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FURTHER RESULTS OF MAPPING GNEISSIC AND PLUTONIC ROCKS OF THE NAIN AREA, LABRADOR

B. Ryan
Labrador Mapping Section

ABSTRACT

Recent investigation of the Nain area has resulted in a modification of previous results and the discovery of new rock units and relationships.

Deformed anorthositic to gabbronoritic rocks occur south of Nain Bay both as units within the Archean gneisses and as part of the Middle Proterozoic Nain Plutonic Suite (NPS). The largest NPS body is named the Pearly Gates intrusion; it exhibits a foliated marginal zone, has a discontinuous monzonitic halo having the same fabric as the anorthositic rocks, and is intruded by a foliated, 1-km-wide, olivine + clinopyroxene monzonite dyke. Other intrusions demonstrate that the NPS in the Nain Bay area evolved by repeated intrusion of noritic to anorthositic plutons, each basic pluton being accompanied by monzonitic stocks on its margins.

North of Webb Bay, granulite-facies quartzofeldspathic gneisses contain units of mafic granulite, migmatized leucogabbroic and anorthositic gneiss, and lesser paragneiss. A somewhat enigmatic deformed anorthositic to gabbronoritic intrusion, injected by foliation-parallel pink aplitic granite dykes and a buff-weathering coarser grained orthopyroxene-bearing granitic network, forms an extensive unit northwest of Webb Bay. All the above rocks are intruded by metamorphosed basic dykes of probable Early Proterozoic age. The Nain Plutonic Suite in the Webb Bay area is represented by the variably recrystallized Mt. Lister intrusion and several other plutons varying from mildly deformed to undeformed igneous rocks. Crosscutting relationships indicate a temporal evolution from more-deformed to less-deformed and undeformed intrusions; here, too, the basic plutons have monzonitic marginal associates.

The Conch Bay—Sachem Bay region is underlain by several discrete igneous intrusions of the NPS, also varying from deformed and recrystallized to massive subophitic rocks.

The only indication of base-metal mineralization occurs in the anorthositic rocks south of Nain Bay; there, sulphide-bearing noritic dykes, enriched in Ni and Cu, are the best prospects.

INTRODUCTION

The 1992 field season was the third consecutive one devoted to examination of selected parts of the Nain area (Figure 1). Previous work in the area has been primarily concerned with the Archean gneisses exposed on the archipelago east of Nain (Ryan, 1991, 1992). Some work has, however, been carried out on a septum of gneisses within anorthositic rocks of the Nain Plutonic Suite (NPS) south of Nain Bay in 1991 (Ryan, 1992), and a coastal reconnaissance of the Webb Bay area was undertaken in 1990 (Ryan, 1991). During the course of surveying the Nain Bay and Webb Bay areas, significant amounts of deformed and recrystallized anorthositic, noritic and monzonitic rocks were discovered within the NPS. Such rocks within the anorogenic NPS seem to have gone unrecognized by most previous workers, but their presence may aid in understanding processes active during the formatin of the NPS. Consequently, parts of the NPS were earmarked for more detailed work in 1992 than in previous years.

This writer's mapping of the deformed NPS rocks had, until the 1992 field season, been largely restricted to their border zones against the gneisses, the latter rocks having been the main focus of the project. The border zones occupied by the deformed plutonic rocks in the areas investigated in 1990 and 1991 were largely straight and structurally simple. Data obtained from these zones were used to suggest that the interface between older NPS plutons and the gneisses were the sites of episodic reactivation as ductile shear zones when crustal extension occurred and younger plutons were emplaced; it was also proposed that such ductile shear movement was preferentially concentrated along younger monzonitic dykes emplaced into already-deformed anorthosite. One pluton—gneiss contact that has been examined more extensively during the 1992 survey has now made it apparent that the zones of deformation and recrystallization are not straight, linear features, but are, instead, features that follow the curved outline of the mapped contact between the pluton and its country-rock. It thus seems that the deformed and recrystallized plutonic rocks in these

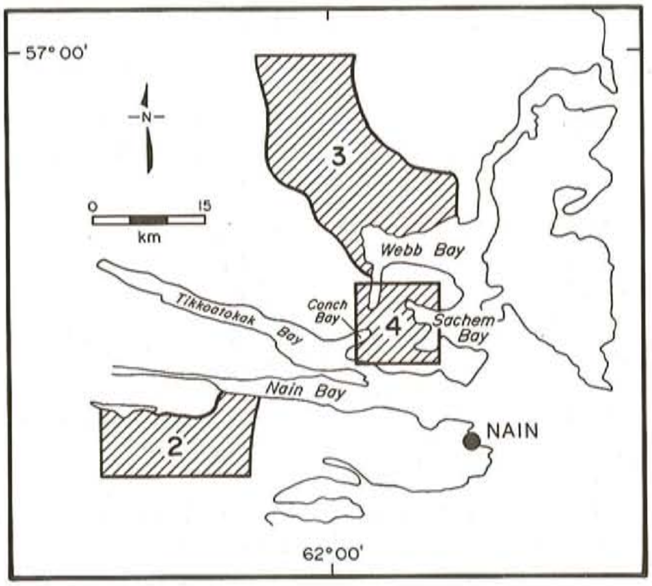

Figure 1. *Cross-hatched pattern shows areas investigated during the 1992 field season. Numbers correspond to the locations of other text figures.*

settings are an artifact of the emplacement process rather than a significantly later zonal simple shear phenomenon (see discussion below).

The 1990 reconnaissance survey of the Webb Bay area had shown the presence of rocks that bear a strong resemblance to the Early Archean gneisses of northernmost Labrador. No rocks of this character were discovered during surveys of the archipelago east of Nain, so the possibility of two distinct crustal blocks in the Nain area was entertained (cf. Connelly *et al.*, 1992). The Webb Bay survey of 1992 was designed to examine the extent of the possible Early Archean crust; in addition, the survey was meant to investigate the distribution of foliated anorthositic and noritic rocks discovered in 1990. An important outcome of work in the Webb Bay area has been the recognition of several variably migmatized and foliated to gneissic anorthositic units within the Archean gneiss complex, another feature that sets it apart from the gneisses of the eastern islands.

The variety of rock types in the areas investigated during the 1992 field season are described in the following sections, and the significance of some of the new data and the refined data of previous surveys are discussed in a closing section.

An attempt was made to establish the geological relationship between as many of the major map units as possible. This is especially critical in parts of the area underlain by the NPS, because in some places only remnants of early plutonic bodies are preserved within or between younger plutons. The establishment of relative ages has not always been successful, stymied in some cases by absence of outcrop in crucial areas.

The terminology employed here for rocks of the NPS follows recommendations of the IUGS (Streckeisen, 1975), although in some cases field names have not been verified by petrographic data. In view of inconsistencies in the naming of rocks of the NPS by previous workers, predicated in some cases on feldspar composition (see Appendix), the following nomenclature is adopted here: orthopyroxene + plagioclase rocks are norites, clinopyroxene + plagioclase rocks are gabbros, and plagioclase + two-pyroxene rocks are gabbronorites. In some cases, it seems that the gabbronorites are, in fact, derived from gabbros in which pigeonite had been the primary mafic phase (cf. Wiebe, 1979); inversion and complete separation and/or subsequent recrystallization of this primary pyroxene gave rise to a discrete two-pyroxene assemblage. Although potassium feldspar occurs in some of the rocks above, a perusal of thin sections indicates that the volume present in most does not justify use of the prefix monzo- as recommended by IUGS criteria.

NAIN BAY AREA

The distribution of the gneissic and the plutonic rocks south of Nain Bay was initially investigated by Wheeler (unpublished manuscript maps), and examined in more detail in 1991 (Ryan, 1992). Further study has refined some of the previous conclusions and expanded the scope of the previous work to the south and west. The following brief account of the geology augments and revises information previously presented (Ryan, 1992), and Figure 2 illustrates the distribution of rock units as deduced from the 1992 mapping program. Several changes in interpretation and unit distribution are obvious when Figure 2 is compared with the map produced from the 1991 data (Ryan, 1992, Figure 4).

