic Dykes

Black and dark-grey "granulitic" or gabbronoritic (ferrodioritic?) dykes, locally biotite-bearing, include a diverse group of fine- to medium-grained, two-pyroxene rocks likely of several generations. Regionally, they exhibit combinations of any of the following features: granular, massive, foliated, straight-walled, lobate-walled, sinuous, steeply inclined, and subhorizontal. Such dykes are most abundant in the Unity Bay intrusion and the Mount Lister intrusion. The foliated ones seem to have been locally deformed prior to complete crystallization by movement of opposite walls of their host. Biotite produces a prominent foliation locally, and many dykes are oxide-rich.

Composite Mafic–Silicic Dykes

Mafic-silicic dykes are believed to be of several generations. One dyke of this type has intruded deformed Paleoproterozoic(?) metagabbro on George's Island. Numerous brown to dark-grey composite dykes are found within the Mount Lister pluton and its sheath of monzonite; these vary from a few tens of centimetres to tens of metres in thickness. The composite dykes are subhorizontal in the anorthositic rocks in the vicinity of Mount Lister peak and Nain Bay, but subvertical in the monzonite east of Ugjutoarsuk (Webb) Bay. The dykes in the Mount Lister–Ugjutoarsuk (Webb) Bay area generally comprise a pyroxene-bearing granitic network separating a more abundant component of fine-grained two-pyroxene mafic rock having a pillow form. It is apparent from field relations that these dykes postdate the deformation and recrystallization of their hosts, but are themselves internally foliated and deformed (including having small-folds between the two components; Plate 16). A single undeformed composite dyke, unrelated to the foregoing, occurs within the eastern ferrodiorite of the Barth Island intrusion at Webb Neck along the north shore of Nain Bay; here a biotite-hornblende diorite is in a pillowed relationship with aplitic biotite leucogranite.

Plate 16. *Folds, some of which are partly transposed and intrafolial, defined by the contrast between the felsic and mafic components of a deformed, gently dipping, composite dyke on Mount Lister. The original, pre-deformation, relation here was probably pillows of the mafic component surrounded by the felsic network.*

Gabbro, Diabase and Feldsparphyric Dykes

This group of olivine + Ti-augite gabbro and diabase, and feldspar porphyritic dykes encompasses several generations of straight-walled intrusions. The marginal zones of coarse east-trending gabbro dykes at the entrance to Tikkoatokak Bay, the shoreline of Kauk Harbour, and the entrance to Ten Mile Bay have a spongy and diffuse layering normal to the dyke walls. The majority of the dykes are east and north trending (Wiebe, 1985), but the relative age of these two "swarms" has not been determined in this area. There is, however, some evidence of the relative age of other dykes. A densely feldsparphyric dyke on the ridge above the town of Nain trends southeast and crosscuts a north-trending olivine diabase. A northeast-trending diabase crosscuts a coarse-grained east-trending olivine gabbro at the entrance to Ten Mile Bay, but other dyke intersections have not been seen.

Granitic Dykes

These rocks abound in the area. They include pink, grey, and white aplitic and pegmatitic granitic dykes of several ages. Most of these dykes have biotite as the mafic constituent, and many contain allanite. Some dykes have pronounced graphic texture between quartz and microcline. They vary from subhorizontal to subvertical, but rarely exceed a metre wide. A particularly large subhorizontal dyke, approximately 8 m thick and composed of layered aplitic and pegmatitic phases, has intruded the Satorsoakulluk dyke on northern Barth Island. Included with this group of minor intrusions are grey- to white-weathering hornblende-bearing quartz–monzodioritic or granodioritic dykes cutting the Satorsoakulluk dyke on northern Base Island. One grey granitic dyke included in this group, within leuconorite on a small island near Base Island, is charnockitic, i.e., it contains orthopyroxene and clinopyroxene. The grey granitoid dykes, at least locally, pre-date a pink granitic type. It is possible that, in some cases, the granitic dykes could be used to distinguish between plutons. For example, the Unity Bay intrusion and the South Channel Cairn intrusion have dykes showing several strike orientations but the Hosenbein Lake intrusion seems to have only a northeast-trending group (Ryan, 2000a, page 267), implying that the first two anorthositic intrusions were affected by more episodes of granitic dyking than the last.

