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THE GEOLOGY OF LABRADOR BETWEEN TIKKOATOKAK BAY AND THE QUÉBEC BORDER (NTS 14D, NORTH HALF): A RECONNAISSANCE EXAMINATION

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ABSTRACT

A reconnaissance survey of the bedrock geology of a 30- to 60-km-wide by 120-km-long corridor between Nain Bay and the Québec border was conducted in 2002. The survey resulted in a preliminary large-scale subdivision of the metamorphic and igneous rocks. The eastern half of the survey corridor is underlain mainly by anorthositic and granitic rocks of the Mesoproterozoic Nain Plutonic Suite (NPS), but also includes basic rocks of probable Paleoproterozoic and Archean age. The plateau area of the western half of the corridor is underlain by a variety of interlayered, foliated to gneissic metaplutonic and supracrustal rocks of likely Archean and Paleoproterozoic age, including a wide belt of the Paleoproterozoic Tasiuyak metasedimentary gneiss.

Plutonic rocks of the eastern part of the corridor comprise many nested and interfering anorthosite and monzonitic to granitic NPS intrusions, but also comprises some anorthositic rocks that may belong to the Paleoproterozoic Arnanunat Plutonic Suite, as well as gneissose anorthositic and layered mafic rocks thay may belong to the Archean Nain Province. The oldest NPS anorthositic intrusions have foliated borders, and are separated from enclosing gneisses by haloes of foliated monzonite. Younger NPS intrusions lack foliated border zones. Contact metamorphic aureoles were generated in the enveloping rocks to some NPS intrusions. Gneissic septa between NPS intrusions comprise quartzofeldspathic metaplutonic and metasedimentary gneisses as well as enigmatic rocks of anorthositic character. The latter have features in common with known Archean, Paleoproterozoic and Mesoproterozoic intrusive rocks, although critical age data are unavailable.

Metamorphic rocks of the western part of the corridor contain granulite- and amphibolite-facies assemblages, and vary mesoscopically from polydeformed migmatites to foliated granitoid rocks. Locally, the migmatites contain leucogabbroic and anorthositic inclusions and are cut by metamorphosed basic dykes suggesting that at least some rocks in the western part of the corridor are correlative with Archean rocks south of the study area. Some of the foliated metaplutonic rocks appear to be derived from intrusions that cut the migmatites, and may be a manifestation of both Archean and Paleoproterozoic magmatism. The latter age is clearly indicated by the presence of sheets of metaplutonic rock within the Tasiuyak gneiss.

Widely scattered showings of sulphide and oxide mineralization are present in the study corridor. A few showings were studied in detail in the mid-1990s, although none of the largest showings has proven to be of sufficient economic interest to warrant long-term investigation. Assays from new showings found during the 2002 survey did not yield any anomalous metal content values.

INTRODUCTION

The Geological Survey is currently anticipating the commencement, in the summer of 2003, of a 1:50 000- and 1:100 000-scale mapping program covering one of the few remaining areas of northern Labrador not previously mapped at these scales, namely the northern half of NTS map-sheet 14D (Tasisuak Lake) and the adjacent eastern edge of 24A (Figures 1 and 2). This project area comprises an east–west tract of country that is approximately 30 to 60 km wide by 120 km long. The eastern edge of the proposed survey area is situated on the coast, at Tikkoatokak Bay, and the western edge is demarcated by the Québec border; Anaktalik Brook is situated along the southern edge of the area, and the northern boundary is 20 km north of Kingurutik Lake. The limited time and resources available for the 2002 field season dictated that the initial survey in northern Labrador was devoted to a rapid reconnaissance – 45 hours of helicopter-supported investigation over 12 days – of a little over half of the proposed survey area, that covered only map sheets 14D/9,10,11,12 and 16 (Figure 2).

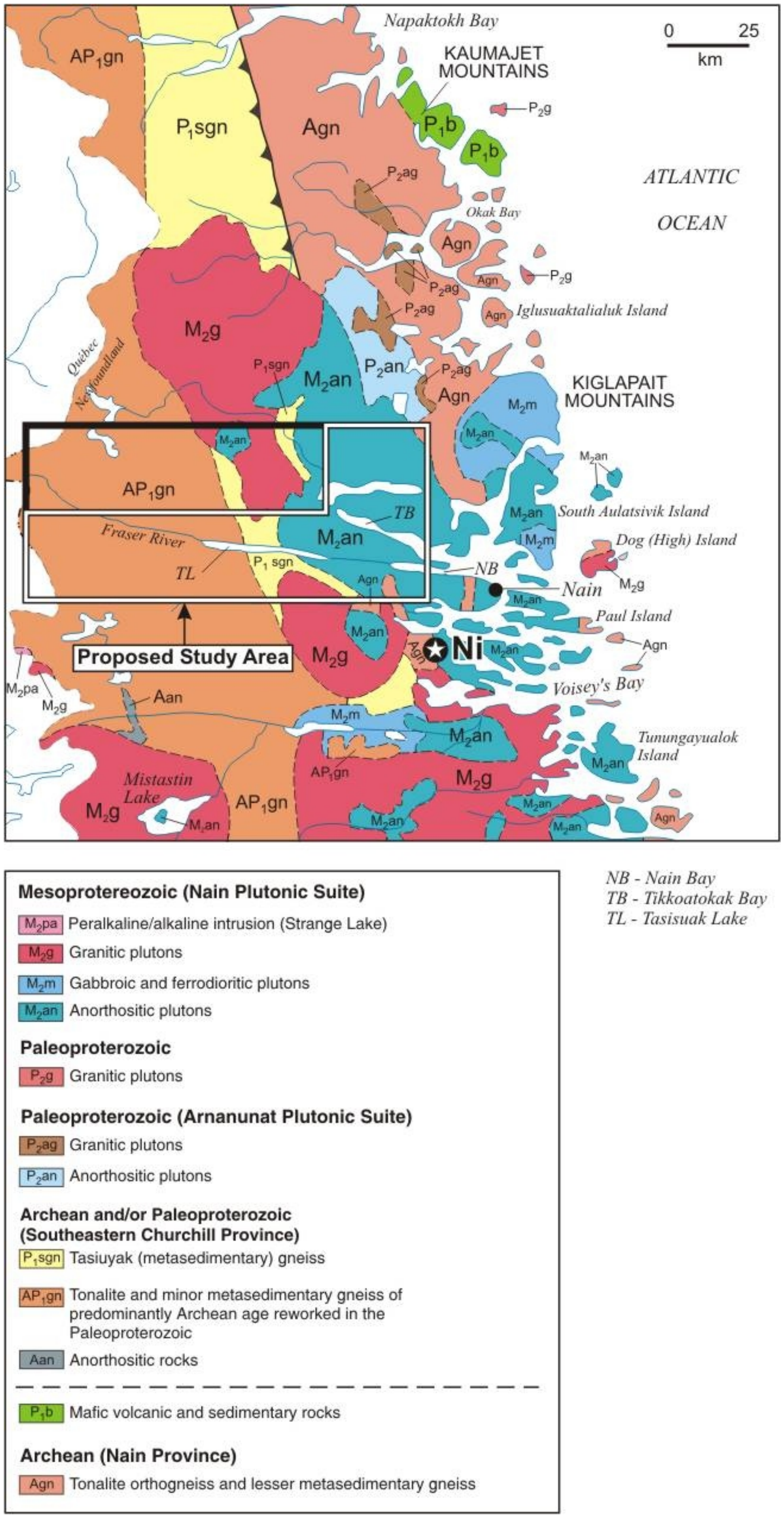

Figure 1. *Regional geological setting of the Labrador project area slated for 1:50 000- and 1:100 000-scale mapping over the next few years. The part of the region examined during the 2002 reconnaissance survey is shown here by the white line, and is depicted in more detail in Figure 2. Ni designates the Voisey's Bay nickel–copper deposit.*

The topography of the eastern half of the proposed survey corridor, underlain mostly by plutonic rocks, is rugged, and local relief is nearly 1000 m (Plate 1). This mountainous terrain gives way westward to a low-relief upland area, situated at 500 m above sea level, developed upon a gneissic substrate (Plate 2). The Fraser River canyon, in which Tasisuak Lake is located, is a major through-going east–west break in the topography west of Nain Bay. Bedrock outcrop is superb in the east, but a blanket of boulder-strewn gravel and sand masks the bedrock over a significant percentage of the plateau (Plates 1 and 2).

At present, the general distribution of major rock units underlying most of the northern half of NTS map area 14D is known at scales that permit only preliminary regional compilation maps to be drawn (cf. Taylor, 1977a; Ryan, 1990a; Wardle *et al.*, 1997). There are very few parts of the area for which the geology within the existing database can be reliably transferred to anything finer than maps at 1: 100 000 scale. This state of knowledge is a barrier to many discussions of the specifics of geological relationships, and is an impediment to determining the geological setting of mineral prospects discovered over the last decade.

REVIEW AND OBJECTIVES

Previous regional geological mapping within the northern half of NTS map area 14D has been sparse. The pioneering surveys of Wheeler (1942, 1960, 1969) and, to a lesser extent, Christie (1952) provided the basic distribution of the major igneous and metamorphic rock units. [Note: In addition to his published work, Wheeler also recorded data from this region on a set of manuscript maps and in an unpublished report. The report and maps are on file with the Department of Mines and Energy, and the map data were transferred to 1:200 000-scale bases and published in 1984.] It appears, as well, that British Newfoundland Exploration (BRINEX) Limited had conducted some regional mapping here in the 1950s, because the distribution of some units for this area compiled on an undated hand-coloured geological map of Labrador (BRINCO, undated) in the Geological Survey files differs from the maps of earlier and contemporary workers. Taylor (1977a) presented a more detailed view of the general geology of NTS map area 14D, derived from a monumental program of helicopter-supported systematic "4-mile" mapping of northern Labrador, northeastern Québec and part of the Northwest Territories undertaken in the late 1960s, and he partitioned the region into several tectonostratigraphic subunits (Taylor, 1979). Plutonic rocks of the eastern coastal region were a focus of study for personnel of the Nain Anorthosite Project during the 1970s (cf. Morse and Wheeler, 1974; Deuring, 1976). The 1994 discovery of the Voisey's Bay nickel–copper deposit within the NPS (Figure 1) set in motion a whole new wave of interest in the intrusive rocks, as well as the bounding gneisses. Most of the companies participating in the subsequent exploration of the NPS were focussing on areally-limited claim blocks and rarely examined regions distal from these blocks. Consequently, these targeted exploration-oriented surveys provided mineral evaluation information for small areas (*see* Economic Geology section below) but rarely dealt with the regional distribution of the different rock units or the chronological relationships.

The previous regional surveys, referenced above, have allowed for the general demarcation of the major geological subdivisions within the proposed corridor of investigation. Employing the tectonostratigraphic nomenclature of Taylor (1971, 1979) and Ryan (1990a), these subdivisions are, i) Archean gneisses of the Nain Province, ii) Archean and Paleoproterozoic gneisses of the Churchill Province, and iii) Mesoproterozoic igneous rocks of the Nain Plutonic Suite (NPS), which are products of aggregated anorogenic plutons emplaced into the older metamorphic terranes (Figure 1). The junction between the Nain and Churchill provinces is a ca. 1.8 Ga continental collisional suture, and the thermotectonism associated with this collision is termed Torngat Orogen. Some of the salient aspects of the regional geology of the proposed survey area, based mainly on the works referenced in the foregoing paragraph, are summarized below. These are augmented by relevant allusions to the geology of bordering areas immediately to the north and south.

Metamorphic rocks, which can be assigned with some degree of confidence to the Archean Nain Province, are rare along the northern part of the 14D map area. The only possible representatives of the Nain Province are those gneisses that occupy the very northeastern margin of the corridor. There, granulite-facies quartzofeldspathic rocks and metamorphosed leucogabbronoritic rocks form the immediate envelope east of the troctolitic to anorthositic plutons of the NPS. Archean rocks may also be present among the gneisses south of Nain Bay, but their "provincial" status is equivocal (*see below*, and the Discussion section).