PEARLY GATES INTRUSION

Reconnaissance examination of the southern, western and internal parts of the large, variably recrystallized, coarse-grained, anorthosite and leuconorite pluton forming the western half of the study area leads to the proposition that it is quite likely the southward extension, across Nain Bay, of the Bird Lake Massif described by Morse and Wheeler (1974) and Morse (1983). However, until further work demonstrates a firm correlation, the pluton is here called the 'Pearly Gates' intrusion because of an iridescent labradorite occurrence of that name near its centre. The marginal zone of the Pearly Gates intrusion is strongly deformed and recrystallized (Plate 1). The marginal foliation dips 30° to 85° outward, and in some places the tectonic fabric is so intense that the foliated rocks can be best described as augen blastomylonites. The development of a penetrative fabric is most evident in areas where noritic rocks are present; in these, the orthopyroxene defines a foliation that varies from a weak flattening of original poikilitic pyroxene ('clotted fabric' of Wheeler, 1955) to a schistosity formed by elongate grain aggregates derived from coarser recrystallized pyroxenes. Very coarse, variably recrystallized orthopyroxene having aspect ratios of 50:1 have been noted in some marginal zone outcrops. Parts of the pluton margin are composed of anorthosite, leuconorite and norite interlayered on a centimetre to metre scale. The development of a layer-parallel foliation in these rocks gives them a gneissic appearance. The

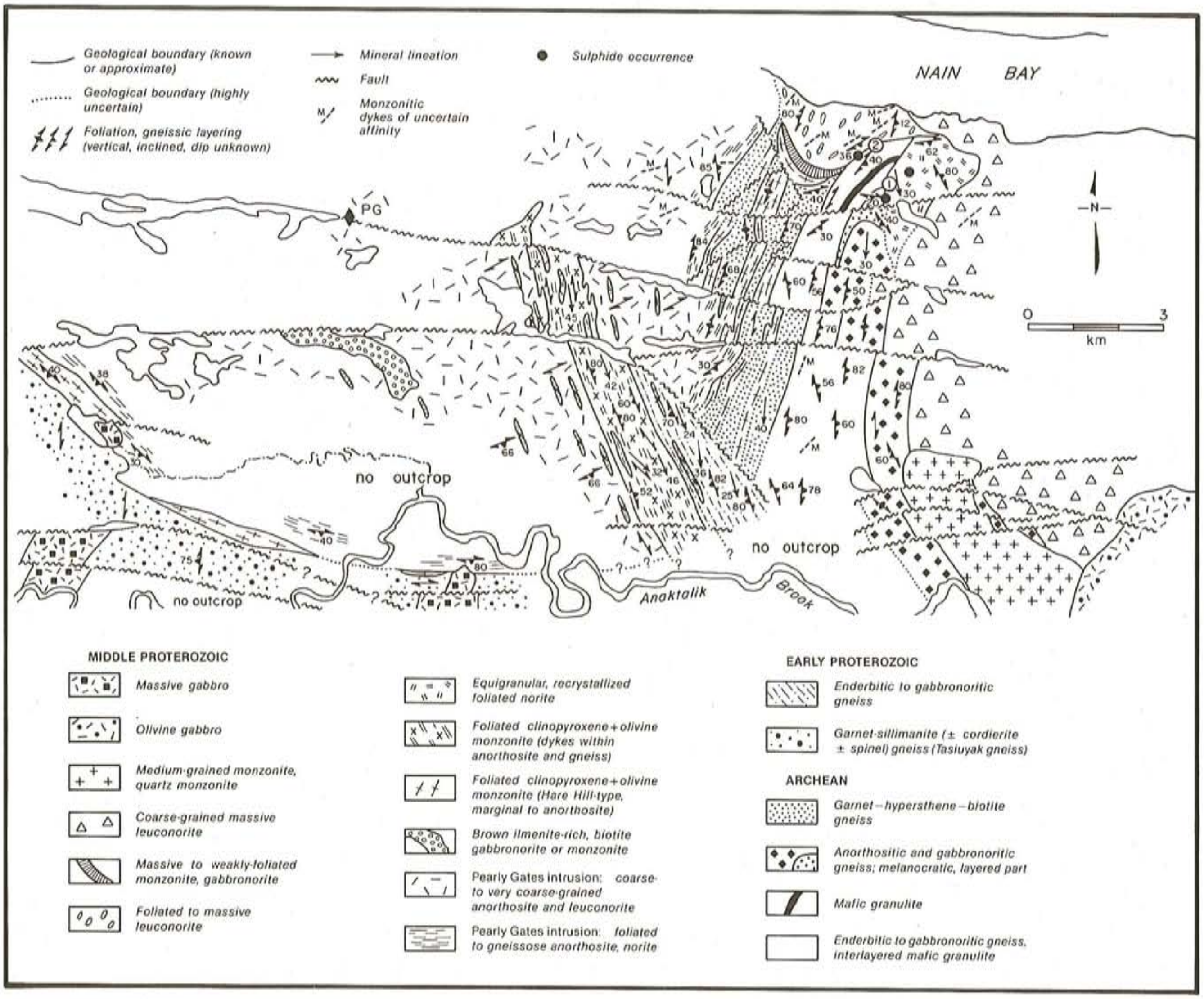

Figure 2. *Revised geological map of the area south of Nain Bay. PG and diamond indicate the location of the Pearly Gates labradorite occurrence.*

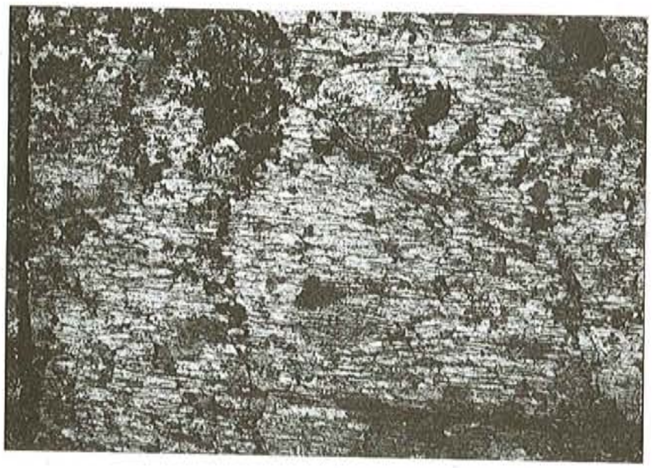

Plate 1. *Strongly foliated noritic rock from the margin of the Pearly Gates intrusion.*

internal part of the Pearly Gates intrusion comprises coarse- to very coarse-grained leuconorite and anorthosite—some labradorite crystals at the Pearly Gates occurrence are in excess of 1 m in maximum dimension. Ryan (1991) noted the variable deformation and recrystallization of these massive rocks, which, in the Pearly Gates labradorite, are expressed as abundant fractures and 'white zones' where alteration and recrystallization have obliterated the colour. The coarse pyroxenes, which locally exhibit well-developed subophitic intergrowth with plagioclase in addition to being of apparent xenocrystic origin, are commonly kinked, and may show marginal and kink-plane recrystallization to fine granular aggregates. Finer grained, rusty, friable, ilmenite + biotite-bearing gabbronorite or pyroxene monzonite ('buff facies' anorthosite of Wheeler, 1960), which forms dykes and irregular intrusive masses within the interior of the pluton, generally shows a greater degree of foliation development than the coarse anorthositic rocks, and is the best indicator of the deformation that has affected the pluton.

HARE HILL MONZONITE

Schistose to gneissic, brown- to buff-weathering, olivine + clinopyroxene monzonite forms a narrow discontinuous halo between the foliated anorthositic margin of the Pearly Gates intrusion and the country-rock gneisses. The foliation in the monzonite is parallel to, and considered to have developed coeval with, the fabric in the abutting anorthositic rocks. This writer has observed the monzonitic rocks at the western and eastern sides of the anorthositic intrusion; those in the vicinity of Anaktalik Brook (Figure 2) along the southern margin of the pluton are interpreted from E.P. Wheeler's manuscript maps. The marginal monzonites seem to be, from present data, restricted to the interface between anorthosite and gneiss along the southern and western parts of the area. Along the eastern margin of the anorthosite, however, the monzonite forms a series of subvertical sills within garnetiferous Archean paragneiss; garnet is present in the monzonite adjacent to the paragneisses. This monzonite within the paragneiss underlies several prominent hills south of Nain Bay; samples from one such hill, informally named Hare Hill, have been collected for zircon geochronological study. The name Hare Hill monzonite is applied to all the marginal olivine + clinopyroxene-bearing rocks in this area. The marginal monzonites are considered to be nearly coeval with the anorthosite, and the age of the Hare Hill occurrence will thus provide an indication of the time of crystallization of the Pearly Gates pluton.