ECONOMIC GEOLOGY

The immediate Nain area was subjected to close scrutiny by several exploration companies during the intensive search for Ni–Cu sulphides following discovery of the Voisey's Bay deposit, in 1994. Particularly noteworthy in this regard were efforts by NDT Ventures proximal to Nain and on Paul Island. Archean Resources Limited examined the composite Barth Island intrusion, and Kernow Resources conducted an examination of the dioritic rocks on the southern shore of Sachem Bay. Some claim blocks initially staked over the rocks of this area were never the focus of anything beyond cursory geophysical, geological and prospecting surveys by the stakeholders, following which interest was lost and nothing further was done.

The most dedicated examination, by far, of the economic potential of the rocks in the type-area of the NPS was that undertaken by NDT Ventures Limited between 1996 and 1998. It concentrated its effort at determining the source of sulphide gossans developed on the ridge immediately behind Nain and to the northwest of Akpiksai Bay. The results of the work have been documented in several assessment reports on file with the Geological Survey (*cf.* Barbour and Dearin, 1996). The setting of the gossans is also given by Kerr (1998), Hinchey *et al.* (1999), Hinchey (1999), Ryan (2000a) and Kerr and Ryan (2000), all of which give additional details of the sulphide prospects based on independent field work and examination of NDT core.

The most prominent zone of gossanous rock in the immediate area of Nain is located west of Akpiksai Bay where Fe-staining affects magnetite-rich dioritic rocks and the anorthositic rocks they intrude. NDT referred to this area as the "Valley Zone". The extent of the gossans gives a false

impression of the amount of sulphide present – the dioritic rocks here are a stockwork of subvertical to subhorizontal sheets, and the sulphide that contributes to the rusty colour is simply widely distributed across the surface but has limited thickness. Drilling indicated that several such sheets and associated veins are probably present in the subsurface, but none have extraordinary volumes of Ni–Cu bearing sulphide minerals (*cf.* Hinchey *et al.*, 1999).

The ridge west of Nain, and for a couple of kilometres to the west, displays rusty zones associated with sulphide mineralization. NDT referred to these prospects as the "Unity Zone" (*cf.* Hinchey *et al.*, 1999). In most cases the mineralization is within centimetre- to metre-scale-wide magnetite-rich dioritic and pyroxenitic dykes that intrude, fragment, and postdate foliation and recrystallization of, the Unity Bay intrusion. Many of these dykes appear to have limited strike length, and some bifurcate and terminate along strike as narrow fingers. The most prominent gossan of the eastern part of the Unity Zone is visible in the cliff above the town, where a pyrrhotite vein, probably genetically linked to the dioritic dykes, has intruded mafic granulite. Lesser sulphide stain is present within and adjacent to oxide-rich dykes. Pyroxene-rich dykes in the western Unity Zone are similarly sparsely mineralized. Oxide-rich dykes like those that host the mineralization in the Unity Zone do not intrude the Hosenbein Lake intrusion, indicating that the particular episode of dyking represented by these mineralized rocks predates emplacement of the Hosenbein Lake intrusion. Therefore, such dykes would not be expected to occur westward of the contact between the Hosenbein Lake intrusion and the Unity Bay intrusion, except within inclusions enclosed by the former.

NDT also conducted exploration and a limited drill examination of a sulphide prospect within the northern part of the dyke defining the western extent of the leucotroctolite unit on western Paul Island (Barbour and Dearin, 1996). Several subhorizontal lenses of massive to disseminated magmatic sulphide, covering several square metres, occur in this area, and were tested by drilling in 1996 (Miller *et al.*, 1996). Surface sampling indicated nickel at 1.29%, Cu at 2.01% and 0.91% Co. The drilling intersected disseminated and stringer-style sulphides and confirmed the nickel contents of the surface sampling, but no subsequent work was carried out. The setting of the mineralization here indicates that it is associated with a troctolitic dyke filling a roof-fracture in older leuconorite, but the genetic relationship – if any – of the troctolite to the mineralization is not known.