The gneisses of the northern part of the 14D map area comprise mostly rocks that Taylor (1971) assigned to the Paleoproterozoic Churchill Province. These gneisses can be regionally subdivided, mainly from the work of Wheeler (1984) and Taylor (1979), into i) a major northwesterly trending belt of garnetiferous paragneiss in the east and ii) granulite- and amphibolite-facies rocks of diverse origin in the west. The paragneiss unit, termed Tasiuyak gneiss (Wardle, 1983), is a distinctive geological subdivision through the central coastal region of Labrador, where it is one of the major components of the Churchill Province (cf. Wardle *et al.*, 1997). It has been demonstrated from work to the north and south that the Tasiuyak gneiss also locally encloses dis-

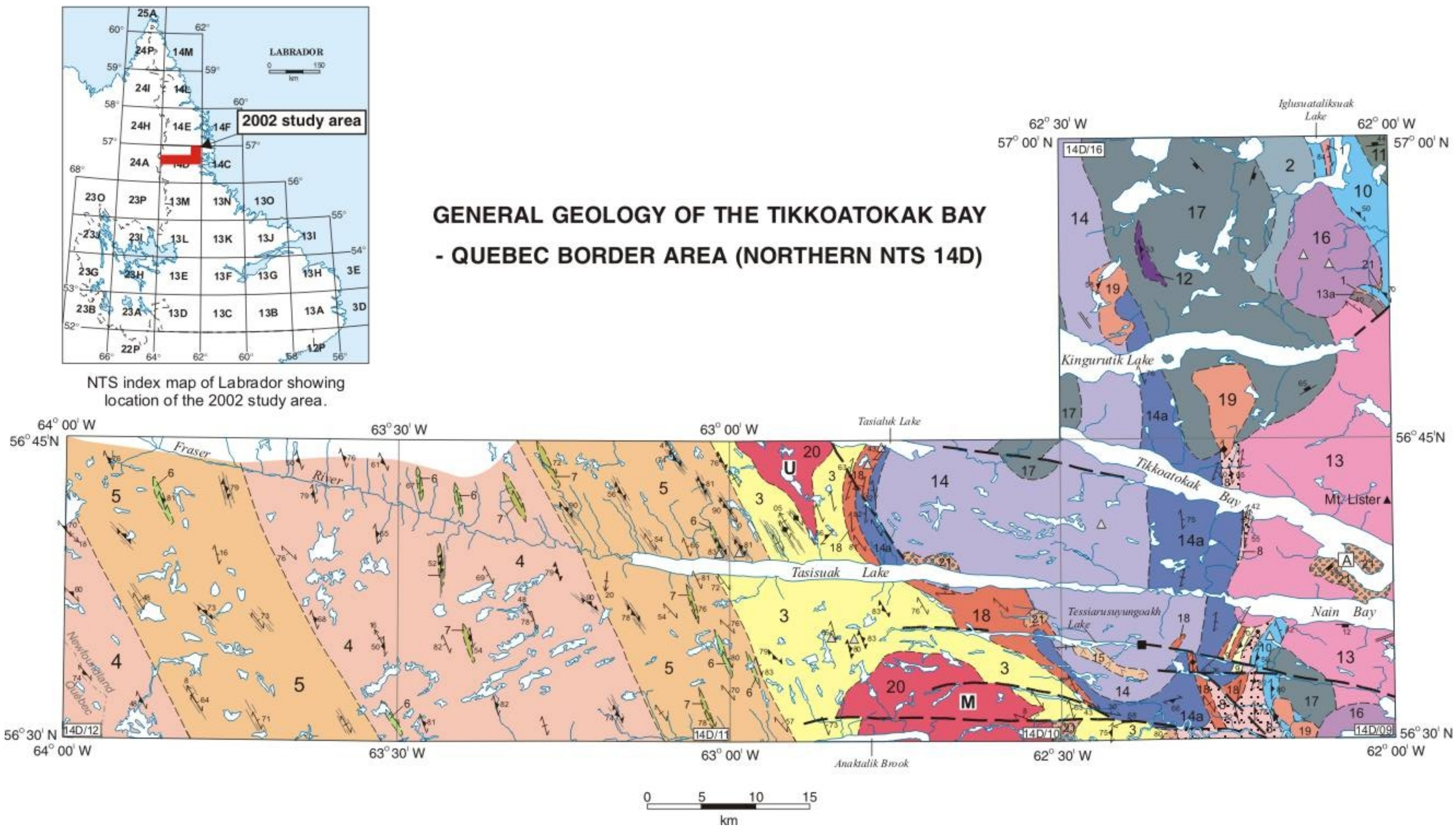

Figure 2. *First-pass compilation map of the geology of the Nain Bay–Kingurutik Lake–Fraser River region. Most of map pattern here is interpreted from data collected during the 2002 survey, but it also incorporates information from unpublished regional geology maps of E. P. Wheeler II, as well as work south of Nain Bay and northeast of Kingurutik Lake by B. Ryan in the early 1990s (see text). The inset map shows the study area in relation to the NTS grid for Labrador.*

LEGEND (for Figure 2)

MESOPROTEROZOIC

Nain Plutonic Suite (NPS)

Granitic and dioritic rocks

- 21 Diorite and ferrodiorite: Akpaume (A)
- 20 Rapakivi granite: Umiakovik (U) and Makhavinekh (M)
- 19 Massive monzonite and quartz monzonite
- 18 Foliated monzonite and quartz monzonite

Anorthositic and leuconoritic rocks

- 17 Undivided anorthositic to leuconoritic rocks
- 16 Olivine gabbro, troctolite and olivine leuconorite
- 15 Oxide-rich olivine leuconorite
- 14a Pearly Gates intrusion - foliated margin
- 14 Pearly Gates intrusion - interior
- 13a Mount Lister intrusion - foliated margin
- 13 Mount Lister intrusion - interior
- 12 Layered olivine melagabbro and leuconorite

PALEOPROTEROZOIC AND ARCHEAN

Gneisses of uncertain affinity

- 11 Layered mafic rocks
- 10 Anorthositic to gabbronoritic gneisses
- 9 Metasedimentary rocks
- 8 Undivided gneisses

Southeastern Churchill Province gneisses

- 7 Metasedimentary rocks
- 6 Mafic rocks
- 5 Charnockitic gneisses
- 4 Grey migmatite (orthogneiss)
- 3 Tasiuyak paragneiss (Paleoproterozoic)

Arnanunat Plutonic Suite (Paleoproterozoic)

- 2 Leuconorite, leucogabbro

Nain Province (?) gneisses

- 1 Undivided gneisses

SYMBOLS

Unit contacts (assumed) ....

Faults (assumed) ....

Igneous layering 27

Dyke 71

Foliation (dip known, dip vertical, dip unknown) 43

Gneissosity (dip known, dip vertical) 57

Mineral elongation lineation 14

Intense foliation or planar fabric in ductile high-strain zone 69

Sulphide and/or Fe-Ti oxide showing / mineral prospect ....

Labradorite occurrence ....

Plate 1. *View of the rugged topography and rock exposure along the northeast side of Tasialak Lake, typical of the terrain underlain by anorthositic rocks in the eastern part of the study area. Cliffs of anorthosite bordering the lake here are about 350 m high.*

Plate 2. *Westward expanse of fluted gravels on the plateau south of Tasisuak Lake. This overburden blankets most of the gneissic bedrock of the western half of the survey area.*

crete bodies of garnetiferous megacrystic leucogranite, and is interlayered with numerous sheets of metaplutonic rocks that range from gabbronorite to charnockite in composition (cf. Ryan and Lee, 1986; Ryan and Martineau, 1992; Ermanovics and van Kranendonk, 1998). The metaplutonic rocks are more prominent among the amphibolite- and granulite-facies gneisses west of Tasiuyak gneiss, but within this western terrrane there are paragneisses like the Tasiuyak gneiss, marble and calc-silicate rocks, mafic gneisses derived from layered intrusions, and Archean meta-anorthositic and migmatitic rocks (cf. Ryan, 1990a, 1992).

The Nain Plutonic Suite straddles the collisional junction between the Churchill and Nain provinces (Figure 1). Up until the mid-1970s, the NPS had been internally separated simply into its anorthositic and granitic components (Wheeler, 1942, 1960; Emslie *et al*., 1972), but at the end of the Nain Anorthosite Project (NAP) a more refined assessment of the NPS was made (*see* Morse, 1977, p. 1-3; 1983a). Work during the decade of the NAP led to the recognition of the polyphase aspect of the magmatism, the demarcation of some of the individual intrusions and internal subunits (cf. Berg, 1974; Wiebe, 1976; Morse, 1983a), and a four-fold subdivision to the igneous rocks (generalized as anorthosite, troctolite, diorite and granite; Ryan and Morse, 1985). Of particular relevance to the present survey is the reconnaissance work of Morse and Wheeler (1974), which first outlined a tripartite subdivision to the anorthositic rocks along Tikkoatokak Bay that they termed, from west to east, the Bird Lake massif, the Susie Brook slab, and the Lister massif.

Within the last couple of decades the Geological Survey of Newfoundland and Labrador (GSNL) has undertaken several mapping programs in the Nain region. The initial surveys in the mid-1980s were designed primarily to examine the Nain Plutonic Suite and its west-margin gneisses for the presence of rare-element-enriched granitic intrusions (cf. Ryan and Lee, 1986). The surveys in the late 1990s, instigated following the discovery of a nickel–copper deposit within basic rocks of the Nain Plutonic Suite, were designed to attempt to subdivide the Nain Plutonic Suite into its constituent plutons, increase knowledge of the diversity of the gneisses, and to ascertain the stratigraphic setting of other nickel–copper discoveries reported by exploration companies in poorly known parts of the NPS and its envelope (Ryan *et al.*, 1997, 1998).

Several important geological results have accrued from the Survey's recent mapping programs within the Nain Plutonic Suite. One of the main outcomes has been the subdivision of the regionally monotonous anorthositic component of the NPS into numerous smaller plutons (cf. Ryan *et al*., 1998; Ryan, 2001a, b), attesting to the protracted magmatism and nested style of intrusions that make up the batholithic "massif" (*see also* Morse, 1982; Wiebe, 1992). It was also discovered that several of the largest anorthositic plutons within the NPS have marginal zones that have been significantly deformed and recrystallized where they abut gneisses, and that these plutons have sheaths of monzonitic to granitic rocks that are similarly deformed (cf. Ryan, 1993, 2001b). Another important result of the surveys in the Nain area was the recognition that nearly the whole northeastern section of the area of rocks historically designated as being part of the Mesoproterozoic NPS prior to 1995 (Wheeler, 1969; Taylor, 1977b; Ryan, 1990a) is, instead, Paleoproterozoic in age (Figure 1; Ryan *et al.*, 1998). These rocks, though superficially similar to the Mesoproterozoic intrusions, are products of magmatism some 800 million years prior to the emplacement of the NPS (Hamilton *et al.*, 1998). Deformational fabrics and low-grade metamorphism in these older plutonic rocks, and in a suite of basic dykes that intrudes them, are considered to be products of tectonism during formation of the Torngat Orogen (ca. 1860 to 1770 Ma). Consequently, these older intrusions are now stratigraphically excised from the NPS and provisionally named the Arnanunat Plutonic Suite (Ryan *et al*., 1999; Figure 1).

The northern part of NTS map area 14D encompasses a variety of plutonic rocks that are, without evidence to the contrary, mostly assigned to the NPS, as well as high-grade metamorphic rocks into which the NPS was intruded. The survey that commenced in 2002 has as one of its objectives the subdivision of both these regional-scale units into finer scale constituent parts. This is considered to be helpful from both the stratigraphic and exploration perspective for several reasons. First, subdivisions of the gneisses will provide a picture of the extent of Archean and Paleoproterozoic rocks, and the extent of metaplutonic rocks and supracrustal rocks. Second, subdivision of the NPS will provide some idea of the extent of individual intrusions and it will help in understanding how this vast batholithic terrane evolved. Third, the subdivision of both regional units will aid in targeting or focussing exploration activity because it may be possible that only very restricted units or subunits are mineralized. The 2002 survey was too broad-based to offer rigid subdivisions for either of the regional units, and the geological map (Figure 2) that has been compiled from the current data is heavily dependent on information gleaned (and in some cases re-interpreted) from the manuscript maps of E.P. Wheeler (*see also* Wheeler, 1984) or extrapolated from directly adjoining map-sheets examined as part of earlier GSNL programs (*see above*).

GENERAL GEOLOGY

The results of the 2002 survey, in combination with earlier work in the Nain–Tikkoatokak bays region, permit the following summary of the geology of the northern part of NTS map area 14D (*see* Figure 2).

GNEISSIC ROCKS (NAIN PROVINCE?) EAST OF THE NPS IN KINGURUTIK LAKE AREA (UNIT 1)

Granulite-facies quartzofeldspathic gneisses, and associated metamorphosed leuco-gabbronoritic rocks of uncertain affinity (*see below*), occupy a small part of the survey area near Iglusuataliksuak Lake. These are intruded by metamorphosed mafic dykes which, by correlation with rocks directly to the north (Ryan *et al*., 1997), implies that this area is underlain by Archean rocks that may represent Nain Province; a Paleoproterozoic age for this assemblage of metamorphic rocks cannot, however, be ruled out. A narrow screen of gneissic rocks believed to be Archean in age outcrops directly northeast of Kingurutik Lake, between the Mount Lister anorthosite and an older recrystallized and gneissose anorthositic rock. This unit comprises laminar-banded and mylonitic quartzofeldspathic gneisses having lenses of mafic and ultramafic rock, pink foliated granite containing rafts of the foliated anorthosite, and younger white granitic sheets having the same foliation as the host. This mylonitic group of rocks is intruded on its western margin by the abutting foliated oxide-rich ferrodiorite that forms the sheath to the Mount Lister intrusion in this area.