MONZONITE DYKE

It is now obvious from the map pattern (Figure 2) that the large north-northwest-trending, foliated, olivine + clinopyroxene monzonite dyke near the eastern margin of the Pearly Gates intrusion is highly discordant to the foliation orientation in the anorthositic rocks and thus was emplaced after the development of the foliation in the anorthositic rocks. This regional map scale feature supports numerous outcrop observations that clearly indicate that small monzonite dykes truncate a foliation in the anorthositic rocks and confirms that the anorthositic rocks had been deformed prior to emplacement of this large dyke (cf. Ryan, 1992; Plate 2). The offset of the margin of the Pearly Gates pluton across the monzonite and a wedge of Early Proterozoic gneisses indicates that the dyke was intruded along a fault or shear zone that penetrated the pluton after final emplacement. The margin-parallel foliation in this dyke implies that the dyke acted as a locus of post-emplacement shear.

OTHER NPS INTRUSIONS

The anorthositic rocks directly south of Nain Bay have been subdivided to a greater degree than was possible following the 1991 field season. However, unequivocal field contacts between some of the units have not been established. Foliated, ilmenite-bearing, medium- to coarse-grained leuconorite on the south shore of Nain Bay is separated from the Pearly Gates pluton because the former intrusion lacks the very coarse anorthosite and the very coarse deformed orthopyroxene of the Pearly Gates body. In addition, dykes

Plate 2. *Fragment of foliated norite containing a fabric that predates incorporation by the surrounding foliated olivine + clinopyroxene monzonite.*

of massive to weakly foliated monzonite, considered to be derived from a monzonite marginal to the shoreline leuconorite intrusion, clearly transect strongly foliated and gneissic monzonite interpreted to be part of the Hare Hill intrusion (the marginal monzonite of the Pearly Gates intrusion). Foliated, finer grained, equigranular norite, previously considered to comprise the northern part of a gneissic anorthosite unit (see below), is now interpreted to be a remnant of a separate pluton. Although no direct contact was seen with adjacent rocks to the west, the map distribution implies that the pluton truncates the fold structure affecting the gneissic anorthositic layered intrusion and the quartzofeldspathic gneisses (Figure 2). On its eastern margin, the equigranular norite is intruded by a younger coarse-grained (pegmatoidal) pale-grey to dark-grey leuconorite (Ryan, 1992). The coarse leuconorite is bordered on its southwestern side by an elongate marginal stock of olivine-free, two-pyroxene (± inverted pigeonite) quartz monzonite containing dark-grey plagioclase megacrysts that are interpreted to be derived from the leuconorite. East of this stock, a dark-grey- to brown-weathering olivine gabbro forms a shallowly south-dipping intrusion atop white leuconorite. Poor outcrop has prohibited the precise definition of the contact between the quartz monzonite and the olivine gabbro, but map distribution of the two units is interpreted as indicating the gabbro is intrusive into the monzonite, truncating the contact between the monzonite and the leuconorite with which it (the monzonite) is associated. Brown-weathering, undeformed, fine-grained gabbro (plagioclase + complexly exsolved clinopyroxene; equivalent to diorite and ferrodiorite as used by R.A. Wiebe and R.F. Emslie; see Appendix) containing scattered feldspar phenocrysts, intrudes Tasiuyak paragneiss and the foliated margin of the Pearly Gates pluton on a prominent hill south of Anaktalik Brook. Diorite mapped by Wheeler (manuscript maps) to the west is interpreted to be correlative with this intrusion, and all are considered to be part of an assemblage of such rocks associated with the 1.32 Ga Makhavinekh Lake rapakivi granite to the south and west (Ryan, 1990). This therefore indicates a minimum age of 1.32 Ga for the Pearly Gates pluton.

GNEISSIC ANORTHOSITIC ROCKS

A gneissic anorthosite, leucogabbronorite and gabbronorite unit, derived from a layered mafic intrusion, separates quartzofeldspathic granulite from pegmatitic leuconorite in the eastern part of the study area. Ryan (1992) had suggested a Middle Proterozoic age for this unit, based on its proximity and similarity to the deformed and recrystallized rocks of the Pearly Gates intrusion. Re-examination of this unit, however, suggests that it is more likely to be part of the regional Archean gneiss terrane rather than being correlated with the younger plutonic rocks. An Archean age for this unit was not ruled out by previous studies (Ryan, 1991, 1992). Foliated gabbronorite and layered melagabbronorite (mafic granulite) that occur at the northern end of this anorthositic gneiss unit have been interpreted to form a fold closure truncated by a younger equigranular norite (Figure 2). This interpretation invalidates an earlier suggestion that these layered rocks are continuous with a layered mafic granulite to the north (Ryan, 1992) and avoids the structural contortions necessary to account for continuity of the two mafic units. The distribution of the melanocratic rocks, as a folded wedge at the north end of the gneissic anorthositic unit (Figure 2), suggests that the structure folds an already oblique (tectonic?) contact between the gneisses and the layered intrusion. Alternatively, the igneous protolith to the quartzofeldspathic rocks intruded across large-scale compositional layering in the basic intrusion prior to the tectonism that produced the present gneiss complex; there is, however, no field evidence of such an intrusive relationship.

WEBB BAY AREA

A north-northwest-trending septum of gneisses northwest of Webb Bay was termed the Webb Valley Metamorphic Complex by Berg (1973). These gneisses separate 'pale facies' anorthosite and 'granulite of uncertain origin' of Wheeler (unpublished manuscript maps) in the west from the Hettasch layered intrusion (Berg, 1973, 1974) in the east. A shoreline reconnaissance survey of Webb Bay in 1990 indicated the presence of granulite-facies gneisses containing podiform, plagioclase-porphyritic mafic units that resemble the Saglek dykes described by Bridgwater *et al.* (1975) within the ca. 3.8 to 3.6 Ga Uivak gneisses of northern Labrador. No such indications of probable Early Archean crust have been found on the archipelago east of Nain (Ryan, 1991, 1992), so the possibility exists that the Webb Bay gneisses constitute a different assemblage from the gneisses to the east. An additional incentive for surveying the Webb Bay area was provided by observations along the west shore of Webb Bay in 1990 (Ryan, 1991) that indicated Wheeler's 'granulite of uncertain origin' comprises strongly deformed and recrystallized anorthosite, leucogabbronorite and gabbronorite that form the eastern margin of a coarse-grained anorthositic pluton termed the Lister Massif by Morse and Wheeler (1974). The results of the 1992 Webb Bay project are shown in Figure 3. Unfortunately, outcrop is absent from the Webb Brook valley because it is floored by glaciofluvial deposits; rock exposures are largely restricted to the valley flanks and to a few prominent hills.

QUARTZOFELDSPATHIC GNEISS AND MAFIC DYKES

Quartzofeldspathic granulite-facies migmatite comprises the main rock-type. These are cassonade-brown-weathering rocks, well displayed along the south shore of Webb Bay where the porphyritic mafic pods were initially observed. Along this coastal stretch, the gneisses also contain numerous small (centimetre- to metre-sized) pods and rafts of pyroxenite and massive mafic granulite, and scattered screens of quartzite and cordierite-bearing pelitic gneiss. Metamorphosed basic dykes (two-pyroxene + hornblende-bearing rocks) are present along the coastline, some of which occur within shear zones in the gneisses, where they appear to have been emplaced syntectonically. North of Webb Bay, the granulite-facies gneisses similarly contain rafts of mafic and ultramafic granulite, but no porphyritic Saglek-dyke type units have been seen. The dykes observed in this area are straight-walled metamorphosed basic intrusions at amphibolite facies that cleanly transect gneissic layering. It is possible that all these post-gneiss dykes are equivalent to the Early Proterozoic Napaktok and Domes dykes that occur in the Saglek–Hebron area, 60 to 100 km north of Webb Bay (Ermanovics and Van Kranendonk, 1990) but an earlier swarm may also be present (cf. Connelly *et al.*, 1992). The northernmost gneisses adjacent to the Hettasch intrusion appear to be predominantly at amphibolite facies. These are pale-pink- to grey-weathering rocks containing lenses and layers of amphibolite. A diffusely layered pink to white granitic gneiss constitutes a local component in this area. Opalescent quartz in parts of the granitic gneiss suggests derivation from a granulite-facies protolith. Metadiabase dykes within this northernmost area are also at amphibolite facies. Gneisses that crop out at the northwest corner of the study area are similar to those near Webb Bay, being quartzofeldspathic granulite containing mafic granulite screens.