Archean Resources Limited conducted a cursory examination of the Barth Island intrusion in 1995 for Voisey's Bay Nickel Company Limited, which included reconnaissance geological mapping, prospecting and ground follow-up of airborne geophysical anomalies (Butler and Osmond, 1996). One prospective target was defined north of Nain Bay – termed the Lucy showing – comprising semi-massive pyrrhotite, but assays of samples from it failed to indicate significant nickel or copper values (maxima of 3210 ppm and 6080 ppm, respectively). A surface showing of semi-massive pyrrhotite west of Akpiksai Bay also yielded low base-metal assays (6030 ppm Ni; 4010 ppm Cu) . The settings described by Butler and Osmond (*op. cit.*) indicate that the showing north of Nain Bay occurs within the troctolitic member of the Barth Island composite intrusion, whereas the Akpiksai Bay showing may be within oxide-rich dioritic rocks akin to those on the abutting NDT Ventures claim block.

Magnetite-rich ferrodiorite south of Sachem Bay was investigated by Kernow Resources in 1996 (Watters, 1996; Scott, 1997). Two north-trending magnetite-rich zones were identified during the initial surface investigation of the claim area, each over a metre wide and several tens of metres in strike continuity. Base-metal values determined from surface sampling are low, but the oxide-rich layers contain over 15 percent each of iron and titania (Watters, 1996). A gossanous zone is also reported in gneisses of this area (Hattie, *in* Watters, 1996), but no information regarding metal values is available. Five holes drilled into the ferrodiorite in late 1996, to test geophysical anomalies, encountered several zones, up to several metres thick, of massive to semi-massive and disseminated magmatic sulphide and oxide mineralization within 200 m of the surface (Scott, 1997). Metal values from the best sections were found to be low (2950 ppm Ni, 3890 ppm Cu, 861 ppm Co).

At least three gossanous zones, reaching several tens of metres in maximum dimension, occur within the partly recrystallized leuconorite and anorthosite of the central Itilialuk Peninsula. These zones (*cf.* Plate 12) are irregular to elongate and have sharp to diffuse contacts with the host rock. It is difficult to conclude from outcrop if these are inclusions of mineralized rock within a younger host or whether they represent pockets of trapped sulphide liquid indigenous to the intrusion. The freshest mineralized samples indicate that the sulphides form thin networks that follow the boundaries of silicate grains and occupy hairline fractures of the silicate grains. Surface samples of typical rusty leuconorite from the zone on the northeast shore of the Itilialuk Peninsula returned values of 0.27% each of Ni and Cu. Rusty zones similar to those on Itilialuk are also evident on southern Hillsbury Island, but only one was directly traversed. Here the host is a reddish-tinged dark-grey to pale-grey leuconorite in which olivine can be identified as cores to some of the orthopyroxene. An assay of one sample from this area returned very low base metal concentrations (<20 ppm).