PALEOPROTEROZOIC INTRUSIONS (ARNANUNAT PLUTONIC SUITE) WEST OF IGLUSUATALIKSUAK LAKE (UNIT 2)

Anorthositic and granitic intrusions of Paleoproterozoic age were demarcated within Archean(?) gneisses in the vicinity of Iglusuataliksuak Lake in 1996 (Ryan *et al*., 1997), were subsequently traced north toward Okak Bay (Ryan *et al.*, 1998), and have been assigned to a new plutonic subdivision for this part of Labrador, namely, the Arnanunat Plutonic suite (Ryan *et al.*, 1999). The crystallization ages of several of these intrusions indicate magmatism extended at least from 2130 Ma to 2040 Ma (Hamilton *et al*., 1998; unpublished data). The southern extension of one (or more) of the anorthositic intrusions into the present study area seems to be restricted to the west side of Iglusuataliksuak Lake, where there is a grey, variably recrystallized rock of leucogabbro or leuconorite composition, which has localized shear zones, which is intruded by a network of aplitic to pegmatitic granitic veins and in which the pyroxene locally has amphibole rims. The extension of the Arnanunat Plutonic Suite southward from Iglusuataliksuak Lake as shown on Figure 2 is somewhat conjectural; its distribution reflects the approximate outline of the area having the same regional aeromagnetic signature as the leucogabbronoritic outcrops examined west of the lake.

GNEISSIC ROCKS WEST OF THE NPS (UNITS 3 TO 7)

Tasiuyak Gneiss

The most distinctive continuous unit of the envelope to the NPS is the Tasiuyak gneiss (Unit 3), a Paleoproterozoic garnet-rich migmatitic metasedimentary gneiss and associated diatexite. The sedimentary precursor to the Tasiuyak gneiss seems to have been composed of detritus shed from Paleoproterozoic sources (possibly volcanic arcs), with little input from any potentially proximal Archean crust (Scott and Gauthier, 1996). The composition of rocks within the Tasiuyak gneiss ranges from micaceous, rusty, graphitic-sulphiditic schists through to garnetiferous leucogranite. The most widespread type of metasedimentary rock is a semipelitic gneiss having abundant mauve to red to pink garnets within a buff matrix of quartz and feldspars; biotite, sillimanite, and lesser orthopyroxene are regionally distributed (cf. Taylor, 1979). Quartzite (or metachert) is locally present, but no calcareous rocks are known from the unit here. Sillimanite seems to be rare in, or completely absent from, the Tasiuyak gneiss in the 2002 survey area, but some of the rocks within the contact aureoles of the younger intrusions have, around the garnet porphyroblasts, the arcuate black "eyelids" that are an earmark of the replacement of regional sheaves of sillimanite by spinel+cordierite (cf. Lee, 1987).

Contact metamorphism imposed upon the Tasiuyak gneiss adjacent to the NPS intrusions is variable. Mesoscopic regional metamorphic features of the gneiss are still preserved adjacent to the Umiakovik Lake granite north of Tasisuak Lake but orthopyroxene atolls are developed around garnet (Plate 3). Extreme contact metamorphism along the southern part of the survey area has destroyed most of the earlier character of the gneiss, and transformed the original garnet-rich rock to quite a visually striking cordierite-rich rock. The cordierite has been derived from the breakdown of garnet (and probably sillimanite; *see above*) under conditions of pyroxene hornfels facies (cf. Berg, 1977; Lee, 1987), and the resulting rock is a brown-weathering gneiss having spots and discontinuous streaks of dark to light blue cordierite. Cordierite is rare or completely absent from the gneiss in the region of Tasiuyak Lake, but some gneisses have a dark orthopyroxene and/or biotite halo on garnet.

High-strain foliations and a well-developed shallowly plunging mineral-stretching lineation, likely a result of Paleoproterozoic transcurrent shear (Korstgaard *et al*., 1987; van Kranendonk, 1996), characterize some of the Tasiuyak gneiss west of the anorthositic rocks of the Tasisuak Lake area.

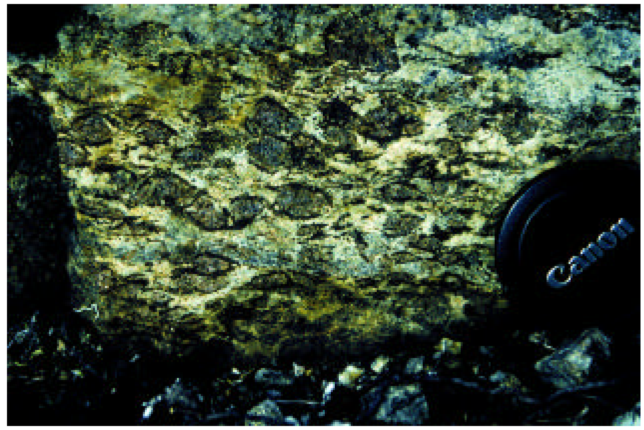

Plate 3. *Contact metamorphosed Tasiuyak gneiss (Unit 3) north of Tasisuak Lake: dark atolls of orthopyroxene (plus plagioclase) surround remnants of garnet.*

Intercalated with Tasiuyak gneiss are numerous metre- to hundreds-of-metre-scale units of granulite-facies, locally garnetiferous, gneisses spanning the compositional range from gabbronoritic to enderbitic to charnockitic. Hornblende-rich "mela-granulites" are present and apparently locally extensive; ultramafic rocks seem to be rare. None of the immediately foregoing rock types are extensive enough to portray on Figure 2.

Quartzofeldspathic and Other Gneisses West of Tasiuyak Gneiss

Most of the gneisses of the survey area are layered rocks of diverse composition, which can be divided only in a very general manner at the scale of the present survey. On the accompanying map (Figure 2) they are separated into broad belts on the basis of their apparent metamorphic grade and overall mesoscopic character: i) grey amphibolite-facies orthogneiss migmatites (Unit 4), and ii) brown, granulite-facies, deformed, charnockitic rocks (Unit 5). Within each major subdivision are lesser volumes of mafic (Unit 6) and metasedimentary (Unit 7) gneiss, some of which are extensive enough to portray diagrammatically on Figure 2. The boundaries of the major units in the area north of the upper reaches of the Fraser River on Figure 2 should be considered as "best guess" contacts, because a variety of rock types was encountered there, but the data collected were insufficient to ascertain the regional patterns or to make reliable extrapolations across the river from the south.

The amphibolite-facies grey migmatites (Unit 4) comprise a veined quartz dioritic and granodioritic host in which there are metre-scale "exploded" mafic units, metasedimen-

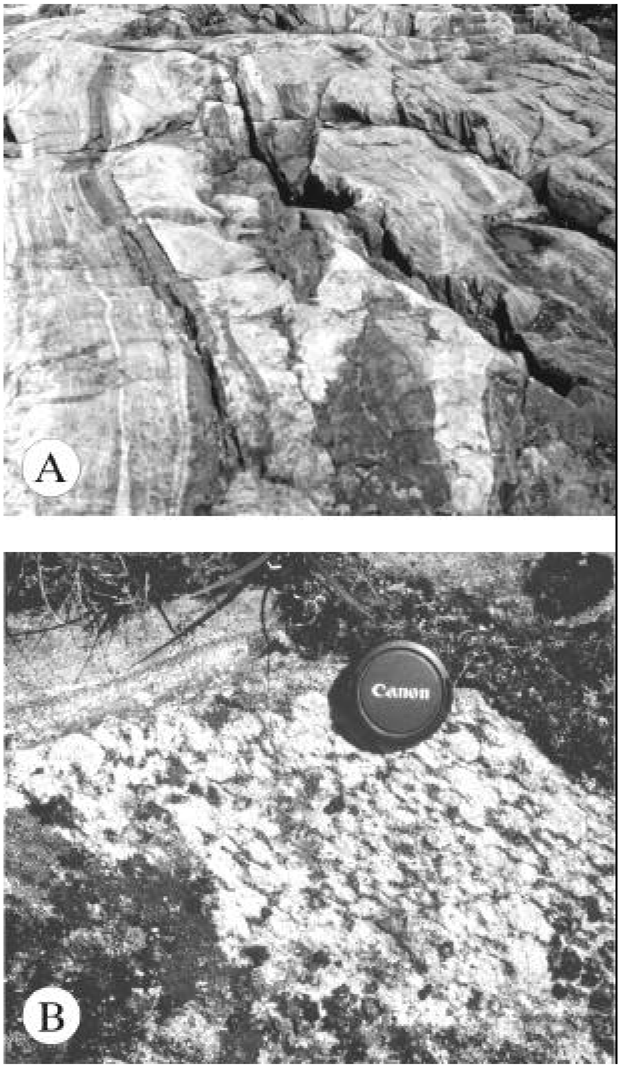

Plate 4. *Amphibolite-facies grey gneiss (Unit 4). (a) Migmatite gneiss of overall quartz dioritic composition has lenses and layers of mafic gneiss, and is intruded by dykes and sills of nebulous granite to granodiorite. (b) Meta-leuocogabbroic raft within grey migmatite.*

tary lenses and pods of ultramafic rock (Plate 4a). South of the upper reaches of the Fraser River these migmatites contain trains of meta-anorthositic to hornblende-bearing meta-leucogabbroic rocks (Plate 4b), a feature that has proven diagnostic of Archean-age gneisses of the plateau area to the south (cf. Ryan, 1990b). Some of the dioritic and granodioritic orthogneisses originally had porphyritc textures, and these bimodal plutonic variants are converted to augen-textured schists and gneisses. Some outcrops of foliated granitoid rocks have massive to foliated mafic components that were probably dykes; based on interpretations and geochronological data from south of Anakatalik Brook (Ryan *et al*., 1991b) these relations could indicate late Archean plutons intruded by Paleoproterozoic dykes.

Plate 5. *"Grey-and-pink" variety of charnockitic orthogneiss (Unit 5). High-strain fabric here has attenuated and disrupted the granitic vein network in the tonalitic host, the latter of which retains remnants of its original porphyritic texture.*

The charnockitic rocks (Unit 5) that are broadly interbanded with the grey migmatitic gneisses are generally simply foliated, clearly derived from plutonic protoliths that were equigranular to slightly porphyritic (Plate 5). Some of these meta-igneous rocks were originally grey tonalitic plutons having networks of pink granitic veins, now forming a "grey-and-pink" orthogneiss, where significantly deformed. Quartz-bearing rock types prevail among the orthogneisses in the west, but the eastern belt contains quartz-poor rocks including gabbronoritic variants. The rocks of the latter belt are diagnostic of the calc-alkaline "enderbitic suite" that intrudes, and is regionally interlayered with the Tasiuyak gneiss (cf. Ermanovics and van Kranendonk, 1998). Interspersed with the orthogneisses are layered mafic gneiss derived from gabbroic intrusions (Unit 6), and metasedimentary gneisses having arkosic, calcareous and pelitic precursors (Unit 7). Among the metasedimentary rocks is a distinctive unit comprising mostly calcareous meta-arkose, a rock type known to extend at least 40 km southward toward Cabot Lake from the current area (cf. Ryan and Corriveau, 1989; Ryan *et al*., 1991a).

High-strain fabrics seem to be more prevalent in the granulite-facies rocks than in the amphibolite-facies ones. In the former, there is widespread development of a high-grade mylonitic-style of foliation that locally produces "straight belts" in which the components of the rock are attenuated to produce a regularly layered gneiss. Sheets of foliated pink granite, having aplitic to pegmatitic character and up to several metres wide, are locally prominent; these have a simple foliation that may be indicative of their emplacement and deformation during the waning stages of the high-strain event(s) that affected the surrounding gneisses.

The ages of the gneissose rocks in the study area, by comparison with those on the plateau to the south of Anaktalik Brook (Ryan *et al*., 1991b), likely range from late Archean to Paleoproterozoic. The mesoscopic character of some of the migmatitic and granitoid rocks, (including the presence of dykes and disrupted anorthositic units, as noted above), certainly lends itself to the interpretation that these rocks are of Archean age. The foliated charnockitic metaplutonic rocks have few field characteristics that would indicate a possible age, and they probably include both deformed Archean and Paleoproterozoic intrusions.