MAFIC AND ULTRAMAFIC ROCKS

Mafic granulite units within the Webb Brook valley gneisses comprise several types. South of the Hettasch layered intrusion, an arcuate belt comprises massive to layered rocks broken into agmatite structure by veins and sheets of white granite. Minor peridotitic pods are locally associated with these. Several outcrops of layered mafic granulite, locally displaying relict gabbroic texture, suggest the presence of an extensive deformed plutonic mafic unit in the northern part of the valley. It may correlate with a 'granulite of uncertain origin' shown by E.P. Wheeler (manuscript maps) to form two prominent hills just east of Iglusuataliksuak Lake. The relationship between this unit and adjacent gneisses is unknown. Finely layered to massive, black- to dark-green-weathering, mafic granulite (gabbronorite) and rusty-red layered peridotitic rocks (Berg, 1973) form a refolded unit just west of Ado's Brook. Minor units of meta-anorthosite

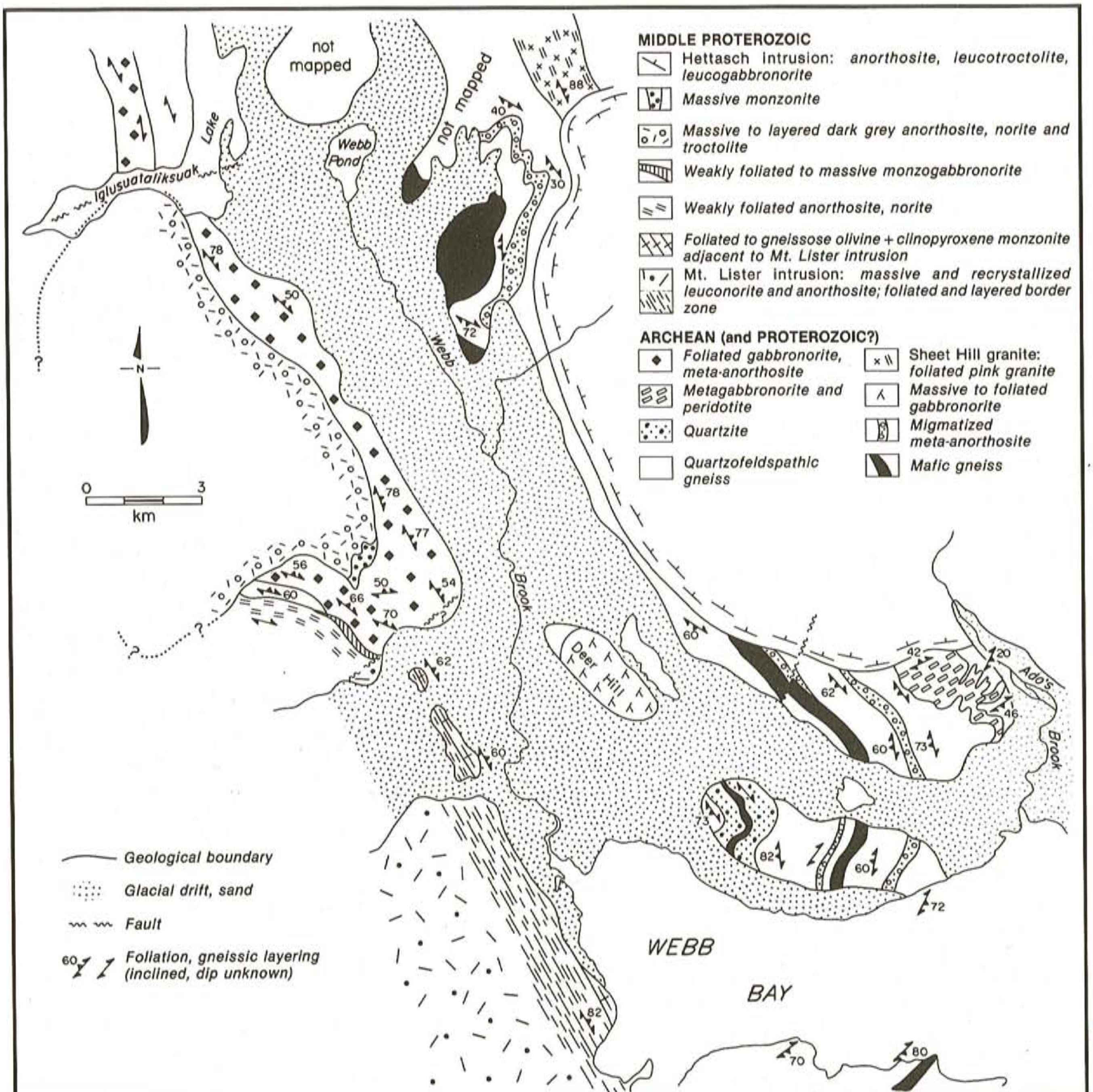

Figure 3. *Geological map of the area north of Webb Bay. Outline of Hettasch intrusion and related rocks is based on Berg (1973, 1974).*

are associated with this mafic granulite, notably along the mafic-quartzofeldspathic gneiss contact. More massive portions of this body retain relicts of igneous texture and scattered phenocrysts of grey plagioclase and oikocrysts of pale-brown olivine, features clearly indicative of its plutonic origin and demonstrating the protolith to have been a layered ultramafic to mafic intrusion.

ANORTHOSITIC GNEISS

Several units of massive to well-layered, pale-grey- to white-weathering anorthositic to melagabbroic rocks have been identified north of Webb Bay. Rafts of these within the abutting quartzofeldspathic gneisses, coupled with the general migmatized aspect of parts of these units, indicate that they are older than the felsic rocks. The anorthositic assemblage in the least-migmatized outcrops comprises equigranular anorthosite, streaky-textured norite or gabbro and its amphibolitized equivalent, melagabbro and mela-amphibolite, and pyroxenite and hornblendite. Snow-ball type metagabbroic rocks can be identified in some outcrops; these comprise ovoid white plagioclase aggregates surrounded by mafic minerals. Finely layered (5 to 10 cm) anorthosite and amphibolitized melagabbro or hornblendite (pyroxenite) are locally present, and are especially well developed in part of the folded unit in the northern part of the Webb Brook valley. The meta-anorthositic gneiss units, like the quartzofeldspathic rocks, are cut by weakly foliated to massive metadiabase dykes.

PARAGNEISS

White- to slightly rusty-weathering garnetiferous quartzite underlies a hill directly north of Webb Bay. Except for a few narrow screens of cordierite-bearing pelitic gneiss (hornfels) in the northern part of the area, these arenaceous rocks are the only metasedimentary supracrustals seen in the map area.