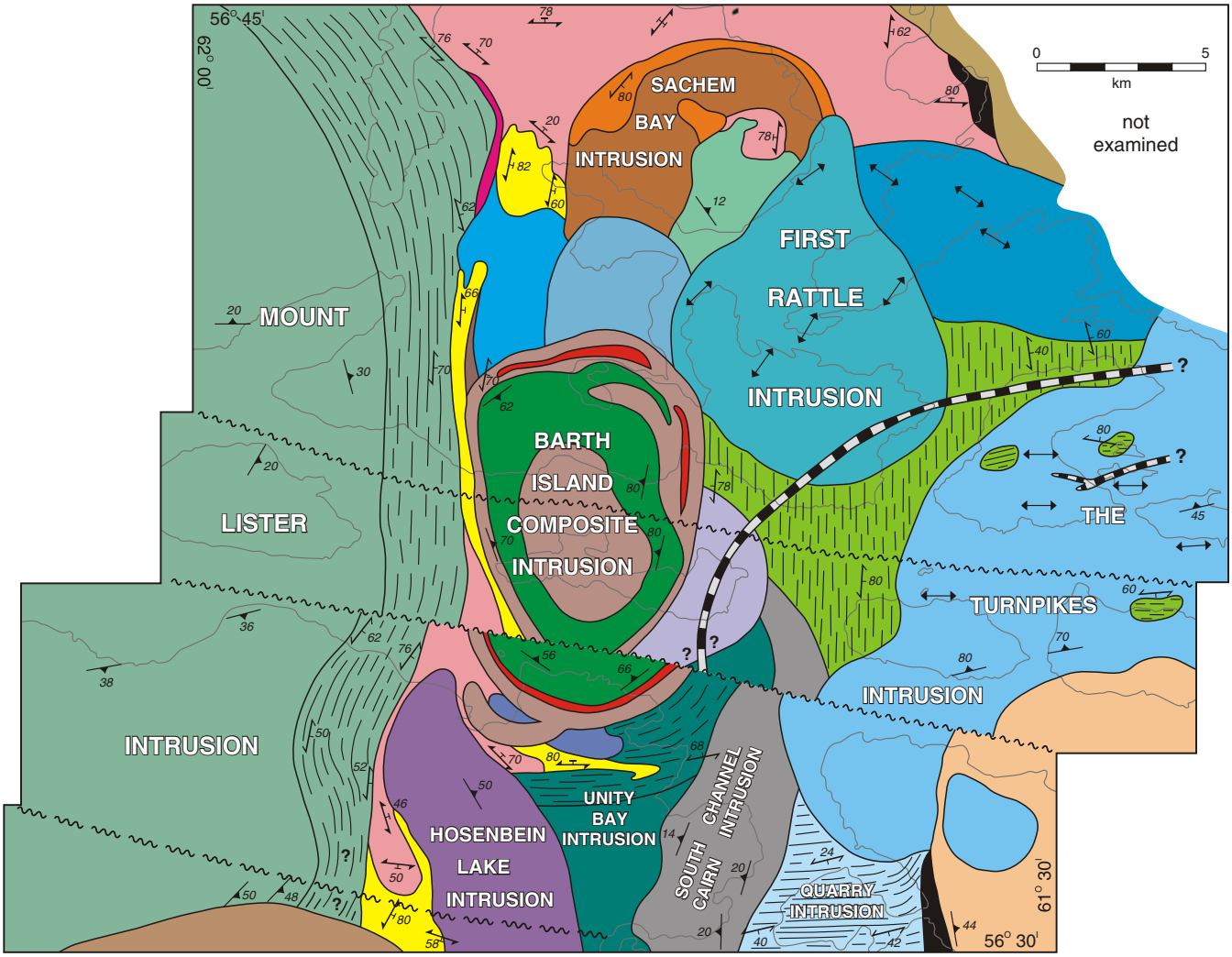


Figure 2. *Interpretation of the geology of the Nain area in terms of nested and impinging intrusions. The pattern is derived by removing the offset of units along the east-by-south, assumed vertical, sinistral faults (*see *Figure 1). Note that the southern part of the Barth Island composite intrusion has been "centred" by removing the 3 km of strike-slip movement on the fault south of Barth Island; the projection of contacts, along with the inclination of layering in the intrusion, indicate that this fault has approximately 2000 m of up-throw to the north, a feature not adjusted for in this reconstruction of projected boundaries. The up-throw on the Barth Island block across the northern fault is on the order of 400 m and has been ignored here in joining the off-set contacts. See Figure 1 for complete legend.*

The various locations and colours of labradorite were documented in last year's report (Ryan, 2000a, p. 272-3). The yellow-green variety in the Turnpikes intrusion of the Shoal Tickle–Base Island area occurs within a rock that has a grain size similar to the stone having the blue colour being quarried at Ten Mile Bay. Outcrop areas with a wide distribution to the yellowish colour were not encountered, but larger areas of such rock having appropriate structural integrity for exploitation as dimension stone may be present in this general area. Sites suitable for dimension-stone extraction may also exist within the massive pale-grey anorthosite underlying the hills between First Rattle and the south arm of Sachem Bay.