GNEISSIC ROCKS AS SEPTA BETWEEN NPS INTRUSIONS (UNITS 8 AND 9)

Wheeler's earliest examinations of the NPS igneous rocks (cf. Wheeler, 1942, 1960; unpublished maps) revealed within the plutonic terrane the presence of gneissic screens, on the order of hundreds of metres to several kilometres in width and length. The largest of these gneissic septa occurs south of Nain Bay; another belt stretches across Tikkoatokak Bay. The rocks in the septa have mineral assemblages of the granulite facies, and in many cases were easily amenable to interpretation by Wheeler as country-rock remnants preserved between intrusions. Some of the rocks in this setting, however, proved problematic in their origin and designation, and he opted to categorize them as "granulites of uncertain origin" (cf. Wheeler, unpublished manuscript; 1984). It seems from recent work (cf. Ryan, 1991a, 1992) that this "uncertain" category includes quite a range of compositions, encompassing rocks that are typical of quartzofeldspathic gneisses distal from the plutons as well as basic rocks that are compositionally similar to those of the enclosing intrusions. In this report, the basic rocks are addressed in a separate section below.

The belt south of Nain Bay comprises granulite-facies quartzofeldspathic gneisses (Unit 8), metasedimentary gneiss (Unit 9), and leucocratic rocks of overall gabbronoritic and anorthositic composition (*see* following section). The latter rock types constitute one of the units that Wheeler (unpublished manuscript) had in this area assigned to his "granulites of uncertain origin" (*see* following section). Taylor (1977a) incorporated all the rocks of this area into the Nain Province, but Wheeler's more detailed data suggested to Ryan (1990a) that there could be an alternative interpretation. On a regional compilation map of the Nain region, Ryan (*op. cit.*) assigned the quartzofeldspathic granulites an Archean age and interpreted the metasedimentary gneisses as Tasiuyak gneiss. The junction between these two units, based on contemporary interpretations from northern Labrador, marked the contact between the Archean Nain Province and the Paleoproterozoic Churchill Province. The anorthositic rocks were assigned, on that map, to the NPS. Subsequent field work in the area (Ryan, 1993) indicated that this data interpretation is in error, and that all rocks are likely part of the same terrane. Although there is no indication of their absolute age, these rocks were tentatively assigned an Archean niche, but their "provincial" status is open to debate. They could be true representatives of the Nain Province, or they could be part of the Churchill Province that is not preserved to the north.

A north-trending gneiss belt (Unit 8), up to 1500 m wide, crosses Tikkoatokak Bay about halfway along its length, and is shown on Wheeler's unpublished maps as "granulites of uncertain origin" (*see also* Wheeler, 1984). Taylor (1977a) included these rocks within the Nain Province, but Ryan (1990a) opted to re-assign them to the Churchill Province. A brief examination of the part of the belt to the north of the Bay during the 2002 survey has indicated that here it comprises quartzofeldspathic granulites, mafic granulites and ultramafic granulites, as well as one or more units of foliated and granular anorthositic to leucogabbronoritic rocks like those south of Nain Bay. The belt is bordered on its western side by foliated monzonite, typical of the deformed rocks that constitute the discontinuous sheath surrounding the Pearly Gates intrusion (*see below*). The continuation of Wheeler's belt of "granulites of uncertain origin" across Tikkoatokak Bay to the south was visited at just a couple of locations, and seems, likewise, to contain a diversity of rocks. Within this belt, there are certainly cordierite-bearing metasedimentary rocks, but there are also foliated monzonitic plutonic rocks, containing anorthositic inclusions, that may be spatially and temporally associated with the foliated margin of the Pearly Gates intrusion to the west.

GNEISSOSE ANORTHOSITIC AND GABBRONORITIC ROCKS OF PROBLEMATIC STRATIGRAPHIC DESIGNATION (UNITS 10 AND 11)

Wheeler (unpublished manuscript) and Ryan (1991a, 1993) documented the existence of enigmatic, granoblastic-textured, massive to distinctly gneissic, meta-anorthositic and associated gabbronoritic rocks proximal to some of the NPS plutons. Wheeler opted to include them in his "granulites of uncertain origin" subdivision, a subdivision that also included rocks now known to be foliated marginal zones to the NPS plutons themselves. Both Wheeler (*op. cit.*) and Ryan (*op. cit.*) noted that it was difficult to stratigraphically categorize the meta-anorthositic rocks within the context of the major regional subdivisions, and some – especially those that are migmatized and/or interlayered with granulite-facies gneisses – could be Paleoproterozoic or even Archean in age. Because his investigations of the country-rock to the NPS were limited, Wheeler (*op. cit.*) thought that most such rocks of this type are proximal to the

NPS, and he ventured the possibility that they were "intercallations [*sic*] of anorthositic rock penetrating the basement complex adjacent to the main anorthosite mass". Ryan (1993), Ryan *et al*. (1997) and Ermanovics and van Kranendonk (1998) have documented such anorthositic to gabbronoritic rocks as clearly interlayered with, and an integral part of, Archean gneisses distal from NPS anorthositic intrusions. In addition, granite-veined meta-anorthositic rocks northeast of Kingurutik Lake have been shown to be pre-1870 Ma (*see below*); such old rocks are clearly not genetically allied to the NPS. Nevertheless, the occurrence of so many of these meta-anorthosites in a seemingly close association with compositionally comparable intrusions of the NPS does make for interesting speculations as to their overall significance in the geological evolution of the region (cf. Ryan and Connelly, 1996) – is it a coincidence or is there a long-lived repetition of similar magmatism?

Plate 6. *Variably foliated to gneissose, Archean or Paleoproterozoic, anorthositic to leucogabbronoritic rocks (Unit 10). (a) The original coarse-grained nature of this basic rock north of Kingurutik Lake is evident from the morphology of its components, even though the primary pyroxene here is replaced by granular aggregates of two-pyroxenes+hornblende, and the primary coarse plagioclase has nearly totally recrystallized to a finer grained granoblastic mosaic. (b) Streaks of granular pyroxene set in a plagioclase matrix, in strongly deformed "leucogabbro" south of Nain Bay. This rock is derived, by deformation and recrystallization, from an originally coarse-grained rock like in (a).*

An extensive unit occurs north of the east end of Kingurutik Lake, and other anorthositic to melagabbronoritic units are interlayered with amphibolite- to granulite-facies migmatitic gneisses just east of the present study-area between Webb Bay and Webb Pond on NTS map sheet 14C/13 (*see* Ryan 1993, Figure 3). The unit northeast of Kingurutik Lake (Unit 10) comprises deformed and recrystallized, white- to pale-brown-weathering gabbronorite, leucogabbronorite and anorthosite, as well as rare peridotite, all intruded by numerous pink aplitic dykes. One of these dykes has yielded a crystallization age of ca. 1873 ± 4 Ma (Connelly and Ryan, 1999), clearly indicating a Paleoproterozoic or earlier age for the surrounding anorthositic rocks. This unit locally contains very coarse-grained leucocratic rocks, and it is both locally and regionally texturally inhomogeneous with respect to primary characteristics and those imparted by subsequent deformation. The deformation of the unit is polyphase, exemplified by the local folding of the elongate pyroxene foliation, and this sets it apart from adjacent simply foliated rocks of the NPS. Some of the anorthositic rocks within this unit display a pale-blue labradoresence, and some of the largest pyroxene aggregates have a morphology consistent with total recrystallization of an original coarse subophitic pyroxene (Plate 6a), perhaps pigeonite.

The anorthositic and gabbronoritic rocks have their greatest known extent south of Nain Bay (Ryan, 1992, 1993), where a 1200-m-wide compositionally and texturally variable unit extends at least 8 km along strike (Unit 10). Similar rocks continue from there southward across Anaktalik Brook toward Voisey's Bay (Ryan and Lee, 1989). Like the unit north of Kingurutik Lake, white-weathering, granular, anorthosite and slightly buff-weathering leucogabbronorite and gabbronorite predominate among this group of foliated and recrystallized rocks, and a blue labradorescence is locally visible in the feldspar. Mafic layers – in some cases derived from mafic dykes – are locally present. Some varieties of this rock contain podiform and irregular granular aggregates of clinopyroxene + orthopyroxene (Plate 6b); the morphology of these granular aggregates in the least deformed rocks is compatible with derivation from a recrystallized original coarse pyroxene, another feature in common with the unit north of Kingurutik Lake. The polycrystalline aspect of even the largest original pyroxenes in these gneissose anorthositic and leucogabbronoritic rocks sets them apart from similar deformed and recrystallized rocks belonging to the NPS – in the strongly deformed and recrystallized leuconoritic types of the NPS all sizes of pyroxenes are still widely preserved as kinked relics, the largest ones especially so.

There are massive to diffusely layered melagabbronoritic rocks (Unit 11) at the northeast extremity of the 2002 corridor that may be temporally allied with the stratigraphically enigmatic anorthositic and leucogabbronoritic types addressed above. The rocks here were examined briefly by B. Ryan (unpublished data) in 1992, and they were visited at one location during the 2002 survey. These rocks are intruded by metamorphosed mafic dykes, and may be the southward continuation of a belt of similar mafic (and ultramafic) rocks that straddles Iglusuataliksuak Lake and continues for 8 km to the north on NTS map sheet 14E/1 (Ryan *et al*., 1997). Massive to layered mafic and ultramafic rocks that represent the continuation of this unit occur immediately to the east on NTS map sheet 14C/13, on the eastern side of the Webb's Brook valley (Ryan, 1993).

NAIN PLUTONIC SUITE (UNITS 12 TO 21)

Layered Mafic and Ultramafic Rocks north of Kingurutik Lake (Unit 12)

A group of layered igneous rocks (Unit 12), a small part of which is shown on Wheeler's unpublished geological maps as "granulites of uncertain origin" (*see also* Wheeler, 1984) and on the map of Taylor (1977a) as Archean gneiss, was examined north of Kingurutik Lake in 1991 (Ryan, 1992). This well-preserved, seemingly singular, layered sequence comprises well-defined metre-scale units of alternating reddish-brown olivine melagabbro and pale, greenish-grey leucogabbronorite (Plate 7), and probably represents part of a (once?) much larger intrusion. The full extent of the layered unit, or any other rocks that may be allied with it, is still not known, but it has been estimated from aerial observation that the sequence is approximately 6 km long and 1 km wide. Relationships between the layered rocks and their surroundings are not completely known, the only established contact being that with a younger massive leuconorite on its eastern side. A brief examination of the northern part of this intriguing unit during the present survey has indicated that it contains lenticular inclusions of cordierite-rich paragneiss of Tasiuyak type; it is, therefore, likely to be part of the Mesoproterozoic NPS, but an older age cannot be discounted.

Plate 7. *General aspect of a well-layered series of olivine melagabbro and gabbronorite (Unit 12) of unknown extent, north of Kingurutik Lake.*

Anorthositic Intrusions

Prior to the 1970s, the anorthositic rocks were divided mainly on the basis of their weathering colour – the pale, buff and dark "facies" erected by Wheeler (1960). It was apparent to both Wheeler (unpublished manuscript) and to Morse (1971, p. 9) that there were intrusive relations between anorthosite rocks having different colours, but, in spite of this, the demarcation of the extent of individual intrusions was not – except in rare cases (cf. Morse, 1969) – attempted before the initiation of the Nain Anorthosite Project (NAP) in 1971. Over the next decade great advances were made in understanding the internal architecture of the anorthositic "massif", such that by 1981, Morse (1983a, p. 9) was able to confidently conclude that it consisted of "many dozens of individual basic plutons".

It has become apparent, with the application of precise U–Pb radiometric dating to appropriate compositions within the NPS, that the magmatism that produced the aggregated intrusions of the NPS had lasted tens of millions of years (cf. Hamilton *et al*., 1994; Emslie *et al*., 1994), probably beginning ca. 1350 Ma and lasting until 1290 Ma. Mapping of different parts of the "massif" began to demonstrate that it was possible to discriminate between its constituent plutons, and showed that its construction by the coalescence of many individual intrusions was comparable to typical batholitic welts elsewhere (cf. Wiebe, 1992; Ryan *et al*., 1998). One of the features of the NPS that became apparent as mapping proceeded in the 1990s was that deformation of the plutonic rocks was much more extensive than previously known or appreciated, and that certain plutons were surrounded by marginal deformation zones that could be used to demarcate the extent of these intrusions. Geochronological investigations indicated that these intrusions are the oldest within the "massif".

Mount Lister Intrusion (Unit 13, 13a)

The Mount Lister intrusion – the "Lister massif" of Morse and Wheeler (1974) – is named after the prominent 1000 m bald mountain along its eastern side at the north-side entrance to Tikkoatokak Bay. This somewhat elliptical body is assumed to extend north–south for 40 km from Kingurutik Lake to Anakatalik Bay and east–west for 20 km from Barth Island (on NTS map sheet 14C/12; Ryan, 2001b) to midway along Tikkoatokak Bay. With its characteristic white- to light-grey-weathering, it represents a typical example of Wheeler's "pale facies" intrusions.

The salient aspects of the eastern side of the Mount Lister intrusion, largely outside the current survey area, have already been documented by Ryan (1993, 2000, 2001a, b). These are a foliated marginal zone of anorthosite and mafic-rich leuconorite, succeeded inward by variably recrystallized and diffusely layered, pegmatitic anorthosite and leuconorite. The outermost part of the intrusion is separated from the eastern gneisses by a discontinuous, variably deformed, monzonitic sheath.