GNEISSIC AND DEFORMED ANORTHOSITIC AND NORITIC ROCKS

The northwestern sector of the area examined during the 1992 survey comprises deformed and recrystallized white- to pale-brown-weathering gabbronorite, leucogabbronorite and anorthosite of uncertain age and affinity. This unit differs from the anorthositic rocks on the east side of the Webb Brook valley in being overall coarser grained, and in being texturally more inhomogeneous both at outcrop and on a regional scale. It is also characterized by foliated aplitic, medium grained, and pegmatitic granitoid sheets up to 3.5 m wide. The easternmost outcrops of this unit are migmatitic; in these exposures foliated and folded basic rocks occur as blocks within a pervasive network of brown-weathering orthopyroxene-bearing granitoid and pink aplite. It is assumed, therefore, that this unit predates the quartzofeldspathic granulites to the east. Compositional variation within the unit ranges from anorthosite to pyroxenite, but a gabbronorite to leucogabbronorite predominates. Grain size is normally on the order of several millimetres because of thorough recrystallization, but relicts of primary dark-grey plagioclase, up to 5 cm in size, are preserved in some outcrops and a pale-blue labradorite schiller is obvious in some of the feldspar. Although original pyroxene outlines remain in rocks with relict subophitic texture, most primary pyroxene is recrystallized; pyroxene forms aggregates that comprise both a dark-brown orthorhombic and a dark-green monoclinic pyroxene suggesting that the clots represent inverted and recrystallized pigeonite or subcalcic augite. Some parts of the unit have remnants of original subophitic texture in which igneous minerals were on the order of several tens of centimetres in size (Plate 3). Deformation in this unit is very inhomogeneous. In any one outcrop, there may be gabbronoritic blocks within an anorthositic matrix in which the block foliations have highly oblique orientations. In other outcrops, recrystallized but little-deformed gabbronorite may pass abruptly into a strongly foliated to gneissic equivalent (Plate 4). Multiple deformation of this unit is obvious from the fact that in some outcrops the regional foliation, defined by elongate pyroxene aggregates, is folded. Deformed metadiabase dykes are locally present in the northern half of this unit. The presence of these dykes, probably representatives of the Early Proterozoic Napaktok and Domes dykes in the area to the north (Ermanovics and Van Kranendonk, 1990), give credence to an interpretation of an Archean age for this NPS-like rock. However, an Early Proterozoic age cannot be ruled out.

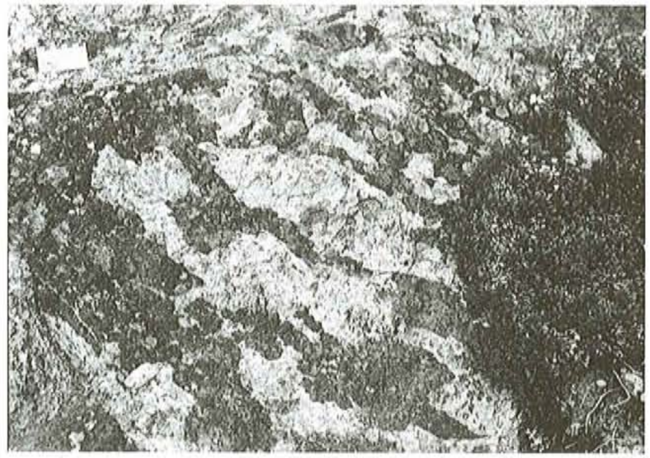

Plate 3. *Relicts of igneous texture, involving coarse-grained pyroxene and plagioclase, preserved in foliated to gneissic gabbronorite unit.*

Plate 4. *Deformed equivalent of texture shown in Plate 3, offset by later brittle fault.*

SHEET HILL GRANITE

The Sheet Hill granite (Berg, 1974) is a pink, fluorite-bearing biotite ± hornblende granite at the northern edge of the study area. The granite is variably recrystallized and deformed, especially on its southwestern margin where the original hypidiomorphic-granular-textured rock has been transformed into a ribbon mylonite. The recognition of deformed dykes at amphibolite facies and recrystallization features within the Sheet Hill granite had previously prompted Ryan (1992) to postulate that, contrary to Berg's (1974) conclusions, the granite predates the Hettasch intrusion. J. Berg (written communication, 1992) has indicated, however, that he reached a similar conclusion following a 1981 re-examination of the Hettasch intrusion–Sheet Hill granite contact area. Zircon geochronological investigation of samples from the Sheet Hill granite is in progress.

DEER HILL GABBRONORITE

A prominent ridge, known locally as Deer Hill (Figure 3), is underlain by massive, dark-green-, dark-grey- and brownish-green-weathering, fine- to medium-grained gabbronorite that resembles finer grained rocks of the NPS. Indigenous plagioclase is purplish grey but a dark-grey xenocrystic plagioclase is locally present. Biotite porphyroblasts are a conspicuous feature on freshly broken surfaces from some parts of the intrusion. The internal part of this small igneous body is massive and retains pristine primary igneous textures, the only evidence of deformation being centimetre-scale localized ductile shear zones. The eastern margin, however, is amphibolitized and foliated, having fabric-parallel, narrow, foliated granitic veins and dykes. The writer proposes correlation of this gabbronorite with similar amphibolitized and foliated rocks intruded by deformed dykes on Georges Island at the entrance to Webb Bay (see Ryan, 1991). Assuming the deformed dykes to be Early Proterozoic in age provides a younger limit for the time of emplacement of this gabbronorite.

MT. LISTER INTRUSION AND ITS ASSOCIATED MONZONITE

The NPS in the Webb Bay project area is represented by at least three anorthositic intrusions west of Webb Brook valley, and by the Hettasch layered intrusion to the east; for details on the latter body, the reader is referred to Berg (1973, 1974). The eastern margin of Lister massif (Morse, 1983), herein termed the Mt. Lister intrusion, is exposed on the western shore and ridges west of Webb Bay. A brief visit to several outcrops in this area in 1990 provided this writer with the first indications of the degree to which parts of the NPS had been deformed and recrystallized (Ryan, 1991). Steeply dipping, foliated to gneissic, variably recrystallized anorthosite, leucogabbronorite and gabbronorite form a regularly banded marginal zone to the Mt. Lister intrusion that is in excess of 1 km wide (Plate 5). The foliation is expressed by tailed-out and partly recrystallized brown to black orthopyroxene + clinopyroxene in a matrix of grey- to white-weathering partly recrystallized plagioclase. Unlike the polydeformed gneissic gabbronoritic unit to the north, the Mt. Lister intrusion marginal zone rocks are homogeneously layered on outcrop scale, are affected by just a single period of deformation, and lack the foliation-parallel, pink, leucocratic, aplitic sheets that characterize the older unit. The internal part of the Mt. Lister intrusion comprises mostly very coarse-grained anorthosite and leuconorite, displaying varying degrees of recrystallization. It locally contains gently dipping foliated dykes of fine-grained granular hornblende–biotite gabbronorite (Figure 4) not unlike some of the 'mafic granulite' dykes found on the islands east of Nain (Ryan, 1991, 1992). The gneissic margin of the Mt. Lister intrusion is bordered externally by a brown- to greenish-grey-weathering, foliated to gneissic olivine + clinopyroxene monzonite (Plate 6), a situation analogous to the relationship between the Pearly Gates pluton and the Hare Hill monzonite south of Nain Bay. Limited examination of the western shore of Webb Bay, coupled with the lack of outcrop north of the bay, has prevented full definition of the extent of the monzonite; hence its relationship to the gneisses to the east is uncertain. The foliated margin and associated

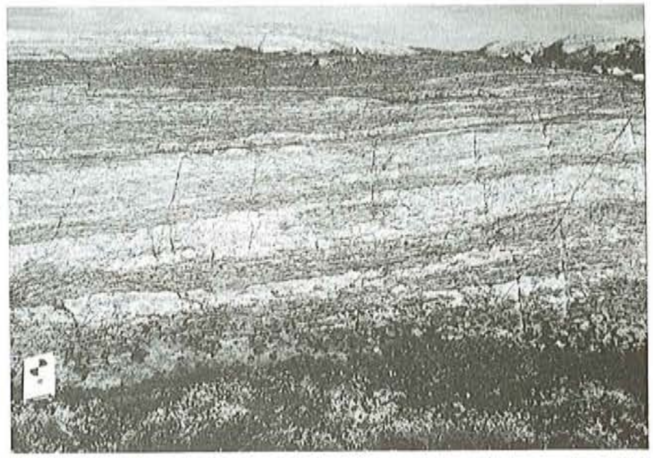

Plate 5. *Banded and foliated anorthositic to gabbronoritic rocks on the margin of the Mt. Lister intrusion.*

Plate 6. *Gneissic olivine + clinopyroxene monzonite along the eastern margin of the Mt. Lister intrusion.*