SUMMARY AND DISCUSSION

Sufficient data are now available to allow for a reasonable subdivision of the geology of the Nain area at a 1:50 000 scale. Over twenty different intrusions, or parts thereof, are present, some of them partly encased by gneissose rocks (Figure 2). Field observation and map patterns have been used as the main basis for arriving at the relative ages between some of the units. The fact that the absolute age of many of the defined units is unknown is a big impediment in establishing a more concrete geological history of the Nain area. The current state of knowledge indicates that the Nain area represents an overlapping region of Paleopro-

terozoic and Mesoproterozic magmatism, with similar basic rocks being the products of both episodes. The oldest igneous rocks for which geochronological data are available are those of The Bridges, a Nd–Sm investigation indicating crystallization ca. 1667 ± 75 Ma. The youngest rocks for which a precise age has been determined is the Satorsoakulluk dyke, which crystallized at 1301 Ma. The country-rock to both the Paleoproterozoic and Mesoproterozoic intrusions is a gneissic terrane of assumed Archean age, but even within this latter group are rocks that bear a strong resemblance to those of the younger magmatism.

Important geological questions are raised by the present work, the answers to many of which are dependent on geochronological data. For example:

1. Are the well-layered ultramafic and mafic rocks between Sachem Bay and the southern part of the study area, assigned herein to the Nain Province, really Archean? If not, does this imply that the quartzofeldspathic gneisses, which contain numerous inclusions of mafic and ultramafic rock like that of the layered sequence, are likewise not Archean? Are the "garnet ghosts" in these layered rocks a signature of decompression prior to NPS magmatism or were the disequilibrium conditions induced by tectonic conditions extant during the emplacement of the NPS itself?

2. Is The Bridges intrusion really a remnant of an otherwise unknown period of magmatism in the Nain area? Knowing for certain that the Quarry leuconorite predates The Bridges intrusion, as suggested herein on the basis of map pattern, would add another Paleoproterozoic pluton to the list of intrusions of this age known in the Nain area (*cf.* Connelly and Ryan, 1999). Rather than being part of the early Paleoproterozoic group, however, this intrusion may be part of the magmatism recorded by the abutting Bridges sequence. An "old" age for this leuconorite pluton may account for the unique characteristics that make it an attractive dimension stone (*cf.* Ryan, 2000a).

3. Preliminary data derived from a geochronological study of zircon from foliated monzonite proximal to the Mount Lister intrusion indicate a crystallization age of 1343 ± 3 Ma (Connelly and Ryan, 1994), making it one of the earliest manifestations of NPS magmatism. Does this similarly provide a reasonable age for the crystallization of the Mount Lister intrusion itself? Does this age also signify the time of imposition of the (syn-emplacement? early post-crystallization?) deformational foliation common to both the Mount Lister intrusion and its monzonite sheath? Is the Unity Bay intrusion, which includes a marginal-type foliated zone in the north, also an "old" NPS intrusion? What is the age of the swath of foliated anorthositic rocks that occurs between Base Island and Rhodes Island?

4. One interpretation of the map pattern indicates that emplacement of the Sachem Bay ferrodiorite is temporally separated from emplacement of the Barth Island ferrodiorite by the intrusion of at least one anorthosite pluton (Halfway Point leuconorite) – is this a valid absolute relationship? Are both these dioritic (gabbronoritic) intrusions products of open-system magma chambers, as suggested by the relationship with the local granitoid rocks?

5. Is the First Rattle intrusion really, as indicated here, the youngest such intrusion in the immediate area?

6. What is the cause of the widespread chloritization and epidotization (Ryan, 2000a) evident in the rocks of the study area? Were some of the coarse epidotes in the anorthositic rocks generated by late magmatic processes?

7. Is the intense deformation locally evident in the gneisses proximal to the deformed margin of the Mount Lister intrusion a product of pluton emplacement?