The western half of the Mount Lister intrusion (Unit 13), falling within the 2002 survey area, has not been examined in sufficient detail to ascertain if all the anorthositic rocks now assigned to the body (Figure 2) are, in fact, part of that intrusion. These pegmatitic anorthositic rocks south of Nain Bay, instead of having a deformed contact against older rocks to the west, have a clear intrusive contact with some – if not all – of them (Plate 8), and a similar relation seemingly holds to the north of the bay. Another difference between the eastern and western margins is that the monzonitic rock that intervenes between the Mount Lister intrusion and its eastern gneissic envelope is missing from the western contact. It is possible that the current stratigraphic correlation is incorrect, and that all the coarse-grained rocks currently considered to be the western half of the Mount Lister intrusion are, in fact, a separate and younger pluton of similar grain-size and composition. A graduate-level mapping project presently underway at Memorial University of Newfoundland will shed more light on the relations south of Nain Bay.

Foliated anorthositic and leuconoritic rocks assigned to the marginal zone of the Mount Lister pluton (Unit 13a) occur northeast of Kingurutik Lake. Where examined, these are separated from mylonitic quartzofeldspathic gneisses by a very narrow body of foliated monzonite (Unit 18, *see below*).

Plate 8. *Dykes of pegmatitic leuconorite, interpreted (with reservation) as being related to the Mount Lister intrusion (Unit 13), emplaced across the fabric of a foliated leucogabbronorite of unknown (Unit 10) age south of Nain Bay.*

The age of the Mount Lister intrusion is open to discussion, but all indications point to it as being one of the oldest such units within the NPS. The marginal monzonite (Unit 18, *see below*), east of the present study area near Webb's Bay, interpreted by Connelly and Ryan (1994) to be intimately connected with, and quite probably closely age-related to, the anorthosite intrusion, has given a crystallization age of 1343 ± 3 Ma. The Akpaume ferrodiorite intrusion (Unit 21, *see below*), dated at 1333 ± 2 Ma (Hamilton *et al*., 1994) crosscuts, and contains foliated fragments of, the Mount Lister intrusion. In addition, olivine-bearing, pegmatoidal ferrodiorite(?) dykes on the south shore of Nain Bay occupy brittle fractures in the Mount Lister anorthosite and crystallized at ca. 1328 Ma (M.A. Hamilton, written communication, 2001).

Pearly Gates Intrusion (Unit 14, 14a)

The name Pearly Gates intrusion was originally coined by Ryan (1993) to refer to a semi-circular body of coarse anorthosite and leuconorite south of Nain Bay, which, like the Mount Lister intrusion, has a massive interior (Unit 14) and a foliated margin (Unit 14a). The stratigraphic name is derived from a well-known labradorite prospect within the intrusion. Like the Mount Lister intrusion, the Pearly Gates intrusion represents a very large "pale facies" body of anorthosite, and also like the Mount Lister intrusion it has an external sheath of monzonitic rock (*see below*). As used herein, the Pearly Gates intrusion encompasses the "Bird Lake massif" and the "Susie Brook slab" of Morse and Wheeler (1974), the former being the northward extension of the interior of the body and the latter being the northward extension of the eastern foliated margin. The Pearly Gates intrusion, as thus defined, is about 35 km in an east–west direction. Its north–south extent is unknown because correlative rocks have not been definitely identified north of Kingurutik Lake, an area where the Pearly Gates intrusion appears to be invaded by younger undivided intrusions (Figure 2). It is possible that the Ikatsiak Brook pluton of the upper Kingurutik River area, immediately abutting the northern margin of NTS map sheet 14D/16 on NTS map sheet 14E/2 (Ryan *et al.*, 1998), is the northern part of this body. Rocks that could be the southerly extension of the Ikaisiak Brook body toward Kingurutik Lake were found at the northwest corner of NTS map sheet 14D/16 during the current program. The extension of that pluton on the western edge of Figure 2 is added to the Pearly Gates intrusion, thus making the latter intrusion some 65 km in a north–south direction.

The interior zone of the Pearly Gates intrusion (Unit 14) comprises predominantly pale-grey pegmatoidal anorthosite, having individual plagioclase and pyroxene crystals that reach a metre or more in maximum dimension. The coarse orthopyroxene normally displays a subophitic relation to the plagioclase, but some irregular patches and aggregates of very coarse crystals seem to be xenocrystic masses.

The marginal foliated zone (Unit 14a) of the Pearly Gates intrusion, including the “Susie Brook slab”, comprises variably deformed and recrystallized, diffusely to distinctly layered, medium-grained to very-coarse-grained anorthositic and leuconoritic rocks. The foliation, and any layering present, dip outward at 30 to 80°. The largely monominearlic (anorthositic) rocks are sugary and generally do not show foliation, but lozenges of the original igneous feldspars may locally define a crude fabric. The pyroxene-rich leuconoritic compositions, on the other hand, display the penetrative fabric well because the constituent pyroxenes are disposed as mildly to totally recrystallized lozenges and streaks in the sugary feldspar groundmass (Plate 9). Kinked cleavage is a nearly universal feature of the orthopyroxenes of the foliated marginal zone; internal recrystallization accompanies the kinking in many crystals.

The age of the Pearly Gates intrusion is not known, but a marginal monzonite (Hare Hill monzonite, *see below*) that is probably contemporaneous with the anorthosite has given a U–Pb crystallization age of ca. 1351 Ma (Connelly, 1993; *see below*). Another indication that the Pearly Gates intrusion is one of the “early” anorthositic plutons is that the large monzonitic dyke (Anaktalik Brook dyke, *see below*) crossing the foliated margin north of Anaktalik Brook has yield zircons indicating dyke crystallization at ca. 1326 Ma (R.F. Emslie, unpublished age, personal communication, 2002).

Plate 9. *Anorthosite to leuconorite, having elongate aggregates of granular pyroxene and kinked remnants of larger grains (near camera lens) in a granoblastic feldspar matrix, part of the marginal zone of the Pearly Gates intrusion (Unit 14a) south of Tikkoatokak Bay.*

Coarse-grained, Ilmenite-rich Leuconorite and Norite (Unit 15)

The southern and western interior anorthositic parts of the Pearly Gates intrusion are intruded by irregular bodies of brown-weathering, oxide-rich, olivine-bearing leuconorite (coarse ferrodiorite?), locally having abundant zircon. Though clearly intrusive into the Pearly Gates anorthosite – they cross-cut large-scale outcrop compositional variations in the anorthosite – they could actually be genetically and/or temporally related to their host. Some of the area underlain by the largest of these bodies is outlined south of Tessiarsuyungoakh (Figure 2). These more mafic rocks are equivalent to Wheeler’s “buff facies” anorthosite for this area (Wheeler, unpublished maps), and in some respects they resemble the ca. 1328 Ma dykes mentioned above. The oxide-rich rocks locally exhibit a pronounced deformational fabric, something absent from the abutting and older mafic-deficient pegmatoidal anorthositic and leuconoritic rocks.

Leucotroctolite and Leuconorite (Unit 16)

An oval pluton of dark-grey troctolite, leucotroctolite, and leuconorite was partially outlined in 1992 during an examination of the region directly north of the east end of Kingurutik Lake (Ryan, 1993). It is intruded into gneissic meta-anorthosite and leucogabbroic rocks on its eastern margin, and it truncates the northern extension of the Mount Lister pluton along its southern edge. A lack of ground data on the distribution and shape of the pluton precludes definition of other relations, but the aeromagnetic pattern for the region (GSC data) suggests that it is pear shape in plan, and that it abuts and partly truncates the southern extension of the Paleoproterozoic(?) leucogabbroic rocks to the west of Iglusuataliksuak Lake. The intrusion comprises an outer zone of fine-grained olivine gabbronorite, which passes internally into a zone of locally layered coarse-grained leucotroctolite, olivine-bearing leuconorite, leuconorite and anorthosite. It is bordered along its southeast side by massive ferrodiorite (Unit 21, *see below*).

A "dark facies" anorthosite was outlined along the north shore of Anaktalik Bay and north of the lower reaches of Anaktalik Brook by Wheeler (unpublished maps; 1984). This unit was subsequently shown by Ryan (1993, 2001a, b) to be a pluton of troctolite, olivine gabbro and olivine leuconorite that has intruded several older rock units, including the Mount Lister intrusion and its eastern gneissic envelope. It has been provisionally named the Tessiuyarsuk intrusion. In the present area, it sits atop medium- to coarse-grained leuconorite, and comprises brown-weathering, fine-grained olivine gabbro and medium-grained olivine leuconorite.

Undivided Anorthositic Rocks of the Region (Unit 17)

Most of the anorthositic rocks of the Kingurutik Lake area, by the very nature of the 2002 survey, have to remain undivided, and that is how they are portrayed on Figure 2. The summer's reconnaissance has shown that among them are rocks of diverse texture and composition that must, by comparison with the map sheets to the north and east (Ryan *et al*., 1997, 1998; Ryan, 2001b), encompass several separate plutons. Boundaries to individual bodies cannot even be crudely outlined at this time. Textures within these undivided intrusions include megacrystic, oikocrystic, seriate, and equigranular. Massive, layered, and foliated varieties of rock are present. Compositions range from leuconorite to anorthosite, some of which may contain olivine.

Seriate to clotty textured, massive, leuconorite south of Nain Bay is also assigned to the "undivided" category. This unit is texturally different from the proximal pegmatoidal rocks assigned to the Mount Lister intrusion. It is assumed to be younger than the Mount Lister intrusion because it contains rafts of recrystallized and foliated anorthosite that are interpreted to be derived from that intrusion.

Monzonitic, Granitic and Dioritic Rocks

Rocks of monzonitic to granitic composition were recognized by Wheeler (1942, 1960) as a major component within the NPS, and contributed to his two-fold description of the igneous rocks as an "anorthosite–adamellite complex". He used the mafic minerals to subdivide the "adamellites" into fayalite, hornblende and biotite "facies". Wheeler's earliest mapping indicated the general distribution of the granitoid rocks – narrow units separating anorthositic intrusions from the proximal gneisses, and large bulbous bodies without such a well-defined structural setting – but he did not temporally separate any of them. Detailed mapping and allied geochronology has subsequently indicated that these rocks exhibit variable degrees of deformation, and they record a considerable period of "granitic" magmatism, ranging from ca. 1350 to ca. 1290 Ma. Parts of two of the largest intrusions, the Makhavinekh Lake intrusion and the Umiakovik intrusion, both of which were emplaced ca. 1320 Ma, crop out in the study area. In addition, several older and smaller intrusions, ranging texturally from massive to gneissose, also occur in the area. The deformed intrusions are associated with similarly deformed anorthositic rocks, and are some of the oldest such granitoid intrusions recognized in the NPS.

Hare Hill Intrusion and Similar Foliated Rocks (Unit 18)

As noted above, Wheeler had outlined the general distribution of the granitoid rocks, and in the late 1960s he gave a detailed account of the setting, structure, and petrology of some of the narrow intrusions along the western margin of a large anorthositic body in the Tasisuak (Tessersoakh) Lake – Tessiarsuyungoakh Lake region (Wheeler, 1969). The eastern side of this anorthositic pluton, now referred to as the Pearly Gates intrusion (*see above*), between Nain Bay and Anaktalik Brook was investigated in a cursory manner in the early 1990s by Ryan (1992, 1993), and the whole western half of the pluton south of the Fraser River is currently the subject of a graduate student thesis at Memorial University. Monzonitic rocks on the eastern side of the pluton, in a comparable setting to those described by Wheeler (*op. cit.*) from the western side, were termed by Ryan (1993) the "Hare Hill monzonite". This marginal sheath is also present between gneisses and the eastern edge of the Pearly Gates intrusion on both sides of Tikkoatokak Bay, but is too narrow to show on Figure 2. Perhaps the term "Tessiarsuyungoakh Lake monzonite" would be more suited for the whole marginal monzonitic halo because, from the data provided by Wheeler (1969), the unit has its widest areal extent and is more extensively exposed in the vicinity of that lake than it is elsewhere around the Pearly Gates intrusion. It is possible, however, that the more widespread distribution of the unit in this area is a function of erroneous "lumping" of two or more intrusions of differing age. The original stratigraphic name of "Hare Hill monzonite" is thus retained here for the eastern body and "Tessiarsuyungoakh Lake monzonite" is used for the western intrusion, pending further work. The deformed state of the western intrusion was noted by Wheeler (1969), and this feature seems comparable to that of the Hare Hill intrusion documented by Ryan (1993). The Hare Hill monzonite is also disposed as layer-parallel sheets in the gneisses distal from the largest masses. Sheets of monzonite also occur in gneisses west of the arcuate extension of the western body south of Tasialuk Lake. Where the monzonite occurs as narrow sills within the garnetiferous paragneisses, the igneous rock is likewise garnet-bearing. Zircon extracted from the Hare Hill monzonite south of Nain Bay indicated a crystallization age of 1351 ± 3 Ma (Connelly, 1993) making it one of the oldest such bodies within the NPS.