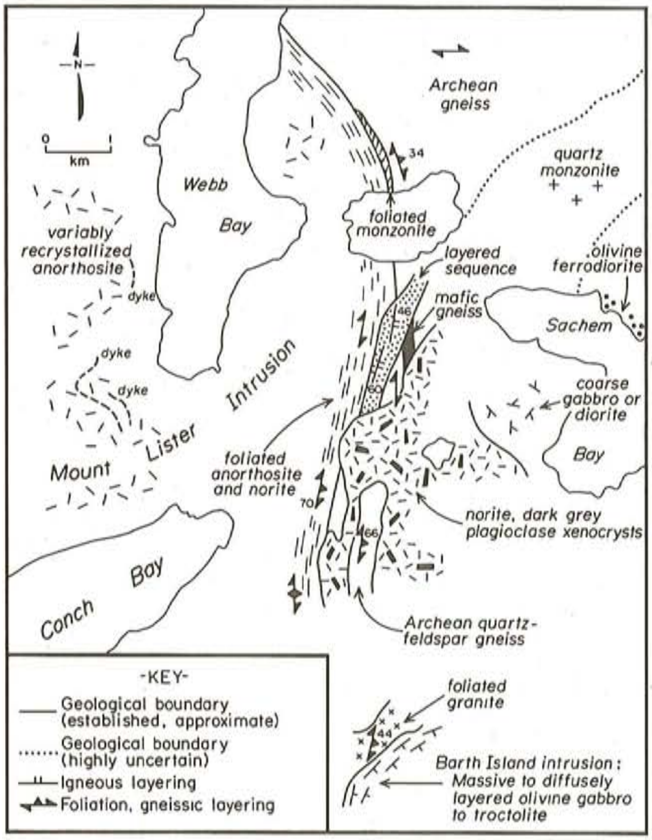

Figure 4. *Geological sketch map (based on very limited work) of the area between Conch Bay and Sachem Bay.*

monzonite of the Mt. Lister intrusion strike northward into the inhomogeneous gabbronoritic gneiss unit and are interpreted to be truncated by a northeast-trending fault (Figure 3) that probably predates emplacement of the Hettasch layered intrusion.

WEAKLY DEFORMED LEUCONORITE

A medium-grained leuconorite and anorthosite intrusion, having a weak marginal foliation, occurs north of the Mt. Lister intrusion across the above mentioned fault. This NPS unit differs from Mt. Lister pluton in its lack of layered and gneissic marginal rocks, its overall finer grain size, and the presence of sheets and irregular bodies of rusty-brown-weathering, friable, oxide-rich gabbronorite or pyroxene monzonite. It is in concordant contact with mylonitic, laminar-banded, granulite-facies quartzofeldspathic gneisses at its northern margin and is separated from the foliated and gneissic gabbronorite unit along its northeast margin by a fine- to medium-grained, diffusely layered, massive to weakly foliated, brown-weathering monzogabbronorite.

UNDEFORMED NORITE TO TROCTOLITE INTRUSION

The anorthositic to gabbronoritic gneiss unit, the granulite-facies quartzofeldspathic gneisses, and the foliated leuconorite described above are all intruded by a massive, dark-grey-weathering, labradorite-bearing, undeformed noritic pluton (Figure 3). This pluton, the youngest NPS intrusion in the area, displays primary igneous structures and textures, and comprises rocks that range from fine-grained olivine gabbronorite along the margin to coarse-grained troctolite and layered leuconorite and anorthosite in its interior (R.F. Emslie, personal communication, 1992). A pale- to dark-brown-weathering, fine- to medium-grained clinopyroxene monzonite forms a lensoid intrusion separating a south-pointing lobe of this basic pluton from gneissic gabbronorite. The northern and western extents of the basic pluton have not been investigated, but (i) aeromagnetic patterns, (ii) topography, and (iii) the presence of shear-foliated partly recrystallized norite transected by an array of fine granular gabbronoritic and monzonitic to rapakivi granitic dykes to the west of Igusuataliksuak Lake, all imply that the unit is a pear-shaped pluton on the order of 11 by 7 km in size that has punctured an array of older metamorphic and igneous rocks.

SACHEM BAY–CONCH BAY AREA

Two short traverses were conducted in the upland area between Conch Bay and Sachem Bay. A brief visit here by this writer in 1990 revealed that gneisses, deformed leuconorite and massive norite are present in this area. The limited examination of the upland during the 1992 field season was aimed at elucidating relationships in one small area (Figure 4). The Conch Bay–Sachem Bay area had previously been investigated by Rubins (1971), who had identified what he termed 'pale facies anorthosite', 'enderbite-bearing granulites', and 'enderbite-free pyroxene-plagioclase granulites'.

The western part of the area examined is underlain by pale-grey- to white-weathering recrystallized anorthosite and leuconorite, and strongly foliated layered anorthosite and gabbronorite, all interpreted to be the southward continuation from Webb Bay (Figure 3), of the border zone of the Mt. Lister intrusion. Several, gently west-dipping, granular, two-pyroxene + hornblende (gabbronorite or mafic granulite) dykes, exhibiting a diffuse banding and a biotite foliation, occur within variable recrystallized anorthosite and leuconorite north of Conch Bay. A narrow zone of schistose, porphyritic monzonite separates the foliated anorthositic rocks from gneiss in the northern part of the area.

The gneisses east of the Mt. Lister intrusion are quartzofeldspathic granulites, mafic granulites and ultramafic granulites; within 10 to 15 m of the intrusion the gneisses are laminar, mylonitic rocks whose layering is concordant with the intrusion's foliated border.

A diffusely layered, pink- to brown-weathering, moderately east-dipping, olivine + clinopyroxene-bearing, fine-grained monzonite has intruded along the contact between the mylonitic gneisses and recrystallized leuconorite and anorthosite in the central part of the area; narrow screens of gneiss occur within the layered sequence. The igneous rocks in this area also include a fine-grained brown- to grey-weathering gabbronoritic phase, which shows mingled contacts against the monzonite. This layered sequence may be an offshoot of a larger body of olivine-bearing gabbronoritic ('ferrodioritic') to quartz monzonitic rocks that occupies the rugged terrain directly north of Sachem Bay (see below).

A medium-grained white- to pale-grey-weathering, subophitic textured norite, characterized by an abundance of fractured dark-grey plagioclase (1 to 30 cm across), intrudes the gneisses, the margin of the Mt. Lister intrusion and the layered sill. The dark, broken plagioclase crystals that make this young intrusion distinctive are derived from the disaggregation of an older anorthositic cumulate, coherent blocks of which occur in some outcrops. The darker plagioclase diminishes in abundance toward the margin of the intrusion, the border zone being subophitic norite containing isolated xenocrysts. A poikilitic texture along the western margin locally shows a slight elongation of the pyroxene oikocrysts; this is a late, primary crystallization feature and quite distinct from the solid-state fabrics of the Mt. Lister margin. Gneissic inclusions occur in the norite within 5 m of its contact with the country rock, and irregular noritic dykes pervade the gneisses for a metre or so from the contact. Fragments of recrystallized and foliated anorthosite and norite occur within the subophitic norite adjacent to the Mt. Lister intrusion.

The full distribution of the rock assemblage described above is unknown. The subophitic norite is bordered to the east by a coarse-grained, friable rock of gabbroic (plagioclase + inverted pigeonite) composition, containing irregular oikocrystic pyroxene and disseminated ilmenite; its relationship to the subophitic norite has not been established. Brief reconnaissance directly north of Sachem Bay indicates a significant area of dark-brown-weathering, locally porphyritic olivine-bearing gabbronoritic ('ferrodioritic') rocks, more massive fine-grained rocks of probable troctolitic or olivine gabbroic affinity, and medium-grained quartz monzonite and granite. If correlation with the layered sill described above is correct, then these gabbroic and monzonitic rocks must predate the massive norite.