Regardless of the answers to the above questions, it is difficult to escape the conclusion that the NPS in its type-area is an amalgamation of plutons of diverse composition, reflecting some 50 million years of magmatism. Emplacement mechanisms seem to have varied, and the inferred geometry of the intrusions points to morphologies including broad domal (e.g., Mount Lister intrusion), bowl-shaped (e.g., Barth Island composite intrusion), and monoclinal sheet-like (e.g., South Channel Cairn intrusion) forms. One interpretation of the structural data for the Mount Lister intrusion and its sheath of monzonite, for example, is that the two ascended simultaneously in the solid state from below the current erosion level, and were deformed simultaneously. The Barth Island composite intrusion, on the other hand, represents a magma chamber that evolved by periodic influxes of several magma types at the present level. Junctions between foliated and unfoliated rocks within the Barth Island intrusion imply that the lower part of the body, comprising ferrodiorite, quartz monzonite, and hybrids of both, was locally deformed as a crystal mush, perhaps due to sagging of the chamber floor, prior to the emplacement of the overlying troctolite and another ferrodiorite. Deformation prior to complete solidification is also a mechanism that can account for the structures exhibited by the composite dykes within the Mount Lister intrusion. The Hosenbein Lake intrusion and the South Channel Cairn intrusion are both sheet-like bodies that seem to have been passively emplaced

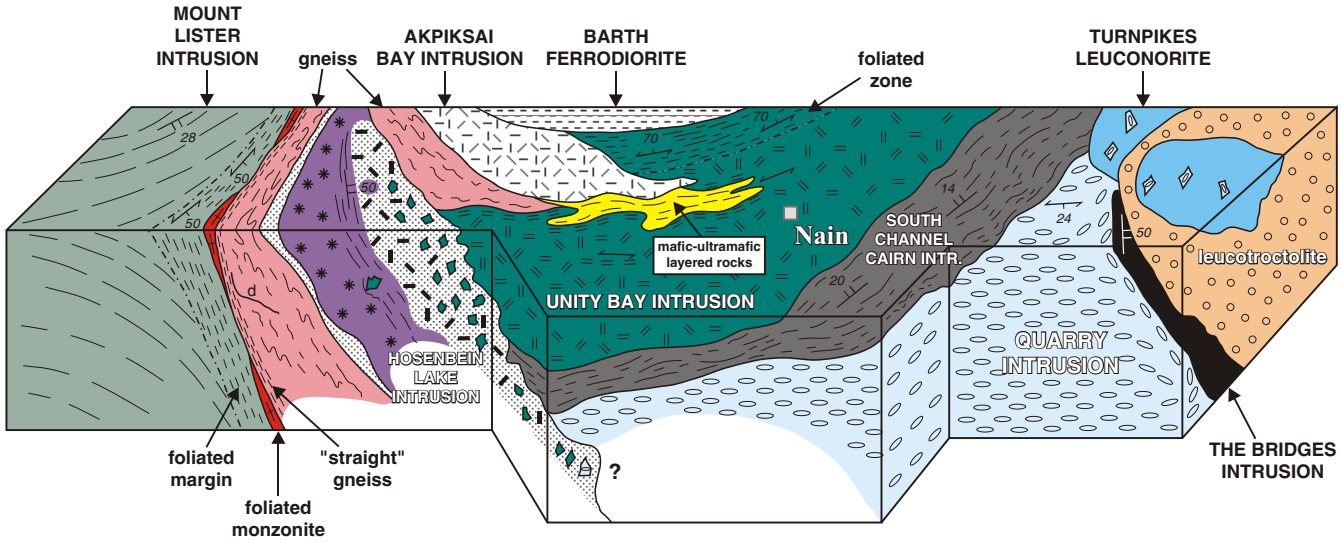


Figure 3. *A schematic block diagram to illustrate the interpreted relationships between some of the units across the southern part of the study area. This rendering is not to scale, and is meant only to illustrate the possible differing geometries and contact relationships of the intrusions (*see *text for discussion). d = dyke in Archean gneisses. Patterns in Hosenbein Lake intrusion represent the internal zonation, from troctolitic rocks at the base, through clotty-textured leuconorite, layered leuconorite, to seriate leuconorite with numerous rafts of older rock at the top.*

into the Unity Bay intrusion, but have opposing dips and are assumed to be of differing ages. Some of the surmised relations between, and internal configuration of, the intrusions south of Nain Bay are shown in a schematic fashion in Figure 3.