The Hare Hill monzonite is a variably deformed, polylithologic, charnockitic intrusion, in places having a paucity of potassium feldspar. The compositional range is from enderbite to mangerite to farsundite. In some places it is a uniformly textured rock, the grain size of which may be fine or very coarse; in other places, it is broadly bimodal, being distinctly feldspar porphyritic or having one grain-size variant as enclaves in the other; in other places it is a diffusely to distinctly layered and a foliated to gneissose rock (Plate 10a). Inclusions of granular anorthosite within the intrusion are likely derived from the nearby Pearly Gates body, and were present prior to the imposition of the fabric of their host (Plate 10b). Overall the intrusion displays features of classic rapakivi granites: it is locally friable, the perthitic feldspars are locally mantled with plagioclase, and some quartz has a "drop" morphology. Olivine, orthopyroxene (including inverted pigeonite) and clinopyroxene are the chief mafic minerals, but green hornblende is locally a minor constituent.

A peculiar feature noted in the monzonitic rocks south of Tasialuk Lake is the rare occurrence of dense angular masses (inclusions?) composed of olivine – in some cases extremely coarse grained – having networks of ilmenite; the latter mineral seems to be the product of an oxide liquid that has cemented the silicate.

The foliation in the Tessiarsuyungoakh Lake monzonite and the Hare Hill monzonite is regionally parallel to the boundaries of the units, and can be very weak to very pronounced. In some places, it is best discernable as an alignment of tabular feldspars; in others, it is a streaky fabric defined by elongate to anastomosing aggregates of mafic minerals that can be disposed on the foliation plane as a well-developed lineation. The deformational fabric enhances any compositional layering to the point of producing a gneissose rock.

A foliated ferrodioritic to monzonitic (?) unit (too small to portray on Figure 2) that seems to be in a similar setting to the Hare Hill and Tessiarsuyungoakh Lake intrusions is located near the eastern end of Kingurutik Lake. This narrow body is situated along part of the contact between the foliated margin of the Mount Lister intrusion and the

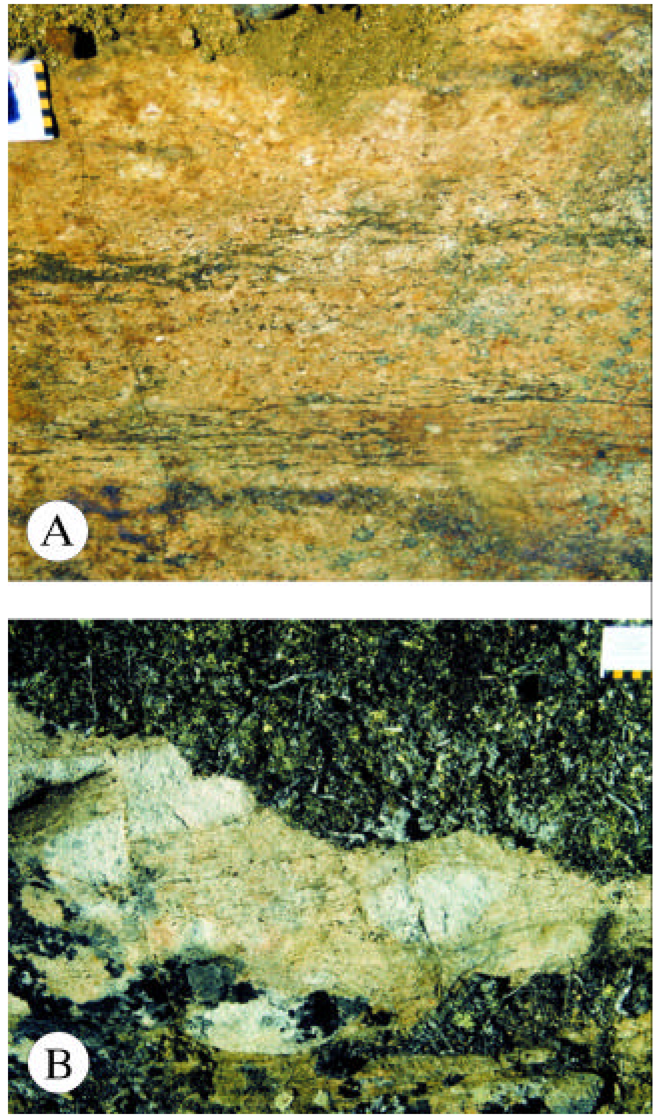

Plate 10. *Hare Hill monzonite (Unit 18) as exposed in a narrow sheath east of the Pearly Gates intrusion at Tikkoatokak Bay. (a) Foliation defined by lenticular and anastomosing olivine+clinopyroxene aggregates. (b) White, recrystallized anorthosite fragments having their long axes aligned parallel with the deformational fabric of the enclosing monzonite.*

mylonitic quartzofeldspathic to anorthositic gneisses to the east. An intrusive contact with the mylonitic gneisses is evident, but the nature of the contact with the Mount Lister intrusion is uncertain.

Wheeler (1969, 1984; unpublished manuscript) identified a northwest-trending "olivine-clinopyroxene ferromangerite" intrusion north of Anaktalik Brook. Ryan (1993) demonstrated that this intrusion is, in fact, a large dyke that seems to have intruded along a shear or fault zone between the foliated margin of the Pearly Gates intrusion and its bounding granulite-facies gneisses. It is herein termed the "Anaktalik Brook dyke", and it differs from the Hare Hill intrusion in being devoid of quartz. The dyke comprises predominantly a speckled, pale-brown to dark-brown, medium-grained rock in which olivine+clinopyroxene streaks are surrounded by a matrix of mesoperthitic feldspar; phenocrysts of mesoperthite are locally present. In places, there are very coarse-grained variants mingled with the more widespread medium-grained rock. Several sills of similar rocks occur in the gneisses, and numerous dykes of it are found in the anorthosite; those smaller dykes proximal to the main dyke in the latter setting have a sheeted and streaming aspect with the anorthositic host, and give rise to a "sheeted complex" of alternating brown dykes and white subparallel screens of anorthosite (Plate 11). The Anaktalik Brook dyke is internally foliated, and it crosscuts the deformational fabric in the marginal zone of the Pearly Gate intrusion. It also contains foliated fragments derived from the leuconoritic and anorthositic host (*see* Ryan, 1993, Plate 2). A crystallization of ca. 1326 Ma (determined from zircon by C. Roddick; R.F. Emslie, personal communication, 2002) for the Anaktalik Brook dyke places a lower limit on the time of fabric development in the Pearly Gates margin.

Monzonites North of Eastern Anaktalik Brook and near Kingurutik Lake (Unit 19)

An elongate, northwest-trending, composite, pluton of clinopyroxene-bearing quartz monzonite (in the north) to ferrodiorite (in the south) intrudes gneissic anorthosite and massive leuconorite north of the entrance to Anaktalik Brook (Ryan, 1993). This intrusion differs from others south of Nain Bay in being devoid of olivine. Even though this body has a planar fabric, the foliation is less intense than that exhibited by either the Hare Hill, Tessiarsuyungoakh Lake, or Anaktalik Brook intrusions. In this intrusion the fabric seems to be a magmatic alignment of feldspar megacrysts (plagioclase xenocrysts and potassium feldspar phenocrysts) rather than a penetrative foliation and lineation of streaky mineral aggregates. All rocks belonging to this intrusion have complexly exsolved pyroxenes, in some cases exhibiting poikilitic form, which signify derivation from inverted pigeonite.

Wheeler (unpublished maps; 1984) outlined two oval granitic bodies north and south of Kingurutik Lake, which were examined in a couple of places in 1990 by B. Ryan and were visited again during the 2002 survey. Both intrusions are white- to brown-weathering, appear to be olivine+clinopyroxene monzonite, and both contain inclusions of foliated leuconorite and granulite-facies quartzofeldspathic gneiss. The southern intrusion also contains a layered component; within the layered rocks are centimetre-scale dykes and sills of opaque oxide containing suspended anhedral grains of olivine and plagioclase.

Plate 11. *A subparallel array of monzonitic dykes, marginal to the main Anaktalik Brook dyke (Unit 18), intruded into variably foliated and recrystallized anorthosite and leuconorite of the marginal zone to the Pearly Gates intrusion (Unit 14a), south of Nain Bay.*

Umiakovik Lake Intrusion (Unit 20, U)

The Umiakovik Lake intrusion is the largest of the broadly granitoid intrusions in the Nain area, occupying all the western margin of the NPS northwest of Kingurutik Lake (cf. Ryan, 1990a). It was, apparently, never completely traversed by Wheeler (unpublished maps; 1984) during his limited visits to the area, but its overall extent is shown on the undated (late 1950s?) BRINEX geological map of Labrador (BRINCO, undated) in the files of the Geological Survey. The distribution of the intrusion on that map is similar to that deduced from the later "4-mile mapping" of Taylor (1979). The Umiakovik Lake intrusion comprises at least three phases, *viz.*, coarse-grained fayalite–pyroxene quartz monzonite, coarse-grained hornblende–biotite granite, and fine-grained monzodiorite to ferrodiorite (Emslie and Russell, 1988; Ryan *et al*., 1998). U–Pb investigation of zircon from this intrusion in its type-area to the north (Emslie and Loveridge, 1992) has indicated a crystallization age of 1319 ± 2 Ma for the fayalite–clinopyroxene-bearing phase and 1316 ± 3 Ma for the hornblende–biotite-bearing phase. Most of the rocks of the Umiakovik intrusion are characterized by a dark, chocolate-brown, deep-weathering surface; grus is developed on the most friable outcrop areas. Only a small part of the Umiakovik Lake intrusion is present within the present map area – a narrow projection from the southern half of the main intrusion extends to Tasisuak Lake on NTS map sheet 14D/10, where it is bounded by mildly contact metamorphosed Tasiuyak gneiss. A visit to the western margin of the pluton with A. Kerr during the 2002 survey, northwest of Kingurutik Lake, and outside the region covered by the geological map of Figure 2, has indicated the presence of brownish to greenish-brown pyroxenites that may also be allied with the Umiakovik Lake intrusion. These pyroxenites had previously been delineated during nickel exploration in the area by North (1998) who described their distribution as a "large ultramafic intrusion of anorthosite and troctolite"; drilling indicated disseminated, but non-economic, contents of copper and nickel sulphide. It is possible that these pyroxenitic rocks are part of the ferrodioritic phase of the intrusion or that they represent mafic cumulates on the floor of the magma chamber in which the whole intrusion developed.

Makhavinekh Lake Pluton (Unit 20, M)

The Anaktalik Brook area is underlain by the northern extension of a large polyphase granitoid intrusion, the Makhavinekh Lake pluton, most of which is located to the south of the current survey area (Ryan, 1991b). It has yielded two independently derived, identical U–Pb ages of ca. 1322 Ma, one (1322 ± 1 Ma) from zircon separated from a sample collected south of Anaktalik Brook (Krogh and Heaman, 1989) and the other (1322 ± 3 Ma) from samples collected along the northern edge of the intrusion in the present area (C. McFarlane, written communication, 2000). The Makhavinekh Lake pluton in the current survey area comprises quartz monzonite and granite. The rocks are light-pink-weathering, massive, and contain ovoid potassium feldspar phenocrysts (locally having plagioclase mantles), coarse-grained grey quartz, and approximately 10 percent fine- to coarse-grained hornblende. The northern contact of the Makhavinekh granite against the Tasiuyak gneiss is subvertical where recently examined by McFarlane *et al.* (2001), but Wheeler (unpublished manuscript) indicated that the pattern of granite and gneiss in relation to topography points to a local low-angle contact between the intrusion and its country rocks.

Ferrodiorite (Unit 21)

Undeformed ferrodiorite just north of Anaktalik Brook is interpreted, from its setting, to be the northward extent of the unit associated with the Makhavinekh Lake pluton south of this waterway (Ryan and Lee, 1989). In the survey area it comprises massive granular gabbronoritic rocks and hybrid varieties in which both isolated and aggregated potassium feldspars are scattered throughout. Extensively digested inclusions of Tasiuyak gneiss give rise to cordierite streaks within the ferrodiorite in some places.

The distribution of the ferrodiorite units depicted north and south of Tasisuak Lake have been taken from the unpublished maps and manuscript of E.P. Wheeler and from Wheeler (1969). Analyses provided by Wheeler (1969) indicate a range of compositions – orthopyroxene diorite, syenodiorite (monzonite) and mangerite.

A small fine- to medium-grained, ilmenite-rich ferrodioritic rock also separates massive troctolite from gneissose anorthositic rocks northeast of Kingurutik Lake.