The Barth Island troctolitic intrusion (Rubins, 1971) occurs at the southern margin of the area investigated (Figure 4). It was considered by de Waard (1973b) to pass gradationally into medium-grained anorthositic rocks to the north. From de Waard's description, these anorthositic rocks are part of the subophitic norite containing the dark-grey plagioclase xenocrysts described earlier. Although this writer has not seen this contact zone, in all likelihood an intrusive contact exists, and the Barth Island troctolite is younger (Rubins, 1971). A very brief examination of the western margin of the Barth Island body just north of Nain Bay by this writer and R.F. Emslie indicates that some units assigned to the Barth intrusion by de Waard (1973b) need to be re-evaluated; foliated granitic rocks in this area (Figure 4) are in all likelihood older than the troctolitic rocks of the Barth Island body and should be divorced from it.

Further work is necessary between Conch and Sachem bays to firmly define the structural and intrusive relationships among all the units but it seems that several ages of rocks, varying from deformed to massive, are present. The Conch Bay–Sachem Bay relationships that have been documented here between gneisses, the Mt. Lister intrusion and the younger norite seem to continue south of Nain Bay (Rubins, 1971), where the assemblage is intruded by a younger olivine gabbro (Rubins' 'dark facies anorthosite').

ECONOMIC GEOLOGY

The most promising mineral prospects are Cu–Ni sulphide showings that are present within noritic rocks in the Nain Bay–Tikkoatoktok Bay area (Figure 5; Ryan and Swinden, 1992). Three settings are recognized for this mineralization.

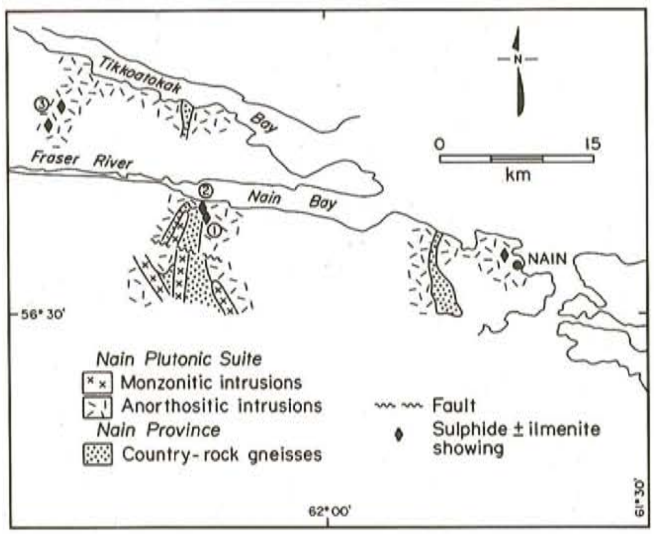

Figure 5. *Location of sulphide showings in the Nain Bay–Tikkoatokak Bay area.*

The largest rusty zone occurs 5.5 km southeast of the mouth of the Fraser River on the south side of Nain Bay (No. 1 on Figures 2 and 5). This is a conspicuous gossanous cliff at the southwest end of a 1200 ft (400 m) hill, reflecting pyrrhotite, pyrite and chalcopyrite mineralization in an ilmenite-bearing pegmatoidal leuconoritic to noritic dyke that intrudes older recrystallized fine- to medium-grained norite (Figure 2). Grab samples yielded maximum values of 9076 g/t Cu, 6772 g/t Ni, 125 g/t Zn and 25 g/t Pb. Smaller ilmenite–sulphide-bearing dykes of this type are common in the recrystallized anorthositic rocks in the valley northeast of the main showing (Figure 2).

Rusty zones on a steep north-facing scarp, 4 km southeast of the mouth of the Fraser River near the shore of Nain Bay (No. 2 on Figures 2 and 5), appear to be developed over several hosts. The largest zones were not visited because of scree instability and indications of recent rockslides. The main rock type in the area is a foliated and variably recrystallized norite to anorthosite. The sulphide zones are irregular and randomly developed within the anorthositic intrusion, and appear to be disseminations associated with pyroxene and ilmenite in the igneous rock itself, as well as being associated with basic and ultrabasic xenoliths presumably derived from adjacent gneisses (Figure 2). Grimley (1955), however, noted that 'more massive material' occurred in float near the *in situ* mineralization. This author has sampled several rusty zones from the scarp area, but no assay results are available at this time.

Rusty sulphide-bearing zones and massive to granular ilmenite concentrations occur adjacent to a series of topographic linears in coarse anorthosite south of Tikkoatokak Bay (Grimley, 1955; No. 3 on Figure 5). The rusting in the one area examined is related to disseminated and veinlet-type sulphides, in some cases in association with pods of granular secondary ilmenite that is morphologically distinct from the massive, coarse, ilmenite indigenous to the surrounding anorthosite.

Iridescent labradorite can be found in most of the anorthositic and noritic rocks in the area. The largest and most spectacular occurrences are at the 'Pearly Gates' on the south side of Nain Bay (Watson, 1980; Meyer and Dean, 1986; Figure 2), where plagioclase crystals are, in some cases, in excess of a metre across. The schiller varies from deep blue to pale-yellowish green, with colour zonation visible in some crystals. The anorthosite in the surrounding area likewise displays local zones of similar character. Unfortunately, the stone seems to lack potential as a source for large pieces of gemstone quality as it is criss-crossed by numerous small white fractures and bleached zones. These alteration features are a result of the physical fracturing of the crystals caused by deformation during emplacement, a feature that in places is enhanced by epidote alteration related to later faulting. Polished specimens from the Pearly Gates occurrence make very attractive souvenir and display material.

SUMMARY AND DISCUSSION

The latest investigations of the area south of Nain Bay have led to a revision of earlier conclusions. It is proposed that the gabbronorite–anorthosite gneiss unit in the eastern part of the area, rather than being a deformed NPS body, is instead part of the pre-NPS gneissic terrane and is thus equivalent to Archean anorthosite south of Anaktalik Brook (Ryan and Lee, 1986). Lithological variation and intrusive relationships indicate that the area contains remnants of several different anorthositic NPS plutons. The largest, the Pearly Gates intrusion, is characterized by a margin-parallel foliation in recrystallized noritic and anorthositic rocks, and by localized internal zones showing similar fabric development. The parallelism between the foliation and the pluton boundary strongly implies solid-state deformation of the pluton during post-crystallization diapiric emplacement rather than the development of discrete linear ductile deformation zones following emplacement as previously advocated (Ryan, 1991, 1992). The Hare Hill monzonite, a discontinuous marginal sheath to the Pearly Gates pluton, was deformed with the anorthositic rocks, but a large foliated dyke was intruded later along a fault zone that had sinistrally displaced the anorthosite–gneiss contact. Other anorthositic NPS plutons in the area have felsic intrusions in marginal zones analagous to the setting of the Hare Hill monzonite of the Pearly Gates pluton. The close spatial relationship between anorthositic plutons and marginal felsic stocks in this area implies a temporal relationship between them as well. It is proposed that many, if not all, the noritic–anorthositic plutons that have been amalgamated to form the basic component of the NPS in this area have an associated coeval monzonite to granite. Therefore, absolute timing of basic pluton intrusion can be ascertained by dating the monzonitic rocks, which, unlike the anorthositic rocks contain an abundance of zircon. If this model of the close association between anorthositic plutons and marginal monzonites is correct, then careful investigation in areas of multiple intrusion should uncover the hitherto unseen field relationship of a basic pluton emplaced across a monzonitic intrusion. Such field relations are also predicted by Emslie and Loveridge (1992) based on absolute geochronology of the NPS.