Field relations and absolute ages, from here and elsewhere, indicate that the magmatism of the NPS is repetitive, and cannot be viewed as a single long-lived event during which the anorthositic and granitic rocks are derived by fractionation from a single precursor magma. De Waard and his students (*cf.* de Waard and Mulhern, 1973; Levendosky, 1975; de Waard, 1976), for example, did not recognize multiple magma pulses in the Barth Island composite intrusion nor the possible existence of several different anorthositic plutons as the county-rock. They genetically linked the Barth and all its envelope of anorthositic rocks, which manifested itself in a rather fanciful model of gravitative overturn between dense and lighter magma resulting from differentiation of a single parent (*cf.* de Waard and Mulhern, 1973). Other past models have also linked rock types in the NPS as being simple differentiation of a single magma. Morse (1969) had suggested that the anorthositic and granitic rocks of the NPS could be fractionally derived from a basaltic parent. He postulated ultramafic cumulates at lower levels of a large magma chamber, the lighter plagioclase floating to the top to form anorthositic rocks, and the granitic residuum that developed between the two being expelled upward around the plagioclase cumulates and peripheral to the roof by "frequent tectonic pulses". He viewed the troctolitic rocks as separate intrusions. De Waard and Wheeler (1971) took a slightly different approach, suggesting that a single granodioritic magma fractionated to produce troctolite and syenite at deeper levels and anorthosite and granitic compositions at higher levels. In this model a large pool of magma is gradational from acidic compositions at the top to troctolitic compositions at the base. Morse (1972) revised his view of the NPS when he proposed a two magma model – a low-potassium, high-alumina basalt for the anorthosite, and an andesitic one to produce the granitic (adamellitic) rocks. Other models for anorthosite genesis have evolved over the past thirty years (*cf.* Morse, 1982; Duchesne, 1984; Longhi *et al.*, 1999), all familiar to students of anorthosite studies, the most widely accepted being that of Emslie *et al.* (1994). Simply put, in the last-mentioned model the anorthositic rocks are products of contamination of an upper mantle basaltic magma pond by lower crustal residual mafic granulite following expulsion of mobile components from the region as granites. The simplicity of this model is attractive, and the existing geochronological data broadly support it, in as much as most of the largest granitic units of the NPS are older than most of the anorthositic intrusions. The generation of anorthositic rocks over a 60-million-year interval does pose problems, however, because it requires continuous "basification" of the lower crust in order to provide the required contaminent for the mantle magma. There is some indication from the absolute ages of intrusions that the plutonism migrated from

northwest to southeast (Hamilton, 1994) and the anorthositic rocks, therefore, reflect the impact of the magma pond on differing parts of the crust over the interval of NPS construction.

Current field and geochronological data clearly point to the fact that simple models of short-lived magmatism and one large differentiated magma mass cannot apply to the rocks in the Nain area. Magmatism here is long lived, is repetitive, has migrated through time from west to east, and has produced a multitude of different plutons at different times. It is still intriguing, however, why the largest granitic intrusions of the NPS are located principally along its western side and within the Paleoproterozoic crust of the Churchill Province (*cf.* Ryan,1990). Were such magmas produced only from juvenile Paleoproterozoic crust and not from (previously depleted?) Archean gneisses? Did granitic magmas originally reside everywhere in the crust above the subcrustal basaltic magma pond but were subsequently centrally elevated by emplacement of anorthosite underneath and are now eroded? Clearly the anorthositic rocks of the NPS represent amalgamated plutons, so one has to wonder why no large granitic intrusions are present within the main mass of such rocks, preserved, for example, as part of the envelope to some of the basic plutons. To date there has been no documented unequivocal occurrence of anorthositic plutons directly intruding any of the large masses of granitoid rock within the NPS; rather, the reverse is true. It is unlikely that the anorthositic part of the NPS coalesced at depth and rose buoyantly as one massive body through the crust into the granitic "pool"; still, the paucity of significant granitic intrusions internal to the anorthositic terrane is puzzling. Taken together, however, the NPS has the characteristics of any batholith, namely being a large mass of conjoined plutons of differing composition for which evidence of a supporting crustal floor is sadly lacking.

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Note: Geological Survey file numbers are included in square brackets.