Akpaume Intrusion (Unit 21, A)

This oval monzonitic to dioritic pluton underlies Ukpaume (Akpaume) Island and the adjacent mainland at the entrance to Tikkoatokak Bay. It has been emplaced into the Mount Lister intrusion, and has yielded a crystallization U–Pb age from zircon of 1333 ± 2 Ma (Hamilton *et al*., 1994). The intrusion was the subject of a mapping and geochemical study by Deuring (1976, 1977), who determined that it is a polyphase body containing at least two different components, which he designated as a layered group comprising ferrodiorite to ferrosyenite and a massive coarse-grained "hybrid intrusive" of overall ferromonzodiorite composition.

FAULTS

Regional compilation maps (Wheeler, 1969; Taylor, 1977a; Ryan, 1990a) clearly indicate that some of the broad east–west valleys and prominent linears in the Nain region are the expression of subvertical faults. The strike–slip movement on the largest of these faults is generally on the order of hundreds to thousands of metres, and the throw is likely of similar magnitude. Tasisuak Lake and the Fraser River occupy one such depression, a fault trace that extends eastward to merge underneath Nain Bay with another following Tikkoatokak Bay. Calculations of offset across the Nain Bay fault indicate a dip–slip displacement of 3 km (Ryan, 2001a).

Some, if not all, of the valleys and steep-walled canyons at a high angle to the trend of the Fraser River, Tasisuak Lake and Anaktalik Brook are also faults. These prominent scars in the landscape are normally occupied by streams draining from the plateau, and display hematization, chloritization, and epidotization of rocks on their walls and floors.

ECONOMIC GEOLOGY

The Nain region, along with most of Labrador, was subjected to scrutiny during the 1950s and 1960s for deposits of base metals by British Newfoundland Exploration (BRINEX) Limited. Some base-metal sulphides and iron–titanium oxide occurrences were documented, but were not significant enough to warrant substantial follow-up. The Nain Bay area and some of the interior were subsequently prospected and examined in varying degrees of detail for

Cu–Ni sulphides during the height of the "Voisey's Bay frenzy" in the mid-1990s. At that time, several claim blocks were foci of differing degrees of investigation, but widespread staking activity was restricted because most of the prospective ground in the Nain region had been designated as "Exempt Mineral Lands". The three properties within the present survey area that received the most work were the "Michelle showing" of Archean Resources Limited and Voisey's Bay Nickel Company to the south of Nain Bay, the "NBK" property of Castle Rock Exploration to the north of Kingurutik Lake, and the Tasisuak Lake property worked by Consolidated Magna Ventures south of Tasisuak Lake. Copper–nickel sulphide in a coarse-grained leuconorite was the focus at the Michelle showing, mineralized anorthosite was the unit of interest north of Kingurutik Lake, and a mineralized foliated mafic unit was the object of attention at the Tasisuak Lake site.

SUMMARY OF PAST WORK ON BASE-METAL PROSPECTS

Below is given a brief review of some of the previous investigations of the sulphide mineralization in the study area. The authors have not seen all these prospects, and have used company assessment files and press releases on file at the Department of Mines and Energy as the main sources of data.

Nain Bay Area

Exploration interest in the Nain Bay region was initially sparked in the mid-1950s, and aimed at rusty sulphide-bearing zones in anorthosite south of Nain Bay. BRINEX undertook an investigation of two of these occurrences, and during that exploration program pin-pointed another nearby zone that was not visited (Grimley, 1955). The zones initially investigated by BRINEX are on a north-facing scarp south of inner Nain Bay. They comprise irregular and randomly developed sulphide occurrences within foliated and variably recrystallized leuconorite and anorthosite, both as disseminated mineralization within the plutonic rocks as well as being associated with mafic rafts in the plutons (Ryan, 1993).

The announced discovery of the Voisey's Bay deposit in 1994 was followed by a flurry of exploration in the Nain region. Among the most extensively investigated showings of the general Voisey's Bay region in the current survey area was one south of Nain Bay (Figure 2), that had been initially seen from a distance but never visited by BRINEX personnel in the 1950s (*see above*) and later described by Ryan (1993). It was staked in the mid-1990s by Archean Resources Limited and termed the "Michelle showing". Ryan (*op. cit.*) noted that the mineralization comprises coarse pyrrhotite, pyrite and chalcopyrite within a pegmatitic leuconoritic dyke cutting foliated granular leuconorite and layered gabbronoritic rocks, the dyke being related to a nearby leuconoritic intrusion (*see also* Myers, 2001). Archean Resources Limited and the Voisey's Bay Nickel Company Limited conducted a detailed examination of the Michelle showing area, including geophysical surveys and exploratory diamond drilling, and also discovered other localized sulphide concentrations nearby. Two holes drilled at the Michelle showing in 1996 failed to intersect any significant sulphides in the subsurface (Butler *et al.*, 1996), and no subsequent work appears to have been done there.

Kingurutik Lake Area

Castle Rock Exploration Corporation announced, in a press release on July 14, 1995, the discovery of an otherwise unknown Ni–Cu–Co sulphide occurrence north of Kingurutik Lake. Given the geographic location of the discovery outcrops, the occurrence is assigned to the western part of the oval leucotroctolite to anorthosite pluton south of Iglusuataliksuak Lake (Figure 2). This mineralized area, which comprises three distinct and geographically separated zones, was subsequently termed the "NBK" showings. The sulphide mineralization comprises semi-massive to massive pyrrhotite, chalchopyrite, and pentlandite along fractures in anorthosite (O'Sullivan, 1996). The company reported that assay results from field samples returned maximum metal values of 1.70% Ni, 1.90% Cu and 0.23% Co. Geophysical surveys were conducted over the showings and defined several anomalies (company press release, October 4, 1995). A planned drilling program to test the subsurface extent of the NBK surface mineralization was abandoned in favour of what appeared to be more promising prospects farther north (company press release, November 4, 1995). A. Kerr visited the NBK showings for the Department of Mines and Energy during his 1996 examination of newly discovered sulphide occurrences in Labrador. He observed that the several sulphide occurrences in the NBK group are disseminated to podiform concentrations within a coarse, locally labradorite-bearing, anorthosite to leuconorite. He also noted that these sulphide showings are unusually chalcopyrite-rich in comparison to similar showings in comparative settings elsewhere in this part of Labrador (A. Kerr, 1996 field notes; personal communication, 2002).

Tasisuak Lake Area

Consolidated Magna Ventures Limited, in a company press release on August 16, 1995, announced that sulphide mineralization had been discovered south of Tasisuak Lake (Figure 2). The area in question is underlain by Tasiuyak gneiss along the northwestern margin of the Makhavinekh Lake pluton, but the company's exploration program indicated that there are several gabbro dykes in the area (Reeves and Brewer, 1995). The sulphide discoveries were described by the company as being within one of the basic dykes as well as in the country-rock envelope (company press release, October 25, 1995; Reeves and Brewer, 1995). Selected assays of drill core from several test holes returned base-metal values having maxima of 2.06% Ni, 1.41% Cu and 0.06% Co (company press release, October 25, 1995). Further drilling in 1996 to test geophysical anomalies did not intersect any rocks having significant sulphide mineralization (Brewer and Reeves, 1996). The authors, along with A. Kerr, briefly examined part of this area of showings during the 2002 survey, and determined that at least some of the sulphide here occurs in a 2-m-thick, deformed and metamorphosed gabbronoritic unit that is part of the charnockitic suite of rocks emplaced into the Tasiuyak gneiss. This mafic rock in the vicinity of the showings forms part of a composite unit, of uncertain extent, consisting of very strongly foliated to mylonitic charnockite and white- to light-green-weathering, metamorphosed gabbronorite to leucogabbronorite.

Tikkoatokak Bay Area

Pockets of coarse to granular ilmenite and lesser base-metal sulphides (pyrite, pyrrhotite, chalcopyrite), associated with coarse hypersthene, are exposed along the walls of several linears transecting pegmatoidal anorthosite of the Pearly Gates intrusion between Tasisuak Lake and Tikkoatokak Bay (Figure 2). These showings were initially investigated by BRINEX in the mid-1950s (Grimley, 1955), but they are so localized that they warranted no more than a cursory examination at the time. The showings were subsequently staked by Absolut Resources Corporation (company press release, July 25, 1995). One of the largest pockets, a rusty zone about 4 by 8 m in area, was re-examined by Absolut, but the showings were abandoned after assays failed to show significant Cu and Ni contents and when geophysical surveys failed to indicate anomalous geology compared to the enclosing anorthosite (McGillivary, 1996; Thériault, 1997).

LABRADORITE OCCURRENCES

Schiller in the plagioclase crystals of the anorthositic rocks is widespread, but generally restricted in extent. The most impressive exception to the areal restriction of such coloured feldspar is at the east end of Tessiarsuyungoakh Lake (Figure 2) where large feldspars displaying a labradorescence in shades of blue and green were documented from anorthosite by Wheeler (1969, p. 196), who was struck by the “unusually extensive and rich development of iridescent plagioclase crystals” in this area. The best-known labradorite occurrence in this region is locally referred to as “The Pearly Gates”, and it and others in the region were evaluated from the perspective of a semi-precious gemstone and dimension-stone resource by Watson (1980) and Meyer and Dean (1986). The numerous hairline fractures throughout the plagioclase at the Pearly Gates location detracts from its overall appearance in polished slabs because the colour is destroyed along the fractures, leaving the blue and green color of the feldspar as a chatoyant background to crisscrossing white lines. These fractures may also prove to be an impediment to using larger stone pieces for jewelry settings because the weakened parts of the mineral may be plucked out during polishing. In spite of these imperfections, however, the vivid hues of the Pearly Gates material still make it attractive to collectors of labradorite.

MINERALIZED ZONES EXAMINED IN THE GNEISSES AND PLUTONIC ROCKS IN 2002

Several oxidized, sulphide- and/or oxide-bearing zones were examined and sampled during the 2002 survey.

The zones within the gneisses were found in the Tasiuyak gneiss, other metasedimentary gneisses and mafic gneisses (Figure 2). Fresh rock samples collected from the rusty outcrops indicate the sulphide minerals form interconnecting vein networks clearly of epigenetic origin but possibly derived and concentrated from the original metal contents of the precursor. Several such specimens were assayed for base and precious metals. The ICP trace-element chemical analyses of these sulphide-bearing gneisses are presented in Appendix 1. Elevated Fe and Ti contents imply that pyrite and an iron–titanium oxide are likely causes of the gossanous surfaces. Low concentrations of Ni, Cu, Pb and Zn indicate that no significant volume of minerals having these elements is present.

Two grab samples from the irregular rafts of coarse olivine and Fe–Ti oxide that are found in the arcuate monzonite south of Tasialuk Lake were analyzed for their metal contents. Results of the analyses do not contain any highly unusual metal contents (Appendix 1).

DISCUSSION

The limited time frame of the 2002 survey did not allow for a concerted examination of any particular part of the Kingurutik Lake – Québec border corridor. The survey did, however, make it clear that the currently understood general patterns of rock distribution could be refined, and deficiencies in the existing maps could be identified. It also indicated that some enigmatic rock units have to remain so for the time being! The following points offer insights and speculations that have arisen from the 2002 survey:

1. It seems that parts of the gneiss terrane of the Paleoproterozoic Churchill Province, to the west of the Mesoproterozoic Nain Plutonic Suite, are likely Archean in age. The main basis for this suggestion is the similarity of these gneisses to those shown to be Archean to the south of the present survey area. Among the criteria used to reach this tentative conclusion are the presence of inclusions of golf-ball textured meta-leucogabbro and anorthosite, and discordant to concordant massive mafic units likely derived from early Paleoproterozoic basaltic dykes. If this notion is validated, the extent of Archean rocks, and thus remnants of Archean crust, in this part of Labrador will be greatly increased. The confirmation of such Archean crust will provide more evidence that a substantial part of the Churchill Province west of the Tasiuyak gneiss is actually a re-worked older cratonic block.

2. Foliated charnockitic rocks appear to be unrelated to the migmatitic gneisses. These charnockitic types may all be younger rocks that were derived from "dry" plutons emplaced into the gneisses. The age range for this younger plutonism is not known, and the rocks may reflect both Archean and Paleoproterozoic magmatism.