The Archean gneiss complex north of Webb Bay comprises predominantly migmatitic quartzofeldspathic granulites, derived from a plutonic parentage. Intercalated with the felsic gneisses, and probably mostly older than them, are layered basic rocks of gabbroic to anorthositic composition, mafic to ultramafic granulites (some of which may be younger than the quartzofeldspathic rocks), and quartzitic to pelitic paragneisses. Remnants of Early Archean quartzofeldspathic gneisses appear to be preserved on the south shore of Webb Bay. Metamorphosed basic dykes of probable Early Proterozoic age transect all the above units. The Sheet Hill granite and the Deer Hill gabbronorite, in many respects similar to rocks of the NPS but cut by deformed and metamorphosed basic dykes, may be Late Archean or Early Proterozoic in age. A coarse-grained foliated to gneissic gabbronoritic to anorthositic unit west of Webb Brook is somewhat enigmatic – it encompasses rock types similar to those of the NPS, yet is much more inhomogeneous and is migmatized by orthopyroxene-bearing granite sheets and foliated aplite dykes. An Archean or Early Proterozoic age is also probable for this unit because it is intruded by deformed basic dykes. Rocks of the NPS exposed in the Webb Bay area clearly include several different plutons. Large bodies, such as the Mt. Lister intrusion, display gneissose and strongly foliated margins concordant with enclosing gneisses, exhibit granular textures resulting from recrystallization of primary igneous phases, and have associated foliated to gneissose monzonitic sheaths; such rocks are considered to be early members of the NPS suite. Younger members (e.g., the dark-grey, labradorite-bearing, norite) show chilled margins, clearly truncate older plutons and structures, have pristine igneous textures, and their marginal monzonites are similarly nonfoliated igneous rocks. The association of anorthositic and monzonitic rocks in this area, just as south of Nain Bay, implies that the absolute age of a particular basic pluton can be ascertained by dating the generally zircon-enriched monzonitic rocks on its margin; the gneissose monzonite of the Mt. Lister intrusion has been collected for such a study.

The Sachem Bay–Conch Bay sector is another area in which it is possible to demonstrate clear intrusive relationships between different members of the NPS. Here again, the Mt. Lister foliated margin is in concordant tectonic contact with mylonitic granulite-facies gneisses; the contact zone is then exploited by a later layered sill, and the whole assemblage is subsequently intruded by a massive noritic pluton.

All three areas – Nain Bay, Webb Bay and Sachem Bay–Conch Bay – clearly corroborate and reinforce conclusions reached by previous workers in the Nain area, such as Berg (1974), Wiebe (1976) and Davies (1975), that systematic mapping will allow demarcation of individual pluton boundaries in the anorthositic terrane. Wheeler's 'facies' classification has outgrown its relevance to rocks of the NPS and its use should now be abandoned. For instance, his use of 'pale facies' (cf. Wheeler, 1969) as a blanket term for all the anorthositic, leuconoritic and noritic rocks in all three areas investigated by this writer gives no inkling of the clear field indications of several different types and ages of plutons in these areas. More meaningful information can be portrayed by the use of the IUGS nomenclature and the establishment of the relationships among different igneous units.

Although the petrogenesis and formation of plagioclase-rich rocks is still a subject of much debate, is is also apparent that the actual mechanism of formation of the anorthositic lithodemic member of the NPS is not strikingly different from that by which other batholiths are constructed, namely by the coalesence of many smaller plutons during a finite period of igneous activity. It is thus perhaps also time to re-evaluate the use of the term 'massif-type' in referring to anorthositic rocks such as those of the Nain area. This topographic/geomorphic appellation harks back to the original observation that these rocks tend to form highland areas, a function of their relative resistance to erosion rather than a petrogenetic peculiarity. (Many granitoid terranes, such as the Sierra Nevada, also form topographic highs, but no one uses the term 'mountain-type' granite! Similarly, no one calls varicoloured sandstone 'canyon-type' or 'mesa-type' sedimentary rocks just because they are hosts to such erosional topographic features in the southwestern U.S.A.). A feature of these anorthositic batholiths that may set them apart from other plutonic terranes, however, is that solid-state deformation appears to be characteristic of many of the (earliest?, deepest?) constituent plutons, and must be intimately linked to their emplacement probably as diapirs ascended from lower crustal levels (Duchesne, 1984). The continuity between the fabric in the anorthositic rocks and in the marginal monzonitic rocks implies that the latter were already in place and solidified at time of diapir ascent; this is analogous to Emslie's (1985) concept of composite diapirs, but differs from it conceptually in that Emslie's model visualized the granitiod rocks as being still viscous liquids at time of emplacement and acting as the primary agents of buoyancy, the anorthosites riding passively inside them during ascent. This is not to imply that at initial emplacement levels the granitiod rocks were not largely liquid, but it is apparent that the solid-state deformational fabrics in these rocks require some degree of ascent following solidification.

The presence of small Cu–Ni sulphides showings in the Nain Bay–Tikkoatokak Bay area may indicate the presence of more extensive mineralization in the anorthositic rocks of the Nain Plutonic Suite. The showings occur in at least three different settings and in igneous rocks of three relatively different ages; the most metal-enriched rocks are coarse-grained to pegmatoidal ilmenite-bearing noritic dykes. A focussed examination of the anorthositic rocks for more sulphide showings is warranted.

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APPENDIX

Persistent problems have existed for many years regarding nomenclature of some igneous rocks in anorthositic terranes, and the Nain rocks are no exception (cf. de Waard, 1969, 1973a, 1974). Foremost among the problems with which this writer has been confronted is the apparent inconsistency in the use of the terms 'gabbro', 'norite' and 'diorite' by the various researchers working in the Nain area. Streckeisen (1975) wrestled with this terminology in his IUGS classification scheme, but allowed some latitude in the use of the terms. Although he favoured use of plagioclase composition as an identifying criterion (i.e., An < 50 in diorites; An > 50 in gabbro and norite), he noted that in some cases 'mafic minerals and paragenetic relationships carry more weight than the composition of the plagioclase'. One of the associations he specifically notes as being a candidate in which An content is superseded by other factors is that of anorthosite terranes. Unfortunately, the above observations on the IUGS system mean that two rocks with identical mineralogy take on two different names depending on the bias of the geologist. This seems to be the case in the NPS. For instance, Morse (1977) showed that large regions of noritic and anorthositic rocks of the NPS contain plagioclase having compositions less than An_{50}; he did not, however, refer to these rocks as diorites or leucodiorites. Brand (1976), however, did subdivide some of the igneous rocks of the east central part of the NPS into dioritic members, largely utilizing colour index. Some of his coarse-grained diorites (plagioclase (An_{41}) + orthopyroxene) are mineralogically equivalent to his anorthosites (plagioclase (An_{41}) + orthopyroxene). Davies (1974) opted for the term 'hypersthene diorite' for fine-grained orthopyroxene + plagioclase (An_{37-41}) rocks in her area of investigation at the southern edge of the NPS, and, noted the presence of other pyroxene + plagioclase 'diorites' in the area. Wiebe (1979) used the term leuconorite for plagioclase + pyroxene rocks farther south within the NPS, even though some of these contain plagioclase having An < 50. Wiebe (*op. cit.*) used the term 'diorite' for 'all the associated fine-grained mafic rocks', although some of these also appear to be mineralogically akin to his noritic rocks. Wiebe and Wild (1983) used the term dioritic to refer to 'rocks ranging from leuconorite to Fe-rich diorite', and more recently Wiebe (1990) classed the dioritic rocks of the NPS as high-Fe rocks in which plagioclase compositions are typically between An_{50} and An_{30}. Adding to this confusion is the introduction of the term 'ferrodiorite' by Emslie (1991) to refer to the same Fe-rich, fine- to medium-grained mafic members of the NPS, rocks which in other areas have been called jotunites, monzonites, monzogabbro and monzodiorite (cf. de Waard, 1974).

The above few examples illustrate that the ratios of different minerals in rocks — the basis of the IUGS system — has not been consistently used in the Nain area. Instead, colour index, grain size, and feldspar composition have played a role, which in some cases has led to such paradoxical terms as the 'black leucodiorite' of Davies (1974). In this report, an attempt has been made to adhere to the IUGS classification where possible, relying solely on the mineral content for naming the plutonic rocks. There is some inconsistency, however, inasmuch as field names have not always been augmented by petrography. Streckeisen's (1975, p. 19) suggestion regarding mafic mineral content and rock association has been followed, and thus use of the term diorite is avoided for any of the leucocratic mafic rocks in the area. Fine-grained mafic rocks that would be termed dioritic or ferrodioritic by Wiebe (1979, 1990) and Emslie (1991) are present as a few isolated bodies but are herein named according to modal mineral content as gabbros, norites and gabbronorites. Wiebe and Emslie interpret these finer grained rocks as being representative of residual liquids from crystallization of the anorthositic and noritic plutons, a distinction that sets them apart from the coarser leucocratic cumulates.

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