3. Some of the granular and foliated meta-anorthositic and meta-leucogabbroic rocks within the gneisses proximal to the NPS (including some of Wheeler's "granulites of uncertain origin") certainly appear to be unrelated to the NPS, even though indications of their absolute age are lacking. The only hint of the antiquity of some such rocks comes from northeast of Kingurutilk Lake, where a foliated pink aplitic dyke within them has given a U–Pb crystallization age of 1873 ± Ma (Connelly and Ryan, 1999). Field features suggest that most, if not all, gneissic types are older than the NPS, and that the proximity of the two compositionally similar groups of rocks in this area is coincidental. These features include, i) the greater degree of compositional diversity over restricted areas among the gneissic types, ii) the polyphase nature of the deformation of the gneissic rocks, iii) the local migmatitic aspect of these rocks, iv) the common occurrence of mafic layers (dykes?) within them, and v) the absence of coherent pyroxenes even within the least deformed of these gneissic units. If all such rocks are pre-NPS then they must be Archean or Paleoproterozoic. The absence, from most of these rocks, of the characteristic "snowball plagioclase" of Archean leucogabbros is, perhaps, a negating factor to their Archean age assignment. If they are Archean, however, and if the unit south of Nain Bay is equivalent to that to the northeast of Kingurutik Lake, then stratigraphic assignment of the rocks in these two areas becomes complicated. On one hand, if those of the Kingurutik area are Nain Province rocks, then gneisses south of Nain Bay must likewise be Nain Province. On the other hand, if the gneisses south of Nain Bay are Archean rocks within the Churchill Province, then those to the north must be within the Churchill Province as well. If the anorthositic rocks, and the quartzofeldspathic gneisses which enclose them, are Paleoproterozoic instead of Archean, again current regional stratigraphic assignments are in doubt. It is possible that the anorthositic gneisses south of Nain Bay are Paleoproterozoic, part of the calc-alkaline plutonic association in the Churchill Province that has been shown to have been emplaced between ca. 1910 and 1880 Ma (Ryan *et al.*, 1991b; Rawlings *et al*., 2001). If the rocks of the Kingurutik Lake area are also part of this plutonism, then Churchill Province extends much farther to the east here then presently believed. In either case, whether Archean or Paleoproterozoic, the position of the boundary between the Nain and Churchill provinces in this part of Labrador may need revision. To add even more questions to the uncertainty of the absolute age of some of these rocks is their overall compositional similarity to the NPS. Other characteristics suggestive of an affinity with the Mesoproterozoic intrusions are the former presence of pyroxene megacrysts (now granular aggregates of two pyroxenes) morphologically similar to the orthopyroxene megacrysts of the NPS, and the local occurrence of a pale blue labradoresence in some of these rocks.

4. Even though only limited data regarding the internal architecture of the NPS can be gleaned from the 2002 survey, the information on hand does offer intriguing insights into the development of the "anorthositic massif". One of the features that is becoming evident from the expansion of the mapping across the NPS is the previously unappreciated extent of foliated rocks within it. The full distribution of such rocks is still not known, but the pattern becoming apparent is that the deformed parts of the NPS are generally, though not universally, proximal to the enveloping gneisses (*see* Wheeler, 1960, p. 1761), and that these deformed rocks are confined to what are probably the oldest plutons within the suite (*see also* Morse, 1983a). There are, however, inconsistencies. The pegmatitic Pearly Gates intrusion seems to be completely surrounded

by a foliated zone of leuconoritic and anorthositic rocks, separated from the gneissic envelope by a monzonitic sheath that displays a similar fabric. Similarly, the eastern margin of the pegmatitic Mount Lister pluton, along with its sheath of monzonite, is deformed where it abuts gneisses between Nain Bay and Kingurutik Lake. Yet, a similar coarse-grained rock appearing to represent the western margin of the Mount Lister intrusion south of Nain Bay is clearly intrusive into Archean(?) gneissose and foliated anorthositic and leuconoritic rocks, and it lacks the external monzonitic halo. The northward continuation of this western margin between Nain Bay and Tikkoatokak Bay likewise seems to have an intrusive contact with abutting rocks, including those that are possibly part of the eastern margin of the Pearly Gates intrusion. Conceivably, the rocks herein assigned to the western part of the Mount Lister intrusion could be a superficially similar younger pluton that has excised the actual foliated rocks from this western side. If, however, the pattern of "old" plutons having foliated contacts against enveloping gneisses, but intrusive contacts against internal, even older, plutons is real, then the assembly of parts of the NPS may have occurred in the deeper crust prior to the ascent. The whole amalgamated plutonic assemblage may have risen subsequently as a single entity through the crust to the present level of exposure. In this way internal intrusive contacts are retained, whereas the original marginal intrusive relations are structurally modified during the ascent of the mass.

5. The rocks formerly designated as the "Susie Brook slab" seem to be spatially associated with the eastern side of what is now termed the Pearly Gates intrusion. Along this side, the marginal monzonite sheath to the Pearly Gates intrusion is very thin or completely missing (or, as yet, undiscovered). If it is assumed that the anorthositic rocks of the Pearly Gates and the Mount Lister intrusions, along with their outer monzonitic haloes, were largely crystalline, simultaneously emplaced, "two-component intrusions" from a staging area deeper than their present erosional level, then the thickest parts of the monzonitic halo may have acted as a lubricant and/or absorbed most of the strain during the ascent. Where the halo was missing, or had been structurally excised during uprise, the strain was transferred to a much greater degree into the anorthositic rocks. The presence or absence of the monzonitic sheath thus seems to control the width of the foliated zone within the anorthositic intrusions. The possible pre-ascent spatial relationships for both the Pearly Gates and the Mount Lister intrusions may have been like those postulated by Ryan (1992) for the Makhavinekh Lake rapakivi granite pluton, the latter seeming to have formed a cauldron-subsidence-like halo to its proximal and internal anorthosite. This geometry may have originally been the case for the older intrusions and their monzonitic sheaths prior to subsequent simultaneous ascent of both components as a single diapiric body.

6. Deformational foliations within the anorthositic parts of the NPS were recognized by Wheeler during his earliest investigations in the Nain area (Wheeler, 1942, 1960), and he subsequently described them in more detail in the monzonitic rocks that cross Tasisuiak Lake (Wheeler, 1969). It seems, however, that even though Wheeler had observed the foliation over a large area of the NPS, and noted its particular presence along anorthosite contacts against gneisses, he either equated the fabric with banding or he downplayed it. For example, he described, somewhat cryptically, the deformed anorthositic rocks as being "stretched", and he did not use a specific map-symbol to differentiate these imposed penetrative fabrics from primary compositional layering on either his published or unpublished maps. This apparent indifference to the presence of deformed and recrystallized rocks among an otherwise pristine group of intrusions may have been anchored in the belief that such features should not be present in the suite because it was anorogenic. Morse (1982) also contended that the "anorthosites of northern Labrador ..... are undeformed and unrecrystallized". Subsequently, he acknowledged the existence of deformed rocks in the NPS, relating the "stretched layering" and recrystallization features in the "Susie Brook slab" along Tikkoatokak Bay to the foundering of an extraordinarily large anorthositic block "which was then deformed by rotation and hot plastic stretching of layers and megacrysts due to its engulfment by magma" from which the "Bird Lake massif" crystallized (Morse, 1983b). Wiebe (1992) documented weak deformational fabrics in anorthosite on western Paul Island, and using the Egersund–Ogna body from the Rogaland area of Norway as his type model, he proposed that such foliated zones marked the margins of diapirs. The Paul Island rocks, however, do not display the intensity of foliations seen in the margins of the Mount Lister intrusion and the Pearly Gates intrusion (R.A. Wiebe, personal communication, 1994;

Ryan, 2001b), and there is reason to suggest that the deformed rocks of this area are older than the NPS (Ryan, 2001a). Ryan (1991) pointed out the presence of solid-state deformational fabrics within the NPS following a reconnaissance examination of the area south of Nain Bay in 1990, but the scale and distribution of the deformation zones did not become apparent until later (Ryan, 1992, 1993). With the results of mapping over the last five years, it is now possible to better define the extent of the deformed rocks, and to note that they have differing settings. For example, anorthositic plutons are deformed on margins against gneisses. Monzonites in marginal settings are likewise foliated, and with the same fabric as the abutting anorthosites, and dykes of such rocks internal to the largest anorthosite plutons are foliated parallel to their trend. The Anaktalik Brook dyke, the largest of the dykes, has a foliation that is sigmoidal across strike, perhaps indicative of fabric generation under a shear regime. None of the large ferrodiorite, troctolite nor granite intrusions of the NPS is known to be foliated to the same extent as the "early" anorthosites and monzonites.

The genesis of the deformational fabrics in the foliated rocks is not definitive. Certainly, in the case of the anorthositic rocks it can be demonstrated in many outcrops that minerals having a subophitic relationship have been deformed, implying that the deformation is subsolidus. Yet, in the monzonitic rocks the foliation seems to be, in some cases, "late magmatic", imposed on a partly crystalline magma or crystal mush. The latter certainly seems to be the case for the Anaktalik Brook monzonite dyke and the Hare Hill monzonite along the eastern side of the Pearly Gates intrusion. Both of these monzonitic intrusions locally have strained and oriented subhedral tabular feldspar phenocrysts enclosed by a coarse crystalline matrix in which many of the grains have what appear to be igneous crystallization boundaries rather than recrystallized and annealed ones. Wheeler (1969) attributed the foliation to the deep-seated stresses associated with the intrusion along a contact between anorthosite and gneiss.

7. Contact metamorphic haloes marginal to NPS plutons are most obvious in Tasiuyak gneisss, where garnet and sillimanite are altered, respectively, to cordierite+hypersthene and cordierite+spinel. These thermal overprint zones do not seem to be developed to the same extent everywhere. For example, along the eastern and western margins of the Pearly Gates intrusion there is limited development of the contact metamorphic assemblage, yet along the southwest and southern margins of the same body near Anaktalik Brook there is an extreme development of the cordierite, hypersthene, and spinel (and osumilite?). Cordierite, hypersthene, and spinel have been previously described from south of Anaktalik Brook where the Tasiuyak gneiss abuts the Makhavinekh Lake rapakivi granite pluton and its associated ferrodiorite (Ryan and Lee, 1986). These two plutonic units also extend into the current study area north of the brook, and it is probable, therefore, that the greater areal extent of the contact metamorphic aureole in the Tasiuyak gneiss north of Anaktalik Brook is a consequence of these gneisses being adjacent to the rapakivi granite and the ferrodiorite rather than coming under the influence of the thermal imprint from the Pearly Gates intrusion. The differences in the nature of the contact aureole around the Pearly Gates intrusion and around the Makhavinekh Lake pluton and its associated rocks could be related to several factors. For example, the "older" intrusions, such as the Pearly Gates, may have been intruded at a depth where the regional garnet and sillimanite were still relatively stable under the conditions of contact metamorphism, whereas the "younger" intrusions were emplaced after that crust (and its contained older intrusions) had risen to a level where the minerals could be readily transformed to their more stable contact metamorphic equivalents. Alternatively, the Pearly Gates anorthositic intrusion and its halo of monzonite may have been relatively cool because it was emplaced as a diapiric, crystalline, likely near-solid, body, whereas the Makhavinekh rapakivi granite and the ferrodiorite were both relatively hot mixtures of crystals and magma that passively stoped their way into the crust.

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Appendix 1. ICP trace-element analyses, Department of Mines and Energy, Geochemical Laboratory

Sample	Mo ppm	Cr ppm	Zn ppm	Pb ppm	Co ppm	Ni ppm	Fe %	Cd ppm	Ti ppm	V ppm	Be ppm	Nb ppm	Cu ppm	Dy ppm	Sc ppm	Y ppm	Mn ppm	Sr ppm	La ppm	Ce ppm	Ba ppm	Li ppm	As ppm
DJ-02-028	23	15	161	30	35	86	8.72	0.1	2716	145	1.0	10	95	5.2	16.9	36	705	159	16	44	66	4.2	2
DJ-02-038	ND	5	183	8	33	18	11.74	0.2	14070	337	1.6	17	84	7.6	39.5	48	1619	439	32	77	470	7.0	ND
DJ-02-042	ND	ND	37	11	18	8	47.25	3.0	470	4	0.1	22	16	8.6	67.1	44	6939	2	42	138	5	17.2	ND
DJ-02-043	23	675	675	ND	53	21	37.69	ND	125099	1073	1.7	62	ND	ND	95.0	3	2802	ND	ND	47	28	2.1	2
DJ-02-065	ND	104	104	3	95	120	13.80	0.2	6524	601	0.9	8	359	1.3	54.5	11	1810	64	ND	18	15	10.1	ND

Sample	UTM East	UTM North	Grid Zone	NTS	Description
DJ-02-028	509545	6271821	20	14D/10	gossanous Tasiuyak (metasedimentary) gneiss (Unit 11)
DJ-02-038	500928	6279549	20	14D/10	gossanous mafic granulite gneiss contained in charnockite gneiss (Unit 10)
DJ-02-042	512934	6286856	20	14D/10	0.5-m-thick, olivine and oxide-rich pod contained in quartz monzonite (Unit 22)
DJ-02-043	513821	6288241	20	14D/10	olivine and oxide-rich pod contained in quartz monzonite (Unit 22)
DJ-02-065	499155	6279622	20	14D/10	gossanous mafic (hornblende + pyroxene + plagioclase) gneiss (Unit 8)

ND = not detected